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"PROANA" A USEFUL SOFTWARE FOR TERRAIN ANALYSIS AND GEOENVIRONMENTAL APPLICATIONS – STUDY CASE ON THE GEODYNAMIC EVOLUTION OF ARGOLIS PENINSULA, GREECE.

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1. ABSTRACT

The specific software "PROANA" was developed within the framework of a PhD thesis in the Faculty of Geology of the University of Athens. The aim of the "PROANA" software was to produce and to handle all associated data and maps for terrain analysis relating to the geodynamics of Argolis Peninsula. "PROANA" is a useful tool for geo-environmental applications related to the terrain analysis.

2. INTRODUCTION

The specifically developed software, called "PROANA" was named after the Greek initials "Prototype Analysis Anaglyfou (Terrain)". However, a stand alone GIS package is not by itself capable neither of solving problems, nor of providing the correct answer to specific questions.

"PROANA", therefore, was developed within the framework of a PhD thesis (VASSILOPOULOU, 1999), in the Faculty of Geology of the University of Athens. The aim of this thesis was to study the recent geodynamic evolution of the Northern Argolis Peninsula based on terrain analysis by G.I.S development, and the use of Remote Sensing Data. A large number of data was compiled and new layers and maps related to the terrain analysis, as well as a relational database, were produced.

When all the maps were produced the qualitative terrain analysis, as well as quantitative terrain analysis of the region followed, based on the above maps as well as on the layers and their database. So that diagrams and rose-diagrams were produced after statistical analysis and the geodynamic evolution of the Argolis Peninsula was outlined.

3. DESCRIPTION OF "PROANA"

3.1. General Prerequisites of "PROANA"

The "PROANA" software is characterised as prototype, mainly because of the following reasons:

- It deals with a good analysis of the problem set, which is required to be processed in a specific and broad sense of the term.
- Handling of the problem set by a computer language. It is attainable by the data type, the selection and the value of specific parameters, the development and handling of the data-base, as well as the automated procedures for the results outcome.
- Immediate possibility of scale maps change and change of other specific parameters.
- User friendly interaction.

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- Development and acceptance of results.
- Immediate possible amendment of various procedures.
- Implementation of the software in other field area, but other type of data would be required, including thematic maps.

3.2. Functioning of "PROANA"

3.2.1. Input Data

- Topographic Data: Contour lines of 20 m, 10 m, partially 5 m, trigonometrical points, spot heights and additional elevation points from the topographic maps of scale 1:50000.
- Morphological Data: Streams from the topographic maps of scale 1:50000.
- Geological Data: geological formations, slope and direction of formations etc, from field work observations in scale 1:50000 and from other scientific studies.
- Tectonic Data: Faults, thrusts, over-thrusts and other tectonic contacts from field work observations represented in scale of 1:50000.
- Data from Satellite Images: Two satellite images (SPOT Pan and LANDSAT 5, TM) were processed and interpreted. Mainly tectonic as well as geological contacts were determined.

A data preprocessing step is necessary before the analysis. This step can be divided into the following stages: layer compilation, error correction, conversion of co-ordinates in map projection system, building topology, and data base organization (VASSILOPOULOU, 1999).

3.2.2. Output - Results

The geological and tectonic data were manipulated by "PROANA" and the following maps were compiled with their data base (scale 1:50000):

- "Geological Map of Northern Argolis Peninsula"
- "Tectonic Map of Northern Argolis Peninsula"
- "Tectonic Data from Satellite Images"

Several layers for terrain analysis (planation surfaces, morphological discontinuities, etc) were produced by "PROANA" automatically. These were related to the geological and tectonic layers so that new synthetic layers and maps were produced (scale 1:50000). The following maps with their data base were produced:

- "Digital Elevation Models (cell size: 20m and 60m)"
- "3-D Models"
- "Map of Drainage Network and Basins"
- "Slope and Aspect Map"
- "Range Map"
- "Map of Discontinuities of Morphological Slopes"
- "Map of Planation Surfaces Classified in Depositional and Erosional with theirs Slope Direction and Categorized with Respect to their Slope"
- "Planation Surfaces Categorized Related to their Elevation"
- "Map of Terrain Analysis (Synthetic Map)" etc.

The flow chart of "PROANA" is given at the figure 1.

3.3. Compilation of Representative Maps for Terrain Analysis

3.3.1. Digital Elevation Models (DEMs)

3.3.1.1. General

The surface of the landscape presents various formations like mountains, hills, plain, valleys, that differ among areas composing the terrain under consideration.

