An attempt of GIS analysis of the damages of the January 8, 2006 Kythira earthquake, Greece.

MARIA KOULI & FILIPPOS VALLIANATOS

Department of Natural Resources & Environment,
Laboratory of Geophysics and Seismology
Technological Educational Institute of Crete
Romanou 3, Halepa, 73133, Chania, Crete
GREECE

Abstract: - In this paper we present the results of the use of Geographic Information Systems (GIS) in mapping information on the effects of the Kythira earthquake of 8th of January 2006 on the surrounding area of Chania municipality. The damaged sites were located on a QuickBird pan-sharpened satellite image (with a spatial resolution of 0.6m) of the city of Chania. The tabular data concerning building damages for Chania city were collected from the local authorities and were converted into GIS layers and analyzed. The end-product is a thematic map of the expected damage on the Chania city from an earthquake in the Kythira area with energy comparable to that of the 8th of January 2006 earthquake. The overlay of geological and tectonic maps gave some preliminary results for the contribution of geological and tectonic structures to earthquake intensity.

Key-Words: - Kythira earthquake, GIS, seismic hazard, Chania city.

1 Introduction

During the past decades, GIS has proved to be a useful tool for natural risk analysis such as earthquakes which involve interactions with the natural and human-made environment. The application of GIS and spatial modeling in natural hazard risk management is an emerging research sector and the ability to provide a spatial and physical context for risk is critically important for risk reduction [2, 3, 6, 9, 10].

The ability of Geographic Information Systems (GIS) to store a large quantity of related information (e.g. spatial, geographical, economical, demographical etc.) and analyze data in vector and raster format makes their use extremely valuable in the field of seismic zoning, as the latter is based on the processing of data regarding the damage produced by historical and present earthquakes and its spatial distribution [3]. Moreover, all the above mentioned recorded data can be utilized by many categories of users, such as scientists, engineers, professionals, public employees, but also institutions of the private as well as the public sector.

In the present work we use GIS in order to map and analyze the damages which occurred in the city of Chania, Crete Island, Greece due to the Kythira (SW Hellenic Arc) earthquake of 8 January, 2006 and we show how GIS can be used in order to create maps of potential damage on the city of Chania from an earthquake similar with that of January, 8th. The tabular data concerning building damages for Chania city were collected from the local authorities and were converted into GIS layers and analyzed as automated mapping and quantitative data analysis using GIS have been successfully applied to the investigation and mitigation of natural disasters in several countries.

The SW segment of the Hellenic Arc is one of the most active parts of the Western Eurasia due to the subduction of the African lithosphere under the Aegean microplate and has a long historical record of earthquakes with magnitudes up to about 8.0. The SW Hellenic Arc (Peloponnesus – Kythira – Crete) generates large shallow- and intermediate-depth earthquakes many of which have been reported since the early historic times. Magnitudes of up to 8.0 have been reported in the literature, (e.g. [4, 5]) signifying the great seismogenetic potential of the area [7].

Therefore, it is obvious that the models developed with the help of GIS spatial analysis tools may assist the local authorities in decision-making for emergency management.

2 The Earthquake of 8 January 2006

On January 08, 2006 at 11:34:53 (UTC) a strong earthquake of magnitude M=6.9 shook Greece and most of the eastern Mediterranean causing only minor damages and no casualties. The earthquake's epicenter was located at 36, 21°N - 23, 34°E at a depth of about 70 Km near the island of Kythira [8] (Fig. 1).

The main shock as well as the aftershocks were recorded by the stations of the seismological network of the Laboratory of Geophysics and Seismology of the Technological and Educational Institute of Crete in Chania which is the closest seismological observatory in southern Aegean, about 90 Km SE of the epicenter [8].

