European Climate Vulnerabilities and Adaptation

A Spatial Planning Perspective

Editors
Philipp Schmidt-Thomé
Stefan Greiving

WILEY Blackwell

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Chapter 1

Introducing the pan-European approach to integration on climate change impacts and vulnerabilities into regional development perspectives

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Abstract

There is a political demand towards a territorial response to climate change. Since the development of territorially differentiated adaptation strategies calls for an evidence basis, a cohesive approach to developing an integrated vulnerability assessment is introduced. Although the European Observation Network for Territorial Development and Cohesion (ESPON) Climate project was the first attempt at a pan-European and cross-sectorial climate change vulnerability assessment, the further research that is needed in just about every aspect of climate change that the project touched upon is discussed. The three parts of the book are then outlined.

1.1 Introduction

Territorial development is generally considered to be very important when dealing with climate change. For example, it is regarded as being responsible for and capable of reducing regional vulnerabilities

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to climate change as well as developing climate mitigation and adaptation capacities against the impacts of climate change (Stern, 2007; IPCC, 2007). The World Bank Report '*The Global Monitoring Report 2008*', which deals with climate change and the Millennium Development Goals, concludes that the advancement of adaptive urban development strategies is a fundamental field of action for dealing with the challenges of climate change (World Bank, 2008). The European Union (EU) White Paper '*Adapting to Climate Change: Towards a European Framework for Action*', explicitly relates to spatial planning and territorial development, respectively, stating that 'a more strategic and long-term approach to spatial planning will be necessary, both on land and on marine areas, including in transport, regional development, industry, tourism and energy policies' (Commission of the European Communities, 2009, p. 4). In the EU Territorial Agenda it is stipulated under Priority 5 that '. . . joint trans-regional and integrated approaches and strategies should be further developed in order to face natural hazards, reduce and mitigate greenhouse gas emissions and adapt to climate change. Further work is required to develop and intensify territorial cohesion policy, particularly with respect to the consequences of territorially differentiated adaptation strategies' (BMVBS (Federal Ministry of Transport, Building and Urban Development), 2010, p. 7).

The above-mentioned quotes show that there is a political demand towards a territorial response to climate change. Since the development of territorially differentiated adaptation strategies calls for an evidence basis, this book presents a cohesive approach to developing an integrated vulnerability assessment. The methodology was developed under the European Observation Network for Territorial Development and Cohesion (ESPON) 'Climate' project. The ESPON Climate project was given the task of developing a pan-European vulnerability assessment as a basis of identifying regional typologies of climate change exposure, sensitivity, impact and vulnerability. On this basis, tailor-made adaptation options were derived to cope with regionally specific patterns of climate change. In the ESPON Climate project, this regional specificity was addressed by several case studies from the trans-national to the very local level.

This book summarises the results achieved by the ESPON Climate project. It is structured into several chapters that display the development of the methodology, the selection, evaluation and assessment of data sets, towards the production of indicators and maps. Following the European overview, there are applications of the approach for local case studies to test and approve the methodology.

The territorial perspective and dimension on climate change vulnerabilities displayed in this book are somehow unique, because so far most of the existing vulnerability studies have a clear sectorial focus, that is, addressing very specific impacts of climate change on single elements of a particular sector. To date, such a comprehensive methodological approach, especially one covering almost an entire continent, has not available. Specialised research is sensible and necessary, but the findings of such focused studies are not easily transferable between sectors or between regions. Research results are often not comparable due to methodological differences. This is particularly troublesome in an international policy context such as the European Union, when it needs to be determined what the consequences of climate change are on the competiveness of Europe as a whole, or on the territorial cohesion of European regions. This book therefore shows the development of a new comprehensive vulnerability assessment methodology, applying it to all regions belonging to 'ESPON space'. The methodology may be applied to develop a response to climate change from the perspective of a European territorial development policy.

