ΓΕΩΜΟΡΦΟΛΟΓΙΑ ΚΑΙ ΡΗΓΜΑΤΟΓΕΝΕΙΣ ΖΩΝΕΣ: ΠΡΟΣΕΓΓΙΣΗ ΕΠΙΛΕΓΜΕΝΩΝ ΠΕΡΙΟΧΩΝ ΤΗΣ ΕΛΛΑΔΟΣ, ΜΕ ΧΡΗΣΗ Γ.Σ.Π. ΕΦΑΡΜΟΓΗ ΛΟΓΙΚΗΣ ΠΟΛΛΑΠΛΩΝ ΚΡΙΤΗΡΙΩΝ

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Περίληψη

Σε αυτή την εργασία διερευνούμε την συσχέτιση μεταξύ του ασυνεχούς τεκτονισμού και της εξέλιξης των γεωμορφών. Για την διεκπεραίωση της εργασίας υιοθετήθηκε μία μεθοδολογία πολλαπλών βαθμίδων. Βάσει αυτού, κατά πρώτον εξετάζουμε την τοπογραφία της εν λόγω περιοχής και ταξινομούμε τις γεωμορφές. Στη συνέχεια εξετάζουμε τους γεωλογικούς σχηματισμούς της περιοχής, το υδρογραφικό δίκτυο, τις χρήσεις γης, τη βλάστηση και τον βαθμό της ανθρώπινης παρέμβασης.

Εν τέλει, εξετάζουμε τις τεκτονικές ζώνες της περιοχής (ρήγματα και ρηγματογενείς ζώνες). Επίσης, επεξεργαζόμαστε δεδομένα από την ανάλυση αεροφωτογραφιών και της δορυφορικής εικόνας της περιοχής. Οι παραπάνω πληροφορίες αναλύονται σε περιβάλλον GIS με τη χρήση μεθοδολογίας έμπειρων συστημάτων. Στα πλαίσια της εργασίας αυτής, εφαρμόσαμε την παραπάνω διαδικασία σε επιλεγμένες περιοχές της Ελλάδος.

GEOMORPHOLOGY AND FAULTED ZONES: AN APPROACH ON SOME SELECTED AREAS OF GREECE USING G.I.S. A MULTI-CRITERIA INFERENCE MECHANISM

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Abstract

In this paper we investigate the relations between the landforms and the discontinuous tectonism. A multistep methodology has been adopted. Thus, first we study the topography of a given area and by proper procedures we classify the geoforms. We next examine the geological formations of the area, the drainage system, the landuse, the vegetation and the human impact.

Finally, we study the tectonic zones of this area (faults and fractures zones). Data has also been obtained by airphotos and satellite images. All the above information is analyzed in a G.I.S platform using expert system methodology. This procedure has been applied to some selected places of the Greek territory.

1. Introduction

The land surface is the result of the interaction between the internal and external processes. The discontinuous deformations such as the faults and fractures are the principal neotectonic manifestations. The most common kind between faults are the normal faults which create abrupt topographic areas (fault scarps); the processes of erosion and deposition modify this original structure.

The aim of this paper is to investigate the relation between the geomorphology and the internal neotectonic processes. We have approached this problem, using expert system methodology in order to classify different levels of information such as topography, geology, drainage system, vegetation-land use.

2. Methodology

For the documentation's and analysis' needs of this research, a Geographical Information System has been developed; the primary spatial information that is the topography, the drainage system and the geological formations has been inserted in the spatial database. These data resulted in separate information layers and they have been compiled for each region. Processing the aforementioned spatial data resulted in a series of secondary information layers, such as the relief. Together with geographical information, a vast amount of attribute data has also been inserted in the database; attribute data has been collected after fieldwork, photointerpretation of aerial photographs and satellite images.

