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Application of the Coastal Hazard Wheel to assess erosion on the Maltese coast

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ABSTRACT

This study provides an assessment of erosion hazard on the Maltese coast via application of the Coastal Hazard Wheel, a tool that also facilitated analysis of a number of other inherent coastal hazards including ecosystem disruption, gradual inundation, salt water intrusion, and flooding. The CHW characterises the coastal environment by considering geological layout, wave exposure, tidal range, flora and fauna, sediment balance and storm climate. Application of the CHW identified coastal erosion to present a high to very high influence on the Maltese coastline, with 45.7% of the coast exhibiting a low level of erosion hazard, 12.1% a moderate level, 12.6% a high level and 18.4%, a very high level of erosion hazard.

Application of the CHW suggested somewhat higher erosion hazard levels than prior studies using different methodologies; it also confirmed the ease of application of this climate change sensitive coastal hazard identification tool. Management considerations identified a wide range of options the applicability of which is highly dependent on specific coastal configuration and that characterisation of the latter is crucial to allow appropriate management.

The study generated management-useful maps describing coastal susceptibility to various hazards and hazard levels. It further provided a description of the entire Maltese coast in terms of ten different coastal configurations that infer management considerations of six coastal characteristics and five hazards. The study outputs are presented as a contribution to more effective management and decision-making by civil protection and planning agencies and as a key first step in the risk analysis process.

1. Introduction

The study of climate change is a relatively recent topic that has rapidly gained attention in present day societies. Gradual changes in climatic features of the earth are relatively normal, but the fast rate of industrialization, together with scientific and technological advances have led to the disruption of such natural patterns. In fact, the anthropogenic influence on our atmosphere due to the emissions of CO_2 and other greenhouse gasses has changed climatic patterns that we have been used to and has led to a phenomenon known as global warming (Hardy, 2003). The IPCC fifth assessment report has clearly shown that some of the main evidence of climate change is the increase of land and ocean temperatures in past decades, the alterations to hydrological patterns and also the modification of biological systems such as the migration of both terrestrial and marine species in order to adapt to the ever changing climate. Last but not least, research has also shown that humans are already being affected by climate change and in the longer-term, such impacts are very likely to get worse leading to modification of living standards (IPCC, 2014). Apart from higher global temperatures, we have been experiencing an increase in catastrophic events such as hurricanes, intense rainfalls and an accelerated melting of polar ice sheets, which in turn lead to sea level rise (USGCRP, 2014).

The influence of climate change is particularly relevant to coastal zones and associated coastal communities (Nicholls et al., 2007). According to Creel (2012), about half of the global population live within 200 km of the coast and these figures are likely to double by 2025. Furthermore, the relatively small size and low topographic coastlines of small island states such as Malta, together with limited financial and technical opportunities and adaptive capacities, makes these countries very susceptible to extreme weather events, flooding and sea level rise (Mimura et al., 2007; Galdies, 2015). The United Nations Framework Convention on

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Climate Change (UNFCCC) also identifies small island developing states (SIDS) as the most vulnerable to the extreme weather events arising from climate change. As a result, consideration and implementation of adaptive measures on a national scale take on a high priority, in order to ensure protection of the limited resources present on such islands and at the same time ensure that the public is able to adapt to different conditions brought about by climate change (UNFCCC, 2005; Baldacchino and Galdies, 2015).

Located centrally within the Mediterranean Sea, the Maltese archipelago has a total area of about 316 km^2, of which approximately 252.8 km^2 are coastal areas (Planning Authority, 2002). The three main islands of Malta, Gozo and Comino share a total coastal length of about 173 km (National Communication of Malta to the UNFCCC, 2014), 60% of which is quite inaccessible due to its relief and/or geological features. The other 40% is highly urbanized, especially in the Grand Harbour area on the north-east coast of Malta which houses the main concentration of the island's population (Policy Research Corporation, 2009). Circa 5% of Malta is about 7.6 m above sea level and 1%, about 1 m above sea level (Briguglio, 2000). It follows therefore, that Sea Level Rise (SLR) and coastal floods constitute an increased threat for this part of the Maltese coast.

Tectonic activity and faulting have tilted the island with a south-west (up to 253 m) to north-east (less than 1 m above sea-level) slant (Magri, 2006). For such reasons, the different geomorphological characteristics present along the coast, have led to over-development of most of the north-eastern low-lying coastal zones. Demand for urban and industrial development within the coastal zone is still on the increase due to the expansion of the tourism sector (MEPA, 2015) and the very high local population density of over 1200 persons per km^2, making it is one of the highest in the world (NSO, 2015). As a consequence of its heavy utilisation, this low-lying coast of Malta has been classified as being relatively vulnerable to sea level rise and inundation (Policy Research Corporation, 2009). The main physical and socio-economic indicators of the coastal zone of the Maltese islands have also been considered by several European Commission-led studies. According to these, under medium sea level rise conditions, the Maltese coastline subject to erosion is approximately 7 km (or 0.04% of the total).

