The coastal vulnerability of the north-eastern sector of Gozo Island (Malta, Mediterranean Sea)

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Conceptual Framework

The sustainable conservation of coastal areas and their adaptation to a changing climate are worldwide issues. Coastal vulnerability evaluation and risk assessment are therefore of paramount importance for supporting integrated coastal management and identifying suitable management actions. Nevertheless, these concepts often result in conflicting interpretation by various sectors of researchers and policy makers. For these reasons, this study presents an *apriori* discussion of different definitions of risk, exposure and vulnerability. Only in recent years, a common and shared definition of the vulnerability concept in Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR) fields has been provided by United Nation bodies (UNDRR, IPCC). By mirroring physical exposure as "physical vulnerability" and combining it with "social vulnerability", an Overall Vulnerability Index is proposed in this research to identify areas that can be negatively affected by climate- and marine-related processes (cf. Rizzo et al., 2020). Specifically, the study was focused on the assessment of the vulnerability to coastal erosion, landslides and sea level rise along the NE sector of the Island of Gozo (Maltese archipelago) to which the island is particularly prone.

Study area

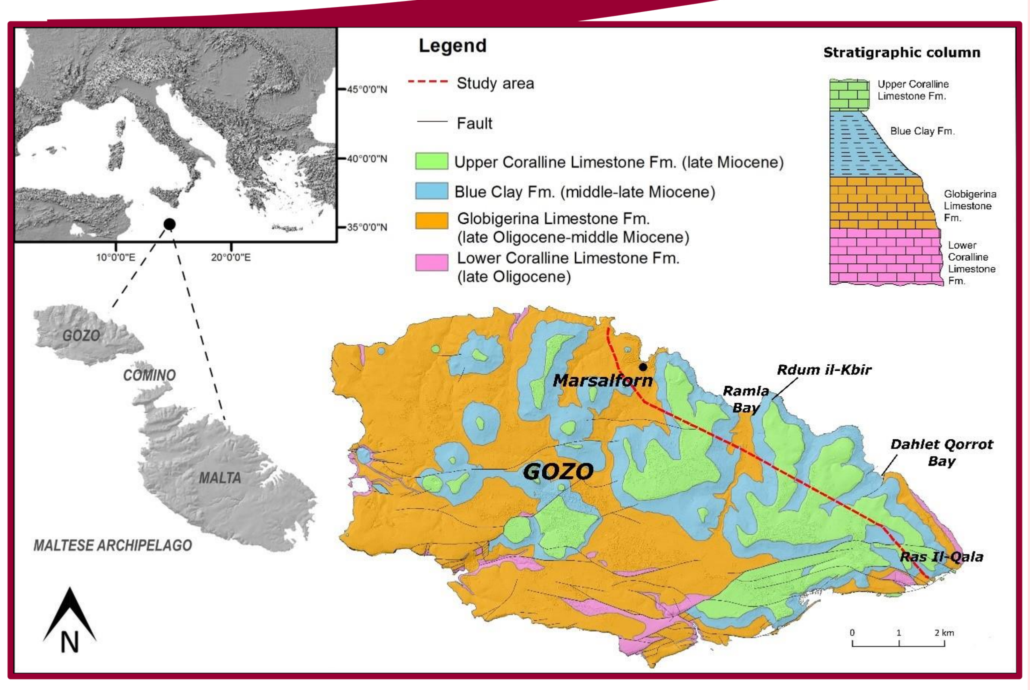


Fig. 1 – Geographic and geological setting of Gozo Island located in the Maltese archipelago (central Mediterranean Sea) and location of the study area (red dashed line).

The Maltese archipelago is located in the central Mediterranean Sea and comprises the main islands of Malta, Gozo and Comino (Fig. 1). Due to their geological and geomorphological setting, these islands are particularly prone to different marine-related and gravity-induced processes. The Island of Gozo is characterized by varied landforms, including (a) block slides; (b) rock falls at the bottom of limestone plateaus; (c) plunging cliffs; (d) sloping coasts; (e) shore platforms; (f) pocket beaches; (g) cliffs shaped in Blue Clays; (h) built-up coasts (Prampolini et al., 2018). Detailed geomorphological investigation, integrated with the analysis of marine geophysical data, has allowed characterization of the main coastal features and identification of areas susceptible to coastal hazards along North Eastern coast of the island (Figs. 1 and 2). Furthermore, Gozo features a high economic value derived mainly from tourist activities and natural protected areas, that altogether make coastal vulnerability a major concern.

Fig. 2 – Main geomorphic features of the study area. Their spatial distribution is shown in the pie diagram in Fig. 1. After Rizzo et al. (2020).