The flow diagram (Fig. 1) shows the main step of this methodology. Firstly we have introduced the input data, and then, using qualitative and quantitative criteria we have proceeded to a classification of geoforms in order to locate faulted zones. The main qualitative criteria which we have used are the slope gradient maps, the indicator slope maps, while in order to characterize the possible faulted zones we have used altitudinal analysis, morphological slopes, stream length gradient (Keller and Pinter, 2002), and moving window statistics, the front mountain sinuosity and the fractal dimension. Finally to detect lineaments in satellite images we have applied convolution filters using Erdas software (Erdas Imaging, 2000).

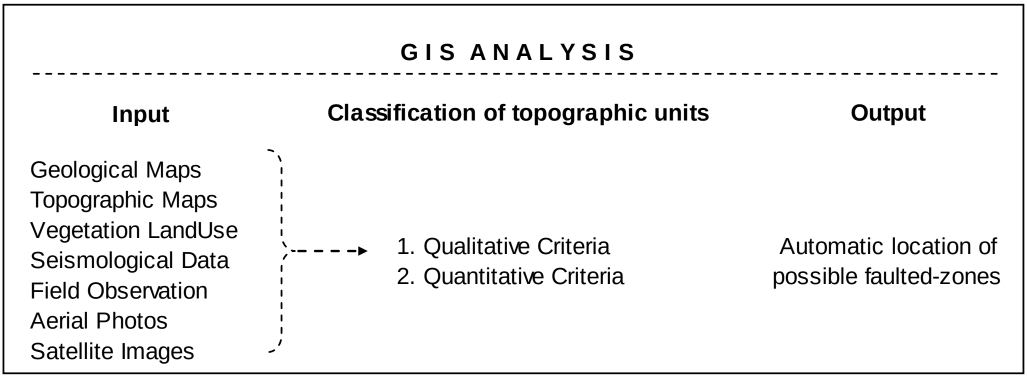


Fig. 1. Flow diagram

3. Case study

We have applied this methodology to the islands of Corfu, Lefkas, Kefallonia, Zante and to the area of Trichonis Lake (Fig. 2). These places are very close to the Ionian subduction zone and present intense earthquake activity. The geological evolution of these areas is characterized by the alpine structures and the neotectonic faulting (IGME, 1963; Bornovas, 1964; I.G.S.R. N. Corfu Sheet, 1970; I.G.S.R. S. Corfu Sheet, 1970; British Petroleum Co. Ltd., 1971; Caputo, 1984; IGME, 1985; Leivaditis, 1987; Livaditis and Verikiou-Papaspiridakou, 1987a,b; Doutsos et al, 1987; Underhill, 1989; Gournellos et al. 1997; Maroukian et al. 2004; Gournellos et al. 2005). The geomorphological processes of these areas have been studied by numerous authors (Gournellos et al. 1997; Gournellos et al. 1999; Verikiou et al. 2000; Vassilopoulos, 2001; Verikiou et al. 2002; Gournellos et al. 2005).

