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Article

Comparing Climate Impact Assessments for Rural Adaptation Planning in Germany and the Netherlands

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Abstract
The consensus nowadays is that there is a need to adapt to increasingly occurring climate impacts by means of adaptation plans. However, only a minority of European cities has an approved climate adaptation plan by now. To support stakeholder dialogue and decision-making processes in climate adaptation planning, a detailed spatial information and evidence base in terms of a climate impact assessment is needed. This article aims to compare the climate impact assessment done in the context of two regional climate change adaptation planning processes in a Dutch and a German region. To do so, a comparison of guidelines and handbooks, methodological approaches, available data, and resulting maps and products is conducted. Similarities and differences between the two approaches with a particular focus on the input and output of such analysis are identified and both processes are assessed using a set of previously defined quality criteria. Both studies apply a similar conceptualisation of climate impacts and focus strongly on issues concerning their visualisation and communication. At the same time, the methods of how climate impacts are calculated and mapped are quite different. The discussion and conclusion section highlights the need to systematically consider climatic and socio-economic changes when carrying out a climate impact assessment, to focus on a strong visualisation of results for different stakeholder groups, and to link the results to planning processes and especially funding opportunities.

Keywords
adaptation; climate change; Germany; impact assessment; stress test; the Netherlands

Issue
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1. Introduction

The need to adapt to increasingly occurring climate impacts by means of adaptation plans is more or less a consensus among scholars. However, so far only a minority of European cities has an approved climate adaptation plan. Reckien et al. (2018) found that only about 11% had a dedicated climate adaptation plan in 2018, with western European cities being better represented than eastern European cities. Aguiar et al. (2018) analysed that large cities can often fund the development of adaptation plans locally, while smaller and more rural municipalities depend on external funding and subsidies. The degree of the cities’ vulnerability to climate change (Aguiar et al., 2018) is a driving factor, among others.

In line with that, scholars report a multitude of barriers affecting the development of climate adaptation plans (e.g., Archie et al., 2014; Runhaar et al., 2012). Biesbroek et al. (2013) distinguish, based on the fourth Intergovernmental Panel on Climate Change (IPCC) assessment report (Adger et al., 2007), institutional, social, informational, financial, and cognitive categories of barriers to adaptation. While institutional and social aspects, such as lack of political commitment or limited awareness of climate adaptation needs, are found to be key barriers to adaptation (Greiving & Fleischhauer, 2012), informational barriers, such as the lack of scientific knowledge on climate impacts and vulnerability, are hardly found to be important in empirical studies. However, Ford and King (2015) describe, for a region in Canada, that the existence of impact, vulnerability, and adaptation assessments is crucial for the adaptation readiness of the community, and Runhaar et al. (2012) report that the lack of insight into local impacts of climate change is making it difficult to translate climate change challenges to the local level.

We conclude that a detailed spatial information and evidence base in terms of a climate impact assessment is needed to stimulate adaptation planning (Greiving, 2019). However, it is not only the demand for more information that is important, but rather the quality of the information and how it is presented and made available. Hanger et al. (2013, p. 98) found in eight European countries the “need of policymakers at all stages of adaptation planning was not a lack of information but the need for better filtered and accessible information.” Therefore, the “art in geovisualisation supporting climate change adaptation” (Neset et al., 2016, p. 3) is essential. In other words, besides the methods and data used for climate impact assessment, the way potential impacts are presented and communicated also determines its usability for adaptation planning. In science and practice, there are different definitions and methods for determining climate impacts. Therefore, this article aims at international comparative research, analysing two different analytic approaches in rural areas in the Netherlands and Germany, two neighbouring countries in central Europe, that face similar challenges in terms of climate adaptation.

This article investigates the research question of whether the two climate impact analyses serve to provide quantitative evidence supporting (regional, local, and individual) climate adaptation focussing on rural areas in Germany and the Netherlands. To answer the question, the following sub-questions will be discussed:

- What are the similarities and differences concerning the input and conduction of climate impact assessments?
- What are the similarities and differences concerning the output of the climate impact assessments?
- How can the quality of both methodologies be evaluated based on defined quality criteria?

2. Background

To discuss the differences of the named climate impact assessments, the term climate impact is defined as follows: Climate impacts result according to the IPCC (2014, p. 5) “from the interaction of climate-related hazards with the vulnerability and exposure of human and natural systems.” Climate hazards, in this article referred as climate stressors, are extreme weather events such as flooding or extreme heat, while sensitivity refers to the presence of people, infrastructure or other assets in places and settings that are affected by the hazard, and vulnerability depicts their predisposition to be adversely affected, e.g., because of high sensitivity and a limited capacity to adapt to it. In this article, we will make use of the following terminology to distinguish the different components of a climate impact assessment. Climate stressors describe the potential effect of the changing climate on the system taking a spatial occurrence into account. Climate sensitivity describes the affected systems (e.g., economic sector, population group, ecosystems) due to their characteristics. Climate impacts describe the observed or potential effect of the climate (change) on the system, taking into account the corresponding sensitivity and climate stressors.

Assessment methods generally serve to inform evaluation processes with evidence. Accordingly, they consist of a factual model, a target system and a set of allocation and aggregation rules. Overall, there is no one-size-fits-all assessment method, but more or less appropriate procedures, whereby the appropriateness can only be judged in the individual case and by considering the given context, while it is undisputed that the chosen methodological approach must be consistent in itself (Faßbender, 2012). In science, there are different criteria to judge the different approaches. Whereas some criteria strongly focus on the technical conduction of the assessment (see Greiving, 2019; Scholles, 2005), others focus more on the overall process, stakeholder integration, communication, and visualisation (see Hanger et al., 2013; Neset et al., 2016).

