Development of a GIS - based methodology to analyze geological, geomorphological and environmental data of the island of Zakynthos.

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ABSTRACT: In this paper, we use GIS technology to investigate the complex interrelation between geological, geomorphological and environmental variables. In some cases, external packages are also used. The analysis of such variables requires a big number of spatial and temporal data, which were obtained from various sources. The final results are the creation of different levels of databases and thematic maps. The purpose of this study is to develop appropriate strategies for resources management, environmental protection, hazard assessments and regional planning.

1. Introduction.

Zakynthos belongs to the Ionian islands and is the third larger in size. It is located 9.5 nautical miles from the Peloponnesus peninsula. The area of the island is 406 Km^2. The shape of Zakynthos resembles an irregular triangle.

The aim of this paper is to study the geology, geomorphology and environment of this island using GIS techniques. The different stages of this work were a) data collection b) the data analyses c) the creation of different thematic maps. The various data sources were:

a) Different field works and literature,
b) Aerial photographs and satellite- photos,
c) Topographical maps (scale 1:50.000, Geographical Military Service) and geological maps (Geological map of Zakynthos scale 1:50.000, Institute of Geology and Mineral Exploration : I.G.M.E).

All data have been stored using MapInfo software to produce thematic maps and for further analysis of data, the SPSS software program was used.

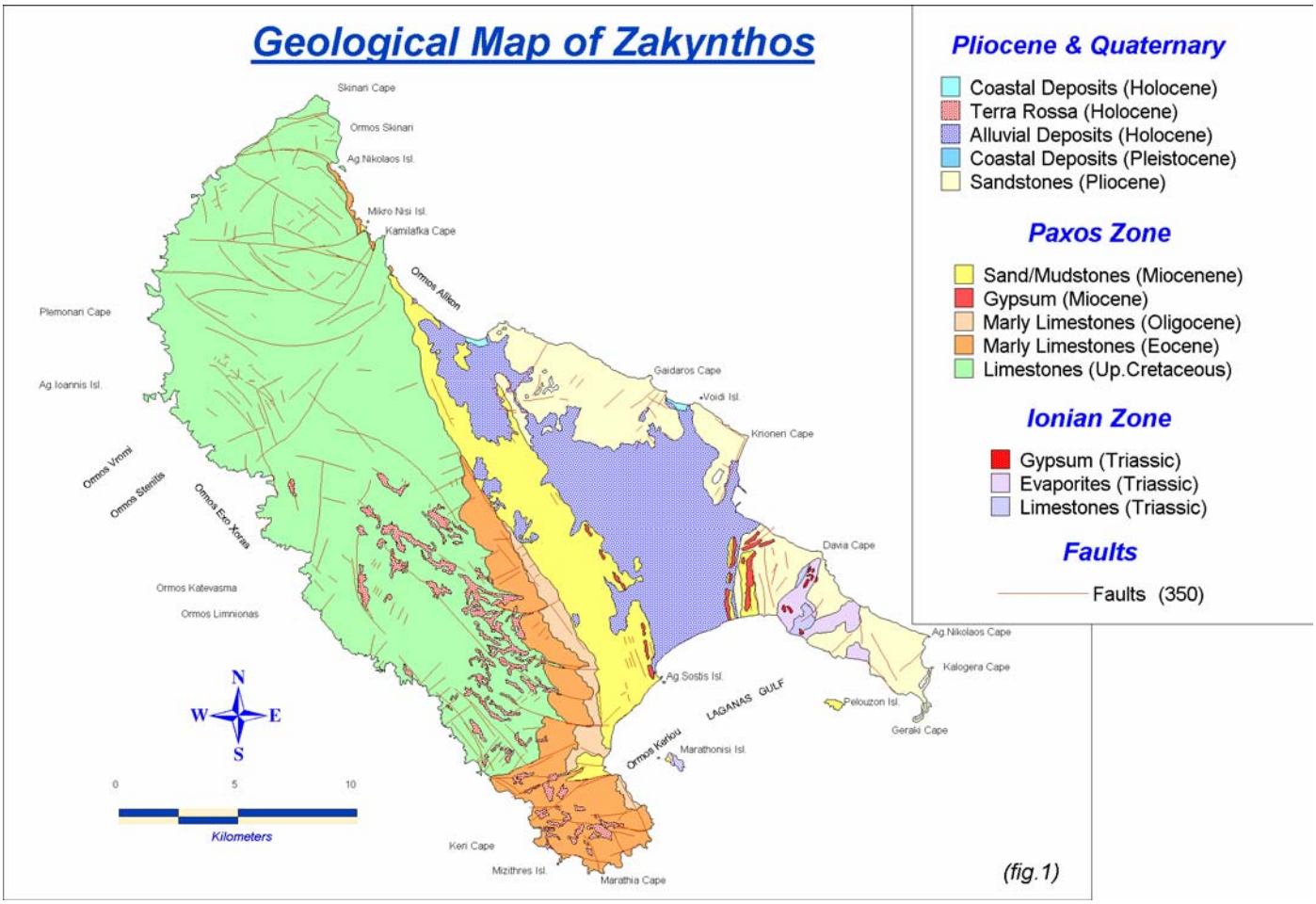
2. Geological setting.

