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Vulnerability to sea level rise: A novel local-scale indicator-based assessment methodology and application to eight beaches in Shoalhaven, Australia

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ABSTRACT

Vulnerability of a socio-ecological system to one or more climatic hazards depends on climatic, geophysical, socio-economic and institutional factors. In addition, vulnerability is a scale- and place-dependent concept. While decision-making on adaptation is often made by local government, only a small number of local-scale assessments have been conducted. When indicators are used, global utility functions based on additive or multiplicative aggregation implicitly assume complete compensation between indicators, implying that one source of vulnerability (e.g., proximity to the sea) can always be compensated for by an advantage in another source (e.g., strong social or economic capital) when evidence shows that this is not always the case.

This paper presents an indicator-based assessment of vulnerability of eight beaches in Shoalhaven, New South Wales, that are especially exposed to sea level rise. Its goal is twofold. First, it illustrates how indicator-based vulnerability assessments can be applied at a local scale – and not just sectoral, regional and national scales – with the aim of informing local government adaptation planning and resource allocation. In the process, models operationalising the concepts of exposure, sensitivity and adaptive capacity are developed for two valued attributes identified through discussions with the local council, namely the well-being of beach residents and the well-being of users of infrastructure systems located at the beaches.

Second, the paper studies, for the first time, the way outranking procedures can be applied in real-life vulnerability assessments as a form of data aggregation that better reflects the non-compensatory nature of many vulnerability indicators. The strengths and weaknesses of the outranking approach are discussed, especially the extent to which the concepts of preference, indifference and dominance thresholds can be conveyed to, and their values elicited from, stakeholders.

1. Introduction

Sea level rise may accelerate the erosion of coastal margins, threatening surrounding land, property and infrastructure systems. Forty-five out of 63 most populated cities of the world – namely those with 5 million or more inhabitants in 2011 – are located on or near the coast (United Nations, 2012). The vulnerability of coastal settlements, communities and infrastructure systems to sea level rise has received increasing attention in the literature over the last decade (Walsh et al., 2004; McInnes et al., 2016).

Vulnerability assessments, both quantitative and qualitative, can be useful analytical exercises informing and rationalising decisions on adaptation (Birkmann, 2007; Kienberger et al., 2013). The concept of vulnerability takes into account both geo-physical and socio-economic components of risk (Kelly and Adger, 2000; O'Brien et al., 2007). In other words, it is not just the extent of exposure of a socio-ecological system (SES) to the hazard in question that matters but the ramifications of that exposure, including the SES's ability to cope with and adapt to it.[1] Assessments of vulnerability found in the literature suffer from a number of limitations, two of which are of particular concern to us here.

First, where indicators are used, utilitarian aggregation approaches – such as additive or multiplicative aggregations – do not take into account the non-compensatory nature of different processes generating vulnerability (e.g., beyond a certain threshold of sea level rise, no level of adaptive capacity of small Island states can help overcome the impacts of the hazard, i.e., an increase in adaptive capacity may not compensate for an excess in exposure to the hazard). Most indicator-

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[1] We follow Norgaard (2006) in defining a Socio-Ecological System (SES) as SES as a coupled human-environment system which includes a 'bio-geo-physical' unit and its associated social actors and institutions.

