Bulletin de la Société belge de Géologie	99-1	pp. 43-50	Bruxelles 1990
Bulletin van de Belgische Vereniging voor Geologie	99-1	pp. 43-50	Brussel 1990

MAPPING OF SOIL MATERIALS IN THE MESSINIA AREA (SW-GREECE) BY SUPERVISED IMAGE INTERPRETATION OF SPOT DATA[1]

by

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ABSTRACT

The purpose of the study is the evaluation of SPOT-data for the interpretation and mapping of soil material in a hilly area in Greece (Messinia district). Field data were collected. Augerholes as well as soil and profile descriptions were made, together with the indication of the land use and the vegetation cover.

The methodology of the supervised image classification was used for the digital image classification. Because of the appearence of some curtosis, the method of maximum likelihood was selected. These procedures led to a classified image, indicative for the major groups of soils developed on limestone, flysch, alluvial and colluvial material. The overlap of the classes is acceptable. To reduce this overlap, especially of flysch and limestone soil material at the shade-side of the ridges, we introduced morphographic parameters. To achieve this, a morphological map was made using SPOT panchromatic images in stereoview. Different geomorphological parameters were mapped : the forms of valleys and ridges, the density of the valleys, etc...

By comparing the classified image with the geomorphological map it became possible to establish a decision scheme for the final image classification. The method here presented is an integration of digital and visual image interpretation for the mapping of soil material in a hilly region.

KEY WORDS

SPOT, image classification, stereoview, soil material, Greece.

SAMENVATTING

Het doel van deze studie is de evaluatie van SPOT-beelden voor de interpretatie en kartering van bodemmateriaal in een heuvelachtig gebied in Griekenland (Messinia). Veldgegevens werden verzameld. Bodemboringen en profielbeschrijvingen werden gemaakt, samen met aantekeningen in verband met het bodemgebruik en de vegetatie.

De digitale beeldclassificatie gebeurde door middel van de methodes van gesuperviseerde beeldinterpretatie. Doordat sommige histogrammen gekenmerkt zijn door curtosis werd het "maximum likelihood" classificatie algoritme weerhouden. Deze procedure leidde tot een geklasseerd beeld waarop de belganrijkste bodems zijn weergegeven : bodems ontwikkeld op kalksteen, op flysch, op alluvium en op colluvium. De spectrale overlapping tussen de verschillende klassen is aanvaardbaar. Om de overlapping te reduceren tussen bepaalde klassen, b.v. tussen bodems ontwikkeld op kalksteen en deze op flysch aan de schaduwzijde van een rug, werden morfografische parameters geïntroduceerd. Hiervoor werd een morfologische kaart gemaakt aan de hand van stereoscopische SPOT-panchromatische beelden. Verschillende morfografische parameters werden gekarteerd : de valleivormen, de vormen van de ruggen, de intensiteit van de valleien, enz...

Door de vergelijking van het geklasseerde beeld en de geomorfologische kaart was het mogelijk een "beslissingsboom" te construeren voor de uiteindelijke beeldclassificatie. De methode die hier is voorgesteld is een integratie van digitale beeldclassificatie en visuele beeldinterpretatie voor het karteren van bodemmateriaal in een heuvelachtig gebied.

SLEUTELWOORDEN

SPOT, beeldclassificatie, stereobeeld, bodemmateriaal,

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[1] Paper presented on the 7th June 1989 at the 3th Symposium on Remote Sensing, at Tervuren.

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1. INTRODUCTION

This study fits with the program for the development of the less favoured areas in the European Community. The work was executed in colla- boration with the Geography departments of the University of Reading (U.K.) and Athens (Greece). Some work, based on remote sensing data had already been executed in the frame of soil erosion risk mapping, in the eastern part of the Messinia district (Styles, 1988 and Hardy & Moutsoulas, 1988). This paper concentrates on the western part of the Messinia district, north of the town of Methoni. The aim of the study is to evaluate SPOT satellite data for the mapping of soil material. Since a classical field mapping is rather expensive and time consuming, the possibilities of supervised image interpretation methods were investigated. SPOT data were used to obtain an overview mapping of soil material. The major aim of the study is to evaluate on the one hand the interpretation results on their relevancy and on the other hand the usefulness of the utilized interpretation and classification methods.

