Towards a Rational Utilization of Satellite Imagery for Lisbon's Metropolitan Planning

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ABSTRACT

The knowledge of the actual structure and intensity of land cover is a fundamental information for the urban planning. Some aspects of the seeked information can be extracted from satellite imagery. This presentation gives some exemples over the Metropolitan area of Lisbon. First, an image segmentation is accomplished over an XS3 band. This process leads to a rather valid subdivision of the region in morphological units (Fig. 1.). Secondly, the urban and vegetal categories, issued from a land cover classification, are modeled in the form of statistical surfaces (Fig. 2 and 3). The statistical surfaces take advantage of the analytical power of a raster solving approach. Finally, the urban and vegetal intensity surfaces are merged. The result can be considered as an attempt of ecozoning the considered region (Fig. 4). The paper discuss also the possibilities of using remotly sensed data for urban planning.

1. INTRODUCTION

1.1 Objectives

Remote sensing is particularly effective in the field of the survey and the study of the evolution of land uses over relatively extended regions, knowing a strong growth but missing current and homogeneous information. The metropolitan area of Lisbon (MAL) meets this definition. The need for urban planning in the MAL requires the execution of inventory studies at a reasonable cost, rather accurately and in acceptable delays. One solution is the processing of remotely sensed data.

This investigation presents fundamental and applied aspects.

The fundamental approach concerns for instance:
the execution of mathematical morphology methods in order to improve the segmentation of images and the quality of classifications;
the modelling of some groups of information coming from classifications.

Among many others, applied aspects relate to:
the achievement of cartographic inventories and statistical surveys of land covers;
the integration of some results in the framework of the urban planning policy.

1.2 The Metropolitan Area of Lisbon (MAL) and its characteristics

The MAL is located in the southern part of the Lisbon Peninsula and in the northern district of the Setubal Peninsula. The MAL consists of sixteen local administrative units or municipalities.

From the topographic and the geological points of view, the area of interest is particularly heterogeneous. The original site of Lisbon is very much transformed. It corresponds to the depression situated between the basaltic hills of Monsanto to the west and the marly hills of Retalho de Planalto to the east. On the southern side of the river, the hills of Almada are characterized by a monoclinal structure with a limestone bedrock.

"Although small in area, about 2 600 km^2 (3% of the national territory), the MAL concentrates a significant part of the country socioeconomic structure. In fact, in 1981, it sheltered 1/4 of the national population, retained about 1/3 of the national employment, providing for 2/5 of the national employment in the tertiary sector, and having more than half of the headquarters of the main national societies located within the region" (Vasconcelos and Geirinhas, 1991, p. 1).

1.3. Urban planning policy

The fast and chaotic urbanization of the agglomeration of Lisbon and the projet of building a bridge over the Tage have justified as early as the end of the 50's the conception of a first metropolitan plan (Plano director da regiao de Lisboa PDRL). It has been closely followed by the achievement of a master-plan of the municipality of Lisbon ("Plano director" of Camara municipal de Lisboa) and also by an attempt to match these two town planning tools.

The 1981 demographic census has revealed important differences between the forecasting and the reality. Besides, the authorities have lost the control of the development of the residential function. Everywhere, illegal residential settlements and touristic allotments are increasing in number.

Previous town planning instruments are obsolete and the realization of a regional master plan ("plano regional de ordenamento do territorio da àrea metropolitana de Lisboa") is starting now. The publication of this report has been delayed because of the difficult selection of the site of a new bridge over the Tage river.

Recently, the enacted legislation of (DL 338/83) recognizes the need to develop a land use plan for the whole metropolitan area of Lisbon (Vasconcelos and Geirinhas, 1991, p. 8).

2. METHODOLOGY AND APPLICATIONS

2.1 Satellite imagery

The metropolitan area of Lisbon is featured by a great heterogeneousness in building materials, natural land covers and allotment, and by the dynamism of the urbanization. Consequently, frequent spatial alterations appear in the nature and the intensity of the land cover.

These constraints, as well as the considered applications, impose the use of both TM, XS+P images. TM image provides the synoptic view and the required radiometric informations. Owing to their geometrical quality, XS data allow to discriminate spatial structures which are significant in urban environment.

The paper deals only with intermediate results which are limited to the processing of the sole XS+P image. The communication concerns the core region of the MAL, especially the municipality of Lisbon on the right side of the river and the municipality of Almada on the left side.

Recently we obtained a cover of aerial photographies taken in august 1986 at the average scale of 1/28,000. No updated aerial cover is available.

