Integration of Remotely Sensed Data Into a GIS for the Assessment of Land Suitability

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ABSTRACT

A methodology based on the use of an integrated Land Information System (LIS) is put forward to assess the influence of ecological factors on the distribution of vegetated cover types. Digitized maps in raster format concerning some major ecological factors can be inserted into the system. A precise land use inventory can be obtained from multitemporal Landsat 5 Thematic Mapper scenes by means of advanced classification procedures. Thus, the quantitative assessment of the influence of each factor can be made by the use of statistical procedures such as mutual information analysis and frequency histogram examination. Finally, on the basis of this information, a land suitability map can be drawn for each cover class relying on probabilistic principles. The methodology has been applied to a case study in a hilly zone of Tuscany (Central Italy). The case study has allowed the definition of the importance of the ecological factors examined (soil type, elevation, aspects) and the generation of land suitability digital maps.

INTRODUCTION

In recent years the integration of remotely sensed data into Geographic Information Systems (GIS) has shown interesting potentials, especially connected with the capability of the former for providing synoptic and cost effective surveys over wide areas (Walsh et al., 1990).

A typical example of integrated GIS for land management is the Land Information System for Agriculture (LISA), developed in the computer center of IATA-CNR (Conese et al., 1989). As shown in figure 1., ground collected data can be inserted into the system by digitizing the relevant information (tables, graphs, maps); also, satellite data can be processed and integrated in the system mainly for updating the condition and distribution of land cover types.

In the current paper a methodology is presented for the assessment of the environmental factors which are most influential on the distribution of some agricultural and forestry species; in a second phase, the information obtained has been used to classify the land examined according to its suitability for substaining those species.

The study site is a rural area south of Florence (Central Italy) mainly covered by olive groves, vine-yard and deciduous and coniferous woods. Conventional information about morphology, climatology and pedology has been digitized and inserted into the Land Information System for Agriculture, and an accurate land use inventory has been obtained by processing multitemporal TM scenes through advanced classification procedures specifically developed in the Institute.

The effects of the enviromental variables on the spatial extent and distribution of the principal cover types have been evaluated by using techniques based on the concept of common entropy (information analysis) and probabilistic (nonparametric) multivariate statistical methods. This procedure has allowed the assessment of the most influential environmental factors for each culture and a comprehension of the relevant relationships, with a consequent evaluation of land suitability.

The first results of the methodology appear decisively encouraging, and its application to other areas has already been planned for further investigation.

STUDY AREA

A rural area of about 10x10 km. south of Florence (43° 40' North lat, 11° 20' East long) was chosen as test site corresponding to a geografic map 1:25000.

The area, which is mainly coverd by deciduos woods, olive graves and vineyard, is placed on a gently undulated terrain, with altitudes ranging from 100 m. to 700 m. More complete description of the area is reported in Conese and Maselli (1991a).

Several sources of ground information were available about this area. A digital terrain model (DTM) was constructed by digitizing the contour lines every 50 m.; the resulting raster images with elevations and aspects were then used as environmental parameters. A soil map was also digitized; ten soil associations were considered, which are fully described in Conese et al. 1991.

A land cover map was obtained by the use of LANDSAT 5 TM data. Three scenes from the years 1988 were utilized to exploit the relevant multitemporal information. A supervised classification procedure recently developed by the Authors (Maselli et al. 1991) was emplojed, trained on representative ground samples collected during some direct surveys. Seven cover types were considered (table 1), with a classification accuracy of about 85%.

To give an idea of all the information available, the proportion of the different levels of the four parameters considered (cover and soil types, elevation and aspects) are reported in figure 2.

Mutual Information Analysis

To evaluate the levels of association between the distribution of the ecological factors (elevation, aspects, soil type) and that of the vegetated cover types, mutual information analysis (MIA) was applied to the relevant pairs of digitized maps.

As explained in Davis and Dozier 1990 and in Conese and Maselli 1991b, MIA is a statistical method to evaluate the amount of information shared between different discrete variables with common distribution.

