THE GEOMORPHOMETRIC DESCRIPTION OF CLUTER MAPS

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ABSTRACT:

The aim of this paper was to describe from the geomorphometric point of view a cluter map derived by classification. More specifically an ASTER image of the study area was radiometrically and geometically corrected. Maximum likelihood classification defined the landcover classes of the study area (various types of forest, cultivated land and bare ground). The digital elevation model of the study area was derived by contour lines digitization from topographic maps. The landcover classes were parametrically represented with attribute-value pairs. The attributes corresponded to the following geomorphometric parameters, mean elevation, maximum elevation, roughness, local relief, meant gradient. It was found that the fir forest presents the greatest mean elevation while the mixed forest and the bare ground class follows. The cultivated landcover class occupies areas with lower mean elevation. The greatest mean gradient values are observed for both the fir forest and the mixed forest classes. The cultivated lands also present the lowest mean gradient values while the barren class to present high mean gradient value. Then, a connected component labeling algorithm identified distinct objects in the barren class. Each object was described by geomorphometric parameters and the objects were ranked on the basis of landslides susceptibility. The most interesting finding was the greatest in size objects of the barren class occupy the highest in elevation places and presents the greatest gradient values. Additionally the spatial distribution of these polygons is along the main road connecting the capital with the main port of the island.

1. INTRODUCTION

The landcover mapping is of great significance in change detection, urban planning and environmental protection. On the other hand due to the severe climatic change and abrupt meteorological incidences that take place recently, the correlation between landcover and geomorphometry is of great importance (Elumnoh and Shrestha, 2000). The risk and hazard assessment studies for flash floods, landslides caused by heavy rainfalls etc. (Miliaresis, 1999a; 1999b; 2001; White, 1993) require knowledge of landcover type (Panagou and Miliaresis, 2003) and the geomorphometry (Pike, 2002) of the local landscape neighbourhood (Treitz and Howarth, 2000). The aim of the study is to a)parametrically represent the landcover map derived by image classification techniques on the basis of geomorphometrical parameters, and b)interpret the spatial distribution of landcover types within the landscape.

2. METHODOLOGY

A terrain partition framework was composed on the basis of the landcover types and objects (pixel arrangements with the same landcover) were defined. Then, each object was parametrically described on the basis of geomorphometric attributes and mapped.

2.1 Study Area

The study area was Kefalonia Island in Ionian Sea.

Figure 1. The study area.

The island stands in the sea between Greece and Italy. The study area is in the south east part of the island (Figure 1) and enclosed by rectilinear coordinates as follows: X minimum = 200,137, X maximum = 222,337, Y minimum = 4,215,922and Y maximum = 4,233,802.

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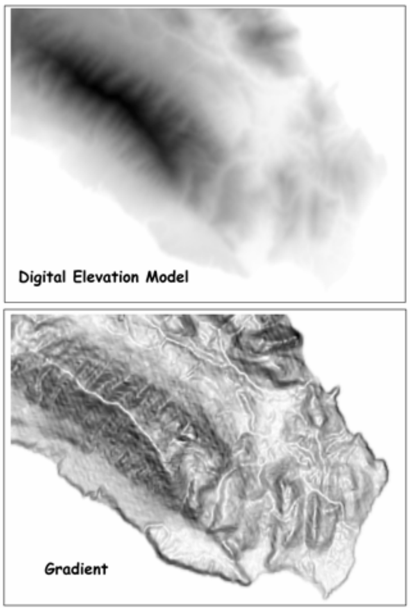

Figure 2. DEM and Gradient image. The higher elevation/gradient, the darker a pixel is. The elevation is in the range (0,) m.

