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Short Paper
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Integrated Assessment for Vulnerability to Climate Change in Germany - A Brief Overview of Methodology and Results

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Abstract

Within the scope of the German Adaptation Strategy (DAS), a standardized, cross-sector assessment of current and future climate change impacts and vulnerabilities for Germany was carried out from 2011to 2015. For this assessment, an institutional Vulnerability Network was established, composed of sixteen Federal agencies and institutes. Supported by a scientific consortium, the Vulnerability Network developed a collaborative scientific concept for an integrative and spatially explicit assessment. For each pre-defined action field, impact chains were generated as the basis for the selection, prioritization and assessment of indicators. Exposure, sensitivities and adaptive capacities were described by means of quantitative and semi-quantitative approaches, leading to a variety of products at different conceptual levels of aggregation. This paper introduces the methodology pursued for the assessment and then presents some examples illustrating the variety of outcomes produced. The conclusions drawn are based on critical procedural and methodological reflection.

Keywords:

co-production of knowledge, integrated vulnerability assessment, climate change, vulnerability mapping

1 Introduction

In the current century, climate change represents one of the most threatening stressors for societies worldwide. Adaptation measures need to be planned and implemented in order to respond to the progressive impacts of a changing climate on our environment and societies. Those impacts can already be observed and will most probably become aggravated in the short term, and even more in the distant future. Whilst defining mitigation goals is usually fairly straightforward, the identification of adaptation needs and adaptation strategies is strongly context-specific, varying significantly between different social-ecological systems with regard to their respective locations, populations, and thematic sectors at stake etc. The thorough and target-oriented assessment of the vulnerability to climate change of a system (or certain parts of it) is therefore key to identifying the adaptation planning required.

Moreover, the participation of stakeholders and end-users in the process of carrying out such a vulnerability assessment represents an important factor for its wider acceptance and its integration into concrete policies (Greiving et al., 2014).

In this context, vulnerability is not simply represented by one or more measurable variables of a system. Rather, it is understood as a concept identifying and describing the complex interrelations of factors that determine a system's susceptibility to being adversely affected by climate change.

This paper elaborates on the recent vulnerability assessment to climate change in Germany. It introduces briefly the methodology pursued for the assessment and the network of federal authorities established in this context. The paper then presents examples of the varieties of outcomes produced, and finishes with conclusions based on critical procedural and methodological reflection.

2 The German Vulnerability Network and the methodology applied

In 2008, the German Federal Cabinet adopted the German Strategy for Adaptation to Climate Change (DAS) to mitigate the impact of climate change in Germany (Bundesregierung, 2008). This strategy sets the framework for Germany's adaptation process at national level. Within this context, an Adaptation Action Plan (APA) was developed and adopted in 2011, specifying that 'Germany needs an up-to-date cross-sectoral vulnerability assessment prepared in line with uniform standards' (Bundesregierung, 2011). In response to this statement, a comprehensive, nationwide, cross-sectoral and consistent vulnerability assessment was implemented in 2011 to 2015. The core objective of this vulnerability assessment was to identify spatial and thematic vulnerability hotspots in Germany. The results were taken up by the DAS progress report, which paves the way for further development of the German adaptation policy.

Future progress reports of the DAS require a general vulnerability assessment to be repeated every five to seven years. The methodology will be developed further, in line with scientific progress. Because of the stepwise and interactive approach, the adjustment of the methodology will be part of the new assessment process. This includes consideration of new data and model results, but also adjustment of the climate impact chains, a new prioritization of climate impacts to be investigated and described by selected indicators, as well as improved estimations of the adaptation capacities for the action fields (e.g. agriculture, or industry and commerce).

The work was commissioned by the German Environment Agency within a project sponsored by the Federal Ministry for the Environment. The project consortium was composed of adelphi, plan + risk consult, the European Academy of Bolzano (EURAC) and IKU.[1] The main task of this consortium was – besides the development and implementation of a methodology for the vulnerability assessment itself – the establishment of a platform for the exchange of information and knowledge about climate change vulnerability in Germany.

[1] The outputs presented here are the results of the work of the whole consortium.

For this platform, a network of central federal authorities was set up with the aim of including in the project the vast knowledge that already exists in Germany. The project was therefore called "Vulnerability Network", in recognition of the fact that results achieved in cooperation with authorities responsible for adaptation are better understood, better accepted and more likely to be integrated into the further adaptation process than outcomes from work carried out solely by scientists (Greiving et al., 2014; Weichselgartner & Kasperson, 2009). The overall methodology developed to meet the project objectives was therefore strongly collaborative: the participation of the network partners as well as the scientific exchange between the project consortium and these partners were crucial.

