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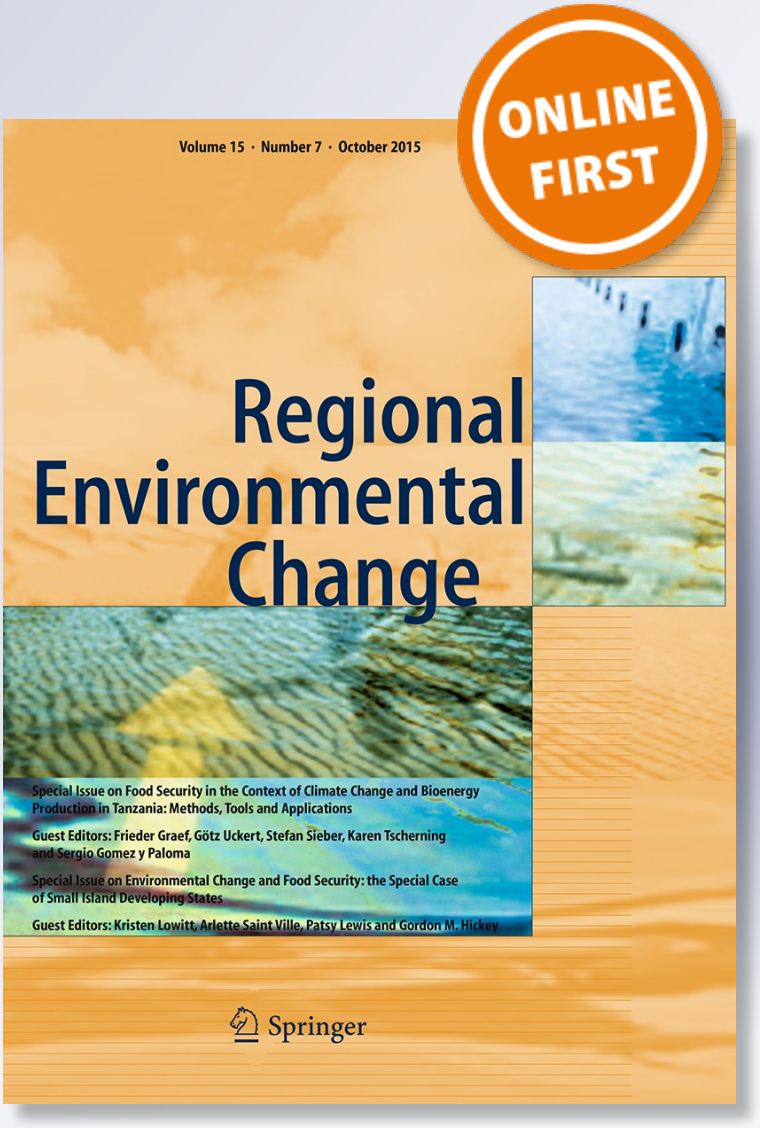

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ORIGINAL ARTICLE

Prepared for climate change? A method for the ex-ante assessment of formal responsibilities for climate adaptation in specific sectors

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Abstract Climate change-related risks encompass an intensification of extreme weather events, such as fluvial and pluvial flooding, droughts, storms, and heat stress. A transparent and comprehensive division of responsibilities is a necessary—but not the only—precondition for being prepared for climate change. In this paper, we present, and preliminarily test, a method for the ex-ante assessment of the division of public and private responsibilities for climate adaptation in terms of comprehensiveness, transparency, legitimacy, and effectiveness. This method proofs particularly suited for the assessment of adaptation responsibilities in combination with a sectoral approach. It helps identifying a number of shortcomings in divisions of responsibilities for climate adaptation. We conclude that this method is useful as a diagnostic tool for identifying the *expected* climate change preparedness level, and recommend to combine this with ex-post analyses of real-life cases of extreme events in order to assess the *actual* preparedness for climate change. Besides the scientific purpose of providing a generally applicable assessment method, with this method, we also intend to assist policymakers in developing and implementing adaptation plans at various levels.

Keywords Adaptation to climate change · Governance · Responsibilities · Internet · Assessment method · Critical infrastructures

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Introduction

Adaptation to climate change is considered necessary, as mitigation efforts are not sufficient to stop global warming, and effects of climate change are already perceptible (WMO 2013; IPCC 2014). The European Environmental Agency recently concluded that there is good progress in the development of National Adaptation Strategies and National Adaptation Plans (EEA 2014). Yet, concerning the implementation of concrete adaptation measures at the level of cities, regions, critical infrastructures, and economic sectors, in practice, adaptation takes place slowly (Amundsen et al. 2010; Biesbroek et al. 2010; Gilissen 2013; Runhaar et al. 2012). This is problematic because it could result in under-adaptation and hence in increased climate risks (Gilissen 2013; Mees et al. 2012).

An important reason for the observed slow progress in climate adaptation is a lack of clarity about the division of responsibilities for adaptation (Storbjörk 2007; Driessen and Van Rijswick 2011; Gilissen 2013; Mees et al. 2014a). On the one hand, climate change as such is usually not specified in legislation designating responsibilities to public or private actors (Gilissen 2013). On the other hand, often a variety of actors is (potentially) involved in the case of specific climate risks (Driessen and Van Rijswick 2011), take for instance, the expected intensification of heat stress

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among the elderly, particularly in urban areas. In the Netherlands, elderly care is organised by public actors (e.g. municipal health services) as well as private actors (the elderly themselves, their families, general practitioners, professional health organisations, retirement homes, etc.). It seems logical that these actors would take some responsibility in reducing heat stress and associated health impacts. However, also other actors could play a role in reducing heat stress and its effects. For instance, municipalities could invest in more green space in order to reduce the "urban heat island effect", landlords could retrofit houses (e.g. improving insulation), and project developers could invest in green roofs to cool houses (Mees et al. 2014a). Yet, most of these actors bear no direct responsibility for dealing with heat stress, let alone for reducing the expected intensification of this health risk due to climate change. This may lead to insufficient levels of preparedness for adaptation to climate change in terms of the timely implementation of a set of adaptation measures in the face of potential climate change-related disasters.

In this paper, we present a novel method for the assessment of the preparedness for dealing with climate change, based on an analysis and evaluation of responsibilities for climate adaptation. Ideally, preparedness is measured ex-post in terms of the extent to which adaptation measures result in an *actual* reduction or even avoidance of climate-related risks. However, this is often not possible, since adaptation to climate change has a relatively short history and implementation of adaptation policies is in an infant stage, and "test cases" are still scarce (Chapman et al. 2013; EEA 2014). Therefore, we present a method for the *ex-ante* assessment of (expected) preparedness based on an analysis and evaluation of responsibilities. Ex-ante assessments also fit in the recent shift from disaster risk management and reduction towards a more preventive approach in order to prevent rather than react to negative consequences, adopted by the United Nations Office for Disaster Risk Reduction[1] the European Union and Member States such as the Netherlands. This raises the question *who* should take proactive measures to avoid recovery-oriented measures as much as possible.

