Estimating Slopes with GIS methods.

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Abstract :

The estimation of average % slopes is among the most difficult calculation problems of classical geology and geomorphology. This paper indicates a modern method, based on a mathematical equation and GIS technology, that helps this operation by significantly reducing the needed time, and increasing the accuracy of the results.

This calculation gives the average slope number for the center of each cell of a given grid. The grid size can vary depending on the contour intervals and the relief characteristics. This method, according to a known mathematical equation, adds the length of the contour lines included in each cell, multiplies this by the contour interval number and devides it with the area of the cell.

This methodology has been applied to the island of Sifnos (Cyclades), and the results have been cross-tested with field measurements. The results, are expressed through thematic maps, statistical tables and histograms.

Περίληψη :

Ο υπολογισμός των μέσων % κλίσεων είναι ένα από τα μεγαλύτερα υπολογιστικά προβλήματα της κλασικής γεωλογίας-γεωμορφολογίας. Η εργασία αυτή έχει ως σκοπό την παρουσίαση μιας μοντέρνας μεθόδου που βασίζεται σε γνωστή μαθηματική εξισώση και στη τεχνολογία των Γεωγραφικών Συστημάτων Πληροφοριών (GIS), που βοηθά τη μεθοδολογία αυτή μειώνοντας τον απαιτούμενο χρόνο και αυξάνοντας την ακρίβεια των αποτελεσμάτων.

Ο υπολογισμός αυτός δίνει τη τιμή της μέσης κλίσης για κάθε κυψελίδα του δημιουργούμενου κανάβου. Το μέγεθος του κανάβου ποικίλει ανάλογα με την ισοδιάσταση που χρησιμοποιείται και τα μορφολογικά χαρακτηριστικά της υπό μελέτη περιοχής. Η μέθοδος αυτή, βασιζόμενη σε μία γνωστή μαθηματική εξίσωση, αθροίζει το μήκος των τμημάτων των ισοϋψών που περιέχονται σε κάθε κυψελίδα, πολλαπλασιάζει το άθροισμα αυτό με την ισοδιάσταση και διαιρεί με το εμβαδό της αντίστοιχης κυψελίδας.

Η μεθοδολογία αυτή εφαρμόστηκε για τη νήσο Σίφνο (Κυκλάδες) και τα αποτελέσματα επαληθεύτηκαν με μετρήσεις υπαίθρου. Τα αποτελέσματα εκφράστηκαν με θεματικούς χάρτες, στατιστικούς πίνακες και ιστογράμματα.

1. Introduction

The need of computers and especially computer methods, arises when complicated measurements and calculations must be repeated a hundred or a thousand of times, to perform a single task. In these cases, GIS can offer significant results when it comes to speed and accuracy.

One of these cases, that geologists and geomorphologists use frequently, is the estimation of the slopes over a surface. One of the methods is to divide the area into small rectangles (cells) and find the number that represents the average slope of the rectangle. This is done by the following equation:

$$P = 100 * \frac{\Sigma L * i}{E} \quad \text{(equation A)}$$

,where ΣL is the summit of each contour's length included into the cell,
      i is the contour interval,
      E is the area included into the cell.

This equation gives the percentage of the slope of each cell. It is obvious that near the boundaries of the studied area, or near the coastline, the cells will be cut smaller, following the edge of the surface. The accuracy of such operations, is increasing when the contour interval and the cell size is getting smaller, which means that for accurate calculations the needed time is very long. Another problem that arises, is the sensitivity of the instruments we are using, which makes the length count of very small lines impossible. These two factors control the higher level of the accuracy, and forces the geologist to limit his expectations.

On the other hand, using a GIS, we have no time or measurement limit. The software applies the measurements to the segments, no matter what their size or number is. In this paper, we are going to describe the full method, used to estimate the slopes over a surface. The maps and figures are demonstrating the method applied to Sifnos island. The estimated slopes, given at the end of this paper are cross tested with field measurements.

2. Geography - Geology

The island of Sifnos belongs to Cyclades islands and especially to west Cyclades. It lays southeast of Seriphos island, west of Antiparos and northeast of Kimolos. Its shape and coastline is very irregular. The highest point in the whole island is 678m and is located at the peak of Profitis Ilias.

The Stratigraphical column of the island of Sifnos consists of the following layers starting from the lower to the upper layer (Gournellos 1980):

1. Schist and Gneiss almost 500-600m thick, which have been metamorphosed primarly in high and secontly in low pressures.
2. Lower marble 120m thick.
3. Marble in the form of conglomerate 60-80m thick.
4. Upper Schist and Gneiss almost 80m thick which have been metamorphosed in 2 phases.
5. Upper marble most of which has been secontly dolomitized.

3. The GIS based method

The first step is to generate a grid, with a suitable cell size. In the study of average slopes in Sifnos island the selected cell size is 500*500m = 0,25Km^2. After this, the grid cells are cropped, along the coastline.