Any climate change vulnerability assessment will definitely be confronted with uncertainties, which are based on the uncertainties of the underlying models and emissions scenarios. The vulnerability assessment methodology presented in this book used the COSMO model in Climate Mode (CCLM) as a regional climate model that covers almost the entire ESPON space. The forcing scenario used was the SRES A1B scenario of the Intergovernmental Panel on Climate Change (IPCC). It is important to underline that the methodology is not tied to any specific models, emissions scenarios or indicator data sets. Therefore, the results displayed here may be improved at some point in the future if better input data becomes available, both at this scale and in a comparable format. The developed methodology is scientifically acknowledged, and may thus be used for other similar assessments on entire continents or specific regions.

This book thus displays one possible vulnerability scenario that shows what Europe's future in the wake of climate change might look like. The results are not a forecast, but they give some evidence-based hints as to what European adaptation should address in view of the identified regional typologies of climate change, from a regional development perspective. For example, the book shows that key patterns of regional climate change vulnerability run counter to a major pillar of European policy: territorial cohesion. Several regions in the South and East of the continent are highly vulnerable to climate change. Simultaneously, the current economic performance of those vulnerable regions is weak, as compared with other European regions. This underlines the need for a tailor-made adaptation policy at the European level.

1.2 Further research

The ESPON Climate project was the first attempt at a pan-European and cross-sectorial climate change vulnerability assessment. The project succeeded in developing and implementing a comprehensive methodology that integrates data and interrelations across a vast range of relevant fields. For each indicator a detailed methodology was developed, building on existing research findings, establishing causal relations to other indicators and utilising most appropriate and up-to-date data. Through this course, the project developed several advanced methods for assessing climate change impacts for the pan-European study on a very fine-grained scale. For example, the assessment of many indicators was performed on a 100 × 100 meter grid cell basis, for example to identify exactly those parts of a region's population that are sensitive to river flooding inundation or which live in urban heat islands and are especially sensitive to heat waves.

Further research is needed in just about every aspect of climate change that the project touched upon. This includes research on second-order and indirect effects of climatic changes. For example, the project estimated the potential effects of a changing climate on the tourism sector of each NUTS 3 (Nomenclature of Territorial Units for Statistic) region. Through backward and forward linkages, these direct effects have multiplier effects on other (sub-) sectors. Such further analysis is certainly possible and would allow a more complete assessment of the economic impacts of climate change. Relevant economic linkages are likely to, for example; also reach into adjoining regions, thus adding an additional layer of complexity. This would require more economic modelling, which was clearly beyond the scope of this project.

Besides a deeper understanding of detailed mechanisms of climate change, what are needed are pan-European methodologies and comparative research. There are many studies that have been conducted at a national or a regional level, which should be scaled up to a European level. An expert-based, multi-criteria classification of all 231 habitat types of the NATURA 2000 directive in regard to their climate change sensitivity is one example, as so far only about 80 of the central European habitat types have been classified accordingly.

Besides expanding, up-scaling and integrating existing research approaches, this book identifies a great need to make qualitative and institutional aspects of climate change, as well as adaptation and mitigation, compatible with the quantitative assessments conducted. The Alpine space study charted a way forward in this regard, but systematic, pan-European methodologies, including reviews and classifications are needed to integrate institutional aspects into pan-European studies.

Current climate models differ greatly in their projections of future climatic conditions. It should be important that future research projects on climate change vulnerability are resourceful enough to use of all, or at least the major, climate model data. This would, first of all, decrease the uncertainty, which is very high when using only one climate model and one emission scenario, as done exemplarily here. Using more models and scenarios would also lead to a more robust database upon which to perform sensitivity, impact and vulnerability analyses.

Most importantly, further research is needed with respect to projecting sensitivity indicators into the future. ESPON's DEMIFER project broke new ground in projecting demographic trends up to the year 2100. However, what about other social and economic trends? Of course it is difficult, some may say impossible, to make such long-term projections for issues and variables that are volatile and constantly shaped by human intervention. Thus the challenge of climate change and the advances made in modelling future climates puts pressure on other disciplines to also develop sophisticated models or scenarios. Without such research, any climate change impact or vulnerability assessment is fraught with the great weakness that one can only relate dynamic, future-oriented climate data to static sensitivity data.

