

GIS based Drainage Morphometry of Ikaria Island, Greece

A morphometric analysis of Ikaria Island (Aegean Sea, Greece) has been carried out using geoprocessing techniques in open software GIS (QGIS, SAGA). These techniques are found relevant for the extraction of drainage basins and their river networks. The extracted river network of Ikaria Island was classified according to Strahler's system of classification and the basic morphometric parameters of the basins were outlined. The outputs reveal that the terrain exhibits dendritic to sub-dendritic drainage patterns. Moreover, the correlation of the streams with the faults (captured by the geological map of IGME, scale 1:50.000) regarding azimuth values indicates that tectonics have affected significantly the spatial distribution of the river network of Ikaria Island.

Keywords: Geomorphometry, GIS Modelling, River Network, Ikaria Island

Introduction

Ikaria Island is geographically situated at the eastern part of the Aegean Sea, covering an area of approx. 250 km² (Figure 1). From a geomorphological point of view, the island has an elongated shape with a general SW to NE direction and is characterized by a great diversity regarding its terrain morphology (Skentos, 2018). In particular, the eastern part of the island is dominated by Mount Atheras, rising up to 1.043 meters above sea level (Figure 1). Elongated valleys are formed on both sides that are characterized by moderate to steep slopes (Skentos & Ourania, 2017). The western part of the island features Pezi plateau (Figure 1). The plateau lies at an elevation that ranges from 500 to 700 meters above sea level. The gradually northeast lowering of the plateau, results to a developed hydrographic network that drains most of the island. Generally, the gradient of the terrain is much lower close to the south coast and the hydrographic network much more developed along the north flank of the island (Stiros et al., 2011). Therefore, as expected, the main rivers Chalaris, Charakas and Voutsides end to the northern coast. Lastly, in between Mount Atheras and Pezi plateau is situated the region of Messaria (Figure 1). Messaria occupies the central part of the island where several distinctive environments occur (Skentos, 2018).

The presented complex geology of the island is due to its geotectonic position (Ktenas & Marinos, 1969). According to Stiros et al. (2011), the geological formations of Ikaria Island correspond to an anticline with a NE-trending axis. With regards to lithostratigraphy, the western part of the island is occupied by granites, interrupted only by in situ Holocene deposits (Figure 2). Messaria region (lying at the centre of the island) and Faros peninsula (located at the easternmost part of the island) consist of carbonate metamorphic rocks and schists. On both sites, Neogene formations and Holocene deposits appear at the end of the valleys, just before the beach front (Figure 2). Lastly, the eastern part of the island is dominated by gneisses, followed by granodiorites and small extents of Holocene deposits

(lying at the mouth of the rivers). Besides the above distinctive lithostratigraphic units, a significant extent of molassic ophiolitic formation appears at Faros peninsula (Figure 2).