MIA was applied to the land use classification in relation to the various digitized maps; its results, expressed as percentage of mutual information of an ecological factor relevant to the cover type distribution, are presented in table 2.

Analysis of frequency histograms

For each cover class considered, its distribution over the 3 ecological factors was also evaluated by means of frequency histograms. In figures 3-5 the relative frequency of different levels of each factor are drawn for all the vegetated cover classes.

CREATION OF LAND SUITABILITY MAPS

On the basis of the analyses performed, land suitability maps could be drawn for the 6 vegetation cover categories. The percentages of M.I. found by the analysis were used to weight the three ecological factors depending on their influence on the distribution of the cover types. Then, the relative frequency found in the second step were used to make each level of a factor correspond to a different suitability value.

The rationale for this is that distribution of the vegetation cover classes can be an indicator of their ecological preferencies.The product of the land suitabilities found for each factor gave the global land suitability for all the factors simultaneously considered; two examples of the digital maps obtained are shown in figures 6-7.

RESULTS

As can be seen from figure 2, in the study area there is a prevalence of oak wood among the natural cover types, while olive grove and vineyards are practically the unique agricultural cover types. The dominant elevations are between 250 and 400 mt., whilst aspects are rather evenly distributed and several types of soil are present.

The results of MIA (table 2) indicate that aspects are the factor most closely linked to vegetation distribution, followed by soil type and elevation. From this, it can be assumed a symilar order of importance among the enviromental factors in affecting the distribution of the vegetated cover types.

The different distributions of the six cover categories can be appreciated from figures 3-5. The pine wood class (1) seems to prefer middle elevations, with north-west faces and various soils. The chestnut category (2) shows a marked preference only for the soil type (associations 15-16, acid soils), in accordance with its ecological requirements. The oak classes (3-4) are also rather ubiquitarious with regard to elevation and soil, but have opposite distributions with respect to aspects; this behaviour is probably due to the higher water availability of the northern slopes, where a thicker wood is present. Finally, as regards the agricultural cover types, the only relevant feature is the slight preference of the vineyard class for lower altitudes.

From the two examples of land suitability classes (pine wood and thick oak wood) shown in figures 6-7, marked differences can be appreciated. The low absolute values found can be ascribed to the number of enviromental factors used and, above all, to the lack of definite correspondances between these and the cover types considered. Clearly, these values are only relative to the environmental situation of the study area. However, the two maps can give useful indications on the ecological preferences of the woody species.

CONCLUSIONS

In the present work a methodology to evaluate the different effects of influential enviromental factors on the distribution of some vegetated cover types is presented, based on the use of an integrated land information system.

From a methodological viewpoint, interesting potential has been shown by the use of mutual information analysis joint to the analysis of frequency histograms. This methodology is easily implemented into a land information system and can be simply applied.

In general, the relationships found are in good accordance with the ecological behaviours of the species examined. As was seen, the output of the analyses can also be utilized to draw land suitability maps relying on probabilistic principles. These maps can find their maximum utility to give essential indications for land planning and management, especially for agricoltural and forestry applications.

ACKNOWLEDGEMENTS

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Table 1

Cover types considered in the automatic land use inventory from TM scenes.

Class 1 = pine wood
Class 2 = chestnut wood
Class 3 = thick oak wood
Class 4 = thin oak wood
Class 5 = vine-yard
Class 6 = olive grove
Class 7 = urban area

Table 2

Percentage of mutual information expressed by the three ecological factors about the distribution of the cover types as derived from the analyses.