Following Scholles (2005) and Greiving (2019), we consider the following criteria to be relevant concerning the conduction of climate impact assessments. It should be possible to carry out a climate impact assessment objectively, i.e., independently of the person conducting it. In other words, a repeated run of the assessment under the same contextual conditions should produce the same results. At the same time, individual cases must be treated according to uniform standards based on a politically legitimised target system and, if they are comparable, must also be treated equally. Both criteria—intersubjectivity and reliability–are only given when the climate impact assessments entail a high degree of standardisation. Furthermore, the process and result of the climate impact assessment need to be transparent and comprehensible for the decision maker, but also for those who are affected by these decisions (Greiving, 2019; Scholles, 2005).

Several studies have demonstrated that it is not only a matter of how a climate impact assessment is conducted but how it is communicated to policymakers

(Mabon, 2020; Neset et al., 2016). Particularly, the communication of the uncertainty of a climate impact assessment is of great importance (Hanger et al., 2013). Therefore, the tools used for their visualisation are essential. In 2016, Neset et al. developed four categories of tools, distinguishing between their data content and functionalities (Neset et al., 2016, p. 14). Accordingly, the categories differentiate between viewers with basic interactive functions and explorers with a high amount of interactive features and therefore more possibilities for the users. Also, they differentiate between the content, meaning climate data and impacts. Whereas some tools only contain information on climate data, others include information such as climate impacts, risk zones, and vulnerabilities. Namely, the four categories are: climate data viewers, impact viewers, climate data explorers, and impact explorers (Neset et al., 2016, p. 14). Moreover, Hanger et al. (2013, p. 92) especially emphasise the need for participation and dual accountability to cross the science-policy boundary.

3. Case Study

The location of the two case study areas is shown in Figure 1. The Dutch RIVUS region (RIVUS, 2021) is a cooperation of the cities of Zwolle and Deventer and six rather rural municipalities (Kampen, Zwartewaterland, Staphorst, Dalfsen, Raalte, and Olst-Wijhe) located to the west of the province of Overijssel. The seven German regions lie within the federal state of North Rhine-Westphalia (NRW). The seven regions are formal administrative counties consisting of different numbers (100 in total) of municipalities and responsible for governing environmental issues including climate change challenges and required response actions. In the following, these regions will be referred to as Evolving Regions (ER). As both regions are rather vulnerable concerning heat and too much as well as too little water and both have a rather rural character, a comparison is possible.

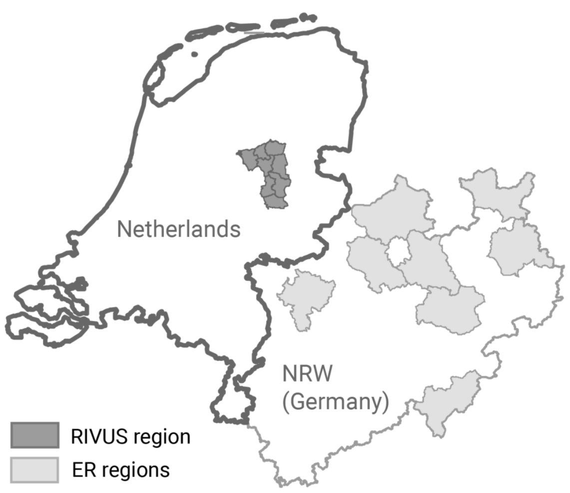

Figure 1. Location of the case study.

3.1. RIVUS Region

The following localisation of the case study RIVUS into the Dutch climate adaptation system aims to clarify the overarching setting. The Netherlands has a long history of adapting to water-related issues due to its low land topography with more than 60% of the country being prone to river flooding and storm surges. The start of the Dutch knowledge portal for climate adaptation (Foundation Climate Adaptation Services, n.d.-a) in 2014 marked the beginning of a new era in Dutch climate adaptation planning (Laudien et al., 2019). Two policy documents are key to the current Dutch adaptation policymaking. The National Climate Adaptation Strategy describes the main climate risks the Netherlands is facing and sets the goals and objectives for addressing these risks (Ministry of Infrastructure and the Environment, 2016). The Delta Plan on Spatial Adaptation (DPRA) defines key elements and steps of spatial adaptation plans and processes (Ministry of Infrastructure and the Environment & Ministry of Economic Affairs, 2018). According to the DPRA from 2018 to 2020, all Dutch municipalities, district water boards, provinces, and the central government have to develop a so-called DPRA based on three main steps: (1) an analysis of climate impacts and vulnerabilities in the so-called stress test; (2) the conducting of a risk dialogue with relevant stakeholders for drawing up a climate adaptation strategy; and (3) the development and approval of an implementation agenda. According to the Ministry of Infrastructure and the Environment, the analysis aims to collect and create information about the effects of the present and future climate on the sensitivity of various objects and functions in a certain area (Ministry of Infrastructure and the Environment & Ministry of Economic Affairs, 2018). Next to the formal planning levels, working regions, consisting of water boards, provinces, and municipalities, were established to structure and monitor the process and address the challenges of climate change beyond administrative borders.

In the Netherlands, the case study is the working region RIVUS, which is also part of the research project ER. Next to the named climatic challenges, the region can be characterised as rather vulnerable to flooding due to its location in the IJssel-Vecht river delta. In the context of the conduction of nationwide stress tests on different spatial levels, the regional cluster RIVUS collected all the data and published them online. The RIVUS stress test does not aim at conducting a new stress test and generating new data, but rather collecting and visualising different data from the mentioned planning levels to tackle climate adaptation across administrative borders. The results of the stress test are made public and are accessible via https://tinyurl.com/hsny2da6.

3.2. ER Regions

The following localisation of the case study in NRW into the German climate adaptation system aims to clarify the overarching setting. The German national climate adaptation process started in 2008 with the publication of the German Adaptation Strategy, further specified through the Adaptation Action Plan (Bundesregierung, 2011), most recently updated in the Adaptation Action Plan III (Bundesregierung, 2020). The German spatial planning law stipulates the identification and balance of climate issues with other public and private interests. Thus, climate adaptation is one concern of many within the German planning process. According to the German building code, significant impacts on the climate as an object of protection are described as relevant for consideration. According to Annex IV of the German Federal Building Act, the report to an environmental impact assessment must contain a description of the effects of the project on the climate and the vulnerability of the plan or project (Othmer et al., 2020). In 2017, the Federal Environment Agency published a guideline providing methodological recommendations for conducting regional and national climate impact and vulnerability analyses (Buth et al., 2017). The guideline suggests the conduction of the following three steps: First, preparing and designing the analysis; second, conducting the climate impact and/or vulnerability analysis; and third, communicating and using the results (Buth et al., 2017, p. 14).