A transparent and comprehensive division of responsibilities is a necessary, but not the only, precondition for effective adaptation to climate change. Responsible actors also need to possess resources and competencies to exercise their responsibilities (Lorenzoni et al. 2000; Crabbé and Robin 2006; Cvitanovic et al. 2014). In addition, responsibilities will have to be considered legitimate at least by those who bear them, in order to be fully exercised. We therefore take these aspects explicitly into account. The method focuses on sectors, i.e. "cluster[s] of economic activities, such as construction, transportation, manufacturing, and financial services" (Mulder 2006: 82). Sectors also encompass critical infrastructures, e.g. the provision of electricity or ICT. Sectors encompass companies or in some cases, public organisations that deliver similar products or services (Dalziel 2007). We also take into account public actors with a regulatory function; hence, all public and private actors who bear responsibility for climate adaptation are taken into account. The method distinguishes between a broad range of adaptation responsibilities: preventive, mitigation-oriented, and recovery-oriented (these concepts are described in detail in "Responsibilities for climate adaptation" section).

Our method complements other methods that have been developed for the ex-ante assessment of climate adaptation governance. Some of these methods have concentrated on *capacities* and, in particular, the *adaptive capacity,* of societal groups, institutions, or regions (e.g. Tompkins and Adger 2005; Gupta et al. 2010; for an overview of methods, see Juhola and Kruse 2015). These methods assess the presence or absence of conditions that will enable the timely and effective adaptation to climate change (e.g. learning capacity, availability of resources, etc.); not so much the (expected) outcomes in terms of climate risk reduction. Other ex-ante assessment methods address public climate change policies and plans and aim to assess these by looking at their substance, the associated resources and capacities, and the extent to which the whole "policy cycle" is covered (e.g. Heidrich et al. 2013; Khan and Amelie 2014). There are also methods that focus on specific aspects of climate change policy; e.g. Mees et al. (2014b), who focus on policy instruments for promoting the implementation of particular adaptation measures, such as green roofs.

Our method differs from these other methods as it starts from responsibilities. Responsibilities have an important impact on what adaptation action occurs (or not); different actors may have different incentives to take adaptation measures and have different types of measures at their disposal. Our method therefore addresses another level of analysis than the above methods. Our method differs from those employed in other studies on responsibilities for climate adaptation. Various empirical studies have been conducted on this subject (e.g. Storbjörk 2007; Lundqvist and Von Borgstede 2008; Amundsen et al. 2010; Gilissen 2013; Mees et al. 2014a; Wamsler and Brink 2014). Private responsibilities are analysed by Schneider (2014), whereas Wamsler (2014) addresses citizens' institutions' responsibilities for adaptation. At a different level, Adger et al. (2012) discuss responsibilities for adaptation in terms of social contracts. Some of these studies are mono-disciplinary in nature (e.g. by employing a legal perspective; Gilissen 2013, 2014). Most studies however take a

[1] See for instance http://www.wcdrr.org/uploads/Sendai_Framework_for_Disaster_Risk_Reduction_2015-2030.pdf.

multidisciplinary perspective (e.g. Mees et al. 2014a, c). Next to empirical studies, we find more normative work that specifies principles that should guide the division of responsibilities for climate adaptation or other forms of environmental management (e.g. Berkhout 2005; Aakre and Rübbelke 2010; Driessen and Van Rijswick 2011; Mostert 2015). However, whereas in these studies the method is usually instrumental, in our case the goal is to develop an explicit method. In addition, our method integrates methods used in the above studies, such as the analysis of legal documents, and literature, case studies, interviews, and focus groups. Finally, our method encompasses both problem analysis and (re)design.

The remainder of this paper unfolds as follows. In "Key concepts" section, we will define our key concepts. In "Assessing responsibilities for climate adaptation: a stepwise approach" section, we will present our method. In "Illustration: applying the assessment method to the Dutch internet sector" section, the method will be illustrated by the assessment of the Dutch Internet sector, a critical infrastructure. In "Conclusions and reflection" section, we will reflect on our method and summarise our main conclusions.

Key concepts

Climate adaptation

The Intergovernmental Panel on Climate Change (IPCC) defines climate adaptation as "The process of adjustment to actual or expected climate change and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate change and its effects" (IPCC 2014, p. 5). In the same vein, the European Environmental Agency defines adaptation as "(…) actions taken in response to current and future climate change impacts and vulnerabilities (as well as to the climate variability that occurs in the absence of climate change) in the context of ongoing and expected socio-economic developments. It involves not only preventing negative impacts of climate change, but also building resilience and making the most of any benefits it may bring" (EEA 2014: 6). In both definitions, climate change adaptation is about dealing with the effects of climate change, which may be negative but also positive, providing new opportunities and benefits. Adaptation can take various forms—it can be planned or take place autonomously (Brooks and Adger 2005), be incremental or radical (or "transformative") in nature (Rickards and Howden 2012), etc. In "Responsibilities for climate adaptation" section, we will elaborate on the specific categorisations of climate adaptation we employed in our method.

Responsibilities

In the literature, there is discussion about the operationalisation of the concept of "*responsibility*" (Mees et al. 2012). Responsibilities are often approached in more or less neutral ways, by looking at existing legislation that specifies "who does what" Gilissen 2013, 2014). Mostert (2015) in this context distinguishes between three types of responsibilities: for policy-making, for taking measures, and for financing measures. Responsibility entails both competences that are required to exercise responsibilities, as well as accountability and sometimes financial liability for the extent to which responsibilities are fulfilled (Gilissen 2013; Van Rijswick et al. 2014; Mostert 2015). But sometimes also a more normative understanding of responsibility is adopted; in that case, issues of "who should do what" according to a particular ethical position are addressed (see e.g. Miller 2007), or to a more political understanding of responsibilities depending on what kind of adaptation policies is favourable in a certain society or political context (Driessen and Van Rijswick 2011; Keessen et al. 2013).

In our paper, we employ the "who does what" approach to responsibility. Our focus is on which tasks are explicitly or implicitly associated with climate adaptation,[2] and subsequently which actors (public and private) bear formal responsibilities for executing these tasks and can be held accountable for doing so in a proper way. This approach, consequently, is rather straightforward and replicable, and avoids normative debates, which facilitates its application in a wide variety of contexts.