2.2. Contributions of the mathematical morphology

The mathematical morphology allows, on the one hand, the image segmentation and, on the other hand, it contributes to the improvement of the classification process and to the cartographic representation.

a. image of texture

The image of texture was completed by the Canadian Textran software (D. Marceau, 1990). Values read in the band 3 of the image was reduced to 16 grey levels. A 25 x 25 convolution window was used to compute all kind of neighbourhood (for 16 levels and the four main directions). The algorithm computes statistics only on pixels having at least one point in contact. After normalization, between 0 and 1, these values were regrouped into 16 x 16 co-occurrence matrix.

The entropy was calculated on this matrix according to (2) in which Pij represents the value of the matrix in the (i,j)th cell and Ng represents the quantization level of the image (here, Ng=16):

$$\text{ENTROPY} = \sum_{i=1}^{Ng} \sum_{j=1}^{Ng} Pij * Log\, Pij \qquad (2)$$

b. segmentation of the texture image

A mask containing the most contrasted curves is obtained by levelling the image of entropy. This mask is submitted to a network-like processing. It includes: restoration of the line continuity, major filtering and "skeletization". Then the binary image is converted by a algorithm of propagation into an integer image (I2 or I4) in order for each pixel to contain the number of its own zone.

Zones presenting concavities are splitted according to an erosion process followed by several dilatations completed from the fundamental nucleus. In this example, 165 new zones were added by this procedure to the 1433 initial ones.

The next step consists of replacing the number of zones featuring the pixels by any kind of radiance statistic such as the average value of the zone. Various processes can then be applied : zonal classification, functional subdivision, etc. In this example, zone are simply clustered in a few categories by density slicing (Fig 1.).

Fig. 1 - Lisbon: discrimination of urban land cover by segmentation.

2.3. Inventory by land cover classifications

A classification of landcovers was performed on the core of the agglomeration (Lisbon and Almada). At the beginning, this classification included about forty items defined, notably, according to the Corinne landcover legend. Classes were grouped into a dozen of categories, in order to comply with the requirements of the Lisbon master plan and also to meet the modelling needs. The classification was improved with mathematical morphology processings.

The legend used in the application is the following:

- water bodies
- industry and services
- housing (continuous)
- housing (discontinuous)
- crops
- meadows
- forest
- building sites and bare soils
- transportation network
- not classified

This legend must be compared with the one designed for the fulfilment of the master-plan. It is composed of the following classes:

"specific zones"
  natural ecosystems (valuable from the tourism and landscape point of view)

urban zones
  consolidated housing
  peripheral housing
  illegal housing

suburban zones

rural zones with dispersed settlement

agricultural zones
  consolidated agriculture adapted to natural conditions
  agriculture with uncertain vocation

forest zones
  consolidated forest zones of sufficient size and density
  fallow land with regeneration

industrial zones
public plants
transportation networks
small dwelling nuclei

This list is unusual to some extents, but it seems well adapted to user's requirements. A substantial part of this information is available through digital remote sensing. This classification has not yet been validated. However, it is likely to be of sufficient accuracy and fidelity for the modelling and the segmentation achieved in the current state of investigation.

2.4. Modelling of thematic content

Another objective of the study consists in the modelling of some groups of land covers issued from the classification. A well-known method used to process land covers consists in their transformation into a surface model according to the potential formula (Nadasdi and al., 1991). However, experience shows that many users are not able to interpret correctly this concept. For this reason, other indices are proposed in this research: the built-up area (so called "emprise au sol" in Belgium and CES in France) and the floor area index (P/S in Belgium and IOS in France).The latter takes into account the height of buildings. These indices are morphological indicators which are of prime importance for urban planners.

a. built-up area

In image processing, this index consists of counting the number of pixels belonging to the urban classes within a moving window of appropriate size. The rate of urban pixels, expressed in percentage, is attributed to the central pixel of the window.

b. floor area index (urban intensity) and vegetation intensity

The floor area index (FAI) requires a selection of weighting coefficients for each class of urban cover (Fig. 2.). A rather similar approach must be applied to the vegetation classes to express the vegetation intensity (Fig. 3.). This index is called vegetation intensity. The FAI statistical or urban intensity surface highlights the structure and the gradients of density. It is more attractive than the unweighted model.

c. ecozoning

The informative value of these constructions can be amplified by their synthesis and produces ecozoning (Fig. 4.).