In Germany, the focus lies on seven regions in NRW, which are part of the research project ER, and for which a climate impact analysis (CIA) is being conducted. The analyses aim to identify both spatial hot spots and specific local areas with high climate impacts and thus afford measures for adaptation to climate change (Buth et al., 2017). A scenario-based approach is carried out to map possible future scenarios in addition to current conditions (Greiving et al., 2018). To be able to classify and interpret the results of the climate impact analyses in individual regions, a schematically uniform and transferable methodological approach across all regions is essential. This explicitly includes the normalisation of the values concerning climatic influences and sensitivities. An essential point is an understandable presentation of the results in the context of interactive dashboards to increase the willingness of the stakeholders to use the results. The results of the CIA will be made available through the project but are not public yet. This case study aims at operationalising national-level guidelines and tools, leading to a scientific and research-driven approach, with the ER project being a project of the EU-Life programme.

4. Method

This case study analysis compares the stress test conducted for RIVUS, a regional Dutch cooperation that comprises 11 municipalities located in the province of Overijssel (RIVUS, 2021) with the methodology applied for seven regions, comprising 100 municipalities in NRW (TU Dortmund University, n.d.). Two remarks are essential in this respect. First, it is important to note that the focus of this article lies on the comparison of the analytic approaches and less on the spatial specifics of the case study areas. Second, the impact assessment of the Dutch region is already partially institutionalised into administrative actions, as the region has conducted it independently, whereas the assessment of the German regions is being conducted as part of the research project ER.

A comparative research study draws attention to the relevance of the contextual environment for a specific outcome and therefore helps to understand how the context shapes the actions in different settings (Esser & Vliegenthart, 2017, p. 4). Referring to climate adaptation, Purdon and Thornton (2019, p. 175) name comparative methods as one major strategy within the research concerning adaptation policies, as this "allow[s] researchers to draw on the rich trove of existing adaptation case studies to identify generali[s]able trends across them." Therefore, this comparison aims to create a mutual learning process, generate as well as transfer knowledge across national borders, and lead to a richer international research environment. The goal is to identify differences and similarities of the stress test in RIVUS and the CIA of the regions in NRW to create synergies and improvements for both approaches and to discuss the quality of both approaches.

The methodology of this research entails secondary and primary data collection. The methods applied include the analysis of relevant documents and climate impact maps, the conduction of expert interviews, and a follow-up discussion of the results with the interviewees. The expert interviews were conducted on July 7 and November 11, 2020, with two planning practitioners in charge of the climate adaptation process and the analysis in the Dutch region. Three of the co-authors, as researchers, developed and implemented the CIA for the German case study.

We aim to analyse and compare the climate impact assessment done in two case studies in two neighbouring countries facing similar climate stressors to elicit good practices and lessons to be learned. Building on the theoretical background, a distinction between the methodological and technical realisation and the presentation and communication of the results is made. Also, quality criteria will be applied for the discussion of the comparison. Therefore, our analysis is conducted at two levels: (1) comparing the input and output of the conducted climate impact assessments, meaning the methodology and data as well as the results obtained and how they are made available and communicated; and (2) discussing both approaches according to defined quality criteria (see Figure 2).

For the comparative analysis, the categories input and output need to be further differentiated and conceptualised to enable a structured comparison of both climate impact assessments. Concerning the input, the working steps, methodology, climate stressors and sensitivities, data, time reference and scenarios, and the involve-

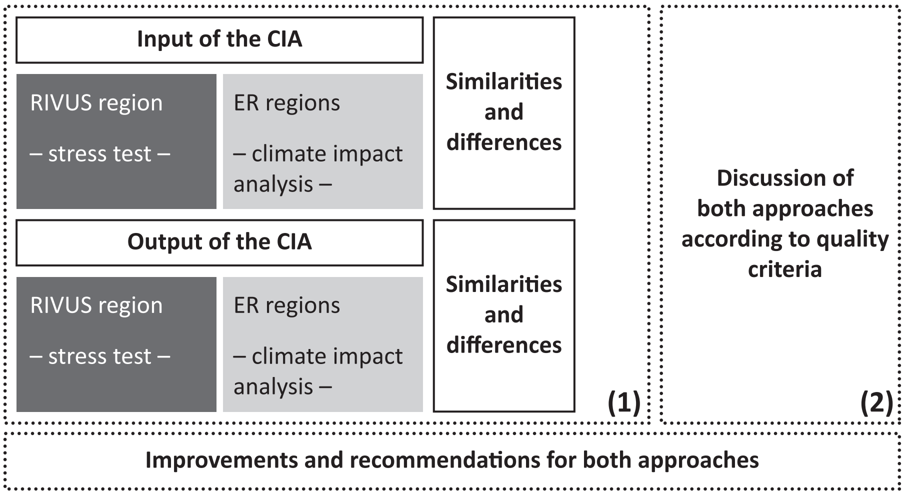

Figure 2. Methodological approach of the international comparative research.

ment of stakeholders will be considered (see Table 1). Concerning the output products, visualisation, availability, and integration will be compared (see Table 2).

From the multitude of technical and process-related criteria discussed in the background chapter, the following selection was made for the discussion of the two approaches:

1) Standardisation: High standardisation of the assessment process and methodology leads to high intersubjectivity and reliability;
2) Transparency: Transparent documentation of the analysis steps leads to an independent and clear interpretation and understanding of the results;
3) Communication of uncertainty: As no data is perfect and the future climatic and socio-economic situation is dependent on various factors, there are always sources of uncertainty that are essential for the users to understand;
4) Stakeholder involvement: A clear separation of factual and value elements requires the involvement of stakeholders for certain decisions within the conduction of the climate impact assessment;
5) Comprehensibility of visualisations: The processing and visualisation of the results play a central role when it comes to application and usability for the stakeholders.