2.2 Data

The A.S.T.E.R. image captured on 22/09/2001 with ID pg-PR1A0000-2001092201_019_057 was used. It covers the area geographic coordinates (38.3235, 20.5307), (38.2266, 21.2362), (37.6733, 21.0737), (37.7694, 20.3734). The bands 01 (green), 02 (red), 03 (near infrared) of the V.N.I.R. sensor were used with spatial resolution 15 m (Fujisada, 1998; Kahle et al., 1991). The radiometric conditions (gains) for it's band during the data acquisition was high gain for bands 01 and 02, normal for band 03 (Abrams and Hook, 2002; Chavez, 1996)

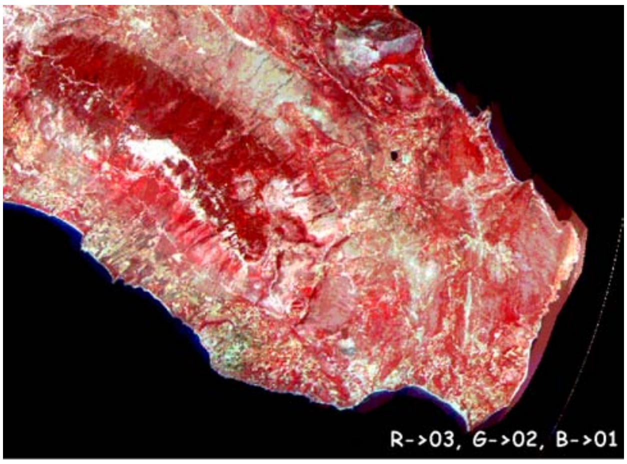

Figure 3. Color composite image

Additionally a digital elevation model (DEM) was used (figure 2). Contour lines were digitised from a topographic map produced by the Hellenic Military Service. The map scale was 1:50000 and the contour interval was 20 m. A DEM with grid size 30 m was derived by interpolating the contour lines. The gradient is in the range (0,) degrees (figure 2).

2.3 Pre-processing of A.S.T.E.R. Imagery

First radiometric correction was implemented. Each band was distriped by using the histogram matching technique. Then digital values were converted to radiance on the basis of the corresponding band gain. Finally path radiance was removed on the basis of linear regression of green and red band to the near infrared band (Eastman, 1999).
Then non parametric geometric correction was implemented by the use of a second degree polynomial and ground control points (gcps) derived by field survey with a hand-held Garmin G.P.S. The root mean square error of the transformation was 16.47 m for 14 gcps. The images were resampled to 30 m. A color composite image of the corrected bands is given in figure 3.

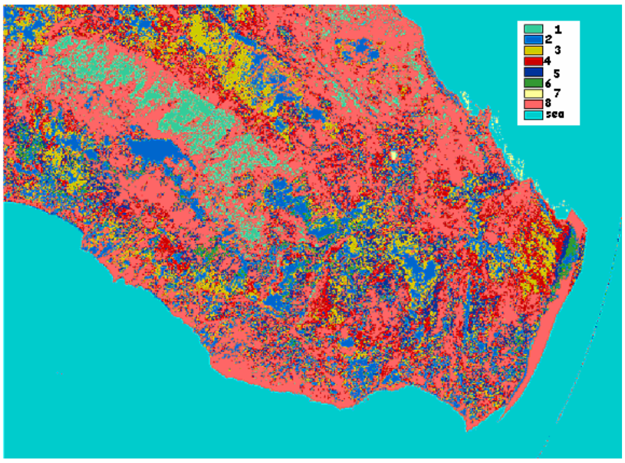

Figure 4. Cluter Map

2.4 Cluter Map

Training areas were selected for the major thematic classes occurring in the study area (Table 1).

ID	Thematic Class	Occurrence (number of pixels)
1	Fir Forest	9,660
2	Barren	24,023
3	Cultivated 1	22,757
4	Cultivated 2	21,714
5	Cultivated 3	20,609
6	Cultivated 4	3,307
7	Lake	329
8	Mixed Forest	86,242

Table 1. The thematic classes and their occurrence in the cluter map.

