APPLICATION OF LANDSAT AND SKYLAB DATA FOR LAND USE MAPPING IN ITALY

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ABSTRACT

Utilizing LANDSAT and Skylab multispectral imagery of 1972 and 1973, a land use map of the mountainous regions of Italy was evaluated at a scale of 1:250 000. Seven level I categories were identified by conventional methods of photointerpretation. Images of multispectral scanner (MSS) bands 5 and 7, or equivalents were mainly used. If the quality of the data is good and if the interpreter has a general knowledge of the country, categories of levels II to IV can be mapped.

Areas of less than 200 by 200 m could be classified. It is possible to establish standard procedures for interpretation of multispectral satellite imagery. In this manner, land use maps can be produced for central and southern Europe. The results proved that the existing land use maps could be updated and optimized.

The complexity of European land use patterns, the intensive morphology of young mountain ranges, and time-cost calculations are the reasons that the applied conventional techniques are, for the near future, superior to automatic evaluation.

INTRODUCTION

For many earth scientific activities, land use maps form the basis for further planning and inventory preparation. Very often, the existing land use maps are many years old and do not correspond any longer to the existing situation.

Task

For several purposes, the Italian authorities plan a revised geoscientific "atlas" of the mountainous regions of Italy (Fig. 1). The land use map at the scale of 1:500 000 is part of this project and was carried out by order of the GEOTECNECO S.p.A. at S. Lorenzo in Campo (Pesaro, Italy). In collaboration with the geoscientists of this institute, the map was evaluated from multispectral satellite imagery.

The following seven level I categories had to be mapped:

1. Barren land (rocks, gravel)
2. Permanent snow cover, glaciers
3. Urban areas (including industrial areas and larger transportation patterns - streets)
4. Pastureland (areas covered by grass)
5. Agricultural areas (including plantations)
6. Forested areas
7. Water bodies, rivers, and lakes

For the identification of the land use units, conventional methods of photointerpretation were applied. In addition to this task, the possibilities were examined to which degree LANDSAT and Skylab imagery can be classified by the applied techniques.

Data Source

LANDSAT-1 MSS images taken during 1972 and 1973 were used as the data source. The 9-inch negatives (scale 1:1 000 000) were photographically enlarged to a scale of 1:250 000.. For most of the areas, the information loss acquired through repeated photographic processing of the images did not interfere with the detection of level I categories. For some key areas, a direct production of images from tape was carried out by PRAKLA Company. These images, showing maximum information of the MSS data, were generated on a scale of 1:200 000.

Furthermore, for some middle Italian and Sicilian areas, Skylab photographic data were produced in panchromatic and false color. By this means, a total cloud-free coverage of the areas of interest was obtained.

EVALUATION TECHNIQUES

Background Information

The basis of any photointerpretation is not only the experience of the interpreter but also detailed background information. The background information for our project consisted of

1. Existing land use maps at a scale of 1:200 000, produced 20 to 40 years before
2. Existing field data obtained through geological field investigations of the last 10 years
3. Detailed vegetation profiles

Information gained through field work proved to be the most accurate information and could be utilized with high confidence.

Interpretation Key

LANDSAT-1 multispectral scanner data.- For conventional photointerpretation, there are no significant differences of information between MSS bands 4 and 5 and between MSS bands 6 and 7. On the other hand, MSS bands 5 and 7 show the best contrasts of gray tones in vegetated and nonvegetated areas. Therefore, images of these two bands were chosen for the land use mapping.

From an earth scientific point of view, the utilization of data representing different vegetation cycles would be the best. This requirement could not be fulfilled over all areas because of the lack of continuous data. It turned out that, for the production of a preliminary base map, channel 5 was optimally suited. Band 7 was used to obtain additional information for discriminating various types of surface features. So, for example, the use of band 7 allows the separation of coniferous forest from deciduous forest and the clear identification of barren land. For the level I classification, the sensitivity of band 7 to soil moisture has been somewhat disadvantageous.

The diagrams of Figure 2 represent a qualitative comparison of gray tone classes obtained from bands 7 and 5. In the coordinate system, the land use categories were plotted as a function of their gray tone in both channels. It is evident that such schematic representations give only a very rough idea of the principles of evaluation. Of course, such diagrams do not reflect the experience of the interpreter, his ability to differentiate subtle gray tones, and his analytic ability to recognize the same category under different environmental conditions.

Furthermore, both diagrams do not express important criteria such as texture and morphology and also the synoptic knowledge of the geological conditions. An interpretative decision can be made by a combined analysis of all criteria, as shown for grass in Figure 3.

Skylab data (color and false color images).- Color photographs of Skylab (for example, 190 a, taken in September 1973) were projected on a scale of 1:250 000. Because of the outstanding color quality of these images, the following surface features could be clearly identified: forested areas, agriculturally used areas, grassland, and barren land. False color composites of Skylab data and also of LANDSAT-1 MSS data served as basic information for differentiating areas with grassland from agricultural land. The determination of borders between those two features has been very difficult in black and white images taken during late autumn, summer, or winter. During these seasons, the fields are not planted or are already harvested. In relatively dry areas, grassland and agricultural areas appear in almost unidentifiable gray tones when the field patterns are far below the resolution capabilities of the sensor system. The only reliable criterion for differentiation is a distinct red color represented in false color images.

Gray Tone and Color Tone

With respect to the physical properties, various surface features reflect incoming radiation at different intensity levels. The reflection intensity is translated on photographic data into a gray or colored tone. Therefore, the photographic density is one of the most important interpretative criteria. In addition, the density is very sensitive to uncontrollable factors caused by natural phenomena or by photographic processing techniques.

Impact of natural phenomena on photographic density.- In general, pictorial representations of the earth's surface are a combination of all possible factors expressed by the image density. Problems arise concerning the identification of surface features, regarded to be homogeneous from any earth scientific point of view. This is because such a homogeneity does not necessarily correspond to a homogeneous distribution of gray tones.

Therefore, in order to decide whether to deal with category a or b, further decisionmaking criteria have to be introduced. So, for example, a well-cultivated, fertilized, medium humid meadow may have a darker gray tone than an uncultivated grassland under the same environmental conditions. Grassland in an Alpine valley, for example, has a different gray value from grassland in a southern Italian Apennine valley. Grass growing on clay has a different dark gray tone than grass on limestone. The gray tone, the intensity of reflections, is mainly dependent on natural factors such as soil moisture, soil type, climatic zone, and local climate. Figure 4 represents some of the basic relationships between environmental parameters and gray values.

Another important factor, not taken into account, is the exposure of the surface to an illumination source - the sun. In areas with great relief, the identification of surface features is extremely difficult, not only because of the shadows themselves but also because of the change of the relative sun angle.

Another important factor is the changing state of vegetation during the year, that is, the change of reflectance depending on the seasons. Therefore, multitime imagery allows better identification and further differentiation of land use categories.

