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An index-based method to assess risks of climate-related hazards in coastal zones: The case of Tetouan

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ABSTRACT

The regional risk assessment carried out within the ClimVar & ICZM Project identified the coastal zone of Tetouan as a hotspot of the Mediterranean Moroccan coast and so it was chosen for the application of the Multi-Scale Coastal Risk Index for Local Scale (CRI-LS). The local scale approach provides a useful tool for local coastal planning and management by exploring the effects and the extensions of the hazards and combining hazard, vulnerability and exposure variables in order to identify areas where the risk is relatively high. The coast of Tetouan is one of the coastal areas that have been most rapidly and densely urbanized in Morocco and it is characterized by an erosive shoreline. Local authorities are facing the complex task of balancing development and managing coastal risks, especially coastal erosion and flooding, and then be prepared to the unavoidable impacts of climate change. The first phase of the application of the CRI-LS methodology to Tetouan consisted of defining the coastal hazard zone, which results from the overlaying of the erosion hazard zone and the flooding hazard zone. Nineteen variables were chosen to describe the Hazards, Vulnerability and Exposure factors. The scores corresponding to each variable were calculated and the weights assigned through an expert judgement elicitation. The resulting values are hosted in a geographic information system (GIS) platform that enables the individual variables and aggregated risk scores to be color-coded and mapped across the coastal hazard zone. The results indicated that 10% and 27% of investigated littoral fall under respectively very high and high vulnerability because of combination of high erosion rates with high capital land use. The risk map showed that some areas, especially the flood plains of Restinga, Smir and Martil-Alila, with distances over 5 km from the coast, are characterized by high levels of risk due to the low topography of the flood plains and to the high values of exposure. The CRI-LS provides a set of maps that allow identifying areas within the coastal hazard zone with relative higher risk from climate-related hazards. The method can be used to support coastal planning and management process in selecting the most suitable adaptation measures.

1. Introduction

Mediterranean coastal zones support a very high population density that leads to high social and bio-geophysical vulnerabilities as coastal infrastructures are exposed to direct waves and the lack of space for these vulnerable systems to be moved to less vulnerable areas. The increased risks of natural hazards generated and/or exacerbated by sea level rise and marine storms and the growing concentration of people and activities on the coastal zone, requires updated information and a better understanding on coastal zones vulnerabilities and risks at the local scale (Satta, 2014). Even if extreme events often cannot be predicted, adaptation measures can be planned to reduce the potential risks and to cope with uncertainties. Notwithstanding these emerging risks, lack of robust scientific knowledge, lack of local data, local experts have led to coastal decision makers under-evaluating sea level rise as an immediate threat (Özyurt and Ergin, 2010). These uncertainties demand a high degree of flexibility to adapt to climate and non-climate driven changes and, in this sense, designing and implementing a method to assess current and future risks to coastal hazards is a challenging issue for research.

These issues are even more acute in some coastal areas of the southern shore of the Mediterranean, where local reliable data are often lacking and where local capacities to conduct risk assessment

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need to be strengthened. Therefore the development of a simple and cost-effective method to assess vulnerability and risk, which allows coastal managers and planners to rapidly determine high-risk areas in the coastal zone, is crucial to manage the coastal zone effectively over the next decades.

In scientific literature several models and tools to assess coastal vulnerability and risk exist that differ in complexity, in the number of processes that they include, the application at various scales and in their outputs. Just few comprehensive reviews were made to assist coastal managers in the selection of an appropriate method for conducting a coastal vulnerability assessment (Mcleod et al., 2010; ETC-CCA, 2011; Satta, 2014).

Satta (2014) prepared a review and analysis of existing methods for the assessment of coastal vulnerability and risk to climate and non-climate induced hazards at different spatial scale (from regional to local). In this work, 26 tools were selected and then clustered in four main categories (Index-based tools, tools based on dynamic computer models, GIS Based Decision Support tools, Visualization tools). The tools must meet three main criteria (including climate and non climate drivers and related impacts; suitable with the conditions of a local coastal community; outputs useful to support local adaptation), which in turn are divided into nine requirements (Fig. 1). These requirements intend to describe the needs of a Mediterranean coastal community in terms of assessment to current and future risks to coastal hazards (Satta, 2014).

