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A spatially explicit scenario-driven model of adaptive capacity to global change in Europe

Lilibeth Acosta [a,b,*], Richard J.T. Klein [c,d], Pytrik Reidsma [e], Marc J. Metzger [f], Mark D.A. Rounsevell [f], Rik Leemans [g], Dagmar Schröter [h]

[a] Potsdam Institute for Climate Impact Research (PIK), Telegrafenberg A62, 14473 Potsdam, Germany
[b] School of Environmental Science and Management (SESAM), University of the Philippines, Los Baños, 4031 Laguna, Philippines
[c] Stockholm Environment Institute, Kräftriket 2B, 106 91 Stockholm, Sweden
[d] Centre for Climate Science and Policy Research and Department of Thematic Studies, Linköping University, Sweden
[e] Plant Production Systems Group, Wageningen University, The Netherlands
[f] Centre for the Study of Environmental Change and Sustainability, School of Geosciences, The University of Edinburgh, Drummond Street, Edinburgh EH8 9XP, UK
[g] Environmental Systems Analysis Group, Wageningen University, The Netherlands
[h] Risk, Policy & Vulnerability, International Institute for Applied Systems Analysis, Schlossplatz 1, 2361 Laxenburg, Austria

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ABSTRACT

Traditional impact models combine exposure in the form of scenarios and sensitivity in the form of parameters, providing potential impacts of global change as model outputs. However, adaptive capacity is rarely addressed in these models. This paper presents the first spatially explicit scenario-driven model of adaptive capacity, which can be combined with impact models to support quantitative vulnerability assessment. The adaptive capacity model is based on twelve socio-economic indicators, each of which is projected into the future using four global environmental change scenarios, and then aggregated into an adaptive capacity index in a stepwise approach using fuzzy set theory. The adaptive capacity model provides insight into broad patterns of adaptive capacity across Europe, the relative importance of the various determinants of adaptive capacity, and how adaptive capacity changes over time under different social and economic assumptions. As such it provides a context for the implementation of specific adaptation measures. This could improve integrated assessment models and could be extended to other regions. However, there is a clear need for a better theoretical understanding of the adaptive capacity concept, and its relationship to the actual implementation of adaptation measures. This requires more empirical research and coordinated meta-analyses across regions and economic sectors, and the development of bottom-up modelling techniques that can incorporate human decision making.

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) defines adaptive capacity as the ability to adjust to climate change to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (IPCC, 2007). The concept of adaptive capacity emerged to account for the fact that the mere existence of options to adapt to global change impacts does not mean that everybody has access to these options or is able to implement them. Factors that determine a sector's, society's or country's adaptive capacity include its economic wealth, its technology and infrastructure, the information, knowledge and skills it possesses, the nature of its institutions, its commitment to equity and its social capital (Smit et al., 2001). Since the publication of the IPCC Third Assessment Report (TAR; IPCC, 2001), adaptation research has aimed at better understanding the factors that influence adaptive capacity (e.g., Smit et al., 2001; Adger et al., 2004, 2009; Brooks et al., 2005; Pelling and High, 2005; Grothmann and Patt, 2005; Acosta-Michlik et al., 2006; Vincent, 2007; Acosta-Michlik and Espaldon, 2008; Pahl-Wostl, 2009; Williamson et al., 2010) and at developing and applying methods to assess and compare adaptive capacity (e.g., Moss et al., 2001; Yohe and Tol, 2002; Luers et al., 2003; Ivey et al., 2004; Brooks and Adger, 2004; Haddad, 2005; Adger and Vincent, 2005; Alberini

* Corresponding author at: Potsdam Institute for Climate Impact Research, Telegraphenberg A62, 14473 Potsdam, Germany. Tel.: +49 331 2882643; fax: +49 331 2882695.
E-mail addresses: lilibeth@pik-potsdam.de (L. Acosta), richard.klein@sei-international.org (Richard J.T. Klein), Pytrik.Reidsma@wur.nl (P. Reidsma), marc.metzger@ed.ac.uk (M.J. Metzger), mark.rounsevell@ed.ac.uk (Mark D.A. Rounsevell), Rik.Leemans@wur.nl (R. Leemans), Dagmar.Schroeter@gmail.com (D. Schröter).

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et al., 2006; Tol and Yohe, 2007; Acosta-Michlik et al., 2008; Carpenter and Brock, 2008; Sharma and Patwardhan, 2008; Gupta et al., 2010; Acosta and Galli, 2013).

This paper presents an indicator-based model for making spatially explicit future projections of Europe's adaptive capacity based on the storylines of IPCC's Special Report on Emissions Scenarios (SRES) (Nakićenović and Swart, 2000). The model was developed as a contribution to a European (i.e., the 15 European Union member states in 2001, plus Norway and Switzerland) vulnerability assessment of changes in the provision of ecosystem services caused by global change (Schröter et al., 2004, 2005; Metzger et al., 2008). Thus far, no scenario-driven adaptive capacity model exists, which can support the implementation of an integrative assessment framework of vulnerability to climate change. This assessment adopted the vulnerability concepts put forward by the IPCC TAR, which describes vulnerability as "a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity", and is described in detail by Metzger and Schröter (2006) and Metzger et al. (2006, 2008). Alternative scenarios of future climate (Mitchell et al., 2004) and land use (Rounsevell et al., 2006) formed an expression of the exposure in three future time slices (2020, 2050, 2080), whilst a suite of ecosystem models captured the system's sensitivity to these changes to identify potential impacts. Here, we describe the spatially-explicit, scenario-driven model of adaptive capacity, the third element of vulnerability.