2. ENVIRONMENTAL SETTINGS

The studied area is situated in the SW of the Peloponnese, westwards of Messini and southwards of Pilos. The geological descriptions are given according to Fytrolakis (1980). Different lithological formations are present in the area forming different types of soil parent materials. The soils are classified according to the U.S.D.A. taxonomy system after having done the field work and the laboratory analyses. The western part of the study area is dominated by a ridge of bedded limestone (Upper Cretaceous). At the eastern edge, the ridge is characterized by a narrow strip of limestone dating from the Eocene-Paleocene age. As there is almost no soil present on the ridge, vegetation cover is very poor, it is a phrygana. The soils present on the limestone ridge are Lithosols with intercalations of Alfisols. This area is used as an extensive graze land. The central part of the studied area is a flysch zone from the Eocene-Oligocene age. This zone is densely dissected by a hydrographical network due to the high sensitivity to erosion. The main land use of the flysch zone consists of orchards of olive trees, sometimes in association with a second crop as wheat. The soils that are developed in the flysch substratum are classified as Inceptisols Xerorthents in combination with (Paralithic) Xerochrepts. These soils are often described as stony land. The soils are developed directly in the flysch substratum. Between the limestone ridge and the dissected flysch plateau occurs a depression, which is filled up with quaternary materials as colluvium (Entisols Xerofluvents) and more close to the rivers with alluvium (Entisols Fluvaquents and Xerofluvents). The main land use here is cropland for wheat, grapes and vegetables. Vegetables are mostly (and recently) cultivated in greenhouses. It is remarkable that an important part of these fertile soils is not cultivated.

East of the flysch zone is a zone of marls with intercalations of sandstone from the Pliocene age. Wheat and grapes are the major crops here. In the northern part of the study area a massif of limestone from the Eocene-Paleocene age is occurring. The soils on the limestone massif are classified as Alfisols Rhodoxeralf. The massif is covered for the greatest part with shrubland, namely a maquis vegetation.

3. DOCUMENTS USED

Three multispectral scenes of the SPOT satellite, dating from 01.08.1986, 12.08.1986 and 18.08.1986, were at our disposal. The scene from the 12th of August was the most useful because of the low cloud cover. Besides the multispectral scenes we also had a couple of panchromatic SPOT scenes suitable for stereoview (recording dates : 13.08.1986 and 27.08.1986).

Geological (Institute of geology and mineral exploration, 1980) and topographical maps (Hellinic Army Geography Service, 1977) of the study area were also at our disposal.

4. METHODS

4.1. Fieldwork

During August and September 1988, a field survey was perfomed in the neighbourhood of Methoni and Kallithea.

Due to the state of the terrain it was only possible to do soil augering in the alluvial material. 25 augerings were executed in the alluvial plain of Methoni. Six of these were also analysed in the laboratory. Outside of the alluvium the soils were too stony to perform soil augerings. On the other geological substrata descriptions were made from the soil superficial layer, the soil parent material and the vegetation cover. Because of the low vegetation cover the colour of the top soil largely effects the pixel values. Fourty five sampling points were investigated outside the alluvium. Notes concerning the geomorphological characteristics of the area were made at each observation point.

4.2. Digital image classification

A supervised image classification was opted for from the beginning on. Before starting the image classification procedure the statistics from the desired classes were studied to find out if the spectral overlap was not too big, and to see if the same soil material did not have different reflections from place to place and if the statistical populations had a more or less normal distribution. This was obtained by studying the means, the standard deviations and the curtosises.

