



Guest Working Paper
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GIS – what can and what can't it say about social relations in adaptation to urban flood risk?

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Urban flooding cannot be avoided entirely and in all areas, particularly in coastal cities. Therefore adaptation to the growing risk is necessary. Geographical Information Systems (GIS) based knowledge on risk informs location-based approach to adaptation to climate risk. It allows managing city-wide coordination of adaptation measures, reducing adverse impacts of local strategies on neighbouring areas to the minimum. Quantitative assessments dominate GIS applications in flood risk management, for instance to demonstrate the distribution of people and assets in a flood prone area. Qualitative, participatory approaches to GIS are on the rise but have not been applied in the context of flooding yet. The overarching research question of this working paper is: what can GIS, and what can it not say about relationships / social relations in adaptation to urban flood risk? The use of GIS in risk mapping has exposed environmental injustices. Applications of GIS further allow modelling future flood risk in function of demographic and land use changes, and combining it with decision support systems (DSS). While such GIS applications provide invaluable information for urban planners steering adaptation they however fall short on revealing the social relations that shape individual and household adaptation decisions. The relevance of networked social relations in adaptation to flood risk has been demonstrated in case studies, and extensively in the literature on organizational learning and adaptation to change. The purpose of this literature review is to identify the type of social relations that shape adaptive capacities towards urban flood risk which cannot be identified in a conventional GIS application.

Qualitative GIS, adaptive capacity, urban risk, social vulnerability, institutions, risk governance

1. Adaptation to urban flood risk

Because of the interaction of multiple pressures in urban areas, urban flood risk cannot be entirely prevented from happening. Instead adaptation to urban flood risk conditions is needed. This section gives an overview on trends in urban flood risk, conventional flood risk management measures, and stresses the urgency of adaptation measures to urban flood risks. Differences between measures for flood risk mitigation and adaptation to flood risk are made explicit.

Floods rank among the disasters with most detrimental impacts worldwide. Losses of people and assets due to flooding are particularly high in cities, and are likely to continue to rise in the context of ongoing urbanisation and climate change (Few 2003; Levy, Hall 2005). As urbanisation continues at disproportionate rates in coastal areas, large river floods, coastal inundation and storm water surges are putting an increasingly large number of urban dwellers at risk, and among them the poor are particularly vulnerable (Huq et al. 2007; McGranahan et al. 2007). Four types of urban flooding are distinguished in the literature, namely localised flooding due to inadequate drainage, small stream overflow often linked to rainfalls and clogged drains, large river floods and coastal flooding (Douglas et al. 2008, p.191). The former two are occurring with increasing frequency in areas that undergo rapid urban development and are simultaneously exposed to changing rainfall patterns and sea level change as a result of climate change. This is the case in many African cities and led Action Aid to analyse vulnerabilities and adaptive capacities in 5 African cities (Action Aid 2006). The results highlight the disproportionate exposure and limited adaptive capacity among the urban poor and the lack of commitment and capacity in national, regional and local governments to reduce urban flooding in the cities analysed (Douglas et al. 2008; Bhattacharya, Lamond 2011). This is a typical condition of risk not only in urban Africa but in rapidly urbanising regions across the world (Bündnis Entwicklung Hilft 2014).

While current trends exacerbate urban flood risk in many cities, it has been part of urban life for centuries in cities such as London, New York, Hamburg, Amsterdam - all close to the sea and partly built on reclaimed land. Structural engineering measures of flood risk control such as dikes, levees, canals, flood gates, pumping, etc. have been developed to protect these cities. With more and more structural flood control measures necessary to protect cities however, flood risks have been diverted and resulted in unjustifiable costs. The 2002 Elbe flooding in Germany for example was partly the result of river flow modifications serving the protection of settlements and agricultural lands. It has triggered a reorientation of flood risk management from structural mitigation to non-structural preventive measures such as spatial planning (Kruse 2010). Similar shifts from mitigation to adaptation have shaped recent flood risk management approaches in the Netherlands, Switzerland and the UK (Handmer 2001; Kruse 2010; van Herk et al. 2013; Weichselgartner 2003). Nevertheless, reoccurring flood events and their devastating impacts in recent years show that the availability of knowledge, data and experience in dealing with flooding do not translate directly into action that minimises flood risk.