In Malta, coastal protection policy is carried out at a national level by a number of government-led institutions. These include the Ministry for Sustainable Development, the Environment and Climate Change with the support by the Environment and Resources Authority (located within the same Ministry) in terms of environmental regulation under the Environment Protection Act, and by the Planning Authority (within the Planning Directorate, Office of the Prime Minister), in terms of land use and spatial planning (planning and regulation of land development) under the Development Planning Act. Actual maintenance and protection measures are normally undertaken and financed by individual entities carrying out development on the coast (MRRA, 2012).

While much work remains to be done with regards to the study of vulnerability to climate change-sensitive hazards and related adaptation measures, the Maltese government has to date formulated a 2009 National Mitigation Strategy and a 2012 National Climate Change Adaptation Strategy together with legislation targeting climate change-relevant emission reduction targets (MRRA, 2009, 2012; National Communication of Malta to the UNFCCC, 2014). While the National 2014 Communication of Malta to the UNFCCC lacked any detailed study on specific coastal area susceptibility to coastal hazards, it did highlight predicted sea level rise and increasing extreme weather events as a considerable threat to the island's highly populated coastal areas (in view of their potential impacts of inundation, coastal erosion and damage by storm surges, waves and high winds particularly on the Blue Clay geological formation when exposed at sea level). Furthermore, the Communication identified 1.11 km^2 or 0.36% of the island's coastline as being susceptible to sea level rise, with beaches particularly prone to erosion. While coastal development, protected areas, ports, infrastructures and roads were highlighted as being particularly vulnerable to sea level rise, a wider range of largely coastal land-uses were considered as vulnerable to climate change in general. These included low-lying road networks in the North of the island, coastal land reclamation projects and man-modified (including urbanized) low-lying coastal areas. A possible indication of the priority that coastal erosion holds within Government agenda may be reflected by the use of European Union funds by the Maltese Government to address hazard-related issues such as the development of a national Storm Water Project against flash flooding and other smaller flood relief projects. Coastal protection against extreme storm events and sea level rise is largely limited to road/seafront protecting sea walls and harbour breakwater protection structures (Walker-Leigh, 2006). Between the 2000–2015 period, the local expenditure against flooding and coastal erosion was in the region of Euro 91 million. Of this, only Euro 1.7 million was allotted to coastal erosion in the form of beach nourishment projects (GHK, 2006). This is surprising given the inherent value of the Maltese coast. Given its small size, the entire island has been considered a coastal region and the GDP for this coastal zone has been calculated at Euro 6414 million (EEA, 2006; Doody et al., 2004; EUROSTAT, 2016).

The aim of this research was to carry out an assessment of erosion hazard levels along the Maltese coastline. The objectives included application to the Maltese coast of the Coastal Hazards Wheel (Appelquist and Halsnæs, 2015), a hazards assessment tool that assesses ecosystem disruption, gradual inundation, salt-water intrusion, erosion and flooding. This was achieved via the evaluation of:

- publicly available data;
- freely available, remotely sensed data;
- field data collected via ground-truthing exercises.

The significance of this study revolves around the absence of island-wide evaluation of coastal erosion hazard levels and the need to integrate such data into the longer-term process of risk assessment for the Maltese coast.

2. Methodology

Appelquist and Halsnæs (2015) have described the Coastal Hazard Wheel (CHW, 2.0 version), as a particularly versatile and standardised way to objectively assess the degree of erosion hazard of entire coastal stretches. The CHW has been recommended by the United Nations Environment Programme (UNEP) as a risk assessment tool to aid coastal managers, planners and policy makers assess how coastal areas are likely to be affected in relation to different hazard levels induced by climate change (Appelquist, 2013). This tool was mostly designed to enhance decision-making in developing states (Appelquist and Balstrøm, 2014), since it can be applied without the need of having extensive digital data availability (UNEP, 2012).

At its most basic, the CHW can be applied to assess hazard levels where data availability is limited to publicly available data and the use of freely available (e.g. Google Earth) remotely sensed data. This option facilitates a preliminary assessment of hazard types and location. While a more accurate (intermediate level) result may be obtained with the inclusion of ground-validated (in addition to remotely sensed data), a high accuracy and locally focused hazard