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Challenges and prospects in the application of space-based information and technologies for disaster management

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Author's declaration

No portion of the work referred to in this dissertation has been submitted in support of an application for another degree or qualification of this or any other university or other institute of learning.

Furthermore, this dissertation contains no materials previously written and/or published by another person, except where appropriate acknowledgment is made in the form of bibliographical reference, etc.

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Climate change and urbanization, combined with other natural and man-made causes, are leading to more frequent and devastating disasters. As such events are inherently spatial phenomena, the use of geospatial information and communication technologies (GeoICTs) is crucial for effective disaster management. At the same time, despite the growing diversity and accessibility of GeoICTs, in some cases, their implementation remains rather limited or not as successful. A mismatch can be noticed between the availability and potential benefits of modern GeoICTs and their practical application.

This dissertation explores existing challenges in the application of geospatial technologies, particularly space-based, for disaster risk reduction (DRR) and management. The overall aim is to contribute to strengthening the disaster resilience of countries by analyzing the current state of the use of space-based information and technologies by national authorities across the world. The conceptual framework of the dissertation is based on the disaster management theory and diffusion research traditions. A combination of methods was used to ensure that the research topic is explored in a comprehensive manner, as well as to confirm and validate the findings. Among others, it included the analysis of the reports from the Technical Advisory Missions carried out by the United Nations Office for Outer Space Affairs, network analysis of the satellite-based emergency mapping (SEM) mechanisms' activations, and participant observation.

Some of the most prominent mechanisms that support the wider diffusion and application of the GeoICTs in DRR were identified and discussed. The focus on the three SEM mechanisms allowed exploration of their activities and highlighted some of the potential gaps and common challenges. While studied mechanisms formally aim to get involved in different phases of the disaster management cycle, it was clear that the overall focus remains on disaster response, and pre-disaster activities are yet to be fully supported.

A number of specific challenging issues related to the application of GeoICTs in DRR were identified through the analysis of the Technical Advisory Missions' reports from 33 countries. Overall, six groups of topics were defined, which included promotion of geospatial technologies, awareness-raising and capacity building, coordination and cooperation, availability and use of resources, data and information management, and new technologies and tools.

The main identified challenges in the diffusion of space-based information and technologies included: lack of access to useful, timely, and credible data and information; confusing and fragmented landscape of existing platforms and tools, together with the lack of guidelines; need for equal access to the right data across various fields and regions; Global North dealing with difficulties in navigation in all the available data, while Global South still suffering from the lack of data; need for better cross-sectoral collaboration and knowledge-sharing; lack of feedback mechanisms between data providers and end-users needs. Discussion of the challenges was accompanied by potential solutions to address them. The findings were also generalized in a form of a concept map which might help raise awareness about the complexity of the situation and existing opportunities.

Keywords: geospatial technologies, disaster management, disaster risk reduction, satellite-based emergency mapping

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List of Abbreviations

ADRC	Asian Disaster Reduction Center
ARD	Analysis ready data
AU	Authorized User
BBK	Federal Office of Civil Protection and Disaster Assistance (Germany)
CADRI	Capacity for Disaster Reduction Initiative
CECOP	Centro de Coordinacion Operativa de la Direccion General de Proteccion Civil y Emergencias (Spain)
CEOS	Committee on Earth Observation Satellites
CEU	Central European University
CNSA	China National Space Administration
COGIC	Centre Operationnel de Gestion Interministeriel des Crises (France)
CONAE	Argentinian National Space Activities Commission
DG ECHO	Directorate-General for European Civil Protection and Humanitarian Aid Operations
DGSCGC	General Directorate for Civil Protection and Crisis Management (France)
DLR	German Aerospace Center
DM	Disaster management
DMPTC	Disaster Management Policy and Technology Center, Disaster Management Authority, MARD (Viet Nam)
DRR	Disaster risk reduction
EEAS	European External Action Service (EU Services)
EM-DAT	Emergency Events Database
EMS	Emergency Management Service (Copernicus)
EMs	Expert Missions
EO	Earth observation
ESA	European Space Agency
EVs	Essential Variables
EWS	Early warning systems
FAO	Food and Agriculture Organization of the United Nations
FEMA	Federal Emergency Management Agency (USA)
GEE	Google Earth Engine
GEO	Group on Earth Observations
GeoICTs	Geospatial information and communication technologies
GEOSS	Global Earth Observation System of Systems (GEO)
GIS	Geographic information systems

GNI	Gross national income
GNSS	Global Navigation Satellite Systems
GPS	Global Positioning System
GP-STAR	Global Partnership Using Space-based Technology Applications for Disaster Risk Reduction
ICIMOD	International Center for Integrated Mountain Development
ICTs	Information and communication technologies
IFRC	International Federation of Red Cross and Red Crescent Societies
IRDR	Integrated Research on Disaster Risk
IRP	International Recovery Platform
ISEPEI	In-Service ICT Training for Environmental Professionals
ISM	Institutional Strengthening Missions
ISRO	Indian Space Research Organisation
IT	Information Technology
IWG-SEM	International Working Group on Satellite-based Emergency Mapping
JAXA	Japan Aerospace Exploration Agency
JPT	Joint Project Team (Sentinel Asia)
JRC	European Commission's Joint Research Centre
LAPAN	Indonesian National Institute of Aeronautics and Space
LDC	Least Developed Country
LLDC	Landlocked Developing Country
MONRE	Ministry of Natural Resources and Environment of Viet Nam
NARL	National Applied Research Laboratories (Taiwan)
NASA	National Aeronautics and Space Administration (USA)
NDRCC	National Disaster Reduction Centre of China
NFIP	National Flood Insurance Program (USA)
NGO	Non-governmental organization
NRC	National Research Council (USA)
NSDI	National Spatial Data Infrastructure
NSPO	National Space Organization of Taiwan
ODCs	Open Data Cubes
OECD	Organisation for Economic Co-operation and Development
OGC	Open Geospatial Consortium
PDNA	Post Disaster Needs Assessment
PHIVOLCS	Philippine Institute of Volcanology and Seismology

PSIPW	Prince Sultan Bin Abdulaziz International Prize for Water
QZSS	Quasi-Zenith Satellite System (Japan)
RQ	Research question
RSO	Regional Support Office (UN-SPIDER)
SAR	Synthetic aperture radar
SDGs	Sustainable Development Goals
SEM	Satellite-based emergency mapping
SFDRR	Sendai Framework for Disaster Risk Reduction
SIDS	Small Island Developing State
SIFEM-DNPC	Sistema Federal de Emergencias - Dirección Nacional de Protección Civil
SNA	Social network analysis
SOPs	Standard Operation Procedures
TAM	Technical Advisory Mission
UN	United Nations
UN OCHA	United Nations Office for the Coordination of Humanitarian Affairs
UNDP	United Nations Development Programme
UNDRR	United Nations Office for Disaster Risk Reduction (formerly UNISDR)
UNISDR	United Nations International Strategy for Disaster Reduction
UNITAR	United Nations Institute for Training and Research
UNOOSA	United Nations Office for Outer Space Affairs
UNOSAT	UNITAR Operational Satellite Applications Programme
UNSD	United Nations Statistics Division
UN-SPIDER	United Nations Platform for Space-based Information for Disaster Management and Emergency Response
USA	United States of America
USGS	United States Geological Survey
VGI	Volunteered geographic information
WFP	World Food Programme
WG	Working Group
WMO	World Meteorological Organization
ZKI	Center for Satellite based Crisis Information at the DLR

1. Introduction

1.1. Problem definition and background

In the modern changing environment, the probability of extreme weather events is constantly growing. While some regions experience severe droughts, others suffer from unpredictable and devastating floods. Climate change is often regarded as one of the forces that can amplify the frequency and intensity of natural disasters (Coronese *et al.* 2019). At the same time, there is a number of other factors that also can affect communities' exposure, vulnerability, and the overall risk of disasters. These can include unsustainable development practices, such as deforestation, food insecurity, unsustainable use of water resources, pollution, as well as uncontrolled or poorly planned urban development and expansion (Barasa 2018). All of these factors, combined with natural causes, can lead to more frequent and devastating disasters with increasing losses, both economic and human. Vulnerable populations, namely the poor, elderly, children, and women, are often among the most severely affected by such extreme events (Benevolenza and DeRigne 2019).

A major part of the ongoing population growth will belong to urban areas. Already in 2009, the global urban population exceeded the rural population (UN DESA 2010). By 2050, it is expected that 66% of the total world population (or more than 6 billion people) will live in cities (UN DESA 2014). This will inevitably lead to the appearance of new settlements and to the rapid growth of the existing ones. Such trends will result in huge challenges to be faced by cities in terms of basic infrastructure and availability of financial and other resources. In addition, the growing population of highly dense communities can lead to increasing rates of urbanization and related colonization of traditionally unoccupied and potentially unsafe territories, for instance, floodplains.

In the past, a traditional approach to dealing with disasters focused more on managing emergencies post factum, through disaster response and recovery. Nowadays, much more attention is paid to the pre-disaster phase, particularly disaster risk reduction (DRR). However, even though investments in prevention and preparedness are believed to bring down the costs of post-disaster activities, the availability of financial resources and the level of involvement often remain a significant challenge (Meerkatt *et al*. 2015; UNDP 2015; World Bank and United Nations 2010). While the need for a proactive approach in dealing with disasters is already widely recognized, this crucial principle is still not fully realized in many aspects of disaster management. The adoption of new technologies must happen before the disaster to ensure the thoughtful and deliberate application of such tools in case of an event. The importance of the "shift towards managing risks rather than emergencies", as emphasized by Brecht et al., remains a valid concern (Brecht *et al.* 2013).

Another noticeable change in recent years is the wider use of the term disaster resilience, which can be considered as more positive and proactive in nature (Simonovic 2016). At the same time, the role and influence of the global frameworks which promote such changes and shifts in approaches might be considered limited in terms of actual implementation due to their non-binding nature and resistance embedded in the institutional structures of the countries (Raikes *et al.* 2022).

Continuing information revolution reshapes perception and spheres of application of the existing and emerging information and communication technologies (ICTs). Throughout the past decades, these changes affected every aspect of the functioning of modern societies, including the domains of disaster management and humanitarian response (Quarantelli 1997; Stephenson and Anderson 1997). In recent years, the rise of "big data" could be considered as one of the most noticeable shifts which can bring a lot of new opportunities, as well as sometimes unexpected challenges (Yu *et al.* 2018). The information revolution was accompanied by drastic changes and advances in various scientific disciplines, including geography, and related approaches, methods, and technologies (Li *et al.* 2022). The field of geography now includes new branches, such as geographic data science, which incorporates novel data-driven applications, incorporating big data, artificial intelligence, and other innovative approaches (Li *et al.* 2022; Scheider *et al.* 2020).

As disasters in most cases are inherently spatial phenomena, the use of geospatial information and related technologies is crucial for successful disaster risk reduction and management activities (Herold and Sawada 2012). The value brought by the applications of the geospatial data and technologies for addressing the risk of emergencies and dealing with their consequences is quite widely accepted (Abdalla and Li 2010; Herold and Sawada 2012; Manfré *et al.* 2012; National Research Council and Mapping Science Committee 2007; Pirasteh and Varshosaz 2019). As one example, satellite observations can serve as a complementary source of data to traditional in situ measurements (Manfré *et al.* 2012), but such remotely sensed information can also help fill in any gaps in data collection or provide information on the areas which otherwise cannot be easily accessible or need most rapid data provision. This aspect is particularly crucial in the case of disaster response, for which it is difficult to overestimate the role of timely and concise information (Voigt *et al.* 2016). In addition, geospatial technologies, particularly free and open source solutions, can be of great support for developing countries, which often might not have enough resources and infrastructure to address the increasing risks of disaster caused by natural hazards (Herold and Sawada 2012; Thapa 2021).

An important issue lies in the existing discrepancy between the diversity of relatively easily accessible space-based information and technologies and their sometimes limited or not as successful application by the end-users. On one hand, this gap might lie between more and less developed countries, due to the differences in the availability of required resources and local capacities to make use of geospatial ICTs (GeoICTs). Particularly, the need to promote and disseminate space-based data, technologies, and related services, including through technological transfer, and enhancing related capacities, was expressed in Sendai Framework for DRR, specifically mentioning the need to support developing countries (UNISDR 2015b).

To propose any solutions to tackle existing challenges, it is important to first identify existing gaps, particularly in terms of the area (countries, territories) covered by such ICTs. Since it is a very difficult task to establish the actual adoption rate of geospatial technologies overall and on a global scale, it might make sense to limit the scope to a specific case of such innovations. For instance, satellite-based emergency mapping (SEM) mechanisms can be used as such an example due to their global scale, open archives, consistent reporting, and relatively easy and free process for countries to get involved (the potentially low threshold for adoption).

Another gap that needs to be bridged lies between the research communities and data providers, which develop new technologies, on one hand, and the community of actual end-users that are applying these innovations to address specific issues. One of the serious issues in the field of disaster management is the absence of a common understanding of how ICTs should be developed, how they should be distributed among potential users, and how the results of the technology application can be assessed (Mendonça and Bouwman 2008). Deeper cooperation between the research community and practitioners can provide many benefits for both sides (Mendonça and Bouwman 2008; National Research Council 2007). To ensure deliberate data-driven decision-making in securing community resilience, there is a need to enhance or even establish such connection, to help both groups make better-informed decisions, knowing each other's actual demands and issues.

1.2. Aim and research questions

This research explores existing challenges in the application of geospatial technologies, particularly space-based, for disaster risk reduction and management, focusing on the diffusion of such innovations in the field. The aim is to contribute to strengthening the disaster resilience of countries by analyzing the current state of the use of space-based information and technologies by national authorities across the world. To fulfill this goal, three main research questions (RQ) are answered:

RQ1: What are the existing mechanisms of promotion, diffusion, and application of relevant geospatial technologies in DRR?

RQ2: What are the major gaps in the application of space-based technologies, the main needs of end-users, and corresponding obstacles and challenges in the diffusion and adoption of such technologies?

RQ3: What are the suitable solutions and potential approaches, as well as promising innovations, that can help tackle or at least mitigate these challenges?

Corresponding objectives and respective main steps of the research are presented in chapter 4. Research design and methodology.

1.3. Contribution and expected outcomes

The collection of data from various sources on the existing international mechanisms that support dissemination and adoption of geospatial ICTs, as well as on encountered issues in their application, allowed to produce the work that can help facilitate a better understanding of the process of diffusion of geospatial innovations, identify related challenges and opportunities, specific for the disaster management field, as well as contribute to the promotion of the application of modern space-based technologies across communities in need.

There is a limited number of studies that apply the diffusion of innovations theory in the disaster management context and that do not focus specifically on post-disaster crisis communication (Secara and Bruston 2009; Taylor and Perry 2005). The satellite-based emergency mapping (SEM) mechanisms were introduced as an example of both a successful and still expanding initiative, that helped identify the most prominent gaps in their dissemination across the world. While a comprehensive review of the SEM mechanisms was conducted by Voigt *et al*. (2016)

relatively recently, current research is introducing an unconventional approach to studying the network structure of organizations and countries involved in the SEM activations, covering a wider timeframe. Network analysis was applied to assess the performance of mechanisms' members and partners, identify the most affected countries and most frequent connections between organizations and territories struck by disasters, investigate clustering patterns of organizations and countries. To the author's best knowledge, no similar study had examined SEM mechanisms using such methodology and exploring them in this detail and in comparison to each other.

Another noticeable contribution of the research is in the analysis of the reports from the Technical Advisory Missions (TAMs) carried out by the United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER), a programme implemented by the United Nations Office for Outer Space Affairs (UNOOSA). These reports normally are not published and are not accessible to the public. However, these documents were made available for analysis through the internship at UNOOSA, and permission to use them for the PhD research was granted. These reports provide a detailed and comprehensive overview of the current state and main challenges faced by the countries visited by the UN-SPIDER. Due to the sensitivity of this information, it was agreed that the results of the analysis would be provided in a generalized form, without references to particular countries. Still, to the author's best knowledge, TAM reports were never analyzed jointly, as one dataset, summarizing the challenges and proposed recommendations.

Finally, the research attempts to present and explore the diversity of existing challenges in the application of geospatial technologies in a systematized way and provide corresponding solutions. While a number of studies discuss issues typical for the application of GeoICTs in the DRR field, the current dissertation tries to introduce a comprehensive list of the challenges by bringing together findings from the analysis of various data sources. An interesting aspect that was explored was the reasons that prevent a timely adoption of innovations, from the positions of both technology developers/providers and end-users (potential adopters). Apart from some well-known difficulties, like financial issues or lack of specially trained users, it was possible to identify more complex problems that limit the diffusion of space-based technologies and to propose some ways to successfully overcome related challenges.

1.4. Structure of the dissertation

The dissertation is structured around the following chapters:

- Chapter 1 introduces the problem and presents the main aim and research questions.
- Chapter 2 reviews relevant literature on DRR, including the main definitions used in the field and this study, global trends in the occurrence of natural disasters, and main concepts of the disaster management theory, including the disaster management cycle.
- Chapter 3 covers geospatial technologies and the diffusion of innovations theory, exploring existing literature on the known challenges and issues in the implementation of ICTs in general and GeoICTs specifically.
- Chapter 4 presents the research design and methodological approach of the present research, as well as the faced limitations. It introduces the main data collection and analysis techniques used in this study, while some additional details of specific aspects of such processes are also mentioned in empirical chapters.
- Chapter 5 introduces international mechanisms that support the wider diffusion and adoption of GeoICTs. It provides the analysis of the main international frameworks for DRR, particularly addressing the role assigned to information and knowledge management, technology, and innovations. It explores the situation with the SEM mechanisms that can be considered as facilitators of the GeoICTs diffusion. Finally, the chapter introduces UNOOSA and its UN-SPIDER programme, as one of the main global

initiatives involved in the assessment and development of countries' capacities in terms of the application of GeoICTs in disaster management.

- Chapter 6 provides an analysis of activations of the selected SEM mechanisms (initiatives that provide access to satellite-based information and technologies in case of disasters), including network analysis.
- Chapter 7 explores the main issues and needs related to the application of geospatial ICTs in disaster management from the perspective of end-users, through the analysis of the UN-SPIDER missions’ reports.
- Chapter 8 discusses the main identified issues, following the structure determined by the results of the TAM reports’ analysis, bringing together findings from various data sources. It examines the challenges faced by various stakeholders, mainly end-users from developing countries, and considers various potential mitigating factors, solutions, and recommendations to tackle these challenges.
- Chapter 9 presents the overall conclusions of this study and discusses the main considerations and areas for further research.

2. Disaster risk reduction and management

The first part of the following chapter introduces basic definitions used in disaster management (*Hazard*, *Disaster*, *Exposure*, *Vulnerability*, *Risk*), presents the main concepts of the disaster management theory, and discusses some of the existing challenges in the field. It is followed by a more detailed review of the elements of the disaster management cycle and related notions. The next section discusses information and knowledge management in DRR. The last part of the chapter briefly introduces some trends in the occurrence of natural disasters.

2.1. Disaster management theory

2.1.1. Main definitions

Before introducing the definition of the term "*Disaster*", it is important to focus on the basic understanding of the notion itself. In this regard, the most significant aspect is the interconnection between natural hazards, as sources of various perils, and the affected population, as the receiver, characterized by its vulnerability. Disaster occurs at the intersection of these two features. The disaster risk arises when hazards interact with vulnerabilities (physical, social, economic, environmental).

The main definitions are presented in Table 1, in the form of a comparison of two relevant sources – Emergency Events Database (EM-DAT) and the updated UNISDR Terminology on Disaster Risk Reduction, modified following the report of the intergovernmental expert working group on indicators and terminology relating to DRR (adopted by the United Nations General Assembly in 2017) (UN General Assembly 2016).

In the disaster management field, there is a lack of common opinion even regarding some of the most basic definitions (which is discussed in the following section in more detail). The comparison provided in Table 1 might help clarify some general aspects of the terms Hazard, Disaster, Vulnerability, and Risk. The specificity of the EM-DAT definitions can be explained by the fact that EM-DAT is an international disaster database and its understanding of the basic concepts aims at facilitating comprehensive and comparative data collection and storage. The UNDRR terminology, on the other hand, exists for the promotion of a common understanding among various stakeholders, particularly in relation to the implementation of the Sendai Framework for DRR (SFDRR) and achieving Sustainable Development Goals (SDGs).

Table 1. Comparison of main definitions in DRR

	EM-DAT Glossary	**UNDRR Terminology on DRR**
Hazard	Threatening event, or probability of occurrence of a potentially damaging phenomenon within a given time period and area.	A process, phenomenon or human activity that may cause loss of life, injury or other health impacts, property damage, social and economic disruption or environmental degradation.
Vulnerability	Degree of loss (from 0% to 100%) resulting from a potential damaging phenomenon.	The conditions determined by physical, social, economic and environmental factors or processes which increase the susceptibility of an individual, a community, assets or systems to the impacts of hazards.
Risk	Expected losses (of lives, persons injured, property damaged and economic activity disrupted) due to a particular hazard for a given area and reference period. Based on mathematical calculations, risk is the product of hazard and vulnerability.	The potential loss of life, injury, or destroyed or damaged assets which could occur to a system, society or a community in a specific period of time, determined probabilistically as a function of hazard, exposure, vulnerability and capacity.
Disaster	Situation or event, which overwhelms local capacity, necessitating a request to national or international level for external assistance; an unforeseen and often sudden event that causes great damage, destruction and human suffering.	A serious disruption of the functioning of a community or a society at any scale due to hazardous events interacting with conditions of exposure, vulnerability and capacity, leading to one or more of the following: human, material, economic and environmental losses and impacts.

Source: EM-DAT Glossary (Guha-Sapir et al. 2016) and updated UNDRR Terminology on DRR (UN General Assembly 2016).

According to the introduced definitions, *Hazard* is characterized as a threatening event (or phenomenon) that can potentially cause some losses and damages. An additional important term that is not clearly identified in EM-DAT Glossary, but certainly should be mentioned, is *Exposure*, which is defined by the UNDRR terminology as “[t]he situation of people, infrastructure, housing, production capacities and other tangible human assets located in hazard-prone areas” (UN General Assembly 2016). Following this definition, the conditions that increase susceptibility to hazards are represented through *Vulnerability*. The *Risk* manifests itself through the combination of potential hazardous events and characteristics related to exposure, vulnerability, and available capacities. And finally, the *Disaster* is an event that causes serious disruption through widespread losses and damages. The term *Emergency* is often used interchangeably with the term *Disaster* (UN General Assembly 2016).

While climate change may influence the frequency and severity of natural hazards through changes in temperature and rainfall patterns, disasters themselves are defined by the presence of people or assets at risk, so the impact of the disaster depends on the distribution of population and assets and other related characteristics.

The earlier definition of the UNISDR (UNISDR 2009) mentioned that disasters cannot be overcome using only the own resources of a community, which rather clearly corresponds to the definition used by the EM-DAT. The updated UNDRR terminology removed this aspect from the definition while acknowledging them in the comments to the proposed terminology. This aspect remains important for EM-DAT, as this database is particularly focused on collecting records only of major disasters. The UNDRR introduces a more general definition that covers both local and more widespread disasters, allowing more events to correspond to this term.

In addition, the UNDRR terminology provides definitions for a number of other relevant concepts, which should be introduced. First of all, *Resilience* is defined as “[t]he ability of a system, community or society exposed to hazards to resist, absorb, accommodate, adapt to, transform and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions through risk management”. Among other important definitions, UNDRR introduces *disaster management* as “[t]he organization, planning and application of measures preparing for, responding to and recovering from disasters”. *Disaster risk reduction* is defined as “aimed at preventing new and reducing existing disaster risk and managing residual risk, all of which contribute to strengthening resilience and therefore to the achievement of sustainable development”. *Disaster risk management* is “the application of disaster risk reduction policies and strategies to prevent new disaster risk, reduce existing disaster risk and manage residual risk, contributing to the strengthening of resilience and reduction of disaster losses” (UN General Assembly 2016).

2.1.2. What is a disaster?

One of the crucial components of the disaster management theory, the notion of a “*disaster*”, has been a subject of serious debates. An American sociologist working on the social aspects of the disasters, Enrico Louis Quarantelli, has been concerned with this topic for a long time and has edited two books on the issue – “What is a Disaster?: A Dozen Perspectives on the Question” (1998) and “What is a Disaster?: New Answers to Old Questions” (2005). Big parts of these books discuss the issues with technological or man-made disasters (such as industrial accidents or terrorist attacks). However, taking into account the concept of vulnerability and, thus, regarding any particular disaster as a socially constructed event, the distinction between technological and natural disasters becomes relatively vague. So, the notion of a disaster should be found in this intersection of social and natural components.

Theoretical issues in the field of disaster management are indeed worth dealing with since existing misunderstandings can complicate the data collection and processing. Applied concepts and definitions determine the way of interaction with the disaster events, what information is considered to be relevant, and what potentially can be omitted (Perry and Quarantelli 2005). However, the goals of the researchers and end-users of the produced research quite often can be considerably different. The tasks, identified by practitioners, can have very little use for deepening knowledge and understanding of the concept of disaster (Perry and Quarantelli 2005).

2.1.2.1. Basic equation

It is possible to introduce a simple formula that describes the main variables, leading to a disaster:

$$D = T + V,$$

where T represents a *Trigger (*in the case of disaster management we can say, a natural hazard); V stands for *Vulnerability*; and a combination of these two factors results in a *Disaster* (McEntire 2004). While natural hazards most of the time cannot be directly controlled, when dealing with disasters we should address vulnerabilities, which can be managed (McEntire 2004). Some later studies expended the equation, focusing more on the aspect of risk (Olson *et al.* 2020). The updated formula is defined as:

$$DR = H + Ex * V,$$

where the *Risk of a Disaster* (DR)[1] is a function of a *Hazard* (H) (similar to a *Trigger* in the earlier version of an equation) and human and asset *Exposures* (Ex) crossed with the *Vulnerabilities* (V) of those exposures (Olson *et al.* 2020). Such changes in the basic understanding introduce a more comprehensive approach to a community's resilience in the face of a disaster, as well as show a clear shift toward the need for proactive measures to address the risks.

However, disaster management still does not have a very clearly developed theoretical base. Some of the issues in the field can be identified right at the level of main definitions – what is

[1] Or a risk of an emergency or a catastrophe, as introduced in the original equation (Olson *et al*. 2020).

a disaster, disaster (or emergency) management itself, resilience, etc. (McEntire 2004). At the same time, the process of preparation and formulation of the SFDRR helped overcome some of the related challenges. Similar is the role of all the following activities aimed at the monitoring and implementation of the related international frameworks and agreements, including the work of the intergovernmental expert working group on indicators and terminology relating to DRR (UN General Assembly 2016).

2.1.2.2. Main concepts

Disaster

As a social scientist, Quarantelli supported a social construction viewpoint on disasters and argued that any disaster is rooted in the shortcomings of each particular social system, and that disaster is not a consequence of some external hazard but of internal weaknesses of the affected community (Perry and Quarantelli 2005). So it is important not to focus only on direct losses and damages, but rather on the disrupted social systems and processes:

> "If there are no negative social consequences, there is no disaster" (Perry and Quarantelli 2005)

According to Perry and Quarantelli (2005), two fundamental features of the disasters are:

1. disasters are inherently social phenomena;
2. source of disasters is rooted in the social structure or social system.

While scholars generally accept this understanding of disasters, often it is not actually implemented in research or applied studies (Perry and Quarantelli 2005). For these ideas to be fully accepted, there is a need to change some of our basic notions related to disasters – to move from natural concepts of time and geographic space to social time and social space (Perry and Quarantelli 2005).

Another related issue that should be considered is the need to focus on disasters and not hazards. As long as the disaster is regarded as a consequence or some kind of by-product of the hazard, it will be perceived as a secondary event, while the disaster phenomenon itself is indeed much more important than the hazard (Perry and Quarantelli 2005).

A wide range of different approaches to addressing disaster management was collected in books, edited by Quarantelli ("What is a Disaster?" 1998 and 2005). Quarantelli expressed the idea that while disasters can be regarded as social events, sociological theories rarely are used to study such events (Perry and Quarantelli 2005). Such relevant and potentially practical theories include: the "Attribution" theory (Social Psychology); "Satisficing" theory (Social Organizational Theory); Diffusion Studies (diffusion of innovations), which according to some studies might be successfully applied in case of, for instance, GIS technologies (Gatrell and Vincent 1990); Networking Theory; the concept of "Social Capital" (Perry and Quarantelli 2005); as well as Systems theory and Chaos theory.

Vulnerability

In the past, physical characteristics of disasters were getting much more attention than such a vital element of disaster management as vulnerability, which hasn't been considered among the most important issues (McEntire 2004). Natural hazards were regarded as the direct and principal cause of the community's vulnerability (Anderson 1995). However, what is actually converting hazards into disasters are social aspects. Already in the Yokohama Strategy and Plan of Action for a Safer World, it was expressed that vulnerability is a result of human activity (UN IDNDR 1994). Without affected people or assets, there is no disaster.

Nowadays, the importance of the concept of vulnerability is widely accepted, nevertheless, further acknowledgment and development of the concept are needed (McEntire 2004). While hazards cannot be controlled, as well as risks cannot be eliminated, one of the most effective ways to deal with disasters is to mitigate existing vulnerabilities (McEntire 2004).

In a number of his works, McEntire emphasized the importance of the concept of vulnerability (McEntire 2003, 2004, 2005; McEntire *et al.* 2002). He stresses that vulnerabilities represent the only aspect of disaster management that actually can be controlled. Drabek as well supports the relevance of *community vulnerability*, as one of the most significant concepts in disaster management, which according to him is "a reflection of prior events and community social trends such as population changes including both size and physical location" (Drabek 2004).

Exposure

The role of community exposure, as a crucial component that defines the disaster (particularly disaster risk), was introduced later than the other two main elements. Perry and Quarantelli in their work did mention the exposure to the hazards, however in a rather brief way, generally in terms of simple geographic scale, the actual space that is affected by an event (Perry and Quarantelli 2005). While in the earlier periods of disaster management theory formulation, exposure was not fully recognized, growing damages to constantly increasing human population, expanding infrastructure and other assets indicated the need for this additional component (Olson *et al.* 2020). The concept of exposure helps capture the situation with the people and tangible assets that potentially can be affected by the hazards, and helps better reflect and address current challenges, partially related to global urbanization patterns (UN General Assembly 2016).

Resilience

Assessing the efficiency of disaster management activities is commonly recognized as a quite problematic issue (Abrahamsson *et al.* 2010; McConnell 2011; Owen *et al.* 2016), particularly due to the subjective nature of "success" in this field. The great number of actors involved in disaster management, especially during the response stage, can perceive achievements differently depending on their agenda and goals. Most attempts at evaluation focus on some specific aspect of the situation, while only an overarching approach can help assess the bigger picture (Owen *et al.* 2016).

In recent UN publications, the term "resilience" is often used as an overall outcome of disaster risk reduction activities, as well as climate change adaptation, poverty alleviation, and sustainable development (UNISDR 2017a). After the adoption of the Sendai Framework, the UNDRR updated its older terminology, and some particularly interesting changes can be noticed in the case of the "resilience" definition (phrases that are bold and underlined were added to the definition):

> *Resilience*: "[t]he ability of a system, community or society exposed to hazards to resist, absorb, accommodate, **adapt to, transform** and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions **through risk management**" (UN General Assembly 2016).

The new definition clearly emphasizes the importance of disaster risk management activities and incorporates adaptive capacity as one of the essential elements of any resilient system. Following this trend, it is possible to use the concept of "community resilience" and its improvement over time to reflect on the work done and even to measure the overall progress in DRR. In the new paradigm, the focus is shifted from disaster management to risk management, thus the efficiency of activities can often be regarded mainly in relation to risk prevention.

2.1.3. Challenges

Disaster management (or emergency management, as referred to in some countries, for instance in the USA) is a relatively new field that can be characterized as an intersection of various contributing disciplines, like geography and sociology (the two disciplines, from which the disaster management have started its development), as well as economics, urban studies, psychology, engineering, education, medicine, etc. (McEntire 2004). There remains a lack of agreed-upon definitions in the disaster management theory's main concepts (for example –

disaster, vulnerability, risk, resilience, etc.), which at the same time does not lower the relevance of the discipline itself (Jensen 2010). The present study generally relies on the main definitions, as defined by the UNDRR, which were introduced earlier in this chapter (UN General Assembly 2016).

In the disaster management field, the notions of the general concepts and definitions are intimately connected to each other, and determine each other, starting from the most basic concept of hazard. Those interlinks between the main concepts are still not revealed entirely and understood completely. The same type of issues can be applied when dealing with other components of the theory, yet there is an additional problem of the underuse of already existing, more or less developed, classifications, typologies, and theoretical models, which should be recognized (Jensen 2010).

The disaster management theory itself might not be that well recognized due to some obstacles like the lack of consensus on some of the main definitions or prioritization of the disaster phases (McEntire 2004). This situation brings the need for additional research, which could be based on a point of view different from the deep-rooted concepts of the discipline. A number of interesting approaches and theoretical models already exist in the field and their possible applications in emergency management should be explored and studied further (Perry and Quarantelli 2005).

At the same time, there are two quite different positions on whether there is a way to formulate a solid theory of disaster management. It either will be possible at some point in the future, or it is both impossible and not actually necessary, due to the very nature of this specific field (Drabek 2004; McEntire 2004). Thomas Drabek (2004) advocates for the creation, or rather construction, of the theory of disaster management based on various existing concepts, models, relevant micro theories, etc., and even regards this as a main goal for the research community.

Nevertheless, even he considers the theory in its current state as quite functional and useful for practitioners (Drabek 2004).

As already mentioned, there is a widely recognized need for a shift from a reactive to proactive approach, without forgetting that it is impossible to completely avoid all risks (McEntire 2004). Perrow introduces the notion of "normal accidents" when discussing the problems related to high-risk technology and the inability to escape all risks in such complex systems (Perrow 1984). Quarantelli extends this notion to the disasters as unavoidable consequences of over-complicated social systems (Perry and Quarantelli 2005).

Already in 1994, at the World Conference on Natural Disaster Reduction, it was clearly stated and formulated in the Yokohama Message, that the focus on disaster response and recovery is inefficient and it is essential that such an approach is changed (UN IDNDR 1994). Yet, up until now, the discussion continues, and this need is expressed again and again.

Nowadays adherence to a reactive approach in disaster management can still be clearly seen through the patterns in the funding of related activities. The share of humanitarian assistance going to prevention activities increased from 0,1% in 2001 to 0,7% in 2008 (Harmer *et al.* 2009). While international aid to address disasters is increasing, including spendings before such events (on prevention, mitigation), as well as after (on emergency response, reconstruction), the share of funds going towards DRR activities remained relatively small (Watson *et al.* 2015). Humanitarian assistance of the OECD DAC[2] donors in 2013 reached 5% (Swithern 2015), in 2015 - already 8.4% (CRS 2021). Humanitarian aid (immediate relief and response) generally provides crucial, but often short–term effects, while the actual development requires long-term expenses on prevention and mitigation activities (World Bank and United

[2] Organisation for Economic Co-operation and Development (OECD) Development Assistance Committee (DAC)

Nations 2010). Samaritan's Dilemma: "The inability to deny help following a disaster to those who have not taken sufficient prevention measures" (World Bank and United Nations 2010).

Another issue is related to the fact that is hard to measure the progress in building the resilience of any particular community. There remains a need to establish a comprehensive system of indicators, to accurately measure the changes and overall progress (Clark-Ginsberg *et al.* 2020).

2.1.4. Community involvement in disaster management

International frameworks and strategies, starting from the Yokohama Message in 1994, emphasized the importance of community involvement in disaster management (UN IDNDR 1994; UNISDR 2005b, 2015b). Community, resilient to disasters, can be described as "the safest possible community that we could design and build in a natural hazard context" (Twigg 2009). Communities must be well informed about existing risks. Cities, local governments, and communities play a key role in the implementation of disaster management programs. And ultimate objective of DRR in cities is to produce resilient cities. There is a need to step back from the command and control tactic in disaster management and promote more decentralized decision-making and community-based approach, where communities act as active participants in disaster management programs.

The World Disasters Report for the year 2015, developed by the International Federation of Red Cross and Red Crescent Societies (IFRC), was even devoted to the local actors and the role they play in disaster management (IFRC 2015). The importance of a community-based approach was specified, including the capacity development at town and district levels, and the promotion of active participation of NGOs (both local and international). However, the need for better cooperation and coordination was expressed, since the implementation of such a local approach will inevitably lead to an increase in the total number of involved participants.

At the same time, IFRC highlighted that access to technology remains a serious problem – the *digital divide*, "the inequalities created by technology", is changing in nature, but still exists (IFRC 2015). Some of the traditional reasons for inadequate access are poverty and location, yet there are some other relevant barriers, such as digital illiteracy, language, and gender, not the coverage or cost (IFRC 2015).

Apart from various positive aspects of the application of technology in facilitating disaster response and humanitarian assistance, there is a dark side to widespread technology. Sometimes it can be especially harmful in cases of disasters or conflicts, for instance, the unconscious or deliberate distribution of inaccurate or false information (IFRC 2015).

While technological innovations in the field of disaster management might have great relevance and potential significance, the IFRC World Disaster Report emphasized that end-users should be familiar with technology to be able to successfully apply it. In case of a disaster, there is often no option for time-consuming training (IFRC 2015). In the report, IFRC provides a short checklist, which can help communities to identify the leave-behind technologies (IFRC 2015), which covers the following aspects to consider:

- relevance;
- maturity level of actors or organizations;
- project management;
- exit strategy;
- electronic waste.

Talking about the involvement of local actors, IFRC notes that it is important not to focus only on what the international community can give to them, but also on what is possible to get from them (IFRC 2015). Since approximately 2009, a new phenomenon related to technological exchange was popularized – the *reverse innovation*, which brings "low-end products created specifically for emerging markets into wealthy markets" (Immelt *et al.* 2009). This approach is regarded as the opposite of globalization, through which generally Western technology is distributed worldwide. The IFRC provides a few examples of such reverse innovation, when technologies, developed in low- and middle-income countries, later find their application in emergency response globally (IFRC 2015): missed calls; laptop-based portable ultrasound device; Ushahidi (crowdsourcing platform).

Taking into account this trend, it is possible to consider the shift from the traditional "assess and build" approach in humanitarian assistance ("assess the situation, gather requirements, specify the project, build it, test it and deliver it"), to "discover-and-harvest" approach, which is about looking for potentially useful technologies at the local level, and then "harvesting" them for wider application (IFRC 2015). The "discover-and-harvest" approach has several advantages: the pilot study on a local level had already been done and it is known that the technology is working; it was tested in the field; it was already adopted by some group of people (IFRC 2015).

2.2. Disaster management cycle

2.2.1. Main definitions

The disaster management cycle (sometimes also called the disaster phase model), which describes the progression of activities in relation to a disastrous event through several clear stages, remains the most commonly used and widely applied model in emergency management (Dahlberg *et al.* 2015). Most often, the cycle includes four stages – response, recovery, mitigation (reduction), and preparedness (readiness). The visual representation of the cycle is introduced in Figure 1. Apart from such interpretation, the stages can also be presented as parts of an infinite spiral, which ideally should be bringing communities closer to the adaptation with each round (Christoph *et al.* 2013).

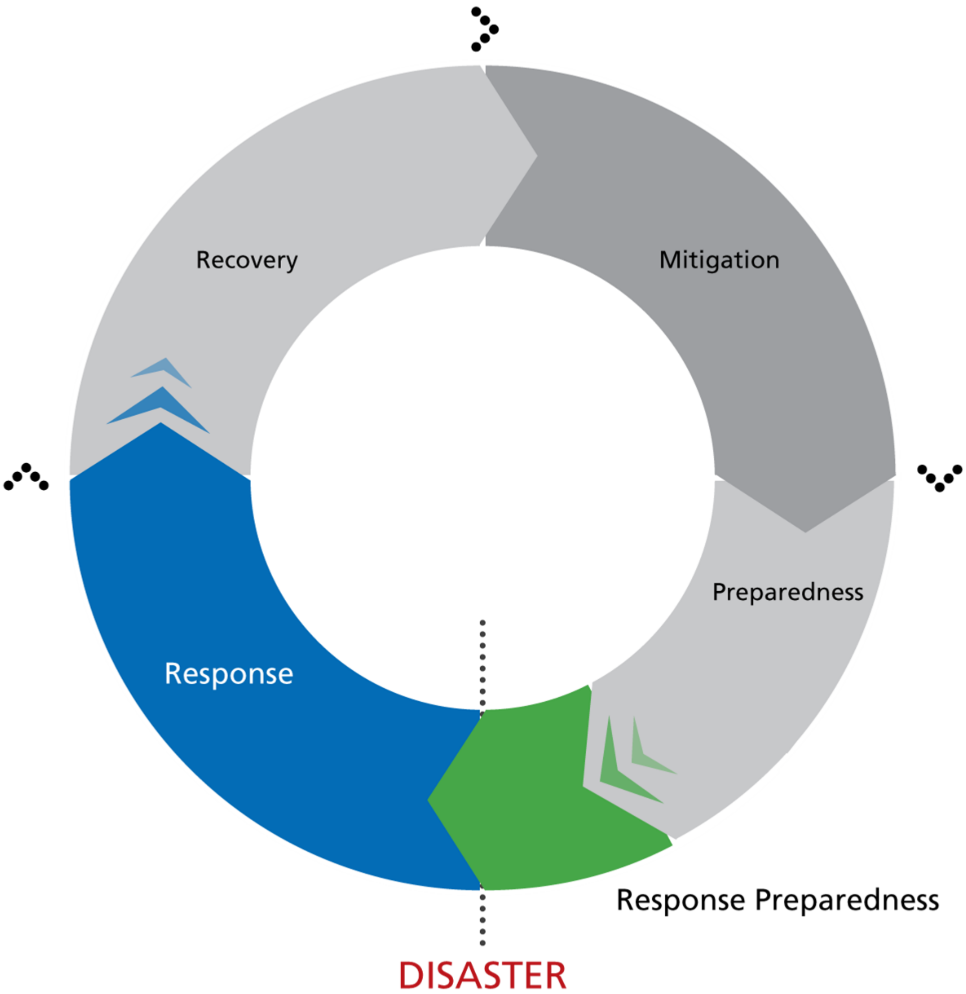

Figure 1. Disaster management cycle

Source: UN OCHA 2018.

At the same time, it is important to mention that the number and names of the phases of the cycle, as well as corresponding definitions, may vary depending on the specific organization or country (for instance, using prevention in addition or instead of mitigation, etc.). Table 2 presents definitions of the main stages of the disaster management cycle, according to the UNDRR terminology on DRR (UN General Assembly 2016), including prevention. Just as an example of the differences in interpretations of the basic DRR terminology, the most recent UNDRR's definition of the response phase includes activities even before the disaster if they directly contribute to the preservation of life, and not only during or immediately after a disaster. A relatively recent publication of the UN Office for the Coordination of Humanitarian Affairs

(OCHA) still was referring to disaster response in terms of interventions only during or immediately after a disaster. At the same time, it introduced a notion of emergency response preparedness, as a set of related activities that take place before the disaster (UN OCHA 2018).

The Yokohama Strategy and Plan of Action for a Safer World (UN IDNDR 1994) even stressed the need to incorporate these four phases in international, national, and local strategies and plans (the elements were listed as prevention, mitigation, preparedness, and relief).

Table 2. Definitions of main stages of the disaster management cycle

Phase	Definition
Response	Actions taken directly before, during or immediately after a disaster in order to save lives, reduce health impacts, ensure public safety and meet the basic subsistence needs of the people affected.
Recovery	The restoring or improving of livelihoods and health, as well as economic, physical, social, cultural and environmental assets, systems and activities, of a disaster-affected community or society, aligning with the principles of sustainable development and "build back better", to avoid or reduce future disaster risk.
Prevention	Activities and measures to avoid existing and new disaster risks.
Mitigation	The lessening or minimizing of the adverse impacts of a hazardous event.
Preparedness	The knowledge and capacities developed by governments, response and recovery organizations, communities and individuals to effectively anticipate, respond to and recover from the impacts of likely, imminent or current disasters.

Source: UN General Assembly 2016.

2.2.2. Oversimplification of the disaster management process

The disaster management cycle as a concept is effective to some extent, however, due to the oversimplification of the phases, this most commonly used representation of a disaster management process can limit the overall understanding of such events (McEntire 2004). While the importance of a four-phase cycle in the development of disaster management should not be neglected, there is a need for some alternative points of view, different perspectives on the same issue, and various interpretations, which would include a wider explanation of the disaster phenomena (McEntire 2004).

Some other models exist, but they are not known so well as the disaster management cycle (Jensen 2010), while, it is recognized that this model is oversimplified and does not always reflect the actual inherently complex nature of emergency management (Jensen 2010). Although these four disaster phases are very often considered to be too simple and do not express the real-life situation (McEntire 2004), at the same time, because of their simplicity the disaster management workflow can be expressed very clearly.

As the field of disaster management itself is inherently multidisciplinary, comprehensive and relevant research related to the use of ICT in disaster and crisis management requires consideration of various perspectives on the issue (Mendonça and Bouwman 2008). The implementation of multidisciplinary approaches in education at all stages (undergraduate, graduate, professional) and training for disaster management can be favorable both for future scientific research and practical aspects of disaster management, however, it is often omitted (Mendonça and Bouwman 2008).

The continuous development of GIS, modeling techniques, information and communication technologies in general, and various innovations in the field, have a great influence on the state of disaster management. Sometimes this technological progress has a positive effect, sometimes it can be negative (McEntire 2004). Open information on hazard risk can have unintended consequences – in some places in the US low prices for housing lead to overbuilding along hazard-prone areas (like floodplains), which were occupied by the poorest part of the population, since such territories were the only affordable sites.

Most often countries that are in a state of a disaster emergency find it challenging to coordinate the abundance of resources offered by various relief organizations. Cooperation and coordination among concerned actors is a crucial aspect of disaster management, at all phases of the disaster cycle, and these interactions are clearly social in nature (Perry and Quarantelli 2005). The communication between multiple actors and, consequently, the *control* issue, is the central problem in disaster management, which is especially distinct in the active phase, during and right after the disaster (Mendonça and Bouwman 2008).

All activities and actions in disaster risk management should focus on reducing vulnerabilities and improving capacities. Depending on the nature of the potential risks, it is possible to distinguish two types of risk management actions:

- Planning actions - to reduce vulnerabilities where risk can be controlled.
- Establishing protective mechanisms - to prepare for uncontrollable factors.

Table 3 provides an alternative representation of the main disaster management stages, through the basic activities related to disaster risk management, grouped by just two phases - before the disaster and after. While presenting the disaster management cycle in such form, we can note that these actions may not be actually fixed in some kind of loop, but rather as a continuum. For a proper shift to a pro-active approach, the main focus should be on the pre-disaster phase (ex-ante actions).

Table 3. Basic disaster management actions

Pre-Disaster Phase	Ex Ante Actions	Risk identification
		Risk reduction
		Risk transfer
	Prior	Preparedness
Post-Disaster Phase	During and After	Relief (emergency response)
		Rehabilitation and Recovery
		Reconstruction

2.2.3. Build Back Better

The concept of Building Back Better is an integral part of the recovery phase. The idea and importance of Building Back Better (or Creative Reconstruction) were particularly stressed during the discussion with the International Recovery Platform (IRP), during the research visit to Japan. The idea of creative reconstruction was introduced in Japan after the Great Hanshin-Awaji Earthquake of 1995. The importance of finding a new approach became quite clear after this event since statistics showed that 90% of all deaths that occurred during the earthquake were caused by collapsing buildings. The government decided not to just restore the area as it was before the disaster, but to use this event as an opportunity to address potential future challenges and to "build back better". In the case of Kobe, the city most affected by this event, the area where the earthquake hit the most was transformed into HAT Kobe (Happy Active Town), as a symbol of this reconstruction and new beginnings after such a devastating event (World Bank 2018). This territory near the coast was changed completely and is now a place with a lot of open space and parks, as well as home to many international organizations working in the field of DRR and humanitarian aid.

The Build Back Better approach, widely promoted by the UN, IRP, as well as being indicated in Priority 4 of the Sendai Framework, does not focus only on physical infrastructure (structural measures), but also on non-structural aspects of the reconstruction. It addresses the need to restore all other parts of the society which were damaged by the disaster, including societal systems, people's livelihoods, economies, environment, etc. (Fernandez and Ahmed 2019). This concept also highlights the opportunities provided by such devastating events, urging to use them during the reconstruction. The need to restore some parts of a community/settlement can push the progress further and this process should be used as a way to improve what was before, not to restore the same flawed structure which could not withstand the disaster (Fernandez and Ahmed 2019).

On a similar note, restoring everything in the same way as it was before the event might even be considered unethical, to some degree. The identified vulnerabilities of the old structures should be addressed in the new improved system. It is an especially important topic for highly dense urban areas which were developed without appropriate urban planning, where the most vulnerable population quite often resides (Wisner 2017).

Pre-disaster recovery planning is one of the approaches that can help communities identify their needs and main priorities for recovery and reconstruction before the event. This way, communities would have enough time to thoroughly think about this plan, which later can also help guide post-disaster activities (Kennedy *et al.* 2008; Matsubara and Yamori 2021; Wasley 2014). However, changing people's attitudes towards disaster planning and beliefs is very hard. As was indicated by the representatives of the IRP, if a reactive mindset is dominant and people do not believe in the importance of disaster preparedness, additional data supporting the cause might not be enough to change that.

2.3. Managing data, technology, and knowledge in DRR

2.3.1. Information and knowledge management in DRR

Before introducing examples of international mechanisms that determine common approaches in managing and sharing data, technological innovations, and experience, it is worth defining some relevant concepts. There is a certain level of confusion between *information management* and *knowledge management*, which can often be seen as almost similar notions (Terra and Angeloni 2003). Nevertheless, they deal with different features and have quite considerable contrast with each other.

One of the most significant differences, and probably the one that is determining knowledge management as a discipline, is the focus on people and the processes of learning and sharing experience (Frost 2014). We are dealing with information management when we are handling data, facts, statistics, pure technology; however, knowledge is not so easily understood since it is not as tangible. By moving from just focusing on data to focusing on people, end-users, and their needs, we are shifting from information management to knowledge management (Terra and Angeloni 2003).

In some sense, we can regard knowledge management as a broader concept that includes information management, which can be especially relevant in the case of the DRR, where handling available data can play a critical role in extreme situations. So knowledge management can be considered as a management of a structured understanding, wisdom, know-how, and experience targeted to people (Frost 2014).

As was discussed in earlier sections, disaster risk can be represented as a function of hazard, exposure, vulnerability, and capacity. These four factors should be clearly defined to be able to manage the risk of natural disasters. There are many factors influencing disaster risk management, but some of the most problematic include (De Silva and Burton 2008):

- lack of mechanisms;
- lack of capacity and inefficient use of resources;
- rigid bureaucratic structure;
- lack of knowledge (of disaster risk factors);
- lack of awareness (of populations and institutions).

Local institutions and the general public might not be aware of the risks with which they coexist. In their prevention decisions, people are often guided by available information on hazards. Letting people know they live in a disaster-prone area, for instance, by making disaster risk maps available and easily accessible, could make developers and property owners more aware of the hazards and motivate them to relocate or build appropriately. However, there are cases when such strategy had led to quite opposite results – for example, USA's National Flood Insurance Program (NFIP), run by FEMA.

Introduced in 1968, NFIP allowed individuals to purchase flood insurance, which otherwise they wouldn't be able to afford (Brown 2016). However, instead of encouraging the population of hazardous territories eventually move to safer areas, as was planned initially, the way the program was implemented led to some other results. Besides being a burden for taxpayers, it was stated several times by Congress and in various reports, that this program is operating using outdated and/or just inaccurate flood risk maps (Kunreuther 2017). So being based on, in many cases, actually unreliable zoning, in its current form, the NFIP was even facilitating the constrictions on unsafe territories because the charges were too low and did not reflect the actual cost of building with such risks (Williams 2017). This situation is attracting the poorest population to buy houses in flood-prone areas, while homeowners who actually want to leave and whose only house is situated here, cannot do so, because of the low prices. So, in the end, it is possible to conclude that just the fact that the population is aware of risks and has access to risk maps is not sufficient enough to motivate people to move to safer territories if appropriate and well-developed policies are not in place. As well as the seemingly available risk maps won't automatically help the case, especially if in practice they do not correspond with reality. Some suggestions can be proposed to improve the existing system, including more accurate flood maps, long-term loans, well-enforced building codes, means-tested vouchers (to partially cover the cost of insurance), and private flood insurance (Kunreuther 2021).

Going back to knowledge management, it is possible to list particular aspects of it in relation to DRR:

- information management and communication (appropriate channels and networks; databases on disasters; forms and availability of end-user products);
- education and training (incorporation into basic curricula in schools; locational training; traditional knowledge);
- public awareness (media coverage; visibility raising activities);
- research (risk reduction; improvement in quality and availability of data; methodology-related development; regional collaboration in research).

Tree phases related to the use of information, similar to disaster management phases, can be distinguished:

1. Information pre-disaster – data collection, forecasting, modeling, training.
2. Information during disaster – relief, humanitarian assistance; information distribution; damage assessment.
3. Information post-disaster – Post Disaster Needs Assessment (PDNA).

Already in 1994, in the Yokohama Message, the availability of data and technologies and free distribution of knowledge were mentioned as a necessity for successful disaster reduction activities (UN IDNDR 1994).

2.3.2. Information overload and information deficit

The wide distribution of computers and the internet, the outburst of relevant technologies, that happened in the last two decades, as well as access to online databases and online communities of experts, created great opportunities for better data gathering, data processing, and analysis (Perry and Quarantelli 2005). It is not only possible to collect and aggregate the information much faster today, but now we can obtain some kinds of data that previously was almost impossible to get (like real-time organizational information, and various types of primary data); analyze comparative case studies; make the visualization of the results much more vivid and demonstrative (Perry and Quarantelli 2005). However, most of the time, the deficit of information, affecting the decision-making process, was mentioned as one of the main problems in disaster management:

> "Disasters are almost always characterized by a lack of information" (McEntire 2004).

Prevention decisions are often defined by the available information on hazards, risks, and vulnerabilities. However, there are no universal standards for the collection and storage of data on hazards and other related information. Due to this, sometimes the data exchange, as well as analysis and mapping become difficult. Heterogeneity of available data and sometimes overabundance of duplicated information from various sources can considerably complicate and slow down the decision-making process, which can have disastrous consequences in case of emergency management. Data to examine long-term effects on human welfare also are very limited (Jakubicka *et al.* 2010). Some open-source projects, like Post GIS, Geoserver, Mapserver, and GeoNode.org, can help in dealing with the issue of collecting and sharing information.

Quarantelli often mentions the issue with data collection and particularly the problem or reliability of the available statistical data (Perry and Quarantelli 2005; Quarantelli 1997). From his point of view, it can be quite challenging to distinguish accurate statistics from the abundance of the numbers and various data that can be now easily accessed (Perry and Quarantelli 2005). So he advocates for better statistics, more accurate and even skeptical data gathering (Perry and Quarantelli 2005).

Representative of the Hungarian MAGOR NGO Association for Disaster Response, which brings together professional volunteers supporting disaster management activities, particularly stressed the challenges and complicated aspects of the availability of data in disaster response settings. In the case of victims under the rubble, the highest changes of rescues are within the first 24 hours and start to drastically reduce with every passing day, while the overall information deficit is most common for these first hours after a disaster. This period can be generally characterized by inaccurate maps, no situational overview, and unnecessary risks taken by the first responders. However, within a day or two, the situation can flip, when the reports and maps from various humanitarian and other organizations are starting to come through. At that time, disaster responders might suddenly be overwhelmed by all the information overflow, which still might not always be the most accurate, sometimes duplicating or even contradicting. The response to an earthquake in Haiti in 2010 is often mentioned as an example of such information overload (Van de Walle and Dugdale 2012).

2.4. Global trends in natural disasters

2.4.1. Disaster databases

One of the most comprehensive and detailed international databases on disasters is the EM-DAT: the International Disaster Database, developed by CRED and functioning since 1988. This database is collecting information related to natural and technological disasters starting from 1990, incorporating data from various resources, generally UN agencies, national governments, NGOs, IFRC (Guha-Sapir *et al.* 2015). Compared to other databases, EM-DAT is collecting a wide range of data on all main types of both natural and technological disasters, as well as gathering information on various loss indicators (affected population and damaged assets) (IRDR 2014). DesInventar, as a conceptual and methodological tool, is another important source of information about past disasters.

The EM-DAT has adopted the classification and glossary from the Peril Classification and Hazard Glossary developed by Integrated Research on Disaster Risk (IRDR) research program, promoting standardization of data collection and storage (IRDR 2014). According to IRDR (2014), some of the main issues in existing disaster databases, related to data gaps, include:

1. inconsistency in data collection – temporal coverage (missed years, months);
2. inconsistency in data collection – spatial coverage (regions, communities);
3. absence of the data related to some low-impact/high-frequency events;
4. inconsistent completeness of some indicators.

Other studies mention some additional challenges, related to the limited availability of information on disaster losses, biases in data reporting depending on the source of information, and reporting errors (Kron *et al.* 2012). DesInventar is particularly aiming at addressing some of these challenges, particularly in terms of access to data on disaster losses (Panwar and Sen 2020). While EM-DAT data has been traditionally widely used in academic studies and policy research, DesInventar as a tool is more commonly applied for monitoring and reporting of progress in the implementation of the SFDRR, particularly disaster loss data (Panwar and Sen 2020). The present study is primarily relying on the data available through the EM-DAT, particularly concerning the occurrence of major disasters.

According to the classification developed by IRDR and implemented in EM-DAT, six subgroups of disasters caused by natural hazards can be distinguished, which are then subdivided into several more specific main types (Appendix 1). The EM-DAT also covers technological disasters in their statistics, however, such events were not included in the original classification proposed by IRDR (Guha-Sapir *et al.* 2016).

2.4.2. Temporal trends in disasters occurrence

Available statistical data on the occurrence of disasters across the globe from 1950 to 2021 (based on EM-DAT records) is presented in Figure 2. In this chart, only selected most common types of disasters can be differentiated by different colors, while the total number of all disasters recorded in the database per year is shown by the red line.

A constantly growing number of reported events can be rather clearly seen from this graph. On one hand, the observed trend could be indicating that in recent decades more and more people and assets were affected by disasters. Yet, on the other hand, this situation can be explained by several reasons, including increased uncertainty and frequency of natural hazards due to climate change, as well as the higher vulnerability of the population at risk because of the greater exposure (occupation of disaster-prone areas), or even simply by improved reporting of such events in the last decades.

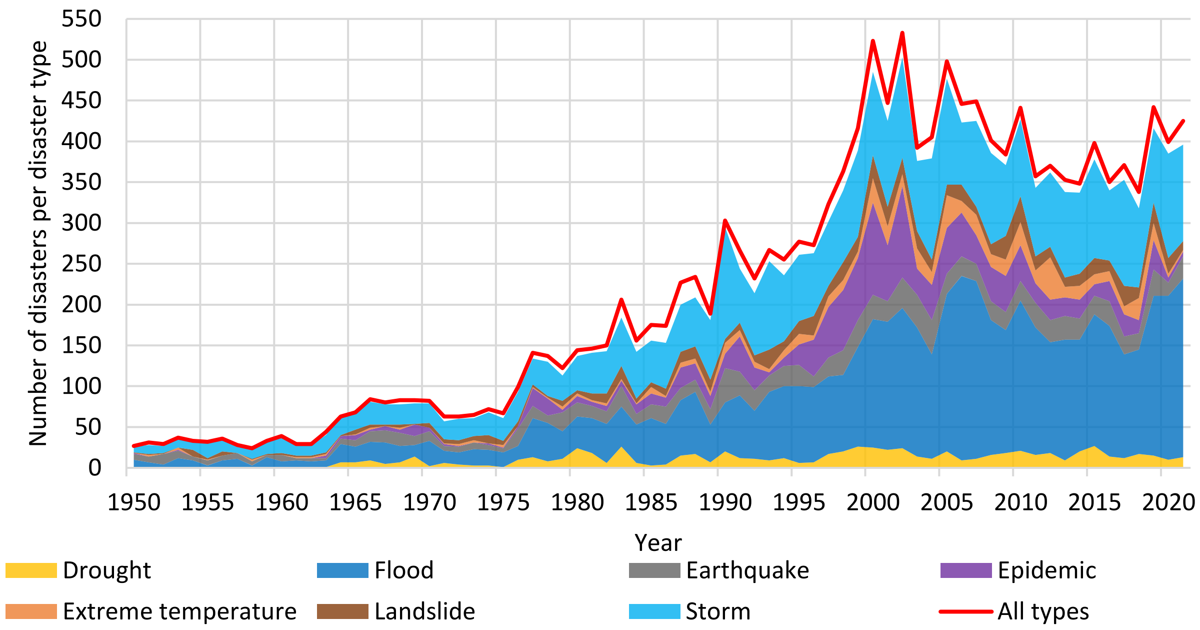

Figure 2. Number of recorded natural disasters that occurred between 1950 and 2021

Data source: EM-DAT (Guha-Sapir et al. 2016).

Overall, almost three-quarters of all events recorded over the 1900-2021 period were hydrological or meteorological in nature. Flood is the most common type of disaster that can be observed globally, followed by storms. Together, they accounted for 63% of all disasters that happen since 1950 (Guha-Sapir *et al.* 2016). Weather-related disasters, particularly floods and storms, apart from being some of the most common types of extreme events, also demonstrated a considerable increase in frequency over the last 50 years (WMO 2021).

Through the review of other recorded data on past disasters, it can be noticed that overall the total number of people killed during such events can even be characterized by a slightly decreasing trend (Guha-Sapir *et al.* 2016; WMO 2021). At the same time, both the total number of affected people, as well as total economic damage are noticeably increasing over the last decades, as can be seen in Figure 3. While economic damages are growing quite noticeably, the number of affected people in recent years could be even considered as slowly decreasing (Coronese *et al.* 2019). Floods and droughts were the two types of disasters that affect the biggest number of people (Guha-Sapir *et al.* 2016).

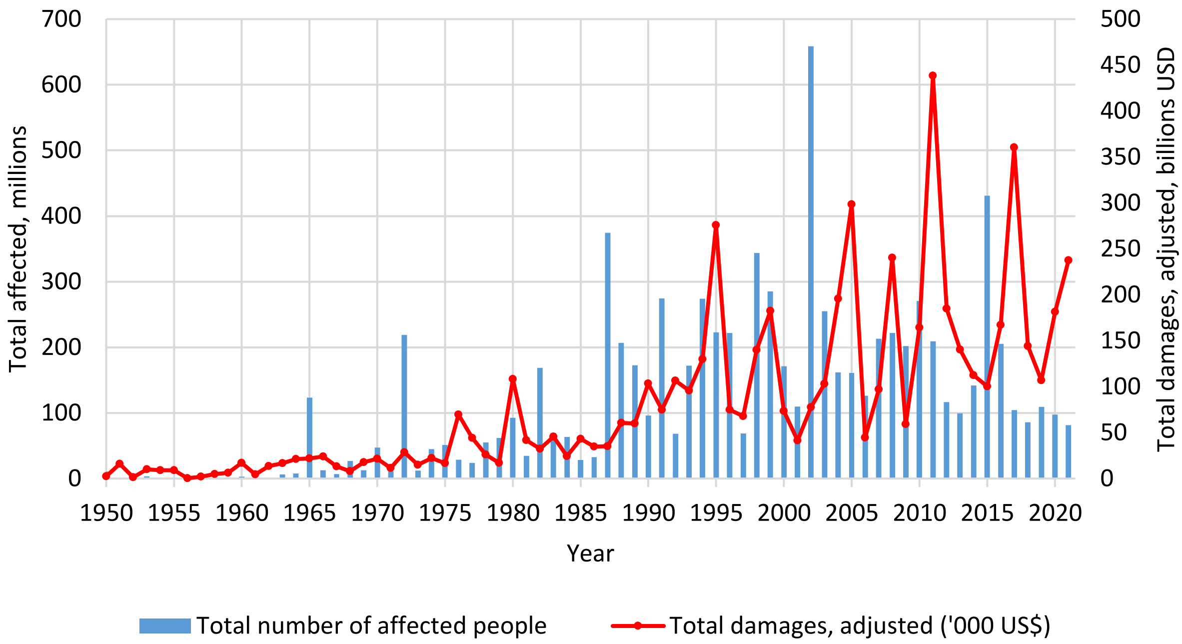

Figure 3. Total number of affected people and total economic damage from natural disasters occurred between 1950 and 2021

Data source: EM-DAT (Guha-Sapir et al. 2016).

2.5. Summary

This chapter introduced the main definitions used in the field of DRR and management, as well as discussed some of the differences and recent changes in the terminology. The main concepts of the disaster management theory were presented, particularly hazard, disaster, vulnerability, exposure, and risk. The disaster management cycle, as one of the most commonly used and generally accepted concepts, was introduced as well, particularly its four stages - mitigation, preparedness, response, and recovery. Overall, the need for the paradigm shift from the reactive approach in dealing with disasters to the proactive approach was stressed. While the importance of understanding potential risks, addressing the challenges, educating and preparing people and organizations before the event seem to be commonly accepted, there remain many instances when pre-disaster activities are somewhat overlooked (for instance in terms of funding). Finally, the occurrence of natural disasters and corresponding damages were discussed, mainly relying on the records of past events stored in the international EM-DAT database on disasters. Available data indicated the prevalence of hydrological and meteorological disasters, particularly floods and storms. While an increasing trend in total damages caused by natural disasters can be observed rather clearly, the total number of affected people overall remains rather stable or even slightly decreasing, as well as the number of reported deaths.

3. Geospatial technologies and challenges in their application in disaster management

This chapter addresses the notion of geospatial information and communication technologies (GeoICTs) and some examples of the identified studies on the issues and problems in the application of ICTs in disaster management.

3.1. Information and communication technologies (ICTs)

Information and communication technologies (or ICTs) is an umbrella term that incorporates a range of various tools, services, devices, or applications in the sphere of information manipulation and communication by electronic means (OECD 2007). Some systematization of the ICT sector already exists. The sector of such technologies is divided into "ICT Manufacturing" and "ICT Services", however, due to such a broad definition, the list of the particular ICTs can be almost endless. Apart from radio, television, phones, and computers, it also includes hardware, software, all applications, services, etc. (UNCTAD 2009). The definition and basic classification provided by the United Nations Conference on Trade and Development (UNCTAD 2009) are important tools for information economy statistics, though such systematization is not very useful for our purposes (for instance, classification of the existing ICTs in flood risk management). Considering the fast-paced enhancement of the existing tools and technologies and the development of the new ones, the need for some system or classification is rather clear.

At the stage of initial data collection and literature review, a couple of studies with lists of potential and identified issues and challenges in the application of ICTs in disaster management were found. Studies, presented below, deal with quite different aspects of the applications of ICTs – while Quarantelli provides arguments from the position of a social scientist, not focusing on technical aspects (Quarantelli 1997), report of the National Research Council (NRC), USA, listed challenges dealing primarily with the organizational issues (National Research Council

2007). These lists of identified issues were included in the questionnaire distributed among the participants of the CEU summer schools to identify which factors are considered to be the most important and relevant (see section 4.2.4 Expert survey). Participants were asked to rate the statements from these lists in terms of their importance and credibility. The following section briefly discusses these studies and presents corresponding lists, while the results of the survey are introduced at a later stage.

3.2. Challenges in the application of ICTs in disaster management

3.2.1. Social science perspective

At the time of the information revolution, when information and communication technologies began expanding on every side of human life, the fact that this process would significantly alter disaster management was unquestionable. However, apart from the positive aspects of such development, it is even more important to identify its negative consequences.

Reflecting on the occurring changes and the expanding use of ICT, Quarantelli, as one of the first researchers in the field of the sociology of disaster, formulated a list of ten problems and questions of information/communication revolution for disaster planning and research, which can arise due to the excessive application of ICTs (Quarantelli 1997). He focused on non-technical issues, as he believed that social, human perception of the occurring changes in the field was much more crucial than the technological side of the problem. As a sociologist, Quarantelli stated that such a comprehensive phenomenon as the information revolution, always will contain both positive and negative consequences, and that undesirable effects must not be ignored (Quarantelli 1997). The full list of these problematic aspects of the ICTs, as defined by Quarantelli (1997), is presented below:

1. ***The probability that the "rich will become richer" in dealing with disasters***

   This issue is related to the fact that, apparently, rich developed countries are more likely to obtain relevant innovative technologies than less developed countries, and so they will be able to take advantage of these technologies. Thus, the gap between rich and poor countries will only increase.

2. The possibility that technology that is a "mean" will be turned into an "end" in itself

We can identify two aspects of this specific problem. First, the unnecessary and needless application of ICTs, especially innovative technologies, in cases, which do not require technological superiority, and where such development does not lead to a noticeable improvement in the situation. The second issue appears when someone is choosing to deal with problems that can be easily addressed by the available technologies, and deliberately or unconsciously ignore other problems, because it is problematic or impossible to handle them as easily.

3. The inevitable information overload problem

After the information revolution and wide application of computer-based technologies, this kind of problem is more or less obvious. However, in the field of disaster management, this kind of issue can have severe consequences since information plays a crucial role during a disaster. The need for a deliberate decision is evident during crises, and the decision-maker must have enough data to make this decision. But, too much information, information overload, can lead to uncertainty. Another specific aspect of this problem is the processing and interpretation of the data.

4. The loss of, or outdated, information

According to Quarantelli (1997), this problem rises from the confrontation of the two ways to preserve data: the modern way to store data in digital form and traditional "paper" records. He argues that it is easier to lose immaterial Web data, while permanent "hard" data is more reliable. In this case, we can once again mention the second problematical aspect, such as the accumulation of old and misleading information, which can be stored on the Web, complicating the process of finding relevant and reliable information.

5. The greater likelihood of the diffusion of inappropriate disaster relevant information

This issue is associated with the greater access to information that can be provided by modern technologies. This mostly positive process can have such negative consequences as fast and uncontrolled distribution of unreliable and unchecked data.

6. The implications of even further diminution of non-verbal communication

Modern communication technologies have connected the whole world, providing the possibility to communicate with anyone at any time, regardless of the distance. However, this brings up some sociological problems in meaningful human communication, which normally include body language, tone of voice, etc.

7. Intra- and inter-level group communication will be made even more difficult

While communication between various actors plays an essential role in disaster management, even in traditional hierarchy these links and flows are very complicated. With the further development of ICTs not only does the number of potentially relevant actors increase but the number of interlinks and possible relations between them as well. This issue is also related to information overload, which does not always lead to a good result. The growing complexity of this system might have more negative consequences, than positive ones.

8. The negative consequences of the probable acceleration of fads and fashions associated with computer use

This problem is related to such characteristics of modern technologies as wider access, high speed of communication, and "democratization" of the process of information distribution when it is hard to identify expert opinion on the issue. As a result, the Web can get "flooded" by some fashionable, popular views, which might be considered "obvious" and will not be confronted or even questioned.

9. The kinds of general social infrastructures and cultures necessary for the adequate functioning of disaster relevant technology

This problem is associated with the lack of some kind of social infrastructure, required for adequate use of modern ICTs. It also includes the issues with communication between organizations, involved in disaster management. Quarantelli identifies the necessity of the adaptation of social and cultural structures to the new technologies. The preparedness to function in case of technological disruptions must as well be taken into account, since societies, especially during disasters, should not be completely dependent on technologies.

10. The certainty of computer system-related disasters

With the information revolution and wide distribution of computer-based technologies, the risk appearance of computer-related disasters is increasing. And the more society is dependent on new technologies, the greater the hazard and its consequences.

Some of the issues Quarantelli presented, were considered just assumptions, as was mentioned in the article by the author himself since at the time when this work was published, it was just the beginning of the full-scale adoption of innovative information and communication technologies in disaster management (Quarantelli 1997). Still, we can try to assess the relevance of these issues, or rather problematic aspects of the revolution in ICT, identified 20 years ago, in comparison to the current situation in the field.

3.2.2. Technological/organizational perspective

Another interesting study, a report published by National Research Council in 2007, requested by the USA's Federal Emergency Management Agency (FEMA), explores the current situation and prospects of the use of information technology (IT) in disaster management, as well as gives some recommendations (National Research Council 2007). Though this report deals mainly with the state of information technology in the USA, the result of this study can be useful for the analysis of the international status of the ICTs and existing obstacles in the field.

While the enhancement of this specific aspect of disaster management can be identified as the purpose of this report, various subjects are discussed in this work, like adoption and adaptation of existing technology, development and innovations, applied and theoretical research (National Research Council 2007).

In this report, the importance of the yet-unrealized potential of modern information and communication technologies is stressed, and at the same time, the constant progress in the field is recognized (National Research Council 2007). Not only the further development and refinement of the ICTs are discussed, but rather the deliberate use of already existing technologies is emphasized since present-day ICTs embodied great capabilities and opportunities (National Research Council 2007).

According to the National Research Council's report (National Research Council 2007), the following general actions can result in better use of ICTs:

- making smarter use of existing technologies;
- creating opportunities to develop and adopt new technologies;
- evolving organizational practices to best employ those technologies.

The report identified six potential key areas for the research and development in the field of application of ICTs in disaster management, one of which deals directly with information distribution and open access to data: "Better engagement of the public by supplying information and making use of information and resources that members of the public can supply" (National Research Council 2007). However, a particularly interesting part is the presented list of main challenging issues in the field of adoption of ICTs in disaster management, as presented below (National Research Council 2007):

1. Disaster management organizations often lack the resources needed for the acquisition of required equipment and software.

2. It might be too risky and costly to develop and apply promising innovative technologies.
3. In most cases agencies involved in disaster management do not have an employee, whose responsibilities will include the monitoring of modern ICTs, identifying potentially relevant technologies, and managing the process of purchase and training.
4. While local organizations must work together at all phases of the disaster management cycle to ensure the best outcome of such cooperation, when talking about ICTs such organizations tend to make decisions independently.
5. Uncertainty and instability are inherent in the field of disaster management due to its very nature, which leads to chaos and problems with communication and control.
6. Financial issues related to the fact that the greatest amounts of funds are traditionally provided only after the disaster happened (reactive approach) and should be spent rather quickly. While a reasonable application of technologies requires funds, particularly in the pre-disaster phase (proactive approach).

This list shows a different side of an issue, compared to the non-technical problems that were anticipated by Quarantelli. While many years passed already since the "information/communication revolution" and the publishing of the Quarantelli article discussed above, the main issues addressed in the National Research Council's report are organizational and financial in nature.