Places where field work was performed were sampled for this statistical research. The following groups of soil material were sampled : soils devel-

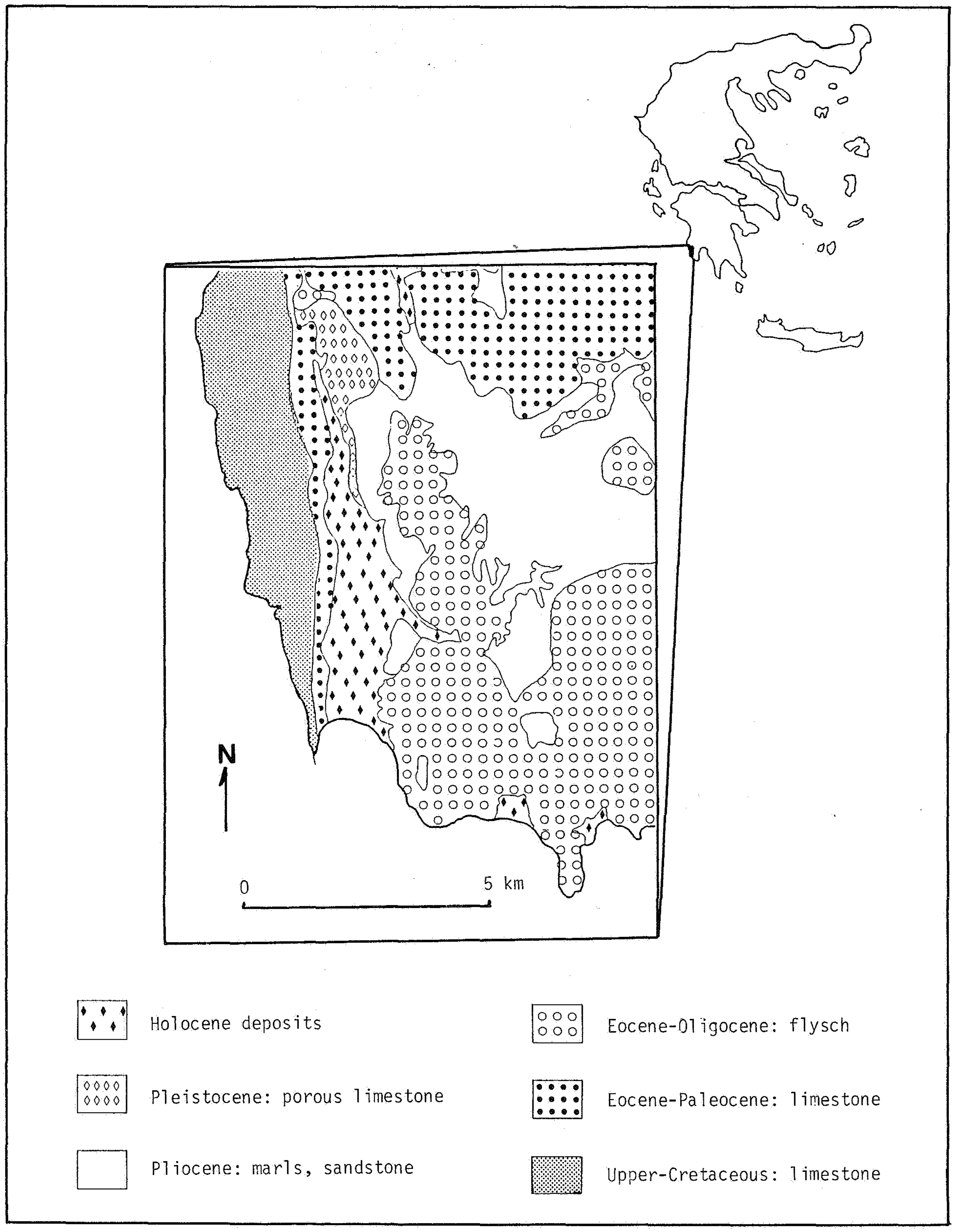

Figure 1. : Location and geology of the study area.