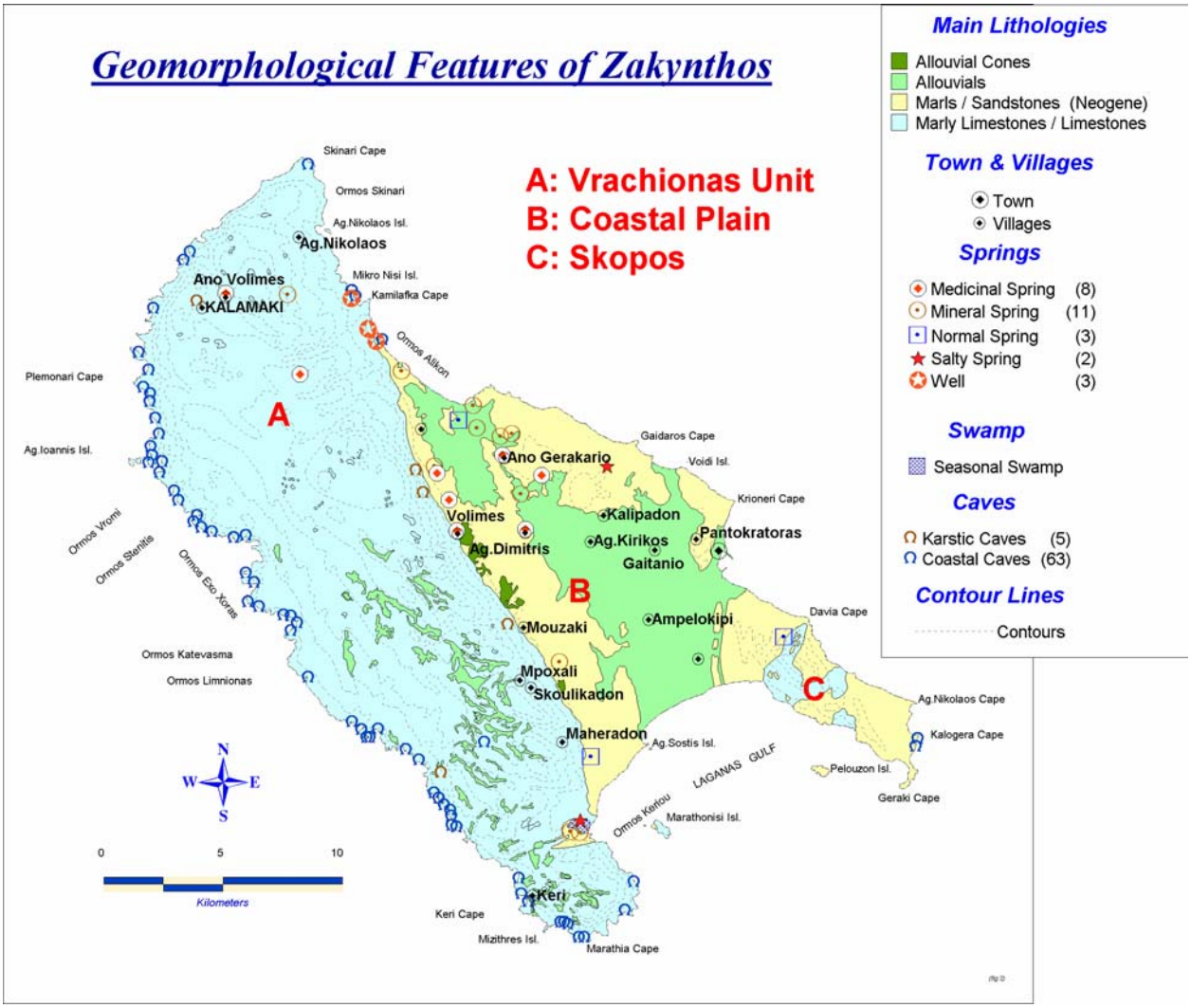
Two distinct "isopic zones" exist in Zakynthos island: The Pre - Apulian and the Ionian zone (Aubouin and Dercourt, 1962). The first one is characterized by Upper Cretaceous to Miocene sediments (limestones, marly limestones) and it constitutes the dominant Alpine zone, on the contrary the Ionian zone appears in the South-East of the island and it consists of limestones and evaporitic rocks of Triassic age. The post Alpine deposits are marls of Pliocene age, quaternary marine and continental formations (Horstmann 1969, Mirkou 1974, Sorel 1976, Dermitzakis et al 1977, Dermitzakis 1978, Underhill 1989).