3.3. Role of geospatial ICTs in disaster management

3.3.1. Defining GeoICTs

The range of technologies potentially related to the current scope of the study was narrowed by focusing on a particular type of ICTs that primarily deals with the spatial component of information analysis – geospatial information and communication technologies (or GeoICTs). This is particularly relevant since disasters are inherently spatial phenomena (Herold and Sawada 2012). Initially, the concept of GeoICT was introduced as an attempt to ensure better integration of geospatial technologies into the ICT domain (Tao 2010). And while over the years such an approach became relatively common and GeoICTs are now quite widespread, it still might be hard to find a clear definition of what exactly this concept means, even in the literature that focuses directly on this topic (Abdalla 2016; Srivastava *et al*. 2016). Overall, the most straightforward approach would be to define GeoICTs as an umbrella term that brings together a number of various geospatial technologies, particularly such types as Remote sensing, Geographic Information Systems (GIS), Internet Mapping Technologies, Global Navigation Satellite Systems (GNSS), etc. (AAAS 2021; Abdalla 2016).

Before moving forward, it is important to provide basic definitions of these concepts:

- *Remote sensing* in very general terms is a process of gathering information at a distance and taking measurements without coming in contact with the observed object. But within the concept of GeoICTs, remote sensing is a practice of deriving information about the Earth's surface using imagery collected from an overhead perspective using electromagnetic radiation (Campbell and Wynne 2011). Such data can be collected from the various camera and sensors platforms, including space-borne (satellites) or airborne (aircrafts, drones) (Yamazaki 2001)
- *GIS* is a suite of specialized software tools that can manage and analyze spatial data (data which is georeferenced) (AAAS 2021; Abdalla 2016).
- *Internet Mapping Technologies* normally include various web-based software programs like Google Earth, Google Maps, ArcGIS Online, and similar platforms. Available features and parameters might differ, but overall, in many cases, such tools allow users to have easier access to geospatial technologies, compared to more traditional GIS, which might require specific hardware and more technical knowledge (AAAS 2021; Abdalla 2016).

- *GNSS* is a system (or network) of satellites, that provides location or position information to its users and has global coverage (AAAS 2021; Abdalla 2016). Some examples of functioning GNSS are USA's Global Positioning System (GPS), European Union's Galileo, and Russia's Global Navigation Satellite System (GLONASS).

In addition, it is important to also introduce the definition of space-based information and technologies. *Space technologies* generally refer to satellite Earth observation (EO), communications satellites, and satellite navigation and positioning systems, and their applications, including remote sensing, weather forecasting, global positioning systems, etc. (ECOSOC 2020; UN General Assembly 2006a). The notions of *space-based* and *geospatial data and information* are used rather interchangeably in this study and refer to data and information that have implicit or explicit "spatial" (or "locational") component.

An important role of modern geospatial tools, in disaster management particularly, is to assist in this process through improving access to relevant data (sometimes near real-time data), enabling more complicated and accurate geo-referenced analysis and planning, supporting monitoring activities, and overall facilitating related practices (Srivastava *et al.* 2016). Similar benefits of the application of GeoICTs extend to disaster management as well (Abdalla 2016). However, while GeoICTs are becoming more commonly used in various fields and industries and the advantages of their implementation are becoming more and more recognized, still quite often traditional technologies and methods are applied in some areas, where users can greatly benefit from modern technologies.

While GeoICTs are evolving quite rapidly, especially in recent years, it is possible to say that their classifications are not very well developed, particularly in the field of disaster management. Similar things can be said regarding the ICT sector in general. Extensive classifications in the ICT sector might not be very useful for the field of DRR and management as the proposed categories determine plain services (like internet access, telecommunication, online information and database retrieval, etc.), which are not quite informative and meaningful characteristics for the sector (Weber and Burri 2012). New ICTs and GeoICTs relevant to disaster management are being developed constantly. Sometimes quite innovative approaches are introduced, providing users with access to various data, and new ways to explore and analyze specific situations, possible risks, and vulnerabilities. A systematization focused on hazards and disaster management is needed, which could incorporate more relevant factors, like the purpose of the ICT, coverage area, or disaster phase.

3.3.2. Remote sensing platforms

The role of remote sensing is discussed in a bit more detail compared to other types of technologies, due to some incline of the research towards this topic, particularly in relation to satellite-based emergency mapping. It is possible to distinguish different types of remote sensing *platforms* - structures or vehicles which are carrying remote sensing instruments (Horning 2004). The most common classification includes the following types of platforms (Figure 4) (Horning 2004):

- Spaceborne (satellites),
- Airborne (airplanes, helicopters, drones),
- Ground-based (held-held devices, tripods, towers, etc.).

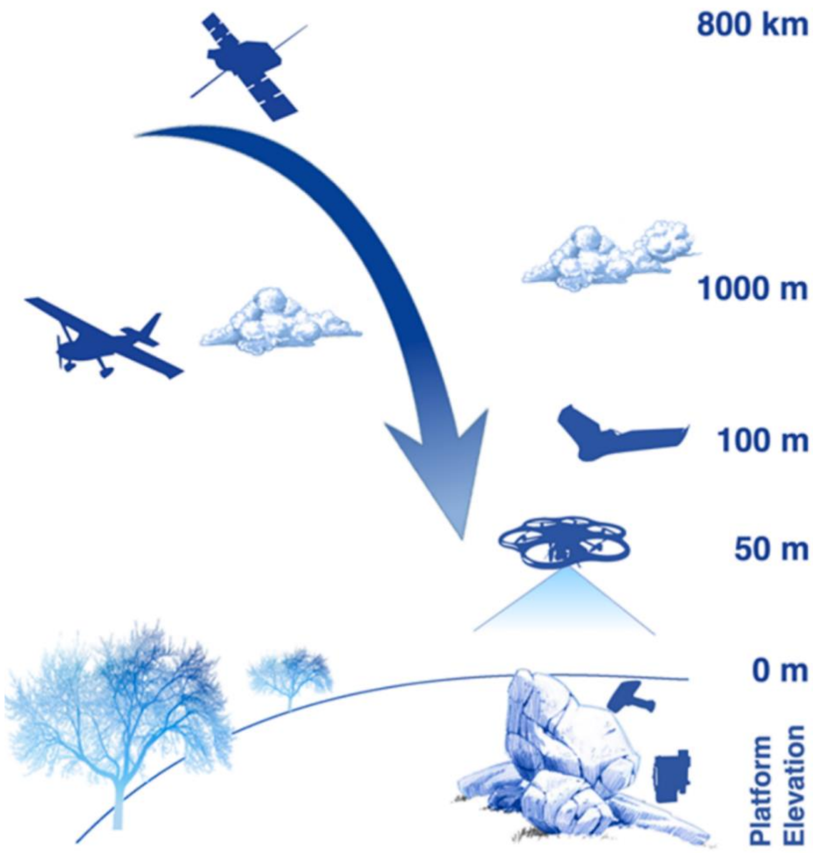

Figure 4. Different types of remote sensing platforms

Source: Booysen et al. 2019.

Sometimes, airborne type can be divided into two additional subgroups (Kakooei and Baleghi 2017; Lodhi *et al.* 2018):

- Manned aircrafts and
- Unmanned aerial vehicles (UAVs) or drones.

Table 4 summarizes some of the main differences between the main types of remote sensing platforms. Depending on the sphere of application and available resources, each approach might have its advantages and disadvantages. In many cases, data coming from different platforms are combined in one project (Kakooei and Baleghi 2017). Particularly, in-situ data from ground-based platforms are often used to validate information collected through other sources.

Table 4. Differences in characteristics of the remote sensing platforms

	Satellites	Manned aircrafts	UAVs	Ground-based
Pre-disaster data	Available	No	No	Probable
Acquisition timing	From hours to days	Several hours	Within hour	Days
Spatial resolution	From low to high	High	Very high	Very high
Coverage	Large coverage, no restrictions	Large coverage, potential regional restrictions	Small coverage, potential regional restrictions	Small coverage, potential regional restrictions
Cost	Depending on resolution – from free to very high	Moderate	Relatively low	High
Flexibility	No	Average	High	Flexible availability
Weather conditions	Depending on the sensors, clouds might affect the results (not an issue for radar)	Depends on weather condition	To some level, depends on weather condition	To some level, depends on weather condition
Angle of view	Vertical	Vertical + oblique (might suffer from occlusion)	Vertical + oblique (might suffer from occlusion)	Oblique (line-of-sight issues)

Source: based on Chang and Clay 2016; Emilien *et al.* 2021; Kakooei and Baleghi 2017; Stockdale *et al.* 2015; Zhang *et al.* 2020; Zhuo *et al.* 2017.

3.3.3. Remote sensing and the disaster management cycle

Remote sensing data can support various disaster management activities, while the same kind of data is not limited to only one specific application. To provide some structure, it is possible to group potential applications of such technology according to the main stages of the disaster management cycle – response, recovery, reduction (mitigation), and readiness (preparedness). Figure 5 introduces some examples of remote sensing applications, but in no way lists all potential approaches.

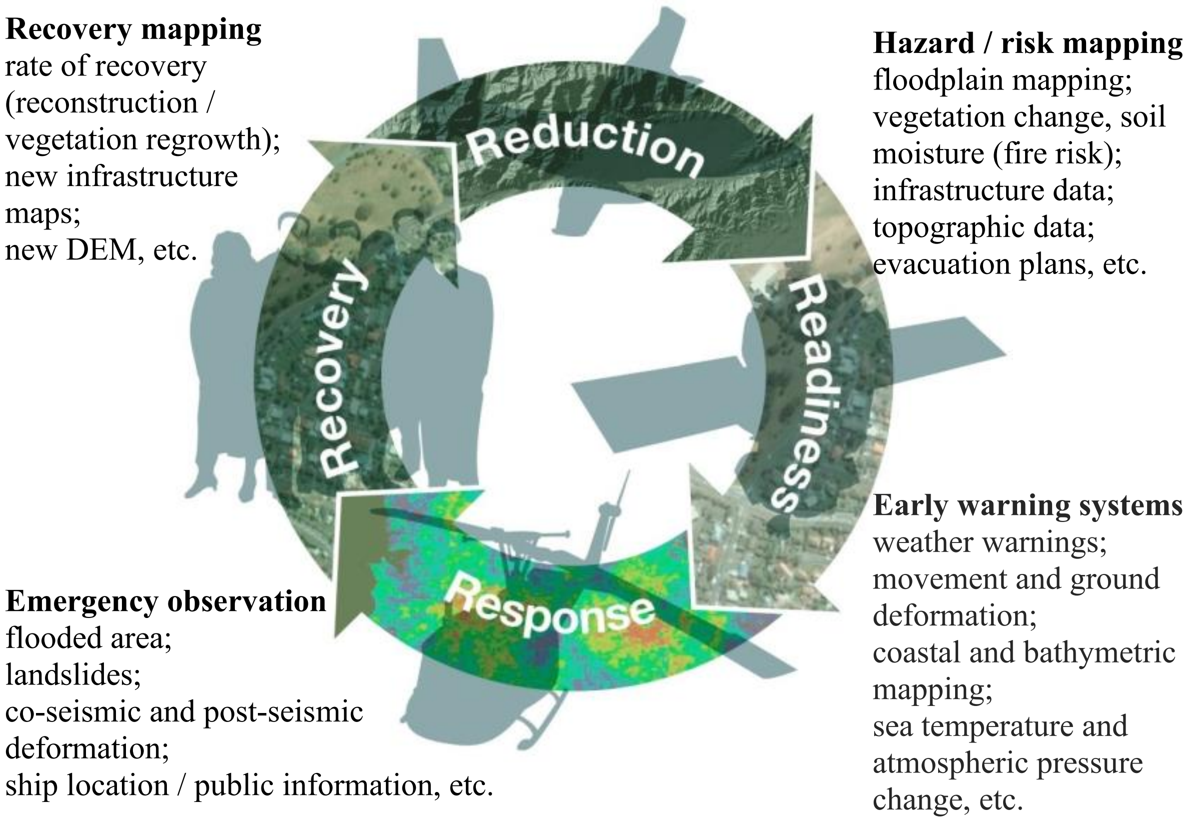

Figure 5. Potential remote sensing applications according to the disaster management cycle

Source: based on Joyce et al. 2009; Le Cozannet et al. 2020.

While space-based information and Earth observations (EO) can provide valuable support to disaster management activities, some reviews highlight that application of such technologies often remains rather limited to some specific areas and not fully implemented in other cases. Le Cozannet *et al*. (2020) emphasized that nowadays most efforts are normally focused on hazard assessment and disaster response, while there are a lot of potential opportunities in other areas, such as vulnerability and exposure mapping, disaster prevention, and early change detection, particularly in relation to climate change consequences (Le Cozannet *et al.* 2020).

3.3.3.1. Satellite imagery in rapid response

Over the last years, the availability of space-based information is growing at an exponential rate, while the spatial, temporal, and spectral resolution of satellite imagery is improving (Voigt *et al.* 2016). As it is becoming easier to access this kind of remotely sensed data, applications of space-borne information are expanding in multiple areas, including risk and emergency management, urban development, energy and infrastructure, agriculture and forestry, environment and resource management, among many others (Kansakar and Hossain 2016).

In terms of emergency management, satellite EO plays a crucial role in both emergency preparedness and immediate response to disasters, as such data can provide a valuable overview of the situation in times when information from the ground might be chaotic (Denis *et al.* 2016; Voigt *et al.* 2016). First hours (and up to a couple of days) after a disaster are essential for saving people in imminent danger, as the survival curve of victims drops considerably after each day that passes. Depending on the type and resolution of the satellite imagery, it can provide vital information on the extent of destruction (area flooded, buildings collapsed, roads destroyed, etc.), help plan emergency response activities for a humanitarian organization on the ground, be useful for post-disaster needs assessment and overall support every phase of the disaster management cycle (Boccardo and Tonolo 2015). Besides that, there also might be situations when international assistance on the ground is not possible or even not allowed, like in the case of tropical cyclone Nargis that hit Myanmar in 2008. At that time international community was able to assess the consequences of this disaster based on the collected satellite imagery.

The first 24 hours after the event can often be characterized by information deficit, when it is hard to get a clear picture of the situation, sometimes inaccurate maps are available and there is limited access to the affected area (Arneson *et al.* 2017). However, as time passes, this situation can drastically change to information overflow. Coordination centers start receiving multiple reports from various organizations, often consisting of duplicating or contradictory information, raw or only partially analyzed data, which is not always reliable or even correct (Kersten *et al.* 2021; Voigt *et al.* 2011). Such a sudden avalanche of information is often only complicating the work of emergency response teams (Bharosa *et al.* 2010). Still, provision of the latest information from the field within the first hours after a disaster plays a crucial role in speedy and effective emergency response. While it is becoming more and more common for search and rescue teams to use drones (unmanned aerial vehicles or UAVs) for real-time information collection (Ofli *et al.* 2016), nowadays some satellite data providers are slowly approaching near real-time frequency of observations (Kwak 2017). The era of information overload has arrived, and it also affected the field of satellite-based remote sensing, as now it is possible to monitor any area on Earth daily through satellite imagery (Mandel 2020). This situation makes it even more important to ensure the efficient and effective use of all the opportunities provided by modern satellite-based technologies, as well as avoid communication issues in this increasingly expanding and increasingly complex network of involved organizations and initiatives.

3.4. Diffusion of technology

3.4.1. Main elements of the diffusion of innovations theory

To explore the process of diffusion of technology (or any innovation in general), potential benefits, and arising issues in the distribution, adoption, and adaptation of the available geospatial technologies in DRR and management, the diffusion of innovations theory is considered a theoretical framework for the current study. Since its introduction in the 1960s by Everett Rogers, this theory had been widely applied in various sectors, from organizational adoption (Peansupap and Walker 2005) to technological diffusion in industries using investment data (Hur *et al.* 2005). In general, this theory studies the consistent process of implementation of an innovation (new technology, idea, or way of application of existing tool, etc.) by different groups of adopters, from first innovators to laggards (Rogers 2003). As a communication studies theory, introduced information channels between relevant actors play an essential role in the understanding of the process of innovations' diffusion within a social system. At the same time, factors preventing wider adoption of new technology remain less studied (Selwyn 2003).

According to Rogers (2003), many things can be considered to be an *Innovation* (technology, idea, application, etc.). The unifying characteristic, in this case, is the novelty or originality, which determines the innovation (Rogers 2003). Another principal component of the theory is *Diffusion*, which is “a *general process*, not bound by the type of innovation studied, who the adopters were, or by place or culture” (Rogers 2003). While the process of diffusion is inherently universal, studies dealing with the distribution of innovations are often primarily interested in ways to speed up the rate of diffusion.

In short, Rogers defines diffusion as:

> “the process in which an innovation is communicated through certain channels over time among the members of a social system” (Rogers 2003)

While in the normal communication process participants create and share information to reach understanding, *Diffusion* is considered as a certain type of communication in which the messages are about a new idea (Rogers 2003). This makes the diffusion of innovations a social process to a greater extent, rather than a technical one (Rogers 2003). Many developers often believe that the innovative tools they are offering will “sell themselves” because of how valuable and elaborate they are from the technical point of view and that potential adopters will easily see these benefits, which will lead to the rapid diffusion of the innovation. Yet such a scenario is rarely fulfilled (Rogers 2003).

Following the definition of the term *Diffusion*, introduced earlier, four main elements of the considered theory can be identified:

1. Innovation;
2. Communication Channels;
3. Time;
4. Social System.

These concepts are key in the theory and should be recognizable in every diffusion research (Rogers 2003).

3.4.1.1. Innovation

According to Rogers (2003), an *Innovation* is

> “an idea, practice, or object that is perceived as new by an individual or other unit of adoption”.

The following section is focused on the diffusion of technologies, as one of the feasible types of innovations.

There are usually two aspects of technology that we can easily differentiate: *the hardware* aspect (as a physical object); and *the software* aspect (as “the information base for the tool”) (Rogers 2003). Technologies are very often considered as hardware tools, yet in many cases, new technologies can consist of only intangible information or ideas (Rogers 2003). Diffusion of such innovations is no less important or relevant, however, there is a considerable difference, as "diffusion of software innovations has a methodological problem since their adoption cannot be so easily traced or observed" (Rogers 2003). Rogers (2013) as well emphasizes that such innovations can be characterized by a slower rate of diffusion as they are less visible to adopters.

Another connected issue is related to the “overlapping” innovations, since in many cases it might be hard “to determine where one innovation stops and another begins" (Rogers 2003). As it's easier to investigate the diffusion of each particular innovation, scholars are often doing so, yet such an approach can lead to oversimplification of the real situation. To deal with this problem, Rogers (2003) proposed the concept of the "package" of innovations – *technology cluster* – study of which should be much closer to reality. According to him, a technology cluster "consists of one or more distinguishable elements of technology that are perceived as being closely interrelated" (Rogers 2003).

Some characteristic features of innovations can be identified and explored to have a better understanding and explanation for different rates of their adoption (Table 5). The first two (relative advantage and compatibility) are considered particularly important in explaining an innovation's rate of adoption (Rogers 2003).

Table 5. Characteristics of innovations that can affect their rate of adoption

Characteristic	Definition
Relative advantage	The degree to which an innovation is perceived as better than the idea it supersedes.
Compatibility	The degree to which an innovation is perceived as being consistent with the existing values, past experiences, and needs of potential adopters.
Complexity	The degree to which an innovation is perceived as difficult to understand and use.
Trialability	The degree to which an innovation may be experimented with on a limited basis (such innovation represents less uncertainty to the individual who is considering it for adoption, as it is possible to learn by doing).
Observability	The degree to which the results of an innovation are visible to others.

Source: Rogers 2003.

3.4.1.2. Communication channels

Another essential concept of the diffusion theory is the communication channel, through which innovation is disseminated. A *Communication Channel* is

"the means by which messages get from one individual to another" (Rogers 2003).

As it was mentioned earlier, diffusion itself is recognized as a type of communication, and now we can split this process into at least four elements (Rogers 2003):

- an innovation;
- an individual (or another unit of adoption) with knowledge (or experience) of the innovation;
- another individual (or another unit) without knowledge (or experience) of the innovation;

- a communication channel connecting the two units.

According to Rogers (2003), there are two main types of communication channels: *mass media channels* (which allow individuals to send their message to an audience of many, through means like radio, television, etc.) and *interpersonal channels* (“face-to-face exchange between two or more individuals”). He also mentioned Internet communication as an additional type of communication channel (Rogers 2003). In his opinion, interpersonal channels are more effective in facilitating the diffusion of innovation, compared to mass media (Rogers 2003). Thus "diffusion is a very social process" (Rogers 2003).

Rogers (2003) pointed out that there are particular characteristics of the interaction of individuals, which can significantly affect the rate and success of diffusion of innovations – *homophily* and *heterophily*. Generally, communication between participants who share similar qualities (*homophilous* communication) is much more effective, than between individuals who don’t have much in common (*heterophilous* communication) (Rogers 2003). These attributes, that individuals (or other units of adoption) may share, can include education, socioeconomic status, beliefs, etc. Since diffusion as a type of communication has a very specific aspect of innovation in it (one participant has the knowledge of a new idea or technology, while the other doesn’t), some level of heterophily is always required (Rogers 2003). Ideally, all other characteristics should be homophilous to facilitate the dissemination of innovative information (Rogers 2003). However, Rogers (2003) emphasized that "[o]ne of the most distinctive problems in the diffusion of innovations is that the participants are usually quite heterophilous".

3.4.1.3. Time

Time dimension can be regarded as a distinctive feature of diffusion research since behavioral studies are usually "timeless", however, this particular characteristic can often be criticized (Rogers 2003). Time can be included in the diffusion process in three aspects (Rogers 2003):

1. the *innovation-decision process* by which an individual passes from first knowledge of innovation through its adoption or rejection;
2. the *innovativeness* of an individual or other unit of adoption (that is, the relative earliness/lateness with which an innovation is adopted) compared with other members of a system;
3. an innovation's rate of adoption in a system, usually measured as the number of members of the system who adopt the innovation in a given time period.

But first of all, an *innovation-development process* proposed by Rogers (2003) could be briefly introduced. This process, presented in Figure 6, has six clearly defined steps. These include the initial identification of existing needs or problems and corresponding research (or investigation) of the situation, followed by the actual development of the innovation. The final three steps could be grouped together as they represent the implementation of the innovation. At the same time, it is important to emphasize that in reality, these steps do not necessarily have to follow the proposed order, as well as that some of them might be even skipped (Rogers 2003).

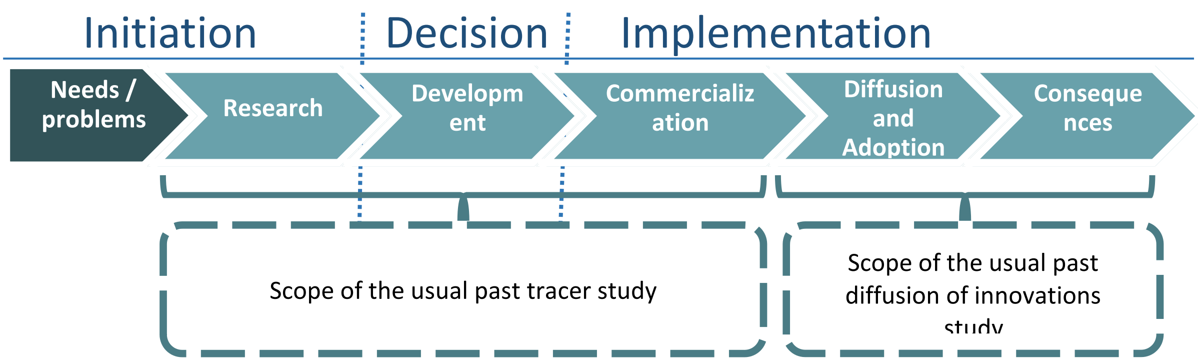

Figure 6. Six stages of the innovation-development process

Source: based on Rogers 2003 and Beausoleil 2018.

The *innovation-decision process* may involve not only individuals but any other unit of adoption (for instance, the organization as a whole) and often it can be a base for the diffusion studies (Rogers 2003). An understanding that decisions made by organizations/individuals, should not be regarded as a singular act, but rather as an outcome of a chain of choices and conclusions that preceded this decision, Rogers had developed a basic model of the *innovation-decision process* divided into five main stages of this process of decision-making (see Figure 7). A very general definition of this process, proposed by Rogers, mentions every stage and how they flow, one into another:

> "The *innovation-decision process* if the process through which an individual (or other decision-making unit) passes from first knowledge of an innovation, to forming an attitude toward the innovation, to a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision" (Rogers 2003).

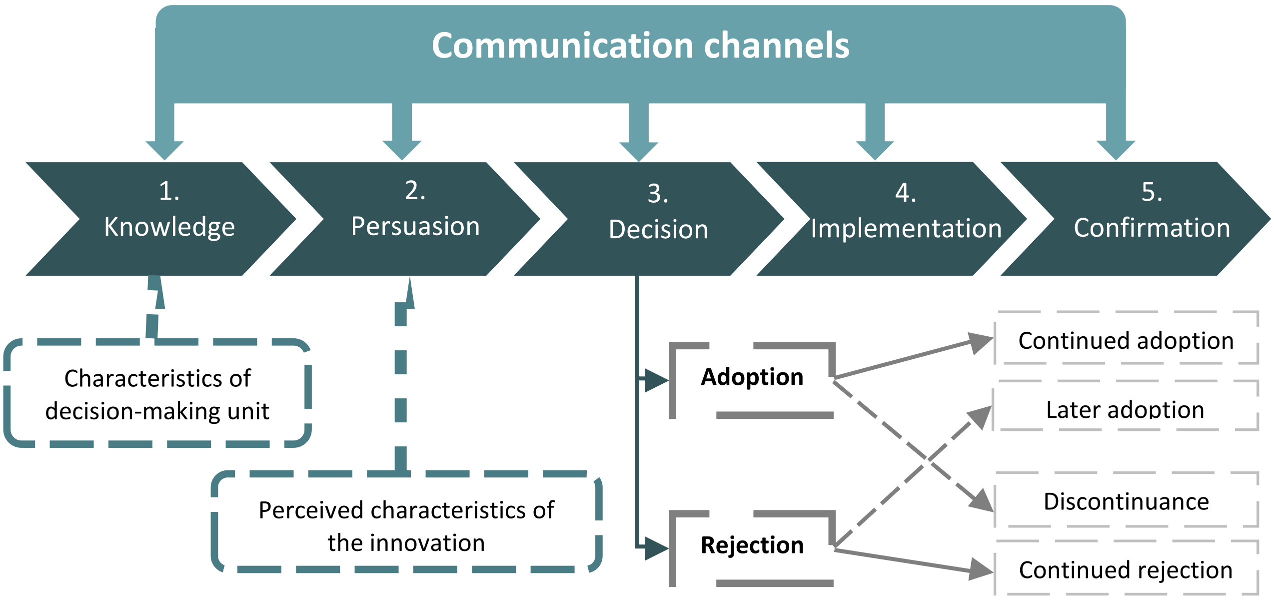

Figure 7. Five stages of the innovation-decision process

Source: based on Rogers 2003.

In addition to these five main successive steps (knowledge → persuasion → decision → implementation → confirmation), the presented model incorporates some other elements of the diffusion of innovations theory, such as communication channels, which play an essential role in every stage of this process.

However, depending on the particular situation, some of these stages can be skipped or rearranged (for instance, if a high-level official decided to adopt some innovation and made it obligatory for the whole organization) (Rogers 2003). The innovation-decision process can lead to the *adoption* or *rejection* of the innovation, yet this decision can be revised in the future (Rogers 2003). If an individual is not satisfied with the innovation after its implementation, he can decide to reject it, and Rogers (2003) called this kind of decision a "*discontinuance*".

The concept of *innovativeness* allows us to classify individuals (or other units) based on how early they decided to adopt an innovation. Rogers (2003) introduced five categories of adopters:

1. innovators;
2. early adopters;
3. early majority;
4. late majority;
5. laggards.

3.4.1.4. Social system

The last main element of the diffusion process, *Social System,* Rogers (2003) defined as:

> "a set of interrelated units that are engaged in joint problem solving to accomplish a common goal" (Rogers 2003).

Much like in the concepts discussed previously, these units may be represented in a social system in various forms – individuals, organizations, informal groups, etc. (Rogers 2003). While a common objective unites separate members of a system, through the diffusion process some particular communication flows can be identified (Rogers 2003). This self-organization allows to explore social and communication structures of the system, can help study the existing network, links between individual units, and potentially identify *opinion leaders* (who are "able to influence other individuals' attitudes") and *change agents* ("who influence[s] clients' innovation-decision in a direction deemed desirable by a change agency") within the system (Rogers 2003).

Through the concept of a social system, it is possible to introduce another important classification – of the *innovation-decisions* (Table 6). The prevailed type of the innovation-decision can vary across different fields, types of organizations, and communities (Rogers 2003).

Table 6. Types of innovation-decisions

Type	Definition
Optional innovation-decisions	Choices to adopt or reject an innovation that are made by an individual independent of the decisions of the other members of the system.
Collective innovation-decisions	Choices to adopt or reject an innovation that are made by consensus among the members of a system.
Authority innovation-decisions	Choices to adopt or reject an innovation that are made by a relatively few individuals in a system who possess power, status, or technical expertise.

Source: Rogers 2003.

The last categorization, concerning the main elements of the diffusion process, which Rogers (2003) introduced, deals with the *consequences of innovations*. They can be grouped as follows (Rogers 2003):

- *desirable* versus *undesirable* consequences;
- *direct* versus *indirect* consequences;
- *anticipated* versus *unanticipated* consequences.

3.4.2. Diffusion research traditions

Based on the analysis of a great number of diffusion research publications, Rogers (2003) provided an overview of some of the identified main diffusion research traditions, which included: rural sociology; marketing and management; communication studies; public health and medical sociology; and others. The scope of various fields, where the diffusion theory was and can be successfully applied, is naturally much wider (Rogers 2003). Some particularly interesting, to the current research, outcomes of this analysis are, for instance, the most popular methods applied in the process of data collection and analysis (Rogers 2003). Preferred methodologies in conducting diffusion studies vary across different disciplines, yet there is a quite distinctive list of traditional approaches, including both qualitative and quantitative methods: survey interviews, questionnaires, statistical analysis, data from secondary sources, participant/non-participant observation, case studies (Rogers 2003).

The methodology used in the communication studies (as one of the diffusion research traditions) seems like the most applicable in the case of current research. Such studies typically are exploring technological innovations and new communication technologies, focus on such units of adoption as individuals or organizations and apply methods like survey interviews and statistical analysis (Rogers 2003). According to Rogers (2003), "[o]ne of the special advantages of the communication research tradition is that it can analyze *any* particular type of innovation". So, focusing on the process of diffusion (as a specific type of communication) it is possible to explore the network of potential adopters, communication structure, and study characteristics of particular units that might determine the rate of adoption. Sometimes, "being connected mean being innovative" (Rogers 2003).

However, by exploring the diffusion process, it is possible to choose what aspect of it to concentrate on. According to the analysis presented by Rogers (2003), a great number of studies focus on the members of a social system (individuals or organizations) as the units of adoption, yet in such cases, the attributes of innovations, that considerably influence the rate of adoption, can be overlooked. Giving the most attention to the new technologies in order to explore how their characteristics influence the diffusion process, members of the system are not ignored, since only through the adopter's perception these features of innovations can be analyzed (Rogers 2003).

At present, studies that apply the diffusion of innovations theory specifically to the disaster management field are both relatively limited in numbers and at the same time quite diverse in selected approaches (Albayrak 2006; Cumbie and Sankar 2010; Dillette and Ponting 2021; Samaddar *et al.* 2022; Secara and Bruston 2009; Taylor and Perry 2005; Wachtendorf *et al.* 2018). Quite often such studies would focus more on the situation after a disaster. For instance, innovation diffusion was applied in research on the use of the Internet in crisis communication – the study was comparing the application of traditional and innovative communication tactics (Taylor and Perry 2005). While it was focused only on one particular aspect of modern technologies (Internet usage) a series of studies throughout the years were required to collect enough data to explore the issue and monitor the consistent change in the rate of adoption of the technology (five studies in total from 1998 to 2003) (Taylor and Perry 2005). It is not always possible to conduct this type of research due to time and fund limitations.

GeoICTs in most situations can play an important, yet mainly supporting role, unlike the use of the internet, so it might be hard to expect and measure whether such technologies should and would at some point be adopted universally. Considering the great number of existing relevant technologies and the focus of current research mainly on existing issues, not on the time dimension of the process itself, the application of diffusion of innovations theory to explore the actual rate of adoption of modern geospatial technologies in DRR might be potentially interesting, however not fully achievable in the scope of the current study.

If the diffusion of new technologies is defined as a specific dimension of communication (Rogers 2003), it becomes clearer that while communication studies in DRR often include a technological aspect of the issue, in most cases ICTs are considered more as an additional channel for information. The main concern lies in the interpersonal communication regarding the crisis itself between individuals, groups of individuals, or organizations (Acar and Muraki

2011; Thelwall and Stuart 2007). However, these studies often do not explore the process of dissemination of the innovations, which can be also seen as a type of communication.

Studies that do focus on the technical side of the problem might include only traditional technologies as tools for communication during disasters, and do not take into account various emerging innovative ICTs, for instance, online services (referred to as "alternative media") (Holladay 2010; Samaddar *et al.* 2022). As well, in general, existing studies are focusing on "Post-Crisis", "Post-Disaster" communication (Acar and Muraki 2011; Holladay 2010; Tanner *et al.* 2009; Taylor and Perry 2005; Thelwall and Stuart 2007), which by its nature has significant differences compared with the communication before the event. The "Pre-Disaster" communication, as well as the application of relevant ICTs, are no less important since actions before the disaster ensure the implementation of mitigation and adaptation mechanisms (Stal 2013).

Existing studies on the application and diffusion of modern technologies, for instance, integration of the Internet into crisis response, often follow the same path, focusing on the communication and application of available tools after the event (Perry *et al.* 2003). The same is with the studies on more specific and innovative technologies, like blogs or Twitter as an emerging media, which provide the analysis of the communication only during the crisis itself (Acar and Muraki 2011; Thelwall and Stuart 2007).

A more theoretical approach in the application of diffusion of innovations theory, which was demonstrated in some research largely based on the participatory observation (Secara and Bruston 2009), seems as much more suitable for the present study. Modern technological issues related to the development of the ICTs for DRR do matter, however, it seems that the social aspect of the problem deserves much more attention than it is currently receiving (Secara and Bruston 2009). Continuous support of the further development of new technologies would not automatically boost the rate of dissemination of such innovations. The weakness of the link between the satellite-based products and service providers and the actual end-users is an important obstacle that can prevent the wide-scale adoption of geospatial technologies (Secara and Bruston 2009). In terms of the flow of information, communication channels determine the diffusion of new technologies (or ideas), so there is a need to ensure their operability and reliability. While the article by Secara and Bruston (2009) is focusing on quite similar issues regarding the dissemination of geospatial technologies, the present study tries to explore the gap between the data and technology provider and the end-users, identifying the challenges and the needs of the users of geospatial technologies.

Apart from the fact that only a relatively small number of studies on the diffusion of geospatial technologies in disaster management exists nowadays (Bojovic and Giupponi 2020; Secara and Bruston 2009; Taylor and Perry 2005), often they analyze the effects or results of this diffusion, trying to find reasons determining the process of distribution (Perry *et al.* 2003). As well such studies primarily deal with adopters, overlooking the particular characteristics of innovations, which as well determine the diffusion process. At the same time, it is worth noticing that some studies combine the diffusion of innovations framework with the application of network analysis to explore the situation with applications of geospatial solutions in DRR (Bojovic and Giupponi 2020).

The notion of networks is an inherent part of the diffusion process, representing the combined "Social system" and "Communication channels" elements, as defined by Rogers (2003). The social network of potential adopters, its structure, and characteristics are not less important for the rate of adoption than are the characteristics of the innovation itself (Rogers 2003). However, in some cases, it might be difficult to keep the balance between these two dimensions, while exploring the process of dissemination of particular innovation. Some studies might focus more on technical characteristics while overlooking more "social" factors affecting adoption (Secara and Bruston 2009). And while interconnections between developers/providers of geospatial goods and services and actual end-users play an important role, attributes of these innovations should not be neglected as well.

Some of the most common methods of data collection and analysis in studies exploring innovation diffusion are presented below.

3.4.2.1. Surveys and interviews

As Rogers (2003) mentioned, surveys and interviews are among the main methods applied in studying the diffusion of innovations. Such an approach was successfully applied already in some of the earlier cases, fundamental for diffusion research. Ryan and Gross (1943) in their study on the diffusion of hybrid seed corn used structured interviews in the form of retrospective survey interviews as the main method for data collection, asking farmers particular questions about the time of adoption, sources of information regarding the innovation, and consequences of their decisions (Ryan and Gross 1943). Still, this remains one of the most common approaches in recent studies as well (Bojovic and Giupponi 2020; Dillette and Ponting 2021; Eurisy 2016; Samaddar *et al.* 2022).

3.4.2.2. Case study

It is quite common to limit research area by some specific geographic location and/or type of technology or innovation (Bojovic and Giupponi 2020; Cumbie and Sankar 2010; Samaddar *et al.* 2022). This case study approach can help better focus the aim of the study and explore the situation, diffusion process, and underlying social network in more detail, helping avoid any potential gaps. The narrowing down process largely depends on the specific innovation to be studied, the current situation, and available means of data collection. For instance, focusing specifically on internet-based crisis communication (Perry *et al.* 2003), or limiting the study to exploring the situation in specific countries and very particular services and products (Bojovic and Giupponi 2020).

3.4.2.3. Network analysis

In some studies, collected information on individuals involved in the diffusion process and their connections allows to present and explore data in a form of a network, most often, a social network (Bojovic and Giupponi 2020; Samaddar *et al.* 2022). This method, most often combined with the case study approach, remains relatively common for diffusion research.

3.4.2.4. Qualitative data analysis

Some studies also often rely on the analysis of long texts, aiming at either detecting specific topics discussed in such documents (Cumbie and Sankar 2010) or at identifying the main elements or actors involved in the process (Bojovic and Giupponi 2020). Such analysis can evolve transcripts from interviews or group discussions (Cumbie and Sankar 2010), as well as secondary sources, like preexisting documentation (Bojovic and Giupponi 2020).

3.4.2.5. Participatory observation

From the diffusion of innovations point of view, small-scale in-depth studies that focus on participant observation are often not very useful for the generalization of the acquired results (anthropological research). This type of research can as well take a great amount of time to complete. Other research traditions seem to apply the participant observation method quite rarely, while it might bring interesting insights into the process of innovation diffusion from the point of view of actors from the different positions along this process (Rogers 2003). While participatory observation might not be the best method to explore the overall diffusion process, it can provide valuable insights into the underlying factors that might influence adopters' decisions to accept or reject an innovation (Secara and Bruston 2009).

3.5. Summary

This chapter introduced the notion of GeoICTs and challenges related to the diffusion of such technologies and innovations, as identified through the literature review. Since GeoICTs overall can be considered as a subgroup of ICTs, some of the known problems in the adoption and implementation of ICTs in disaster management were introduced and discussed. Considering the critical importance of having the right information at the right time, particularly during disaster response, it is important to explore distinctive features of issues most common for the DRR, which might not be so prominent or crucial for other fields. The role of remotely sensed data and space-based applications in support of each step of the disaster management cycle was highlighted.

Main components, concepts, and processes of the diffusion of innovations, as a theoretical framework, were introduced, particularly its main elements - innovation (which can be new technology as well as an idea or practice), communication channels, time, and social system. Exploration of the diversity of techniques typically used in studying diffusion helped identify the most appropriate for the present research, as well as compile the overall methodological framework, which allows mixed methods approach and triangulation of the data.

4. Research design and methodology

The developed methodology of the present research included several methods and approaches typically used in the diffusion studies (such as surveys, discussions with experts, participant observation, network analysis, data from secondary sources, and a case study approach). It was decided to combine qualitative and quantitative methods, to study specifics of the geospatial technologies' diffusion in the field of DRR and associated issues of this process.

The data collection that involved a variety of sources was particularly important at the initial stage of the research. It helped explore existing geospatial information and communication technologies applicable for the DRR, identify the most relevant organizations and initiatives involved in the work on this issue, and preliminary define some challenges common to the field, which might be considered the most urgent. Additional data collection was performed at a later stage of the project, if needed, in parallel with the analysis, for instance, to add missing information on particular technology identified through initial research.

4.1. Research design

4.1.1. Research workflow

Formulated main research questions and corresponding objectives helped fulfill the aim of the current research and explore the situation with the application of GeoICTs in DRR and identify corresponding issues in the dissemination and adoption of such technologies.

The main stages and the overall workflow of the present research are presented in Figure 8. A preliminary list of issues and challenges of innovation diffusion and adoption in the field of disaster management was identified through literature review and web search, as well as was the initial list of most important mechanisms that promote and facilitate wider adoption of GeoICTs. This stage of the research particularly covered the main international frameworks related to DRR, existing global SEM mechanisms, and activities of the UN-SPIDER programme. Data collection continued with conducting expert surveys, internships, and participation in relevant events and discussions with practitioners working in the field of disaster management and geospatial technologies.

Following the examples of similar studies that explored innovation diffusion (Bojovic and Giupponi 2020; Cumbie and Sankar 2010; Samaddar *et al.* 2022) and considering the diversity and complexity of existing GeoICTs, it was decided to apply a case study approach in studying the diffusion process and involved actors. It was mainly done to provide a specific example of a technology that has a prominent place in a global arena and explore it in enough detail without the need to limit the research in terms of its geographic coverage. SEM mechanisms were selected as such a case study due to their involvement in rapid response on a global scale and their role as mechanisms that facilitate the dissemination of GeoICTs. The coverage and activations of the selected mechanisms were analyzed, exploring potential gaps and barriers that prevent the wider application of such services.

Main topics of interest and problematic aspects were discussed based on the analysis of the available reports of the UN-SPIDER's TAMs. In parallel to this work, additional insights were collected through participant observation, consultations with experts, and desktop research, where needed. At the final step of the research, the results of the performed analysis were brought together for the overall discussion. This stage of the research focused on further analysis and consolidation of the main challenges that hinder the wider application of GeoICTs, specific needs expressed in the collected data, and any potential solutions to address these issues. In addition, for simplification main findings were generalized and presented in a form of a concept map.

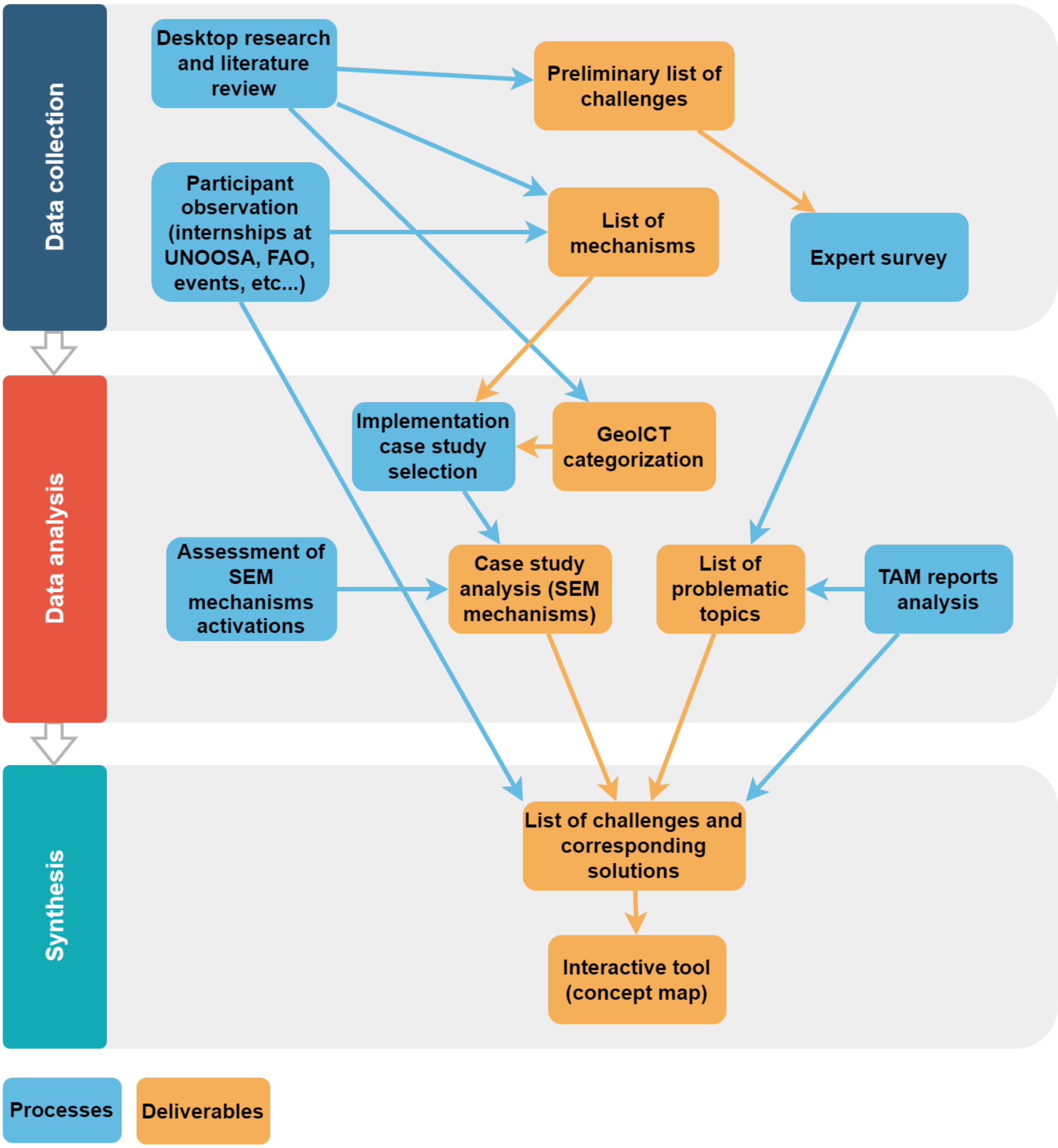

Figure 8. Research design

More technical details of the conducted work, with the indication of the performed tasks and corresponding methods used, are presented in Table 7. Selected methods did not always follow one after another in a stepwise manner and often they did overlap, depending on the available opportunities and intermediate findings, which sometimes required a return to previous steps (like further literature review and web search).

Table 7. Research objectives and methods

Research Question		Objectives		Steps	Methods
RQ1	*What are the existing mechanisms of promotion, diffusion, and application of relevant geospatial technologies in DRR?*	**Ob1.1**	Analyze the evolution of international agreements, practices, and policies on the application of ICTs in DM	Identifying international agreements and policies relevant to disaster management	Desktop research Discussion with experts
				Assessing the technological aspect in these documents	
		Ob1.2	Identify the most relevant initiatives involved in the promotion of the application of geospatial technologies and related capacity development	Exploring the diversity of existing initiatives and identifying the most relevant for further analysis	Desktop research Participant observation Discussion with experts
				Reviewing the main activities of such initiatives and their coverage	
		Ob1.3	Explore the status and role of satellite-based emergency mapping (SEM) mechanisms	Exploring the diversity of existing international SEM mechanisms and selecting the most relevant for further analysis	Desktop research Participant observation Discussion with experts
				Studying the functioning of these mechanisms and identifying any gaps in their coverage	
RQ2	*What are the major gaps in the application of space-based technologies, the main needs of end-users, and corresponding obstacles and challenges in the diffusion and adoption of such technologies?*	**Ob2.1**	Examine activations of selected SEM mechanisms to identify any gaps and related challenges	Developing a database of recorded activations of the selected SEM mechanisms	Web-scraping Discussion with experts
				Identifying patterns and trends in activations, performing network analysis	Analysis in Python Network analysis
		Ob2.2	Study the needs of end-users and the issues they are facing	Identifying the source of information about the actual needs of end-users and collecting the data (TAM reports)	Desktop research Participant observation
				Systematizing available information on the needs and challenges, identifying main issues, and analyzing observed patterns	Qualitative data analysis

Research Question		Objectives		Steps	Methods
		Ob2.3	Study existing challenges in DRR, in terms of diffusion and application of geospatial technologies	Creating a preliminary list of issues based on a literature review	Desktop research
				Conducting an expert survey to collect and assess expert opinions	Expert survey
				Discussing existing challenges with experts and practitioners to deepen understanding of the situation and problematic aspects	Participant observation Discussion with experts
RQ3	*What are the suitable solutions and potential approaches, as well as promising innovations, that can help tackle or at least mitigate these challenges?*	Ob3.1	Analyze and discuss the most problematic aspects and contributing factors limiting wider diffusion and application of GeoICTs	Expanding the preliminary list of issues through bringing together findings from earlier stages of the research and discussing them in a systematized format	Desktop research Expert survey Participant observation Qualitative data analysis
		Ob3.2	Propose solutions to overcome identified challenges in the diffusion and application of GeoICTs in DRR	Discussing potential solutions for presented challenges, identifying the most promising technologies and innovations in the field, and proposing recommendations that can support more successful diffusion of GeoICTs	Desktop research Participant observation Discussion with experts Qualitative data analysis
				Summarizing the results of the analysis and presenting the main findings in a coherent format	

4.1.2. Mixed methods and triangulation

To ensure that the topic of this research is explored thoroughly, as well as to confirm and validate the findings, a combination of methods (both qualitative and quantitative) was used. Such mixed-methods research allows the application of triangulation to improve understanding of the situation and affirm conclusions, supported by different sources (Bekhet and Zauszniewski 2012; Carter *et al.* 2014). The term "*triangulation*" itself simply means the application of various methods and data sources to study a specific phenomenon and was initially taken from land surveying. It is assumed that no single method could adequately and fully explore a situation and provide a comprehensive overview. Different aspects of the problem must be addressed using multiple and diverse sources of data (Patton 1999).

Triangulation was particularly important to confirm findings from the analysis of the reports from the UN-SPIDER missions, since some of them could be potentially considered rather dated, due to the years when these missions were conducted. In addition, triangulation helped identify and focus the analysis on the selection of the most prominent technologies and initiatives, which seem to potentially play a crucial role in the development of the field.

4.1.3. Ethical considerations

Present research fully complied with the CEU Ethical Research Policy and followed CEU Ethical Research Guidelines.

In the case of the online survey, to ensure informed consent, all participants were provided with information on the nature and main goal of the project and who will have access to the collected information, and assuring that all provided responses would be kept confidential and safe and that the results of the survey will be presented only in an aggregated format, providing contact detail of the researcher collecting the data and confirming voluntary nature of participation in this survey. This information was presented on the first page of the online platform used to collect responses. To continue with answering the questions, all responders were first asked to confirm their consent to participate in this survey, which was collected together with all the answers. Most of the questions in the survey, particularly open-ended, were optional and could be skipped, in case participants didn't feel that could address them.

While the survey was distributed only among attendees of the CEU summer schools (over the 2016-2019 period), this was done to ensure that responses are provided by experts and practitioners already involved or interested in the application of geospatial technologies. The survey was normally distributed right before the beginning of the summer schools and in no way it affected participation in these workshops. There was no expectation for any rewards or benefits.

The survey had one question to provide the name of the responder, which was included solely to ensure that any duplicating entries could be later removed from the dataset. There were few such cases since some participants took part in more than one workshop throughout the years. No details that could allow individuals to be identified were indented to be published or made available to a third party. All results were presented in an aggregated format and all personal information was deleted after the analysis of the responses was performed.

In the case of participant observation during internships, all responsible officers, supervisors, and colleagues working in the same department were made aware of the author's affiliation with the CEU and the conducted work on the research project. In the case of participant observation at the events (workshops, conferences, etc.), research was carried out only in a public context. Observation of the presentations and discussions occurred only in case of open public events, where those observed would expect to be observed by strangers.

In the case of UN-SPIDER's TAM reports, which are normally not shared in their entirety with the general public, permission from the UNOOSA has been obtained to use information from the TAM reports for this PhD research. UNOOSA is not responsible for any interpretation and representation of this data in the present research. It was agreed that all results of the analysis of these reports would be presented only in a generalized form, without referring to specific countries. The responses were grouped by geographic regions, geographic locations, income, and development levels. Groups were defined to ensure that each group had enough representatives so that no country could be singled out. All mentions of a specific country in the text of the present study, particularly in the Discussion chapter, are coming from sources other than TAM reports. These sources include participant observation at public events, analysis of the open archives, and desktop research which did not require concealing such details.

4.2. Data collection

4.2.1. Desktop research

While the use of secondary data can bring some specific challenges common for this kind of data source, it still plays an important role in research (Hox and Boeije 2005). Considering the growing number of available publications, relevant studies, initiatives, and other similar sources of information, secondary data is playing an increasingly important role in research and it should be taken into account in the analysis (Sarkar *et al.* 2020). Appropriate information on identified issues and challenges, available GeoICTs, relevant organizations, and initiatives involved in the field were initially explored through literature review, internet data search, review of mass media, etc. An overview of available literature on the application of various technologies for disaster mitigation, preparedness, response, and recovery was conducted to identify the main challenges in the dissemination and adoption of GeoICTs in DRR. Reports, international frameworks, and articles were analyzed to identify the overall understanding and awareness of the role of such technologies, as well as commonly recognized problems and any potentially neglected or missed issues (Boslaugh 2007).

4.2.1.1. UN-SPIDER Technical Advisory Missions' reports

Reports of the Technical Advisory Missions (TAMs) conducted over the years by the UN-SPIDER play a significant role in the present study, as the main source of insights into the specific needs of a number of developing countries. The secondary data can serve not only as viable but also as a significant source of information, that overwise might not be covered due to the limitations of the study (Johnston 2017). The richness of data presented and recommendations discussed in these reports (that were developed through a comprehensive analysis by the participating team of experts) proved to be important to consider and explore in the current study. In more detail, these missions and the structure of the prepared reports are discussed in corresponding sections of this thesis.

TAM reports are normally shared only with the officials of the visited countries, but not with the general public, sometimes apart from a general summary of the outcomes and proposed recommendations. Access to the available TAM reports was provided during the internship at the United Nations Office for Outer Space Affairs (UNOOSA) in 2017. The data was obtained from UN-SPIDER TAMs with the consent of the UNOOSA, who is not responsible for any interpretation and representation of this data in the present research. Due to the sensitivity of this information, the results of the analysis are provided in a generalized form, without references to particular countries.

Each report is the result of extensive discussions and in-depth analysis of the existing disaster management policies and organizational structures. It includes observations, conclusions, identified challenges and needs, possible recommendations, and follow-up activities. These reports comprise a thorough review of the state of the countries' disaster management systems in terms of the use of space-based information and geospatial technologies, as key actors are involved in the missions through meetings and discussions. The involved stakeholders in the countries involved particularly: disaster management and development departments and offices of the government, local, regional and international organizations and initiatives, as well as the private sector (UNOOSA 2021a).

TAM reports normally include the following components: objectives of the mission and main activities; overview of the statistical data on hazards and disasters common to the country; the institutional context of DRM, main institutions, and organizations involved; mission observations on the status of the use of space-based information in DRM; overall assessment, identified challenges and current gaps, recommendations, and proposed follow-up actions. The last sections are particularly interesting as they in a condensed way discuss and list the main issues that should be addressed by the government of a country, as well as provide recommendations and suggestions for improvement.

Overall, 33 reports from the missions that took place over the 2008-2017 period were used for the analysis in the current study - 32 reports of the actual TAMs and an additional report from an Expert Mission to Haiti, since it was detailed enough and had a similar structure. In total, these reports came from the missions from three geographic regions - Africa (13 reports), Asia-Pacific (13 reports), and Latin America and the Caribbean (7 reports).

4.2.1.2. Records of occurred disasters

In some cases, the analysis required consulting with the available records of the occurred disasters. For this purpose, the data from the EM-DAT international disaster database was used (Guha-Sapir 2021). This database was already introduced earlier in Chapter 2. Disaster risk reduction and management, not only as a source of statistical information on past disasters but also in terms of the terminology and classification used by this global platform. Compared to other similar databases, particularly DesInventar, EM-DAT focuses on disasters of a higher magnitude (Guha-Sapir 2021; Panwar and Sen 2020). This was decided to be more useful in the course of this project, since, in general, only major disasters require the involvement of international players, when local capacities are not enough to address the threat.

4.2.1.3. Web-search

Additionally, web search was used to explore the diversity of existing geospatial technologies, relevant tools, and applications. As a method of data collection, internet search and monitoring of websites were used in a number of similar studies exploring the diffusion, adoption, and implementation of modern technologies (Acar and Muraki 2011; Paul 2001; Perry *et al.* 2003; Tanner *et al.* 2009; Taylor and Perry 2005). Through the same web search, additional information on some characteristics of the discussed technologies, tools, and services, relevant to the successful diffusion process, were collected, when needed, and analyzed.

Due to the great diversity of existing GeoICTs, only some specific technologies were discussed in more detail than others. These were identified using methodological triangulation, through the fact that some technologies were repeatedly mentioned in various sources more often than others, for instance, through participant observation at different events and UN-SPIDER reports (Bekhet and Zauszniewski 2012; Carter *et al.* 2014).

4.2.2. Web scraping

An important part of the research aimed at exploration of the coverage and access to the satellite-based emergency mapping (SEM) mechanisms. This kind of analysis had to rely on quantitative data - records of actual activations. Out of several existing global, regional, and national SEM mechanisms, the three most relevant were selected for the analysis. These include International Charter “Space and Major Disasters” (Charter), Copernicus Emergency Management Service (EMS), and Sentinel Asia. These mechanisms were selected for a combination of reasons: they can be considered as some of the most active at the moment; they have noticeable differences in their coverage (or potential members or activations in general); detailed records of conducted activations are openly and freely available for the general public.

Since selected SEM mechanisms are already active for many years, responding to multiple disasters across the world, their portals store information about hundreds of activations. Information about all activations of a particular mechanism could not be downloaded directly in a manageable form, so other approaches had to be explored. Manually converting such information for all three mechanisms to a more analysis ready form (a spreadsheet) would have resulted in a very time-consuming and repetitive process, which could also potentially include some human errors in data transferring. Because of that, it was decided to apply the web scraping technique, where possible.

Web scraping allows extracting data from websites (in the current case from webpages of individual activations) to a spreadsheet. This process helps convert original unorganized data into a more structured format, which can be easily analyzed and visualized (Mitchell 2018). Beautiful Soup Python library was used to conduct web scraping (Patel 2020).

It was identified that records of the activations of the Copernicus EMS were stored in a most consistent way (compared to other SEM mechanisms), keeping track of all activations through its GeoRSS[3] feed, which contained some general information on the activations. This data supported web scraping by parsing HTML. Required code was written and run online in *Google Colaboratory (Colab)* notebook (Jupyter notebook).

However, records of the other two selected SEM mechanisms were not stored in a similar consistent way, which did not always allow to use of web scraping to collect data. In the case of Sentinel Asia, the original dataset of activations until 2018 was provided by the supervisor

[3] RSS – Really Simple Syndication.

at ADRC (in a form of a spreadsheet). The remaining activations for 2019 and 2020 were added to the dataset manually at a later stage. Unfortunately, it was not possible to receive a dataset of activations of the Charter, so it was mainly developed manually.

Records of the activations of the three selected mechanisms were stored in a similar tabular format - with the same names of the columns, to help with further analysis and comparison. In the case of all three mechanisms, additional data cleaning had to be performed before the data could be considered ready for analysis. This was done to ensure consistency in the datasets and normalize the terminology, mainly in terms of the names of the types of disasters, countries, and involved organizations (Mitchell 2018).

4.2.3. Participant observation

While participant observation might be seen as a complementary research method (Angrosino 2007), it can provide a great amount of information on the topic, support other research methods, as well as allow triangulation of the data. Participant observation is often applied in emergency management research since it can be used in various settings – to study immediate disaster response in the field (Horsley 2012), or routine communication within the emergency management agency (Horsley 2010; Secara and Bruston 2009). However, its potential can often be underestimated (Phillips 2002).

4.2.3.1. Events

Additional information on the actual situation with the application of GeoICTs in disaster management and any innovative approaches could be collected by participation in various relevant events, like conferences, workshops, and meetings (Mackellar 2013). Through such events, the context of the application or overall knowledge about available technologies can be explored, while some potentially relevant tools and technologies might be identified. Moreover, participation in such events serves as a good opportunity to identify potential experts for discussion (member checking). Analysis of the collected information was mainly done through the prepared field notes, printed informational material, gathered at the events, and, if available, additional review of the recorded presentations and discussions (Mackellar 2013; Moeran 2009). The list of attended events, where the participant observation was conducted includes:

- Climate Change Adaptation Training, organized by the International Federation of Red Cross and Red Crescent Societies (IFRC), 6-10 June 2016, Budapest, Hungary.
- 6th International Disaster and Risk Conference (IDRC) "Integrative Risk Management - towards resilient cities", 28 August - 1 September 2016, Davos, Switzerland.
- United Nations / Pakistan / PSIPW[4] 4th International Conference on the Use of Space Technology for Water Management, 26 February - 2 March 2018, Islamabad, Pakistan. Particularly, observation of the working group discussion on the topic of "Space Technology in Water-related Disaster Risk Management" (which is referred to throughout the study mainly as "working group discussion").
- 3rd Group on Earth Observations (GEO) Data Providers Workshop, 2-4 May 2018, Frascati, Italy.
- Asian Conference on Disaster Reduction (ACDR), 30 October - 1 November 2018, Hyogo, Japan.
- 6th Joint Project Team Meeting for Sentinel Asia STEP-3, 1-2 November 2018, Hyogo, Japan.
- GEO Data Technology Workshop, 23-25 April 2019, Vienna, Austria.
- United Nations/Austria World Space Forum "Access to Space4All", 18-22 November 2019, Vienna, Austria.

[4] Prince Sultan Bin Abdulaziz International Prize for Water

- A series of "In-Service ICT Training for Environmental Professionals" (ISEPEI) project Summer Schools that took place at CEU over the 2016-2019 period, focused on the innovations in DRR and the application of geospatial technologies and remote sensing in monitoring SDGs and water management.

Preliminary data collection through participant observation

Participation in short events, like workshops and conferences, can provide additional data on the issue. At the preliminary stage of data collection, to check the validity of selected methods, participant observation was conducted at the climate change adaptation training, organized by the IFRC), and the 6th International Disaster and Risk Conference. Participation in these events provided interesting insights on some aspects of the applications of GeoICTs in the DRR field, as well as proved to be a suitable method for the research.

Through participation in the workshop organized by the IFRC, some potentially relevant issues were identified. Several representatives from various National Red Cross and Red Crescent Societies participated in this training (from Kazakhstan, Tajikistan, Kyrgyzstan, Uzbekistan, German Red Cross office in Central Asia, Armenia, Azerbaijan, Georgia, Hungary, Nepal, Belarus, Russia, Bulgaria, Italy). Even though it is considered that National Societies mainly provide their support and assistance only after the disastrous event, during the response and recovery phases, some societies are also promoting mitigation and adaptation practices, raising public awareness about disasters and potential risks.

While the application of geospatial technologies in many cases could be very beneficial for National Societies, it seems like they tend to use only a limited number of specific tools, for instance, those developed in cooperation with IFRC (IRI Climate and Society Map Room), and probably are not aware of other sources of spatial data and information on disasters, even free, user-friendly, and potentially relevant. A short presentation of some of the existing online tools on flood monitoring and forecast, which were given by the author during this training, showed that introduced tools were not known by the participants, but interest in the application of these services in the future was expressed.

4.2.3.2. *Internships and research visit*

International organizations working on the promotion of the application of existing GeoICTs in DRR and supporting the development and implementation of emerging innovative tools and services play a major role in the dissemination of geospatial technologies. Involvement in the everyday activities of such organizations can help develop a more comprehensive understanding of the issue and support the overall relevance of the research findings (Iacono *et al.* 2009; Moeran 2009). Internships, as a way to get engaged in the activities from the institutional side, provide opportunities for deep involvement in the actual work of the organization and help develop the trust of the employees, as potential sources of additional data (Horsley 2010). Overall, participant observation was conducted at three organizations, all engaged in the DRR activities in a different capacity - through internships at UNOOSA and the Food and Agriculture Organization of the United Nations (FAO), and a research visit to the Asian Disaster Reduction Center (ADRC). Field notes were prepared throughout the internships and research visit, supported by additional data sources (taking photos, gathering available printed materials), to help with the further analysis (Mackellar 2013; Moeran 2009).

Internship at UNOOSA

One of the most important international organizations working in the field of the promotion of the wider application of space-based technologies and data is UNOOSA. Activities of the UN-SPIDER programme implemented by this office were particularly relevant for the current study. This programme serves as a bridge between the providers of space-based services and end-users, ensuring access and ability to use corresponding technologies by relevant actors at every stage of the disaster management cycle (UN General Assembly 2006a). The internship at UNOOSA took place in 2017 and was conducted at the Space Applications Section (Vienna, Austria), mainly focusing on the activities related to the UN-SPIDER, particularly to the TAMs and other missions. It was partially supported by the Research Project Grant from the CEU Foundation of Budapest.

Internship at FAO

FAO is a specialized agency of the United Nations that leads international efforts to defeat hunger and improve nutrition and food security. Its strategic framework is acknowledging the challenges that can be brought by climate change and natural disasters. An earlier version of the framework included a dedicated objective to "Increase the resilience of livelihoods to threats and crises". The most recent strategic framework for 2022-2031 mentions resilience and climate change adaptation throughout, but particularly clearly in three out of four "*betters*", that act as organizing principles: Better production, Better environment, and Better life (FAO 2021).

The internship at the FAO took place in 2019, at the Regional Office for Europe and Central-Asia (Budapest, Hungary), supported by the Internship Support Program Grant from CEU Foundation of Budapest. Work was focused on the activities of the DRR team, mainly through involvement in the FAO Regional Initiative 3 on "Managing natural resources sustainably and preserving biodiversity in a changing climate". Through this initiative, the organization is assisting countries in managing their resources sustainably, while coping with climate change and reducing the risk of disasters affecting agriculture, forestry, and fisheries. One of the projects implemented by the Regional Office is focusing on the preparation of baseline studies on DRR and management, early warning systems (EWS), and agro-meteorological services in selected countries, particularly on the identification of existing gaps and needs. While FAO's priorities do not always directly address issues related to DRR, due to the characteristics of this project (on which the internship was focusing), participant observation at FAO still proved to be a great opportunity to observe the situation in terms of overall interest in and application of GeoICTs from a perspective of an agency with different spatialization. As well as, it helped identify additional aspects of the situation in the countries in the sub-regions, which were directly covered by the project (Caucasus, Central Asia, Eastern Europe, and Western Balkans).

Research visit to ADRC

ADRC is a regional center that aims at enhancing the disaster resilience of the countries in Asia, building networks, and overall developing DRR capacities (ADRC 2021). Most importantly, the center acts as a central component of the Sentinel Asia initiative, coordinating mechanism's activations across Asia-Pacific, as well as serving as a formal partner of the Charter. Such unique activities and roles performed by the ADRC make it one of the most interesting organizations in the region that address issues related to DRR and build related capacities, particularly in terms of GeoICTs. The research visit to ADRC (Kobe, Japan) took place in autumn 2018 and was supported by the CEU Doctoral Research Support Grant. It started together with the arrival of the new batch of visiting researchers, invited by the center through one of their core initiatives. Such timing allowed participation in most of the visits and trips organized by the ADRC for the visiting researchers, including visits to local areas affected by recent disasters, main disaster management, and response services, meetings with relevant organizations and companies, attendance of conferences and workshops, etc.

In addition, during the research visit, one month was spent at the Center for Research and Application of Satellite Remote Sensing of Yamaguchi University (Ube, Japan). Yamaguchi University is also a member of the Sentinel Asia initiative, however, it has a very different role than ADRC. University acts as a data analysis node, being among the first organizations which process raw satellite imagery and prepare maps for disaster responders and decision-makers, in case of an activation of a mechanism.

4.2.3.3. Response validation

In addition, to confirm and validate the findings of the participant observation, response validation (or member checking) was regularly performed through the data collection and initial analysis. Member checking is also known as participant/respondent validation or informant feedback and is an important tool in qualitative research (Hallett 2013). It was done mainly through conversations and discussions with the experts - either participants at the attended events or supervisors and colleagues during the internships and research visit.

Discussions with the relevant experts in the field also took place to ensure that any important issues or technologies are not overlooked, in relation to the current state of the dissemination process and application of GeoICTs in DRR. Such conversations allowed to discuss not only the findings of participant observation but also issues identified at the previous stages of the research, through desk research, and from the surveys. Some additional aspects of the situation were discovered during such discussions. In this aspect, response validation served not strictly just as a validation tool but is helping fill the gaps in the data as well (Hallett 2013).

4.2.4. Expert survey

To explore the current situation in the application of satellite technologies and ICTs in general, sources of information on such tools and services (communication channels), particular motivation of end-users in their decisions to adopt or reject an innovation, it was decided to conduct a survey among the experts (practitioners, academics, officials) working in the disaster management or related fields. A semi-structured survey can help explore experts' opinions on the already formulated issues, to collect and analyze the collective wisdom of the respondents. A questionnaire, which addresses quite specific topics, also allows to include in the research opinions of a greater number of people, compared to individual in-depth interviews.

Some expert surveys methods allow a rather limited number of respondents – for instance, the Delphi method normally requires approximately 10 to 18 participants per panel (Kenyon *et al.* 2008; Okoli and Pawlowski 2004; Ross *et al.* 2016; Tsai and Chen 2011; Yang *et al.* 2021), but sometimes may include more – for instance, 55 experts participated in the research on the exploration of information needs for flood damage analysis (Elmer *et al.* 2010). Yet it might be extremely hard to ensure participants' commitment to this particular type of research method since it takes from weeks to months to complete all stages of the Delphi survey, while the compositions of the experts' group must remain the same throughout the whole research process (Kenyon *et al.* 2008; Okoli and Pawlowski 2004).

The number of responses from experts collected through surveys should be adequate – approximately ≥ 100. In addition, a number of experts for the survey might be identified during the professional conferences and meetings (Alberini *et al.* 2006). Studies focusing on the experts' opinions on various matters often involve a comparable number of participants, for instance, conjoint choice survey – 100 respondents (Alberini *et al.* 2006), a survey of expert opinion – 118 respondents (Gabre-Madhin and Haggblade 2004). Results of similar surveys allowed to conduct a more complicated and interesting analysis of the participants' responses since a number of homogenous groups of respondents can be formed through disaggregating results by their background, experience, region, etc. Supported by other sources of data, such surveys contribute to the exploration of the situation in the field.

The questionnaire prepared for the expert survey within the current study is focusing on the overall use of GeoICTs and the identification of the main issues and challenges in the adoption and adaptation of such geospatial technologies, recognized by responders through their professional work. It also aims at exploring the overall awareness of existing applications of GeoICTs and information sources about such innovations in the field. The questionnaire includes questions about participants' background, their knowledge, and previous experience in the application of the GeoICTs. Some parts, or particular questions of the survey, were developed using available examples of similar activities, identified through initial data collection. For instance, the section on the application of satellite-based technologies was developed using the report by Eurisy, which presented the results of the survey "Operational uses of satellite-based services in the public sector" (Eurisy 2016). The section from this survey on the “Challenges for the Public Authority” proved to be particularly relevant for the current study.

In the last section of the survey participants were asked to assess their competence to answer the questions of the survey. Later this information was used to add a specific weight to the participants’ answers depending on this self-assessment (Okoli and Pawlowski 2004). The developed survey questionnaire used in the survey is presented in Appendix 2.

Due to the overall purpose of the research, the conducted survey had some features similar to the Delphi method. Since the questionnaire is focusing on quite specific issues, respondents must have deeper knowledge in the field, compared to the general population. Since participants of the ISEPEI summer schools were already preselected through a review of the applications, they were not chosen randomly and were considered as having enough expertise. For similar reasons, the sample size might not be as great as in the case of traditional surveys (Okoli and Pawlowski 2004). Other features similar to the Delphi method are the flexibility of the questionnaire, meaning that it allows a researcher to modify the questions if some new relevant information appears. Another feature is the ranking of respondents’ expertise (in the current case it was made through self-assessment) as well as ranking various factors or issues (Okoli and Pawlowski 2004). Participants were asked to assess statements on the challenges in the application of the GeoICTs in terms of their importance and credibility (the “SDGs” group rated only the list from the NRC report, while the “DRR” group received both lists).

At the initial stage of the research, the "In-Service ICT Training for Environmental Professionals" (ISEPEI) project’s summer schools at CEU were considered a good source of data, not only due to the main focus of these events but also due to the targeting and selection of potential participants. Workshops that took place over the 2016-2019 period covered topics on the innovations in DRR and the application of geospatial technologies and remote sensing in monitoring SDGs and water management. The target group included mainly practitioners, particularly representatives of UN organizations, focal points of international conventions, relevant governmental agencies, and civil society, but also included academia. It was decided to use this opportunity and the involvement in the organization of the workshops, not only to conduct participant observation but also to carry out expert surveys among participants.

A preliminary semi-structured questionnaire was developed and tested at two CEU summer courses (week-long each) in 2016. It was shared with participants as a Google Form application before the beginning of the workshops. After slight adjustments, six more surveys were conducted in the following years (two per year) to collect enough responses for the analysis. Overall, after removing duplicating entries (since some responders participated in more than one summer school), responses from 133 participants were collected and analyzed. Participation in the survey was encouraged but remained voluntary, so not all people who participated in the summer schools filled in the questionnaire.

4.3. Data analysis

4.3.1. Qualitative data analysis

Collected qualitative data, particularly reports of the UN-SPIDER's TAMs, were analyzed using two complementary approaches - thematic network analysis and applied thematic analysis (Attride-Stirling 2001; Guest *et al.* 2011). Most data processing, coding, and analysis were done using qualitative data analysis and research software ATLAS.ti (Rambaree 2014, 2018).

4.3.1.1. Thematic network analysis

Overall, thematic network analysis follows general steps common for the analysis of qualitative data - preprocessing of the collected data, initial review of the material, coding, combining codes into larger themes, and refining themes. The main feature lies in the representation of the findings - organization of the identified themes in a form of a network (Attride-Stirling 2001).

This approach can help structure the findings and detect overarching themes, which might be quite crucial depending on the kind of analyzed data and the purpose of the study.