A graphical and original processing consists in the overlay of the FAI and the vegetation intensity. Each surface is sliced and then displayed in a fundamental colour, respec-

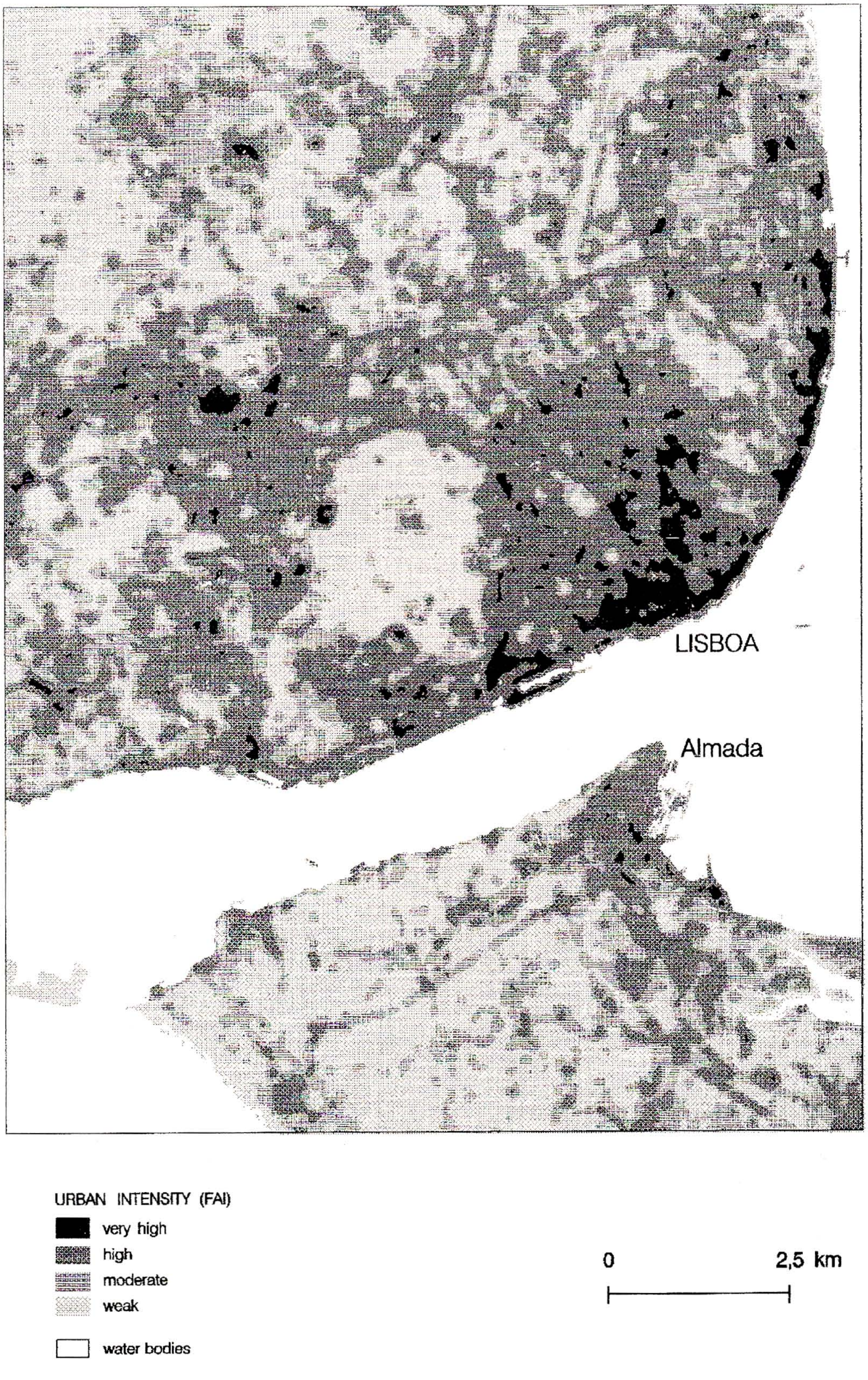

Fig. 2 - Core region of Lisbon's metropolitan area.

