Risk and vulnerability maps for selected coastlines in Malta & Turkey with regard to tsunamis & SLR

DURATION: 2012

TARGET COUNTRIES : Euro-Mediterranean countries

PARTNERS INVOLVED :
Coordinating Centre: ICoD La Valletta, Malta
Other Centres:
Other Partners: Middle East Technical University (METU), Turkey

OBJECTIVES OF THE PROJECT

Global objective for 2012-2013:
Identification and mitigation of risk and vulnerability to Sea Level Rise and Tsunamis for selected low lying coastal areas in the Maltese islands and Turkey.

Specific yearly objectives :
2012:
3-year project conclusion (see expected results)

EXPECTED RESULTS

2012:
- Development of Risk / Vulnerability maps.
- Comparison of the scenario solutions and computational results.
- GIS based inundation mapping.
- Producing vulnerability risk maps under the conditions of tsunami and sea level results.

RESULTS OBTAINED PREVIOUSLY (if any)

2010: Identification of historical events, selection of study areas from Turkey and Malta subject to possible effects of tsunamis, collection of necessary data (near-shore bathymetry and topography, distribution of coastal and marine structures and their characteristics, wind, wave and sea level data), public surveys, processing of data and database development for the computational tools.
2011: Development of regional / local scenarios (e.g. forecasted climate change impact on Sea Level Rise and possible tsunami events, downscaling from global to regional to local scenarios); Correlation of Mediterranean regional history of tsunamis to local vulnerability, wind and wave climate studies for selected sites, wave transformation studies, tsunami simulations and computations of the near shore tsunami parameters at selected sites, development of database for the vulnerability risk maps.

RESULTS OBTAINED IN 2012

Work package 1 (prepared by ICoD, Middle East Technical University):
Description: Development of Risk / Vulnerability maps.
Associated deliverables: see above

Work package 2 (prepared by ICoD, Middle East Technical University):
Description: Comparison of the scenario solutions and computational results.
Associated deliverables: see above

Work package 3 (prepared by ICoD, Middle East Technical University):
Description: GIS based inundation mapping
Associated deliverables: see above

Work package 4 (prepared by ICoD, Middle East Technical University):
Description: Producing vulnerability risk maps under the conditions of tsunami and sea level results.
Associated deliverables: see above

Selected sites for vulnerability assessment

The selected sites are Fethiye Bay in Turkey and Grand Harbour and Salina Bay in Maltese Islands. Previous assessments for Gocek, Bodrum and Goksu regions of Turkey and selected sites in Maltese Islands can be found in the previous years' progress reports of this project.

Malta
With a 315km2 surface area and 137km shoreline, Malta has a considerable population of 380.000 people, especially

located on east coasts of the island. The east part of the island has low-lying coastal areas starting from 11.3° whereas the western coasts have steeper slopes up to 1.15° (Figure 1). Due to the being low-elevated area with a very mild slope, the impact of physical parameters seems to be much greater in this low-lying marsh land in Salina Bay (Caruana, 2012). Due to being an industrial and recreational region, Grand Harbour, where there exists low-lying inlet and a drowned valley system, is protected by seawalls, jetties and breakwaters. Urban development, engineering works and various forms of physical changes to the coastline have endangered Grand Harbour (Caruana, 2012).

Turkey

Fethiye region (Figure 2), the district of Mugla City is placed in the south-western part of Turkey. Population in the city centre is 68285 while in nearby provinces is around 110000 according to 2009 population census. Fethiye has a surface area of 2686km2 (District Governship of Fethiye, 2008).. Settlements are common in the vicinity of the bay area with slope values between 0° - 10°. Outside of the bay towards Mediterranean Sea, high cliffs with very steep slopes can be observed where there exists no settlement (Figure 2).

Vulnerability Studies

Tsunami

In 1693 and in 1908, two destructive earthquakes and tsunamis occurred in the Southern Tyrrhenian and Eastern Sicily source. However, the most devastating one was Eastern Sicily earthquake with an approximate magnitude of 9 (Mw=9) and a tsunami event resulted in 60000 casualties occurred (M.A. Gutscher, 2006). This source is towards eastern and north-eastern coasts of Malta having more low-lying slope characteristics. Additionally, in the past, around Algeria-Tunisia source zone, there were several different earthquake phenomena which generated tsunami thereafter (Tinti S., 2005). In the past, the last destructive seismic event occurred on May 21, 2003 with a Mw=6.8 earthquake located on east of Algiers (Bounif et al., 2004). More than 2000 people were killed, 11.000 injured and 200.000 became homeless (Yelles et al., 2004). The past events showed that eastern coasts of Malta as a whole are more prone to inundation after possible tsunami scenarios. Since it is a low-lying coastal area and most of the population has settled down around the eastern coasts of the island. Thus, it is essential to determine the vulnerability of Maltese Islands to possible future tsunami events. Working with scenarios is a very beneficial technique for determination and evaluation of tsunami hazard and risk for any given region, and it is a simple starting point for tsunami mitigation, preparedness and sustainable coastal zone development (Tinti S. et al, 2005). In the light of the past events, the impact of a set of tsunamis occurring after an earthquake generated by two of the major fault zones of the Mediterranean Sea was modelled and its probable effects were analysed on different coasts of Maltese Islands as a part of this project. The impacts of these two scenarios were simulated on NAMI-DANCE 5.9 Tsunami Modelling Program (METU, 2011) and the results were discussed.