1.3 Structure of the book

This book is structured into three parts, each of which starts with introductory chapters. The first part starts with the methodological framework and approach and explains the selection of the forcing scenario and the climate model. The following chapters then analyse the climatic stimuli and the climatic exposure of Europe towards selected climate change parameters. Two chapters assessing economic impacts and an integrated impact assessment to determine regional vulnerability patterns follow this. European adaptive and mitigative capacities, respectively, are subsequently analysed. The adaptive capacity is then integrated into the climate change impacts to determine European regional vulnerabilities.

The second part of the book describes how the methodological approach of the project was both applied and further developed in several case studies. These case studies represent different scales, starting from multi-national river regions through national scales towards a federal state. The case studies also represent different geologic, climatic and socio-economic settings.

The book concludes with future challenges for Europe in integrating climate change vulnerabilities into regional development, for example, cohesion funds.

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Chapter 2

Methodology for an integrated climate change vulnerability assessment

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Abstract

The ESPON Climate project is based on an IPCC conceptual framework that is widely used in the climate change and impact research community. According to this framework, rising anthropogenic greenhouse gas emissions contribute to global warming and thus to climate change. This anthropogenic contribution runs parallel to natural climate variability. The resulting climate changes differ between regions, that is, each region has a different *exposure* to climate change. In addition, each region has distinct physical, environmental, social, cultural and economic characteristics that result in different *sensitivities* to climate change. Exposure and sensitivity together determine the possible *impact* that climatic changes may have on a region. However, a region might in the long run be able to adjust, for example, by increasing its dikes. This *adaptive capacity* enhances or counteracts the climate change impacts and thus leads to a region's overall *vulnerability* to climate change.

2.1 Introduction

This chapter describes a methodology that addresses the major climate change vulnerability. After a short overview of the main phases of the methodology, each step of the assessment is defined in detail. The chapter closes with methodological reflections on strengths and weaknesses of the described method and what challenges are ahead for climate change vulnerability assessments in the coming years.

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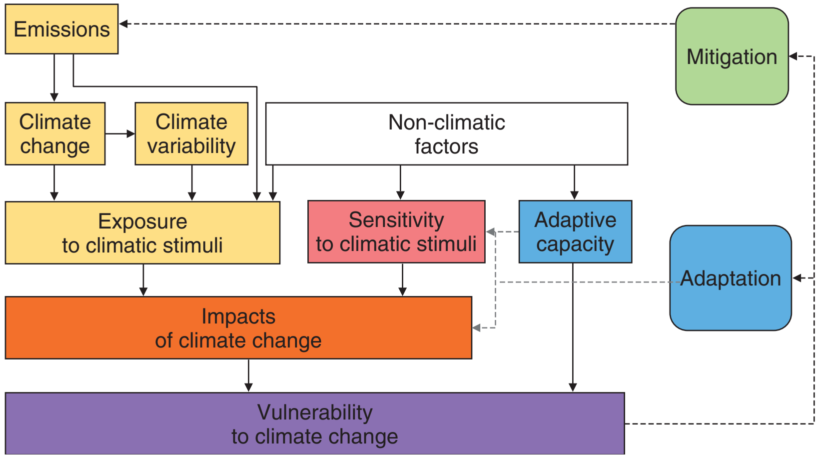

Figure 2.1 Climate change research framework. Adapted from Füssel & Klein, 2002 and 2006.

2.2 Overview of the methodology

Following the conceptual framework given in Figure 2.1, the ESPON project's methodology (see McCarthy *et al.*, 2001) consisted of five main components (see Figure 2.2 for a graphic overview).