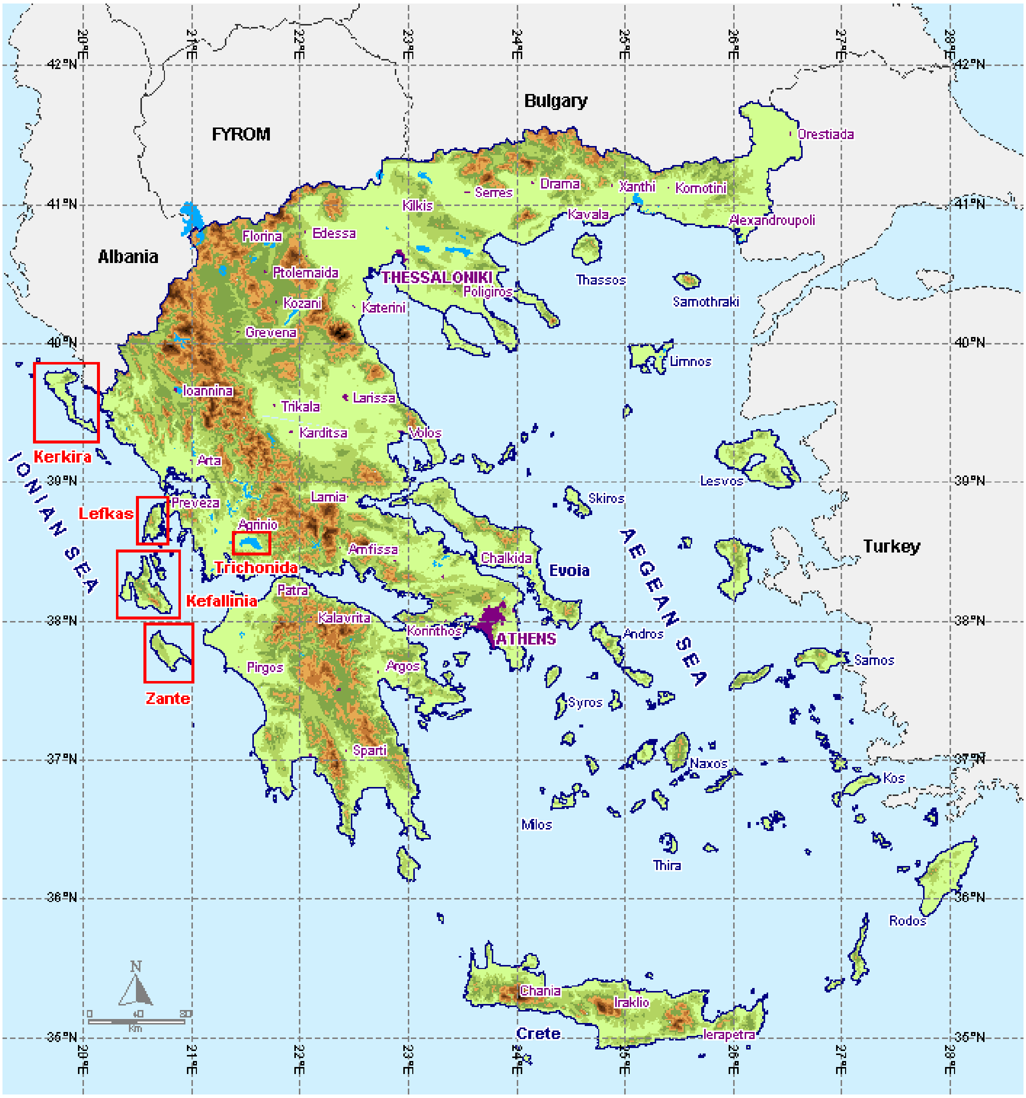
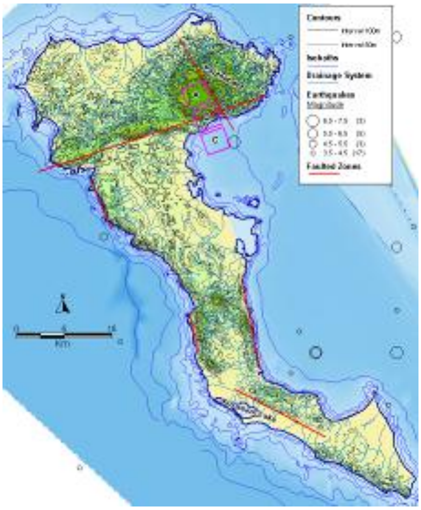
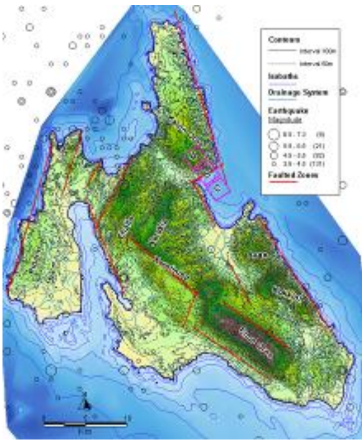
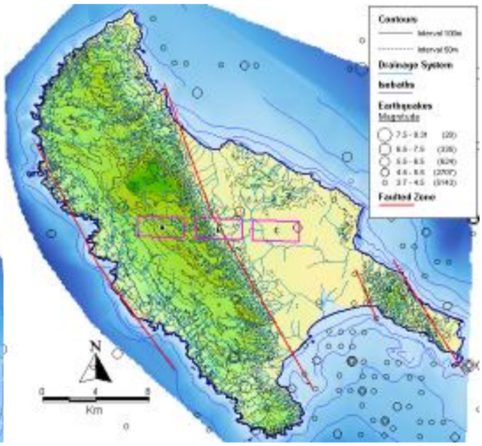