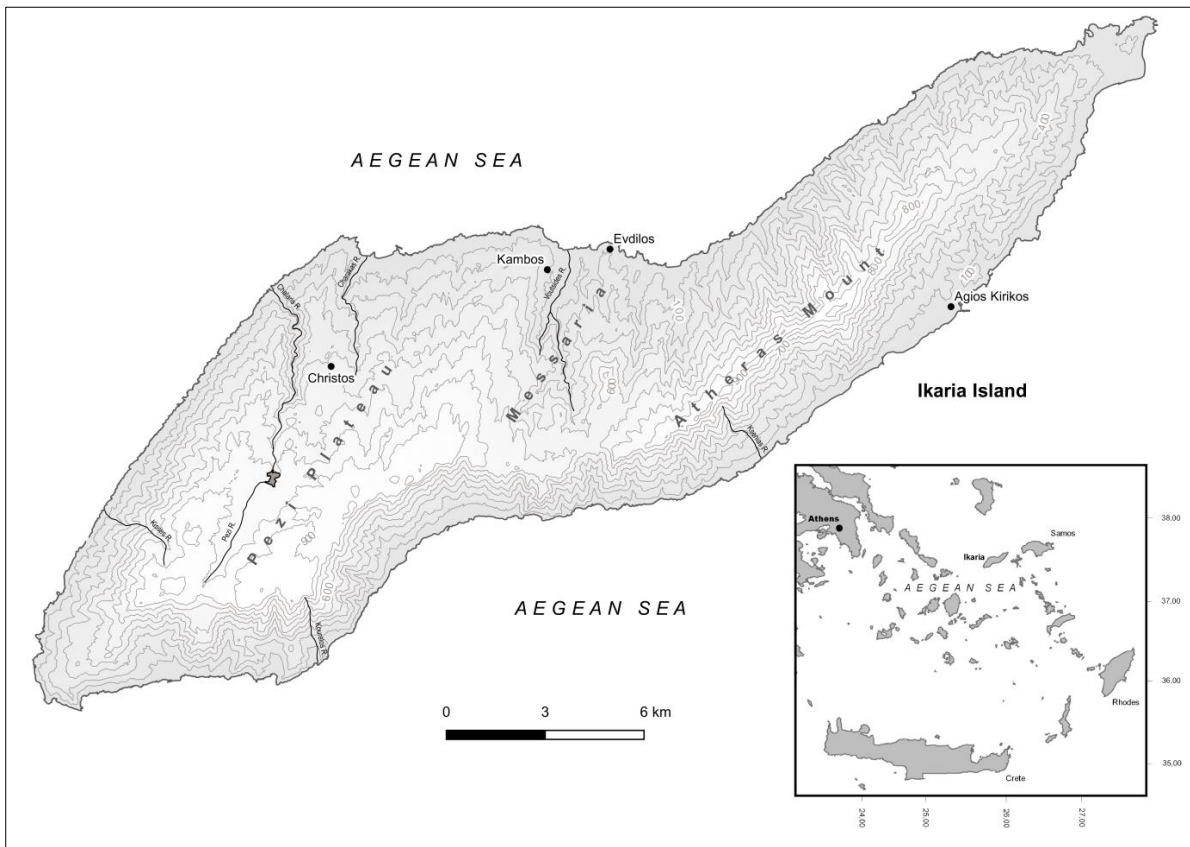


Figure 1. Simplified topographic map of Icaria Island

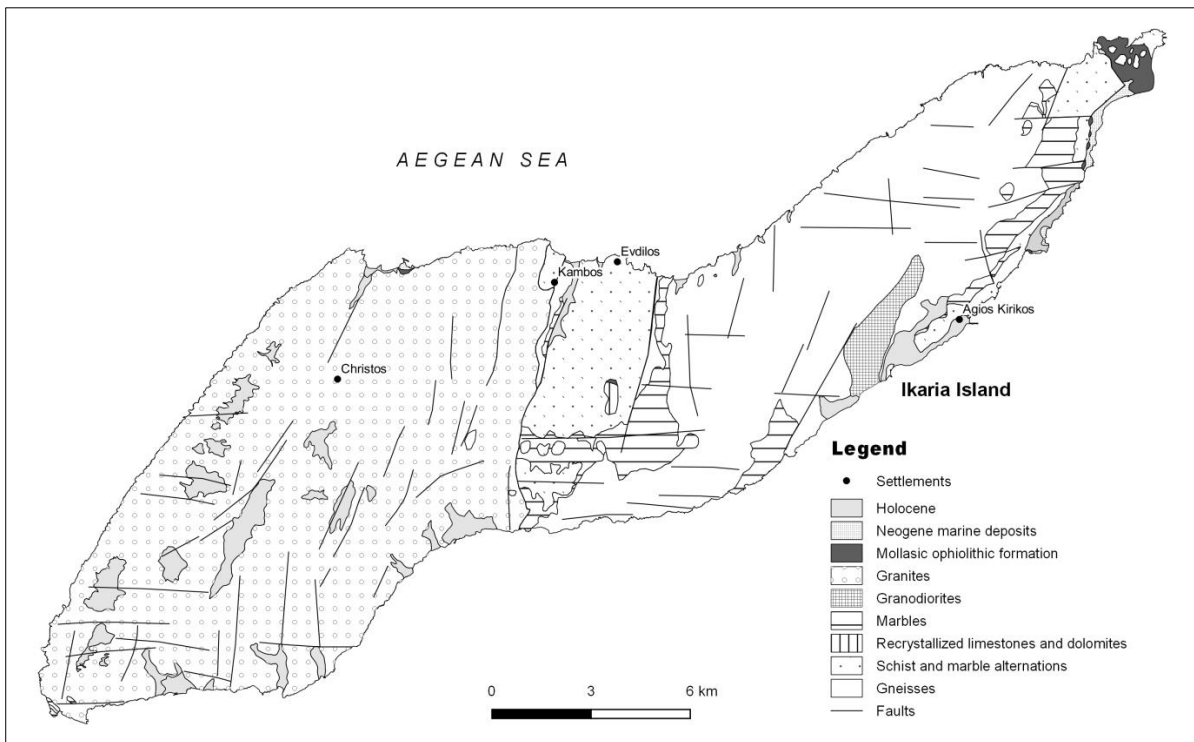


Figure 2. Simplified geological map of Icaria Island

Methodology

The stream network of Ikaria Island was extracted from a large scale DEM (25m² cell size) obtained by Ktimatologio SA by applying geoprocessing techniques in open software GIS (QGIS, SAGA). The pre-process included on the one hand the implementation of the *Fill Sink* module in SAGA based on Planchon/Darboux algorithm (Planchon & Darboux, 2001) in order to remove data errors or result from the averaging involved in assigning elevation values to cells of finite area, and on the other the application of a 20-meter radius Gaussian filter for smoothing the terrain. The morphometric parameters and the *Strahler Order* classification of the river network were modelled by applying selected modules of the libraries *Hydrology* and *Channels* in SAGA (Conrad et al., 2015). Lastly, the faults that were captured in QGIS by the geological map of Greece (Photiades, 2002) were statistically related to the river network (rose diagrams interpretation).

Results

According to the applied methodology, Ikaria Island was divided into 302 drainage basins. The extracted stream network indicates that the terrain exhibits dendritic to sub-dendritic drainage patterns (Figure 3). In order to be addressed the hydrodynamic power of each and every drainage basin the channels were segmented and ordered using the hierarchical ranking proposed by Strahler (Strahler, 1957).