The *exposure analysis* focused on the climatic changes as such. It made use of existing projections on climate change and climate variability from the CCLM climate model, whose results have been used, among others, by the 4th IPCC assessment report on climate change. Using the IPCC climate scenario A1B (Nakicenovic *et al.*, 2000), the ESPON Climate project aggregated data for two time periods (1961–1990 and 2071–2100) for eight climate stimuli.[1] River flooding and sea level rise were added as two immediate 'triggered effects' of these climate stimuli.

Each region was then assessed with respect to its climate change *sensitivity*. For each sensitivity dimension (physical, environmental, social, economic and cultural) several sensitivity indicators were developed. Each of the 24 sensitivity indicators[2] were calculated in absolute and relative terms and then combined. This integrates two equally valid perspectives on sensitivity: while relative sensitivity (e.g. density of sensitive population) is advantageous from a comparative point of view, the absolute sensitivity (e.g. absolute number of sensitive inhabitants) is more relevant from a policy/action point of view.

Exposure and sensitivity were then combined to determine the potential *impacts* of climate change. The analysis thus focused on what would be the consequences on human and natural systems if climate change took place unrestrictedly and impacted on the regions without further preparation. To determine impacts, each sensitivity indicator was related to one or more specific exposure indicator(s). For example, heat sensitive population (persons older than 65 years living in urban heat islands) was related to changes in the number of summer days (above 25 °C), while forests sensitive to fire were related to summer days and summer precipitation. After determining the individual impacts,

[1] Exposure indicators used by ESPON Climate related to changes in annual mean temperature, frost days, summer days, winter precipitation, summer precipitation, heavy rainfall days, snow cover days and evaporation.

[2] Sensitivity indicators used by ESPON Climate related to roads, railways, airports, harbours, thermal power stations, refineries, settlements, coastal population, population in river valleys, heat sensitive population in urban heat islands, NATURA 2000 protected areas, occurrence of forest fires, soil organic carbon, soil erosion, museums, cultural World Heritage Sites, energy supply and demand, agriculture and forestry employment and GDP, tourism comfort index and tourist beds.

Table 2.1 Weights resulting from the Delphi survey.

Impacts		Adaptive capacity	
Environmental impacts	0.31	Knowledge and awareness	0.23
Economic impacts	0.24	Technology	0.23
Physical impacts	0.19	Economic resources	0.21
Social impacts	0.16	Institutions	0.17
Cultural impacts	0.1	Infrastructure	0.16

all impacts of one dimension were aggregated. The impact values of the five sensitivity dimensions were finally combined to give one overall impact value.

This aggregation of the various impact dimensions (and later the integration of exposure, sensitivity and adaptive capacity) raises normative issues induced by the theoretical framework. At these stages of the assessment process weighting takes place, even if no weighting is deliberately performed: no weighting amounts to giving equal weights to each dimension. The weighting ultimately refers to cultural beliefs and political preferences, for example, how one values human lives in comparison with economic damage. The ESPON Climate project decided to address these normative issues openly and conducted a survey based on the *Delphi* method among the members of the ESPON Monitoring Committee, which represented the European Commission, 27 European countries and four Partner States. Committee members were asked to propose individual weights for the major phases and dimensions of the assessment (see results in Table 2.1).[3]

A third major component of the project was the assessment of *adaptive capacity* in regard to climate change, that is, the economic, socio-cultural, institutional and technological ability of a region to adapt to the impacts of a changing regional climate. This could mean preventing or moderating potential damage, but also taking advantage of new opportunities. In total 15 adaptive capacity indicators were developed, grouped into the five adaptive capacity dimensions: economic resources, knowledge and awareness, infrastructure, institutions and technology. The indicators were combined for each dimension and finally aggregated into an overall adaptive capacity. This aggregation was again conducted on the basis of the Delphi survey results.

To determine the overall *vulnerability* of regions to climate change, the impacts and the adaptive capacity to climate change were combined for each region. The underlying rationale is that a region with a high climate change impact may still be moderately vulnerable if it is well adapted to the anticipated climate changes. On the other hand, high impacts would result in high vulnerability to climate change if a region has a low adaptive capacity.

