Strengthening capacities for the use of GIS in disaster risk reduction

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Abstract:
Geographic Information Systems (GIS) are a powerful tool for supporting disaster risk reduction (DRR). International agreements such as the Sendai Framework for Disaster Risk Reduction call on high-income countries and other partners to support lower-income countries in strengthening their DRR capacities. This thesis explores the experiences of stakeholders in strengthening GIS capacities for DRR in lower and middle-income countries. It presents the theoretical concepts of DRR and capacity development as well as the applications of GIS in DRR. Based on semi-structured interviews with practitioners from different regions and a literature review, this thesis analyses practices and challenge encountered in strengthening GIS capacities for DRR as well as possibilities for overcoming these challenges. The findings show that there is a broad range of initiatives for strengthening GIS capacities. Whilst some of the challenges such as culture, politics and power relations are specific to the context, this study finds that stakeholders in different context often experience similar challenges such as lack of data, costs of GIS and lack of decision-maker support for GIS. Sustaining the capacities in the long-term was identified as a major challenge. To overcome these challenges and make GIS capacity development sustainable this thesis recommends tailoring the GIS solutions to the specific situation, developing low-cost solutions, integrating GIS into the organisational structure and demonstrating the benefits of GIS for DRR to decision-makers. This requires a long-term approach and strong stakeholder involvement in the capacity development process.

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POPULAR SCIENCE SUMMARY

A map is worth a thousand word. Geographic Information Systems (GIS) - systems comprised of software, hardware and data can be used to capture, store, manipulate and analyse all kinds of different geographically referenced data and then visualise this data on a map. This can be used in disaster risk reduction– take for example a city with a river that regularly floods. In GIS, a map of the flood prone areas can be combined with a map of the city's infrastructure so we can see where there is a risk of flooding. If we add population data to the system, we can also find out how many people will be affected, if we add the road network we can simulate evacuation routes and so on. In other words, GIS can be a very useful tool in disaster risk reduction. Most of the disaster losses occurs in lower income countries. GIS could help reduce risk in these countries, but at the same time, authorities in these countries often do not have the knowledge, resources or structures to use GIS for disaster risk reduction. Therefore, there is a need to strengthen these capacities, this is often done with the support of external partners, whether it is a national authority bringing GIS to the local level or an international agency trying to support a national disaster management authority. This research aims to identify challenges and success factors for such capacity development interventions.

Therefore, 15 different practitioners from a wide range of regions were interviewed and the literature on GIS capacity development was studied. The results of this research indicate that there are several challenges to strengthening GIS capacity. First of all, GIS can be costly, particularly hiring qualified staff, buying proprietary software and collecting data. Secondly, there are challenges specific to the context: sometimes people may be unfamiliar with technology, there might be language barriers or security concerns over data sharing. However, the biggest challenge was sustaining the GIS capacities in the long-term. Data needs to be updated to be useful and GIS needs to be used for decision-making to have any effect. The study found two main factors leading to this, first the lack of support from the decision-making or management level, second the turnover of staff. The former may be either due to a lack of awareness of the benefits of GIS or be due to the fact that there are competing priorities for a limited budget. The latter is a frequent issue and sometimes related to the capacity development intervention, as the new GIS skills allow staff to find better employment elsewhere.

This research thus identifies several considerations for strengthening GIS capacities – 1) GIS needs to be adapted to the specific context that means the needs of the organisation, the resources available to maintain it as well the wider cultural and political context; 2) to be maintained and used in the long-term GIS needs to be integrated in the organisation's work practices; 3) lower the cost of GIS through using open source software, freely available data and creating synergies with existing institutions and 4) availability of quality data should be improved, mostly through policies and legislation for data collection, standardisation and sharing.

These lead to two overarching considerations that are particularly relevant to those implementing and funding GIS capacity development interventions. First, changes such as changing an organisation's practices or national legislation take a long time, therefore strengthening GIS capacities needs to be part of a long-term partnership with regular follow-ups. Second, strengthening GIS capacities is not simply the provision of a technical solution, it requires the ownership of those using GIS in order for them to be willing to maintain and use it. Therefore, the partner should be involved throughout the entire process and particular attention should be paid to convincing management of the benefits of GIS.

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ABBREVIATIONS

CADRI	Capacity for Disaster Reduction Initiative
DRR	Disaster Risk Reduction
GIS	Geographic Information System
SDI	Spatial Data Infrastructure
UN-GGIM	United Nations Initiative on Global Geospatial Information Management
UNISDR	United Nations International Strategy for Disaster Reduction
VGI	Volunteered Geographic Information

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1. INTRODUCTION

1.1. Background

Throughout history, disasters have caused significant human suffering and led to serious setbacks to development. Future losses from disasters are projected to increase even further - as the Global Assessment Report on Disaster Risk Reduction 2015 puts it "*most disasters that could happen have not happened yet"* (UNISDR, 2015, iv). This threat has been recognised by the international community through the Sendai Framework for Disaster Risk Reduction 2015–2030, which aims to substantially reduce disaster risk and disaster associated losses.

A Geographic Information Systems (GIS) is *"an organised collection of computer hardware, software, geographic data, and personnel designed to efficiently capture, store, update, manipulate, analyse, and display all forms of geographically referenced information"* (ESRI, 1990, 1.2). Since disaster risk is closely tied to geographic location, GIS can serve as a powerful tool in disaster risk reduction (DRR), for example through the creation of risk maps. It is explicitly mentioned in the Sendai Framework's Priority for Action 1: "understanding risk" which calls for promoting *"real time access to reliable data, make use of space and in situ information, including geographic information systems "* (UNISDR, 2015, 15).

Whilst disaster risk is a global challenge, the largest portion of disaster losses occurs in low and middle-income countries (UNISDR, 2015). The Sendai Framework therefore calls on the high-income countries and other partners to support these countries through technology transfer and capacity building.

The use of GIS can increase the capacity for DRR through an improved understanding of risk, but certain capacities are needed to effectively use GIS in DRR. Currently, there is still a gap between the state of the art in geospatial information technology and how it is used to support DRR (UN-GGIM, 2016b). In low-income countries in particular, the uptake of GIS for DRR has been slow (Teeuw, Leidig, Saunders, & Morris, 2013). Building on the Sendai Framework, in May 2016, the United Nations Initiative on Global Geospatial Information Management (UN-GGIM) presented a Draft Strategic Framework on Geospatial Information and Services for Disasters with the goal of making quality geospatial information services available and accessible to stakeholders to support decision-making across all phases of DRR and management. During the 6th session of the UN-GGIM in August 2016, its members acknowledged that robust plans for capacity building to assist developing countries in reaching this goal are necessary (UN-GGIM, 2016a).

1.2. Research purpose and research questions

The introduction has shown that there is both a need for strengthening GIS capacities for DRR, particularly in low and middle-income countries, as well as some global momentum towards tackling this issue. This leads to the question of what should be done in practice to strengthen these capacities.

The purpose of this qualitative study is to explore the experiences of stakeholders in capacity development for the use of GIS in DRR in lower and middle-income countries. The objectives are to identify common challenges, good practices and factors to consider when planning and implementing capacity development interventions for the use of GIS in DRR. The results of the research can contribute to informing those funding, designing and implementing such capacity development interventions in order to improve their effectiveness.

The research is guided by the main research question: What are important considerations when attempting to strengthen capacities for GIS use in DRR?

To further focus the research, the following sub-questions are posed:

- SQ1: What are the findings on challenges and good practices for strengthening GIS capacities in the existing literature?
- SQ2: What practices have stakeholders used to strengthen capacities for the use of GIS for DRR?
- SQ3: What challenges have stakeholders in projects for strengthening capacities for the use of GIS for DRR encountered and how can these challenges be addressed?

2. METHODS

The research approach should be determined by the research question. Since there has been relatively little research on the topic, I took qualitative approach (Creswell, 2007) to explore the issue of GIS capacity development for DRR and gain a deeper understanding of the stakeholder's experiences. To find answers to the research questions, I reviewed the existing literature and conducted-semi-structured interviews with stakeholders in capacity development initiatives.

2.1. Data collection

2.1.1. Literature study

The topic of this thesis touches upon different fields of research, such as capacity development, DRR and geographic information science, thus I studied a wide range of literature to set up the theoretical framework to introduce the main concepts. I gave preference to academic literature; however, particularly capacity development and DRR are relatively new fields, closely tied to practice. Therefore, I also consulted grey literature, particularly guides and policy documents from international agencies to account for the current thinking in the practitioner community.

To find answers to the last sub-question, I conducted a more systematic literature review. Academic literature on the specific topic of capacity development for DRR was sparse, still, through studying the literature, I found that related topics such as the implementation of GIS in developing countries can provide relevant insights to the research questions. The preliminary reading helped identify key words for a systematic search for peer-reviewed literature in Scopus (see Table 1).

Topic area	Scopus search results	Relevant
GIS capacity development for disaster risk reduction[1]	5	2
GIS and capacity development[2]	55	8
GIS for disaster risk management in developing countries[3]	72	7
GIS implementation in developing countries[4]	84	13
Total	201*	24*
**Duplicates of articles found through more than one search string were not included in the total count*		

Table 1 Literature search strategy

[1] Search string (TITLE-ABS-KEY ("geographic information system*" OR gis OR geoinformation) AND TITLE-ABS-KEY ("capacity development" OR "capacity building" OR "strengthening capacities" OR "capacity enhancement" OR "capacity strengthening")

[2] Search string: (TITLE-ABS-KEY (gis OR "geographic information system*") AND TITLE-ABS-KEY ("capacity development" OR "capacity building" OR "strengthening capacities" OR "capacity enhancement" OR "capacity strengthening"))

[3] Search string: (TITLE-ABS-KEY (gis OR "geographic information systems*") AND TITLE-ABS-KEY ("developing countr*" OR "low income countr*")

[4] Search string: (TITLE-ABS-KEY (gis OR "geographic information systems*") AND TITLE-ABS-KEY ("developing countr*" OR "low income countr*")

First based on titles and abstracts, and in a second step, through searching the full text, I decided if an article was relevant to the research question, i.e. whether it contained information on challenges or good practices regarding the introduction of GIS. In a second step, I used the references of the relevant papers found in Scopus, as well as similar articles suggested in journal databases to find additional literature. This led to 39 articles in total used in the literature review.

2.1.2. Interview study

To answer the remaining sub-questions, I conducted semi-structured interviews with different stakeholders in capacity development interventions for the use of GIS. To see whether general considerations for strengthening GIS capacities for DRR emerge, I decided to interview both internal partners trying to strengthen their own GIS capacity and external partners supporting the capacity development of another entity. Since the most pressing need for improving GIS capacities is in lower-income countries and capacity development initiatives thus generally take place in this context, I only interviewed stakeholders who had worked in those countries. To capture and compare the wide range of experiences, I aimed to interview people with experiences in various regions and from different organisations.

As I was looking for the experiences of a very specific group of experts, I used a purposive sampling approach. To identify potential participants, I searched the internet for GIS-related capacity development projects in the field of DRR and then tried to find contact details of persons involved. I sent out e-mails to these individuals or organisations, explaining my research project and asking for an interview. In addition, I used a snowballing approach, asking participants if they could refer me to someone in their network. This mixture of snowballing and purposive sampling, also helped cast a wide net of different experiences and avoid selection biases. Between February and June 2017, I sent out 48 requests, of which 22 received a response. Except for two responders, who felt the request was outside their area of expertise, all responses were positive, although, a number of those who had responded at first did not reply to subsequent attempts to schedule an interview. In total, I conducted 15 interviews between April and June 2017.

All interview participants had at least five years of experience and came from a range of backgrounds (see Table 2 on page 5). To preserve the anonymity of the participants, each participant was assigned a number to identify them. This number is also used for citations in the results section.

ID	Gender	Type of institution	Role in capacity development	Regional experience
1	male	academia	external partner	South America; Pacific; Caribbean; Central Asia; Southeast Asia
2	male	UN organisation	external partner	Southeast Asia; East Africa; West Africa
3	male	UN organisation	external partner	Latin America, Africa, Asia
4	female	NGO	external partner	Pacific; Middle East
5	male	academia	external partner	Southeast Asia; Caribbean; Central Asia; South America; Central America
6	male	provincial authority	external partner	Southeast Asia
7	male	provincial authority	external partner	Southeast Asia
8	male	NGO	external partner	Southeast Asia
9	female	regional organisation	external partner	Caribbean
10	female	national authority	internal partner	Caribbean
11	male	various	both	Southeast Asia; South Asia
12	male	national authority	external partner	Southeast Asia; South Asia
13	male	national authority	internal partner	South America
14	male	academia	external partner	Central Asia; East Africa; Middle East
15	male	NGO	external partner	Central Asia; Southern Africa

Table 2 Interview participants

As the participants were located around the world, face-to-face interviews were not feasible and thus almost all interviews took place via Skype. Before the interviews, I informed the participants about the research project, gave them a possibility to ask questions and asked for their permission to record the interview. Two respondents preferred answering in writing. After reading their responses, I sent them further follow-up and clarification questions to make this process as close to an actual interview situation as possible. The interviews lasted between 20 minutes and one hour. In general, I followed an interview guide with open ended questions (see appendix), which I modified according to the situation of the participant and their responses. The interview guide itself was developed based on the research question and informed through the conceptual framework. Interviews always carry a risk of being influenced by the biases of the researcher. Since the interviews took place via skype, there was less of a risk of my body language influencing the answers. In addition, I took care to formulate questions as neutrally as possible and always asked if there was anything else that I should have asked about on the topic in order to avoid biasing the results by underlying preconceived notions that I may have had when formulating the questions.

2.2. Analysis

All interviews were recorded and transcribed. For the analysis, I used what Hsieh & Shannon (2005) refer to as conventional content analysis. This approach tends to be appropriate in situations with limited existing theory and research, where the main goal is to gain knowledge about a phenomenon. It differs from similar approaches such as grounded theory in that it does not

attempt to develop theory but rather focusses on systematically describing the meaning of the data by extracting categories (Cho & Lee, 2014). I chose this approach, because the aim of my research is to inform practice in capacity development for DRR by identifying common practices, challenges and strategies to overcome them, rather than developing theory and examining the relationship between different categories.

For the analysis process, I followed the steps outlined by Elo & Kyngäs (2008) (see Figure 1). Since I did not base the research on an already existing theory, I took an inductive approach and began with open coding of the data. To organise my data and facilitate the coding process, I used RQDA, a qualitative data analysis software (Huang, 2016), which made it easier to assign and re-assign codes to the transcripts. After several rounds of open coding, similar open codes were grouped together under one code and the data was coded again, applying the new codes. Then, I used these codes to form categories and themes, which allow for abstraction from the empirical data.

Figure 1 Asnalysis process

3. CONCEPTUAL FRAMEWORK

This section outlines the main concepts – DRR and capacity development – which provide the general background for this research and have informed the formulation of the interview questions. It also introduces GIS and explains how it can be used as a tool for DRR.

3.1. Disaster Risk Reduction

Many argue that disaster risk emerges from a combination of hazards, exposure to the hazard and associated vulnerabilities. These three factors can be increased through unsustainable developments e.g. climate change, uncontrolled urbanisation, or growing inequality. Therefore, disaster risk and disaster losses are both an outcome of human development as well as a threat to it (Pearson & Pelling, 2015).

