Climate services for flood risk management

Climate services usage by water authorities in the Netherlands and their German counterparts in the border region to adapt to flooding: A case study

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Executive summary

Climate change is on top of the mind of many people. In scientific literature, the interest in climate change adaptation has also increased tremendously over the past forty years. Adapting to climate change is mainly done on a local or regional level, by municipalities and regional governments. The impacts of climate change and the adaptation measures are felt across these regional borders, thus requiring cross-border cooperation. For adapting to an increased risk of flooding, cross-border cooperation can best be done on a river basin level.

Flood risk management is to identify flood risks and implement measures to manage these risks. To make good decisions in flood risk management, a decision support system can be used. One form of decision support systems is climate services. Climate services make climate information accessible to people and organisations to base decisions on.

If these climate services do not meet the needs of the user, there are usability gaps. A range of usability gaps can be identified regarding the validity, readability and interactivity of a climate service.

This research focusses on a case study of water authorities in the East of the Netherlands and bordering German regions. Here, two 'waterschappen' and three 'Kreise' cooperate on water issues, including flood risk management. The research compares the flood risk management, the characteristics of the climate services, the use of climate services for flood risk management and the usability gaps in this use between the Dutch and German water authorities.

This comparison was done with a qualitative methodology. A theoretical framework was developed by describing flood risk management, the use of climate services and the theory of usability gaps from literature. Based on this theoretical framework, a conceptual model was made.

The main empirical data of the qualitative research were interviews. For each of the five organisations, one respondent was interviewed. The interviews were semi-structured, allowing organic exploration of the subject, while still ensuring consistency. Both the interview guide and the operationalization used for analysing the interviews were based on the conceptual model. In addition, some policy documents were used in the results of this research.

The findings of the research follow the same structure as the theoretical framework. The first finding is that flood risk management is different between the Dutch and German water authorities. The difference lies in the organisation of tasks regarding flood risk management in either country. In the Netherlands, waterschappen are a specialised organisation for flood risk management, with a large amount of competences and corresponding financial and knowledge resources. In Germany, the field of flood risk management is complex and highly

compartmentalised. There is a more pronounced focus on law and hierarchy in the German flood risk management structure.

The second finding is that the characteristics of the climate services used most by each organisation, described though the climate information design template, are mainly similar. They all have similar stakeholders, purposes, and visual formats. Some slight differences are in the information of the climate service, where the Dutch climate service has an additional flood event probability.

The third finding is that the Kreise use climate services less than waterschappen, which can be attributed to their having less competences in flood risk management. There are climate services available, but they are not relevant for their level of flood risk management. The waterschappen use a larger amount of climate services for flood risk management and also produce climate services themselves.

The fourth finding is that as climate services are used only to a limited amount by the Kreise, not many usability gaps could be identified. The climate services they do use are fulfilling their needs. Only few usability gaps have been identified in the climate services currently used by the waterschappen, too. This has a different cause than for Kreise, however. Waterschappen have the capability to develop climate services themselves and can eliminate usability gaps in this way.

Overall, this thesis found that the use of climate services for flood risk management on both sides of the border is not hindered in many ways. One aspect where climate services could be improved is for the use by citizens. Such climate services could inform the citizens on flood risks and flood risk measures, helping them understand the implementation of flood risk management.

A recommendation for the practice of cross-border cooperation with flood risk management is to produce and use climate services not bound by administrative borders, but by geophysical borders, such as river basins. Also the difference in responsibilities between Dutch and German water authorities should be kept in mind when making and using cross-border climate services.

As the results of this research are based on the specific organisations in the case study and rely on just one respondent per organisation, the findings can be generalized only to a limited extent. A survey could be set out within these organisations to gain a better overview of all uses and usability gaps within these organisations. Also, since flood risk management involves many different (levels of) government organisations and civil society, future research could broaden the scope of research across more stakeholders.

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1. Introduction

This chapter will first introduce the reader to the research context and case study area. Next, the societal and scientific relevance of this research are addressed. After the research objective, the research questions are presented. It ends with a reading guide for the entire thesis.

1.1 Research context

Climate change is happening, and the effects can already be felt in all regions across the world (Allan et al., 2021). The impact of climate change is also across the climate system, with changes in extremes such as heatwaves, heavy precipitation, droughts, sea level rise and a compounding of these extremes (Allan et al., 2021). Awareness of the need for climate action is growing, especially among the younger generation. This can be seen in the global Fridays for Future movement, initiated by Greta Thunberg in 2018. Her action can be seen as a tipping point, with multiple governments declaring a climate emergency in response to the movement, including the European Parliament (Lenton et al., 2022; Whiting, 2022).

The current movement focusses on climate change mitigation, but climate change adaptation is important, too (Cashmore & Wejs, 2014). Research on climate change adaptation has gone up from 20 papers written in the 5 major languages in the period 1980-1990 to 4.239 in the period 2001-2010 (Burkett et al., 2014). This increase in research is a response to the increase of social relevance and plays an important role in contributing to knowledge about adaptation in society and policy.

Climate change adaptation is reported to be most often implemented at the municipality level, with the regional governments coming in second (Ford et al., 2011). As the effects of climate change are felt across municipal and regional borders, adapting to climate change requires cooperation across these borders (Barchiesi et al., 2014). This is especially relevant for managing floods in river basins (Barchiesi et al., 2014), since measures taken upstream can impact downstream communities. In addition to municipal and regional borders, national borders might have to be crossed in order to manage the water flow of international rivers. For instance, dams for hydropower built in Germany were helpful to manage the flow of the international Meuse basin in the Netherlands (Barchiesi et al., 2014). The Netherlands is the endpoint of four of these international river basins: The Ems, Scheldt, Rhine and Meuse. There are also smaller international rivers within these river basins between the Netherlands and Germany, which necessitate cross-border cooperation (*Implementatieproces ROR*, 2017).

In the Netherlands, regional water authorities, waterschappen[1], are responsible for "flood protection, water quality management and preventing droughts or water surpluses" (*About Dutch Water Authorities*, n.d.). Germany does not have special independent water authorities for water management. Instead, Germany has a governmental level between municipalities and the Bundesländer, called a 'Kreis', which is responsible for some of the same tasks as a waterschap (Bundesumweltministerium, n.d.; *Kreise | Landkreistag NRW*, n.d.). In a Kreis, multiple municipalities are organised to cooperate on diverse topics, including adapting to climate change and managing water.

Cross-border climate adaptation between the Netherlands and North Rhine-Westphalia has been researched by van Eerd et al. (2014), who concluded that due to a high degree of similarities, cross-border climate adaptation has a high degree of success potential. This is because of a high compatibility of the policy arrangements between the two territories at multiple governmental levels. Van Eerd et al. (2014) also identified the urgency to integrate themes, issues, and sectors to come to an adequate climate adaptation strategy, as for example floods will impact agriculture, living and mobility.

That floods do indeed present a major cross-border risk has been shown with the 2021 flooding in Belgium, the Netherlands and Germany, where it mainly concerned North Rhine-Westphalia and Rhineland-Palatinate. The flooding made over 180 casualties in Germany and caused considerable damage to infrastructure (Fekete & Sandholz, 2021). This flooding was between 1.2 and 9 times more likely to happen than in a 1.2 °C cooler climate, showing the impact of climate change (Kreienkamp et al., 2021). As flooding may become more frequent in the future, it is important to find vulnerabilities and to examine the exposure to flooding (Kreienkamp et al., 2021). This can be done in part by using climate services.

Climate services are a relatively new and wide ranging field of services. Therefore the definition of climate services is not always clear. There are slightly different definitions proposed by various authors (Jacob et al., 2015; Tall, 2015; Vaughan & Dessai, 2014). Since this research is set within a European context, the definition by the European Commission is used:

> [Climate services cover] the transformation of climate-related data - together with other relevant information - into customized products such as projections, forecasts, information, trends, economic analysis, assessments (including technology assessment), counselling on best practices, development and evaluation of solutions and any other services in relation to climate that may be use for the society at large. (European Commission et al., 2015, p. 10)

[1] The native language terms Bundesland (federal state), Bezirksregierung (regional district), Kreis (municipal district) and waterschap (water board) will be used throughout the thesis to indicate the context-specificity of these organisations.

Climate services are tailored to the stakeholders' needs and aid in adapting to climate change. Local governments, such as municipalities, and regional governments, such as water authorities, use climate services to support decision making. However, climate does not adhere to administrative borders. In addition, the effects of climate change can be felt across borders. Even within the European Union, the impact and the mitigation and adaptation of climate change are still often thought of within national borders (Challinor et al., 2017). For example, systematic overviews of climate services in the European Union use geographical delineations within national borders to categorise the data (Cortekar et al., 2020; Ford et al., 2011).

Only acting within the administrative borders might hinder complete and effective climate change adaptation (Carter et al., 2021). People living in the European border regions may already live without feeling the border, but the governments are still two separate systems (Verdoold, 2014). The climate services used by governmental organisations are therefore often not tailored to cross-border cooperation. As climate services have to be designed with stakeholders in mind, it is imperative that the needs and wishes of the stakeholders are clear (Raaphorst, Koers, et al., 2020). By researching in what ways climate services are being used by the water authorities, later research and climate services can be better tailored to the stakeholders and their needs for cross-border cooperation. The specific water authorities in this case study are presented in the next subchapter.

1.2 Case study area

The study area for this research consists of the five affiliated organisations of the Cross-border Platform for Regional Water Management (GPRW). These are from the Netherlands: 'waterschap Vechtstromen' and 'waterschap Rijn en IJssel', and from the German side: 'Landkreis Grafschaft Bentheim', 'Kreis Borken' and 'Kreis Steinfurt'.[2] Figure 1 shows the five organisations, with the three states and important cities.

The need for regional water management became apparent in 2010, when heavy rainfall caused major flooding in waterschap Rijn en IJssel and Kreis Borken. The Dinkel river flooded the city centre of Gronau and evacuation precautions were made in the Netherlands (*Overstroming Dinkel*, 2010). Since this was the biggest flood event since 1998, it was thoroughly evaluated (van der Wiele et al., 2012). One of the areas for improvement the evaluation found, was the need for a formalisation of communication and cooperation between Dutch and German water authorities. At the start of 2011, talks between the Bezirksregierung Münster, province Overijssel, Kreis Borken, waterschap Regge en Dinkel and waterschap Rijn en IJssel led to agreements to better cooperate (van der Wiele et al., 2012). This resulted in the

[2] Within this thesis, the terms 'waterschap' (water board) and 'Kreis' (municipal district) will refer to respectively the Dutch water authorities or German water authorities of the GPRW

Figure 1. Case study area with the five partners and four rivers of the GPRW. Source: GPRW, with river names added. Used with permission

founding of the GPRW in 2012 (Schmitz, 2022). The goal of the GPRW is: "Strengthening of cross-border cooperation in Deltarhine-East" (Schmitz, 2022, p.3). The four main areas of the cross-border cooperation are: 1. Cross-border exchange of knowledge and information, 2. Coordination of joint German-Dutch strategies, 3. Operational cooperation (emergencies), 4. Initiation and implementation of German-Dutch measures and projects. A recent addition is the Letter of Intent on Cross-border Climate Change Adaptation, signed by the five organisations of the GPRW and waterschap Drents Overijsselse Delta in March 2021 ('Gezamenlijke intentieverklaring grensoverschrijdende klimaatadaptatie GPRW', n.d.). This declaration includes strengthening cooperation on flood risk management.

The four main water bodies in the GPRW region are the Vechte, Dinkel, Berkel and Issel (or Oude IJssel in Dutch). They are displayed in Figure 1. The Steinfurter Aa flows into the Vechte and is also of importance in the region. The rivers have a high variability between the seasons; most of the time the rivers discharge less or around

1 m3/s, but with some high peaks (*GRDC Data Portal*, n.d.). For example, the Vechte discharges less than 1 m3/s in 95% of the time, but in peak periods this can go up to 500 m3/s (Verdonschot & Verdonschot, 2017).

1.3 Relevance of the research

1.3.1 Societal relevance

It is generally seen as a task of the government to ensure the safety of its citizens by protecting them from flooding (Thaler & Hartmann, 2016). This thesis contributes towards knowledge for relevant organisations to more effectively do so. This knowledge is important, also in the future, in order to adapt to flooding related to climate change. Climate services, when made and used effectively, can help improve decisions in adaptation.

The results of this research can be used by water authorities and other relevant organisations to develop better climate services for their flood risk management needs. In addition, the results can contribute to the effective use of current climate services within their organisations. This thesis can be seen as an evaluation of the current use of climate services and the process they are used in.

The findings from this research will contribute to a better understanding of the use of climate services by each water authority in the Dutch-German border region. This understanding can be used to improve existing climate services in order to serve the needs of their users. When climate adaptation becomes more interregional across borders, climate services can be developed to support cooperation within the border region.

1.3.2 Scientific relevance

This research will contribute to the knowledge on flood risk management related to the use of climate services and their usability gaps. A lot of research has been done on identifying usability gaps of climate services (Carr et al., 2020; Guido et al., 2020; Lemos et al., 2012; Mukherjee, 2019; Vincent et al., 2020), but only a limited amount of research focused on the usability gaps of climate services for flood risk management. The ones that do are more concerned with a general understanding of the usefulness of climate services for flood risk management (Craciunescu & Stancalie, 2006; Donnelly et al., 2018; Pantalona et al., 2021; Vollstedt et al., 2021) or the product itself (van Vliet et al., 2015), but less with the service to end users. This research looks at this missing piece, the connection between flood risk management, climate services and their respective usability gaps.

None of the research has looked at climate services for flood risk management in the study area this research focusses on. The Dutch-German flood risk management has been compared in research before, but not in relation to climate services (Renner, 2022; Thaler & Hartmann, 2016; van der Molen, 2011). The use of

climate services in cross-border adaptation to climate change has been done by Panenko et al. (2021), but it is about general climate change adaptation, not flood risk management. This research contributes to the scientific knowledge on adaptation on the two sides of the Dutch-German border by comparing the two flood risk management systems and their use of climate services.

1.4 Research objective and questions

The objective of this research is to describe in what ways the use of climate services by staff involved with flood management at Dutch water authorities and their German counterparts in the border region is hindered.

Main research question:

- *In which ways is the use of climate services by regional Dutch and German water authorities for flood risk management hindered?*

Sub research questions:

1. *In what ways are flood risks managed in the Dutch and German regions?*
2. *What are the characteristics of the climate services used in the Dutch and German regions?*
3. *To what extent are climate services used in flood risk management in the Dutch and German regions?*
4. *What usability gaps can be identified in the usage of climate services in the Dutch and German regions?*

1.5 Reading guide

Each chapter starts with an introductory reading guide that explains in short what the chapter is about. Chapter 2 develops the research questions by laying out the theoretical framework. The conceptual model is presented at the end of that chapter. In chapter 3, the methodology that is used in this research is explained. The results from the empirical data, collected and analysed as explained in the preceding chapter, are presented in chapter 4. The conclusion in chapter 5 answers the sub research questions and the main research question. At the end, recommendations for the practice and for future research are given. Finally, in chapter 6, the results and process of the research are discussed.

2. Theoretical framework

This chapter describes the theoretical considerations for managing flood risks, climate services, and the gaps between climate services and users. These theoretical considerations result in the conceptual model which is used as the basis of this research.

2.1 Flood risk management

2.1.1 Concepts of flood risk management

The Netherlands and Germany have a long history of managing the risk of flooding with man-made earth mounds to build on (Sayers et al., 2013). These mounds would protect the early inhabitants in regions threatened by flooding. For the majority of history, people considered flood protection as only technical and engineering in nature. The first cooperation of local communities in water boards to build and maintain flood protection measures started around the 12th century (te Brake, 2002).