Mitigation of climate change refers to actions that are aimed at reducing concentrations of greenhouse gases and thus global warming. Mitigation is highly relevant for territorial development and cohesion since climate policy implementation and the transition to a low-carbon society will have differential effects on sectors and regions. Mitigation measures, even implemented at the regional level, will not have significant effects on regional climate but only contribute to an overall reduction of global climate change. Therefore, the project's mitigation analysis could only determine the mitigation capacity of each region but could not determine what effect this would have locally or regionally.

Finally, seven *case studies* at the trans-national, regional and local level cross-checked and deepened the findings of the pan-European assessment and explored the diversity of response approaches to climate change. Basically, the same methodology was applied in the case studies as in the pan-European analysis. However, additional methods as well as data sources were utilised in order to explore special regional aspects of climate change impacts, adaptive capacity and vulnerability (Chapters 10–16).

2.3 Methodology in detail

The following section describes in detail the individual steps that needed to be performed within

[3]The survey yielded equal weights for exposure versus sensitivity in addition to impact versus adaptive capacity.

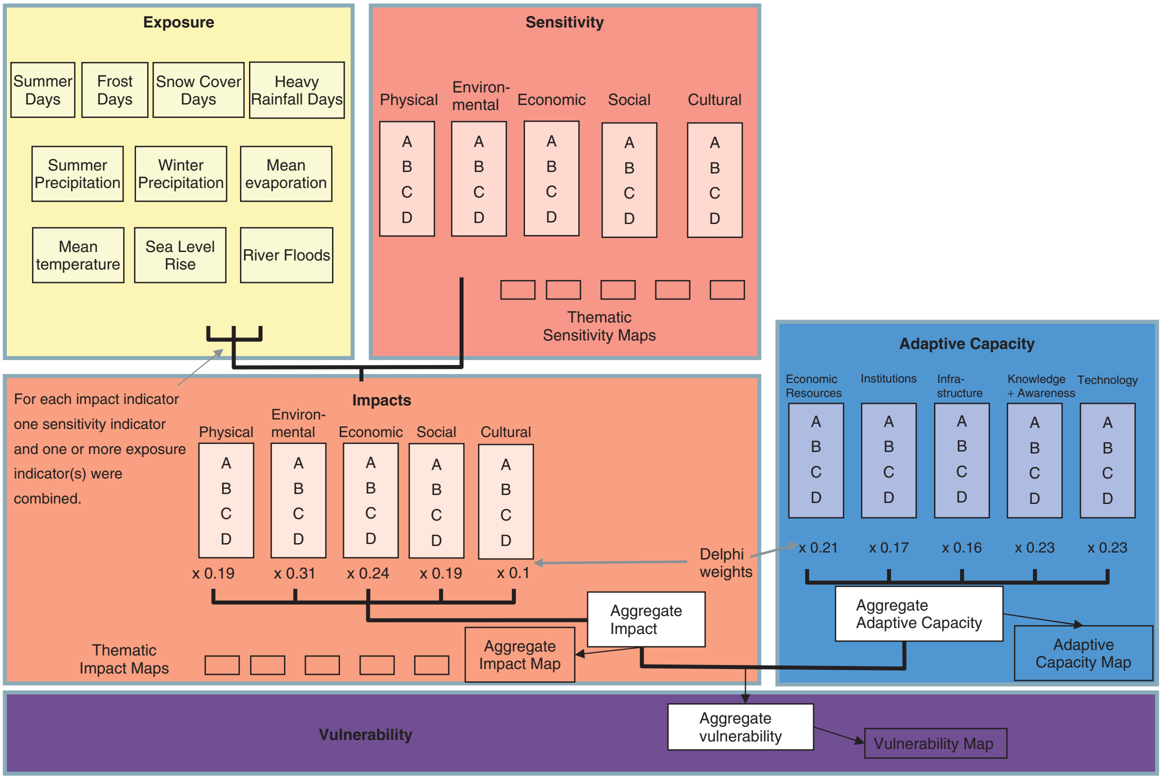

Figure 2.2 Overview of the ESPON Climate vulnerability assessment.

each component of the climate change vulnerability assessment. Figure 2.2 summarises the various steps and may serve as an orientation for the textual explanations.