This concern has been at the core of the Sendai Framework for Disaster Risk Reduction 2015-2030. Its predecessor the Hyogo Framework for Action was a first step towards a focus on disaster prevention, rather than response (Tiwari, 2015), yet it was still focussed on the substantial reduction of disaster losses. The Sendai Framework took this further - the desired outcome of this voluntary and non-legally binding agreement between UN member states is the substantial reduction not only disaster losses but also disaster risk. The Sendai Framework thus marks a shift in focus from disaster management towards a more holistic approach to DRR and addressing underlying risk factors such as poverty, climate change, or unplanned urbanisation and poor land management (Wahlström, 2015).

UNISDR defines disaster risk reduction 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"* (UNISDR, 2016, 16). DRR can be considered as the policy objective, which is implemented through disaster risk management. The next section will explain how GIS can be used to support DRR.

3.2. Use of GIS in DRR

In the simplest terms, GIS deals with spatial information. Disaster risk is a spatial phenomenon, as all components of disaster risk vary across space and time (Herold & Sawada, 2012; Westen, 2010). For example, a volcanic hazard only exists in certain locations, vulnerable and exposed populations reside in a certain area and response capacities differ between locations. Thus, knowing where things are is fundamental for understanding, reducing and managing risk (Alexander, 2002).

Whilst GIS itself cannot reduce disaster risk, it is an instrument to support DRR. The strength of GIS as a tool for DRR is that it can integrate different types and large quantities of data, such as social, economic, physical, and political data, tied to a geographic location into one system (Dash, 1997; Thomas, Ertuğay, & Kemeç, 2007), and allows users to manipulate and analyse this data for many different purposes (Masser, 2001). This leads to a plethora of applications in DRR and a number of authors have produced overviews of the application of GIS throughout the disaster management cycle (Cova, 1999; Teeuw et al., 2013; Thomas et al., 2007).

In section 3.1, the shift from the disaster management cycle towards a more holistic view of DRR was mentioned, marked by the Sendai Framework for action. Therefore, instead of explaining the uses of GIS throughout the disaster management cycle, Table 3**Fehler! Verweisquelle konnte nicht gefunden werden.** (page **Fehler! Textmarke nicht definiert.**) provides an overview of the uses of GIS within the four priority areas for action of the Sendai Framework. Research and development of new GIS applications has increased rapidly over the past years; therefore Table 3 only provides a few examples of the uses of GIS in DRR found in the literature to illustrate how GIS can be applied throughout the four priority areas of the Sendai Framework.

Sendai Priority	Area of GIS application	Examples
Understanding disaster risk	Disaster Risk Assessment/mapping	Multi-hazard risk assessment, including cost of potential damage (van Westen et al. 2002) Tsunami Disaster risk maps based on hazard, vulnerabiltiy and capacity (Farhan and Akhyar 2017)
	Hazard mapping and modelling	Modelling landslide hazard (Biswajeet and Saro 2007)
	Risk education and communication	Web-GIS on landslide hazard with prevention information for the public (Chen et al. 2016) Web-GIS for disseminating risk information on volcanic hazard (Le Cozannet et al. 2014)
	Integration of indigenous, traditional and local knowledge	Participatory vulnerability assessment (Kienberger and Steinbruch 2005) Community based flood risk assessment combining hazard and vulnerability information (Guarín, Westen, and Montoya 2004) Community based Flood risk mapping (Tran et al. 2009) Participatory 3D mapping for the integration of traditional and scientific knowledge in disater risk reduciton (Gaillard and Maceda 2009)
Strengthening disaster risk governance to manage disaster risk.	Facilitating information sharing and cooperation between stakeholders	Multi-agency GIS for planning, mitigating and responding to wild-fires (R. Johnson 2005) Web-based GIS to for citizens, experts, and government to strengthen risk governance (Nagasaka 2006)
Investing in disaster risk reduction for resilience	Integrating disaster risk information into urban and land use planning	GIS for multi-criteria land use suitability analysis for development planning (including flood risk) and land use change modelling (Y. Liu et al. 2007) GIS-based system to integrate seismic risk into land-use planning (Çabuk 2002)
	Evaluation of mitigation options	Using GIS to simulate and evaluate green roof systems to mitigate flash floods (C. Liu, Li, and Li 2017)
	Prioritising areas for mitigation	GIS analysis to map relative vulnerability to earthquake and tsunamis within a community and identify "vulnerability hotspots" (Wood and Good 2004)
Enhancing disaster preparedness for effective response and to "Build Back Better" in recovery, rehabilitation and reconstruction.	Evacuation Planning	Using GIS model to optimise distribution of evacuees (Saadatseresht, Mansourian, and Taleai 2009)
	Stockpiling	Identifying ideal location for relief supply stockpiles (Maniruzzaman, Okabe, and Asami 2001)
	Monitoring and Early Warning	GIS based real-time landslide monitoring and early warning system (Yin, Wang, Gao, & Li, 2010)
	Supporting contigency planning	Development and analysis scenarios in GIS to plan for flood emergency logistics (Chang, Tseng, and Chen 2007) GIS analysis for preselection of suitable sites for emergency shelters (Omidvar, Baradaran-Shoraka, and Nojavan 2013)

Table 3 Applications of GIS in DRR

3.3. Capacity Development

The previous sections have explained DRR and GIS. Another important theoretical point of departure for this thesis is capacity development, which is introduced in the following sections.

3.3.1. History and importance

The notion of capacity development is rooted in the context of international development cooperation. It emerged in the late 1980s, partly in response to criticisms and shortcomings of earlier approaches to development cooperation (Whyte, 2004). Yet, it incorporates many older ideas that have developed following the decolonisation and the ensuing rise of organised international development cooperation since the 1950s (Becker, 2014; Eade, 1997; Tadele & Manyena, 2009).

Since then, capacity development has taken on a central role in international development theory and practice (Lucas, 2013; Scott & Few, 2016) and is often considered key in achieving sustainable development outcomes. Capacity development has been a core issue over the course of the OECD High Level Forums on Aid Effectiveness and takes on a central role in the resulting international declarations such as the 2005 Paris Declaration for Aid Effectiveness, the 2008 Accra Agenda for Action or the 2011 Busan Partnership Agreement. Similarly, target 17.9 of the UN Sustainable Development Goals (SDG) is explicitly dedicated to capacity development to support countries in implementing the SDGs. The SDGs in turn contain strong linkages to DRR and resilience (Uitto & Shaw, 2016). In the same vein, in the field of DRR, capacity development is continuously named as an important means to reduce losses from disasters (Hagelsteen & Becker, 2014). The Sendai Framework repeatedly calls for developing capacities to reduce disaster risk at all levels. Strengthening capacities for disaster management is also a big part of the development cooperation activities of the European Union and its member states (Few & Anagnosti, 2010).

3.3.2. What is capacity

Between different academic disciplines, organisations and individuals, there are many different understanding on what capacity is and there is no widely-accepted definition (Armstrong, 2013; Brinkerhoff & Morgan, 2010; Morgan, 2006; Scott & Few, 2016). In the broadest terms *"capacity is the ability to achieve a desired purpose"* (Tiwari, 2015, 34). Within the context of DRR, the UNISDR defines capacity as *"the combination of all the strengths, attributes and resources available within an organization, community or society to manage and reduce disaster risks and strengthen resilience"* (UNISDR, 2016, 12).

Inherent in this and other definitions is the notion that there are both different types and different levels of capacity.

Even though the number and classification of different levels of capacity defined by development agencies and scholars varies - some divide it into six levels (Schulz, Gustafsson, & Illes, 2005), others into four (Bolger, 2000), or three (CADRI 2011; Fukuda Parr, Lopes, & Malik, 2002; Lopes & Theisohn, 2003; OECD, 2008; UNDP, 2009), the notion that capacity can be situated at different but interconnected levels is found throughout the literature (Becker, 2014). Specifically related to capacity for DRR, CADRI (2011) defines three levels of capacity – the enabling environment, the organisational level, and the individual level (see Figure 2).

Figure 2 The three levels of capacity. Adapted from CADRI 2001

DRR capacity can include infrastructure, institutions, knowledge and skills, and collective attributes such as social relationships, leadership and management (UNISDR, 2016). CADRI (2011) further distinguishes between functional and technical capacities, wherein technical capacities relate to a particular sector or theme, e.g. conducting risk assessments and functional capacities are more managerial capacities needed across sectors, such as policy making and implementation, stakeholder engagement, budgeting and evaluation.

3.3.3. Capacity development concept

Despite the significant role capacity development plays in international development cooperation in general as well as in DRR in particular, there is no consensus on what capacity development actually is (Bolger, 2000; R. James & Wrigley, 2007; Tadele & Manyena, 2009; Ubels, Acquaye-Baddoo, & Fowler, 2010). It follows that there is no overall theory of capacity development, how it takes place or what factors lead to sustained capacity (Tiwari, 2015; Whyte, 2004)

Various disciplines such as international development, public administrative sciences, organisational development science and management theory have researched capacity development (Scott & Few, 2016) and the way capacity development is analysed varies across fields (Christoplos, Engstrand, & Hedqvist, 2014). But even within one field, such as DRR, there is not one consensual definition of capacity development (Hagelsteen & Becker, 2014; Scott & Few, 2016; Tiwari, 2015).

Despite this confusion and some criticism that the notion of capacity development is too abstract or broad and cannot be operationalised and translated into practical actions (Hagelsteen & Becker, 2014; Lopes & Theisohn, 2003; Lucas, 2013), there are many common elements across different definitions (see Figure 3).

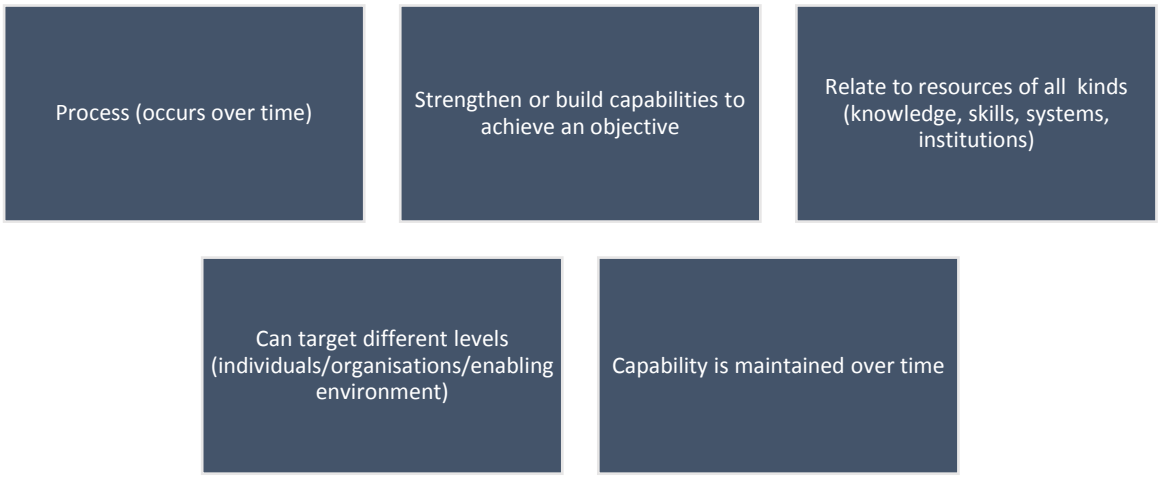

Figure 3 Common elements of capacity development definition; based on Scott et al. 2016, p.147

Following a literature review, Scott and Few (2016, 147) define capacity development for DRR as: *"the process by which individuals, organisations and societies strengthen and sustain their abilities to take effective decisions and actions to reduce disaster risk"*. This is a useful point of reference for this thesis as it relates the most common elements of the concept of capacity development to DRR. Inherent in this

definition is a commonly found notion - that of capacity development as an endogenous process (Brinkerhoff & Morgan, 2010; EuropeAid, 2010; Rick James, 2010; Kühl, 2009). Yet, this leaves out an important point that is not explicit in most definitions. Even though, capacity development is considered an internal process, the term is mostly used in contexts where an external partner supports the capacity development process of an internal partner (Becker, 2014; R. James & Wrigley, 2007). The actors in the capacity development process can thus be divided into external partners, who provide support and internal partners, the recipients of such support, even though there are some calls for challenging this norm (Scott & Few, 2016). External partners in capacity development for DRR are often international agencies, offering support in lower income countries, but could also be national agencies, civil society organisations, academics or private sector organisations. The main groups of internal partners are government agencies, non-government DRR practitioners and vulnerable communities (Becker, 2014; Scott & Few, 2016).

Various authors have proposed principles or key aspects of effective capacity development (see for example Becker, 2014; Keijzer, 2013; Lopes & Theisohn, 2003). Based on a literature review and multiple case studies of DRR capacity development initiatives, Few et al. (2016) have defined six principles for effective capacity development for DRR (see Figure 4).

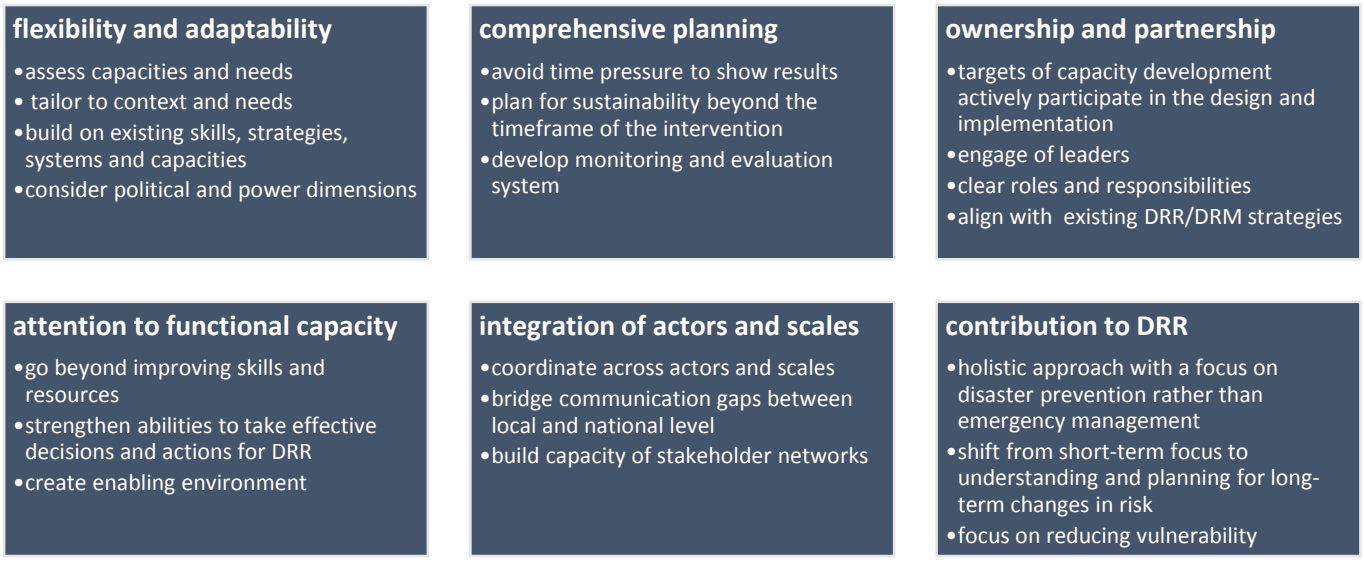

Figure 4 Principles for effective capacity development for disaster risk management based on Few et al. (2016)

However, despite a growing understanding of what effective capacity development entails, there are still many gaps between theory and practice (Hagelsteen & Becker, 2013; Rick James, 2010; Tiwari, 2015) andas Hagelsteen and Burke (2016) point outcapacity development for DRR is still an emerging practice with limited academic research.