Next step is to update the database of the cells, with their precise area number in square meters.

The third step, is to split the contour lines in line segments. The algorithm, splits the contours when they enter into the next cell. The outcome is a big number of line segments, included inside each cell.

One of the basic parts of the method is the summit of the length of all the line segments included inside each cell, and the update of the cell database with these numbers.

After this step the cell database has all the data columns needed to apply the equation (A) and evaluate the slope. With a simple calculate method, we can finally estimate the slope of each cell, using the values (sum of length, area) measured in previous steps. The results are added in a new column, to the row representing each cell.

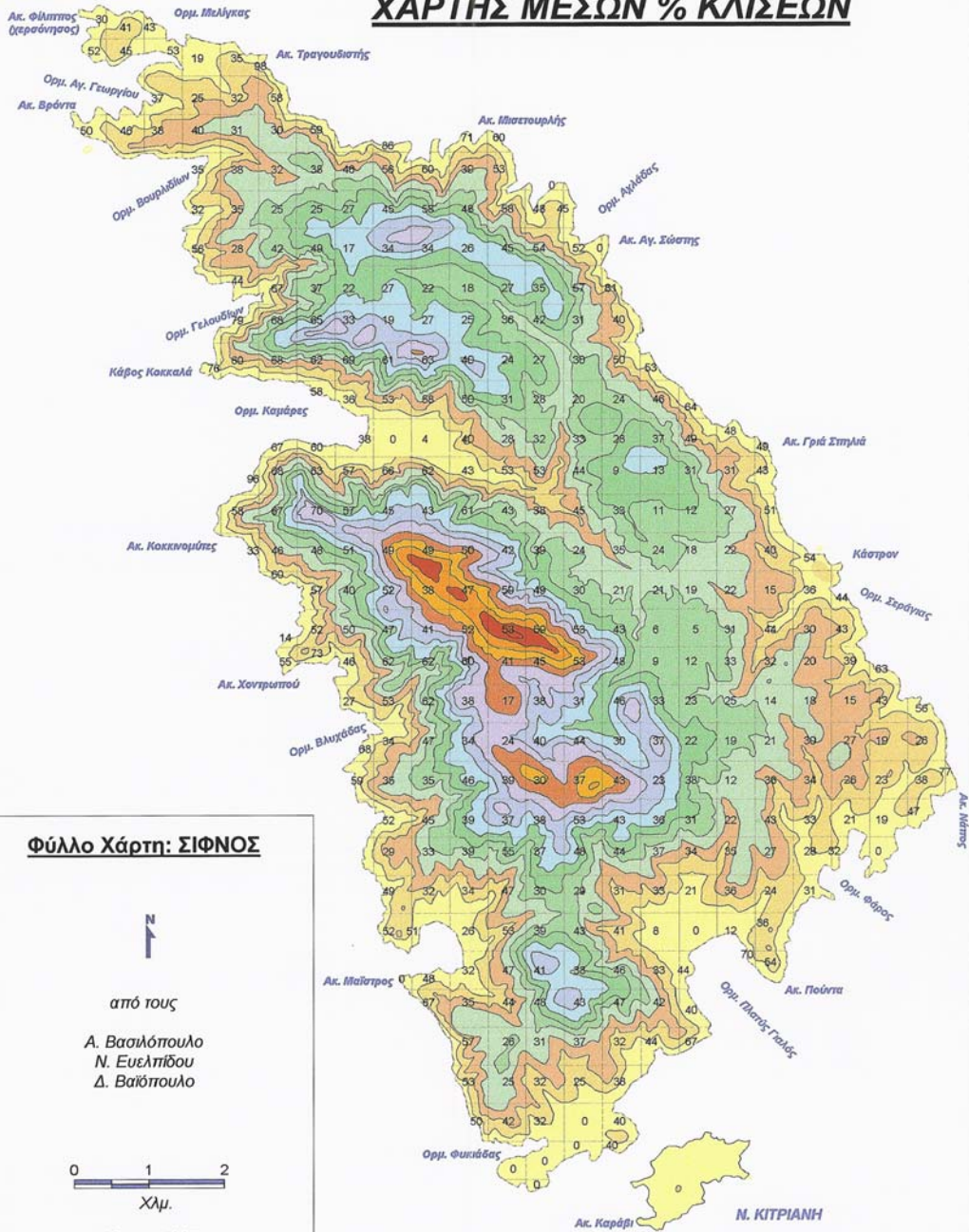## 4. The output of the slope results

This part of the paper, will demonstrate some of the output types used to analyze the slopes of the studied area. As well known, GIS softwares can generate a vast number of maps and diagrams to display and analyze the output results.