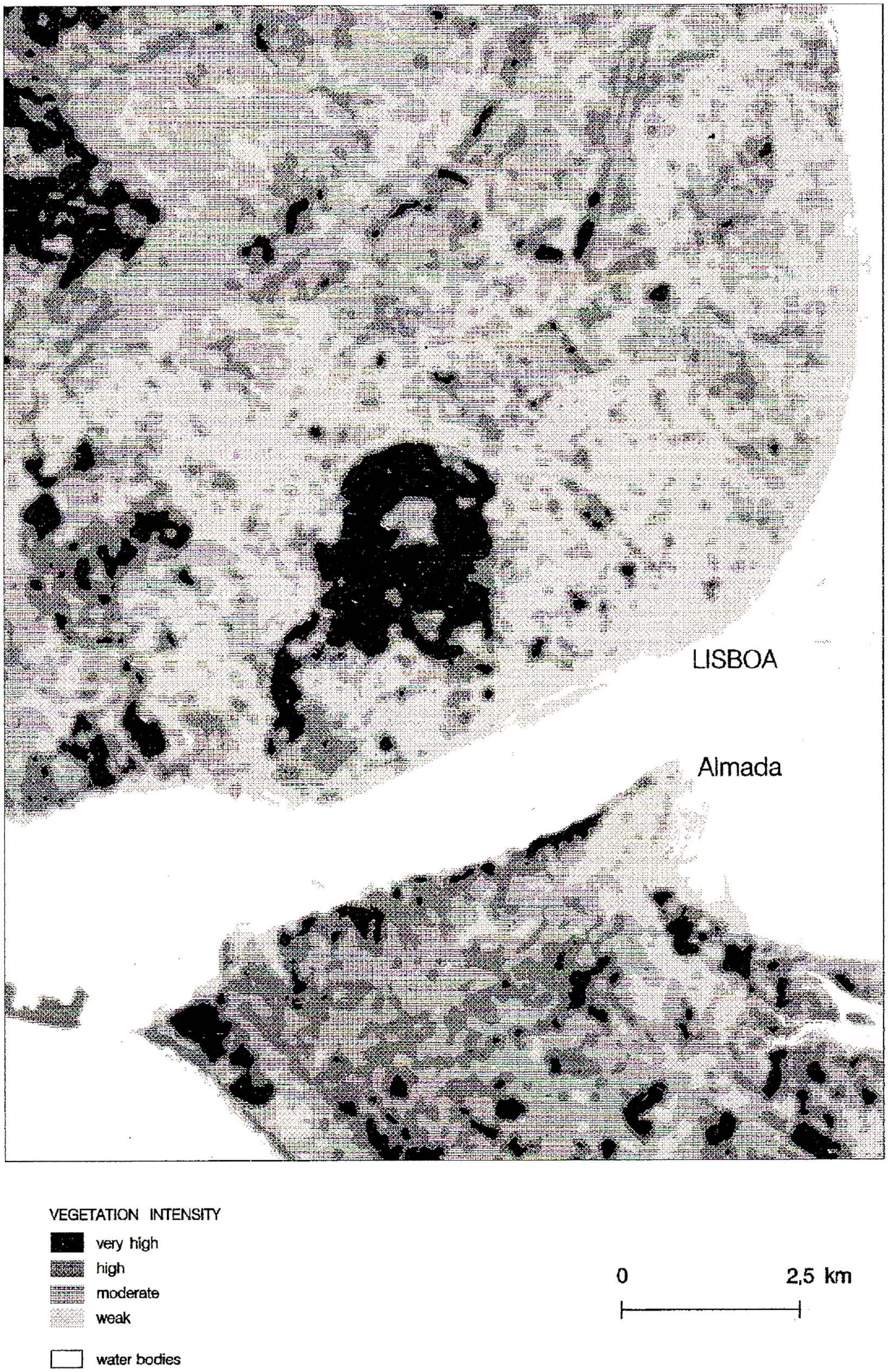

Fig. 3 - Core region of Lisbon's metropolitan area.