Table 1. Conceptualisation of the input.

Element	Content
Working steps	Which working steps are conducted within the analysis?
Methodology	What methodology is applied? How is the climate impact measured or calculated? How is the sensitivity combined or intersected with the climate signal?
Climate stressors and sensitivity	What climate stressors and sensitivities are taken into account? Which correlations and impact chains have been analysed?
Data	What data is used for the assessment? Is additional data collected?
Time reference and scenarios	What time references are modelled? What climate and sensitivity scenarios are used?
Stakeholder involvement	Are any stakeholders involved in the assessment and the development of the methodology? If so, which stakeholders, and in what steps?

Table 2. Conceptualisation of the output.

Element	Content
Products	What outputs and products are being produced?
Visualisation	How are the outputs visualised?
Accessibility	How is the analysis made available and for whom is the data accessible?
Integration	How is the outcome of the analysis integrated into other planning processes and funding schemes?

5. Results

In the following section, we compare the climate impacts assessments conducted in the two case study regions, divided into two parts. First, we compare the inputs to the analysis, i.e., the general approach and methodology, the role of different actors, climate stressors and sensitivities considered, and input data and scenarios used for the analysis (see Table 1). Then, we study the outputs of the analysis and its dissemination, i.e., the results that have been developed, and how the results are visualised, communicated, and made available (see Table 2).

5.1. Input

Concerning the overall approach of the CIA, both regions follow a similar process and apply a comparable conceptualisation of climate impacts and how to assess these. Both approaches follow a similar order of working steps: first the data collection, followed by the selection of climate stressors and sensitivities, and finally the identification and visualisation of climate impacts. In both cases, climate stressors are mapped as specific spatial indicators, such as the number of days per year above 25°C, and sensitivities are mapped as the spatial distribution of certain indicators which represent sensitive sectors. Both analyses build on mainly existing data. Concerning the climate stressors, the same aspects were covered in both approaches, namely heat, drought, heavy rain, and river flooding. Concerning the selection of sensitive sectors, not identical but similar sectors are addressed in both approaches, namely water, nature, agriculture, forestry, recreation, health, infrastructures, and civil protection. Next to the named similarities, four main differences can be ascertained and will be discussed in detail in the following:

- First (1), the impact assessments are conducted within a different context, the approach of RIVUS already being embedded into the administration, and the ER approach being developed within the named research project, leading to different overall approaches and especially different stakeholder settings;
- Second (2), the approach of RIVUS is a pure data collection, processing, and visually overlaying data, whereby the ER approach generates new data and is not only a visual but mathematical intersection of data;
- Third (3), the RIVUS approach of mapping climate impacts considers single climate stressors and sensitivities, while the ER approach combines various indicators which are aggregated into one index per climate impact;
- Fourth (4), while the RIVUS approach maps one reference and one future climate stressors scenario and the future scenario does not consider the future sensitivity, the ER approach maps different future scenarios concerning the climate stressors and sensitivity, according to the concept of parallel modelling.

(1): As both processes are conducted in a different context (see Section 3), the role of different actors participating in the stress test varies slightly. The RIVUS stress test was coordinated by the regional RIVUS steering group and conducted by a consultancy. Various regional stakeholders were involved in deciding which climate impacts need to be addressed at the regional level, and for interpreting climate impacts for the five selected topics. In the ER case study, the process was coordinated and conducted by a university research group in close cooperation with administrative stakeholders from various departments of the region and experts from different sectors. The regular exchange took place in the context of the research project to constantly improve the methodology and data basis for the CIA.

(2): The RIVUS approach is a collection of climate and sensitivity data, and climate impacts are assessed by visually overlaying climatic indicators with one or more spatial indicators for sensitivity (see Figure 3). The RIVUS stress test used data from various national, provincial, and municipal databases, such as the climate impact atlas and stress tests conducted at national, provincial, and water board levels. Depending on data needs discussed during the stakeholder activities, the database was partially enriched with local data, e.g., data for the local sewage system. The main task was the filtering of issues to be addressed at the regional level.

For the ER regions, existing data sets from the regional authorities (LANUV, 2020) and relevant data sets from national-level agencies were used. Where needed, data was produced, e.g., by means of heavy rainfall-runoff modelling. In the ER approach, sensitivities and climate stressors are normalised across all involved counties and intersected based on multiple (climate and sensitivity) indicators to calculate climate impacts (see Figure 4). The analysis thus determines the comparative impacts of climate change.

(3): The RIVUS process aims at collecting and visualising existing climate and sensitivity data that mainly comes from the national climate impact assessment programme. For assessing climate impacts in the RIVUS region single indicators of climate stressors are combined one to one with single indicators of sensitivity. In ER, the climate signal and sensitivity are represented by different indicators, which are integrated by applying a spatial multi-criteria analysis. This normalisation process leads to abstract values that represent the comparative level of affliction (see Figure 5).