Both the African and the European experiences illustrate the need for adaptive management of urban flood risk because its mitigation is unsustainable and bears the danger of a technical lock-in (Few 2003; van Herk et al. 2011). Adaptation to flood risk involves both structural and non-structural measures. Next to large scale engineering works as mentioned above, structural measures include drainage systems, as well as ecosystems that provide natural protection such as wetlands (Bhattacharya, Lamond 2011; Elliott, Trowsdale 2007). Non-structural measures instead of fighting the floods pursue a 'living with the river' approach focussing on exposure and vulnerability reduction (Few 2003; Handmer 2001; Weichselgartner 2003). Early warning systems, spatial land use planning, building codes and emergency response planning are key components (Handmer 2001; Few 2003). Structural and non-structural measures can be

complementary, but can also be incompatible where structural measures enhance risk in the future or on adjacent sites by diverting water, or by creating incentives to settle on exposed sites.

In adaptation to urban flooding, key challenges arise from the multiple dimensions of complexity in vulnerability reduction which Barroca and colleagues have summarised as the complexity of the hazard itself, the complexity of elements at risk, and the complexity of relations between elements at risk (Barroca et al. 2006). Corresponding to these complexities, the Action Aid study shows that first of all, urban floods in Africa occur as the result of multiple interacting social and environmental processes that are poorly monitored. Secondly, they affect slum dwellers with particular severity. Within these, migrant settlers from different regions who have little understanding of local environmental conditions, indigenous groups, women, children, and other groups are considered to be particularly vulnerable in multiple ways (Abdallah Imam, Tamimu 2015; Adelekan et al. 2015). Finally, local flood risk is increasing because disaster risk reduction approaches are top-down lacking local enforcement, and local collective action strategies practically non-existent. The authors of the Action Aid study as well as further studies conclude that improved infrastructure and land use planning at different levels of scale (local, river basin, coastal systems) and poor people's participation in planning is needed to improve adaptation to flood risk in African cities (Action Aid 2006; Bhattacharya, Lamond 2011; Douglas et al. 2008). However, enforcing urban planning for disaster risk reduction in rapidly developing cities remains a challenge particularly where governments have limited resources and basic data is lacking and as a result of institutional and cultural divides between urban planning and DRR workers (Wamsler 2006).

This brief review of recent approaches and challenges in urban flood risk management points to the increasing complexity involved in decision-making in relation to urban development and risk reduction. Complexities range from understanding the causes of floods to understanding vulnerabilities and taking decisions on management options that involve trade-offs. Geographic information science including Geographic Information Systems (GIS), remote sensing (RS), environmental modelling and decision support systems (DSS) are increasingly used to handle these complexities. The following section is a review on how these different tools have been used in flood risk management, and what their contribution is to managing flood risk in conditions of high complexity and uncertainty. It is followed by a discussion of factors that are not yet adequately addressed in these approaches, based on social science's insights on disaster risk and adaptation. Finally the concept of bricolage is introduced as a frame for gaining a better understanding of networked relations of power in adaptation to flood risk.

2. GIS in adaptation to urban flood risk

Computerised spatial analysis emerged in the 1960s and was developed as a Geographic Information System (GIS) by landscape architects in the 1980s. The interest in spatial analysis goes beyond cartography or mapping – it allows linking complex databases to spatial coordinates to derive, for instance, the availability of public infrastructure in relation to the density of population in a given place. As such it has become an important tool in public infrastructure and land use planning, as well as for private companies. The visualisation of spatial information is a key component in communicating the results of such analyses, particularly in public decision-making. As GISystem applications have become increasingly complex, GIScience emerged as a separate field, looking into the models, algorithms and ontologies behind the systems (Schuurman 2004).