In the case of TAM reports, the application of thematic network analysis proved to be quite useful in the identification of organizing and global themes, which otherwise could not be that easily detected. At the same time, it is important to notice that reports were not analyzed in their entirety. The focus was made on the proposed recommendations, as they represented the main findings of these missions, both discussing existing needs and gaps, as well as suggesting solutions to overcome these challenges. ATLAS.ti software has a building network function, which allowed to develop a thematic network of main topics identified through the analysis of TAM reports (Rambaree 2014, 2018).

4.3.1.2. Applied thematic analysis

Applied thematic analysis as a methodological framework can be defined as a combination of techniques, tactics, and features common to other analytical approaches, like grounded theory and phenomenology (Guest *et al.* 2011). It allows a combination of qualitative and quantitative interpretations of the data, as well as non-theme-based techniques, depending on the needs. It followed similar steps as the thematic network analysis, particularly the initial review of the data, coding, and joining codes into larger themes, followed by the preparation of the list of specific topics of concern. This allowed to introduce and explore the overall main framework and topics raised in the TAM reports, and analyze them in a more qualitative way. As well as it was possible to present and discuss specific concerns as a narrative and combine the results of the TAM analysis with findings from other sources, like participant observation.

Main themes identified through the initial analysis of the reports were then used as guiding topics for the following discussion, which incorporated findings from the analysis of multiple data sources, including participant observation, survey, and network analysis of SEM mechanisms' activations.

4.3.2. Quantitative data analysis

4.3.2.1. Network analysis

Network analysis, particularly social network analysis (SNA) is a quite common method used in studying the diffusion of innovations across various systems (Larsen 2011; Shih and Chang 2009; Wang *et al.* 2020). This approach normally allows exploring connections (communication channels) between actors in the network, particularly the structure of such interactions as well as the components of the developed system. This approach relies on qualitative data analysis to extract relevant information and indicators on the characteristics of the network and its components - individual actors (nodes) and connections between them (edges) (Shih and Chang 2009). Analysis of the data in a form of a network also allows conducting topological and visual analysis (Yang *et al.* 2021).

Depending on the focus of the study or its scale, it might not always be possible to address the diffusion process from the position of individuals. Sometimes, depending on the data collection approaches, network analysis can focus on different types of actors, including organizations, sectors, countries, etc. (Chang and Shih 2005; Shih and Chang 2009). Several methods can be potentially applied to collect data needed to develop such networks, including surveys, interviews, and content analysis (Ceci and Iubatti 2012; Larsen 2011; Wang *et al.* 2020). Another approach is to use preexisting datasets that store data that in some way reflects information flows and can be converted into networks (Shih and Chang 2009; Yang *et al.* 2021).

Due to the global coverage of the present research and related limitations in terms of time, resources, and general feasibility, it was not possible to use surveys or interviews for the data collection, as it, in any case, could reflect the situation only partially. The existing system of organizations involved in the promotion of the wider application of GeoICTs in DRR is increasingly diverse. And while some attempt to visualize a network of at least the main actors in this field was made, the overall complexity of the system and a number of involved elements resulted in a higher probability of some actors (organizations or countries) being overlooked. An analysis of this kind of incomplete system could have led to some incorrect conclusions, which had to be avoided.

Because of these concerns, it was decided to focus analysis specifically on the activations of selected SEM mechanisms, as a case study. These mechanisms play a crucial role in disaster response, connections between organizations requesting activation and affected countries reflect information flow, while the level of formal involvement of a country in any initiative could serve as an indicator of the presence of basic technology and capacity required to make use of the mechanisms. At the same time, developed networks of activations could be considered complete and comprehensive, since this kind of data on its own provided clear frames both in terms of time and scope. Limiting the data source to a record of requested activations helped ensure that no actors were overlooked - if an organization or a country were involved in at least one activation, they would be included in the network and the analysis.

Developed datasets of activations (spreadsheets) had to be adjusted before they could be converted into networks. For activations when more than one specific organization had sent a request, such cases had to be split accordingly into separate elements, to reflect the actual connections between individual organizations and countries. In the developed networks *nodes* represented both unique affected territories and activation requestors (AUs), while *edges* represented the links between different nodes. Edges were aggregated for cases with more than one activation between the same pair of AU and a country. The networks could be characterized as *directed* (links always go from AU that requested an activation towards the country, where the disaster happen), *bipartite* (meaning that no two nodes from the same group can have a connection between each other - no AU-AU or country-country links), and *disconnected* (have isolated elements not connected to the main network). At the same time, for later analysis, the undirected versions of the networks were used as well.

Original datasets of activations, as well as network files, were created and analyzed online in Google Colab notebooks (Jupyter notebooks) (Perkel 2018). Pandas and NetworkX Python libraries were used to develop the code and conduct the analysis (Zinoviev 2018). While the quantitative analysis of the networks was conducted in Colab notebooks, visualization was done using a specialized tool, Gephi software, since Jupyter notebooks generally are not considered the best platform for network visualization. This allowed to additionally perform visual network analysis, a more qualitative interpretation of the results, in contrast to focusing exclusively on quantitative findings (Decuypere 2020; Venturini *et al.* 2014).

Bipartite network projection

Since the developed networks of the activations of the SEM mechanisms were all bipartite in nature, they could have been *projected* - transformed from a two-mode network (that includes the nodes of two types - countries and organizations) into a one-mode network (representing one specific type of the nodes). As a result of this process information stored in the network is compressed, as well as also simplified, helping identify some patterns which might have been hard to see in the original system (Zhou *et al.* 2007). In the case of the networks of activations, this transformation highlighted clusters of organizations or countries which were grouped due to the similarities in the approaches they followed (in terms of requesting activations or receiving support).

Not to lose some important characteristics of the original network, it is often preferred to apply a *weighted projection* (Banerjee *et al.* 2017; Zhou *et al.* 2007). In general terms, the *weighted projected graph* is the projection of a bipartite network into specified nodes with weights of the edges representing the number of shared neighbors. The nodes are connected in the resulting graph if they have an edge to a common node in the original graph. In relation to the networks of mechanisms' activations, this means that if any two organizations made an activation request for the same country, in the projected network they would have a link between them. The weight (thickness) of this link depends on how many common countries they supported. A bit more complicated and interesting type of such analysis is the *overlap weighted projection* - the projection of a bipartite network into specified nodes with weights representing the Jaccard index between the neighborhoods of the two nodes in the original network. *Jaccard index* (or Jaccard similarity coefficient) illustrates similarity and diversity between two sets. It is used to compare members of the sets and indicate the overlap between them, ranging from 0 (no overlap) to 1 (100% similar). For the analysis of the mechanisms' activations, both types of projections were applied.

The clustering coefficient is one of the characteristics of the developed graphs that could be explored - in graph theory, this measure shows the degree to which nodes in a graph tend to cluster together. *The local clustering coefficient* (of a particular node) is calculated as a proportion of connections among its neighbors (in relation to the maximum number of possible connections between them). In real-world social networks, nodes tend to cluster together, forming groups with a relatively high density of ties (Zhang *et al.* 2008). Different clusters in the developed networks were identified through modularity scores calculated using the Louvain method (Louvain algorithm for community detection available in one of Python's packages). *Modularity* is a property of the network that shows the tendency of nodes to cluster, helping in detecting different communities (Newman 2006). The exact number of identified communities depends on the method that is used to find them.

Visualization and analysis software

This section briefly introduces the main software that was used to develop some of the figures presented in this study. These tools were generally used to visualize developed networks, however, overall they can have a variety of other applications. Since visual network analysis is an important approach in qualitative analysis and interpretation of the structure, clusters, and components of such systems, it was considered important to present some of the tools that can be applied in similar research and well as support the presentation of the results (Decuypere 2020; Venturini *et al.* 2014).

Gephi

Gephi (https://gephi.org/) is a free open-source software for network analysis and visualization (Bastian *et al.* 2009). Overall, it is possible to use this tool to develop networks based on the available tabular datasets (or even manually) and conduct a relatively complex analysis of the networks' features. However, the most practical approach is typically to conduct the initial analysis elsewhere (for instance, in Jupyter notebooks), extract the graph file, and later visualize it using Gephi (Zinoviev 2018). This was the approach used in the current study as well. Gephi was particularly used to visualize all the networks related to the SEM mechanisms: a network of members, partners, and authorized users of the mechanisms; a network of formal partners of selected organizations facilitating the diffusion of the GeoICTs; activations of the Charter by geographic regions; overall networks of mechanisms' activations; projected network of Sentinel Asia activations. "Force Atlas 2" and "Yifan Hu Proportional" were the main layout algorithms used for the visualizations (Hu 2005; Jacomy *et al.* 2014).

Flourish

Flourish (https://flourish.studio/) is a versatile online platform for data visualization and storytelling. A free version of its services allows the creation of web-based interactive visualizations. By default, it makes all data public, which, however, was not considered an issue for the present study. Flourish features a diversity of templates for data visualization, including line, bar, and pie charts, animated line charts (illustrating races), maps, scatter plots, radar charts, pictogram charts, Sankey diagrams, chord diagrams, network graphs, word clouds, and many more. In the present research, Flourish was used to develop an interactive network of the generalized and summarized findings of the discussion, as a sort of byproduct of the overall research. This network reflects interlinkages between main identified problems in the field, more specific related needs, and proposed solutions. It could be used as a general tool for wider promotion of the findings, as well as makes them more easily accessible and engaging, due to its interactive nature.

diagrams.net

In the case of relatively simpler concept networks/maps, there was no need to use specialized network analysis software, or related interactive features. Diagrams.net (https://www.diagrams.net/), which is a free open-source online platform for building diagram applications, proved to be a good solution for developing figures for the present study. It provides a number of templates that can be used to create various organizational charts, mind maps, networks, and diagrams. Diagrams.net was used particularly to provide better visualization of the thematic network developed through thematic network analysis of the TAM reports (initially done via ATLAS.ti software).

4.4. Limitations

4.4.1. Geographical coverage

The complex nature of the studied problem along with the global scope might affect the generalizability of acquired results, however, implementation of a combination of various methods as well as diverse data sources should help mitigate the related shortcomings. The universality of the raised issue of access and application of modern geospatial information and communication technologies determines the absence of a particular regional focus in the study. At the same time, developing countries in general experience more problems in implementing such technologies and might face more severe consequences in case of a disaster, and the emphasis in the discussed topics was on these states. Overall, the study covers issues that can be experienced universally, however, the nature of the explored field, and the work done by the UN and other organizations, somewhat shift the focus on the challenges faced by the most vulnerable states. This tendency should not be considered a bias, since the need for more support for the Global South expressed in international agreements and confirmed by the recorded statistics of the disaster damages and losses, should compensate for this limitation.

While the initial idea of the research suggested using floods as the only type of studies disasters, selected data sources, in general, covered the DRR field overall (various hazards and disaster management stages). Discussed issues, challenges, and solutions were largely applicable to various types of disasters and could not be clearly differentiated based on that. Excluding all other hazards, apart from floods, from the research would require disregarding a significant portion of data, readily available for the analysis, which was considered wasteful. At the same time, one section of the research still is focusing specifically on floods - the proposed categorization of GeoICTs. This exercise in the collection and classification of the existing tools was used to highlight the potential diversity and complexity of available ICTs, using floods as a case study.

4.4.2. Limited data

One aspect of this kind of limitation is related to the use of secondary data, UN-SPIDER's TAM reports, as an important source of information. Reports of these missions provide a rich and comprehensive overview of the situation in each of the visited countries, as well as discuss main needs and propose solutions. At the same time, the total number of conducted missions (and visited countries) is limited. Due to the nature of this data, it was not possible to in any way affect what, how, where, and when information was collected. Still, considering the overall value brought by these reports, it was decided that the benefits outweigh related limitations. Analysis similar to the one conducted by the team of experts involved in TAMs could not be in any way performed within the format of a PhD project. At the same time, a comprehensive analysis of the cumulative set of these reports was not yet conducted and it was believed that it could reveal meaningful insights.

Another related issue that can be mentioned is based on the selection of events and organizations where participant observation was conducted. Organizations, where internships and research visit took place, were selected keeping in mind the different roles and perspectives they could add to the research but also depended on available opportunities. Considering the diversity of international organizations involved in the field, it was not possible to cover all angles using such involved and time-consuming tactics. Participation in major events that generally brought together various actors and stakeholders, including data providers, software developers, as well as end users, helped compensate for some of the limitations and fill in potential gaps.

And finally, in relation to SEM mechanisms, it was decided to focus the review only on the three most prominent and relevant initiatives. While such limitation was justified by the overall availability of the comprehensive records and the focus of the research project, in theory, a more comprehensive overview could have covered all major mechanisms.

4.4.3. Errors in data collection

Some errors in data collection might have potentially taken place during the preparation of the datasets on activations of the selected SEM mechanisms. While some of the data was collected automatically, using web scraping techniques, which to some degree reduce the likelihood of errors, or was provided directly by organizations, in some cases information had to be collected manually (for instance, on activations of the Charter). In addition, some errors might have been overlooked during the data cleaning stage, which also sometimes had to be performed manually. Still, some presence of human errors even during the initial data entering always can be expected (Panwar and Sen 2020). Considering the rigorous multistep data cleaning process and the generalization performed during the analysis, a limited number of potential errors should not have a significant effect on the final results. Records of activations were examined and assessed as a whole, in order to explore any prominent trends or tendencies (for instance, in terms of the geographic location of disasters), which overall should not be noticeably affected by single errors in original datasets.

4.4.4. Methods of data analysis

Interpretation of the qualitative data largely depends on the aim of particular research, any underlying predispositions of researchers that conduct the study, as well as methods selected to perform the analysis (Queirós *et al.* 2017). Sometimes it is argued that the coding, applied in this study as well, could lead to some loss of the context (Graue 2015). Overall, it is believed that throughout the current research project impartiality in observations and data interpretation was maintained. During the analysis, having a clear aim on issues related specifically to diffusion and application of GeoICTs helped to keep focus, consider collected data from a particular position, and correspondingly, formulate the findings.

5. GeoICTs in disaster management and global implementation mechanisms

The following chapter introduces the diversity of existing GeoICTs and proposes their categorization, as well as presents the most relevant international frameworks and mechanisms that are shaping and defining information and knowledge management in the DRR field. Most significant aspects of international frameworks for DRR, particularly related to the application of technologies are highlighted and discussed. The next part of this chapter introduces emergency mapping mechanisms that provide access to remotely sensed data and relevant expertise. The final section is dedicated to United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) and related activities.

5.1. GeoICT categorization

5.1.1. Diversity of GeoICTs

While a great number of tools, services, and applications relevant to disaster risk management can be found nowadays and with innovations appearing at a fast rate, the systematization of such technologies can be considered surprisingly weak. Some of the overviews on the existing ICTs offer classifications, based on the disaster type the technology is dealing with – natural (earthquake, flood, drought, etc.) or technological (chemical spill, radiation, transport accident, etc.) (World Bank 2014). However, it is usually not possible to implement even such basic classification, since often available tools, platforms, and services do not focus only on one particular type of hazard, but on a range of them. Or in some cases it is not possible to assign such class due to the specific applicability of the technology – for instance, services, providing data on population distribution, human settlements cannot be designated to disaster type, while at the same time it is an important characteristic for various disasters since it defines the exposure to the hazard.

The diversity and growing number of available and constantly developing geospatial ICTs complicate the process of their potential classification and categorization. To propose an example of such distribution of available tools, services, and technologies, a case of GeoICTs that could be used in flood management was selected for review and analysis. ICTs selected for this exercise were identified through desk research, as well as participant observation and discussions with practitioners. At the same time, in no way the provided list of tools and technologies should be considered comprehensive and complete - the proposed classification can serve just as an example and illustration of the diversity of existing GeoICTs and their potential applications.

Overall, existing classifications based on the types of disasters seem not suitable for the purposes of this study. At the same time, considering the diversity of available technologies and tools to attempt at proposing own classification the scope of the review had to be limited. It was decided to focus particularly on the GeoICTs which had some relevance to addressing flood resilience and risk management. This choice was determined by the fact that flood is the most common type of disaster affecting countries across the globe and are expected to become even more frequent (WMO 2021), as well as since there is a very long tradition of using geospatial technologies in flood risk mapping, assessment, and disaster response.

Overall, 51 relevant GeoICT were selected for the review to propose several potentially useful systematizations and classifications. An extended list of selected ICTs with short descriptions is presented in Appendix 3. The review was focusing mainly on free and open access technologies with the emphasis on the online GeoICTs which do not require long training or additional costly equipment and can be easily accessed everywhere around the world. In an attempt to find the most meaningful way of ICTs systematization, each tool was analyzed by several characteristics, as well as was marked by various tags. Different approaches could be used to classify selected ICTs by their characteristics and functions: type of the ICT; spatial coverage; purpose; disaster management phase; data access; data source; organization in charge; etc.

5.1.2. Example of proposed classification

While several potential classifications were explored, only one of them is presented here in detail – classification based on data sources. The number of potentially relevant GeoICTs can be quite big, however, the number of data sources for such tools is generally more limited. Therefore, one way to classify, or at least group selected tools, is based on the systematization of the data sources that these tools utilize. In Figure 9, a small snippet of an example of such systematization is presented. For this attempt, the tools, which operate mainly with the remotely sensed data, were selected. Blue elements on the top of the image represent the satellites, yellow elements on the bottom – the tools (GeoICTs), while green – intermediate elements, which could serve as a data archive, accumulating and storing the collected data, or as processing and analytic components.

The presented scheme includes only nine tools and is quite basic, but still can illustrate some aspects of the connections between data sources (satellites) and GeoICTs that act as portals/platforms and provide easy access to the related information, through which this data became available for common users. For instance, it is seen how the data from the Tropical Rainfall Measuring Mission (TRMM) satellite and its successor, the Global Precipitation Measurement (GPM) mission (NASA 2021b), are used in a wide range of ICTs – Japan Aerospace Exploration Agency (JAXA) Global Rainfall Watch, ITHACA's Extreme Rainfall Detection System, Worldview of the National Aeronautics and Space Administration (NASA), Global Flood Detection System of the European Commission's Joint Research Centre (JRC), etc. At the same time, data from some sources sometimes could be available through some particular tool, depending on its application, for instance, the camera on the International Space Station – ISS SERVIR Environmental Research and Visualization System (ISERV).

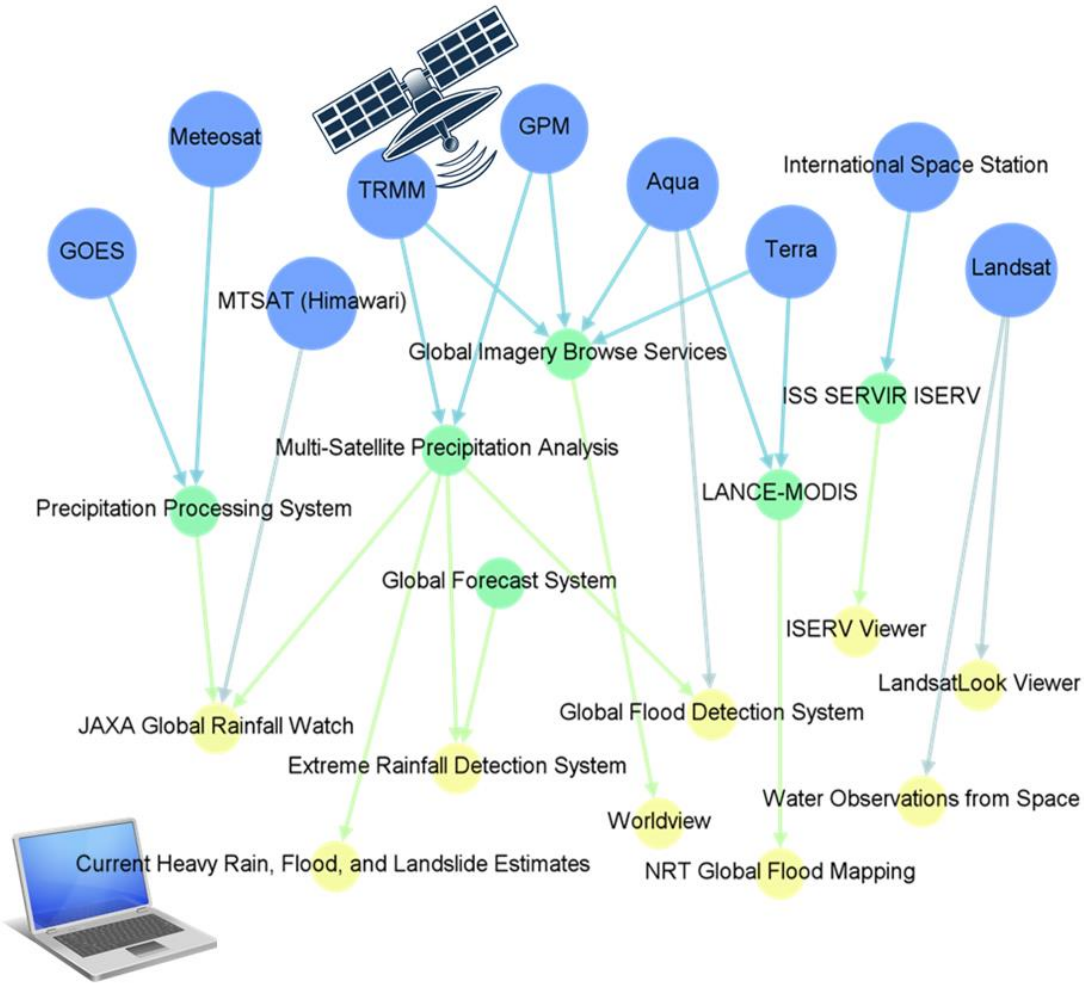

Figure 9. Example of connections between data sources and GeoICTs

Note: blue circles represent satellites; green – intermediate, processing services; yellow - GeoICTs

It is important to indicate, that this small example already includes rather many connections between introduced elements, the actual situation appeared to be incomparably more complex and confusing. For example, the United States Geological Survey (USGS) EarthExplorer online search, discovery, and ordering tool incorporates the remotely sensed data from such a great number of sources (including the ISS SERVIR ISERV), that it seems almost impossible to include it in a scheme (USGS 2021). NASA EOSDIS Global Imagery Browse Services (through which Worldview receives the data) includes over 1000 satellite imagery products, while in 2016 it had access to only around 200 (NASA 2021a). Such services as Giovanni, Socioeconomic Data and Applications Center (SEDAC), JAXA products, Global Human Settlement Layer (GHSL) also incorporate data from a great number of sources, and not only remotely sensed, but of various types. An elaborate and deep analysis of the data sources could potentially provide some interesting results, and show the overall picture of the data flow within this particular sector of GeoICTs relevant for DRR and management.

5.1.3. Aggregated classification

Finally, after the review of various features of the selected GeoICTs (relevant for flood management), an aggregated classification was composed, based only on the few selected characteristics, which were considered the most appropriate and meaningful. The proposed categorization is presented in a form of a table in Appendix 4. This classification comprises all tools selected for the overview. The most significant characteristics include the purpose of the tool, the spatial coverage (or the scale), and access to manageable data. In the proposed final classification, all tools were divided into specific groups, based on their main function and the scale. Even though several other features of the GeoICTs were initially examined, after the analysis, only a few of them were considered to be most relevant for the indicated purpose of the study, or it was not possible to explore some of them to the satisfactory level for the proper systematization (for instance, data sources or the "popularity" of the tool).

5.2. International frameworks for disaster risk reduction and management

5.2.1. Technology and innovations in international frameworks on DRR

In the following section international frameworks in the field of DRR and management, as well as other relevant initiatives, are presented and discussed, with special attention to such aspects as the importance of information and technology dissemination, cooperation, and other issues related to the application of innovations, mentioned in these agreements. Figure 10 presents the timeline of the frameworks and agreements, that are discussed in this chapter.

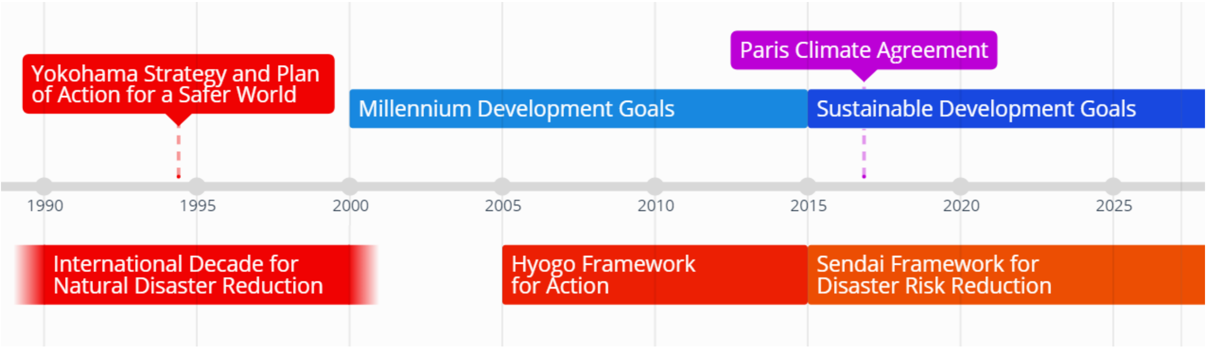

Figure 10. Timeline of the discussed international agreements and frameworks

5.2.1.1. International Decade for Natural Disaster Reduction (1990-2000)

In the United Nations General Assembly resolution A/RES/44/236 (22 December 1989) the International Decade for Natural Disaster Reduction (1990-2000) was announced, and at the same time, the International Framework of Action for the declared decade was adopted (UN General Assembly 1989). This resolution was followed by several amended international strategies and frameworks, which sequentially replace one another. Each time they determine the priorities in disaster management, revising and rethinking main goals, taking into account revealed and arising issues in the field.

It is important to note, that all five goals of the International Framework of Action for the International Decade for Natural Disaster Reduction include the need for wider application, development, and distribution of the relevant technologies, knowledge, and data, in one form or another (UN General Assembly 1989).

5.2.1.2. Yokohama Strategy and Plan of Action for a Safer World (1994)

At the First UN World Conference on Natural Disaster Reduction, held in Yokohama, Japan, in 1994, the Strategy and Plan of Action for a Safer World were adopted (UN IDNDR 1994). The Yokohama Message, which precedes the Strategy and Plan for Action, notes the particular emphasis on “[t]echnology sharing, the collection, the dissemination and the utilization of information”, together with “[h]uman and institutional capacity-building and strengthening” and “[m]obilization of resources”, in order to strengthen international cooperation in disaster management (UN IDNDR 1994).

Being accepted almost in the middle of the International Decade for Natural Disaster Reduction, the Yokohama Strategy and Plan of Action adopted 10 Principles, one of which deals specifically with the technological aspect of disaster management:

> “8. The international community accepts the need to share the necessary technology to prevent, reduce and mitigate disaster; this should be made freely available and in a timely manner as an integral part of technical cooperation” (UN IDNDR 1994).

Another important feature of the strategy is the analysis of the main progress and failures, identified during the first years of the International Decade for Natural Disaster Reduction (UN IDNDR 1994). Some of these issues include:

- Limited awareness of the importance of disaster reduction, especially among policymakers and the general public (due to the lack of attention and limited resources).
- Unsatisfactory results of the educational and training activities, as well as the insufficient involvement of media, private sector, industrial sector, and scientific community.
- Focus on the reactive approach in disaster management, regardless of the importance of the proactive measures stated in the United Nations General Assembly resolution A/RES/44/236.
- The need to identify and spread successful practices, particularly existing tools, which often are not used to the full extent.
- Support the local communities’ resilience, taking into account their traditional knowledge and practices.

The proposed Strategy and Plan of Action emphasize the need for the strengthening of national, regional, and international cooperation, information exchange, and wider application of existing technologies (UN IDNDR 1994).

5.2.1.3. Hyogo Framework for Action (2005-2015)

The Second UN World Conference on Disaster Reduction, held in Hyogo, Japan, in 2005, was marked by the adoption of the "Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters". This document took into account the Millennium Development Goals, announced in 2000, to encourage a more holistic approach to disaster management (UNISDR 2005b).

The important feature of the Hyogo Framework is the analysis of the issues identified during the implementation of the Yokohama Strategy and Plan of Action. Once again, the need for a more proactive approach was stressed, as well as the financial aspect of the problem was mentioned – the lack of resources devoted to the DRR activities and development (UNISDR 2005b). The necessity to engage local communities in the disaster management process was also stated – to inform the local population, need to involve people in the decision-making process, and training (UNISDR 2005b).

The review of the implementation of the Yokohama Strategy and Plan of Action identified five main problematic areas:

1. Governance: organizational, legal and policy frameworks;
2. Risk identification, assessment, monitoring and early warning;
3. Knowledge management and education;
4. Reducing underlying risk factors;
5. Preparedness for effective response and recovery (UNISDR 2005b).

While the lack of systematic approach and cooperation between involved actors were mentioned among general challenges, it is interesting to note that the knowledge management and technological component were common issues in almost every identified problematic area (UNISDR 2005b). The challenging actions include comprehensive data collection and dissemination; hazard mapping; risk assessment; education and training; cooperation and collaboration of various actors (local communities, private sector, practitioners, scientists, etc.); availability of relevant technologies (UNISDR 2005a).

In the Hyogo Framework, five Priorities for action for 2005-2015 were formulated (unlike the ten priorities from Yokohama Strategy). Apart from these priorities, some general considerations were stated, including the need for stronger cooperation and support on different levels (international, regional, and local). This interrelation should be expressed in various forms, but the essential part of it is technology transfer, interchange of knowledge, best practices, data, etc. (UNISDR 2005b).

Among these five Priorities for action (UNISDR 2005b), at least two directly deal with knowledge management and ICT:

> Priority 2. Identify, assess and monitor disaster risks and enhance early warning.
>
> Priority 3. Use knowledge, innovation and education to build a culture of safety and resilience at all levels.

The most important aspect of the second priority (disaster risks and early warning) is the capacity building aimed at the support of scientific and technological capabilities and methods, development of databases, stimulation of open access and free information dissemination, and promotion of various technologies (RS, GIS, Modeling, etc.) (UNISDR 2005b). The third priority (knowledge, innovation, and education) is focused on knowledge management, information exchange, education, research, and public awareness (UNISDR 2005b).

5.2.1.4. Sendai Framework for Disaster Risk Reduction (2015-2030)

The successor of the Hyogo Framework for Action was adopted in 2015 at the Third UN Word Conference on Disaster Risk Reduction, in Sendai, Japan. The most recent international framework on disaster management, the Sendai Framework for Disaster Risk Reduction 2015-2030, incorporates the knowledge and understanding gained during the implementation of the previous frameworks and strategies. One of the most important changes in the current Sendai Framework is the shift toward disaster risk management, and the focus on the issue of risks in general (UNISDR 2015b).

The Sendai Framework is taking into account the problematic aspects, identified during the Hyogo Framework operation. The most relevant for us are such recognized limitations as the availability of technology; lack of coordination, communication, and cooperation between important actors (general public, private sector, practitioners, researchers, academia, etc.); need to support research and innovation technologies relevant for the field (UNISDR 2015b).

Following the example of the Millennium Development Goals and its successor, the Sustainable Development Goals, adopted the same year as the Framework, the Sendai Framework for Disaster Risk Reduction identifies seven global targets to be reached by 2030, one of which is formulated as “Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030” (UNISDR 2015b). Apart from goals, four Priorities for action are stated in the Framework (Figure 11).

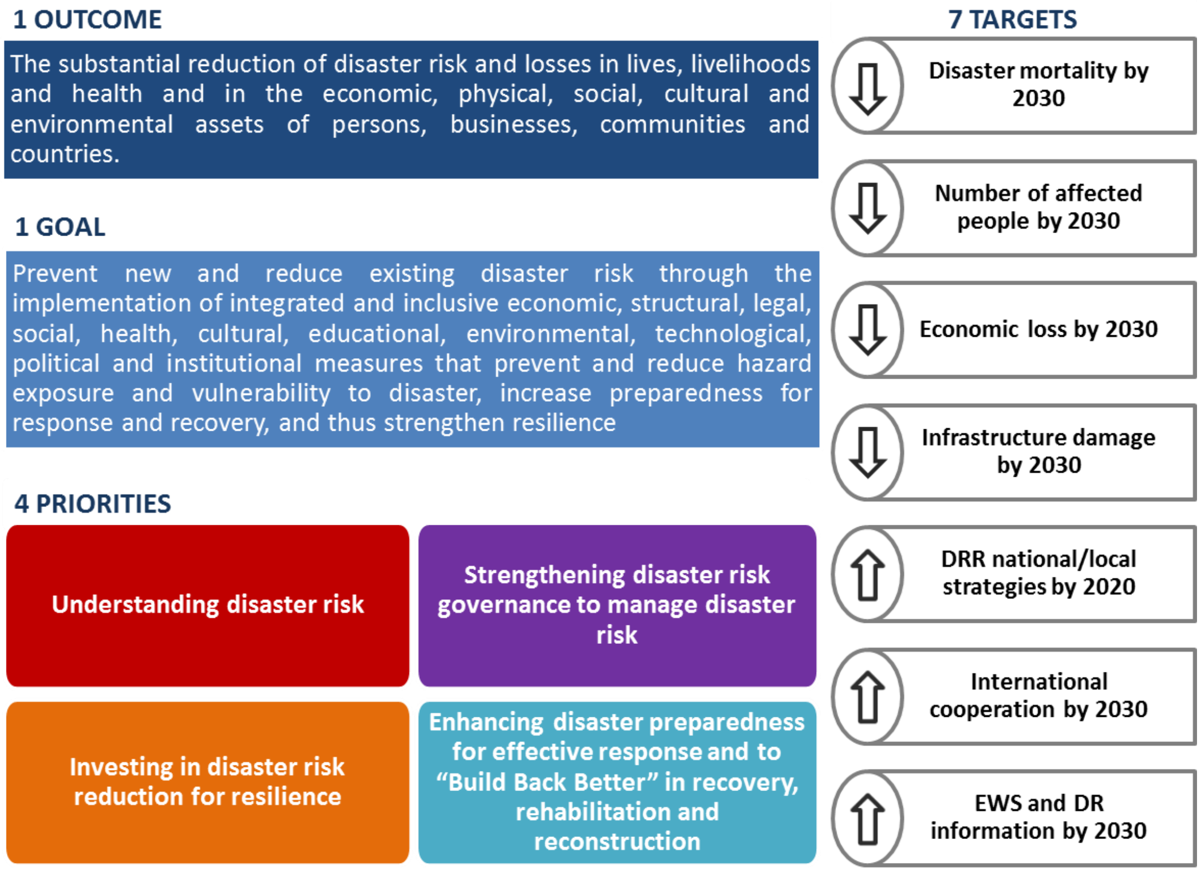

Figure 11. Main elements of the Sendai Framework for DRR

Source: based on UNISDR 2015b.

While priorities defined in the previous frameworks each time to some extent included knowledge management and included technological component, the "Priority 1: Understanding disaster risk" of the present Sendai Framework is clearly targeted towards the strengthening, further development of technologies, and open and free distribution of the data and knowledge (UNISDR 2015b).

Priority for Action 1: Understanding Disaster Risk

Each Priority of the Sendai Framework contains the most important activities to be implemented through two groups of levels: national and local levels; and global and regional levels. While there are a lot of common issues to be faced on every level (like the development and implementation of new methods and technologies, data access and distribution, and investments), the global and regional levels focus mainly on comprehensive cooperation and the coordination of the complex system of actors, at the same time supporting further research in the field through this cooperation and collaboration (UNISDR 2015b). On the other hand, the precise data collection, open access, mapping, and modeling, as well as the involvement of the general public in the decision-making get more attention on the national and local levels. The promoted international cooperation in disaster risk reduction implies, among other things, the distribution of knowledge, open access to data, and availability of relevant technology (UNISDR 2015b). The role of geospatial and space-based technologies is clearly highlighted only in this Priority.

After the short overview of the main international frameworks, focused directly on disaster management, it is possible to note that while even the earlier goals of the International Framework of Action for the International Decade for Natural Disaster Reduction, announced in 1989, indicated the need for the application of the relevant technologies and better data collection and manipulation, the most recent Sendai Framework distinguished this priority the most clearly. With each adopted framework the number of main priorities, defining the driving direction in the disaster management field, reduced, as well as the overall flow and approach was changing. Today, the noticeable shift from *disaster management* (re-active approach) to *disaster risk management* (pro-active approach) can be identified. However, this change cannot be achieved fully without the basic, essential component – the comprehensive understanding of the risk itself, which can be achieved by better information and knowledge management, enhanced research, and cooperation among all stakeholders.

Targets and indicators

Out of seven global targets of the Sendai Framework, the one most directly related to the dissemination of technologies and innovations in DRR is the target F: “Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of this framework by 2030” (UNISDR

2015b). Out of eight indicators recommended for measuring this target, two (F-4 and F-5) address the issue of transfer and exchange of technologies and innovations (UNISDR 2017b):

F-4 Total official international support (ODA[5] plus other official flows) for the transfer and exchange of DRR-related technology.

F-5 Number of international, regional and bilateral programmes and initiatives for the transfer and exchange of science, technology and innovation in DRR for developing countries.

5.2.2. Other relevant international frameworks

This section is devoted to the discussion around several international frameworks and initiatives, which are not focused exclusively on disaster management but are shaping and affecting trends in global development and thus are relevant. Later examples of such agreement are especially important since they were developed and formulated with regard to the most recent Sendai Framework for Disaster Risk Reduction and they in a sense complement each other.

5.2.2.1. Millennium Development Goals (2000-2015)

In 2000 UN General Assembly, at the Millennium Summit, adopted the Declaration, which included values, principles, and objectives to be respected by the international society (UN General Assembly 2000). Sometime later, as a follow-up to the Summit and the Declaration, Millennium Development Goals (MDGs), were proposed, to ensure the successful implementation of the principles introduced earlier (UN General Assembly 2001). In Millennium Declaration itself the issue of disaster response and reduction was mentioned very briefly, and only in relation to the objectives on Protecting our common environment ("To intensify cooperation to reduce the number and effects of natural and manmade disasters") and Protecting the vulnerable (UN General Assembly 2000). However, a number of other objectives related to poverty are indirectly linked to the issue of disaster management, since the poorest

[5] Official development assistance.

part of any community is especially vulnerable to various hazards, and countries in need are often among the most insecure (Mitchell 2003).

Roadmap towards the implementation of the Millennium Declaration had much more attention towards disaster management – the objective on Protecting our common environment at this point already included the specific goal to reduce the consequences of the disasters (UN General Assembly 2001). In the proposed strategies the enhancement of the research in the field and technological transfer, as well as the focus on the urban areas, especially megacities, were mentioned (UN General Assembly 2001). Nevertheless, the final eight Millennium Development Goals did not include a special goal, or target, or indicator, directly related to disaster reduction. However, there was an indirect connection within the two goals - *Goal 7. Ensure environmental sustainability* and *Goal 8. Develop a global partnership for development*, mainly through poverty reduction: improvement of lives of slum dwellers and cooperation to help developing countries (UN General Assembly 2001).

5.2.2.2. Sustainable Development Goals (2015-2030)

As a follow-up to the MDGs, the Sustainable Development Goals (SDGs) were adopted at the UN Sustainable Development Summit in 2015 through the resolution "Transforming our world: the 2030 Agenda for Sustainable Development" (UN General Assembly 2015a). This time, 17 goals were presented, incorporating and refining the previous eight goals. But before going into the review of the most relevant goals (for the present study), it is necessary to mention article 76, from the "Follow-up and review" section of the resolution. This article, for the first time in such documents, is actually mentioning Earth observation and geospatial information and clearly indicates their importance:

> 76. We will support developing countries, particularly African countries, least developed countries, small island developing States and landlocked developing countries, in strengthening the capacity of national statistical offices and data systems

to ensure access to high-quality, timely, reliable and disaggregated data. We will promote transparent and accountable scaling-up of appropriate public-private cooperation to exploit the contribution to be made by a wide range of data, including **Earth Observation** and **geospatial information**, while ensuring national ownership in supporting and tracking progress (UN General Assembly 2015a).

A study on the applicability of Earth observations, geospatial, and remotely sensed data in monitoring and achieving the 2030 Agenda for Sustainable Development identified that each of the 17 formulated Goals can benefit from the use of such data in various ways (DigitalGlobe 2016). Around 40% of all targets (65 out of 169) directly benefit from using geo-location and Earth observation data, across all SDGs (UNOOSA and European GNSS Agency 2018).

While there was no goal particularly focused on disaster vulnerability, several targets included the issue of natural hazards and man-made risks. Furthermore, issues related to urban areas' problems and development have been introduced as a stand-alone goal on Sustainable Cities and Human Settlements (UN General Assembly 2015a). Therefore, while almost any SDG can indirectly facilitate disaster preparedness and mitigation, the most relevant goals for disaster management currently include – *Goal 1: End poverty in all its forms everywhere*; *Goal 9: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation*; *Goal 11: Make cities inclusive, safe, resilient and sustainable*; and *Goal 13: Take urgent action to combat climate change and its impacts* (UN General Assembly 2015a).

The main targets aimed at the disaster risks and vulnerability reduction deal with ending poverty, improving the adaptation capacity of the communities, mitigating the disaster consequences (including loss of life and damage to assets), strengthening resilience and adaptive capacity of local communities, promoting technological innovations and scientific research (UN General Assembly 2015a). Moreover, Goal 11 (Sustainable Cities and Human Settlements) includes targets, developed in line with the Sendai Framework for DRR, particularly:

11.5. By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations.

11.B. By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels (UN General Assembly 2015a).

5.2.2.3. Paris Climate Agreement

At the end of 2015, on the twenty-first session of the Conference of the Parties (COP) to the United Nations Framework Convention on Climate Change (UNFCCC), which took place in France, the Paris Climate Agreement was adopted. It entered into force on 4 November 2016, after reaching the threshold of ratification/approval of "at least 55 Parties of the Convention accounting in total for at least an estimated 55 percent of the total global greenhouse gas emissions" (UNFCCC 2015). Currently, 169 parties (out of 195 who signed) have ratified the agreement (UNFCCC 2017).

While the general aim of the agreement is to keep global temperature rise below 2 degrees C above pre-industrial levels (with a stricter goal to keep it below 1,5 degrees C), the necessity to strengthen the response and adaptation of countries to climate change threats is recognized as a crucial component of the agreement (UNFCCC 2015). There might be different drivers for disasters to become more frequent and result in greater damages (anthropogenic causes together with natural), however, it is already unquestionable that changing climate plays a great role in this situation, at least by making hazards less predictable.

UNISDR emphasized the intention of promoting disaster risk reduction and adaptation in the climate change agenda at the COP21 (UNISDR 2015a), and the political will to support activities in this domain was stressed in the agreement, particularly in Article 7 and Article 8 (UNFCCC 2015). These two articles resonate deeply with the text of the Sendai Framework (Wahlström 2015), even though there is a lot of critique towards the agreement itself for being too "weak" to change trends in global development and climate change policy (Spash 2016).

Of course, many other articles of the Paris agreement correspond closely to various aspects of frameworks on DRR and disaster management in general (Article 6 on promoting "sustainable development and environmental integrity"; Article 9 on providing financial support and assisting developing countries; Article 11 on capacity-building). However, articles 7, 8, and 10 are discussed in a bit more detail, as the most relevant for this particular research.

Article 7

In Article 7 the "global goal on adaptation of enhancing adaptive capacity, strengthening resilience and reducing vulnerability to climate change" is established (UNFCCC 2015). The needs of the most vulnerable developing countries are acknowledged and emphasized, as well as the necessary support of such countries. Adaptation is thus recognized as a key component of the global response to climate change. With regard to Cancun Adaptation Framework, actions to strengthen cooperation for enhanced adaptation and resilience to climate change are listed in this article:

1) Sharing information, good practices, experiences and lessons learned;
2) Strengthening institutional arrangements;
3) Strengthening scientific knowledge on climate, including research, systematic observation of the climate system and early warning systems;
4) Assisting developing countries in identifying effective adaptation practices, needs, priorities, challenges and gaps;
5) Improving the effectiveness and durability of adaptation actions (UNFCCC 2015).

Focus on the needs and support of vulnerable developing countries particularly correspond with the current research, as the work of UNOOSA on assessing the situation in mainly developing countries in terms of space science and technology applications are analyzed and discussed in the later parts of the dissertation (particularly, sections "5.4. Global capacity building initiatives" and "7.1. UN-SPIDER's TAM reports").

This Article provides as well another list of adaptation planning and implementation actions that may be taken by involved parties:

1) Implementation of adaptation actions;
2) Formulation and implementation of national adaptation plans;
3) Assessment of climate change impacts and vulnerability;
4) Monitoring, evaluation and learning from adaptation plans, policies, programmes and actions;
5) Building the resilience of socioeconomic and ecological systems (UNFCCC 2015).

Article 8

Article 8 of the Paris Agreement is particularly related to the Sendai Framework for DRR and disaster management in general, though the terms "disaster" or "hazard" are never actually mentioned in the text of the agreement. Instead, the notion of "extreme weather events and slow onset events" is introduced in this article, and that's the only time the concept of disasters is so clearly mentioned in the agreement. In general, this article is dealing with addressing and minimizing losses and damages and reducing risks associated with climate change (UNFCCC 2015). The need to "enhance understanding, action, and support" is mentioned in this article, as well as a bit more specific list of related actions is presented. Areas of potential activities and support may include:

1) Early warning systems;
2) Emergency preparedness;

3) Slow onset events;

4) Events that may involve irreversible and permanent loss and damage;

5) Comprehensive risk assessment and management;

6) Risk insurance facilities, climate risk pooling and other insurance solutions;

7) Non-economic losses;

8) Resilience of communities, livelihoods and ecosystems (UNFCCC 2015).

Article 10

This article is emphasizing the importance of technology development and transfer, mentioning the need to support dissemination activities and strengthen cooperation in this dimension. Innovativeness should be encouraged and supported, assistance in research and development should be provided, while access to technologies should be facilitated, with special attention to developing countries (UNFCCC 2015).

5.3. Satellite-based emergency mechanisms

5.3.1. Existing satellite-based emergency mapping mechanisms

In the last 20 years, a number of successful global and regional satellite-based emergency mapping (SEM) mechanisms were established, including: International Charter "Space and Major Disasters" (active since 2000); European Copernicus Emergency Management Service (since 2012, but including its previous phase as "Global Monitoring for Environment and Security" - since 2005); Sentinel Asia initiative[6] (since 2005); United Nations (UN) programs, particularly the United Nations Institute for Training and Research (UNITAR)'s Operational Satellite Applications Programme - UNOSAT (since 2003) (Voigt *et al.* 2016). In addition, several commercial data providers also support such commitments and are providing open and

[6] It is important to understand the distinction between "Sentinel Asia", an SEM mechanism that covers the Asia-Pacific region, and "Sentinel satellites", which are part of the ESA's satellite missions developed to support the operational needs of the European Union's Earth Observation Programme "Copernicus".

free access to their observations in case of major disasters. Some of these initiatives include: Maxar Open Data program[7] (since 2010, as DigitalGlobe, since 2017 - as Maxar), Planet Disaster Data[8], through a partnership with other SEM mechanisms (Maxar, Planet, Airbus, ICEYE, etc.).

These mechanisms exist to support emergency response by rapidly providing satellite data which is then promptly processed and analyzed by the involved organizations. This is possible through efficient coordination between all members/users of such initiatives. An example of a final product developed as a result of an activation of a mechanism is presented in Figure 12.

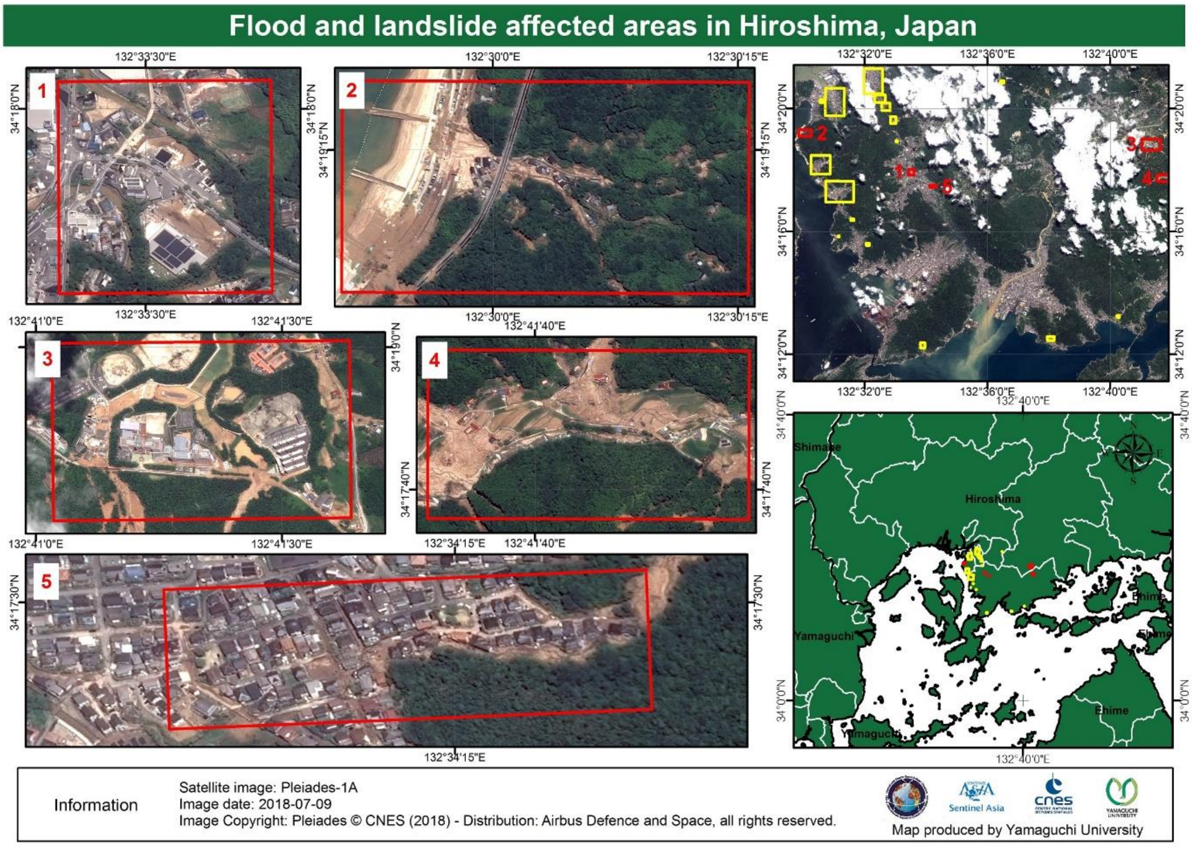

Figure 12. Product developed as a result of the Charter activation on 7 July 2018

Source: International Charter 2021.

[7] https://www.maxar.com/open-data

[8] https://www.planet.com/disasterdata/

Some of these SEMs focus only on natural disasters (Sentinel Asia, for instance), while others also include man-made emergencies. Most of the mechanisms mention disaster prevention/preparedness as one of the objectives they support (or plan to support), however, the vast majority of activations across all existing SEMs mechanisms still cover mainly the emergency response phase.

In addition, some organizations might focus more on mapping services (developing value-added products - maps), not necessarily on the provision of satellite data. Some examples of such entities would include UNITAR-UNOSAT, ICube-SERTIT, Center for Satellite based Crisis Information (ZKI) at the German Aerospace Center (DLR), SERVIR, Humanitarian OpenStreetMap, Missing Maps, MapAction.

To coordinate related activities, a number of international initiatives could be mentioned:

- International Working Group on Satellite-based Emergency Mapping (IWG-SEM);
- Working Group on Disasters of the Committee on Earth Observation Satellites (CEOS);
- Working Group on Geospatial Information and Services for Disasters of the UN Committee of Experts on Global Geospatial Information Management (UN-GGIM).

This section is focusing on the exploration of regional and organizational patterns of activations of some of the main SEM mechanisms - International Charter “Space and Major Disasters” (Charter), European Copernicus EMS, and Sentinel Asia, looking at them from a network science perspective. While a comprehensive review of the most relevant satellite-based emergency mapping mechanisms and their activations in terms of spatial patterns and temporal trends was conducted rather recently (by Voigt et al., 2016, for the 2000-2014 period), current research is introducing an unconventional approach in studying network structure of organizations and countries involved in the SEM activations, covering a wider timeframe. Network analysis was applied to assess the performance of mechanisms’ members and partners, identify the most affected countries (in terms of activations) and most frequent connections between organizations and territories struck by disasters, investigate clustering patterns of organizations and countries through their interrelationships and neighborhood overlap.

Not to duplicate the efforts and analysis already completed by Voigt et al. (2016), this chapter takes a closer look at three closely related initiatives (Charter, Copernicus EMS, and Sentinel Asia), to explore their organizational structure and discuss some of the challenges and potential opportunities. The reasons for selecting these particular mechanisms for the detailed analysis are threefold: leading role and importance of these mechanisms in satellite-based emergency mapping for disaster response (Ajmar *et al.* 2017; Boccardo and Tonolo 2015; Voigt *et al.* 2016); differences in regional coverage (Charter is international in composition and can provide support across the globe; Copernicus EMS is a European based initiative but allows worldwide activations; Sentinel Asia is focusing only on one region); easy access to archives of past activations and availability of detailed metadata.

5.3.1.1. Selected SEM mechanisms

International Charter "Space and Major Disasters" is a global collaboration of space agencies aiming at providing satellite-based information to support disaster response. Activations can be triggered in case of fast-onset disasters, both natural and man-made, but cannot be requested in case of slow-onset disasters like droughts. It is active since 2000, making it the oldest SEM mechanism.

Copernicus Emergency Management Service (EMS) is an initiative that provides on-demand emergency information on a global scale, implemented by the European Commission. Mapping services can be provided in case of natural and technological disasters as well as humanitarian crises. The current study explores the activations of this initiative since 2012, when it was formally established, but does not cover its previous phase "Global Monitoring for Environment and Security" (which was active since 2005). Copernicus EMS is providing quite a unique service, compared to any other major international SEM mechanism, called "Risk and Recovery Mapping", which can be requested irrespective of an actual disaster and used to assess the potential risks or slow-onset disasters like droughts, which are rarely covered by other initiatives of this sort (Copernicus EMS 2021). Due to their uniqueness, activations within the "Risk and Recovery Mapping" service were not considered for the analysis in this study (only "Rapid Mapping").

Sentinel Asia is an international cooperation platform that aims at supporting disaster management efforts in the Asia-Pacific region, by demonstrating the value of Satellite Earth observation technologies and Web-GIS mapping tools. Historically, Asia is affected by natural disasters disproportionally compared to the rest of the world, especially in terms of the affected population and death toll (Abe and Thangavelu 2012; Guha-Sapir 2021). As an initiative, Sentinel Asia was proposed in 2005, and since 2007 it started actively providing EO data and related products to affected countries within the region. It covers only natural disasters (JAXA 2021b). Current Step 3 of the initiative (which started in 2013) is expected to cover not only emergency observations (post-disaster imagery) but all other phases of the disaster management cycle (recovery, mitigation, preparedness). While "pre-disaster" activations seem to be theoretically possible, at the moment, Sentinel Asia still focuses only on the response.

5.3.2. Main actors involved in mechanisms' activation

The process of activation of different SEM mechanisms follows quite similar steps. Figure 13 illustrates the main steps in the typical SEM product generation, starting from the mechanism activation request after the disaster, to the dissemination of information and products. Data collected through the SEM mechanism as well as developed value-added products (maps) are shared with the end user free of charge. Products, collected and developed through this process are also often made available to the public.

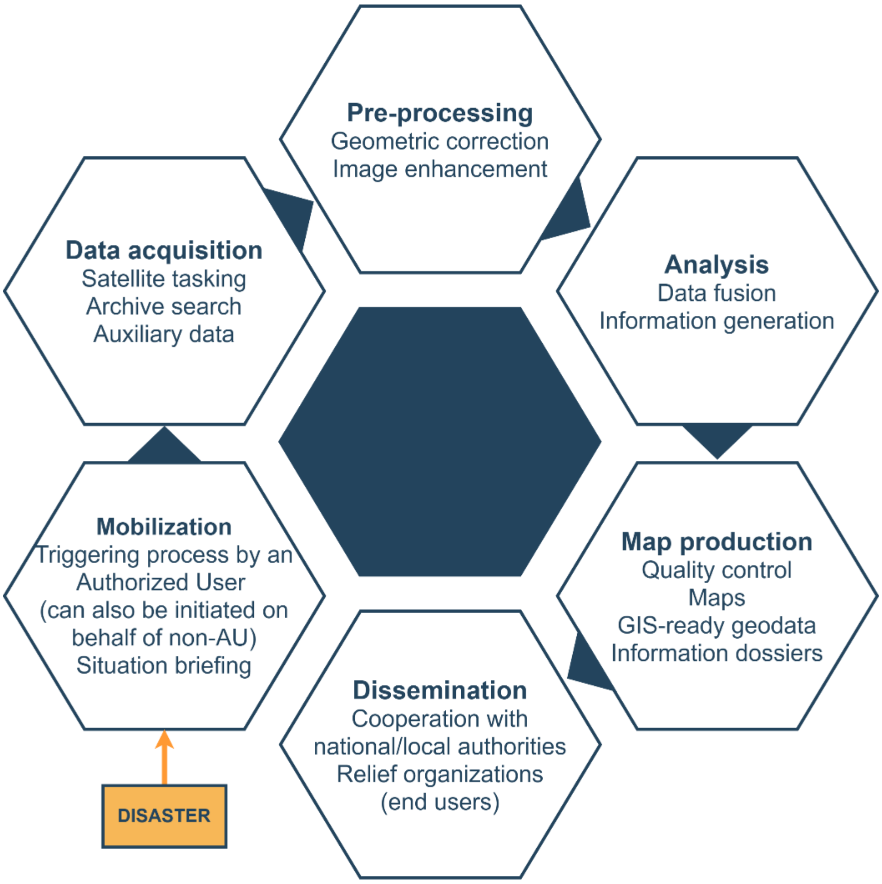

Figure 13. Main steps involved in SEM product generation

Source: adapted from Voigt et al. 2016.

Actors involved in the activations can be divided into a number of typical roles (with some variations), common for major SEM mechanisms. These roles and corresponding responsibilities normally include (based on Copernicus EMS 2021; International Charter 2021; JAXA 2021):

- Authorized User (AU) - an entity (often a national disaster management authority or a representative organization), that is officially registered within the system and can request activation or submit it on behalf of an affected End User, who is not an AU (in case of Sentinel Asia these actors are referred to as members of initiative's Joint Project Team (JPT) or ADRC members, for both Charter and Copernicus EMS, they are called AUs);

- On-duty Operator - checks the request and in case it is approved, sends it to an Emergency On-call Officer;
- Emergency On-call Officer - processes the request, prepares a draft plan, contacts Data Providers (Space Agencies, commercial satellite companies), and the Project Manager;
- Project Manager - liaises with Emergency On-call Officers and AU regarding data acquisition, and feedback;
- Data Providers - task their resources (satellites) according to the plan (in case of Charter, that would be Charter Members; in case of Copernicus EMS - Sentinel satellites and Copernicus Contributing Missions[9]; in case of Sentinel Asia - Data Provider Nodes);
- Value Adder - processes and interprets the collected data, and delivers the value-added products (maps) to the AU or End User via the Project Manager (for Charter, that would often be Charter Partners; in case of Copernicus EMS - contracted Service Providers; in case of Sentinel Asia - Data Analysis Nodes);
- End User - receives final products.

Authorized Users (AUs) play a critical role in the satellite-based emergency mapping, as only they have the right to directly request an activation - this is a common rule for all three selected SEM mechanisms. But it is important to emphasize that if a major disaster happens in a country that is not officially registered within the service (does not have an AU), the country's government still has a way to trigger the activation, but not directly. In such cases, it has to be done through coordination with an actual AU (quite often, a UN agency, or regional organization, or a disaster management authority of a country with which they cooperate for disaster relief) (CNES *et al.* 2021). Copernicus EMS identifies such users, who have to coordinate the activation via the AUs, as a separate group and calls them “Associated Users”,

[9] Contributing Missions are missions from ESA, their Member States, EUMETSAT, and other European and international third-party mission operators that make some of their data available for Copernicus.

which include, for instance, International Governmental Organizations (UN agencies, World Bank), local, regional, and other public entities, national and international NGOs, etc. (Copernicus EMS 2021). At the same time, the Charter even formalized two types of such indirect activations, to improve access to their services (International Charter 2021):

- Activation via the UN for UN users - through the agreement with UNOOSA and UNITAR-UNOSAT which may submit requests on behalf of users from the United Nations.
- Activation via Sentinel Asia's partner, the ADRC, for Asia-Pacific users - since 2009 the ADRC may submit requests on behalf of national users of Sentinel Asia ("escalation").

5.3.2.1. Rejection of activation requests

Not all activations that are requested by the AUs are in the end accepted and processed by the mechanisms. Information on such rejections is sometimes published in the annual reports of the initiatives, though quite often they do not include many details. While the cases of such rejections are rather rare, the reasons behind them might be interesting to explore.

Annual reports of the Charter's activities include information on the denied requests for activations. Some of the earlier reports mention various causes for rejection, including both more bureaucratic reasons, like a request submitted by a non-AU, or no indication of an end-user in the form, as well as more technical, like the low magnitude of an event, little use of the EO data for the assessment, or requests submitted too late after the event (ESA 2014, 2017). Unfortunately, more recent annual reports rarely mention the exact reasons for rejections (CNES *et al.* 2021).

Copernicus EMS does not provide much information on the rejection of activation requests. The general rules of this service mention which situations fall into its scope (large-scale emergencies, and humanitarian crises) and clarify that unreasonable requests or those that are related to the ongoing conflicts or crisis with EU military operations, or focus on politically sensitive territories, could be rejected (Copernicus EMS 2021).

Sentinel Asia's annual reports provide the most comprehensive statistics on the number of rejected requests. Since this initiative was established in 2007 and until the end of 2020, 47 requests in total were denied (12.1% of all received requests). Forest fires, oil spills, and "other" types of disasters had the largest share of rejections - in the case of fires, more than half of all requests were rejected (JAXA 2021a). Unfortunately, annual reports do not discuss the reasons for such rejections. Still, provided dataset of activations included information not only on accepted activations but on the denied as well. In some cases, available comments explained the causes of the rejections. Some of the reasons included: requests that were sent too late after the events, when there is already no urgency, or the issue is already resolved; proactive activation to develop an evacuation plan (had to be denied since it did not follow the current principles of the SEM mechanism); request submitted before the occurrence of a disaster; not a natural disaster; little use of EO data in particular cases.

5.3.3. Organizational structure of the selected mechanisms

One of the main differences between the three SEM mechanisms selected for the analysis lies in their regional coverage – Charter is a worldwide collaboration of various space agencies and other organizations and is acting on a global scale; Copernicus EMS is inherently a regional initiative, but can support any country in the world; while Sentinel Asia is focusing specifically on the Asia-Pacific region. This differentiation also largely defines the composition of mechanisms' participants: members (normally space agencies as data providers), partners (various organizations whose roles can vary from contributing additional data to map development and monitoring), and Authorized Users (AUs). Often roles played by organizations involved in SEM mechanisms can be roughly divided into three groups based on their main function in the system - data provision, data analysis, and use of the end product. However, quite often one entity can combine these different roles, depending on its capacities and the situation.

The Charter, as the oldest SEM mechanism, being active since 2000, and a global collaboration of 17 Charter Members (space agencies) and 18 Charter Partners (a more diverse group of organizations, including the private sector and other SEM mechanisms) (as of 2021). Its Universal Access principle allows direct access to the mechanism for 67 countries of the world (through registered AUs). Only AUs have the ability to directly submit a request in case of a major disaster through the Charter Operational System, however, in some cases, Charter Members also can have the right to request data. The only conditions for becoming an AU are: to be a national disaster management authority/agency of the country; to have the capacities to download and use maps; to be able to submit activation requests in English (International Charter 2021).

As can be seen from Figure 14, most of the continent of Africa, as well as many countries in the Middle East, Central America, Asia and Oceania are not registered within the mechanism (do not have an AU). At the same time, Charter still plays an important role in these regions through some of the available alternative ways of requesting an activation. With the appearance and growth of other SEM mechanisms, Charter becomes increasingly complemented by these similar initiatives in different regions of the world (for instance, by Copernicus EMS in Europe and Sentinel Asia in Asia-Pacific). Africa, the Middle East, Central America and the Caribbean are often additionally supported by the United Nations mapping initiatives, for instance, UNOSAT Rapid Mapping Service (Voigt *et al.* 2016).

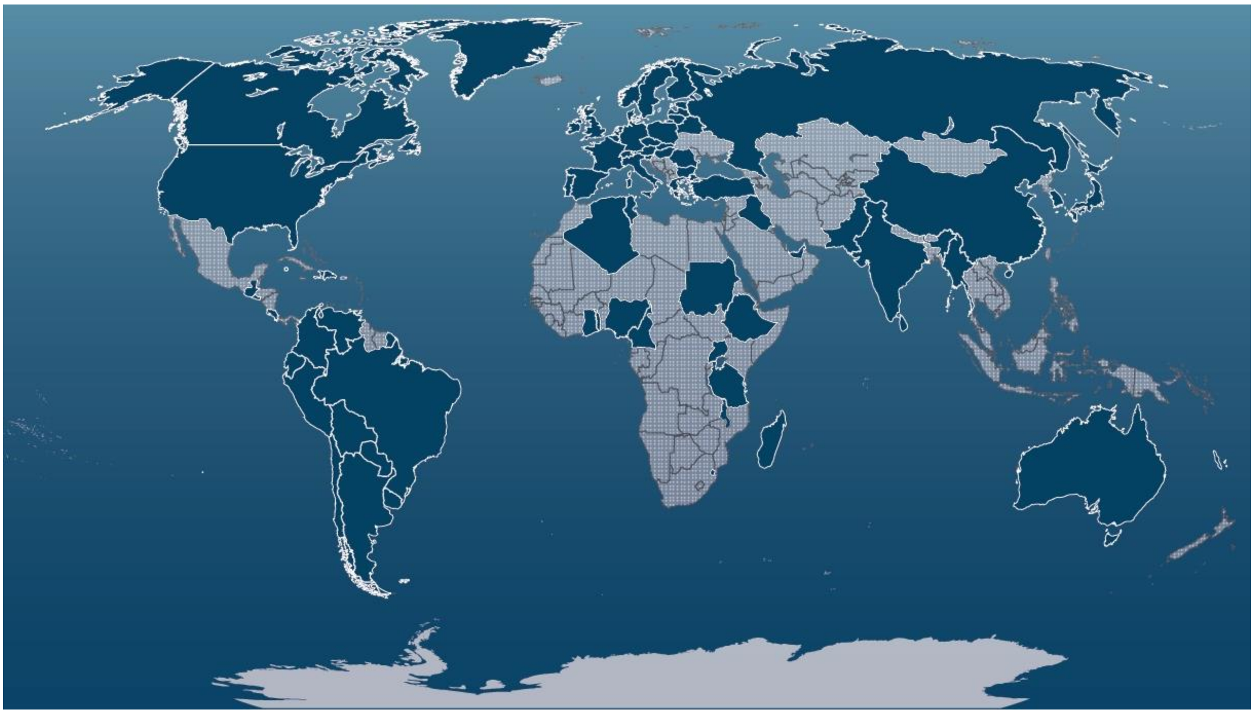

Figure 14. Countries (in dark blue) with direct access to the Charter (as of February 2021)

Source: International Charter 2021.

Copernicus EMS is one of the Charter's partners and overall has a quite similar structure and mechanism of activation request. The mechanism has Authorized Users in 29 countries (EU member states, plus Iceland and Norway). Some EC and EU Services are also regarded as AUs, and, formally, only European organizations have direct access to the service. International organizations, including UN organizations, are falling under the category of "Associated Users" (in contrast to Authorized Users), and in order to trigger the service, they have to coordinate with an actual AU. Some international organizations, specifically UNOOSA, UNITAR-UNOSAT, and World Bank, have additional agreements with the Copernicus EMS which allow streamlining the activation of the service when requested on their behalf. As such activations cannot be rejected, it can be argued that these organizations also enjoy direct access to the mechanism. Still, in the mechanisms' open archives, such activations will indicate an official AU (like EC Services) and not the international organization that initially requested the activation (Copernicus EMS 2021).

Sentinel Asia directly covers 28 countries/regions in Asia-Pacific (Joint Project Team members), as well as member countries of the Asian Disaster Reduction Center (ADRC) (JAXA 2021b). The ADRC currently has 31 member countries (plus, 5 advisor countries and 1 observer) (ADRC 2021). There is significant overlap in member countries of Sentinel Asia and ADRC, still, such an arrangement provides access to this SEM mechanism to 7 additional countries. The ADRC acts as a "window" of the Sentinel Asia initiative, receiving calls from member countries and forwarding these requests to data providers. It is the only unit responsible for such activations and it often acts as a bridge between Sentinel Asia and the Charter. Both Sentinel Asia and ADRC themselves are official partners of the Charter, this way providing access to Charter services for their regional network of countries and organizations (International Charter 2021).

5.3.3.1. Composition and overlap of mechanisms' members

To illustrate the composition and interlinkages of SEM mechanisms' participants, they are visualized as a network in Figure 15. Such representation provides a nice overview of the overall structure, regional differences, and overlaps of these initiatives. In the network, each formal member, partner, or authorized user of the Charter, Copernicus EMS, and Sentinel Asia is presented as a circle (node), interconnected through links with these mechanisms (shown as slightly larger nodes in the center of these *star structures*). To clarify, an actual AU of an SEM mechanism is normally a specific national organization responsible for emergency management or civil protection in the country. However, to make the network below clearer and more concise, such organizations are represented by the name of their respective countries. International and regional organizations, as well as Charter's Members and Partners, are included as separate nodes. Additionally, the ADRC and its members are also presented in this network, as a vital part of the Sentinel Asia initiative, responsible for handling emergency observation requests from members of both - the initiative, and the Center itself.

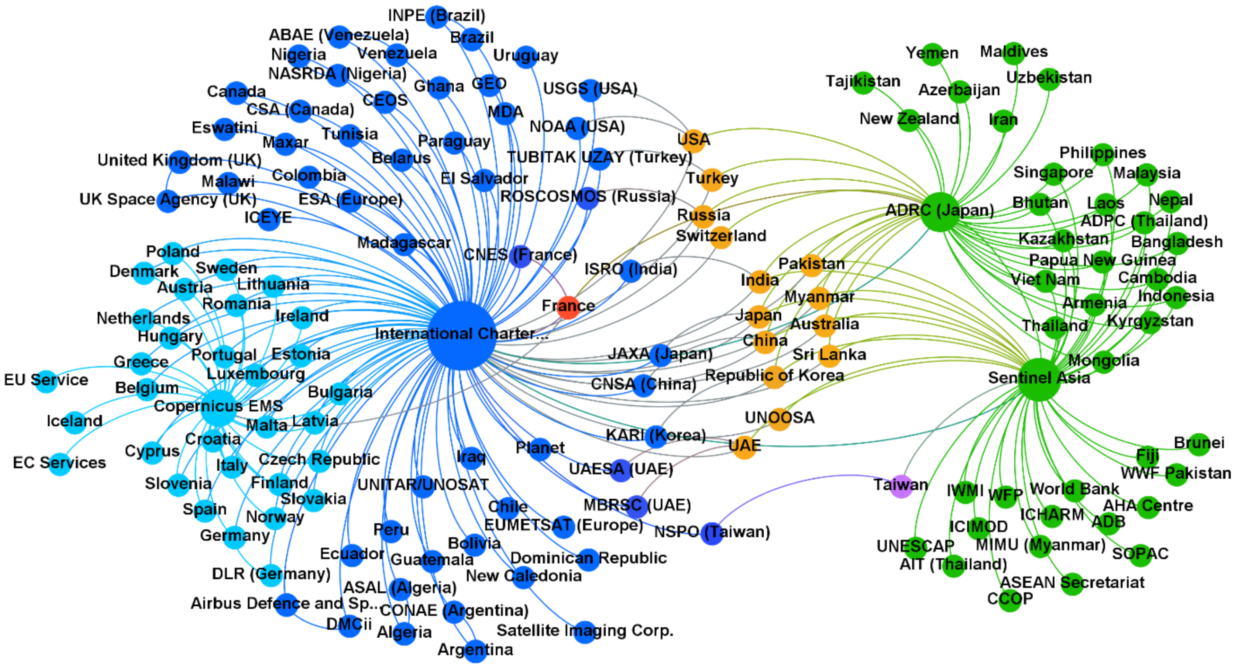

Figure 15. Network of members, partners, and authorized users of the selected SEM mechanisms

Note: Charter - dark blue nodes on the left, Copernicus EMS - light blue on the left, and Sentinel Asia - green on the right.

Data source: ADRC 2021; International Charter 2021; JAXA 2021b.

The network of the mechanism participants shows clear groups - Sentinel Asia (and ADRC) on the right side (in green), Charter (dark blue) together with Copernicus EMS (light blue) on the left side. What first catches the eye is the fact that almost all AUs of the Copernicus EMS are also part of the Charter - the only exception being Iceland, and EU and EC Services. Such major overlap is particularly noticeable in comparison with the members of the Sentinel Asia initiative, which generally are quite separated from the Charter. A limited number of countries (colored in orange) participate in both Charter and Sentinel Asia / ADRC - 14 countries and one international organization (UNOOSA). Out of this group, France, Switzerland and the United States of America do not fall into the regional interests of Sentinel Asia, but they are advisor countries for the ADRC. In this network, France (colored in red) is the only country that is in some way directly involved in all three SEM mechanisms, which in a way puts it in a very important position as a bridge connecting the initiatives.

One important aspect that should be mentioned but might not be clear just from the network in Figure 15, is related to the differences in rules of different mechanisms that allow registration of Authorized Users. While Charter can register national disaster management authorities as AUs, Sentinel Asia accepts more diverse types of users, for instance, universities (which often act as data analysis nodes). Such more relaxed rules for registration allowed Taiwan (colored in violet) to be a full member of the Sentinel Asia initiative, while it could not be an official AU of the Charter, since the United Nations is recognizing Taiwan as a part of China, and not as an independent country. At the same time, it is worth mentioning that the National Space Organization of Taiwan (NSPO) (space agency of Taiwan) is participating in the Charter as its Partner (International Charter 2021). The only two activations of the Charter mechanism that covered Taiwan (over the analyzed period of time) were done by the ADRC and United States Geological Survey (USGS). In the case of Copernicus EMS, the rules for AUs are quite limiting, allowing only EU Member States and countries participating in the European Civil Protection Mechanism (Copernicus EMS 2021).