Sampling class	Minimum pixel value			Maximum pixel value			Mean pixel value			Standard deviation		
	B3	B2	B1	B3	B2	B1	B3	B2	B1	B3	B2	B1
water	14	22	39	21	37	58	16.5	25.0	43.2	1.2	1.5	3.4
limestone1	47	24	39	72	49	54	60.5	32.3	44.9	4.5	3.1	2.0
limestone2	50	25	40	82	58	68	62.6	37.9	49.5	4.1	5.6	4.3
limestone3	60	47	57	88	71	78	76.3	56.9	66.3	4.8	4.3	3.7
flysch	43	27	41	69	60	65	53.6	36.5	48.2	3.8	4.7	3.6
alluvium	53	29	43	94	83	94	74.3	41.5	52.8	5.0	7.4	5.8
colluvium	54	32	44	83	65	69	69.1	47.9	55.2	4.1	4.1	3.1

Table 1. : Statistics for the different sampling classes for each spectral band.

oped on limestone material, soils developed on flysch material, soils developed on alluvium and soils developed on colluvium. Training areas were delineated for the different classes. It could be noticed from the statistical analysis of the histograms that the soils developed on limestone would cause some difficulties concerning the classification. This was due to the differences in vegetation cover. For this reason the soils developed on limestone were split up in three subclasses, namely :

- the "dense" vegetated limestone massif in the northern part of the study area, covered with maquis (limestone 1) ;
- the sparse vegetated limestone ridge in the western part of the study area, covered with phyrgana (limestone 2) ;
- limestone with almost no vegetation. These spots mostly occur on the top of the western ridge (limestone 3).

These three subclasses were treated as independent classes during the image classification. Afterwards the three subclasses were merged into one class : soils developed in limestone material. This procedure was followed because of the different spectral characteristics of these soils. If this procedure had not been followed one would have obtained a statistical class that was very wide and with many peaks. During the image classification this would have led to one mean and one standard deviation for the different subpopulations present in one class. This could only disturb the image classification.

From the point of view of land use one could expect a big spectral overlap of soils developed on flysch material and on colluvium since they are both covered by orchards of olive trees. However, on the image display one could recognize the flysh zones by their darker colour. This could also be concluded from the statistics from the training areas (table 1).

Generally spoken the areas with soils developed on flysch material are less reflecting in the three bands. The highest contrast difference appears in the infrared part of the spectrum, but also in the visual part of the spectrum. There is a significant difference between soils developed on flysch material and on colluvium. These differences had to be due to the difference in the colour of the top layer of the soil. Since orchards of olive trees have a low leaf cover, the spectral response of the underlying soil had to play an important role in the final reflection registered by the SPOT sensor. The soil developed on flysch material had generally a darker colour than the other types of soil materials present in the study area. This can explain why the flysch zones are clearly visible on the image display.

More detailed investigations of the statistics, and more especially the histograms for each class and each band, show that some curtosises are present in some classes. Fig. 2 shows two examples of the curtosises, namely "flysch" and "limestone2", both in band 2.

Since some curtosises are present in the statistics of the different classes, the best way of classifiying an image is the method of maximum likelihood (Richards, 1987). By using the maximum likelihood classifier, the statistical chance that a pixel is belonging to a certain population is taken into account instead of the distance to the class means, as the minimum distance classifier is doing. For this reason the maximum likelihood classifier was chosen to perform the digital supervised image classification.

4.3. Morphological mapping

A morphological map of the study area was made by using stereoscopical SPOT panchromatic images. Since there was a strong relationship in the area between the soil parent material and the geological substratum, it was felt as a necessity to analyse the morphological forms as well. During the fieldwork it was noticed that the different geological formations were recognizable by their morphology. The morphology was introduced as a second discrimination criterium to interpret the soil material from SPOT images. During the geomorphological mapping special attention was paid to the forms of the relief, e.g. the rounded forms of ridges and massifs, the forms of the valleys, the density of the hydrographical network which differed from area to area and differences in slope. The geomorphological legend used was based upon Gardiner & Dackombe (1983). The relief forms were mapped with a stereoscope with a vertical exaggeration of 2.5. The mapping scale is 1/43400 (Fig. 3).