Materials and Methods

The proposed vulnerability analysis is based on a conceptual interpretation of "overall vulnerability", defined as the combination of two distinct components: physical vulnerability and social vulnerability. They are evaluated by means of a set of indicators that allow taking into account both the exposure level of the local land uses and anthropic assets located in the study area ("physical indicators") and the social vulnerability in terms of population capacity to respond to and cope with a hazardous event ("social indicators"). Data aggregation makes possible the derivation of the overall coastal vulnerability map.

1 Indicators selection

Physical Indicators

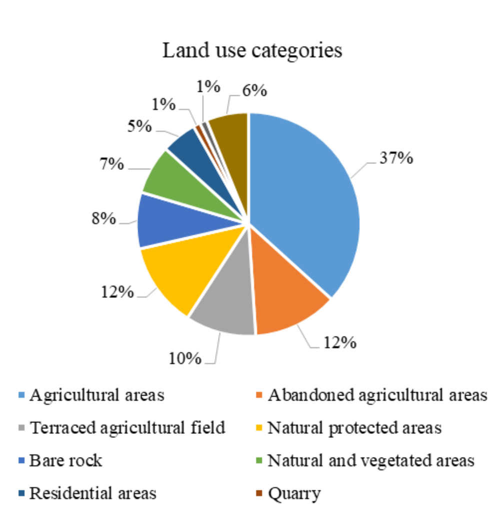
- ✓ Land Use
- ✓ Transport Network
- ✓ Utilities

Social Indicators

- ✓ Health care function
- ✓ Disability function
- ✓ Old age function
- ✓ Family/children function
- ✓ Unemployment function
- ✓ Population

2 Data Analysis

Following the methodological approach proposed in previous studies (Armaroli and Duo, 2018; Aucelli et al., 2018, Ballesteros et al., 2018; Van Dongeren et al., 2018), an exposure level (ranging from 1 – very low to 5 – very high) was assigned to each physical indicator based on expert judgement. These layers were overlaid to estimate the physical vulnerability of the area. The social indicators allowed characterization of the districts located in the investigated area by evaluating, directly and indirectly, the social characteristics of the population. They were also ranked in five levels. The social data were provided by the Malta National Statistics Office (2019).



Physical vulnerability	Surface (km²)	Surface (%)
VERY LOW	2.0	21.7
LOW	5.4	57.8
MEDIUM	0.7	7.4
HIGH	0.005	0.1
VERY HIGH	1.2	13.0

Based on data available on: https://msdi.data.gov.mt/geoportal.html; https://download.geofabrik.de/europe/malta.html.

3 Data Overlay

The overlay of the two sets of indicators enabled the coastal zonation showing the grade of the overall vulnerability, calculated by means of the following index:

Overall Vulnerability Index = (Physical vulnerability * Social vulnerability) ^ 0.5