GIS is applied at all stages of the emergency response cycle (Cutter 2003). In flood risk management GIS is applied in risk assessment to inform preventive spatial planning, early warning systems and emergency response systems (cf. table 1). A typical GIS application in flood risk management is the spatial overlay of asset values, population size and flood prone areas, the later for instance by calculation of 20, 50, 100 year events. Environmental modelling is often applied in GIS flood risk assessments because of the extent of data needed to obtain spatial information in uncertain conditions of change with regard to climate and

demography (Levy, Hall 2005). Overlaying a digital terrain model with hydrological models and land use classifications from aerial images for instance serves to identify floodplains and estimate potential inundation areas, e.g. (Benke et al. 2000; Mirza et al. 2013; Townsend, Walsh 1998). Such risk assessments can be combined with spatial socio-economic data to identify population at risk or suitable locations for emergency shelters, e.g. (Rodríguez-Espíndola, Gaytán 2015; Szlafsztain and Sterr 2007). The data generated in GIS based flood risk assessment is a central input to Decision Support Systems (DSS) which facilitate flood risk management decisions. A DSS is a “customized, interactive computing environment that integrates models/analytical tools, databases, graphical user interfaces, and other systems” designed to facilitate decision-making by weighting and adding priorities of alternative options (Levy 2005, p. 441). DSS have been applied in flood emergency evacuation, mitigation and control, and preventive planning (Levy 2005).

Table 1 GIS and DSS applications in flood risk management. Key literature identified by keyword search on ‘flood’ and ‘GIS’ or ‘DSS’, respectively, on Web of Science® and Google Scholar*

Research objective	Data sets	Data progressing technology	Case studies	Reference
Description of inundation dynamics	Aerial photography, time series of runoff records	GIS	Ogeechee River/ USA	Benke et al. 2000
Causal tree and hazard mapping to detect minor flooding from sewer blockage	Sewer flood event records, expert knowledge	GIS	Bordeaux/ France	Cherqui et al. 2015
Identifying people's exposure to flooding	Geospatial map, socio-economic census data	GIS based modelling	Manchester/ UK	Kaźmierczak, Cavan 2011
Adaptation of a novel method of multicriteria flood risk assessment, that was recently developed for the more rural Mulde river basin, to a city	Raster data, land use data, census data	DSS, GIS	Leipzig/ Germany	Kubal et al. 2009
Modelling run-off under climate change: identifying possible changes in the magnitude, extent and depth of floods	Time-series for precipitation and discharge, climate change scenarios	Hydrological model, GIS	Ganges, Brahmaputra and Meghna rivers/ Bangladesh	Mirza et al. 2013
Define the proper location of shelters and distribution centers for flood victims	Raster data	GIS, optimization model	Villahermosa/ Mexico	Rodríguez-Espíndola, Gaytán 2015
Identifying hydrological impacts of urbanization for integrated flood risk management	Satellite imagery, GPS data	Land use classification, Rainfall runoff modelling, flood hazard mapping using RS and GIS, Flood zone mapping using 1D model	Thirusoolam watershed, Chennai/ India	Suriya, Mudgal 2012
GIS based composite vulnerability index for the coastal zone of the state of Pará	Raster data, maps and socio-economic statistics	GIS, modelling	Pará/ Brazil	Szlafsztain and Sterr 2007

Model the potential of flood inundation	DEM, digital hydrography datatran	GIS based raster/grid and vector/network analysis and modelling	Roanoke river floodplain, NC/US,	Townsend, Walsh 1998
Vulnerability analysis	hydrological information and flood records; geographical information on topography and land use; river morphology; meteorological information relating to flood seasons; information about existing infrastructure demographic and socio-economic conditions; and information on the damage and loss caused by previous flood disasters; participatory mapping	GIS	Thua Thien Hue province, Vietnam	Tran et al. 2009
Scenario-based risk assessment	Building attributes from council databases and fieldwork mapping, DEM	Commercial relational database management system, a GIS-based decision support system.	Cairns/Australia	Zerger, Wealands 2004
Developing a framework for analysis of flood risk in urban areas	quantitative and qualitative environmental and socio-economic indicators	Risk mapping	Santiago de Chile/ Chile	Müller 2012

