Land use map of Lisbon metropolitan area: information for monitoring urban sprawl - The CARTUS project

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LAND USE MAP OF LISBON METROPOLITAN AREA: INFORMATION FOR MONITORING URBAN SPRAWL - THE CARTUS PROJECT

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ABSTRACT

CARTUS-AML project[1] (Land Use map of Lisbon Metropolitan Area) is based on three general ideas:

1. Land use can express, although partially, the complex relation between Man and Territory;
2. The understanding of this complex relation requires spatial and time referenced information**.** To understand this complex relation spatial information, that must be time referenced is required;
3. This spatial and time referenced information helps the agents/actors of production and transformation of the metropolitan space, in the decision-making process.

These three general ideas admit the measurement of one of the physical dimensions of the metropolitan phenomenon: land use change. This measurement (by surface) consists, basically, on the location and calculation of areas of change and areas that remained unalterable.

In the context of the presented arguments, an idea was developed to yield and produce land use maps using the most evolved tools of spatial data acquisition and management: Remote Sensing (aerial photographs and satellite images) and Geographic Information Systems.

At the current research stage, we give privilege to land use cartography (the qualitative or the map as the visual support of *knowledge*!) and the measure of occupied areas (the quantitative or the statistical data as a way to make reality 'accurate').

The project was started with the Lisbon Metropolitan Area (AML) land use inventory, referring to 1990. This date, considered 'moment zero', was chosen because quantified land use areas can be crossed with 1991 Census data, despite a one-year gap.

Change survey will cover map production for the years of 1998 and 2005. This project, anchored to the Geography and Regional Planning Centre of Studies (CEGPR) of New University of Lisbon, is being developed with the support of the Lisbon Metropolitan Area. It has involved, in its start (digitalisation, field and image-interpretation works), Geography and Regional Planning graduating students that have chosen Remote Sensing and Thematic Cartography as optional background knowledge.

This project has become part of a dynamic study of Land Use Observation, that aims to achieve historic Meta Data base of Land Use Changes at Metropolitan Area Of Lisbon, with more and more accuracy of statistical values obtained by the use of New Technologies of Information, mainly GIS and Remote Sensing.

Also Coastal Management is a particular matter that has occupied our attention and therefore has been a leitmotiv for more detailed studies on a bigger scale concerning man's pressure on this part of the territory, over the resources that are insufficient to the growing needs of the population living there. Guided by the principles of the Brunndtland report ('Our Common World') about Sustainable Development, we hope to dedicate more efforts to the coastal management theme.

1. CARTUS PROJECT - THE GENERAL IDEAS

The Lisbon Metropolitan Area (LMA) is located on the riverbanks of the Tagus estuary (one of the largest estuaries in Europe, with 325 km^2), and it spreads south towards the Sado estuary, in a continuum of buildings, which were progressively raised in a landscape of exceptional beauty and richness due to its morphologic diversity of fauna and flora. The LMA is an independent institution with deputies elected from 19 municipalities that belong to this area. The southern bank is composed of 9 of the 19 municipalities,

and has 658,320 inhabitants while the northern part has a population of 1,897,860 inhabitants, of which 591,480 live in the capital, Lisbon, one of the 10 municipalities located along this bank.