The conceptual framework for the assessment of the various possible vulnerabilities that Germany has to tackle follows the concept described in the IPCC Assessment Report 4 (AR4) (IPCC, 2007). This approach has been used widely to structure climate change vulnerability studies logically. It separates exposure, sensitivity and adaptive capacity conceptually as sub-components of a system's vulnerability. For the present study, this approach has been slightly modified (Greiving et al., 2014).

Any approach to assess cross-sectoral vulnerabilities to climate change requires working steps to reduce the complexity of the functional relationships of the system's components. That is, the unmanageably high number of interconnections and feedback loops within a social-ecological system need to be prioritized and simplified to a manageable number of relevant factors and relationships, which are finally assessed. Within the Vulnerability Network, this task was supported by the definition of so-called impact chains, which visualize relationships of cause and effect that are of particular significance in a context of changing climate conditions (Schneiderbauer et al.; 2013; Fritzsche et al., 2014). These chains were defined at the start of the project, in close cooperation with the consortium and the federal authorities. They represented the thematic backbone for the assessment and served as guidelines for the selection of those indicators that were finally assessed and mapped for the vulnerability report.

The indicators selected and prioritized were analysed with respect to three time slots, namely the present, the near future (2021 to 2050), and the distant future (2071 to 2100). For the near future, two scenario-combinations were considered in order to cover the range of possible developments – one representing 'strong changes' and one representing 'weak changes', each of which was based on one selected combination of socioeconomic and climate change scenarios. The distant-future analysis was based solely on climate change scenarios, since no socio-economic scenarios were available. The climate scenario data were provided by the German National Meteorological Service (Deutscher Wetterdienst, DWD) and were computed using an ensemble of 17 climate projections based on the SRES-A1B-Scenario data. The socio-economic scenarios were based on different models, reflecting, amongst other things, economic and demographic development and future changes in land-use patterns (Umweltbundesamt, 2015a).

A detailed description of the conceptual approach is given by Greiving et al. (2014) and the final study report published by the German Federal Environmental Agency (Umweltbundesamt 2015a).

3 Types of products generated by the Vulnerability Network

The work within the Vulnerability Network produced various types of scientific and policy-relevant results, of which some of the most relevant are listed below.

Impact chains were developed for each of the sectoral action fields of the DAS (for example: 'agriculture' or 'industry and commerce'). These chains were developed in collaboration with the members of the network and visualized as flow diagrams (see Umweltbundesamt, 2015b). They support the overview of which climate signal may trigger or amplifywhich potential effect. In addition, they provide an indication about interrelationships between individual action fields. Responding to a prioritization request, the network partners chose 72 climate impacts as potentially relevant, taking into consideration their social, economic, ecological, cultural and spatial significance for Germany.

Maps of relevant **climate parameters**, such as air temperature, precipitation, hot days, tropical nights, frost days etc., were produced for Germany. For most parameters, the underlying datasets consist of bias-corrected daily data represented in a consistent spatial grid of 5 x 5 km. Each climate parameter map shows firstly the absolute values for the 30- year average of the reference period, 1961–1990. Secondly, it shows the changes in the climate signal for the 'near future' (2021–2050), as well as for the 'distant future' (2071–2100) in relation to the reference period. Since the data for these future periods are based on modelled scenarios and suffer from uncertainty, for each of the periods a scenario representing a possible weak change and a scenario representing a possible strong change were visualized (see Figure 1).