In both GIS and DSS applications in flood risk management shortcomings in the assessment of vulnerability are currently a limiting factor because indicators of vulnerability are not as universally applicable and quantifiable as, for instance, those of bio-physical exposure (surface water runoff, rainfall, geomorphological conditions, etc.). Table 1 summarising state of the art research on GIS and DSS in flood risk management illustrates the tendency to use statistical data and quantitative socio-economic indicators to assess vulnerability. However, the use and meaning of vulnerability indicators is context specific and needs to be adjusted accordingly to be used in modelling and DSS, particularly in the urban context. New approaches are needed to enable context-specific flood risk assessments (Barroca et al. 2006). The authors have developed a flexible set of social, economic and ecologic/environmental indicators of urban vulnerability, which is yet to be linked to GIS. Limited data availability on variables that influence socioeconomic vulnerability, such as housing prices, household income and purchasing prices constrain urban DSS (Kubal et al. 2009). With regard to GIS in DRR, (Cutter 2003) identifies 4 limitations that parallel those identified in DSS based flood risk assessment, namely the need for development in integration of ecological processes and social models, improved visualisation of social vulnerability, capturing mobile groups (tourists, migrants) in social vulnerability analysis, and the need for coherent technological and data infrastructure.

While the literature reviewed above is mainly concerned with technical limitations of vulnerability assessments in GIS and DSS, another strand of literature points to limitations in understanding vulnerability from a critical GIScience perspective. These studies aim towards a better understanding of differential vulnerabilities and critical engagement with relations of power embedded in decision-making structures as well as the practice of GIS itself (Schuurman 2004; Elwood 2011; Pickles 1995a, 1995b). Critical applications of GIS adopt participatory and qualitative data collection methods and visualise them in a GIS (Elwood 2011). Qualitative, participatory and public participatory GIS (QGIS, PGIS and PPGIS, respectively) has rarely been applied in flood risk research (cf table 1), but is increasingly being explored in DRR and environmental governance research more generally (cf table 2). This body of research points out the role of data ownership among marginalised groups as a tool in vulnerability reduction and empowerment (Kyem 2002; Dennis 2006, amongst others).

Table 2 QGIS, PGIS and PPGIS applications in risk management. Literature identified by keyword search on 'risk', 'vulnerability', 'adaptation' and 'Qualitative GIS' or 'Participatory GIS', respectively, on Web of Science® and Google Scholar

Research objective	Data sets	Data progressing technology	Case studies	Reference
Developing a method for assessing vulnerability in spatial terms using both biophysical and social indicators.	Historical data, socio-economic indicators, social vulnerability index	GIS,	Georgetown County, North Carolina/ USA	Cutter et al. 2000
Engaging youth in PGIS	Participatory planning, participatory data collection	GIS	Youth Planning Project (USA?)	Dennis 2006
Developing a QGIS approach	Narratives	Narrative analysis, 3D GIS-based time-geographic methods, and computer-aided qualitative data analysis	Ohio/ USA	Kwan, Ding 2008
Applying PPGIS in collaborative forest governance	Data from participatory mapping in workshops, survey	Stakeholder analysis, GIS	Kofiase/ Ghana	Kyem 2002
Applying QGIS in conflict studies	Narrative interviews, remote sensing data	GIS	Uganda	Madden, Ross 2009
Applying PGIS to gain understanding of the nature and variation of risks	Data from participatory risk mapping, questionnaire data	GIS	Ethiopia, Kenya	Smith et al. 2000
Integrating GIS in qualitative data analysis software (ATLAS.ti)	Field notes from observation, in-depth interviews with key actors, urban documents and plans, photographs, press releases, documents of formal communication between the actors	Qualitative document analysis, georeferencing, GIS	Barcelona	Verd, Porcel 2012

In what ways can/ do these approaches improve flood risk assessment and adaptive management?