Terrain's morphological peculiarities, among others, basically depend on tectonic phenomena. Interesting results can be produced concerning tectonics – morphotectonics – geodynamics etc., of an area, from a close study of terrain.

A means of presenting terrain in a digital format using GIS can be considered the production of a Digital Elevation Model (DEM). The DEM is the basic feature for the terrain analysis of a region, not only because it represents a modern digital topographic map in 3-dimensions and serves as a base for thematic applications (geology, volcanology, geophysics, geochemistry, orthorectified satellite images, interferometry etc.), but also serves as a base for production of a great variety of maps relating to the terrain analysis (3-D maps, slope – aspect maps etc.).

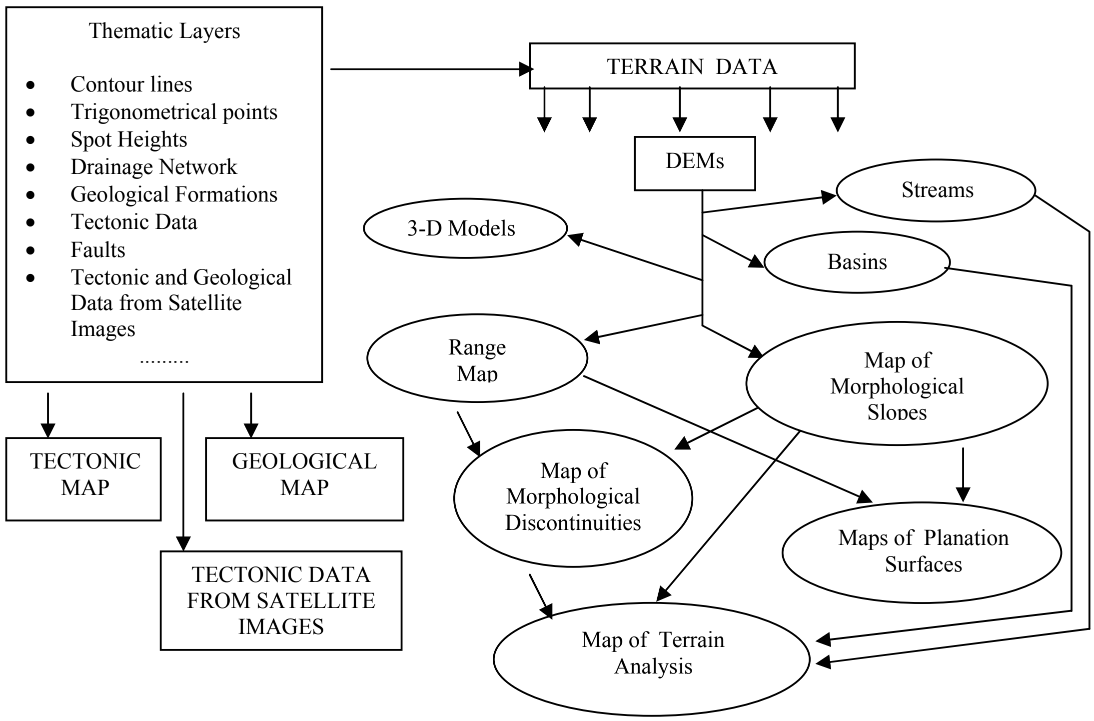

Figure 1. Flow chart of the specific software "PROANA" for the production of Terrain Data

3.3.1.2. Methodology

The applied methodology for obtaining a DEM, depends on numerous 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. These DEMs will serve as the base for the production of a great variety of thematic and synthetic layers and maps relating to the terrain analysis (slope – aspect maps, maps of discontinuities of morphological slope etc). 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 generates a hydrologically correct grid of elevation from point, line, and polygon coverages.

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. (fig. 2).

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

3.3.1.2.1. Pre-Processing

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: 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: Except contour lines and trigonometrical points, more elevation points are important for the production of a DEM, in specific regions (planation surfaces, etc.).
- Creation of a polygon coverage – boundary for the region: This coverage represents the outer boundary of the interpolated grid.

3.3.1.2.2. 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).

3.3.1.3. Creation of DEMs

The topogrid algorithm with specific parameters related to the study area was applied to a selection of DEMs in grid format, with various resolutions (cell size from 20m to 60m) in the scale 1:50000 (VASSILOPOULOU, 1999).

3.3.1.3.1. Input data

Contour lines: Contour data is used for two purposes in topogrid. It is first used to generate a generalized morphology of the surface based on the curvature of the contours. The contours are then used in their more traditional role as sources of elevation information.

Also, trigonometrical points, spot heights, points that were produced from contour lines, additional elevation points in specific areas and streams were input.