4. RESULTS

This chapter first provides a brief overview of the literature identified in the literature study that was carried out to answer SQ1. The results of the literature study are elaborated on in the discussion chapter in order to compare them to the findings of the interview study to answer the main research question. The following sections present the findings of the interview study that was done to answer SQ2 and SQ3.

4.1. Academic literature on strengthening capacities for the use of GIS in DRR

Notwithstanding the rapid growth in DRR related GIS research (see **Fehler! Verweisquelle konnte nicht gefunden werden.**), relatively little has been written on strengthening capacities for the use of GIS in DRR.

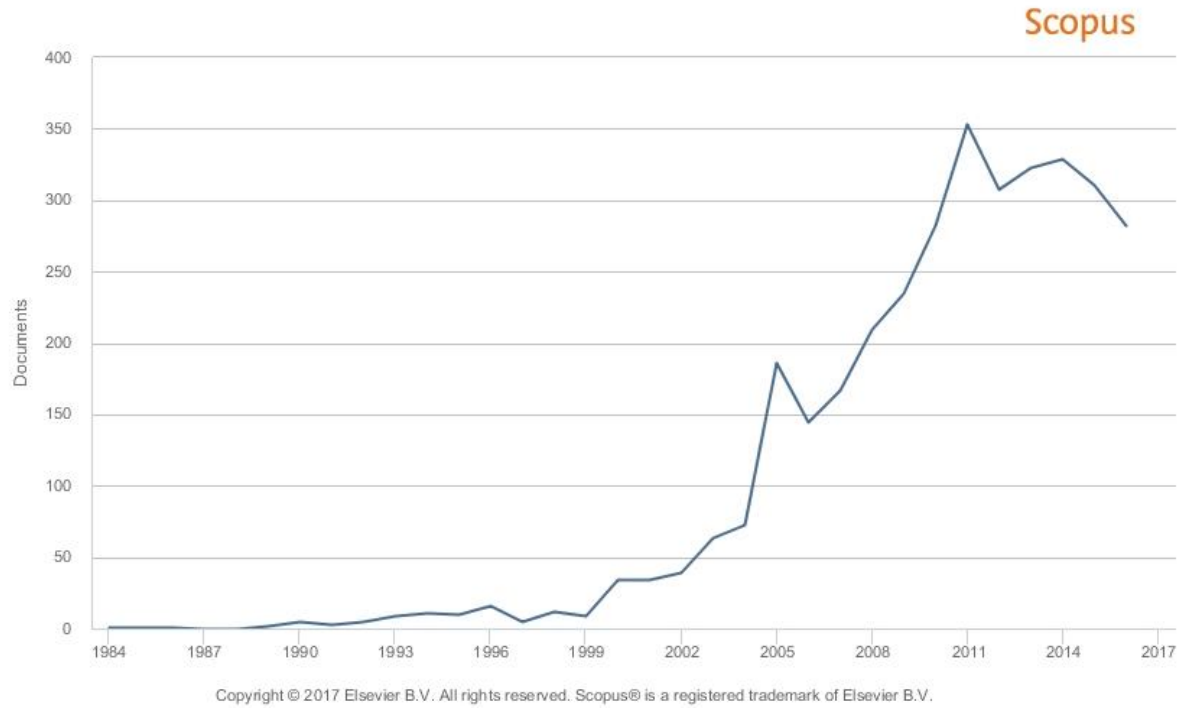

Figure 5 Scopus search for the keywords "disaster" and "GIS"

However, a number of scholars have dealt with general challenges encountered in the use of GIS for DRR (Coppock, 1995; Fekete et al., 2015; Manfré et al., 2012; Thomas et al., 2007).

Others have written specifically about issues regarding GIS for DRR in low-income countries (Herold & Sawada, 2012; Iglesias, 2005; Teeuw et al., 2013) and some of the capacity gaps encountered (Ganz et al., 2016). Furthermore, there is some literature on capacity development for GIS albeit not for the purpose of DRR and whilst some of this is based on case studies in the US (Miranda et al., 2005; Miranda, Casper, Tootoo, & Schieb, 2013), others have written about GIS

capacity development in low-income countries in various regions such as Africa (Jensen et al., 2002; Ofori-Amoah, 2008) and the Pacific (Britton, 2000; Smith Jr., 2009). However, despite the heterogeneity of these regions, many commonalities with regards to GIS capacity development were found (Hall, 2006).

Closely related to this is the literature on GIS implementation in low-income countries, which often includes some elements of capacity development. Mennecke and West Jr (2002) and Ramasubramanian (1999) have analysed issues regarding GIS use in developing countries in general, others have carried out case studies in various countries such as Iran (Taleai, Mansourian, & Sharifi, 2009), India (Walsham & Sahay, 1999), Lebanon (Iaaly, Jadayel, & Jadayel, 2016), Uganda (Eria & McMaster, 2017) or Botswana (Cavric, Nedovic-Budic, & Ikgopoleng, 2003) as a point of departure for their analysis. In addition, there is a strand of literature focussed on challenges in the use of GIS in the health sector in developing countries (Gebreslasie & Bauwens, 2015; Owolabi, Sonoiki, Salet, & Gignac, 2015), since some of this is directly linked to DRR for instance in the case of epidemic prevention, some of the general challenges found in this research might be transferable to strengthening GIS capacities for DRR.

4.2. Practices for strengthening GIS capacities

The findings regarding the capacity development practices employed by the participants can be divided into three major themes – the actors involved, how the initiatives were designed and the actual activities to strengthen capacities. Together these themes help paint a clearer picture of the variety of practices and provide some background to better understand challenges and ways to address them.

4.2.1. Actors

The interviews showed that almost all initiatives the stakeholders were involved in included more than two actors. These types of actors can be broadly divided into three main categories, providers of funding, external implementing agencies as well as targets of capacity development (see Table 4 on page 16). The data also shows that some types of institutions, such as government authorities can take on different roles in capacity development, depending on the project.

Category	Subcategories	Respondents
target of capacity development	national level authority	1, 2, 3, 5, 8, 7, 9, 10, 15
	regional organisation	2
	individual professionals	1, 2, 5, 8
	subnational level authority	4, 6, 8, 7, 9, 11, 12, 14
	university	5, 14, 15
external implementing partner	community	1
	NGO	4, 8, 6, 7, 1
	UN agency	2, 3, 6, 7, 8, 15
	private sector	1
	regional organisation	1, 9
	national/provincial authority	6, 7, 9, 12
	private sector	1
provider of funding	international financial institution	1, 5, 8, 11, 15
	foreign government	1, 2, 5, 8
	UN organisation	7, 8
	regional organisation	5
	national government	1, 6, 7, 9, 10, 12, 13

Table 4 Actors

Target of capacity development

The first group of actors involved in GIS capacity development are those trying to strengthen their own capacities to use GIS in DRR. In the experiences of the participants, these were most frequently government authorities, e.g. National Disaster Management Authorities or those in charge of physical planning, the environment or public health. Many of the participants worked for or with national level authorities, some were also involved with authorities at the sub-national level, often in the case of national agencies trying to strengthen capacities at the more local level. Sometimes, universities were also targets of capacity development intervention, often in combination with other stakeholders. In one case *"they were people from a university who wanted to know about the advantages of GIS and how it can be used in emergency management to be able to introduce it later to the government"* (Participant 14).

In addition, one participant had worked with a regional organisation wanting to strengthen its capacities for GIS use and another had worked with community members. Whilst most of the projects targeted organisations, a few participants also mentioned initiatives targeting individual professionals who were not necessarily affiliated with a specific organisation, particularly through international training courses and university programmes.

External implementing partner

Most of the interview participants were affiliated with organisations trying to facilitate the capacity development of another institution or individuals, so naturally, such external partner agencies that were implementing projects in support of another institution featured in virtually all interviews. These implementing agencies can be divided into different subcategories. In many cases, there was more than one external partner involved in the implementation of the project. Many projects involved universities, either national or foreign. Similarly, NGOs and specialised UN agencies often took on the role of the implementing agencies. Sometimes, regional organisations facilitated

capacity development within their region. In a few cases, national or provincial authorities supported GIS capacity development on the local level. In a project mentioned by one participant, the private sector was also involved in developing the GIS application for the project.

Providers of Funding

In most cases, a donor agency provided the funding for the capacity development initiative, without being directly involved in the project implementation on the ground. These include international financial institutions such as the World Bank and regional development banks such as the Asian Development Bank; foreign governments through their bilateral development cooperation mechanisms, regional organisations, such as the EU or UN organisations. However, in a few cases, notably when a national authority was involved in developing capacities at the local or provincial level, project funding was provided by the national government.

4.2.2. Project design process

Whilst the interviews did not go into depth about the project design process, there are a few findings from the interviews related to the drivers and considerations in planning GIS initiatives that can help paint a clearer picture of the practices that stakeholders used to strengthen capacities in this area. These findings can be divided into five broad categories (see Table 5) – the importance of context, the needs identified, the objectives of the initiatives and the driving forces behind capacity development interventions.

Category	Subcategories	Respondents
importance of context	partner	2, 3, 5, 14, 11
	political situation	1, 4
	geographical area	4, 6
	culture	4, 1
	level of interest	1, 14
	existing capacities	1, 6
assessment of needs and/or capacities	questionnaires	4, 11
	other	9, 2, 11
	workshop	1
	expert mission	3
	review of documents	3, 4
Identified needs	data	5, 6, 9, 14,
	skills and knowledge	2, 7, 9, 10, 13
	software	2, 7, 9
	hardware	1, 7
objectives	understanding risk	2, 3, 8, 9, 10
	mitigation	2, 9
	preparedness	2, 3, 4, 6, 7, 9, 10
	mainstreaming DRR into development	3, 4, 7, 8, 9, 10, 11
driving forces	internal demand	2, 3, 6, 7, 11,
	donor interest	2, 4, 5, 7, 11, 15

Table 5 Project design process

Importance of context

Several participants mentioned that the design and implementation of the capacity development initiative was context-dependent. Factors that influenced the initiatives explicitly mentioned by the participants included the type of partner that they were working with and their specific needs and

capacities and the level of interest; the geographic area that they were working in, including its accessibility and the types of hazards present there; the political situation in that area, the local culture, as well as the level of existing capacities such as knowledge, resources and infrastructure available.

Identified needs

Some participants explicitly mentioned carrying out a needs assessment, others simply mentioned things that their own or their partner organisation needed to use GIS for DRR. In the words of one participant: *"I break GIS down in my head as the user […] so the human, the person behind it; the hardware so the tech needed, what you got available to use, is it a computer, is it a GPS, is it lots of computers; the data and that can be free or that can be very expensive, it can be something you've drawn yourself and, and then the software and again, is it free and open source or is it commercial? And when I break things down into those four, that's kind of how I'll start to approach a group of people or a local emergency management authority that I may be wanting to work with. How do they see each of those, what's their current capacity, do they really understand GIS? Get them to understand GIS and then work out what they want, how they can use it, by also putting the time in to understand their procedures."*

Many participants talked about technical skills and knowledge about GIS as the main need in the organisations, on the level of the technical staff as well as on the decision-maker level. The actual skills needed varied, in some cases there was a lack of basic GIS skills, in others, the organisation already had experiences with GIS but needed more specialised training for instance in processing satellite imagery or using web-GIS.

Moreover, the need for data was brought up frequently, one participant said *"lack of data is a major problem in different countries or at least those countries that I have been involved in. If you go to Central Asia, if you go to Middle East, if you go to Africa, they have big, big problems with the data, they don't have the data, they don't have reliable data"* (Participant 14).

Software and hardware seemed to be a less important need for most participants, although some of those working with local governments said they were lacking the resources to buy proprietary software, however, in many other cases either proprietary or open source software was available, as one participant put it *"one of the key lessons for us, we're still unfortunately learning that lesson, is that, if it is, you know, you're going to invest in GIS, on the one hand, yes, you need to invest in the hardware and software, but on the other hand - that's what's critical or possibly more important - is to build the capacity, the technical capacity as well as to have the human capital, that human resource internally to use the GIS"* (Participant 10).

Objectives

The GIS capacity development initiatives that the participants were involved in pursued a variety of objectives and aimed to support different aspects of DRR. Several initiatives also had more than

one aim, and some participants were involved in various projects, yet, generally the different purposes of the capacity strengthening initiatives can be grouped into a few categories, although there might be some overlap between them. First, there were those that primarily aimed to understand risk, mostly through using GIS to map hazards and vulnerabilities, even though this of course could then form the basis for decision making for actual risk reduction measures and due to the nature of GIS as an information system, all projects ultimately helped understand risk in some form. Others aimed more directly at preparedness by using GIS to model scenarios for preparedness plans, or for mitigation measures such as water resource management. In addition, many projects had a stronger focus on mainstreaming DRR into development, by using GIS to integrate information on disaster risk into development planning, as in the case of the participant who explained *"mainstreaming DRR into development process - that is our prime focus and for this we are developing a template for disaster impact assessment, for impact analysis, especially, for scoring any infrastructure, how vulnerable it is, is how risky it is...we are utilizing GIS analysis"* (Participant 11).

Driving forces

The driving forces behind the capacity development projects can be divided into an interest from the donor side and internally driven projects that sought out external partners to support their initiatives. Both were mentioned by roughly the same number of participants, but the data from the interviews demonstrates that often there is not one single driving force, but both and internal demand and an interest from the donor leads to capacity development initiatives.

4.2.3. Activities

Participants reported a wide range of activities for strengthening GIS capacities and most projects included a mixture of activities. The projects activities reported by the stakeholders can be divided into different categories; technical training, advocacy, provision of GIS tools, data collection, development of GIS products and technical advice (see Table 6).

Category	Subcategories	Respondents
technical training	international training course	1, 3, 8
	university programmes	2, 5,
	training for staff of an organisation	1, 2, 3, 4, 5, 6, 7, 8, 1,12, 13, 15
	manuals	3, 5, 15
advocacy	workshops for decision-makers	2, 3, 8, 14
	conferences	3
	meeting decision makers	2, 3, 9
provision of GIS tools	web GIS	2, 5, 14, 11, 13, 15
	databases	2, 5, 10
	spatial decision support systems	2, 11
	mobile data collection application	1
	hardware	1
	methodology	5
	unspecified	2, 11
data collection	remote sensing	1, 3
	community level data collection	1
	standardisation of data	5
development of GIS products	hazard maps	1, 5, 11
	risk assessments	6, 8, 11
technical advice	creation of strategies for GIS implementation	9, 10
	technical working groups	3, 9,
	sharing of resources	9

Table 6 Activities

Technical training

All participants participated in or provided technical training on GIS as part of the capacity development initiatives. The most common practice amongst the participants was to conduct a short-term face-to-face training for the staff of a specific organisation, often along with the introduction of GIS software in the organisation or the use of a specific GIS application, for instance a geoportal for data sharing. In some cases, this face-to-face training was combined with the development of training manuals, detailing step-by-step procedures for GIS use, often provided online. A few participants also talked about short term, often fee-based international training courses that were open to individual professionals from different organisation training them on using GIS or remote sensing in DRR. A few participants also provided more long-term training through the establishment of university programmes specialising on GIS.