(4): Both climate impact assessments are conducted for the current situation and future scenarios, in the German case for the year 2040, in the Dutch case for the year 2050. In the ER case study, two alternative scenarios are included, contrasting a moderate development with weak, and a worst-case scenario with strong, climatic,

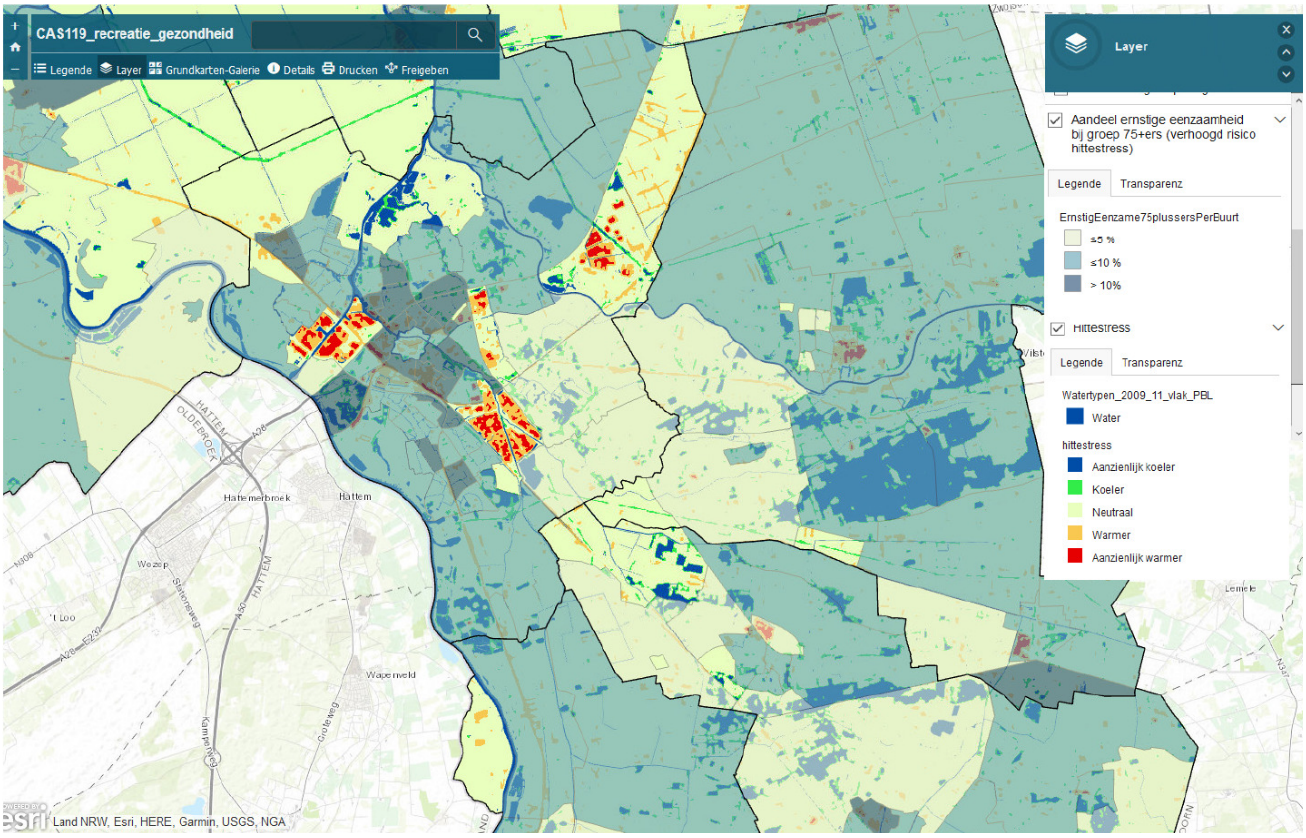

Figure 3. RIVUS region: Overlay of climate stressors and sensitivity, example heat, and population. Source: Foundation Climate Adaptation Services (n.d.-b).

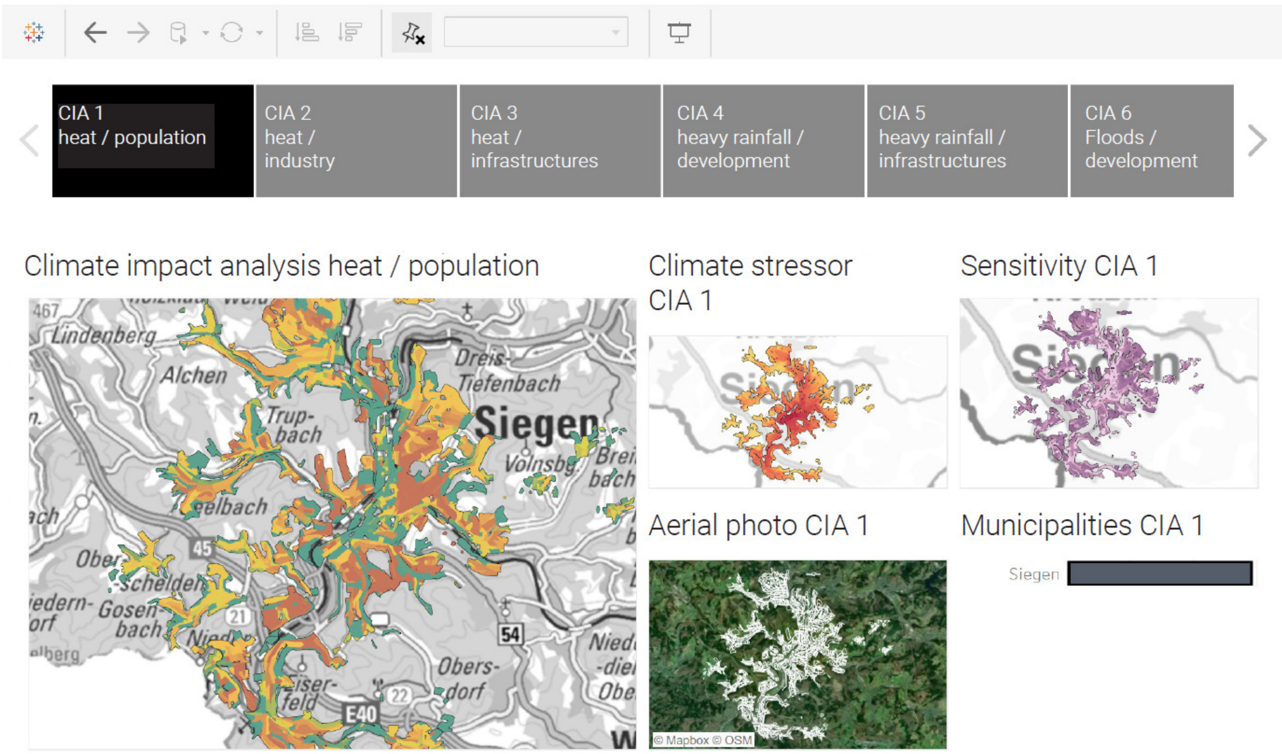

Figure 4. ER regions: Intersection of climate stressors and sensitivity, example heat, and population. Source: Schmitt and Wright (2021).