Impact of technical factors on photographic density.- The main technical factors influencing the density of images are related to the image generation itself. Concerning the generation of images from a digital tape, restrictions result from the dynamic range of the output device. The equipment used for data generation has an overall dynamic range of 16 gray levels. In comparison with the theoretical performance of the MSS scanner, with a dynamic range of 128 (MSS 5) and 64 (MSS 7) gray levels, the applied generated images represent reduced information. To minimize this effect, the available interval of 16 gray tones was adapted to the actual sensitivity range of the scenes. To obtain maximum gray resolution for the areas of interest, the adaption was carried out on scenes that did not show maximum reflective contrasts, such as snow and water, in infrared images.

A second important parameter that influences the quality of the film material is the degradation effect resulting from photolab processings such as enlarging, etc. During these processes, the gray tones are influenced by the various film emulsions, by various exposure times, and by the state of the chemical ingredients.

Another degradation effect that occurs mainly in channel 7 is caused by the high contrast between water and land masses. The extreme dark water areas interfere in such a way that the coastal areas always appear in darker gray tones.

The above-mentioned photographic factors may especially degrade the possibilities and the accuracy of conventional photointerpretation techniques. In other words, the interpreter has to revise his interpretation results not only from image to image but also within the evaluation of one scene.

POSSIBILITIES AND LIMITATIONS OF THE CONVENTIONAL CLASSIFICATION

The possibilities of identifying surface features are extremely dependent on the resolution capabilities of the sensor and on the target size. Figure 5 demonstrates to what degree, under optimum conditions, the differentiation of trees can be made.

With regard to trees or tree-cones, two points have to be considered. With respect to the resolving power of the multispectral scanner, larger areas with a dense tree population can be identified as uniform reflecting areas. It is understood that, with a dense population of trees, there is no interfering reflection from the ground. Furthermore, because of the poor resolution of the satellite data, the differentiation between bushes and forests cannot be made.

Conventional definition based on the percentage of trees within a certain area can not be made. To a certain degree, gray tone and background information enable the interpreter to map areas with different densities of wood. The geometric resolution of LANDSAT-1 images, however, does not permit the interpreter to map woods by quantitative measurements of percentage of trees per area. Therefore, areas with, for example, 10 percent trees, which are conventionally defined as wood, do not appear on the evaluated land use map.

Further difficulties arise when comparing forests and plantations. Densely planted hazel or citrus plantations and vineyards have the same reflection characteristics as deciduous forest, at least for the eye. Basic local knowledge and experience in examining textural information may sometimes help to overcome the above-mentioned difficulties. Plantations, for example, are very often characterized by geometric borders; in contrast, vineyards often show a kind of chaotic texture.

Cultivations with clearly separated rows of plants such as olive yards are characterized by a uniform medium gray value. These gray values are originated by intensities reflected from the ground coverage and the foliage of the trees.

The following images demonstrate areas with plant units that have characteristic signatures. Figure 6 shows coniferous and deciduous forest of Pratomagno Mountains southeast of Florence; Figure 7, Mediterranean oaks in the Apennine west of Rieti; Figure 8, olive yards of the Tuscany; and Figure 9, an area with bush and grassland near Valle Taleggio (Bergamasc Alps). The last example (Figure 9) especially indicates the difficulties that result from the limits given by the geometric and spectral resolution of LANDSAT-1 images.

Areas with mixed reflections are very difficult to classify without knowledge of the local conditions. Normally in such cases, textures can not be detected and the surfaces appear rather uniform. The limitations of differentiating between various surface features become evident if we are looking at interface regions between meadows and areas with dried-out grass and barren rocks. Barren rocks are clearly detectable but a distinct tracing of the border between the grassland and areas without vegetation is impossible.

DISCUSSION OF THE RESULTS

The possibilities of conventional interpretation mentioned above are based on extreme situations. With respect to the seven level I categories, the results are good.

Mapping of Land Use Categories

The land use classification followed the USGS system established by Anderson, Hardy, and Roach (Ref. 1) for the interpretation of remote sensing data. For our special problems, there was introduced the level I category "grassland," which in the USGS system belongs to "agricultural land" if it is pasture and to "range land" if it is uncultivated.

Table I shows to what degree LANDSAT and Skylab images can be used for mapping land use categories of level I and II. The table is based on our experiences during this work and therefore is valuable for European mountainous regions.

Good satellite data and good background information enable the interpreter to subdivide the level I categories 2, 4, 5 and 6 in the level III and IV categories. Table II shows these subdivisions, which are not included in the USGS system. Many categories, however, are not sharply bordered because of a gradual change of gray tone, that is, a zone of mixed vegetation. Even if the categories can be identified, such cases produce great uncertainty and errors in bordering different land use categories, especially if the scale is large.

Cartographic Accuracy

Besides methodological problems and their solution, it is important to calculate the cartographic accuracy. At the scale of 1:1 000 000, no important differences in the geometric accuracy between LANDSAT-1 images and topographic maps are remarkable. During mapping, the enlargements (squares of 10 by 10 cm) were rectified by using exact topographic features identical in the images and in the topographic maps. Finally, the geometric accuracy was as good as required for maps at a scale of 1:250 000. Areas of 1 by 1 mm (i.e., 250 by 250 m) were mapped so that the geometric resolution of topographic maps also was obtained.

Comparison With Other Methods of Mapping

The quality of new methods is generally compared with the results of former "conventional" techniques. Existing land use maps could be modified and generally updated. Borders between categories could be drawn more objectively compared with conventional maps. For example, with respect to woods, the borders taken from satellite images were more accurate than those of existing land use maps. This can be explained by two reasons: (1) those areas which were mapped from aerial photographs lost their initial accuracy by the generalization necessary for a scale of 1:250 000, and (2) if the map is based on field work, the borders can only be drawn roughly. In both cases, the need for time and costs is much higher than for the interpretation of satellite imagery.

Comparison With Automatic Digital Classification

Because of the difficulties described in the above chapters and because of the digital original MSS data, the question must be asked whether an automatic digital classification would not be preferred to the conventional methods of photointerpretation. Only a time-cost calculation can answer this question.

At first, there are two important facts:

1. A <u>European mountainous region of approximately 200 000 km^2 was mapped</u>. This area would be covered by six LANDSAT frames.
2. <u>Level I categories were mapped</u>. They include many subcategories that had to be combined. The subcategories result from differences in vegetations and soils.

For comparison, the time needed for the conventional interpretation has to be taken in consideration.

2 months	mapping	five photogeologists
1 month	photographic laboratory work	one photographer
1 month	ground truth	two geologists

Because of the overlapping of processes, the entire map was done in 3.5 months.

Furthermore, at the recent state of automatic digital classification, there must be done some premises:

1. All necessary computer programs must be established; that is, programs for the statistics and programs for the correction of gray tones, which is very important especially in mountainous areas with an intensive relief and with a small-scale pattern of different soils.