Ecological Factor	Perc. M.I.
Elevation	2.2%
Aspects	9.4%
Soil type	4.0%

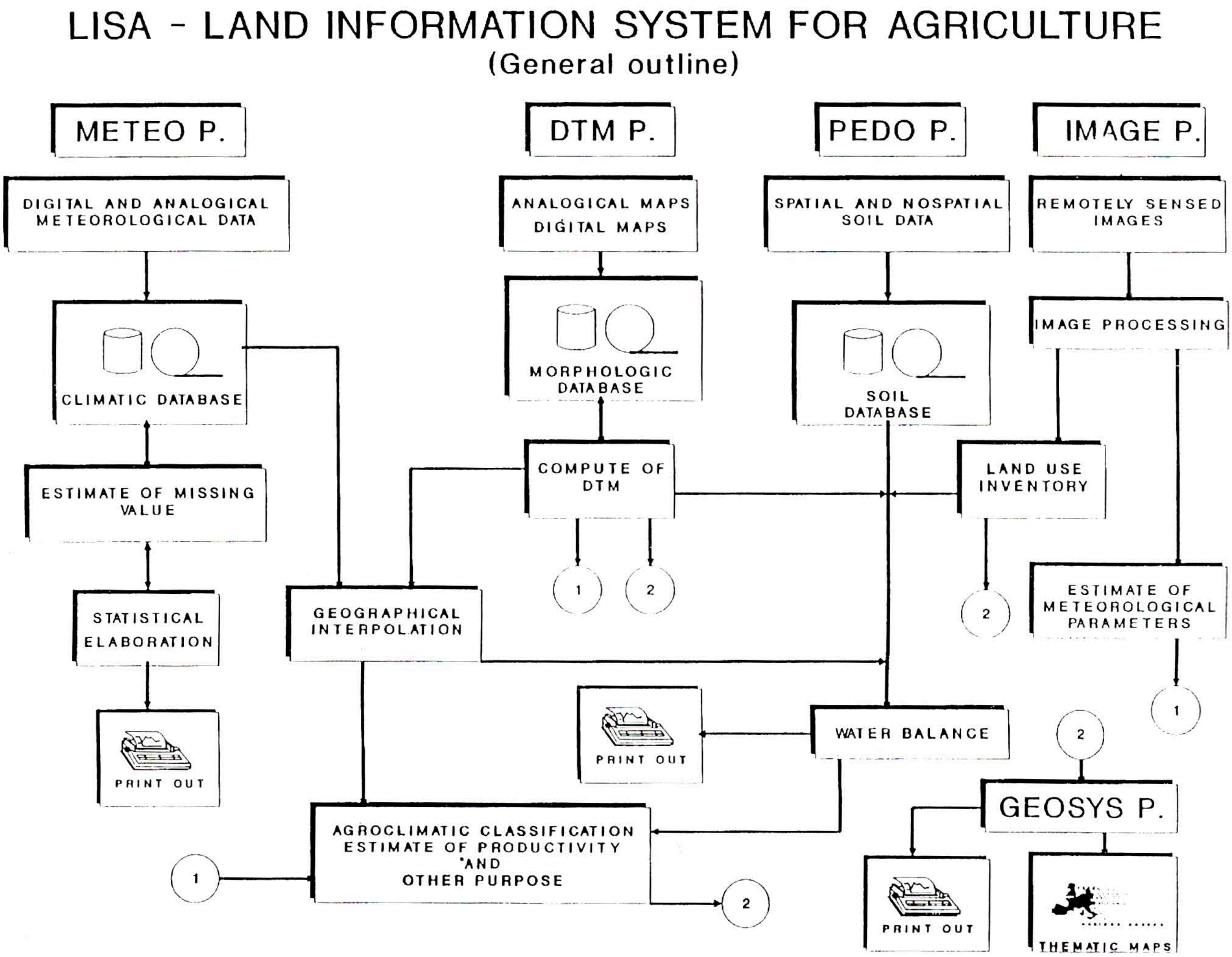

Fig. 1 - Scheme of the Land Information System for Agriculture developed in the computer center of I.A.T.A.-C.N.R..