3.3.1.3.2. Output- Results

As result several cell size DEMs were produced.

Any surface that is created should be analysed to ensure that the data and parameters supplied to provided in a realistic representation of the surface. There are many ways to evaluate the quality of an output surface, function of the available input type. In our case contours were produced by latticecontour command.

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

The resulted DEMs will serve as a base for production of a great variety of maps related to the terrain analysis.

3.3.2. Shaded Relief - 3-D Models

A DEM can be used to produce shaded relief as well as 3-D models which use shading to effect the appearance of the third dimension of height. This process demand the computation of shaded areas from an assumed solar position.

The observer position, the target position and the solar position (sun azimuth and sun altitude) are the parameters that are used for the production of the shaded relief. These parameters depend on the study area (geomorphology, tectonic etc) as well as the kind of the study (determination of faults and other tectonic data etc). Mainly faults as well as other tectonic contacts will be determined at the present study, so that the solar position has to be vertical to the direction of faults (E-W, NW-SE, NE-SW).

Draping thematic maps (gelogical map, tectonic map, etc.), satellite images, or aerial photos over the DEM, produce more realistic images. These images can be used for terrain analysis as well as for geology, tectonic, etc.

3.3.3. Slope – Aspect Map

The "Slope – Aspect Map" or "Map of Morphological Slopes" represents the slopes of the terrain classified in regions, as well as the aspect of the slopes. This map is compiled of two layers: slope and aspect.

3.3.3.1. The estimation of the slopes:

- The estimation of the slopes is based on a classic methodology (PAPANIKOLAOU, 1978). This was programmed within "PROANA". The stages are as follows:
- The slopes at the region of Argolis Peninsula are categorized: 0-5%, 5–15%, 15-30%, 30–45%, 45-60%, slopes >60%.
- The planation surfaces are categorized: 0-1%, 1-5%, 5-10%, 10-15%.
- A look up table is created with specific items so that the slopes of the region can be counted and a new thematic layer (the layer of morphological slopes) is compiled.
- The above layer is a polygon – layer. The size of the smaller polygon is 20x20m (cell size of the DEM).
- Each polygon includes information related to the look up table.
- After processing, unuseful information is removed.
- New items are added containing useful information for the production of morphological slope as well as planation surfaces.

3.3.3.2. The estimation of the slopes aspect

The thematic layer of the slopes aspect is estimated from the DEM as follows:

- A look up table is created related to the angles – aspect of slopes.
- The angles are categorized by 45^0 and are transformed in to Arc/Info format.
- The layer of slopes aspect is produced. The classification of aspect is based on the look up table.
- Unuseful information is removed, after processing.

3.3.3.3. The compilation of "Map of Morphological Slopes"

The "Map of Morphological Slopes" is produced as follows:

- The thematic layer of slopes is related to the layer of aspect so that a new synthetic layer is produced.
- Each polygon in the new layer includes information of both slope and aspect.
- The categories of slopes are represented using specific colors. The aspect of slopes is represented using arrows.

3.3.4. Range Map

The thematic layer of "range" is produced from the DEM:

- The study area is divided in categories of 20 meters elevation zones. These zones are contained in the range - polygon layer.
- The mean elevation of each zone is computed and counted in a new item.
- The resulted layer is useful for many applications. Within the present study it will be used for the definition of the morphological discontinuities of slopes as well as for the production of specific diagrams.

3.3.5. Map of Planation Surfaces

The layer of planation surfaces is produced using the layer of morphological slopes. The planation surfaces are regions of the terrain where their slope take values from 0-15%. At the present study, the planation surfaces are classified in: 0-1%, 1-5%, 5-10%, 10-15%. (fig.2.)

The following parameters must be calculated and analyzed:

- At first, a new layer is produced based on the layer of morphological slopes.
- The categories of slopes are: 0-1%, 1-5%, 5-10%, 10-15%.
- The above layer is related to the thematic layers of range, geology, and aspect.
- After processing, the final layer of the planation surfaces is produced. The planation surfaces are classified as depositional and erosional function of their slope direction and categorized with respect to their slope.

3.3.6. Planation Surfaces categorized related to their Elevation

- As a first step a new layer is produced, based on the above layer of planation surfaces. This layer includes the planation surfaces with slopes 0-5%.
- A diagram having the terrain percentage of planation surfaces is given. The mean elevation of the planation surfaces is related to their percentage (%) area, in this diagram. Four maxima are distinguished at elevation levels of 0-30 m, 170 – 210 m, 70 – 110 m, 350 – 390 m.
- A new map is then compiled based on the above four elevation segments.

