THE USE OF DIGITAL ELEVATION MODELS IN EMERGENCY AND SOCIO-ECONOMIC PLANNING: A CASE STUDY AT KOS - YALI - NISYROS - TILOS ISLANDS, GREECE

Spyridoula Vassilopoulou *,
Lorenz Hurni
Institute of Cartography
Swiss Federal Institute of Technology (ETH)
ETH-Hönggerberg
CH-8093 Zürich
Phone: +41-1-633 30 33
Fax: +41-1-633 11 53
E-mail: pepy@karto.baug.ethz.ch
hurni@karto.baug.ethz.ch

1. ABSTRACT

The use of a Digital Elevation Model (DEM) is important for any geo-environmental study. The aim of the present study was the production of a selection of DEMs in different scales with various resolutions for the Kos - Yali - Nisyros - Tilos island area in Greece. These DEMs will serve as the base for thematic applications as well as the base for production of a great variety of maps. All the layers (raster or vector) are included in a GIS database of the selected region for a multidisciplinary study relating to Emergency and Socioeconomic Planning.

2. INTRODUCTION

The islands of Nisyros, Yali, Kos, Santorini, Milos, Poros, Aegina and the peninsula of Methana constitute the Hellenic Volcanic Arc. The eastern sector of the arc, including the islands of Kos, Yali and Nisyros seems to be geodynamically very active since it comprises the largest volumes of volcanic products and is at present a region of high tectonic unrest.

Active volcanoes represent several natural hazards for populated regions. These hazards often occur as combinations of earthquakes, gas-explosions and hydrothermal eruptions, volcanic eruptions, landslides, mudflows, tsunamis etc. For that the research project GEOWARN financed by the European Union has been established. The objectives of this scientific study are to conduct an integrated informative, volcanological, geophysical and geochemical project to assess volcanic and seismic hazards related in the most active part of the eastern Mediterranean by the help of a GIS database as well as an integrated geo-spatial multimedia system for the region. Eight institutions collaborate in this project and a large amount of heterogeneous information has to be produced and treated.

The aim of the present study was the production of a selection of DEMs in different scales with various resolutions for Kos - Yali - Nisyros - Tilos islands. The use of a Digital Elevation Model (DEM) is important for any geoenvironmental study of a region not only because it represents a modern digital topographic map in three dimensions and serves as a base for thematic applications (geology, volcanology, geophysics, geochemistry, orthorectified satellite images, interferometry e.t.c.) but also serves as a base for production of a great variety of maps (3-D maps, slope - aspect maps etc.).

A large number of various topographic data from different sources, in different format, scale and map projections was been compiled. Layers in vector format were produced in a common cartographic system and Digital Elevation Models were produced with an appropriate resolution.

* Permanently at: National and Kapodistrian University of Athens, Faculty of Geology, Geophysics Laboratory, Space Applications Unit in Geosciences, Panepistimiopolis – Ilissia, Athens, 15784 GR, Phone: +301 – 7274392, Fax: +301 – 7274787, E-mail: vassilopoulou@geol.uoa.gr

3. METHODOLOGY

Generally, the cartographic baseline data of the islands of Kos - Yali - Nisyros and Tilos as well as the oceanic environment was compiled using ArcInfo and ArcView. This work involved work-consuming time in cartographic design, reduction, unification, digitizing and vectorisation.

3.1. Data Processing

All the data (topographic, geological, seismological, geodetic, volcanological, geochemical, etc) had to be processed. For data processing the Arc/Info 8.02 as well as Arc/View 3.2 software (NT environment) were used. All the data were categorized into geographical units – coverages where each piece of data was characterized by its geographical position (spatial information) and by descriptive attributes (descriptive information). Three categories were distinguished, namely:

- Lines (faults, roads, etc)
- Polygons (geological formations, etc)
- Points (earthquake epicenter, etc)

The data processing can be divided into the following stages:

3.1.1. Data Input – layer compilation

Raster and vector data input by scanning or digitizing and thematic layers - coverages were produced according to the above categories.

The topography, in the form of 1:5000 and 1:50000 scale maps was scanned and saved in Tagged Image Format (Tiff), which was geo-referenced in a common projection system. The digitization of the topographic data (contour lines, building, roads, etc) was based on the same files.

The digital satellite images were processed and geo-referenced in the same projection system. They were saved in "geo-tiff" or "img" format. The format depends on the software that was used for the image processing (ERDAS/Imagine ver. 8.2 and 8.4).

There existed data in ascii files (GPS measurements, geochemical data etc), that were also included and new coverages created.

Input of the rest of the data (geological, tectonic etc) was done after digitizing (on screen after scanning like topography or using digitizer from the original maps).