2.3.1 *Exposure assessment*

2.3.1.1 Aggregation of exposure data

The exposure analysis, based on the CCLM climate model, yielded data for each NUTS 3 region for each of the eight exposure indicators (Chapter 3). For further analysis these exposure variables E_i were normalised. In order to account for the direction of change (decreasing or increasing climatic stimulus), the maximum absolute change in either direction ($E_{\max}$) was used as the reference point for the normalisation.[4] Thus, the exposure variables are defined by:

$$E_{\text{norm}} = E_i / |E_{\max}| \qquad (2.1)$$

A special type of exposure indicators need to be highlighted, which were termed 'triggered climate effects' as they are directly triggered by other climatic stimuli. For example, globally rising mean temperatures lead to rising mean sea levels, or the amount of winter precipitation in a river catchment area determines the likelihood and extent

[4] In the impact analysis where exposure indicators were related to sensitivity indicators it was sometimes necessary to reverse the mathematical sign of some exposure variables. For example, increased forest sensitivity has to be related to *decreased* (not increased) summer precipitation.

of river flooding in downstream areas. These two triggered climate effects are therefore dependent on global climate changes or on the accumulated effects of climate changes in larger regions. The data for these two triggered climate effects are therefore not taken from the CCLM climate data for a particular raster cell, but are derived from global climate change projections and special hydrological models, respectively.

A cluster analysis was then performed using all eight exposure variables as an informative overview (Chapter 3). The subsequent impact and vulnerability assessment maintained and used only the individual exposure indicators.

2.3.2 *Sensitivity assessment*

2.3.2.1 Identification of sensitivity indicators

To assess the sensitivity of regions to climate change, five sensitivity dimensions were identified, namely physical, environmental, economic, social and cultural sensitivity. For each of these dimensions indicators were identified based on current literature in order to capture the most important regional sensitivities to the climatic changes projected in the exposure analysis (see Chapters 5 and 6 for detailed discussions of each dimension).

2.3.2.2 Determining individual sensitivities

Each sensitivity indicator was calculated individually, that is different data were used and possibly combined to develop meaningful indicators. For some indicators this was relatively straight forward, for example, calculating the relative p of senior citizens in a NUTS 3 region. For other indicators it was necessary to use additional data and perform more complex calculations, such as, when determining the settlement area sensitive to heavy rainfall flash floods (see details in Chapters 5 and 6).

For each sensitivity indicator one absolute and one relative indicator was calculated. For example, for roads sensitive to river flooding the percentage of the region's road network and the total length of roads sensitive to river flooding were calculated for each NUTS 3 region. Both of these aspects are important, because a sparsely developed region might only have a few kilometres of flood sensitive transport infrastructure, but in relation to the total transport infrastructure of that region this is quite relevant. On the other hand, a more densely developed region might have many kilometres of flood sensitive transport infrastructure, which might nevertheless only account for a small fraction of the total infrastructure of that region. But for e.g. policy-making or disaster management it is still quite relevant that in absolute terms one region only has a few kilometres and the other many kilometres of flood sensitive infrastructure. Thus, absolute and relative indicators used in combination yield a more comprehensive measure of a region's sensitivity.

2.3.2.3 Normalisation and aggregation of sensitivity data

The sensitivity data for all indicators were transformed to be able to first aggregate and later relate them to the exposure indicators. In a first step, the absolute and the relative values for a particular sensitivity indicator were normalised separately using the MinMax normalisation method, that is, the sensitivity values S_j are based on the minimum (S_{min}) and maximum (S_{max}) values within the data range. Thus, the sensitivity values were defined by

$$S_{norm} = (S_j - S_{min})/(S_{max} - S_{min}). \qquad (2.2)$$

This normalisation procedure yields values ranging from 0 (low sensitivity) to 1 (high sensitivity). On this basis the arithmetic mean of the relative and absolute value of each sensitivity indicator was calculated and afterwards normalised again as described above.