3.3.7. Map of Morphological Discontinuities of Slopes

The “Map of Morphological discontinuities of slopes” is represented the differences in slope more than 10%.

- At first, a new DEM with cell size of 60 m is produced.
- The morphological discontinuities are boundaries of polygons with specific characteristics in the layer of the slopes.
- A new thematic layer of morphological slopes is produced based on new DEM.
- The data processing of the layer of slopes is followed. Line topology as well as polygon topology is built and all the parameters and information are given in the items.
- A new thematic layer is produced. It contains morphological discontinuities represented as arcs.
- Further processing conduct to the final thematic layer of the morphological discontinuities. The arcs – morphological discontinuities are then taking the proper shape to be subsequently represented by the analogous symbol. So that, the “Map of Morphological Discontinuities of Slopes” is produced.

3.3.8. Map of Terrain Analysis

The “Map of Terrain Analysis” is a synthetic Map. It includes all the features for terrain analysis. Specifically it includes all the information of the thematic and synthetic layers of slope, aspect, morphological discontinuities, drainage network and basins (Fig. 3)

This map as well as the map of planation surfaces can be used not only as an image but also as information. It represents the basic feature for the qualitative and quantitative terrain analysis of a region.

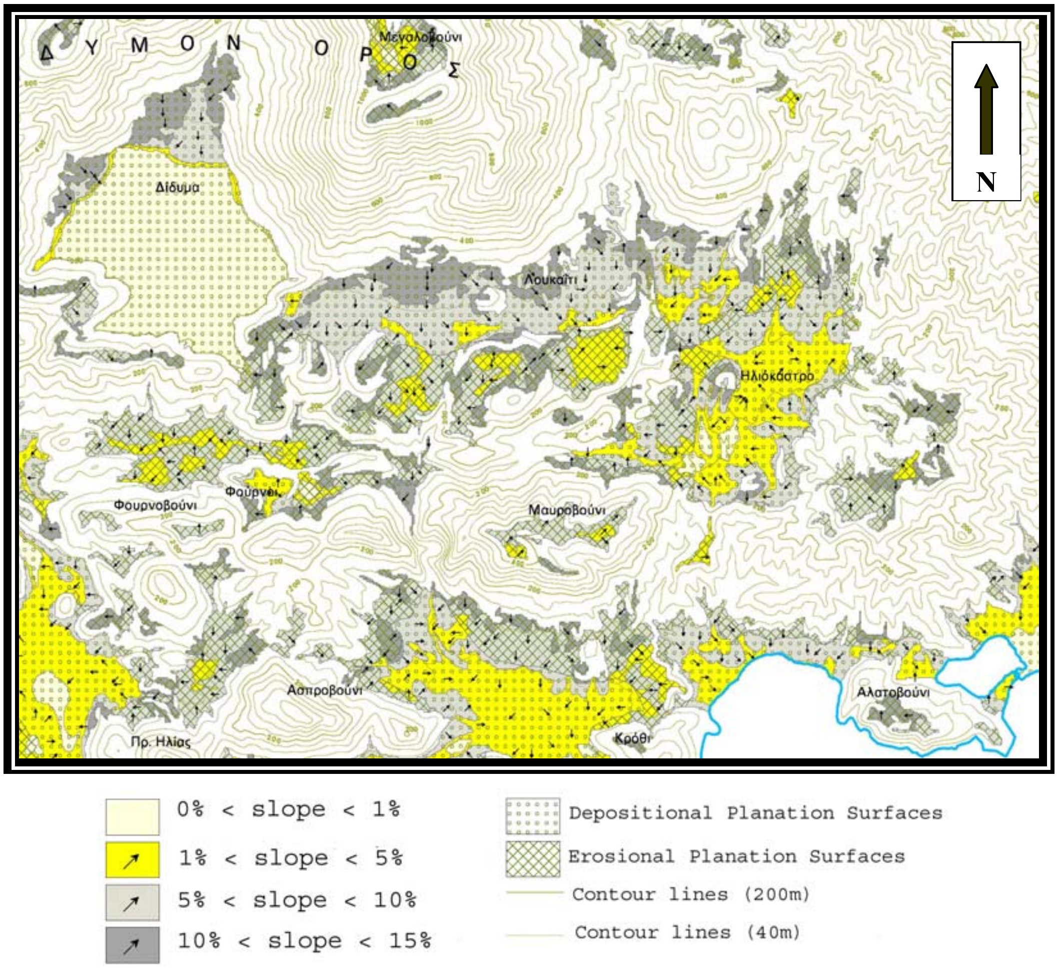

Figure 2. Part of the Map of Planation Surfaces of Northern Argolis Peninsula

4. CONCLUSIONS

A large number of data was compiled and new layers and maps as well as a relational database were produced. The qualitative as well as the quantitative terrain analysis of the region was made, based on the above mentioned maps as well as on the layers and their related database. So that, diagrams and rose-diagrams were produced after statistical analysis. As result, the geodynamic evolution of the Argolis Peninsula was outlined, based on terrain analysis.