Advocacy

Although not as common as technical training, many of the projects described by the participants included activities aimed at raising the awareness of GIS or related geospatial technologies such as remote sensing, mostly aimed at decision makers. One participant, working on a regional level said

"all countries have some level of exposure [to GIS], but it's how do they use it for disaster preparedness, specifically, it varies. So, for me I'm really pushing, one, to increase the awareness of it and help them understand what the benefits are" (Participant 9). These activities included workshops for decision makers, conferences, as well as individual meetings and discussions with high-level decision makers.

Provision of GIS tools

Another set of activities, that was part of many initiatives was the provision of GIS tools to an organisation. Although one participant reported buying smartphones for their project partners to run a mobile GIS application, overall the provision of hardware did not seem to play a big role in the experiences of the participants. Similarly, acquiring general purpose GIS software for their own or their partner organisation was not mentioned by many participants, although one participant explained that they helped their partner organisation install open-source GIS software. Another participant who had experience in several capacity development projects for the government sector in Asia recounted *"if one donor is providing funding to them, they will engage GIS experts, they will buy software also, they will buy computers also, they will buy remote sensing satellite images also"* (Participant 8). However, more common among the participants was the development of DRR-specific GIS applications, which was brought up by around half of the participants. They frequently developed web-based GIS systems, particularly for storing and sharing data among different stakeholders, sometimes also for sharing information with the public or including further functionalities for GIS analysis. In other cases, external partners helped with the development of GIS databases for an organisation, or developed spatial decision support systems for the partner organisation.

Data collection

Some participants also took part in data collection activities. In some cases, this took the form of community-level data collection, for instance household level surveys on vulnerability or gathering local knowledge on hazards. In a few cases the organisations supported their partners in acquiring and processing remote sensing data. In one case, instead of collecting new data, a participant's organisation helped their partner organisation to standardise and correct errors in existing data to be able to use it for DRR purposes.

Development of GIS products

Sometimes instead or in addition to acquiring GIS skills or resources, the projects focussed on developing GIS end products for an organisation, such as hazard maps or risk assessments. In a few cases, these GIS products were developed by the staff of the partner organisations as part of the training process, as one participant explained *"we formed multidisciplinary teams involving people from the government organizations and they had to also, yeah, really be part of the of the team, they had also to deliver*

hazard maps on each of the hazards available" (Participant 5). In other cases, they were developed by external partners and provided to the target organisation.

Technical advice

Lastly, the interviews revealed various activities that can be grouped together as technical advice for the implementation of GIS in DRR, mostly provided to government institutions. Activities in this category include the formation of technical working groups comprised of different institutions, such as Civil Protection Agencies, other related ministries, research institutes, etc to exchange knowledge and develop strategies to develop GIS capacities. In one participant's case, such a group was established on a regional level to *"examine risk and risk assessment methodologies across the region with the intent of setting some standards for how that is supposed to look like in the region"* (Participant 9). In another case technical working groups were established on the national level in different countries to share expertise and resources between agencies and facilitate the use of GIS and remote sensing for DRR. Moreover, in a few cases external partners developed policy recommendations and strategies to help governments or individual organisations implement geospatial technologies for DRR.

4.3. Challenges encountered by participants

This section presents the challenges the participants have faced. These challenges can be divided into two main themes – challenges during project implementation and challenges regarding the sustainability of the capacity strengthening initiative.

4.3.1. Challenges related to project implementation

The challenges the participants faced in implementing their projects can be grouped into political barriers, resource barriers and cultural barriers (see Table 7).

Category	Subcategory	Respondents
political barriers	bureaucracy	1, 3, 6, 11
	security concerns / access	1, 4, 6, 8, 12, 14
	competing priorities	9, 10, 12,13, 14
cultural barriers	language barriers	1, 4
	unfamiliarity with technology	1, 2, 4, 8, 11, 12, 13
resource barriers	project funding	3, 6,
	cost of data	1, 6, 8, 9, 11, 14
	cost of software	6, 8
	lack of infrastructure	15
	time constraints	4, 5, 14

Table 7 Challenges related to project implementation

Political barriers

First, many participants recounted challenges that were related to the political context their capacity development initiatives took place in. In many cases, there were security concerns in providing

foreign organisations with existing data or access to communities for data collection. One participant recounted her experiences in Pakistan, saying there was *"significant scrutiny from the affected population's government because they, you know, to them and they might not fully understand what the data is that you're collecting or why you should be creating something, which to them may look like a form of intelligence"* (Participant 4). A different participant had similar difficulties in gaining access to the local communities in several post-soviet states that he was working in. Whilst not encountered by all participants and in all regions, this issue is not restricted to foreign agencies; a government official from the Philippines remarked that there were some concerns in passing on remote sensing data to the local level as government officials worried how these would be processed and used by the local governments. Another participant working in capacitating local governments talked about political apprehension of having risks officially declared on a map.

Some participants also mentioned strong bureaucratic systems as a challenge that slowed down project implementation, for instance in terms of changing procedures or acquiring data.

Another issue, that was raised particularly by the participants working for national authorities in different countries was that they were facing many different competing priorities for limited funds and that GIS implementation or maintenance was not a high priority for the decision makers. One participant stated: *"at a more national scale, or Minister perspective, they'll tell you that, you know, other agencies or departments have more dire needs and so it is not necessarily treated with the level of priority or importance as you would like it to be treated with*" (Participant 10). Moreover, participants from national authorities in three different regions also reported that due to ongoing and recurring disasters that required response, there was little time or resources for the implementation of GIS for DRR, a participant from South America said about his experiences: *"disaster preparedness is not an important topic in our job. Stakeholders only think in emergency attention, the use of GIS for example only is important after the disaster happened"* (Participant 13).

Resource barriers

Many participants brought up the costs associated with GIS as a significant challenge. The cost of data, particularly that of conducting surveys or purchasing satellite imagery was a challenge for GIS implementation for many participants. Due to financial constraints, they had to work with low quality or outdated data, which then in turn produced GIS products that were less reliable. In the words of one participant: "*challenge is - most important in this is […], data collection. Is that data is of bad quality which produce the output - less output, you can say. So, data is the most important and most of the time is spent on collecting those information, those data and this can be a primary data as well as secondary data, but the reliability is very important. How reliable those that are they. There is lot of data now, but reliable data is very less"* (Participant 8).

Another sparse resource that some participants mentioned was time, particularly for external implanting agencies that were only in the country for a limited period, often defined by the donor – one participant explained *"many of these projects work with, well, sometimes unrealistically tight schedules and to work…because […] if they are in tender procedures, you have to bid for it, then you have to have the best value-for-money project, so you promised a lot in a short period of time and the question is whether you can deliver those things"* (Participant 5).

In addition, a challenge encountered by some participants was the level of existing infrastructure in the countries they were working in, such as access to remote communities or technical infrastructure, such as internet connectivity to use Web GIS software.

Cultural barriers

Participants also encountered challenges regarding the cultural context. Participants from various regions reported an unfamiliarity with technology in general and often a certain amount of scepticism towards new technologies that made it challenging to introduce a technical solution such as GIS to these institutions and individuals, particularly on the more local level, a participant who had been involved in a project in the Philippines said: *"the difficulty we had is the agency, government agency which is responsible for this project, they are mostly doing community-based work and they don't have this mobile phone technology or satellite technology, no idea at all, so […] we spent a lot of time to convince them that this is good and how it will be helpful"* (Participant 1).

Whilst this did not appear to be a major challenge in most cases, some participants named language barriers as a big challenge, particularly when trying to develop training materials or applications for countries with many different local languages.

4.3.2. Challenges related to sustainability

Despite the challenges in the implementation of the project, the challenges the participants put the most emphasis on and perceived as the most difficult aspects were related to the sustainability of the capacity development projects. Whilst some participants were still in the project implementation phase many had at least experiences with other capacity development projects in the field of GIS for DRR in the past and whilst some were confident about the overall success of their projects, many said that overall impact was difficult to measure and others talked about projects that in their eyes had failed, one participant said: *"with the GIS especially, when we talk about the sustainability, I'm really very much serious and I know that after working with many organizations - our projects never went successful. Like for example these four projects, we work in different government organisations. But now I know that none of that single organisation is using that data which we have developed for them*" (Participant 8). The challenges to sustainability can be clustered into three categories –maintenance of GIS, human resources and decision-maker support (see Table 8 on page 25)

Category	Subcategory	Respondents
maintenance of GIS	project-to-project approach	5, 7, 8, 9, 11
	data needs to be updated	4, 6, 8, 11, 14, 15
human resources	staff turnover	2, 3, 4, 5, 6, 7, 8, 9
	other job duties	3, 6, 5, 7, 8, 10, 11
decision maker support	awareness of uses of GIS at decision maker level	1, 2, 14, 15
	communication between technical staff and decision makers	2, 5, 7, 8, 13
	instability	3, 14

Table 8 Challenges related to sustainability

Maintenance of GIS

Maintaining the GIS has been described as a challenge by many of the participants, one reason for the lack of maintenance of the system was that organisations were working *"project-to-project"* (Participant 8) and once the project ended the system was no longer maintained and used – *"everybody focussed on projects and projects have a definite end and - a start and end. And when it ended, where do you put it?"* (Participant 9). In some cases, external support ended once the system was set up and the target organisation did not have a plan or funding to maintain the system on its own, one participant recounted: "*we also had situations where we, we were asked to, to make a web-based system and, say, there was a lot of money during the project and when the project stops, we need like every month, say, a hundred dollars to keep the system alive, but the donor did not want to give"* (Participant 5).

Another challenge with regards to maintaining the system was keeping the GIS up to date, as new developments change the risk. Sometimes, data input into the GIS was a *"one-time requirement"* (Participant 11), and no new data was added, so that system became outdated and of little use.

Human resources

Participants across regions and initiatives brought up difficulties with having and maintaining the human resources to effectively use GIS for DRR within the organisation. A major issue mentioned by many of the participants was staff turnover. Many reported that the GIS skills gained through the intervention, enabled staff of public institutions to find better job opportunities elsewhere, often in the private sector, abroad or with UN agencies or international NGOs, one participant who had first worked for the government in his own country cited his own career as an example for this: "*I get opportunity to go to...go to good salary, go to UN jobs, go to the international position, so the salary difference was like maybe 20 000 and 100 0000. So, then I have to go to 100 000 salary, not to stay to with the 20 000 salary. That is another consideration, in these developing countries, normally the GIS people never stay and they go to good structures, good opportunities with the UN and other donors"* (Participant 8). Other participants mentioned similar difficulties, however, the problem of staff turnover was not always due to staff seeking better paying jobs. In the case of one participant who was working with local government authorities in the Philippines, staff were frequently reassigned within the organisation following elections. In another case, staff were recruited and placed in the national disaster management

agency for the duration of the project, their salaries paid by the external partner who left once the project closed, leaving the organisation incapable of opening the GIS products.

Another challenge pertaining to human resources often brought up in the interviews was that even if staff had received training in GIS and remained in the organisation, they often already had other job duties and their existing work load allowed little time to apply their GIS skills, a participant from a national agency in the Caribbean explained: "*the human resource, […] is still a challenge for us, if I'm to be honest with you, because we still don't have on board a GIS officer or a GIS manager and so GIS is tagged basically – literally - to an existing position that historically was not responsible for GIS and so I still think that the agency is not fully utilizing and benefiting from the full scope of what a GIS can do"* (Participant 10).

Decision maker support

An issue that was brought up in some form by almost all participants was a lack of support of GIS for DRR at the decision-maker level. In some cases that meant the management of targeted organisations, in others the government of the country in question. The participants cited this as a major obstacle to sustainability.

First, many participants explained that decision-makers were not committed enough to provide resources or change policies or strategies to maintain the system in the long term. Whilst some of this lack of support was also attributed to the competing priorities and generally scarce resources, many participants said that a lack of awareness about the benefits of GIS for DRR among decision makers led to their lack of support.

Secondly, even if a GIS for DRR was in place, a problem, some participants mentioned was the communication between GIS experts and decision makers – *"Studies and maps are not effectively applied because there is no a clear language between technical people and decision makers. Sometimes, studies don't have a great importance because the experts have not thought in what kind of decisions they must support"* (Participant 13), as one participant working in a technical role for a government agency explained. Another participant attributed the lack of communication to the overall organisational structure and a different participant pointed out that the experts often used very technical language that was not clearly understood by the decision-makers.

Lastly, some participants noted that sometimes once decision-maker support had been won, due to electoral cycles and or changes in management new decision-makers came into power and they had to restart the process.

4.4. Addressing the challenges

Based on their experiences of past failures and successes, the participants suggested ways to address some of the challenges presented in the previous section to make GIS capacity development initiatives more effective. Analogous to the last section, these suggestions can be divided into those regarding the improvement of project implementation and those for ensuring sustainability.

4.4.1. Facilitating project implementation

The suggestions for facilitating project implementation fall into two main categories - suggestions on how to better adapt GIS to the context and those related to dealing with financial constraints (see Table 9).

Category	Subcategories	Respondents
adapt GIS to the needs	understanding context	1, 4
	on the job training	3, 4, 6, 7, 11
	tailor GIS application to user needs	1, 4, 11, 14, 13
lower costs	open source software	3, 4, 5, 7, 9, 15
	open data	1, 4, 3
	build on existing capacities	9, 15
	harmonise efforts of donors	2, 4, 6, 7

Table 9 Facilitating project implementation

Adapt GIS to needs

As outlined in section 4.2.2, the context of the GIS capacity development initiative can vary widely and the many participants stressed that for the initiative to be effective, it needs to be adapted well to the context and needs of the partner – as one participant said, "*try and fit it into their structure not fit what they're doing into your GIS structure"* (Participant 4). Since those working for external partner agencies often come from abroad, one participant strongly recommended hiring experienced local consultants to serve as a bridge between the internal partner and the external partner.

One way of tailoring the capacity development initiative to the target organisation brought up by many participants was through on-the-job training. That way the training was tailored to the organisation's work and new knowledge was applied directly. One participant who was involved in training local government officials said: *"you know they are the expert of their locality so we train them how to do GIS or make the disaster plan, basing, tailor making it to their, the needs of their locality"* (Participant 6).

With regards to the development of GIS applications, many participants underlined that these had to be based on user requirements and be simple to use, especially when administrative or other non-technical staff were supposed to use the application.

Decrease costs

Secondly, since cost of data, software and staff was one of the major challenges in GIS implementation, many participants talked about ways to reduce these costs. Free and open source software was frequently used in one case, the donor supported the development of an open source data sharing platform. However, whilst this does cut out the costs for software licences, one participant mentioned that these had sometimes more limited functions compared to proprietary software and as another participant said, *"you don't have to spend money on licenses, but it's not free, because you have to spend money in training people, so that is something that it's not always understood from management"* (Participant 15).

Another participant recommended the use of open data, such as that on Open Street Maps, however, the availability and accuracy of that data depended on the area. In this case the participant's organisation also organised "mapathons", to recruit volunteers to digitise data and add to open street maps.

Another strategy to reduce costs was to find ways how already existing capacities in GIS within the country, for instance in related authorities such as planning or surveying institutions could be used for DRR purposes, one participant from the Caribbean illustrated this: *"I'm trying to build on existing arrangements. So, you find all these smaller islands, there is a close relationship already with like, say, Physical Planning or Sustainable Development Ministries, they tend to have a lot of GIS capacity. So what we're doing is, ok, so we don't necessarily need to transfer all that capacity in the disaster offices, but we need to build the partnerships a lot more stronger, and much more focused and already doing it, and see if we could integrated into their work"* (Participant 9). In addition, in this case, a GIS expert from one the Ministry of Physical Planning was willing to give introductory training in GIS to community level disaster practitioners, to teach them how to use GIS products.