2.3.3 *Impact assessment*

2.3.3.1 Combination of exposure and sensitivity

The combining of climate change exposure with the climate change sensitivity results in the (potential) impact of climate change. This process of relating exposure to sensitivity is not performed at the aggregate level but at the indicator level, taking into account that for each sensitivity indicator a different combination of exposure indicators is relevant (see Table 2.2 for an overview). In order to ensure that in cases of no exposure to climate change ($E_i = 0$) the calculated impact I_i would also be zero, multiplication of exposure and sensitivity values was chosen as the most suitable aggregation method. Thus, for each region the value of a particular sensitivity indicator was multiplied with the arithmetic mean of the particular exposure indicators considered relevant for this sensitivity indicator. For example, the climate change impact value for airports was defined by:

$$I_{\text{phys\_air}} = S_{\text{norm\_air}} \times (E_{\text{norm\_river}} + E_{\text{norm\_coast}})/2 \tag{2.3}$$

where $E_{\text{norm\_river}}$ and $E_{\text{norm\_coast}}$ refer to the normalised exposure values for river flooding and sea-level rise adjusted coastal flooding, respectively. Afterwards each impact value was normalised following the procedures described above.

2.3.3.2 Aggregating impact scores based on a Delphi survey

In a next step the normalised values of all indicators belonging to one dimension (e.g. social impacts) were combined. Usually this was done by calculating the arithmetic mean of all indicators of a particular dimension; but within the physical and the economic impact dimensions some closely related indicators were first grouped.[5] As an example of the standard procedure, the total social impact (I_{soc}) was defined by:

$$I_{\text{soc}} = (I_{\text{soc\_river}} + I_{\text{soc\_flash}} + I_{\text{soc\_coast}} + I_{\text{soc\_heat}})/4 \tag{2.4}$$

where the individual social impact indicators relate to impacts on population due to river flooding ($I_{\text{soc\_river}}$), flash floods ($I_{\text{soc\_flash}}$), coastal flooding ($I_{\text{soc\_coast}}$) and heat days ($I_{\text{soc\_heat}}$). The combined average for each impact dimension was subsequently normalised as described above, resulting in one impact value for each impact dimension for each region. On this basis, comparable summary maps were created for each impact dimension (Figure 2.2, Chapters 5 and 6).

Then all dimensions' impact values were aggregated once again to yield one overall impact score. However, averaging the values of the five dimensions would have implied that all dimensions are equally important, that is, that the sensitivity of humans to climate change is as important as, for example, the sensitivity of cultural monuments to climate change. In order to make such normative assumptions transparent and allow the perspectives and preferences from various ESPON countries to enter into the assessment, an internet-based Delphi survey was conducted.

The Delphi method is based on a structured process for collecting and synthesizing knowledge from a group of experts. The aim is to achieve a maximum level of agreement among the participants through several rounds of anonymous opinion surveys that are, nevertheless, informed by the summary results of the preceding round(s) (Helmer, 1966; Linstone and Turoff, 1975; Cooke, 1991). The principle advantages of this approach are that it: (i) avoids key persons exerting a higher influence on a group's responses, (ii) overcomes the geographical constraints and costs of bringing together a group of experts and (iii) allows Delphi participants to express their personal views freely due to the anonymity of answers.

Furthermore, by design the Delphi method is particularly useful for a topic where strong differences

[5]In the physical impact dimension, arithmetic means were first calculated for the indicator pairs: road and rail transport, airports and harbours, thermal power stations and refineries. Also in the economic impact dimension, the indicators relating to one sector were first grouped before calculating the overall economic impact across sectors.