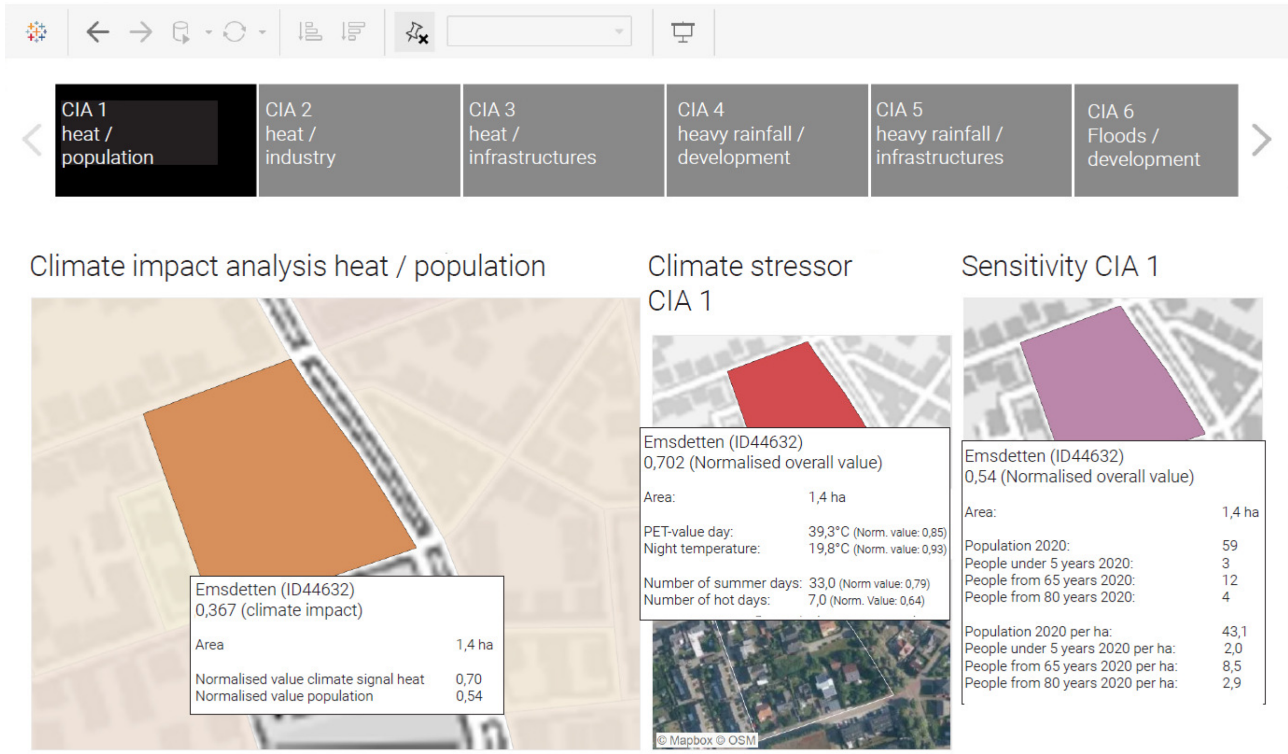

Figure 5. ER regions: Methodology of multi-criteria analysis. Source: Schmitt and Wright (2021).

and socio-economic changes (in terms of demographic and land-use changes). The RIVUS case makes use of one future scenario "that in most cases shows the most forceful changes" (Foundation Climate Adaptation Services, n.d.-c). While the RIVUS future scenario only considers changes in climate stressors and overlays these with the current sensitivities, the ER approach integrates future climate stressors and sensitivities based on a population projection and reasonable alternatives of further settlement expansion or urban renewal (Greiving et al., 2018; see Table 3).

5.2. Output

In both case studies, results of the climate impact assessments have been produced, visualised, and made available to address various target groups. Also, both outputs show different levels of data presentation for different stakeholders and a varying degree of complexity and depth. While some products aim at visualising basic interrelationships between climate stressors and sensitivities, interactive maps allow professional users to study a combination of single factors at a high spatial resolution. Next to the named similarities, three main differences can be ascertained and will be discussed in detail in the following:

- First (1), the visualisation of the relationship between climate stressors and sensitivities is more striking and memorable in the Dutch example, as more pictures than words were used;
- Second (2), in the Netherlands, the data and different levels of results are made available via a public accessible story map, while the ER approaches use the interactive tool Tableau to bundle and present the data within dashboards;
- Third (3), the conduction of stress tests in the Netherlands is linked to national adaptation funding, providing a clear timeframe and creating incentives for municipalities and regions. In NRW, such a formal linkage does not yet exist.

(1): The pictorial illustrations in birds-eye views of the spatial complexities and interdependencies of regional climate impacts for each topic provide a simple non-spatial overview for the RIVUS region (see Figure 6). Especially when it comes to raising awareness among homeowners, such pictorial representations are helpful to raise awareness and clarify possible impacts. In the German case study, mainly textual fact sheets and posters were produced uncovering the complexities of regional climate impacts. Although these represent a compression of knowledge, they use fewer pictorial elements.

(2): All results in the Dutch example, as well as the spatial data, are publicly available and accessible in an online story map (Tauw, n.d.). This story map contains three different levels of information for different actors. For the German ER case study, interactive maps are being prepared and the overall results are made available to the county and its municipalities in the form of an interactive dashboard (Schmitt & Wright, 2021). It is planned

Table 3. Overview of the comparison criteria of the input.