Responsibilities for climate adaptation

In order to identify the specific responsibilities for climate adaptation, we take the phase in the adaptation process in which adaptation measures are taken as a starting point. An often employed distinction is that between *proactive* and *reactive* adaptation measures (e.g. Bryant et al. 2000; Amundsen et al. 2010). Proactive measures are taken before a climate change-related event happens with the aim to reduce the risks in terms of chances or consequences; reactive measures are taken after the occurrence of such an event. Both types of measures can be planned, and hence, they do not necessarily have to succeed each other in time. An example of a proactive measure in the context of flood risks, for instance, is the provision of "green roofs" for storm water retention; a reactive measure would be pumping excess

[2] Climate adaptation tasks can be explicitly assigned (e.g. in National Adaptation Strategies that are being developed now in the European Union) or be more implicit in nature. In the latter case, we think of, for instance, urban water management; a task which existed before climate adaptation was on the policy agenda, but which is influenced by the intensification in flood risks due to climate change.

water and repair damage. Other dimensions that are used to categorise adaptation measures are the spatial scale at which measures can be taken, the actor(s) involved, and the institutional level (Bryant et al. 2000; Runhaar et al. 2012). For the purpose of this paper, we decided to employ a framework that was inspired on the literature at the intersection of climate adaptation, planning, resilience, and disaster risk management, and in which (although not always in these exact terms) distinction is made between *prevention, mitigation,* and *recovery* (e.g. Keim 2008; Davoudi et al. 2013; Wamsler et al. 2013; IPCC 2014). Based on these concepts, we distinguish between the following categories related to specific types of responsibilities for adaptation:

- *Prevention:* responsibilities for the reduction in the chance of being exposed to or confronted with climate impacts, e.g. responsibilities for locational choice of vulnerable objects;
- *Mitigation:* responsibilities for reducing the consequences of climate impacts, e.g. hospitals often are obliged to have backup power supply and hence are often equipped with emergency generators;
- *Recovery:* responsibilities for repair, clean-up, and continuation of services after an extreme climate change-related weather event.

These categories are primarily used to systematically identify and classify adaptation responsibilities.

Evaluation criteria for responsibilities for climate adaptation

We evaluate divisions of responsibilities for climate adaptation in terms of how these promote the implementation of prevention-, mitigation-, and recovery-related adaptation measures in such a way that climate risks will be reduced up to acceptable levels. To this end, we propose the following evaluation criteria: *comprehensiveness* of responsibilities, their *transparency*, their *legitimacy*, and the expected *effectiveness* of the ways in which those who are responsible will implement their responsibilities. These criteria are chosen as they are regularly employed in research into climate adaptation governance (e.g. Adger et al. 2005; Van Rijswick and Salet 2012; Gilissen 2013; Hegger et al. 2014; Mees et al. 2014b), and moreover, they are associated with principles of "good governance" (Van Buuren et al. 2014).

We operationalised our criteria as follows (based on Mees et al. 2012, 2014b):

- *Comprehensiveness:* the extent to which responsibilities for prevention-, mitigation-, and recovery-related adaptation measures are (explicitly) assigned to public and/or private actors in legislation or in other documents that possess a more or less formal status (e.g. covenants);
- *Transparency:* the extent to which responsible actors have conscious knowledge of their responsibilities and those of others;
- *Legitimacy:* this criterion is defined in many different ways in the literature (see Bekkers and Edwards 2007). For the purpose of this paper, we define legitimacy as the extent to which the division of responsibilities is considered reasonable and acceptable by those who are held responsible and accountable; this will be related to the perceived balance between benefits and costs, and the perceived relation between responsibilities and available competences and resources (also compared to other actors);
- *Expected effectiveness:* the extent to which those who bear responsibilities for adaptation are likely to implement adaptation measures in such ways that climate risks are reduced to acceptable levels. The expected effectiveness of climate adaptation action depends on the comprehensiveness, transparency, and legitimacy of the division of responsibilities for adaptation. We expect that effectiveness will be higher when adaptation responsibilities encompass not only recovery-related adaptation, but also prevention- and mitigation-oriented adaptation (Mees et al. 2014c). If responsibilities for adaptation are not transparent, it is not clear who should take what adaptation action, which will probably go at the expense of expected effectiveness. Finally, the probability that responsible actors will act according to their responsibilities will probably depend on the extent to which they consider the responsibilities reasonable and acceptable. Next to a comprehensive, transparent, and legitimate division of responsibilities, literature suggests expected effectiveness will depend on available competences and resources (Lorenzoni et al. 2000; Crabbé and Robin 2006).

Assessing responsibilities for climate adaptation: a stepwise approach

In order to systematically assess responsibilities for climate adaptation on the basis of these four criteria, we suggest six research steps that are based on steps or stages that are often found in "intervention-oriented" research, namely problem analysis, diagnosis, and intervention design (Verschuren and Doorewaard 2010). The ex-ante character of our method implies we have to form a picture of how responsibilities might be exercised rather than evaluating revealed decisions and behaviour.

Below we specify the research steps, and for each research step, we suggest specific activities and data sources.

- *Step* 1: Delineation of the scope of analysis. Responsibilities for climate adaptation can be assessed for a wide range of objects, actors, activities, sectors, etc. (Mees et al. 2012, 2014a). During the development of our method, we realised that our method was particularly suitable for the assessment of responsibilities at the *sector* level (for a definition, see "Introduction" section). At this level, all three categories of adaptation responsibilities (prevention-, mitigation-, and recovery-related) can be identified. This is less the case if the focus is on a particular actor, such as an administrative body. In addition, the sector level allows for a comparative analysis of responsibilities in the light of different types of climate change risks, in contrast to a single climate change risk perspective. The choice for a specific sector evidently depends on policy priority, the research aim, and research questions at issue. Within a particular sector, further selections may be based on reasons of time, budget, etc. Another important choice that needs to be made concerning the scope of the ex-ante assessment is the time horizon of the assessment as this is of importance regarding climate projections and associated risks (IPCC 2014);
- *Step* 2: Setting the scene: characterisation of the sector at issue. Relevant aspects are the basic products or services delivered, the primary processes, the actors involved, physical objects that can be directly affected by climate change-related extreme weather events (such as buildings and infrastructures; Bozza et al. 2015), and trends that may have an impact on divisions of responsibilities for adaptation or on the vulnerability to climate change (Bahinipati and Venkatachalam 2014; Onozuka and Hagihara 2015). Important data sources for this step are literature (academic and non-academic) and interviews with specialists;
- *Step* 3: Exploration of the main climate change-related risks of the sector. A risk assessment in order to identify major climate risks related to the object at issue requires climate projections and a translation of these projections to the sector at issue (e.g. Arndt et al. 2015). This in turn requires different types of technical expertise. Again, literature and interviews are useful data sources. The outcome of the risk assessment could be presented in a matrix, with in the columns climate risks (e.g. flood- or heat-related risks) and in the rows the key physical objects or processes in the sector at issue that are at risk due to the identified climate risks (e.g. Luiijf and Van Oort 2014; see "Step 1: Delineation of the scope of analysis" section);
- *Step* 4: Examination of which actors are responsible for adaptation and what their responsibilities encompass. In "Responsibilities for climate adaptation" section, we argued that adaptation can be aimed at the prevention of climate risks, mitigation of their potential impacts, or on the recovery after an extreme weather event that is expected to intensify as a consequence of climate change. In order to identify responsibilities and responsible actors, we recommend an analysis of the responsibilities prescribed in the legislation at issue and, if relevant, other formal documents (Gilissen 2013, 2014). This analysis requires specialised legal expertise. It is important to realise that adaptation is not always the responsibility of a single actor. For instance, a prevention-related adaptation measure is a ban on locating vulnerable objects in flood-prone areas. In the Netherlands, at least two actors are involved in decision-making: municipalities via land use plans and the owners of the objects who make the investment decision (Hegger et al. 2014). It is thus important to specify who is responsible for what particular tasks and decisions. Subsequently, in order to develop a first understanding of how adaptation responsibilities might be exercised, it is recommended that an overview is made of examples of adaptation measures, clustered around the dimensions of prevention, mitigation, and recovery. Relevant sources for the identification of these measures are literature (e.g. Roders et al. 2013) and interviews with technical experts from a wide range of disciplines (depending on the object, e.g. engineers, planners, and behavioural scientists);
- *Step* 5: Assessment of responsibilities for climate change. The responsibilities for prevention, mitigation, or recovery are evaluated against the four criteria of comprehensiveness, transparency, legitimacy, and expected effectiveness (see "Evaluation criteria for responsibilities for climate adaptation" section). This step can in part be based on judgements on the part of the researchers themselves (e.g. regarding the comprehensiveness of responsibilities, based on the analysis of legislation), and in part on case study literature (e.g. evaluations of cases of weather extremes). However, we expect the evaluation of responsibilities will have to be based primarily on expert judgements due to the ex-ante character of our method (cf. De Bruin et al. 2009; see also the Introduction of this paper). Experts can be found within the sectors (representatives of companies, regulators, etc.) and at research institutes and universities. The confrontation of expectations and ideas seems important in this step, as initial expectations and ideas may be incomplete or biased;
- *Step* 6: Optimisation of responsibilities for climate change. Shortcomings in responsibilities should logically follow from the previous step. For instance, it may appear that particular responsibilities are lacking (i.e. are not comprehensive), that responsible actors do not know exactly how far-reaching their responsibilities for