Fig. 2. Study areas

Thus, using the multi criteria procedure we have located the main faulted zones as they have been mapped in figure 3. The slope maps and the indicator maps (Fig. 4) were very useful tools. Then we proceed to estimate some characteristic parameters of the fault zones such as the front mountain sinuosity, slope, stream length gradient index, fractal dimension, altitudinal analysis (Table I), fault orientation and length (Table II). It must be noted that we have also investigated the mapping of lineament by analyzing satellite images.






Contours
Interval 100m
Interval 50m
Drainage System
Isobaths
Earthquakes
Magnitude
Faulted Zone
N
0
4
8
Km


Contours
Interval 100m
Interval 50m
Drainage System
Lakes
Earthquakes
Magnitude
5.0 - 5.8 (5)
4.5 - 5.0 (14)
4.0 - 4.5 (16)
3.7 - 4.0 (16)
Faulted Zone
N
0
3
6
Km
A
B
C

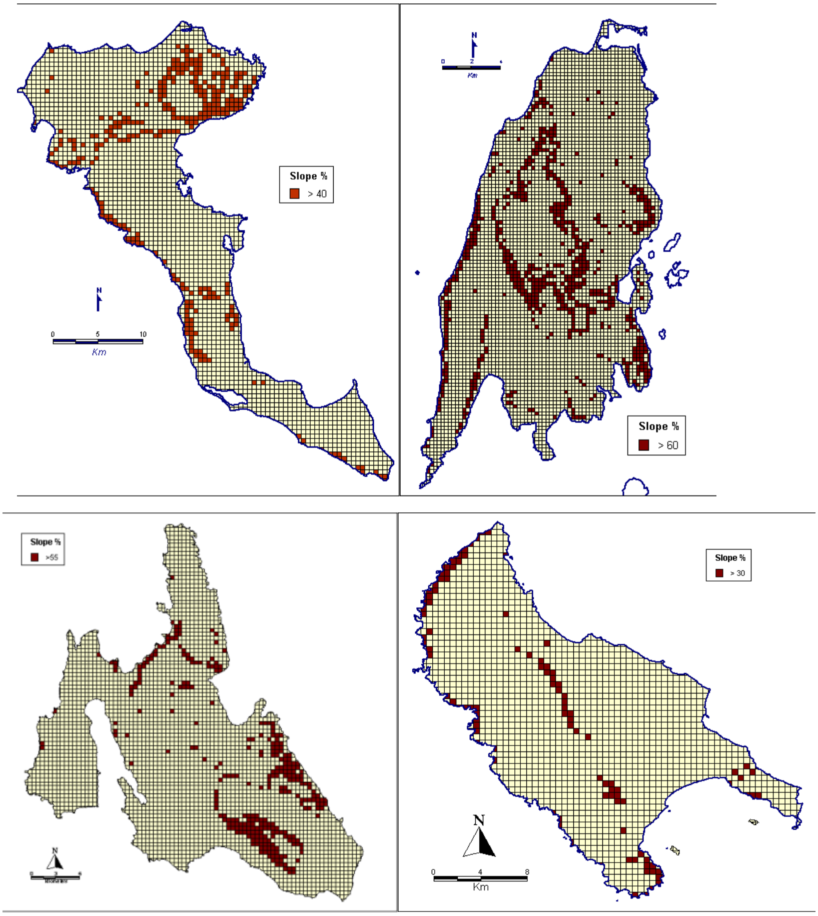


Fig. 3. Location of the main faulted zones using a multi-criteria procedure.