Criteria	RIVUS region	ER regions
Working steps	1. Data collection and preparation; 2. selection and interpretation of regional stressors and sensitivities per topic; and 3. visualisation of climate impacts	1. Data collection and preparation; 2. mapping of relevant climate stressors and sensitivities; and 3. calculation and visualisation of climate impacts
Methodology	Visually overlaying spatial indicators for relevant stressors and sensitivities to indicate levels of impacts	Intersecting spatial indicators for multiple relevant climate stressors and sensitivities to calculate levels of impact
Climate stressors	Heat, drought, heavy rain events, river flooding	Heat, drought, heavy rain events, river flooding
Sensitivities (topics)	Water and space, nature and agriculture, recreation, health, critical infrastructures	Human health, buildings, agriculture, forestry and forest management, transport infrastructure, civil protection
Input data	Collection of data sets concerning climate stressors and the sensitivities from existing databases and national, provincial and water board level stress tests	Collection of different data sets concerning climate stressors and the sensitivities from existing state-level databases, open data sets, national meteorological service
Time reference and future scenarios	Current situation: reference period climate 1980–2010, socio-economic 2018–2019; climate scenario: KNMI Wh scenario 2050 including most forceful changes; no socio-economic scenario	Current situation: reference period climate 1981–2010, socio-economic 2020; climate scenario: IPCC representative concentration pathways 4.5 and 8.5 scenarios 2040 (weak change/strong change); socio-economic scenario based on population projections 2040 and new settlement areas laid down by regional plans
Involvement of actors	Analysis led by a regional steering group, conducted by consultancy; interviews with relevant stakeholders, stakeholder workshops per topic	Development and application of methodology by German university in close cooperation with State Agency for Nature, Environment and Consumer Protection NRW; normative decisions are made by planners concerning the selection of climate scenarios, the spatial development scenario.

to make the data accessible as online maps, web map services, and geodata download within the duration of the project. The interactive maps enable the display of large amounts of data for large areas compactly and interactively. This added value was confirmed by participants in the workshops.

(3): In the Netherlands, the DPRA, which is a central guideline for promoting climate adaptation, gives clear and chronological specifications on the elements and their chronological procedure for climate adaptation, including the stress test. This clear timeframe was rated as very helpful during the expert interviews as it set a clear starting point for all Dutch municipalities and regions. In Germany, such a structured process does not exist. So far, the analyses have been used in the context of formal environmental assessments and for the acquisition of funding for selective cases.

6. Discussion

The two case studies for regional climate impact assessment show quite specific and different approaches, mainly because they are conducted in two different countries and thus under two different planning frameworks, but also because of the different contexts they are developed in. Despite these specific details, similarities, as well as significant differences in the approach and methodology, can be observed, which help to derive overall conclusions for the conduction of climate impact assessments. As mentioned in the methodology, there is no universally correct method, but only consistent methodological approaches that are appropriate for the set objectives and target system. Regardless, the five defined quality criteria will be used to discuss both approaches.

6.1. Standardisation

In the Netherlands, the conduction of a stress test is required, although not legally binding, but the details concerning the conduction are unclear. The stress tests are typically carried out by various consultancies. These consultancies have certain flexibility concerning the conduction of the analyses. The interviews showed that this

Figure 6. RIVUS region: Example of a birds-eye view to illustrate potential climate impacts in the region. Source: Foundation Climate Adaptation Services (n.d.-b).

Table 4. Overview of the comparison criteria of the output.

Criteria	RIVUS region	ER regions
Products	Illustration of climate impacts and their interrelations for relevant topics; interactive map of climate impacts; data download for further analysis	Modelled regional climate stressors; interactive maps and dashboards of climate impacts; fact sheets and posters on the complexity of climate change impacts; report including methodical approach and indications for the interpretation of results
Visualisation	Report with all results and interpretation as an online story map	Interactive dashboard showing climate impacts with the software Tableau
Availability	Online story map and spatial data of climate stressors and sensitivities publicly available	Dashboards and interactive maps accessible for county and municipalities, data available as WMS and download (planned)
Integration	Clear and chronological procedure for climate adaptation, including the stress test (DPRA)	Use of CIA as part of the workshops in ER; CIA already used in the context of environmental assessments and for the acquisition of funding for selective cases

procedure should be further standardised to achieve comparable results. Concerning heat (De Nijs et al., 2019; Koopmans et al., 2020) and flooding (Stowa, 2020) such specifications are available, but for drought and heavy rainfall, they are still lacking. In Germany, there is the guideline of the Federal Environment Agency, which creates a basis but leaves space for specific technical implementation. The aim of ER is to develop a methodical approach with a high degree of standardisation, which can ideally be transferred to the entire federal state of NRW. As there is a strong need for standardisation of climate impact assessments (Greiving, 2019; Scholles, 2005), both approaches should further improve this aspect.

6.2. Transparency

Both approaches aim for a high degree of transparency, which is essential to raise the comprehensibility and acceptance of decision-makers and affected stakeholders (Greiving, 2019). However, the Dutch case conducted in the RIVUS region only complies partly with this ambition. The presentation and accessibility of the results on the website fully match the criterion of transparency. Nevertheless, the methodology and process of conducting the climate impact assessment are not presented transparently at all. As the analysis for the regions in NRW has not yet been completed, this aspect cannot be assessed conclusively. Nevertheless, all working steps are documented and will be made available.

6.3. Display of the Uncertainty

Typical characteristics of the ER approach are that two alternative future climate scenarios are developed. Socio-economic scenarios are also modelled to reflect the bandwidth of potential future conditions, the latter often being mentioned as missing in current climate risk and vulnerability studies (Rohat et al., 2019). The main reason for the stronger data production and modelling-focused approach is that most of the involved regions do not yet have sufficient data nor the competencies and capacities to conduct an impact assessment on their own. In RIVUS, no bandwidth of possible scenarios is considered, with only one scenario showing the greatest changes. Thus, this approach does not represent a range of uncertainties, but only a possible state. Also, the RIVUS approach does not consider future sensitivities.