Qualitative and participatory methods in GIS and DSS reveal differential social vulnerability, making marginalised experiences and perceptions visible. In her review of QGIS studies, Elwood (2011) lists the method's contribution to an understanding of the 'spatial and temporal unfolding' of an event (or hazard) through the interpretation of qualitative data based on spatial information. This is particularly valuable where information is difficult to obtain and heavily biased such as in conditions of conflict or crisis (Madden, Ross 2009). Tran and colleagues explore the potential of integrating local knowledge in GIS based flood risk mapping and find that besides eliciting local knowledge on risk and vulnerability, participatory mapping raised awareness on risk among the population and created a space for dialogue among stakeholders and thus actively triggered adaptive learning (Tran et al. 2009). Similar observations of empowerment have been made in the context of youth engagement in urban planning (Dennis 2006) and natural resource management (Kyem 2002).

However, these studies also highlight the constraint local power relations can place on PPGIS (also Smith et al. 2000). Power relations come into play not only in decisions on who participates, but also on how information is visualised and translated into analytical categories (Smith et al. 2000; Elwood 2011; Wood et al. 2010). Craig and colleagues conclude their collection of PPGIS studies by pointing out that PPGIS potentially facilitates the democratisation of spatial decision-making (planning), but current case studies do not provide more than anecdotes on this (Craig et al. 2002). PPGIS is both a tool of empowerment and disempowerment, depending on where, how, by whom it is applied. Case studies reveal that the political context is more of an obstacle to PPGIS than technological issues. In the context of flood risk reduction and adaptation this means that QGIS, PGIS and PPGIS are potentially tools to make vulnerability of marginalised groups visible and integrate it in risk assessments and planning decisions, but only so if it is

applied cautiously of power relations and political context. Hence whether GIS supported assessments create authoritative, top-down or empowering, bottom-up knowledge on flooding and risk depends not only on the tool and who uses it, but importantly on the context and process of its application.

In summary GIS facilitate understanding of complex social, economic and ecologic interactions that contribute to flood risk. DSS moreover facilitate decision-making under conditions of complexity and uncertainty, a crucial factor in adaptive flood risk management / non-structural measures which always involve trade-offs. Critical GIS approaches crucially add to the assessment of vulnerability and adaptation options by eliciting local knowledge, raising awareness, making differential vulnerability visible, and ultimately democratising the dialogue on policy options and decisions by empowering marginalised groups. However, GIS and DSS continue to come short on understanding and identifying underlying drivers of social vulnerability and adaptive capacity to flood risk such as power relations and political context. The objective of the next section is to identify relational aspects of social vulnerability and adaptive capacity that cannot be identified in GIS.

3. Assessing adaptive capacity in urban flood risk research

Research on social capital and social learning in adaptive processes has shown that (networked) social relations are a key factor in successful adaptation to change. Accordingly, a third strand of literature on flood risk, vulnerability and adaptive capacity is engaged in the analysis of social relations, networks, and learning. These studies pay little attention to spatial data and are less concerned with hazard and vulnerability assessment. They rather analyse data from empirical field research, literature and document reviews to derive theoretical concept and gain an understanding on social processes that create risk and adaptive capacity (cf. table 3). Capacities are analysed at different scales, going down to household level. The underlying argument of these studies as opposed to spatial analyses has been summarised by Adger: "I argue that many aspects of adaptive capacity reside in the networks and social capital of the groups that are likely to be affected. This capacity to adapt suggests that some groups within society may be less at risk than modelling studies have portrayed because of their latent ability to cope in times of stress. It will always be difficult to test this proposition because future changes in climate are likely to be outside the range of institutional memory or lived experience" (Adger 2003, p.401). The diversity of aspects of adaptive capacity is illustrated by the findings of the studies listed in table 3. Comparing research objects and aspirations with the findings moreover indicates the complexity of indicators of adaptive capacity when further development of analytical frames is aspired (e.g. Barroca et al. 2006) or findings revealed factors beyond the scope of the research (e.g. Pelling 1999).