2. The computer must be capable of combining the level I categories from the very large number of subcategories that are often very similar to one another.

Although automatic digital classification is already done for small European areas and also because of the intensive experiments on this field, it is obvious without an exact calculation:

1. The computer will probably classify much more quickly than an interpreter.

2. The classification pixel by pixel will be much more exact than a conventional interpretation.

3. The costs for computer time will be much higher than the costs for interpreters, materials and field work.

Furthermore, the high degree of resolution is not necessary because areas of 80 by 80 m can not be figured out at a scale of 1:250 000 or less.

Despite the possibilities offered by statistics and by computers, the automatic digital classification must solve the same problems as the conventional photointerpretation. A computer needs background information as well as the human interpreter. It is very difficult, however, to code all important background information in a way that a computer can work with them.

Summarizing, the discussion shows that for large mountainous areas with small-scale land use pattern and intensive morphology such as in Europe, the conventional photointerpretation for the moment is superior to automatic methods. For operational use, digital evaluation has to pass the experimental stage.

REFERENCE

J. R. Anderson, E. E. Hardy, and J. T. Roach: A Land-Use Classification System for Use With Remote Sensing Data. Geological Survey Circular, 671, 1-16, Washington, 1972.

TABLE I.- QUALITY OF LANDSAT-1 AND SKYLAB IMAGERY FOR LAND USE MAPPING IF LEVEL I AND II CATEGORIES ARE WANTED

Level I	Level II	Multispectral Imagery[a] LANDSAT	Skylab
1) Built-up Land		++ o	++
	Residential	+	+
	Commercial	+	+
	Industrial	+	+
	Communications	+	+
2) Agricultural Land		+++ o	+++
	Fields	+++ o CIR	+++ HP/A
	Plantations	++ o CIR	+++ HP/A
3) Grassland		+++ o CIR	+++ CN/CIR/A
	Pasture	+ o CIR	++ HP/CN/CIR/A
	Uncultivated	+ o CIR	++ HP/CN/CIR/A
4) Woods		+++ S	+++ S/A
	Deciduous	+++ S	+++ CIR
	Coniferous	+++ o	+++ CIR
5) Water		+++	+++
	Streams, Waterways	+++ (o)	+++
	Lakes	+++	+++
	Reservoirs	+++	+++
6) Barren land		+++	+++
	Beach	+++	+++
	Sand	+	+
	Rocks	+	+
7) Permanent snow/ glaciers		+++	+++

[a]Legend:

+++ Identification ≥ 90%

++ Identification ≤ 90%

+ Identification only in special cases; ground truth knowledge

o sequential imagery

S Images taken in summer

A Images taken in autumn

HP High precision photograph

CN Natural colors

CIR False colors

TABLE II.- LEVEL III AND IV CATEGORIES WHICH CAN BE

DISTINGUISHED ON LANDSAT-1 IMAGERY OF ITALY

Level 1	Level II	Level III	Level IV
2. Agricultural land	Acres	Grain	Wheat Rice
	Plantations	Truck crop Vineyards Orchards Olive yards Citrus Nut-plantations	
4. Woods	Deciduous	Deciduous Evergreen	Chestnuts Mediterranean Oak
		Deciduous	Macchia
	Coniferous	Spruce Pines, Stone pines Larches	
5. Water	Lakes	Natural Artificial	Shallow Deep
	Rivers Channels		Plus suspension
6. Barren land	Barren rock	Volcanic Sedimentary	 Limestone Sandstone Marles, shales

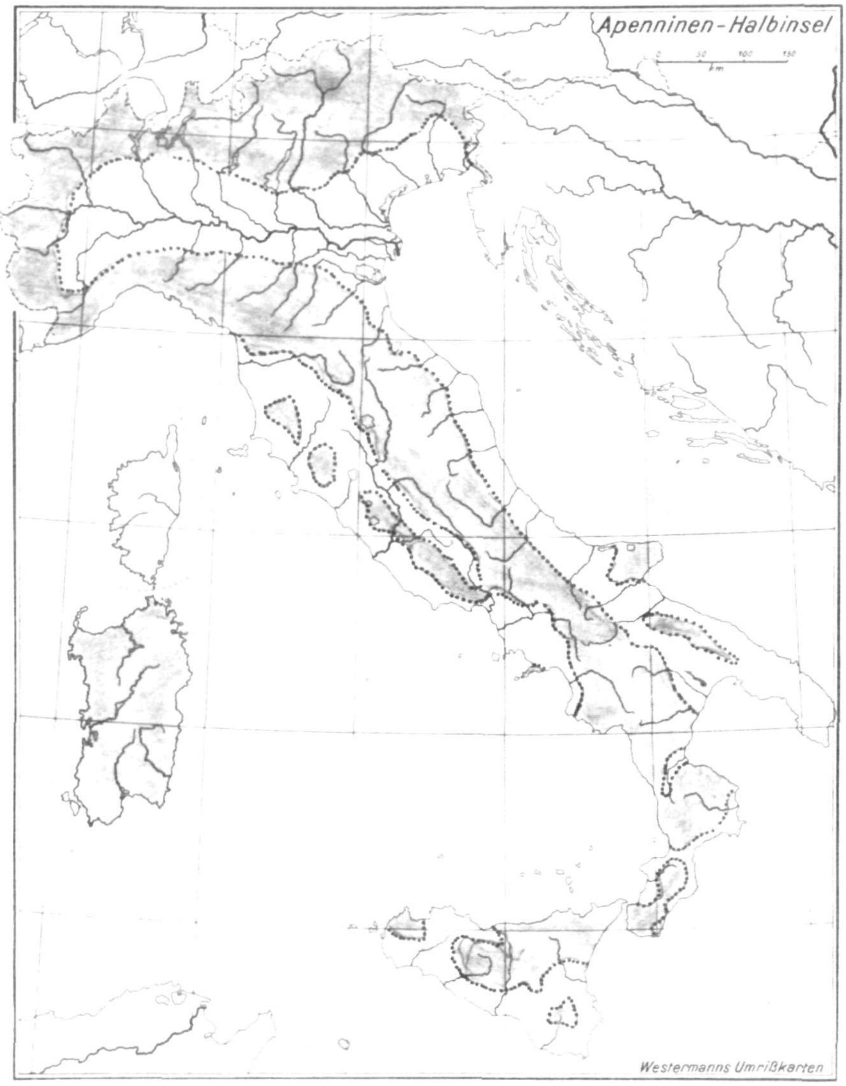


Figure 1. - The mountainous regions of Italy (gray = mapped area).