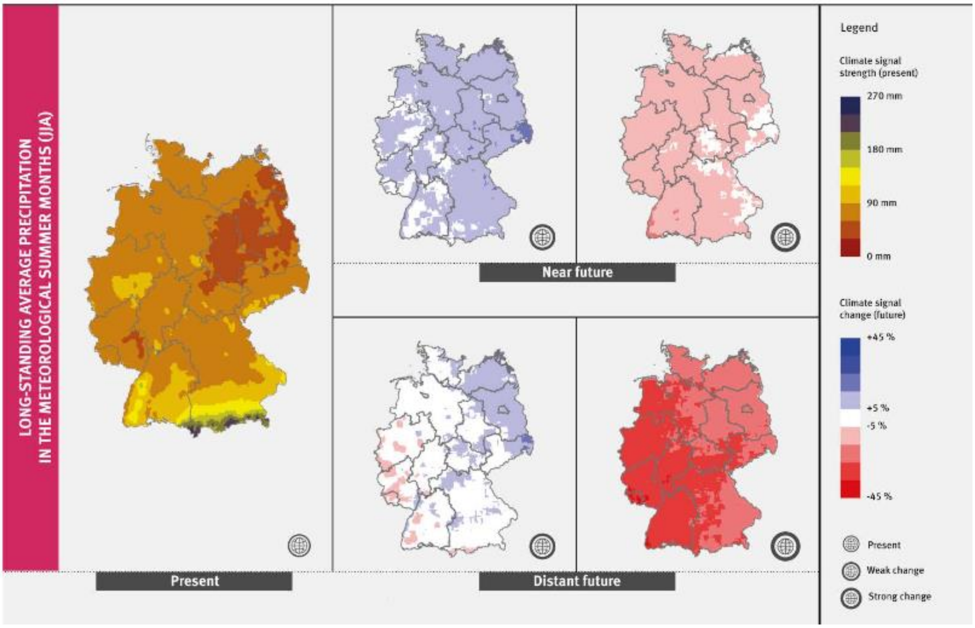

Figure 1: Example for mapping a climate parameter: Long-term average precipitation in the meteorological summer months (June, July, August) and changes in the climate signal between the projection periods and the present. (Source: Umweltbundesamt, 2015)

Climate impact maps were produced for the near future at the level of German NUTS 3 regions for the 38 of the 72 relevant potential impacts selected for which quantitative data was available or could be generated. When data was not available, the maps represent the values of carefully chosen proxy-indicators. All climate impact maps have the same design (see Figure 2), showing the results for the reference period (the 'present' situation – large left-hand map) in comparison to the values of the projected situations in the near future for both weak and strong changes (the four small maps). The upper two of these four maps show the absolute values of the projected impact; the lower two show the change of the two future slots relative to the values of the reference period.

Figure 2 shows an example of a climate impact map for the indicator 'risk of forest fires'

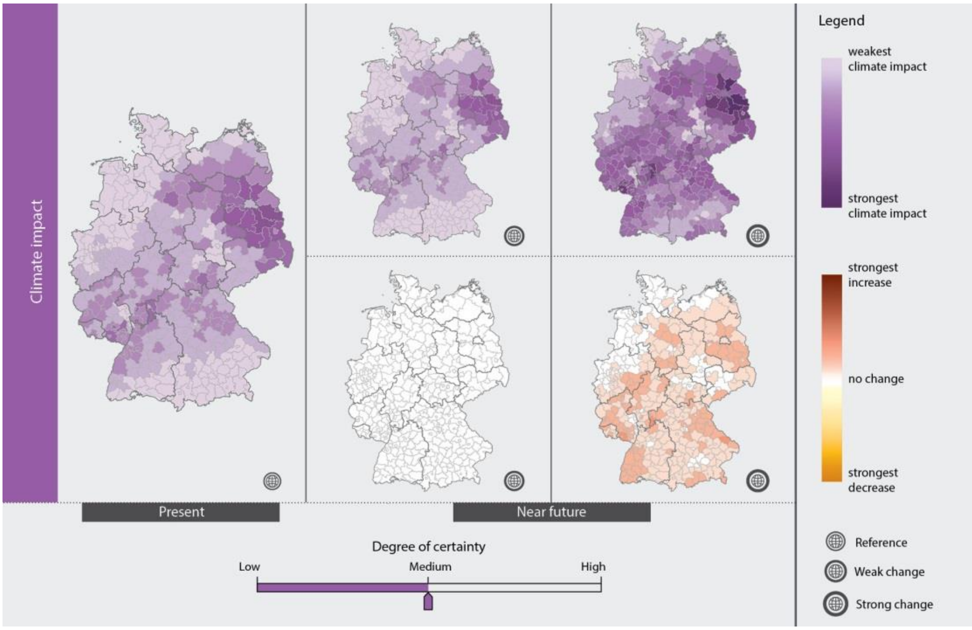

Figure 2: Climate impact map for the indicator 'risk of forest fires'. The map on the left shows the situation in the reference period; the four smaller maps show the projected situation in the near future. Of these four maps, the upper two show absolute values; the two lower ones show the change of the two future slots relative to the reference period; the two maps in the centre show the projected situation for a weak change, and the two on the right show the projected situation for a strong change. In addition, the level of certainty is given below the map as low, medium or high. (Source: Umweltbundesamt, 2015)