In the case of disaster response, having a variety of options for satellite-based emergency mapping can be a positive thing, which supports the overall resilience of the system. However, from a different point of view, a very clear chain of actions must be followed by every user of such services to avoid unnecessary duplication of efforts. The network presented in the current study focuses only on direct members of the three selected mechanisms, while the global system of organizations involved in SEM is much more complicated. For instance, we do not discuss in detail the United Nations initiatives (UNITAR-UNOSAT) or important national level mechanism - National Disaster Reduction Centre of China (NDRCC) (Voigt *et al.* 2016). With the diversity of available initiatives, virtually any country in the world can now send a request for activation through one of the involved international or regional organizations or an active AU of another state.

5.3.3.2. Gaps in direct access to the selected SEM mechanisms

Before moving on to the characteristics of triggered activations and territories covered, another important aspect that has to be considered and which might be even more relevant is the identification of the existing gaps in the coverage of SEM mechanisms. As mentioned, the current study does not state that it would provide a comprehensive review of all mechanisms that currently exist in the world. While the three selected initiatives are recognized as the most well-established, active, and accessible, several other major mechanisms exist. They might be filling some of the gaps, not currently covered by the three initiatives, as argued by Voigt *et al*., 2016.

Keeping in mind these limitations, it is still possible to assess the formal coverage of the selected mechanisms. In terms of formal membership, 93 countries and territories (including Taiwan) currently have direct access to at least one of the three initiatives (out of 193 member states of the United Nations). The EU is covered by the Copernicus EMS, and the Asia-Pacific region - by the Sentinel Asia, major global gaps that remain are rather similar to those seen on the map of the countries with access to the Charter (Figure 14) – leaving Africa, Middle East, Central America and the Caribbean. Such gaps still can be covered by indirect access, as well as by the United Nations mapping initiatives (Voigt *et al.* 2016).

Network of organizations facilitating the diffusion of the GeoICTs

Apart from looking specifically into direct members of the SEM mechanisms, it might also be important to look at the bigger picture. Particularly to explore the international system of the organizations that promote wider diffusion and application of GeoICTs, for instance, UNOOSA's UN-SPIDER, UNITAR-UNOSAT, Group on Earth Observations (GEO), Committee on Earth Observation Satellites (CEOS).

A network of formal members and partners of such organizations, as well as of selected three SEM mechanisms, is presented in Appendix 5. The original dataset was simplified to focus on the coverage by countries (individual national organizations participating in each organization or initiative were replaced by the corresponding country they belong to). The developed network should not be considered all-encompassing - it is focusing specifically on selected organizations that are relevant or particularly active in the promotion of the application of satellite-based technologies or EO for the common good. Still, it helps create a clearer picture and further support the detection of potential gaps. One important aspect to consider is that all UN member states were automatically linked with the UN organization (UNOOSA and UNITAR) - while this illustrates the fact that they all have the capacity to receive support via these UN entities, this also helps see how involved or separated are the countries in terms of direct connections with SEM mechanisms or other relevant organizations.

In the developed network, there are few quite distinctive groups, in particular, large and rather isolated cluster of Participating Organizations of the GEO. These are mainly international, regional, and various nonprofit organizations which joined the GEO community but seem not to be directly involved in any other similar initiatives. There are similar clusters that consist only of organizations (not national governments), that have established formal connections to either UNITAR or UNOOSA, but no other organization. Most national governments are tightly grouped in the middle of the network, located between the main actors (UNOOSA, UNITAR, GEO, and SEM mechanisms). Such position in the network is defined by the larger number of links connecting countries to various elements of the system.

Still, a particular group of countries without any direct connections to the selected three SEM mechanisms can be distinguished. In the developed network (Appendix 5), they are highlighted in red color. Visually, this group can be further divided into two rather separate clusters - those countries which only have connections to the UN entities, and those which in addition are also members of the GEO. Still, this position in the network indicated that the countries do not have direct access to any of the three main SEM mechanisms. In terms of geographic distribution, this group represents most of the African countries (87% of all countries in this region), as well as a rather significant number of countries from the Middle East, Pacific, Central America and the Caribbean. It also includes some European countries, particularly, Western Balkan countries and some European microstates.

Weak ties[10] play a crucial role in the diffusion of innovations in the social networks (the discussed network of organizations facilitating the diffusion of the GeoICTs can be considered as an example of such structure). Such ties connect separate, often homogeneous clusters, and allow the flow of new ideas to spread and reach otherwise isolated communities, increasing the diversity. The composition of a particular network can significantly affect the diffusion of innovations, however, this process also highly depends on the characteristics of this specific innovation. An innovation, which requires adoption by a large proportion of the group in order for it to express its actual value, can be considered to have a high threshold of adoption. On the other hand, an innovation that has its independent value, even if fewer close contacts also use it, is defined as having a low threshold of adoption (Reich 2020).

The use of GeoICTs, and particularly participation in the SEM mechanisms, can be considered an innovation with a rather low threshold of adoption, since the benefits that such technologies provide do not directly depend on their use by close contacts. At the same time, the overall likelihood of adoption grows the more common becomes the innovation. For such technological innovations with a low threshold of adoption, the presence of weak ties plays a more important role than *strong ties*[11] within cohesive groups. These innovations can spread without the need for collective decision-making. The diffusion in such situations would depend on the structures with a larger number of weak ties and fewer strong ties. On the opposite, the spread among

[10] Weak ties are weaker (thinner) links with more distant neighbors, characterized by infrequent interactions.

[11] Strong ties are stronger (thicker) links between close-knit nodes (in most cases within the same cluster), characterized by frequent interactions.

isolated groups can be hindered by the presence of strong ties within these clusters (Reich 2020).

At the same time, it is important to emphasize, that country-to-country transfer of innovations depends on the various networks of different scales - inter-state, subnational (within one country), and within particular organizations. In general, successful diffusion of innovations (for instance, the adoption of GeoICTs supporting DRR) would depend on the presence of cross-national weak ties, and strong ties among the relevant organizations within the country, particularly governmental organizations (Djelic 2004).

Coverage by the actual need (based on the records of past disasters)

However, apart from just formal membership in the initiatives, it is also important to check which countries were actually supported by any SEM mechanisms and which were not. To roughly identify this kind of gap, records of the actual past disasters can be compared to the information on the activations that took place. To do that, data from the EM-DAT international disaster database can be used - all records of natural, technological, and complex disasters that happen across the globe were taken into account, within the timeframe when the SEM mechanisms already existed. The reason for using the EM-DAT and not another widely known disaster database, DesInventar, is that EM-DAT tends to focus more on including disasters of a larger scale, response to which might require the support of the SEM mechanisms with a higher probability (Guha-Sapir 2021; Panwar and Sen 2020).

At the same time, during the research visit to Japan, at the meeting with the representatives of the Fujitsu company, the issue of the quality of data presented in the international disaster databases was discussed. Particularly the fact that it is almost impossible to check how reliable is the data since records in the databases depend on whatever the country is providing, combining with potential human errors during data entering (Panwar and Sen 2020).

Overall, for the 2000-2020 period, the EM-DAT database recorded 13 896 disasters in total, which covered 218 unique territories (countries or areas, according to UN M49 standard) (UNSD 2021). This significantly surpasses the total sum of all activations triggered by the selected mechanisms (1 481). However, it is important to take into account that not every case of the recorded disasters actually required (or requested) international support or might have benefited from the EO data (depending on the type of the disaster or its scale). Another aspect to consider is that it is possible that not all disasters that happened (even if they were of a rather large scale) were in the end reported and recorded in the database. However, considering the overall volume of the dataset and provided details, it was not possible to overcome these limitations.

Keeping this in mind, it is possible to estimate that around 79% of all territories, that experienced disasters according to the EM-DAT, were covered by at least one activation by one of the considered SEM mechanisms. This leaves 46 countries not being directly supported, a full list of which is available in Appendix 6. If we take into account all accumulated cases of recorded disasters (according to EM-DAT), the vast majority of these seemingly "unattended" countries would be closer to the end of the list, with relatively few cases of recorded emergencies. The top four countries with quite a high number of disasters were all coming from Africa (Tanzania, Mali, Libya, Côte d'Ivoire). And while these countries did not request activations of the three selected SEM mechanisms, all of them at some point received support through the UNOSAT Rapid Mapping Service (which is not reviewed in detail in the current study). For the sake of the identification of the gaps in the coverage of the three selected mechanisms, territories directly supported by the UNOSAT services are kept for analysis.

At the same time, some countries which were not covered by any activations were already formal members of either one of the initiatives. This list includes, particularly, all four territories from Europe (Belarus, Malta, Estonia, Isle of Man), one country from the African continent

(Eswatini), and seven - from the Asia-Pacific region. There might be a few reasons why these countries didn't use the opportunity provided by the mechanisms, while they had direct access, including the small scale of the disasters, use of some other similar services, rather recent registration within the mechanisms.

Overall, this leaves us with 34 countries without direct support from the three SEM mechanisms. In terms of geographic distribution, 14 countries (41.2%) were from Africa, 13 (38.2%) were from the Asia-Pacific region, and 7 (20.6%) were from Latin America and the Caribbean. Two-thirds of all countries are categorized as either Landlocked Developing Country (LLDC), Least Developed Country (LDC), or Small Island Developing State (SIDS). Interestingly, all Caribbean countries from this list are SIDS.

All things considered, there seem to be rather few gaps remaining in the coverage of the SEM mechanisms. Most noticeable probably would be in Africa, as many countries from that region historically experienced a large number of various disasters. Still, all mentioned limitations should be taken into account, while these roughly identified gaps are considered. As mentioned, at the moment, virtually any country in the world can get access to the services provided by SEM mechanisms (one of the three selected, or some other). Specifically, most of the countries, characterized by a high number of recorded disasters, were already receiving support from the UNOSAT services.

At the same time, keeping in mind the diversity and relatively easy access to the existing SEM mechanisms, as well as the support that they can provide in disaster response, such potential gaps should not be overlooked. The coverage of the explored mechanisms, as well as the noticeable incline towards the exclusion of the countries that can be considered as being in a somehow disadvantaged position, raise the question of justice in the diffusion of such innovations (Papaioannou 2021). Limited or slow diffusion of an innovation that can bring great benefits can have two problematic aspects in terms of justice: innovation does not solve the problem unless it is widely disseminated and adopted by the disadvantaged; slow diffusion causes new injustices in itself (Buchanan *et al.* 2011). In terms of GeoICTs, limited diffusion of such technologies contributes to the first form of injustice. It can be argued that the lack of direct access to the SEM mechanisms by some nations put them at a disadvantage, even though this issue can be partially overcome by the existing opportunity to receive help through indirect requests. A number of programs and activities support the diffusion and wider adoption of such technologies, to promote justice by removing such disadvantages and ensuring universal access to SEM services. There are multiple international and regional organizations working in this direction, namely some of them: UN-SPIDER, UNITAR-UNOSAT, GEO, ADRC, Eurisy.

5.4. Global capacity building initiatives

5.4.1. Overview of the existing mechanisms providing needs assessment

On a global level, several initiatives support countries' efforts in DRR and provide the assessment of local capacities and needs. These include, for instance, services provided by the Capacity for Disaster Reduction Initiative (CADRI), and advisory missions of the UN-SPIDER, a programme implemented by UNOOSA.

CADRI Partnership is a global initiative that brings together UN and non-UN partners, including UNDRR, UNDP, UN OCHA, International Federation of Red Cross and Red Crescent Societies (IFRC), as well as FAO and WFP. Its mission is to provide countries with a "one-stop shop" mechanism to mobilize and use the risk reduction expertise of various participating organizations. The services provided by CADRI include capacity diagnosis, prioritization, and planning, training, referral services (CADRI 2019).

UNOOSA is working on the promotion of international cooperation in the field of space use and exploration, as well as a wider application of space science and technology. UN-SPIDER is a programme implemented by UNOOSA, which is dedicated specifically to activities related to DRR. It aims to ensure that all countries and relevant organizations have the capacity to benefit from the application of all available space-based information to support DRR activities. Through its missions, UN-SPIDER is providing countries with technical advisory support, particularly in a form of Technical Advisory Missions (UNOOSA 2021b).

In a way, both UN-SPIDER's Technical Advisory Missions and CADRI's scoping missions and capacity diagnosis are aiming to achieve similar goals. However, while CADRI's methodology does include the in-depth assessment of the areas of knowledge management and technology, the work done by UN-SPIDER is much more focused on the issue relevant to the current study. CADRI's approach, while being much more comprehensive and inclusive, might not provide enough details and concrete conclusions related to the application of geospatial technologies and space-based information. UN-SPIDER missions, on the other hand, address specifically the needs of Member States related to the application of geospatial technologies and data for risk and disaster management, as well as provide recommendations on the areas of improvement.

5.4.2. UN-SPIDER

The United Nations Platform for Space-based Information for Disaster Management and Emergency Response (UN-SPIDER) was established in 2006. An expert group of the Committee on the Peaceful Uses of Outer Space identified the need for an international entity that would coordinate and facilitate the use of space-based technologies and services in disaster management (UN General Assembly 2006a). UN-SPIDER's main mission was summarized the following way (from A/AC.105/893):

> "to provide universal access to all countries and all relevant international and regional organizations to all types of space-based information and services relevant to disaster management to support the full disaster management cycle by being a gateway to space information for disaster management support, serving as a bridge to connect the disaster management and space communities and being a facilitator of capacity-building and

institutional strengthening, in particular for developing countries" (UN General Assembly 2007)

Being implemented by UNOOSA, UN-SPIDER works in various areas to carry out its mission:

- as part of its **Knowledge Management** efforts, in 2009 an online Knowledge Portal (http://www.un-spider.org/) was established, to ease access of stakeholders to information about existing sources of geospatial data, available tools, good practices, news, and events.
- providing **Technical Advisory Support** to countries in need through a number of various activities – organizing *Advisory Missions* (Technical Advisory Missions, Institutional Strengthening Missions, and Expert Missions); conducting *technical trainings* to develop local capacities; and providing *Emergency Support* through acting as a bridge between disaster management agencies and geospatial data providers or activating emergency mechanisms in case of disasters (Charter, for instance).
- conducting **Outreach** activities and building a **Network** of international, regional and national organizations through setting up *Regional Support Offices (RSO)* on a base of existing entities, to promote cooperation activities (by now, there are 26 RSOs across the globe); requesting all Member States to appoint a *National Focal Point* to work with UN-SPIDER on improving national disaster management policies and encouraging the application of geospatial technologies; as well as through the Global Partnership Using Space-based Technology Applications for Disaster Risk Reduction (GP-STAR), International Network Multi-Hazard Early Warning Systems (IN-MHEWS), and IWG-SEM (UNOOSA 2021a).

5.4.2.1. Technical advisory support

UN-SPIDER programme was established to address the gap between providers of space-based data and information and the end users. The disconnect between these two communities is manifested particularly through the seeming abundance of advanced geospatial technologies on one hand and the common lack of awareness or capacity to use such technologies by some countries, particularly developing, on the other (UN General Assembly 2006b). Some of the UN-SPIDER's main activities that focus on raising awareness and building stakeholders' capacities are provided through Technical Advisory Support, to help countries make the most use of the space-based information and services (UNOOSA 2021a).

This support can come in various forms, as was already mentioned, but particularly through Advisory Missions, which can take place as a meeting (or series of meetings) with stakeholders, workshops, or trainings. The most extensive and comprehensive type of such support is **Technical Advisory Missions** (TAMs), which can be carried out only after receiving an official request from the country (UNOOSA 2021a). TAMs are normally conducted by a group of experts gathered by UNOOSA, they last for around a week and consist of a series of meetings with the country's key stakeholders involved in disaster management and development activities (governmental officials, regional and international organizations, private sector, etc.) (UNOOSA 2021a). The goal of such missions is to assess a country's existing capacities to access and use available geospatial information and services, as well as identify needs and potential obstacles and propose some recommendations and ways for improvement.

UN-SPIDER can also organize Expert Missions (EMs), often shorter and not as thorough as TAMs. Such missions normally consist only of one expert from UN-SPIDER, conducting one meeting with local representatives, however, the format can vary, depending on particular situation (UNOOSA 2021a). Expert Missions often precede TAMs as they aim to investigate the possibility to carry out a bigger mission, however, they might act as a follow-up activity as well. The last type of Advisory Missions is Institutional Strengthening Missions (ISM), which normally focuses on follow-up activities related to capacity development, such as workshops and training sessions. The exact activities often depend on needs and recommendations expressed during TAMs (UNOOSA 2021a).

The main focus of the current research was on the Advisory Missions, particularly Technical Advisory Missions (TAMs) since this kind of activity provides the most comprehensive overview of the state of the disaster and risk management in a particular country. After each mission, a report is developed, which includes, among other things, specific needs and recommendations. These reports are normally not published publicly but shared only with the countries' officials. At the same time, for the sake of present research, these reports were provided for analysis during the internship at UNOOSA. A number of other activities often precede or follow these missions, which are also mentioned in the next sections of the chapter. However, TAMs remain the main focus of the analysis.

Advisory missions

Some conclusions regarding UN-SPIDER’s efforts in providing technical support to countries can be made by simply exploring the total number of conducted advisory missions per year (Figure 16). It is important to keep in mind, that these missions represent only a share of all the activities (trainings, workshops, meetings, etc.) conducted by UN-SPIDER under the advisory support scheme. However, since dedicated missions are generally more comprehensive and thorough (particularly TAMs), they play a crucial role.

Overall, it can be noticed that the total number of all missions per year peaked back in 2010, with the largest share of expert missions (EMs). In terms of the total number of conducted missions, there is a general declining trend, though ISMs are still being conducted quite regularly, even with some increase in frequency. In the case of technical advisory missions, their number per year fluctuated in the 2009-2015 period (with around 3-6 missions per year). Yet, over the last few years, there was only one TAM per year. At the same time, EMs became extremely rare. In 2020, there is a noticeable lack of missions (apart from one TAM to Tunisia, which took place in March), which can be largely explained by the outbreak of COVID-19 which halted in-person activities for most of the year. Still, in 2020 and 2021, UN-SPIDER continued to provide most of their activities but in a virtual format (UN General Assembly 2022). Figure 16 indicates only missions which involved face-to-face meetings and activities.

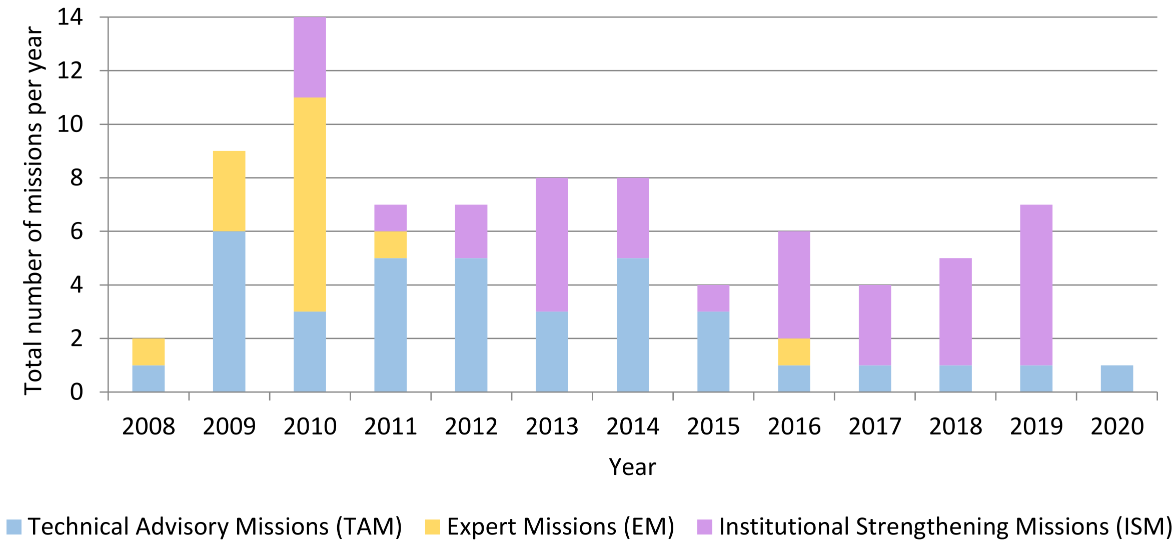

Figure 16. Total number of the UN-SPIDER's Advisory Missions conducted since the establishment of the programme

Data from the official reports on activities implemented by the UN-SPIDER (UN General Assembly 2009a, 2009b, 2010, 2011, 2012, 2013, 2014, 2015b, 2017a, 2017b, 2019, 2020).

According to UNOOSA's officer, the main reason for the decrease in the number of conducted activities is the lack of funds to conduct proper advisory missions, particularly TAMs, which cost a minimum of around USD 12 000-15 000 per trip (as UNOOSA is paying for the travel of most participating international experts). At least for the 2010-2017 period, UNOOSA's regular budget was reducing at a rather constant rate (UNOOSA 2018). Voluntary contributions from the UN Member States to UN-SPIDER were decreasing as well, particularly since 2015, when Austria decided to stop offering voluntary contributions, which were provided since 2007 (UN-SPIDER 2012). In more recent years (2018-2020), some increase in UNOOSA's regular budget could be noticed, which, however, does not mean more funding for UN-SPIDER (UNOOSA 2021b).

At the same time, the decrease in the number of TAMs could also be explained by the fact that by now UN-SPIDER had visited 36 countries (Figure 17) and most of them rather require follow-up visits, ISMs, and related activities to meet their needs identified during missions, not that much the missions themselves. It is also possible to assume, following the innovations diffusion theory, that the most active countries already received the initial assistance they asked for. Now mainly the slower "laggards" might be left, who might not be aware of this opportunity or be reluctant to officially request a visit from UN-SPIDER (Rogers 2003).

Figure 17. Countries where UN-SPIDER's TAMs took place

According to the UNOOSA's Programme Officer, there are still some countries that already requested a mission and are awaiting the visit (or expressed their potential interest), for instance, Niger, Benin, Sierra Leone, Rwanda, and Uganda. This makes the lack of funding more apparent and prominent, however, the situation with the organization of a mission in each particular country can vary.

Overview of the visited countries

Normally, UN-SPIDER organizes advisory missions exclusively to developing countries, the only exception being Georgia which is regarded by the UN as an economy in transition (UN DESA 2022). Table 8 lists all the countries where UN-SPIDER had conducted an advisory mission and indicates the country's income group, whether the country is (or was at the time of the mission) among the Least Developed Countries (LDC) and whether it is a Small Island Developing State (SIDS) or a Landlocked Developing Country (LLDC), as well as country's World Risk Index rank and level (as of 2021). Appendix 7 provides more details on the activities conducted by UN-SPIDER as part of its Technical Advisory Support. While the income group is determined by gross national income (GNI) per capita (World Bank 2021b), the LDC identification uses three criteria: income (GNI per capita); human assets (Human Assets Index); and economic vulnerability (Economic Vulnerability Index), which considers both economic and environmental shocks, particularly, one of the indicators is the number of victims of natural disasters (UN DESA 2021).

Appendix 7 shows the basic timeline of UN-SPIDER's Technical Advisory Support main activities. It provides some overview of the events that preceded TAMs as well as the follow-up activities – trainings and meetings. The main focus of the presented table is on the countries where actual Advisory Missions were conducted (TAMs and EMs, ISMs), keeping in mind that there is a number of other countries where UN-SPIDER and UNOOSA had conducted other related activities as well.

While the official invitation from the country is the main requirement to conduct the mission, illustrates that UN-SPIDER was mainly assisting Low-income and Lower middle-income countries. Main activities covered Sub-Saharan Africa, South and South-Eastern Asia, Oceania, Latin America and the Caribbean. Overall, according to the World Bank classification, as of 2021, there were only three Low-income countries outside of the Sub-Saharan Africa region - Afghanistan, Democratic People's Republic of Korea, Syrian Arab Republic (UN DESA 2022).

One of the guiding principles of the Sendai Framework for DRR focuses on the needs of the developing counties, addressing specific challenges faced by LDC, SIDS, LLDC, African countries, as well as middle-income countries (UNISDR 2015b). Most of the countries visited by UN-SPIDER through their missions fall into one of the mentioned categories (all were low or middle-income at the time of the mission).

The World Risk Index can be used to explore the risk of natural disasters in the countries in focus. In 2021, this index covered 181 countries and was calculated by taking into account exposure to natural hazards, vulnerability, coping, and adaptation capacities. It was developed together with the United Nations University's Institute for Environment and Human Security (UNU-EHS), while in the later years it was revised and now is calculated by the Institute for International Law of Peace and Armed Conflict (IFHV) of Ruhr-University Bochum (Aleksandrova *et al.* 2021).

From Table 8 it can be noticed that most of the countries visited by UN-SPIDER fall into "very high" and "high" risk categories, particularly those located in the Caribbean, Central America, as well as Oceania, and Sub-Saharan Africa. By now, UN-SPIDER had visited the top three countries by disaster risk (Vanuatu, Solomon Islands, Tonga). It is important to keep in mind the methodology used to calculate this index – even if a country's exposure to hazards is relatively high, sound preparedness can significantly reduce the risk, though won't be able to eliminate potential hazards completely (Aleksandrova *et al.* 2021). At the same time, this methodology is being constantly revised and updated, as well as the availability of data depends on each particular country. As a result, the rank and the risk level might change rather noticeably from year to year.

There are also some examples of countries supported by UN-SPIDER with a very low level of risk - Mongolia, Bhutan, and the Maldives. Even though they are falling behind some countries in terms of adaptive and coping capacities, as well as overall vulnerability and exposure of the population in these countries is so low that it successfully mitigates the total disaster risk (Aleksandrova *et al.* 2021).

While, as mentioned, Expert Missions (EMs) often were needed to explore the possibility of a bigger mission, the situation in the case of a particular country can vary and depends on the available opportunities for the mission, financial and time limitations, political and security situation, etc. For instance, in 2009 two consecutive expert meetings were conducted in Kenya and Uganda, which aimed at developing working relationships between UN-SPIDER and local government and agencies as well as potential follow-up activities including technical advisory missions (UN General Assembly 2009b). In the case of Kenya, the TAM was eventually conducted in 2014, preceded by the organization of the Regional Support Office (hosted by the Regional Centre for Mapping of Resources for Development) and the participation of the country experts in a number of trainings. However, while the meeting in Uganda in 2009 included discussions about possibilities of conducting TAM already in 2010 (UN General Assembly 2009b), by now it still hasn't been organized. As clarified through the discussion with UNOOSA's Programme Officer, though the interest in TAM was expressed by Uganda's government, an official invitation was never received by UN-SPIDER, without which the mission cannot be organized.

Table 8. List of countries where UN-SPIDER had conducted an Advisory Mission (2008-2020)

Geographic region		Country	Other groupings	Income group	World Risk Index rank and level (2021)	Advisory Missions
Africa	Northern	Sudan	*LDC*	Low-income *(was Lower middle-income in 2011)*	60 **(high)**	TAM (2011) ISM (2013)
		Tunisia		Lower middle-income	97 (medium)	TAM (2020)
	Sub-Saharan	Burkina Faso	*LDC; LLDC*	Low-income	35 **(very high)**	TAM (2008)
		Madagascar	*LDC*	Low-income	39 **(high)**	EM (2010)
		Malawi	*LDC; LLDC*	Low-income	52 **(high)**	EM (2010) TAM (2013)
		Mozambique	*LDC*	Low-income	50 **(high)**	TAM (2012) ISM (2013)
		Togo	*LDC*	Low-income	36 **(very high)**	TAM (2009)
		Uganda	*LDC; LLDC*	Low-income	59 (**high**)	EM (2009)
		Ethiopia	*LDC*	Low-income	67 (**high**)	ISM (2019)
		Ghana		Lower middle-income *(was Low-income in 2008)*	48 **(high)**	EM (2008) TAM (2013) ISM (2018)
		Kenya		Lower middle-income *(was Low-income in 2009)*	41 (**high**)	EM (2009) TAM (2014)
		Cameroon		Lower middle-income	25 **(very high)**	TAM (2011) ISM (2019)
		Cape Verde	*SIDS*	Lower middle-income	11 **(very high)**	TAM (2012)
		Nigeria		Lower middle-income	26 **(very high)**	TAM (2011)
		Zambia	*LDC; LLDC*	Lower middle-income	72 **(high)**	TAM (2014)
		Zimbabwe	*LLDC*	Lower middle-income	49 **(high)**	TAM (2018)
		Gabon		Lower middle-income	91 (medium)	TAM (2015)
		Namibia		Lower middle-income	96 (medium)	TAM (2009) ISM (2010)

Geographic region		Country	Other groupings	Income group	World Risk Index rank and level (2021)	Advisory Missions
Asia	Eastern	Mongolia	*LLDC*	Lower middle-income *(was Upper middle-income in 2014)*	153 (very low)	TAM (2014) ISM (2019)
		China		Upper middle-income	95 (medium)	ISM (2013)
	South-eastern	Myanmar	*LDC*	Lower middle-income *(was Low-income in 2012)*	79 (medium)	TAM (2012) ISM (2012, 2016, 2017, 2019)
		Lao PDR	*LDC; LLDC*	Lower middle-income	126 (low)	TAM (2015) ISM (2016, 2019)
		Philippines		Lower middle-income	8 **(very high)**	EM (2010)
		Viet Nam		Lower middle-income	43 **(high)**	TAM (2013) ISM (2014, 2016, 2018)
	Southern	Afghanistan	*LDC; LLDC*	Low-income	63 **(high)**	EM (2009)
		Bangladesh	*LDC*	Lower middle-income *(was Low-income in 2011)*	13 **(very high)**	TAM (2011) ISM (2013, 2015)
		Nepal	*LDC; LLDC*	Lower middle-income *(was Low-income in 2014)*	122 (low)	ISM (2014, 2018) TAM (2017)
		Bhutan	*LDC; LLDC*	Lower middle-income	145 (very low)	TAM (2014)
		India		Lower middle-income	90 (medium)	ISM (2010)
		Maldives	*SIDS* *(LDC in 2010)*	Upper middle-income	175 (very low)	TAM (2010)
		Sri Lanka		Lower middle-income	75 (medium)	TAM (2011) ISM (2012, 2014, 2017, 2018)
	Western	Georgia		Upper middle-income *(was Lower middle-income in 2016)*	108 (medium)	TAM (2016)
		Turkey		Upper middle-income	113 (low)	EM (2010)
Oceania		Samoa	*SIDS* *(LDC in 2009)*	Lower middle-income	109 (low)	TAM (2009)
		Solomon Islands	*SIDS; LDC*	Lower middle-income	2 **(very high)**	TAM (2012) ISM (2017)
		Vanuatu	*SIDS; LDC*	Lower middle-income	1 **(very high)**	EM (2010)

Geographic region		Country	Other groupings	Income group	World Risk Index rank and level (2021)	Advisory Missions
		Fiji	*SIDS*	Upper middle-income	14 **(very high)**	TAM (2009)
		Tonga	*SIDS*	Upper middle-income	3 **(very high)**	TAM (2012)
Latin America and the Caribbean	Caribbean	Haiti	*SIDS; LDC*	Lower middle-income *(was Low-income in 2010)*	21 **(very high)**	EM (2010)
		Dominican Republic	*SIDS*	Upper middle-income	32 **(very high)**	TAM (2010) ISM (2011, 2013, 2016)
		Jamaica	*SIDS*	Upper middle-income	29 **(very high)**	TAM (2009)
	Central America	El Salvador		Lower middle-income	18 **(very high)**	TAM (2014) EM (2016)
		Honduras		Lower middle-income	34 **(very high)**	TAM (2015)
		Guatemala		Upper middle-income *(was Lower middle-income in 2010)*	10 **(very high)**	EM (2010, 2011) TAM (2010)
	South America	Ecuador		Upper middle-income *(was Lower middle-income in 2009)*	55 **(high)**	TAM (2009) ISM (2019)
		Colombia		Upper middle-income	88 (medium)	EM (2010)
		Peru		Upper middle-income	86 (medium)	TAM (2019)
		Chile		High-income *(was Upper middle-income in 2010)*	23 **(very high)**	ISM (2010)

Data sources: disaster risk index rank and risk (Aleksandrova et al. 2021); income group (UN DESA 2022; World Bank 2021a); other groupings - LDCs (UN OHRLLS 2021c), LLDCs(UN OHRLLS 2021b), SIDS (UN OHRLLS 2021a); information on the advisory missions is based on the review of the official reports on activities implemented by the UN-SPIDER (UN General Assembly 2009a, 2009b, 2010, 2011, 2012, 2013, 2014, 2015b, 2017a, 2017b, 2019, 2020).

Emergency response through SEM mechanisms

Data from the EM-DAT allows to roughly assess the situation with past disasters that occurred in the countries visited by UN-SPIDER through one of their advisory missions (Guha-Sapir 2021). Overall, for most of these countries, a rather significant number of disasters were recorded. At the same time, as discussed earlier in relation to EM-DAT, only part of the disasters stored in this database required international intervention or, specifically, any support through SEM mechanisms. Over the 2000-2020 period, at least one activation of one of the three explored SEM mechanisms (Charter, Copernicus EMS, or Sentinel Asia) was recorded in 46 out of 48 countries visited by UNOOSA. The remaining two countries were Mongolia (which is a member of the Sentinel Asia initiative) and Gabon. The lack of activations in the case of these countries does not necessarily mean that there were no disasters, but probably that such events could be handled using local or national capacities. At the same time, it is important to mention, that almost all of the countries on the list at some point were also supported by UNOSAT Rapid Mapping services (a UN mechanism that is not specifically covered in much detail by the present research) - apart from Bhutan, Mongolia (both being members of the Sentinel Asia) and Gabon.

Still, the fact that most of the countries were supported by the SEM mechanisms, does not necessarily mean that the national authorities had established direct contact with the mechanisms and requested the activation on their own. None of the countries in the list are from Europe, so there was no option to have direct access to the Copernicus EMS services. Overall, 17 countries (35.4% of all) had authorized users registered within the Charter, while 14 (29.2%) - had direct access to Sentinel Asia. From this list, five countries were registered with both mechanisms, namely China, India, Myanmar, Sri Lanka, and Turkey. However, this still leaves 22 countries, or 45.8% of all visited by UN-SPIDER with a mission, without direct access to any of the reviewed SEM mechanisms. Specifically, this share is rather disproportional in

Africa, as it includes 72% of all visited African countries and only 30% of countries from Asia-Pacific and Latin America and the Caribbean.

At the same time, it might be important to check whether countries that do register with SEM mechanisms actually start using such services directly or are they still relying on support from outside. Available information on the history of countries being granted AU status and thus receiving direct access to the Charter allows exploring the changes in activation patterns. Unfortunately, it was not possible to find complete information on the time countries were joining the Sentinel Asia initiative, thus present analysis is based only on the data from the Charter.

Table 9 lists all countries which were at some point visited by UNOOSA with an advisory mission and which, as of 2020, have direct access to the Charter. It is important to notice, that the Universal Access initiative of the Charter, which allows any country to register an AU, was launched only in 2012. The four countries on the list that had access to the mechanism before that joined it as formal members: India's Space Research Organisation (ISRO) as one of the first members; Nigeria and Turkey as part of the Disaster Monitoring Constellation of DMCii (DMC International Imaging); China through its National Space Administration (CNSA).

Overall, a noticeable difference in the activation patterns can be seen in Table 9. For most of the recorded activations, as soon as a country is granted direct access to the SEM mechanism, it uses its own AUs to request activations. Still, some exceptions can be noticed, particularly around the first years of access to the Charter (maybe in these cases activations were requested before countries finalized AU registration), or in years when multiple disasters occurred (often indicated in the table as "O, X"). Nonetheless, this simple representation clearly illustrates that countries that were granted access to the mechanism in most cases do exercise their new rights and take the burden from international organizations and other countries that were supporting them in this regard.

UN-SPIDER and UNOOSA are very keen on promoting the wider use of the SEM mechanisms and work on facilitating access to such services. UNOOSA is often proposing to serve as a bridge between countries and SEM mechanisms, facilitating communication in case of a disaster. Still, one of the recommendations regularly expressed in the TAM reports is to encourage national governments to register within one of the existing free emergency mapping mechanisms. After such missions some countries indeed joined one of the mechanisms, for instance, Malawi, El Salvador, Myanmar, and Sri Lanka registered within the Charter (CNES *et al.* 2021). Sometimes this process can take a rather long time, as well as there can be multiple factors affecting the decision of the government to participate in a mechanism, apart from advisory missions. Still, such a gap in nations without direct access to mechanisms among the countries already visited by UN-SPIDER is rather noticeable.

Table 9. Records of the International Charter "Space and Major Disasters" activations for the countries which were both visited by UNOOSA with advisory missions and have direct access to the SEM mechanism as of 2020

Years when at least one activation of the Charter took place are indicated in the corresponding cell: if activation was requested by own Authorized User (AU) of the affected country, it is marked with "O"; if activation was requested on behalf of the affected country by international organization or another state, it is indicated as "X". Shared areas represent the years when each country had direct access to the mechanism (had officially registered an AU).

	Direct access to Charter since	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
India	2001	X		O	O	O		O			O	X	O	O	O	O, X	O		O	O	O
Nigeria	2005										O	O	O								
Turkey	2005			X						O	O	O				O					
China	2007					X		O	O		O		O	O	O	O	O	O	O		
Malawi	2014									X						O, X					
Dominican Republic	2015			X	X			X							X		O	O			
Chile	2015							X	X	X	X	X		X	X	O		O		O	
Colombia	2015				X			O, X	X	O	X	X				X		O			O
Guatemala	2016					X					X		X			X			O		X
El-Salvador	2016	X				X				X		X									O
Sri Lanka	2017				X		X		X						X		X	X	O		O
Myanmar	2017				X				X		X			X		X					O
Ecuador	2017	X							X				X				X				
Sudan	2018				X		X							X	X		X			X	O, X
Madagascar	2018							X			X		X	X		X		X			O
Peru	2018							X		X	X		X	X	X			X		O	
Ghana	2019											X									
Tunisia	2019																				
Togo	2020								X												O
Ethiopia	2020					X	X														
Haiti	2020				X				X		X		X				X	X			

Data source: CNES et al. 2021; International Charter 2021.

5.5. Summary

The presented chapter introduced some of the main international mechanisms that support the wider diffusion and adoption of GeoICTs in DRR and management.

First of all, to illustrate the diversity of available GeoICTs, as well as somewhat explore potential approaches in their categorization, a number of geospatial tools and technologies applicable in flood management were explored and presented in a systematized way. A new approach to the classification of such technologies was proposed.

The next section covered the past and present of existing international agreements and frameworks that help shape modern DRR policies. Particularly, it focuses on the aspects related to data, technology, and knowledge management and how these issues are addressed in corresponding documents. The explored timeline covered International Decade for Natural Disaster Reduction, Yokohama Strategy and Plan of Action for a Safer World, Hyogo Framework for Action, Sendai Framework for Disaster Risk Reduction, as well as Millennium Development Goals, Sustainable Development Goals, and Paris Climate Agreement. It was presented and discussed how topics related to sharing technology, knowledge, and data were carried out and transformed in each consecutive document. The overall importance of open access to data, knowledge, and available technology was stressed, together with the clear need and appeal to support developing countries, which can be particularly susceptible to various disasters.

The following section of this chapter introduced satellite-based emergency mapping (SEM) mechanisms. First of all, the importance of rapid response to disasters was highlighted, which nowadays can be supported through the provision of satellite imagery, due to recent advancements in the field, which, correspondingly, paves the way to various SEM mechanisms. From the diversity of existing mechanisms, three were selected for more thorough analysis – Charter, Copernicus EMS, and Sentinel Asia. The general workflow, main steps, and actors involved in mechanisms' activations were discussed and presented. The analysis of the composition of members of these initiatives highlighted some clear differences as well as overlaps, particularly in the case of Charter and Copernicus EMS. Finally, an attempt to identify any particular gaps in direct access to the selected SEM mechanisms was performed. In terms of formal involvement in the initiatives, the most significant gap covered the African continent, with the vast majority of the countries in this region without direct access. However, there were other "blank spaces" as well - in the Middle East, Pacific, Central America and the Caribbean, as well as Western Balkan. In terms of actual need in activations (based on records of past disasters), Africa again seemed to have the most noticeable gaps.

Finally, the last section presented activities of the UN-SPIDER, as one of the important international initiatives involved in the assessment of countries' capacities in terms of the application of geospatial technologies in DRR and management. UN-SPIDER programme aims at providing support to countries in need through various activities, including knowledge management, technical advisory support, and outreach. Technical advisory support, particularly through various missions, was of the most interest for the current study. A general overview of the conducted missions was provided, highlighting the focus of such activities on low and lower middle-income developing countries, which also often fall into the category of LDC, LLDC, or SIDS. Finally, the activity and involvement of the countries visited by UN-SPIDER in terms of activations of the selected SEM mechanisms were assessed, which to some level highlighted how they take ownership in emergency response once they join such initiatives as formal authorized users.

6. Network analysis of SEM mechanisms

To explore a specific example of the application of GeoICT innovation in enough detail and to help capture the diffusions process, SEM mechanisms were selected as a case study. This chapter is focusing on the analysis of three selected mechanisms (Charter, Copernicus EMS, and Sentinel Asia), particularly their activations that took place from the foundations of these initiatives till the end of 2020. This review includes basic statistical analysis using Python as well as network analysis.

6.1. Exploring mechanisms' activations

6.1.1. Datasets used for the analysis

The datasets for the analysis of activations were developed by gathering information on individual activations through publicly accessible archives of three selected SEM mechanisms: Charter, Copernicus EMS, and Sentinel Asia.

The compiled datasets of activations covers the period from November 2000 (first Charter activation) till the end of 2020 (Copernicus EMS 2021; International Charter 2021; JAXA 2021b). Over that time, 692 activations were recorded for the Charter, 447 – for Copernicus EMS, and 342 – for Sentinel Asia. It is important to notice that in some cases, the same disaster could have triggered the activation of more than one mechanism – such incidents are particularly relevant in the case of Charter and Sentinel Asia. The developed database includes relevant parameters of each event, particularly information on the type of the disaster, event location (country/territory), date of the activation, and activation requestor (organization) (Table 10). Developed datasets of organizations and activations were analyzed in Python, while the networks were visualized in Gephi (network visualization software). Qualitative data on challenges in the implementation of these mechanisms were collected through discussions with professionals working in the field and research visits to organizations deeply involved in the operation of SEM mechanisms, particularly to the United Nations Office for Outer Space

Affairs (UNOOSA) and the Asian Disaster Reduction Center (ADRC). All figures and tables presented in this chapter were developed by the author based on the analysis of the datasets of activations and corresponding networks, unless specified otherwise.

Table 10. Basic parameters of analyzed datasets of activations for the selected SEM mechanisms

SEM mechanism	Total number of activations	Unique types of disasters	Unique affected countries/territories	Unique activation requestors (organizations)
Charter	692	17[12]	150	72
Copernicus EMS	447	10[13]	106	31
Sentinel Asia	342	12[12]	33	76

6.1.2. Temporal trends

As mentioned, the developed dataset of activations included information from the first activation of the Charter in 2000 till the end of 2020. The distribution of activations by year for the selected SEM mechanisms is presented in Figure 18. The figure also shows the total number of all activations, however, it is important to keep in mind that the current analysis covers only three particular mechanisms, and not others (for instance, not UN programs, which are also quite active in the field of satellite-based emergency mapping). In addition, some activations might be missed from our analysis, since they are classified as sensitive (related to a sensitive topic or geographic area) and information about them is not publicly available. Still, from the accessible information (presented in Figure 18), since 2000 we can notice more or less constant growth in total activations.

[12] This includes "combined" disasters, like "Storm and flood", "Flood and landslide", etc.

[13] The original "raw" dataset included 12 types of disasters, but outdated types of "Forest fire, wild fire" and "Wind storm" were renamed to more recent types - "Wildfire" and "Storm" correspondingly.

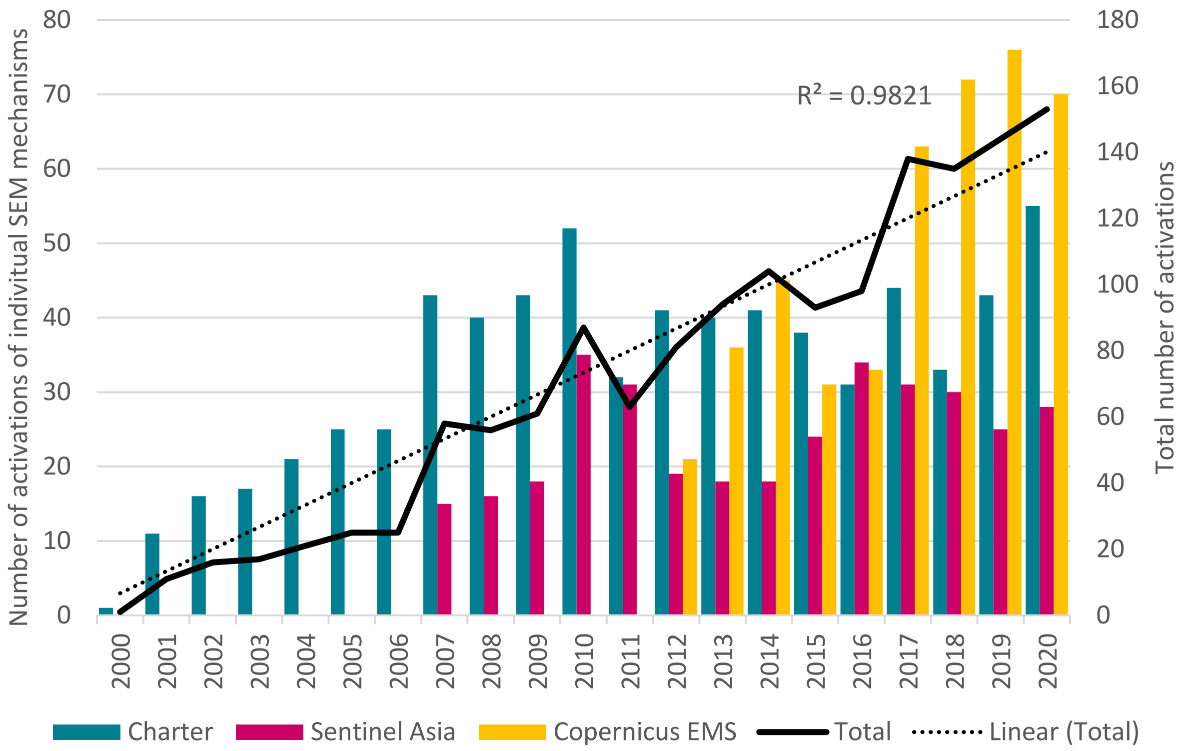

Figure 18. Number of activations per year of different SEM mechanisms for the 2000-2020 period

Note: data on activations of the previous phase of Copernicus EMS ("Global Monitoring for Environment and Security") is not covered by this study.

When looking at the situation with individual SEM mechanisms, the rapid growth in activations of the Copernicus EMS over the last few years becomes particularly clear. Copernicus EMS still might have some room for expansion, compared to other mechanisms which seem to be getting close to reaching their potential in terms of maximum activations per year (Voigt *et al.* 2016). Charter is probably close to reaching its capacity - there was a rapid growth in the number of activations until 2007, but after that, a "plateau" was reached. Recent years were characterized by around 40 activations per year, though in 2020 this number reached 55 - the absolute maximum since the beginning of this initiative. For Sentinel Asia, the number of activations per year were fluctuating over the years - in 2010 and 2011 there was a sudden growth in the number of activations, followed by a rapid decrease. Over the last 4-5 years, it seems like the mechanism reached its limit, as the number of activations stopped growing and has stabilized at around 30 activations per year. Since 2017, around half of all activations per year (among the three analyzed SEM mechanisms) were initiated by Copernicus EMS alone.

6.1.2.1. Duplicating activation requests (Sentinel Asia escalation procedure)

As mentioned earlier, the Charter has an agreement with Sentinel Asia for "escalation" of the activation requests in the Asia-Pacific in case of major disasters – to make use of the resources of this global SEM mechanism, if what is available through Sentinel Asia is not enough. These, in a way indirect, activations, submitted by the ADRC, help improve access to the Charter services for users in the region, which at the moment is largely underrepresented (International Charter 2021). The decision to escalate can be made only by the country where the disaster happen (original requestor of the activation), not by the ADRC.

According to the ADRC representative responsible for managing these requests, sometimes confusion in such activations can occur - when countries send duplicating requests both to the Charter (directly or through some other partner organization or the UN) and to the ADRC, without informing the responsible officers of such actions. Some members of Sentinel Asia are also official members of the Charter (for instance Japan, China, India, Sri Lanka, Myanmar, Pakistan, etc., as shown in Figure 15). According to Sentinel Asia's rules, members of this regional initiative should always request escalation to Charter only through the ADRC and never on their own. However, the cases of "double activation requests" do happen and not only with the countries-members of both the Charter and Sentinel Asia. This confusion can be quite frustrating for the responsible on-call officers who have to manage these duplicated requests in a short time, while they have to provide the necessary assistance and forward the requests further. Such double actions in receiving the same requests from different entities should be avoided to ensure the smoother operation of the SEM mechanisms.

Out of all Sentinel Asia activations recorded over the analyzed period of time, for 62 events (or 18.1%), there was also a corresponding activation via Charter. However, in the case of 13 activations (3.8%), the proper "escalation" process was not officially requested. Requests for such activations were sent to Charter either directly by the authorized users or indirectly: in most cases, requests were coming from UN organizations (UNITAR and UNOOSA), mainly on behalf of other international organizations; in many other cases the requests came directly from the country-level entities, AUs of the Charter; in a couple of cases - from AU of another country, active users of the Charter.

In terms of the formal escalation process, most such requests were coming from Indonesia and the Philippines (both by 11 cases), followed by Japan (5 cases). For the parallel Charter and Sentinel Asia activations that happen without formal requests, there is no clear leader - apart from Sri Lanka with 2 activations, all other countries had only 1 such case. Such parallel activations were recorded only in some years (in 2016, 2017, 2018, and 2020). Most such activations happen in 2017 (6 cases).

6.1.3. Time of activation

6.1.3.1. Data availability

Three analyzed SEM mechanisms are normally activated only after the disaster had happened (Copernicus's "Risk and Recovery Mapping" service was not considered in the present analysis). Knowing when the event took place and when the mechanism was actually activated, it is possible to estimate the delay. However, the level of detail in data on the time of activation and experienced delay varied significantly among the selected initiatives:

- The public portal of the Charter includes information on the date of each activation, however, started indicating the exact time of activation only at the end of 2006 (and even then - not always). At the same time, the date or time of the actual disaster event is not provided at all, which makes it impossible to use the data from the Charter to assess the delay in activations.

- Copernicus EMS has the most detailed information on the date and time for both the event itself (disaster) and activation (for 99.5% of all activations).
- Data on Sentinel Asia was less precise since it included information only on the date, not the exact time. In addition, there was a more considerable number of cases with no information about the date of the event itself - overall, only 86.8% of all activations included detailed enough information for the analysis. Still, it was possible to calculate the delay in activation in days.

Since crucial data on Charter activations was not available, the following analysis focused on the remaining two mechanisms. Interestingly, while the considered SEM mechanisms normally do not accept activations before the actual disaster, there were still few such cases for both initiatives, which are briefly discussed in a later section. For the analysis of the delay, these cases of activation in advance were excluded from the dataset. The main descriptive statistics for the developed datasets are presented in Appendix 8.

6.1.3.2. Delay in activations

As it was already mentioned, the first hours (sometimes days) after the disaster play a crucial role in saving lives and the delay in providing support can be very noticeable for the emergency responders in the field. SEM mechanisms are aiming at providing reliable data, maps of the affected areas, and such services ideally should be activated as soon as possible in case of a need. Available data shows that most activations are triggered rather quickly, within the first days after the emergency. However, there are always a few odd activations that were requested with a very long break after the actual disaster. In 2013, Copernicus EMS was activated for the two events that both happen more than 260 days earlier. Both activations were assigned the “other” type and focused on preparing the reference maps for the refugee camp in Al Azraq (in

Jordan near the Syrian border) and the population displacement in Myanmar. The Sentinel Asia dataset also included one case of an activation triggered more than 4 months after the event. As can be seen, such cases are quite rare. In general, activations with a long delay after the disaster often include special requests and might need to be reviewed on a case-by-case basis.

To explore the characteristics of the datasets without such cases, it is possible to exclude all activations that were triggered 20 days after the disaster or even later (considered as special cases). Still, this process kept the majority of activations in the dataset - almost 95% for Copernicus EMS and almost 98% for Sentinel Asia. On average, an activation was triggered around 2.5 days after the actual disaster (for both mechanisms). More than 41% of all Copernicus EMS activations were triggered within 24 hours after the disaster. A similar value is a bit hard to calculate for Sentinel Asia since no information on the exact time is available, but roughly 22% of activations happen less than one day after the event. In the case of Copernicus EMS, 75% of all activations happen within 3.5 days, for Sentinel Asia – within 3.

For both mechanisms, a slight trend can be observed over the analyzed period of time - on average, the delay in activations is becoming shorter. For Copernicus EMS this tendency is clearer, however, significant fluctuations of this parameter can be noticed for both initiatives. The year 2020 is characterized by the shortest average time it took to activate both mechanisms - 1.84 days for Copernicus EMS and 1.25 for Sentinel Asia.

6.1.3.3. Delay in delivering data

Unlike other mechanisms, the available dataset for Sentinel Asia also covered some additional aspects of activations, including information on delays in delivering archive data (before the event), post-disaster data (satellite imagery), and analyzed products (maps). This information was available not for all activations - the available dataset included such data only for the 2010-

2018 period. Overall, only around 61% of all cases covered information on delivery of satellite imagery, and 52% - on delivery of products.

Still, even this partially incomplete dataset provides an opportunity to analyze the average delay in the provision of data and products after the activation of the Sentinel Asia mechanism and assess any potential trends. Overall, in 2018, all three recorded types of data delivery showed quite similar average delay - around 3-days for satellite imagery and 3.8 days - for value-added products (maps). All three types could be characterized by the quicker provision of data in 2018 compared to 2010, however, there were some noticeable fluctuations in between (Figure 19). Still, data recorded for the 2015-2018 period showed much more consistent changes.

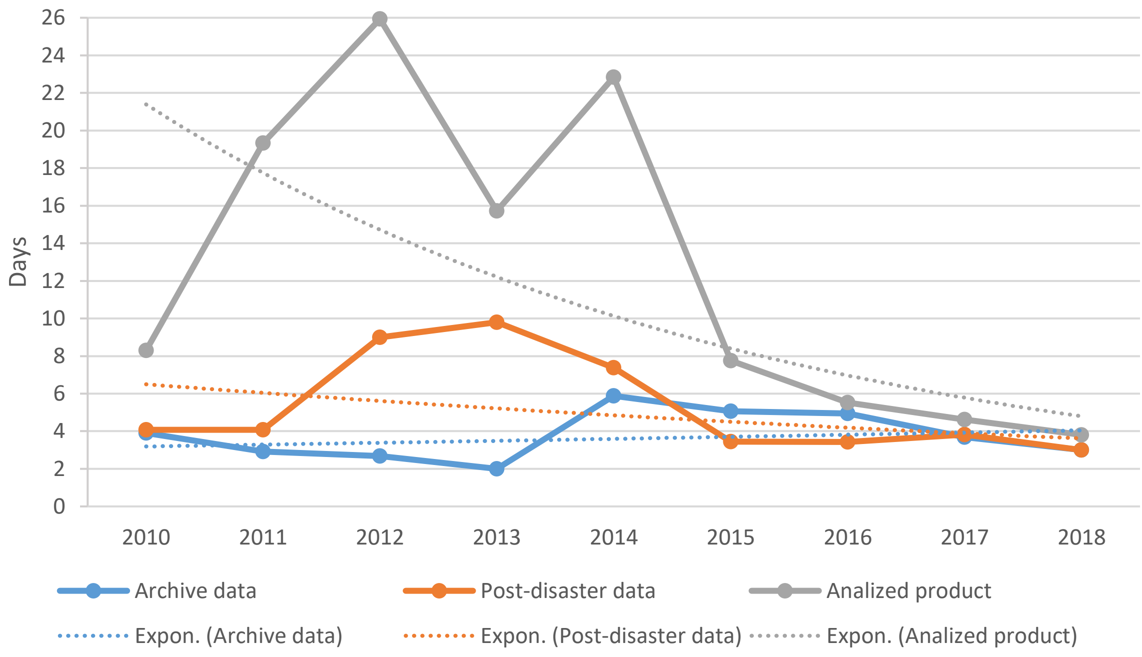

Figure 19. Average delay in delivering data and products for Sentinel Asia

In terms of any noticeable trends, it can be mentioned that the delay in delivery of archive data is even showing slightly increasing trend, while the delay in delivery of post-disaster data - slow, but quite steady decrease, and the delay in delivery of analyzed products - quite rapid drop. While the delivery of post disaster imagery depends on the availability of satellites and, in case of some sensors, on weather, delivery of value-added analyzed products keeps accelerating due to automatization of many analytical steps in this process (through the use of cloud computing, AI, machine learning).

6.1.3.4. Activations in advance

As mentioned earlier, while the analyzed SEM mechanisms normally could be activated only after a disaster happen, all three of them had cases of activations in advance. Normally Charter can be activated only after the actual disaster happen, proactive activations are quite rare. Due to the fact that there was no data on the time of the event in the dataset of the Charter activations, through manually review of the Charter portal, it was possible to identify only few of such examples, for instance, predicted eruption of the Merapi volcano, Java (Indonesia), in April 2006, and potential collapse of a tailing pit dam, Ukraine, in February 2010. Another example is the case of the Typhoon Haiyan (Yolanda) that hit the Philippines in 2013. It was possible for an AU to submit the request for activation before the actual event, since typhoon's direction was known. This gave additional time for space agencies to task their satellites accordingly so there were more chances to collect required data in a timely manner using all available resources. Still, such proactive approach in Charter activations is rather rare.

Much more detailed dataset of Copernicus EMS activations allowed to clearly identify which activations were made in advance. Overall, there were only 30 such cases (6.7% of all activations) when the service was activated before the actual disaster (with the delay time <=0). Still this number is rather noticeable, compared to other SEM mechanisms. The inclination towards such activations in advance depends on the type of the disaster. No such activation took place for earthquakes, industrial accidents, mass movement and volcanic activity (which can be understood, as such events are hard to predict). At the same time the only two cases of epidemics both were activated in advance, as well as 15 storm activations (which amount to 22.1% of all storm activations) and 9 floods (5.4% of all flood activations). Activations for storms on average happen 0.84 days in advance, for floods - 0.68 days in advance. One of the activations classified as humanitarian (out of 5 in total) was activated 11 days in advance, to support Portugal with the preparation for the visit of Pope Francis (due to Fátima 100th Anniversary).

In case of Sentinel Asia, due to less detailed data on time of the event and activation, only six cases were clearly identified as activations in advance. All activations were requested due to storms and floods caused by storms.

As can be seen, storms prove to be the most common type of disaster, for which the activation can be triggered in advance. Storm's direction and speed of movement can be predicted with rather high level of certainty, which allows to request activation of the SEM mechanisms before the actual disaster (Alemany *et al.* 2019; Kim *et al.* 2015). This gives more time to plan and prepare the system, so it is in full readiness by the time the storm hits, allowing to use all opportunities provided by such services.

6.1.4. Regional patterns

Using the developed datasets, it is also possible to take a closer look at the differences in coverage of different SEM mechanisms based on the geographic regions: on one hand - what territories were covered by these activations; and on another - from where the AUs, organizations that requested the activations, are coming. To define geographic regions for this analysis, a United Nations Statistics Division's methodology on a standard country or area codes for statistical use (known as the M49 standard) was applied (UNSD 2021). However, it is important to notice that cases for Asia and Oceania were joined into the new Asia-Pacific region due to a very small number of events and AUs associated with the Oceania region, as well as since many regional AUs focus on the whole Asia-Pacific region (and not Asia or Oceania separately). The shares of different geographic regions in activations are presented in Figure 20 – pie charts on the left side illustrate the differences in the location of such activations (where disasters happen); on the right side - the location of the AUs. For AUs, one more “region” was added to the analysis - “International”- that shows the share of the UN and other international organizations.

The differences between the assessed SEM mechanisms and their regional specialization can be seen quite clearly in Figure 20. Charter is the most diverse in terms of both the location of activations and the location of involved AUs. It is most active in Asia-Pacific and Latin America and the Caribbean, while international organizations play a major role in its activations. The remaining two SEM mechanisms both are very homogeneous in terms of AU composition. According to its regulations, direct activation of Copernicus EMS is possible only through the European organizations, which explains such uniformity. At the same time, more than a quarter of the initiative’s activations address disasters happening outside Europe. Sentinel Asia has several international organizations among its members, but the activations are largely initiated by organizations within the focus region of this mechanism.

Another interesting observation that can be made based on the presented information, is the differences in the involvement of AUs in activations affecting different geographic regions. However, this feature can be clearly observed only in the case of the Charter, due to the homogeneous nature of AUs in Copernicus EMS and Sentinel Asia initiatives - all AUs in Copernicus EMS are located in Europe, while the absolute majority of Sentinel Asia’s AUs are from Asia-Pacific region (and the remaining are represented by international organizations).

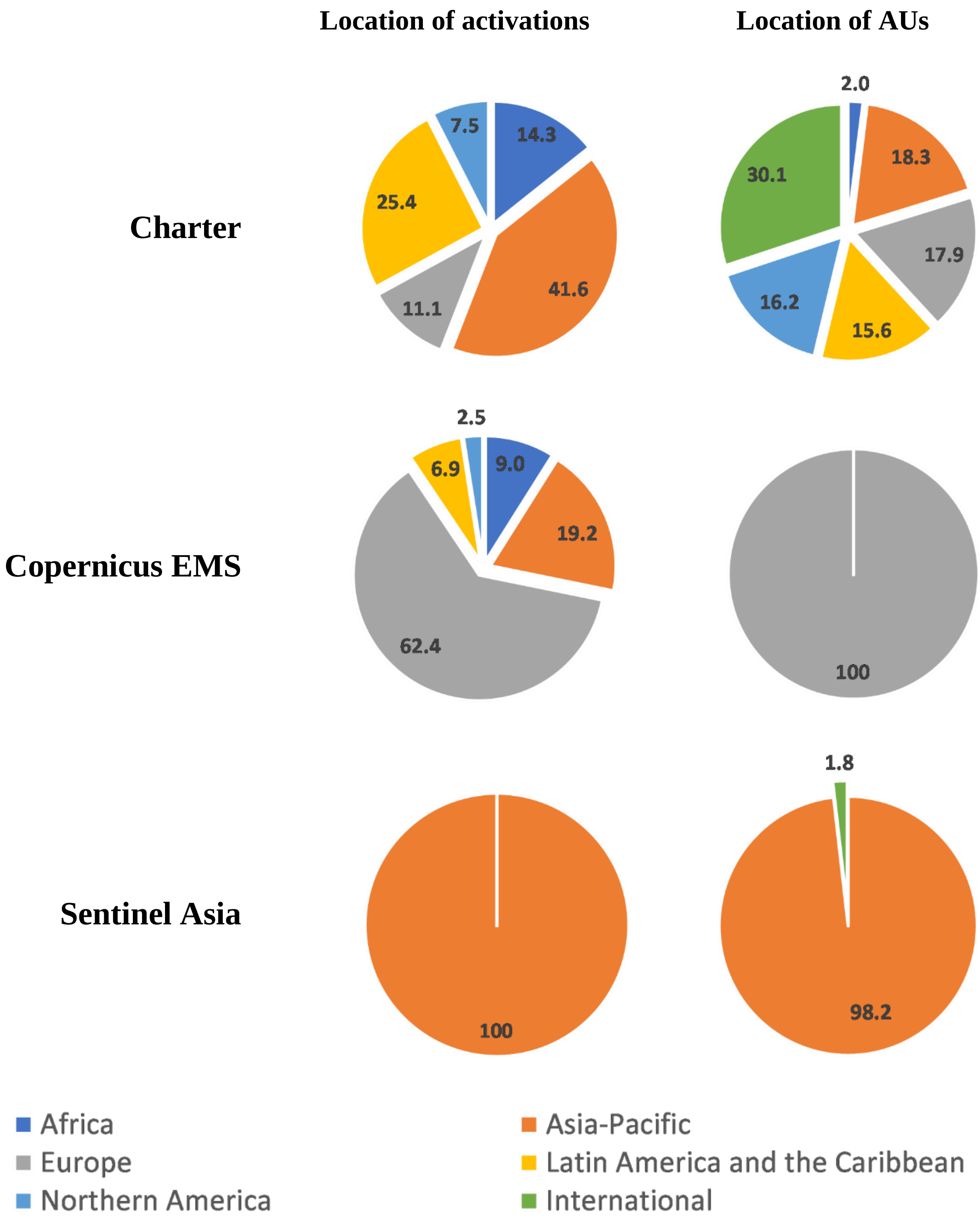

Figure 20. Location of activations and AUs, by geographic region (share, %)

Note: the same data in a tabular format can be found in Appendix 9 and Appendix 10.

6.1.4.1. Interregional and intraregional activations (Charter example)

For Charter, the most affected regions (in terms of the number of activations) were Asia-Pacific (41.6%), Latin America and the Caribbean (25.4%), and Africa (14.3%). At the same time, in comparison, the overall share of AUs coming from the corresponding regions is significantly lower - 18.3% for Asia-Pacific, 15.6% for Latin America and the Caribbean, and only 2% for Africa. More than 30% of all activations were initiated by the UN organizations (represented in Figure 20 by the “International” region). This distribution of activations among regions can be explored in more detail through network analysis.

The generalized version of Charter activations by geographic regions is presented in Figure 21, in a form of a network developed using the Gephi software. It consists of six nodes, representing different geographic regions, connected by edges (links), which show the “direction” of activations - AU of which region requested activation for the disaster in which region. The thickness of links shows the overall number of activations that happen in this “direction” over the analyzed period. The size of each node very approximately shows the total number of all disasters (activations) that happen in this region.

To assess the situation, it is important to understand the concept of “self-loops” – when the AU in any region requested an activation for the disaster that happened within the same region. In Figure 21, the self-loop is shown as a “hoop” on the right side of a node, the thickness of which represents the overall number of activations that happen in this “direction” (similarly to normal links between different nodes). The “International” node on the figure (in green) shows combined activations of the three UN organizations participating in the Charter (UNOOSA, UNITAR, and UN OCHA) and it does not have any self-loops since it is not a geographic region itself and cannot experience a disaster.

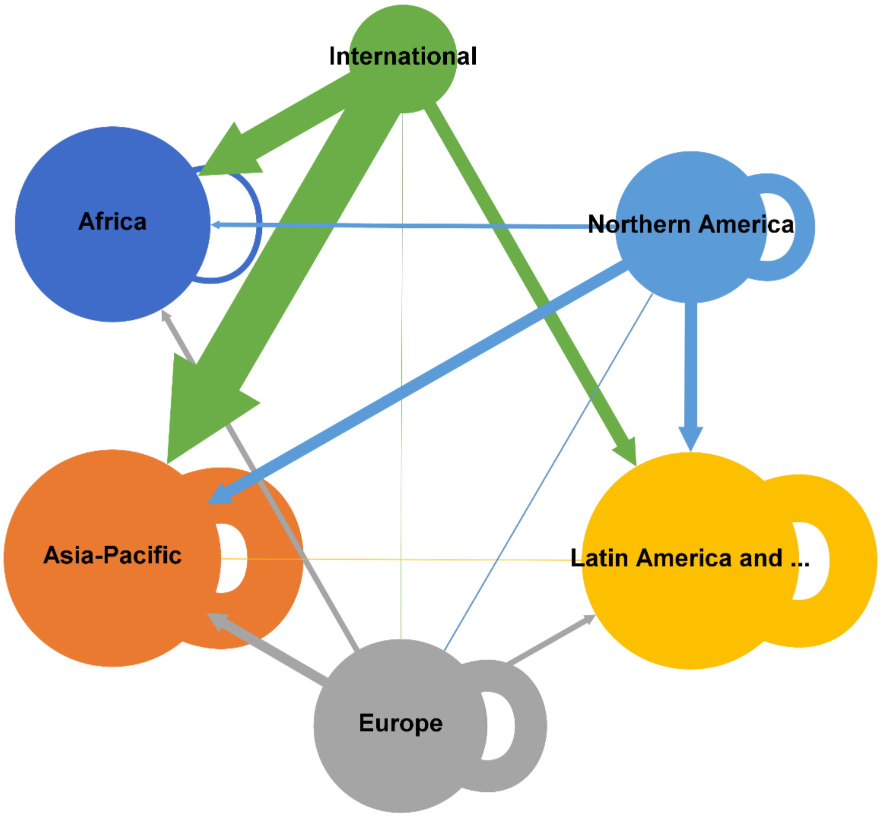

Figure 21. Generalized activations of the Charter by geographic regions

It is possible to assume that regions with a high number of self-loops have enough capacities to deal with disasters on their own – they have AUs that can request a Charter activation in case of need. Excluding the "International" node, three different types of behavior among the geographic regions can be observed based on the proportion of existing self-loops and the character of the links with other nodes (requesting activations on behalf of other regions or receiving support from "outside"):

- One group could be represented by Europe and Northern America – almost all activations are covered by their own capacities, as indicated through thick self-loops (95% and 92% correspondingly). At the same time, they also actively support countries from other regions. Almost no activations were requested from "outside".
- Next group consists of Asia-Pacific and Latin America and the Caribbean – these regions are able to cover a large portion of necessary activations using their own

resources (44% and 60% correspondingly). At the same time, they still quite heavily rely on AUs from other regions and international organizations for additional support.

- The last group includes Africa – this region covers only a few activations through its own AUs (only 13%) and quite heavily relies on support from outside, particularly from UN organizations, which covered around 63% of all activations. This region also never provided direct support through activations for countries from other regions (which is understandable, since at the moment there seem to be not enough capacities to cover their own needs).

While the scheme in Figure 21 provides some insights into the various approaches common for activations in different geographic regions of the world, it is important to remember that it only shows the situation with the Charter. While European AUs are playing an important part in activations through this initiative, this region also has its own SEM mechanism besides Charter – Copernicus EMS – which provides significant support not only to European countries but to other regions as well, Asia-Pacific in particular. Similar to Europe, the Asia-Pacific region also has its own mechanism - Sentinel Asia - though, still relying on Charter and UN services. UN mechanisms, like UNITAR-UNOSAT, play a major role in Africa and Latin America and the Caribbean, regions that do not currently have any specific regional SEM mechanism in place (Voigt *et al.* 2016).

6.1.5. Types of disasters

6.1.5.1. Differences in the used classifications

Each SEM mechanism uses a slightly different classification of disaster types. Sometimes the approach in assigning the disaster type or just the name used for the type itself can change over time. Table 10, presented at the beginning of this chapter, shows that there is a noticeable difference even in the total number of unique types of disasters indicated in the datasets of the three analyzed mechanisms.

Charter had some significant inconsistencies in the raw dataset, regarding the recorded types of the disasters. This dataset was cleaned manually to normalize used terminology, particularly to create the general disaster type "Storm" (based on the various variations of its sub-types - Hurricanes, Cyclones, Typhoons) (Guha-Sapir 2021), as well as to fix the differences in the wordings of other types (wildfires, floods). Compared to other SEM mechanisms, Charter seems to be less strict in assigning one particular type of disaster per activation. Overall, this dataset includes a considerable number of "combined" disaster types like "Storm and flood", "Earthquake and landslide", and even - "Storm, flood, landslide, volcanic activity", which results in a considerably large number of disaster types - 17 in total. This "feature" of the dataset makes the analysis a bit different compared to other mechanisms, which use a more clear classification of disasters.

Copernicus EMS has a particularly clear classification system. The raw dataset included 12 types of disasters, which was then reduced to 10, after the minor manual fix - the names "Forest fire, wild fire" and "Wind storm" types were used in the earlier activations, but later were renamed to just "Wildfire" and "Storm" correspondingly.

Sentinel Asia, similarly to the Charter, uses some "combined" disaster types, however, the variations were more limited, so in the end, the dataset included only 12 unique types.

6.1.5.2. "Other" disasters

In addition, the datasets of all three SEM mechanisms also included the *"other"* type of disasters. For Charter, this type covered mainly the events of the technological nature (aircrafts crashed or missing, submarines, dam failure, industrial accidents), as well as some cases related to snow and ice. Copernicus EMS has a more diverse combination of disasters, gathered under this "other" type, both natural and technological (related to population displacement and refugee camps, conflicts, as well as epidemics, landslides, floods, and cyclones). At the same time, it is worth noticing that in recent years, the use of the "other" type of events became quite rare for the Copernicus EMS mechanism - only one such event was recorded in 2019 and 2020, compared to 16 "other" disasters that took place in 2014 alone. In the case of Sentinel Asia, the "other" type similarly includes both natural and technological disasters: oil spills, explosions, missing boats, blizzards, mudflows, storm surges. Interestingly, it can be noticed that the events associated with extreme temperatures (mainly cold waves or severe winter conditions), while being considered a natural disaster, still generally were recorded as "other" events.

6.1.5.3. Most common disasters

For all three analyzed SEM mechanisms, floods and storms were among the most common disasters (Table 11), which corresponds to the general global tendencies, according to the EM-DAT database (Guha-Sapir 2021). In the case of Sentinel Asia, over half of all activations were targeting floods. Interestingly, wildfires, which are typically not among the most widespread disasters (according to EM-DAT), play a major role for Copernicus EMS, which is not the case for the other two mechanisms. One of the possible explanations for the prevalence of activations for wildfires could be that most Copernicus EMS activations are located in Europe – EU member states are generally well equipped to handle storms and small floods, so they sometimes might not need satellite monitoring support for these types of disasters, but could require additional help in case of wildfires. "Other" type is also rather common for the Copernicus EMS, compared to the other mechanisms.

Table 11. The share of most common types of disasters, based on all activations of the SEM mechanisms

	SEM mechanism		
Disaster type	**Charter**	**Copernicus EMS**	**Sentinel Asia**
Flood	41.8	37.6	50.3
Storm	15.2	15.2	12.6
Earthquake	9.5	5.6	12.9
Wildfire	7.4	26.4	2.3
Other	2.6	10.3	2.3

It is hard to say whether there is a clear pattern in the distribution of different types of disasters in different months of the year. One of the more obvious conclusions is related to the prevailing presence of Copernicus EMS activations triggered by wildfires around the summer months (especially in July and August). For all three SEM mechanisms, the period around Summer-Autumn is generally characterized by the largest number of activations, the busiest months being August, September, and October (for Sentinel Asia – also July).