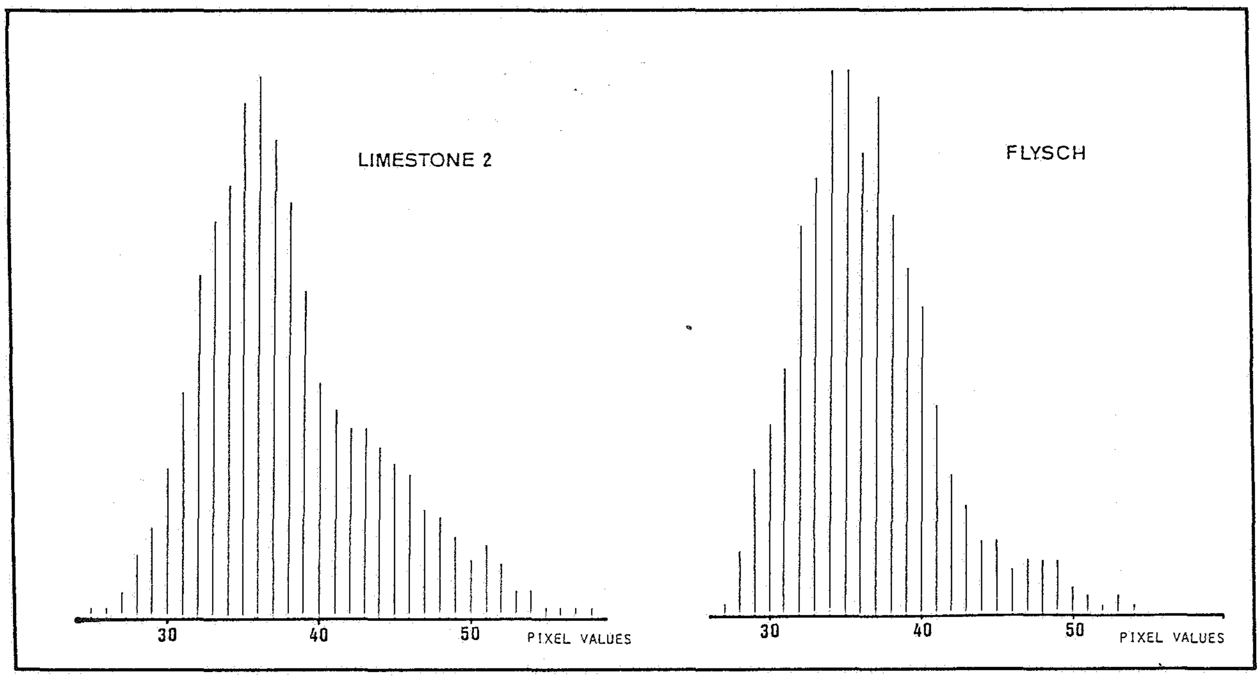

Figure 2. : Histograms of "flysch" and "limestone 2" in band 2.

5. RESULTS AND DISCUSSION

Before the maximum likelihood classifier was applied, a commission-omission matrix and a divergences matrix had been calculated in order to evaluate the discrimination possibilities between the different classes. The results are presented in the tables below (table 2 & 3).

From the tables 2 and 3 can be concluded that there is a considerable overlap of the classes "limestone1" and "limestone2". But this was not important since the decision was taken to merge these two classes after the image classification. After merging the classes "limestones 1, 2 & 3", only one class remains, namely soils developed on limestone material. A more important overlap, and for that reason a lower possibility of separability, is the overlap of the classes of soils developed on limestone material and those on flysch material. The rest of the values of separability can be considered as acceptable. As table 2 shows the overlap of limestone and flysch soil materials is mainly a commission error of limestone soil material.

classified as :								
trained as :	1	2	3	4	5	6	7	reject
1. water	4978	0	0	0	0	0	0	472
2. limestone1	0	3521	721	945	46	0	0	16
3. limestone2	0	1235	2979	345	230	563	88	10
4. flysch	0	103	143	994	0	22	1	34
5. alluvium	0	3	70	3	1151	231	97	29
6. colluvium	0	4	180	10	298	928	112	0
7. limestone3	0	0	0	0	25	14	336	15

Table 2. : commission-omission matrix based on the statistics of the training areas.

class	1	2	3	4	5	6	7
water	.0	100.0	100.0	100.0	100.0	100.0	100.0
limestone1	100.0	.0	51.9	61.3	95.3	96.2	100.0
limestone2	100.0	51.9	.0	59.5	78.7	57.6	90.6
flysch	100.0	61.3	59.5	.0	96.9	90.3	98.9
alluvium	100.0	95.3	78.7	96.9	.0	73.8	89.3
colluvium	100.0	96.2	57.6	90.3	73.8	.0	90.8
limestone3	100.0	100.0	90.6	98.9	89.3	90.8	.0

Table 3. : divergences matrix based on the statistics of the training areas.