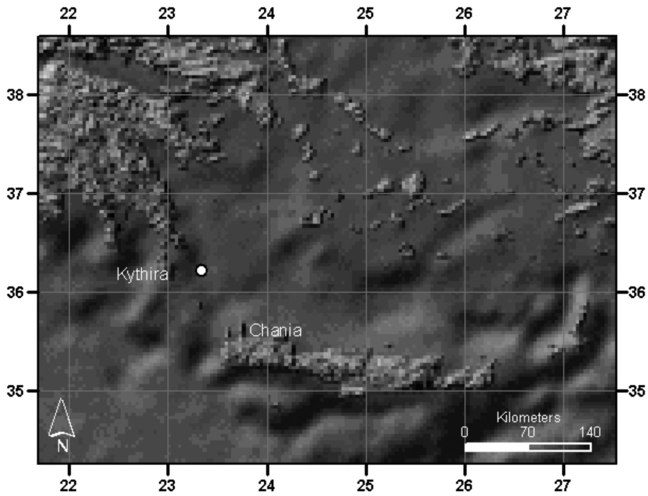

Figure 1. Location map of the epicenter of the Kythira earthquake of 8th of January 2006.

3 GIS construction

The 8th of January, 2006, earthquake affected especially the city of Chania. The available data on the effects of the seismic event were documented immediately after the earthquake by the Department of Civil Protection of the Chania Prefecture.

High-resolution QuickBird pan-sharpened satellite images (with a spatial resolution of 0.6m) acquired on 2 May 2002, were used in order to accurately delineate the building boundaries.

The data gathered were digitized with the insertion of points, each point representing a damaged building. Each point is connected with a record which reports the location of the building, its use, and the description of damage to a total of 70 buildings.

In a next step, geological and tectonic maps were digitized in order to provide the electronic data files of basic map components such as geological formations and faults.

All the above digital information were integrated and analyzed into a Geographic Information System with the aim to examine a probable spatial relation between the occurred building damages and the factors that usually affect the damage level and the seismic intensity. The mapping and interpolation functions of GIS were used for the spatial distribution analysis of building damages.

4 Results and Conclusions

The suffered buildings are distributed mainly in the northern sector of the Chania city (Fig. 2). From a total number of seventy affected buildings, twenty correspond to public ones, six are schools and the rest are residences. The level of damages was classified into four classes (1, 2, 3, 4) with an increasing level of damage; Eleven buildings were seriously damaged with the need of total reconstruction (class 4), thirty were moderately damaged and could be used after repair (class 3), four could be used without repair (class 2) and twenty-three were very slightly or no damaged (class 1) (Fig. 2).

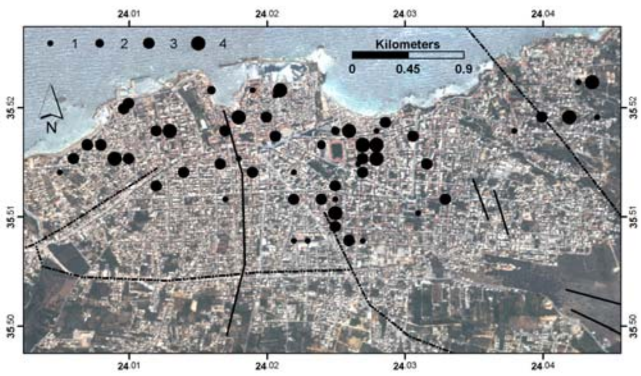

Figure 2. The classified building damages overlaid to QuickBird satellite image of the city of Chania. The major tectonic faults of the city are shown with black lines.

The construction year of the damaged buildings ranges from 1500 to 1999 (Fig. 3). The seriously damaged buildings were all constructed prior to 1970 (Fig. 3) while the buildings constructed after 1970 were moderately to no damaged (Fig. 4). Thirteen of the suffered buildings were constructed during or after the year 1980 and five of them were moderately damaged with the need of repair.