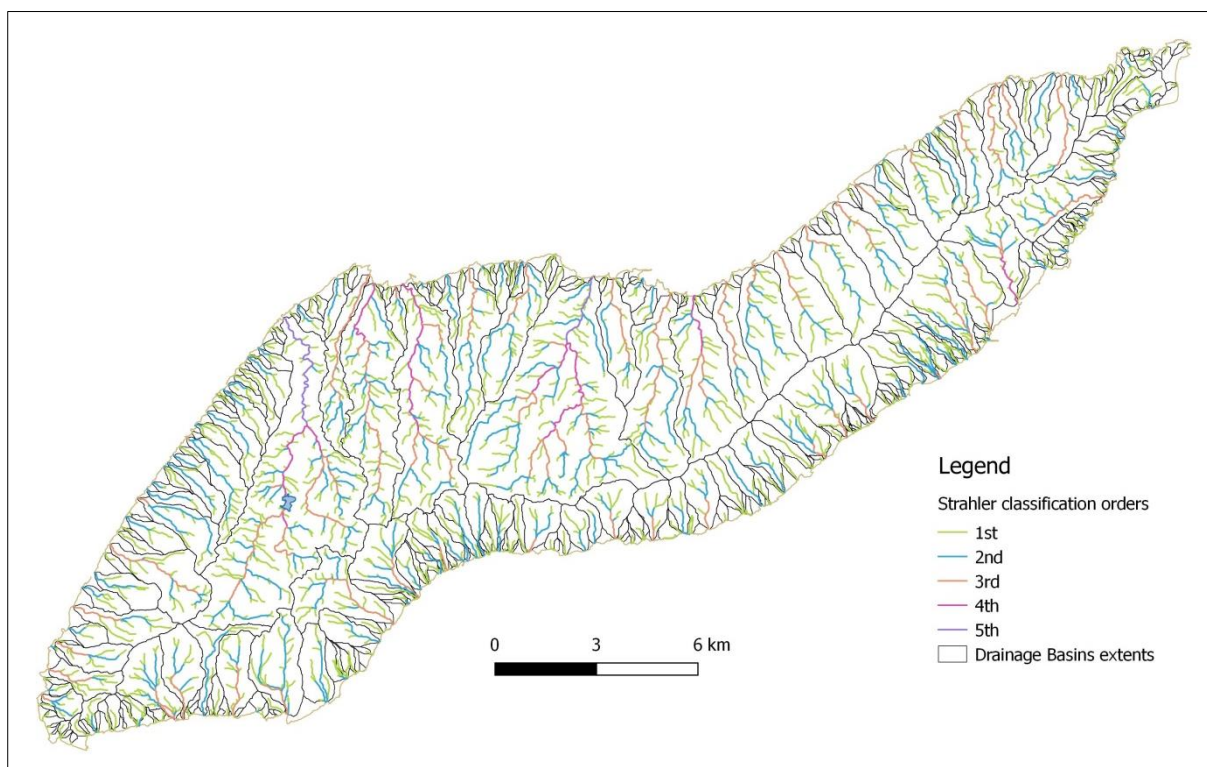


Figure 3. The classified river network of Ikaria Island

A total of 1.916 streams were identified that were classified into five orders (Table 1). The total stream length is 806,078 km of which the 1st and 2nd order streams constitute 82,54% (Table 1). The 5th order includes two representatives with a combined length of 7,356 km

(Table 1). Both 5th order streams end to the northern coast of the island (Figure 1). The variation of L_{ur} between successive stream orders is due to the greater number of streams belonging to lower orders indicating that the river network of Ikaria Island is still in its youthful stage of development (Table 1).

Table 1. Basic statistics of the river network of Ikaria Island

Order	Number of streams	Length (km)	Mean Length (km)	Length ratio (L_{ur})
1 st	1500	435,587	0,290	
2 nd	334	229,763	0,688	2,37
3 rd	71	110,108	1,550	2,25
4 th	9	23,264	2,585	1,67
5 th	2	7,356	3,678	1,42
Total	1.916	806,078	0,420	

Basin geometry is controlled by structure, lithology, relief, and precipitation and varies from narrow elongated forms with irregular basin perimeter to circular or semi-circular ones. The elongation ratio (R_e) ranges from 0,23 to 1,25 with low values (<0,60) dominating most of the terrain of Ikaria Island (Figure 4). The low R_e values are associated to elongated basins characterised by low side flow for shorter duration and high main flow for longer duration and are less susceptible to flood hazard. The highest R_e value appears at the heart-shaped main basin of Voutsides River at the centre of the island (Figure 4). Although it is more efficient in the discharge of run-off (in contrast to the dominant elongated basins), it is at greater risk from flood hazard.