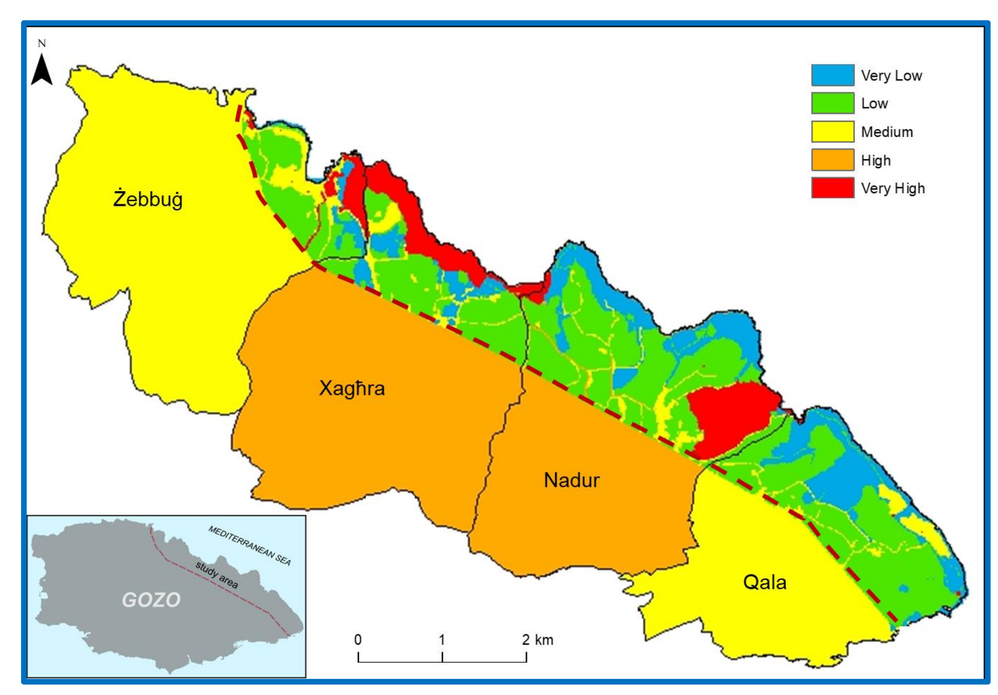
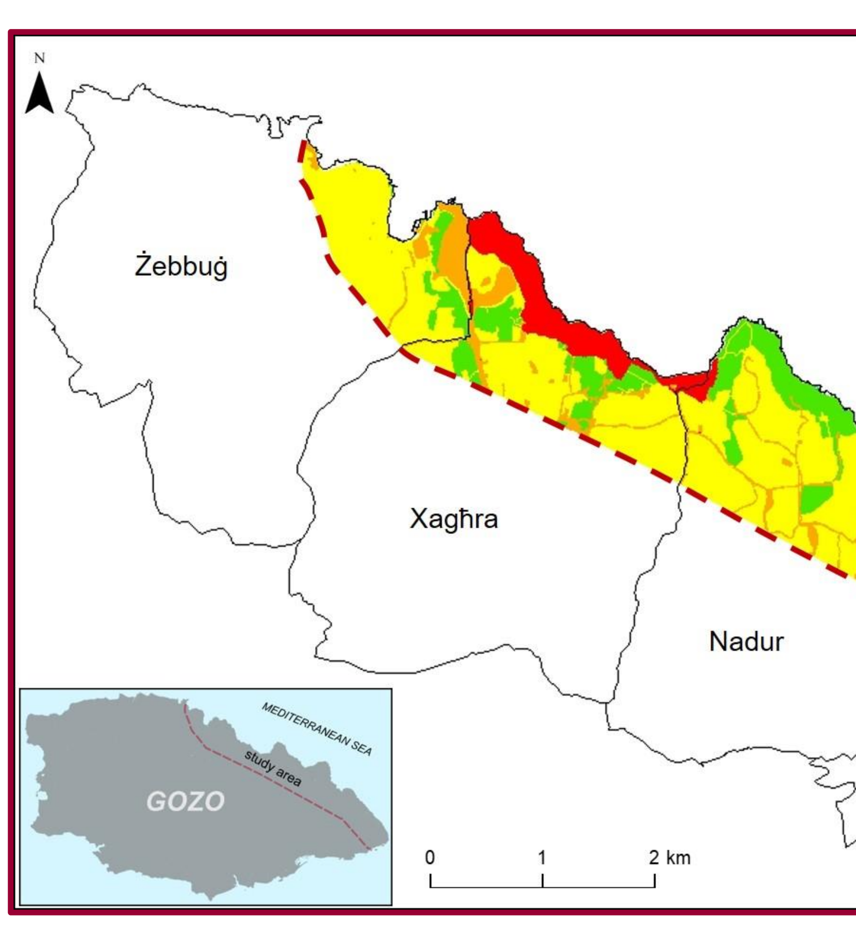


Fig. 3 – Physical and social vulnerability classification. The red dashed line identifies the inland boundary of the study area. The districts' colour is referred to their social vulnerability level.

Resulting Vulnerability Map



Overall vulnerability	Surface (km²)	Surface (%)
VERY LOW	-	-
LOW	1.9	20.4
MEDIUM	5.6	61.3
HIGH	0.7	7.3
VERY HIGH	1	11

Fig. 4 – Overall vulnerability map resulting from the spatial aggregation of the physical vulnerability and social vulnerability levels over the investigated area.

Results and Discussion

The proposed index-based method allowed zoning of the investigated coastal stretch into different levels of vulnerability to climate- and marine-related processes. Results show that the study area can be divided in four zones, since there are no areas with a very low level of vulnerability. The coastal sectors located east of Marsalforn Bay, which include an important tourist attraction hosting the largest sandy beach in Gozo (Ramla Bay), show the highest overall vulnerability level. This is due to the combination of very high physical vulnerability levels pertaining to the presence of two Natura 2000 sites and high social vulnerability levels for the Xagħra and Nadur districts. The coastal sector surrounding Marsalforn Bay is mainly characterized by a medium level of overall vulnerability as a result of the combination of a medium physical vulnerability level, explained by the presence of residential areas, and, a medium social vulnerability level obtained for the Żebbuġ district. Beyond the site-specific results, the proposed method represents an important contribution toward more comprehensive risk assessment, also in terms of its potential transferability and replicability to different hazard types, including the local effects of climate change from extreme events and sea level rise, responding to the main requirements of the international agreements on CCA and DRR. Finally, it should be highlighted that the outputs of the method provide stakeholders with readily available data for the identification of the most exposed and vulnerable zones (hotspot areas) that require action for their protection as a matter of priority.

Further details on this research are available in Rizzo et al., 2020 (Water - MDPI).

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