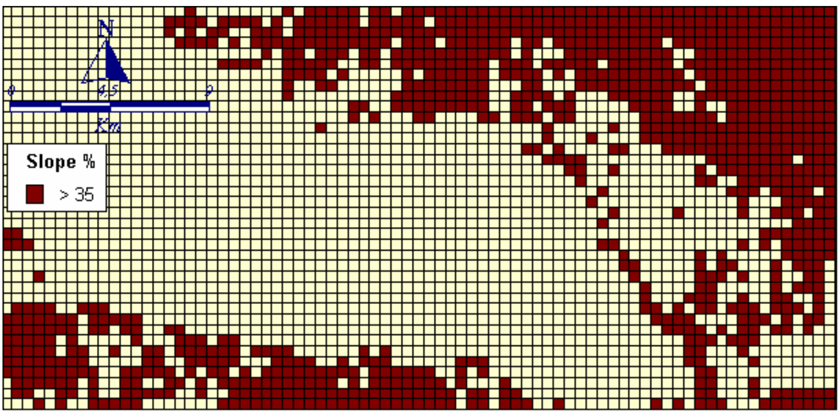


Fig. 4. Slope maps for the study areas.

We applied convolution filters on a Landsat image of Zakynthos Island, taken in July 1984, in order to detect lineaments which possibly express fault zones.

We first applied a 3x3 high pass filter, which is incorporated in the standard convolution masks of ERDAS Imagine 8.5 software. The coefficients of the mask are the following:

-1	-1	-1
-1	9	-1
-1	-1	-1

(1)

The filtered 432 RGB image of the island, according to mask (1), shows a NW-SE lineament which is estimated to be a faulted zone. This lineament, may also be seen as a border zone in dark tones and an adjacent region with bright tones, if another filter, proposed by Richards & Jia 1999, is applied on the same image. The coefficients of this filter are given by:

0	+1	+1
-1	0	+1
-1	-1	0

(2)

Finally we applied a filter proposed by Skianis et. al. 2005, which is defined by the following 5x5 mask:

-0.014	-0.101	-0.003	-0.101	-0.014
0.000	-0.101	-0.199	0.000	-0.101
-0.003	-0.199	3.159	-0.199	-0.003
-0.101	0.0000	-0.199	0.000	-0.101
-0.014	-0.101	-0.003	-0.101	-0.014

(3)

This filter has had a remarkable effect on the thermal infrared band 6 of the Landsat image. A lineament with dark tones has been observed, at the same location with the NW-SE lineament of the other filtered images.

4. Conclusion

We have approached the relations between geomorphology and faulting using a multi-criteria procedure. Thus using various data levels such as topography, lithology, earthquake distribution, air-photo, satellite image and field observation, we have achieved to locate possible faulted zones in the Ionian islands of Corfu, Leukas, Kefallinia, Zante and in the area of Trichonis lake. All those areas are characterized by intense active deformation, related to the general geotectonic field.

Thus, the results of this paper can be very useful in local and regional scale for future decisions concerning development and environmental protection.