The main structural elements of the island of Zakynthos are the occurrence of the overthrust between the pre-Apulian limestones and the Ionian zone and the presence of fault tectonics (*Fig.1*, based on the map of *I.G.M.E.* 1980 and modified by our observations).

3. Geomorphology.

Geomorphological observations of the island of Zakynthos were firstly made by Muller-Miny (1965), the most recent papers were published by Livaditis (1987), Livaditis and Alexouli (1994). The relief of Zakynthos can be divided into three geomorphological units.





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a) Vrachionas mountain in the western part of the island,
b) The central flat area from Alikes to Laganas,
c) Skopos mountain in the Southeastern part of the island.

a) Vrachionas unit is characterized mainly by limestone formations of the pre-Apulian zone. This unit can be further divided into three subunits :

1. The western coastal area, which is a big faulted zone with very steep coasts and deep dissected ravines.
2. A central relatively flat inclined plateau. It is a big karstic feature, which is formed after chemical weathering. There are numerous pronounced surface karstic forms (dolines, karstic valley) as well as subground karstic forms (caves).
3. The eastern area from Katastari to Limni Keri, which can be described as the zone of alluvial cones. This is another enormous faulted zone which is responsible for the development of the coastal basin.

b) The central flat unit, a faulted basin structure can also be divided into the follow geomorphological sub-units.

1. A flat area with alluvial deposits and sand formation in the coastal region.
2. A hilly region on the borders of the previous area, which is dominated by Miocene and Pliocene sediments, remnants of a differential erosion.

c) Skopos mountain area consists of Ionian limestones, evaporitic rocks and Pliocene and quaternary deposits. It is characterized by the main thrust structure of the Ionian zone to pre-Apulian. The Skopos alpine rocks are certainly an uplift faulted block.

The climate of Zakynthos is temperate. The analysis of different meteorological variables was done, after we had created the correspondent database. The mean lowest temperature values of Zakynthos are about 8-12°C and are observed during January and February, the highest mean are about 30°C, during the Summer months. The analysis of precipitation have shown that in rare cases can exceed 400mm or even 450mm.

The drainage system of Zakynthos is characterized by a central divide parallel to Vrachionas mountain (NW-SE direction) and drainage basins of different orders develop mainly perpendicular to this direction. There are no rivers in Zakynthos only the two principal torrents which are situated close to the town of Zakynthos and in Alykes village. The underground drainage is dominant in the Vrachionas limestones. This is a typical karstic plateau. The surface karstic forms are mainly dolines and karstic valleys. The subground karstic forms are sinkholes and caves (*Fig.2*). It has been observed that after prolonged rainfalls many dolines become temporary lakes because of sediment accumulation to some underground drainage. In *Fig.6* we observe the distribution of the area and the altitude of the closed karstic forms.

4. Population evolution and economic activity.

The geomorphological mega-features define the population distribution of the island of Zakynthos (*Fig.3*). For this reason the central flat area is very densely populated, while Vrachionas mountain area, is not.