In figure 1 we can observe all the cells, with the estimated average slope number in the center of them. In figure 2 we have a thematic classification of the slopes in five categories: 0-20%, 20-40%, 40-60%, 60-80%, >100% as described by the relevant legend. Finally figure 3, displays the thematic representation of figure 2, in superimposition with the 3-dimensional surface model, where we can observe the zones of low, medium and high angle slopes.

5. Bibliography

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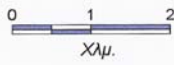8. Γεωλογικός χάρτης ΙΓΜΕ κλίμακας 1:50.000, έτους 1966.

ΧΑΡΤΗΣ ΜΕΣΩΝ % ΚΛΙΣΕΩΝ

Ακ. Φίλιππος (χερσόνησος)
Ορμ. Μελίγκας
Ακ. Τραγουδιστής
Ορμ. Αγ. Γεωργίου
Ακ. Βράντα
Ακ. Μισετουρλής
Ορμ. Βουρλιδίων
Ορμ. Αρλιάδας
Ακ. Αγ. Σώστης
Ορμ. Γελουδίων
Κάβος Κοκκαλά
Ορμ. Καμάρες
Ακ. Γριά Σπηλιά
Ακ. Κοκκινομύτες
Κάστρον
Ορμ. Σεράγκας
Ακ. Χοντρωπού
Ορμ. Βλυχάδας
Ακ. Νάτος
Ορμ. Φάρος
Ακ. Μαΐστρος
Ακ. Πούντα
Ορμ. Πλατής Γιαλός
Ορμ. Φυκιάδας
Ακ. Καράβι
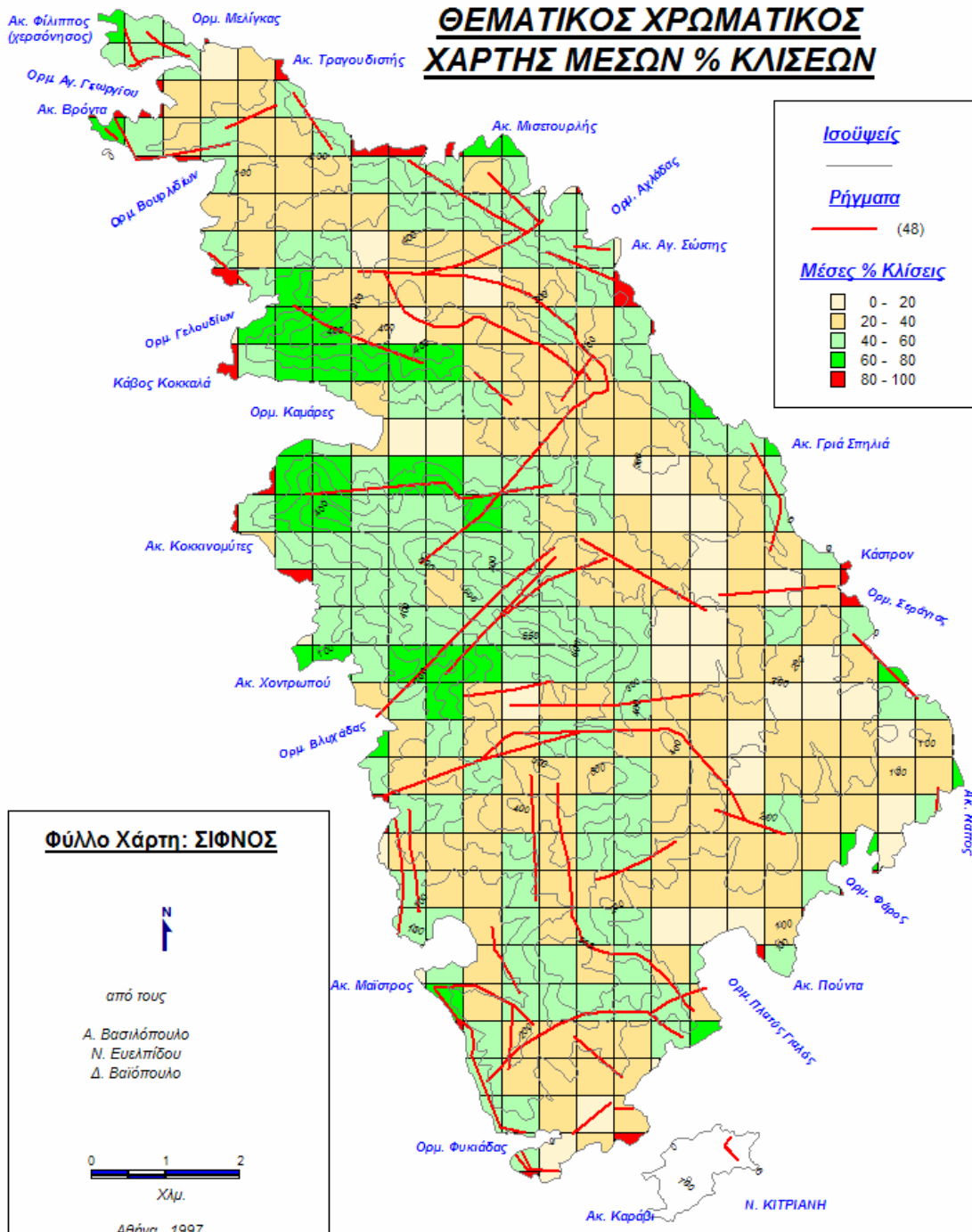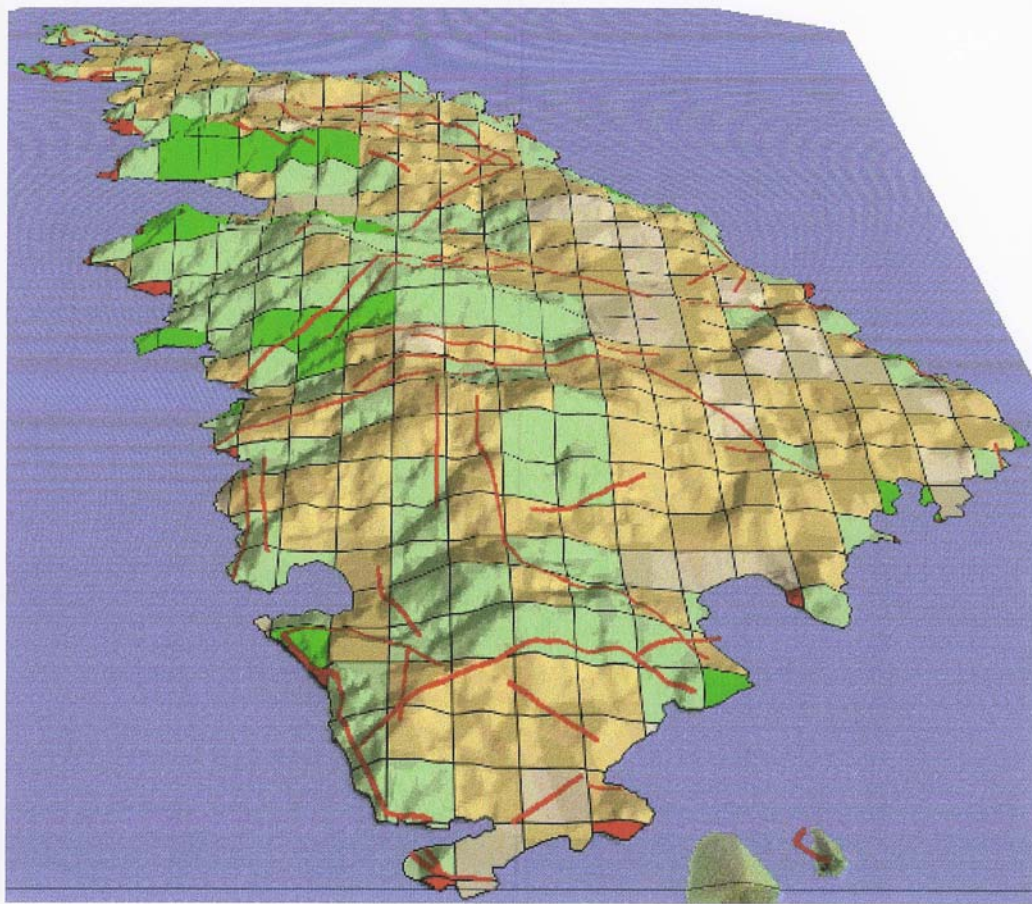Ν. ΚΙΤΡΙΑΝΗ

Φύλλο Χάρτη: ΣΙΦΝΟΣ

N

από τους

Α. Βασιλόπουλο
Ν. Ευελπίδου
Δ. Βαϊόπουλο

0   1   2
Χλμ.

Αθήνα , 1997

ΘΕΜΑΤΙΚΟΣ ΧΡΩΜΑΤΙΚΟΣ ΧΑΡΤΗΣ ΜΕΣΩΝ % ΚΛΙΣΕΩΝ

Ισοϋψείς

Ρήγματα

(48)

Μέσες % Κλίσεις

- 0 - 20
- 20 - 40
- 40 - 60
- 60 - 80
- 80 - 100

Ακ. Φίλιππος (χερσόνησος)
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Ορμ. Πλατύς Γιαλός
Ορμ. Φυκιάδας
Ν. ΚΙΤΡΙΑΝΗ
Ακ. Καράβι

Φύλλο Χάρτη: ΣΙΦΝΟΣ

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από τους

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Ν. Ευελπίδου
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Χλμ.

Αθήνα , 1997

ΣΧΗΜΑ 3