The Dutch felt confident in their measures, but this changed in 1953 when a major coastal flood caused by a surge tide made a lot of casualties in England, Belgium and the Netherlands (Wesselink et al., 2007). About 1,800 people lost their lives in the Netherlands alone (ten Brinke et al., 2008), which caused a significant increase in flood risk awareness. In the Netherlands, the Delta commission was installed to investigate new strategies to respond to flood risk (Roos & Jonkman, 2006). The new flood protection approach was less focused on the possible occurrence of a flood event, but used a cost-benefit analysis (Roos & Jonkman, 2006). This means that instead of preventing flooding for all areas, some areas were selectively protected better than others by using statistical criteria and scientific methods (Wesselink et al., 2007).

After big near fluvial flooding in 1993 and 1995, the Netherlands became more aware of flood risks for the rivers and implemented the program 'room for the river'. This program also introduced more 'soft' flood risk management strategies, by including some river restoration measures (Wesselink et al., 2015). The new approach resulted in a shift from flood protection to flood risk management (Hartmann & Albrecht, 2014). Similarly, Germany relied mostly on dikes and other technical protection throughout history (Hartmann & Albrecht, 2014). After being safe for a long period, there was little awareness of flood risks from rivers (Hartmann & Albrecht, 2014). The flooding of 1993 and 1995 also initiated a paradigm shift in Germany, causing them to adopt the 'room for the river' program, as well (Hartmann & Albrecht, 2014; Warner et al., 2012). This program was included in the first national comprehensive flood protection plan in 2002 (Warner et al., 2012). In 2004 the Netherlands initiated the European flood policy, which eventually led to the creation of the European Floods Directive (Hartmann & Spit, 2016).

Flood risk management is a comprehensive term defined by Sayers et al. (2013) as:

> The process of data and information gathering, risk analysis and evaluation, appraisal of options, and making, implementing and reviewing decisions to reduce, control, accept or redistribute flood risks. It is a continuous process of analysis, adjustment and adaptation of policies and actions taken to reduce flood risk (including modifying the probability of flooding and its severity as well as the vulnerability and resilience of the receptors threatened). FRM is based on the recognition that risks cannot be removed entirely but only partially, and often at the expense of other societal goals. (p. 9)

A shorter definition is given by Schanze et al. (2005; as cited in Gouldby et al., 2009) who define flood risk management as: "Continuous and holistic societal analysis, assessment and mitigation of flood risk." (p. 15). Both definitions show that flood risk management is more than just putting a dike next to the river. It is a continuous performance based process where probability and consequences of a flooding event are weighted and in which not only 'hard' flood protection plays a role (Hartmann & Albrecht, 2014). The possibility that there might be no protection against a flood event is also anticipated with other measures; for example, parts of agricultural land use areas are allowed to flood (Wesselink et al., 2015).

According to Hegger et al. (2016), there are five strategies to flood risk management that can be combined according to need: 1) Flood prevention (such as proactive spatial planning, 2) flood defence (such as dikes), 3) flood mitigation (such as flood retention), 4) flood preparation (such as warning plans) and 5) flood recovery (such as rebuilding areas). This research focusses on strategies 1, 2 and 3, since strategies 4 and 5 do not concern adapting to an increased risk of flooding caused by climate change in advance, but are only relevant during or after a flood. In short, managing the risk of flooding is the flood management that this research is concerned with, not crisis or recovery management. The definitions by Sayers et al. (2013) and Gouldby et al. (2009) mentioned above also did not include strategies 4 and 5. Strategies 1, 2 and 3 are merged for the purposes of this research in the term *flood prevention*.

This research focusses on the flood risk management that is done by the government, as through the European Floods Directive 2007/60/EC the European member states are required to make flood risk management plans (Kapović Solomun et al., 2022).

2.1.2 Flood risk management in the study area

Flood management is heavily influenced by European regulations and directives. The Floods Directive (Directive 2007/60/EC) of the European Union is a directive on the assessment and management of flood risks. This requires member states and their relevant (sub)-governmental organisations to assess the risk and develop plans to mitigate this risk. Since the Netherlands was an initiator of the European Floods Directive, they are expected to have implemented the directive well (Hartmann & Spit, 2016). This is indeed the case; an example of successful implementation of the directive is that every land use plan needs a section on water issues (Hartmann & Spit, 2016).

In the context of this research, the flood risk management of the Netherlands and Germany with special attention to North Rhine-Westphalia and Lower Saxony are discussed.

Flood risk management in the Netherlands

National

The national flood risk management is done by the Ministry of Infrastructure and Water Management, through the Rijkswaterstaat organisation (Mostert, 2019). They are responsible for the larger waterways in the Netherlands. The smaller waterways are the responsibility of the waterschappen (Mostert, 2019).

The Netherlands has variable flooding norms, ranging from 1/10.000 year chance of flooding for the major coastal cities to 1/1250 year for more rural parts (Thaler & Hartmann, 2016). These norms are for the large waterways. For smaller regional water systems, the chances of flooding are accepted to be lower. They can range from 1/10 year to a 1/100 year chance (*Normering Regionale Wateroverlast*, n.d.). These norms are based on the mid-range of the climate scenario of the Royal Netherlands Meteorological Institute (KNMI) for 2050 (*Normen voor wateroverlast*, n.d.).

Regional/Local

In the Netherlands, flood risks are mainly managed by waterschappen (Mostert, 2019). These waterschappen are the main manager of surface water. This means that they manage and maintain the waterways and water infrastructure, such as dams and dikes. They also regulate use by third parties, such as granting permits for discharges and larger water abstractions (Mostert, 2019).

The provinces have no direct flood risk management tasks, but can regulate parts of the water such as discharge quality (Mostert, 2019). They also are the main coordinator and controller of nature conservation (Mostert, 2019). The norms for flooding are put into law by the province (Artikel 2.8 van de Waterwet, 2021).

Flood risk management in Germany

Federal level

Germany has implemented the European Flood Directive downwards, with the Bundesländer having the main competences regarding flood risk management. This means that there are 16 different flood risk management laws and structures in Germany. Different from the Netherlands, the flood risk is not determined by performing a cost-benefit analysis and assigning different levels of acceptable flood risks. Rather, a general risk of 1/100 year is used almost everywhere (Thaler & Hartmann, 2016). The European Flood Directive allows this different interpretation. As a result, the risk of flooding is more accepted in Germany than in the Netherlands. People can insure themselves against flooding in Germany, which is not possible in the Netherlands (Thaler & Hartmann, 2016). The allocation of financial resources is also based on the 1/100 years chance, and not on the actual risk and vulnerabilities of the area. Reaching the norm set is an important factor for German policy makers (Thaler & Hartmann, 2016).

North Rhine-Westphalia

The administrative structure of the Bundesland North Rhine-Westphalia consists of four governmental levels: Bundesland, Bezirksregierung, Kreise, and Kommunen (municipalities and cities). Next to these there are Verbände. The ministry of the Bundesland, Bezirksregierung and Kreise are respectively the highest, middle and lowest water authorities (§ 114 LWG NRW).

North Rhine-Westphalia is the only Bundesland which has specific water associations based in law, called 'sondergesetzliche Wasserverbände' (special statutory water associations), with tasks given by the Bundesland. It could be said that they resemble the Dutch waterschappen (Hartmann & Spit, 2016). These 'Verbände' are responsible for some of the water management tasks, but it differs from Verband to Verband (*Wasserverbände*, n.d.).

Lower Saxony

The situation is different in the Bundesland Lower Saxony with only three governmental levels, as they have no Bezirksregierung, which leaves the Bundesland, Landkreise and Kommunen. The Niedersächsisches Umweltministerium (Lower Saxony Ministry of Environment) and the Landkreise are the respectively highest and lowest water authority for the inspection of water management and the implementation of European water law (Bundesumweltministerium, n.d.).

Lower Saxony also has Verbände which have the responsibility of building and maintaining dikes, but they are not explicitly put into law (Hormann, 2015). In the absence of a Verband, the municipalities take this responsibility (Hormann, 2015). The Kreise have the task of checking if they uphold their tasks (NLWKN, n.d.).

In general, the Kreise are a more executive organisation. In Lower Saxony, the Bundesland designates certain areas for flooding, and the Kreise are then responsible for the execution of the necessary steps to implement it (Nds. Ministerium für Umwelt, Energie, Bauen und Klimaschutz, 2018).

Main differences in flood risk management

Renner (2022) summarises the differences between the Dutch and German water management in just one sentence:

> The more governance-oriented, decentralized approach to water management of the Dutch collides at the border with a relatively traditional, hierarchical top-down setting in Germany and a legalistic tradition where the degrees of policy freedom of regional water authorities is limited. (p. 74)

An impression of the water sector in the three states is given in table 1. The governmental levels are displayed from top to bottom, with some organisations of the three states at different heights.

<table>
<tr><th>North Rhine-Westphalia</th><th>Lower Saxony</th><th>The Netherlands</th></tr>
<tr><td>Federal (national) level</td><td>Federal (national) level</td><td rowspan="2">Ministry of Infrastructure and Environment + Rijkswaterstaat</td></tr>
<tr><td>Umweltministerium (MUNLV) + Landesamt für Natur, Umwelt und Verbraucherschutz (LANUV)</td><td rowspan="2">Umweltministerium (MU) + Niedersächsischer Landesbetrieb für Wasserwirtschaft, Küsten- und Naturschutz (NLWKN)</td></tr>
<tr><td>Bezirksregierung</td><td rowspan="2">Provinces</td></tr>
<tr><td>Kreis</td><td>Kreis</td></tr>
<tr><td>Verbände (Associations) + Municipalities</td><td>Verbände (Associations) + Municipalities</td><td>Waterschappen + Municipalities</td></tr>
</table>

Table 1. Water sector in the three states. Adapted from van der Molen (2011)

2.2 Climate services

2.2.1 Development of climate services

Climate services originate from a history of making data available from scientific research to the public (Vaughan & Dessai, 2014). The World Meteorological Organization (WMO) was instrumental in starting the development with the World Climate Conference (WCC 1) in 1979 (Vaughan & Dessai, 2014). However, climate services were only first supported in 2009 at the WCC 3 (*Building a Legacy through World Climate Conference-3*, 2010). The drastic improvement of technology from this

point onwards also meant an increase of climate services, and all this new information that the technology provided led to the question how it should be used (Vaughan & Dessai, 2014). The Global Framework for Climate Services, implemented in 2012, aims to help support decisions with climate information. Also, with the improved technology, new forms of climate services were added to the toolbox. Recent additions are story maps and augmented/virtual reality.

National climate service providers are often state meteorological agencies (Vaughan & Dessai, 2014). This is especially the case for water (Vaughan & Dessai, 2014). In the last few years, some countries have made central competence centres for providing climate services. These National Climate Services (NCS) are important in consolidating all available data into products for the stakeholders, public and private (Miles et al., 2006). They can show the national level, but as climate change has different effects regionally, they can also show regional levels.

Although the use of climate services may always seem very positive, there are some limitations to the use of climate services. First and foremost, climate services are only part of a larger effort in adapting to climate change. Knowledge and financial resources are also needed to adapt (Lawrence et al., 2015). Climate services should therefore not only focus on the climate, but also on non-climate aspects of adaptation (Räsänen et al., 2017). It has been proposed that there is a need for "climate adaptation services", that include other factors than just climate data, such as socio-economic information, and helping the informing, making, implementing and monitoring of climate adaptation policies (Lourenço et al., 2016).

2.2.4 Climate services for flood risk management

Climate services can be used in the flood risk management policy cycle at five stages: Inform, Advise, Monitor, Evaluate and Revise, short IAMER (Pantalona et al., 2021). As climate services are a decision support system (DSS) (Palutikof et al., 2019), they should be integrated into all stages of the flood management policy cycle (Pantalona et al., 2021). The five stages can be characterized as follows:

- *Inform* means that the decision maker is presented with all the information needed to make policy. Climate services can show, for example, where potential flood risks are and thus contribute to informed decision making.
- *Advise* is the Climate Service's ability to show the decision maker what the potential impact of the policy is. Once a flood risk management measure is chosen, the climate service can, for example, advise on the height of a dike.
- *Monitor* is to see how the policy behaves when in effect and to make sure it is in line with the goal of the policy. Climate services for flood risk management can monitor, for example, the water levels and show which areas are flooded.

- *Evaluate* means to assess what kind of effect the policy has and if it achieves the desired outcome. Climate services can help compare the real world effect of the measure taken to the goal of the policy. For example, the climate service might show that despite the new dike, the area has been flooded.
- *Revise* is needed when the policy has to be adapted in order to achieve the policy goals. Climate services can help to iteratively change the measure in order to achieve the policy goals. For example, the climate service can advise on new heights of the dike.

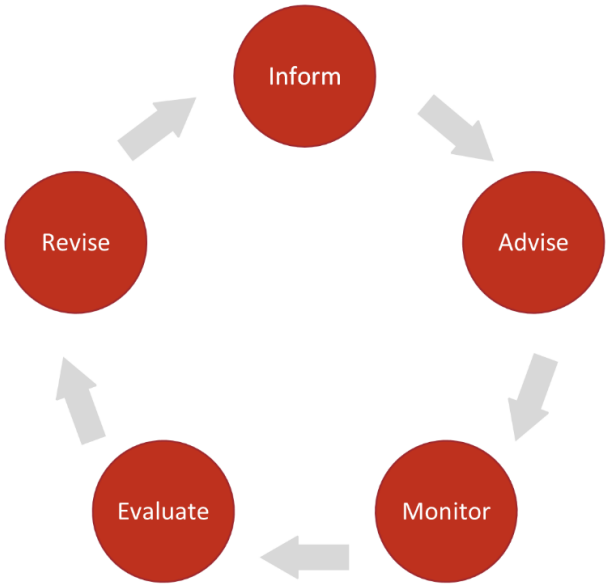

Figure 2. IAMER circle

These five stages can be seen in a linear path, but are better imaged in a circle, as depicted in figure 2. When revising, the prior four stages are run through again. For regions without extensive flood management the first two stages are the most important when starting, as there is no flood risk management policy to monitor, evaluate or revise. Informing on what policy is necessary and advising on that policy is helped greatly by climate services as a decision support system (Pantalona et al., 2021).

2.3 Usability Gaps

As explained above, climate services are a useful support instrument for mitigating and adapting to climate change (Bowyer et al., 2015). However, this instrument is often not fully suitable for the users and therefore not effective. Swart et al. (2021) use a term from innovation theory called “valley of death” to describe this as “the gap between suppliers and users of climate information”. According to Kirchhoff et al. (2013), the usability gap is where the needs of the users are not met by the products from scientific research. This scientific research provides data that is then used by boundary organisations to provide boundary objects (Kirchhoff et al., 2013). A

boundary organisation can be, for example, a specialised government organisation. They would produce a boundary object, for example a climate scenario. This boundary object is positioned between social worlds, for example climate modelling data and climate adaptation policy (Kirchhoff et al., 2013).

It speaks for itself that the use of climate services can be hindered by usability gaps. These usability gaps are mainly due to a lack of accessibility and relevance (Bruno Soares & Dessai, 2015); however, they can be diverse across uses and stakeholders (Bessembinder et al., 2019). Many studies have looked into this phenomenon and proposed solutions to close the gaps; one of them is by Raaphorst, Koers, et al. (2020). That study proposed a climate information design template showing the characteristics of a climate service as a basis for climate service developers to discuss the needs with the stakeholders. The climate information design (CID) template comes from a framework for visual content analysis developed by Raaphorst, Roeleveld, et al. (2020). This framework was then adapted by Raaphorst, Koers, et al. (2020) to fit analysis of climate services. If the climate service does not meet the intended goal, this can be due to inconsistencies in the following four points: "(1) the desired interpretation (and resulting action) by its intended audience, (2) the framing of a message for a specific audience with a specific purpose in mind, (3) the appropriate information, (4) the readability of the choice of visual expression and appropriate medium of presentation" (Raaphorst, Koers, et al., 2020, p. 5). Figure 3 shows these four points with examples.