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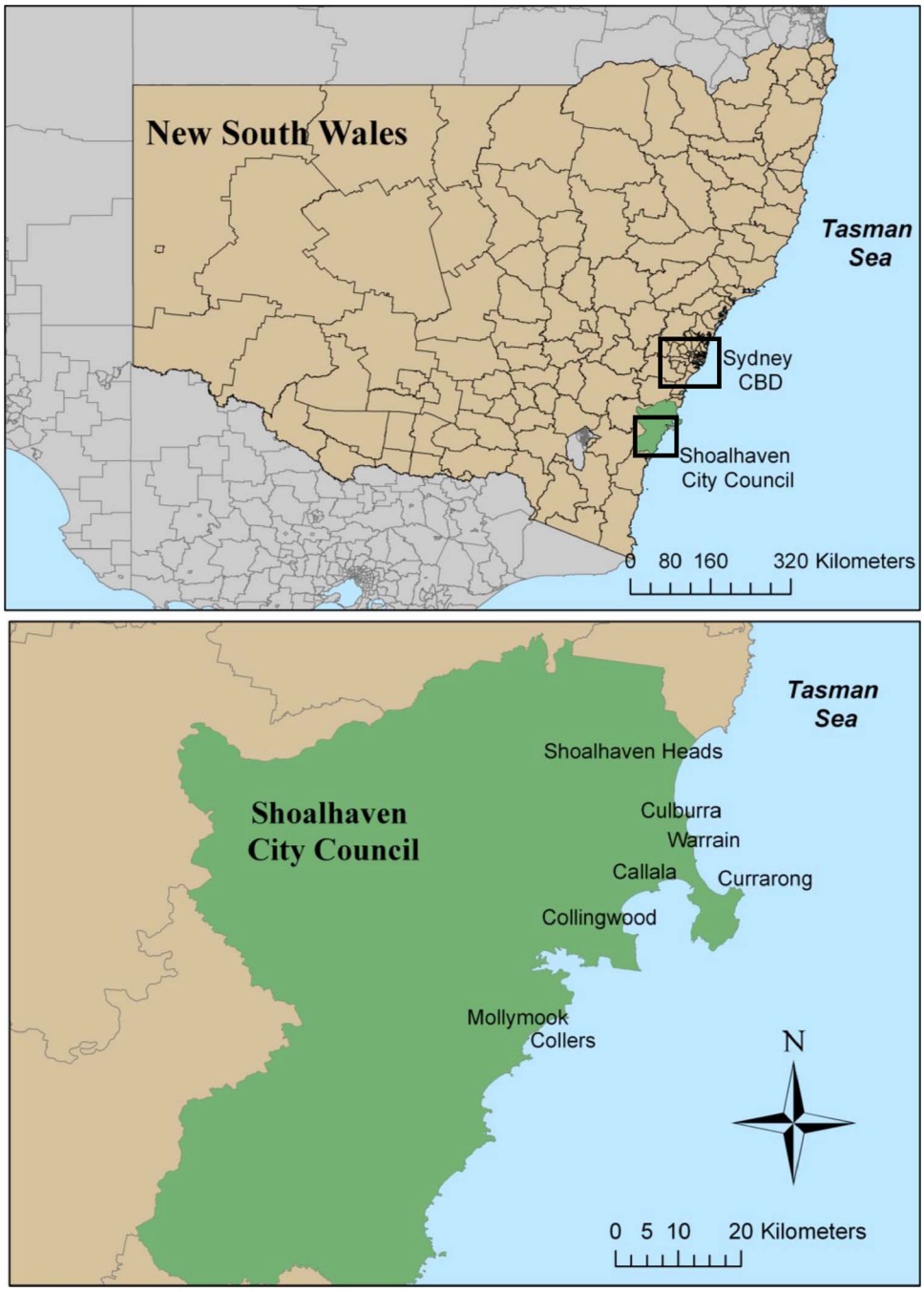

Fig. 1. Study Area.

based assessments use additive aggregation with equal weights without providing justification for the utility function as a proxy for vulnerability and without discussing how a different choice of weights might affect analytical outcomes (Tonmoy et al., 2014). Additive aggregation is ideally suited to contexts in which all indicators are convertible to a single (usually monetary) value. However, many scenarios exist where this single-value approach may not be well suited.

Outranking procedures, developed in decision science precisely to deal with the non-compensatory nature of decision criteria, use pairwise comparisons of SESs to rank their vulnerabilities, without the need for any global utility function. They have recently been suggested as better aggregation alternatives for ranking vulnerabilities and better identify the structure of stakeholder preferences and norms (Cinelli et al., 2014; El-Zein and Tonmoy, 2015; El-Zein and Tonmoy, 2017). However, these procedures typically require additional data to be elicited from stakeholders in order to characterise the extent and limits of compensation. There is no literature on this topic in the vulnerability literature and very little in the decision-science outranking literature (e.g., Figueira and Roy, 2002; Kodikara et al., 2010). To date, no attempt appears to have been made at applying outranking procedures to a real-life assessment case study; hence, their ability to offer a viable aggregation alternative has not been tested.

Second, vulnerability is a scale-dependent concept, i.e. it is likely to be conceived of, operationalised and assessed, differently at different spatial and temporal scales (e.g, Sterr et al., 2003; McLaughlin and Cooper, 2010; Tavares et al., 2015). In addition, it is place-dependent which means that processes generating vulnerability are determined by place-specific factors, in addition to regional, national and global ones (Dolan and Walker, 2006; Douglas et al., 2012). The scale at which assessments are actually conducted is usually determined by the policy questions and institutional structures and processes that have brought them about, rather than the scale at which key processes occur. Hence,