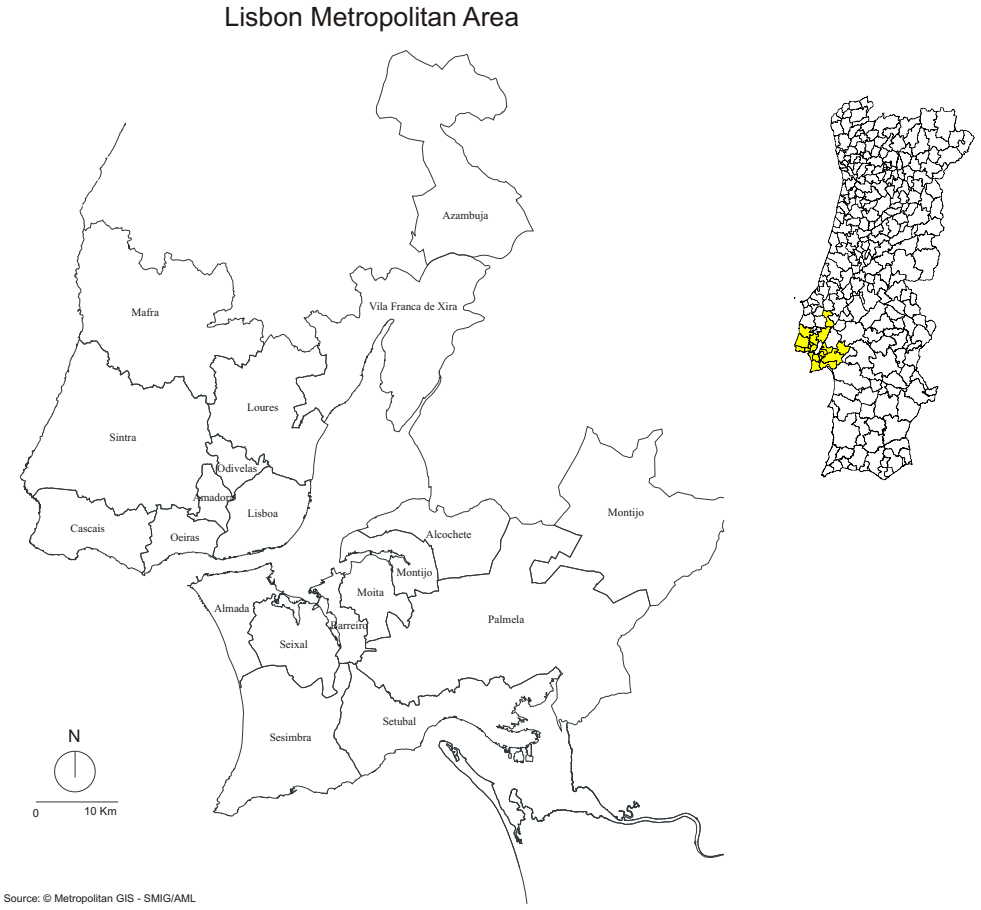

Figure 1. Portugal and the Lisbon Metropolitan Area

Table 1. Statistical Indicators 1991, INE.

	Persons per Km2	Population by age			Unemployment	
		0-14	15-64	65+	Total	%
LMA North	1185,0	17,6	69,6	12,8	63460	6,9
LMA South	421,0	19,3	69,8	10,9	27625	9,3
LMA Total	812,0	18,0	69,7	12,3	91198	7,5

2. INFORMATION

The Land Use Map is produced at a 1:25000 scale, with 15 classes (level 1) on a first step, and 19 at the second step. The information was taken from visual analysis (photo interpretation) computer aided design with vertical aerial photographs, and orthophoto maps, satellite images SPOT XS and LANDSAT TM with the topographic base taken from Portugal Military Map.

Considering the project's thematic detail and the final presentation required scale, actual land use cartography was accomplished with vertical aerial photography (panchromatic and color infrared) and photo-identified and/or information update field work support.

The minimum cartographic unit for the CARTUS Land Use Map at 1:25 000 scale is 0,5 ha.