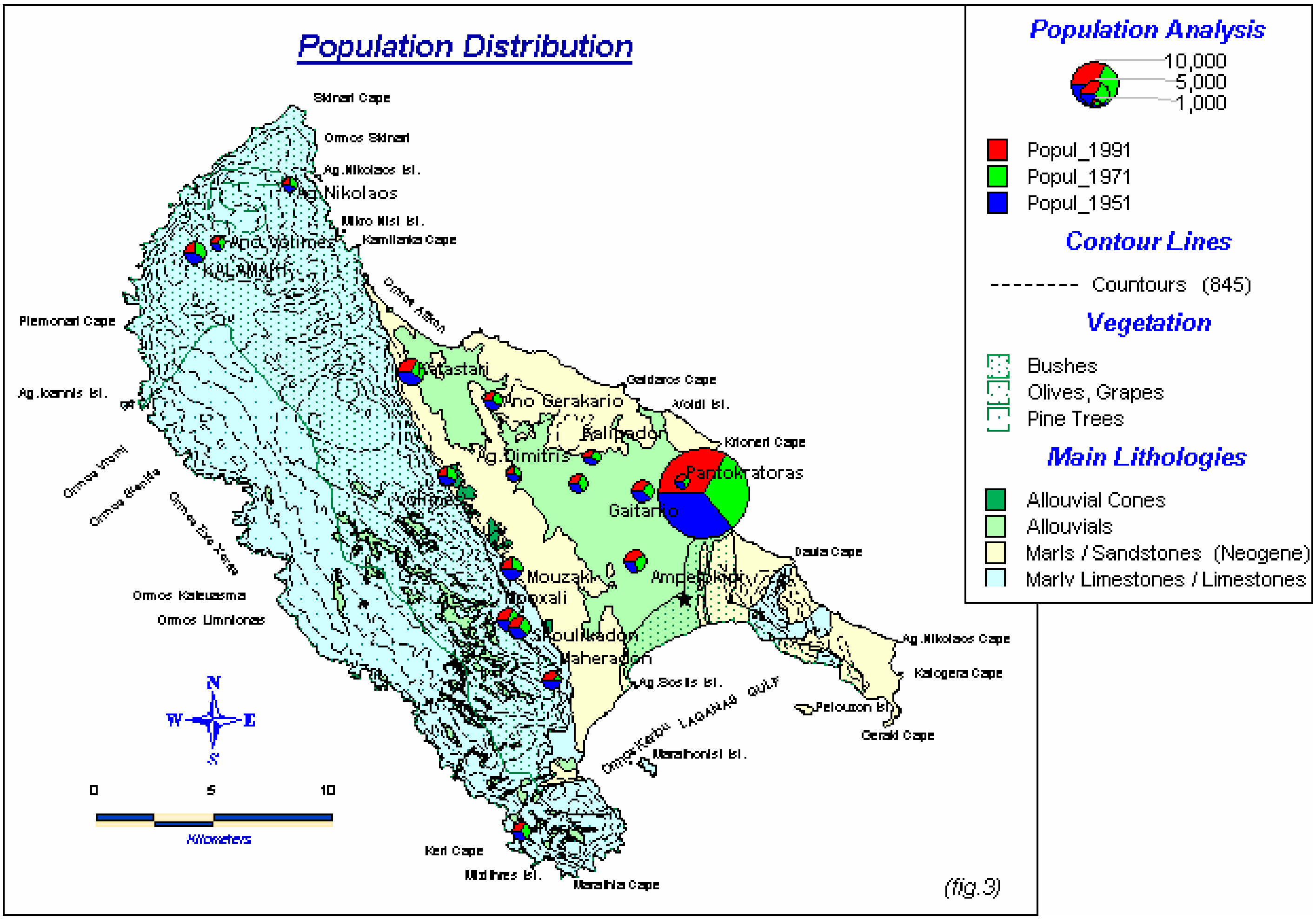
The physical characteristics of Zakynthos produce different micro-climatic conditions and soil distributions, which in turn define certain vegetation variations. One can divide the island of Zakynthos into three vegetation zones (*Fig.3*):

1. The upper Vrachionas zone which is situated in relatively high altitude and is characterized by the lack of trees and the presence of shrubs and wild vegetation.
2. The west Vrahionas zone, which is mostly consisted of pine trees forest.
3. The central plain zone with its hilly formations and the eastern flank of Vrahionas where olive trees, vine yards and lemon trees dominate.