The paper is organised into five sections: model development (Section 2) describes the construction of the indicator framework and scenario development for the socio-economic indicators. The model outputs are presented for the components of the indicator framework (Section 3.1) and for current and future adaptive capacity (Section 3.2). The validity of the adaptive capacity model is tested with respect to these outputs (Section 3.3) and the relevance of the model outputs is discussed for research and policy (Section 4). The weaknesses of the adaptive capacity model are emphasised in the conclusions to provide guidance for future research (Section 5). The study presented in this paper demonstrates that spatial patterns of adaptive capacity can be identified, assessed and projected into the future.

2. Model development

The development of the adaptive capacity model consisted of three distinct steps, as summarised in Fig. 1: the development of an indicator framework, the construction of scenarios and the aggregation of indicators.

2.1. Constructing an indicator framework

It was not possible to collect primary socio-economic data for the assessment of adaptive capacity given the spatial coverage of the vulnerability assessment. An indicator framework was developed therefore as the basis of a generic index of adaptive capacity, relying on secondary data and using the literature on adaptive capacity and on socio-economic indicators. The indicator framework was structured around four questions that address different dimensions of adaptive capacity, and these were used to identify three components and six determinants of adaptive capacity (Table 1). Framing adaptive capacity through questions that relate to '*awareness*', '*ability*' and '*action*' is consistent with previous work, such as the approach to assess intervention strategies in the context of the Millennium Ecosystem Assessment (Simpson and Vira, 2010). The identification of determinants is also consistent with earlier studies (e.g., Carpenter et al., 2001; Smit et al., 2001; Smit and Skinner, 2002; Yohe and Tol, 2002; Adger et al., 2005; Carpenter and Brock, 2008).

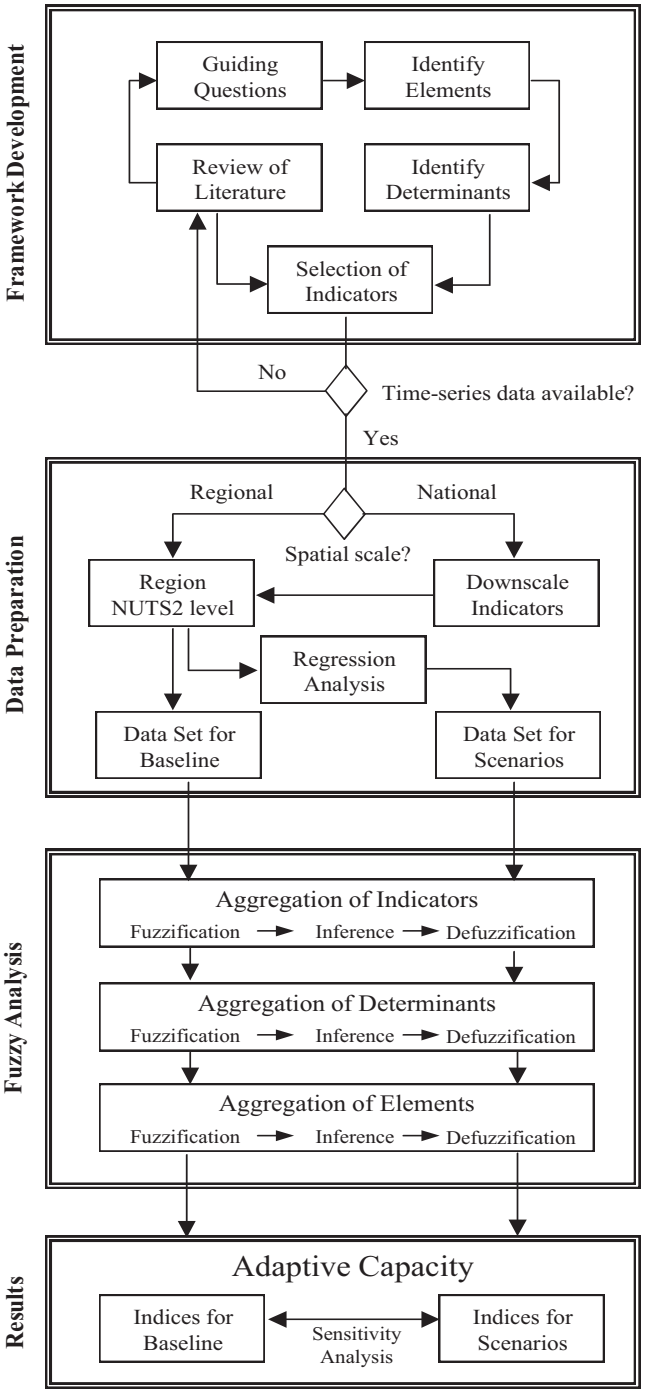

Fig. 1. Methodological steps involved in the development of the adaptive capacity model.

Two indicators were selected to represent each of the six determinants, based on theoretical assumptions and data availability. Time series data were required for the scenario development (Section 2.2). Fig. 2 shows the indicator framework, whilst Table 2 presents an overview of the collected data for each indicator. Where available, sub-national administrative indicators were used at the NUTS2 data level (i.e., Nomenclature of Territorial Units for Statistics with 216 NUTS2 regions in EU15) (Table 2).

It was straightforward to identify appropriate indicators for some of the determinants listed in Table 1 since these are used extensively in the literature: female activity rate and income inequality are standard indicators of equity (e.g., Grown et al.,

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