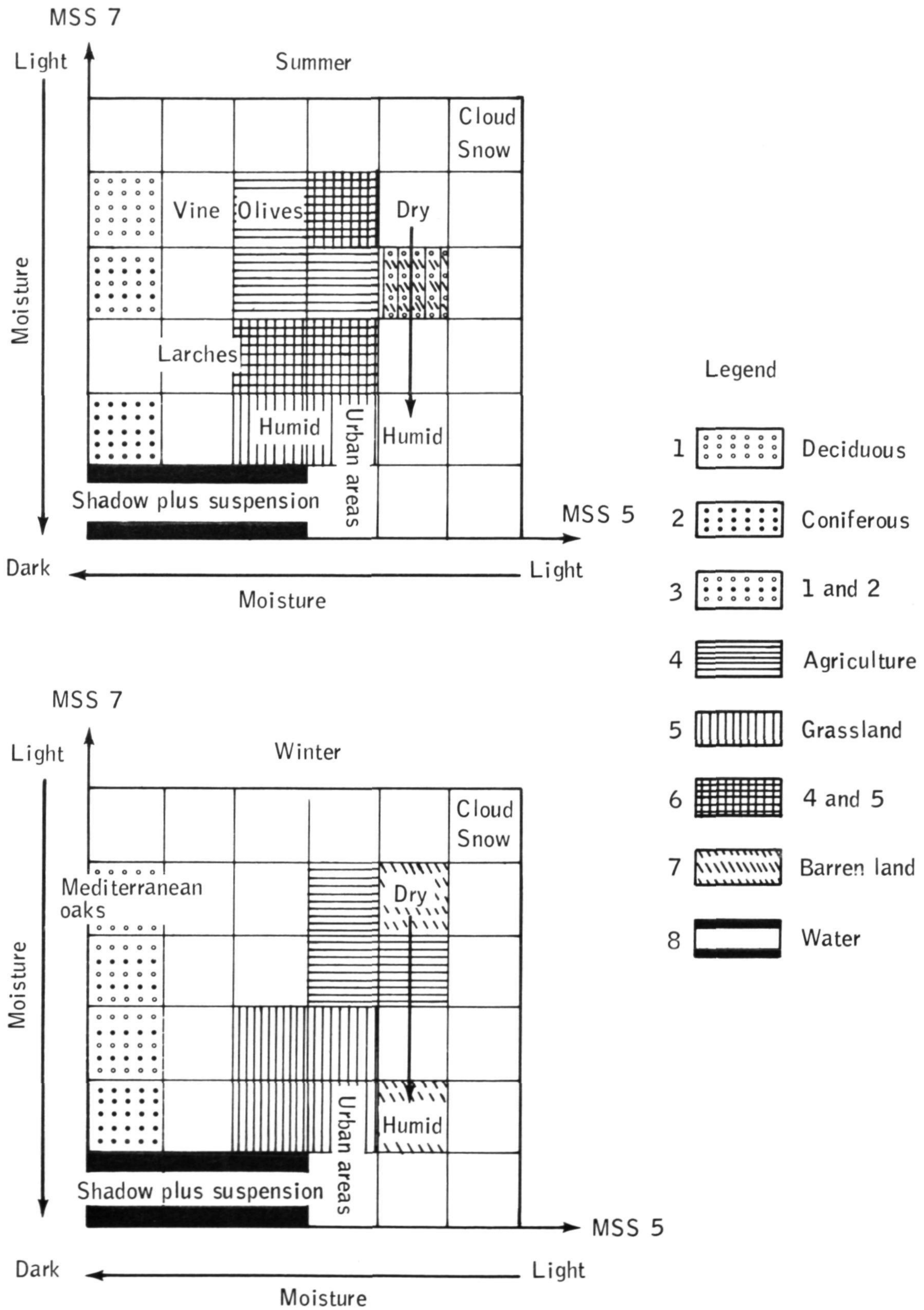


Figure 2. - Schematic position of land use categories in a coordinate system based on the gray tone in LANDSAT images of MSS 5 and 7.

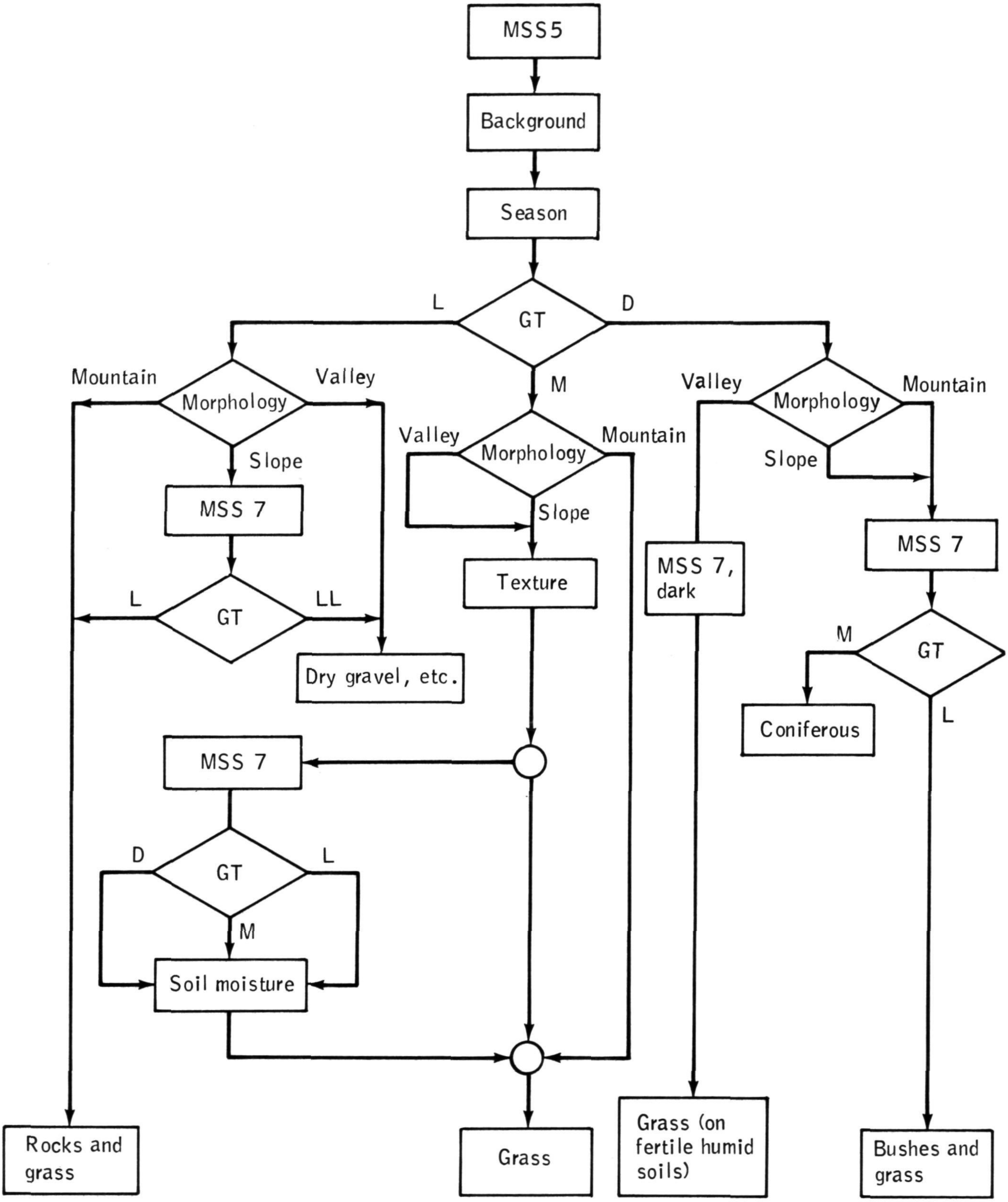


Figure 3. - Identification of grassland: schematic diagram for the interpretation of LANDSAT MSS data (GT = gray tone, L = light, LL = very light, M = medium, D = dark).