Most of the vulnerability and risk assessment studies, developed so far, are primarily driven by top-down processes in which local managers and other local stakeholders are not involved (Satta, 2014). Moreover most existing vulnerability and risk assessment methods were not developed starting from the needs of the local communities (Satta, 2014). Another important limitation is that adaptive capacity and response of systems to climate change drivers and related impacts are often unknown (Mcleod et al., 2010). These aspects represent a concrete weakness common to several existing tools. Nevertheless, four methods were identified as meeting these nine requirements: CVI-SLR (Özyurt, 2007), Multi-scale CVI (McLaughlin and Cooper, 2010), DESYCO (Torresan et al., 2010), SimCLIM (CLIMsystems Ltd). The Index-based methods (CVI - SLR and Multiscale – CVI) present several advantages like to be easily upgradeable (variables can be added or eliminated) and algorithms employed for the calculation are readily understandable for coastal managers and practitioners. DESYCO, developed by Torresan et al. (2010) consists of identifying vulnerability indicators and indices for the evaluation of climate change impacts in coastal zones and it aims to identify and prioritize areas and targets at risk in the considered region (ETC-CCA, 2011). DESYCO implements a Regional Risk Assessment (RRA) methodology and it is based on Multi-Criteria Decision Analysis (MCDA). The main limitation of DESYCO, as reported by ETC-CCA (2011), consists in the potential geographical errors induced by the diversity of data sources formats and spatial scales. Among the methods based on dynamic computer models, SimCLIM is very flexible, and can be customized to local conditions (climatic, physical and socio-economical). Indeed, its strengths are the 'open-framework' features that allow its use in very different geographical and spatial conditions, which meet the requirements, set by Satta (2014). However, as all the dynamic computer models, the main limitation consists in the upgradability of the algorithms and variables, which requires medium to high expertise for its customisation to new regions (ETC-CCA, 2011). A fifth method, which meets the nine requirements, is the Regional Vulnerability Assessment (RVA) methodology developed by Torresan et al. (2012). The RVA is an index-based methodology with a heterogeneous subset of bio-geophysical and socio-economic vulnerability indicators (Torresan et al., 2012). The only limitation of this method to the objectives of this work, is that its theoretical framework refers to the concept of vulnerability defined in AR4 (IPCC, 2007).

Based on the analysis of main advantages and disadvantages (Mcleod et al., 2010; ETC-CCA, 2011; Satta, 2014) the following conclusions can be drawn in relation to the possible use of these methods to assess coastal risk to climate change at the Mediterranean local level:

- methods refer to vulnerability concept as mainly incardinated in the theoretical framework of IPCC (2007). All these studies have been carried out before the definition of a new conceptual framework for coastal risk as proposed by IPCC (2014a; 2014b);
- most of these methods does not take into account the feedback loops that operate between different subsystems and process at various scales, which is a limitation of classical approaches based on the sectorial analysis of the ecological or socio-economical components (Satta, 2014);
- just few methods address coastal risk at an appropriate scale showing low flexibility to operating at various spatial scales;
- several methods attempt to provide absolute predictions about the impacts of climate change rather, than providing information about the coastal areas likely to be affected more severely than others (Torresan et al., 2010).

To overcome these limitations a method, called Multi-scale coastal risk index (MS-CRI), was developed by Satta et al. (2015). The conceptual framework adopted in the MS-CRI was initially defined by Satta (2014). The MS-CRI was implemented and tested within the framework of the ClimVar Project[1] to carry out the regional risk assessment of eleven Mediterranean countries and the local risk assessment in one Mediterranean coastal spot. The overall goal of the Climvar project, funded by GEF and coordinated by UNEP, was to promote the use of ICZM in the participating Mediterranean countries as an effective tool to deal with the impacts of climate variability and change in coastal zones by mainstreaming them into the ICZM process.

The MS-CRI was deemed to be the method that best fitted the purpose of the ClimVar project, due to the following characteristics: it is a multi-scale risk assessment approach; integrates the theoretical framework of AR5 (IPCC, 2014a); integrates a large set of socio-economic variables; risk assessment targets are represented by variables that are separated into three sub-indices; takes into account the interaction among different subsystems, presents an easy calculation process to analyze the different vulnerability factors; and outcomes consist of vulnerability and risk maps. The MS-CRI combines multiple variable layers, representing different aspects of risk, in sub-indexes (hazard, vulnerability and exposure) layers, in such a way that risk 'hotspots', as well as areas of relatively lower risk, emerge from the integration of the layers. The application of the MS-CRI at the local scale (CRI-LS) aims to support policy makers and coastal managers to evaluate how climate and non-climate forcing interact with existing hazards to impact the coastal zones. As direct policy implication the CRI-LS provides the definition of the coastal hazard zone, under the 2100 scenario, and a set of risk maps that can assist policy makers to prioritize coastal management efforts that need to be undertaken to minimize risks or mitigate the consequences of climate and non-climate related hazards. Such a tool can be easily integrated into an overall coastal management and adaptation strategies to support the implementation of the ICZM Protocol. To test Multi-Scale Coastal Risk

[1] http://planbleu.org/en/activites/changement-climatique/climvar-project.