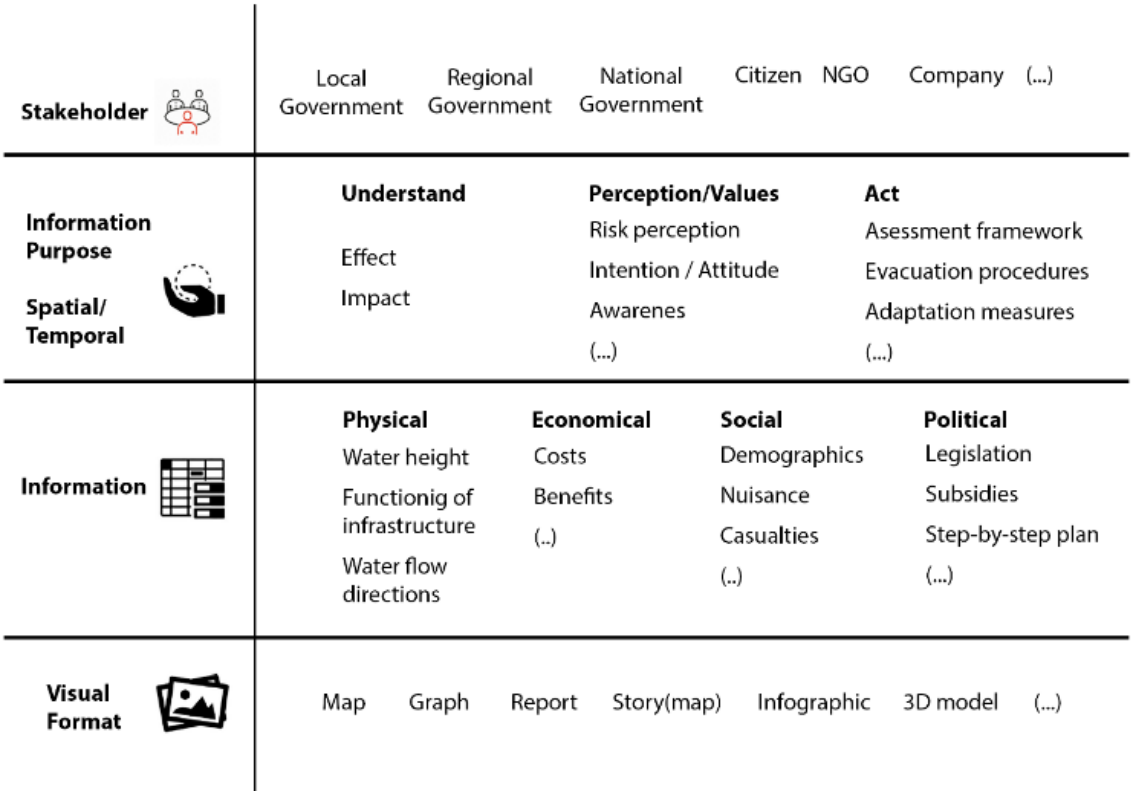

Figure 5. The climate information design (CID) template with examples. From "Mind the Gap: Towards a Typology of Climate Service Usability Gaps" by K. Raaphorst, G. Koers, et al., 2020, *Sustainability, 12*(4), p. 5 (https://doi.org/10.3390/su12041512). CC

According to Raaphorst, Koers et al. (2020), the maker of climate services should have three central aspects in mind: Validity, Readability, and Interactivity. Each of them should then be applied to Stakeholders, Purpose, Information and Visual format. Based on this framework, 12 different elements of usability gaps can be defined (Raaphorst, Koers, et al., 2020). These will be used for the research; they are elaborated in the subchapters below.

2.3.1 Validity

The validity of a climate service is determined by how well the tool used fits the goal (Raaphorst, Koers, et al., 2020); this greatly depends on the appropriateness and correctness of the information. A climate service also needs to be accurate, credible, salient and timely to fit the usability (Lemos et al., 2012).

A climate service has high validity for stakeholders if the goal of the climate service fits the goal and means of the stakeholder (Raaphorst, Koers, et al., 2020). If the stakeholder cannot act on the climate service, the validity of the climate service is non-existent. For example, a climate service on coastal flooding has probably no validity for mountain range nature conservers.

This relates to the next usability gap, validity of the purpose. The purpose of the climate service needs to help support the decision process (Raaphorst, Koers, et al., 2020). In the IAMER circle, this means that the climate service should reflect the correct phase within the circle, the purpose of the climate service is informed by the stage within the IAMER.

Then the information shown with the climate service needs to be valid. This means that the information needs to be correct and trustworthy, to not cause doubt on the validity of the use of the climate service in the decision-making process (Raaphorst, Koers, et al., 2020).

Lastly, the visual format needs to be valid (Raaphorst, Koers, et al., 2020). This means that the visual format chosen needs to represent the climate data and modelling in an accurate way. The wrong choice of visual format for a climate service can cause misrepresentation of the actual climate data and modelling.

2.3.2 Readability

The readability of a climate service is how well the end user can understand the climate service (Raaphorst, Koers, et al., 2020). This can be the literal visual elements of the climate service, but also if the user understands the purpose and what information is displayed. Lemos et al. (2012) have coined the term interplay, under which gaps arise when the current knowledge of the user is not sufficient for the introduction of a new climate service.

The readability for stakeholders entails the understanding of the climate service by the stakeholders (Raaphorst, Koers, et al., 2020). The climate service should

use visual language that the user can understand and interpret correctly. New and creative ways of visualising climate services such as story maps and augmented reality can improve the readability for stakeholders, if used appropriately (Vollstedt et al., 2021).

The purpose of a climate service should be supported by the readability (Raaphorst, Koers, et al., 2020). If the purpose of a climate service is to reach a broad audience, a complicated, technical document is not fit for the purpose (Raaphorst, Koers, et al., 2020). Better readability could be achieved by, for example, using infographics in a flyer.

It should also be clear what information a climate service uses, how reliable it is, and what it exactly means (Raaphorst, Koers, et al., 2020). The readability of information on a climate service can be improved by explaining the information and communicating the reach and limits.

The visual format and readability are quite inherently connected, as the visual format determines the readability to a significant extent (Raaphorst, Koers, et al., 2020). The information of a climate service can be great, but if the visual format does not communicate it, the climate service is not readable. For example, complex graphs can be hard to read; a different visual format could improve the readability in this instance.

2.3.3 Interactivity

The interactivity of a climate service relates to the visual literacy of the stakeholder of the climate service and in what ways the service can be re-purposed, information changed or added and the visual format modified (Raaphorst, Koers, et al., 2020).

Interactivity and stakeholder meet in the visual literacy of the stakeholder, which can facilitate the understanding and use of the climate service (Raaphorst, Koers, et al., 2020). Vollstedt et al. (2021) were able to find the optimal visualisation for each of part of the climate service through a participatory process with the stakeholders, adapting the climate service where needed. An example of a very accessible climate service is an art installation, as the user can actually walk through it (Raaphorst, Koers, et al., 2020). Compared to an advanced Geographic Information System (GIS) portal, it does provide less information, but is accessible to a broader public.

A climate service with high interactivity can be easily repurposed by its user (Raaphorst, Koers, et al., 2020). This can also mean that the climate service is used for multiple purposes or by different audiences. For instance in the inform stage of the IAMER cycle, the climate service not only has to answer questions, but could also inform where there are possible gaps in the climate adaptation.

Providing the option to change or add to the information on which the climate service builds, increases the information interactivity of the climate service

(Raaphorst, Koers, et al., 2020). If a user needs information added or changed on a climate service, high interactivity would facilitate it.

If the climate service contains a lot of information, making the visual format interactivity high helps the user making the most of it (Raaphorst, Koers, et al., 2020). For example, the data underlying the climate service might be on a very local level, but covering a large area. This climate service could then possibly benefit from giving the user the option to zoom in and out. Other examples of interactivity aspects are colour scheme and selecting different layers.

2.4 Conceptual model

The theoretical framework shows that climate services play an important role in flood risk management. The use of these climate services for flood risk management is affected by usability gaps. In this conceptual model, these gaps relate to validity, readability and interactivity. The effect of usability gaps on the relation between climate services and flood management is always negative, as the optimal situation between climate services and flood risk management is achieved when there are no usability gaps. A schematic overview can be seen in figure 4.

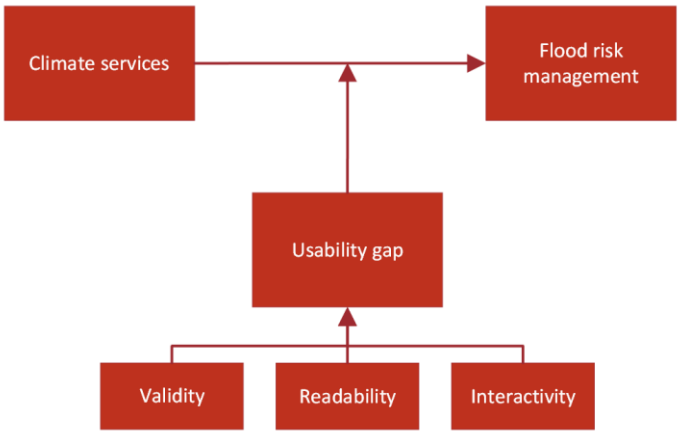

Figure 6. Conceptual model

2.5 Operationalisation

The interview guide is based on the original research questions and the conceptual model. It therefore includes questions on flood risk management and the challenges encountered, the usage of climate services for flood risk management, and the usability gaps that have been identified. The interview guide can be seen in appendix 1.

The operationalisation in sub-dimensions and indicators is also based on the theoretical framework, with the three main dimensions subdivided in relevant sub-dimensions with identifiers. This operationalisation is used as the starting point for coding the interviews. The final operationalisation after coding can be seen in appendix 2.

3. Methodological approach

This chapter explains the design of the research. First, the general approach of this research is explained, followed by an argumentation for the research design. Second, the data collection and analysis are explained and argued. Lastly, the positionality of the researcher and ethics are discussed.

3.1 Research approach

There are four different methodological goals a research can have: Understanding a problem, finding workable solutions, working towards solutions and evaluating change (O'Leary, 2017). The main question of this research is: "In which ways is the use of climate services by regional Dutch and German water authorities for flood risk management hindered?" This question tries to understand a problem, with the usage of climate services for flood risk management. The methodological goal of this research is thus understanding a problem.

In order to come to an understanding of the problem, this research makes use of a qualitative approach, which allows for the in-depth exploration of the users' experiences. This research covers a relatively wide subject, from climate services to the flood risk management cycle with the usability gaps between them. By using semi-structured interviews as the qualitative method, the wide range of topics can be combined with in-depth exploration. The validity is improved by the researcher being able to ask elaboration questions (Vennix, 2019).

The selection of the case study is practical, as the scale of a bachelor thesis cannot be across all organisations (O'Leary, 2017). The case study has a manageable number of organisations, five, which means that from every organisation someone can be interviewed.

3.2 Research design

The foundation of the research are the theoretical framework and the resulting conceptual model. The main results come from the analysis of interviews conducted with stakeholders. These stakeholders are staff from organisations participating in the GPRW organisation. Insights from this analysis are then discussed to find answers to the research questions. Additionally the climate services used by the organisations were analysed to get objective data about the climate services. This was then compared to how the respondents use them.

The respondents are experts or highly experienced within their field and organisation, which means they are key informants according to O'Leary (2017). These key informants were asked questions about their experience and role within the organisation to establish their key informant status. The ethics when working with key informants are discussed at the end of this chapter.

3.3 Data collection

The main data source were the five interviews conducted by the researcher with each GPRW partner organisation. Since a broad range of topics can be discussed during an interview, the data obtained through the interviews allowed for an in-depth analysis of the users' experiences. As some interview questions can demand an honest answer that is perceived by the interviewee as unfavourable, the interviews were anonymised to the organisational level. This means that the interviewee is not mentioned with a full name in connection to a statement that is exposing something, so they could therefore answer more freely (O'Leary, 2017).

The interview guide was based on a deliverable as part of the EVOKED project. Deliverable 3.2 by van der Brugge et al. (2020) contains materials to identify and research climate service usability gaps. In particular, the interview guide from the EVOKED project "that can be used to collect information about information needs and climate service use by selected end-users" (van der Brugge et al., 2020, p.1) has been consulted. It was expanded for this research to also include questions on flood risk management. In addition, the interviews made use of open questions that allowed the respondent to explain their needs for climate services.

The COVID-19 pandemic has made finding respondents willing for an interview easier, because a lot of communication has moved online (Sah et al., 2020). This means that the respondents already had experience with video-call services.

All interviews were done with employees with direct experience in flood risk management. Most are senior employees or department heads. Not all interviewees are directly involved with the GPRW, but all have something to do with it or at least know it. Additional data was gathered from a small amount of policy documents, published on the organisations' websites, that explain elements of the flood management or relevant laws. This allowed for more triangulation of data, resulting in more reliable results. All interviewees were asked what climate service they use the most for flood risk management. These climate services ware analysed, resulting in data on the characteristics of each climate service.

3.4 Data analysis

The interviews were transcribed from the audio recordings made during the interviews. The transcript was then coded in the Atlas.ti program. The coding process was iterative in nature. Starting with the operationalisation from the conceptional model, the first coding iteration was made. During this process, new codes emerged and were added to the code list. After coding all interviews, the codes were sorted by combining similar codes and deleting codes that were not relevant to answering the research questions. The codes were used to find common themes in and between the interviews. The analysis did not serve as a basis for a new theory, but compared the empirical data with the existing theory.

3.5 Positionality of the researcher

The position a researcher has towards the respondent is important, as a good power relationship between the researcher and the respondent can help the data gathering process (O'Leary, 2017). This relationship is influenced in part by the language, culture, nationality or region of origin between the researcher and respondent (O'Leary, 2017). The research was done in the East of the Netherlands and bordering German regions. The researcher has the Dutch nationality, and may therefore have a better relationship to the respondents from the Netherlands. However, the slight power imbalance the researcher and German respondents might have, could be negated by the fact that they felt a greater sense of wanting to explain to the researcher. The researcher has a good German language level, so there is no barrier for understanding. In addition, the author of this research has previous experience with interviewing Dutch and German policy makers.

3.6 Ethical accountability

At the beginning of the interview, all respondents were explained what the aim and purpose of the research are. The interviews were recorded with consent to be able to transcribe the interviews afterwards. It was explained to the respondents that they could withdraw from the research at any point before publication for any reason. The respondents were explained that their answers are used anonymously within the research.

4. Results

This chapter presents the results for the sub questions from the analysis of the interview transcripts and climate services. Firstly, the flood risk management done by the respondent's organisation is laid out. Secondly, the characteristics of the climate services used are given. Thirdly, the extent of the climate service usage for flood risk management is described. Lastly, the usability gaps in the usage of climate services for flood risk management are identified.

4.1 Flood risk management

From the interviews, it becomes clear that flood risk management is approached differently by the organisations of the GPRW on either side of the border. On the Dutch side, the waterschappen have a lot of competences regarding flood risk management. On the German side, however, the Kreise have a lot less competences regarding flood risk management. They are more a collaborator in projects with other organisations and an advisor to local municipalities on flood prevention measures.