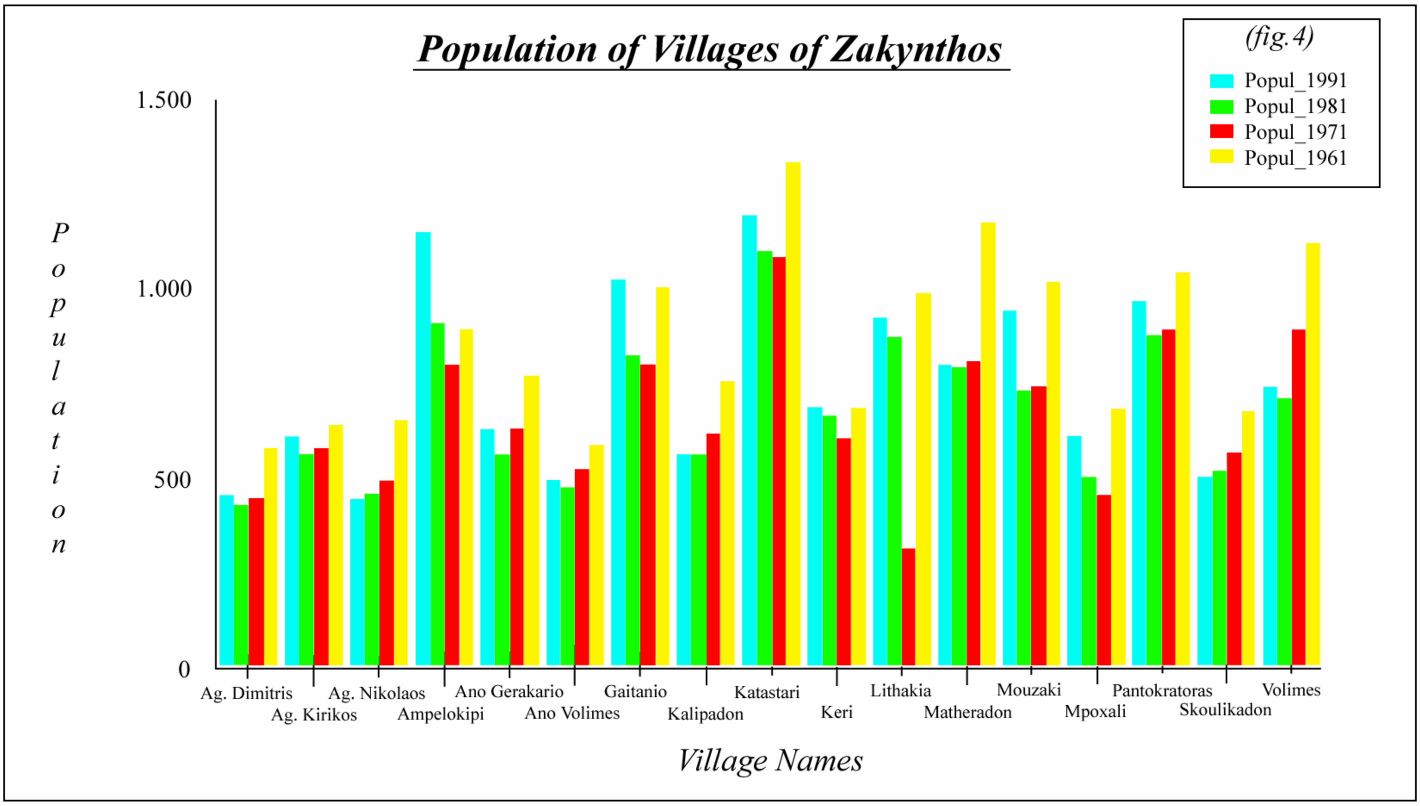
It must of course be noted that this is a simplified division of vegetation zones. What we really observe, is mostly a mixture of vegetation types.

The analysis of the demographic data after the last census shows a continuous growth of the population on a coastal area and a strong depopulation in mountainous areas (*Fig.4*). These facts reflect the different socio-economic growth of the two contrasting physical environments. The central coastal area experiences an enormous tourism development, while the Vrachionas mountain area contributes very little to the economy of the island because of its geographical marginality.

The topography variation of Zakynthos is fundamental to the distribution of population and consequently to all other human activities. The low land and especially the coastal region grows continuously as the focus of tourism activities. The main primary activity in the island is agriculture. The total cultivated surface was 164.000 acres in 1971, there was an important decline in the decade 1971-1981 (161.000 acres) and it was increased by 1992 (166.492 acres). Generally a stabilization of the



Population Distribution
Population Analysis
10,000
5,000
1,000
Popul_1991
Popul_1971
Popul_1951
Contour Lines
Countours (845)
Vegetation
Bushes
Olives, Grapes
Pine Trees
Main Lithologies
Allouvial Cones
Allouvials
Marls / Sandstones (Neogene)
Marly Limestones / Limestones
Skinari Cape
Ormos Skinari
Ag.Nikolaos Isl.
Ag.Nikolaos
Mikro Nisi Isl.
Ano Volimes
Kamilieria Cape
KALAMAKI
Plemonari Cape
Ag.Ioannis Isl.
Katastari
Ano Gerakario
Geldaros Cape
Voidi Isl.
Kalipadon
Krioneri Cape
Ag.Dimitris
Pantokratoras
Volimes
Gaitanio
Daula Cape
Mouzaki
Ampelokipi
Mpoxali
Skoulikadon
Maheradon
Ormos Kaleuasma
Ormos Limnionas
Ag.Sostis Isl.
LAGANAS GULF
Ag.Nikolaos Cape
Kalogera Cape
Pelouzon Isl.
Geraki Cape
Marathonisi Isl.
N
W
E
S
0
5
10
Kilometers
Keri Cape
Mizithres Isl.
Marathia Cape
(fig.3)