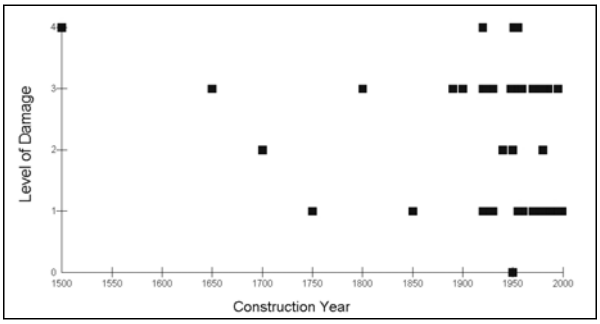

Figure 3. The relationship between the level of damages and the construction year of the buildings.

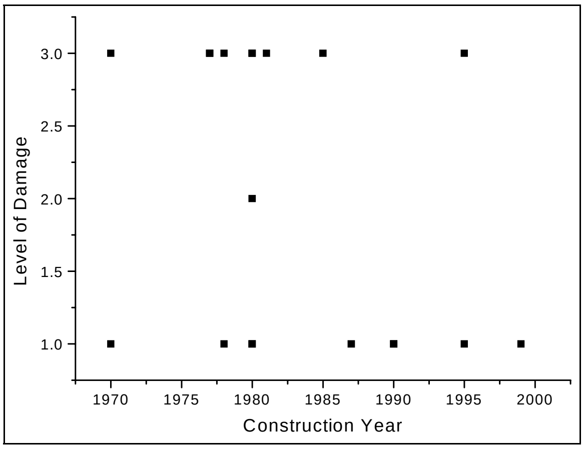

Figure 4. The relationship between the level of damages and the construction year of the younger buildings.

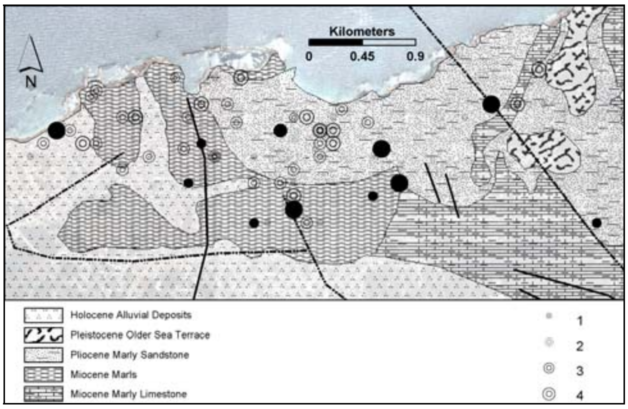

Figure 5. Map of damages overlaid on the geological and structural map of the city of Chania. With black circles we show the buildings constructed after 1980.

Since GIS allows the integration of variable data, the comparison between geology and tectonics and the earthquake damages is shown in Fig.5. Seventeen of the seriously or moderately damaged buildings are located in the Pliocene Marly Sandstone formation, sixteen in the Miocene Marls formation and only eight in the Marly Limestone (Fig. 5). The damaged buildings constructed after 1980, are mainly distributed either along the major tectonic faults of the study area or near to the transition boundaries of the geological formations. In these sites, the mechanical properties of the rocks are probably worse producing local amplifications of the seismic waves [3].

Finally, using the interpolation functions available in the GIS environment we created a map of the expected damage in the city of Chania in the case of a future earthquake event in the Kythira area (Fig. 6). The map identifies four areas with different level of expected damage. The areas with the most serious expected damages are located in the western part of the Chania city (contact of Miocene Marls with the Alluvial deposits) as well as near the existed tectonic structures (Fig. 6).