6.4. Stakeholder Involvement

Specific to mention about the Dutch case is the rather strong involvement and participation of various stakeholders already in the stress test phase. This can be explained by a quite strong tradition of consensus-oriented policy-making in the Netherlands, which is often referred to as the "polder model" (Van Eerd et al., 2014, p. 103). The climate impact analyses done in the project ER is strongly embedded in a roadmap process within the research project. Concerning the conduction of the analysis, the planners were involved in the selection of climate and spatial development scenarios.

In the context of governance of climate adaptation, both approaches enable an extension of spatial governance to contribute and offer potentials for each of the governance modes distinguished in the discussion (Molenveld et al., 2020). In the network mode of governance, both approaches target fostering co-creation and self-organisation (Molenveld et al., 2020). The development of a shared analysis of different stakeholders can be based on mutually intelligible and visualised data. Network governance, characterised by lateral leadership without issues directives (Birke et al., 2015), can frame issues and moderate individual interests with back reference to a piece of spatial evidence.

6.5. Comprehensibility of the Visualisation

A classification of the tools into the four previously mentioned tools (Neset et al., 2016) leads to the result that the ER approach is an impact viewer and the RIVUS approach is something between a climate data and impact viewer. The RIVUS story map shows climate impacts which are mapped by visually overlaying climate stressors and sensitivities. The user can make choices in the dashboard, but no weighting of indicators or similar can be done. The ER approach clearly visualises climate impacts as an aggregated result based on multiple climate stressors and sensitivity indicators are calculated and used for mapping regional and local hotspots. Particularly this mapping of hotspots through the normalisation has been perceived positively by planning practitioners in workshops of the ER project as it allows identifying areas that require particular attention for climate adaptation interventions and thereby provides arguments when applying for funds for the implementation of such measures. However, the interpretation of normalised values is a challenge for some users in this context. The used software Tableau has an interactive character that entails selection options but does not allow further individual settings.

One key difference between the two approaches is how climate impacts are analysed and mapped. The provision and availability of results can be singled out as a significant difference between the two case studies. In the Dutch case, the reports and resulting maps and illustrations, as well as the raw data, are made available to all stakeholders, including the general public for further use. In the German case, reports, results, and data are being made available in the first instance to the regional administration and the involved municipalities as the methodology and database are being improved constantly throughout the research project. However, all data and results of the ER approach will also be made freely accessible.

7. Conclusion

Key similarities between the two case studies are that both studies apply a similar conceptualisation of climate impacts and do map these, but not explicitly vulnerabilities. What is remarkable is that both processes put quite some focus on the issues of visualisation and communication of the climate impact (Mabon, 2020) through developing and using different platforms and tools to disseminate the results and knowledge. How these platforms contribute to bridging the information gaps discussed above and support better climate adaptation decision-making would need to be explored in follow up study.

What is specific about the Dutch case study is that the climate stress test is initiated through a national programme and conducted more or less parallelly in the entire country and at various planning levels. That results on the one hand in broad availability of relevant data as well as specific tools and methods for conducting a stress test. On the other hand, it might abet, as seen in the RIVUS case study, rather a collecting, filtering, and selection of topics with a strong focus on visualising data for different target groups. While the conducting of a stress test as part of a climate adaptation process has a strong statutory role in the Dutch governance system through its embedding in the Delta act (Bauer & Steurer, 2015, p. 348), there is no legal obligation to carry out a stress test as the DPRA has no binding character.

What is specific about the German case study is the strong consideration of scenarios and especially the attention also on future sensitivities according to the method of parallel modelling (Greiving et al., 2018). The consideration of future sensitivity is relevant for at least two reasons. First, it reflects and underlines the significance of the sensitivity for the extent of climate impacts, as this is not only determined by climatic changes but also future planning decisions. Second, the collection and inclusion of future planning offers a climatic pre-assessment and builds upon this the development of reasonable planning alternatives.

Accordingly, the following recommendations can be derived for the respective impact assessment approaches. The innovative, interactive and target group-oriented presentation of results can be identified as a key improvement for the ER approach and therefore the regions in NRW. The importance to also consider scenarios and future sensitivity can be identified as a key learning for the RIVUS approach. The RIVUS approach can potentially benefit from the consistent method of parallel modelling, which considers different scenarios and periods for the climate stressors, as well as the sensitivity.

The following overall conclusions and lessons learned can be derived from the comparison:

- Modelling alternative scenarios of both climate stressors and sensitivities allows identifying reliable scenarios for future patterns of climate change impacts, but requires careful communication to gain the necessary data and to enable stakeholder participation. Experience from the ER research project has shown that collecting data on future sensitivities is very time-consuming and often involves sensitive data that municipalities are careful to share. However, the added value for practice and science is clearly present.
- Engaging decision-makers and stakeholders in climate adaptation-related planning activities requires the availability and accessibility of results from climate impact assessment studies in intuitive and interactive formats and digital platforms that address different the levels of knowledge and capabilities of stakeholders.
- Linking climate impact assessment and adaptation planning to the provision of funds for implementing suitable interventions strengthens the execution of adaptation planning processes. However, such a timeline should be discussed and coordinated with the capacities and resources of the municipalities so as not to set unrealistic targets, as especially smaller municipalities often do not have sufficient financial and human resources at their disposal.

As already mentioned, the comparability of both approaches can be seen critically. While the officially adopted stress test in the Netherlands is already being carried out by regions with the support of consulting companies, the analysis for the regions in NRW is currently being conducted within a research project and is not fully completed. Nevertheless, the comparison leads to clear and beneficial improvements for both approaches. In the case of the ER regions, the results can be implemented into the on-going process of the research project and subsequently be used by the participating municipalities within their land-use planning. The RIVUS region is planning to implement the results into the conduction of the next stress test, which will take place in approximately five years. The relationship between the results of the analysis and the implementation as well as the financing of such implementation should be further investigated from a scientific perspective. Accordingly, further research should be conducted for further case studies in other European countries.

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Conflict of Interests

The authors declare no conflict of interests.

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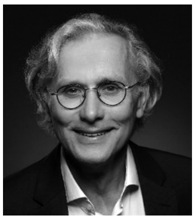

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