Maximum likelihood classification (Mather, 1987) defined the landcover classes of the study area. The cluter map derived is given in figure 4 while the occurrence of it's class is given in table 1 and figure 5.

2.5 Geomorphometric description of cluter map

Each thematic class was described on the basis of mean maximum and standard deviation of both elevation and gradient (table 2 and table 3) (Evans, 1980; Florinsky, 1998; Mark, 1975).

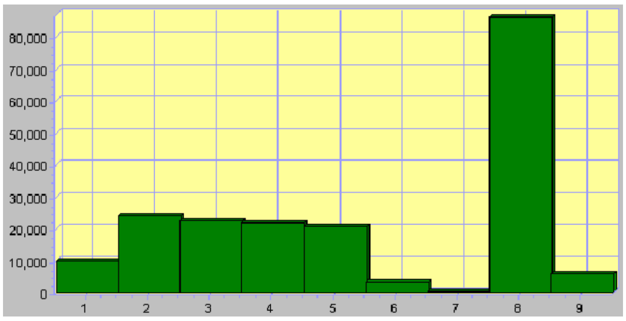

Figure 5. Histogram depicting the occurrence (special extend) of each class.

Thematic Class	ID	H (m) mean	H (m) maximum	St. dev
Lake	7	10.6	91	26.7
Cultivated 3	5	360.2	1614	283.3
Cultivated 2	4	370.6	1597	286.5
Cultivated 1	3	409.1	1601	274.3
Cultivated 4	6	425.1	1601	316.2
Barren	2	481.1	1599	389.9
Mixed Forest	8	481.6	1618	413.9
Fir Forest	1	978.8	1610	357.9

Table 2. Elevation statistics for the thematic classes (presented in increasing mean elevation order)

Thematic Class	ID	G(^{o}) mean	G (^{o}) maximum	St. dev
Lake	7	1.52	28	3.68
Cultivated 1	3	14.00	43	7.82
Cultivated 3	5	14.02	44	8.27
Cultivated 2	4	14.13	43	7.70
Cultivated 4	6	15.85	41	10.65
Barren	2	16.06	45	9.88
Mixed Forest	8	17.14	45	9.41
Fir Forest	1	23.20	43	6.95

Table 3. Gradient statistics for thematic classes (presented in increasing mean gradient order)

The table 2 indicates that fir forest terrain class presents the greatest height, while mixed forest and barren terrain classes follow. The cultivated landcover types are developed in lower elevation. These finding are in accordance with the local geomorphometric conditions of the study area (high mountain and limited plains).The most interesting finding of Table 1 was the relative high elevation of the barren terrain class.

The table 3 indicates that fir forest and mixed forest present the higher gradient values, followed by the barren terrain class. The explanation given is that the forests are developed on the highest areas which are quite steep in order to be protected by human activity. Human activity (cultivated lands) is limited to plain areas or to areas with lower gradient value. The high gradient of barren terrain class indicates that these polygons are of high risk relative to flash floods. That is why the relative distribution of barren polygons with high gradient/height values will be identified and studied in more detail in the following section.

2.6 Title

A connected components labelling algorithm is applied to the barren terrain class (Figure 6).

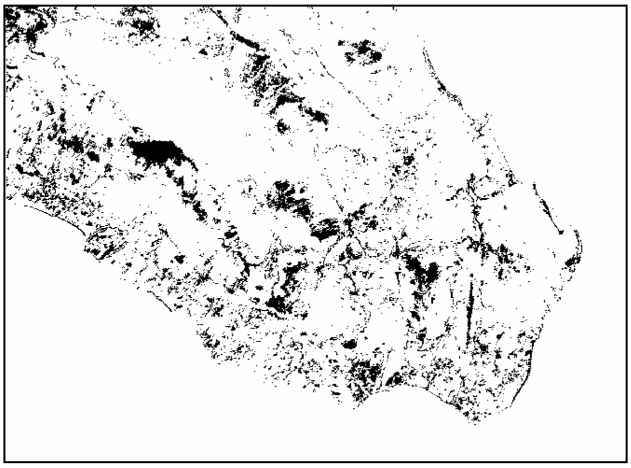

Figure 6. Barren class

A total of 1314 objects (adjacent pixels of the barren terrain class) were found with various size dimensions as it can be observed in figure 7