Thus thematic layers – coverages were created like contour lines, trigonometrical points, geological formations, faults, earthquake epicenter, etc.

3.1.2. Error correction

After the digitizing process and before any kind of analysis, all digitized data were corrected. This step includes the corrections of the arcs, nodes and polygons during the digitization process.

3.1.3. Conversion of co-ordinates in map projection system

The data originated from different sources, in different format (ascii, raster, vector), scale (1.5000, 1.50000 etc) and map projections. There existed data in Greek HATT or in UTM projection systems, in geographic coordinates (longitude, latitude) or real coordinates (x,y), in different Datums (European 1950, WGS84 etc), with different ellipsoids (Bessel, International 1909, WGS84 etc). All the data were geo-referenced in a common projection system: in the Hellenic Geodetic Reference System 1987 (HGRS87). The parameters of HGRS87 are as follows:

Projection: **TRANSVERSE**
dx = -199.87, dy = 74.79, dz = 246.62
Spheroid: **GRS80**
Scale Factor at Central Meridian: **0.9996**
Longitude of Central meridian: **24 00 00**
Latitude of Origin of Projection: **00 00 00**

False Easting: **500000**
False Northing: **0**

3.1.4. Topology

In this stage the topology of each coverage was separately built. The spatial relationship between geographical data was established. The following attribute tables were created:

AAT	Arcs Attribute Table (Table of characteristic linear data)
PAT	Polygons Attribute Table (Table of surface data)
PAT	Points Attribute Table (Table of point data)

3.1.5. Database organization

The compilation of the data base is necessary not only for map creation but it is also a perquisite for the exploitation of GIS capability in order to treat and manipulate data. For this purpose the update of the attribute tables was done through the introduction of some codes common to the homogeneous data of every coverage. Regarding the linear and point data the IDs had been assigned during digitizing. After the corrections, label were assigned to polygons and the updated coverages were obtained.

Also, the addition of some items in the attribute tables of each coverage is necessary. Thus, the following item was added to the coverage of buildings:

character	characterization of building (house, ruin, church, etc)

The following item was added to the coverage of roads:

type	The type of the road (roadhard, trailpath, etc)

So that, numerous of items can be added to every coverage with descriptive information. After the data base was updated with sufficient amount of data, its analysis and management can provide solutions to certain target –oriented queries. The database can constantly be updated with new data, depending on the current needs.

3.2. Creation of the DEMs

3.2.1. Methodology

After the data processing as described above, the production of the DEMs followed. The applied methodology depends on numerous of parameters like the type of the data (contours, points, drainage network etc), the quality and the density of the data, relating to the morphology of the study area as well as the use of the DEM. The result depends on the parameters of the algorithm, the cell size, the scale, etc (VASSILOPOULOU, 1999).

A selection of DEMs had to be produced at the present study. The basic input data was contours with a good density. Also, as input were points and drainage network. The Topogrid algorithm of Arc/Info 8.2, with specific parameters related to the study area was applied to a selection of DEMs in grid format, in different scales (from 1:5000 to 1:50000) with various resolutions (cell size from 2 m to 20 m).

Each cell of the grid presents the elevation (z) in relation to position. The position is defined either by geographical coordinates (longitude, latitude), or by its orthogonal coordinates (x, y) in a cartographic projection system.

More specifically, the DEM corresponds to an image in black and white, where the pixels in low digital number (black pixels) correspond to areas with low elevation, while the ones having high digital

number (white pixels) correspond to areas with high elevation. It is possible to provide colors (in concordance to elevation) for better visualization results.

Before Topogrid algorithm is applied the data have to be pre-processed.

3.2.1.1. Input Data

The digital elevation models (DEMs) of the islands of Nisyros, Kos, Tilos and the oceanic environment based on pre-existing topographic and bathymetric data. These data were as follows:

- Topographic data of all the islands: contour lines 20 m, 10 m, partially 5 m, trigonometrical points and spot heights from topographic maps 1:50000.

- Topographic data of the island of Nisyros: contour lines 10 m, 5 m, partially 4 m and 2 m, trigonometrical points and spot height from topographic maps 1:5000.

- Bathymetric point data was provided by ship navigation from National Center for Marine Research (NCMR) and University of Hamburg – Institute of Geophysics (UHIG).

- Morphological data of all the islands: drainage network from the topographic maps 1:50000.

- Morphological data of Nisyros island: drainage network from the maps 1:5000.

3.2.1.2. Pre-Processing of Input Data

Some of the input data need more processing, as well as new layers have to be created, before topogrid algorithm is applied:

- Correction of the orientation of the streams: Stream data are a powerful way of adding more topographic information to the interpolation procedure, further ensuring the quality of the output DEM. All streams are included in a line cover. All arcs streams in this cover must be oriented to point downstream.