adaptation go (i.e. a lack of transparency), that responsibilities are conflicting, or that other actors may more effectively exercise adaptation responsibilities. Alternatively, responsible actors may be hampered by bureaucratic barriers, such as rules, limited budgets, or a lack of political support (Jantarasami et al. 2010; Cvitanovic et al. 2014). We would advise to explore and discuss alternative divisions of responsibilities or a revision of existing ones in cooperation with the above experts (i.e. specialists and stakeholders), also in order to explore the feasibility of suggestions for optimising responsibilities for climate adaptation (Nagy et al. 2014).

Illustration: applying the assessment method to the Dutch Internet sector

In this section, we will illustrate our method by means of an assessment of climate adaptation responsibilities in a specific sector in the Netherlands. This case is meant to illustrate the method; the outcomes are not necessarily representative of Dutch sectors in general. The data are taken from commissioned research for the Dutch Knowledge for Climate programme (www.knowledgeforclimate.nl). The research aimed to support the preparation of the Dutch National Adaptation Strategy 2016, by identifying and evaluating public and private responsibilities for climate adaptation.[3] The research team consisted of six researchers with backgrounds in law, environmental governance, planning, and policy evaluation, and much experience in multidisciplinary research into climate adaptation (for the full report, see (Runhaar et al. 2014a, b).

Step 1: Delineation of the scope of analysis

In the above research project, the focus was on critical infrastructures and sectors of special importance to the Dutch economy, of which the Dutch ICT sector was one. It was quickly realised that further delineation was necessary, as this sector consists of too many subsectors to be analysed completely in the available time given for the research. The selection of the Internet subsector was based on a quick scan analysis of the relative significance of climate risks, diversity of public and private responsibilities for adaptation, and signs of potential shortcomings in divisions of responsibilities (which could intensify climate change-related risks).

The Internet subsector was selected because a preliminary Dutch risk assessment by Luiijf and Van Oort (2014) showed a relatively high risk within this subsector and for datacentres in particular (see Table 1; the darker the cells, the higher the climate risks). There also seemed to be a potential tension between private responsibilities and public interests. A quick scan survey conducted by the Dutch Ministry of Economic Affairs had shown that it was unclear whether or not datacentres are subject to the Telecommunications Act, which contains specific regulations for ensuring continuity of critical telecommunication services in the light of extreme events. As a consequence, suppliers of Internet services and datacentre operators may employ safety levels that are adequate from a commercial perspective, but not from a societal perspective given the increasing dependence on Internet.

We therefore further delineated the subsector by concentrating on datacentres. The time horizon chosen was 2030, with an outlook to 2050; this was in line with the climate change risk assessment referred to above.

Step 2: Setting the scene: characterisation of the sector at issue

The Internet datacentre subsector was characterised in terms of primary processes (e.g. transport and server services such as storage and applications), physical components (nodes such as datacentres, servers, and Internet exchanges; backbone networks; local distribution networks, etc.), and the public and private actors involved (e.g. international backbone operators; Internet service providers; (mobile) network operators; data hotels; public regulators, etc.). Subsequently, we explored trends in the selected subsectors that could affect vulnerability to climate change (again, until 2030, with an outlook to 2050). For the Internet datacentres subsector, the increasing storage of data "in the cloud" reduces the need for short physical distances between datacentres (and, with that, the proximity of backup datacentres). If, for instance, a datacentre is located in a flood-prone area and is lost during a flood, a backup datacentre outside of the flood-prone area may automatically take over the services. In this way, it becomes easier to organise backup capacity ("redundancy") on a larger geographical scale, reducing (local) vulnerabilities. We also looked at trends in related sectors—for instance, the increase in Internet-based services in the energy and transport increases the dependency on the Internet subsector (which reinforces the need for climate change preparedness in the Internet subsector).

[3] In this research project, we analysed and evaluated responsibilities for climate adaptation from four perspectives: the sector perspective (looking at the internet/datacentre subsector, electricity supply, and inland navigation), a territorial level (by looking at the organisation of large-scale evacuations in areas near large rivers), the perspective of a specific climate change-related risk (namely, heat stress reduction among independent living elderly), and an administrative perspective (by evaluating the role of the Dutch Regional Safety Authorities in managing situations in which multiple extreme weather events occur, resulting in so-called cascade effects).

Table 1 Assessment of climate change-related risks in the ICT sector: vulnerability of ICT infrastructure or objects (rows) to climate change-related weather phenomena (columns)

Phenomenon / ICT-infrastructure/ objects	High temperatures/ heat wave	Drought	Extreme winds	Heavy precipitation (with thunderstorms and hail)	Flooding as a result of sea level rise or high level river discharge
General					
All physical components	Reduced product life	Reduced product life		Reduced product life	
International backbones					
Trans-Atlantic cables					
Satellite communication			Lower signal strength / Signal interference	Lower signal strength / Signal interference	
Fibre connections		Land settlement	Uprooting	Land settlement Lightning damage	
(National) backbones telecom/ICT-operators and closed networks					
Fibre connections		Land settlement	Uprooting	Land settlement Lightning damage	
Microwave transmissions/ beamforming			Lower signal strength / Signal interference	Lower signal strength / Signal interference	
Buildings/physical objects					
- Computer centres - Server hotels / hosting/ cloud - Datacentres of internet and application service providers	Temperature control Legionella Energy supply	Humidity		Humidity (Partially) flooded	(Partially) flooded
Technical switches and exchange points incl. local exchange	Temperature control Legionella Energy supply	Humidity		Humidity (Partially) flooded	(Partially) flooded
Transmitter parks				Lightning damage	(Partially) flooded
Distribution networks					
Fixed network (copper, coax, fibre) and street cabinets		Land settlement		Land settlement Lightning damage Water in street cabinet	(Partially) flooded
Antenna	Temperature control (of attached cabinets)		Mechanical damage Uprooting	Lightning damage Flooded switchboards and batteries	Flooded switchboards and batteries
Mobile signal propagation				Lower signal strength / Signal interference	