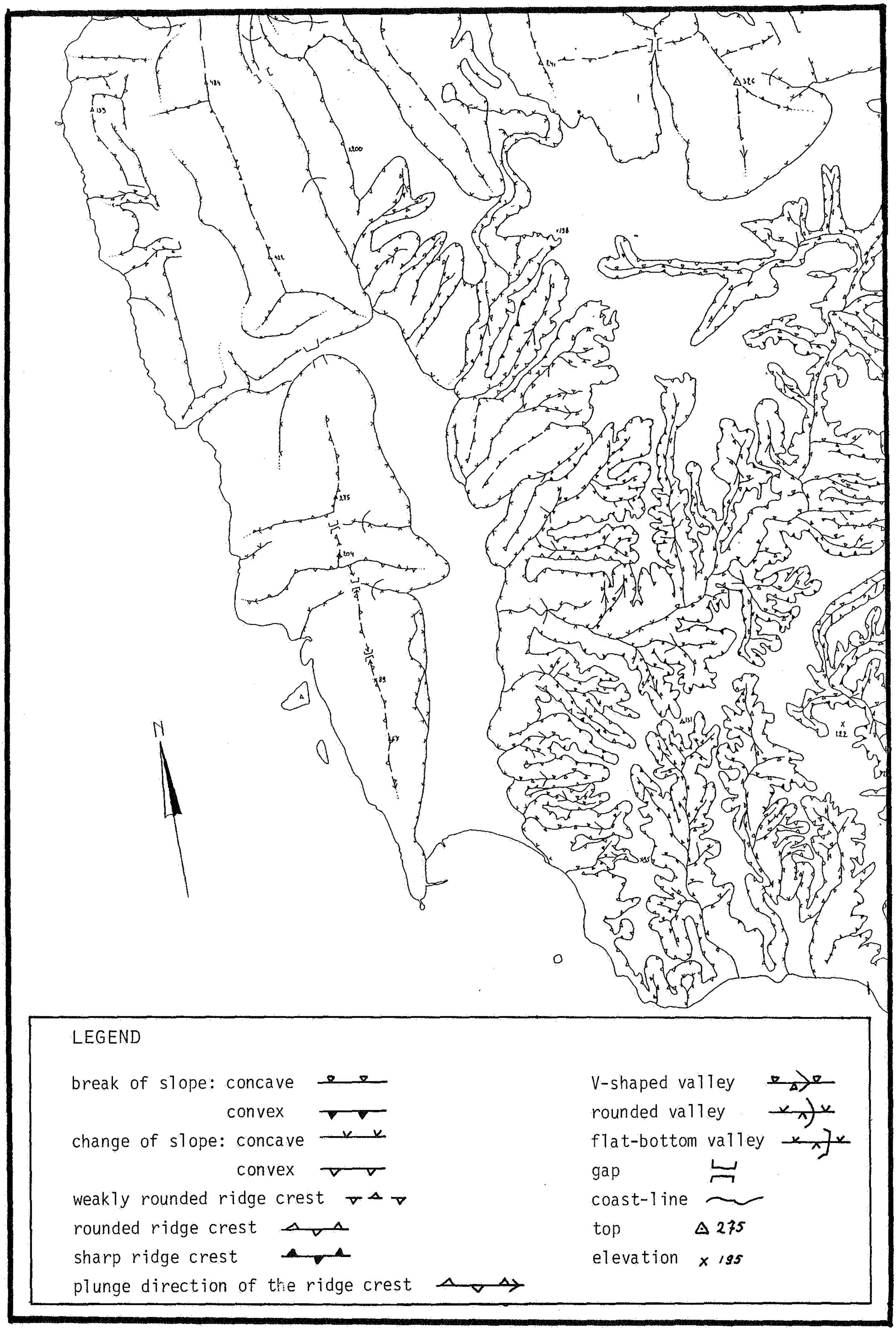

Figure 3. : Geomorphological map of the study area.