Population of Villages of Zakynthos
(fig.4)
Popul_1991
Popul_1981
Popul_1971
Popul_1961
Population
1.500
1.000
500
0
Ag. Dimitris
Ag. Kirikos
Ag. Nikolaos
Ampelokipi
Ano Gerakario
Ano Volimes
Gaitanio
Kalipadon
Katastari
Keri
Lithakia
Matheradon
Mouzaki
Mpoxali
Pantokratoras
Skoulikadon
Volimes
Village Names

agricultural area is observed, but we expect it to decline again in the future. The main factors which define agriculture are the relatively limited appropriate land and the luck of water. The stock breeding (sheep, cows, goats, pork, chickens), was drastically decreased, between 1981-1991, from 60325 to 42940 animals.

The secondary activities are mainly different units, which process and pack mainly agricultural products as olives, grapes, cheese, etc. or units which have as final product construction materials (cement, iron, sand). The tertiary activities on the island of Zakynthos are very limited. They mainly are the different fields of public services.

5. Environmental assessment.

For the environmental alteration, two main reasons are responsible: natural processes and the human impact. The first category comprises all natural hazards, the soil and wave erosion and the geotectonic processes. In the second category we include all the human activities which affect the environment as for example stream modifications, mining, wastes, tourism growth etc. Finally the wave erosion has sculptured magnificent coastal caves (*Fig.2*), all around the island.

5.1. Natural Hazards.

We approach natural hazards gathering any qualitative and quantitative information from the island of Zakynthos and creating the corresponding data base. The most destructive natural hazard was by far the earthquakes, one of them in 1953 was responsible for extensive collapse of the majority of the houses of the old town. The map of natural hazards shows the epicenters distribution. It is known that this area is in the border of the subduction zone, process which is responsible for the existence of numerous.

The geological substratum is also responsible for the extensive damages by earthquakes. The limestone areas are less vulnerable than the alluvials of the central plain. In *Fig.6* we observe the distribution of magnitude of earthquakes in Zakynthos.

The only site where floods have happened is in Katastari village. The principal causes of these flooding effects in this area are the storms of relatively low duration and the increased erosion of the slope because of local fires. The last flood happened in 1993 while the previous one approximately ten years before.

The mass movements in Zakynthos are mainly triggered by earthquakes. In some cases such movements are the results of heavy rains. In both cases the slopes become unstable and landslides or rockfalls are produced.

To study mass movements, a temporal and spatial database is necessary. In Zakynthos we mapped the principal zones of mass movements but in general there is a lack of data concerning the chronological evolution of mass movements. Looking at the map of natural hazards we note that the landslides movements are located in the east flank of Vrachionas and in Neogene basin. Rockfalls are observed in the western coastal area of Zakynthos, which is very precipitous and is made of cretaceous limestones.

The forest fires, which are very frequent in the summer period, depend on the meteorological conditions, the vegetation cover and *topography (fig. 3,9*).