Social capital can be defined as social networks and norms that create relations of trust, reciprocity and exchange (Pelling, High 2005; Adger 2003). It has been applied to case studies of coping with and adaptation to flood risk (Aßheuer et al. 2012; Adger 2003). In a case study from Vietnam informal institutions, bonding (informal relations such as kinship) and networking (regulated by external norms and institutions) social capital replaced state planning in adaptation to flood risk (Adger 2003). (Aßheuer et al. 2012) identified trust relations and informal resource exchange as strategies among slum dwellers in Dhaka to overcome flood related situations of crisis which had, however, no impact on their long-term adaptive capacities. The comparison of the two analyses highlights the role of informal institutions that provide networking capital particularly where the state is absent. In the Dhaka case the households analysed seem to have limited adaptive capacity because their social capital predominantly consists of bonding relations. Both assessments are situational in so far as an individual's capacity to build relations is constantly changing (Pelling, High 2005).

The case studies by Pelling and Næss by contrast shed light on the interaction of formal and informal institutions where the state is (partly) present in flood risk management. In Guyana a politicised context facilitated community organisations' engagement in vulnerability reduction among better-off residents

but hindered the formation and political participation of horizontal networks in urban and periurban poor neighbourhoods (Pelling 1999). In Norway local capacities for proactive flood risk management were dormant as a result of high incentives to rely on national emergency response systems, different governance cultures at national and local level, and personalised rather than institutionalised learning (Næss et al. 2005). Both studies reveal the decisive role of individuals' interests within governments and organisations in creating adaptive capacities. Informal, personal relations shape those of formal institutions engaged in flood risk management, particularly in the context of adaptive learning (Pahl-Wostl et al. 2013). Van Herk et al. 2011 show how informal relations can be used proactively in learning and action alliances on the integration of flood risk reduction in urban planning. However, the Guyana case indicates that for such an approach to contribute to enhanced adaptive capacities also among the most vulnerable, power relations must be understood and taken into account in its design.

Table 3 Social analyses of adaptation to flood risk. Literature identified by keyword search on 'flood' and 'social capital', 'adaptive capacity' or 'vulnerability assessment', respectively on Web of Science and Google Scholar*

Reference	Research objective (aspiration)	Findings	Data collection and analysis methods	Case studies
(Aßheuer et al. 2012)	Understanding the role of social capital in coping with floods in slum dwelling, i.e. how various aspects of social capital lead to social support during severe floods	Social capital is formed in networks at multiple levels (micro, meso, macro). Microlevel bonding ties are strongest yet not sufficient in times of crisis when other members of the network are affected themselves. Linking ties, norms and trust are key elements that are drawn on in coping with flooding	Comparative case study analysis, household surveys, qualitative interviews	Dhaka/ Bangladesh
(Barroca et al. 2006)	Developing a tool for local vulnerability assessment - organize into a software tool the choice of vulnerability indicators and the integration of the point of view of various stakeholders	Tool developed with 7 indicator groups: testers appreciate flexibility of the tool, further improvement based on stakeholders' knowledge needed in terms of variety of indicators, links to further decision support tools and data input	Indicators derived from literature, reports, case studies; tool test runs	France
(Næss et al. 2005)	Identifying the role of institutions in adaptation to climate change taking floods as an example	Institutional structures of decision-making reflect and consolidate existing power relations through learning processes and flood protection measures, and thus hinder local adaptation	Semi-structured interviews, comparative case study analysis	Glomma-Lågen river basin/ Norway
(Næss et al. 2006)	How to improve vulnerability assessments for their use in local level adaptation to climate change	Conflicts of interests in the generation of data between scientific validity and local relevance, institutional challenges around the use of vulnerability assessments relate to the terminology used (communication), the perceived relevance of the topic, institutional capacities and the ability of institutions to learn and change. A multi-level approach to vulnerability assessment integrating top-down and bottom-up indicators is suggested	Literature-based comparative case study analysis of top-down and bottom up indicator development	Norway