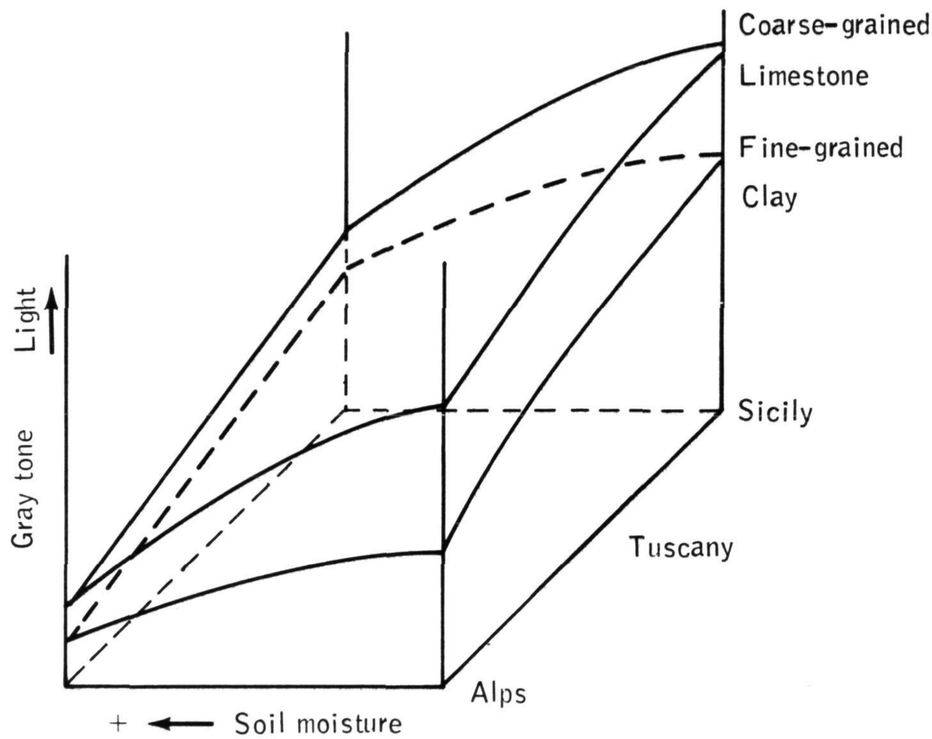


Figure 4. - Gray tone levels of grass; schematic representation for the factors of soil type, soil moisture, and climatic zone.