Light grey = possible risk factor requires attention; mid-grey = possible temporary outage, recovery takes a few days; dark grey = possible serious, enduring damage, recovery takes time. *Source* Luiijf and Van Oort 2014: 24

Step 3: Exploration of the main climate change-related risks

The risk assessments were based on the study by Luiijf and Van Oort (2014), referred to above, as well as other studies that were available (e.g. RoyalhaskoningDHV 2012; Delta programme 2014). These risk assessments were (logically) qualitative of nature and were based on climate change projections conducted by the Royal Netherlands Meteorological Institute (KNMI 2014). The study by Luiijf and Van Oort (2014) was the most comprehensive risk assessment for the Internet datacentre subsector. It consisted of a translation of the projections of the Royal Netherlands Meteorological Institute to the subsector at issue, based on expert judgements, which were validated during workshops with sector specialists—stakeholders, researchers, and policy-makers. The risk assessments made clear what aspects of the Internet datacentre subsector were particularly vulnerable to which climate change-related risks.

For the Internet datacentre subsector, an increased risk of flooding appeared to be the main climate-related risk, not only for datacentres but also for other Internet-related assets (see Table 1). Heat waves can also cause problems in terms of cooling of datacentres; too little surface water might be available for either direct cooling or the cooling of electricity plants. During the focus group session, which

we organised later on in the project in particular for step 5 (see "Step 5: Assessment of responsibilities for climate change" section), these conclusions were confirmed. Climate risks may also affect the Internet datacentre subsector indirectly, namely in the case of disruption of power supply caused by e.g. floods (Luiijf and Van Oort 2014).

The societal consequences of calamities in the Internet datacentre subsector may be huge. In the risk assessment conducted by Luiijf and Van Oort (2014), no specific assessment is made of the potential societal consequences of disruption of the Internet datacentre subsector. For the ICT sector as a whole, estimations are made. Severe downpours (with a probability of about once every 5 years) may affect 1000–100,000 people. Extreme, large-scale floods (1/500–1000 years) may affect 100,000–10,000,000 people (Luiijf and Van Oort 2014: 30).

Step 4: Analysis of responsibilities

An analysis of relevant national (read Dutch) legislation revealed the formal responsibilities of actors within the Internet datacentre subsector. Most responsibilities were enshrined in the Telecommunications Act. Regarding locational choice of datacentres, also the Spatial Planning Act is relevant, as this Act assigns the authority to allow or ban the location of particular activities to municipalities. Subsequently, an analysis was made of which responsibilities are (potentially) relevant for adaptation to climate change. Since adaptation is not explicitly mentioned in the legislation at issue, this analysis was quite an effort. The typology of prevention-, mitigation-, and recovery-related responsibilities outlined in "Responsibilities for climate adaptation" section nevertheless helped identifying responsibilities for adaptation. An important *prevention-related* adaptation responsibility concerns locational choice. Regarding *mitigation*, responsibilities for the architecture of datacentres are important (consequences of floods depend in part on e.g. the thickness of walls or the positioning of equipment within the datacentre). Finally, regarding *recovery*, the responsibility for developing and implementing emergency plans for repairing damaged equipment of datacentres is important. Examples of concrete adaptation measures related to these responsibilities are locating new datacentres in, and relocate existing ones to, less flood-prone areas in order to avoid exposure to floods (prevention), an elevated position of equipment, thick walls, high thresholds but also the provision of backup capacity in other locations (mitigation), and repair plans (recovery).

As part of the legal analysis we looked at how detailed responsibilities were defined. For instance, the Spatial Planning Act charges municipalities with the responsibility to take care of a "good spatial planning". This includes a safe allocation of spatial functions; however, climate risks are not mentioned as such in this Act. The Telecommunications Act states that providers of public electronic communication networks and services have the legal obligation to "develop and test continuity plans which specify the technical and organisational measures that will be taken in order to reduce risks and to recover after calamities". A public agency is charged with inspection of these plans. Internet datacentres do not provide services that are subject to these inspections. "Risks" and "calamities" seem to include climate risks, but that is not explicitly stated. The Telecommunications Act also leaves a lot of discretion to companies to develop and implement specific measures and strategies to reduce risks and recover from calamities. Therefore, the level of reliability of Internet and datacentre services is largely determined by market forces.

Step 5: Assessment of responsibilities for climate change

The assessment of responsibilities for climate adaptation was among the most important, but also most complicated activities. We assessed each of the three categories of adaptation responsibilities in a qualitative way against the four criteria of comprehensiveness, transparency, legitimacy, and expected effectiveness, which in combination provide an estimation of the level of preparedness for climate change (see "Evaluation criteria for responsibilities for climate adaptation" section). In the online Electronic Supplementary Material document, we show our operationalisation of the four evaluation criteria measured on a four-point scale in order to support this step. Regarding the expected effectiveness, adaptation measures were assessed against the specific aspect of adaptation to which the measure relates (i.e. prevention, mitigation, or recovery).

First, we made a preliminary assessment based on the analysis of how formal responsibilities were described in laws, on three interviews that we conducted with sector specialists (one security officer working for a large ICT company, one urban planner in a city where relatively many datacentres are located, and one IT and ICT specialist working for an editor of professional journals in these sectors), and on literature. This gave us an impression of how responsible actors in practice are likely to act upon their responsibilities. Second, the preliminary assessment was validated and refined during a focus group session, in which experts participated. The participants had different backgrounds (two representatives of companies in the subsectors at issue; one representative of policy-making and regulatory public agencies; one representative of a municipality that hosts many datacentres in the Netherlands). One researcher could not attend the focus group meeting, but responded on the results of the meeting afterwards. The participants all had senior positions.

Anticipating on or dealing with extreme weather events formed part of their work. We had identified the participants during the workshops that formed part of the risk assessments (see"Step 3: Exploration of the main climate change related risks" section [4]) and by contacting organisations that appeared to bear responsibilities for climate change (see "Step 4: Analysis of responsibilities" section). One of the participants was interviewed prior to the focus group session in order to collect data for step 2–4. The focus group session aimed at validating our conclusions regarding steps 1–5 and to validate, refine, and complement our preliminary findings regarding step 6. A focus group is "a research technique that collects data through group interaction on a topic predetermined by the researcher" (Morgan 1996, in Säynäjoki et al. 2014: 6625). A key characteristic of focus groups (as opposed to individual expert interviews) is the interaction between participants, which allows for confronting perspectives, which in turn may make individual reasoning explicit and facilitate reflecting on these individual perspectives and how they relate to other perspectives (Säynäjoki et al. 2014). Focus groups thus often result in richer pictures of the subject of issue than individual interviews.