The respondents from the German side explained that the direct flood prevention measures are implemented by the municipalities and communities. They are not concerned with making policies in the sense of having a long term vision, but rather execute the policies from higher hierarchical organisations, such as the Bundesländer. The respondent from Kreis Borken explained:

> Der Hochwasserschutz liegt ja bei den Kommunen, also bei den Städten und Gemeinden. Aber wir spielen da eine koordinierende und beratende Rolle. Wir beraten also Kommunen bei Umsetzung von Konzepten zum Hochwasserschutz… . [*The flood protection lies with the 'Kommunen', meaning with the cities and municipalities. But we play a coordinating and advising role. We advise 'Kommunen' with the implementation of concepts for flood protection.*] (Kreis Borken, personal communication, 20 June 2022)

Having all municipalities following their own plan causes patch works of flood protection. The Kreis is an organisation that can unite the municipalities within its area to work together and streamline the measures:

> Also jede Stadt muss für sich Hochwasserschutz machen. Da wir aber eigentlich immer ein bisschen mehr globaler denken müssen … versuchen wir als Kreis diese Gemeinden zusammenzuführen und sagen lass uns einen zusammen ein gemeinsames Konzept machen. Und nicht nur jeder für sich. [*So every city has to do flood protection for itself. But since we always have to think a bit more globally […], we as a district try to bring these communities together and*

say let's create a common concept together. And not just everyone for themselves.] (Kreis Borken, personal communication, 20 June 2022)

The respondent from Kreis Steinfurt said that flood risk management is in the first place situated at the Bundesregierung for the larger rivers. Managing the flood risks for the smaller rivers is placed at the Kreis and municipalities. The prime task in relation to flood risk management of the Kreis Steinfurt is the implementation of the Federal Water Act (Wasserhaushaltsgesetz, WHG).

The Kreise are a government layer that is more administrative in nature. When the Bundesland competence centres have calculated which areas are accepted to be flooded, the Kreise have to put this data from maps into actual practice:

> Wir haben die Aufgabe, diese berechneten Überschwemmungsgebiete festzusetzen. Es ist ein Verwaltungsakt, also es ist dann nicht nur berechnet auf dem Papier zu sehen, sondern wir haben das behördlich festzusetzen, so dass es auch offiziell ein festgesetztes Überschwemmungsgebiet gibt. [*It is our job to establish these calculated flood plains. It is an administrative act, so it is not only calculated on paper, but we have to determine it officially, so that there is also an official flood zone.*] (Landkreis Grafschaft Bentheim, personal communication, 23 May 2022)

The respondent from the waterschap Vechtstromen explained that all areas of land have a norm assigned with the level of protection, so for example a 1/10 or 1/100 chance per year (personal communication, 25 May 2022). These norms are then used by the waterschap to inform flood risk management, with climate change also accounted for:

> Maar die normen zijn gewoon gebiedsdekkend, zijn ze vastgesteld, en als wij dus waterlopen dimensioneren bijvoorbeeld, houden we ook rekening met klimaatverandering, dat soort dingen en we kijken ook naar de normen die gelden voor die gebieden. [*But those norms are simply area-wide, they have been established, and so when we dimension watercourses, for example, we also take climate change into account, things like that and we also look at the norms that apply to those areas*.] (Waterschap Vechtstromen, personal communication, 25 May 2022)

Compared to the situation in Germany, it becomes clear from the interviews that the structure is simpler in the Netherlands. The waterschappen are the main flood risk management organisation. Other government organisations are not really concerned with it. These differences in institutions between the Netherlands and

Germany make it difficult for the Dutch water authorities to cooperate with the German side. The waterschappen are a more autonomous organisation with far-reaching competences, from policy making to hands-on implementation and crisis management (Waterschap Rijn en IJssel, 2021). The respondent from waterschap Rijn en IJssel mentioned this, too, and added that the cooperation within the GPRW is not entirely ideal, because of the different institutional tasks and competences. The respondent from waterschap Rijn en IJssel sums it up like this:

> …op gebied van water hebben wij in Nederland alles relatief centraal rondom die waterschap georganiseerd, een stukje ligt nog bij de provincie en Rijkswaterstaat. Het waterbeheer an sich, als waterschap heb je een beleidsafdeling, je bepaalt gewoon een deel je eigen strategie en beleid, je hebt je eigen financiën, belastinginkomsten. We hebben waterbeheerders, die adviseren en die het gebied inrichten. We hebben de uitvoerende onderhoudsdiensten, ze hebben alles eigenlijk onder één dak, zeg maar. En je merkt dat het in Duitsland behoorlijk versnipperd is. [*in terms of water, we in the Netherlands have organized everything relatively centrally around the water authority, a small part of which is still with the province and Rijkswaterstaat. Water management in itself, as a water authority you have a policy department, you simply determine part of your own strategy and policy, you have your own finances, tax revenues. We have water managers who provide advice and who design the area. We have the executive maintenance services, they basically have everything under one roof, so to speak. And you notice that it is quite fragmented in Germany.*] (Waterschap Rijn en IJssel, personal communication, 20 June 2022)

A common feature is due to the fact that the rivers in the case study are all smaller; both in the Netherlands and in Germany, the management of the rivers is delegated to a lower government level. In the Netherlands, Rijkswaterstaat delegates to the waterschappen:

> De beheerder van de andere wateren, de zogenaamde “regionale wateren”, wordt aangewezen bij provinciale verordening (art. 3.2 Waterwet). In principe is de beheerder het waterschap. [*The manager of the other waters, the so-called “regional waters”, is designated by provincial ordinance (art. 3.2 Water Act). In principle, the manager is the waterschap*.] (Mostert, 2019, p. 17)

and in Germany the Bezirksregierung delegates to the Kreise and municipalities:

> Wobei für die kleineren Gewässer ..., also wir haben bei uns im Kreis beispielsweise [für] die Ems nicht die Zuständigkeit, [die ist] bei der Bezirksregierung, für alles andere sind wir dann auch zuständig. [*Whereby for the smaller bodies of water..., we don't have responsibility for the Ems in our district, for example, [it's] with the district government, but we're responsible for everything else*.] (Kreis Steinfurt, personal communication, 24 May 2022)

4.2 Characteristics of the climate services

The characteristics of the climate services used by the Dutch and German organisations for flood risk management are explained in this chapter. As discussed in chapter 2, the characteristics can be described using the CID template developed by Raaphorst, Koers, et al. (2020). The results are displayed in tables 2 and 3. Examples of the climate services are given in figures 5, 6 and 7.

The climate service used most by Kreis Borken and Kreis Steinfurt is ELWAS-WEB from the Ministry for Environment, Agriculture, Conservation and Consumer Protection of the State of North Rhine-Westphalia (MULNV) (Kreis Borken, personal communication, 20 June 2022; Kreis Steinfurt, personal communication, 24 May 2022). The State Agency for Nature, Environment and Consumer Protection (LANUV) provides the data and maps for the ELWAS-WEB. This is the climate service for water management, including flooding, for everyone involved or concerned with water management in the Bundesland North-Rhine Westphalia. This results in a lot of stakeholders for the climate service (*ELWAS-WEB*, n.d.-a). The purpose is to create understanding of the impact of flood risks and to help stakeholders to act. Table 2 contains the information used for flood risk management (*Inhalte und Symbole*, n.d.). The visual format is a GIS portal, allowing the stakeholder to select layers and zoom. Data from the GIS portal can be downloaded by the user, and the user can upload their own data, allowing for great interactivity of the climate service.

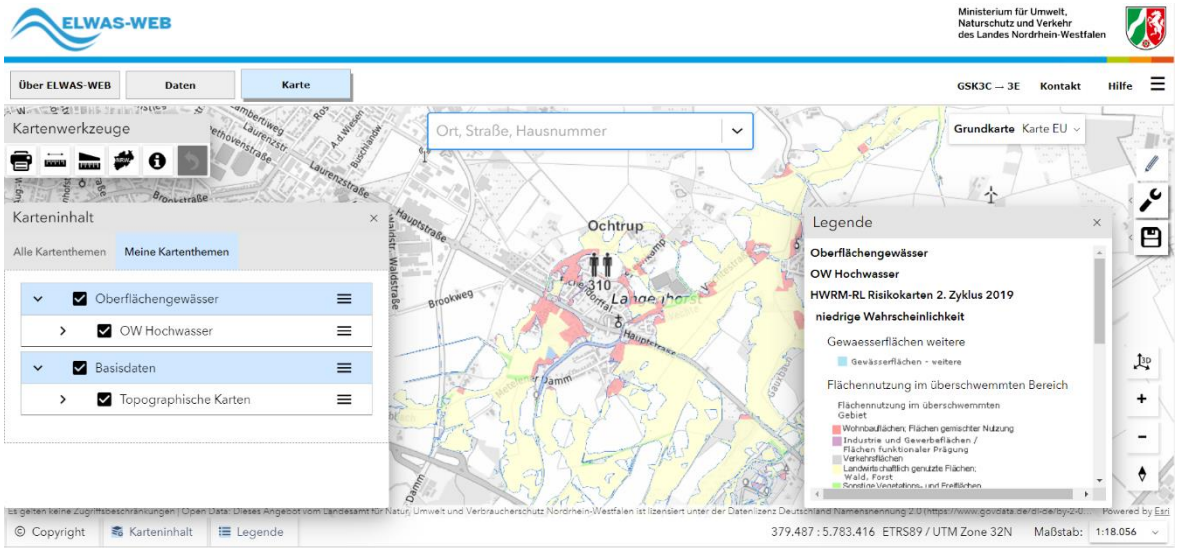

Figure 5. Example of ELWAS-WEB used by Kreis Borken and Kreis Steinfurt showing the flood risk maps (*ELWAS-WEB*, n.d.-b).

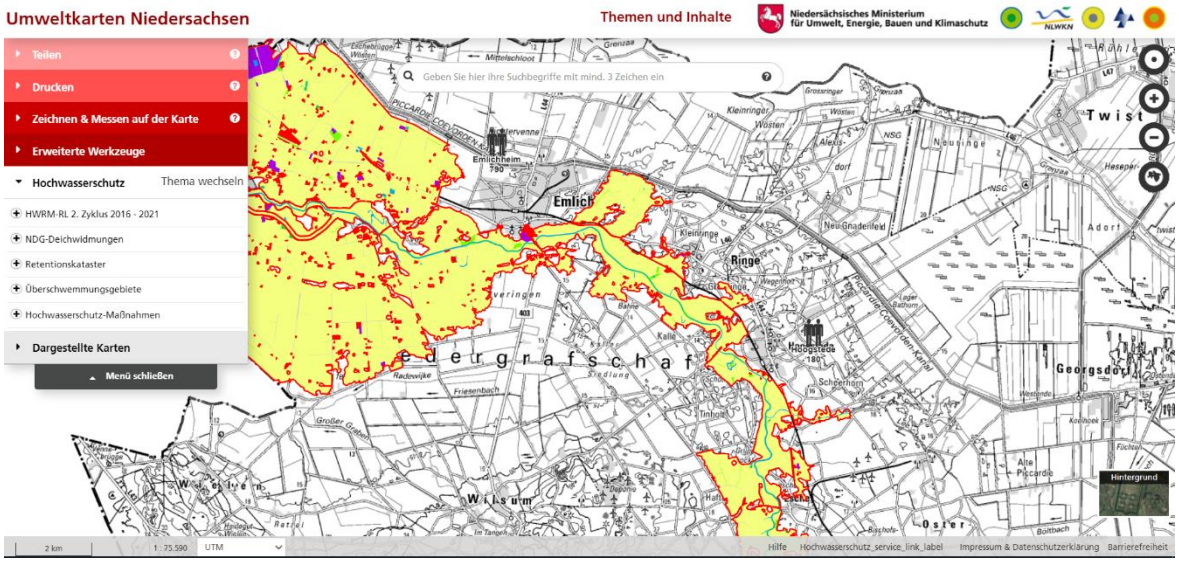

Figure 6. Example of Umweltkarten used by Landkreis Grafschaft Bentheim showing the flood risk maps (*Umweltkarten Niedersachsen*, n.d.).

The climate service used most by Landkreis Grafschaft Bentheim is from the Ministry for the Environment, Energy, Housing and Climate Protection of the State of Lower Saxony (MU) (Landkreis Grafschaft Bentheim, personal communication, 23 May 2022). The State Agency for Water Management, Coastal Defence and Nature Conservation (NLWKN) provides the data and maps for the Umweltkarten. This climate service can display a wide variety of data and maps about the environment, such as data and maps concerning air quality, hydrology, nature, climate change and flooding (*Umweltkarten*, n.d.). It also has a wide variety of stakeholders, being both open to the public and used by professionals. The purpose of the climate service is to show the impact of flooding and help stakeholders to act. Table 2 contains the information used for flood risk management (*EG-HWRM-RL*, n.d.). The visual format is a GIS portal, allowing for a high degree of flexibility. Layers can be selected and users can zoom in and out. The climate service allows users to download the data and to upload their own data. Another feature is that users can compare two layers with a slide bar in the middle. For example, the water depth of flooded areas for low and high flood probability can be compared.

	Landkreis Grafschaft Bentheim	Kreis Borken	Kreis Steinfurt
Stakeholder	Bundesland, Kreise, Verbände, municipalities, citizens, businesses, cultural institutions, homeowners	Bundesland, Bezirksregierung, Kreise, Verbände, municipalities, citizens, businesses, cultural institutions, homeowners	Bundesland, Bezirksregierung, Kreise, Verbände, municipalities, citizens, businesses, cultural institutions, homeowners
Purpose	Understand, Act	Understand, Act	Understand, Act
Information	Topographical or orthophoto background, surface water, height data, retention areas; for low, mid and high flood probability: flood extent, flood depth, flood defences, affected population, land use, IED installations, vulnerable areas (such as drinking water extraction, swimming water, nature reserves and UNESCO locations)	Topographical or orthophoto background, surface water, height data; for low, mid and high flood probability: flood extent, flood depth, flood defences, affected population, land use, IED installations, vulnerable areas (such as drinking water extraction, swimming water and nature reserves locations)	Topographical or orthophoto background, surface water, height data; for low, mid and high flood probability: flood extent, flood depth, flood defences, affected population, land use, IED installations, vulnerable areas (such as drinking water extraction, swimming water and nature reserves locations)
Visual format	GIS portal	GIS portal	GIS portal

Table 2. Climate information design qualities of the climate services used by the German organisations for flood risks.

	Waterschap Vechtstromen	Waterschap Rijn en IJssel
Stakeholder	National government, citizens, (agricultural) businesses, waterschap, municipality, safety region, province	National government, citizens, (agricultural) businesses, waterschap, municipality, safety region, province
Purpose	Understand, Act	Understand, Act
Information	Topographical or orthophoto background, height map, electricity infrastructure, waste water; for extremely low, low, mid high and high flood probability: flood extent, flood depth, affected population, land use, IED installations, vulnerable areas (drinking water extraction, swimming water and nature reserves locations)	Topographical or orthophoto background, height map, electricity infrastructure, waste water; for extremely low, low, mid high and high flood probability: flood extent, flood depth, affected population, land use, IED installations, vulnerable areas (drinking water extraction, swimming water and nature reserves locations)
Visual format	GIS portal	GIS portal

Table 3. Climate information design qualities of the climate services used by the Dutch organisations for flood risks.

Waterschap Vechtstromen and waterschap Rijn en IJssel use a variety of climate services, but the climate service that is used the most is the Atlas Leefomgeving which contains all the information of the flood risk maps (Waterschap Rijn en IJssel, personal communication, 20 June 2022; Waterschap Vechtstromen, personal communication, 25 May 2022). Flood related data is provided by the waterschappen, provinces and Rijkswaterstaat (Slager, 2019). The climate service has many stakeholders, and to simplify the information for some stakeholders the layers can be filtered. The purpose of the climate service is to show the impact of flooding and help stakeholders to act. Table 3 contains the information used for flood risk management (Slager, 2019). The visual format of the climate service is a GIS portal. This allows for flexibility for the stakeholder to, for example, select layers and zoom in and out.

Figure 7. Example of Atlas Leefomgeving used by waterschap Vechtstromen and waterschap Rijn en IJssel showing the flood risk maps (*Atlas Leefomgeving*, n.d.).