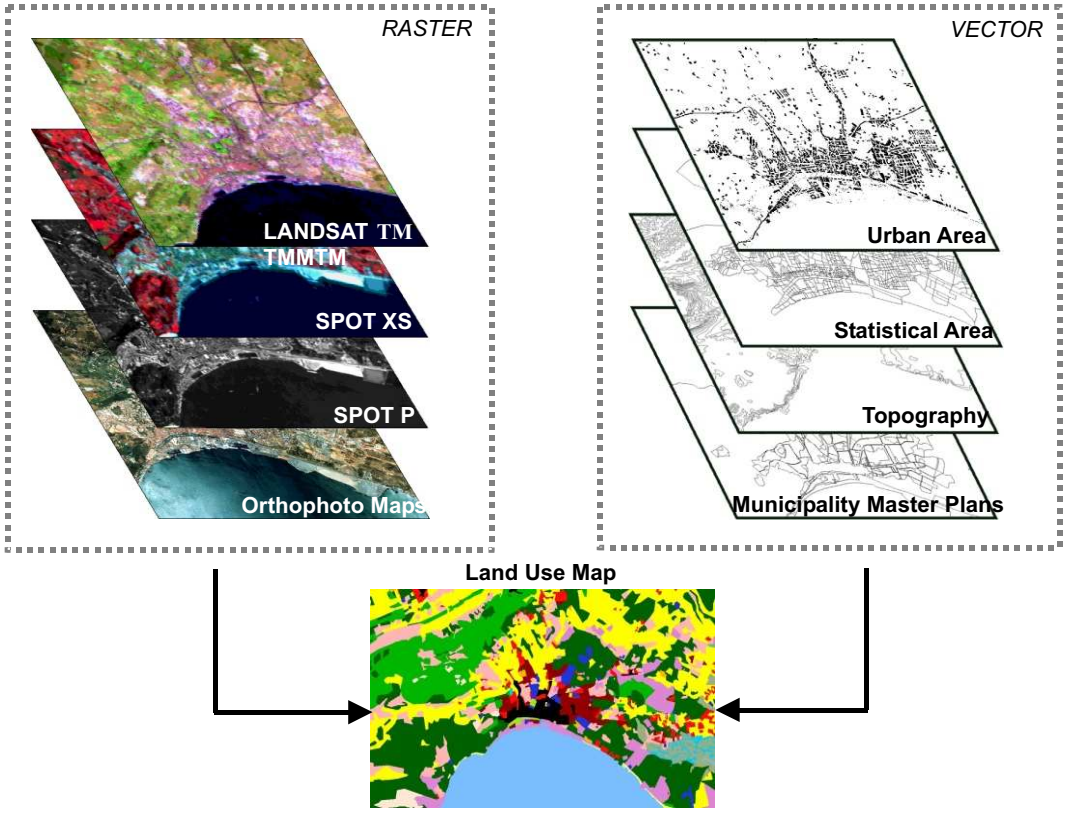

Figure 2. Information sources

3. GENERAL METHODOLOGY

A visual analysis computer aided information deduced from orbital remote sensors LANDSAT TM and SPOT HRV spectral band association was also included.

Applied land use classes are exposed in table 2. The classification considers output scale production (cartographic generalization level) and images resolution allowable detail (analysis level).

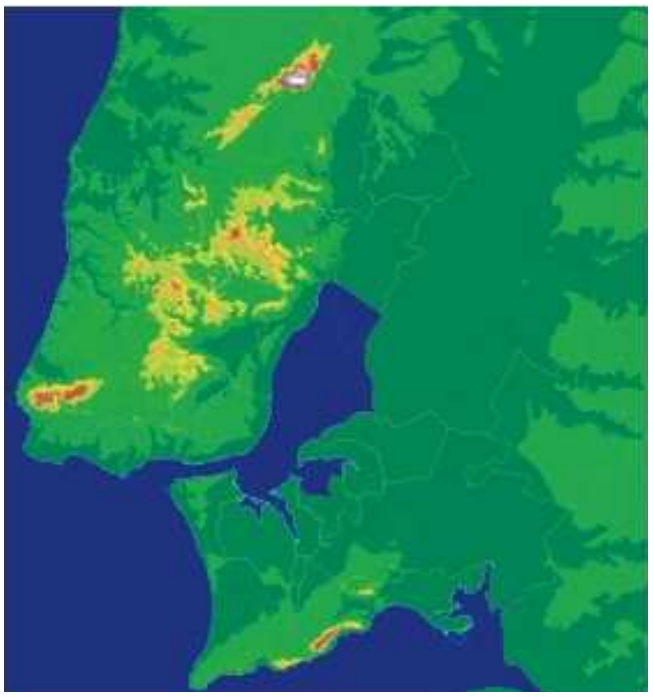

Figure 3. Altimetry Data of LMA

Table 2. Used Land Use Codes

	CODE	LAND USE
1	Mu	Multi-functional area
2	Ca	Historical Centers
3	Hp	Multi-Family Housing Area
4	Hu	Single Family Housing Area
5	Ge	Metropolitan Equipments
6	Pi	Ports, Industrial and Storage Area
7	Ap	Mining Area / Quarry
8	Gc	Shopping Centers
9	Am	Area of Military Installations and Fortifications
10	L	Allotted Areas
11	A	Agricultural Area
12	Aa	Agro-forestry Area
13	Iv	Unused and Uncultivated Fields
14	M	Shrub
15	Af	Forested Area
16	Pc	Beach, Rocky Coast and Coastal Vegetation
17	As	Marshy places
18	Pa	Lagoons Salines and Salt-Pan
19	Av	Green Urban Area

The Classes (see also table 1) next described, were determined as a function of the territorial and temporal dimension that the project involves, the detail and accuracy of the available features.