Moreover, some participants suggested that harmonising efforts between donors could maximise the benefits and avoid duplications of efforts. This had not always been the case in the experiences of the participants, one participant recounted: *"we were implementing a little training but there were so many other agencies implementing the same training, so basically […] at least four or five different organizations from UN and non-UN implementing training and capacity development for the same target, in the same department within a year, you know. And then, basically, you know, there was not a common vision"* (Participant 2).

4.4.2. Ensuring sustainability

The participants made many suggestions on how to sustain GIS capacities in the long-term. These can be grouped into four main categories: fostering the internal partner's ownership of the initiative, creating long-term partnerships, institutionalisation of GIS and strategies to mitigate the risks to sustainability (see Table 10)

Category	Subcategory	Respondents
foster ownership	involve partner throughout the process	4, 5, 8, 11, 15
	demonstrate benefits of GIS to decision makers	1, 3, 4, 5, 6, 7, 8, 9, 10, 12, 14
	create incentives	5, 8, 12, 15
long terms partnerships	follow up	2, 4, 5, 6, 12
	continuous support	1, 3, 4, 5, 6, 8, 15
	continuous training	3, 6, 8, 15
institutionalise GIS	integration into organisational strategy	2, 3, 4, 11, 14
	integration into legislation	9, 10, 14
	integration into policy	1, 3, 9
mitigate risks	training of trainers	4, 6, 7
	manuals	4
	create backups	6, 9

Table 10 Ensuring sustainability

Foster ownership

Many participants stressed that the internal partner should be involved and have responsibilities in all stages of the initiatives, especially with regards to developing GIS end products to avoid producing GIS products that are not being used or maintained once the project ended. One participant said: *"I think the most important is the involvement of the stakeholders. So, without their involvement, this is not working. I think there are too many projects where stakeholders are not really…they don't have a role to play, they are just beneficiaries"* (Participant 5).

As the lack of decision-maker support was often a critical issue, most participants brought up the need to raise awareness of the benefits of GIS at the decision-maker level. Yet, how this awareness could be raised was not always clear. One strategy participants from different regions brought up was adding a training component for the management when providing GIS training to an organisations technical staff. One participant explained: *"the participants provide him an output and show it to the management. oh, this is the what we learned, this is the GIS map of our municipalities and cities, the hazard map, the risk map, these are the buildings and they can explain it to the management, then they will have an appreciation on how important GIS is"* (Participant 7). Nevertheless, in the experience of other participants, workshops for decision-makers did not always lead to more support of GIS – a few participants pointed out that if the language and examples used were too technical they failed to reach the decision makers and simpler materials and emphasis needed to be put on the actual practical value of GIS for their specific organisation. As one participant said: "*those GIS experts, they use very technical language, they never look through that angle, where a district officer, who is a very young guy...or*

maybe very senior guy and you are telling him very technical things, he never operates laptops except sending an email and you are telling him big-big formulas, you can tell them that's how you will make analysis - their mind does not accept. You have to make a curriculum to make it a very simplified way and try to convince them that this is not your job, that you will make an analysis. The analysis will do technical people for you, but you as a district officer, you should know how this GIS can work for you then their mind will work. Otherwise, if you teach them oh, this is GIS, you will apply this long formula and it will make analysis for you - no, their minds never accept, no?" (Participant 8).

In some cases, the participants also mentioned the provision of some form of incentive to maintain the GIS capacity. One participant called for stricter surety bonds to stay with an organisation for a few years, following training, particularly in the case of professionals who had received university training abroad.

Another participant underlined that subsequent development projects should ask for the inclusion of GIS in the project so that the GIS would be maintained, however, besides this the participant pointed out that the GIS needed to be tailored to the organisations needs in such a way that its usefulness to the organisation's work should be an incentive to maintain it. Related to this, a few participants mentioned that the recent experience of a disaster acted as an incentive to invest time and resources in GIS as the stakeholders realised the need for more information.

Long-term partnerships

Several participants talked about the eventual failure of short-term interventions and called for more long-term partnerships.

A point made by many participants was the need for follow-up with the partners after the end of the project to encourage them to continuously use their GIS capacity, one participant emphasised *"especially these donors, whenever they are coming, they are coming for one, two years and then they're gone. No, it should not be like this, no. There should be some mechanism, where are after the project closes out, there should be some way, some system, where they should still have regular interaction on the use of their data, on the refresher courses, these kind of things, no? It will develop the capacities, because these government organizations, they are very slow responders, no? It's not only our country, it's everywhere in the developing countries."* (Participant 8).

Related to this, participants pointed out a need for continuous technical support to maintain the capacity. Besides more formalised follow-ups, participants recommended remaining available for questions to those who had taken part in GIS trainings, as one participant described it "*I actually have found it very useful in, all the places that I've gone, including actually Iraq, to be quite humorous and personal around it to make sure that people feel like they can approach me once I've left the country, if they wanted to follow up with any particular queries"* (Participant 4). Participants also established different forms of peer-support group, one mentioned that it was helpful to train various people from a region together,

to create a regional momentum and connect them so they could support each other. Another participant created a Facebook-group for everyone who had taken part in his training so that they could share resources and ask each other questions.

Some participants pointed out that their partners had to be kept up-to-date with the advancements of GIS technology. As one participant said, *"keep them trained - allow them to attend conferences, allow them to stay always updated on the world of GIS and geomatics and specifically open source, which is a, which a world that is continuously evolving, so it's very important to stay updated"* (Participant 15). One participant stressed that staff were often expected to update themselves in their spare time and suggested that continuous learning needed to become part of an organisation's human resource policy instead.

Institutionalise GIS

The last point leads to the next issue – when asked when they would consider a capacity strengthening initiatives truly successful, many participants emphasised that GIS needed to be institutionalised. This, depending on the level that the participants were working, at meant either integrating GIS into policy and legislation or into an organisations strategy and work routine.

On the organisational level, many participants brought up integrating GIS into standard operating procedures and allocating human resources and a budget to GIS. One participant stressed that short-term capacity strengthening projects needed to be linked to an organisational strategy, *"always keep in mind that the project deliverables should feed into a programme"* (Participant 9). Other participants explained that for this required not only decision-maker support and involvement of all stakeholders, but also resources. Thus, either the GIS had to be designed so that it could be maintained with the organisations existing resources, as one participant said: *"making sure that it's sustainable with their resources, not just in the current day but sort of moving forward. There's no point in putting a plan in place which works with the resources you bring into country, it needs to be something that they can do"* (Participant 4), or the target organisation should be supported in finding new external funding sources to maintain their system.

On the national level, participants called for working with decision-makers to integrate GIS into policy and legislation to secure government funding for GIS, improve data sharing and collaboration between stakeholders and standardise methodologies. Particularly the need to create a legislative framework for data-sharing and collection, i.e. a national or regional spatial data infrastructure (SDI) was underlined by several participants, however, they also pointed out that this is a slow and expensive process. One participant working on a regional strategy for the use of GIS in DRR said *"one of the things I learned […] is some kind of legislation, data gathering, central repository that will inform your data sets and the metadata and you think that we would have that here, too. So once persons come from different fields, looking for different types of data, it's all there. So, we have...we recognized a need to address*

that, but, that takes a little longer…" (Participant 9). To support this process, apart from activities to raise awareness and demonstrate the benefits of GIS, one participant explained that they supported the national governments by providing policy recommendations tailored to the situation. In another case, an external partner carried out pilot projects in one location and then worked with the governments to integrate these tested practices into policy and scale them up across the country.

Mitigate risks

To mitigate some of the risks to sustainability, particularly with regards to staff retention, some participants suggested to take a training-of-trainers approach and creating manuals, so that the knowledge could be preserved and filtered down even if there was a high turnover of staff. One participant working with local government also explained that he ensured the data was preserved even if the staff changed: *"I mean at least for me, you know, I have a database of all their shape files and KML files, their outputs on, on the capacity development training. So, it's just a stopgap, because whether the mayor or the politician will, you know, say okay we'll call another capacity development intervention and then they'll assign a new person, then we can also, we can already give them the data that was left by the other one, so they can start, they don't have to start from zero, so, you know, it's the things that we have to improvise"* (Participant 6). Furthermore, one participant mentioned that despite using modern technology, physical copies of maps and manual techniques should not be forgotten in case technology fails.

5. DISCUSSION

This chapter returns to the research questions posed in the beginning of the thesis. To answer these questions, I analyse the empirical findings (i.e. the answers to RQ 2 and 3) to in relation to the findings of the literature review (i.e. the answer to RQ1) and then place them in theoretical framework on capacity development introduced in section 3.3.3. This aims to point out the implications of this research for the design of future capacity development projects in this sector.

5.1. Diversity of capacity development practices

RQ2 was: what practices have stakeholders used to strengthen capacities for the use of GIS for DRR?

The interview study shows a great diversity of practices in the initiatives to strengthen GIS capacities for DRR. The findings demonstrate that capacity development involves a collaboration between several actors and can take place on the regional, national or subnational scale. This is consistent with the observations of Scott and Few (2016) that DRM capacity development is a multi-actor and multi-scale process. They, however, based on their literature review, only divide these different actors into providers and recipients, others group them into internal and external partners (Hagelsteen & Becker, 2013) as presented in the theoretical framework in chapter 3. Based on the results of the interview study, I argue that this division might be too broad, and the provider-side can be divided into funding providers and implementers. This distinction is important for the analysis of the interventions since the interviews revealed some conflict between the requirements of the donors and what those implementing the interventions deemed best, which is important for understanding at which levels challenges can be addressed.

Moreover, this study shows that the design of the capacity development interventions varies greatly according to the context and to fully explore these variations and the relationship between the context was beyond the scope of this research. However, despite the different contexts and varying existing capacities, the findings show that the general needs in the target organisations were similar and echoed those found in the literature. One of the primary needs mentioned in the interviews was GIS skills and knowledge, which is consistent with many authors citing a lack of local human resources with GIS skills in developing countries in general (Britton, 2000; Cavric et al., 2003; Eria & McMaster, 2017; Iaaly et al., 2016; Mennecke & West Jr, 2002; Ramasubramanian, 1999; Smith Jr., 2009) and for the use of GIS in DRR in particular (Herold & Sawada, 2012; Manfré et al., 2012; Teeuw et al., 2013; Thomas et al., 2007). However, it is important to point out that this need mentioned by the participants mostly referred to the target organisations and in contrast to some of the findings of the earlier literature, the interviews showed that in many cases GIS skills were in

fact available at the country level, e.g. in universities or other government institutions. The implication of this is that whilst in some cases it might be necessary to build up new skills through a capacity development intervention, it may also be possible to fulfil the need for GIS skills through facilitating coordination and creating synergies with institutions that already have strong GIS skills in the country.

The other important need identified in this study is reliable data which is also found throughout the literature (see for example Abdullah, Abdullah, & Zahari, 2010; Eria & McMaster, 2017; Farthing & Ware, 2010; Herold & Sawada, 2012; Iaaly et al., 2016; Manfré et al., 2012; Mansourian, Rajabifard, Valadan Zoej, & Williamson, 2006; Mennecke & West Jr, 2002; Taleai et al., 2009; Thomas et al., 2007; Vatsa & Joseph, 2003).

Lack of appropriate GIS hard- and software is an often reported problem in the literature (Britton, 2000; Cavric et al., 2003; Fekete et al., 2015; Mennecke & West Jr, 2002; Ramasubramanian, 1999). Whilst this is also found in this study, it seemed secondary to the need for human resources and data, particularly hardware seems rarely an issue, which contrasts some of the earlier literature. This is likely due to the general advances in technology and decrease in prices for hardware. It also shows that the conditions for implementing GIS for DRR have improved in recent years, since the necessary hardware is more readily available.

The findings demonstrate that GIS capacity strengthening has different objectives ranging from understanding risk over facilitating decision-making for preparedness and mitigation to using GIS for mainstreaming DRR into development planning. These findings reflect the many uses of GIS for DRR presented in section 3.2. I would argue that if GIS is integrated into the operations of an organisation rather than just used to create a product, e.g. a risk map, it can serve in more than one of the priority areas and be a support tool for the reduction of risk as well as for preventing the creation of new risks.

The empirical findings show a range of different activities to strengthen GIS capacities for DRR and projects often combined a mixture of different activities, nevertheless technical training seems to be the most prevalent.

5.2. Challenges in strengthening DRR capacities using GIS

SQ1 and SQ3 were about the challenges and ways to overcome them encountered in the literature and by the stakeholders interviewed. In this section, I focus on the first part of these questions - the challenges.

This study identifies two sets of challenges, one related to implementation and one to sustainability of capacity strengthening, although I would like to underline that this is not a clear-cut distinction,

i.e. if the challenges related to implementation are not properly addressed, the initiative will not be sustainable.

5.2.1. Difficulties in project implementation

Context related challenges

During implementation participants reported cultural and political barriers as well as resource constraints. Cultural barriers were also be found in the literature on GIS in developing countries (Britton, 2000; Ramasubramanian, 1999). Based on their observation in India, Walsham and Sahay (1999) concluded that GIS implementation requires map-oriented thinking, which might require a long-term change in social attitudes and structures. Clearly, these challenges are very much related to the specific context of the initiative. Regarding these barriers, Iaaly et al. (2016) point out that employees can be resistant to change in their routines and thus are reluctant to integrate GIS in their work. While this was not explicitly brought up in the interviews, in the cases mentioned where GIS created additional work for the staff this appears likely. On the contrary some participant reported that the participants of their GIS training were enthusiastic once they saw how GIS could be used to facilitate DRR. In line with this, a case study on the introduction of a regional disaster management plan in India reports enthusiasm among the local authorities about the introduction of new GIS once they realised that the technology would also facilitate their day to day administrative work (Vatsa & Joseph, 2003). In the cases discussed in the interview study, often organisational structures hindered employees from applying their GIS skills. Resistance to change on the management level might be one of the reasons why these structures were not changed. In addition, the study did find that there was an issue in communication between technical experts and those without a technical background. Therefore, if GIS is presented in a more technical way, this might lead to resistance and lack of interest, which also has implications for the sustainability of the project.

Another challenge related to the context identified in this study are political barriers such as bureaucracy and concerns over security and allowing outsiders access to data. This backs the findings of a review on GIS for natural hazard management that in many regions governments place strict security restrictions on the access to data (Herold & Sawada, 2012). Fekete et al. (2015) point out that these security concerns, particularly with regards to DRR, are not necessarily unfounded since data on vulnerability hotspots could be misused, e.g. for planning attacks or sabotage acts. In addition, Mennecke and West (2002) explain that the possession of information, including GIS, can influence power relations as having information is linked to power and thus power conflicts can lead to reluctance to implement GIS or sharing data with other institutions. In this study, one participant mentioned that officials were sometimes reluctant to declare risks

officially on the map. This may be because this information could lead to others challenging their actions and thus be a threat to their position of power.