Prior to the meeting, the participants of the focus group sessions received the slides of a presentation with the preliminary findings. Our preliminary assessment of responsibilities was summarised in three tables (for prevention-, mitigation-, and recovery-related responsibilities, respectively; see the online Electronic Supplementary Material document for the format of these tables). This presentation formed the basis of the discussions during the focus group session, which lasted for about 2 h. Two researchers were involved: one facilitated the session, whereas the second observed and made notes. In order to avoid one or more participants dominating the discussion (one of the potential downsides of focus group sessions; Wilson 2012; Säynäjoki et al. 2014), we tried as much as possible to ask inputs from each participant and, when making intermediate conclusions, asking whether everyone agreed. We felt the focus group session had clear advantages over individual interviews, because it allowed us to discuss inputs from individual participants that were not mentioned by the other participants (which in this case did not yield disagreement) and to refine (the argumentation behind) the assessment of responsibilities for climate adaptation. The results were summarised and returned to the participants for comments. Two of the participants responded, which led to some minor revisions of the analysis.

In the online Electronic Supplementary Material document, we summarise the final assessment of responsibilities for prevention-, mitigation-, and recovery-related adaptation measures, in the form of short narratives. The general impression is that responsibilities for climate adaptation are (almost) comprehensively assigned, and that responsibilities in general are clear to the actors involved and hence are transparent. In addition, the focus group confirmed our impression that the division of responsibilities for adaptation is largely perceived as legitimate by those bearing responsibilities. We have identified various problems regarding the expected effectiveness of responsibilities for adaptation. The first problem is that responsibilities are formulated at a very abstract level; adaptation to climate-related risks is not mentioned as such (see "Step 4: Analysis of responsibilities" section). Public and private actors therefore have a relatively large degree of autonomy to exercise their responsibilities, including how they anticipate climate change-related risks. This is not problematic in terms of the expected effectiveness of adaptation measures to be implemented as long as actors involved are aware of climate risks, have knowledge of their magnitude, and if necessary, feel a sense of urgency to timely act upon these risks. Yet, from the interviews and the focus group session, it appeared that climate change-related risks are not considered as urgent in the subsector, although there seems to be an increasing awareness of these risks.[5] The perceived lack of urgency in the Internet datacentre sector may have two causes: (a) risks and responsibilities to adapt to these risks are insufficiently known; (b) risks are considered relatively unimportant. Although risk management measures and plans are developed in the Internet datacentre subsector, these deal with risks in general and not in relation to climate change. In addition, risk management measures and plans are primarily aimed at mitigation and recovery; think of redundancy in Internet networks and connections, the provision of backup capacity, and continuity plans (Luiijf and Van Oort 2014).[6] It seems that chances are missed to reduce risks by means of prevention-related measures. In sum, the Internet datacentre subsector seems only moderately prepared for climate change if we look at divisions of responsibilities. This forms a risk, given the recent climate change risk assessment for the ICT sector (see Table 1) and the growing dependence of (the Dutch) society on Internet and datacentres (see also Muilwijk et al. 2014).

[4] These workshops were organised by research institute TNO with the aim to refine the climate risks for (among toher things) the internet datacentre sector and to explore how the sectors could respond to these risks (i.e., identify adaptation measures). In contrast to the focus group session that we organised, the workshops did not aim to generate consensus about some specific research questions; instead, the workshops were more open and exploratory of nature.

[5] Similar findings were found in the other sectors that we analysed as part of the commissioned research project referred to at the start of this section.

[6] Again, this is also what we found in the analysis of the other sectors.

Step 6: Optimisation of responsibilities for climate adaptation

The final step was also based on a preliminary assessment of the project team, validated, refined, and complemented by means of the focus group sessions. An important issue for the Internet datacentre subsector is that climate change-related risks are still rather uncertain. More accurate projections are required to assess the magnitude of specific risks, as well as how well-prepared the subsector is. A more explicit formulation of responsibilities for climate adaptation could both provide an incentive to companies in this subsector to conduct climate risk assessments and raise awareness. In addition, a legal requirement to explicitly assess and consider available adaptation measures, including prevention-related ones, is expected to contribute to preparedness to climate change. Too strictly formulated requirements, however, could go at the expense of the legitimacy of responsibilities for dealing with climate change-related risks as perceived by the sector.

Conclusions and reflection

In this paper, we propose a method for the ex-ante assessment of preparedness for climate change. The method deviates from other methods by taking formal responsibilities as the starting point of the assessment. Responsibilities for adaptation matter, among other things because vague responsibilities are often considered a barrier to climate adaptation (Mees et al. 2012). We illustrated the method by applying it to the Dutch Internet datacentre subsector. This example showed that our method is a useful diagnostic tool to qualitatively assess preparedness for climate change by identifying (potential) shortcomings in divisions of responsibilities and how these are implemented. If possible, we recommend to combine an ex-ante assessment with ex-post analyses of real-life cases of extreme weather events (storms, downpours, etc.), in order to assess the actual preparedness for climate change. An alternative could be scenario analysis, in order to explore how actors who are responsible for climate adaptation act or expect to act in the light of a particular extreme weather event (see e.g. Yang et al. 2014).

As we indicated in the Introduction of this paper, the method is based on the sectoral level: the set of actors involved in the supply and consumption of particular products and services. This also seems the most appropriate level for this method. It is relatively delineated, with specific end services or products, and allows identifying a reasonable amount of actors, responsibilities, and variables associated with expected effectiveness. Other levels, based on spatial scales (e.g. cities) or on specific themes (e.g. water safety), seem more difficult to assess by means of our method, as they are less demarcated in terms of legislation. At this level, a capacity-oriented approach, which assesses conditions rather than outcomes (see "Introduction" section), seems more appropriate.

In the application of our method, we learned a couple of lessons about how the method can best be used and refined. First, we realised that the focus group session is a very important source of information, not only for steps 5 and 6, but also for steps 1–4. For instance, a focus group can shed light on *informal* responsibilities: actors who do more regarding climate adaptation than what the law prescribed.[7] Second, we concluded that the geographical delineation (part of step 1) should be more explicitly considered. The Internet datacentre subsector, for instance, is increasingly organised at the international level; breakdown of backbones or failure of foreign datacentres may have large impacts on Dutch users of Internet services. Focusing on multiple countries complicates the legal analysis, but may yield more policy-relevant assessments. Third, we found that our set of evaluation criteria (see "Evaluation criteria for responsibilities for climate adaptation" section) should be expanded. As the Internet datacentre subsector case showed, expected effectiveness of adaptation measures to be implemented not only depends on a comprehensive, transparent, and legitimate division of responsibilities, but also on the *explicitness* of responsibilities for adaptation, and on *availability of climate risks, awareness* of these risks, and an associated *sense of urgency* (cf. Uittenbroek et al. 2013; 2014; Juhola and Kruse 2015). These four criteria should therefore be included in the assessment of responsibilities. Fourth, and finally, our method does not directly allow for the assessment of the *relative* expected effectiveness of each of the three categories of adaptation responsibilities (prevention, mitigation, or recovery), since the assessment is based on the extent to which responsibilities are expected to be effective regarding each of these dimensions of adaptation. This policy-relevant issue should be added to step 6 (optimise responsibilities); we also suggest to use a focus group session in order to provide input for this issue.