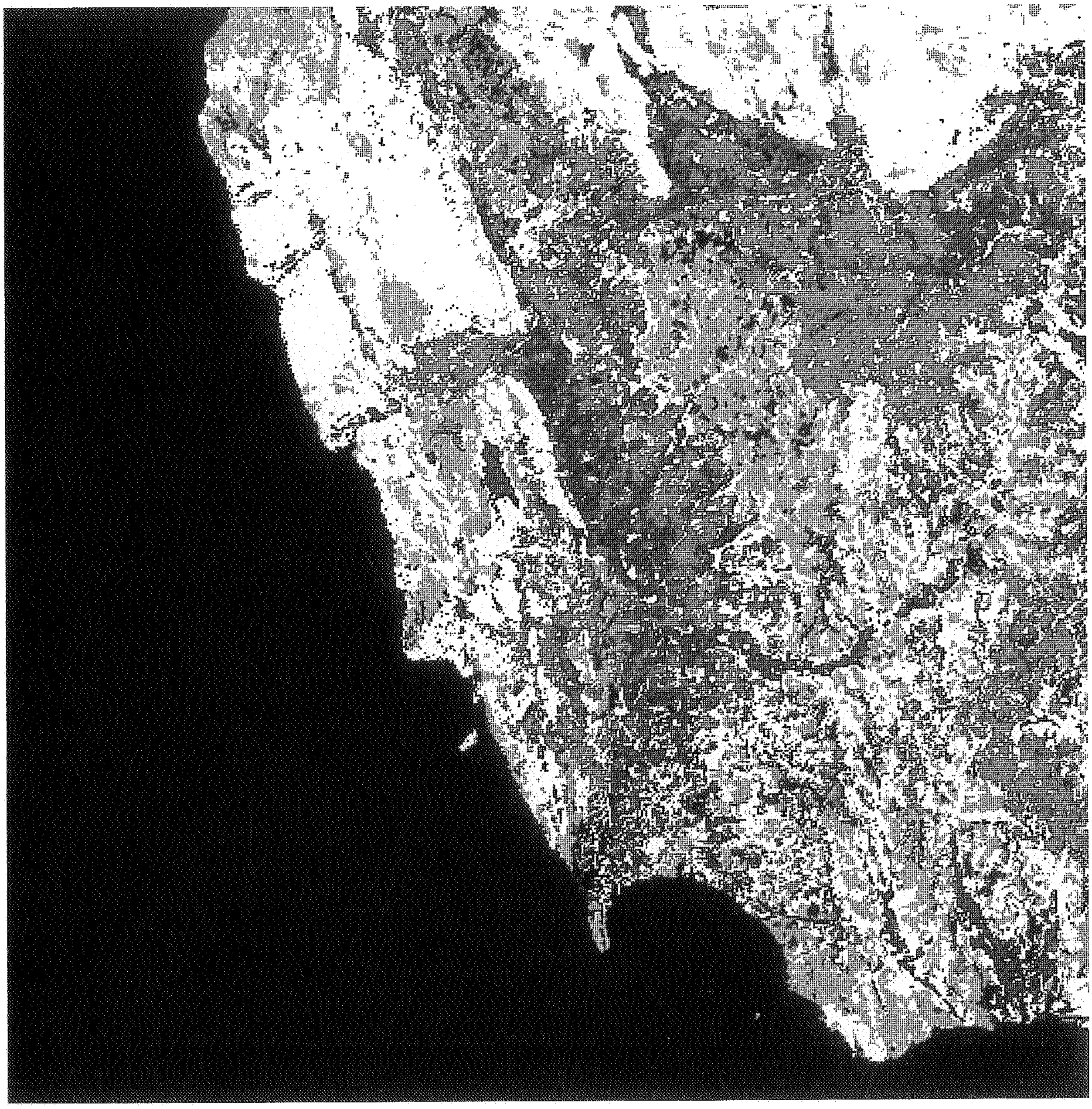

Figure 4. : Classified images of the study area.