4.3 Climate service usage for flood risk management

When the respondents were asked about the use of climate services for flood risk management, the German side responded rather dismissive at first. This seems to stem from the fact that flood risk management is heavily law and regulation based from above. The Kreise and their substituent municipalities are implementers of laws and regulations from the Bundesland. That is why the forecast of flooding is centrally situated at the Bundesland-wide competence centres, LANUV for NRW and NLWKN for Lower Saxony. The water level predictions are done by the LANUV for the Kreis Borken, while in the Netherlands it is generally done by the waterschappen:

> Ook [water]hoogte voorspelling is thema van het [Bundes]Land NRW. En dat doen in Nederland vaak de waterschappen. Die horen de voorspellingen te

> doen voor de Vecht of voor de voor de Oude IJssel, ook voor zoiets. Maar dat is in Duitsland alles centraal bij het [Bundes]Land. En dan bij de vakbehörde LANUV. [*Also water level prediction is task of the [Bundes]Land NRW. And that is often what the waterschappen do in the Netherlands. They have to make the predictions for the Vecht or for the Issel, also for something like that. But in Germany everything is central to the [Bundes]Land. Specifficly with the competence centre LANUV*.] (Kreis Borken, personal communication, 20 June 2022)

The climate services provided by the Bundesland-wide competence centres are not just informative in nature:

> Wir sind ja nun mal ne öffentliche Verwaltung und das muss dann auch Hand und Fuß haben ja, und die Daten vom LANUV, die sind durchaus so, dass man sie auch vor Gericht nutzen kann. [*After all, we're a public administration and that has to hold water, and the data from LANUV is definitely such that it can also be used in court*.] (Kreis Steinfurt, personal communication, 24 May 2022)

The climate services used by the waterschappen are made by themselves, or adapted to their need. The underlying climate modelling for flood risks is also done by them, with the use of national software:

> … die modellen, die worden landelijk ontwikkeld. Wij gebruiken gewoon software van Deltares daarvoor. Er zijn meerdere aanbieders, maar daar gebruiken we landelijke software voor. [*… those models are developed nationally. We simply use software from Deltares for this. There are several providers, but we use national software for that.*] (Waterschap Rijn en IJssel, personal communication, 20 June 2022)

In the interviews it also became clear that the Kreise are short term oriented. To the question if, for example, the Kreis Steinfurt would be interested in what precipitation patterns could be expected by 2050, this was the answer:

> Ich habe mir ehrlich gesagt noch nie so langfristig Gedanken darüber gemacht, wie geht der Niederschlag sein? [*To be honest, I've never given such long-term thought to, how is the precipitation going to be?*] (Kreis Steinfurt, personal communication, 24 May 2022)

The following quote also shows how the Kreise are more focused on the execution of law and regulations, and not on making policies on flood risk management:

> Vielleicht lassen wir uns auch durch den Gedanken blockieren, dass wir nur darauf fixiert sind, wir brauchen Retention, wir brauchen Volumen, wo welche Fläche ist verfügbar, wie viel Fläche brauchen wir? Mehr Sicherheit zu schaffen. [*Perhaps we also allow ourselves to be blocked by the thought that we are only fixated on, we need retention, we need volume, where what area is available, how much area do we need? Creating more security.*] (Kreis Steinfurt, personal communication, 24 May 2022)

Following up on this answer further clarifies the use of climate services for the Kreise. Because flood risk management is spread out between multiple levels of government in Germany, the lower levels are less concerned with longer term climate services:

> Vielleicht mag es auch sein, dass es das auch schon gibt von Seiten des Ministeriums auf ministerialer Ebene, dass man da schon mal nach vorne geschaut wird, wie entwickeln sich die Niederschlagspatronen. Mag ja sein, aber das hat für uns aus, für uns als untere Wasserbehörde, damit haben wir noch nicht so intensiv mit beschäftigt. [*It may also be that the ministry already has this at the ministerial level, that people are already looking ahead to see how the precipitation patterns are developing. Maybe so, but for us as the lower water authority, we haven't dealt with it that intensively yet.*] (Kreis Steinfurt, personal communication, 24 May 2022)

If a climate service were developed to show the impact of an increase in flooding due to climate change, this should be done cross-border; as the interviewee from Landkreis Grafschaft Bentheim puts it:

> Ich glaube, wenn man so ein Klima Dienst aufstellt, das muss größer gedacht werden, also das muss für ein großes Gebiet dann auch dargestellt werden. Und das muss definitiv ganz grenzüberschreitend erfolgen. [*I think that if you set up a climate service like this, you have to think bigger, so it has to be presented for a large area. And that definitely has to be across borders.*] (Landkreis Grafschaft Bentheim, personal communication, 23 May 2022)

Despite their different experiences, all five respondents saw value in the use of climate services to inform the general public and residents affected by the policies. The German Kreise saw the use mainly as a way to legitimise and create understanding for the flood prevention measures they are taking. Expanding the use of climate services to inform citizens about the risks and measures is identified as a possible usage of climate services to be further developed in the future.

In relation to the IAMER policy cycle from the theoretical framework, it can be said that the main use of climate services is to inform, advise and monitor. Flood risk management policies on both sides are informed by climate services. For example in the Netherlands, the map with flooding norms and the map with inundations are compared to identify points of interest. The resulting map is then used to inform possible flood risk management strategies (Vechtstromen, n.d.). When asked at what point climate services are used in the IAMER cycle, the interviewee from waterschap Vechtstromen mentioned the inform and advise phases:

> … bij het identificeren van problemen of aandachtspunten daarvoor in ieder geval en ook voor het uiteindelijk oplossen van die situaties daar zullen we ook voor gebruiken. [*in identifying problems or points of attention, anyway, and also for ultimately solving those situations, we will also use it for that*.] (Waterschap Vechtstromen, personal communication, 25 May 2022)

In the Netherlands, the monitor, evaluate and revise steps of the cycle are done by the waterschappen at least every 6 years. The waterschap describes what they have to do, what they want to do and what they are allowed to do in the water management program, which has to be updated every 6 years (Omgevingsbesluit artikel 10.16, 2018). This program is referred to by waterschap Vechtstromen as follows:

> … dan gaan we die vlekjes of die die gebiedjes die niet voldoen [aan de norm], die gaan we aanpakken, dus die komen ergens op een plan van het waterschap waarin we nog eens een keer goed kijken van hé, wat is hier nu aan de hand en moeten we dat niet aanpassen aanpakken? [*then we will deal with those spots or those areas that do not meet [the norm], we will tackle them, so they will be included somewhere on a plan of the water authority in which we take another good look at what is going on here and mustn't we deal with that?*] (Waterschap Vechtstromen, personal communication, 25 May 2022)

On the German side on the Kreis level, the monitoring is also done, but not as structured every 6 years. As the lowest water authority, the Kreise are responsible for making sure that the current flood protections measures are up to standard:

> Wir haben auch zu schauen, dass diese Überschwemmungsgebiete auch aktuell bleiben. [*We also have to make sure that these flood areas remain current*] (Landkreis Grafschaft Bentheim, personal communication, 23 May 2022)

4.4 Usability Gaps in the climate services used

4.4.1 Validity

The validity of a climate service depends on how well the tool used fits the intended goal (Raaphorst, Koers, et al., 2020). The validity can be applied to the four categories of the CID template: stakeholder, purpose, information and visual format.

Stakeholder

In chapter 4.1, the quote from Landkreis Grafschaft Bentheim shows how the Kreis has the administrative task to put the calculated flood areas from paper into administrative reality. They are not interested in other climate services than the output from the NLWKN. The respondent did acknowledge the existence of other climate services, but they do not use them:

> Die sind zugänglich, aber wir benutzen sie nicht. [*They're accessible, but we don't use them*.] (Landkreis Grafschaft Bentheim, personal communication, 23 May 2022)

There is no usability gap for the stakeholder validity, as the climate services used by the Kreise and waterschappen are made for the use by respectively the Kreise and waterschappen.

Purpose

The results in the previous chapter showed that the waterschappen and Kreise use the climate services to inform, advise and monitor in the policy cycle. The identified purposes of the used climate services are understand and act, which are suitable for the phases in the policy cycle (Pantalona et al., 2021). Therefore, no useability gap is identified for stakeholder purpose.

Information

Regarding the validity of the information of the climate services that are used for flood risk management, the respondent from Kreis Steinfurt mentioned that the delineation of climate services according to administrative boundaries hinders their use, while being able to see across the borders would be helpful:

> Die werden dann meistens ausgeblendet, … verschwommen da gestellt also würde definitiv helfen für die Arbeit ja. [*They are then usually hidden … they are put there in a blurry way, so it would definitely help for the work, yes.*] (Kreis Steinfurt, personal communication, 24 May 2022)

This means that in the current situation, the validity of information is impacted, because not all the information is displayed for the user's need. The used climate services all stay within the administrative state borders, with the exception of the Dutch Atlas Leefomgeving, which includes the water depths for low, mid and high flood probability in North-Rhine Westphalia.

The situation for the waterschappen is different, as they use nationally standardised tools and coordinate their climate services. This means that within the Netherlands, administrative borders do not hinder the waterschappen in flood risk management. Working across the administrative border with Germany is more difficult:

> Ik denk dat die bestuurlijke grenzen nog wel meevallen. Kijk, die grens is er altijd, maar dat dat op zich wel redelijk gedekt is. Ja, met Duitsland is het in die zin wat ingewikkelder. [*I think those administrative boundaries are not that bad. Look, the border is always there, but that in itself it is reasonably covered. Yes, with Germany it is a bit more complicated in that sense.*] (Waterschap Rijn en IJssel, personal communication, 20 June 2022)

Although the respondent mentioned that there are efforts made to better cooperate across the border, there are still strides to be made, especially with modelling:

> Zeg maar de modellenwereld dat dat wordt nog wel apart opgetuigd en eigenlijk willen we daar ook een soort van slag in maken. Kunnen we dat niet veel meer op elkaar aansluiten nog en dat wil niet zeggen dat je alles precies hetzelfde hoeft te doen. … Maar dat je toch wel … naar hetzelfde dashboard kijkt of naar hetzelfde kaartbeelden dat je niet Duitse kaarten hebt en Nederlandse kaarten met een raar verloop op de grens. … Want volgens mij is dat nu nog wel in een aantal situaties het geval dat je denkt, ja, we hebben allemaal onze eigen werkelijkheid opgetuigd. [*Let's say the modelling world is still being done separately and we actually want to make some progress in that regard. Can't we connect much more, and that does not mean that you have to do everything exactly the same. … But that you are … looking at the same dashboard or at the same map, that you do not have German maps and Dutch maps with a strange course at the border. … Because I think that is still the case in a number of situations that you think, we have all set up our own reality.*] (Waterschap Rijn en IJssel, personal communication, 20 June 2022)

From the analysis of the climate services in chapter 4.2, it is clear that the information comes from reputable institutes. In chapter 4.3, a quote from Kreis Steinfurt shows that the climate service has to trustworthy enough be able to be used in court, which

the data from LANUV is. There is thus no further usability gaps identified for the stakeholder information for the Kreise and neither for the waterschappen, as they collect some of the data themselves and have the competences to check the reliability of the data.

Visual format

The climate services are used by a variety of stakeholders and contain multiple data sets. This data is not selected on the basis of an area with a consistent need, but on the basis of state borders. This can, for example, cause misrepresentation of flooding effects, as the scale of water depth my need to change between areas for better representation of the actual situation.

4.4.2 Readability

The readability of a climate service is how well the end user can understand the climate service (Raaphorst, Koers, et al., 2020). The readability can be applied to the four categories of the CID template: stakeholder, purpose, information and visual format.

Stakeholder

One aspect of readability that is mentioned by the respondents is how to involve the general public as stakeholder in flood risk management. The climate services are often complicated too understand for people that are not experts in the matter:

> ...ich glaube, für die Öffentlichkeit ist das durchaus schwer. Es gibt ja auch öffentliche Programme. Da ist es schwer, das verständlich zu machen. [*...I think it's really difficult for the public. There are public programs, too. It's difficult to make that understandable*.] (Kreis Steinfurt, personal communication, 24 May 2022)

To explain the effects of climate change to the citizens, the climate services should contain as little text as possible, rather focussing on images and maps:

> ... man muss den Leuten, das auch vernünftig zeigen können, auf Grundlage vereinfachter wissenschaftlicher Ergebnisse. Und das kann man nur am besten mit Bildern, mit Karten und wenig Text. [*you have to be able to show people that properly, based on simplified scientific results. And that can only be done best with pictures, with maps and little text.*] (Landkreis Grafschaft Bentheim, personal communication, 23 May 2022)

The interpretative frames of the users should match the climate service; however, the available climate services for flood risk management can be difficult to understand:

> Es gibt ja auch öffentliche Programme. Da ist es schwer, das verständlich zu machen. ...die Informationen dann verschneiden, das können wir natürlich, weil wir das alltäglich machen. Für den Laien, glaube ich, ist das relativ schwer. [*There are also public programs. It's difficult to make that understandable. ... we can blend the information, of course, because we do it every day. I think it's relatively difficult for the layperson*.] (Kreis Steinfurt, personal communication, 24 May 2022)

Purpose

Since the purposes of all climate services used most by the organisations in the study area are to understand and act, the readability of the service should make it clear to the stakeholder what the purpose is. For the waterschappen and Kreise, this is the case and there are therefore no readability purpose usability gaps when they use the climate service. This may not be the case when using climate services for citizens, as citizens they act on the climate service, without first understanding the issue through the data and maps in the climate service.

Information

The climate services most used by the five organisations are publicly accessible and are made with citizens in mind as one of the stakeholders using the climate service. This does not mean, however, that the climate service's readability is optimal for the use by citizens. As mentioned in the quotes above about the use of climate services by citizens, it is not always clear for them what information is presented.

As far as internal usage is concerned, the presentation of information in climate services for flood risk management does not hinder the respondents, so no readability gap is identified here. The respondent from Kreis Steinfurt thinks that the current form of presenting the information poses no problems (Kreis Steinfurt, personal communication, 24 May 2022). At waterschap Vechtstromen, they are able to adapt readability themselves in order to achieve the intended goal:

> Ik denk dat elke soort informatie die we gebruiken om een bepaald doel te bereiken, dat we die uiteindelijk wel zo vormgeven dat we dat doel daarmee bereiken. [*I think that any kind of information that we use to achieve a certain goal, we eventually shape it in such a way that we achieve that goal.*] (Waterschap Vechtstromen, personal communication, 25 May 2022)

Visual format

The content of the climate services is readable for all respondents, possible problems would only occur when not used by the respondents. For example, citizens might not understand the legend of the climate service, which gives the level of abstraction of the actual data.

4.4.3 Interactivity

The interactivity of a climate service relates to the visual literacy of the stakeholder of the climate service and in what ways the service can be re-purposed, information changed or added and the visual format modified (Raaphorst, Koers, et al., 2020). The interactivity can be applied to the four categories of the CID template: stakeholder, purpose, information and visual format.

Stakeholder

The waterschappen and Kreise have experience in working with GIS portals, which gives them the required visual literacy to understand the climate services. According to Kreis Steinfurt, the information does not need to presented in a different form to become better for the user (Kreis Steinfurt, personal communication, 24 May 2022).

Next to the existing and established climate services, a new and creative application of climate information in a climate service is being developed by the waterschap Rijn en Ijssel for the use by the general public:

> We zijn bijvoorbeeld bezig met een museum om het ja zo'n overstroming dan weer in een 3D setting, dat je bij wijze van spreken een bril opzet en dat je in het overstroomde gebied rond kunt lopen. [*For example, we are working with a museum to represent such a flood in a 3D setting, so that you put on glasses, so to speak, and you can walk around in the flooded area*.] (Waterschap Rijn en IJssel, personal communication, 20 June 2022)

This decreases the level of visual literacy required by citizens to understand the issue and also creates awareness for the flood risks.