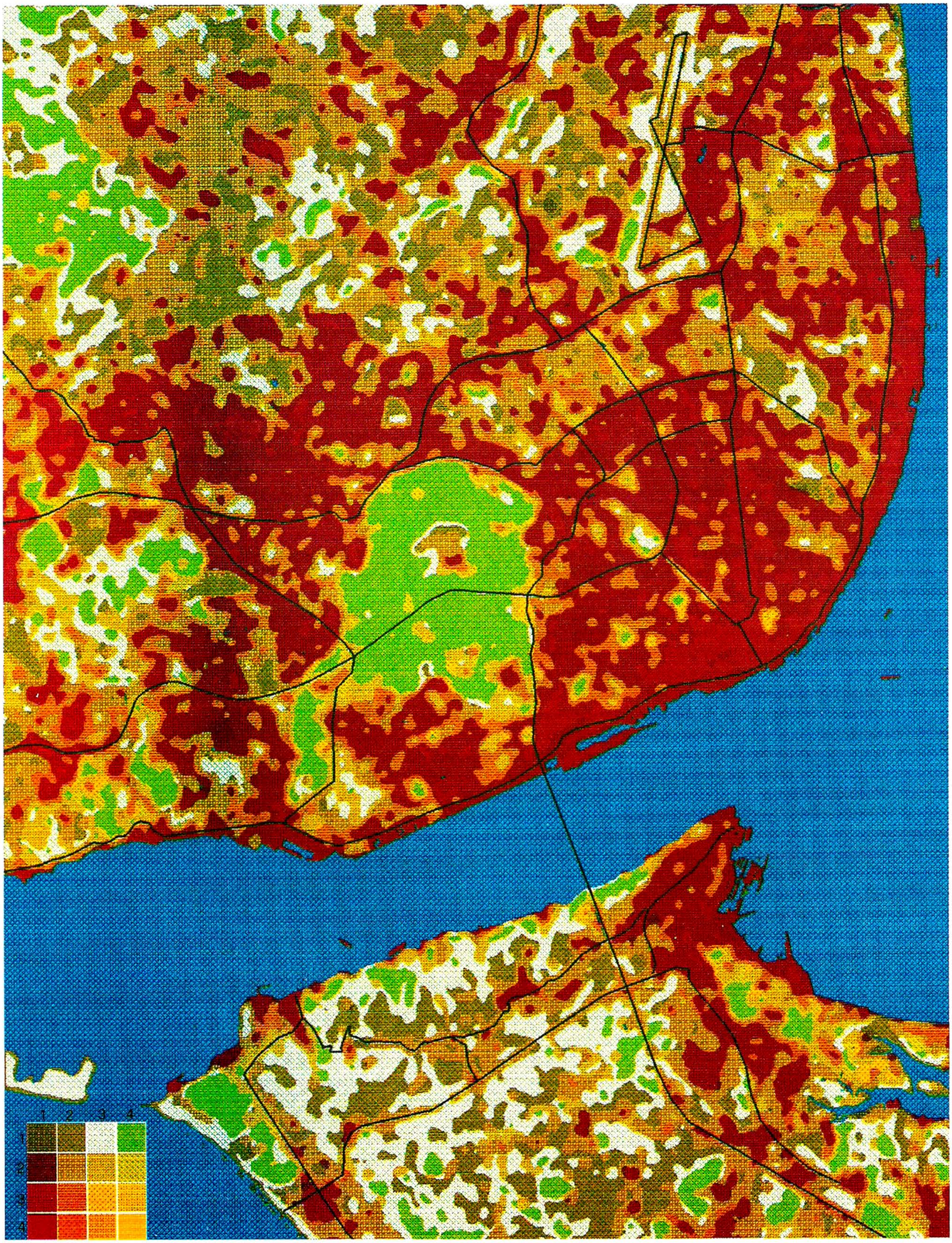

Fig. 4 - Lisbon: ecozoning.

tively red and green. The result of the colour composite is a choropleth map of the residential environment where the yellow colour indicates the simultaneous presence of high intensity of both phenomena.

The urban intensity increases according to the columns, from top (1) to bottom (4), and the vegetation intensity according to the lines, from left (1) to right (4). The matrix of ecozones includes 16 categories delimited by the following classes:

1-1. both urban and vegetation intensities null or very weak

1-4. urban intensity very high and intensity of vegetation null or very weak

4-1. urban intensity null or very weak with high vegetation intensity

4-4. both urban and vegetation intensities very high

The other classes correspond to intermediate combinations. In this application, the last three classes (2-4, 3-4, 4-4) are not present.

It is worth noting that the classes 2-3, 2-2 and 3-2 express a gradient of housing, relating to essentially unifamilial residential areas with increasing vegetation. This can be seen as a more detailed subdivision of the housing settlement according to its degree of vegetation environment. Nevertheless, the validation of these results is required before any definite conclusions.

CONCLUSIONS

For the next phase of the investigation, classifications and segmentations will be realised using TM imagery over the entire area of the MAL. With the help of our Portuguese Colleagues, the information obtained from satellite imagery will be completed with introduction of socio-economic data.

Geographical entities defined by segmentation and regrouped from considerations of morphological and fonctionnal criteria will be submited to a multivariate statistical typology. The opportunity of an utilisation of these results for population census sampling is considered. Results of land cover classification will be integrated in the futur monitoring of the metropolitan area.

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