The scientific contribution of our paper is the provision of a novel method for assessing preparedness for climate change, focusing not only on conditions for preparedness, but also on the expected effectiveness of adaptation measures to be implemented, by looking at who does or will do what. Other novel features of the method are its broad approach to adaptation (including prevention-, mitigation-, and recovery-related responsibilities), the possibility to

[7] In the Netherlands, for instance, in a few cities where climate adaptation measures were implemented, it was found that the municipality had taken action, although from a legal perspective also owners of land and buildings are responsible for the management of rain water and protection against flooding (Runhaar et al. 2012).

take both public and private actors into account, and its focus on specific services and products instead of actors, institutions, or specific adaptation measures.

In the light of studies that have found that society is not prepared well enough for climate change (see "Introduction" section), we encourage policy-makers and companies to use our method to assess responsibilities for climate adaptation in sectors vulnerable to climate risks and (perhaps more importantly) to structure thinking and deliberating about if and how to address climate change-related risks, and who should do what—the normative and political dimension of "responsibilities".

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References

Aakre S, Rübbelke DTG (2010) Objectives of public economic policy and the adaptation to climate change. J Environ Plan Manage 53(6):767–791

Adger WN, Arnell NW, Tompkins EL (2005) Successful adaptation to climate change across scales. Glob Environ Change 15(2):77–86

Adger WN, Quinn T, Lorenzoni I, Murphy C, Sweeney J (2012) Changing social contracts in climate change adaptation. Nat Clim Change. doi:10.1038/nclimate1751

Amundsen H, Berglund F, Westskog H (2010) Overcoming barriers to climate change adaptation—a question of multilevel governance? Environ Plann C Gov Policy 28:276–289

Arndt C, Tarp F, Thurlow J (2015) The economic costs of climate change: a multi-sector impact assessment for Vietnam. Sustainability 7(4):4131–4145

Bahinipati CS, Venkatachalam L (2014) Role of climate risks and socio-economic factors in influencing the impact of climatic extremes: a normalisation study in the context of Odisha, India. Reg Environ Change. doi:10.1007/s10113-014-0735-4

Bekkers V, Edwards A (2007) Legitimacy and democracy: a conceptual framework for assessing governance practices. In: Bekkers V, Dijkstra G, Edwards A, Fenger M (eds) Governance and the democratic deficit. Assessing the democratic legitimacy of governance practices, Ashgate, pp 35–60

Berkhout F (2005) Rationales for adaptation in EU climate change policies. Clim Policy 5(3):377–390

Biesbroek GR, Swart RJ, Carter TR, Cowan C, Henrichs T, Mela H, Morecroft MD, Rey D (2010) Europe adapts to climate change: comparing national adaptation strategies. Glob Environ Change 20:440–450

Bozza A, Asprone D, Manfredi G (2015) Developing an integrated framework to quantify resilience of urban systems against disasters. Nat Hazards 78(3):1729–1748

Brooks N, Adger WN (2005) Assessing and enhancing adaptive capacity. In: Lim B, Spanger-Siegfried E, Burton I, Malone E, Huq S (eds) Adaptation policy frameworks for climate change: developing strategies, policies and measures. Cambridge University Press, Cambridge, pp 165–181

Bryant CR, Smit B, Brklacich M, Johnston TR, Smithers J, Chiotti Q, Singh B (2000) Adaptation in Canadian agriculture to climatic variability and change. Clim Change 45(1):181–201

Chapman L, Azevedo JA, Prieto-Lopez T (2013) Urban heat & critical infrastructure networks: a viewpoint. Urban Clim 3:7–12

Crabbé P, Robin M (2006) Institutional adaptation of water resource infrastructures to climate change in eastern Ontario. Clim Change 78:103–133

Cvitanovic C, Marshall NA, Wilson SK, Dobbs K, Hobday AJ (2014) Perceptions of Australian marine protected area managers regarding the role, importance, and achievability of adaptation for managing the risks of climate change. Ecol Soc 19(4):33

Dalziel M (2007) A systems-based approach to industry classification. Res Policy 36(10):1559–1574

Davoudi S, Brooks E, Mehmood A (2013) Evolutionary resilience and strategies for climate adaptation. Plan Pract Res 28(3):307–322

De Bruin K, Dellink RB, Ruijs A, Bolwidt L, Van Buuren A, Graveland J, De Groot RS, Kuikman PJ, Reinhard S, Roetter RP, Tassone VC, Verhagen A, Van Ierland EC (2009) Adapting to climate change in the Netherlands: an inventory of climate adaptation options and ranking of alternatives. Clim Change 95(1–2):23–45

Delta programme (2014) Dashboards. Ministry of Infrastructure and the Environment, The Hague

Driessen PPJ, Van Rijswick HFMW (2011) Normative aspects of climate adaptation policies. Clim Law 2:559–581

EEA (2014) National adaptation policy processes in European countries—2014. European Environment Agency, Copenhagen

Gilissen HK (2013) Adaptatie aan klimaatverandering in het Nederlandse waterbeheer. Verantwoordelijkheden en aansprakelijkheid. Dissertation, Utrecht University, Kluwer, Deventer

Gilissen HK (2014) The integration of the adaptation approach into EU and Dutch legislation on flood risk management. J Water Law 24(3/4):157–165

Gupta J, Termeer C, Klostermann J, Meijerink S, Van den Brink M, Jong P, Nooteboom S, Bergsma E (2010) The adaptive capacity wheel: a method to assess the inherent characteristics of institutions to enable the adaptive capacity of society. Environ Sci Policy 13(6):459–471

Hegger D, Driessen P, Dieperink C, Wiering M, Raadgever T, Van Rijswick M (2014) Assessing stability and dynamics in flood risk governance, an empirically illustrated research approach. Water Resour Manage 28(12):4127–4142

Heidrich O, Dawson RJ, Reckien D, Walsh CL (2013) Assessment of the climate preparedness of 30 urban areas in the UK. Clim Change 120(4):771–784

IPCC, 2014: Summary for policymakers. In: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Field, C.B., V.R. Barros, D.J. Dokken, K.J. Mach, M.D. Mastrandrea, T.E. Bilir, M. Chatterjee, K.L. Ebi, Y.O. Estrada, R.C. Genova, B. Girma, E.S. Kissel, A.N. Levy, S. MacCracken, P.R. Mastrandrea, and L.L. White (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, pp 1–32

Jantarasami LC, Lawler JJ, Thomas CW (2010) Institutional barriers to climate change adaptation in U.S. national parks and forests. Ecol Soc 15(4):33