6.1.6. Developed products

Activations of SEM mechanisms result in the provision of satellite imagery and value-added products to the end users. Open portals of all three initiatives provide some information on the delivered products, sometimes just final maps, in other cases even raw datasets and shapefiles. However, such publicly available data was often inconsistent and probably does not always reflect how many and which products were actually developed and provided to the end user. Still, since to a certain degree, this information is available, it was worth exploring it.

For the Charter, a quite significant share of activations did not include information on the number of developed products - some data was available only in the case of 118 activations in total (or a bit more than 17% of all Charter activations). For comparison, in the case of Copernicus EMS, there were only 8 activations with no information on the number of developed products (or 1.8% of all activations). Dataset of the Sentinel Asia activations was missing information on the developed products in 13.7% of cases (47 activations in total).

The average number of products developed for different types of disasters really depended on the situation with each considered SEM mechanism, as well as on how rare were the cases of activations for this particular type.

Some combined types of disasters, particularly common for the Charter, are rather unique, and as a result, it is not possible to draw any definite conclusions regarding them. For instance, the only activation for “storm, flood, landslide, volcanic activity” in Central America in 2005 had 54 products developed. Still, in the case of Charter activations, the largest number of products was delivered for “volcanic activity and earthquake” (only 3 cases) - 35 products on average, followed by “earthquake and tsunami” (11 cases) - 22.86 products, “earthquake and landslide” (4 cases) - 19.5 products, “storm, flood, landslide” (2 cases) - 14.5 products. In terms of “single” types of disasters, for “earthquakes” on average 11.43 products were developed (66 cases), while for “volcanic activity” - 9.46 products (33 cases).

For Copernicus EMS, on average, the largest number of products was developed for humanitarian events - 24.2 products, taking into account that there were only 5 activations of this sort. This is followed by earthquakes (17.32 products), “other” events (14.12 products), storms (13.92 products), floods (12.89 products), and volcanic activity (10.5 products on average, for only 4 activations).

For Sentinel Asia, the highest number of products developed on average per activation was for the “earthquake and tsunami” disaster (53.5 products per only 2 cases), followed by earthquakes (27.6 products per 44 cases), “flood and landslide” (25.3 products per 12 cases), flood (24.1 products per 172 cases), storm (23.9 products per 43 cases), “flood, landslide, storm” (21.3 products per 3 cases). The least number of products were delivered for wildfire (15 products per 8 cases), “storm and flood” (14.2 products per 10 cases), and volcanic eruptions (10.9 products per 16 cases).

6.2. Analysis of the network of activations

6.2.1. Preparation of the datasets

Available datasets of activations also allowed to develop and assess the networks of the selected SEM mechanisms. This kind of analysis provides more information on the level of involvement of various organizations and helps explore the regionality of activations, as well as the overall composition of the existing structures. However, before available datasets could be used for this sort of network analysis, some elements of the tables had to be manually adjusted. This had to be done due to the fact that sometimes one activation could be covering more than one country, or the request has been submitted by more than one AU. In such cases, additional elements were added to the datasets, per each country supported through the SEM mechanism activation or participating AU. Each element in the adjusted table would represent a link between two separate nodes (a country and an AU). This way developed networks would more accurately represent the diversity of all involved organizations and affected territories. Due to these manipulations, the total sum of entries in the adjusted tables would always be higher than the actual number of activations recorded in the original datasets (in which one activation was always represented by only one element).

For instance, in the case of the Charter, the actual number of activations in the original dataset is 692, while the table adjusted for the network analysis includes 761 elements (links). For Copernicus EMS, 447 activations were recorded over the considered period of time, while the updated table covered 465 elements. In the case of Sentinel Asia, the original 342 activations increased to 386 links.

In addition, through this manual review, some minor errors in the datasets were fixed, which didn't affect the earlier analysis of the activations. For instance, the slight variations of the name of the same organization that requested multiple activations (like an additional space between words), which otherwise would have been considered by the analytical software as different organizations.

6.2.2. Main characteristics of the developed networks

Updated datasets, now suited for the analysis, were analyzed and converted into networks using Python. The main characteristics of the developed networks of the selected SEM mechanisms are presented in Table 12. Nodes represent both unique affected territories and activation requestors (AUs), while edges show links between different nodes. The number of edges is less than the number of elements in the tables used to create the networks since links are aggregated for cases when there was more than one activation between the same pair of AU and territory. As was discussed in the section of the Methodology "4.3.2.1. Network analysis", the original networks could be characterized as directed, bipartite, and disconnected.

Table 12. Main characteristics of the developed networks of the selected SEM mechanisms

SEM mechanism	Number of nodes	Number of edges	Directed graph		Undirected graph	
			Average indegree and outdegree	Average edge density	Average degree	Average edge density
Charter	222	333	1.5	0.00679	3	0.01358
Copernicus EMS	137	128	0.9343	0.00687	1.8686	0.01374
Sentinel Asia	109	102	0.9358	0.00867	1.8716	0.01733

The average number of edges (links) per node in the graph, or shortly, the *average degree* of the network (Barabási 2016), in case of Charter activations is noticeably higher, compared to other mechanisms. At the same time, the network for Sentinel Asia is denser than the other two, considering the edge density is defined as the number of actual edges (links) divided by a maximum number of potential edges (Darst *et al.* 2013).

6.2.3. Visualization and basic structure

Sentinel Asia is used to introduce the networks of activations in a more visual way. While all networks were developed and mainly analyzed in Python, they were visualized using Gephi software, as shown in Figure 22. Network of Sentinel Asia activations can be considered the smallest, compared to the other two mechanisms. It has 109 nodes in total, divided into two groups (76 organizations (AUs) and 33 countries), and 102 unique edges (links between the nodes). Interestingly, there are much more participating AUs, compared to the total number of supported countries. Such prevalence is a rather unique feature for the Sentinel Asia initiative, compared to other mechanisms.

In Figure 22, the red nodes represent individual Authorized Users (international, regional, and national organizations) who requested the activations. Blue nodes represent territories, which were affected by the disasters and received assistance through Sentinel Asia. Red links connect AUs (requestors) with corresponding countries (locations of the disaster events), while the thickness of these links represents the number of such activations over the whole assessed period. Networks of activations of the other two SEM mechanisms can be found in Appendix 11 and Appendix 12.

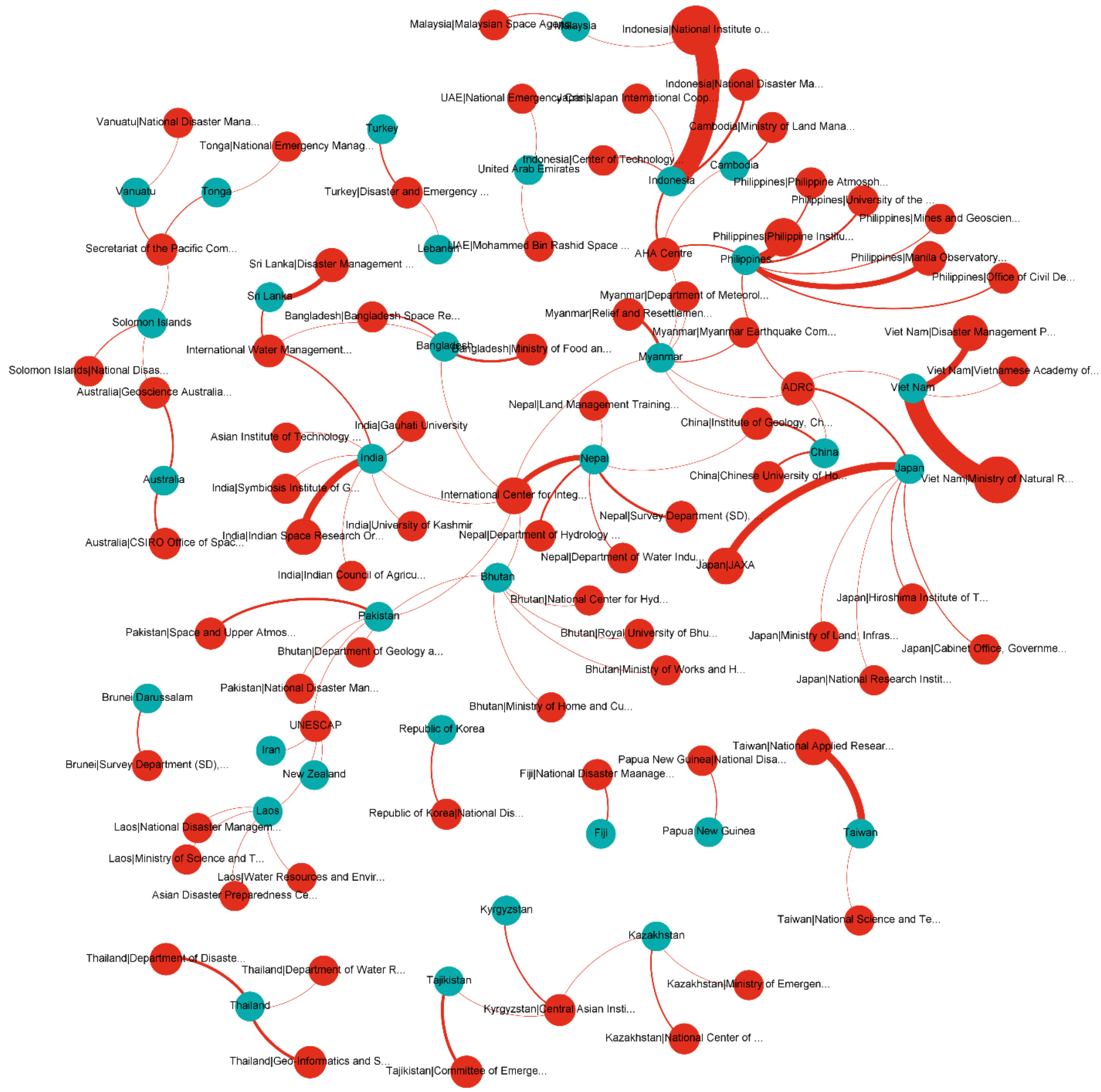

Figure 22. Network of activations of the Sentinel Asia

The main portion of the visualized network of Sentinel Asia is interconnected, however, there is several smaller clusters that are disconnected from the main system (can be found mainly in the lower part of Figure 22). In most cases such small groups represent countries and their national Authorized Users - such self-sustained clusters didn't require any assistance from abroad but also probably didn't support any other activation on behalf of some other country (since there are no links connecting them with the rest of the network). There are no clear central actors in this system, however, some AUs are more active than others.

For comparison, the network of the Charter activations has two UN organizations (UNITAR and UNOOSA), as well as one national organization (USGS) playing central roles in the system. And while they are very active in their support of countries that are not registered as AUs, it also shows that they act as an intermediate link in the activation requests, which ideally should be avoided to ensure a more timely and efficient response to disasters. In the case of Copernicus EMS, the European Civil Protection and Humanitarian Aid Operations (DG ECHO) acts as the central element of the system.

6.2.4. Identified features of the networks

6.2.4.1. Most affected countries

Using the developed networks of activations, it is possible to explore the characteristics of their two types of elements - nodes (countries and organizations) and edges (links that represent an activation). Knowing the weighted degrees of the nodes, it is rather easy to identify the most affected countries (largest in-degree values) and most "active" organizations (largest out-degree values), in regard to the overall number of requested activations.

Table 13 introduces the top ten countries for which the largest number of activations was recorded, across all three SEM mechanisms. The Charter shows a rather diverse group of countries, coming from various geographic regions, though the Asia-Pacific region prevails.

Since Copernicus EMS is primarily a European service, it is logical that the majority of most affected countries are European. However, its activations can be requested worldwide, and they do cover quite many countries from other regions of the world. At the same time, Viet Nam is the only non-European country among the top ten most affected territories. Italy and Spain both received the most activations from this service (11.6% and 10.8% correspondingly). In the case of Sentinel Asia, the top five countries in its list are responsible for 54.3% of all activations.

Table 13. Top 10 countries for which the SEM mechanisms were activated

Charter	Number of activations	Copernicus EMS	Number of activations	Sentinel Asia	Number of activations
USA	37	Italy	54	Indonesia	56
India	31	Spain	50	Viet Nam	55
Philippines	31	Greece	24	Philippines	48
Chile	27	France	23	Japan	26
Indonesia	26	Germany	19	India	25
China	24	Portugal	17	Nepal	24
Argentina	23	United Kingdom	10	Taiwan	16
Viet Nam	20	Viet Nam	10	Sri Lanka	13
Russia	18	Ireland	9	Myanmar	13
Pakistan	17	Sweden	8	Thailand	13

The presented list also illustrates that countries are not limited in receiving support in disaster response only from some particular mechanism. Table 13 includes only the most affected countries, but even among them, four countries from Asia are indicated more than once (Indonesia, Viet Nam, Philippines, and India). Viet Nam can be found in the lists of all three mechanisms. This situation in a way demonstrates the diversity of available opportunities, as well as their potential supporting role - if at the time of the disaster the capacity of one of the mechanisms is reached, other options might be available.

6.2.4.2. Most active organizations

Table 14 lists the top ten organizations which requested activations of corresponding SEM mechanisms most often.

Table 14. Top 10 most active AUs (activation requestors)

Charter	Number of activations	Copernicus EMS	Number of activations	Sentinel Asia	Number of activations
UNITAR-UNOSAT	124	DG ECHO (EC Services)	150	LAPAN (Indonesia)	45
UNOOSA	104	Presidenza del Consiglio dei Ministri - Dipartimento della Protezione Civile - Centro Situazioni (Italy)	54	MONRE (Viet Nam)	39
USGS (USA)	102	CECOP (Spain)[14]	51	PHIVOLCS (Philippines)	20
SIFEM-DNPC (Argentina)	66	BBK (Germany)[15]	35	ICIMOD	16
DGSCGC (France)[16]	49	COGIC (France)[17]	27	JAXA (Japan)	16
ADRC	44	General secretariat for Civil protection - Directorate for Emergency Planning and Response (Greece)	24	ISRO (India)	15
ISRO (India)	35	National Command for Relief Operations - National Authority for Civil Protection (Portugal)	18	NARL (Taiwan)[18]	15
NDRCC (China)	21	Cabinet Office - Civil Contingencies Secretariat (United Kingdom)	14	DMPTC (Viet Nam) [19]	14
DG ECHO (EC Services)	20	EEAS[20] (EU Services)	11	Manila Observatory (Philippines)	11
Public Safety Canada	19	National Directorate for Fire and Emergency Management (Ireland)	9	Disaster Management Centre (Sri Lanka)	10

In the case of Charter, the top four organizations were responsible for more than half of all activations by this mechanism: UNITAR-UNOSAT was involved in 16.3% of all activations, UNOOSA – in 13.7%, USGS – in 13.4%, SIFEM-DNPC[21] – in 8.7%. It also should be noticed that the ADRC, a key actor of the Sentinel Asia initiative, is among the most active Charter

[14] Centro de Coordinacion Operativa (CECOP) de la Direccion General de Proteccion Civil y Emergencias

[15] Federal Office of Civil Protection and Disaster Assistance (BBK)

[16] General Directorate for Civil Protection and Crisis Management (DGSCGC)

[17] Centre Operationnel de Gestion Interministeriel des Crises (COGIC)

[18] National Applied Research Laboratories (NARL)

[19] Disaster Management Policy and Technology Center (DMPTC), Disaster Management Authority, MARD

[20] European External Action Service (EEAS)

[21] Sistema Federal de Emergencias - Dirección Nacional de Protección Civil

requestors. The DG ECHO is also among the most active organizations while playing a major role in the European SEM mechanism.

Similarly, for Copernicus EMS, the top three organizations played a major role in activations, being responsible for almost 55% of all requests. The DG ECHO alone covered 32.2% of all activations. Due to the mechanism’s rules, only organizations from Europe can act as AUs, so there are no international organizations involved.

At the same time, Sentinel Asia's activations could be characterized by quite different distribution, as three of its most active organization were responsible only for a bit more than a quarter of all activations (27.5%). An interesting feature, that in a way distinguish Sentinel Asia from other mechanisms, is that these three major players were responding only to disasters within their own countries:

- Indonesian National Institute of Aeronautics and Space (LAPAN) requested activations only for Indonesia and one joint activation which also partially covered Malaysia;
- Ministry of Natural Resources and Environment (MONRE) of Viet Nam - all activations only for Viet Nam;
- Philippine Institute of Volcanology and Seismology (PHIVOLCS) - all activations only for the Philippines.

The only regional (not national) organization in the top ten list is the International Center for Integrated Mountain Development (ICIMOD). Overall, the number of international/regional organizations involved in Sentinel Asia activations is limited, and only one of them has a global scope and does not focus exclusively on the Asia-Pacific region - International Water Management Institute (IWMI).

Sentinel Asia supported the smallest number of countries/territories compared to other initiatives, but at the same it involved more unique AUs than the Charter, having twice as many actual activations.

An interesting observation was made by the representatives of the ADRC regarding one of the regional issues related to the Sentinel Asia initiative. The worrying observation was related to the fact that most requests for activation were coming from space agencies (which are normally more focused on research) and not from national disaster management organizations (which are focused on practical applications and actually responsible for response activities). It was mentioned that in 2017, 30 requests out of 31 in total came from space agencies. Another relevant issue is related to the fact that in some countries in Asia, the relationships between space agencies and disaster management authorities could be rather complicated. Data and information provided through Sentinel Asia might not always be shared with all relevant organizations in the country.

6.2.4.3. Relation between organizations' activity and the time of their involvement

One more aspect that can be explored, is the potential relationship between the overall activity of an organization and the time when it was first involved in the mechanism - whether the AUs that were the earliest to join the initiatives would prove to be the most active as well. To do this, the year of the first activation request by an AU can be compared to the total number of all recorded activations requested by this organization.

The results for the SEM mechanisms are shown in Appendix 13. In all three cases, more than half of all involved organizations never exceeded five activations, the vast majority never exceeded ten. As was shown in Table 14, there are normally just a few organizations that stand out as the most active.

Data for both Copernicus EMS and Sentinel Asia support the hypothesis that the earliest organizations seem to be the most active as well. For Copernicus EMS all top five AUs initiated their first request back in 2012. In the case of Sentinel Asia, the top five organizations started in 2007 and 2008, the first two years of this initiative being active. At the same time, the situation for the Charter seems to be rather different. Few organizations that started in the very early years of this initiative turned out to be among the most active. At the same time, the top ten of most active AUs all got involved within the first decade after the establishment of the Charter, particularly UNITAR-UNOSAT which first requested an activation only in 2008, followed by UNOOSA (first activation in 2003) and USGS (first activation in 2005).

6.2.4.4. Most important links between countries and organizations

Another interesting aspect of activations, that can be assessed using the available datasets, is the importance of links between an AU and a specific country. These links are visualized in Figure 22, while their thickness represents the total number of activations that happen in this particular direction. It is worth noticing that for all three SEM mechanisms, a significant number of most important links represent "self-loops", which were already mentioned earlier (when the national AU is requesting an activation for its own country).

The list of the top ten most important links for three SEM mechanisms is provided in Appendix 14. Overall, the vast majority of these links are self-loops. For Charter, only three main links out of ten are not self-loops: SIFEM-DNPC (Argentina) - Chile (14 activations in total); ADRC - Philippines (13 activations); UNITAR-UNOSAT - Viet Nam (10 activations). There was only one similar case for Copernicus EMS: DG ECHO (EC Services) - Viet Nam (7 activations). Sentinel Asia also has only one such case with ICIMOD supporting Nepal (11 activations). However, it is worth noticing that ICIMOD, while being an intergovernmental organization, is physically located in Nepal. In addition, in the case of Sentinel Asia, the order of the top ten links is almost identical to the list of most active AUs. Overall, the reasons behind such prevalence of self-loops are rather clear. The national AU would primarily address the needs of its own country, before considering providing support to other states. The AUs that can be considered as active participants of the SEM mechanisms in general, would be active in their countries foremost.

6.2.4.5. "Diversity" of activations

Besides the assessment of the total number of activations, it is also possible to explore the "diversity" of the connections each node has, using the simple degree centrality. Particularly, it is possible to identify how many different organizations ever supported each particular country, as well as, the opposite - and how many different countries each AU has ever helped through requesting the activation.

In the case of the Charter, 42.7% of all countries ever received activations from only one specific AU. At the same time, 15 countries (or 10% of all covered territories) were ever supported by five or more different AUs. Most "diverse" countries include Iran, Indonesia, and Sri Lanka. It is interesting to notice that Indonesia is the only one that is also on the top based on the total number of activations. For Copernicus EMS the situation is quite different, with 81.1% of all supported countries receiving activations only from one particular AU. The highest number of different AUs to ever support one country is three, and only two counties are so "diverse" - the USA and Uganda (out of 106 unique territories covered by this mechanism). With regards to Sentinel Asia, only around 27.3% of all countries ever received activations from just one particular AU. And only eight countries (24.3%) - from five or more different AUs. Philippines, India, and Myanmar received the most "diverse" support throughout the years.

Moving on to the "diversity" of activities of the AUs, out of 72 organizations involved in Charter activations, only 23 (31.9%) ever assisted more than one country, and only ten supported five or more. The most diverse organizations follow the list of the most active AUs in terms of activation requests. For Copernicus EMS, out of 31 organizations in total, 13 (41.9%) assisted more than one country. Only four AU supported more than five different countries (DG ECHO, BBK, EEAS, and COGIC). It is important to notice that DG ECHO is the absolute leader in this list (supporting 65 various territories), while others did not exceed ten. In terms of diversity of support provided by AUs, for Sentinel Asia, only 11 AUs (14.5%) ever supported more than one specific country. Only two organizations from the list supported five and more different countries (ICIMOD and ADRC).

6.2.5. Bipartite network projection

6.2.5.1. Transformation of original networks

Since the developed networks of the activations of the Charter, Copernicus EMS, and Sentinel Asia were all bipartite in nature, it was possible to project them (using weighted projection). More information on this is presented in the corresponding section of the Methodology "4.3.2.1. Network analysis". This transformation of the networks highlighted different clusters of organizations or countries which are grouped together due to the similarities in the approaches they follow (in terms of requesting activations or receiving support).

The main parameters of the developed projected networks for all three mechanisms are presented in Table 15. It includes average values for the networks as a whole on their degree, edge density, and clustering coefficient.

Table 15. Main characteristics of the projected networks of the selected SEM mechanisms

		SEM mechanisms		
		Charter	**Copernicus EMS**	**Sentinel Asia**
Projected networks of organization	Number of nodes	72	31	76
	Number of edges	188	15	177
	Average degree	5.2222	0.9677	4.6579
	Average edge density	0.07355	0.03226	0.06211
	Average clustering coefficient	0.57522	0.06569	0.70515
Projected networks of countries	Number of nodes	150	106	33
	Number of edges	3903	2160	48
	Average degree	52.04	40.7547	2.9091
	Average edge density	0.34926	0.38814	0.09091
	Average clustering coefficient	0.79658	0.77671	0.55034

Note: values for the weighted and for the overlap weighted projected networks were the same.

Some significant differences between the analyzed mechanisms can be noticed just through these few values, some of the more obvious are related to the total number of edges (links) between the nodes and the average degree of the graphs. Mainly such differences can be explained by the different approaches followed by each initiative - the presence or absence of the clearly leading organizations in terms of activation requests, the overall number of supported countries, the level of diversity in provided support, the overall prevalence of self-loops, etc.

6.2.5.2. Networks of organizations

Starting with the projected networks of organizations, Copernicus EMS stands out as a rather interesting example. Its graph is quite sparse, compared to the other two mechanisms, with very few links between the involved organizations. Figure 23 presents the visualization of the overlap weighted projection of organizations for Copernicus EMS. Colors show different clusters identified based on the structure of the network, which were identified through modularity score calculated using the Louvain method. The thickness of the links expresses the overlap between the nodes (how similar they are in terms of activation patterns). The only connected component of this graph reminds an *egocentric network* (star-shaped structure), with the DG ECHO playing the main role.

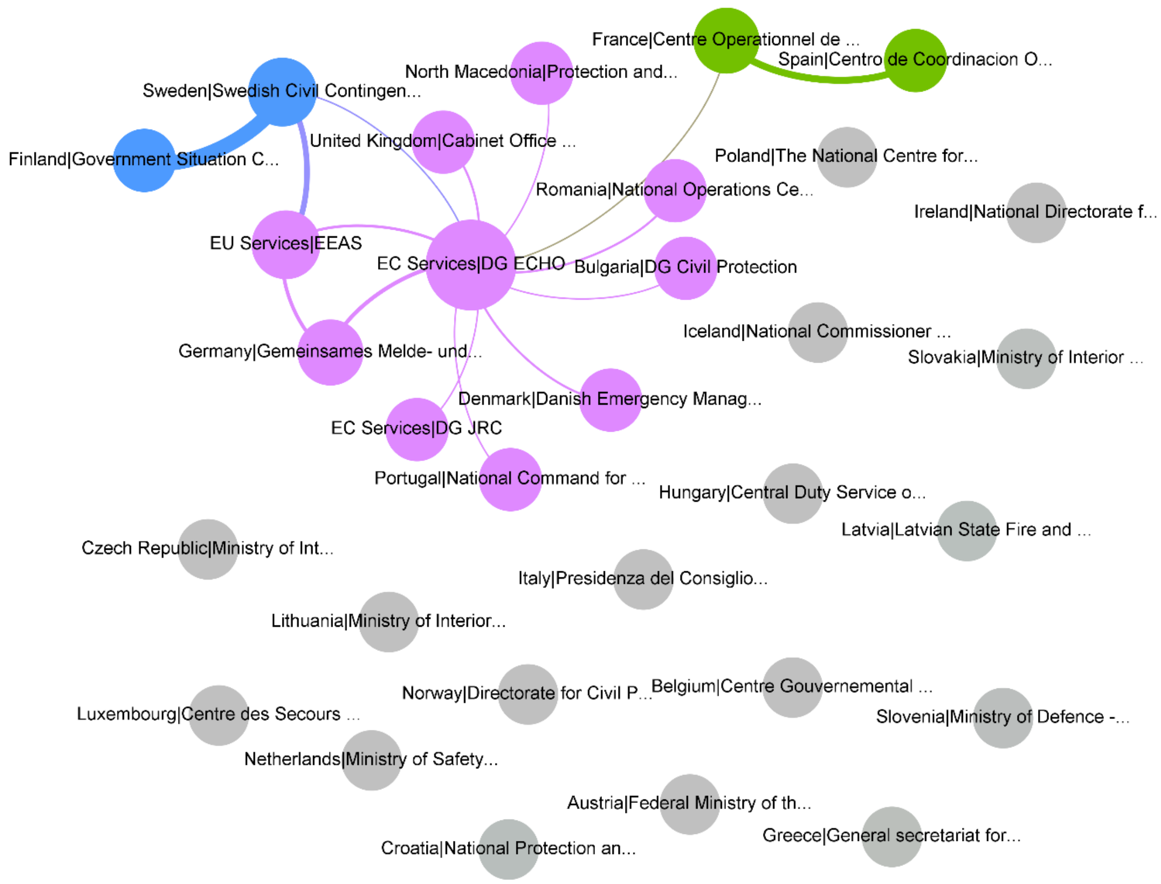

Figure 23. Modularity classes in the Copernicus EMS' overlap weighted projection of organizations

Another case of the overlap weighted projection of organizations for Sentinel Asia is presented in Figure 24. This network has a rather different structure, compared to Copernicus EMS. First of all, it has twice as many organizations, but also much more connections between the nodes. While there are still some rather prominent and central actors like ICIMOD, it is much more common for organizations to group into more isolated clusters.

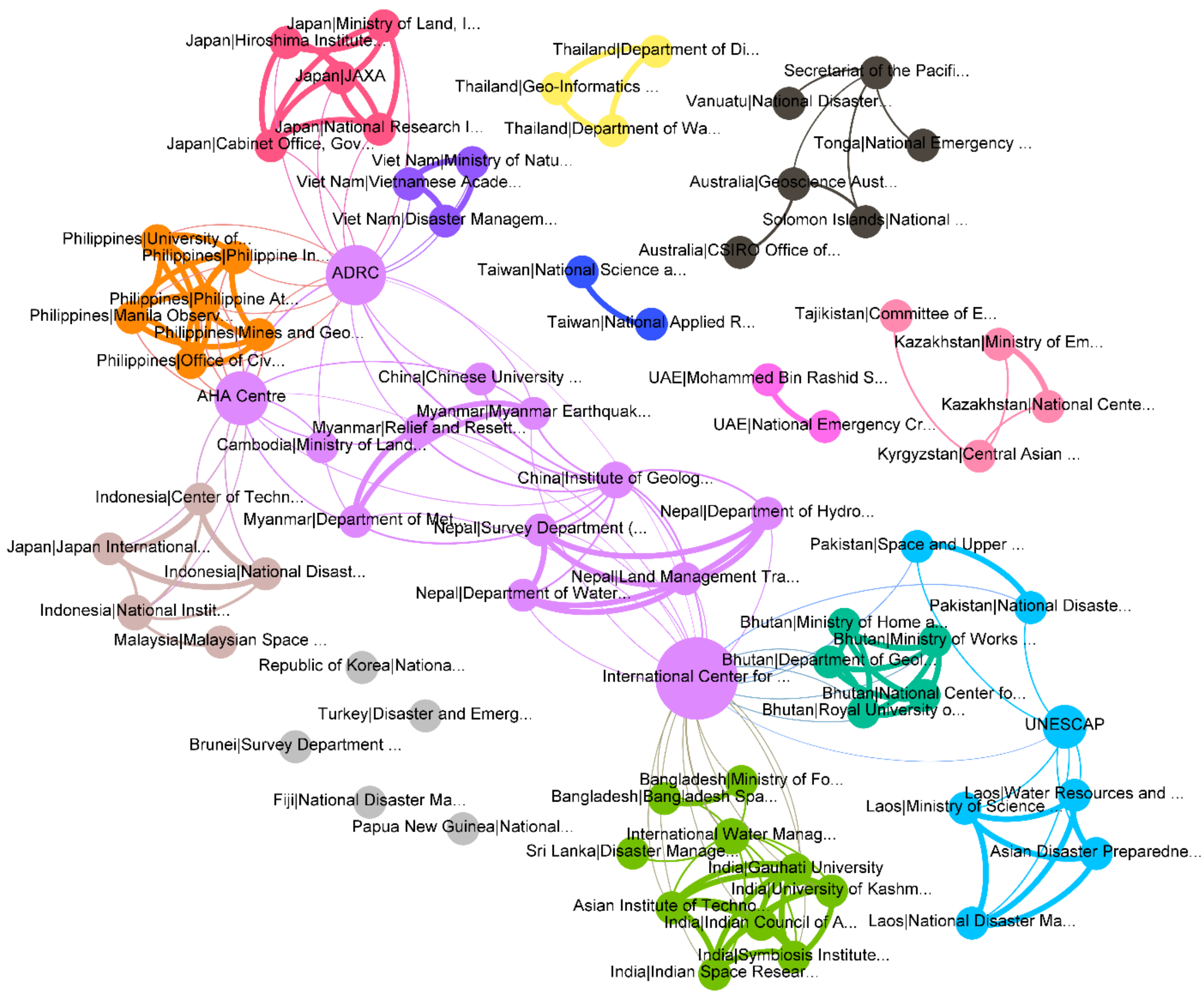

Figure 24. Modularity classes in the Sentinel Asia's overlap weighted projection of organizations

Networks of all three analyzed SEM mechanisms also have some organizations with no links to other nodes, meaning that they do not share any neighbors (countries) with other organizations (these are marked in grey color). In some cases. organizations form their own closed clusters, disconnected from the main system - these are mainly defined by the affiliation of these organizations with the same country, or, more rarely, with the same geographic subregions. The main networks of organizations for the Charter and Sentinel Asia are rather similar in composition and structure, with various clusters mainly defined by the common home country (in the case of Sentinel Asia) or geographic regions or subregions (for Charter). The overlap weighted projection of organizations for Charter can be found in Appendix 15.

All three networks were characterized by the presence of a few key nodes that in a way act as bridges connecting different clusters through weak ties (thinner links). These elements could be identified by the high betweenness centrality. For Charter, such organizations are: UNOOSA, UNITAR-UNOSAT, SIFEM-DNPC (Argentina), DGSCGC (France), and USGS (USA). For Sentinel Asia, these are: ICIMOD, ADRC, and the ASEAN Coordinating Centre for Humanitarian Assistance on disaster management (AHA Centre). For Copernicus EMS - DG ECHO.

The overlap weighted projections have exactly the same links between organizations as the simple weighted projections. However, they were used for visualizations since they with more certainty allow identifying similarities in regional preferences or organizations. Particularly, such an approach rather prominently illustrated that organizations from the same countries tend to have very strong ties (shown through thick links within the interconnected clusters). This shows that organizations from the same regions tend, in a way, to work together in their activations, covering the same countries. However, due to simplification caused by the projection process, from such graphs it is not possible to see which countries are supported by which organizations specifically.

6.2.5.3. Networks of countries

Moving on to the projected networks of countries, Sentinel Asia's network has to be highlighted as having the simplest structure (Figure 25). It has a drastically different composition, compared to the other two mechanisms, which cannot be explained exclusively by the relatively small number of supported countries. While in the networks of the other two mechanisms there are on average more than 20 links per node, for Sentinel Asia this value is less than 1.5. This network is quite sparse, with few clearly defined clusters and a number of isolated nodes. These clusters represent countries that share at least one common AU, potentially indicating a predisposition among some AUs regarding which countries they assist.

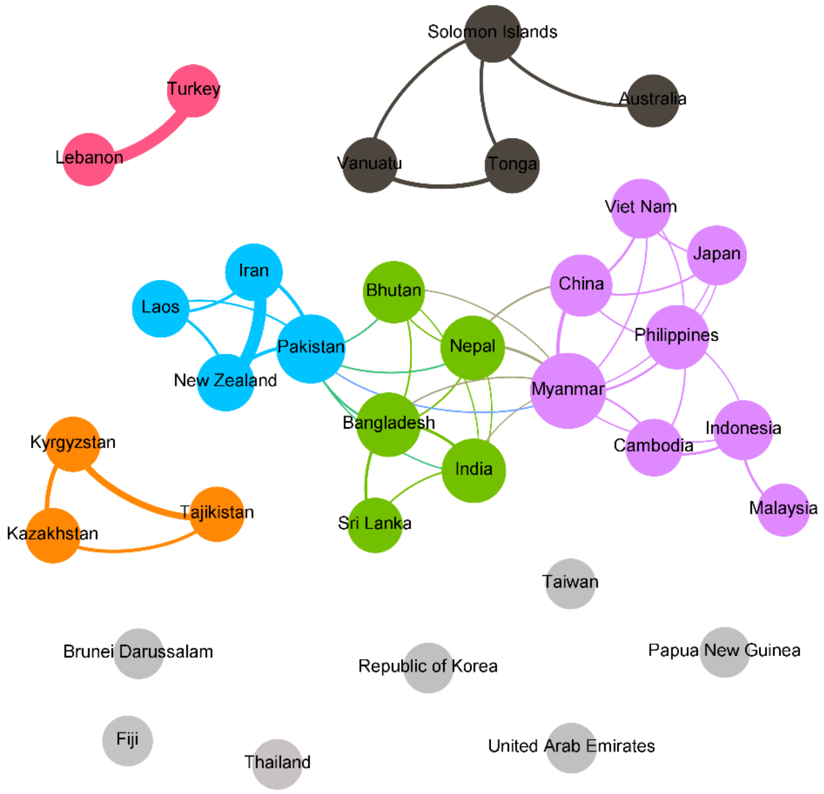

Figure 25. Modularity classes in the Sentinel Asia's overlap weighted projection of countries

Such structure of the network can be explained by the high level of "specialization" of the involved organization - most of them provide support to only one specific country (their home country) or within their region. In the Asia-Pacific, where most of the states have their own AU registered within Sentinel Asia, there is not much need for indirect activations on behalf of someone else.

The projected networks of countries for Charter and Copernicus EMS are much more diverse and similar to each other. In both cases, graphs are rather dense - the number of links is much closer to the maximum number of links that is possible in the network. But still, they also include more or less distinguishable clusters and a number of disconnected nodes.

Overlap weighted projection of countries for Copernicus EMS is presented in Figure 26. This network has one distinctive central element - an extremely interconnected cluster, which formation is dictated by the leading role of the DG ECHO, the organization responsible for a major part of all activations of this mechanism.

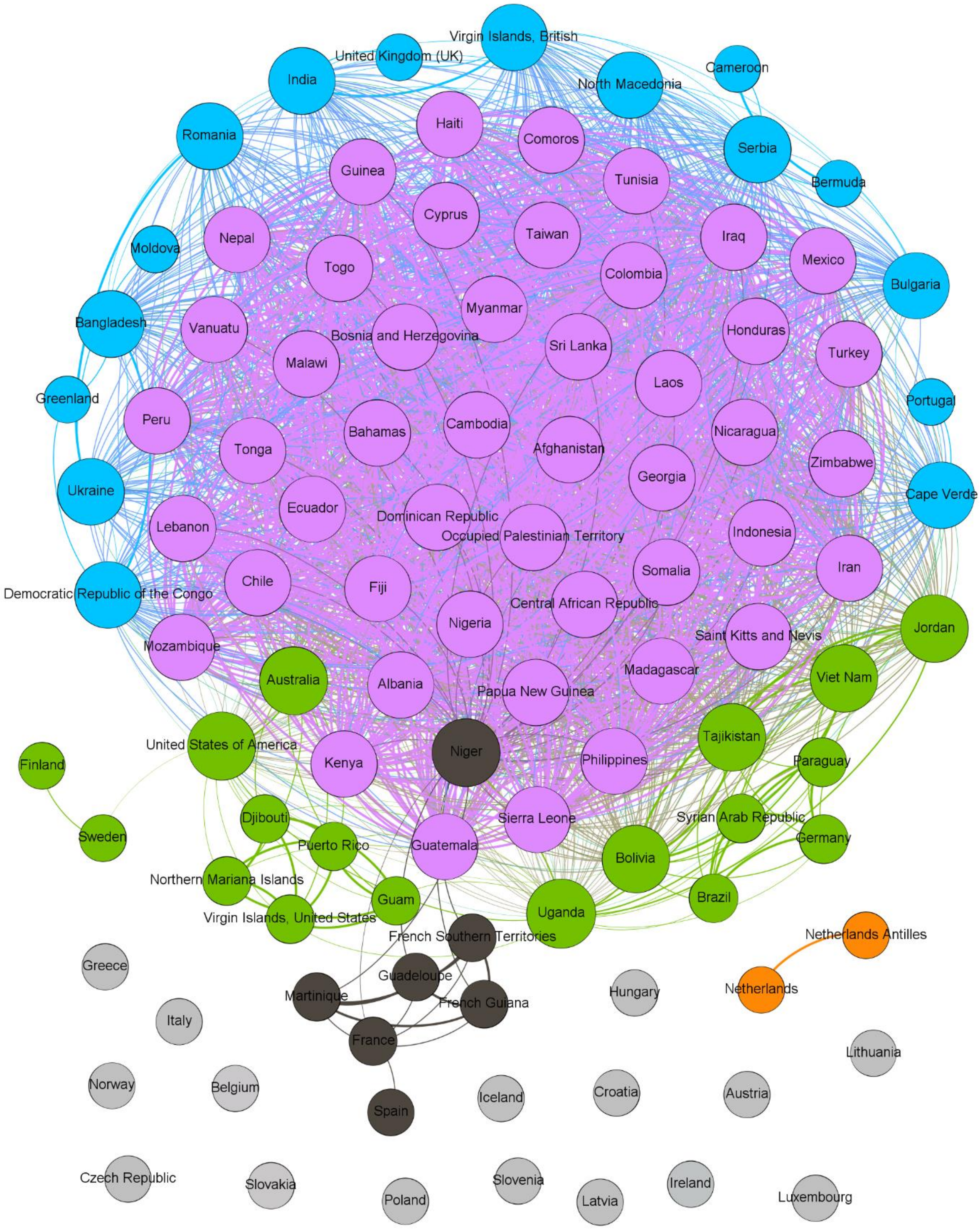

Figure 26. Modularity classes in the Copernicus EMS's overlap weighted projection of countries

The network of the Charter (Appendix 16), on the other hand, while still being very dense, has a number of more prominent clusters. Interestingly, apart from a quite clearly separated group of European countries, it is much harder to distinguish any groups defined by any particular geographic region. Considering the heterogeneity of most of the identified clusters, for both Charter and Copernicus EMS the formation of these groups cannot always be explained just by regional affiliation. Overall, it seems that for the projected networks of countries, regional preferences are not playing as important role as it was for the projected network of organizations.

6.3. Challenges of the satellite-based emergency mapping field

While three selected SEM mechanisms were discussed and analyzed in a quite detailed way, they cannot fully demonstrate the level of complexity of the overall global system, which consists of many more similar mechanisms, some of which were mentioned earlier in section "5.3. Satellite-based emergency mechanisms". And this is in addition to other involved international and regional organizations, which complicate the situation even more as they could act on behalf of other entities. Such a large network with a huge number of participants inevitably faces communication issues, one example of which was illustrated through the double activations happening instead of the formal escalation process of Sentinel Asia activation to Charter. During emergencies, when every hour matters, it is especially important to avoid such complications and confusion at all costs. This might lead to a question of whether countries already covered by Sentinel Asia should actually aim at joining the Charter as well, or not. In the case of countries from other regions without similar regional SEM mechanisms, direct access to initiative seems more clearly advisable.

According to the study by Voigt *et al.* (2016), most SEM mechanisms, apart from Copernicus EMS, already reached their maximum capacity of activations per year. This issue should be taken into account, considering the changing climate and growing risks of natural disasters, their frequency, severity, and variability (Banholzer *et al.* 2014). At the same time, even in the current conditions, existing SEM mechanisms can get overwhelmed if there are too many disasters happening at the same time (this, for instance, was the case during a busy couple of weeks in September 2017). This problem might be addressed through efficient coordination among different mechanisms, making sure to avoid the situation when all initiatives focus on the same large event and overlook other disasters that might be happening at the same time (maybe less severe, but still significant). Cooperation mechanisms among SEM initiatives and programs must be strengthened, particularly through the development of global and regional networks and specialized hubs (Voigt *et al.* 2016).

The disaster management field already experienced an important paradigm shift some time ago - from addressing the consequences of emergencies (disaster management) to focusing on mitigation of and adaptation to potential risks (disaster risk reduction). However, the field of satellite-based emergency mapping is still quite reactive, mainly focusing on post-disaster observations (emergency response). Even though most initiatives do mention the possibility of pre-disaster assessments, in reality, it almost never happens (the only significant exception being the special European Copernicus "Risk and Recovery Mapping" service). So far slow-onset disasters, like droughts and epidemics, are also being mainly disregarded by the existing SEM mechanisms.

6.4. Summary

The analysis of activations of the three selected SEM mechanisms (Charter, Copernicus EMS, and Sentinel Asia) revealed both clear differences as well as similarities in their regional coverage, types of disasters addressed, structures of the networks, and other characteristics.

While the number of activations requested by Copernicus EMS continues to grow over the last years, in the current circumstances, Charter and, particularly, Sentinel Asia, seem to be close to their capacity. Limited data on the delay in delivering satellite imagery and products still allowed to notice that on average this delay is becoming shorter. This pattern could be partially explained by a larger number of available satellites, as well as by the advancements in automatization of some data processing steps.

Differences in regional patterns of activations and locations of AUs were explored. These were largely determined by the focus of a particular mechanism or its regulations that define who could be officially registered as an AU and receive direct access to the mechanisms.

In terms of types of disasters covered by activations, Copernicus EMS can be mentioned as having the clearest classification system, while both Charter and Sentinel Asia sometimes use "combined" disaster types (like "Storm and flood"). For all three mechanisms, floods were the most common type of disaster, followed by storms (for Charter and Sentinel Asia) and wildfires (for Copernicus EMS). At the same time, slow-onset disasters, like droughts and epidemics, were rarely covered by SEM mechanisms.

Developed networks of activations illustrated the complexity and interconnectedness of these systems, different levels of diversity (particularly high for Charter and Sentinel Asia), as well as an example of a more centralized structure, illustrated by Copernicus EMS. Representation of the mechanisms activations in a form of a network allowed to explore the characteristics of the "links" between AUs and countries and, correspondingly, the diversity of activations (for instance, how "specialized" is a particular organization in its support). Bipartite network projection helped highlight some of such specialization through the exploration of networks for countries and AUs separately.

It is important to consider both the opportunities that SEM mechanisms provide, as well as their potential limitations, and find ways to address them – by either expanding the network of involved organizations and countries, adding new data providers, developing capacities and methodologies used to process the data, or improving cooperation. While all three explored mechanisms mention the goal to provide support at different stages of the disaster management cycle, the main focus remains on disaster response. This paradigm has to be somehow shifted, and there are already some examples of this (the Copernicus "Risk and Recovery Mapping" service).

7. Barriers in the application of space-based technologies

As was discussed earlier, UN-SPIDER activities and Technical Advisory Missions (TAMs) particularly served as a rich source of information on the situation with the application of geospatial technologies in DRR. Analysis of the available reports helped identify main areas of concern and uncover specific challenges, as well as potential solutions. The first part of this chapter explores the main themes discussed in TAM reports, as well as the main identified issues. The second part analyzes the results of the conducted expert survey, particularly the ranking of the main challenges in the application of technologies in DRR.

7.1. UN-SPIDER's TAM reports

The overview and analysis presented in the following sections focus specifically on the countries where TAMs were conducted. Particularly, on the corresponding reports that are prepared by the expert team after each mission. These reports normally are not published and not accessible to the public in full - most often only general conclusions are provided. However, these reports were made available for analysis through the internship at UNOOSA, and permission to use them was granted[22]. Due to the sensitivity of this information, it was agreed that the results of the analysis would be provided in a generalized form, without references to particular countries.

TAM reports normally include a detailed overview of the situation in a country, but the final parts of the reports on recommendations and proposed follow-up actions were the most important for the present study. This section in a condensed way discusses and lists the main issues that should be addressed by the government of a country, as well as provide recommendations and suggestions for improvement.

[22] Disclaimer: "The data is obtained from UN-SPIDER TAMs with the consent of the United Nations Office for Outer Space Affairs, who is not responsible for any interpretation and representation of this data in the present research."

Analysis conducted within the present research relied on the information from the missions that took place within the 2008-2017 period. This is mainly related to the availability of these reports, provided for the analysis during the internship at UNOOSA, which took place at the end of 2017. Overall, 33 TAMs took place by that time. Since then, only three additional TAMs were conducted. Out of the 33 TAMs, reports were available for 32 of them (the mission in Tonga took place in 2012, but the report was only 2 pages long with not many details on the situation). In addition, a rather detailed and comprehensive report from an Expert Mission to Haiti was available as well - in the end, it was also considered in the analysis. Overall, the number of reports per region covered was the following:

- Africa – 13 reports;
- Asia-Pacific – 13 reports;
- Latin America and the Caribbean – 7 reports.

7.1.1. Thematic network analysis

While UN-SPIDER has been providing technical advisory support to developing countries around the world for more than ten years, a comprehensive analysis of findings and conclusions collected through advisory missions was never conducted. UN-SPIDER had a practice of dividing all recommendations, summarized in each mission's report, into seven general groups:

- Policy and Coordination;
- Awareness Raising;
- Capacity Building and Institutional Strengthening;
- Accessing and Processing of Data;
- Information Flow and Management;
- Strengthening International Cooperation;
- Local/Regional Recommendations.

The last group on "Local/Regional Recommendations" is the most extensive one and basically includes any recommendations and suggestions which were difficult to place into any other more specific group listed earlier. While not only this division by quite broad topics does not seem like the best option for such valuable and interesting information, it also can result in specific elements and ideas being overlooked or not stressed enough (for instance needs in information and data sharing policies or in further development of communication infrastructure and Global Navigation Technology). The way these recommendations are formulated can often cover more than one issue or topic, and by restricting each recommendation to fall into only one group we might limit the variety of elements and aspects that could be implied.

Due to these issues, groups of recommendations provided by UNOOSA were not used as a basis for the conducted analysis. A potential alternative categorization of the TAM recommendations had to be developed and proposed using the applied thematic analysis. This approach aimed at extracting as much information as possible from this pool of multidimensional data collected through UN-SPIDER's persistent work, while presenting the result in a generalized manner. Main identified topics and issues are discussed, as well as potential regional predispositions are analyzed. Such analysis helped explore different themes raised in the recommendations and group them based on the identified issues related to the application of GeoICTs for DRR. The final list is presented in Table 16, which is discussed later in this chapter.

7.1.1.1. Identified themes

Through examining TAMs' reports, around 440 individual recommendations proposed by the expert teams were identified. These recommendations were then put together and analyzed using the inductive approach to qualitative data analysis, particularly thematic network analysis (Attride-Stirling 2001). This approach not only allows to identify specific concepts expressed in the data but also helps structure the findings and depict the main overarching themes. A qualitative data analysis and research software ATLAS.ti was used to conduct this analysis, particularly code the data and develop a network of identified themes and concepts (Rambaree 2014, 2018).

After the initial stage of coding, these codes were grouped under particular themes. At the next stage, a thematic network was constructed, by arranging the themes and linking the elements with each other (using the network building function of ATLAS.ti) (Attride-Stirling 2001). This process facilitated systematization and exploration of the identified topics of concern. Few less tangible and significant themes (rarely mentioned in the reports) could not be easily included in the network. However, they still are covered in the next sections of the chapter, where appropriate. Due to the sensitivity of the information and the fact that TAM reports are normally shared only with the government of the visited country, it was not possible to include in this chapter any exact citations or explicit examples from specific countries. However, regional and other specifics, if identified, were indicated.

Before starting the discussion on the new categorization of the recommendations and findings related to each proposed group individually, it is important to present an overview of the whole system of topics raised in TAMs' reports. An overall result of the thematic network analysis in the generalized form is provided in Figure 27. This network includes only the main themes identified through the analysis. A more complex and detailed thematic network, which covers basic themes of the lower order, is presented in Appendix 17. Many concepts, while belonging to different themes, still are closely interconnected (which is more visible in the full network in Appendix 17). The generalized version in Figure 27 indicates only main thematic connections, which, however, facilitates the analysis. Overall, this network allows exploring the system or conceptual framework formed around the findings of the advisory missions.

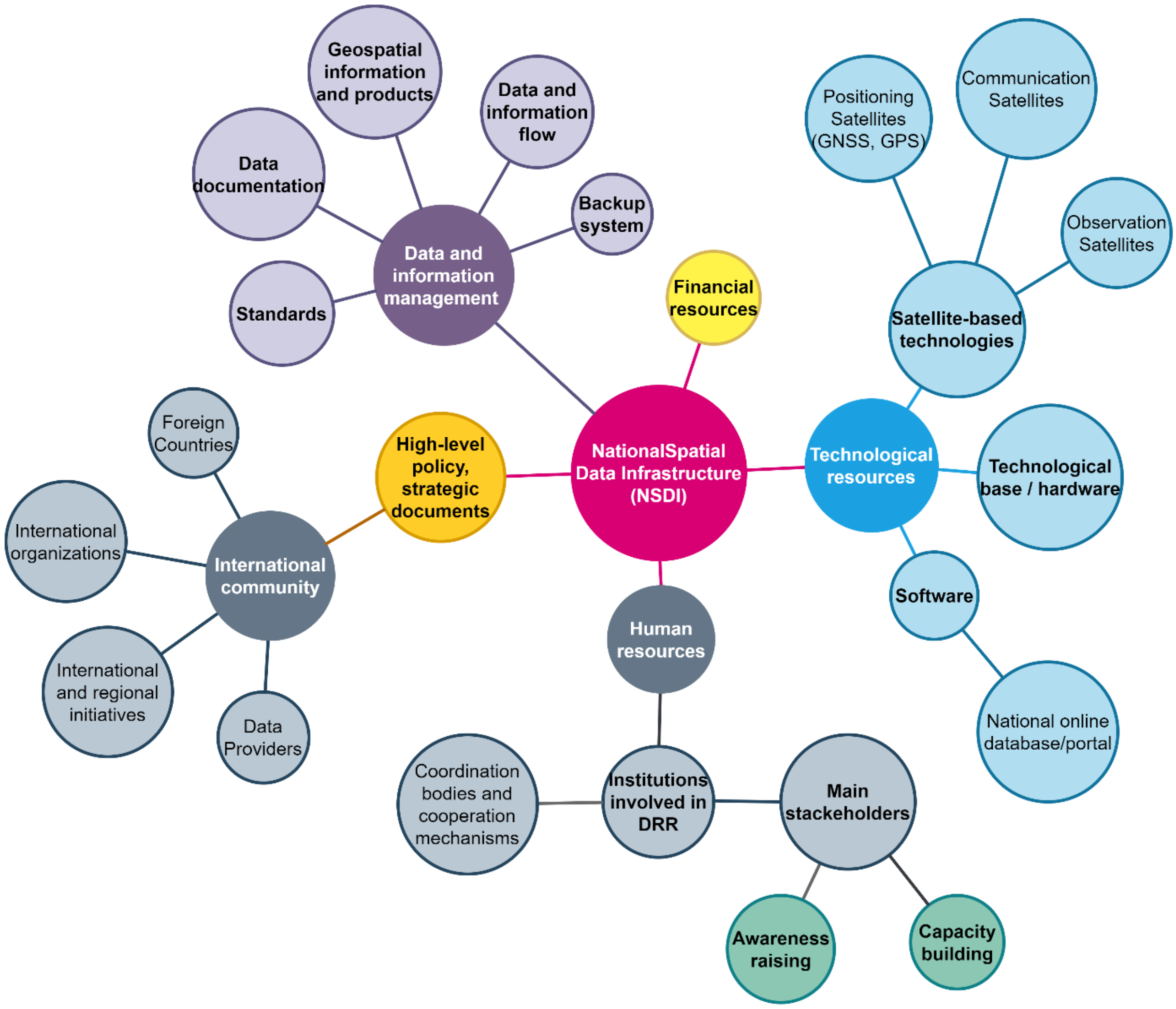

Figure 27. Basic thematic network of the main topics identified through the analysis of TAM reports

Note: colors were used just for visualization of hierarchy of different topics and sub-topics.

Through the conducted analysis it became clear that the identified themes while being introduced in relation to the countries' disaster management system, can be presented as the elements of the National Spatial Data Infrastructure (NSDI).

7.1.1.2. National Spatial Data Infrastructure (NSDI) as the central theme

A Spatial Data Infrastructure is a framework that focuses on the facilitation and coordination of the access, exchange, and sharing of spatial data between stakeholders. It incorporates the spatial data itself, as well as metadata, users, technologies, policies, standards, and any other relevant resources (Crompvoets *et al.* 2004; Yalcin 2014).

Spatial Data Infrastructures can exist at various levels, including local, regional, national, and global (Laura *et al.* 2017). Many countries are developing or willing to develop such infrastructures on a national level - NSDIs. Such frameworks overall aim at improving access, accuracy, exchange, and use of geospatial data, while at the same time reducing excess and duplication of efforts in data creation and maintenance, and, correspondingly, the related costs (National Research Council 2001). The NSDIs should not only involve governmental institutions but all relevant stakeholders, including private and non-profit sectors, as well as academia. Apart from the mentioned improvements in the access and share of geospatial data, Spatial Data Infrastructures also bring various other benefits, including economic (an expanding market for geographic information products and services, job creation, operating costs for public and private sector), social (more efficient and transparent government, time saved in searching for data, more effective emergency planning and response), and environmental (more effective monitoring and management of natural resources) (Yalcin 2014).

Through the development of the thematic network (Figure 27), it became clear that the NSDI seems to play the central role as a *global theme*, that brings together and summarizes the main concepts expressed in the TAM reports (Attride-Stirling 2001). Even though NSDI was not always mentioned in the recommendations directly, other aspects expressed in the reports represented integral parts of the NSDI.

Depending on the regulations, or national or regional circumstances, the main elements of the NSDI can be defined slightly differently. Particularly, the number and type of the core components of the NSDI can vary, sometimes directly including “people” or financial resources as important elements, sometimes not (Jebur *et al.* 2013; Merodio Gómez *et al.* 2019; Rajabifard *et al.* 2002; Snoeren *et al.* 2007). In the analysis, this flexibility in the definitions and main factors of the Spatial Data Infrastructure readiness index were taken into account (Delgado *et al.* 2005). In the end, both human and financial resources were reflected as important elements of the thematic network. This was done particularly since these specific components, as well as various related issues, were raised quite often in the TAM reports.

Overall, the following main elements (or *organizing themes*) of the system were identified:

- data and information management;
- high-level policy and strategic documents;
- technological resources;
- human resources;
- financial resources.

The international community as an important theme also remained in the generalized network as a major component that is related to many other topics (particularly, affecting national policies and strategies, providing financial resources as donors, or sharing data).

Overall, the thematic network incorporates all core components of a typical NSDI (keeping in mind it was developed based not on a specific report, but a collection of all available documents). Some of the elements, normally regarded as main components, like technical standards or fundamental datasets, are represented as themes of a lower order (*basic themes*). Considering the specificity of such elements, as well as their inherent relationships to the themes of a higher order (data and information management, for instance), such a layout seems to be appropriate.

At the same time, it is possible to distinguish some of the potential gaps in the developed network (missing elements). These could be some components that typically are included in an NSDI but were not mentioned or discussed enough in the TAM reports. Two such cases were identified:

- The most prominent theme that was basically missing in the reviewed reports was the involvement of private companies. Public-private partnerships, which can play a very important role in a well-functioning NSDI, were mentioned only in one report (Ali 2008; Jebur *et al.* 2013; Rajabifard *et al.* 2006).

- The involvement of local communities, at least as potential users of the NSDI, was also mentioned very rarely in the reports.

On one hand, this composition of a thematic network, which is missing some seemingly important elements, shows that these topics probably were not considered as relevant, since they were not mentioned in the recommendations. At the same time, these gaps might be highlighting the blind spots of the missions, in case the representatives of the private sector or local communities did not participate in the discussions or didn't present their issues and concerns. It is important to mention, that representatives of the private sector are normally participating in all TAMs conducted by the UN-SPIDER.

7.1.2. Identified issues related to the application of GeoICTs for DRR

Apart from using thematic network analysis of the TAM reports to identify overarching themes and explore the system of main concepts, a more traditional applied thematic analysis was used specifically to study and categorize the main issues and problems that were expressed in the reports (Guest *et al.* 2011). Such an approach allowed to introduce both the overall main framework around which the discussions and recommendations were formulated (NSDI), as well as extract specific concerns raised in the countries during TAMs.

39 basic codes (themes) identified through the coding process were evaluated and reassessed at a later stage of the analysis to form more clearly defined groups, as well as to avoid codes that were not supported by enough evidence from the reports. Codes that were grounded in less than 15 quotations (separate recommendations) were merged or with more populated codes (based on the thematic scope). Sometimes, a specific topic could have been mentioned more than once in a report (in multiple recommendations). Because of that, sometimes the total number of countries where a specific issue was raised ended up being smaller than the total number of

quotations supporting this code (since multiple similar recommendations could be coming from the same country). At the same time, topics pushed by very few states were also merged with more recognized issues. By the end of this multistep review, 20 clear topics were identified and thematically divided into six groups. The following sections of the chapter present the main topics one by one. The categories of the indicated issues in the application of geospatial technologies in support of disaster risk reduction are presented in Table 16, which also indicates the relative relevance of each topic, based on the number of countries that mentioned it.

Table 16. List of identified issues and the number of TAM reports (countries) that mentioned them in the recommendations

Identified issues	Total number of countries
Group: Promotion of geospatial technologies	
• Review of disaster management policy	23
• Promoting the use of geospatial information and technologies	15
Group: Awareness raising and capacity building	
• Awareness raising	22
• Trainings, exercises, and mock drills	29
• Strengthening institutional capacities	25
Group: Coordination and cooperation	
• International and regional cooperation mechanisms	26
• Clarification of roles and responsibilities, identification of focal points	16
• Specialized GIS unit	14
• National coordination and cooperation mechanisms	30
Group: Availability and use of resources	
• Availability and access to geospatial data and information	22
• Efficient use of available resources (human, financial, data, etc.)	27
• Open data policy, resource sharing	21
Group: Data and Information Management	
• National Spatial Data Infrastructure (NSDI)	19
• Data and Information Flow	22
• Guidelines, Standard Operation Procedures (SOPs), and Data Standards	20
• Databases and metadata	24
Group: New technologies, tools, maps	
• GIS tools, imagery, equipment, environmental monitoring	20
• Risk assessment / mapping	15
• Early Warning Systems (EWS)	11
• Emergency Response	19

Based only on the number of countries, the most and least relevant issues seem to be:

Most mentioned:

- National coordination and cooperation mechanisms (30 countries mentioned);
- Trainings, exercises, and mock drills (29);
- Efficient use of available resources (human, financial, data, etc.) (27);
- International and regional cooperation mechanisms (26);
- Strengthening institutional capacities (25).

Least mentioned:

- Early Warning Systems (EWS) (11);
- Specialized GIS unit (14);
- Promoting use of geospatial information and technologies (15);
- Risk assessment / mapping (15);
- Clarification of roles and responsibilities, identification of focal points (16).

The conducted analysis also allows presenting the results in a more quantitative way, as an attempt to explore differences in the prevalence of specific issues and concerns, expressed by countries from various groups (for instance, based on the geographic region, access to the sea, income and development levels). This kind of analysis was providing an assessment based specifically on the total number of countries, not the number of quotations, since the same country could have mentioned each topic in multiple recommendations.

At the same time, it is important to take into account various limitations, mainly related to the nature of the available data (TAM reports). The analysis was based on a limited number of reports from the missions that took place within more than ten years. While TAMs visited countries from various regions and income levels, they cannot serve as a necessarily representative sample. In addition, each mission engaged a different team of experts, each potentially having their own predispositions towards some topics or issues, which potentially also had some effect on the findings of the missions and final reports. However, knowing all these limitations and keeping in mind that the current analysis is based on the reports from around 90% of all conducted TAMs in general, it is still worth exploring the findings of these missions.

7.1.2.1. Analyzing by geographic regions

Geographic regions for this assessment were based on the United Nations Standard country or area codes for statistical use (M49) (UNSD 2021). As mentioned earlier, out of all countries which were assessed, 13 are situated in Africa, 13 in the Asia-Pacific region, and 7 in Latin America and the Caribbean. Figure 28 represents the occurrence of identified topics in a form of a stacked bar chart. The horizontal axis shows the total number of reports that mentioned a particular issue, as indicated in Table 16. Colors show different geographic regions (in the case of the following charts in this section - other types of groupings). Percentage (%) within the colored bars shows the proportion of countries from a specific region that in their reports mentioned a particular issue (for example, 25% for a region with 12 states in total means that 3 countries had mentioned this issue). The same approach in terms of shares (%) is used in the similar charts presented in this section.

Some topics were mentioned at more or less the same frequency across all three regions:

- National coordination and cooperation mechanisms (92-86% of countries within each region);
- Availability and access to geospatial data and information (62-71%);
- Databases and metadata (69-77%);
- GIS tools, imagery, equipment, environmental monitoring (57-62%);
- Risk assessment / mapping (43-46%).

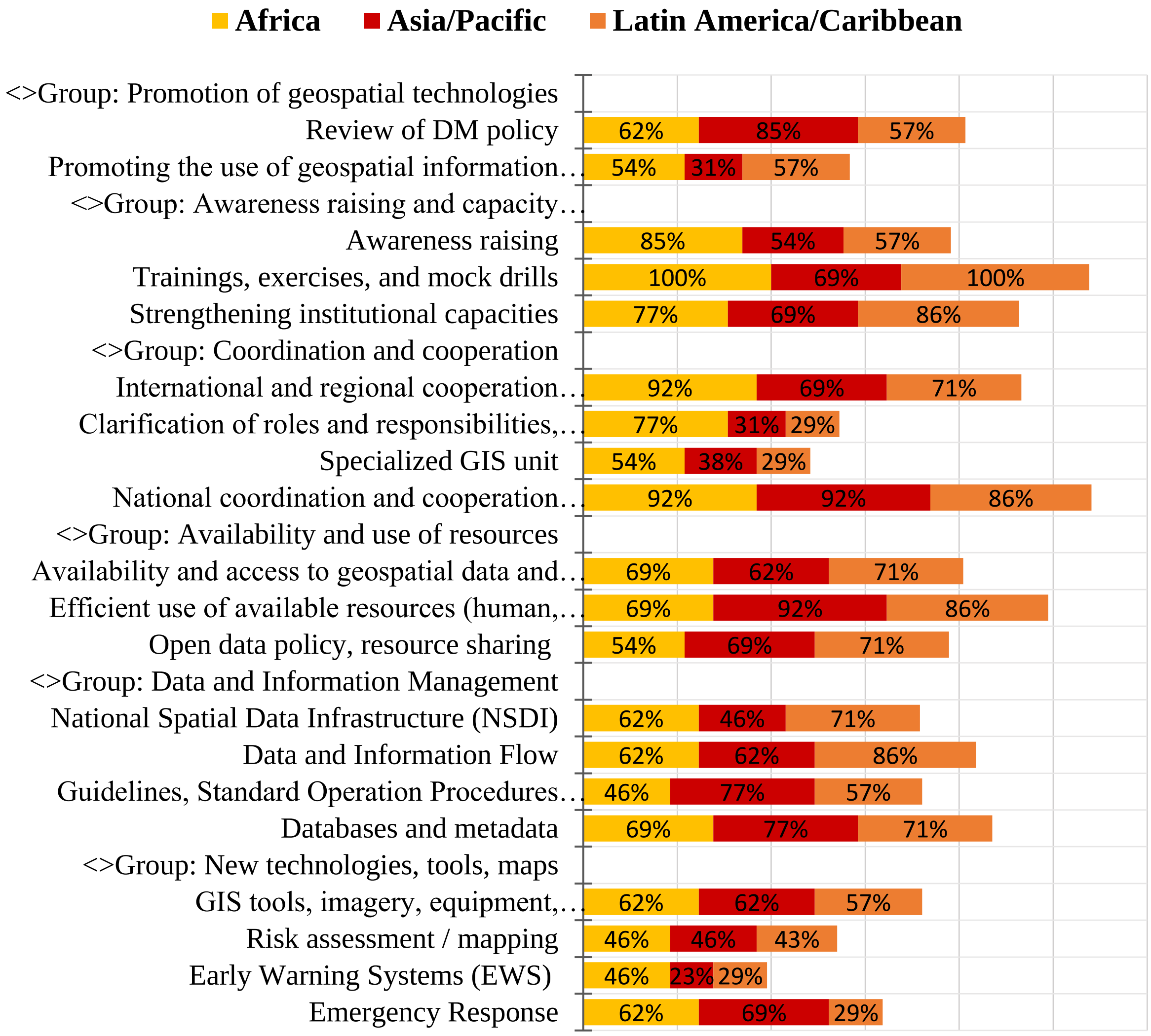

Figure 28. Issues by geographic regions

Note: numbers (%) within the colored bars show the proportion of countries from specific region which in their reports mentioned a particular issue.

At the same time, some other issues seem to be noticeably more relevant to some regions and much less - to others. The list of identified differences is presented in Table 17.

Table 17. Identified differences based on geographic regions

	Africa	Asia-Pacific	Latin America and the Caribbean
More concerned about	- Awareness raising - International and regional cooperation mechanisms - Clarification of roles and responsibilities, identification of focal point - Specialized GIS unit - Early Warning Systems	- Review of DM policy - Guidelines, Standard Operation Procedures (SOPs), and Data Standards	- Data and Information Flow

	Africa	Asia-Pacific	Latin America and the Caribbean
Less concerned about	- Efficient use of available resources - Open data policy, resource sharing	- Promoting the use of geospatial information and technologies - Training, exercises, and mock drills - National Spatial Data Infrastructure	- Emergency Response

7.1.2.2. Analyzing by geographic location

The next aspect that can be explored is based on countries' relative location in terms of access to the sea. Different categories can be defined using the United Nations lists of LLDC and SIDS. The developing countries from these lists tend to experience similar challenges within the corresponding group (Chowdhury and Erdenebileg 2006; Faye *et al.* 2004; Gheuens *et al.* 2019; Shultz *et al.* 2016). Thus, states covered by this analysis can be divided into the following groups:

- Landlocked Developing Countries (LLDC) – 7 countries in total;
- Small Island Developing States (SIDS) – 8;
- all other countries – 18.

Figure 29 visualizes this data in a similar way to Figure 28, showing color groups based on access to the sea and the share of countries within these groups that mentioned a particular issue.

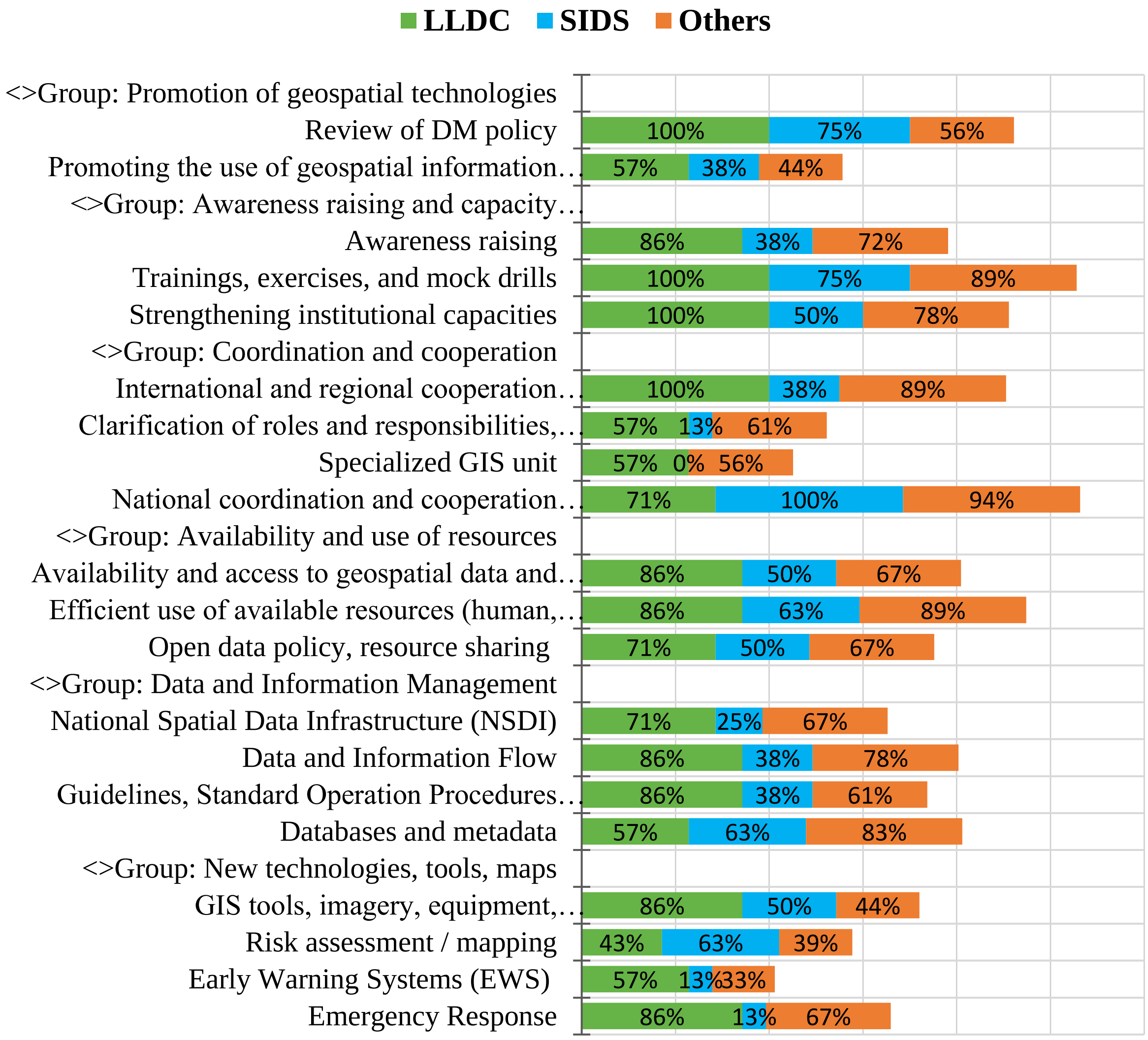

Figure 29. Issues by access to the sea

Note: numbers (%) within the colored bars show the proportion of countries from specific group which in their reports mentioned a particular issue.

Compared to the division by geographic regions, variability in the result for this kind of division seem to be much more significant. Still, some rather clear contrasts between different groups can be noticed - they are listed in Table 18.

Table 18. Identified differences based on access to the sea

	LLDC	SIDS	Others
More concerned about	- Review of DM policy - Strengthening institutional capacities - Guidelines, Standard Operation Procedures (SOPs), and Data Standards - GIS tools, imagery, equipment, environmental monitoring - Early Warning Systems	- Risk assessment / mapping	- Databases and metadata
Less concerned about	- National coordination and cooperation mechanisms	- Awareness raising - Strengthening institutional capacities - International and regional cooperation mechanisms - Clarification of roles and responsibilities, identification of focal points - Specialized GIS unit - Efficient use of available resources - National Spatial Data Infrastructure - Data and Information Flow - Guidelines, Standard Operation Procedures (SOPs), and Data Standards - Early Warning Systems - Emergency Response	- Review of DM policy

A particularly long list of topics that seem less relevant to SIDS compared to other groups can be noticed. However, such peculiarity might be partially explained by the fact that reports from the mission to SIDS were generally providing fewer recommendations (58 recommendations from eight SIDS altogether, compared to 133 recommendations from seven LLDCs).

7.1.2.3. Analyzing by income level

The income level of the countries was identified based on the World Bank's classification of the world's economies. Income groups are defined by the gross national income (GNI) per capita, while the exact thresholds for each category can vary from year to year (World Bank 2021a). For this analysis, the historical classification of the countries was taken into account, and not the present-day situation. This was done due to the fact that since the time when TAMs were conducted, some countries had moved to another income group (such cases were indicated in Table 8). Overall, the countries were divided into the following groups:

- Low-income – 6 countries in total;
- Lower middle-income – 21;
- Upper middle-income – 6.

Figure 30 illustrates the division by income level.