Purpose

The data from the climate services used by the Kreise can be downloaded, allowing them to be used offline. The user can also make a different climate service with the downloaded data, repurposing the data from the original climate service. The purposes of the used climate services are understand and act, but could be repurposed by the organisations to, for example, increase citizens' perception of flood risk.

Information

A usability gap that relates to interactivity is the option for the user to add or adapt information for the climate service. The German Kreise can do this in the climate services they use. The Dutch waterschappen cannot do this in the climate service used most by them, but as the waterschap Rijn en IJssel is the holder of all the water management information, they can add and adapt information according to their needs:

> … in Gelderland is het zo dat wij nu de bronhouder zijn voor de overstromingsinformatie. Dus dat betekent dat wij de scenario's en overstromingsbeelden, dus worden ja we zijn nu ook mee bezig met een soort update ronden. Dus dan krijg je inderdaad kaart beelden met gegeven een bepaalde waterstand met de kans van voorkomen. [*… in Gelderland we are now the source holder for the flood information. So that means we're going to finalize the scenarios and flood images, so yeah we're also doing some sort of update now. So then you will indeed get map images with given a certain water level with the chance of occurrence.*] (Waterschap Rijn en IJssel, personal communication, 20 June 2022)

A specific area where interactivity is mentioned to be important, is to inform the general public. They want to know what the flood risk and subsequent measures mean to them. A climate service where the general public can see just the information that is relevant to them and their situation would help explain the measure taken. Even though the GIS portals can give a high degree of interactivity of the information and visual format, the fact that the service is made for a wide range of stakeholders, does not necessarily make it useful for citizens. As the respondent from waterschap Vechtstromen puts it:

> Maar uiteindelijk willen mensen toch weten van wat het voor hun zelf gaat betekenen en wat zij eraan kunnen doen, of wat wij voor hen kunnen gaan betekenen dat vergt vaak nog iets meer dan een algemene dienst. [*But in the end people still want to know what it will mean for themselves and what they can do about it, or what we can mean for them. That often requires something more than a general service.*] (Waterschap Vechtstromen, personal communication, 25 May 2022)

This need for relevant information does not only apply to the general public, but also to governmental organisations. As the waterschap develops climate services themselves, they take the needs of these other users in mind, for instance by developing a viewer where the user can select the information they need. An example

given by waterschap Rijn and IJssel (personal communication, 20 June 2022) is that users can select the background map, choosing from topological maps, satellite imagery or height maps. An example that shows the need for interactivity in the information is that safety regions (veiligheidsregios) want to know where water is up to 30 cm, as this is the maximum level that they can drive through with cars. From the flood height data, only 30 cm and up should be able to be selected. But for all users, the climate data is the same:

> … voor iedere situatie, voor iedere gebruiker, die heeft een ander type informatie met de dezelfde database zit er wel achter, maar die heeft andere informatie nodig. [*for every situation, for every user, they have a different type of information with the same database, but they need different information.*] (Waterschap Rijn en IJssel, personal communication, 20 June 2022)

Visual format

The ability to use climate services interactively based on GIS in an online portal is perceived positively by the respondents:

> Was ich oder was wir allgemein ganz gut finden, ist, dass diese Programme mittlerweile alle GIS basiert sind also über Kartenmaterial zur Verfügung gestellt werden. Dass man sich dann für die einzelnen punkte die Hintergrundinfos dort dann anklicken kann und raussuchen kann. [*What I, or what we generally find quite good, is that these programs are now all GIS-based, i.e. are made available via map material. That you can then click on the background information for the individual points and search for it.*] (Kreis Steinfurt, personal communication, 24 May 2022)

5. Conclusions

This study was concerned with the usage of climate services by water authorities in the East of the Netherlands and bordering German regions to adapt to flooding. This chapter presents the conclusions of the research. After answering the four sub questions, the main research question will be answered. The answers are based on both the theoretical framework and the empirical results from the case study. Lastly, recommendations for practice and further research are given.

5.1 Flood risk management

Sub question 1: In what ways are flood risks managed in the Dutch and German regions?

Flood risk management is not the same across the Dutch and German regions. On the Dutch side, the waterschappen have competences and tasks ranging from developing a long term flood risk management vision, determining risks, acting on these risks, and monitoring and evaluating the implementation. On the German side, the Kreise have a comparatively small range of competences and tasks. They include the practical implementation of flood risk management measures and the monitoring of these measures. Next to the statutory tasks, they try to be a connecting partner for different organisations, such as municipalities and waterschappen. The empirical results showed the same differences and similarities between the Dutch and German flood risk management as the theory showed.

The norms for acceptable flood risks are also different between the Dutch and German flood risk management. The Netherlands has high norms for the larger waterways, from a 1/10,000 to a 1/1250 year chance, and much lower norms for small regional waterways, from a 1/10 to a 1/100 year chance. Germany only uses a 1/100 year chance standard, which leaves two options: either the flood prevention is upgraded to comply with this standard, or the area is designated as an area where flooding is accepted. The results from the empirics were consistent with the findings from the theoretical framework.

As far as adaptation is concerned, the German Kreise are more focused on the short term than the Dutch waterschappen. Adaptation to an increase of flood events due to climate change is not a prime concern of the Kreise; they rather focus on present day flood risk scenarios. The waterschappen, however, do take climate change into account, looking at longer term flood risk scenarios impacted by climate change. This conclusion from the empirical data follows the theory logically, since the organisations have inherently different tasks.

5.2 Characteristics of the climate services

Sub question 2: What are the characteristics of the climate services used in the Dutch and German regions?

Using the CID template, the following can be concluded about the characteristics of the climate services most used by the waterschappen and Kreise:

The two German climate services have the same wide variety in stakeholders. The Dutch climate service also has a wide variety in stakeholders. The Dutch and German climate services do not have the same stakeholders, as they are in different regulatory systems. However, categorising the stakeholders more abstractly (e.g. regional/local government) shows that the climate services have similar stakeholders.

The information in the climate services for managing flood risks is influenced by the European Floods Directive (2007/60/EC). This causes the information between all three climate services to be similar. One difference, however, is the levels of the chance of flood events. The German climate services use low, mid and high probability, whereas the Dutch climate services use extremely low, low, mid high and high probability. Furthermore, the Kreis Borken and Kreis Steinfurt use the same climate service, as do the waterschappen. Thus state borders impact the extent of the area covered by a climate service for its users.

The purposes of the climate services are the same for all three climate services. They help the user understand the risks of floods with probability and impact of floods and help the stakeholders to act in order to manage the flood risks.

The visual format is essentially the same for all three climate services, as they are all GIS portals. There is one difference, however: The two German climate services allow the user to up and download data, whereas the Dutch climate service does not.

5.3 Climate service usage for flood risk management

Sub question 3: To what extent are climate services used in flood risk management in the Dutch and German regions?

The waterschappen and Kreise both have access to flood risk maps. The waterschappen, however, have additional flood risk maps for the regional waterways where the flooding scenarios can differ from the main waterways. This feeds into the cost-benefit analysis. The Kreise use a single standard from maps provided by the Bundesland to base flood risk management on. Areas are then designated as floodable or needing more protection.

It was found that the Kreise do not use other climate services than flood risk maps with different chance per year scenarios or short term flood predictions. A possible usage of climate services in flood risk management mentioned by the Kreise is to inform the general public about the necessity and approach of flood risk management. The waterschappen do use a broader range of climate services, but as a specialised organisation dedicated to flood risk management, they develop climate

services themselves or in close cooperation. This means that if a climate service is needed, it can be provided. The Kreise do not have this capability and rely completely on climate services provided by governmental agencies higher up in the hierarchy.

The theory also states that there is a need for 'climate adaptation services', climate services beyond climate data. These were not found in the empirics. This could be due to the fragmentation of climate adaptation among governmental levels or the water authorities do not know yet about the benefits these services could provide.

The use of climate services within the IAMER policy cycle corresponds with the theory, although the last two steps of the cycle are not as pronounced. The usage is primarily to inform, advise and monitor the flood risk management. Evaluating the policy and then revising it is done every 6 years by the waterschappen. The Kreise do not necessarily make policy, but execute it; therefore the need for evaluating and revising policy is less relevant. Climate services for informing, advising and monitoring flood prevention are, however, regularly used by the Kreise.

5.4 Usability gaps in the climate services used

Sub question 4: What usability gaps can be identified in the usage of climate services in the Dutch and German regions?

The validity of climate services is hindered by adherence to strict administrative borders. The usability gap, identified by all respondents, is the limitation of climate services to administrative borders, rather than geophysical boundaries such as river basins.

It can be concluded from the results that readability is not a usability gap for the five organisations in this research. The Kreise can use the climate services as delivered by the Bundesland competence centres as intended, without being hindered by readability gaps. The waterschappen can circumvent this usability gap by adapting or developing the climate services themselves. Readability does play a role when communicating flood risk management measures with the general public. For this usage, climate services should be easily interpretable and have attractive visual elements.

Interactivity for use of the respondents is viewed positively and no gaps are identified. However, to explain the flood risk and subsequent measures to the general public, climate services should be interactive so that the user can see what it means for them. This also extends to government organisations, where the same climate service should change depending on the needs of the users.

The theory on usability gaps in the theoretical framework holds only partially when compared to the empirics. The waterschappen can control the climate services, while the theory on usability gaps assumes different producers and users. On the other hand, the Kreise are dependent on external services, and therefore experience more usability gaps, which is to be expected from the theoretical framework.

5.5 Hindrances to the use of climate services for flood risk management

Main Question: In which ways is the use of climate services by regional Dutch and German water authorities for flood risk management hindered?

Three ways have been identified in which the use of climate services for flood risk management by regional Dutch and German water authorities is hindered.

Firstly, the use is hindered by the flood risk management tasks the organisations have. The German Kreise have only a limited use for climate services, as they have only a limited responsibility for flood risk management.

Secondly, the use is hindered by the administrative borders. Current climate services are confined to administrative borders, which means that cross-border flood risk management is hampered. Climate services based on geophysical borders, such as a river basin, would help flood risk management and increase the possibilities of cross-border cooperation.

Thirdly, climate services for flood risk management use present day flood risk scenarios. As climate change increases the risk of flooding, climate services not including climate change impacts hinder effective flood risk management.

5.6 Recommendations for practice

From the conclusions of this research, multiple recommendations can be made to improve the practical use of climate services for flood risk management. Firstly, shared climate services between cross-border water authorities could be developed to support flood risk management. These shared climate services should take into account that that the users on each side of the border have different needs. They should therefore be made to be used interactively, in order to allow each user to select relevant data for their need. In this way, the underlaying data could still be the same.

Secondly, the water authorities could investigate if climate services could be used to inform citizens on climate change impacts and flood risk management measures. If this climate service is an online portal, it should preferably be interactive to allow zooming and selecting layers, thus enabling the citizen to choose what is displayed. Other climate services should be accessible for any citizen through the use of images and maps but little text, via, for example, StoryMaps, brochures or social media.

Thirdly, the difference in climate service usage between Dutch and German water authorities could be addressed in the GPRW to help manage expectations. There is a usage and knowledge imbalance between the waterschappen and Kreise that should be well understood by the partners.

Lastly, specifically for Germany: The producers of climate services could be more active in approaching the users to promote their product. Users may not know what climate services currently exist or what they can be used for.

6. Discussion and reflection

This chapter start with a discussion of the findings of the research. Next, it addresses the limitations of the research process and results. This includes what questions remain unanswered, what shortcomings arose in the method used, how the research could still be improved, to what extent the results can be generalised and how they could be enhanced through alternative approaches.

The results from this research are mostly what could be expected from the theoretical framework. The theoretical framework showed that the organisations have different tasks for flood risk management, which also comes forward in the results. The interviews confirmed that the organisations of the case study use climate services for flood risk management, but this is done more so by the Dutch organisations than the German ones, due to their difference in tasks. The organisations use climate services in all steps of the IAMER policy cycle, which corresponds with the theoretical framework.

Although the research found that the climate services most used have similar characteristics between the five organisations, the Dutch organisations make use of a wider variety of climate services than the Kreise, which use climate services to a limited degree. Also, waterschappen were found to be both user and producer of climate services, which might make then less susceptible to usability gaps. Overall, there were less usability gaps found than expected, while the gap between producer and user is positioned as a major problem in the climate sciences. However, this research did not inventory all climate services available for use by water authorities. This means that it cannot be excluded that there are climate services with such a substantial usability gap that producer and user cannot find each other. The results show an opportunity for producers of climate services to push for more use of climate services by the Kreise and to develop climate services specifically aimed at citizens.

A question that remains unanswered is how climate services are used across the entire flood risk management field. As mentioned in earlier chapters, flood risk management is complex and concerns multiple actors. This research only has results for waterschappen and Kreise. Although they work together on flood risk management, a comparison between the two is insufficient for understanding the use of climate services for flood risk management in the two countries. For a true comparison between regional Dutch and German flood risk management, it should contain the municipalities, waterschappen, provinces and Rijkswaterstaat on the Dutch side and on the German side the municipalities, cities, Kreise, Regierungsbezirke, water and dike associations and the Bundesland. However, that would have been out of scope for a bachelor thesis. This bachelor thesis, with only waterschappen and Kreise, clearly shows the difficulty in comparing the two.

Nevertheless, within the limited scope of the research, the results are reliable, because the different organisations have similar results when similar results are expected based on the legal status and organisational structure.

A limitation of the method is that it was difficult to get into contact with some interview participants. Some organisations were quick with their response, others took a long time. This resulted in a drawn out process of data gathering. As a consequence, the interviews are not optimally consistent. However, this inconsistency is limited, as the interviews were semi-structured; the same interview guide provided structure for all of them. Something that had been underestimated, was that video-calling is quite different from in-person interviews. Online interviews have a less natural 'flow' due to the delay and quality of video and audio. It might not have hampered data collection, and helped find participants more willing to give some of their time, but in-person interviews might still be preferable for the researcher.

Another shortcoming of the method used in this study is the fact that only five interviews were conducted, one per water authority. This means that the results may not encompass the experiences of all employees. Nevertheless, the results can be generalised per organisation, as the respondents were key informants. The respondents were chosen carefully and asked about their experience and role within the organisation to validate that they can give representative answers. However, future research could set out surveys within these organisations to get more views on the subject of the use of climate services for flood risk management.

The results cannot be generalised to different organisations than the five in the case study, due to the complex and specific contexts the respective organisations operate in, which might change between different waterschappen and Kreise.

This study used the definitions from Sayers et al. (2013) and Gouldby et al. (2009), excluding flood risk management strategies 4 (flood preparation) and 5 (flood recovery) from Hegger et al. (2016). Future research could look into usability gaps in the use of climate services for these strategies. This could also include in what ways cross-border cooperation in flood preparation and flood recovery could be improved with the use of climate services.

Future research could study what the needs of citizens for climate services in relation to flood risk management are. To answer this problem, the research should also include an overview of the part citizens have in flood risk management.

Extending beyond the specific topic of this bachelor thesis, it would be interesting for future research to study in depth how the Dutch and German flood risk management, and relevant organisations, relate. There is a lack of a truly holistic comparison of the two systems in current scientific literature, which future research could try to resolve.

Bibliography

§ 114 LWG NRW. Retrieved 4 August 2022, from http://www.lexsoft.de/cgi-bin/lexsoft/justizportal_nrw.cgi?t=16596043570658327 9&sessionID=53664596 7310950373&templateID=document&source=fliesstext&chosenIndex=Dummy _nv_68&xid=167162,121,20160716

About Dutch Water Authorities. (n.d.). Dutch Water Authorities. Retrieved 25 March 2022, from https://dutchwaterauthorities.com/about/

Allan, R. P., Cassou, C., Chen, D., Cherchi, A., Connors, L., Doblas-Reyes, F. J., Douville, H., Driouech, F., Edwards, T. L., Fischer, E., Flato, G. M., Forster, P., AchutaRao, K. M., Adhikary, B., Aldrian, E., & Armour, K. (2021). *Summary for Policymakers* (Climate Change 2021: The Physical Science Basis, p. 32). IPCC.