Diagrams were generated based on expert interviews for those of the selected indicators for which no quantitative data (either model or proxy-indicator) was available. For each of the three present and future situations (reference period, near future with weak change, near future with strong change), the impact was assessed, when possible in a spatially explicit way by distinguishing between sub-national regions. For this purpose, a large number of expert interviews were carried out, resulting in an assessment on a five-step scale, from no impact to strong impact. When experts' assessments varied, the average of their class values was calculated. Figure 3 shows a diagram based on the results of expert interviews for the indicator 'soil biodiversity, microbiological activity'.

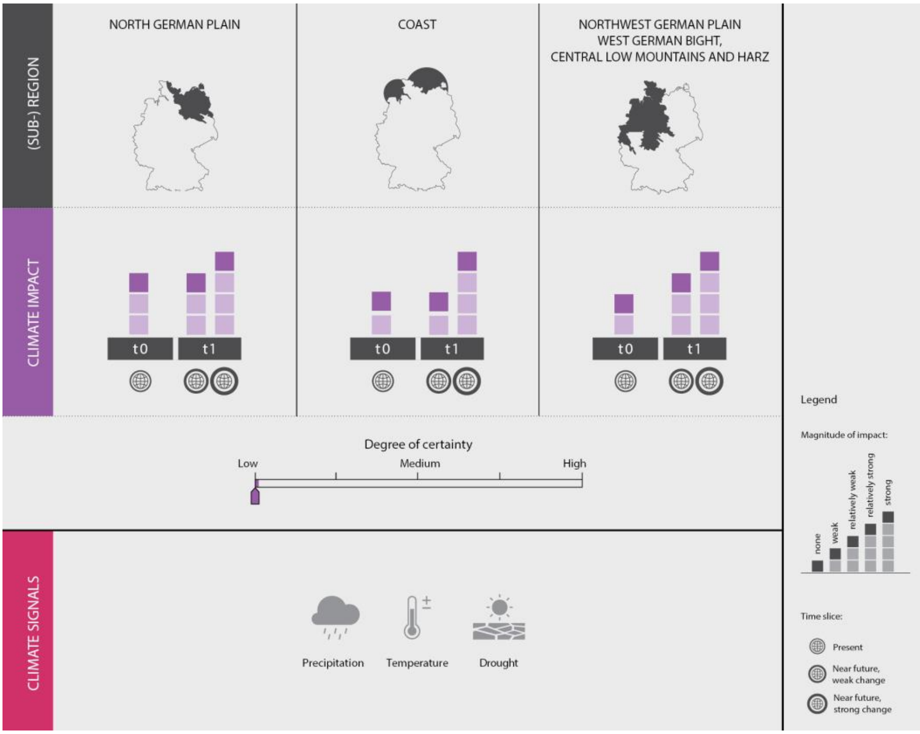

Figure 3: Section of the diagram for the indicator 'soil biodiversity, microbiological activity'. For each of the present and projected situations (reference period [t0], near future [t1] with weak change, near future with strong change), an assessment of the climate impact is given using a scale of 1–5 (no impact to strong impact), distinguished according to sub-regions. (Source: Umweltbundesamt, 2015)

For each action field, an **overview table** was generated showing a summary of the significance of the climate impacts in each field according to its individual indicators (see Figure 4 for an example). In the uppermost section, the table shows the most important climate signals (here temperature, drought …) and most important sensitivities of the action field (here soil type and soil structure …). This section also gives an estimation of the field's adaptive capacity. In the body of the table, for each climate impact indicator an assessment of the significance of climate change is given for the present (the reference period), the near future with weak change, the near future with strong change, and the distant future.