- Addition of elevation points in specific regions: More points have to be added to the planation surfaces etc.

- Creation of a polygon coverage – boundary for the region: This coverage represents the outer boundary of the interpolated grid.

3.2.1.3. Topogrid Algorithm

The TOPOGRID algorithm is an interpolation method specifically designed for the creation of hydrologically correct digital elevation models (DEMs) from comparatively small, but well selected elevation and stream coverages. It is based upon the ANUDEM program developed by Michael Hutchinson (1988, 1989).

3.2.1.4. Tolerances

A set of tolerances and parameters used to adjust the calculations of the interpolation and drainage enforcement process. The values of them depend on the primary input data and the sinks that will be removed:

"tol1", "horizontal_std_err" and "vertical_std_err" are a set of tolerances used to adjust the smoothing of input data and the removing of sinks in the drainage enforcement process.

At the present study were as follows: tol1 = 5 to 10 (half of the contour interval), horizontal_std_err = 1, vertical_std_err = 0.

The "datatype" specifies the primary type of input data. This option optimizes the search method used during the generation of streams and ridges. It was defined: contour.

The "enforce" turns the drainage enforcement routine on or off. It was defined: on

The "iterations": specifies the maximum number of iterations for each grid resolution. It was defined: 30

Also, it is possible to be produced outputs files: "sink_cover", "drainage_cover" and "diagnostic_file": optional outputs providing information used to evaluate the quality of the input data and output DEM.

3.2.1.5. Output - Results

As result, DEMs with a various resolutions were produced.

Any surface that is created should be evaluated to ensure that the data and parameters supplied to the program resulted in a realistic representation of the surface. The most common evaluation is to create contours from the new surface and compare them to the input contour data. It is best to create these new contours at one half the original contour interval to examine the results between contours. Drawing the original contours and the newly created contours on top of one another can help to identify interpolation errors. Contours can be generated with the TIN command LATTICECONTOUR or the GRID function CONTOUR. In our case contours were produced by latticecontour command.

By applying the described procedures and parameters, an optimal result has been archived. Generally, if the result is not satisfactory, it is better to check for errors in the input data before changing parameters.

4. USES OF THE DEMs

4.1. The DEMs serve as a base for thematic applications

At the present study the DEMs represent a digital topography in 3 dimensions and serve as a base for thematic applications like geology, volcanology, geophysics, geochemistry, interferometry, ortho-rectified satellite images e.t.c. A first application was dealing with the ortho-rectification of IKONOS satellite image.

4.1.1. IKONOS – Orthophoto

At the present study a Panchromatic Sharpening image IKONOS 2 with 1 meter resolution was used. The Panchromatic-Sharpening image combines the spatial content of the 1-m resolution panchromatic data with the spectral content of 4-m multi-spectral data. The acquisition time of that particular image was April 30, 2000. This image turns out to generate a new tool for surface visualisation and mapping at flexible scales in 2- and 3-D. In combination with GPS derived geodetic reference points, ortho-rectification of the satellite image can be achieved and implemented into any coordinate system (e.g. HGRS87).
For the ortho-rectification of IKONOS a Digital Elevation Model (cell size: 2 m) was used as well as 38 selected ground control points (GCPs) offering high accuracy. The latter were measured in (x,y,z) using Geodetic Positioning Systems (GPS) receivers. An object to pixel space transformation using the ground control points was computed using the polynomial mapping functions of Kratky. Further processing an ortho-rectified image was produced, in the Hellenic Geodetic Reference System (fig.1).

Subsequently, using on-line GPS receivers, these corrected images can be used as inland navigational tools with high resolution (one meter). Such tools are of essential validity for emergency planning, in crisis management and evaluation procedures in devastated areas due to any natural disasters (floods, forest fires, earthquake devastation, volcanic eruption etc.), as well as for all non-accessible areas without proper maps.