Artikel 2.8 van de Waterwet, (2021).

Atlas Leefomgeving. (n.d.). Retrieved 10 September 2022, from https://www.atlasleefomgeving.nl/kaarten?config=3ef897de-127f-471a-959b-93b7597de188&gm-z=7&gm-x=241879.44802686627&gm-y=513983.1684241134&gm-b=1544180834512,true,1;1638290151499,true,1;1638290151502,true,1;1638290151503,true,1;1638290151500,true,1;1638290151497,true,0.28;1638290151498,true,0.38

Barchiesi, S., Sanchez, J., Cross, K., Madrid, M., & Onencan, A. (2014). *Adaptation Planning – Views towards Resilience and Up-scaling Success to Enhance Transboundary Water Governance (Chapter Five)* (pp. 113–241).

Bessembinder, J., Terrado, M., Hewitt, C., Garrett, N., Kotova, L., Buonocore, M., & Groenland, R. (2019). Need for a common typology of climate services. *Climate Services*, *16*, 100135. https://doi.org/10.1016/j.cliser.2019.100135

Bowyer, P., Schaller, M., Bender, S., & Jacob, D. (2015). *Adaptation as climate risk management: Methods and approaches*. 71–92. https://doi.org/10.1007/978-3-642-38670-1_4

Bruno Soares, M., & Dessai, S. (2015). Exploring the use of seasonal climate forecasts in Europe through expert elicitation. *Climate Risk Management*, *10*, 8–16. https://doi.org/10.1016/j.crm.2015.07.001

Building a Legacy through World Climate Conference-3. (2010). https://public.wmo.int/en/bulletin/building-legacy-through-world-climate-conference-3

Bundesumweltministerium. (n.d.). *Wasserwirtschaftsverwaltung in den Ländern und Kommunen | BMUV*. Bundesministerium für Umwelt, Naturschutz, nukleare Sicherheit und Verbraucherschutz. Retrieved 25 March 2022, from https://www.bmuv.de/themen/wasser-ressourcen-abfall/binnengewaesser/gewaesserschutzpolitik/deutschland/wasserwirtschaftsverwaltung-in-den-laendern-und-kommunen

Carr, E. R., Goble, R., Rosko, H. M., Vaughan, C., & Hansen, J. (2020). Identifying climate information services users and their needs in Sub-Saharan Africa: A review and learning agenda. *Climate and Development*, *12*(1), 23–41. https://doi.org/10.1080/17565529.2019.1596061

Carter, T. R., Benzie, M., Campiglio, E., Carlsen, H., Fronzek, S., Hildén, M., Reyer, C. P. O., & West, C. (2021). A conceptual framework for cross-border impacts of climate change. *Global Environmental Change*, *69*, 102307. https://doi.org/10.1016/j.gloenvcha.2021.102307

Cashmore, M., & Wejs, A. (2014). Constructing legitimacy for climate change planning: A study of local government in Denmark. *Global Environmental Change*, *24*, 203–212. https://doi.org/10.1016/j.gloenvcha.2013.09.019

Challinor, A. J., Adger, W. N., & Benton, T. G. (2017). Climate risks across borders and scales. *Nature Climate Change*, *7*(9), 621–623. https://doi.org/10.1038/nclimate3380

Cortekar, J., Themessl, M., & Lamich, K. (2020). Systematic analysis of EU-based climate service providers. *Climate Services*, *17*, 100125. https://doi.org/10.1016/j.cliser.2019.100125

Craciunescu, V., & Stancalie, G. (2006). *ON-LINE SUPPORT SYSTEM FOR TRANSBOUNDARY FLOOD MANAGEMENT: DESIGN AND FUNCTIONALITY* (Vol. 72, pp. 305–314). https://doi.org/10.1007/1-4020-4902-1_28

Donnelly, C., Ernst, K., & Arheimer, B. (2018). A comparison of hydrological climate services at different scales by users and scientists. *Climate Services*, *11*, 24–35. https://doi.org/10.1016/j.cliser.2018.06.002

ELWAS-WEB. (n.d.-a). Retrieved 11 September 2022, from https://www.elwasweb.nrw.de/elwas-web/index.xhtml

ELWAS-WEB. (n.d.-b). Retrieved 10 September 2022, from https://www.elwasweb.nrw.de/elwas-web/map-

index.xhtml?lang=de&link_json=%7B%22basemap%22%3A%22topo_grau%22%2C%22extent%22%3A%7B%22xmin%22%3A376250.8449378975%2C%22ymin%22%3A5783200.232527185%2C%22xmax%22%3A383507.59982423123%2C%22ymax%22%3A5785746.546124563%7D%2C%22layer%22%3A%5B%7B%22id%22%3A%22nw_dgk5_hoehen%22%7D%2C%7B%22id%22%3A%22risikokarte_niedrige%22%7D%5D%7D

European Commission, Directorate-General for Research and Innovation, Jacob, D., Runge, T., Street, R., Parry, M., & Scott, J. (2015). *A European research and innovation roadmap for climate services*. Publications Office of the European Union. https://data.europa.eu/doi/10.2777/702151

Fekete, A., & Sandholz, S. (2021). Here Comes the Flood, but Not Failure? Lessons to Learn after the Heavy Rain and Pluvial Floods in Germany 2021. *Water*, *13*(21), 3016. https://doi.org/10.3390/w13213016

Ford, J., Berrang-Ford, L., & Paterson, J. (2011). A systematic review of observed climate change adaptation in developed nations: A letter. *Climatic Change*, *106*, 327–336. https://doi.org/10.1007/s10584-011-0045-5

Gezamenlijke intentieverklaring grensoverschrijdende klimaatadaptatie GPRW. (n.d.). *EUREGIO*. Retrieved 9 July 2022, from https://www.euregio.eu/actueel/gezamenlijke-intentieverklaring-grensoverschrijdende-klimaatadaptatie-gprw/

Gouldby, B., Samuels, P., Klijn, F., Messner, F., Sayers, P., Schanze, J., & Wallingford, H. (2009). *Title Language of Risk—Project definitions*.

GRDC Data Portal. (n.d.). Retrieved 24 June 2022, from https://portal.grdc.bafg.de/applications/public.html?publicuser=PublicUser#dataDownload/Stations

Guido, Z., Knudson, C., Campbell, D., & Tomlinson, J. (2020). Climate information services for adaptation: What does it mean to know the context? *Climate and Development*, *12*(5), 395–407. https://doi.org/10.1080/17565529.2019.1630352

Hartmann, T., & Albrecht, J. (2014). From Flood Protection to Flood Risk Management: Condition-Based and Performance-Based Regulations in German Water Law. *Journal of Environmental Law*, *26*(2), 243–268.

Hartmann, T., & Spit, T. (2016). Implementing the European flood risk management plan. *Journal of Environmental Planning and Management*, *59*(2), 360–377. https://doi.org/10.1080/09640568.2015.1012581

Hegger, D., Driessen, P. P. J., Bakker, M., Alexander, M., Beyers, J.-C., Buijze, A., Bruzzone, S., Choryński, A., Crabbé, A., Deketelaere, K., Delvaux, B., Dieperink, C., van Doorn-Hoekveld, W., Ek, K., Fournier, M., Ganzevoort, W., Gilissen, H. K., Goytia, S., Gralepois, M., & Wiering, M. (2016). *A view on more resilient flood risk governance: Key conclusions of the STAR-FLOOD project*. https://doi.org/10.13140/RG.2.1.4402.6001

Hochwasserrisikomanagement-Richtlinie. (n.d.). Retrieved 12 September 2022, from https://www.umwelt.niedersachsen.de/startseite/service/umweltkarten/hochwasserrisikomanagementrichtlinie_hwrmrl/HWRM-RL-121914.html

Hormann, M. (2015). *Zuständigkeiten im HWRM in Niedersachsen*. NLWKN.

Implementatieproces ROR—Overzicht bilaterale afstemming ORBP-en. (2017). https://www.helpdeskwater.nl/publish/pages/132176/overzicht_bilaterale_afstemming_orbp-en_juli_2014.pdf

Inhalte und Symbole. (n.d.). FLUSSGEBIETE NRW. Retrieved 12 September 2022, from https://www.flussgebiete.nrw.de/hochwasserrisikokarten-inhalte-und-symbole-8310

Jacob, D., Runge, T., Street, R., Parry, M., & Scott, J. (2015). *A European research and innovation roadmap for climate services*. Publications Office of the European Union. https://data.europa.eu/doi/10.2777/702151

Kapović Solomun, M., Ferreira, C. S. S., Zupanc, V., Ristić, R., Drobnjak, A., & Kalantari, Z. (2022). Flood legislation and land policy framework of EU and non-EU countries in Southern Europe. *WIREs Water*, *9*(1), e1566. https://doi.org/10.1002/wat2.1566

Kirchhoff, C., Lemos, M., & Dessai, S. (2013). *Actionable Knowledge for Environmental Decision Making: Broadening the Usability of Climate Science*. https://doi.org/10.1146/ANNUREV-ENVIRON-022112-112828

Kreienkamp, F., Philip, S. Y., Tradowsky, J. S., Kew, S. F., Lorenz, P., Arrighi, J., Belleflamme, A., Bettmann, T., Caluwaerts, S., Chan, S. C., Ciavarella, A., De Cruz, L., de Vries, H., Demuth, N., Ferrone, A., Fischer, rich M., Fowler, H. J., Goergen, K., Heinrich, D., … Wanders, N. (2021). Rapid attribution of heavy rainfall events leading to the severe flooding in Western Europe during July 2021. *World Weather Atribution*. http://hdl.handle.net/1854/LU-8732135

Kreis Borken. (2022, June 20). [Personal communication].

Kreis Steinfurt. (2022, May 24). [Personal communication].

Kreise | Landkreistag NRW. (n.d.). Retrieved 25 February 2022, from https://www.lkt-nrw.de/wir-ueber-uns/mitglieder/kreise/

Landkreis Grafschaft Bentheim. (2022, May 23). [Personal communication].

Lawrence, J., Sullivan, F., Lash, A., Ide, G., Cameron, C., & McGlinchey, L. (2015). Adapting to changing climate risk by local government in New Zealand: Institutional practice barriers and enablers. *Local Environment*, *20*(3), 298–320. https://doi.org/10.1080/13549839.2013.839643

Lemos, M., Kirchhoff, C., & Ramprasad, V. (2012). Narrowing the Climate Information Usability Gap. *Nature Climate Change*, *2*. https://doi.org/10.1038/NCLIMATE1614

Lenton, T. M., Benson, S., Smith, T., Ewer, T., Lanel, V., Petykowski, E., Powell, T. W. R., Abrams, J. F., Blomsma, F., & Sharpe, S. (2022). Operationalising positive tipping points towards global sustainability. *Global Sustainability*, *5*, e1. https://doi.org/10.1017/sus.2021.30

Lourenço, T. C., Swart, R., Goosen, H., & Street, R. (2016). The rise of demand-driven climate services. *Nature Climate Change*, *6*(1), 13–14. https://doi.org/10.1038/nclimate2836

Miles, E. L., Snover, A. K., Whitely Binder, L. C., Sarachik, E. S., Mote, P. W., & Mantua, N. (2006). An approach to designing a national climate service. *Proceedings of the National Academy of Sciences*, *103*(52), 19616–19623. https://doi.org/10.1073/pnas.0609090103

Omgevingsbesluit artikel 10.16, (2018). https://zoek.officielebekendmakingen.nl/stb-2018-290.html

Mostert, E. (2019). Nederlands waterrecht voor niet-juristen. *TU Delft OPEN Textbooks*. https://textbooks.open.tudelft.nl/textbooks/catalog/view/23/50/157-1

Mukherjee, U. (2019). *Climate adaptation services and the factors influencing their usability*. 161.

Nds. Ministerium für Umwelt, Energie, Bauen und Klimaschutz. (2018, April 24). *Erläuterungen zu den Überschwemmungsgebieten in Niedersachsen*. https://www.umwelt.niedersachsen.de/startseite/themen/wasser/hochwasser_amp_kustenschutz/uberschwemmungsgebiete/erlaeuterungen-zu-den-ueberschwemmungsgebieten-in-niedersachsen-9421.html

NLWKN. (n.d.). *Aufgaben und Anschriften der Deichverbände*. Retrieved 10 August 2022, from https://www.nlwkn.niedersachsen.de/startseite/hochwasser_kustenschutz/hochwasserschutz/deichverbande/aufgaben-und-anschriften-der-deichverbaende-39168.html

Normen voor wateroverlast. (n.d.). Kenniscentrum InfoMil. Retrieved 10 August 2022, from https://www.infomil.nl/onderwerpen/lucht-water/handboek-water/thema-s/wateroverlast/normen-wateroverlast/

Normering regionale wateroverlast. (n.d.). Retrieved 2 August 2022, from https://vechtstromen.maps.arcgis.com/apps/webappviewer/index.html?id=f76bfdfaa61549ffa96731a0a59a2901

O'Leary, Z. (2017). *The Essential Guide to Doing Your Research Project*. 751.

Overstroming Dinkel. (2010, August 28). https://www.rtvoost.nl/nieuws/114730/overstroming-dinkel

Palutikof, J. P., Street, R. B., & Gardiner, E. P. (2019). Decision support platforms for climate change adaptation: An overview and introduction. *Climatic Change*, *153*(4), 459–476. https://doi.org/10.1007/s10584-019-02445-2

Panenko, A., George, E., & Lutoff, C. (2021). Towards the development of climate adaptation knowledge-action systems in the European Union: An institutional approach to climate service analysis. *Climate Services*, *24*, 100265. https://doi.org/10.1016/j.cliser.2021.100265

Pantalona, G., Tsalakanidou, F., Nikolopoulos, S., Kompatsiaris, I., Lombardo, F., Norbiato, D., Ferri, M., Kovats, L., & Haberstock, H. (2021). Decision support system for flood risk reduction policies: The case of a flood protection measure in the area of Vicenza. *Data & Policy*, *3*. https://doi.org/10.1017/dap.2021.23

Raaphorst, K., Koers, G., Ellen, G. J., Oen, A., Kalsnes, B., van Well, L., Koerth, J., & van der Brugge, R. (2020). Mind the Gap: Towards a Typology of Climate Service Usability Gaps. *Sustainability*, *12*(4), 1512. https://doi.org/10.3390/su12041512

Raaphorst, K., Roeleveld, G., Duchhart, I., Van der Knaap, W., & Van den Brink, A. (2020). Reading landscape design representations as an interplay of validity, readability and interactivity: A framework for visual content analysis. *Visual Communication*, *19*(2), 163–197. https://doi.org/10.1177/1470357218779103

Räsänen, A., Jurgilevich, A., Haanpää, S., Heikkinen, M., Groundstroem, F., & Juhola, S. (2017). The need for non-climate services – Empirical evidence from Finnish

municipalities. *Climate Risk Management*, *16*, 29–42. https://doi.org/10.1016/j.crm.2017.03.004

Renner, T. (2022). *Sharing international rivers: Regional cross-border cooperation between The Netherlands and Germany*. Gildeprint Publishers. https://repository.ubn.ru.nl/handle/2066/250073

Roos, A., & Jonkman, B. (2006). Flood risk assessment in the Netherlands with focus on the expected damages and loss of life. In J. Schanze, E. Zeman, & J. Marsalek (Eds.), *Flood Risk Management: Hazards, Vulnerability and Mitigation Measures* (pp. 169–183). Springer Netherlands. https://doi.org/10.1007/978-1-4020-4598-1_14

Sah, L. K., Singh, D. R., & Sah, R. K. (2020). Conducting Qualitative Interviews using Virtual Communication Tools amid COVID-19 Pandemic: A Learning Opportunity for Future Research. *JNMA: Journal of the Nepal Medical Association*, *58*(232), 1103–1106. https://doi.org/10.31729/jnma.5738

Sayers, P., Li, Y., & Galloway, G. (2013). *Flood Risk Management: A Strategic Approach*. Asian Development Bank. https://www.adb.org/publications/flood-risk-management-strategic-approach

Schmitz, A. (2022). *Cross-border Platform for Regional Water Management*.