5.2. Wave and soil erosion.

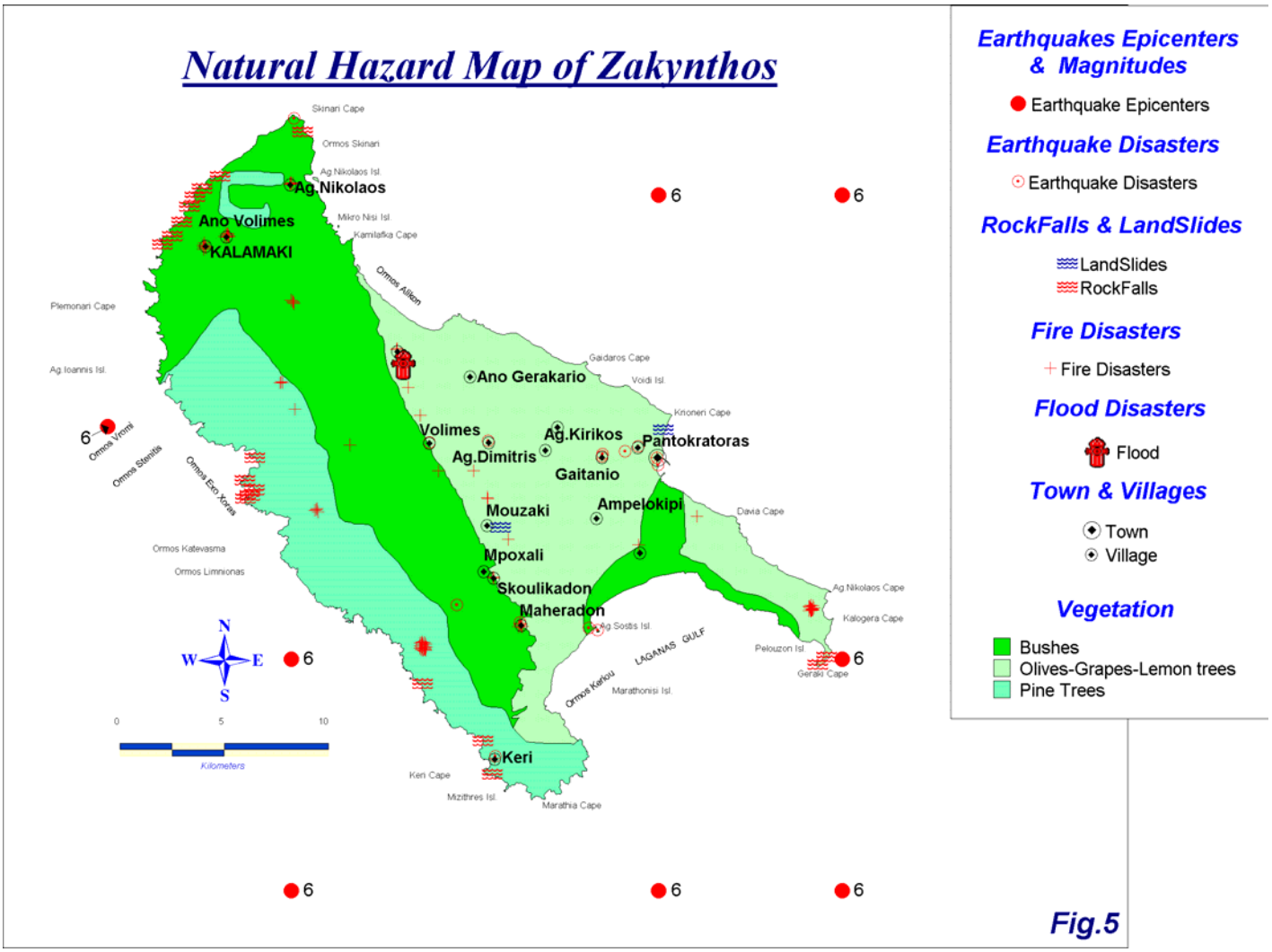
The wave erosion is responsible for the coastal-cave formations (*Fig.2*) in relatively hard rocks in Zakynthos (limestones, neogene). This also affects the advance of sea towards the land as it is the case in Argasi beach, where an old bridge (dating from the previous century), is now surrounded by the sea. Finally, geodynamic forces are the cause of the uplift which is observed in the area of Keri caves.