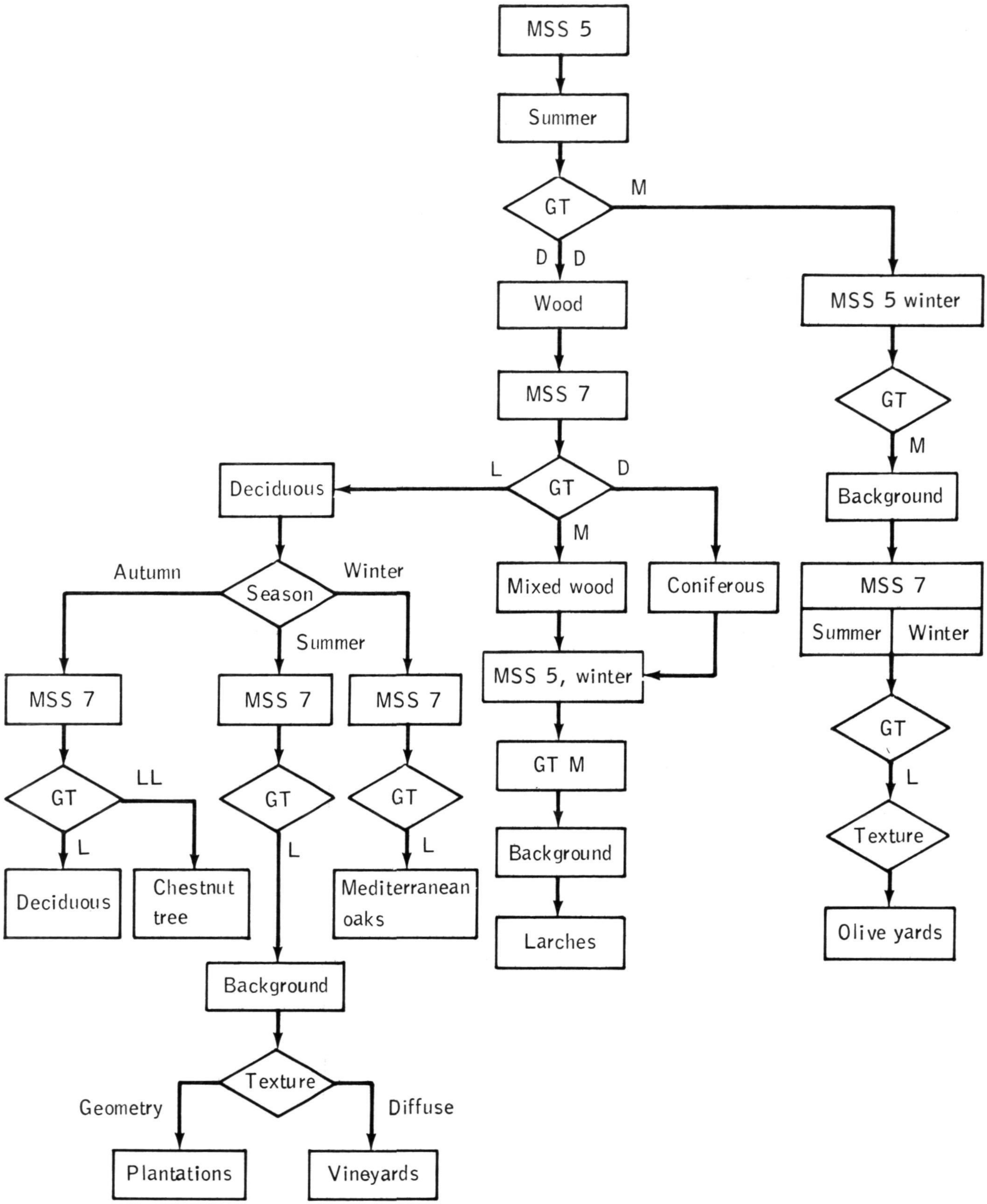
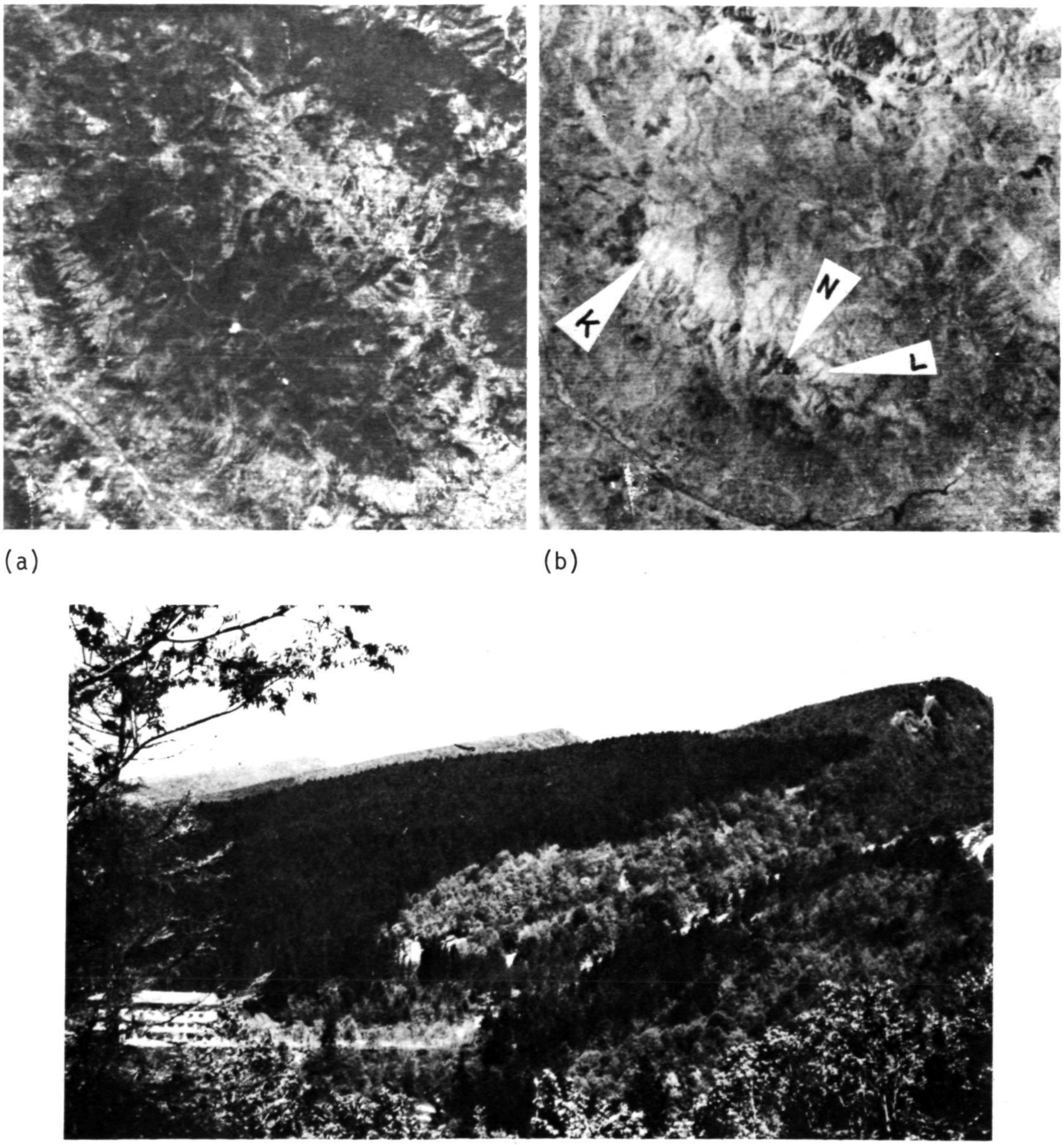


Figure 5. - Identification of wooded areas; schematic diagram for the interpretation of LANDSAT MSS data (GT = gray tone, L = light, LL = very light, M = medium, D = dark, DD = very dark).



(a) (b) (c)

Figure 6. - Pratomagno Mountains southeast of Florence.
(a) Detail of LANDSAT image of 12 Aug. 1972, MSS 5 (dark = woods).
(b) Detail of LANDSAT image of 12 Aug. 1972, MSS 7 (light = deciduous woods, L = general, K = chestnuts, N = coniferous).
(c) Ground truth photograph showing coniferous (dark) surrounded by deciduous.

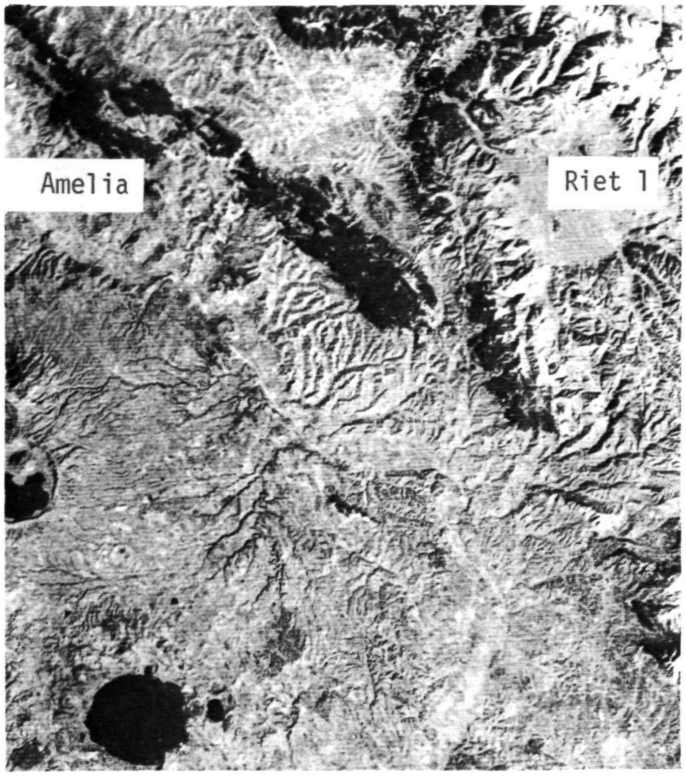


Figure 7(a). - Mountain ranges west of Rieti (detail from LANDSAT image of 6 Feb. 1973; MSS 5) (dark = evergreen, mediterranean oaks).

Figure 7(b). - Ground truth photograph taken in June 1973 near Amelia. The hill is covered by evergreen Mediterranean oaks.