(Pahl-Wostl et al. 2013)	Identifying factors of transformative change in flood risk management - understanding (1) the link between largely informal learning cycles and formal policy processes; and (2) the vertical coordination of governance levels to capture the role of different kinds of activities at various levels with bottom-up and top-down processes.	Different modes of informal learning influenced policy change on flood risk management in the three cases, namely shadow systems in Hungary, advocacy coalitions at local and regional levels in the Netherlands, and local and regional advocacy groups in Germany	Comparative case study analysis, document analysis, expert interviews	Tisza/ Hungary, Rhine/ Germany, Netherlands
(Pelling 1999)	Understanding the process and maintenance of environmental hazard taking coastal flooding as an example	Next to vulnerabilities the analysis revealed beneficiaries of flood hazard, namely contractors in the private sector in reconstruction, political and economic elites. It demonstrates how political environment by focusing on immediate causes of flooding instead of underlying causes and drivers of vulnerability consolidates power relations	Case study analysis, historical review, household survey	Georgetown/ Guyana
(Restemeyer et al. 2015)	Understanding of flood resilience to evaluate the flood resilience of cities, and to recognize potential strategies to build flood resilience - convert the concept of resilience into an operational framework that can be used by both scientists as well as policy- and decision-makers, to evaluate the flood resilience of cities.	Two case studies from Hamburg show that social capital as well as historic trajectory and economic interests shape decision-making between holistic and structural approaches to flood risk management. The separateness of water management and urban planning are a barrier to holistic planning for flood resilience	Literature review, document analysis, comparative case study analysis, expert interviews	Wilhelmsburg; Hafencity, Hamburg/ Germany
(van Herk et al. 2011)	Evaluating a framework for collaborative learning and planning in flood risk management	Learning and Action Alliances (LAAs) were found to support collaborative planning among professionals and politicians. The framework evaluating collaborative learning along activities (system analysis, collaborative design and governance), threads (facts, images and ambitions) and streams (problems; solutions; participants/politics) were found to be a useful framework	Literature review, comparative case study review, expert interviews	De Stadswerven, Dordrecht; Westflank Haarlemmermeer/ Netherlands
(van Herk et al. 2013)	understanding how learning takes place and can be stimulated within a programme, based on a case study of the development of a framework for network learning in a river	Community building among professionals and politicians was stimulated by structures that promoted their interaction in documentation of lessons learned, guidelines, training and networking events. the setup	Document analysis, semi-structured interviews	Room for the River Programme/ Netherlands

	management programme -	allowed for integration of top-down and bottom up learning		
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4. Where to from here?

Relations of power are involved in decisions while ‘doing’ GIS: in choosing data, algorithms, categories and labels in visualisation. Particularly in application of GISystems (as opposed to GIScience) these decisions tend to be taken unconsciously (Elwood 2011). Intertextual analysis of GIS related and planning practices have been suggested as a tool to discover these relations (Pickles 1995b). This literature review has moreover shown that although GIS is an important instrument in identifying adaptation needs and informing adaptation decisions, some components of adaptive capacity are out of reach of GIS based assessments. More specifically, the interaction of informal and formal institutions and relations have shown to be a key factor in the creation of adaptive capacity. Further questions that emerge from this literature review are: How are the different types of floods currently visualised and known through GIS?, and How does the dominant ‘conventional’ use of GIS in urban planning and the respective knowledge of floods produced contribute to the increase of urban floods in specific locations?