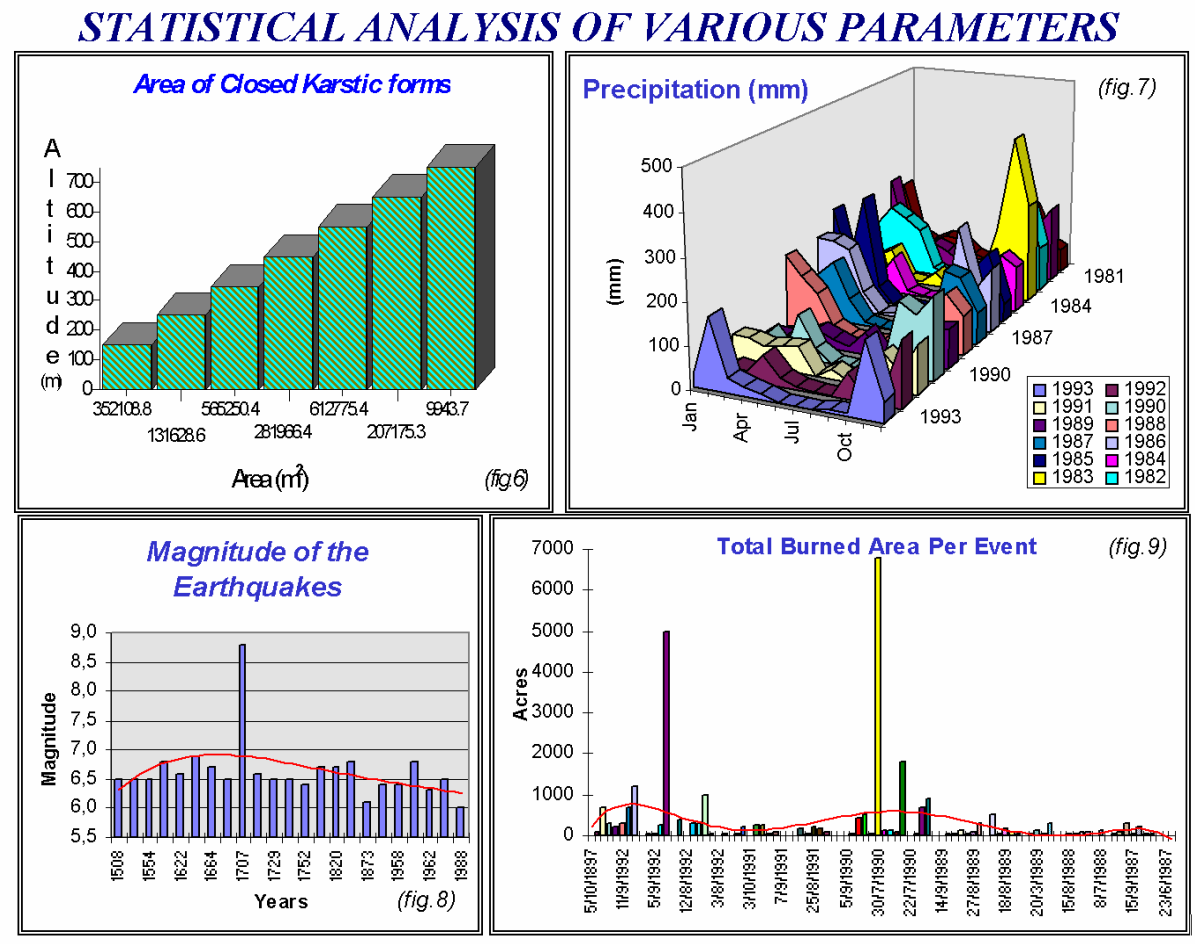
It is also sometimes the cause of numerous coastal rockfalls because of the undercutting of the basal rocks. The soil erosion is due mainly to deforestation after firing (*Fig.5*) or cleaning the land for crops.

5.3. Human impact.

The extensive construction of tourist facilities even when some landscape / scenery standards are kept, have dramatically changed the landscape of Zakynthos. Some surface drainage has been modified either to regulate the water supply for irrigation reasons (coastal plain), or to prevent flooding events (Katastari). The existence of many quarries on the island (Keri, Skopos, Agalas, Vassilicos, Katastari) and the resulting open pits have contributed to destruction of the natural beauty of the environment.

By environmental pollution at Zakynthos the water, soil and air pollution, is meant. The first one is provoked mainly by the wastes of small units of





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the secondary activity like olive and wine factories. The majority of such units, is situated on the coastal plain of the island. The principal causes of soil pollution is the increased use of fertilizers, while the air pollution is not yet very significant.

CONCLUSIONS

This project on local level (Zakynthos) has resulted in the development of a general database which concerns geology-geomorphology, population distribution and environment, which can be easily updated.

This spatial and temporal information can be used for regional planning, management of natural resources, forecasting purposes and preventing environmental deterioration.

The impact of tourism is obvious in all levels (environment and socio-economic structures) of the island of Zakynthos. It influences the growth of the coastal villages and the rapid decline of rural population. It is true that the spatial operations provided through the GIS, combined with the creation of database levels, have given the possibility of various outputs, but in the limits of this paper, it is not possible to present all the available maps and statistical analysis.

This sort of data and analysis can be applied to different natural and socio-economic aspects as to environment, management of resources, ecology, hazard prediction, landuse, tourism, transportation, industrial cities, landscape management. The final aim of this paper is to stimulate the necessity of development in local and regional level, of a long-term monitoring mechanism for future strategic decisions.

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