Juhola S, Kruse S (2015) A framework for analysing regional adaptive capacity assessments: challenges for methodology and policy making. Mitig Adapt Strat Glob Change 20:99–120
Keessen AM, Hamer JM, Van Rijswick HFMW, Wiering M (2013) The concept of resilience from a normative perspective: examples from Dutch adaptation strategies. Ecol Soc 18(2):45
Keim ME (2008) Building human resilience. The role of public health preparedness and response as an adaptation to climate change. Am J Prev Med 35(5):508–516
Khan A, Amelie V (2015) Assessing climate change readiness in Seychelles: implications for ecosystem-based adaptation mainstreaming and marine spatial planning. Reg Environ Change 15(4):721–733
KNMI (2014) KNMI'14 klimaatscenario's voor Nederland. Royal Netherlands Meteorological Institute, Bilthoven. www.knmi.nl/cms/mmbase/attachments/119676/KNMI'14-klimaatscenario's_folder__webversie.pdf. Accessed 25 March 2015
Lorenzoni I, Jordan A, Hulme M, Kerry Turner R, O'Riordan T (2000) A co-evolutionary approach to climate change impact assessment: part I. Integrating socio-economic and climate change scenarios. Glob Environ Change 10(2):57–68
Luiijf E, Van Oort S (2014) Klimaatadaptatie en de sector Informatie- en Communicatie Technologie (ICT), TNO, delft
Lundqvist LJ, Von Borgstede C (2008) Whose responsibility? Swedish local decision makers and the scale of climate change abatement. Urban Aff Rev 43(3):299–324
Mees HLP, Driessen PPJ, Runhaar HAC (2012) Exploring the scope of public and private responsibilities for climate adaptation. J Environ Plan Policy Manage 14(3):305–330
Mees H, Driessen P, Runhaar H (2014a) 'Cool' governance of a 'hot' climate issue: public and private responsibilities for the protection of vulnerable citizens against extreme heat. Reg Environ Change 15(6):1065–1079
Mees H, Dijk J, Van Soest D, Driessen P, Van Rijswick M, Runhaar H (2014b) A method for the deliberate and deliberative selection of policy instrument mixes for climate change adaptation. Ecol Soc 19(2):58
Mees HLP, Driessen PPJ, Runhaar HAC (2014c) Legitimate adaptive flood risk governance beyond the dikes: the cases of Hamburg, Helsinki and Rotterdam. Reg Environ Change 14:671–682
Miller D (2007) National responsibility and global justice. Oxford University Press, Oxford
Morgan DL (1996) Focus groups. Annu Rev Sociol 22(1):129–152
Mostert E (2015) Who should do what in environmental management? Twelve principles for allocating responsibilities. Environ Sci Policy 45(1):123–131
Muilwijk H, Knoop J, de Hollander G (2014) Maatschappelijke ontwrichting en overstromingen. Netherlands Environmental Assessment Agency PBL, Bilthoven
Mulder M (2006) EU-level competence development projects in agri-food-environment: the involvement of sectoral social partners. J Eur Indust Train 30(2):80–99
Nagy GJ, Seijo L, Verocai JE, Bidegain M (2014) Stakeholders' climate perception and adaptation in coastal Uruguay. Int J Clim Change Strateg Manag 6(1):63–84
Onozuka D, Hagihara A (2015) Variation in vulnerability to extreme-temperature-related mortality in Japan: a 40-year time-series analysis. Environ Res 140:177–184
Rickards L, Howden M (2012) Transformational adaptation: agriculture and climate change. Crop Pasture Sci 63:240–250
Roders M, Straub A, Visscher H (2013) Evaluation of climate change adaptation measures by Dutch housing associations. Struct Surv 31(4):267–282
RoyalHaskoningDHV (2012) Analyse waterrobuuste inrichting. Voor nieuwbouw en vitale & kwetsbare functies. Rapportage. By order of the Ministry of Infrastructure and the Environment. RoyalHaskoningDHV, Amersfoort
Runhaar HAC, Mees H, Wardekker A, Van der Sluijs J, Driessen PPJ (2012) Adaptation to climate change related risks in Dutch urban areas: stimuli and barriers. Reg Environ Change 12:777–790
Runhaar HAC, Gilissen HK, Uittenbroek CJ, Mees HLP, Van Rijswick HFMW (2014a) Publieke en/of private verantwoordelijkheden voor klimaatadaptatie. Een juridisch-bestuurlijke analyse en eerste beoordeling. Utrecht University, Utrecht (available from Publieke en/of private verantwoordelijkheden voor klimaatadaptatie. Een juridisch-bestuurlijke analyse en eerste beoordeling)
Runhaar H, Gilissen HK, Uittenbroek C, Mees H, Van Rijswick M (2014b) Public and private responsibilities for climate adaptation. A legal-administrative analysis and a first assessment (fact sheet), Utrecht University, Copernicus Institute for Sustainable Development, Utrecht
Säynäjoki ES, Heinonen J, Junnila S (2014) The power of urban planning on environmental sustainability: a focus group study in Finland. Sustainability 6:6622–6643
Schneider T (2014) Responsibility for private sector adaptation to climate change. Ecol Soc 19(2):8
Storbjörk S (2007) Governing climate adaptation in the local arena: challenges of risk management and planning in Sweden. Local Environ 12(5):457–469
Tompkins EL, Adger WN (2005) Defining response capacity to enhance climate change policy. Environ Sci Policy 8(6):562–571
Uittenbroek CJ, Janssen-Jansen LB, Runhaar HAC (2013) Mainstreaming climate adaptation into urban planning: overcoming barriers, seizing opportunities and evaluating the results in two Dutch case studies. Reg Environ Change 13(2):399–411
Uittenbroek C, Janssen-Jansen L, Spit T, Runhaar H (2014) Organizational values and the implications for mainstreaming climate adaptation in Dutch municipalities: using Q methodology. J Water Clim Change 5(3):443–456
Van Buuren A, Driessen P, Teisman G, Van Rijswick M (2014) Toward legitimate governance strategies for climate adaptation in the Netherlands: combining insights from a legal, planning, and network perspective. Reg Environ Change 14(3):1021–1033
Van Rijswick M, Salet W (2012) Enabling the contextualization of legal rules in responsive strategies to climate change. Ecol Soc 17(2):18
Van Rijswick M, Edelenbos J, Hellegers P, Kok M, Kuks S (2014) Ten building blocks for sustainable water governance: an integrated method to assess the governance of water. Water Int 39(5):725–742
Verschuren P, Doorewaard H (2010) Designing a research project, 2nd edn. Eleven International Publishing, The Hague
Wamsler C, Brink E (2014) Interfacing citizens' and institutions' practice and responsibilities for climate change adaptation. Urban Clim 7:64–91
Wamsler C, Brink E, Rivera C (2013) Planning for climate change in urban areas: from theory to practice. J Clean Prod 50:68–81
Wilson V (2012) Research methods: focus groups. Evid Based Libr Inf Pract 7(1):129–131
WMO (2013) The global climate 2001–2010. A decade of climate extremes. Summary report. WMO-No. 1119, World Meteorological Organization, Geneva, Switzerland
Yang L, Scheffran J, Qin H, You Q (2014) Climate-related flood risks and urban responses in the Pearl River Delta, China. Reg Environ Change 15(2):379–391