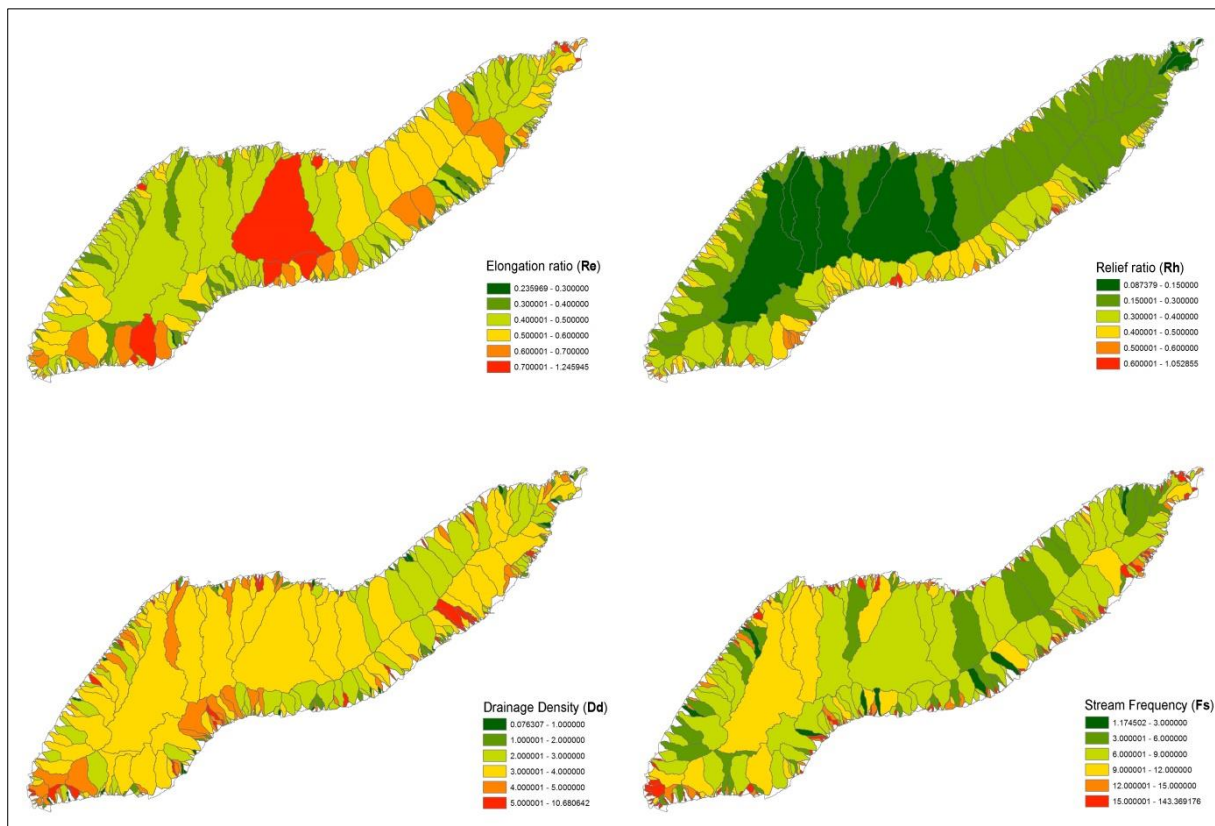


Figure 4. Thematic maps presenting the distribution of Elongation ratio (R_e), Relief ratio (R_h), Drainage density (D_d) and Stream frequency (F_s)

The Relief ratio (Rh) flags the contrast environments regarding North (moderate slopes) and South (Steep slopes). Such terrain alternations affect subsequently the level of development of the stream network (significantly more developed at the northern part of the island).

Stream Frequency (F_s) and Drainage Density (D_s) provide a numerical measurement of landscape dissection and run-off potential. The study area is characterised by high values on both parameters. In particular, the dominant F_s values range from 6 to 12 and the most frequent D_s ones from 2 to 4 (Figure 4). The high values of F_s and D_s that characterize the study area are due to high relief, steep slopes, and low permeability of the underlying geological formations.

According to figure 6, the faults can be grouped into two main categories regarding their direction; a general W-E and a general S-N. The low orders of the stream network (1st & 2nd) do not appear to be related with any of the two fault categories since their dominant general direction is NW-SE (Figure 6). Contrary, the azimuth of the 3rd order channels and above tends to be correlated with the S-N fault category (Figure 6). Therefore, it appears that tectonics has affected the spatial distribution of the stream network during its early stage (3rd order and above).