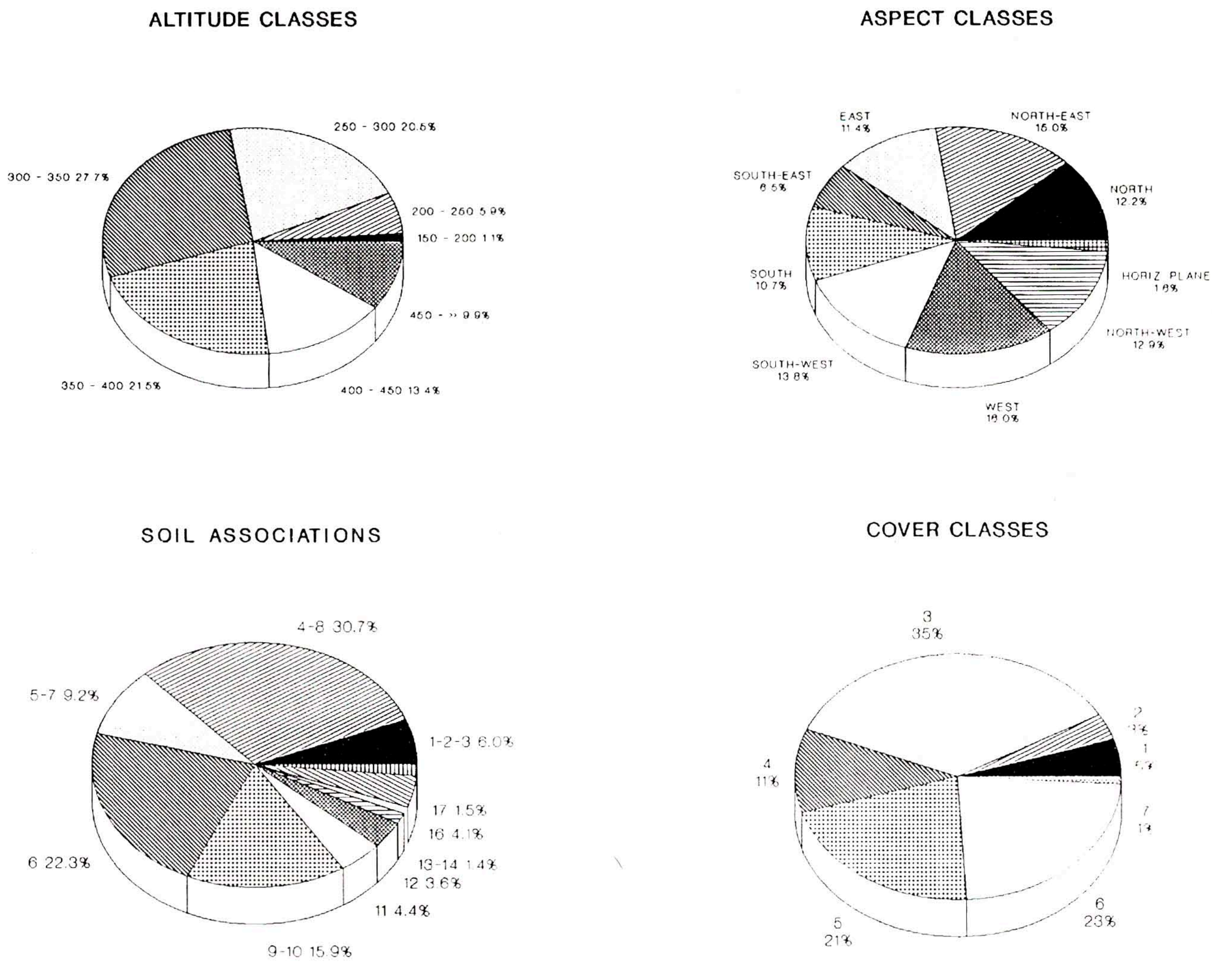

Fig. 2 - Proportions of the levels of the four environmental parameters in the study area (9950 ha).