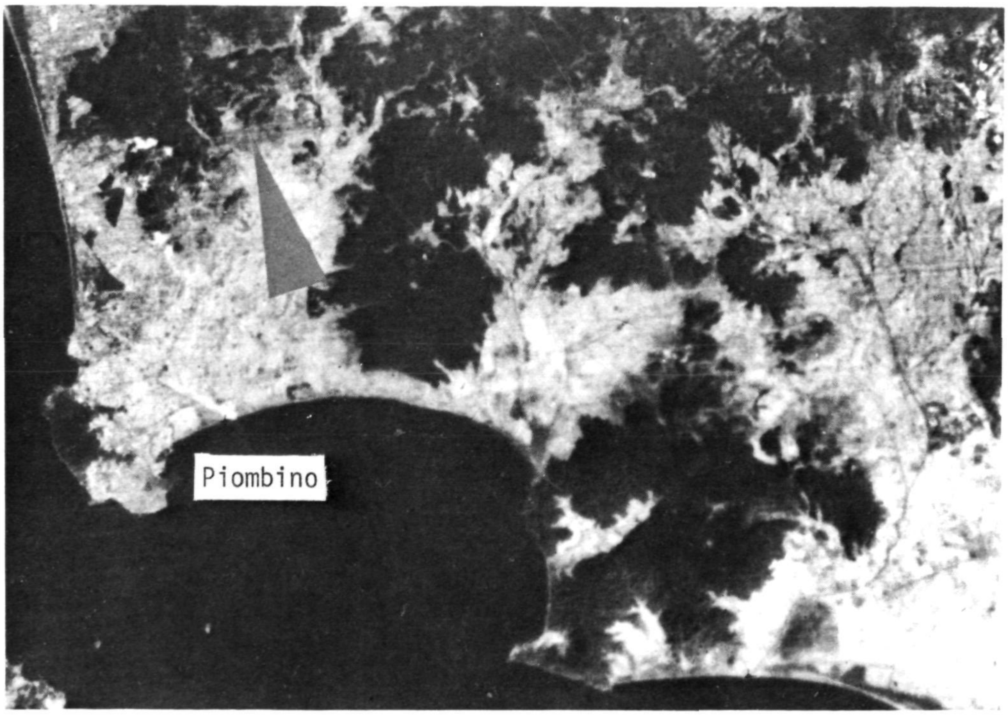
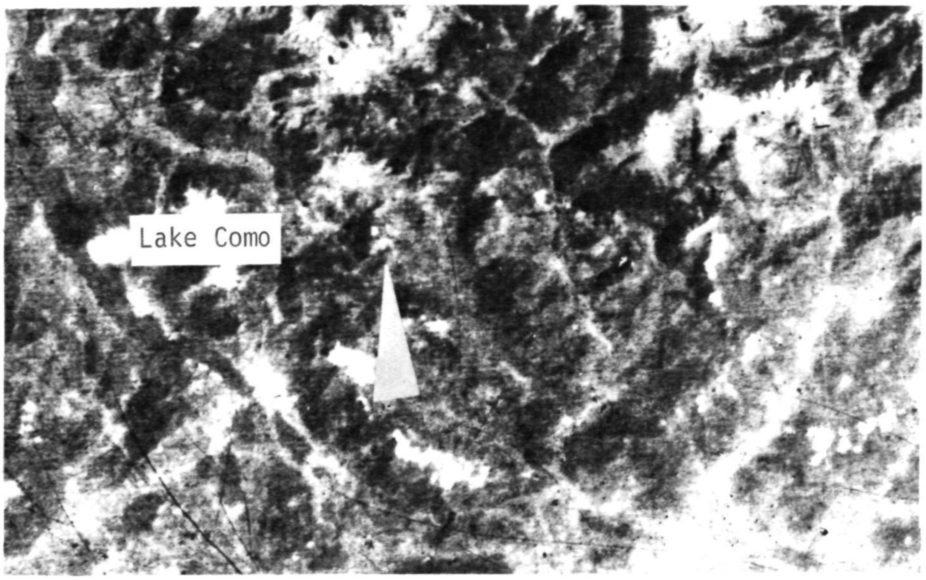


Figure 8. - Lower valley of the Cornia River, east of Piombino (detail from LANDSAT image of 12 Aug. 1972; MSS 5) (dark = woods, middle gray = olive yards (arrow)).



(a)

(b)

Figure 9. - Valle Taleggio (Bergamasc Alps, east of Lake Como). The detail from LANDSAT image of 7 Oct. 1972 (MSS 5; fig. 9(a)) does not show the distinct vegetation pattern as does the ground truth photograph (fig. 9(b)). The arrow in the LANDSAT image marks the moutain ridge shown in the photograph.

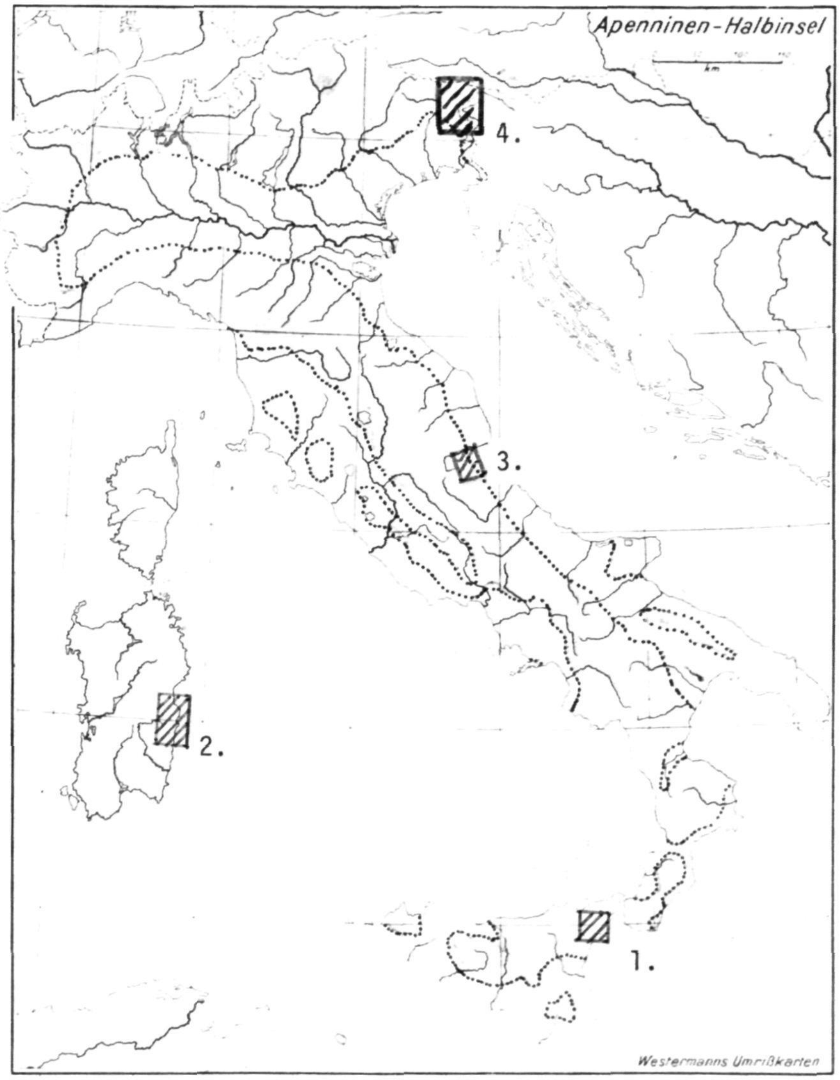


Figure 10. - The map of Italy showing the map sections:
(1) Mount Etna area (see fig. 11).
(2) Eastern Sardinia (see fig. 12).
(3) The Marchigiano Apennines west of Ascoli Piceno and Teramo (see fig. 13).
(4) The Alps north of Udine (see fig. 14).