Soil				
Key climate signals:	Temperature	Drought	Precipitation	Extreme events
Key sensitivities:	Soil type and soil structure, soil cover and land use, soil moisture and slope			
Action field-specific adaptive capacity:	Medium			

Climate impact	Climate signals	Significance	Confidence / analysis method
Soil erosion by water and wind, landslide	Precipitation, heavy rain, flash floods strong wind, drought, heat	Present; Near future: Weak change; Near future: Strong change; Distant future: ~ to ++	Medium to high/ impact model and expert surveys
Soil water content, leachate	Precipitation, temperature, drought	Present; Near future: Weak change; Near future: Strong change; Distant future: ++	Medium to high/ impact model
Production functions (site stability, soil fertility)	Precipitation, temperature, drought, wind	Present; Near future: Weak change; Near future: Strong change; Distant future: ~ to ++	Low to medium/ expert surveys
Soil biodiversity, microbial activity	Precipitation, temperature, drought	Present; Near future: Weak change; Near future: Strong change; Distant future: ++	Low/ expert surveys
Soil organic matter, nitrogen and phosphorus budget, substance discharges	Precipitation, temperature	Present; Near future: Weak change; Near future: Strong change; Distant future: ++	Low to medium/ expert surveys

Legend

Significance of climate impact for Germany:
- low
- medium
- high

Climate signal trends until the end of the century (distant future):
- ++ strong change
- \+ change
- ~ uncertain

Figure 4: Overview table for the action field 'Soil' showing key climate signals, its key sensitivities, an assessment of its adaptive capacities, and the significance of selected climate impacts.

Maps of homogeneous 'climate area types' in Germany were produced, based on cluster analyses scrutinizing the climate parameters provided by the German Weather Service (DWD). Firstly, those climate parameters that were highly correlated with each other were excluded from the analyses. The resulting parameters were strong wind, heavy rain, hot days, tropical nights, frost days, average temperature (winter), average temperature (summer), droughts and precipitation. Secondly, K-means cluster analyses were carried out separately for each of the three time slots 'present', 'near future' and 'distant future', based on a raster covering the whole of Germany. The analyses resulted in six climate area types for each of the time slots (see Figure 5).

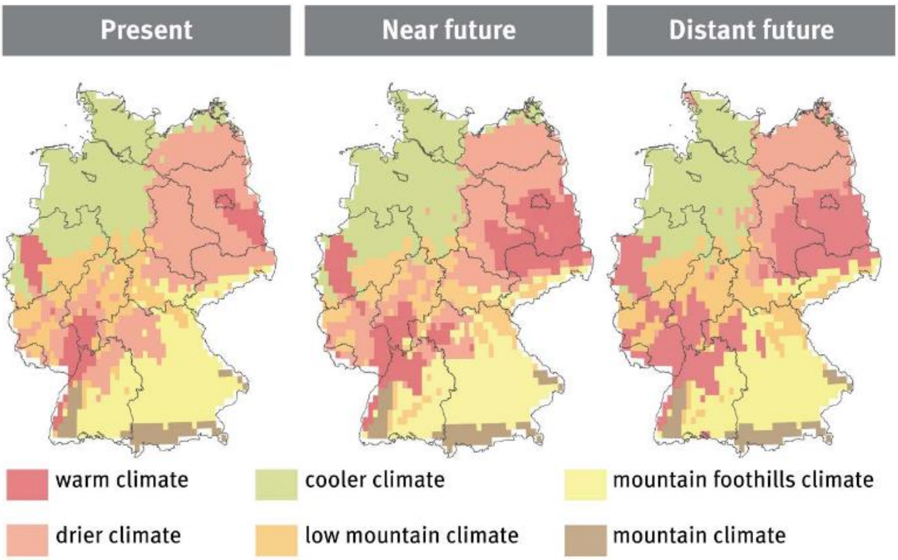

Figure 5: Results of Cluster analyses identifying climate area types in Germany

In addition to the scientific results above, the project generated the German **Vulnerability Network**. The network partners had been involved in the scientific work of the study, from its conceptual design at the start of the project, through the workings steps of selection and prioritization, to the assessment of the final outputs. The network partners' knowledge, data and models formed the basis for the study's results.

4 Conclusions

The integrated assessment of a region's or system's vulnerability to climate is a sizeable task. Reducing this complexity to a manageable (and affordable) task is key for the success of any such integrated assessment. The reduction of the complexity may be done using step-wise prioritization, and it has to be transparent for the end-users and other stakeholders not directly involved in the study.

Continuous and frequent communication between scientists and stakeholders / policy makers is crucial to achieve valid results, but it is both time- and resource-consuming.

The aggregation of data and first-step results supports the clarity of final outputs but bears the risk of losing crucial underlying information. In the course of the assessment, normative aspects play an increasingly important role in the prioritization and selection of those issues to be analysed further and have a significant impact on the types of results produced.

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