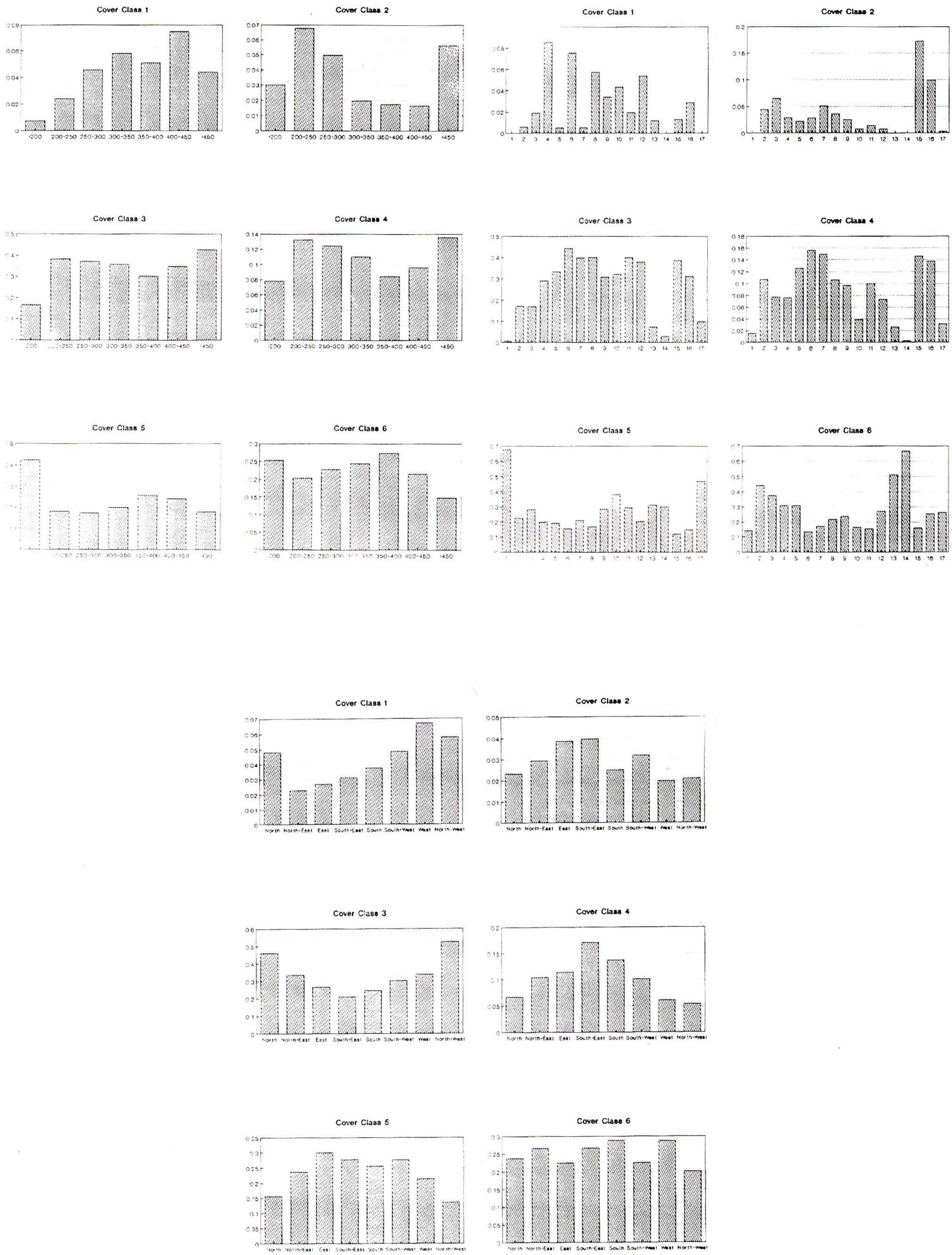

Fig. 3-5 - Distributions of the six vegetated cover classes over the three environmental factors considered (elevation, aspects and soil type).