Appendix 1

Table I. Altitudinal analysis – Moving window statistics for the case studies

Altitude analysis – Moving window statistics - Kerkira			
	A	**B**	**C**
Count	453	1.134	10
Minimum	650	-41	-49
Maximum	800	750	-31
Range	150	791	18
Sum	327.050	406.102	-422
Mean	721,965	358,115	-42,2
Variance	1.366,34	48.651,93	30,36
Standard Deviation	36,964	220,572	5,509

Altitudinal analysis – Moving window statistics - Lefkas			
	A	**B**	**C**
Count	9	175	297
Minimum	-146	-50	260
Maximum	-50	360	700
Range	96	410	440
Sum	-746	24.625	140,380
Mean	-82.8889	140,714	472,66
Variance	1.053,43	12.718,2	13.059,93
Standard Deviation	32,4566	112,2775	114,28

Altitude analysis – Moving window statistics - Kefalinia			
	A	**B**	**C**
Count	518	396	21
Minimum	350	-106	-128
Maximum	822	500	-50
Range	472	606	78
Sum	318.983	55.814	-1.969
Mean	615,797	140,944	-93,7619
Variance	13.037,13	18.769,46	680,562
Standard Deviation	114,18	137,002	26,0876

Altitudinal analysis – Moving window statistics - Zante			
	A	**B**	**C**
Count	385	710	0
Minimum	400	50	-
Maximum	550	550	-
Range	150	500	-
Sum	191.450	206.830	-
Mean	497,273	291,31	-
Variance	1.193,86	20.158,14	-
Standard Deviation	34,5523	141,979	-

Altitudinal analysis – Moving window statistics - Trichonida			
	A	**B**	**C**
Count	16	367	697
Minimum	40	60	140
Maximum	60	240	380
Range	20	180	240
Sum	720	56.180	172,720
Mean	45	153,079	247.805
Variance	75	1.790,79	3.109,24
Standard Deviation	8,66025	42,3178	55,7606

Table II: This table shows the characteristics for each faulted zone; different parameters such as front sinuosity, fractal dimension, stream length index, moving window statistics and fault parameters.

Table II

Location	Sinuosity	Fractal Dimension	SL Index	Fault characteristics: Orientation	Length m	Slope	Code
Corfu	1.27	1.102	413,76	152,01°	6.068		S1
			761,13				S2
			425,99				S3
Lefkas	1.19	1.0369	265,91	24,25°	14.778,61		S1
			1.561,95				S2
			286,80				S3
Kefallinia	1.62	1.0576	545,25	148.73°	6.276,76		S1
			8,57				S2
			813,46				S3
Zante	1.61	1.0305	295,85	135.57°	3.269,93		S1
			430,41				S2
Trichonida	2.44	1.1645	256,27	94,98°	14.134,23	16,26 °	S1
			1.541,74				S2
			28,69				S3

References

Βασιλόπουλος Α., Θ. Γκουρνέλος, Ν. Ευελπίδου, 2000: Κατασκευή περιβαλλοντικής βάσης δεδομένων και αντίστοιχου χάρτη για τη νήσο Κεφαλληνία με τη χρήση τεχνολογίας G.I.S., Πρακτικά 6ου Συνέδριου Χαρτογραφίας, Χ.Ε.Ε.Ε, σελ. 539-545.

Σαμπώ Β., Θ. Γκουρνέλος, Ν. Ευελπίδου, Α. Βασιλόπουλος, 2001: Δημιουργία Βάσης Δεδομένων και χάρτη επικινδυνότητας διάβρωσης της περιοχής της λίμνης Τριχωνίδας χρησιμοποιώντας κανόνες ασαφούς λογικής σε περιβάλλον Γ.Σ.Π., Πρακτικά 9ου Διεθνούς συνεδρίου Ελληνικής Γεωλογικής Εταιρίας, Αθήνα, Vol. XXXIV/1, p.p. 443-450.

Bornovas J., 1964: Geological study of Leukada island. IGSR, Vol. X, No 1: 142.

British Petroleum Co. Ltd., 1971: The geological results of petroleum exploration in western Greece, Athens, Greece, Institute for Geological and Subsurface Research, Report No. 10.

Caputo R., 1984: Geologia della zona trascorrente di Corfu (Grecia), Thesis Univ. Ferrara, 1-130, unpublished.