black = water
dark grey = soils developed on alluvium
grey = soils developped on colluvium
light grey = soils developed on flysch material
white = soils developed on limestone material

This means that too much "limestone" is classified as flysch material. This error is not randomly distributed on the limestone material, but is well localized from a geographical point of view. The mis-classified areas are rather small and are mostly localized at the shady sides of the limestone ridges and massifs. This means that these areas are less insolated than the rest of the limestone material, and due to that phenomenon less reflecting. Table 1 clearly shows that the confusion is mainly present in the spectral bands 2 and 1. The maximum likelihood classified image clearly shows the main structures of the soil material in the landscape but some errors of mis-classification are occuring.

To obviate these difficulties the geomorphological overlay was used as a second decision criterium. Small patches wrongly classified as soils developed on flysch material had to be reclassified as soil material on limestone if those small patches are surrounded by areas classified as soil material on limestone and if they belong to the same geomorphological form of limestone area. Using such a working method one has a double criterium to interpret satellite images : on the one hand the spectral information that is grouped according to statistical classification rules and on the other hand the three dimensional information of the geomorphological relief forms. By combining these two types of information, derived from SPOT satellite data, it becomes possible to construct a decision scheme. The hilly regions consist of limestone or flysch. The digital image classification indicates large zones of limestone and flysch material. These major structures in the landscape are detectable with the digital image classification. The (small) patches of flysch soil material surrounded by limestone material or vice versa give difficulties for a final image classification. To solve this problem one may rely on the geomorphological mapping. If patches of flysch soil material are surrounded by an area classified as limestone material and if the relief forms are smooth and rounded, one may consider these patches as mis-classified "limestone pixels". These patches mostly can be found at the shade side of the relief forms. On the other hand one can correct patches of limestone soil material in the midst of flysch area by introducing the typical flysch morphology. Some parts of the area classified as soil material on flysch are classified as limestone soil material. This is due to some parts in the areas with flysch soil material with a dense maquis vegetation as present in the samples of the class "limestone1" or areas densely covered with olive trees. These patches are eliminated by the geomorphological overlay indicating the typical flysch morphology with sharp relief forms, deeply incised V- shaped valleys and with sharp topconvexities. In the flat areas there is neither a geomorphological nor a tonality criterium to distinguish between soils developed on alluvium or on colluvium. Only the multispectral classified image may provide here a classification criterium.

It is remarkable that two types of soils (soils developed in flysch material and colluvium) with the same land use (olive trees) have a high separability index (90.3). The differences in leaf cover and the background scattering from the underlying soil are responsible for the fact that the two groups can be individualized on the SPOT images. Also rather similar soil groups like soils on alluvium and on colluvium can be discriminated from each other. This is due to differences in land use, but also due to differences in soil texture and stoniness. The alluvial soils have a finer texture, and therefore a higher storage capacity for water than the colluvial soils.

6.-CONCLUSIONS

The image classification shows that SPOT multispectral images are suitable for the interpretation of soil materials. The differences in land use as well as the differences in soil reflection make that the different soil groups can be separated from a statistical point of view. The results obtained for the digital image classification are better for the flat areas than for the hilly areas. Some mis-classified patches occur in the hilly regions. These errors are mostly located on the shady sides of the relief forms or in the valleys. It is clear that differences in insolation are responsible for the errors. To obviate these problems a double interpretation is recommended : an automatic digital classification (to map the major soil groups) and to overlay this classification with a visual interpretation of the geomorphology. In such a way one has a double decision criterium to map the soil material and the related underlying geological structures.

ACKNOWLEDGEMENTS

Imagery was supplied by the EC-LFA project.

The authors like to thank Dr. Morgan De Dapper for his valuable advice concerning the geomorphological mapping.

Comments from Prof. J. Hardy, Dr. A. Millington and P. Styles (Reading University - U.K.) during the work are gratefully acknowledged.

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Manuscript received 15 September 1989 and accepted for publication 2 February 1990.