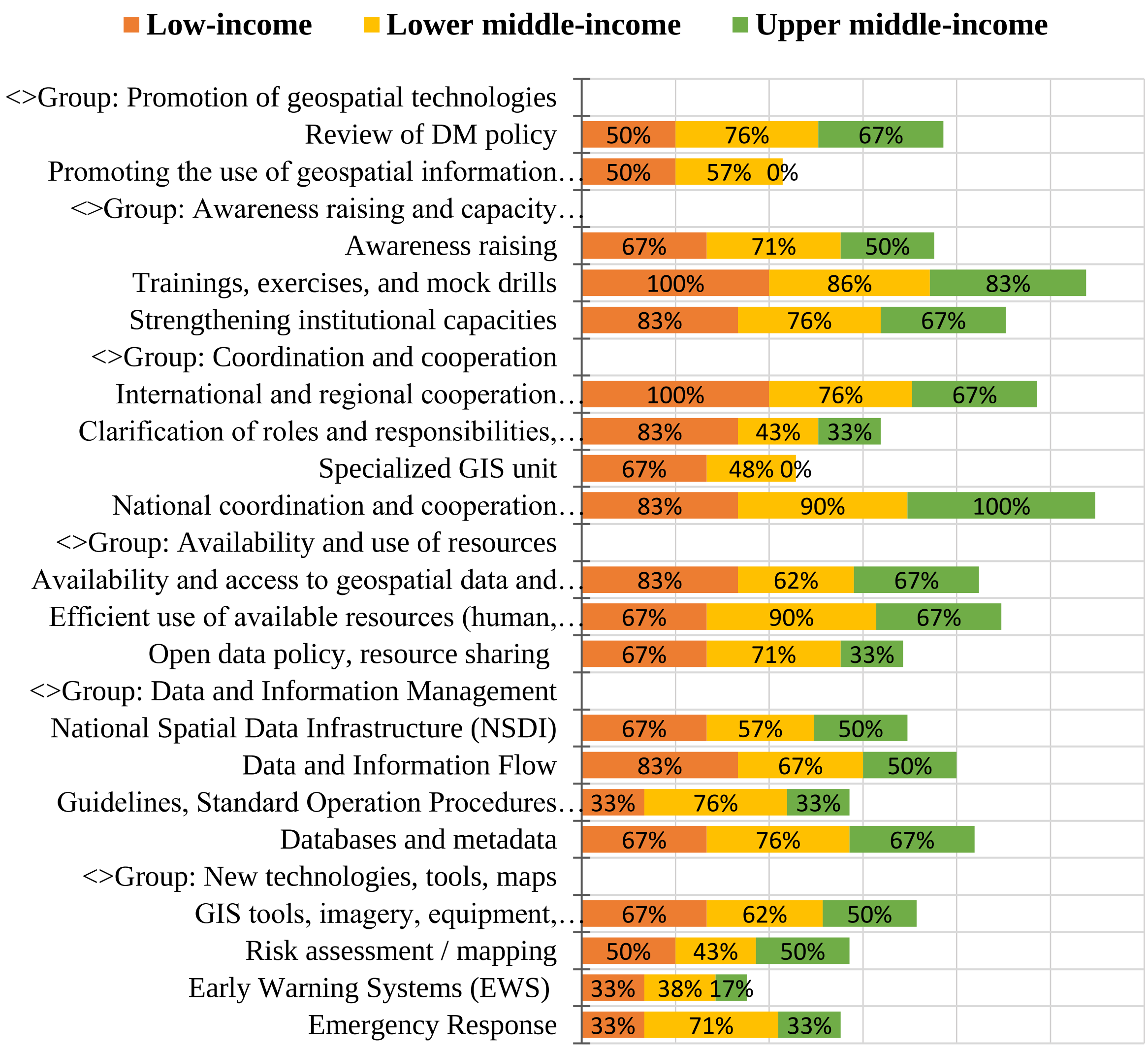

Figure 30. Issues by income level

Note: numbers (%) within the colored bars show the proportion of countries from specific group which in their reports mentioned a particular issue.

While making any generalizations, it is important to notice, that there were relatively few countries from low and upper middle-income groups, compared to the lower middle group. Still, some rather clear contrasts can be noticed, as presented in Table 19.

Table 19. Identified differences based on income level

	Low-income	Lower middle-income	Upper middle-income
More concerned about	- International and regional cooperation mechanisms - Clarification of roles and responsibilities, identification of focal points - Specialized GIS unit - Availability and access to geospatial data and information - Data and information flow	- Efficient use of available resources - Guidelines, Standard Operation Procedures (SOPs), and Data Standards - Emergency Response	
Less concerned about			- Promoting the use of geospatial information and technologies - Awareness raising - Specialized GIS unit - Open data policy, resource sharing - Data and information flow - Early Warning Systems

Interestingly, upper middle-income countries did not indicate any particularly high concern regarding any issues, compared to the other two groups.

7.1.2.4. Analyzing by development level

Apart from exploring potential differences related to income groups, it was also possible to compare countries in terms of the level of their development. Particularly, this can be done using the United Nations list of Least Developed Countries (LDCs). It is important not to confuse the simple income group (defined by only GNI per capita) and criteria used to determine the LDC status, which covers indicators related to income, human assets, and economic vulnerability (UN OHRLLS 2021c). Even if a country moved from a low-income group to the middle-income, it could still remain among the LDCs, since just improved GNI per capita is not enough to graduate from the list (Bhattacharya and Khan 2018). Overall, the analyzed countries could be divided into the following two groups:

- Least Developed Countries (LDCs) – 15 countries in total;
- Others (which we can generally consider as more developed) – 18.

Figure 31 visualizes the divisions among these groups.

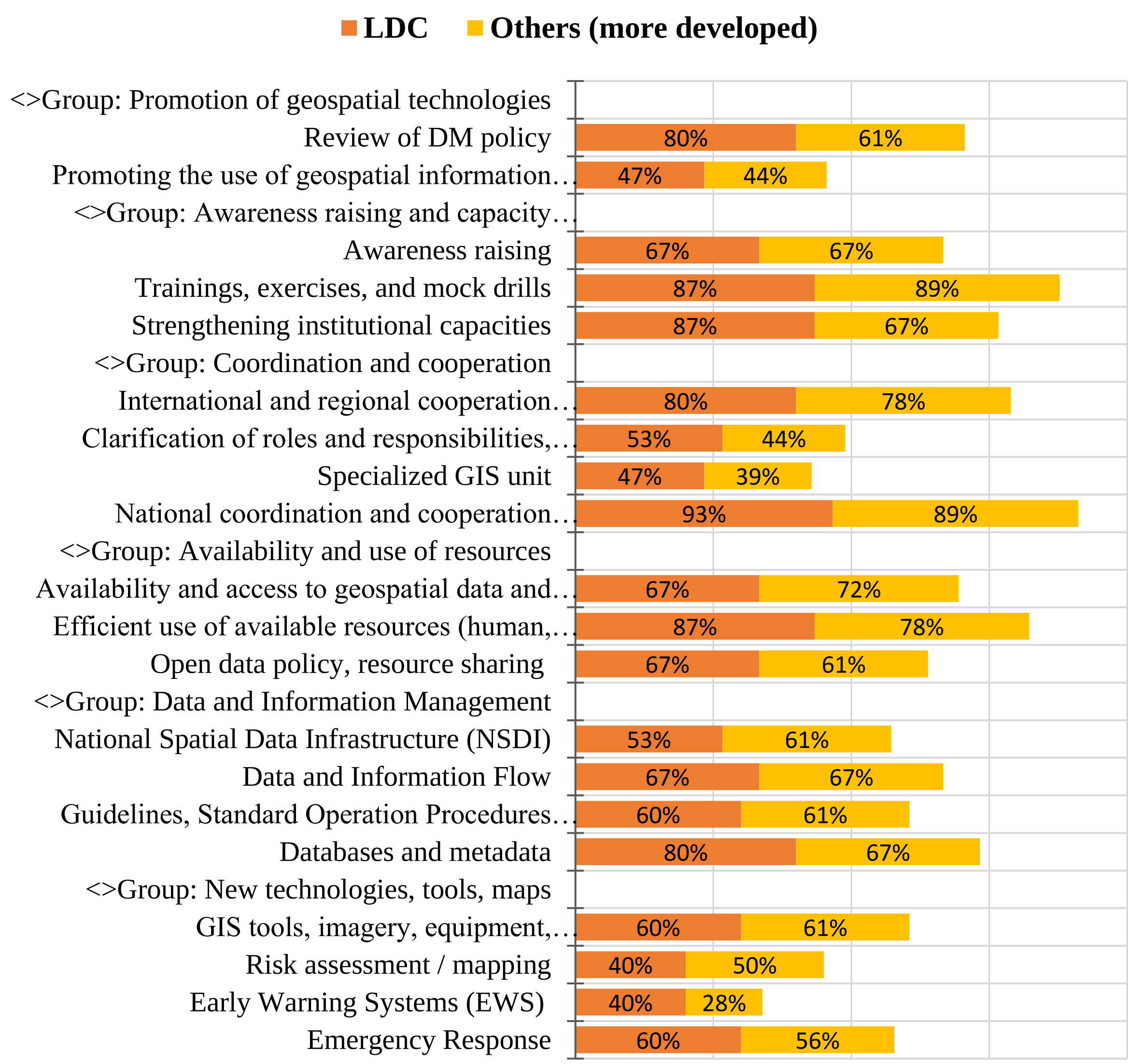

Figure 31. Issues by development level

Note: numbers (%) within the colored bars show the proportion of countries from specific group which in their reports mentioned a particular issue.

Overall, since in this particular case there were only two clear groups, it would be more appropriate to indicate only issues which were regarded as noticeably more relevant by either one of the groups. They are listed in Table 20.

Table 20. Identified differences based on development level

	LDCs	**Others (more developed)**
More concerned about	- Review of DM policy - Strengthening institutional capacities - Databases and metadata - Early Warning Systems	- Risk assessment / mapping

While not that many differences were identified, LDCs seem to have few additional "concerns", compared to more developed countries.

7.2. Expert survey

7.2.1. Main segments of the survey

This section focuses on the analysis of the data collected through the expert survey. Apart from more general questions that later helped disaggregate responses, some sections of the developed questionnaire were heavily based on sources identified through the initial literature review. Particularly, the section on "Challenges in the application of ICT" of the online questionnaire asked to rate the statements that were based on the issues listed in the article by Quarantelli (Quarantelli 1997) and the NRC report (National Research Council 2007) (which were discussed earlier in Chapter 3, section 3.2. Challenges in the application of ICTs in disaster management).

In addition, the section on "Satellite technologies" included many questions from the Eurisy report "Satellites for Society: Reporting on operational uses of satellite-based services in the public sector" and the survey presented in this publication (Eurisy 2016). This work did not focus exclusively on the existing issues in the application of such technologies, but rather on the actual scope of application of satellite-based services, reasons for implementing this kind of technologies, available budget, and identified benefits.

7.2.2. General composition of participants

The survey was shared among participants of the eight ISEPEI summer schools over the 2016-2019 period (two workshops per year). As was mentioned earlier, in total 133 participants provided their responses. Almost three-quarters of this group (74%) indicated that they consider themselves involved in the disaster (emergency) management field. Figure 32 shows the distribution of survey participants by different sectors, which highlights a relatively even distribution among four main categories:

- higher education institutions,
- not-for-profit organizations and NGOs,
- UN agencies and intergovernmental bodies,
- and governmental organizations.

Relatively few participants were working in other sectors - only seven people came from for-profit organizations, and only five indicated their affiliation as “Other”.

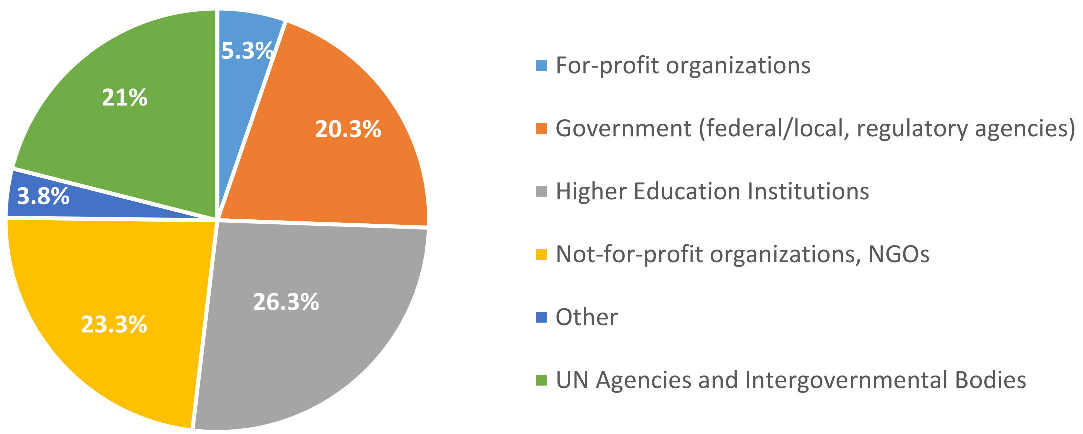

Figure 32. Distribution of survey participants by sector

Most of the participants had either 0-2 years of experience (30.8%) or 2-5 years of experience (Figure 33). Around a quarter had worked for 5-10 years. A relatively small number of responders indicated that they worked for more than 10 years in their current field of work (around 15%).

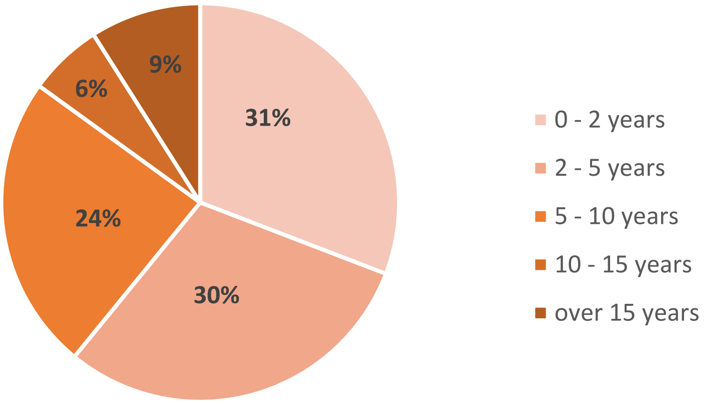

Figure 33. Distribution of survey participants by years of experience

Most of the responders indicated that they either personally use GeoICTs in the workplace (36.9%) or know that such technologies are used by others at work (32.3%). The remaining either did not work with GeoICTs directly but were aware of their use (22.3%), while few were not even aware of the use of such technologies (8.5%).

Most of the participants assessed their competence in answering the questions of the survey as reasonable (44.4%), good (26.3%), or very little (22.6%). Very few rated themselves as experts (6 people) or considered themselves amateurs (3 people).

7.2.3. Main findings

7.2.3.1. Decision to adopt an innovation

When asked who is, as a general rule, making a decision to adopt innovations at a workplace (particularly geospatial innovations), out of the whole pool of answers, only 94 participants (70.7%) provided their responses (since not all questions in the survey were mandatory). Overall, the distribution among the three provided options was rather uniform:

- 36.2% indicated that the decision was made independently by the individual,
- 31.9% said that the decision was made by a higher authority,

- 29.8% specified that the decision was made collectively.

When disaggregated by the years of experience, the only relatively clear trend that was possible to notice is that on average with the growing experience it is becoming less common to make independent (individual) decisions to adopt any sort of innovation (Figure 34).

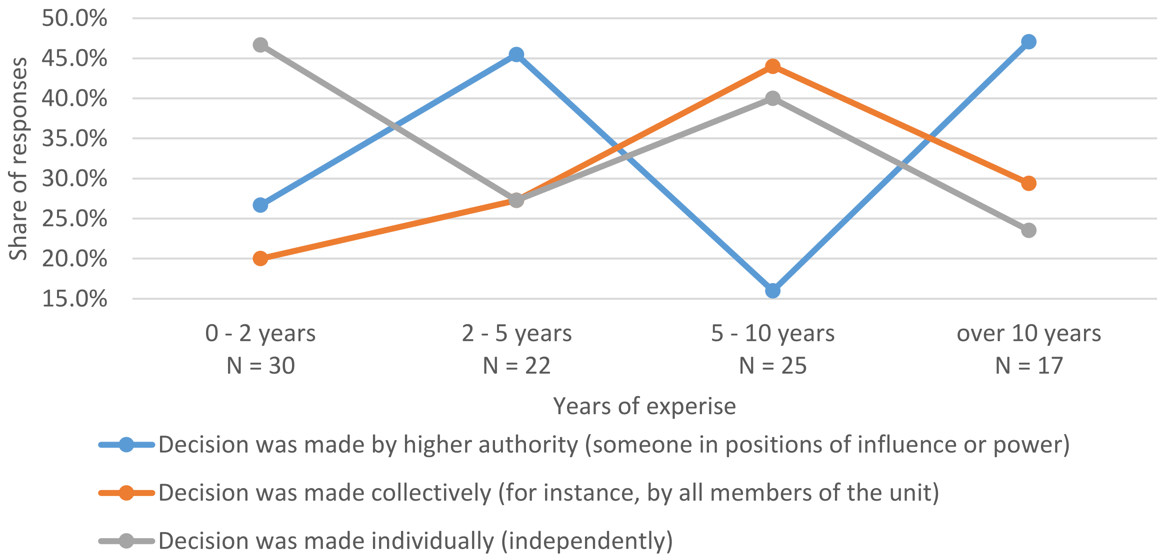

Figure 34. Who is making a decision to adopt innovations in workplace (by years of experience)

It was possible to identify more noticeable differences when participants were divided by their field of work. Figure 35 shows the results of this differentiation, presenting by separate color only four fields that had the largest number of representatives (excluding for-profit organizations and "other"). Responders affiliated with UN organizations indicated that decision to adopt an innovation at the workplace relatively rarely was done independently. For this field, the decisions made by higher authority are much more common, as well as those made collectively, especially if compared to the situation in other fields. On the other hand, representatives of higher education institutions seem to have the highest level of individual freedom in terms of making a decision to adopt an innovation.

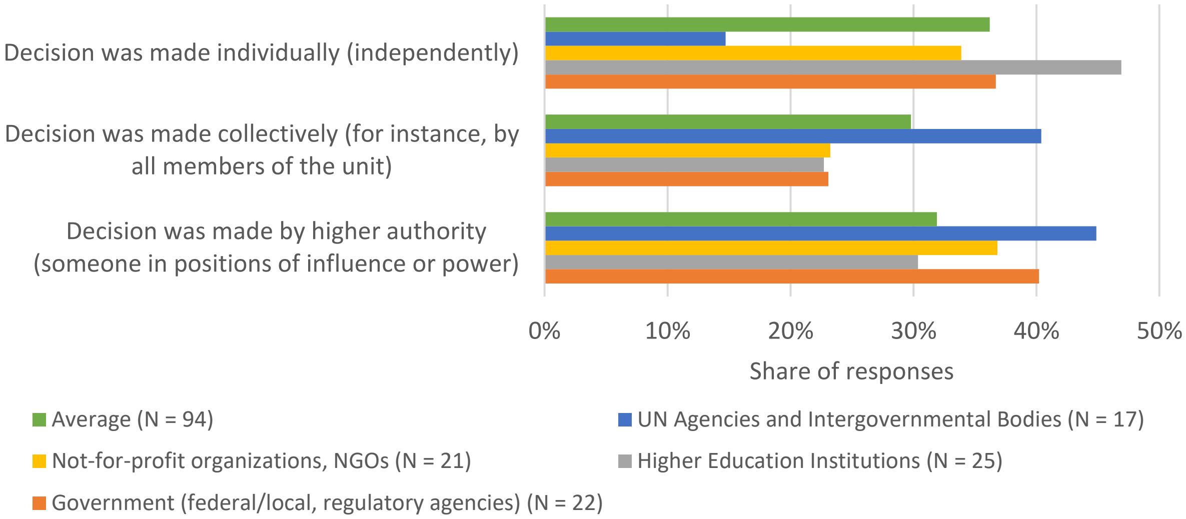

Figure 35. Who is making a decision to adopt innovations in workplace, by field of work

7.2.3.2. Challenges in the application of ICTs

Survey participants were also asked to rank the lists of challenges and problematic aspects, from 1 (least important) to 5 (most important). The original lists were presented and discussed earlier, in Chapter 3, section 3.2. Challenges in the application of ICTs in disaster management.

Social science perspective

First, the list of problematic aspects of the application of ICTs in disaster planning and research, based on Quarantelli (1997), was provided (Figure 36). Based on the votes of the responders (84 in total), the following issues were identified as most important: the lack of a specific kind of social infrastructure required for the use of modern disaster-relevant ICTs; information overload problem; greater likelihood of the diffusion of inappropriate disaster relevant information; and the certainty of computer system-related disaster.

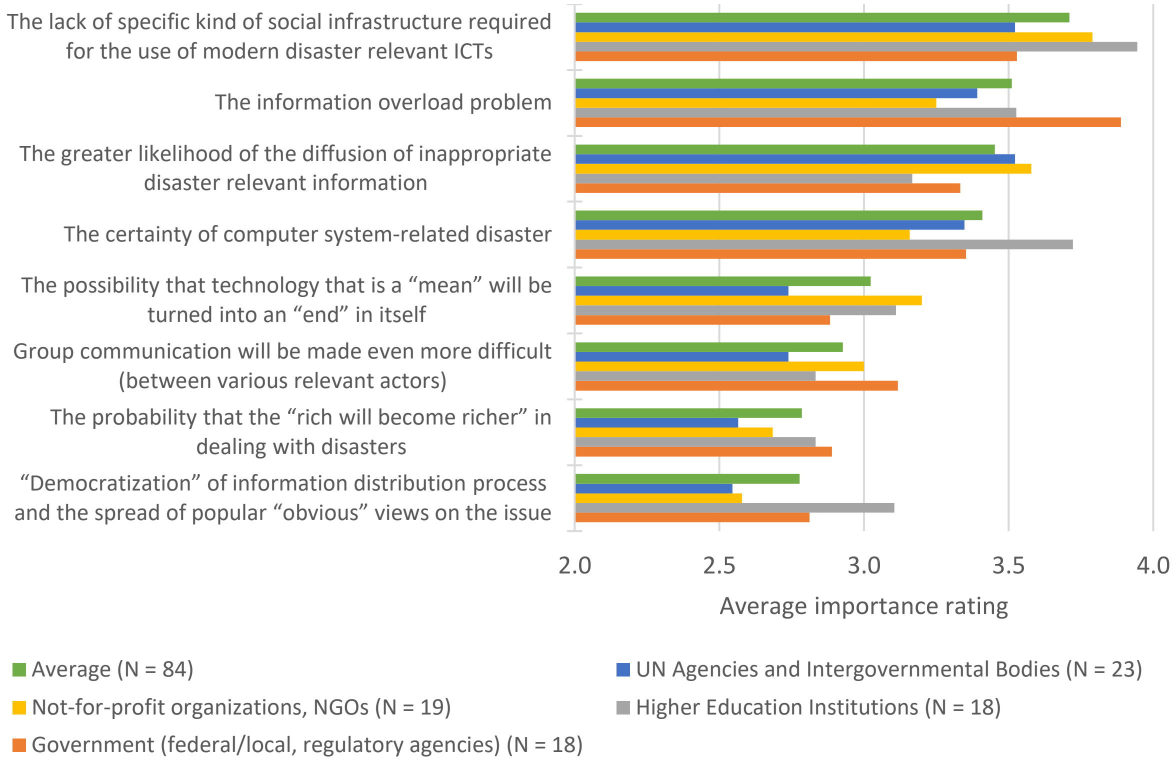

Figure 36. Rating of the challenges based on Quarantelli (1997)

Technological / organizational perspective

In relation to the challenges in the field of ICT in disaster management, as formulated in the report of the USA's NRC (National Research Council 2007), responses were assessed separately - for participants working in disaster management (83 respondents in total), and for those mainly involved in other fields (44 in total). Representatives of the DRR sector rated challenges related to the availability and distribution of financial resources as the most problematic ones (Figure 37). The lack of employees who could be responsible for monitoring and purchasing ICT innovations and organization of the related training was also rated rather highly.

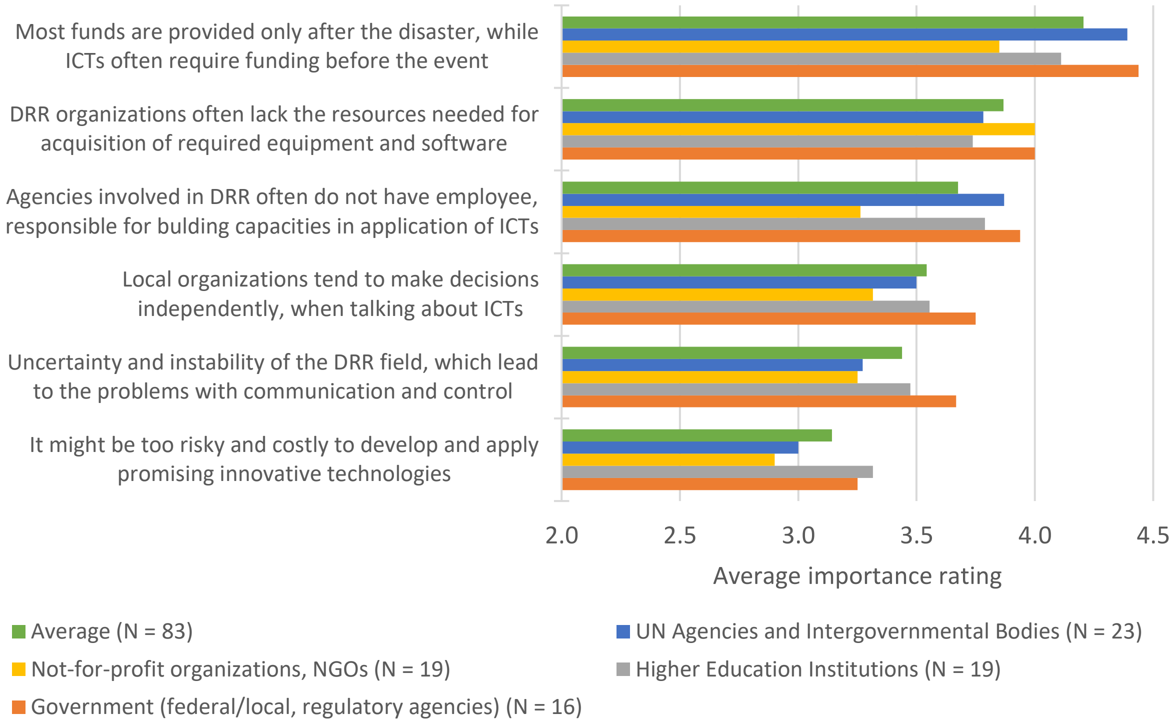

Figure 37. Rating of the challenges based on National Research Council (2007) for DRR

Overall, the group of responders not directly involved in the disaster management field in most aspects replied very similarly to the DRR group (Figure 38). The most noticeable difference is in the fact that the lack of employees was rated as the most important issue, followed by challenges related to the availability of financial resources. The order of preference for the remaining challenges was the same for both groups. Most interestingly, the issue related to the idea that it might be too risky and costly to develop and apply promising innovative technologies was overall rated as the least problematic among both groups.

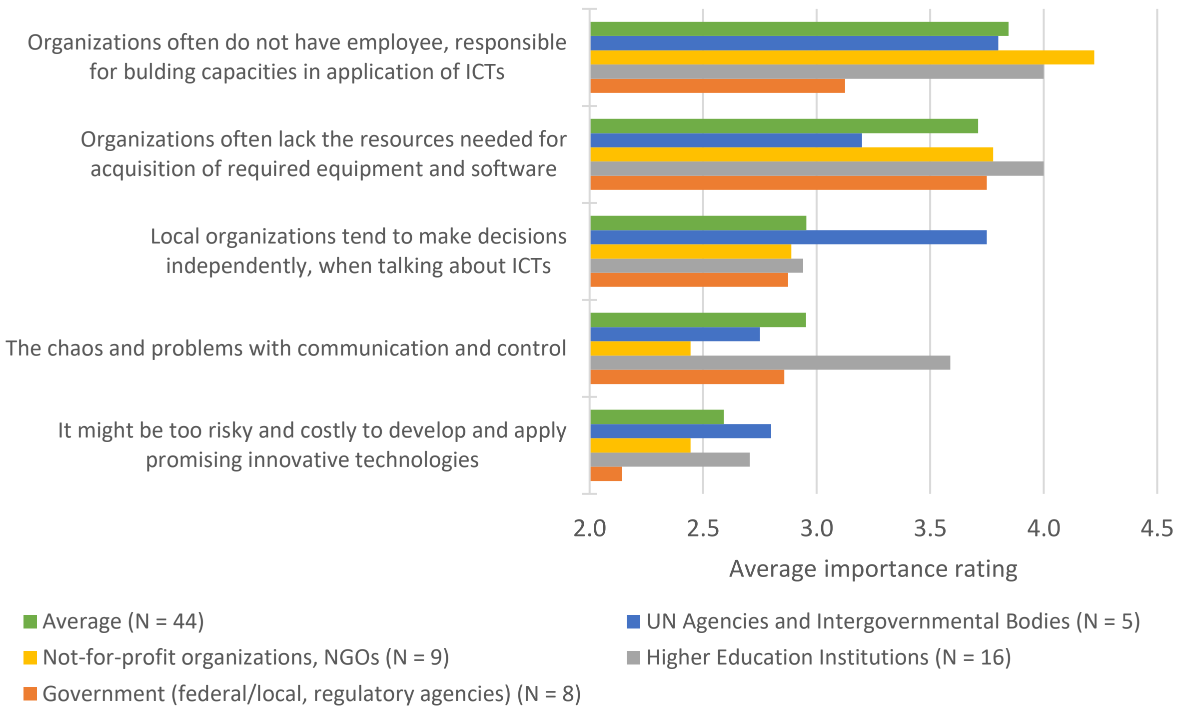

Figure 38. Rating of the challenges based on National Research Council (2007) for non-DRR

7.2.3.3. Challenges in the application of satellite-based technologies

A separate section of the survey was dedicated to the issue of application of the satellite-based solutions. Since it was based on the research conducted by Eurisy (2016), it was also possible to compare the results between this publication and the current study. Interestingly, the overall results and the ranking of the challenges in both the publication and conducted survey turned out to be very similar.

Since only around half of all responders that participated in the survey had experience in working with satellite-based technologies (62 people), only those were asked to provide their understanding of the situation. The most common issues faced while using satellite-based technologies were technical (difficulty to translate needs into technical specifications) and organizational challenges (staff capacities to start using the new service), as was indicated by almost 60% of all responders. The study by Eurisy (2016) had very similar results (Figure 39).

These are followed by issues more closely related to the availability of financial resources - economic (costs of the satellite-based services) and administrative challenges (difficulty in obtaining authorizations or funds) - as supported by 43% of responders. The study by Eurisy (2016) indicated this kind of challenge as a little bit less common, but still recognized by a considerable number of respondents, even though it was highlighted that satellite-based services are becoming more and more affordable nowadays (Eurisy 2016). Material challenges (service availability on the market) were the least mentioned, still indicated in 22% of replies, similarly to the report by Eurisy (2016). Only a few people (10% of responders of the survey) reported that they faced no challenges.

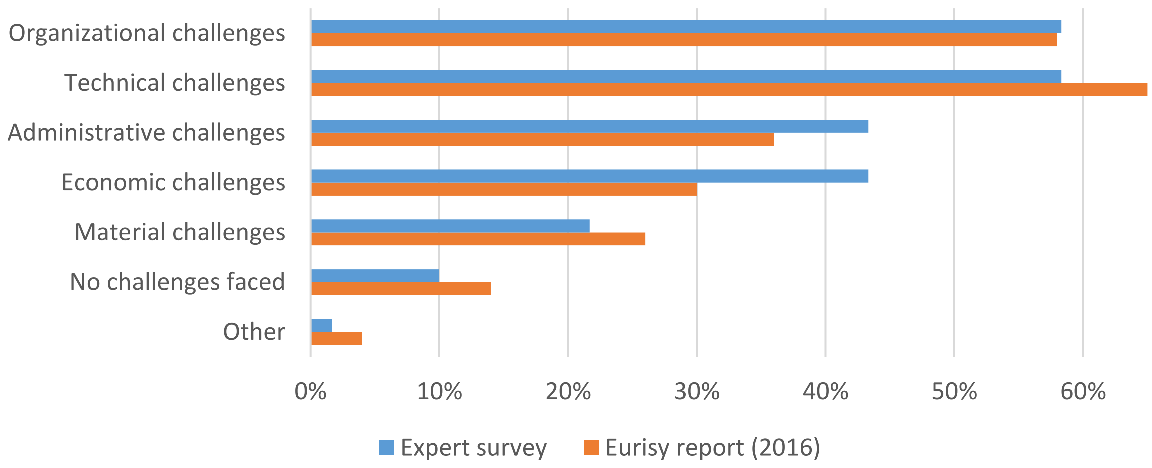

Figure 39. Did you face any of the following challenges while using satellite-based solutions?

Technical and organizational challenges in the first steps of adoption and implementation are seen as much more serious issues for those who are not used to this kind of technology. In relation to the solutions used to solve discussed challenges, the results of the conducted survey and Eurisy study (2016) both indicated that by far the most common approach was to train the staff in using new technology (Figure 40). In both cases, hiring new staff was by far the least popular solution. Alternative approaches, mentioned by around a quarter of survey responders, included using external free support and hiring consultants. At the same time, around 27% of responses mentioned that the challenges were not solved.

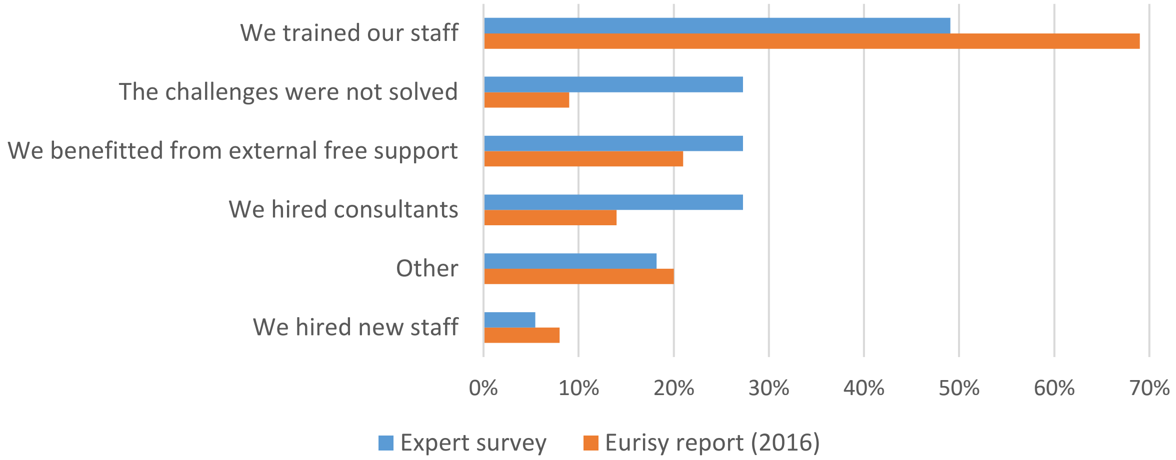

Figure 40. How did you solve the challenges in using satellite-based solutions?

The study by Eurisy also mentioned some important future obstacles in the implementation of satellite-based technologies - the fact that the "usefulness of the service is questioned within the institution or by external stakeholders" and that "other available technologies are being considered to substitute the satellite service" (Eurisy 2016).

7.3. Summary

UN-SPIDER is one of the main international initiatives that promote a wider application of space-based information in disaster risk reduction and emergency response. It facilitates activities related to capacity building and institutional strengthening in the developing and most vulnerable countries. UN-SPIDER's Technical Advisory Missions (TAMs) not only explore the current situation in the countries that requested support through this platform, but also suggest which areas require improvement and which specific activities could be implemented. Over the past years, there has been a noticeable decline in the total number of conducted TAMs, however, at the same time, the number of ISMs was increasing. Still, TAM reports provide an opportunity to explore common issues and challenges experienced by the countries visited by UN-SPIDER.

Thematic analysis of the missions' findings allows systematizing common themes and concepts covered in the reports. Proposed recommendations help identify specific topics which are of most concern to the visited countries. Thematic network analysis not only allowed to explore the main concepts covered in TAM reports but also revealed that the NSDI played a role of an overarching framework, linking all mentioned themes together. The organizing themes included: data and information management, high-level policy and strategic documents, technological, human, and financial resources. At the same time, such important elements of an NSDI as “private sector” and “local comminutes” seem to be largely missing from the network and recommendations of the TAM reports.

In addition, a number of specific issues related to the application of GeoICTs in DRR and emergency response were identified through the conducted analysis. Overall, 20 topics, divided into six groups were defined, which included promotion of geospatial technologies, awareness raising and capacity building, coordination and cooperation, availability and use of resources, data and information management, new technologies and tools. Collected results allowed to analyze how relevant is each issue, based on the division by different geographic regions, access to the sea, income, and development levels. In all cases, some rather clear differences among different groups were identified.

In addition, the current chapter also presented and analyzed the results of the expert survey that was conducted over the 2016-2019 period. It started with the discussion around different approaches to making a decision to adopt a technology. Responses showed that on average all three provided options (decisions made independently, collectively, or by higher authority) seem to be equally common (one-third to each).

However, more interesting were the sections of the survey that dealt with the perception of the problematic aspects and the challenges in the application of ICTs. Such problems as the lack of specific social infrastructure, information overload problem, and a greater likelihood of the diffusion of inappropriate information were ranked among the most relevant from the social science perspective. At the same time, from a more technical/organizational position, financial resources and the lack of an employee responsible for ICT innovations were considered as most problematic.

The final section focused on challenges related to the application of satellite-based technologies specifically. Overall, technical and organizational challenges were reported as most common, while the actual availability of the needed services (material challenges) was considered the least problematic. The most popular approach to deal with the faced challenges was to train the staff while hiring additional staff was the least common.

8. Discussion of diffusion challenges

This final chapter brings together findings presented and explored in the earlier sections of the dissertation. The following structure was defined by the results of the analysis of the TAM reports and the discussion corresponds to the topics identified at that stage. The main part of the chapter introduces and discusses the problematic issues one by one, highlighting both the main associated challenges as well as proposing potential solutions for each of the issues. Finally, an attempt to synthesize the overall findings in a concise and simplified way (in a form of a concept map) is presented.

8.1. Data triangulation

As was discussed in the section "7.1. UN-SPIDER's TAM reports" of the previous chapter, reports from such missions can serve as a good source of information about the needs and wants of the countries in terms of access to and application of geospatial data and technologies in support of DRR. Recommendations proposed in these reports allowed to identify main areas of concern that require improvements. TAMs generally focus on supporting developing countries, fully following the guiding principles of the Sendai Framework for DRR, which pays special attention to the fact that such countries suffer from disasters disproportionally more than developed states (UNISDR 2015b). High-income and developed countries also experience challenges related to the application of GeoICTs and space-based data in support of DRR activities. At the same time, the nature, as well as consequences of the issues faced by the developing countries, might be regarded as the priority, due to the overall higher mortality and economic losses from disasters common for the developing countries (UNISDR 2015b).

It is important to keep in mind that while the available TAMs provided a comprehensive review of the situation in a number of countries from different regions, these missions took place over ten years (2008-2017). Thus, it might be argued that some of the conclusions or proposed recommendations might not be as relevant anymore to these or any similar developing country.

However, additional evidence from other data sources was used to support and explore the findings of the thematic analysis of the TAMS reports. Particularly, these include:

- Participant observation of the day-to-day work of relevant organizations, conducted through internships (at UNOOSA and FAO) and research visits to the ADRC and Yamaguchi University.
- Participant observation at various conferences and workshops (listed in section "4.2.3.1. Events").
- Discussions with experts and practitioners working on capacity development of the countries in the DRR field and facilitating the wider application of space-based technologies (particularly, UNOOSA/UN-SPIDER, FAO, ADRC, Yamaguchi University, GEO, DLR, Google, MAGOR).
- Expert survey.
- Additional desktop research, if needed.

8.2. Main issues in the diffusion of space-based technologies in disaster management

In the previous chapter, the UN-SPIDER's TAM reports were reviewed and the main issues in the diffusion and application of space-based technologies to support DRR and management were identified. Overall, this process helped define the 20 most relevant and pressing issues expressed in the documents. The current section presents and discusses each of these issues one by one, supporting the generalized findings from the TAM reports with information collected from other sources. Some issues might be explored in more detail than others. This mainly depended on the diversity of the grouped recommendations, possible level of generalization, as well as on supporting evidence from other sources. All issues were organized by topic and divided into six distinctive groups, which are:

- Promotion of geospatial technologies

- Awareness raising and capacity building
- Coordination and cooperation
- Availability and use of resources
- Data and information management
- New technologies and tools

These topics are discussed in the following sections of the chapter one by one.

8.2.1. Promotion of geospatial technologies

8.2.1.1. Review of disaster management policy

In reports, recommendations mentioning this issue were most commonly focused on the review of existing disaster management policy to shift towards a more holistic approach and highlight the importance of geospatial information and space-based technologies. It was mentioned that disaster management laws should be revised to shift from focusing on emergency response (reactive approach) to DRR and long-term planning (proactive approach). A similar strategic gap was also discussed by Albris *et al*. (2020) regarding the lack of long-term initiatives related to DRR on the national and local levels in Europe (Albris *et al.* 2020).

Reports mention that new technologies, including GeoICTs and satellite-based data, should be promoted through disaster management strategies and national development plans. In these documents, DRR should be clearly linked to climate change adaptation. The role of space-based information should be introduced into comprehensive national emergency plans. And while adaptation to changing conditions can be seen as a global commitment and responsibility, disaster mitigation is local in nature, and depends on the activities of the country, and thus should be regarded as a national responsibility.

As was discussed during the research visit to the ADRC, serious disasters quite often serve as triggers for the establishment of many modern initiatives, laws, and platforms in the field of DRR, even if similar ideas were already proposed before the events. The fact that modern society tends to learn only when disasters happen can be quite clearly illustrated through the timeline of the development of many DRR-related laws in Japan - for instance, changes in the Building Standard Law following the Miyagi Earthquake in 1978, a series of acts following the Great Hanshin-Awaji Earthquake of 1995, and a number of amendments introduced after the Great East Japan Earthquake in 2011 (GOJ 2015). As another example, the International Recovery Platform (IRP) was established in 2005 at the UN World Conference on Disaster Reduction (Hyogo Conference), in some way as a response to the Indian Ocean Tsunami of 2004. Such serious triggers often lead to a breakthrough and paradigm shifts in terms of a common awareness of the existence of the risks, on both national and international levels. However, at this point in history, it should not be necessary to experience a devastating disaster to adequately update or introduce more appropriate DRR laws as it is possible to follow already existing examples of other nations that maybe be more experienced in this field.

8.2.1.2. Promoting the use of geospatial information and technologies

The lack of awareness of the GeoICTs potential, combined with the existing gap between experts and policy-makers, is hindering the wider application of such technologies. A strategy for the use of space-based information for prevention, mitigation, preparedness, and response to disasters could be promoted to institutionalize the use of GeoICTs. An appropriate methodology needs to be put in place to further promote the integration of EO and spatial data into vulnerability assessments and other kinds of analysis. The overall experiences in the use of geospatial data could be collected and systematized to evaluate the progress in this direction.

Coordination and cooperation mechanisms among stakeholder organizations were mentioned in TAM reports as important elements of the system that could enhance and facilitate the use of geospatial and space-based information and technologies. NSDI could support the exchange of geospatial information and promote the transfer of best practices and technologies (for instance, from the local to national level). Relevant institutions could be motivated to share their best practices and expertise. Best available practices, approaches, technologies, data standards, services, and open data sources could be brought to a particular country through the organization of specific trainings in cooperation with international and regional organizations.

8.2.2. Awareness raising and capacity building

8.2.2.1. Awareness raising

Most TAMs recommendations addressing this issue were related to raising awareness among managers and decision-makers of relevant institutions on the value of open-source GIS software, open data, and EO products. The overall need to increase awareness of the availability of space-based information and geospatial technologies was expressed. Much attention was put on advocacy, outreach, and education of decision-makers, to convince them of the importance of the geospatial technologies for DRR. Through such activities, other elements of the system could be improved as well, for instance, technological components, staff skills, and financial support in general. Outreach could be also done through the publication of best practices and success stories, or even the preparation of an awareness document that would showcase the benefits of geospatial technologies. Information about less known international or regional mechanisms (other than the Charter) could also be shared with relevant organizations.

Concerning this topic, the working group (WG) discussion (that took place at the UN / Pakistan / PSIPW 4th International Conference on the Use of Space Technology for Water Management, 2018) mentioned that it can be hard to motivate people to see the importance of space technologies. It can take years to change the attitude to this field in some countries if such issues were not widely introduced before. Potentially, more conferences on space-related topics could help promote the importance of GeoICTs.

Another aspect mentioned in the reports was that the NSDI implementation needs to be advocated for at all levels and in all relevant institutions. The importance of coordination was also noted – in the case of data purchases, all interested organizations should be informed so that the possibility of shared licensing or cost-sharing could be considered and discussed.

In rare cases, the importance of the involvement of the general public in awareness-raising activities was discussed, however, decision-makers were always the primary focus. This is an important issue to highlight since the Sendai Framework among its priorities does address the need to increase public education and awareness of disaster risks (UNISDR 2015b). In general, the disaster knowledge gap concerning risk awareness among the general public remains an important issue for both developing and developed countries (Albris *et al.* 2020; Handmer and Towers 2015).

8.2.2.2. Trainings, exercises, and mock drills

Trainings for practitioners

TAM recommendations emphasized that building the capacities of practitioners and people responsible for disaster response is an important challenge that should be addressed. Some of the most common recommendations focused on the need for training courses for the technical staff on the application of remote sensing, GIS software, and available international mechanisms. Such regular capacity-building activities could be institutionalized for relevant officers or even specific agencies responsible for such activities could be appointed. The importance of regular trainings and mock drills was especially stressed as such activities could also ensure better use of international support in case of a disaster.

Discussions with the ADRC representatives revealed that some of the problems in the countries of the Asia-Pacific region are largely related to the lack of human resources in national disaster management organizations - for instance, the absence of GIS specialists working in the corresponding agencies. At the same time, ADRC hosts the Visiting Researchers program, through which the Center each year invites researchers/officials in charge of disaster management from the ADRC member countries (normally three experts, for four months, twice a year), to upgrade their knowledge and skills on DRR through participation in various activities, field trips and visits to relevant organizations (ADRC 2021). This program is regarded as one of the most important activities the Center conducts.

From a more international perspective, UNOOSA's Programme on Space Applications established six Regional Centres for Space Science and Technology Education, following the UN General Assembly resolutions 45/72 (of 11 December 1990) and 50/27 (of 6 December 1995). These centres aim to develop skills and knowledge of scientists and government officials in aspects of space science and technology that can contribute to sustainable development (UNOOSA 2021b). Different centres cover corresponding regions of the world: three in Asia; two in Africa (one for the anglophone countries and one for the francophone countries); and one in Latin America and the Caribbean (Agbaje 2017). Such centres are hosted by existing research and higher education institutions. In addition, Regional Centres actively work with UN-SPIDER, supporting capacity development in the field of application of space-based technologies for resilience (UNOOSA 2021b). UN-SPIDER's Regional Support Offices (RSOs) are also involved in capacity-building activities.

The working group discussion was also focusing mainly on the capacity development of the experts or researchers working on the topic, and not the general population. The need for trained space scientists and engineers in African countries was particularly clear (Woldai 2020). At the same time, one of the related issues mentioned during the working group was the lack of funds for such activities. As an example, the situation with the educational center in Nigeria was discussed – while around 35 qualified people applied for training, the center was able to support and train only ten of them, due to the lack of funding. As a possible solution to deal with this issue, potential resources and support from various existing networks (mainly regional groupings) were mentioned.

Another aspect of this situation, discussed by the WG, was related to the fact, that often after such trainings people tend to leave their countries of origin to find a job in a more developed country with more opportunities. It was mentioned as a quite common issue for some African states. This is a serious problem in many aspects, not only in terms of funds allocation, which most probably were provided for specific training in the region but also in regards to human capital flight - as a result, the knowledge of the trained person will no longer be available in the region. This issue also applies to activities focused on Training of Trainers - master trainers, who could then share their expertise within the region.

It is a complicated task to deal with this issue, since restricting the mobility of people, and somehow forcing them to stay would probably only discourage those interested in such training opportunities. Potentially, there might be a special contract developed that would require specialists who completed the training to work for a specific period of time (~5 years) for the governmental organization within their country/region (not in the private sector). However, another issue can arise from this approach – it might not always be possible to provide the right place for the person who was trained. Often there might not be any available suitable position to apply new skills. Overall, the WG agreed that people require support not only during such trainings but also after them. It was mentioned that government should provide some incentives as well.

At the same time, even in a situation with a lack of funding, other potential options for capacity-building activities can and should be considered. For instance, online learning became particularly relevant during the active phase of the COVID-19 pandemic, when most face-to-face activities and trainings had to be suspended. Massive open online courses (MOOCs) are already available on various platforms, including Coursera, EdX, and other dedicated sites. As an example, for some years UNOOSA was planning to develop such a course as part of their support activities. Together with the Centre for Space Science and Technology Education in Asia Pacific (hosted by the ISRO), UNOOSA developed its first MOOC on "Geospatial Applications for Disaster Risk Management", which was launched in 2020. This allowed to overcome some of the obstacles caused by the COVID-19 pandemic and continue the capacity-building activities (UNOOSA 2021b). In addition, experts participating in the WG discussion clearly expressed the idea that multiple online platforms for capacity building already exist and it is important to make proper use of what is already there.

Focus on existing capacities within the country

Another important aspect that was mentioned in TAMs repeatedly, is the need to focus on already existing capacities within the country. This mainly implies relying on national educational institutions rather than on foreign countries or international organizations. An assessment of the country's existing capacities and needs can help better formulate the following steps. Also, it was mentioned that geospatial technologies should become part of university-level courses and that suitable didactic materials and learning modules could be designed and introduced into curricula.

The need to establish a network of expertise within specific countries (sometimes regions) was also mentioned during the working group discussion. In many cases, some local expertise might already be available onsite but it is not utilized properly, since relevant decision-makers might not be aware of it. The proposed networks of experts could potentially include a list of available specialists, indicating their names, contact details, areas of expertise, and any other relevant information. This pool of experts then could be used to identify the most suitable candidates to train other practitioners within the same country, without heavily relying on help coming from outside. This approach could also facilitate the exchange of teaching faculty within the regions, leading to a related topic in the list of identified issues - joint trainings.

Joint international/regional trainings

The importance of specific trainings and workshops conducted in cooperation with international/regional organizations to bring best practices and lessons learned was discussed in the TAMs. Particularly, the possibility to organize joint activities with other countries in the region. To promote and strengthen NSDI, training courses for relevant stakeholders could be organized in cooperation with various international organizations, such as Open Geospatial Consortium (OGC).

The working group discussed another related aspect of the situation. Quite often, training activities are organized in specific centers (often regional), to which students have to travel. In some cases, it might be more useful and efficient, particularly in terms of fund allocation, to send regional experts to teach locally, rather than asking all students to travel. At the same, in the case of some countries (Nepal was mentioned as an example), there just might be no local training opportunities available - no centers, no relevant agencies, no experts. In this case, regional support is crucial in developing such local capacities, particularly through the training of trainers. Another suggestion proposed the development of an online forum for such training activities, on the regional as well as global levels.

An additional aspect of trainings for the project managers of the Charter was discussed during the meeting between representatives of the UN-SPIDER team and RSOs. The need for such activities became more prominent after exercising the role of project manager during a disaster. It was expressed that initial training is required since otherwise the process of Charter activation is unclear and only consulting available documents is not enough. While such training indeed is provided, it is crucial to ensure that all involved officers have a chance to participate. In 2019, UN-SPIDER hosted a dedicated training session for Charter project managers, organized by the ESA and DLR. While this kind of event remains rather rare, sometimes refresher training is organized as well (for instance, one was conducted by USGS in 2019).

Local population

Some TAM recommendations highlighted the importance of conducting capacity-building activities on different levels, including the general public, specialists working in the field, and decision-makers. It is crucial to improve the capacities of the local population, of individuals, as those are almost always the first responders in case of a disaster (Briones *et al.* 2019; IFRC 2020). However, recommendations from TAMs generally focused only on technical staff, much less on decision-makers or the local population. A few times the need to organize emergency exercises on a national level as well as develop a strategy to strengthen capacities at local levels was mentioned.

At the same time, the need to involve and develop the capacities of the local population (through training and outreach) was expressed much more clearly during the participant observation. It was particularly interesting to see that more prepared countries in many cases still experienced similar challenges as less developed states. The research visit to Japan revealed interesting regional challenges related to early warning and some of the ways this issue is addressed. Japan's emergency notification system (J-ALERT) is quite advanced (disseminating alerts through SMS, TV broadcasting, radio, loudspeakers), while always considering the potential for further improvements. At the same time, many people in Japan still decide not to evacuate, even after receiving multiple notifications and in a situation when the danger is clearly approaching. However, in such cases, one of the main issues is not related to the means of transmitting the information to the population, but to how this message is formulated and how aware the population is about the actual risks they are facing.

Identifying the reasons for people not evacuating in the situations, when the EWS is in place, is a serious issue. One cause can be related to the fact that people could be worried about leaving their property unattended. However, a more prominent challenge, particularly for Japanese society, is the large proportion of the elderly population. While every settlement in the country typically has several designated evacuation areas and shelters for different types of disasters, which are often located in schools and community centers (Figure 41), for senior citizens it sometimes might be difficult to reach the safe area on their own (Nakanishi *et al.* 2019).

Figure 41. Sign indicating the location of the designated evacuation areas and shelters, Kobe city, Japan

Local communities always have to act as the first responders to any disaster (IFRC 2020). As in Japan there are no special rules on rural community evacuation measures, it all depends on the community leaders – in most successful communities, neighbors are actively helping each other in case of an emergency. Ideally, communities would have a list of vulnerable people (elderly, disabled) who would require assistance during the evacuation. Such initiatives should be implemented by community leaders to be successful and holistic, however, local governments are often struggling to prepare a complete list of all people who would need assistance during an evacuation, generally due to the lack of those who are available to provide such support (Nakanishi *et al.* 2019).

It should be mentioned that apart from the elderly and disabled there are a number of other groups of the population that are particularly vulnerable during disaster response, namely the poor, women, and children (Benevolenza and DeRigne 2019; Luna and Hilhorst 2022). However, these specific groups were not discussed in enough detail in TAMs, as well as during participant observation, which in a way can also be an indicator that this topic might need more attention.

As another aspect of the situation, different ways of reaching out to a general population through children were mentioned multiple times both at the working group discussion and during the research visit to Japan. Approaching the younger population first (children, students) can in return help involve more adults (parents and relatives) in DRR-related activities. Children can also help share their knowledge about the concept of resilience, potential disaster risks, and the use of related technologies. In Japan, disaster management topic is introduced into different subjects at different levels of school education. Facilitating interest in this field among children helps reach out to their parents. Correspondingly, it also could motivate politicians and decision-makers to address DRR issues, since the wider population would be expressing their concern, not only scientists.

At the same time, another noticeable issue was also raised by the ADRC representative – in Japan community drills are regularly organized, however, the level of participation among adults is constantly going down. Similarly, one of the approaches that are used to attract more adults to such activities is through children. Participation in such community drills is introduced as a part of the school program, thus, kids are required to take part, and, correspondingly, there is a higher chance that this would attract more adults (parents) to attend such events.

Specific activities

Some TAM recommendations were focused on proposing more specific activities, which could not be always clearly generalized. These include: training on spatial modeling, including online modeling (of vulnerability, flood, drought); training on the use of radar imagery (particularly for floods); training on locating the best data sources and available low-cost solutions, open data sources, technologies; training on the application of GPS technology and communication tools; training and dissemination programs and activities; training of trainers.

Several rather specific topics were mentioned during the working group discussions as well. Overall, the discussion highlighted a need for capacity-building methodologies, which would focus on how to conduct such activities and what topics to cover. While it was agreed that there is a lot of data available, there is a need to build capacities in handling it. In many cases, 30-20 m resolution of satellite imagery (freely available Landsat and Sentinel imagery) can be more or less enough for many activities. However, stakeholders need to know how to use this kind of data, while access to training on such topics should be provided. On a similar note, the need for courses on software use, specifically customized for particular applications and specific regions, was expressed. The need to limit the use of illegal software was mentioned as well.

8.2.2.3. Strengthening institutional capacities

This topic, identified through the review of the TAM reports, rather clearly overlaps with the previously discussed issues on trainings and exercises. Some of the most common needs are again related to the training for staff on applications of GIS software. It was proposed that regular trainings for officers from relevant organizations could be institutionalized. The general need to strengthen institutional capacities, and to develop and promote corresponding strategies was mentioned quite often. Capacity development plans and strategies must be revised and upgraded regularly, as well as they should address long-term capacity-building needs on all levels (from high-level decision-makers to technicians). At the same time, the need to strengthen capacities at the local level is rarely even mentioned. A dedicated budget for capacity building and institutional activities should be allocated and/or secured in some other way. It is also especially important to ensure that trained staff remain in their positions within the government and apply developed skills, which in some cases might be an issue on its own, as was discussed earlier.

Recommendations also highlighted that it is important to identify and strengthen national institutions that are in charge of geospatial information and technology. Potentially, it might be needed to plan regular training and other activities, to use in-house capacities to the full extent. Alternatively, a dedicated center or an interinstitutional technical advisory group could be established. It could be coordinated through the NSDI and can help take advantage of the existing capacities in various institutions in the country. A study could be conducted to assess existing cooperation and data dissemination mechanisms between national agencies. Coordination tools and instruments should be strengthened, particularly to enforce multi-user licensing. At least minimal technical expertise for focal points at the relevant institutions should be ensured. In some cases, there might be a need to hire additional staff, to gather a team of GIS experts, rather than relying on only one person responsible for DRR in an institution.

Challenges for national statistical offices in the application of the new data sources (e.g. geospatial and EO) were also discussed at the GEO Data Providers workshop. It was emphasized that capacities in working with geospatial data and information must be improved, particularly in order to ensure reporting of geospatial indicators (Scott and Rajabifard 2017). The main challenge is to have the right expertise in many involved organizations, however, even the use of analysis ready data (ARD) requires considerable knowledge, expertise, and resources.

TAM recommendations suggested that Early Warning Systems (EWS) should be strengthened by building expertise in advanced applications of meteorological satellite data. A holistic approach to EWS should be promoted, while the provision of more accurate and localized early warning information should be supported. Such information could be used on a community level, for local disaster preparedness and response activities. However, basic map reading and land navigation skills must be strengthened across all stakeholders, particularly response communities. On the other hand, the expertise of local institutions that already have very good capacities could be used to promote their best practices and technologies across other national agencies.

Technological capacities are mentioned in the recommendations in terms of a need in: guaranteed minimum computing capacity; satellite communications capacity and high-accuracy GNSS receivers to support real-time sensor networks; radar data (SAR) acquisition and interpretation capacities.

8.2.3. Coordination and cooperation

8.2.3.1. International and regional cooperation mechanisms

TAM recommendations related to this topic were often covering many other related issues as well. Reports quite frequently refer to UNOOSA/UN-SPIDER as a mediator and facilitator of cooperation activities. However, this can be partially explained by the nature of the data used for the analysis - reports of the advisory missions conducted by UN-SPIDER itself. Still, UNOOSA does prove to be a rather active actor in the international arena, which can particularly be seen by its level of involvement in the Charter activations. Overall, a general need to enhance international cooperation and networks was often expressed in the recommendations. Better contacts with international organizations could help in conducting joint activities and trainings, provide access to remote sensing data, as well as identify funding sources. Connections with such organizations could be facilitated even through online conferences. The working group discussion also mentioned the need for more effective regional cooperation, giving the example of Glacier Lake Outburst Flood (GLOF) monitoring systems. To be more efficient it might be possible to merge funds, experience, and ongoing projects.

As a separate topic, the importance of emergency mapping mechanisms was raised quite often. UN-SPIDER traditionally is encouraging countries to participate in such initiatives, particularly to become authorized users of the Charter. Still, as was discussed earlier, around half of the countries visited by UN-SPIDER with a TAM mission as of 2022 did not have direct access to the main SEM mechanisms (Charter or Sentinel Asia). These include, for instance, the Solomon Islands (TAM in 2012), Honduras (TAM in 2015), Gabon (TAM in 2015), Georgia (TAM in 2016). The need to raise awareness about existing SEM mechanisms was expressed repeatedly since the importance of such initiatives was clearly realized by the visited countries. At the same time, to make the most use of such initiatives, support in other areas would be needed as well, including technical (good operational communication structures, fast internet, reliable phone connections) and special trainings and mock drills. The possibility of conducting training in cooperation with international or regional partners was mentioned quite often – such activities could help raise awareness, bring best practices, or conduct training of trainers.

UN-SPIDER is regularly mentioned as a facilitator of cooperation/coordination activities with international emergency mapping initiatives. UNOOSA is often regarded as a mediator through which a country can request assistance outside its own cooperation agreements. For instance, in case of a smaller disaster, a country could ask for UN-SPIDER assistance first, and in case of a larger disaster – activate the Charter (potentially, through UN-SPIDER/UNOOSA as well).

Regional partnerships are clearly valued as their importance is stressed repeatedly in the recommendations. Related activities included: strengthening cooperation with regional centers; enhancing existing regional networks and mechanisms and incorporating DRR aspect in them; making full use of existing regional capacities and facilities. Regional centers of expertise could be organizing courses, trainings and workshops, which potentially could also be institutionalized.

More miscellaneous recommendations covered: international/regional support for NSDI development and enhancement; cooperation with foreign space agencies; assistance in creating a catalog of available space-based data and information; integration of national data with key regional and global data sets to improve early warning and decision support; translation of important international guidelines and SOPs to local languages to support wider dissemination of such practices.

Platform for collaborations

At the working group discussion, the need for a special platform for collaborations was discussed. As an example, an Africa-wide platform to support the development of small satellites was proposed. Similarly, a platform to share encountered problems and challenges could benefit the wider EO community – it can help identify the needs and common issues in the region and find feasible solutions. Determining a shared problem among different countries, common to the region, would also help build trust, as well as help promote this problem among political leaders.

The discussion highlighted that it is important to involve all stakeholders in such sort of platform (portal/forum), as well as, to ensure more centralized coordination. Albris et al. (2020) also discuss the lack of such arenas to share best practices that would incorporate both academia, policymakers, and practitioners (Albris *et al.* 2020). UNOOSA in general is pushing forward such collaboration activities. Overall, in the working group, collaborations were mentioned as the main goal, as there is a clear need to use network opportunities more actively. Existing centers (particularly regional) can play a bigger role in supporting such activities, however, they need to be more active. Centers in Latin America were mentioned as good examples, since they are quite active, established good communication with each other, and provide mutual support. One of UN-SPIDER's Regional Support Offices can be mentioned specifically - the Argentinian National Space Activities Commission (CONAE). Furthermore, in 2021 a Constitutive Agreement on the creation of the Latin American and Caribbean Space Agency (ALCE) was signed by the 18 countries in the region. This international organization, once fully operational, will be responsible for the coordination of cooperation activities in the field of the use and peaceful exploration of outer space (Froehlich and Soria 2021). The only other similar regional organization in the world would be the European Space Agency (ESA).

At the same time, it was mentioned that centers located in Africa and the Middle East are typically less successful in their activities – they are not collaborating that much and do not provide much support. However, they seem to have a lot of potential, in case regional planning and collaborations will be facilitated. There is a need to build a network of experts, to exchange opinions, and expertise. To make this work, more commitment is needed from the key actors. A collaborative approach is regarded as the key element to success.

GEO can serve as a platform for some regional initiatives. Particularly, at the moment this organization includes four regional GEOs: African Group on Earth Observations (AfriGEO), Americas Group on Earth Observations (AmeriGEO), Asia-Oceania Group on Earth Observations (AOGEO), and European Group on Earth Observations (EuroGEO). Just to present an example, AfriGEO is a coordination initiative, focused on the region's participation in the implementation of the Global Earth Observation System of Systems (GEOSS), which is a central part of GEO's mission. The AfriGEO as a regional initiative primarily aims at serving as a coordination platform, as well as at raising awareness, developing regional capacity, strengthening partnerships and collaborations, and acting as a gateway for international partners. Overall, there are 27 African countries and nine regional organizations among the members of GEO (GEO 2019). At the same time, one of the main risks related to such initiatives and related commitments is their voluntary nature (Agbaje and John 2018). On the other hand, there is the EuroGEO, which seeks cooperation with other regional initiatives. EuroGEOSS can serve as a bridge between GEOSS and European Copernicus programme, particularly through attracting additional data, including in-situ (Schouppe 2018).

As an example of cooperation between different initiatives, the activities of the ChinaGEOSS, a national GEOSS initiative, can be mentioned. It contributes not only to AOGEOSS (a regional initiative within GEO) but also to APSCO's data portal, as well as serves as a complementary SEM mechanism, through the ChinaGEOSS Disaster Data Emergency Response mechanism (CDDR) (ESCAP 2020).

Other existing regional cooperative mechanisms mentioned during the working group discussion include the Asia-Pacific Space Cooperation Organization (APSCO), an intergovernmental organization that serves as a cooperative mechanism for developing countries in the region and mainstreams peaceful use of space, and ESA's TIGER initiative that assists African countries and promotes the use of EO for improved integrated water resources management. As a separate issue, it was mentioned that more collaborations between different geographic regions should be promoted.

Coordination between international organizations was also mentioned during the working group discussion as an issue, as well as coordination between international organizations and local disaster managers. In terms of specific recommendations, it was mentioned that different kinds of approaches and activities should be proposed at the international, regional, and local levels.

8.2.3.2. Clarification of roles and responsibilities, identification of focal points

TAM recommendations stressed that the roles and responsibilities of main stakeholders (including focal points) should be clarified and formalized to avoid overlap of the performed functions. To reduce duplicating efforts, a national database of existing DRR-related activities and actions could be established. At the same time, the needs and capacities of all involved agencies could be assessed. Information sharing channels play an especially important role during emergencies, and their functions should be clarified in strategic and legal documents. TAMs also proposed to identify relevant data providers and data users and assess existing information dissemination channels. It was often recommended to formulate special procedures and guidelines for better data management and information flow between involved organizations. Potentially even detailed SOPs with operating flows could be developed to clarify the roles and responsibilities of all involved agencies.

The importance of identification of focal points and clarification of their roles was stressed very often in TAM reports. Focal points for the national platform for DRR could be assigned in each respective governmental agency to facilitate cooperation activities. Such points of contact should also be established to create a link between international organizations, mechanisms, and national governments (for instance, to ease communication with Charter, Sentinel Asia, UN-SPIDER, etc.). A national focal point could also assess the country's capacity-building needs and present the results of this evaluation to UNOOSA and UN donors for the following implementation.

8.2.3.3. Specialized GIS unit

The lack of a specialized unit in the government that is responsible for geospatial data and information management was identified as not the most common, yet quite important issue. Overall, the need for a new entity (specialized unit, centre, or department) was expressed rather often. This central unit should be responsible for the promotion of the applications of space-based information and geospatial technologies (GIS, remote sensing, GNSS), providing support to other governmental agencies, particularly technical support. Depending on a particular country, this unit could also act as a crisis center, dedicated to more effective coordination at all stages of the disaster management cycle, ensuring efficient use of available resources. This single agency system could also help avoid unnecessary purchases of the satellite data since information on all data needs would be going through this specialized entity. Less often recommendations mentioned the need to identify and strengthen already existing institutions in charge of geospatial information and technology, or even transform an entity so it could act as a platform to facilitate NSDI development. Lastly, such national GIS units could also cooperate on a regional level to share their expertise.

8.2.3.4. National coordination and cooperation mechanisms

Though this issue is formulated in a rather general way, it can be considered one of the most important, based on the number of times it was mentioned in recommendations. The overall lack of coordination, communication, and collaboration was clearly stated in the TAM reports. Many recommendations related to this issue were very country-specific, mentioning national agencies that should work on strengthening their interactions. However, in the current analysis, such examples were generalized.

Overall, the need for closer cooperation between key governmental agencies was expressed repeatedly. Stronger coordination, cooperation, resource sharing policy and mechanisms, which would link all relevant organizations (including governmental agencies, UN country team, NGOs, and academia) need to be put in place. Tools and instruments to coordinate activities, existing capacities, and funds related to disaster management should be enhanced. To ensure streamlining of donor support, coordination of government-funded and external donor-funded projects should be facilitated. However, particularly important is the clear communication chain and coordination of all relevant organizations involved in early warning as well as in disaster response. A clear plan specifying the responsibilities of key actors should be developed. In relation to early warning systems, closer linkages with meteorology departments must be ensured and strengthened.

A bit different, yet relevant, aspect of communication between national organizations was also briefly mentioned during the working group discussion. It addressed communication during disasters. It remains a serious issue, especially for the first responders and organizations in charge, since more traditional communication channels might be disrupted during the emergency (Manoj and Baker 2007; Seba *et al.* 2019).

Another important topic that was widely discussed in TAMs is related to cooperation and coordination in the field of data and information management. Potentially, it was even proposed to establish a special multi-sectoral platform (or forum) to promote data sharing and efficient use of common resources and facilitate coordination and discussion on arising issues. Recommendations expressed a general need to improve coordination and cooperation between stakeholders on the use of geospatial data and their involvement in related national initiatives. First of all, it is important to ensure that all relevant organizations are informed about new developments in space-based technologies, as well as about relevant purchases of data or software. Particular importance was given to the multi-user licensing approach to data and software acquisition. If properly managed, agreements with data providers could ensure data sharing between all engaged agencies. Such cost-sharing, data sharing, and multi-user licensing approaches could even be institutionalized through policy and coordination strategies. Agencies should support each other, work collaboratively and share data, especially for emergency planning. In case of technical issues, an interinstitutional technical advisory group, which would include experts from all key agencies, could be established.

The need for strong partnerships with educational institutions at the national level is another important aspect of cooperation activities. Through such cooperation, joint exercises and targeted training activities could be organized, taking advantage of the available expertise and data.

A couple of recommendations also mentioned the need to establish or strengthen the National DRR Platform. Overall, the creation of such platforms is encouraged by UNDRR as well as Sendai Framework, as they can serve as important multistakeholder coordination mechanisms at the country level (UNISDR 2015b).

Private sector

Among other opportunities, potential public-private partnerships were mentioned in recommendations of some reports, however, very rarely. At the same time, the potential of developing and enhancing public-private partnerships in the DRR field was expressed by experts quite clearly during the research visit to Japan. The importance of the private sector as a vital element of a comprehensive NSDI was also discussed in the earlier chapter. An example of the Japan Bosai Platform, established in 2014, can be mentioned as a platform developed specifically for bringing together industry, academia, and government to ensure disaster resilience and promote sustainable solutions (Shaw 2018). This initiative supports collaborations between the private sector, the Japanese government, and international organizations. Such activities also in return bring opportunities for business communities.

During the research visit to Japan, there was also a possibility to join the discussion with representatives of the Fujitsu company (Japan), which is working in IT services. During the meeting, the company presented some examples of their projects related to DRR. However, it was mentioned that there were very few examples of the projects when the company was providing direct financial support. If the potential project can be recognized as profitable in the future, then the company might be interested in investing in it. This can be seen as a common approach for the private sector, which should be recognized.

Communication / diplomacy

A rather different aspect of cooperation activities was discussed by the working group – the language of communication with policy- and decision-makers. The idea that scientists should have their own diplomats to speak with policymakers was expressed. At the meeting, it was called "Science Diplomacy", which can be seen as related to the more specific "Space Diplomacy" promoted by UNOOSA (Polkowska 2020). The working group discussed that there is a particular diplomatic way of approaching donors while looking for support, thus there is a need for science diplomats. Some serious gaps between the scientific community and policy-makers remain. Science diplomacy as an approach can play a big role in data sharing initiatives.

Diplomacy is particularly important in regard to data sharing. At the same time, it was stressed that end-users should express more specific needs, otherwise, the topic becomes too complicated. Without the exact information on what kind of data is needed, the discussion could revolve around universal data sharing of some sort, which is hard to ensure and most likely won't be possible. It is significantly easier to address specific needs and move from there. Good communication can ensure such data sharing, at the same time, information should be provided before the data can be shared.

8.2.4. Availability and use of resources

8.2.4.1. Availability of and access to geospatial data and information

In TAM reports, many governments expressed a general need to improve access to geospatial information, facilitate the acquisition of space-based data, and raise awareness about the availability of such technologies among all relevant governmental bodies. The need to ensure that space-based information and products reach final users was stressed as well. To ensure access to adequate data for all relevant actors on all levels, the need to establish an NSDI was sometimes emphasized. The importance of having easy access to such data should be recognized on high political levels and addressed in national strategies. Such acknowledgment in turn would help improve the technical base. If needed, additional staff could be hired to incorporate required legal terminology to regulate data access within the NSDI. Interagency data sharing should be supported through proper NSDI implementation. There is a need to work on agreements that would address unnecessary formalities and restrictions regarding data sharing.

In some situations, access to remotely sensed data of medium and high resolution can be especially important. The working group discussion also highlighted the need for high and very high-resolution data. For instance, the lack of such type of imagery can lead to weather predictions being significantly less accurate than possible. However, data access remains the question of national security, which is one of the serious issues. Because of it, high-resolution imagery most likely will not be made as widely available as other types of data. At the same time, a need for access to data from below clouds (radar imagery) was mentioned as well. Overall, it was expressed that easier access to other kinds of data, besides Landsat and Sentinel, is needed, for instance to SPOT data (high-resolution, wide-area optical imagery).

TAMs also mentioned the issues related to the technical component of the NSDI, like data download equipment. For African countries particularly, poor ICT infrastructure and internet connectivity serve as another barrier to their development (Woldai 2020). Cooperation with foreign agencies could facilitate access to space-based data. An online database or portal providing information about and, potentially, access to available datasets (with adequate metadata) should be developed to improve access to such data on a national level. Such an online database would also facilitate more efficient use of existing resources. In some cases, the generation of relevant, adequate, and up-to-date basemap layers is needed (like land use, soil, hydro-geomorphology, water resources, socio-economic parameters, and other fundamental datasets). Apart from general awareness raising, appropriate training for relevant actors on the use of online platforms and existing systems might be needed.

On one hand, there is a need to reframe the existing data management system to provide access to humanitarian and development organizations. On the other hand, access to satellite-based resources could be facilitated through participation in relevant initiatives (like Charter or Sentinel Asia), as well as through assistance from international organizations (like UNOOSA) and their cooperation agreements with data providers.