The “PROANA” software can be used in the following domains: geodynamics, morphotectonics, tectonics and neotectonics, geomorphology, geophysics, management of geo-environmental problems - natural hazards (earthquake planning organization, monitoring volcanic activity, monitoring landslides, etc.), large public constructions (dams, roads etc), major building constructions (hospitals, various public services, hotels, etc.), studies regarding hydrogeology (suitable locations for water drilling etc.), waste - disposal areas, land use (cultivation and pasture regions, etc.), etc.

Finally the “PROANA” software can be used as a useful tool for various environmental applications, related to the terrain analysis.

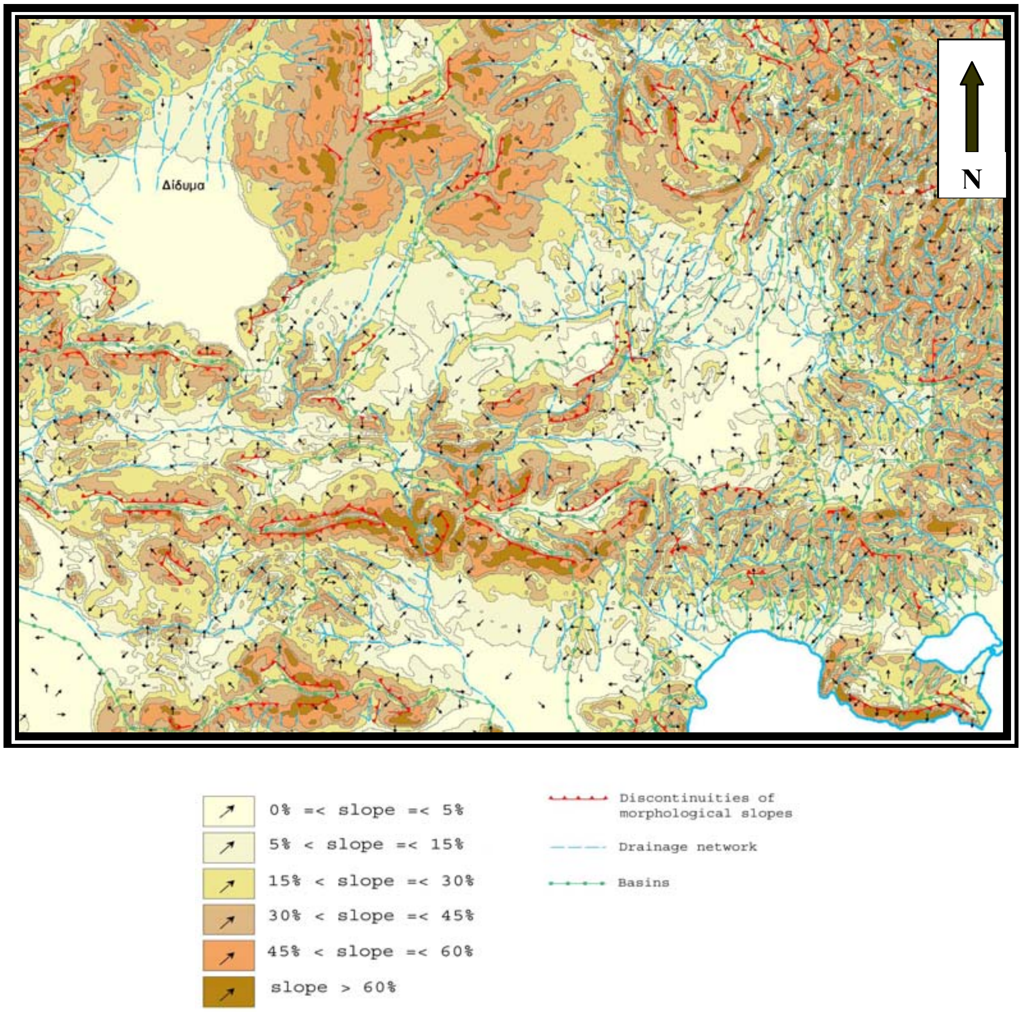

Figure 3. Part of the Map of Terrain Analysis of Northern Argolis Peninsula

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