Tsunami hazard and protection by sand dune in West Naxos Island

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TSUNAMI HAZARD AND SAND DUNE PROTECTION IN WEST NAXOS ISL., GREECE

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ABSTRACT

The west coast of Naxos Isl. was hit in 1956 by the Amorgos tsunami. This study aims to: a) determine the impact of a potential tsunami similar to the one that occurred in 1956, based on the island's contemporary residential and tourist development, and b) explore whether the natural geomorphs (sand dunes) in the 3 study areas (Glyfada, Agios Prokopios, Chora of Naxos) can reduce the tsunami risk.
Risk assessment was based on processing field data (differential GPS) and satellite images with GIS software. Furthermore, the dunes potential risk reduction has been evaluated.
Results show that taller sand dunes and vegetation provides better tsunami protection to the coast of Glyfada, than the one of Agios Prokopios. Uncontrolled tourism development without any sand dunes protection measures undermine their development and, consequently, increases the tsunami risk.

Keywords: Tsunami, Hazards, Naxos, Sand dunes, $ITIS_{2012}$

1. INTRODUCTION

Naxos Isl. belongs to the island complex of Cyclades, located in central Aegean Sea. The island geomorphologically is divided into two parts: the east side is characterized by high altitudes and rocky steep coastlines, while the west side present slow and mostly sandy slopes along the coast. This geomorphic peculiarity along with the higher population concentration (both residents and tourist infrastructures) on the west side, increases the tsunami risk in the western coast of the island [3].
The present study focuses on three areas in western Naxos, for which 1956 run-up data are available. Historically recorded events in the wider area of the southern Aegean, proves that the tsunami risk is real and measurable [1], [6], [7]. The most recent tsunami inundation evidence (collected from a sufficient number of witnesses) are run-up values records (one from each study area) from the 1956 event [6], [7]. These past run-up values are projected in the present landscape, on island's current population and tourism infrastructure.
In the west coastal zone, in the areas of Agios Prokopios and Glyfada the well-developed dune fields [2] are stabilized by vegetation, and could act as a natural barrier, limiting the tsunami impact [4] [8].
Because of the urban expansion and tourism development, sand dunes exist neither to the south of Naxos nor in the third study area (Chora of Naxos).
This study aims to: a) determine the impact of a potential tsunami similar to the one occurred in 1956, based on the island's contemporary residential and tourist development, and b) explore whether the natural landforms (sand dunes) can reduce the tsunami risk.

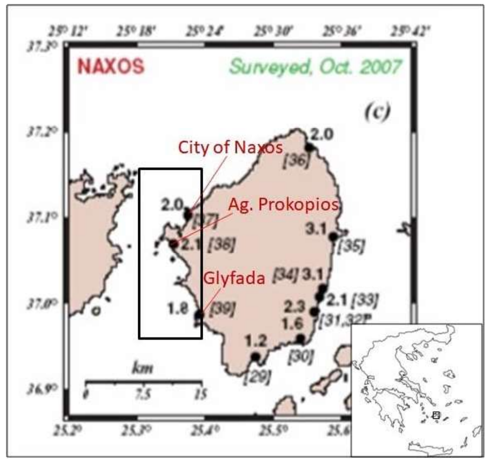

Fig. 1 Tsunami run up sites in Naxos, 1956. With red names are the three study areas in west Naxos. (Modified from Okal et al., 2009)

2. METHODOLOGY

Run-up records are by definition the boundary points of the inundation zone. Based on the historical run-up records, a contour line delimiting the potential inundation zone of each of the study areas has been mapped using GIS software. Satellite images were projected on the map. The resulting maps were compared with 1950s and 1960s aerial photographs.

The potential impacts of a near future event are analyzed based on the 6 main categories of the $ITIS_{2012}$-Integrated Tsunami Intensity Scale [5].

In order to study the role of sand dunes as a natural tsunami wall, sand dunes heights, slopes and vegetation distribution were mapped using differential GPS.

Finally, using satellite imagery and GIS technology, the high-risk areas, in case of an event similar to the 1956 tsunami were located, mapped, evaluated and categorized against $ITIS_{2012}$.

3. RESULTS

3.1. Projecting 1956's tsunami event, in Naxos, today

The contemporary satellite image projection on the run-up map shows a significant increase of tsunami risk, in case of a similar to 1956 event.