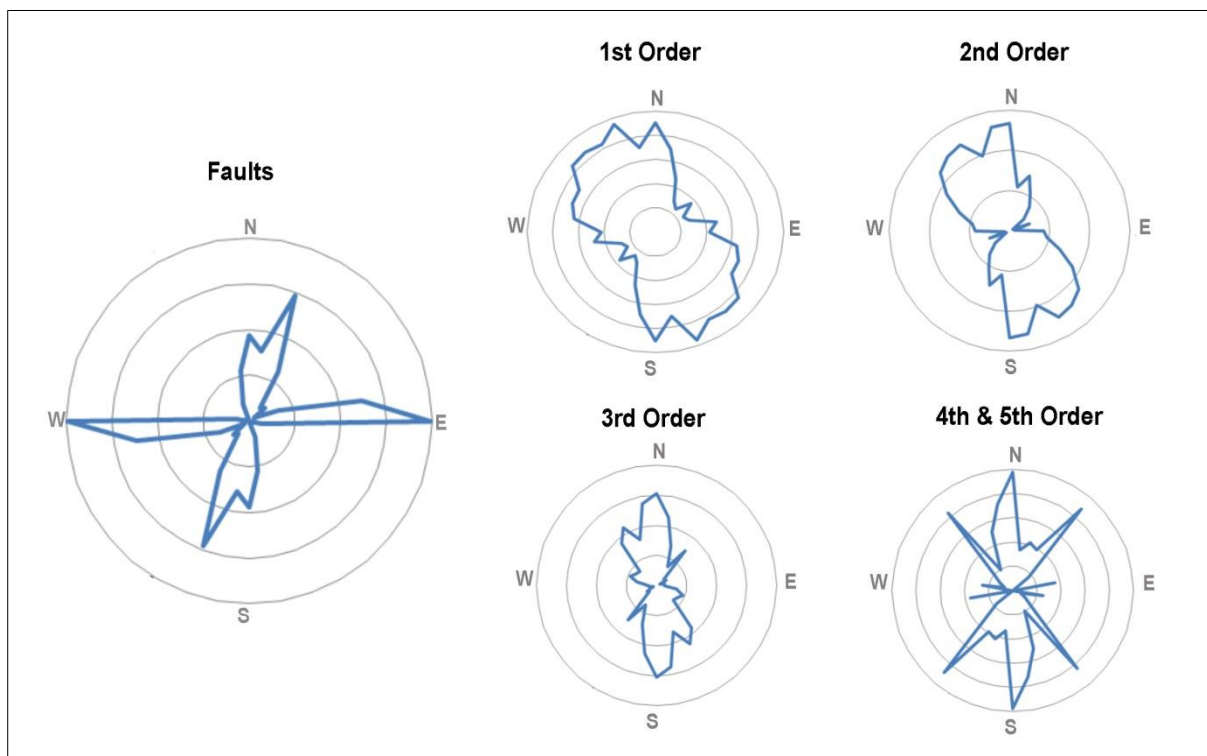


Figure 5. Rose diagrams

Conclusions

According to the GIS outputs, the drainage system of Ikaria Island consists of 1.916 streams with a total length of 806,078 km. The stream network exhibits dendritic to sub-dendritic drainage patterns and is highly developed on the northern part of the island due to its terrain morphology (dominated by moderate slopes). Throughout the island, 302 drainage

basins were extracted in various shapes. However, elongated basins that are characterised by low side flow for shorter duration and high main flow for longer duration appear to be the most common ones. The high values of F_s and D_d are due to the high relief, the steep slopes and the low permeability of both the granites (western part of the island) and the pre-alpine geological formations (eastern part of the island). The stream network is classified into 5 Strahler orders and is still in its youthful stage of development. Lastly, it appears that the stream network was affected during early stage (3rd order and above) by the local tectonics whereas nowadays is mainly affected by the topography.

The importance of studying the morphometry of the island of Ikaria lies in the fact that its outputs compose the basic information in a great variety of studies such as water management, soil erosion, flood hazard risk reduction, geomorphological mapping, etc. Due to its mountainous morphology characterised by high landform diversity, the island suffers from frequent flash floods and landslides. Therefore, one more benefit of such type of studies is the delivery of knowledge and well-validated information for decision making regarding strategic planning and delineation of prioritised hazard management zones.

References

- Conrad, O., Bechtel, B., Bock, M., Dietrich, H., Fischer, E., Gerlitz, L., ... & Böhner, J. (2015). System for automated geoscientific analyses (SAGA) v. 2.1. 4. *Geoscientific Model Development*, 8(7), 1991.
- Ktenas, C. & Marinos, G. (1969). La geologie de l'ile de Nikaria. *Geol. Geophys. Res.*, Volume 13, pp. 58-86.
- Photiades, A. (2002). *Geological Map of Greece, Sheet 'Ikaria Isl.', Scale 1/50.000*, Athens: Institute of Geology and Mineral Exploration (IGME).
- Planchon, O. & Darboux, F. (2001), A fast, simple and versatile algorithm to fill the depressions of digital elevation models. *Catena*, 46:2-3, 159-176.
- Skentos, A. (2018). Topographic position index based landform analysis of Messaria (Ikaria Island, Greece). *Geobalcanica Acta*, 4(1), pp. 7-15.
- Skentos, A. & Ourania, A. (2017). Landform Analysis Using Terrain Attributes. A Gis Application on the Island of Ikaria (Aegean Sea, Greece). *Annals of Valahia University of Targoviste, Geographical Series*, 17(1), pp. 90-97.
- Stiros, S., Laborel, J., Laborel-Deguen, F. & Morhange, C. (2011). Quaternary and Holocene coastal uplift in Ikaria Island, Aegean Sea. *Geodinamica Acta*, 24(3-4), pp. 123-131.
- Strahler, N.A. (1957), Quantitative analysis of watershed geomorphology. *Amer. Geophys. Union Trans.*, 38(6), 1117-1142.