Cost of GIS

The other set of challenges this study finds are less related to contextual factors but rather the cost of GIS, in particular the cost of human resources, software and data, which is mirrored in the literature (Britton, 2000; Cavric et al., 2003; Fekete et al., 2015; Mennecke & West Jr, 2002; Ramasubramanian, 1999). This was especially the case, when government agencies with limited budgets tried to build capacities on the local level, but to some extent also for foreign implementing agencies who were dependent on donor funding. The former is particularly problematic, since disasters occur locally and the primary responsibility and ability to reduce disaster risk is on the local level. Several authors therefore argue that GIS capacities need to be strengthened at the local level (Ganz et al., 2016; Herold & Sawada, 2012), where financial resources to afford GIS are often very limited.

5.2.2. Sustainability challenges

GIS capacities end with the end of the project

Based on the findings of this study, I contend that the biggest challenge in strengthening GIS capacities for DRR is to sustain the capacities in the long-term. Several participants mentioned cases where GIS for DRR in some form, whether through training of staff, provision of an application or a GIS product was brought into an organisation with the support of external partners and then no longer used or maintained past the duration of the project. This is consistent with the literature on externally supported GIS projects in low-income countries (Abdullah et al., 2010; Fekete et al., 2015; Jensen et al., 2002; Ofori-Amoah, 2008). A study by Iaaly et al. (2016) on GIS implementation at the local level in Lebanon found that the majority of the GIS projects were not maintained in the long-term. Furthermore, as Ramasubramanian (1999) points out, the sustainability of GIS implementation efforts is often not measured and failures are not reported. In a similar vein, in the interviews conducted for this study, it seems that in most cases there was no clear evaluation strategy.

Human resource issues

This study indicates a few issues that may impede the sustainability of GIS capacities. First, the human resources needed to maintain and use GIS pose a problem, either because there is no trained staff in the first place, since the GIS product or application was developed by external experts or the personal trained in GIS already had other job duties to fulfil or due to high staff turnover. In fact, the findings demonstrate that sometimes the GIS training itself may lead to a person leaving the organisation as their new skills allow them to find better paying employment in the private

sector or in international organisations. These problems are also well documented in the literature on GIS (Britton, 2000; Mennecke & West Jr, 2002; National Research Council et al., 23).

Decision-maker support

Moreover, this study finds that even if there is technical GIS capacity in an organisation that does not always mean that it is used effectively for decision-making. One reason for this can be inadequate communication between technical experts and management, whether it is due to the use of overly technical language mentioned earlier or due to organisational structures. Perhaps partly due to this, decision-makers may be unaware of the potential of GIS. This may not only lead to GIS not being used to support decisions but also to a lack of support for long-term maintenance of GIS, since decision makers are unlikely to allocate their limited resources to something that they do not see the benefits of. The lack for support and understanding of GIS at the senior leadership level is an often-cited issue literature (Abdullah et al., 2010; Britton, 2000; Eria & McMaster, 2017; Iaaly et al., 2016; King, 1996; Miranda et al., 2005). However, this study also finds that in some cases decision-makers may be aware of the benefits, but it might simply be too expensive to maintain with the organisations own resources which relates back to the costs of GIS outlined earlier and the generally limited resources in low-income countries. As Herold and Sawada (2012) acknowledge, governments are also responsible for providing essential services such as health, education and infrastructure, which might take funding priority as it may be difficult to justify investments in computer systems before these basic needs are met, although of course it could be argued that disaster risk reduction may prevent damage or disruption of these services and thus safe money in the long-term.

5.3. Considerations for strengthening GIS capacities for DRR

The previous section has discussed the challenges encountered, this section will deal with the second part of the research questions on how to overcome these challenges, which leads back into the overarching research question: What are important considerations when attempting to strengthen capacities for GIS use in DRR?

Adapt GIS to the context

First, the study has shown that the context in terms of needs, cultural and political context, power relations and available resources matters and can lead to specific challenges outlined earlier. It follows that GIS need to be adapted to the context, which was also brought up in the interviews. This of course requires a thorough understanding of context. The need to analyse the local and organisational context and adapt the GIS solutions can also be found in the literature on implementing GIS in low-income countries (Britton, 2000; Cavric et al., 2003). Taleai et al. (2009) propose a methodology for a situational analysis before implementing GIS in an organisation.

Adapting GIS to the context means adapting technical applications or GIS products to user requirements, the existing resources and the cultural and political context, but also tailoring training to the actual needs of the organisation. For the latter, on-the-job training was suggested both in this study and the literature (Jensen et al., 2002; Miranda et al., 2005; SERVIR-Mekong, 2015).

Human resource considerations

This leads to the human resource issues described in the previous section. Whilst, it appears to me that the main cause for this are overall financial constraints, leading to limited budgets for DRR and paying GIS staff, which is difficult to address within a capacity strengthening project, the risk of staff turnover and the need for human resources to maintain GIS should be considered in the design of capacity development interventions. This study indicates several mitigation options such as creating manuals, training of trainers or bonds for trained staff to stay in an organisation. However, with regards to the latter, Britton (2000) argues that these might face resistance in certain places, in part because they are a reminder of colonial practices of bonded labour.

Address the organisational level

Yet, even though skilled individuals and technical tools are necessary for using GIS in DRR, the results of this study indicate that this is not sufficient. They show that GIS needs to be integrated into an organisation's strategy, i.e. to keep data updated, integrate GIS into standard operating and decision-making procedures and to set aside a budget and human resources for GIS. This is consistent with a study by Iglesias (2005) pointing out that GIS needs to be integrated into the organisation's routine, i.e. its structure, culture, rules, procedures and strategies (Iglesias, 2005). In terms of the theoretical framework presented in chapter three, this means that capacity also needs to be addressed at the organisational level. For this reason, Britton (2000) suggests that capacity development for the use of GIS needs to extend beyond training in technology, but also include management practice and GIS education not only for those operating the GIS but also for policy makers, managers and researchers (Eria & McMaster, 2017; Ramasubramanian, 1999; Walsham & Sahay, 1999). These suggestions mirror the results of this study, however, the conducted research also indicates that financial constraints might still pose a barrier, even if management is generally supportive of GIS.

Decrease costs

Therefore, decreasing the costs of GIS is another important suggestion that emerged from this research. The findings suggest several points of departure: either through using open-source software and free data or through identifying existing GIS capacities or available data in other institutions that can be used for DRR and improving collaboration. In line with this, Guinau et al. (2007) argue that even in developing countries, data collected for other purposes might be available

for the use in DRR. With regards to software, several authors suggest that a range of free and open-source software already exists, but needs further development for applications in DRR and of course training on the individual level in using the software (Herold & Sawada, 2012; Owolabi et al., 2015; Teeuw et al., 2013) which is also found in this study. Furthermore, Volunteered Geographic Information (VGI) has the potential to provide an additional data source, particularly when official data is not available and data collection is too costly (Genovese & Roche, 2010), this was used to some extend by the participants of the study, especially the use of open street maps data and mobilising volunteers for digitisation was pointed out as a solution if no other data was available. Many studies also bring up remote sensing as a promising technology to acquire large quantities of data to be used in DRR for a relatively low cost, particularly in settings where other data sources are less readily available (Manfré et al., 2012; Mennecke & West Jr, 2002; Morris, 2008; Thomas et al., 2007). Whilst some participants in the interview study also called for increased use of remote sensing data, others said satellite imagery was too expensive, especially for local authorities. This was also stated by Herold and Sawada (2012), which again shows that capacity strengthening initiatives for GIS need to consider the context and the available resources. In this regard, it is also important to consider other capacity development initiatives targeting the same organisations, some participants brought up a lack of a common vision amongst donors, leading to duplications of efforts. Hence better coordination among donors and implementing agencies is necessary to maximise the effectiveness of funding. This issue is not new or unique to GIS, in fact, donor harmonisation is one of the fundamental principles of the 2005 Paris Declaration on Aid Effectiveness. However, the results of this study show, this does not always happen in practice.

Improve data availability

Concerning data - one of the major challenges identified - the findings of the study show that whilst some data issues might be addressed by integrating data collection and updating into the organisation's operating procedures, using freely available data or finding less expensive methods of data collection, eventually this issue needs to be addressed at the level of the enabling environment. For DRR purposes often a lot of different data (i.e. census data, data on infrastructure, etc) is needed and this data might be collected by different institutions. Thus, legal or policy changes for data standardisation might be necessary to create a spatial data infrastructure (SDI)[5], a notion supported by the literature (Herold & Sawada, 2012; Manfré et al., 2012; Mansourian et al., 2006). Mansourian et al. (2006) propose a framework for the development of an SDI in combination with a web-based GIS to facilitate disaster management. A practical

[5] The Global Spatial Data Infrastructure Initiative (www.gsdi.org) defines an SDI as "a coordinated series of agreements on technology standards, institutional arrangements, and policies that enable the discovery and facilitate the availability of and access to spatial data". For a critical discussion of different definitions of SDIs see Hendriks et al. (2012)

example can be found in Molina & Bayarri (2011) who describe the design and implementation of a regional SDI for DRR in the Andean Region. However, establishing an SDI in developing countries can be challenging for many of the same reasons that GIS implementation is challenging, such as resource constraints, lack of political support and institutional weaknesses (Mulaku, Kiema, & Siriba, 2007).

Create long-term partnerships

This leads to two more overarching considerations. The previous discussion has pointed out that for sustainable GIS capacities to be developed, functional and technical capacities have to be strengthened on the individual and organisational level and in the enabling environment. The findings also demonstrate that changes on these levels take time and thus require long-term engagement. Specifically, the findings of this study call for regular follow-ups with organisations or individuals, continuous training to keep skills up-to-date and ongoing support with the maintenance of the GIS. This, however, might require a change in funding practices. These findings are consistent with studies on GIS implementation in low-income countries criticising the frequently encountered short-time frames of projects (Britton, 2000; Cavric et al., 2003). Given the funding constraints, some authors recommend increased collaboration with universities to enhance GIS capacity in general and ensure long-term support and local capacity development (Gebreslasie & Bauwens, 2015; Iaaly et al., 2016; Jensen et al., 2002; Ofori-Amoah, 2008).

Foster ownership

As described in the theoretical section, part of the concept of capacity development is that it is an internal process that can only be supported by external partners. The findings of this study show, that sometimes initiatives are driven significantly by donor interest and whilst there is a lack of support from local decision-makers. Clearly, interest from someone providing the funding for the project is needed and for simply providing resources or training this might be enough, but for changing work routines, organisational strategies, legislation etc. which as previously discussed is necessary for the application in the example to be used and maintained, requires a willingness of the internal partner to make these changes. Thus, the results of this study suggest that the benefits of GIS should be demonstrated to the decision-makers to gain their support. Moreover, internal partners should be involved in the entire process of capacity strengthening, for instance when developing GIS products, in order to foster their ownership and commitment and enhance their skills. Iaaly et al. (2016) refer to this as the "ecological approach" to implementing GIS in low-income countries which they favour as opposed to GIS applications or products developed by external consultants, as their study find that these are generally not sustainable. I would also argue that local stakeholders can add a clear understanding of the context, which as described before is necessary for successful project implementation.

5.4. Placing the results in the framework of capacity development

Overall, this discussion shows that the empirical results of this study support the findings of the wider literature on GIS identified through the literature search. Furthermore, many of the identified challenges such as staff turnover, sustainability of the initiatives, donor coordination and short-term project cycles are not unique to strengthening GIS capacities but are encountered in DRR capacity development in general (Scott & Few, 2016). I therefore argue that this study supports the general principles for effective capacity development for DRR developed by Few at al. (2016) based on their review of capacity development literature and several case studies as presented in chapter 3, and adds specific considerations for GIS to these general principles (see Table 11**Fehler! Verweisquelle konnte nicht gefunden werden.**).

Principle	Considerations for GIS capacity strengthening
Flexibility and adaptability	• have a clear understanding of the context including level of general familiarity with technology, political situation, particularly regarding collection and exchange of data, language and culture, availability of ICT infrastructure, available resources, hazards present in the location, organisational structure • adapt GIS to the context, e.g. through on-the-job training, developing GIS applications that are simple to use, finding lower cost solutions for software and data such as free and open source software and open data and volunteered geographic information • build on existing capacities such as related institutions
Comprehensive planning	• engage in more long-term partnerships • plan for regular follow-up and continuous training opportunities • plan for maintenance of GIS, i.e. long term funding options, updating of data • consider risks, particularly staff turnover and plan for mitigation options
Ownership and partnership	• involve partner in all stages of the development of GIS products • GIS project should feed into programme • GIS should make the work of the partner easier • Value of GIS should be demonstrated to decision makers • Level of technical detail and language should be tailored to audience
Attention to functional capacity	• GIS needs to be integrated into organisational routines and strategies (budget, updating and collection of data, use in decision-making, allocation of staff etc.) • Advocate and raise awareness of the benefits of GIS • Support the development and implementation of policies and legislation that create an enabling environment for the use of GIS in disaster risk reduction, particularly the development of spatial data infrastructures
Integration of actors and scales	• Foster regional cooperation to enhance data sharing and create more awareness for GIS • Consider how GIS can be used at the local level and how local knowledge can be integrated • Connect different institutions and individuals to share resources and knowledge, i.e. through technical working groups or peer support groups • Cooperate with universities to harness their technical expertise • Coordinate with different stakeholders active in GIS capacity development to maximise resources and avoid duplication
Contribution to disaster risk reduction	• Consider how the information produced through GIS can be used to mainstream disaster risk reduction into development

Table 11 Considerations for strengthening GIS capacities for DRR

These considerations can support practitioners in designing and implementing GIS capacities development project but also donors deciding which interventions to fund, as this research indicates that sometimes current donor practices do not lead to sustainable capacity development initiatives. The results also demonstrate, that even though an organisation is often the entry point for the capacity development intervention all three levels of capacity should be considered. Based on the findings of this study, the specific capacities needed for the effective use of GIS in DRR can be placed at the three levels of capacity introduced in chapter 3 (see Figure 6). Just as the previous table, it can support the design of GIS capacity development interventions by providing an overview on what functional and technical capacities are needed to build sustainable GIS capacity for DRR.