Metropolitan Multi-Functional Area: Center of Lisbon City, (grouping multifunctional areas: habitation, services and commercial buildings, urban equipments). This class does not present a unique use but a multifunctional area.

Historical Centers: residential areas, commercial and services buildings; patrimonial buildings; small industries and warehouses; collective equipment; small infrastructures; streets, avenues and squares; empty spaces; street systems; churches and other religious buildings; gardens; public spaces in general. This class was defined from a topographical map, at 1:25000 scale, of dates previous to 1960. It includes urban renovation “lot by lot” but whose modification does not exceed the minimum area of 3x273 mm, defined for the purpose of photo-interpretation.

Multi-family housing area: residential buildings, generally with more than two floors; commercial and services buildings; patrimonial buildings; small industries and warehouses; equipment of collective use; small infrastructures; streets, avenues and squares; empty spaces; road and rail networks; churches and other religious buildings; gardens; public spaces in general. The definition of these areas is based on the predominance of the residential function.

Single family housing area: residential buildings, generally up to two floors, including gardens, vegetable gardens and annexes; commercial and services buildings; patrimonial buildings; small industries and warehouses, equipment of collective use; small infrastructures; streets, avenues and squares; empty spaces; streets systems; churches and other religious buildings; gardens; public spaces in general. The definition of these areas is based on the predominance of the residential function.

Metropolitan equipments: school buildings and of professional formation; hospitals; sport and leisure facilities; parking areas; mills; deposits of water supply deposit; electricity transformation poles; waste water management centers; terminals of public transports; commercial spaces; airports; other spaces of public use. Only, the equipment in proper buildings are included.

Ports, Industrial and Storage area: pavilions, chimneys, pipelines, deposits of materials and containers; general wharves of boarding and sea port installations; areas of parking belonging to the industrial areas.

Shopping Centers: Commercial places in proper buildings.

Mining Area / Quarry: areas for extraction of inert; pluvial water plans in areas for extraction of inert;

machinery of sand depuration; loose sloping lands.

Area of Military Installations and fortifications: materials deposits, guarded parades and fences, forts, rough stonewall areas;

Allotted Areas: lands where the aperture of ways is visible; mesh of streets layout in unasphalted land or already with asphalt; leveling of the ground, without buildings or with buildings in the construction phase;

Agricultural area: Land principally occupied by agriculture, with significant area of natural vegetation, orchards and vegetable gardens, vineyards; cereals of dry and irrigated land; olive groves; other land with agricultural use.

Agro-forestry Areas: agricultural and forestal use found together.

Uncultivated and Unused Areas: abandoned or in fallow ground lands; empty urban areas (empty lots within constructed zones, or areas of bigger dimension contiguous to consolidated urban or growing urban sprawl).

Shrub: covered shrubby and/or herbaceous vegetation associations.

Forest area and Bushes: arboreal covered; pine tree plantation; eucalyptus grove ; plantation of cork-trees.

Beach, Rocky Coast and Coastal Vegetation: beach dunes and sand, maritime or fluvial coastline, arenaceous and/or rocky formation, natural and/or semi-natural vegetation.

Marshy places: silt; vegetation in wet zones; marsh.

Lagoons, salines and Salt Plains: coastal wet lands, small lagoons, natural or artificial and other water bodies; salt plains, salt marshes.

Green Urban Areas: Gardens, urban parks.