Sea level rise

Turkey as a potential country for tourism with its cultural and natural heritage has important coastlines. From the economical and sociological point of view, some important coasts of Turkey need to be investigated in terms of a detailed vulnerability assessment. All these reasons mentioned above create a strong need of a vulnerability assessment study considering the impacts of sea level rise for each region. Decision makers can use the maps created by all vulnerability assessment studies in order to prepare action plans and adopt policies against the actions posing a threat (De Brujin and Klijn, 2009). The model used in this study is based on Ozyurt, 2007. A coastal vulnerability matrix is prepared with the corresponding indicators of impacts of sea level rise. The impacts are categorized into five classes; (i) Coastal Erosion, (ii) Flooding due to Storm Surge, (iii) Inundation, (iv) Salt Water Intrusion to Groundwater Resources, (v) Salt Water Intrusion to River/Estuary. The results of the matrix and coastal vulnerability index (CVI) value will help decision makers to take decision and make policies for the adaptation measures against sea level rise. For each impact, different parameters of both physical and human influence will be indicative (Table 1).

Physical Parameters
Rate of Sea Level rise
Geomorphology
Coastal Slope
Wave Climate
Sediment Budget
Tide Range
Proximity to coast (groundwater)
Type of aquifer
Hydraulic Conductivity
Depth to water table above sea
River depth at downstream
Discharge
Storm surge height

Human Influence Parameters
Reduction of Sediment Supply
River Flow Regulation
Engineered Frontage
Natural Protection Degradation
Coastal Protection Structures
Land Use
Groundwater Resource Abstraction

Table 1: Physical and Human Based Parameters used in the model (Ozyurt, 2007)

In order to contribute to the vulnerability assessment works and and broaden the scope of the sea level rise based vulnerability studies conducted by METU OERC, Fethiye is selected as a second pilot region to be evaluated in terms of its vulnerability to sea level rise.

Results

Vulnerability Score of Fethiye (Turkey)

Turkey, with a 8333 km of coastline is under threat of sea level rise due to its geological location. Although this threat of most of the coastline is not as serious as the countries neighbouring the ocean. Nevertheless, low-lying coastal lines and having tidal range less than 0.5 m pose danger against sea level rise since these features increase the possibility of sea water intrusion to groundwater resources. The vulnerability assessment is focused on Fethiye Bay since the bay is very close to the centre of settlements of Fethiye people. The vulnerability is investigated especially for this central region of the bay due to the high population density. The model study performed is based on two main categories; physical and human based parameters and the impacts are classified into five different categories as Coastal Erosion, Flooding due to Storm Surge, Inundation, Salt Water Intrusion to Groundwater Resources, Salt Water Intrusion to River/Estuary. Each impact related to various parameters different than each other is investigated for Fethiye like the previous study areas of Göcek, Amasra and Göksu (Ozyurt G, Ergin A.,2009). Settlements in Fethiye are common in the vicinity of the bay area with slope values between 0°-10° corresponds to a low-lying zone. Outside of the bay towards Mediterranean Sea, high cliffs with very steep slopes can be observed that no settlement is formed in those areas due to the difficulty of constructing transportation facilities onto such a steep sloped geography. Thus, the suburban zones around Fethiye are not considered in the vulnerability model. Sea water intrusion is really harmful especially for agricultural areas. Economy is based on agriculture and stockbreeding at a large scale, in addition to tourism. 55% of total population is interested in agriculture with a total agricultural area of 64.395 ha (Fethiye District Governship). The main parameters played important role in the vulnerability of Fethiye are tidal range, and proximity to coast. Having a tidal range value of 0.15m for Mediterranean coastlines are really sensitive to sea level rise since the adaptation process against sea water intrusion hasn't been witnessed in these areas yet. In other words, since the tidal range all the year round fluctuates between -0.5m and 0.5m, the region is not ready and needs of an adaptation process for such a rise. Such an adaptation process might be long that stakeholders should be concentrated well. For all these characteristics of Fethiye, Table 11 indicates all parameters both physical and human based with their corresponding vulnerability scores. In the light of these parameters, Fethiye Bay has a vulnerability score of approximately 3.2 which corresponds to a moderate range.