A P P E N D I X

SOME MAP SECTIONS OF THE LAND USE MAP OF ITALY

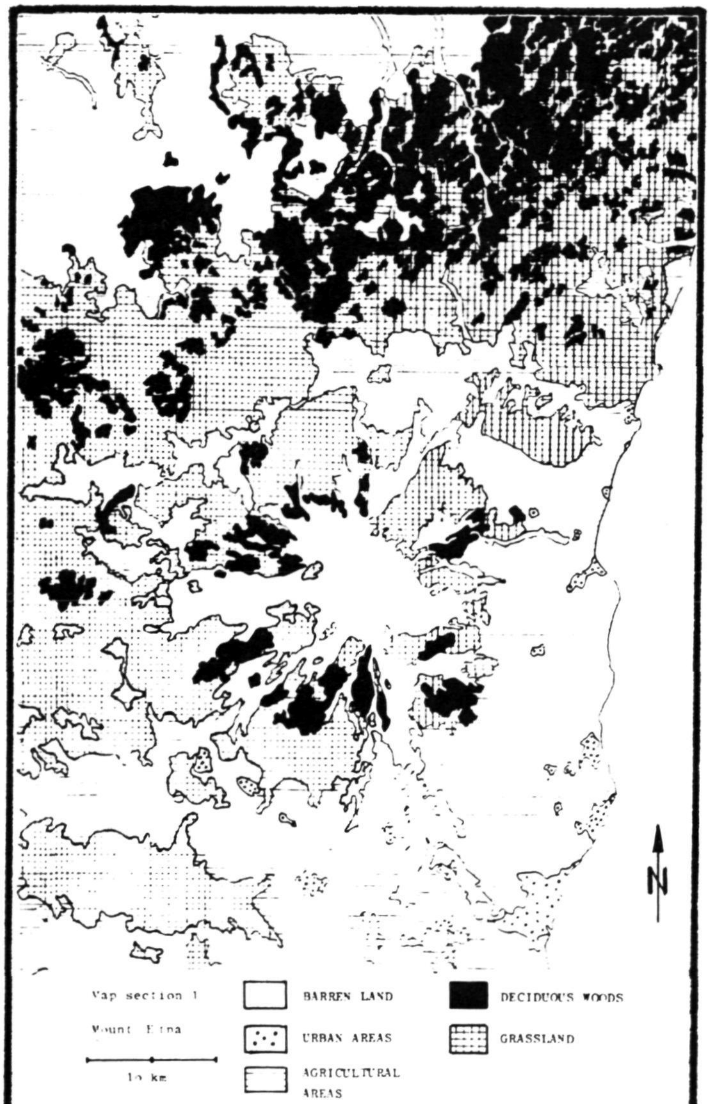


Figure 11. - Mount Etna area (Sicily); section of the land use map of Italy. Especially in the northern part, the plantations (agricultural land) and deciduous woods were separated by Skylab false color photographs.

Figure 12. - Eastern Sardinia; section of the land use map of Italy. The differentiation between grassland and more or less wooded grassland was very difficult. In some areas (northwestern part of the figure), it was possible to map only after the field check.

Figure 13. - Map section 3: The Marchigiano Apennines west of Ascoli Piceno and Teramo. (Legend - see figs. 11 and 12) This area was mapped from Skylab high-precision photographs in natural colors. These kinds of photographs offer best possibilities for the mapping of gradual vegetation changes (grass or woods/barren rocks).

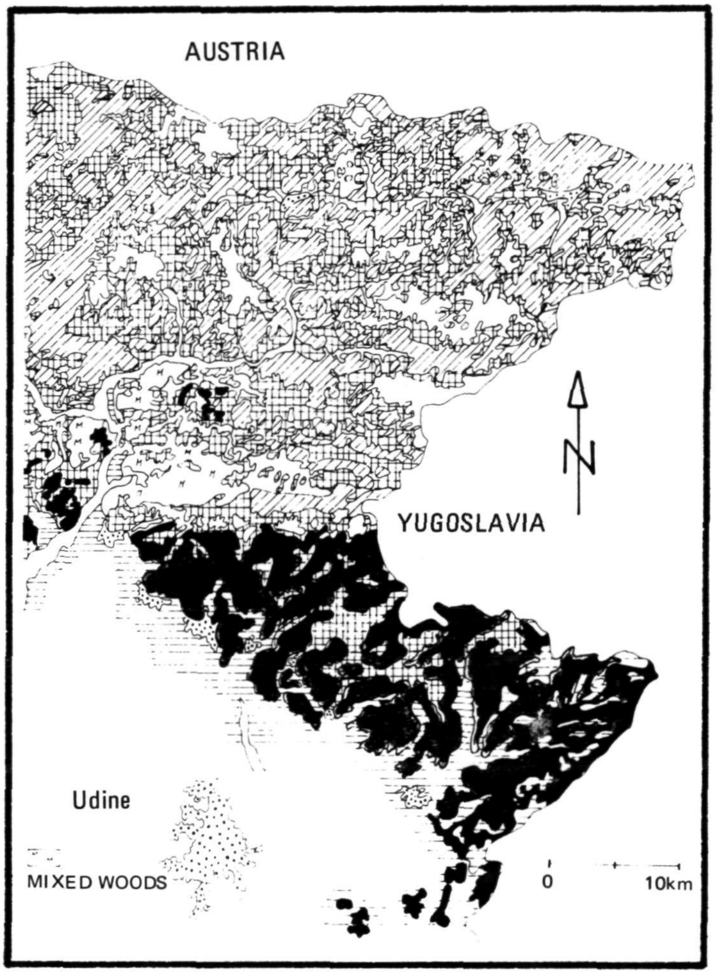


Figure 14. - The Alps north of Udine (legend - see figs. 11 and 12). In this area, it was possible to detect many urban areas. In the middle of the map section, the gray tone of the LANDSAT image indicated mixed woods.