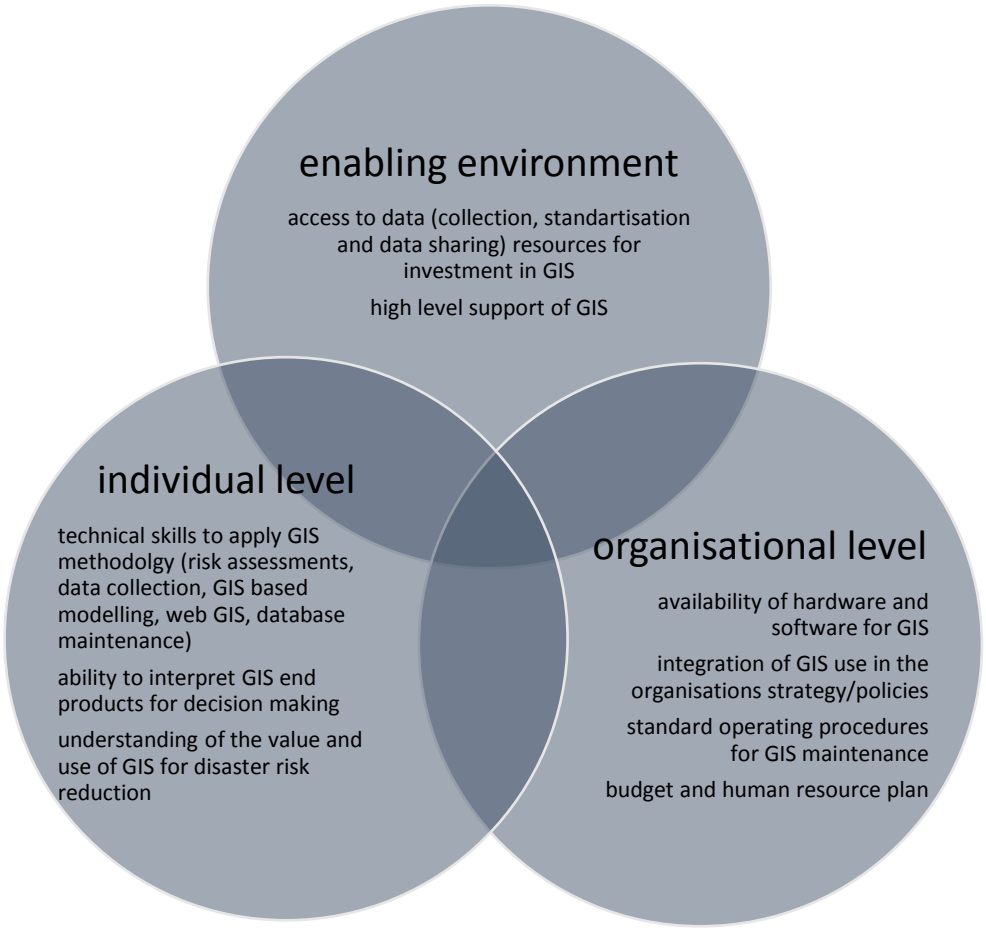

Figure 6 GIS capacities at different levels

5.5. Limitations

Although this research has reached its overall objective of identifying common challenges, good practices and factors to consider when strengthening GIS capacities for DRR, there are some limitations.

First, the sample of participants was limited in that no representatives of funding agencies were interviewed and most participants were working for external implementing agencies rather than the targets of capacity development. Moreover, all participants were part of different initiatives in very different contexts. On one hand, this allowed to find identify common trends and considerations, but at the expense of a more-in-depth understanding on the different situations and a better understanding of how contextual factors influenced the capacity development initiatives. Moreover, as only one individual from each initiative was interviewed, their personal experiences might have had a stronger influence on the result, than in the case of a more in-depth case study considering different perspectives on the same initiative. This could be a subject for further research. Furthermore, the findings rely only on the interviews with the participants and the subsequent analysis. To gain better insights, project documentation could have been studied in addition to the interviews to provide a more in depth-pictures and provide more context to the interviews.

6. CONCLUSION

To conclude, GIS has the potential to be a powerful tool to support DRR and reach the aim of the Sendai Framework to significantly reduce disaster risk. The hurdle to use GIS for disaster risk reduction is not a primarily technical issue as the technologies and methodologies for GIS applications in disaster risk reduction have advanced significantly in the last decades and continue to be developed further. Lower and middle-income countries where most of the losses from disasters occur could benefit greatly from using these technologies. However, as this research shows this cannot be achieved through simply transferring GIS technology to these countries, since the use of GIS requires functional and technical capacities on the individual and organisational level as well as in the enabling environment.

The empirical findings of this study show that many actors are trying to support stakeholders in DRR in strengthening their GIS capacity, frequently through technical training, the provision of GIS products or GIS applications. Albeit important to enhance GIS capacity, the findings show that sustainability of the capacity development interventions remains a major challenge and to maintain GIS capacity in the long-term and use it effectively, training or the development of a GIS database by itself is not sufficient, it needs to be integrated in organisational policies and national legislation, which in turn requires support from the decision-makers.

For external actors supporting GIS capacity strengthening for DRR this means increasing advocacy for GIS use and engaging in more long-term partnerships, involving their partners in the entire process, which turn requires change in donor practices, as this research shows that there are still gaps between theory and practice in this field. This study adds empirical evidence to existing research on GIS and capacity development and demonstrates how it can be applied in the specific case of strengthening GIS capacities for DRR.

REFERENCES

Abdullah, M. F., Abdullah, A., & Zahari, R. K. (2010). GIS implementation in Malaysian statutory development plan system. *Handbook of Research on E-Planning: ICTs for Urban Development and Monitoring*, 435–454.

Alexander, D. E. (2002). *Principles of emergency planning and management*. Oxford University Press on Demand. Retrieved from https://books.google.de/books?hl=en&lr=&id=iLqMSDgecHQC&oi=fnd&pg=PR12&dq=Alexander,+D.+(2002).+Principles+of+emergency+planning+and+management.+New+York:+Oxford+University+Press.&ots=_Vujy040O8&sig=RzXubu5Z8-dGzCeNvsFFQvFF-q8

Armstrong, J. (2013). *Improving international capacity development: Bright spots*. Basingstoke: Palgrave Macmillan

Becker, P. (Ed.). (2014). *Sustainability science: managing risk and resilience for sustainable development*. Amsterdam: Elsevier Science Ltd.

Biswajeet, P., & Saro, L. (2007). Utilization of optical remote sensing data and GIS tools for regional landslide hazard analysis using an artificial neural network model. *Earth Science Frontiers*, *14*(6), 143–151.

Bolger, J. (2000). Capacity development: why, what and how. *Capacity Development Occasional Series*, *1*(1), 1–8.

Brinkerhoff, D. W., & Morgan, P. J. (2010). Capacity and capacity development: Coping with complexity. *Public Administration and Development*, *30*(1), 2–10.

Britton, J. M. R. (2000). GIS capacity building in the Pacific Island countries: Facing the realities of technology, resources, geography and cultural difference. *Cartographica*, *37*(4), 7–20.

Çabuk, A. (2002). A proposal for a method to establish natural-hazard-based land-use planning: the Adapazarı case study. *Turkish Journal of Earth Sciences*, *10*(3), 143–152.

Capacity for Disaster Reduction Initiative [CADRI]. (2011). *Basics of Capacity Development for Disaster Risk Reduction*. Geneva: Capacity for Disaster Reduction Initiative (CADRI). Retrieved

from http://www.cadri.net/sites/default/files/documents/pdf/18061_cadribrochureweb2.pdf

Cavric, B. I., Nedovic-Budic, Z., & Ikgopoleng, H. G. (2003). Diffusion of GIS technology in Botswana: Process and determinants. *International Development Planning Review*, *25*(2), 195–219.

Chang, M.-S., Tseng, Y.-L., & Chen, J.-W. (2007). A scenario planning approach for the flood emergency logistics preparation problem under uncertainty. *Transportation Research Part E: Logistics and Transportation Review*, *43*(6), 737–754. https://doi.org/10.1016/j.tre.2006.10.013

Chen, W., He, B., Zhang, L., & Nover, D. (2016). Developing an integrated 2D and 3D WebGIS-based platform for effective landslide hazard management. *International Journal of Disaster Risk Reduction*, *20*, 26–38. https://doi.org/10.1016/j.ijdrr.2016.10.003

Cho, J. Y., & Lee, E.-H. (2014). Reducing confusion about grounded theory and qualitative content analysis: Similarities and differences. *The Qualitative Report*, *19*(32), 1.

Christoplos, I., Engstrand, K., & Hedqvist, A. L. (2014). *Capacity Development Literature Review*. Sweden: Sida. Retrieved from http://www.sida.se/contentassets/e152ed3b81ab4b9ebaf51362cc2721ea/capacity-development-literature-review_3761.pdf

Coppock, J. T. (1995). Gis and Natural Hazards: An overview from a Gis Perspective. In A. Carrara & F. Guzzetti (Eds.), *Geographical Information Systems in Assessing Natural Hazards* (pp. 21–34). Springer Netherlands. https://doi.org/10.1007/978-94-015-8404-3_2

Cova, T. J. (1999). GIS in emergency management. *Geographical Information Systems*, *2*, 845–858.

Creswell, J. W. (2007). *Qualitative inquiry & research design: choosing among five approaches* (2nd ed). Thousand Oaks: Sage Publications.

Dash, N. (1997). The use of geographical information systems in disaster research. *International Journal of Mass Emergencies and Disasters*, *15*(1), 135–146.

Eade, D. (1997). Capacity-Building: An approach to people-centred development. *Policy & Practice*. Retrieved from http://policy-practice.oxfam.org.uk/publications/capacity-building-an-approach-to-people-centred-development-122906

Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, *62*(1), 107–115. https://doi.org/10.1111/j.1365-2648.2007.04569.x

Environmental Systems Research Institute [ESRI]. (1990). *Understanding GIS: The ARC/INFO Method*. Redlands: ESRI.

Eria, S., & McMaster, R. B. (2017). GIS diffusion in Uganda. *International Journal of Geographical Information Science*, *31*(5), 884–906. https://doi.org/10.1080/13658816.2016.1242131

EuropeAid. (2010). *Toolkit for Capacity Development*. (Tools and Methods Series No. Reference Document No. 6). European Commission.

Farhan, A., & Akhyar, H. (2017). Analysis of tsunami disaster map by Geographic Information System (GIS): Aceh Singkil-Indonesia. *IOP Conference Series: Earth and Environmental Science*, *56*, 012002. https://doi.org/10.1088/1755-1315/56/1/012002

Farthing, D. W., & Ware, J. M. (2010). When it comes to mapping developing countries, disaster preparedness is better than disaster response. *AGI GeoCommunity*, *10*. Retrieved from https://www.researchgate.net/profile/Dave_Farthing/publication/235747321_When_it_comes_to_mapping_developing_countries_disaster_preparedness_is_better_than_disaster_response/links/00b7d53c157234596a000000.pdf

Fekete, A., Tzavella, K., Armas, I., Binner, J., Garschagen, M., Giupponi, C., … Serre, D. (2015). Critical Data Source; Tool or Even Infrastructure? Challenges of Geographic Information Systems and Remote Sensing for Disaster Risk Governance. *ISPRS International Journal of Geo-Information*, *4*(4), 1848–1869. https://doi.org/10.3390/ijgi4041848

Few, R., & Anagnosti, S. (2010). Supporting disaster risk reduction in developing countries (a study for the European Union). Retrieved from https://ueaeprints.uea.ac.uk/18807/1/RPP9.pdf

Few, R., Scott, Z., Wooster, K., Avila, M. F., & Tarazona, M. (2016). Strengthening capacities for disaster risk management II: Lessons for effective support. *International Journal of Disaster Risk Reduction*, *20*, 154–162. https://doi.org/10.1016/j.ijdrr.2016.02.005

Fukuda Parr, S., Lopes, C., & Malik, K. (2002). Overview. Institutional innovations for capacity development. *Capacity for Development: New Solutions to Old Problems*, 1–21.

Gaillard, J.-C., & Maceda, E. A. (2009). Participatory three-dimensional mapping for disaster risk reduction. *Community-Based Adaptation to Climate Change*, *60*, 109–118.

Ganz, D. J., Towashiraporn, P., Arambepola, N. M. S. I., Rahman, A., Perwaiz, A., Basnayake, S., … Dewi, A. (2016). Integrating Earth Observation Systems and Data into Disaster Preparedness in the Lower Mekong: Experiences from the Asian Disaster Preparedness Center, 63–84. https://doi.org/10.1007/978-3-319-33438-7_3

Gebreslasie, M. T., & Bauwens, I. (2015). MALAREO: a user-driven project. *Geospatial Health*, *10*(2), 329. https://doi.org/10.4081/gh.2015.329

Genovese, E., & Roche, S. (2010). Potential of VGI as a resource for SDIs in the North/South context. *Geomatica*, *64*(4), 439–450.

Guarín, G. P., Westen, C. J., & Montoya, L. (2004). Community-based flood risk assessment using GIS for the town of San Sebastian, Guatemala. *International Institute for Geoinformation Science and Earth Observation (ITC)*. Retrieved from http://www.academia.edu/download/45772940/vanwesten_com.pdf

Guinau, M., Vilajosana, I., & Vilaplana, J. M. (2007). GIS-based debris flow source and runout susceptibility assessment from DEM data - A case study in NW Nicaragua. *Natural Hazards and Earth System Science*, *7*(6), 703–716.

Hagelsteen, M., & Becker, P. (2013). Challenging disparities in capacity development for disaster risk reduction. *International Journal of Disaster Risk Reduction*, *3*, 4–13. https://doi.org/10.1016/j.ijdrr.2012.11.001

Hagelsteen, M., & Becker, P. (2014). A Great Babylonian Confusion: Terminological Ambiguity in Capacity Development for Disaster Risk Reduction in the International Community. In

[Host publication title missing] (pp. 298–300). Global Risk Forum. Retrieved from http://lup.lub.lu.se/record/4668192

Hagelsteen, M., & Burke, J. (2016). Practical aspects of capacity development in the context of disaster risk reduction. *International Journal of Disaster Risk Reduction*, *16*, 43–52. https://doi.org/10.1016/j.ijdrr.2016.01.010

Hall, B. (2006). The Information Age, Capacity Building, and the Use of Spatial Information Technologies in Developing Countries. *Cartographica: The International Journal for Geographic Information and Geovisualization*. https://doi.org/10.3138/6184-8L40-W30P-P66G

Hendriks, P. H. J., Dessers, E., & van Hootegem, G. (2012). Reconsidering the definition of a spatial data infrastructure. *International Journal of Geographical Information Science*, *26*(8), 1479–1494. https://doi.org/10.1080/13658816.2011.639301

Herold, S., & Sawada, M. C. (2012). A review of geospatial information technology for natural disaster management in developing countries. *Geographic Information Systems: Concepts, Methodologies, Tools, and Applications: Concepts, Methodologies, Tools, and Applications*, 175.

Hsieh, H.-F., & Shannon, S. E. (2005). Three approaches to qualitative content analysis. *Qualitative Health Research*, *15*(9), 1277–1288.

Huang, R. (2016). RQDA: R-based Qualitative Data Analysis (Version R package version 0.2-8). Retrieved from http://rqda.r-forge.r-project.org/

Iaaly, A., Jadayel, O., & Jadayel, R. (2016). The 'Ecological Approach' to GIS Implementation in Low Income Countries' and the Role of Universities: Union of Municipalities of Joumeh Case Study. *World Academy of Science, Engineering and Technology, International Journal of Environmental, Chemical, Ecological, Geological and Geophysical Engineering*, *10*(3), 290–295.

Iglesias, G. (2005). The Adoption of Geo-information and Geographic Information Systems for Natural Disaster Risk Management by Local Authorities, 1009–1019. https://doi.org/10.1007/3-540-27468-5_71

James, R., & Wrigley, R. (2007). *Investigating the Mystery of Capacity Building: Learning from the Praxis Program. Praxis Paper 18*. Oxford: International NGO Training Research Center (INTRAC).

James, Rick. (2010). Vices and virtues in capacity development by international NGOs. *IDS Bulletin*, *41*(3), 13–24.