Considering the detail of the legend and the scale demanded for final representation, the Land Use Map has been elaborated with vertical feature, panchromatic aerial photograph and infra red colorful, on the average scale of 1:15000, and also with field work for validation of the photo-identified uses. The work also needs data got from orbital remote sensors, nominated SPOT HRV in panchromatic and multi-spectral mode, once the geometric resolution (10 and 20 meters, respectively) guarantees, at least, the necessary identification of the uses with a greater space-time dynamics. The work comprises six distinct steps:

3.1. Classes/criteria matrices development

This phase comprises identification of spatial (texture, structure, position, connectivity, spatial patterns) and spectral (gray levels, color) descriptors of each actual land use and the essential combined fieldwork to produce the photo-interpretation key. The land use classification decision rules were built from the data. The result of this work took form in a matrix made of land use classes and by the selected rules and criterion.

Land use recognition as spatial discontinuous and functionally homogeneous object aggregation provided the identification principles. Each identified use is the combined product of imaging interpretation with the knowledge of the landscape's structure.

3.2. Photo-Interpretation Pre-Validated by Complementary Information

Existent land use was obtained mainly by vertical photography interpretation based on the precedent phase labour and in Figure 2 proposed model. Geo-referenced exogenous information was accessed to complement and/or pre-validate obtained information, specifically in what refers to “Public Buildings” area” and “Agricultural area” themes.

Geo-referenced exogenous information included the consideration of the following elements: CORINE Land Cover cartographic data (1: 100 000 scale), National Ecological Reserve (REN) and National Agricultural Reserve (RAN) cartography, approved MMP's infrastructures and collective equipments' plants, and other thematic cartographic objects published by official institutions and basically related to geology land use capability and topography.

3.3. Identified Land Uses Validation

The identified Land Uses Validation step included stratified samples from fieldwork, respecting step 2 cartographic elements compatibility, relating to scale and thematic desegregation level.

Aerial photography interpretation inaccuracies were recorded in a matrix (Figure 5) where each cell indicates, for the area of each topographic chart, the detected error. The errors were corrected in step 5.