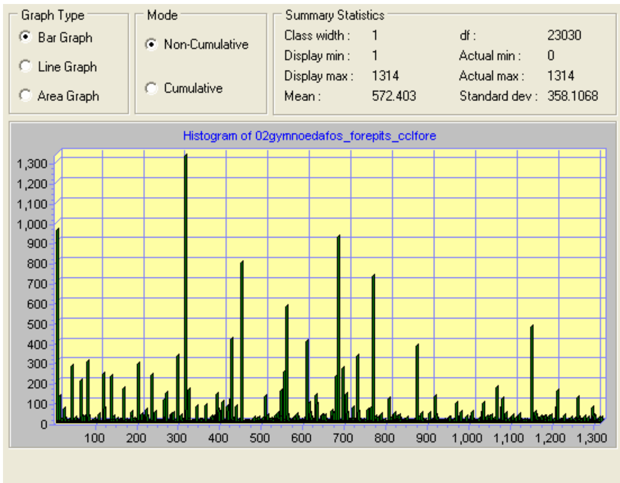

Figure 7. Object dimension for the barren class

Mean gradient and mean elevation as well as roughness (the standard deviation of elevation) and local relief (minimum – maximum elevation) were computed for each object of the barren terrain class (see Table 4). Elevation is expressed in meters and gradient in degrees.

ID	Size in pixels	Mean elevation	Mean gradient
309	1327	1373.2	29.51
1	958	978.9	13.71
677	925	432.0	16.98
446	796	896.2	23.30
763	730	581.8	27.13

ID	Size in pixels	Mean elevation	Mean gradient
552	578	342.7	10.72
1144	476	43.6	3.72
421	417	140.0	12.32
601	404	555.5	25.63
867	383	229.2	13.74
292	332	725.6	29.52
724	330	708.5	29.52
74	305	727.3	23.63
195	290	438.1	11.83
35	279	631.6	5.55
688	267	414.0	19.10
548	252	271.5	16.70
112	241	489.0	12.21
228	234	361.7	8.83
672	232	110.7	11.59
130	231	503.9	7.76
59	207	455.7	15.23
1059	172	0.0	0.00
161	171	425.1	12.93
317	165	803.5	29.82
540	159	1073.3	29.98
1206	157	105.6	14.90
263	146	704.3	29.42
386	142	229.9	15.65
697	140	0.0	0.04
625	132	133.1	9.00
501	131	1084.8	34.22
6	129	638.9	3.67
911	128	193.2	11.93
1254	121	50.3	10.30
419	120	224.0	18.43
1072	120	250.5	18.53
800	119	369.5	17.35
259	112	486.1	15.99
539	104	22.9	7.82
399	101	380.3	22.66
1026	98	347.7	13.81
963	94	253.2	19.50
607	93	166.1	10.29
627	91	1230.1	27.45
359	83	65.9	3.55
337	81	344.5	9.70
432	80	1196.9	32.38
1203	79	68.1	9.48
411	76	16.9	10.14
1070	76	37.7	15.57
756	72	566.0	13.29
712	71	824.4	18.66
1289	71	17.0	8.65
114	69	473.8	29.91
18	67	505.4	10.12
216	63	873.5	26.94
747	61	358.2	14.52
389	60	692.1	25.28
312	59	1084.8	31.49
661	57	242.4	17.72
413	54	831.4	29.48
1023	54	27.1	16.22
179	53	89.2	23.51
972	53	382.0	10.57
1001	50	270.9	23.28
1151	50	113.3	5.70

Table 4. Size (1 pixel occupies 30 times 30 m^2), mean elevation and mean gradient for the 50 objects of the barren terrain class with the greatest size

2.7 Statistical analysis and mapping

Statistics, correlation and linear regression were computed for the parametric representation of the objects of the barren terrain class (Table 5, 6 and 7).