4.2. The DEMs serve as a base for production of a great variety of maps

A great variety of maps can be produced from the DEM: 3-D models in different sun azimuth and sun elevation (fig.2) including different layers like geological data, morphological data as well as satellite images, etc, layers and maps for terrain analysis like slope – aspect maps, maps of discontinuities of morphological slopes, maps of planation surfaces etc. All the above data (DEMs, layers and maps) are useful tools for the study of an area related to the geology, tectonics, morphotectonics, geodynamics etc. (VASSILOPOULOU, 1999).
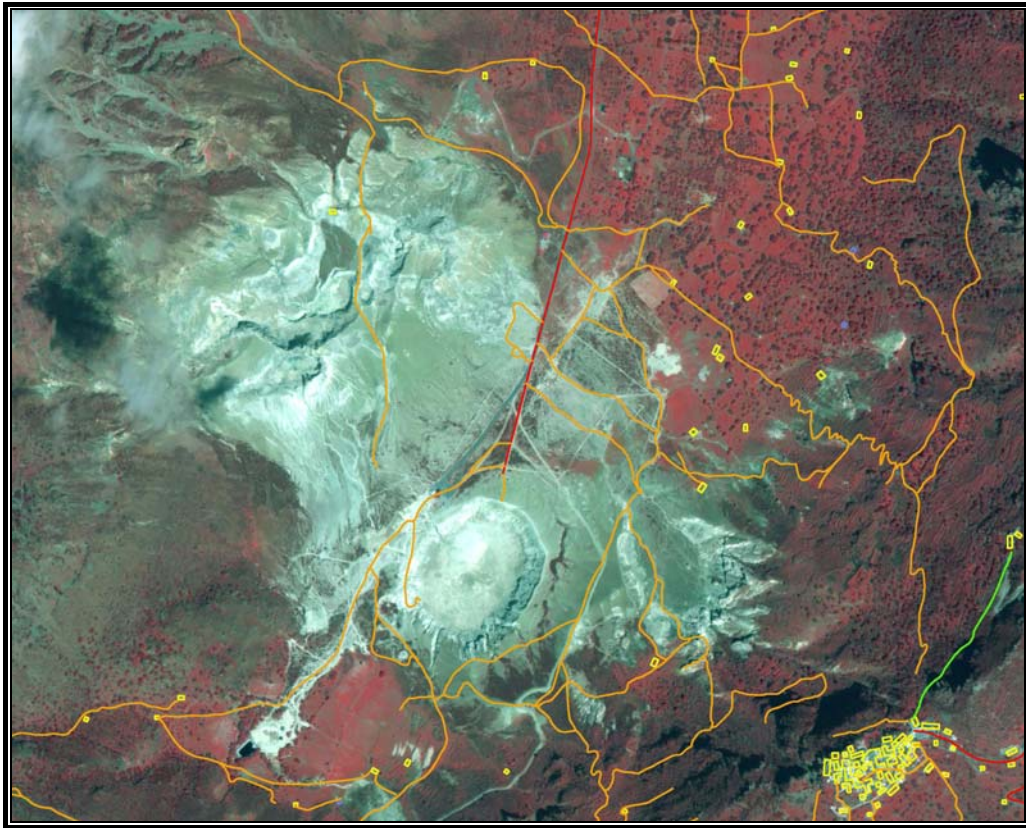
Figure 1. The ortho-rectified Ikonos satellite image overlaid by the topographic information (roads, buildings). It represents a useful support for the topographic map update.
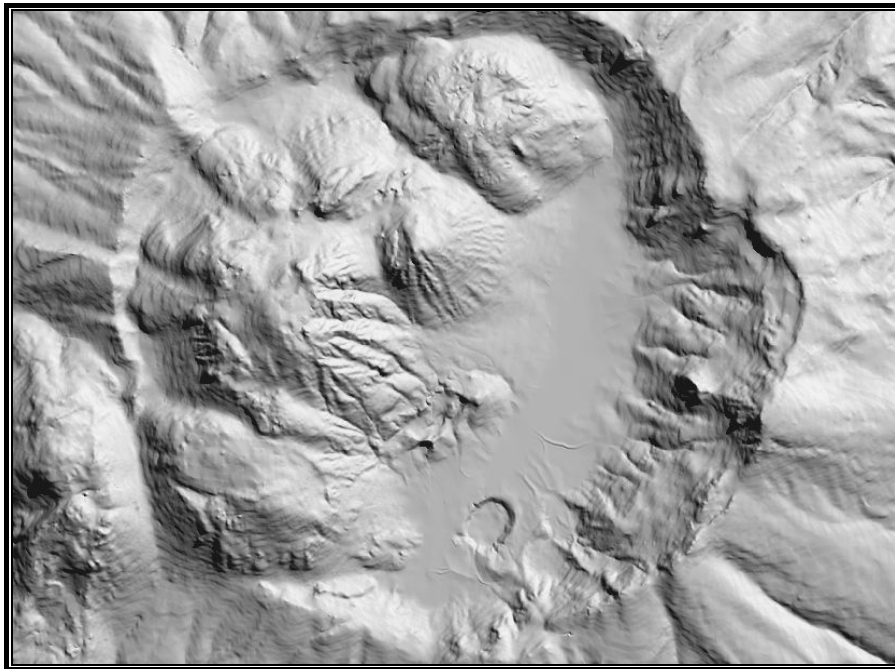

Figure 2. A part of the 3-D model of Nisyros island. The DEM with cell size of 2 meters was used. It is a basic tool for the analysis of the tectonic, the geomorphology, etc.

6. REFERENCES

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More Informations can be found at: www.geowarn.org