Vulnerability Score of Salina Bay and Grand Harbour (Malta)

The modelling results obtained from Caruana (2012) indicate that Salina Bay is vulnerable to flooding and coastal erosion with a score of 3.4 and 3.0 respectively (Table 13). As a geological feature, outcrops can be also found in Salina Bay. Studies show that Salina Bay is vulnerable to sea level rise with an overall vulnerability score of almost 3.67 indicating its moderate vulnerability range but much more than other moderate ones (Caruana, 2012). As one of the low-lying bays, Salina Bay is in danger of having a reduction in area through inundation. The grand Harbour area is moderately vulnerable to coastal flooding due to storm surge and its few pockets of low lying rock are liable to be eroded and inundated. Salina Bay is also moderately vulnerable to coastal erosion (Caruana, 2012). Lack of natural protection degradation increases the vulnerability of Salina Bay. Urban development through boat houses and accompanying facilities along the coast has contributed by their presence to increase flooding and coastal erosion. Modelling results represent Salina bay as vulnerable to flooding and coastal erosion with the following scores of 3.0 and 3.4, respectively corresponding to moderate vulnerability. Although the impact of human pressure is considerable, the impact of physical parameters is much greater in this low-lying marsh land by predisposing the area to a moderate vulnerability to natural hazards. The physical parameters form the 42% of the whole part whereas the human based parameters form nearly 58% in Salina Bay (Caruana, 2012). Urban development, engineering works and various forms of physical changes to the coastline have endangered Grand Harbour, limiting its coping ability in the event of natural hazards and subjecting it to a high vulnerability of coastal flooding. Having low-lying inlet and a drowned valley system makes the Grand Harbour vulnerable to flooding and inundation. Total vulnerability index of 3.4 corresponds to moderate vulnerability range for Grand Harbour (Table 14). However, anthropogenic pressure is overwhelming by changing most parameters from moderate to high vulnerability. Due to being an industrial and recreational region, Grand Harbour is protected by seawalls, jetties and breakwaters which can mitigate its vulnerability to inundation and flooding due to storm surge and erosion. The Grand Harbour area is moderately vulnerable to coastal flooding due to storm surge and its few pockets of low lying rock are liable to be eroded and inundated. The overall vulnerability score of 3.4 for the Grand Harbour is assessed as moderately vulnerable to the impact of sea level rise. The physical parameters form the 44.4% of the whole part whereas the human based parameters form nearly 55.6% in Salina Bay (Caruana, 2012).

Conclusions

In the light of the previous years' studies, additional tsunami scenarios were performed and the results obtained from NAMI-DANCE Tsunami Modelling software are prepared. The two sources, Algerian-Tunisian and Eastern Sicily - Southern Tyrrhenian sources, are selected and the results are observed in the coasts of Maltese Islands based on the previous studies performed in the same area. The Eastern Sicily-Southern Tyrrenian source has more important results compared the Algerian-Tunisian fault. The results of the possible tsunamis generated by these two sources and their maximum flow depth inland, maximum wave height, first wave propagation graphs are drawn on Surfer and Grapher software. Algerian-Tunisian source does not pose a threat for Maltese Islands due primarily to the settlement side facing inside and due secondarily to the distance between the source and its location. On the other hand, Eastern Sicily and Southern Tyrrhenian source has more impacts compared to Algerian-Tunisian fault system. Even in the second scenario, the maximum wave height is not larger than 1 meter.

The indicator based model developed by the Middle East Technical University (METU) will help decision makers and authorities to take decisions in order to prevent the coasts from being defeated and sometimes losing against the sea level rise scenarios. It can be used for all regions in the world in order to create a database and a vulnerability map after a cumulative and detailed study.

Turkey, with a 8333km of coastline is absolutely under threat against sea level rise scenarios due to its geological location. The vulnerability assessment is focused on Fethiye Bay since the bay is very close to the centre of settlements of Fethiye people. The vulnerability is investigated especially for this central region due to the people living around. The study performed is based on two main categories; physical and human based parameters. Impacts are based on physical and human influence parameters can be classified into five different categories. Coastal Erosion, Flooding due to Storm Surge, Inundation, Salt Water Intrusion to Groundwater Resources, Salt Water Intrusion to River/Estuary. Outside of the bay towards Mediterranean Sea, high cliffs with very steep slopes can be observed that no settlement is formed in those areas due to the difficulty of constructing transportation facilities onto such a steep sloped geography. Thus, the suburban zones around Fethiye are not considered in the vulnerability model.

The main parameters played important role in the vulnerability of Fethiye is tidal range, proximity to coast. The least important ones are the significant wave height which is not high (0.4m) and the depth to groundwater level above sea which is larger than 2 meters. All parameters for each impact are tabled and mentioned in Case Study part above.

Sea water intrusion is really harmful especially for agricultural areas. Since the economy is based on agriculture and stockbreeding at a large scale, in addition to tourism in Fethiye, sea level rise scenarios are vital to be investigated. Since the region is not ready to such a scenario, a very coordinated adaptation study must be performed. An adaptation process might be painful to get used to it but it’s inevitable. On the other hand, if the policy makers and decision takers can come to an agreement on common issues, Fethiye would be able to prepare for a possible sea level rise scenario. Being an island poses a serious threat and increases the vulnerability to both sea level rise and tsunami (IPCC, 2007). Since people do not have an alternative place to escape or shelter, Maltese Islands should also be well-prepared.

For future studies, vulnerability database both for tsunami and for sea level rise scenarios may be enlarged considering other coastal regions having economical and sociological importance. Furthermore, additional parameters may be added enrich the content and extent of the study.