Dermitzakis M., D. Papanikolaou and Z. Karotsieris, 1977: The marine Quaternary deposits of SE Zakynthos island and their paleogeographic implications, VI Inter. Congress of Aegean Region, Athens.

Doutsos T., N. Kontopoulos, D. Frydas, 1987: Neotectonic evolution of northwestern continental Greece: logische Rundschau, 76, 433-452.

Gournellos Th., A. Vassilopoulos, N. Evelpidou, 1997: Development of a GIS –based methodology to analyze geological, geomorphological and environmental data of the island of Zakynthos, Proceedings International Symposium on Engineering geology and the environment, Athens, p.p. 1245-1251

Gournelos T., N. Evelpidou, A. Vassilopoulos, 2005: Developing a neuro-fuzzy system to classify the drainage sub-basins according to erosion processes in the island of Lefkas (Greece), presented at the COST Action 634 conference: Reorganizing field and landscape structures in a context of building strategies for water and soil protection, Lublin, Poland, 15-17 September 2005, Abstract.

Gournelos Th., N. Evelpidou, A. Vassilopoulos, 1999: A morphometric analysis using GIS to deduce geomorphological process - natural hazards, at Zakynthos islands, Proceedings of the 6th International conference on Environmental Science and Technology, Samos, Vol. II, p.p. 371-378.

I.G.S.R. (Institute for Geology & Subsurface Research), 1970: Geological Map, North Corfu Sheet, Scale 1:50.000

I.G.S.R. (Institute for Geology & Subsurface Research), 1970: Geological Map, South Corfu Sheet, Scale 1:50.000

IGME, 1963: Geological map of Leukas, 1:50.000.

IGME, 1985: Geological map of Kefallinia, 1:50.000.

Keller E.A. and N. Pinter, 2002: Active Tectonics, Earthquakes, Uplift and Landscape, Second Edition, USA.

Leivaditis G., 1987: Coastal morphology of Zante island, 1st PanHellenic Geographical congress, 195-203.

Livaditis G and E. Verikiou-Papaspiridakou, 1987(a): Coastal morphology of Leukas island, Proceedings of 1st PanHellenic Geographical Conference, Athens, 387-394.

Livaditis G. and E. Verikiou-Papaspiridakou, 1987(b): Coastal sedimentology conditions that formed "Zostiros" formation in Leukada town. 1st Hellenic Geographical Congress, Vol. B, p. 229-235.

Maroukian H., K. Gaki – Papanastassiou, A. Vassilopoulos, N. Evelpidou, D. Papanastasiou, 2004: Coastal configuration variability and retreat of the five largest Ionian islands (W. Greece), Littoral 2004, 7th International Conference Delivering Sustainable Coasts: Connecting Science and Policy, September 20 – 22, Vol. 2, p.p. 654- 659.

Skianis G., D. Vaiopoulos, K. Nikolakopoulos, 2005: A study of the performance of a new sharpening filter. Proc. SPIE, 5982, 323-334, Image and Signal Processing for Remote Sensing XI, Lorenzo Bruzzone; Ed.

Underhill J.R., 1989: Late Cenozoic deformation of the Hellenide forcland, Western Greece, Geological Society of America Bulletin, 101, 613-634.

Vassilopoulos A., 2001: Analysis of Geomorphological and Geographical data, using GIS techniques in Kefallinia island, Thesis, University of Athens, Geology Department, p.222.

Verikiou E., N. Evelpidou, A. Vassilopoulos, 2000: "Processing knickpoints in Leukada island with the use of GIS techniques", Annale Geologique des Pays Helleniques, XXXVIIIc, 211-220.

Verikiou E., A. Vassilopoulos, N. Evelpidou, 2002: Geomorphological characteristics in Leukas island using GIS, Proceedings of the 6th Pan-Hellenic geographical congress of the Hellenic Geographical Society, October 3-6, Vol. I, p.p.395-402.