Statistics	Ln_e(size) lnS	Mean elevation (H)	Roughness (R)	Mean gradient (G)	Local Relief (LR)
Mean	4.99	442.7	46.2	16.8	191.5
St.dev	0.82	345.8	38.9	8.7	156.4

Table 5.Statistics per geomorphometric attribute for the objects with size greater than 50 pixels.

	lnS	H	R	G	LR
lnS	1.000				
H	0.228	1.000			
R	**0.551**	**0.526**	1.000		
G	0.021	**0.704**	**0.649**	1.000	
LR	**0.632**	**0.569**	**0.969**	**0.656**	1.000

Table 6. Correlation coefficient per attribute pairs, for the objects with size greater than 50 pixels.

It is observed that there is a positive correlation between H and G. There is also a great correlation between R and LR. The regression between mean gradient and mean elevation is expressed by the equation:

$$H = 20.07 * G + 86.12$$

The linear regression was found to be statistically significant according to the analysis of variance (ANOVA) presented in table 7. The linear regression line and the scatter diagram of objects is given in Figure 8.

ANOVA	*df*	*SS*	*MS*
Regression	1	38189791	38189792
Residual	1312	107881906	82227.06
Total	1313	146071698	
F=	464.4	*Significance F*	1.96E-88

Table 7. ANOVA of the linear regression between mean gradient and mean elevation of the barren terrain class objects.

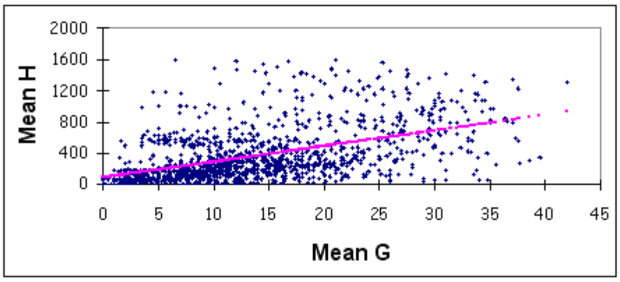

Figure 8. Linear regression line and scatter diagram.

The objects wer sliced to 5 classes in increasing mean gradient and mapped (Figure 9).

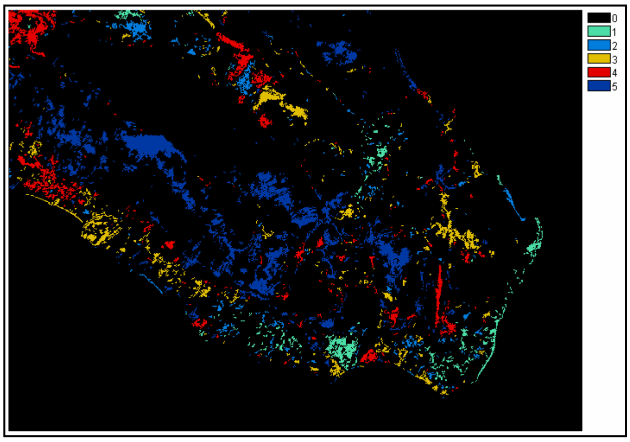

Figure 9. Gradient classes.

3. CONCLUSSION

The geomorphometric description of the cluter map indicated that the major landcover classes (forest versus cultivate land versus bare ground) present specific and distinct parametric representation. The barren class presents high elevation and gradient while the correlation and the linear regression inidicated that the greatest in size objects occupy the greatest in height position and present the greatest gradient. This finding should be taken into account in the urban planning since barren class object are distribute along the major highway that connects the major city with the major port of this island (Kefalonia).

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4.1 Acknowledgements and Appendix (optional)

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