As described in the case studies, the interaction of informal and formal institutions can both hinder and foster adaptive flood risk management. Human geographer Frances Cleaver defines the process of patching together formal regulations and informal traditions and norms in natural resource governance as ‘bricolage’. This process is shaped by people who act as ‘bricoleurs’ – agents who consciously as well as unconsciously shape the way natural resources are managed (Cleaver 2012, p. 112). Analysing the formation of institutions from a bricolage perspective means focussing on linkages and intersections between resources, networks of actors, institutions and domains of action. Power, learning and knowledge are lenses through which linkages and intersections can be explored. In doing so, the approach “allows us to map patterns of adaptation and their outcomes for different people over time” (Cleaver 2012, p. 212). The approach thus promises to provide a better understanding of both the differential vulnerability (as analysed in QGIS studies) and adaptive capacity (a main focus of social flood risk research) when applied to flood risk research.

Many of the factors of adaptive capacity are not spatial, and are linked to power relations that are difficult to capture in GIS based research. Social capital analysis reveals vulnerabilities that cannot be modelled (Adger 2003), but ultimately an integration of such analysis with spatial assessments is needed to improve informed decision-making in adaptive flood risk management. Analysing the creation of flood risk and adaptation from a bricolage perspective may contribute to closing the gap between GIS based risk and vulnerability assessment and non-spatial assessments of adaptive capacity. A step-wise approach may be applied, by first looking at bricolage, before conducting a QGIS assessment of risk and adaptive capacity. This would also add to emerging approaches of ‘fit for purpose’ approaches in adaptive governance, as outlined below.

Adaptation science needs to close a wide range of knowledge gaps in terms of decision processes, knowledge requirements, knowledge production, understanding vulnerabilities, data generation, barriers to adaptation, transdisciplinary learning and communication (Moss et al. 2013; Swart et al. 2014). Given the remaining challenges related to the lack of knowledge in adaptive governance practice, a body of literature on ‘fit for purpose’ or ‘good-enough’ approaches in governance of adaptation to climate and environmental change is emerging. These approaches aim at making adaptation in planning and policy more tangible by focusing on adjustments that are in line with existing institutional arrangements and objectives rather than calling for fundamental change. Rijke and colleagues (2012) and Christoplos and colleagues (2014) make a case for good enough approaches in governance. They propose a ‘fit for purpose’ or ‘good enough’ governance approach that uses existing networks and social learning to adjust

dominant institutions in order to enhance their effectiveness. They moreover argue that while the fit for purpose governance can be interpreted as a 'step back' with regard to adaptive governance principles such as flexibility and self-organisation, it would enable decision-makers to handle uncertainties (Christoplos et al. 2014; (2012)).

Further studies focus on the pragmatic generation of data and knowledge. In a study for the European Commission for example, (Miola et al. 2015) developed a 'fit-for-purpose' index for climate resilient development in an attempt to streamline risk and vulnerability assessments with economic and ecological development objectives. A set of indicators on climate hazards, mitigation, vulnerability and adaptive capacity was identified from academic and grey literature. The authors found it challenging to integrate the variety of indicators particularly when data is missing, and propose a web-based platform for exchange among experts for further development of the index. Enemark (2013) argues that in spatial adaptation planning and land administration a fit for purpose approach does not require more precise data but better understanding and incorporation of trust, reliability, credibility and representation in the generation and use of data. Similarly Haasnot and colleagues (2014) developed a model for decision-making in adaptation planning on the Rhine, focusing on flood protection and water supply for the Netherlands. The model integrates biophysical indicators as well as closed questions to be answered by decision-makers to identify alternative adaptation pathways. A certain level of uncertainty in the model was accepted.

The 'good enough' and 'fit for purpose' approaches in adaptation governance and data generation hence imply integration of practical knowledge where scientific knowledge is absent, imprecise or deemed illegitimate. This review of literature on risk and vulnerability assessments has restated that scientific methods currently used are often inadequate to produce an overall picture of risks and vulnerabilities. However, the review also hints to the danger that both the lack of involvement of decision-makers in risk and vulnerability assessments, and the involvement of the most visible stakeholders implies, namely the reproduction of social relations that create risk and vulnerability. Instead of retreating from science, a wider mix of methods from critical social and spatial sciences is most promising to overcome existing gaps in assessments of adaptive capacity.

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