8.2.4.2. Efficient use of available resources (human, financial, data)

Resources in general

This issue is closely related to the topics of data availability and capacity building. Different types of resources were often mentioned in the reports – human resources, financial resources, data resources, etc. Some general recommendations were asking for more adequate policy concerning NSDI to ensure efficient use of existing resources. There is a clear need to strengthen available instruments, create a specialized coordinating entity, or even establish a specialized platform for effective coordination among various actors and efficient use of common resources. The importance of better coordination is also regarded as a way to use the available budget more efficiently, in terms of both national funds well as donor support. Apart from better coordination on a national level, the importance of formalized cooperation with international and regional organizations and disaster management mechanisms to make full use of existing resources was also stressed. Some additional funding sources could be identified through such international cooperation.

Awareness among decision-makers about the possibilities of geospatial technologies should be raised to ensure that sufficient resources are allocated to the application of space-based information, including capacity-building activities. More elaborated licensing and requirements for the purchased geospatial data need to be set up to ensure multi-user licensing and data sharing across institutions, so that overall costs could be reduced and financial resources could be used more efficiently.

Another frequent recommendation is related to the systematization of available disaster risk information, for instance through an online database, to reduce duplicating efforts and use available resources more efficiently. Better documentation of available geospatial information across involved institutions can ensure more effective use of such data, however good metadata is needed for that. This kind of review could also help assess the current situation with data availability and identify areas that might require further development.

Finally, one of the most common recommendations is related to the need to conduct trainings and foster staff skills in applications of GIS software, particularly among technical personnel. Long-term capacity-building needs must be considered as well, to ensure that trained staff remains in their positions within the government. Another important aspect is related to strengthening capacities at different levels, including the local population: the importance of regular trainings, mock drills, simulation exercises to ensure good use of the international support in case of an actual disaster.

The representative of the MAGOR NGO Association for Disaster Response also listed several challenges from a perspective of an end-user, a first responder to a disaster. These, among others, particularly included the issue related to the limited time available for search and rescue. Other challenges cover the lack of relevant information or no sufficient information and issues related to the management of information that is available. Some of these problems might be addressed through quicker acquisition, processing, and provision of the value-added products, as well as through better coordination of the emergency mapping among participating entities. Other issues include the lack of sufficient equipment, no proper means of communication, and challenges related to the availability of human resources.

Financial resources

Money remains an important issue in terms of the implementation of DRR activities, particularly in developing countries, however, not the only one. Some studies already support the conclusion that investment in disaster preparedness and mitigation brings down the cost of disaster response and reconstruction activities (Meerkatt *et al.* 2015; UNDP 2015; World Bank and United Nations 2010): "*Every dollar spent on preparing for disasters saves seven dollars in economic losses*" (UNDP 2015). However, more studies and wider promotion of this proactive approach are needed to motivate policymakers.

During the research trip to ADRC, a visiting researcher explained some peculiarities of the situation in India. While the government spends a lot of money on "understanding disaster risk", for instance through developing risk maps, quite little can be spent on actual preparedness or response planning. In the case of Maldives, there is a response fund in place, however, there were no funds available for activities related to preparedness or mitigation of natural hazards. In Japan, local municipalities are responsible for developing disaster risk maps. Such an approach often leads to considerable variation in the quality of such maps, their resolution, how frequently they are updated, etc. Since this task depends only on the municipality itself and on the funds available within this municipality, some small rural communities might not have enough financial resources to update disaster risk maps regularly.

The working group agreed that limited financial resources were among the most significant and very common challenges for the countries. However, some ways around this issue were discussed and can be proposed. For instance, as mentioned in the example earlier (in the section on capacity building and trainings), an educational center in Nigeria had to accept only 10 students out of 35 qualified applicants due to the lack of funding. It was proposed to use regional networks to support such activities. Overall, differentiating the sources of funding could be a possible solution - relying not solely on governmental funding, but on resources from international donors, regional groups, and networks as well.

Another issue mentioned in the working group discussion concerned the high cost of utilization of space technologies in general. Developing countries are encouraged to use such technologies more widely, as they are at risk of falling behind if they don't, expanding the digital divide. However, it can often be a serious burden to introduce and maintain the infrastructure needed for the utilization of space technologies. Even if the initial installation of required infrastructure was supported by an international donor, as soon as the project money runs out such facilities and technologies might be abandoned, as there are no funds available in the country to keep them operational (Okereke 2017). In such cases, cheaper options can be proposed as an alternative, for instance, drones, CubeSats (miniaturized satellites), etc. For instance, for a number of years UNOOSA is supporting "orbital opportunities" for developing countries – developing and deploying CubeSats through a cooperation program with JAXA (since 2015) and through cooperation with Avio S.p.A. (Avio); accommodating and operating payloads on the Airbus Bartolomeo external platform on the International Space Station through cooperation with Airbus Defence and Space GmbH; conducting experiments on board China's Space Station (CSS) through cooperation with the China Manned Space Agency (UNOOSA 2021b).

Limited financial resources available in developing countries require creative solutions. Another proposal of the working group was to save some funds through the implementation of pilot projects locally and the wider involvement of local students (Master's and Ph.D. level). Students would benefit from such experience, and they would probably be quite interested and motivated to be involved in such initiatives.

In addition, at the GEO Data Providers workshop, during the discussion, a strong view was expressed by the audience that in the current situation, countries of the Global South will only use EO data that is free at the point of access.

Data / information overload

Data is another important resource that needs to be used most efficiently and effectively, especially in disaster response settings. Remotely sensed data, related products, and information have some characteristic features, which are discussed in the current section.

Starting with the availability of space-based data, it was once again expressed during the research visit to Japan, that just 5-7 years ago satellite imagery would probably be not that useful for rapid response to disasters. This was because there were not too many satellites available and sometimes you would have to wait for weeks to get an image (as some satellites could take 2 weeks to revisit the same area, for instance, Landsat). However, nowadays the number of available satellites is growing rapidly and depending on the situation, it might be possible to receive imagery within the first hours after the event. Some of the new commercial satellites might be able to provide an image for any area on the globe every 90 minutes or so, for instance, Planet's constellation of Dove nanosatellites (Planet 2021). Such technological advancements can be extremely beneficial for the disaster management community as the first hours after the disaster are crucial for saving lives. However, a new problem arises from that – an overwhelming amount of data to process and analyze (Sudmanns *et al.* 2020).

Before the recent technological breakthrough, when satellite imagery was collected with a lower frequency, it was relatively easy to manage the data. It was still manageable to download available images directly on the computer and use its processing capacity for the analysis and to develop an end product. However, increased frequency of acquisitions, as well as often better spatial and spectral resolution, are leading to the situation when much larger amounts of data had to be dealt with. In many cases, traditional methods could no longer be applicable. It is no longer efficient or even feasible to download all the data on an individual computer in terms of both time and processing capacity (Sudmanns *et al.* 2020).

Data science can propose some solutions to overcome this problem. There is a necessity to train more data scientists who would be able to analyze large amounts of remotely sensed data using the variety of available methods and techniques (including cloud computing, big data analysis, artificial intelligence, machine learning, deep learning techniques, etc.). Considering the petabytes of available data, it will soon (if not already) be impossible to work using the traditional approach. Since all this data cannot be downloaded, there is a clear need for cloud-based solutions (Wu *et al.* 2020). The working group also discussed the related issue of internet speed in some countries and the need for improvement.

Similar issues were raised and discussed at the GEO Data Providers workshop, often in relation to GEOSS (due to the nature of the event). As of 2020, GEOSS Platform stored information about 480 million geospatial assets, which was described as “drowning in data” (GEO 2021). However, the actual situation with data availability often depends on the specific geographic region, topic, type of the data (for instance very high resolution - VHR), etc. Another clear issue identified in regard to GEOSS is the compatibility of the available data and how ready it is for the analysis (ARD). While the current situation can be described as data rich and information poor, the Big Data approach can help mitigate related challenges (Tien 2013).

Another aspect of information overload mentioned at the Data Providers workshop was related to the fact there are already a lot of platforms, maybe too many, providing information on available geospatial datasets, apart from GEOSS. The working group also acknowledged this issue and potential overlaps between some existing and planned initiatives (GEOSS, international disaster databases (EM-DAT and DesInventar), etc.). The discussion highlighted the need for better communication between actors in the field, to avoid double effort.

Some of the existing platforms for big data management and analysis include Google Earth Engine (GEE), Sentinel Hub, Open Data Cube (ODC), System for Earth Observation Data Access, Processing and Analysis for Land Monitoring (SEPAL) (Gomes *et al.* 2020). Some data sharing platforms also include USGS Earth Explorer, USGS Global Visualization Viewer (GloVis), NASA’s EarthData portal, Copernicus Open Access Hub. JAXA also started promoting open and free access to a wider range of satellite observation data, integrating some of their portals (for instance, G-Portal) with the GEOSS portal. To name some commercial platforms, which allow open data access - ArcGIS Open Data Hub, Maxar Open Data program.

Another aspect of information overload is related to the general stream of the prepared reports and maps (sometimes duplicating or even contradicting each other) that are shared with emergency responders. Such a flood of information may overwhelm first responders when timely and accurate information is most needed. In addition, most of such products in reality might not be even used at all, which is a sign of a potential waste of resources. Haiti earthquake of 2010 is one example of the situation when information overload in disaster response was quite clear (Van de Walle and Dugdale 2012). The need for better coordination of rapid mapping during disasters was expressed, so as not to waste limited time and resources. IWG-SEM is an example of an international mechanism, working on addressing some of the related issues.

Right information/data at the right time

Related aspects of information overload could also be discussed. In the case of Japan, one of the important problems discussed during the research visit was the flood of messages that are normally sent out to the local population during disasters. In many cases, a lot of information in these messages was not relevant to some people, for instance, was related to hazards affecting a different region. One of the proposed solutions was the use of the Quasi-Zenith Satellite System (QZSS), a Japanese satellite positioning system, in combination with communication satellites, to deliver specific messages only to the affected areas. QZSS is an example of a regional GNSS. Such an approach would be focusing on identifying the proper target for emergency alerts to avoid the unnecessary flood of messages and is currently under development, though it was successfully tested (Shimazu *et al.* 2020).

The working group also discussed the importance of receiving the right information at the right time, which is especially important at a time of a disaster. At the GEO Data Providers workshop this issue also was covered, stressing that without knowing the proper location of the people in need, help might be sent to the wrong place. It is crucial to avoid such situations in disaster response activities, considering limited resources and time. It is also important to take into consideration different types of disasters and correspondingly, different ways of support. While Charter and similar SEM mechanisms could be applied in case of quick response, they do not cover slow onset disasters (like droughts) or the mitigation phase. In such situations, other approaches should be considered, for instance, GEO could be providing support for these events, as well as Copernicus EMS' Risk and Recovery Mapping services.

The basic idea of the 80/20 rule of data analysis, particularly in relation to satellite imagery, is that users could spend 80% of their time finding, cleaning, and reorganizing huge amounts of data, and only 20% of their time on actual data analysis (Carmichael and Marron 2018). To help with this challenge, wider use of analysis ready data (ARD) is often proposed. ARD can be described as satellite data that was preliminarily processed and organized in a way that allows immediate analysis with minimum additional efforts from the user (Dwyer *et al.* 2018). Such data is already stacked in time and calibrated, so that the user can access a time "stack" for any available area and use it to perform, for instance, time-series analysis. Landsat imagery archive is an example of a database with readily available ARD, though this approach is being extended to other data sources (Dwyer *et al.* 2018; Frantz 2019). ARD was also an important topic of discussion at the GEO Data Providers workshop, covered in multiple presentations, particularly by CEOS and Development Seed company. The discussion highlighted different types of ARD: analysis ready data; application ready data; and AI ready data (Schuler 2018). CEOS Analysis Ready Data (CEOS ARD) is one of the initiatives that aim at reducing the burden on global satellite data users and help limit the disconnect between the community of satellite data providers and end-users (https://ceos.org/ard/).

A professor from Yamaguchi University stressed that there remains a significant gap between space agencies (as data providers) and actual data users. From their perspective, the most important element of this issue is data provision. End-users (practitioners) might not have the capacity, time, or skills to make use of the raw data. Because of this, it is important to make such remotely sensed data understandable and useful, to provide value-added services.

Discussions at the GEO Data Providers workshop also highlighted the differences in the needs and capacities of various kinds of users of the EO data. Particularly, three types were defined - casual users (with low skills in the application of geospatial technologies and no interest to invest time in learning), students and researchers (with low to medium skills and desire to learn and explore), and EO specialists (with high skills and expertise in the area). Overall, the population of casual users is incomparably larger than the number of researchers and specialists. Each group has its own goals and thus might require different tools. While the move from “small data” to “big data” in EO continues, the general public is becoming more and more involved (Siqueira and Hosford 2018). Now, since there are many more not-so-sophisticated users, there is a need to reduce the complexity of the provided data and information and improve interoperability. Analysis- and application-ready data supported by modern technologies (like machine learning and deep learning) is seen as a tool that can help ensure wider and more beneficial application of EO data (Schuler 2018; Siqueira and Hosford 2018).

The audience of the GEO Data Providers workshop also mentioned a number of related concerns: too much data being available, which is a problem for end-users as too much time is spent looking for the right data; identification of the best information available on particular applications; lack of the clear policies on the use of EO data and information. The role of UNOOSA was highlighted, as a source of information on the availability, applicability, and reliability of data. The working group also mentioned UN-SPIDER as one of the organizations that could be helping with finding the right data.

8.2.4.3. Open data policy, resource sharing

The need for effective data sharing policy on a national level and free access to all data relevant to disaster management and risk reduction was mentioned repeatedly in the TAM reports. Unnecessary formalities and restrictions should be avoided especially in case of emergencies. Such policy should be supported by appropriate infrastructure and technology. In many cases data, technology and infrastructure might already exist in the country, just not being properly used. One way to facilitate this data-sharing strategy could be done through establishing a special multi-sectoral platform/portal for information exchange, cooperation, and coordination. Data sharing should be conducted in a transparent manner, involving all relevant sectors and on all levels, including local communities, which is critical. Special mechanisms need to be put in place to ensure that not only final products (maps) would be shared, but if needed, raw data as well. Apart from data sharing on a national level within the government, access to relevant information could be also provided to humanitarian and development organizations. Multi-user license agreements were repeatedly mentioned as a great way to facilitate data sharing between all relevant actors and ensure efficient use of available resources. However, such an approach needs to be enforced through policy and coordination.

Another related issue mentioned by the working group is focusing on the situation with countries that launch small satellites using the support from more developed states. Such type of support normally implies that the country that received assistance would have to share the collected data. However, quite often it is not happening, and the data is not shared outside the country. Similarly, in the case of some projects funded by international donors, countries often do not share the data, even with organizations within the same country. Due to the nature of the provided support, there should be no excuse to hide this data. Except for South Africa, this situation seems to be particularly common in the African countries - researchers and the private sector face restrictions in accessing data from satellites launched by their countries.

Bureaucracy and related complications in getting access to this data, lead to Landsat or Sentinel data being the preferred option (Woldai 2020). This issue should be considered and addressed, for instance by including a condition to share the data collected through such collaborative projects in the agreements.

An additional example of a faced challenge in information sharing was noticed by the project manager of a Charter activation. Some disaster management agencies, as end-users of the products developed by this mechanism, were not willing to share data with other agencies or were delaying the provision of this data. To ensure that the relevant data is reaching other agencies as well, a coordination platform might be put in place to facilitate the process.

It is also important to acknowledge not only the scientific and humanitarian benefits of free and open access to satellite and other geospatial data but economic benefits as well. Since 2008 Landsat data has become available for free. The high intrinsic value of the imagery to users was confirmed by the study by Loomis et al. (2015), which calculated that the annual benefit to USA users in 2011 overall was estimated at around 1.8 billion USD, for 2.38 million scenes downloaded (Loomis *et al.* 2015). Another study roughly confirmed these estimations, also indicating that in 2011 free Landsat imagery also can be accounted for 400 million USD for international users (Zhu *et al.* 2019). Similarly, the cumulated economic value generated by the Copernicus programme by 2020 is estimated around 10.8-13.5 billion EUR (with the overall investment in the programme of 7.4 billion EUR). At the same time, it was estimated that the initiative would support from 3 050 to 12 450 jobs years across the EO downstream and end-users markets over 2015-2020 (PwC 2016).

Transboundary data sharing

An issue of availability of transboundary data was mentioned at the GEO Data Providers workshop, as a serious problem especially in the case of water management. Data diplomacy on an intercountry level, as a “willingness to share”, might support resolving this issue. Overall, there remains a need for a common understanding and agreement, and, especially in the case of in-situ data, for greater collaboration. The situation with remotely sensed data is a bit different since there are no boundaries from space and satellites can provide imagery across the globe. As a regional example, it seems that the data sharing among space agencies of the African countries is quite limited at the moment. There is a need to facilitate partnership between the countries to encourage wider access to satellite imagery (Woldai 2020).

The working group also discussed the applicability of space technologies in transboundary issues. It was already briefly mentioned how commercial data could be used and shared among different organizations within the same country, particularly through multi-user licensing. A similar approach could be applied for transboundary data acquisition, which could benefit a number of different countries. Buying licenses for group use, or through other similar initiatives, would help minimize the total costs of the data, which would be particularly beneficial for developing countries. The working group also discussed a potential need to establish a coordination mechanism to collect data from various organizations on the regional level.

Sharing good practices

Another aspect of open access to information is related to sharing good practices. A lot of knowledge on the application of geospatial technologies already exists, however, is not shared or used enough, including information about conducted projects, various successful case studies, lessons learned, etc. It was expressed in the TAM reports that having a platform or a database with at least a list of such activities could be very useful. The issues associated with knowledge transfer were also identified by Albris et al. (2020) as one of the three main challenges within the interface between DRR science and policy. They mentioned that, at least among EU member states, required institutional structures might not even exist at the moment, and because of the lack of a common strategic approach, occurring knowledge transfer most often is happening within a specific sector and on a one-time basis and not in a systematic way (Albris *et al.* 2020).

The need for a dedicated platform also quite clearly coincides with the recent activities of the GEO, which are focusing on capacity building and knowledge sharing. For instance, GEOSS is one of the initiatives that facilitate data sharing, including the provision of open datasets, as well as examples of practical applications. In addition, UN-SPIDER through its Knowledge Portal shares recommended practices on the use of space technologies for DRR (detailed step-by-step procedures), as well as user stories and case studies as examples of the application of space-based information (UNOOSA 2021b). It was highlighted that this platform could potentially be used more widely and promote sharing of such information. UNOOSA's Space4Water Portal can be considered as another example of a similar initiative, this time covering a particular sector. The project is focusing on the application of space-based technologies for increased access to water. One aspect of the value added by the project is by providing a platform for sharing information on related projects, initiatives, software, data portals, capacity-building and training material, conferences, workshops, etc. (COPUOS 2021).

Privacy issue

As was discussed earlier, satellite data with high and very high resolution is becoming more and more widely available, though not always easily accessible. Such technological advancements provide new opportunities not only for research, but also for DRR activities, for instance through more precise risk assessment, more detailed post-disaster damage assessment, or as an alternative for aerial data. At the same time, as satellites do not see borders, access and use of this kind of data are being recognized as a sensitive issue, covering such topics as privacy, data protection, and ethical risks (Santos and Rapp 2019).

National regulations of some countries are already imposing restrictions on the resolution of the satellite products - for instance, in the USA the resolution of the imagery cannot be finer than 0.31 m. At the same time, such regulations do not exist in some other countries and thus are not restricting local satellite imagery companies (for instance, this is the case for India and China). ISRO's Cartosat-3 satellite already provides panchromatic imagery with a resolution of 0.28 m. It is recognized that this situation requires a comprehensive solution on an international level (Coffer 2020). Most likely, high-resolution satellite data will remain not as widely available for the users. Acknowledging the importance of open science, some of the discussions around this topic even propose to introduce a clearing process for individual users, before they can access imagery of such resolution (Coffer 2020).

As a different aspect of the issue, it is important to mention that location information, in general, can be considered more sensitive than other kinds of information. At the same time, in emergencies, information about the location of people is crucial. Still, typical emergency services quite often might not be able to accurately locate the caller since they rely on old technologies, using cellphone towers triangulation and not GPS tracking (Al-Nuaimi *et al.* 2021; Chopvitayakun 2020). Considering how precise are modern taxi or food delivery applications, this issue can be seen as even more pressing.

Even when access to location information is justified by its purpose, particularly, in case of emergency response, this still raises a lot of concerns related to privacy. At the same time, a number of applications and related services are being developed, by commercial companies as well. The following initiatives can be mentioned, just as examples: Facebook Disaster Maps; multiple initiatives by Google, like Google Public Alerts and Google Crisis Map which are now integrated with Google Search and Google Maps (provide official information on disasters from partners), and Google SOS Alerts (which also considered other nontraditional sources, like Facebook and media internet info). Google's Android also has a special emergency location service (ELS) that supports first responders and allows them to locate emergency callers more accurately. The operation of this tool relies on national partners (governments, mobile operators, and public safety providers). Since 2018, Apple devices also support similar technology. Overall, as of 2022, only 29 countries in the world (mainly Europe) had deployed the Advanced Mobile Location, a protocol that allows sending accurate location information of the caller (based on GNSS, Wifi) to the emergency services (EENA 2022).

At the same time, information on the location that can be collected by modern smartphones can create new issues, if not used correctly (Elwood and Leszczynski 2011). For instance, a heatmap published by the fitness tracking app Strava at the end of 2017 unintentionally gave away the locations of military bases across the world. Even though the data was aggregated, to exclude the possibility to identify individual users, the precision of the coordinates collected by the app was enough to highlight some very sensitive territories (Hern 2018). Overall, aggregation seems to be the main way to comply with the privacy requirements, when such data could be made public, particularly through the temporal aggregation of the data, spatial aggregation, and spatial smoothing/filtering.

8.2.5. Data and information management

8.2.5.1. National Spatial Data Infrastructure

The current section discusses TAM recommendations that clearly mentioned NSDI. Due to the quite complex nature of NSDI, many other important aspects and elements of this framework are discussed as parts of other sections of this chapter. Overall, some of the most common recommendations stress the need to establish an NSDI or revitalize already existing structures through updated policies. NSDI is regarded as a key to adequate information management that would enable the exchange and access to geospatial data. In relation to NSDI, special platforms or working groups could be established to facilitate discussion of corresponding issues or coordinate technical activities.

An advocacy campaign on the importance of NSDI for DRR and sustainable development must include all relevant institutions and the local population. NSDI could be strengthened through cooperation with relevant international organizations, for instance, with the support from UNOOSA, if needed. Data sharing was regarded as an especially important aspect of NSDI that has to be clearly defined through policy as well as supported by appropriate infrastructure and technology. NSDI was often regarded as a comprehensive database of all information and resources available, while the need for compatible data standards was also expressed.

On a similar topic, during the research visit to Japan, one of the important issues that were mentioned by the representatives of the Fujitsu company was the lack of universal (unified) databases in the countries. Sometimes there might be no common system even between different departments of the same government. Quite often these governmental entities do not want to share their data, since some data can be considered sensitive by a particular department and not suitable for being made public. Their worry is related to the fact that if such data is to be shared with other departments of the government (for instance, all those involved in disaster management), it could somehow get leaked to the public. There are often no clear regulations on how to deal with this issue.

The working group discussed bad data sharing practices, using the case of Nigeria as an example. At the time of the discussion, no national agency solely responsible for all geospatial data existed in the country. Several separate agencies were working with similar kinds of data. The working group highlighted the need to encourage data sharing and ensure better management on the national level, before moving to regional cooperation. During the research trip to Japan, this approach was also supported - to develop a proper global disaster database, first, a comprehensive database on a national level must be created, before sharing the data with an international repository.

8.2.5.2. *Data and information flow*

Ensuring that geospatial information reaches final users was stressed in the TAM reports as one of the most pressing issues. To ensure this, access and distribution channels should be assessed and strengthened, dissemination programs should be designed, and related policies should be developed. The roles of all entities involved in data and information management in relation to DRR must be clearly stated. Information flow for early warning and during disasters is of particular importance – all organizations involved in early warning must be well coordinated, and sound communication and data dissemination channels between them must be in place. Clear guidelines and contingency plans describing information flows should be developed. Data providers and data users must be identified and a special platform (formal or informal) could be established for these organizations to discuss their issues and challenges. Additionally, the skills of the staff from data-providing agencies could be upgraded through training, if new tasks require this.

Apart from satellite data (ex-situ), it is also important to mention the role of in-situ observations. With the growing availability of remotely sensed data, ground measurements still bring crucial value, not only serving in the validation of satellite data but also bridging the gaps when information simply cannot be collected from space (or not in a sufficient quality) and providing reference data, for instance for modeling (Balsamo *et al.* 2018; Teillet *et al.* 2002). One of the major challenges related to in-situ observations is the difficulties related to coordination in this field. Unlike satellite observations, which have established international controlling bodies (for instance, CEAS - Council of European Aerospace Societies), in the case of in-situ measurements there are no similar mechanisms, leading to a great diversity of data collection methods, standards, techniques being used by various entities. Some other challenges related to the use of in-situ data include the lack of guarantees of long-term availability of this kind of observation, imposed restrictions on the use of in-situ data (by the data owners), remaining data gaps in in-situ observations, particularly data not existing or having an insufficient temporary or spatial resolution, or quality (Copernicus 2021).

As a regional example of the distribution of responsibilities and related information flow, according to the ADRC representative, in Japan municipalities are responsible for issuing evacuation information, not the national agency. Similarly, river management is organized depending on the size of the river: the biggest rivers are managed by the national government; medium – by prefectures; small – by municipalities. At the same time, all related data is shared among stakeholders.

Fundamental datasets and essential variables

Additionally, the lack of key (fundamental) datasets and the need to develop this kind of baseline geospatial layers were mentioned several times, mainly by the countries in Asia. It is also important to identify which fundamental datasets might be currently missing and develop a plan to produce them, as well as ensure that such basic datasets are up-to-date and available to all users. These thematic datasets should be developed at the highest possible resolution and scale. It is also important to be able to integrate national data with other key regional and global data, to make sure that national data is compatible with this kind of datasets. NSDI was often mentioned in relation to the discussed topic as a key element for effective data and information flow (access and exchange).

The concept of Essential Variables (EVs) is in a way related to fundamental datasets and is used increasingly more often among EO communities. EVs can be defined as a minimal set of variables, needed to determine, assess, and predict the developments of the system (Bombelli *et al.* 2015). This set of indicators depends on the focus area, for instance, there could be EVs for climate, weather, biodiversity, agriculture - quite often these can overlap. GEO provides a collection of essential datasets, as well as has a GEOEssential project and plans a number of activities dedicated to the development of EVs, gap and overlap analysis, and expansion to new domains (GEO 2019). Initial analysis and identification of gaps in EO variables were already performed by GEO through developing a graph of the EO networks and their relationships, as well as a graph of the relation among SDGs indicators, EVs, and these networks. However, the project under which the graphs were developed and analysis was performed (European Observatory of Earth Observation Networks - ENEON) focused generally on non-space in-situ observations (Masó *et al.* 2020).

8.2.5.3. Guidelines, standard operation procedures, and data standards

Quite important elements that were frequently mentioned in the TAMs were routine mechanisms for the application of EO and working level SOPs that could be used in various situations, but most importantly – during emergencies. Special guidelines and mechanisms should be developed to describe information flows, data (including raw data), and information transmitting and receiving procedures. To ensure that, SOPs with detailed operation flows, clear roles and responsibilities of all involved entities, could be developed. Depending on the situation, it might be needed to translate guidelines and SOPs produced by international/regional organizations into national languages to ensure their wide distribution. Specific training for relevant stakeholders on the use of such SOPs as well as the data standards might be needed as well.

The lack of guidelines and standards for the generation of geospatial and disaster-related information was also stressed. The importance of such standards must be mentioned in high-level documents for a more reliable NSDI. One important characteristic of geospatial data that might be standardized on a national level is the resolution – in many cases, high-resolution images (with appropriate spectral and spatial resolution) are essential, especially for island states. Additionally, some standards should be applied to metadata creation to guarantee proper data documentation, which is crucial for adequate database inventory.

Representatives of the ADRC highlighted the problematic aspect of the differences in the definitions related to DRR, which are used in different countries. For instance, this situation might lead to some complications with the reporting under the Sendai framework, as well as on the progress in achieving SDGs. For instance, in Japan the general term “affected people” (particularly related to Sendai’s Global target B) is not used at all. At the same time, international frameworks allow countries to use their own definitions and statistical methods.

One of the issues that can arise from the differences in the standards used in various databases is related to the identification of specific disasters, particularly those of multicountry and multiyear nature (Below *et al.* 2007). To deal with this issue, ADRC proposed to develop an international system with would assign a unique identifier to each disaster that happens. This system is called GLIDE (GLobal IDEntifier Number) and it is active since 2004 (www.glidenumber.net). Such an approach reduces the confusion in finding information about a particular disaster, as well as supports more efficient data sharing (Nishikawa 2003).

Data Management Principles

Group on Earth Observations (GEO) formulated its principles for managing and sharing geospatial data, information, and services. Overall, the list includes ten principles grouped into five categories:

1) discoverability (1. metadata for discovery);
2) accessibility (2. online access);
3) usability (3. standard data encoding; 4. well-documented metadata; 5. data traceability; 6. data quality-control);
4) preservation (7. data preservation; 8. data and metadata regular verification);
5) curation (9. review and reprocessing; 10. data tagged with permanent ID).

These principles, as well as corresponding implementation guidelines, can help databases improve their practices and ensure easier and wider access to and application of geospatial data and information (Downs 2017).

Another similar, yet more wide set of guiding principles, which can also be applied to geospatial data, is the FAIR Data Principles. These principles aim at ensuring that data is Findable, Accessible, Interoperable, and Reusable (Wilkinson *et al.* 2016). This approach has a lot of similarities with the GEO's Data Management Principles. However, open access to data and related information is considered more a priority for the EO community, which is reflected in GEO's guidance, but not so definitively in the FAIR principles (Chen *et al.* 2019).

8.2.5.4. Databases and metadata

Databases were often mentioned in TAMs as a crucial part of NSDI. One of the most important requests was to develop a national online database with available geospatial data and satellite imagery, supported by an adequate metadata catalog. In relation to this, a very common recommendation asked for the promotion of interoperability of the geospatial database and generated metadata. To ensure that, clear guidelines are needed to develop such inventories or a portal and ensure their interoperability. A comprehensive list of data resources existing on the national level, supported by adequate metadata, should be developed and be available for search and request to all stakeholders. Additionally, a database on the existing activities in the DRR sector could be developed to improve coordination and reduce duplicating efforts of involved organizations. From the technical point of view, more storage capacity is needed to increase archiving database sizes as part of the long-term development plan.

At the same time, it might be important to mention some rather recent regional developments. In 2019, the Africa GeoPortal was launched (https://www.africageoportal.com/), providing access to various geospatial datasets, at the moment covering seven countries. The platform is powered by Esri technology. Datasets are provided by various organizations, including Esri, regional and international initiatives, national governments of the participating countries, as well as other users including the private sector and academia. At the end of 2021, another regional initiative was launched - Africa Knowledge Platform (https://africa-knowledge-platform.ec.europa.eu/), developed by the Joint Research Centre of the European Commission. This initiative aims at being a "one-stop knowledge shop" to help address development challenges in the region. Apart from geospatial datasets, it provides access to information about various analytical tools, stories, JRC's partners working in the region (JRC 2022).

During the research visit to Japan, representatives of the Fujitsu company mentioned the lack of historical data in the existing databases as one of the main problems. In many cases, such information does exist on the national level, but it is not easily accessible as it must be converted from paper records to the digital version to be usable. If performed manually, this process can be very time-consuming. A potential solution could be to use crowdsourcing techniques, for instance using already existing platforms for people-powered research, like the Zooniverse (https://www.zooniverse.org/). However, this approach cannot be applied in the case of sensitive data, considering that the data related to disasters often are highly sensitive. Another option, suggested by Fujitsu is to use AI to convert paper records into digital format. This approach would be much faster, however, it will still require "supervision" by an actual expert, to avoid errors during the conversion.

8.2.6. New technologies, tools, maps

8.2.6.1. GIS tools, imagery, equipment, environmental monitoring

This section brings together quite a diverse group of recommendations, that were focusing on specific geospatial tools, techniques, and equipment. Some general suggestions mentioned the need to introduce topics on satellite data, geospatial software and hardware into international cooperation agreements. It was mentioned that new national programs on the application of geospatial technologies should cover relevant technical aspects, such as spatial analysis, monitoring, modeling, and development of GIS-based tools. Overall, the decision-making process could be supported by the application of GIS technologies by various actors. An entity focusing on geospatial information generation could potentially be established. It was emphasized that all gathered and generated data should be analyzed and assessed through GIS software to make the most use of it.

Some recommendations proposed to set up adequate and operational telecommunication systems which would cover all relevant organizations. These systems could provide high-speed internet, reliable phone connections, as well a satellite-based emergency communication system. Links between national organizations and international initiatives could be facilitated through, for instance, virtual conferences. Telehealth and telemedicine could also be explored as potential areas of future applications.

Other recommendations were focusing on the type or quality of the satellite imagery. Capacity building in the application of radar imagery (SAR), particularly in the field of data acquisition and interpretation for disaster management, was mentioned several times. The working group also discussed opportunities provided by radar imagery, in terms of flood detection, since radar imageries can "see through clouds" and thus, unlike optical imagery, can be used even during heavy rains.

The need for a network of real-time hydrological and meteorological sensors was also expressed in the reports. The importance of adequate environmental monitoring, modeling, and forecasting was discussed. Also, it was mentioned that satellite navigation systems have to be strengthened, for instance, through high accuracy GNSS receivers and GPS units in cars participating in emergency response activities.

Resolution of remotely sensed data

Recommendations often expressed the need for appropriate spectral and spatial resolution (medium or high resolution depending on the task), to generate value-added products for DRR and emergency response. At the same time, the working group also discussed more technical parameters, particularly the need to enhance not only horizontal but also the vertical resolution of remotely sensed data (elevation, water depth, water extent). The Hydroweb project of Theia Data and Services centre for continental surfaces is currently providing data on water levels of major rivers and lakes around the world, measuring it using satellite altimetry. In the future, it might also provide information on water discharge. Such observations could be used as a support or even an alternative to in-situ measurements in the areas where the ground monitoring network is not present or is degrading (Tarpanelli *et al.* 2019). At the same time, the working group expressed the overall importance of satellite data validation. While some gaps in the ground monitoring could be filled by satellite imagery, data still should be somehow checked.

Modern space-based technologies already allow near real-time monitoring of the Earth, and potentially could even serve as an alternative to aerial data. On one hand, the availability and resolution of satellite-based products are already enough to forecast some disasters, particularly floods, with better precision and quicker than when relying on ground stations (Belabid *et al.* 2019). On the other hand, the diversity of satellites helps collect imagery of a particular area much faster, which could be crucial in case of a disaster. Planet's constellation of Dove nanosatellites is one example of such near real-time EO (Planet 2021). At the same time, satellites remain just a technology. It is already available and operational, however, all potential applications which could benefit from using such data (near real-time, very high resolution) are still being explored.

Yamaguchi University, as well as UNOOSA, introduced some examples of how quick the provision of satellite data could be nowadays. Before it could have taken days to receive usable imagery of the area affected by a disaster. Nowadays fast activations of the SEM mechanisms and a growing number of available satellites resulted in the gradual shortening of this delay. While it still depends on the satellite position, as well as sometimes on the presence of clouds (depending on the type of sensors), with enough luck, satellite images might be available already within the hours after the disaster. The processing of the raw imagery, as well as provision of the value-added products are also taking less time with the wider introduction of automated processes. As an example, Yamaguchi University highlighted how the process of a flood extent map creation could be accelerated through the automatization of some of the steps, bringing the time required for this process from 8 hours to only 2.5 hours (using AI and Deep Learning techniques) (Sirirattanapol *et al.* 2018). In the earlier chapter on SEM mechanisms, the delay in the provision of the satellite imagery and products was briefly discussed.

Big data, cloud computing and Open Data Cubes

The concept of Open Data Cubes (ODCs) is among the most popular and widely discussed nowadays, considering the potential range of applications this technology can bring. This initiative provides an open and freely accessible data exploitation architecture that allows easier and more efficient exploration of the EO data (Killough 2018). Technology is largely based on cloud computing that allows multi-temporal analysis of available satellite images. At the same time, analysis ready data (ARD) is the core element of every data cube and the growing availability of ADR datasets supports the wider expansion of this technology (Killough *et al.* 2020; Killough *et al.* 2021). ODCs are lowering the technical barrier in the exploration and application of satellite-based data and can provide multiple benefits in various domains, including SDGs (Dhu *et al.* 2019).

After the success of the first Australian Geoscience Data Cube project, several other data cubes in various countries around the world were being established or at least proposed. Some of the examples include data cubes in Colombia, Switzerland, Taiwan, and Africa Regional Data

Cube. The latter initially supported five countries in the region, but recently transitioned to the Digital Earth Africa platform that aims at covering the whole continent (https://www.digitalearthafrica.org/) (Killough *et al.* 2020).

Data cubes could support emergency support activities by facilitating the development of value-added products in rapid disaster mapping. One such example is the cooperation between Taiwan Data Cube and Sentinel Asia, one of the discussed SEM mechanisms (Cheng *et al.* 2020).

On a similar note, the working group discussed the availability of the longtime span of satellite images, particularly in terms of the need for historical imagery, not necessarily in high resolution. Data cubes could be a good solution to cover that particular need. Overall, the ODCs initiative was mentioned as a very promising technology, which, however, can be complex in many aspects and bring its own challenges, including installation/configuration burden on the country and the need to scale up this solution to ensure its wider use (Giuliani *et al.* 2020).

According to GEO representative, since ODCs can operate with big data, they can solve some of the big data challenges related to volume, variety, and velocity (3Vs) (Bagheri and Shaltooki 2015; Giuliani *et al.* 2020). Big data requires new concepts and approaches, as it is no longer possible to use traditional techniques, downloading and processing the data on individual computers. Big data problems in terms of EO include, among others, overwhelming diversity and amount of openly accessible imagery (Landsat, Sentinel, etc.), and the lack of knowledge, infrastructure, and/or resources to access and use available space-based information among many developing countries (Chi *et al.* 2016). Particularly, CEOS is often receiving requests from countries to support them in data access, processing, and analysis. Data cubes can help address some of these challenges, as they can provide analytical capacities where needed, taking the burden of the analysis and data processing from the client (user) to the server side. Google Earth Engine (GEE) is another example of a cloud computing platform that was created to address some of the challenges brought up by remote sensing big data processing and analysis (Amani *et al.* 2020).

On another note on the topic of cloud computing, NASA, one of the largest producers and providers of free and open EO data, is developing a cloud-based platform, Cumulus, which will allow ingesting, processing, cataloging, archiving, and distributing NASA's data products (Frederick and Quinn 2018). NASA is already providing access to petabytes of data, and it can be expected that this stream will continue to grow exponentially in the coming years. Cumulus will not serve just as an archive - it is an open-source framework, designed to maximize reuse and shareability, as well as scalability and reliability (Development Seed 2021).

Considering the huge amounts of data that are being constantly collected, stored, and distributed, some innovations in the data compression techniques could also be very beneficial to the field of satellite-based EO. Compressing such data without the loss in quality of the decompressed product could greatly support the field by speeding up data transfer services, as well as improving access to knowledge, allowing easier access to data for users with poor internet connection. DotPhoton is an example of a company working on lossless data compression. On the topic of high-speed data transmission, Airbus through a public-private partnership with ESA is providing SpaceDataHighway services - laser communication infrastructure for data transfer from low-Earth orbit satellites and airborne platforms to receiving ground stations in Europe (Hauschildt *et al.* 2019).

Regarding GEE and available open-source cloud-based platforms, the working group discussed the importance of programming and coding skills. Free cloud computing platforms do provide great opportunities, as they do not require high computer processing capacities and rely mainly on the internet connection, however, the need to develop appropriate skills among the users was expressed. This concern is also related to the limitations in the wider application of big data analysis, AI, machine learning algorithms. In addition, wider availability of analysis ready data, application ready data, and machine learning ready data can benefit the users, since it can facilitate and accelerate the analysis, as a large portion of the data processing would be done in advance (Schuler 2018).

Volunteered geographic information

The importance and applicability of crowdsourced information, particularly in the form of volunteered geographic information (VGI), were often mentioned by the experts and at the visited events. This kind of data can be broadly defined as online user-generated geospatial data, and it is generally accepted that it can provide various benefits at all stages of the disaster management cycle (Haworth and Bruce 2015). At the same time, VGI has a number of its limitations, particularly related to the quality and overall trustworthiness of this data, considering this approach is based on the efforts of private citizens, which generally won't have specific technical knowledge or expertise in the application of geospatial technologies or DRR (Haworth 2018; Senaratne *et al.* 2017). The need to consider citizen science as a potential data provider in GEOSS was particularly expressed at the Data Providers workshop. GEO promotes a greater connection between space-based and in-situ data, which could be collected through various methods, including crowdsourcing. One of the GEO's community activities defined in the 2020-2022 Work Programme cover EO and citizen science (GEO 2019).

Overall, digital humanitarian volunteers represent a rapidly developing and expanding field, bringing new opportunities as well as challenges (Radianti and Gjøsæter 2019). Several well-established crowdsourcing initiatives that support disaster response and provide mapping for humanitarian emergencies already exist, particularly, MapAction (https://mapaction.org/), Ushahidi (www.ushahidi.com/), Humanitarian OpenStreetMap Team (https://www.hotosm.org/), StandBy Task Force (https://standbytaskforce.wordpress.com/). At the same time, most of their activities related to volunteered geographic information take place after the disaster itself. In many cases, most vulnerable territories require support and information in advance, particularly open and accessible maps that first responders will be able to use in case of a disaster. Missing Maps (https://www.missingmaps.org/) is a humanitarian project that addresses this issue. Such crowdsourcing initiatives bring together a great number of volunteers who can process imagery of huge territories - something that otherwise cannot be done as fast, for instance, by commercial companies.

Low-tech, low-cost solutions

Taking into account the diversity of existing innovative technologies, it is still very important to consider scenarios of using EO data in low-tech environments. The topic of the cost and complexity of modern geospatial tools and technologies was raised on multiple occasions. The working group discussed the high costs of the application of space technologies, which is particularly problematic for developing countries. The need for cheaper solutions was highlighted, mentioning drones and nanosatellites as examples.

Several potentially useful technologies were often mentioned throughout the participant observation. In Japan, drones were still not that widely applied, particularly not for the purpose of identifying the location of people. Fujitsu representatives mentioned that the drones were used in the Philippines in situations when other communication means are disabled (Sandvik and Lohne 2014). Overall, the current benefits and potential application of humanitarian drones are widely accepted (Emery 2016; Rejeb *et al.* 2021; Sandvik and Lohne 2014).

Drones, or unmanned aerial vehicles (UAVs), can often serve as an alternative to high-cost and high-maintenance satellite or plane-based aerial EO technologies. Drones can provide low-cost high-resolution imagery, require little preparation and infrastructure, and can support activities in multiple areas, including DRR, search and rescue operations, and damage assessment (Ab Rahman *et al.* 2019; Schaefer *et al.* 2020; Whitehurst *et al.* 2021). Like any other technology, drones have their limitations, which include relatively small coverage of the territory, compared to satellites, their dependence on battery charge and weather conditions, as well as some safety and privacy considerations (Gilman 2014; Schaefer *et al.* 2020).

To address some of the challenges related to access to space technologies, UNOOSA, in cooperation with space agencies, research institutions, and industry, is promoting its Access to Space for All initiative. This initiative is particularly focusing on non-space faring and emerging space-faring nations and aims at bridging the space capabilities gap among countries (UNOOSA 2021b). It provides opportunities to build national capacities in different areas, including hypergravity and microgravity experiments in orbit, satellite development (development, deployment, and operation of satellites, particularly CubeSats), and space exploration. CubeSats are small, light, low-cost nanosatellites that can be put together using available commercial off-the-shelf hardware. The benefits provided by this type of satellite were already proven by the experiences of such commercial companies like Planet. At the same time, it is important to keep in mind that nanosatellites have some specific limitations dictated by their nature (Mateo-Garcia *et al.* 2021).

While nowadays there are opportunities for countries to join space exploration with satellites that are not as expensive as they were before, this technology remains rather complex and requires specific expertise. At the same time, the need for more low-tech solutions in DRR and management is still certain. Technologies are considered to be low-tech if they existed for many years and do not require research and development activities. Mentioned crowdsourcing initiatives that provide VGI could be included in the list of such technologies since they rely on already established technology, generally rely only on internet access, and any specific expertise is generally not required from participants. The advancement of smartphones and their wider spread among the general population across the globe is also an important aspect to take into account, considering their high precision and variety of potential applications. In terms of disaster response, most often low-tech solutions are mentioned in relation to communication and coordination of first responders (Beauregard and Kenn 2007).

In addition, some of the concerns related to the challenges of resource-limited countries in terms of the application of space-based technologies could be addressed through the use of free and open-source GIS software, cloud computing, ODCs, and similar technologies.

8.2.6.2. Risk assessment/mapping

Most recommendations related to this topic focused on hazard, vulnerability, and risk assessment, particularly in terms of map creation or update. To conduct comprehensive risk analysis on a national level, special GIS-based tools could be developed. A risk atlas for the whole country could be created based on the different types of data available (on regional, national and local data), including satellite imagery. If some of the baseline layers or key datasets for this analysis are missing, they should be generated using the raw data with appropriate (or even the highest possible) spectral and spatial resolution. These key datasets would play an especially important role in the generation of rapid emergency response maps.

To combine all these different kinds of information and conduct risk analysis, appropriate methodologies for the integration of satellite imagery, geospatial information, and socioeconomic data should be put in place. Different agencies will have to coordinate with each other to share required data, while a specific entity should be given the mandate to conduct risk analysis and mapping. Additionally, some courses on the application of remote sensing in risk assessment could be conducted.

8.2.6.3. Early Warning Systems

Some TAM recommendations did address the issues of early warning systems (EWS), however, this topic was not too common. Better coordination between organizations involved in early warning was highlighted most often. The importance of guidelines for carrying out early warning and requirements for related training activities were discussed as well. Capacity-building activities on the use of geospatial technologies, improvement of the monitoring and warning service, information dissemination and communication were referred to repeatedly. The need for more accurate and localized early warning information was pointed out. The significance of meteorological data was particularly mentioned in relation to various needs: closer cooperation with meteorological departments; expertise in applications of meteorological satellite data; faster data distribution and issuing warnings.

The application of QZSS (positioning satellites) in combination with communication satellites can be used to deliver warning messages to specific locations to avoid the flood of messages (Shimazu *et al.* 2020). The proposed initiative is focusing on ensuring information exchange between smartphones even in case the ground-based system is down. The initial project included only QZSS satellites, that are covered only the Asia-Pacific region. Following the success in the application of this technology, a global GNSS-based Emergency Warning Service, based on the EU Space Programme Galileo, has been tested. Representatives of the ADRC mentioned that such technology could be especially efficient for island nations. In case it is successful, within the next few years the whole globe could be covered by this technology.

In terms of EWS, ADRC representatives also introduced the Kobe city river monitoring cameras, which provide real-time information through the TV and internet (Figure 42), as well as the Hyogo Interactive CG Hazard Maps (http://www.hazardmap.pref.hyogo.jp/english.html). This system is especially important in case of sudden flash floods, which are quite common in Japan. While many of the rivers are rather narrow and remain shallow most of the year, the presence of mountains near populated areas can result in very quick and dangerous flash floods.

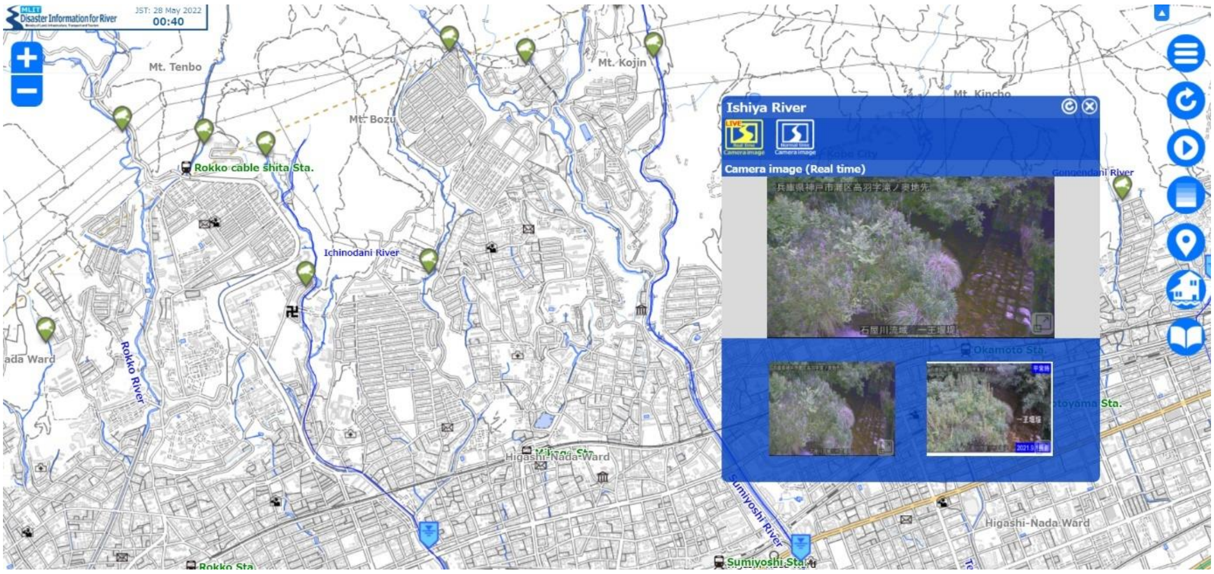

Figure 42. Interactive map on Japan's portal "Disaster Information for Rivers"

Source: MLIT 2022.

The working group also expressed the need for more advanced EWS for flash floods, since these kinds of floods often can be simply missed by the satellites, due to their quick nature. Regional EWS was also discussed, as there might be a need for that, especially among downstream countries.

8.2.6.4. Emergency response

Some of the most common issues on this topic that were mentioned in TAMs included capacity-building activities in the application of remote sensing and geospatial technologies in emergency response. It was also proposed to develop working-level SOPs to facilitate the use of such tools and methods during emergencies. SOPs developed by international/regional organizations could be introduced to the countries and, potentially, translated to local languages to promote the wider dissemination of such guidelines. Routine coordination mechanisms, communication chains, and data sharing channels should be developed or reinforced to ensure effective disaster response while taking advantage of available geospatial information.

Fundamental datasets required for the preparation of rapid response maps should be generated, if not available yet. Such maps, as well as other emergency response products, must be developed using the data with the most appropriate resolution. More accurate and localized information could be efficiently used for disaster response on a community level. Comprehensive emergency exercises could be conducted on a national level. Some agencies expressed the need for GPS equipment and communication tools and corresponding courses in GPS-based mapping in emergency response.

8.3. Synthesis of the findings

8.3.1. "Problem-solution" concept map

To present the findings from the overall discussion in a more summarized way, it was decided to generalize the main mentioned issues and solutions. The "problem-solution" framework was used to approach this task and introduce the results in a logical and coherent way. This relatively simple framework was initially developed to support practitioners working in the field of climate change adaptation to better understand existing issues, select the most appropriate solutions and formulate corresponding activities (Young 2014). An important aspect of this framework is the recognition of the importance of innovations for successful adaptation and the connection between solutions and innovations, in some way as the opposite of problems and risks (Young 2014).

The "problem-solution" framework helped in guiding further analysis and generalization of the findings of the study, particularly in identifying main problems in the field and corresponding specific needs, as well as proposed solutions to address them. Overall, this approach revealed seven general problems: reactive approach to disaster management, information overload, information deficit, information channels and communication flow, digital divide, directly linked to a lack of local expertise and lack of financial resources. Considering the overall scope of the present study and the diversity of discussed issues, it was recognized that defined problems and solutions would be highly interconnected - some solutions might help solve more than just one particular issue and address more than one specific need. Because of that, it was proposed to present the findings of this generalization more as a concept map - as a network with multiple interlinkages between its elements.

The static "problem-solution" concept map was visualized using Gephi software, it can be found in Appendix 18.

8.3.2. Interactive tool

The concept map was also converted into an online interactive tool, in some way as an additional byproduct of this analysis that can be potentially used for wider promotion and dissemination of the results. Flourish software was used to create this interactive network, presenting all the interlinkages between main problems, needs, and solutions. The tool can be accessed and explored via a direct link - https://public.flourish.studio/visualisation/8767716/. A snapshot of the tool is also presented in Figure 43, which illustrates how interconnected are its elements.

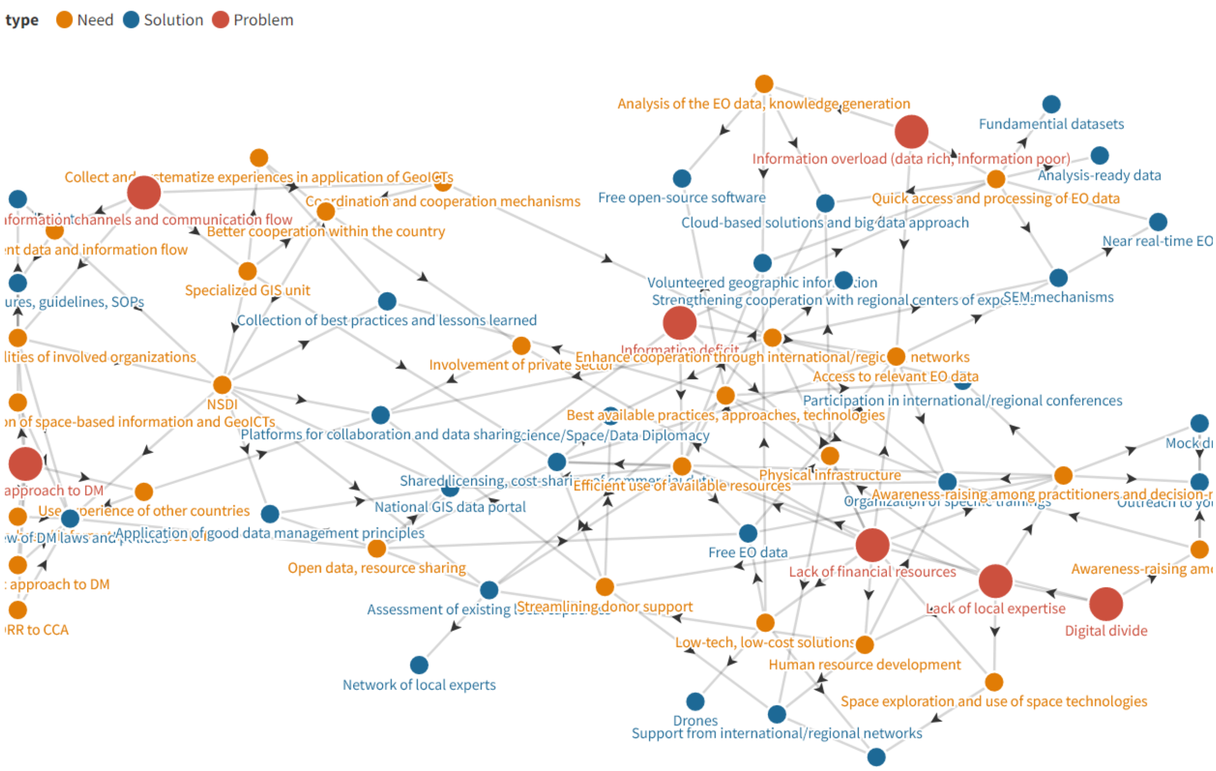

Figure 43. "Problem-solution" interactive tool

Due to the differences in the features provided by different platforms, the overall layout of the static version of the concept map developed in Gephi can be considered more coherent. However, the version made in Flourish allows some level of interactivity for the potential user of the tool, as well as makes it more easily accessible, engaging, and, potentially, useful. An example of this interaction is illustrated in Figure 44 – the selection of any element in the network automatically highlights all its direct neighbors. In the case presented in the figure, selection of the "Quick access and processing of EO data" need illuminates related problems, as well as potential solutions, and dims down everything else.

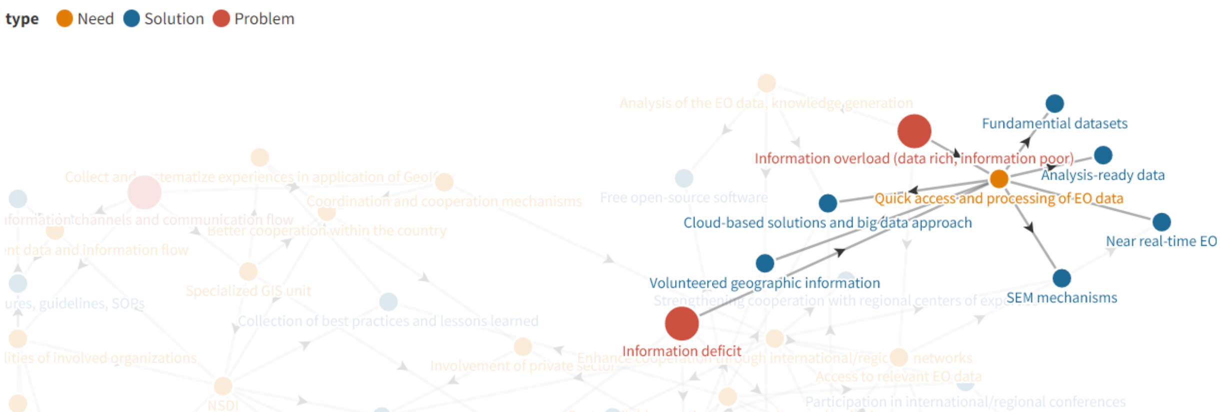

Figure 44. A snippet from an interactive tool, based on selected need

8.4. Summary

This chapter brought together findings based on the analysis of various data sources, including reports of the UN-SPIDER missions, participant observation, and records of SEM mechanisms' activations. The overall structure of the chapter followed the outline identified earlier through the applied thematic analysis of the TAM reports. Topics and needs identified through that process guided the following discussion. The combination of different data sources and analytical methods supported the triangulation of the results which helped explore the situation in a more coherent way, as well as highlight the most challenging and promising areas.

Some of the main challenges related to the application of space-based data can be summarized as: the lack of access to useful, timely, and credible data and information; confusing and fragmented landscape of existing platforms and tools, together with the lack of guidelines on how to understand and manage such data; equal access to the right data across various fields and regions; while the Global North has to deal with difficulties in navigation in all the data being available, the Global South still often suffers from the lack of available and accessible data; need for better cross-sectoral collaboration and knowledge-sharing; lack of feedback mechanisms which could potentially help data providers understand data end-users needs, which only reinforce other challenges (Burke 2018).

Finally, the findings were also generalized in a form of a concept map that reflects the main problems, related needs, and solutions. While in this form the network does not reflect all discussed challenges, risks, mitigating factors, innovations, and potential solutions, it still helps present the general summary of the discussed issues. As an interactive tool, this concept map might support the promotion of the results of this study, as well as raise awareness about the complexity of the situation and existing opportunities.

9. Conclusion

The goal of this research project was to explore the current situation and main obstacles preventing wider diffusion and application of the geospatial ICTs, particularly space-based technologies, in DRR and provide some potential solutions to tackle these challenges. The aim was to contribute to the disaster management field by exploring the current state of the use of space-based information and technologies in order to strengthen efforts in building disaster resilience in countries across the world. This was done through the exploration of the existing situation with the promotion and application of GeoICTs on a global scale, identifying the main needs and issues faced by the end-users, and proposing potential recommendations which might help mitigate associated risks.

The dissertation aimed at answering three research questions, each supported by several objectives:

- *RQ1:* What are the existing mechanisms of promotion, diffusion, and application of relevant geospatial technologies in DRR?
- *RQ2:* What are the major gaps in the application of space-based technologies, the main needs of end-users, and corresponding obstacles and challenges in the diffusion and adoption of such technologies?
- *RQ3:* What are the suitable solutions and potential approaches, as well as promising innovations, that can help tackle or at least mitigate these challenges?

9.1. Overview

To answer research questions and achieve the overall aim of the project, a number of corresponding steps were made, as discussed in more detail in Chapter 4. Research design and methodology.

Desktop research and literature review were in some capacity conducted throughout the whole process but played a particularly important role at the beginning of the research. As the first step, this helped collect initial information on the state of affairs in terms of existing challenges in the diffusion and application of geospatial technologies. The review was done particularly through exploration of available literature on the topic as well as of the major international frameworks related to the DRR field. Most prominent and potentially useful initiatives and organizations working in the field were also identified through this initial desktop research.

UN-SPIDER's TAM reports, as a secondary data source, played a particularly crucial role, providing detailed analytical information on a number of countries, which otherwise couldn't be collected within the scope of the present study. A pack of these reports (33 in total) was analyzed together as a joint data source, to ensure the generalization of the findings as was requested by the UNOOSA. The analysis allowed identify common themes and detect main topics related to the challenges in diffusion and application of geospatial technologies in DRR.

A separate section of the research was focused specifically on the SEM mechanisms, their activations, and coverage, using these initiatives as an example of the implementation of a GeoICT. Three main initiatives explored in most detail (Charter, Copernicus EMS, and Sentinel Asia) were identified and selected through the initial desktop research and discussions with experts. To perform an in-depth analysis of their activity and coverage, detailed information on activations had to be extracted from the openly available archives. Main statistical and network analysis was conducted using Python, while visualization of the results was done using separate specialized software (for instance, Gephi).

Participant observation was another important technique used at various stages of the research. This method of data collection was introduced in two forms - observation at short events (workshops, conferences, meetings), and observation during internships (at UNOOSA and FAO) and a research visit (to ADRC). The decision to participate in multiple events and took on such commitments as internships not only helped develop a much better and complete understanding of the current situation and trends in the field but also facilitated establishing connections with the experts.

As a final step in the research project, findings from the earlier steps were brought together for discussion. The framework of this final chapter followed the structure of the main problematic topics discussed in the TAM reports and identified through thematic analysis. Main issues and suggestions directly expressed in the reports were supported and complemented by the findings of the participant observation, analysis of the SEM mechanisms activations, survey, discussions with experts, and desktop research.

In addition, to summarize the results of the discussion and present them in a more compact and potentially easily accessible way, a "problem-solution" concept map was developed. It was visualized as a network, to better illustrate the interrelated nature of discussed issues, as well as highlight potential solutions, some of which might be rather versatile.

9.2. Findings

Answering the **first research question (on existing mechanisms)** helped set up the stage and identify the main direction for further exploration and analysis. The study identified three main types of international mechanisms that support the wider diffusion and application of GeoICTs in DRR, each highlighting a slightly separate aspect of the situation.

First of all, international frameworks for DRR and management were explored, as the guiding documents that can facilitate changes in national policies across the world and emphasize the role of GeoICTs and EO. The analysis of the changes and the evolution of the DRR frameworks revealed that the overall importance of making more use of the available data and technology, promotion of better knowledge management, and wider sharing of data and applications, were in some way clearly expressed in all covered documents already starting from 1990. Quite prominent was also the need to provide support to developing countries and the most vulnerable communities and strengthen their capacities, particularly through data and knowledge transfer, and data sharing.

In terms of the role of GeoICTs, the frameworks generally did not put such technologies forward, but they were rather assumed within the general discussion. In most recent documents, the geospatial aspect was becoming more noticeable - particularly Sendai Framework most clearly expresses the role of space-based data and technologies in its Priority 1: Understanding disaster risk (UNISDR 2015b). The 2030 Agenda for Sustainable Development, on the other hand, highlights the importance of knowing geographic location when dealing with data availability and specifically mentions EO and geospatial information (UN General Assembly 2015a).

To better understand a more specific case of GeoICT implementation, SEM mechanisms were explored as an example of one of the most interesting global initiatives that support rapid emergency mapping through satellite EO. Formal participation in the SEM mechanisms generally requires rather simple conditions to be met. Particularly this means that often there is no need to establish advanced infrastructure or have highly-skilled personnel, which makes the threshold of adoption relatively low. Still, conducted analysis identified that some rather noticeable gaps remain.

Finally, UNOOSA's UN-SPIDER was discussed, as one of the most prominent and active mechanisms that promote the wider application of space-based information for DRR. This UN programme aims to ensure that all countries can benefit from the application of available space-based information to support DRR activities. While having some limitations, programme provides the most valuable support to those states that express their interest and willingness to participate. Technical Advisory Support is one of the areas where UN-SPIDER operates, particularly through its Advisory Missions. TAMs help assess the existing capacities and needs of the Member States in terms of the application of geospatial technologies and data in DRR, as well as provide recommendations on the areas of improvement. However, over the last years, such missions were conducted rather rarely, partially due to the complications and high cost of their organization, giving way to ISMs.

To address the **second research question (on gaps and challenges)** and illustrate some of the more tangible gaps, in the application of space-based technologies, the coverage of the selected SEM mechanisms was explored. The number of existing SEM mechanisms working on a global and regional scale remains relatively limited, at the same time being rather diverse, particularly in terms of the composition of their formal members/users and their roles and rights. Three mechanisms selected for more detailed analysis (Charter, Copernicus EMS, and Sentinel Asia) illustrated some of such differences, as well as overlaps. For instance, the vast majority of the countries directly involved in Copernicus EMS also participate in the Charter. At the same time, Sentinel Asia can be seen as much more isolated with only few member countries having direct links with the Charter.

Identified differences and similarities between mechanisms can be partially explained by the regulations that limit formal participation in the initiatives - their global or regional scope, as well as the type of organizations that are allowed to join. For instance, Taiwan can be mentioned as an interesting case - it cannot have an official authorized user within the Charter since it is not recognized by the United Nations as an independent country, but at the same time, it remains a formal member of Sentinel Asia, which has different rules for potential members.

Analysis of the activations of the selected SEM mechanisms, while being somewhat limited, still helped identify some of the gaps in the coverage and potential issues in operation. For instance, the formal involvement of some countries in more than one mechanism could potentially lead to communication issues. This was particularly illustrated by cases of double requests for activation sent to both Sentinel Asia and Charter separately, instead of going through a formally established escalation process. Avoiding such complications and confusion during the mobilization of resources is of at most importance in emergency response. The larger and more intertwined the network of involved mechanisms is, the higher might be the chance of similar issues occurring unless proper guidelines and operation procedures are defined and followed.

Regarding the coverage gaps (direct access to SEM mechanisms), a significant number of countries in Africa, as well as many in the Middle East, Pacific, Central America and the Caribbean, and Western Balkan were not directly involved in such initiatives. At the same time, it is important to mention that such countries do still receive support through indirect activations (via UN, third or neighboring states) or other similar mechanisms, not covered in this study in detail. The importance of countries taking ownership in emergency response was illustrated through the analysis of the changes in their behavior in terms of SEM mechanism activation. The analysis of the selected countries showed a clear shift in the behavior among states when they were granted the authorized user status.

In terms of other issues with SEM mechanisms, it is also important to mention that most of the largest initiatives seem to be reaching their maximum capacity of activations per year (Voigt *et al.* 2016). On top of that, in the case of particularly "busy" months, existing mechanisms might be temporally "overwhelmed" with the number of requests, not being able to address all calls. In such cases, some "local" disasters might be overlooked. As a potential attempt to avoid such situations, a network of responsible organizations and initiatives might be needed, that would have an operational platform for cooperation and communication to help clearly distribute responsibilities.

Finally, the need in using SEM mechanisms for activities supporting other stages of the disaster management cycle (apart from disaster response) is becoming more and more clear. Even though most of such initiatives inherently imply the possibility of activation before a disaster, so far this has very rarely happened. The only clear exception is Copernicus's "Risk and Recovery Mapping" service, which provides geospatial information specifically to support activities not related to immediate response (Copernicus EMS 2021).

Analysis of the UN-SPIDER's TAMs reports served as an important component of the present study since TAMs provided detailed information on the existing capacities, challenges, and potential solutions for the visited countries. The analysis of these reports was performed to explore specific needs and recommendations suggested in these documents and formulate common themes and topics of concern.

Thematic network analysis of the topics mentioned in the "recommendations" sections revealed the unifying role of the National Spatial Data Infrastructure (NSDI) as an overarching framework that brought together all concepts expressed in the reports. Representation of the main themes and concepts in a form of a network helped identify potential gaps. These particularly included the roles of "private sector" and "local comminutes", which seem to be largely missing from the TAM reports' recommendations.

In addition to exploring the network of themes raised in the reports, a thematic analysis was performed to group together concerns related to diffusion and application of GeoICTs in DRR. Overall, this process revealed 20 clear topics, grouped into six larger themes, which included:

- promotion of geospatial technologies,
- awareness raising and capacity building,
- coordination and cooperation,
- availability and use of resources,
- data and information management,
- new technologies and tools.

Taking into account some level of diversity among the countries where TAMs were conducted, it was possible to explore potential differences in their priorities (which issues were mentioned the most and which - the least). In all cases of division by geographic regions, geographic location, income, and development levels, some rather clear differences were detected.

The final discussion helped address the **third research question**, by bringing together findings from the earlier sections, including identified gaps and challenges, supported by the corresponding solutions and recommendations. The structure of the last chapter was following the division into six main themes which were identified through the thematic analysis of the TAM reports. To attest to the ideas and suggestions expressed in the reports, and to ensure triangulation of the data, supporting statements and findings from various data sources were put together and discussed. Each of the guiding topics (20 in total) was discussed and complemented with more specific examples, where appropriate.

Overall, all main themes proved to be rather closely intertwined and, in many cases, mentioned challenges could be related to more than just one specific topic. For instance, the need for trained space scientists (and experts in the field, in general) cannot be covered only in relation to capacity-building activities. It also involves the issue related to the topic of cooperation, which might help find opportunities to provide trainings. At the same time, it also covers the challenges related to the availability of financial resources to support such activities, as well as to the management of human resources (for instance, how to ensure that newly acquired skills will be applied within the country, etc.).

The final summarizing process attempted at identifying some general overarching problems, corresponding specific needs, and suitable solutions. This exercise produced a "problem-solution" concept map, which incorporated all elements in a form of a network, helping visualize the complexity and intertwining of the discussed topics.

Overall, seven general overarching problems were indicated: reactive approach to disaster management, information overload, information deficit, information channels and communication flow, digital divide, directly linked to lack of local expertise, and lack of financial resources. Each of these general problems branched out to more specific needs, which then were linked to potential solutions. As a network, the discussed issues were presented in a simplified and generalized way, which help structure and explore the results in a more condensed form. As an interactive tool, this concept map might help promote the results of the study and overall raise awareness about the complexity of the situation and the diversity of approaches to address some of the challenges.

On a final note, the analysis illustrated that there seem to be no crucial barriers that can hinder the wider diffusion of space-based technologies – each identified issue has a potential corresponding solution. The actual availability of the specific tools or technologies on the market overall is not considered a challenge – access is. The diffusion process overall is supported and accelerated by the existing and emerging global mechanisms, growing access to and availability of space-based data and technologies, innovations, and overall integration of digital technologies.

9.3. Further research

Conducted research highlighted a few potential areas for further investigation, particularly studying specific aspects of the situation from different angles and in more detail.

The diversity of the existing and emerging GeoICTs, particularly their applications in DRR, is yet to be categorized in a comprehensive way. At the same time, the rate of technological advancements could complicate any attempts for such systematization of the available tools. A more traditional approach to studying the diffusion of this kind of technology is probably not applicable on a global level, particularly the changes in the adoption rate over time and the exact rate of acceptance. At the same time, a case study approach might be a solution - focusing on a specific tool and a smaller scale (regional, local, or even the level of organization) might allow to approach the issue from a different perspective. To some level, this tactic was used using SEM mechanisms as an example of technology implementation. However, the global coverage of this analysis and the need to limit the review to three selected mechanisms prevented us from diving into a more detailed diffusion study.

On a similar topic, while the present research analyzed all available records of activations of the selected SEM mechanism over the period till 2020, it focused only on three initiatives, which were considered most relevant for the research. To potentially have a more comprehensive overview of the situation and more clearly defined gaps, activations of some other mechanisms could be considered as well, in a way following the example of the Voigt *et al*. (2016) study. Moreover, a portfolio of the Copernicus's "Risk and Recovery Mapping" service can be explored as well, including visualizing it in a form of a network. On a similar note, a combined network of activations coming from different mechanisms could also be developed and explored. In this case, it would be important to exclude duplicating activations initiated for the same events.

In addition, conducted network analysis of the SEM mechanisms could potentially be expanded and deepened further, exploring the topology of the developed graphs and positions of their elements. A more detailed investigation of the potential reasons behind connections between countries supported through indirect activations (on behalf of other countries or organizations) can be conducted.

Finally, the rich data provided by the TAM reports could be explored and applied in some other context, following a different research aim. Interpretation of the qualitative data heavily relies on the focus of the study and the research questions. In the present project, the goal was to identify the main challenges that prevent the wider application of GeoICTs and any potential recommendations. Further research might, for instance, focus on some specific element and explore it in more detail, still ensuring the generalization of the findings. In addition, considering that most of the TAMs took place already quite some time ago, it might be interesting to explore how the situation in the visited countries had changed since the missions, whether proposed recommendations were implemented or not, and what were the consequences of such actions.

