Advances in mapping on Crete

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Geographic information systems techniques combine space imagery with ground-based geophysical data to enhance resource management and build new risk models.

Studies in natural-resource sustainability and risk-model development require the fusion of various types of data collected from both ground-based measurements and satellite imagery. A consortium of institutions has focused its efforts on building a platform with these capabilities for the island of Crete, an ideal study site because it is characterized by frequent seismic activity as well as diverse landforms and vegetation.

The consortium aimed to develop a system capable of combining multiple digital, geographically based information layers and linking them to existing statistical and environmental databases, with the goal of monitoring landscape and environmental changes. Other objectives were creating an open-access databank containing a broad range of geo-information (i.e., geology, hydro-geology, seismology, climatology); building infrastructure for improved analysis and modeling of other environmental and statistical parameters; and developing novel approaches to modeling risk of seismic activity, landslide, and forest fire. Thus, the databank needed to include a geo-spatial component compatible with other geo-spatial data sources, such as satellite images, and digitized-topographic and geological maps.

Geological parameters of Crete’s urban centers were analyzed through ground-based geophysical methods, such as electrical resistance tomography and seismic techniques. One such technique, employing micro-tremor array measurements, was used to investigate the behavior of shear wave velocity with respect to depth. The determination of the response to earthquake activity used the horizontal to vertical spectral ratio of ambient noise recordings (low amplitude vibrations of soil generated by natural disturbances). The results were mapped through interpolation algorithms on enhanced high-resolution satellite images (see Figure 1) for Crete’s three major cities. Then results were processed using a discrete wavelet transform—which breaks the original signal down into component parts—and intensity, hue, and saturation image-fusion techniques were applied to improve the representation of urban characteristics.

At a regional scale, satellite imagery has the ability to provide a wide spectrum of information about land cover, land use, and vegetation patterns. Nine Landsat-5 thematic mapper and Landsat-7 enhanced thematic mapper images (see Figure 2) spanning from 1985 to 2003 were classified to highlight changing patterns of land use. Object-oriented classification—which uses a more sophisticated algorithm to account for various attributes beyond spectral signature—was applied to produce a digital image of vegetation types based on more than 1000 ground-control points. As a result, a draft mesoscale map of Crete’s habitat zones was created (see Figure 3). Spatial spectral coherence analysis indicated high complexity and intensity of land uses in plain

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regions. Complexity estimates based on fractal dimensions of the polygon perimeters of land uses indicated a slightly decreasing trend in the dominant categories.\(^4\)

Quantitative estimates of the island’s morphological attributes were also computed, using directional derivatives of the digital elevation model and classification of loci with common landform characteristics. Morphometric units (see Figure 4) were defined based on results of unsupervised classification and statistical analysis of each class in terms of slope, aspect, and geological attributes. The correlation of the resulting geomorphometric units with the island’s geological properties, such as faults and other formations, was investigated. Ground prospection methods and macroscopic geological surveys were used to verify the results of this correlation.\(^5\)

Images from the advanced spaceborne thermal emission and reflection radiometer (ASTER) aboard NASA’s Terra satellite were analyzed to examine possible correlation of enhanced vegetation and drainage along faults. Principal component analysis, band ratios, and spatial filtering were carried out to extract linear features related to fracturing (see Figure 5). These contributed to regional classification of faults and to landslide risk models (see Figure 6) by applying a simplified weighted-factors model based on geological, hydrolithological, morphometric, and climatic attributes as well as proximity to active faults.\(^6\)

Data resulting from this project was disseminated in the form of technical reports describing methodology, instrumentation, and corresponding results. Resultant cartographic products are available to scientists and the public through a web-based GIS platform (ArcIMS through HTML), which provides various map navigation tools (see Figure 7).

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The project, ‘Development of an Expert System for the Monitoring, Management & Protection of the Natural Landscape & Environmental Resources of the Island of Crete’, is a joint effort of the Institute for Mediterranean Studies at the Foundation for Research and Technology Hellas, the Center of Technological Applications of Crete, the Institute of Technological Education of Crete, the Institute of Technical Seismology and Anti-seismic Constructions, the National Technical University of Athens, the University of Crete, and the Technical University of Crete. Funding was provided by the Region of Crete and the European Union. All results are available (in Greek) through the server of the Institute for Mediterranean Studies.7

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References

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