Given the past run-up measures and based on $ITIS_{2012}$ criteria's complementary relationship, the impact of a similar to 1956 event is expected as follows:

Tsunami Hazard analyzed with $ITIS_{2012}$

Impacts on Buildings: Inundation height up to 2 meters affects a significant number of buildings (homes, tourist accommodation and stores). Mainly in Chora of Naxos, tsunami waves could affect buildings located in a zone between 200 to 300 meters from the coast. The impact on buildings is limited to the area of Glyfada, which is clearly more sparsely populated. The vast majority of buildings are RC.

Impacts on Infrastructure: The main road to Chora of Naxos, in the area of Ag. Prokopios is coastal and located in the inundation zone. Power lines are exposed at an altitude of 2 to 5 meters in all three study areas. A public parking area located in Chora of Naxos could also be affected.

Mobile Objects: Mobile objects potentially displaced are small yachts and leisure boats, marine equipment off the coast, cars on the shore between the coast and the lagoon, as well as cars and machines off the coast, catering equipment, store merchandise, luggage, metal plates, protective wooden fences and other light constructions such as wooden kiosks etc.

Fig. 2 & 3 Ag. Prokopios back in 1960 and today (photos from agersaniotis.blogspot.com, protothema.com, Likouropoulos M.), Chora of Naxos and run up zoning

Impacts on Environment: Erosion at these run up values is limited. The impact on Chora of Naxos will be significantly limited as the sandy material along the coast has been covered by concrete in most zones. Higher level of erosion it is possible in Agios Prokopios, than in the Glyfada area. In all areas, finer sedimentation as well as flooding of agricultural areas are expected.

Impacts on Human: Clearly the number of residents and visitors is exponentially increasing throughout the years. Based on the current population density, about 1/7 of the Chora of Naxos population is estimated to be under the risk of injury or death in the inundated areas; that counts for about 1000 people (permanent residents), at any time of the year. This number is higher during the summer when the population on the coast is increased. In the other two study areas the impacts are seasonal, as resident's number is limited.

3.2. Natural Protection from sand dunes lines

The maximum height of the sand dunes along the Ag. Prokopios and Glyfada, exceed 4 and 5 meters respectively above mean sea level. However, in terms of sand dune vegetation there are significant differences between the two areas. In Glyfada, sand dunes vegetation in some places exceeds 2 meters in height, making this natural tsunami wall even more effective, having higher energy-absorption coefficients.

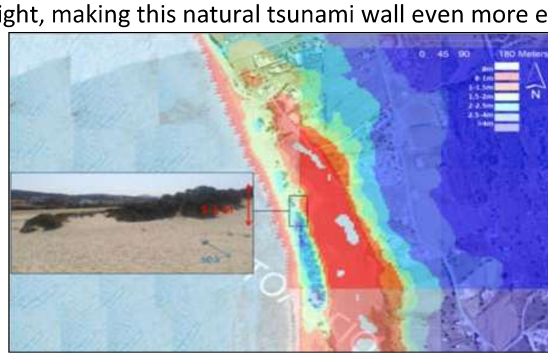

Fig. 4 & 5. Sand dunes in Glyfada area. The blue line (sand dunes line) near the coast is over than 4 meters high. The different vegetation heights and spreading in Glyfada area (top) and in Ag. Prokopios area (down).

In Agios Prokopios area the vegetation height is limited to a few centimeters (<0.60m), except for a few limited sites, where it reached around 1m heights. The width of the vegetation strip is greater than the one of Glyfada.

4. CONLCUSIONS

As expected, the increased presence of humans on the island and its activities increases the impact on all of the $ITIS_{2012}$ categories. The impact of a potential small/medium tsunami on the West Naxos depends on seasonality. However, in any case it will be not as negligible as in 1956.

Sand dunes can reduce tsunami inundation, as they can partially absorb tsunami wave energy. This depends both on the height of the sand dunes and on the vegetation. In conclusion, the settlement behind the sand dunes in Glyfada is better protected than the one in Agios Prokopios, due to lack of restricting measures for the people and vehicles transition on the sand dunes. Uncontrolled tourism development, without any sand dunes protection measures, undermine their development and, consequently, increases the tsunami risk.

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