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Appendices

Appendix 1. General classification of disasters caused by natural hazards

Disaster subgroup	Definition	Disaster main type
Geophysical	A hazard originating from solid earth. This term is used interchangeably with the term geological hazard.	Earthquake
		Mass Movement (dry)
		Volcanic activity
Meteorological	A hazard caused by short-lived, micro- to meso-scale extreme weather and atmospheric conditions that last from minutes to days.	Extreme Temperature
		Fog
		Storm
Hydrological	A hazard caused by the occurrence, movement, and distribution of surface and subsurface freshwater and saltwater.	Flood
		Landslide
		Wave action
Climatological	A hazard caused by long-lived, meso- to macro-scale atmospheric processes ranging from intra-seasonal to multi-decadal climate variability.	Drought
		Glacial Lake Outburst
		Wildfire
Biological	A hazard caused by the exposure to living organisms and their toxic substances (e.g. venom, mold) or vector-borne diseases that they may carry. Examples are venomous wildlife and insects, poisonous plants, and mosquitoes carrying disease-causing agents such as parasites, bacteria, or viruses (e.g. malaria).	Epidemic
		Insect infestation
		Animal Accident
Extraterrestrial	A hazard caused by asteroids, meteoroids, and comets as they pass near-earth, enter the Earth's atmosphere, and/or strike the Earth, and by changes in interplanetary conditions that effect the Earth's magnetosphere, ionosphere, and thermosphere.	Impact
		Space weather

Source: IRDR 2014

Appendix 2. Questionnaire used in the expert survey

Question	Answer options
Section "General information"	
Your name	Open-ended
Which category would you put yourself into?	• Government (federal/local, regulatory agencies) • Not-for-profit organizations, NGOs • UN Agencies and Intergovernmental Bodies • Higher Education Institutions • For-profit organizations • Other
Please briefly specify the organization you work with and your role	Open-ended
How long have you been in your current field of work?	• 0 - 2 years • 2 - 5 years • 5 - 10 years • 10 - 15 years • over 15 years
Do you consider yourself to be working in Disaster (Emergency) Management?	• Yes • No
Section "Sustainable Development Goals (SDGs)"	
On which Sustainable Development Goals are you focusing in your work? (select all applicable)	• Goal 1: No Poverty • Goal 2: Zero Hunger • Goal 3: Good Health and Well-being • Goal 4: Quality Education • Goal 5: Gender Equality • Goal 6: Clean Water and Sanitation • Goal 7: Affordable and Clean Energy • Goal 8: Decent Work and Economic Growth • Goal 9: Industry, Innovation and Infrastructure • Goal 10: Reduced Inequality • Goal 11: Sustainable Cities and Communities • Goal 12: Responsible Consumption and Production • Goal 13: Climate Action • Goal 14: Life Below Water • Goal 15: Life on Land • Goal 16: Peace and Justice Strong Institutions • Goal 17: Partnerships to achieve the Goal
Section "Information and Communication Technologies (ICT)"	
What do you understand by the term "Information and Communication Technology" (ICT)?	Open-ended
For what purposes you are using ICT in your work? (select all applicable)	• Data access • Data visualization • Data analysis • Information exchange

Question	Answer options
	• Coordination • Joined planning • Document management • Monitoring • Assessment • Forecasting • Early Warning • Modelling and simulation • Participatory planning process • Encourage interconnectivity and integration • Community mapping (mapping process carried out by local communities, e.g. risk perception mapping) • E-learning (online workshops, webinars, tutorials, etc.) • None • Other
You can give brief comments and propose additional purposes for the use of ICT which you believe should be added to the list.	Open-ended
Which of the following ICT are you using? (select all applicable)	• Databases, data portals (collections of various types of data, logically organized) • Geoportals (specific type of web portals focused on geospatial information, can provide some basic operations like data visualization and limited analysis) • Online mapping platforms • GIS software (an application through which it is possible to collect, manage, visualize, analyze various types of spatial data, create and publish maps) • Modelling software • Data Viewer (Visualizer) • E-learning training and tutorials • None • Other
You can give brief comments and propose additional ICT which you believe should be added to the list.	Open-ended
Sub-section "ICT innovations"	
The following section of the survey will address the latest ICT innovations (any new technology, idea, practice, etc.) which were adopted at your workplace. If possible, in your answers please focus on geospatial innovations.	
Please, provide some examples of the most recent innovations you had adopted (new software, devices, etc.)?	Open-ended

Question	**Answer options**
How did you first hear about these innovations (from your professional network, head of the unit, media, etc.)?	Open-ended
As a general rule, who was making a decision to adopt these innovations?	• Decision was made individually (independently) • Decision was made collectively (for instance, by all members of the unit) • Decision was made by higher authority (someone in positions of influence or power) • Other
What were the reasons for adoption?	Open-ended
What kind of issues and challenges you faced during the adoption and implementation of these innovations?	Open-ended
Here you can give any comments related to this section of the survey	Open-ended
Section "Challenges in application of ICT"	
In the following section of the survey, you will be provided with lists of various statements about the challenges in application of information and communication technologies (ICT). Please rate each of the statements in terms of its importance and credibility (1 indicates the least important or irrelevant and 5 indicates the most important) (leave blank if no opinion).	
Problematical aspects of ICT for disaster planning and research	• The probability that the "rich will become richer" in dealing with disasters • The possibility that technology that is a "mean" will be turned into an "end" in itself • The information overload problem • The greater likelihood of the diffusion of inappropriate disaster relevant information • Intra- and inter-level group communication will be made even more difficult (between various relevant actors) • The negative consequences of the probable "democratization" of information distribution process and in the result the spread of popular "obvious" views on the issue • The lack of specific kind of social infrastructure required for the use of modern disaster relevant ICTs • The certainty of computer system-related disaster
You can briefly explain the reasons for your ranking. As well, you can add additional problematic aspects to the list, or indicate factors you believe are irrelevant (and why).	Open-ended

Question	Answer options
Main challenging issues in the field of ICT in disaster management	• Disaster management organizations often lack the resources needed for acquisition of required equipment and software • It might be too risky and costly to develop and apply promising innovative technologies • In most cases agencies involved in disaster management do not have employee, whose responsibilities will include the monitoring of modern ICT, identifying potentially relevant technologies, and managing the process of purchase and training • While local organizations must work together at all phases of disaster management cycle in order to insure the best outcome of such cooperation, when talking about ICT such organizations tend to make decisions independently • Uncertainty and instability is inherent in the field of disaster management due to its very nature, which lead to the chaos and problems with communication and control • Financial issues related to the fact that the greatest amounts of funds are traditionally provided only after the disaster happened (reactive approach), while the reasonable and professional application of ICT most of the time funds are required at the pre-disaster phases (proactive approach)
You can briefly explain the reasons for your ranking. As well, you can add additional challenges and risks related to the use of ICT, or indicate factors you believe are irrelevant (and why).	Open-ended
Sub-section "Geospatial Information and Communication Technologies (GeoICT)"	
Do you or others in your workplace use geospatial technologies and/or remote sensing?	• Yes and I work with it • I don't personally work with it but it is utilized within my workplace • No but I am aware of its use • No and I am not aware of its use
Please briefly describe the technology and data you presently use in your activities (e.g. GIS, GPS, satellite imagery, etc.) and the way in which it is used.	Open-ended
Are you using satellite technologies (Earth Observation; navigation; communication) in your current work?	• Yes • No

Question	Answer options
Section "Satellite technologies"	
What kind of satellite application, or combination of them, are you using? (select all applicable)	• Satellite Imagery • Satellite Navigation/Location-based services • Satellite Communication
In which field of application do you use the satellite-based service? (select all applicable)	• Agriculture • Air quality • Building and works • Climate change • Energy • Environmental protection • Forestry • Health • Law enforcement • Mining • Natural and cultural heritage • Risk prevention and management • Sports and leisure • Tourism • Transport and logistics • Urban planning • Water management • Other
Did you face any of the following challenges while using satellite-based solutions? (select all applicable)	• Technical challenges • Economic challenges • Material challenges (e.g. service availability on the market) • Organizational challenges (e.g. staff capabilities to start using the new service) • Administrative challenges (e.g. difficulty in obtaining authorizations or funds) • No challenges faced • Other
How did you solve these challenges? (select all applicable)	• We trained our staff • We hired new staff • We hired consultants • We benefitted from external free support • The challenges were not solved • Other
Do you think it will be a challenge to keep using the satellite solution in the future?	• Yes • No • I do not know
If Yes, could you say why? (select all applicable)	• The service does not provide significant benefits • The service is too expensive • Other available technologies are being considered to replace the satellite service

Question	Answer options
	• The usefulness of the service is questioned within your organization or by external stakeholders • Other
Section "Self-evaluation"	
Please assess your competence (expertise) to answer the previous questions.	• Expert • Good • Reasonable • Very little • Nothing

Appendix 3. List of GeoICTs selected for the review

Note: descriptions were taken from the corresponding sites

№	ICT
1	**EM-DAT: International Disaster Database**
	http://www.emdat.be/ The main objective of the EM-DAT database is to serve the purposes of humanitarian action at national and international levels. It is an initiative aimed to rationalize decision making for disaster preparedness, as well as providing an objective base for vulnerability assessment and priority setting. EM-DAT contains essential core data on the occurrence and effects of over 18,000 mass disasters in the world from 1900 to present. The database is compiled from various sources, including UN agencies, non-governmental organizations, insurance companies, research institutes and press agencies.
2	**CE-DAT: Complex Emergency Database**
	https://www.cedat.org/ CE-DAT is an international initiative that monitors and evaluates the health status of populations affected by complex emergencies. Was created as an outcome of SMART, an interagency initiative to encourage rational, evidence-driven humanitarian decision-making. CE-DAT is a database of mortality and malnutrition rates – the most commonly used public health indicators of the severity of a humanitarian crisis. CE-DAT serves as a unique source of field data for monitoring the health status of conflict-affected populations and for the production of trend analyses, impact briefings and policy recommendations.
3	**Global Change Master Directory (GCMD)**
	https://earthdata.nasa.gov/earth-observation-data/find-data/idn/gcmd-keywords The mission of the Global Change Master Directory is to offer a high quality resource for the discovery, access, and use of Earth science data and data-related services worldwide, while specifically promoting the discovery and use of NASA data. The directory resource is targeted to serve as a valued location for sharing data from multinational sources and, in turn, will contribute to scientific research by providing stewardship of metadata and direct access to Earth science data and services.
4	**SERVIR**
	https://www.servirglobal.net/ SERVIR is improving awareness, increasing access to information, and supporting analysis to help people in Africa, Hindu Kush-Himalaya, Lower Mekong, and Mesoamerica manage challenges in the areas of food security, water resources, land use change, and natural disasters. With activities in more than 30 countries and counting, SERVIR has already developed over 40 custom tools, collaborated with over 200 institutions, and trained more than 1800 individuals, improving the capacity to develop local solutions.
5	**Collect Earth Online**
	https://collect.earth/ Collect Earth Online is a custom built, open-source, satellite image viewing and interpretation system developed by SERVIR, FAO, and other partners as a tool for use in projects that require land cover and/or land use data. The full functionality of Collect Earth Online, including collaborative compilation of reference point databases, is implemented online so there is no need for desktop installation.
6	**ClimateSERV**
	https://climateserv.servirglobal.net ClimateSERV is a web-accessible system that allows users to access, visualize, and analyze historical Earth Observations useful to decision-making across multiple sectors. It provides the ability to perform server-side statistical calculations across long time-series of Earth Observation or modeling data over regions of interest defined by users. The resulting data can be used in interactive mode (with desktop analysis tools), or called by third-party applications through a custom API.
7	**Giovanni (Geospatial Interactive Online Visualization ANdaNalysis Infrastructure)**
	https://giovanni.gsfc.nasa.gov/giovanni/ Giovanni is a Web-based application that provides a simple and intuitive way to visualize, analyze, and access vast amounts of Earth science remote sensing data without having to download the data. From the researcher's point of view, Giovanni is comprised of a number of interfaces, each tailored to meet the needs

of specific fields of Earth science research. Each interface, known as a portal, provides functions and parameters applicable to that specific area of Earth science.

8 Socioeconomic Data and Applications Center (SEDAC)

http://sedac.ciesin.columbia.edu/

SEDAC, the Socioeconomic Data and Applications Center, is one of the Distributed Active Archive Centers (DAACs) in the Earth Observing System Data and Information System (EOSDIS) of the U.S. National Aeronautics and Space Administration. Focusing on human interactions in the environment, SEDAC has as its mission to develop and operate applications that support the integration of socioeconomic and earth science data and to serve as an "Information Gateway" between earth sciences and social sciences.

9 SEDAC Hazards Mapper

http://sedac.ciesin.columbia.edu/mapping/hazards/

The SEDAC Hazards Mapper enables users to visualize data and map layers related to Socioeconomic, Infrastructure, Natural Disasters, and Environment and analyze potential impacts and exposure. The web app mashups layers from various sources including SEDAC, NASA LANCE, NASA GIBS, USGS, NOAA, ESRI, and others. This web mapping application allows users to estimate the populations in proximity to natural disasters, and to assess exposure.

10 Worldview

https://worldview.earthdata.nasa.gov/

This tool provides the capability to interactively browse global, full-resolution satellite imagery and then download the underlying data. Most of the 100+ available products are updated within three hours of observation, essentially showing the entire Earth as it looks "right now". This supports time-critical application areas such as wildfire management, air quality measurements, and flood monitoring.

11 USGS WaterWatch

http://waterwatch.usgs.gov/

WaterWatch is a U.S. Geological Survey (USGS) World Wide Web site that displays maps, graphs, and tables describing real-time, recent, and past streamflow conditions for the United States. The real-time information generally is updated on an hourly basis. WaterWatch provides streamgage-based maps that show the location of more than 3,000 long-term (30 years or more) USGS streamgages.

12 Global Flood Monitoring System (GFMS)

http://flood.umd.edu/

The GFMS is an experimental system using real-time TRMM Multi-satellite Precipitation Analysis (TMPA) precipitation information as input to a quasi-global (50°N - 50°S) hydrological runoff and routing model running on a 1/8th degree latitude/longitude grid. Flood detection/intensity estimates are based on 13 years of retrospective model runs with TMPA input, with flood thresholds derived for each grid location using surface water storage statistics (95th percentile plus parameters related to basin hydrologic characteristics). Streamflow, surface water storage, inundation variables are also calculated at 1km resolution. In addition, the latest maps of instantaneous precipitation and totals from the last day, three days and seven days are displayed.

13 GPM Precipitation and Applications Viewer

https://gpm.nasa.gov/data/visualizations/precip-apps

The Tropical Rainfall Measuring Mission (TRMM) is a joint mission between NASA and the Japan Aerospace Exploration (JAXA) Agency to study rainfall for weather and climate research. Global Precipitation Measurement (GPM) is an international satellite mission to provide next-generation observations of rain and snow worldwide every three hours. The data they provide is used to unify precipitation measurements made by an international network of partner satellites to quantify when, where, and how much it rains or snows around the world.

14 MODIS NRT Global Flood Product

https://earthdata.nasa.gov/earth-observation-data/near-real-time/mcdwd-nrt

The MODIS Near Real-Time (NRT) Global Flood Product (MCDWD) provides a daily global map of flooding. It is derived from the NRT MODIS Surface Reflectance (MOD09) datasets from both the Terra and Aqua satellites. The Flood Product is available for 3 compositing periods: 1-day, 2-day, and 3-day. For each composite, water detections for all observations (Terra and Aqua) over the compositing period

(1, 2, or 3 days) are accumulated, and if the total exceeds the required threshold (1, 2, and 3 observations, respectively), the pixel is marked as water.

15 Extreme Rainfall Detection System (ERDS)

http://erds.ithacaweb.org/

The Extreme Rainfall Detection System (ERDS), developed and implemented by ITHACA (Information Technology for Humanitarian Assistance, Cooperation and Action), is a service for the monitoring and forecasting of exceptional rainfall events, with a nearly global geographic coverage. This system is conceived to be a strategic tool, providing complete, immediate and intuitive information about potential flood events, to be used during the preparedness and response phases of the emergency cycle. Currently the system is one of the tools used by UN World Food Programme (WFP) Emergency Preparedness Unit.

16 Urban Atlas for Europe

https://land.copernicus.eu/local/urban-atlas

Europe's urban areas, which accommodate more than three-quarters of the region's population, have grown rapidly in recent decades. City centers and the wider surroundings have been transformed. The Urban Atlas provides a means to monitor and interpret these changes. The Urban Atlas is a digital mapping tool providing pan-European, reliable and inter-comparable urban planning data with high-resolution maps.

17 Climate change impacts in Europe

https://experience.arcgis.com/experience/5f6596de6c4445a58aec956532b9813d

The map represents change in heavy rain in winter and summer in the period 2071-2100 compared to the present climate (1971-2000) based on high emissions scenario. The largest increases, up to 35%, are projected for central and eastern Europe. Southern Europe could see increases in heavy rain of up to 25%.

18 Urban Adaptation Map Viewer

https://climate-adapt.eea.europa.eu/knowledge/tools/urban-adaptation

The aim of this map viewer is to provide an overview of the current and future climate hazards facing the European cities, the vulnerability of the cities to these hazards and their adaptive capacity. The map viewer collates information from various sources on the observed and projected spatial distribution and intensity of high temperatures, flooding, water scarcity, wildfires and vector-borne diseases. It also provides some information on the causes of cities' vulnerability and exposure to these hazards, linked to the characteristics of cities and their population. Finally, the map viewer provides information on adaptation planning and actions of European cities.

19 PREVIEW Global Risk Data Platform

http://preview.grid.unep.ch/

The PREVIEW Global Risk Data Platform is a multiple agencies effort to share spatial data information on global risk from natural hazards. Users can visualize, download or extract data on past hazardous events, human & economical hazard exposure and risk from natural hazards. It covers tropical cyclones and related storm surges, drought, earthquakes, biomass fires, floods, landslides, tsunamis and volcanic eruptions. The collection of data is made via a wide range of partners.

20 Global Flood Awareness System (GloFAS)

http://www.globalfloods.eu/

The Global Flood Awareness System (GloFAS), jointly developed by the European Commission and the European Centre for Medium-Range Weather Forecasts (ECMWF), is independent of administrative and political boundaries. It couples state-of-the art weather forecasts with a hydrological model and with its continental scale set-up it provides downstream countries with information on upstream river conditions as well as continental and global overviews.

21 European Flood Awareness System (EFAS) Archive

https://www.efas.eu/efas_frontend/#/home

The aim of EFAS is to support preparatory measures before major flood events strike, particularly in the large trans-national river basins and throughout Europe in general. EFAS is the first operational European system monitoring and forecasting floods across Europe. It provides complementary, added-value information (e.g. probabilistic, medium range flood forecasts, flash flood indicators or impact forecasts) to the relevant national and regional authorities. Furthermore, EFAS keeps the Emergency Response Coordination Centre (ERCC) informed about ongoing and possibly upcoming flood events across Europe.

Since 2012 EFAS is running fully operational as part of the Copernicus EMS. The real-time EFAS forecasts are restricted to the EFAS partners, all data that is older than 30 days is open access.

22 Global Flood Alert System ver.2 (GFAS II)

http://gfas.internationalfloodnetwork.org/n-gfas-web/PC/frmMain.aspx

GFAS II is an attempt to make the best use of global satellite precipitation estimates in flood forecasting and warning. GFAS II utilizes the Global Satellite Mapping of Precipitation, GSMaP, as a means of estimation, which Japan Aerospace Exploration Agency (JAXA) makes open to the public on their website. GSMaP is drawn up to the highest levels of precision and resolution in the world, and is published with an approximately 4-hour lag from the time of satellite monitoring (quasi real-time basis). As the aim of the products on this website is to provide reference information about global rainfall, it has nothing to do with flood forecasting and warnings issued under each governmental agency's jurisdiction.

23 JAXA Global Rainfall Watch (GSMaP_NRT)

http://sharaku.eorc.jaxa.jp/GSMaP/

Hourly global rainfall maps in near real time (about four hours after observation) using the combined MW-IR algorithm with GPM-Core GMI, TRMM TMI, GCOM-W AMSR2, DMSP series SSMIS, NOAA series AMSU, MetOp series AMSU and Geostationary IR data. Background cloud images are globally merged IR data produced by NOAA Climate Prediction Center (CPC), using IR data observed by JMA's MTSAT satellite, NOAA's GOES satellites and EUMETSAT's Meteosat satellites.

24 JAXA Realtime Rainfall Watch (GSMaP_NOW)

http://sharaku.eorc.jaxa.jp/GSMaP_NOW/index.htm

The "JAXA Realtime Rainfall Watch (GSMaP_NOW)" is a quasi-realtime version of "JAXA Global Rainfall Watch (GSMaP_NRT)", which provides global rainfall map 4-hour after observation.GSMaP_NOW produces rainfall map over the area of geostationary satellite "Himawari", using passive microwave observations that are available within half-hour after observation (GMI, AMSR2 near Japan, and AMSU direct receiving data).

25 Space-based Measurement, Mapping, and Modeling of Surface Water

http://floodobservatory.colorado.edu/index.html

There are two map series accessible: "Current Flood Conditions", providing daily, satellite-based updates of surface water extent, and the "Global Atlas of Floodplains", a remote sensing record of floods, 1993 to 2015. Links to GIS data supporting the displays are also provided. The Flood Observatory facilitates practical use of space-based information for international flood detection, flood response, future risk assessment, and hydrological research.

26 Aqueduct Floods

https://www.wri.org/applications/aqueduct/floods/#

Aqueduct Floods measures and maps water-related flood risks around the world. It evaluates current and future risks of riverine and coastal flooding, taking into account the impacts that socioeconomic growth and climate change will have. Aqueduct Floods also allows users to conduct comprehensive cost-benefit analysis to evaluate the value of dike flood protection strategies.

27 Digital Earth Australia (DEA) Water Observations

https://www.dea.ga.gov.au/products/dea-water-observations

Digital Earth Australia (DEA) Water Observations uses an algorithm to classify each pixel from Landsat satellite imagery as ‘wet’, ‘dry’ or ‘invalid’. Combining the classified pixels into summaries, covering a year, season, or all of time (since 1987) gives the information on where water is usually, and where it is rarely.

28 Global Flood Detection System (GFDS)

http://www.gdacs.org/flooddetection/

The Global Flood Detection System web application publishes the results of a new processing technique for remote sensing data that allows near real-time detection of flooded areas worldwide. GFDS provides maps, alerts, and the raw data for users ranging from emergency managers and public authorities to scientists and web developers.

29 Global Disaster Alert and Coordination System

http://www.gdacs.org/

GDACS is a cooperation framework under the United Nations umbrella. It includes disaster managers and disaster information systems worldwide and aims at filling the information and coordination gap in the first phase after major disasters. GDACS provides real-time access to web-based disaster information systems and related coordination tools.

30 Global Human Settlement Layer (GHSL)

http://ghslsys.jrc.ec.europa.eu/

The GHSL proposes a new way to map, analyze, and monitor human settlements and the urbanization in the 21st century. The GHSL is an evolutionary system, with the aim of stepwise improving completeness and accuracy of the global human settlement description by offering free services of image information retrieval in the frame of collaborative and derived-contents sharing agreements. GHSL integrates several available sources reporting about the global human settlement phenomena, with new information extracted from available remotely sensed (RS) imagery. So far, the GHSL is the largest and most complete known experiment on automatic image information retrieval using high and very high remotely sensed image data input.

31 FEMA's Methodology for Estimating Potential Losses from Disasters (HAZUS_MH)

https://www.fema.gov/flood-maps/products-tools/hazus

Hazus is a nationally applicable standardized methodology that contains models for estimating potential losses from earthquakes, floods and hurricanes. Hazus uses Geographic Information Systems (GIS) technology to estimate physical, economic and social impacts of disasters. It graphically illustrates the limits of identified high-risk locations due to earthquake, hurricane and floods. Users can then visualize the spatial relationships between populations and other more permanently fixed geographic assets or resources for the specific hazard being modeled, a crucial function in the pre-disaster planning process.

32 FLO-2D

http://www.flo-2d.com/

FLO-2D is a flood routing model that simulates channel flow, unconfined overland flow and street flow over complex topography. Experience the diversity and complexity of the flood simulation details by adding rainfall, infiltration, sediment transport, buildings, levees, embankments, walls (wall collapse), dam breach, mudflows, storm drain, culverts, bridges, hydraulic structures and groundwater. Rainfall, infiltration and most features can be spatially and temporally variable with historical rainfall events replicated with NEXRAD data.

33 QGIS

http://www.qgis.org/en/site/

QGIS is a user friendly Open Source Geographic Information System (GIS) licensed under the GNU General Public License. QGIS is an official project of the Open Source Geospatial Foundation (OSGeo). It runs on Linux, Unix, Mac OSX, Windows and Android and supports numerous vector, raster, and database formats and functionalities.

34 ArcGIS

https://www.arcgis.com/

ArcGIS for Desktop is the key to realizing the advantage of location awareness. Collect and manage data, create professional maps, perform traditional and advanced spatial analysis, and solve real problems.

35 Joint Disaster Management risk assessment and preparedness in the Danube macro-region (SEERISK)

https://keep.eu/projects/5945/Joint-Disaster-Management-ri-EN/

The main purpose of this project is to improve coherence and consistency among risk assessments undertaken by the countries at national and local level, and especially in case of disasters intensified by climate change. The project builds on the EU Council conclusions on "Further Developing Risk Assessment for Disaster Management within the European Union" adopted in March 2011, that aims for a common approach and harmonization on the prevention of natural and man-made disasters setting out an overall disaster prevention framework. SEERisk will test and adapt the EC guidelines to selected pilot areas in the SEE region, focusing on two main activity: risk assessment and the enhancement of joint preparedness in order to strengthen awareness and efficiency of action in emergencies caused by climate change.

36 INSPIRE Geoportal

http://inspire-geoportal.ec.europa.eu/
The INSPIRE geoportal provides the means to search for spatial data sets and spatial data services, and subject to access restrictions, to view spatial data sets from the EU Member States within the framework of the INSPIRE Directive.

37 Flood Manager E-learning
http://daad.wb.tu-harburg.de/
The Flood Manager E-learning Platform is a web-based resource that provides the state of the art knowledge in understanding and implementing Integrated Flood Management and offers the possibility to get exposed to the interdisciplinary aspects of flood management that enable to interact confidently with specialists in this field.

38 USGS Earth Explorer
http://earthexplorer.usgs.gov/
One of the largest databases of remote sensing data. The USGS Earth Explorer is a similar tool to the USGS Global Visualization Viewer (GloVis) in that users search catalogs of satellite and aerial imagery. The USGS Earth Explorer is the new and improved version.

39 Earthdata search
https://search.earthdata.nasa.gov/
Earthdata Search combines the latest EOSDIS (Earth Observing System Data and Information System) service offerings with user experience research and expertise, producing a state-of-the-art client for discovering, searching, visualizing, and retrieving Earth science data. Earthdata Search provides easy-to-use access to EOSDIS services for Earth science data discovery, filtering, visualization, and access. It also serves as a platform to feature planned EOSDIS services as they become available.

40 LandsatLook
https://landsatlook.usgs.gov/explore
LandsatLook is a tool that allows rapid online viewing and access to the USGS Landsat Collection 2 data. LandsatLook leverages resources available via a commercial cloud environment including Cloud Optimized GeoTIFF (COG) and Spatio Temporal Asset Catalog (STAC) metadata.

41 Auckland Council GIS Viewer
https://www.aucklandcouncil.govt.nz/geospatial/geomaps/Pages/default.aspx
GIS map viewer is Auckland Council's mapping and property information service. The service provides layers of data and information that the council and controlled organizations compile or government and utility agencies supply.

42 Floor Level Map: Christchurch City Council
https://ccc.govt.nz/services/water-and-drainage/stormwater-and-drainage/flooding/floorlevelmap
Christchurch City Council (Council) provides in this website the information on the: predicted minimum, maximum and average ground level for properties in the Avon and Styx catchments; predicted water levels in the 50 and 200 year events; an interim likely floor level for a residential dwellings, which is still subject to further analysis being undertaken.

43 Susquehanna Inundation Maps
https://www.srbc.net/our-work/programs/planning-operations/flooding/inundation-maps/
The Susquehanna River Basin Commission (SRBC) maintains inundation maps for a number of National Weather Service (NWS) river forecast points across the basin. These maps display expected area of flood inundation that will occur at a specific river stage above flood stage. The maps are available for viewing online, as available, and by request. Available online inundation map libraries can be accessed through the United States Geological Survey and the National Weather Service map viewers.

44 Scottish Environment Protection Agency (SEPA) Flood maps
http://map.sepa.org.uk/floodmap/map.htm
These flood maps are designed to help understand how you could be affected by flooding. The maps show areas which are likely to flood from rivers, the sea and surface water.

45 African Flood and Drought Monitor (AFDM)
http://hydrology.soton.ac.uk/apps/afdm/

Princeton University in collaboration with ICIWaRM and UNESCO-IHP has developed a drought and flood monitoring and forecasting system for Africa. Its use is in understanding the potential of hydrological forecasts for improved decision-making. The system monitors, in near real-time, the terrestrial water cycle for the region based on remote sensing data and land surface hydrological modeling. The monitoring forms initial conditions for hydrological forecasts at short time scale, aimed at flood forecasting, and seasonal scale aimed at drought and crop yield forecasts. The flood forecasts are driven by precipitation and temperature forecasts from the Global Forecast System (GFS).

46 PDC Disaster Alert

https://disasteralert.pdc.org/disasteralert/

Disaster Alert is an initiative of the Pacific Disaster Center (PDC), which monitors various types of disasters using data collected by satellites. When people open the app or website through personal computer or mobile phone, they could quickly view hazards around the globe on the map. The design of the application also enables individuals to locate hazards in a specific area.

47 Sentinel Asia

https://sentinel-asia.org/

The Sentinel Asia is a voluntary basis initiative led by the Asia-Pacific Regional Space Agency Forum (APRSAF) to support disaster management activity in the Asia-Pacific region by applying the WEB-GIS technology and space based technology, such as Earth Observation satellites data. Water related disaster Working Group works for exchanging ideas with regards to water related disasters reduction by using aerospace technology together with ground survey and GIS/Mapping technology especially in the field of flood, landslide, flash flood, drought, storm surge and so on caused by heavy rain, typhoon, tropical cyclone, monsoon and climate change.

48 International Charter "Space and Major Disasters"

https://disasterscharter.org/web/guest/home

By combining Earth observation assets from different space agencies, the Charter allows resources and expertise to be coordinated for rapid response to major disaster situations, thereby helping civil protection authorities and the international humanitarian community. Pre-defined disaster risk management authorities from all over the world are able to submit direct requests in the immediate disaster response phase.

49 Copernicus Emergency Management Service (EMS)

https://emergency.copernicus.eu/mapping/

The Copernicus Emergency Management Service (EMS) is one of the main services that the Copernicus Programme, the European Union's Earth Observation programme, provides on a global scale. The service supports crisis managers, Civil Protection authorities and humanitarian aid actors dealing with natural disasters, man-made emergency situations, and humanitarian crises, as well as those involved in disaster risk reduction and recovery activities. Copernicus EMS On Demand Mapping provides on-demand detailed information for selected emergency situations that arise from natural or man-made disasters anywhere in the world.

50 DesInventar

https://www.desinventar.net/

The DesInventar Disaster Information Management System is a sustainable arrangement within an institution for the systematic collection, documentation and analysis of data about losses caused by disasters associated with natural hazards. This System is a tool that helps to analyze the disaster trends and their impacts in a systematic manner.

51 ThinkHazard!

https://thinkhazard.org/en/

ThinkHazard! provides a general view of the hazards, for a given location, that should be considered in project design and implementation to promote disaster and climate resilience. The tool highlights the likelihood of different natural hazards affecting project areas, provides guidance on how to reduce the impact of these hazards, and where to find more information. The hazard levels provided are based on published hazard data, provided by a range of private, academic and public organizations.

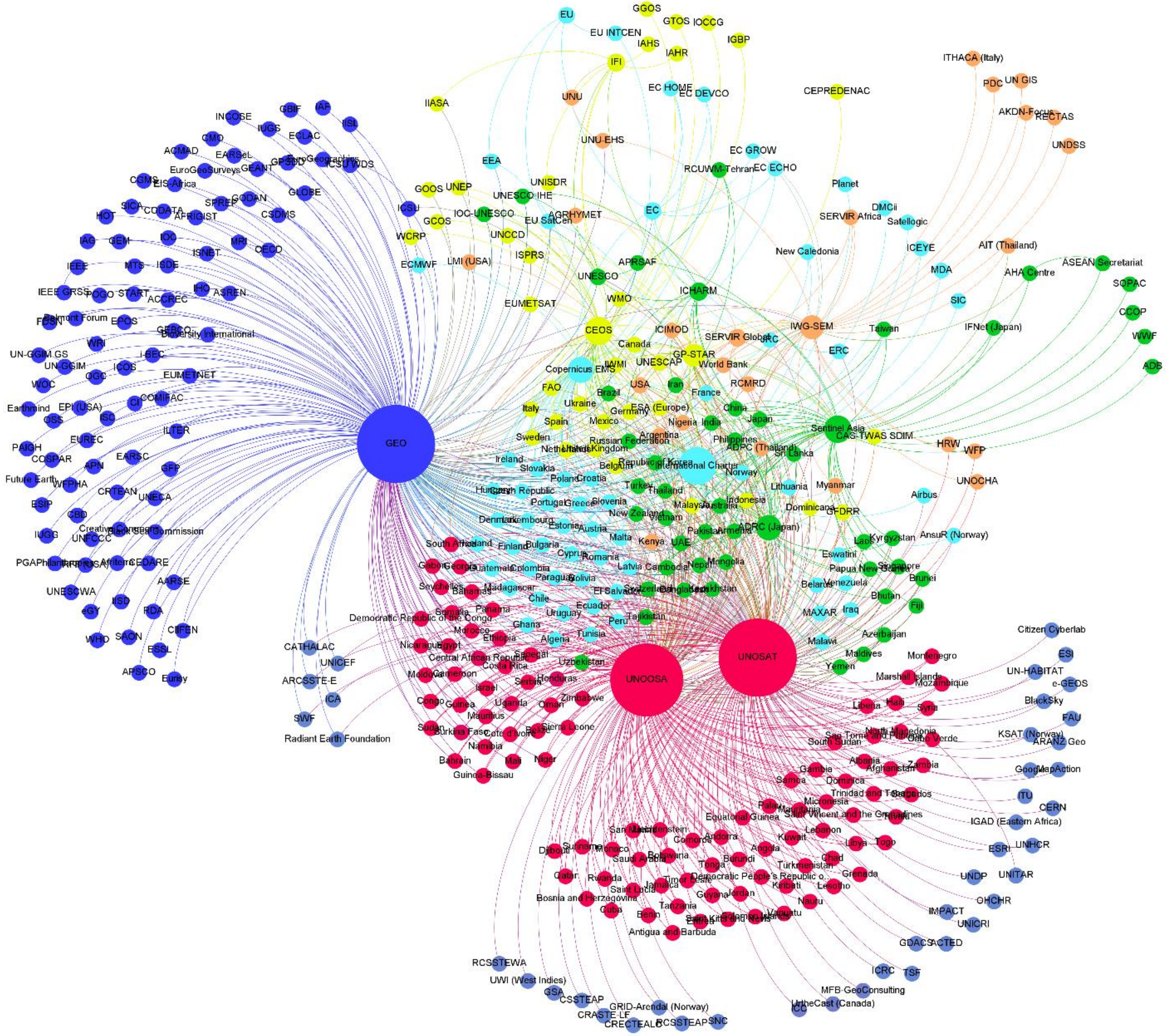
Appendix 4. Proposed aggregated classification of the selected GeoICTs

Classification is based on the purpose and the spatial coverage (scale) of the GeoICTs. Since the majority of the tools allow user to download manageable data, an asterisk (*) after the name of the tool indicates that it is not possible to download geospatial data feasible for the further analysis and processing (only static images).

Scale / Purpose	**Global**	**Regional**	**National and Local**
Data access and sharing	Global Change Master Directory (GCMD) EM-DAT: International Disaster Database SEDAC Worldview PREVIEW Global Risk Data Platform USGS Earth Explorer Earthdata search LandsatLook International Charter "Space and Major Disasters" Copernicus EMS DesInventar	SERVIR (Africa, Hindu Kush-Himalaya, Lower Mekong, Mesoamerica) CE-DAT: Complex Emergency Database (Africa, Asia) INSPIRE (Europe) Sentinel Asia (Asia-Pacific)	Auckland Council GIS Viewer (Auckland, New Zealand)
Awareness and information exchange	Aqueduct Floods Global Disaster Alert and Coordination System PDC Disaster Alert *	Climate change impacts in Europe *	Susquehanna Inundation Maps (Susquehanna River Basin, U.S.) SEPA Flood maps (Scotland) *
Data visualization	Collect Earth Online Giovanni JAXA Global Rainfall Watch (GSMaP_NRT) QGIS ArcGIS	JAXA Realtime Rainfall Watch (GSMaP_NOW) (Asia, Oceania) *	USGS WaterWatch (U.S.)
Understanding disaster risk	ClimateSERV ThinkHazard! *	SEERISK (Danube macro-region) *	Digital Earth Australia (DEA) Water Observations (Australia)
Monitoring and assessment	SEDAC Hazards Mapper * GPM Precipitation and Applications Viewer MODIS NRT Global Flood Product Extreme Rainfall Detection System (ERDS)	African Flood and Drought Monitor (AFDM) (Africa)	

Scale / Purpose	Global	Regional	National and Local
	Space-based Measurement, Mapping, and Modeling of Surface Water Global Flood Detection System (GFDS)		
Modelling and forecasting	Global Flood Monitoring System (GFMS) Global Flood Awareness System (GloFAS) Global Flood Alert System ver.2 (GFAS II) * FEMA’s HAZUS_MH FLO-2D	European Flood Awareness System (EFAS) Archive (Europe) *	Floor Level Map (Christchurch, New Zealand) *
Urban floods	Global Human Settlement Layer (GHSL) *	Urban Atlas (Europe) Urban Adaptation Map Viewer (Europe)	
Distance learning	Flood Manager E-learning *		

Appendix 5. Network of formal partners of selected organizations facilitating the diffusion of the GeoICTs (modularity classes are expressed through different colors)



Appendix 6. List of countries that were not directly supported by at least one of the three considered SEM mechanisms

Country or area	Number of recorded disasters[23]	Geographic region	Other groupings	SEM mechanism
Tanzania	131	Africa	LDC	UNOSAT
Mali	64	Africa	LDC, LLDC	UNOSAT
Libya	62	Africa	-	UNOSAT
Côte d'Ivoire	38	Africa	-	UNOSAT
Guinea-Bissau	21	Africa	LDC, SIDS	-
Gabon	18	Africa	-	-
Equatorial Guinea	14	Africa	-	UNOSAT
Eswatini	14	Africa	LLDC	Charter
Lesotho	14	Africa	LDC, LLDC	-
Botswana	13	Africa	LLDC	-
Canary Islands	11	Africa	-	-
Eritrea	5	Africa	LDC	-
Mayotte	3	Africa	-	-
Sao Tome and Principe	3	Africa	LDC, SIDS	-
Saint Helena, Ascension and Tristan da Cunha	1	Africa	-	-
Mongolia	27	Asia-Pacific	LLDC	Sentinel Asia
Hong Kong	20	Asia-Pacific	-	Sentinel Asia
Azerbaijan	16	Asia-Pacific	LLDC	Sentinel Asia
Timor-Leste	12	Asia-Pacific	LDC, SIDS	UNOSAT
Federated States of Micronesia	9	Asia-Pacific	SIDS	-
Armenia	8	Asia-Pacific	LLDC	Sentinel Asia
Uzbekistan	7	Asia-Pacific	LLDC	Sentinel Asia
Marshall Islands	6	Asia-Pacific	SIDS	-
Bahrain	5	Asia-Pacific	-	-
Qatar	5	Asia-Pacific	-	-
American Samoa	4	Asia-Pacific	SIDS	UNOSAT
Kiribati	4	Asia-Pacific	LDC, SIDS	-
Kuwait	4	Asia-Pacific	-	-
Macao	4	Asia-Pacific	-	Sentinel Asia
Singapore	4	Asia-Pacific	SIDS	Sentinel Asia
Tuvalu	4	Asia-Pacific	LDC, SIDS	-
French Polynesia	3	Asia-Pacific	SIDS	-

[23] According to EM-DAT, for 2000-2020.

Country or area	Number of recorded disasters[23]	Geographic region	Other groupings	SEM mechanism
Turkmenistan	2	Asia-Pacific	LLDC	-
Niue	1	Asia-Pacific	SIDS	-
Tokelau	1	Asia-Pacific	-	-
Belarus	9	Europe	-	Charter
Malta	8	Europe	-	Charter, Copernicus EMS
Estonia	6	Europe	-	Charter, Copernicus EMS
Isle of Man	1	Europe	-	Charter
Belize	12	Latin America and the Caribbean	SIDS	UNOSAT
Saint Vincent and the Grenadines	10	Latin America and the Caribbean	SIDS	UNOSAT
Saint Lucia	9	Latin America and the Caribbean	SIDS	-
Cayman Islands	7	Latin America and the Caribbean	SIDS	-
Barbados	6	Latin America and the Caribbean	SIDS	-
Trinidad and Tobago	5	Latin America and the Caribbean	SIDS	-
Curaçao	1	Latin America and the Caribbean	SIDS	-

Appendix 7. List of countries where UN-SPIDER provided Technical Advisory Support, with indications of main activities

Region	Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Africa	Burkina Faso	TAM	training	emergency	training	*training								
	Namibia	em. *tr.	TAM	ISM	emergency									
	Togo		TAM											
	Nigeria	RSO			TAM	mtg. *tr.					*training			
	Sudan			emergency	TAM	*training	ISM							
	Cameroon				TAM	training	*training						ISM	
	Cape Verde					TAM								
	Mozambique				training	TAM	ISM		*training					
	Ghana	EM			emergency	*training	TAM				*training	ISM		
	Malawi			EM		*training	TAM							
	Zambia							TAM						
	Kenya		EM	RSO	emergency	*training	*training	TAM			*training			
	Uganda		EM	emergency										
	Madagascar			EM										
	Gabon								TAM		training			
	Zimbabwe											TAM		
	Tunisia													TAM
	Ethiopia												ISM	
Asia/Pacific	Fiji		TAM			*training	*training							
	Samoa		TAM		*meeting	*training								
	Maldives			TAM										
	Bangladesh				TAM	*training	ISM		ISM					
	Sri Lanka			emergency	TAM	ISM	*training	ISM	RSO		ISM	ISM		
	Myanmar			emergency		TAM ISM	*training			ISM	ISM		ISM	
	Tonga			emergency		TAM								
	Solomon Islands			emergency		TAM	*meeting				ISM			
	Vietnam					*training	TAM	ISM	*tr. em.	ISM		ISM		
	Bhutan						*training	TAM	training					
	Mongolia						*training	TAM					ISM	
	Lao PDR					*training			TAM	ISM			ISM	
	Nepal			training			RSO	ISM em.	emergency		TAM	ISM		
	Afghanistan		EM					emergency						
	India			ISM	training	training	training			training				
	Philippines		emergency	EM		emergency	*training							
	Vanuatu			EM										
	Turkey			EM			*training							
	China						ISM							

Region	Country	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Latin America/ Caribbean	Ecuador		TAM						*meeting	*meeting			ISM	
	Jamaica		TAM	*training										
	Guatemala		meeting	EM TAM	EM	emergency		*meeting	*meeting	mtg. *mtg.	training			
	Dominican Republic			TAM	ISM		ISM	*mtg. em.	*meeting	ISM				
	El-Salvador				*training			TAM		EM	training			
	Honduras							*meeting	TAM	*meeting				
	Chile			ISM				emergency						
	Colombia			EM	RSO			*meeting	meeting	*meeting				
	Haiti			EM										
	Peru												TAM	
Europe	Georgia								*training	TAM				

*Activities include: Advisory Missions, trainings (tr.) or meetings (mtg.), organization of a Regional Support Offices, or assistance provided during emergencies (em.). Abbreviations: TAM - Technical Advisory Mission; ISM - Institutional Strengthening Missions; EM - Expert Missions; RSO - Regional Support Office; bright orange indicates that the training or meeting was conducted in the country, while * before the word shows that that year the event was organized in another country, but experts from this particular state were present. (Data collected from the official reports)*

Data from the official reports on activities implemented by the UN-SPIDER (UN General Assembly 2009a, 2009b, 2010, 2011, 2012, 2013, 2014, 2015b, 2017a, 2017b, 2019, 2020).

Appendix 8. Main descriptive statistics for the analysis of the delay in activations in days (excluding activations in advance)

Activations		mean	standard deviation	min	Percentiles			max
					25%	50%	75%	
Copernicus EMS	All cases (415 in total)	5.65	20.97	0	0.48	1.35	3.95	283.36
	If remove above 20 days (394 cases)	2.60	3.41	0	0.42	1.19	3.52	19.43
	If remove above 10 days (373 cases)	1.99	2.18	0	0.38	1.06	2.91	9.83
	Within first 72 hours (283 cases)	0.95	0.83	0	0.23	0.78	1.41	2.98
Sentinel Asia	All cases (291 in total)	3.73	10.59	0	1.0	2.0	3.0	126
	If remove above 20 days (285 cases)	2.44	2.93	0	1.0	2.0	3.0	18
	If remove above 10 days (276 cases)	2.06	2.05	0	1.0	2.0	3.0	9
	Within first 72 hours (223 cases)	1.24	1.03	0	0	1.0	2.0	3

Appendix 9. Location of activations, by geographic regions[24]

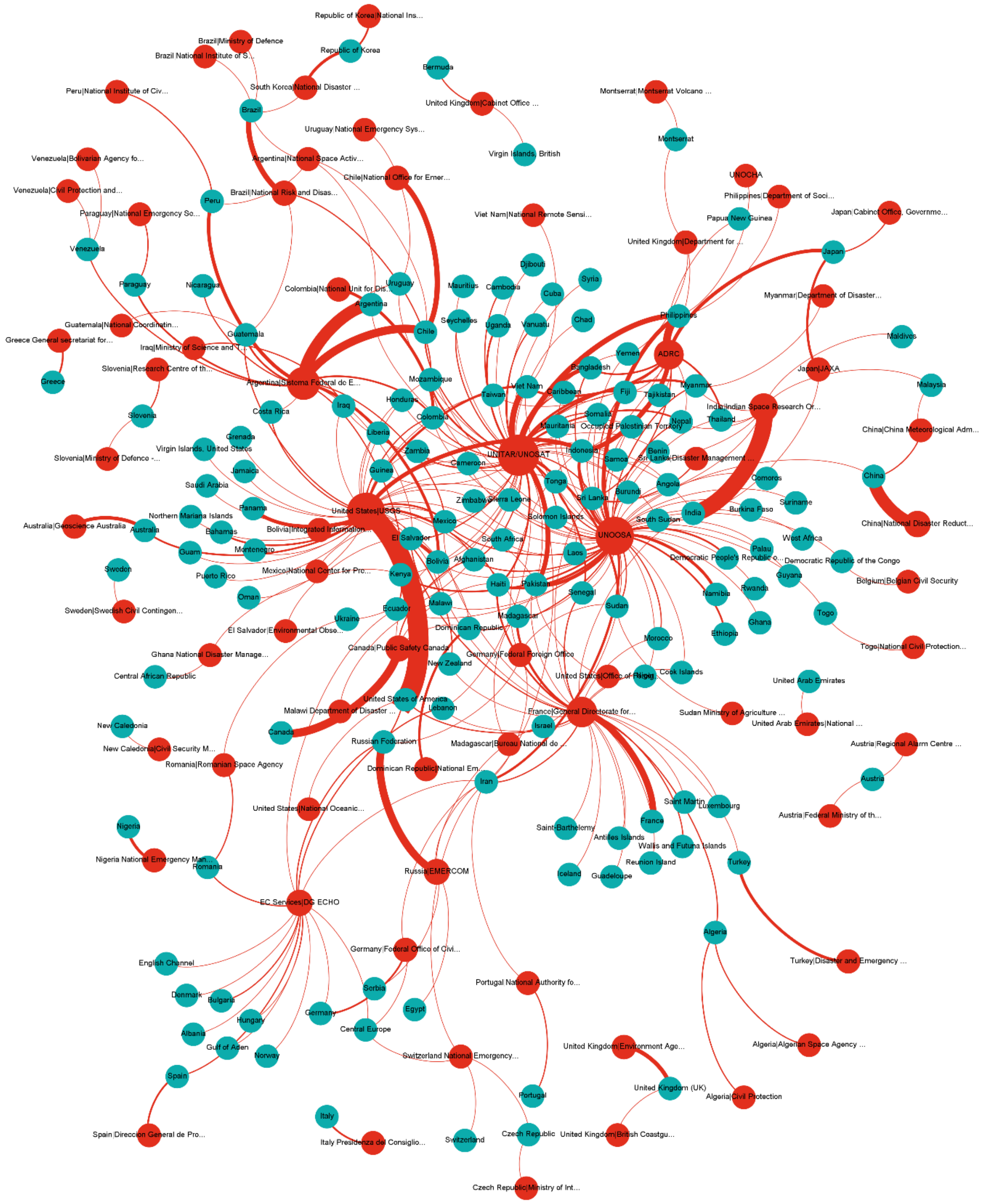
	SEM mechanism					
	Charter		Copernicus EMS		Sentinel Asia	
Geographic region	**Total number**	**%**	**Total number**	**%**	**Total number**	**%**
Africa	99	14.31	40	8.95	0	0
Asia-Pacific	288	41.62	86	19.24	342	100
Europe	77	11.13	279	62.41	0	0
Latin America and the Caribbean	176	25.43	31	6.94	0	0
Northern America	52	7.51	11	2.46	0	0
Total	692	100	447	100	342	100

Appendix 10. Location of AUs requesting the activations, by geographic regions

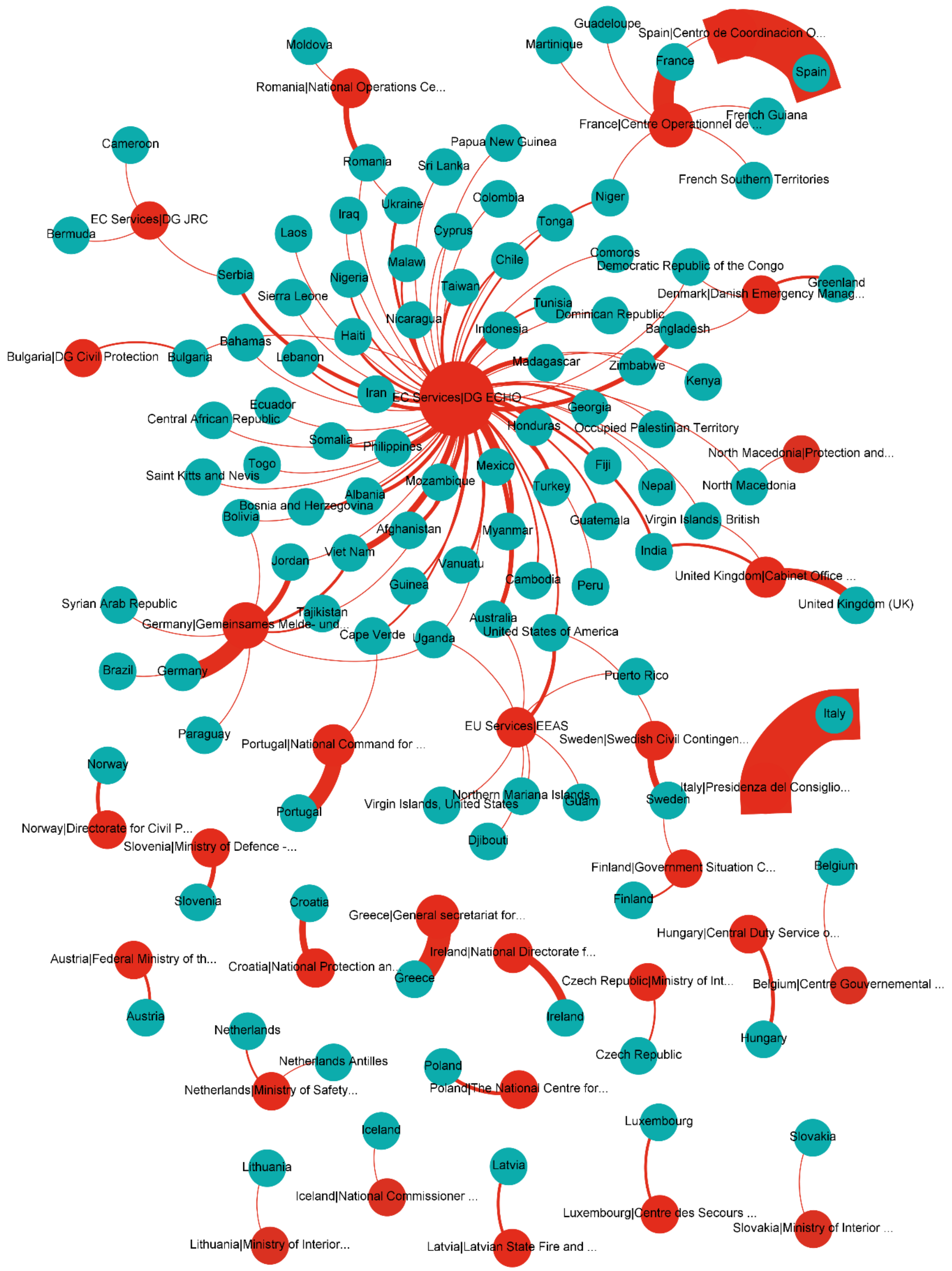
	SEM mechanism					
	Charter		Copernicus EMS		Sentinel Asia	
Geographic region	**Total number**	**%**	**Total number**	**%**	**Total number**	**%**
Africa	15	1.97	0	0	0	0
Asia-Pacific	139	18.27	0	0	379	98.19
Europe	136	17.87	465	100	0	0
Latin America and the Caribbean	119	15.64	0	0	0	0
Northern America	123	16.16	0	0	0	0
International	229	30.09	0	0	7	1.81
Total	761	100	465	100	386	100

[24] Based on actual recorded activations, not network.

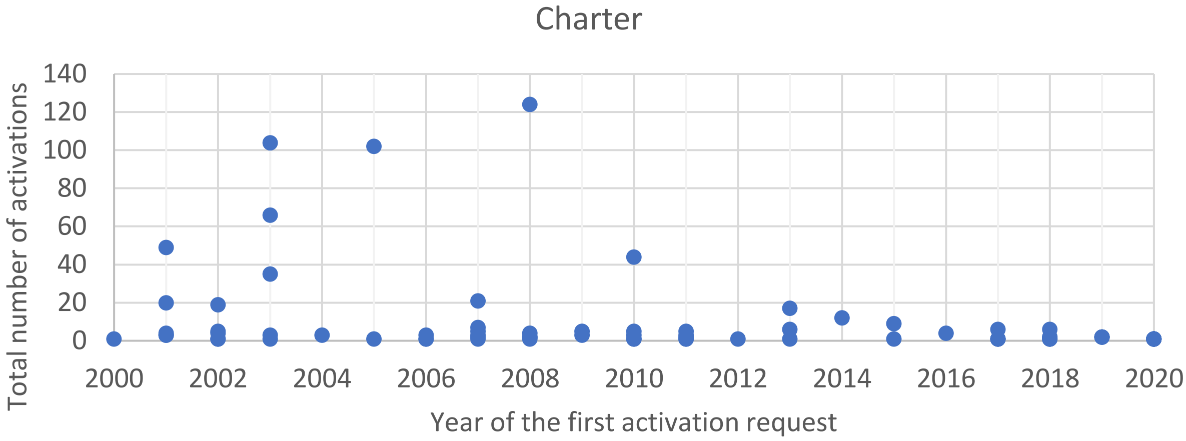
Appendix 11. Network of activations of the International Charter “Space and Major Disasters”

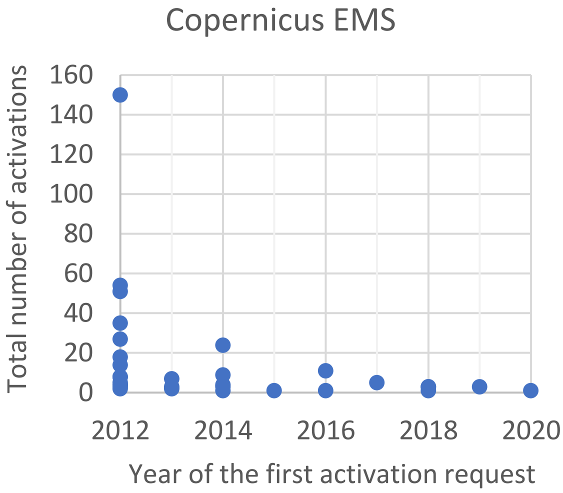


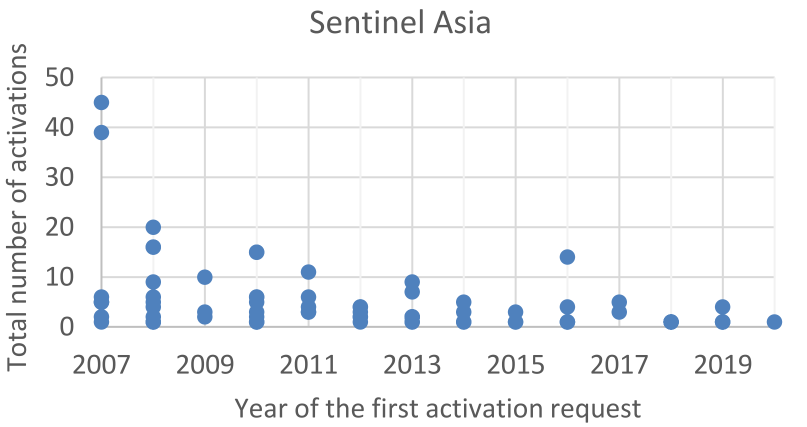
Appendix 12. Network of activations of the Copernicus EMS "Rapid Mapping"



Appendix 13. Activity of SEM mechanisms' AUs based on their first activation request





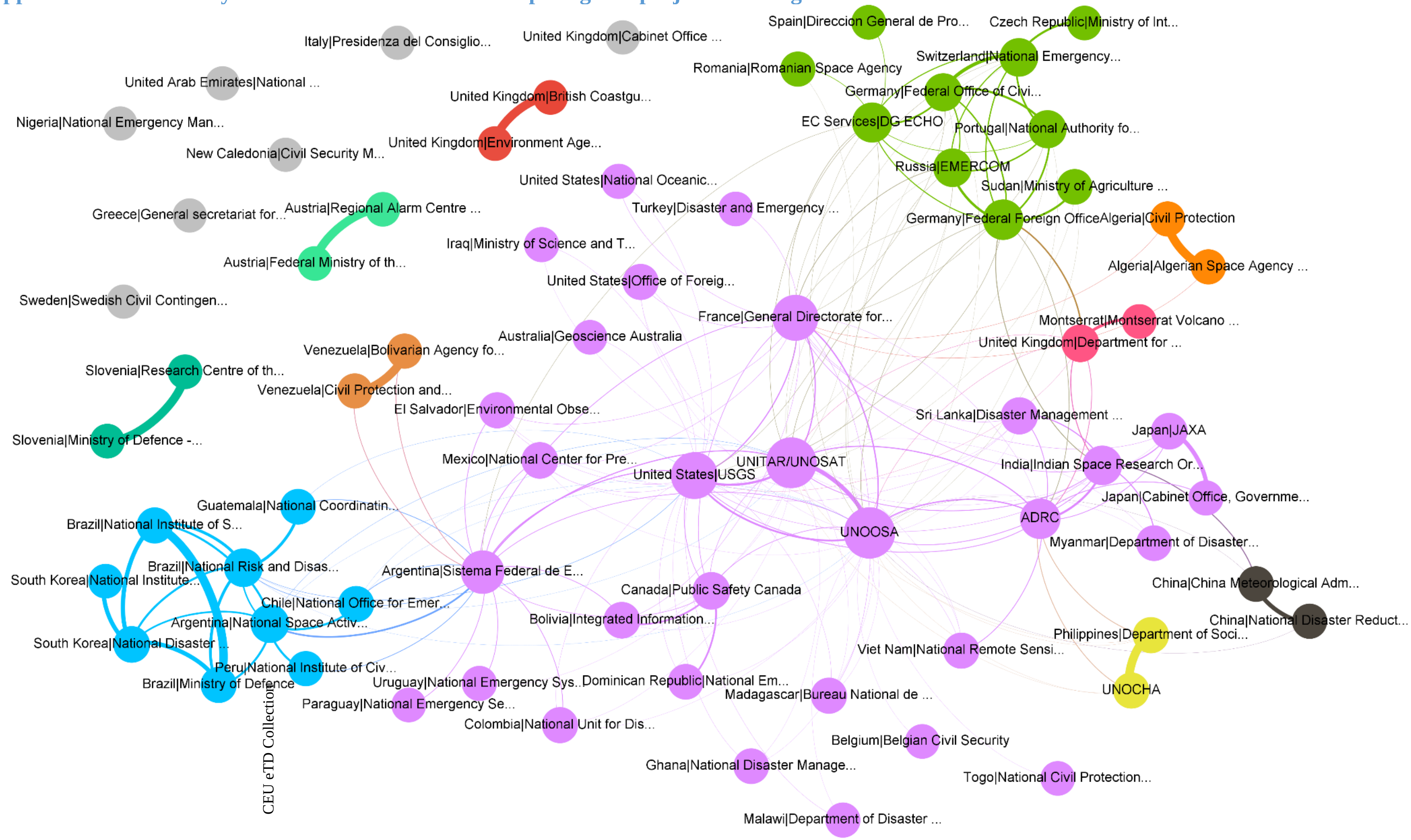


Appendix 14. Top 10 most important links (highest number of activations) between an AU and a country, of the selected SEM mechanisms

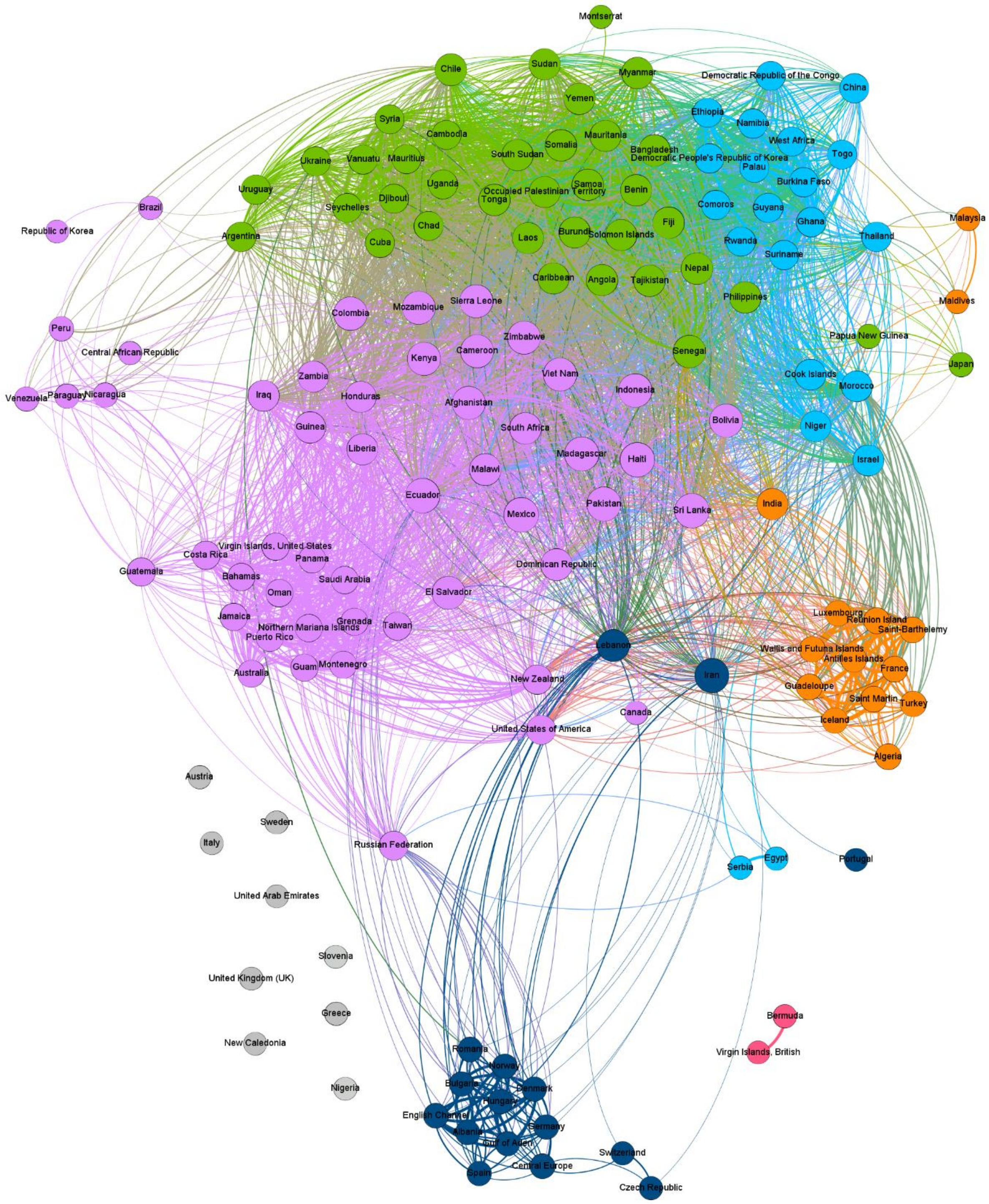
Charter			Copernicus EMS			Sentinel Asia		
Organization (AU)	**Country**	**Number of activations**	**Organization (AU)**	**Country**	**Number of activations**	**Organization (AU)**	**Country**	**Number of activations**
USGS (USA)	*USA*	*34*	*Presidenza del Consiglio dei Ministri - Dipartimento della Protezione Civile - Centro Situazioni (Italy)*	*Italy*	*54*	*LAPAN (Indonesia)*	*Indonesia*	*44*
ISRO (India)	*India*	*28*	*CECOP (Spain)*	*Spain*	*50*	*MONRE (Viet Nam)*	*Viet Nam*	*39*
NDRCC (China)	*China*	*21*	*General secretariat for Civil protection - Directorate for Emergency Planning and Response (Greece)*	*Greece*	*24*	*PHIVOLCS (Philippines)*	*Philippines*	*20*
SIFEM-DNPC (Argentina)	*Argentina*	*21*	*DGSCGC (France)*	*France*	*22*	*JAXA (Japan)*	*Japan*	*16*
SIFEM-DNPC (Argentina)	Chile	14	*BBK (Germany)*	*Germany*	*19*	*ISRO (India)*	*India*	*15*
Public Safety Canada	*Canada*	*14*	*National Command for Relief Operations - National Authority for Civil Protection (Portugal)*	*Portugal*	*17*	*NARL (Taiwan)*	*Taiwan*	*15*
EMERCOM (Russia)[25]	*Russia*	*13*	*Cabinet Office - Civil Contingencies Secretariat (United Kingdom)*	*United Kingdom*	*10*	*DMPTC (Viet Nam)*	*Viet Nam*	*14*
ADRC	Philippines	13	*National Directorate for Fire and Emergency Management (Ireland)*	*Ireland*	*9*	ICIMOD	Nepal	11
DGSCGC (France)	*France*	*11*	*National Protection and Rescue Directorate in the Civil Protection Sector (Croatia)*	*Croatia*	*7*	*Manila Observatory (Philippines)*	*Philippines*	*11*
UNITAR-UNOSAT	Viet Nam	10	DG ECHO (EC Services)	Viet Nam	7	*Disaster Management Centre (Sri Lanka)*	*Sri Lanka*	*10*

[25] Ministry of the Russian Federation for Civil Defence, Emergencies and Elimination of Consequences of Natural Disasters

Appendix 15. Modularity classes in the Charter's overlap weighted projection of organizations

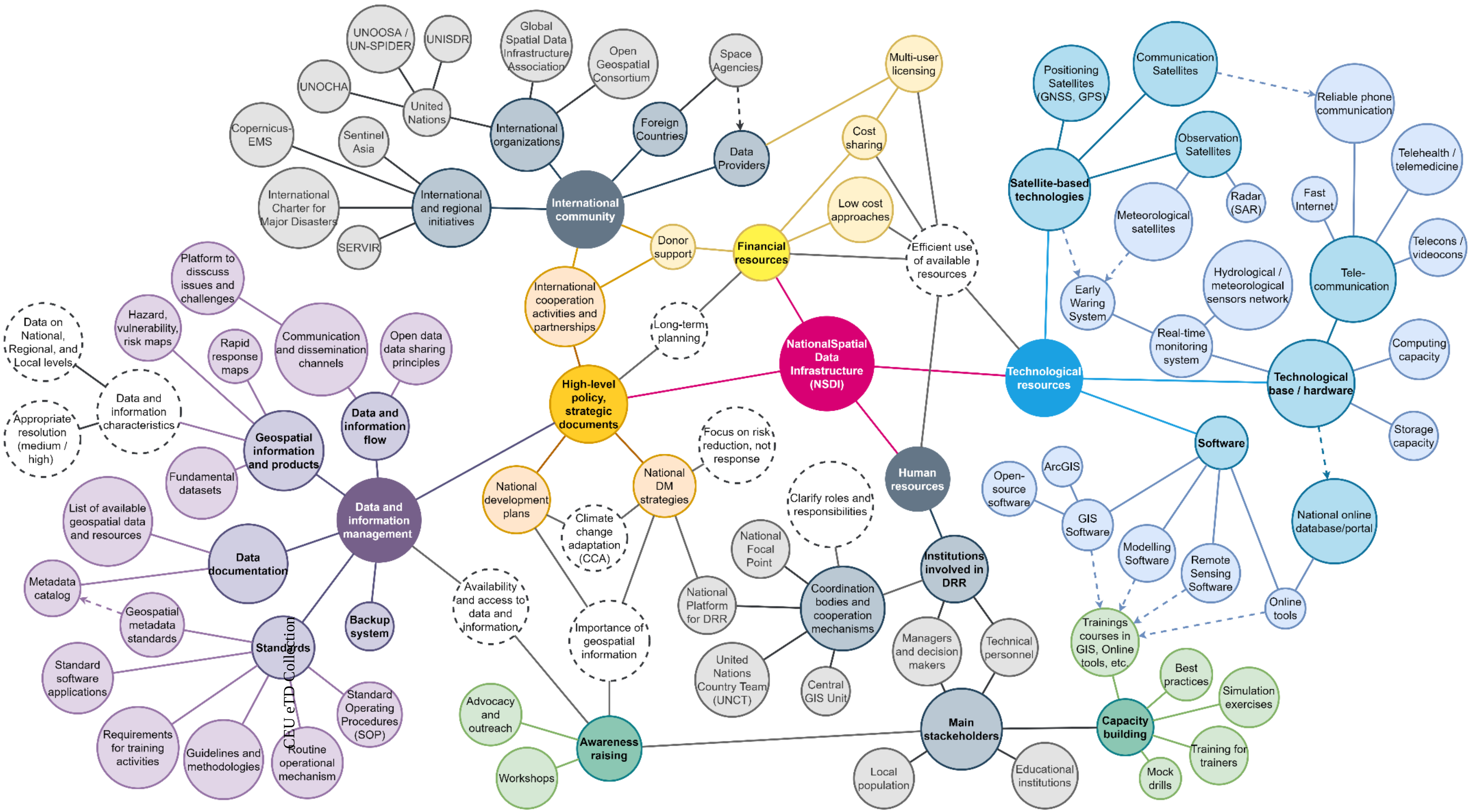


Appendix 16. Modularity classes in the Charter's overlap weighted projection of countries

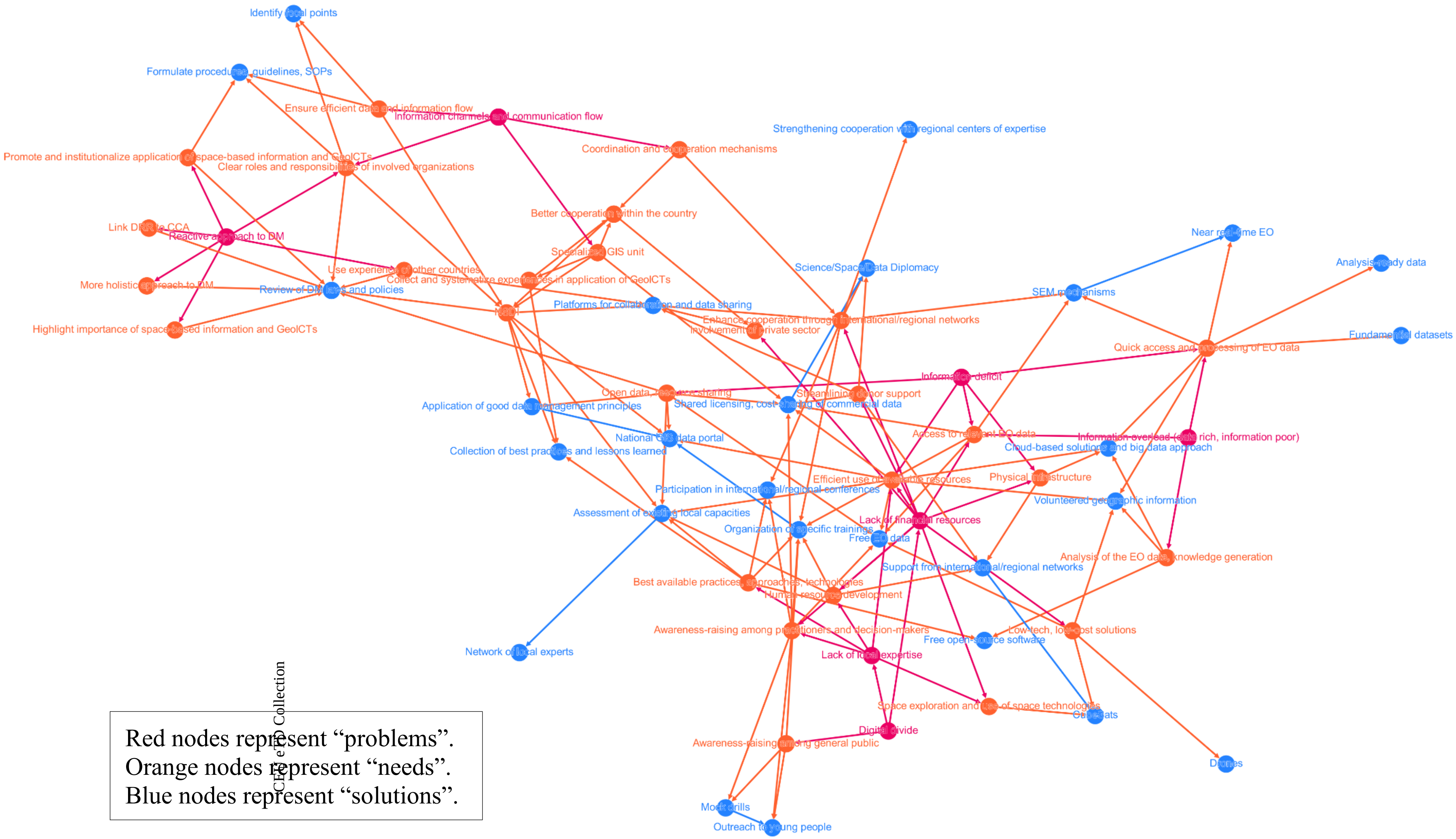


Appendix 17. Detailed thematic network of the topics identified through the analysis of TAM reports.

Colors show different segments of the diagram. Dotted circles represent special characteristics of particular elements of the system. Dotter arrows represent potential thematic relationships between some elements (connections which do not follow straightforward three network topology)



Appendix 18. "Problem-solution" concept map (visualized in Gephi)



Red nodes represent "problems".
Orange nodes represent "needs".
Blue nodes represent "solutions".