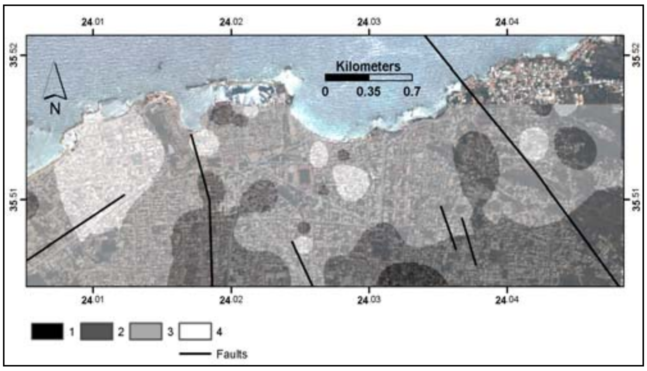

Figure 6. Map of the expected damage on the city of Chania from an earthquake near the Kythira strait with energy comparable to that of the 2006 earthquake.

5 Future work

In this work we showed the ability of GIS to produce maps of potential damage. However, in order to produce reliable maps for risk planning, one should take into account information about the geology, geomorphology, seismo-tectonic, seismicity, soil, site conditions, and earthquake energy attenuation characteristics. Moreover, collection of information on the built environment including building stock, transportation system, lifeline (utilities) system and critical facilities are also needed are of great importance in order to develop a lost estimation methodology for the city of Chania [1, 6].

6 Acknowledgements

This work is supported by the project ARCHIMEDES I: "Support of Research Teams of Technological Educational Institute of Crete", sub-project entitled "Multidisciplinary Seismic Hazard monitoring in the Front of the Hellenic Arc" **MIS 86384**, action **2.2.3.ζ**, in the framework of the Operational Programme for Education and Initial Vocational Training.

We would like to thank the Department of Civil Protection of Chania Prefecture for providing us the January 8, 2006 earthquake building damages reports.

References:

[1] Bendimerad, F., Loss estimation: a powerful tool for risk assessment and mitigation, *Soil Dynamics and Earthquake Engineering*, Vol.21, 2001, pp. 467-472.

[2] Carrara, A. and Guzzetti, F. (eds): Geographical Information Systems in Assessing Natural Hazards Vol.6, *Kluwer Academic, Netherlands*, 1995.

[3] Cubellis, E., Carlino, S., Iannuzzi, R., Luongo, G., Obrizzo, F., Management of Historical Data Using GIS: The Island of Ischia (Southern Italy) *Natural Hazards*, Vol.33, 2004, pp. 379-393.

[4] Papazachos, B. C., Seismicity of the Aegean and surrounding areas, *Tectonophysics*, Vol.178, 1990, pp. 287–308.

[5] Papazachos, B. C. and Papazachou, C. C., Earthquakes of Greece, *Ziti publ. Thessaloniki*, 1997, 304 pp.

[6] Seker, D., Sester, M., Volz, S., Kulur, S., Toz, G., Altan, O., Fritsch, D., Modeling and Analyzing Earthquake Induced Building Damages in a GIS, *D.Fritsch, M. Sester, eds*, "IAPRS", Vol:32/4, ISPRS Commission IV Symposium on GIS – Between Visions and Applications, Stuttgart, Germany.

[7] Tzanis, A, and Vallianatos, F., Distributed power-law seismicity changes and crustal deformation in the SW Hellenic ARC, *Natural Hazards and Earth System Sciences*, Vol.3, 2003, pp. 179-195.

[8] Vallianatos, F., Nikolintaga, I., Kokinou, E., Makris, J., Soupios, P., Moisidi, M., Preliminary results of the Kythira January 8, 2006 aftershock sequence, *European Geophysical Union Conference, Vienna*, 2006.

[9] Wadge, G., Wislocki, A. P., and Pearson, E. J.: 1993, Spatial analysis in GIS for natural hazard assessment, In: M. F. Goodchild, B. O. Parks and L. T. Steyaert (eds.), Environmental Modeling with GIS, *Oxford University Press*, pp. 339–347.

[10] Zerger, A.: 2002, Examining GIS decision utility for natural hazard risk modelling, Environmental Modelling & Software 17, 287–294.