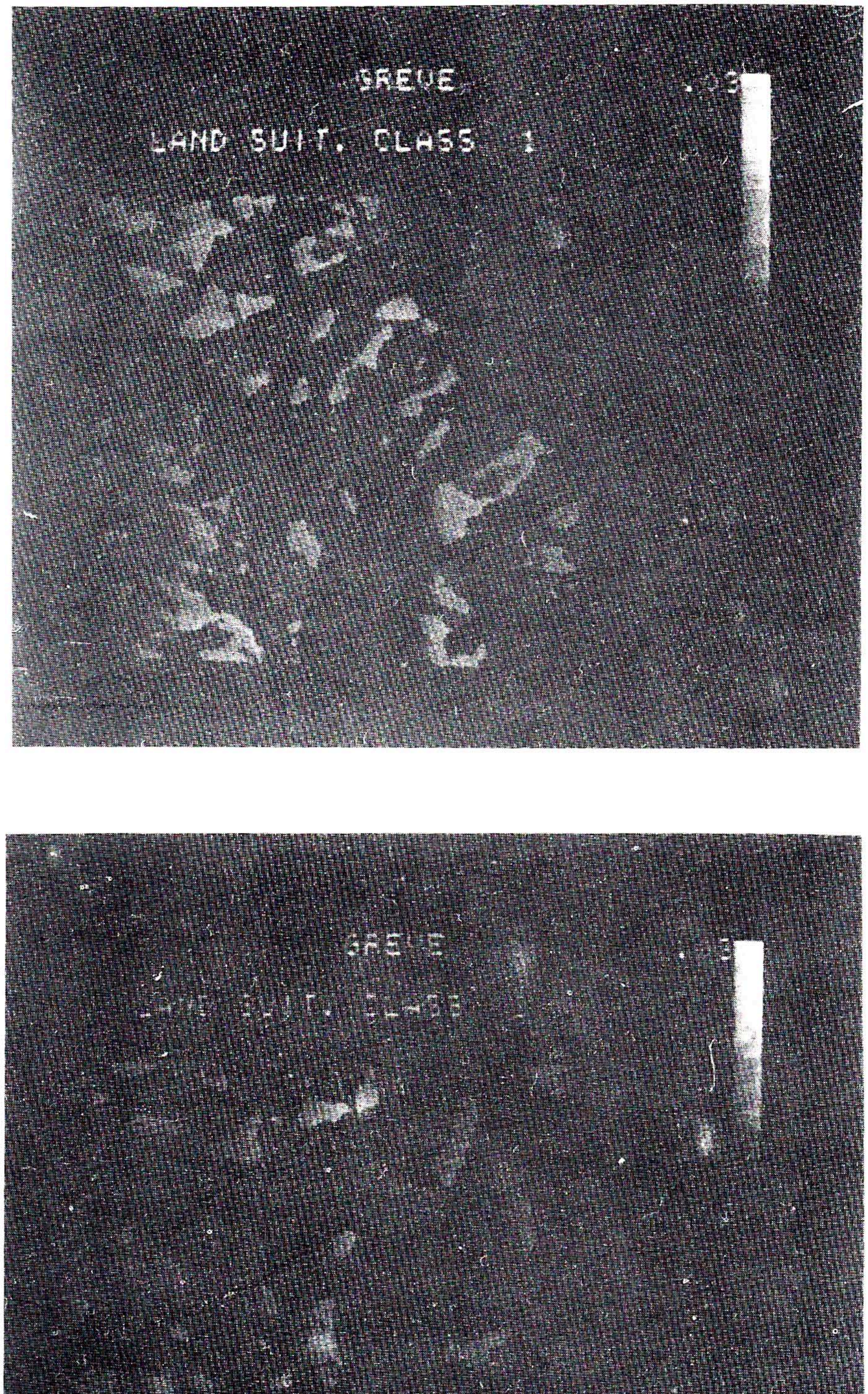

Fig. 6-7 - Land suitability maps of two classes (pine wood and thick oak wood) in the study area as derived from the methodology.