Slager, K. (2019). *Handboek overstromingsrisico's op de kaart*. https://www.helpdeskwater.nl/publish/pages/132175/handboek_overstromingsrisicos_op_de_kaart.pdf

Swart, R., Celliers, L., Collard, M., Prats, A. G., Huang-Lachmann, J.-T., Sempere, F. L., de Jong, F., Máñez Costa, M., Martinez, G., Velazquez, M. P., Martín, A. R.,

Segretier, W., Stattner, E., & Timmermans, W. (2021). Reframing climate services to support municipal and regional planning. *Climate Services*, *22*, 100227. https://doi.org/10.1016/j.cliser.2021.100227

Tall, A. (2015, November 12). *What Do We Mean by Climate Services?* https://public.wmo.int/en/bulletin/what-do-we-mean-climate-services

te Brake, W. H. (2002). Taming the Waterwolf: Hydraulic Engineering and Water Management in the Netherlands During the Middle Ages. *Technology and Culture*, *43*(3), 475–499. https://doi.org/10.1353/tech.2002.0141

ten Brinke, W. B. M., Bannink, B. A., & Ligtvoet, W. (2008). The evaluation of flood risk policy in the Netherlands. *Proceedings of the Institution of Civil Engineers - Water Management*, *161*(4), 181–188. https://doi.org/10.1680/wama.2008.161.4.181

Thaler, T., & Hartmann, T. (2016). Justice and flood risk management: Reflecting on different approaches to distribute and allocate flood risk management in Europe. *Natural Hazards*, *83*(1), 129–147. https://doi.org/10.1007/s11069-016-2305-1

Umweltkarten. (n.d.). Umweltkarten. Retrieved 11 September 2022, from https://www.umweltkarten-niedersachsen.de/Umweltkarten/

Umweltkarten Niedersachsen. (n.d.). Umweltkarten. Retrieved 10 September 2022, from https://www.umweltkarten-niedersachsen.de/Umweltkarten/

Umweltministerium NRW: Wer macht was—Wasserverbände. (n.d.). Retrieved 2 August 2022, from https://www.umwelt.nrw.de/umwelt/wer-macht-was/wer-macht-was-wasserverbaende

van der Brugge, R., Ellen, G. J., Koers, G., & Raaphorst, K. (2020). *Field trial capacity building materials—Appendix E*. Deltares.

van der Molen, J. (2011). *Crossing Borders. Een kader voor het tot ontwikkeling brengen van grensoverschrijdende samenwerking in watermanagement.* https://research.utwente.nl/en/publications/crossing-borders-een-kader-voor-het-tot-ontwikkeling-brengen-van-

van der Wiele, P., Zandstra, B., Nolte, H.-J., & Pelz, S. (2012). *Grensoverschrijdende hoogwaterberscherming—Eindrapportage van de werkgroep grensoverschrijdende hoogwaterbescherming*. https://docplayer.nl/57975792-Grenzuberschreitender-hochwasserschutz-grensoverschrijdende-hoogwaterbescherming.html

van Eerd, M., Wiering, M., & Dieperink, C. (2014). Exploring the Prospects for Cross-Border Climate Change Adaptation between North Rhine-Westphalia and the Netherlands. *Utrecht Law Review*, *10*, 91. https://doi.org/10.18352/ulr.271

van Vliet, M. T. H., Donnelly, C., Strömbäck, L., Capell, R., & Ludwig, F. (2015). European scale climate information services for water use sectors. *Journal of Hydrology*, *528*, 503–513. https://doi.org/10.1016/j.jhydrol.2015.06.060

Vaughan, C., & Dessai, S. (2014). Climate services for society: Origins, institutional arrangements, and design elements for an evaluation framework. *Wiley Interdisciplinary Reviews. Climate Change*. https://doi.org/10.1002/wcc.290

Vechtstromen, W. (n.d.). *Zo werkt normering regionale wateroverlast* [Overzichtspagina]. Vechtstromen; Waterschap Vechtstromen. Retrieved 7 August 2022, from https://www.vechtstromen.nl/werk-0/klimaat-veiligheid/wateroverlast/normering/werkt-normering/

Vennix, J. (2019). *Research methodology—An introduction to scientific thinking and practice*. https://www.managementboek.nl/boek/9789043037884/research-methodology-jac-vennix

Verdonschot, P. F. M., & Verdonschot, R. C. M. (2017). *Meetprogramma Overijsselse Vecht: Nulsituatie 2017 en effecten maatregelen*. Zoetwaterecosystemen, Wageningen Environmental Research. https://doi.org/10.18174/440223

Verdoold, H. (2014). Gedeelde visie maakt grensoverschrijdende gebiedsontwikkeling mogelijk. *1380-2860*, 236.

Vincent, K., Archer, E., Henriksson, R., Pardoe, J., & Mittal, N. (2020). Reflections on a key component of co-producing climate services: Defining climate metrics from user needs. *Climate Services*, *20*, 100204. https://doi.org/10.1016/j.cliser.2020.100204

Vollstedt, B., Koerth, J., Tsakiris, M., Nieskens, N., & Vafeidis, A. T. (2021). Co-production of climate services: A story map for future coastal flooding for the city of Flensburg. *Climate Services*, *22*, 100225. https://doi.org/10.1016/j.cliser.2021.100225

Warner, J. F., Buuren, A. van, & Edelenbos, J. (2012). *Making Space for the River*. IWA Publishing.

Waterschap Rijn en IJssel. (2021). *Waterbeheerprogramma 2022-2027*. https://cdn.arcgis.com/sharing/rest/content/items/3a0795d2930b48afbc57060e52e12efc/resources/28vV4GO6uUCTwx2gb40tG.pdf?

Waterschap Rijn en IJssel. (2022, June 20). [Personal communication].

Waterschap Vechtstromen. (2022, May 25). [Personal communication].

Wesselink, A., Bijker, W. E., Vriend, H. J. de, & Krol, M. S. (2007). Dutch dealings with the Delta. *Nature and Culture*, *2*(2), 188–209. https://doi.org/10.3167/nc.2007.020206

Wesselink, A., Warner, J., Syed, M., Chan, F., Tran, D., Huq, H., Fredrik, H., Thuy, N., Pinter, N., van Staveren, M., Wester, P., & Zegwaard, A. (2015). Trends in flood risk management in deltas around the world: Are we going 'soft'? *International Journal of Water Governance*, *4*, 25–46. https://doi.org/10.7564/15-IJWG90

Whiting, A. (2022, June 10). 'Tipping points' lead to irreversible shifts—Climate experts. *Horizon*. https://ec.europa.eu/research-and-innovation/en/horizon-magazine/tipping-points-lead-irreversible-shifts-climate-experts

Appendix 1: Interview guide

English language

This interview will be processed in the results of the research. The anonymity within this research is guaranteed to the interviewee. The interviewee understands that participation is voluntary and can at any point, without consequence, be revoked by the interviewee.

May I record the interview? The recording will only be available to me and my supervisors. The duration of the interview is between 30-45 minutes.

1. What is your study background?
2. How long have you been at this organisation and in what function?

Flood risk management

3. What is the role and responsibility that your organisation has towards flood management?
4. What flood management challenges is your organisation facing now and in the future?
5. How important are these challenges in different parts of your organisation?

I will be asking questions about climate services now. Climate services make climate information accessible to people and organisations to make good decisions. An example is the Klimaateffectatlas.

Climate services

6. Which information relevant for supporting flood management is already available through climate services and what is still missing?
7. Who is the provider of this climate service and where can it be found?
8. At what stage does your organisation use climate services (setting agenda, designing, implementing, monitoring or evaluating)

Usability gaps

9. Does the form in which the current information is presented make the information understandable? If not, why is this the case?
10. In which form would this information need to be presented to be understandable by the users within your organization.? (e.g. data, images, stories, maps, etc.)
11. In your opinion, how can climate information providers better meet the different needs of users? (E.g. through better engagement, tailoring, synthesising, information formats used etc.)

12. At what scale do you use climate services (very localised to bigger regions)and what would you like to see? Do administrative borders hinder the use of climate services?
13. Do you have any last comments to make or questions to ask?

Thank you very much for your participation, it is very valuable to this research. If you have any questions, you can contact me via email. Again, I will process the answers according to your previously stated privacy preference. May I contact you if I have any further questions? If you'd like to have the results, I can send them to you by email. And again, thank you very much for your participation!

Dutch language

Dit interview wordt verwerkt in de resultaten van het onderzoek. De anonimiteit binnen dit onderzoek is gegarandeerd voor de geïnterviewde. De geïnterviewde begrijpt dat deelname vrijwillig is en op elk moment, zonder gevolgen, kan worden ingetrokken door de geïnterviewde.

Mag ik het interview opnemen? De opname is alleen beschikbaar voor mij en mijn begeleiders. De duur van het interview is tussen de 30-45 minuten.

1. Wat is uw studieachtergrond?

2. Hoe lang bent u al bij deze organisatie en in welke functie?

Flood risk management

3. Wat is de rol en verantwoordelijkheid die uw organisatie heeft ten aanzien van overstromingsbeheer?

4. Met welke uitdagingen op het gebied van overstromingsbeheer wordt uw organisatie nu en in de toekomst geconfronteerd?

5. Hoe belangrijk zijn deze uitdagingen in verschillende delen van uw organisatie?

Ik ga nu vragen stellen over klimaatdiensten, in het Engels climate services. Klimaatdiensten maken klimaatinformatie toegankelijk voor mensen en organisaties om goede beslissingen te nemen. Een voorbeeld is de klimaateffectatlas.

Climate services

6. Welke informatie die relevant is voor het ondersteunen van overstromingsbeheer is al beschikbaar via klimaatdiensten en wat ontbreekt er nog?

7. Wie is de aanbieder van deze klimaatdienst en waar is deze te vinden?

8. In welke fase maakt uw organisatie gebruik van klimaatdiensten (agenda stellen, ontwerpen, implementeren, monitoren of evalueren)

Usability gaps
9. Maakt de vorm waarin de actuele informatie wordt gepresenteerd de informatie begrijpelijk? Zo nee, waarom is dit het geval?

10. In welke vorm moet deze informatie worden gepresenteerd om begrijpelijk te zijn voor de gebruikers binnen uw organisatie? (bijvoorbeeld gegevens, afbeeldingen, verhalen, kaarten, enz.)

11. Hoe kunnen aanbieders van klimaatinformatie volgens u beter inspelen op de verschillende behoeften van gebruikers? (bijv. door betere betrokkenheid, afstemming, synthese, gebruikte informatie vormen, enz.)

12. Op welke schaal maakt u gebruik van klimaatdiensten (zeer lokaal tot grotere regio) en wat zou u graag willen zien? Belemmeren bestuurlijke grenzen het gebruik van klimaatdiensten?

13. Heeft u nog laatste opmerkingen of vragen?

Hartelijk dank voor uw deelname, het is zeer waardevol voor dit onderzoek. Als u vragen heeft, kunt u contact met mij opnemen via de e-mail. Nogmaals, ik zal de antwoorden verwerken volgens uw eerder aangegeven privacyvoorkeur. Mag ik contact met u opnemen als ik nog vragen heb? Als u de resultaten wilt hebben, kan ik ze u per e-mail toesturen. En nogmaals heel erg bedankt voor uw deelname!

German language

Dieses Interview wird in den Ergebnissen der Studie verarbeitet. Die Anonymität innerhalb dieser Studie wird Ihnen zugesichert. Teilnahme ist freiwillig und kann von Ihnen jederzeit ohne Folgen widerrufen werden.

Kann ich das Interview aufzeichnen? Die Aufzeichnung steht nur mir und meinen Begleitern zur Verfügung. Die Dauer des Interviews beträgt zwischen 30-45 Minuten.

1. Welchen Studienhintergrund haben Sie?

2. Wie lange sind Sie schon bei dieser Organisation und in welcher Position?

Flood risk management
3. Welche Rolle und Verantwortung hat Ihre Organisation in Bezug auf das Hochwassermanagement?

4. Vor welchen Herausforderungen beim Hochwassermanagement steht Ihre Organisation jetzt und in Zukunft?

5. Wie wichtig sind diese Herausforderungen in verschiedenen Teilen Ihrer Organisation?

Ich werde jetzt Fragen zu Klimadiensten, auf Englisch “Climate Services”, stellen. Klimadienste machen Klimainformationen für Personen und Organisationen zugänglich, damit sie gute Entscheidungen treffen können. Ein Beispiel ist der Norddeutsche Klimaatlas.

Climate services
6. Welche für die Unterstützung des Hochwassermanagements relevanten Informationen sind bereits durch Klimadienste verfügbar und was fehlt noch?

7. Wer ist der Anbieter dieses Klimadienstes und wo ist er zu finden?

8. In welcher Phase nutzt Ihre Organisation Klimadienstleistungen (Themen setzen/Problemen definieren, Abstimmen/Entscheiden, Umsetzen, Monitoren oder Evaluieren)?

Usability gaps
9. Macht die Form, in der Informationen jetzt präsentiert werden, die Informationen verständlich? Wenn nein, warum ist das so?

10. In welcher Form sollten diese Informationen dargestellt werden, um für die Benutzer in Ihrer Organisation verständlich zu sein? (z. B. Daten, Bilder, Geschichten, Karten usw.)

11. Wie können Anbieter von Klimainformationen Ihrer Meinung nach besser auf die unterschiedlichen Bedürfnisse der Nutzer eingehen? (z.B. durch bessere Einbindung, Abstimmung, Synthese, verwendete Informationsform etc.)

12. Auf welcher Ebene nutzen Sie Klimadienste (sehr lokal bis überregional) und was würden Sie gerne sehen? Behindern administrative Grenzen die Nutzung von Klimadiensten?

13. Möchten Sie abschließend noch was sagen oder fragen?

Vielen Dank für Ihre Teilnahme, sie ist sehr wertvoll für diese Forschung. Wenn Sie Fragen haben, können Sie mich per E-Mail kontaktieren. Auch hier werde ich die Antworten gemäß Ihrer zuvor angegebenen Datenschutzpräferenz verarbeiten. Darf ich Sie kontaktieren, wenn ich Fragen habe? Wenn Sie die Ergebnisse wünschen, kann ich sie Ihnen per E-Mail zusenden. Und nochmals vielen Dank für Ihre Teilnahme!

Appendix 2: Operationalisation after coding

User	Experience	
	Role	
	Area	
Flood Management	Level	City/town
		Municipality
		Kreis
		Water authority
		Bezirk
		Province
		Bundesland
		Country
		Cross-border region
		Germany
		Netherlands
	Stakeholder	Local resident
		Civil servant implementer
		Civil servant policy maker
		Management
		Politician
	Purpose (Cycle)	Inform
		Advise
		Monitor
		Evaluate
		Revise

	Challenges	
	In practice	
	Legal basis	
Climate Service	Time scale	Historical data
		Current data
		Future predictions
		Short term
		Long term
	Scope	Local scope
		Regional scope
		National scope
	Form	Map
		Story map
		Infographic
		Website
		Brochure
		ArcGIS
	Usage	User
		Maker
		Audience
		Challenges
Usability Gaps	Gap	Validity
		Readability
		Interactivity

	No gap	Validity
		Readability
		Interactivity