Jensen, J. R., Botchway, K., Brennan-Galvin, E., Johannsen, C., Juma, C., Mabogunje, A., … Taylor, D. R. F. (2002). *Down to earth: geographical information for sustainable development in Africa*. Washington, D.C: National Academies Research. Retrieved from https://books-google-com.ludwig.lub.lu.se/books?hl=de&lr=&id=Nz2cAgAAQBAJ&oi=fnd&pg=PA1&dq=Down+to+Earth:+Geographical+Information+for+Sustainable+Development+in+Africa&ots=XmIttslVWf&sig=E-xAvpAMJ3re4VBmJADpE7nH0Xc

Johnson, R. (2005). A Case Study in Multiagency GIS for Managing a Large-Scale Natural Disaster. In P. D. P. van Oosterom, D. S. Zlatanova, & E. M. Fendel (Eds.), *Geo-information for Disaster Management* (pp. 155–170). Springer Berlin Heidelberg. https://doi.org/10.1007/3-540-27468-5_11

Keijzer, N. (2013). Who's the Boss? Strengthening the Effectiveness of Capacity Development Support. *Briefing Paper*, (15).

Kienberger, S., & Steinbruch, F. (2005). P-GIS and disaster risk management: Assessing vulnerability with P-GIS methods–Experiences from Búzi, Mozambique. In *International Conference on Participatory Spatial Information Management and Communication, Nairobi, Kenya*. Retrieved from https://www.researchgate.net/profile/Franziska_Steinbruch/publication/228917329_P-GIS_and_disaster_risk_management_Assessing_vulnerability_with_P-GIS_methodsExperiences_from_Bzi_Mozambique/links/00b49538d551b5f160000000.pdf

King, N. (1996). Achieving decision support with GIS: learning from water management applications in South Africa. *Application of Geographic Information Systems in Hydrology and Water Resources Management. Proc. HydroGIS'96 Conference, Vienna, 1996*, (235), 677–683.

Kühl, S. (2009). Capacity development as the model for development aid organizations. *Development and Change*, *40*(3), 551–577.

Le Cozannet, G., Bagni, M., Thierry, P., Aragno, C., & Kouokam, E. (2014). WebGIS as boundary tools between scientific geoinformation and disaster risk reduction action in volcanic areas. *Natural Hazards and Earth System Sciences*, *14*(6), 1591.

Liu, C., Li, Y., & Li, J. (2017). Geographic information system-based assessment of mitigating flash-flood disaster from green roof systems. *Computers, Environment and Urban Systems*, *64*, 321–331. https://doi.org/10.1016/j.compenvurbsys.2017.04.008

Liu, Y., Lv, X., Qin, X., Guo, H., Yu, Y., Wang, J., & Mao, G. (2007). An integrated GIS-based analysis system for land-use management of lake areas in urban fringe. *Landscape and Urban Planning*, *82*(4), 233–246. https://doi.org/10.1016/j.landurbplan.2007.02.012

Lopes, C., & Theisohn, T. (2003). *Ownership, leadership and transformation: can we do better for capacity development?* London: Earthscan Publications.

Lucas, B. (2013). Current thinking on capacity development. *Governance and Social Development Resource Centre, University of Birmingham, Birmingham*. Retrieved from http://www.academia.edu/download/31727021/HDQ960.pdf

Manfré, L. A., Hirata, E., Silva, J. B., Shinohara, E. J., Giannotti, M. A., Larocca, A. P. C., & Quintanilha, J. A. (2012). An Analysis of Geospatial Technologies for Risk and Natural Disaster Management. *ISPRS International Journal of Geo-Information*, *1*(2), 166–185. https://doi.org/10.3390/ijgi1020166

Maniruzzaman, K. M., Okabe, A., & Asami, Y. (2001). GIS for Cyclone Disaster Management in Bangladesh. *Geographical and Environmental Modelling*, *5*(2), 123–131. https://doi.org/10.1080/13615930120086087

Mansourian, A., Rajabifard, A., Valadan Zoej, M. J., & Williamson, I. (2006). Using SDI and web-based system to facilitate disaster management. *Computers & Geosciences*, *32*(3), 303–315. https://doi.org/10.1016/j.cageo.2005.06.017

Masser, I. (2001). Managing our urban future: the role of remote sensing and geographic information systems. *Habitat International*, *25*(4), 503–512. https://doi.org/10.1016/S0197-3975(01)00021-2

Mennecke, B. E., & West Jr, L. A. (2002). Geographic Information Systems in developing countries: issues in data collection, implementation and management. In *Information Technology Management in Developing Countries* (pp. 70–91). IGI Global. Retrieved from http://www.igi-global.com/chapter/information-technology-management-developing-countries/23709

Miranda, M. L., Casper, M., Tootoo, J., & Schieb, L. (2013). Putting Chronic Disease on the Map: Building GIS Capacity in State and Local Health Departments. *Preventing Chronic Disease*, *10*. https://doi.org/10.5888/pcd10.120321

Miranda, M. L., Silva, J. M., Overstreet Galeano, M. A., Brown, J. P., Campbell, D. S., Coley, E., … Sandelé, W. (2005). Building Geographic Information System Capacity in Local Health Departments: Lessons From a North Carolina Project. *American Journal of Public Health*, *95*(12), 2180–2185. https://doi.org/10.2105/AJPH.2004.048785

Molina, M., & Bayarri, S. (2011). A multinational SDI-based system to facilitate disaster risk management in the Andean Community. *Computers and Geosciences*, *37*(9), 1501–1510. https://doi.org/10.1016/j.cageo.2011.01.015

Morgan, P. (2006). The concept of capacity. *European Centre for Development Policy Management*, 1–19.

Morris, N. (2008). Low-Cost remote sensing and GIS for regional disaster risk reduction, North West Costa Rica. *Journal of Maps*, *4*(SUPPL 1), 23–39. https://doi.org/10.1080/jom.2008.9711032

Mulaku, G. C., Kiema, J. B. K., & Siriba, D. N. (2007). Assessment of Kenya's readiness for geospatial data infrastructure take off. *Survey Review*, *39*(306), 328–337. https://doi.org/10.1179/175227007X197237

Nagasaka, T. (2006). New mode of risk governance enhanced by an e-community platform. *A Better Integrated Management of Disaster Risks toward Resilient Society to Emerging Disaster Risks in Mega-Cities*, 89–107.

National Research Council, Division on Earth and Life Studies, Board on Earth Sciences and Resources, Mapping Science Committee, Committee on Geography, & Committee on the

Geographic Foundation for Agenda 21. (23). Building Capacity to Apply Geographic Information to Sustainable Development in Africa. National Academies Press. Retrieved from https://www.nap.edu/read/10455/chapter/10

OECD. (2008). The Challenge of Capacity Development. *OECD Journal on Development*, *8*(3), 233–276. https://doi.org/10.1787/journal_dev-v8-art40-en

Ofori-Amoah, B. (2008). „Building Capacity to Use Geospatial Technology for Development in Africa: Lessons from the Uganda GIS Project". *Global Dialogue on Emerging Science and Technology (GDEST) Cape Town, South Africa*. Retrieved from http://2001-2009.state.gov/documents/organization/110978.pdf

Omidvar, B., Baradaran-Shoraka, M., & Nojavan, M. (2013). Temporary site selection and decision-making methods: a case study of Tehran, Iran. *Disasters*, *37*(3), 536–553. https://doi.org/10.1111/disa.12007

Owolabi, K., Sonoiki, D., Salet, F., & Gignac, N. (2015). Application of FOSS4G and open data to support polio eradication, vaccine delivery and ebola emergency response in West Africa. *International Journal of Geoinformatics*, *11*(3), 31–36.

Pearson, L., & Pelling, M. (2015). The UN Sendai Framework for Disaster Risk Reduction 2015–2030: Negotiation Process and Prospects for Science and Practice. *Journal of Extreme Events*, *02*(01), 1571001. https://doi.org/10.1142/S2345737615710013

Ramasubramanian, L. (1999). GIS Implementation in Developing Countries: Learning from Organisational Theory and Reflective Practice. *Transactions in GIS*, *3*(4), 359–380. https://doi.org/10.1111/1467-9671.00028

Saadatseresht, M., Mansourian, A., & Taleai, M. (2009). Evacuation planning using multiobjective evolutionary optimization approach. *European Journal of Operational Research*, *198*(1), 305–314.

Schulz, K., Gustafsson, I., & Illes, E. (2005). Manual for capacity development. *Stockholm: Sida*.

Scott, Z., & Few, R. (2016). Strengthening capacities for disaster risk management I: Insights from existing research and practice. *International Journal of Disaster Risk Reduction*, *20*, 145–153. https://doi.org/10.1016/j.ijdrr.2016.04.010

SERVIR-Mekong. (2015). *A Needs Assessment of Geospatial Data and Technologies in the Lower Mekong Region*. Bangkok: ADPC. Retrieved from https://servir.adpc.net/sites/servir.adpc.net/files/public/publications/attachments/SERVIR-Mekong_2015_RegionalNeedsAssessment.pdf

Smith Jr., W. J. (2009). Improving access to safe drinking water in rural, remote and least-wealthy small islands: Non-traditional methods in Chuuk State, Federated States of Micronesia. *International Journal of Environmental Technology and Management*, *10*(2), 167–189. https://doi.org/10.1504/IJETM.2009.023524

Tadele, F., & Manyena, B. S. (2009). Building disaster resilience through capacity building in Ethiopia. *Disaster Prevention and Management: An International Journal*, *18*(3), 317–326. https://doi.org/10.1108/09653560910965664

Taleai, M., Mansourian, A., & Sharifi, A. (2009). Surveying general prospects and challenges of GIS implementation in developing countries: a SWOT–AHP approach. *Journal of Geographical Systems*, *11*(3), 291–310. https://doi.org/10.1007/s10109-009-0089-5

Teeuw, R. M., Leidig, M., Saunders, C., & Morris, N. (2013). Free or low-cost geoinformatics for disaster management: Uses and availability issues. *Environmental Hazards*, *12*(2), 112–131. https://doi.org/10.1080/17477891.2012.706214

Thomas, D. S. K., Ertuğay, K., & Kemeç, S. (2007). The Role of Geographic Information Systems/Remote Sensing in Disaster Management. In H. Rodríguez, E. L. Quarantelli, & R. R. Dynes, *Handbook of Disaster Research* (pp. 83–96). New York, NY: Springer New York. https://doi.org/10.1007/978-0-387-32353-4_5

Tiwari, A. (2015). *The Capacity Crisis in Disaster Risk Management: Why disaster management capacity remains low in developing countries and what can be done*. Cham: Springer International Publishing : Imprint: Springer.

Tran, P., Shaw, R., Chantry, G., & Norton, J. (2009). GIS and local knowledge in disaster management: a case study of flood risk mapping in Viet Nam. *Disasters*, *33*(1), 152–169.

Ubels, J., Acquaye-Baddoo, N.-A., & Fowler, A. (2010). *Capacity Development in Practice*. Earthscan.

Uitto, J. I., & Shaw, R. (2016). Sustainable Development and Disaster Risk Reduction: Introduction. In *Sustainable Development and Disaster Risk Reduction* (pp. 1–12). Springer, Tokyo. https://doi.org/10.1007/978-4-431-55078-5_1

United Nations Development Programme [UNDP]. (2009). *Capacity Development: A UNDP Primer*. New York: UNDP.

United Nations Initiative on Global Geospatial Information Management [UN-GGIM]. (2016a). *Committee of Experts on Global Geospatial Information Management - Report on the sixth session (3-5 August 2016)* (Economic and Social Council Official Records No. E/2016/46-E/C.20/2016/15). New York. Retrieved from http://ggim.un.org/docs/meetings/GGIM6/E-2016-46-E-C.20-2016-15_GGIM6%20Report_en.pdf

United Nations Initiative on Global Geospatial Information Management [UN-GGIM]. (2016b). *Draft Strategic Framework on Geospatial Information and Services for Disasters 2016 - 2030*. Retrieved from http://ggim.un.org/docs/draft_UN-GGIM_Strategic%20Framework%20on%20GISD%20-%20Version%203.pdf

United Nations International Strategy for Disaster Reduction [UNISDR] (Ed.). (2015). *Making development sustainable: the future of disaster risk management*. Geneva, Switzerland: United Nations Office for Disaster Risk Reduction (UNISDR).

United Nations International Strategy for Disaster Reduction [UNISDR]. (2016). *Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction*. New York: United Nations General Assembly. Retrieved from http://www.preventionweb.net/files/50683_oiewgreportenglish.pdf

van Westen, C. J., Montoya, L., Boerboom, L., & Badilla Coto, E. (2002). Multi-hazard risk assessment using GIS in urban areas: a case study for the city of Turrialba, Costa Rica. Retrieved from http://doc.utwente.nl/80699/

Vatsa, K. S., & Joseph, J. (2003). Disaster management plan for the state of maharashtra, india: Evolutionary process. *Natural Hazards Review*, *4*(4), 206–212. https://doi.org/10.1061/(ASCE)1527-6988(2003)4:4(206)

Wahlström, M. (2015). New Sendai Framework Strengthens Focus on Reducing Disaster Risk. *International Journal of Disaster Risk Science*, *6*(2), 200–201. https://doi.org/10.1007/s13753-015-0057-2

Walsham, G., & Sahay, S. (1999). GIS for district-level administration in India: problems and opportunities. *MIS Quarterly*, 39–65.

Westen, C. J. (2010). GIS for the assessment of risk from geomorphological hazards. In I. Alcantara-Ayala & A. S. Goudie (Eds.), *Geomorphological Hazards and Disaster Prevention* (pp. 205–220). Cambridge: Cambridge University Press. https://doi.org/10.1017/CBO9780511807527.017

Whyte, A. V. (2004). *Landscape analysis of donor trends in international development*. Rockefeller Foundation New York. Retrieved from http://www.issuelab.org/resources/10017/10017.pdf

Wood, N. J., & Good, J. W. (2004). Vulnerability of port and harbor communities to earthquake and tsunami hazards: the use of GIS in community hazard planning. *Coastal Management, 32*(3), 243–269.

APPENDIX – INTERVIEW GUIDE

Background

- What is your professional background?
- Where do you currently work and what is your position?
- How many years of experience in this position do you have?

Involvement in capacity development projects related to the use of GIS for disaster preparedness

- Please tell me about the capacity development projects involving the use of GIS for disaster preparedness that you have been involved in?

Planning

- What was the driving force behind the capacity development intervention? (regarding the most recent project they were involved in)
    - what triggered the start of the project?
    - what needs was/is it trying to address?
    - what were the objective of the project?
    - what aspects of DRM did/is the project addressing?
    - what level (s) (individual/community/regional/national) does the project target?
    - what was the time span of the project?
- What kind of capacities do you think are most important to successfully use GIS for disaster preparedness?
- What do you think are the most important considerations when planning capacity development projects for GIS?
    - Can you give examples of good practices when planning capacity development interventions based on your experience?
    - What are potential pitfalls and challenges?

Roles and responsibilities

- What were the roles and responsibilities of the different stakeholders involved in the project?
    - Who was involved in the project?
    - What were the roles and responsibilities of the different partners involved in the project?
    - How do you see your role?

Implementation

- What kind of activities (trainings, networking, manuals, etc.) were part of the project
    - what kind of activities do you think work best to strengthen capacity for the use of GIS
- What do you think are the most important considerations when implementing capacity development projects for GIS?
    - Can you give examples of good practices when implementing capacity development interventions based on your experience?
    - What are potential pitfalls and challenges?
    - Which challenges were you able to overcome and how?

Evaluation

- How do you assess the results of the capacity development project?
- In your experience, what are the main factors that make a capacity development successful?
    - what is a successful project in your opinion?
    - what is a failed project?
    - in your experience what factors lead to success?
- In your opinion, what is necessary to make sure that the project is sustainable?

End

- Is there anything you expected me to ask that I did not ask?
- Is there anything else you would like to know?