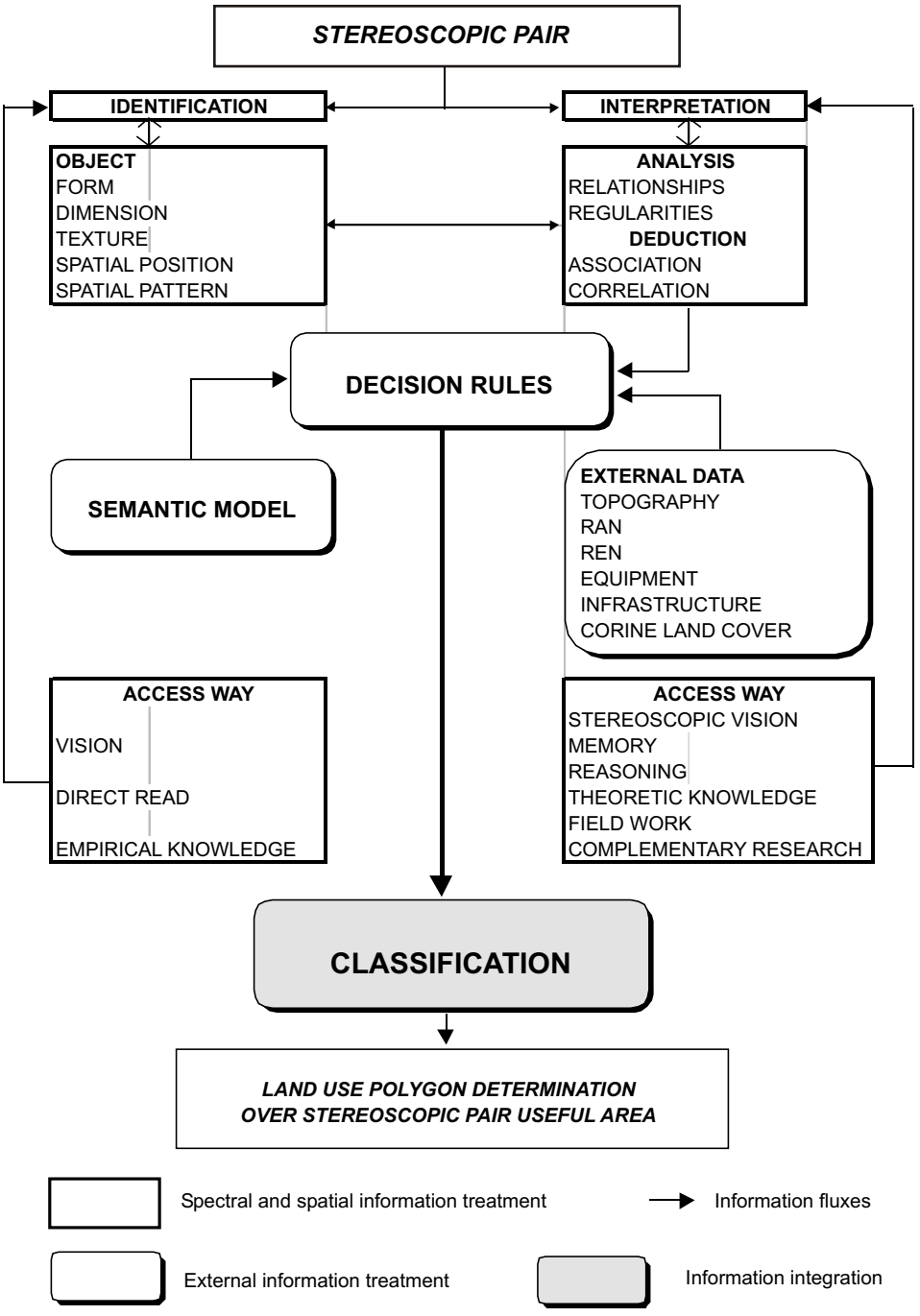

Figure 4 . The result of the current land use polygon model by each useful area of each stereoscopic pair.

		PHOTO-INTERPRETATION															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
	1																1. Constructed Area Before 1970
	2																2. Multi-Family Housing Area
	3																3. Single Family Housing Area
	4																4. Public Buildings
F	5																5. Port, Industrial and Storage Area
I	6																6. Mining Area
E	7																7. Military Area
L	8																8. Allotted Areas
D	9																9. Agricultural Area
	10																10. Unused and Uncultivated Fields
	11																11. Shrub
	12																12. Forested Area
	13																13. Beach, Rocky Coast and Coastal Vegetation
	14																14. Marsh, Salt-Pan and Marine
	15																15. Lagoons

Figure 5. "*Confusion matrix*" structure used for field land use validation.

3.4. Non-Deformable Film Restoration

The restoration of the present land uses polygons was performed over an non-deformable film at the output production scale, as defined in Step 6.

3.5. Scanning and Polygons vectorization

This step allows translation of the information gathered under the previous steps to digital format, including: present land use polygon scanning, vector mode transformation and centromers calculation. Figure 6 illustrates the intermediary output.

3.6. Outputs creation

The final products obtained were:

a) Land use polychromatic chart, at a 1:25 000 scale, under the sectioning of the Army Geographic Institute, with the cartographic background made of the following elements: Gauss coordinates, contour curves, water lines, railroads, roads, altimetry and administrative boundaries.
b) Statistical data matrix with the area occupied by each present land use class;
c) Report of classification, description and quantified characterization of present land uses.

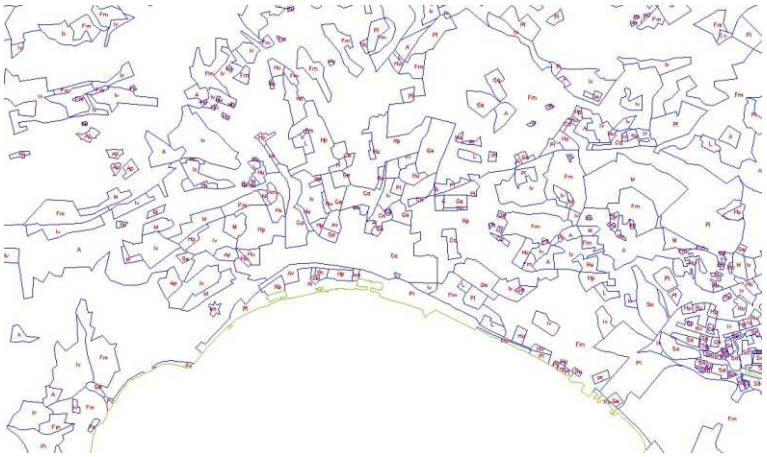

Figure 6. Landscape Use Polygons and Associated Linked Codes: Setúbal

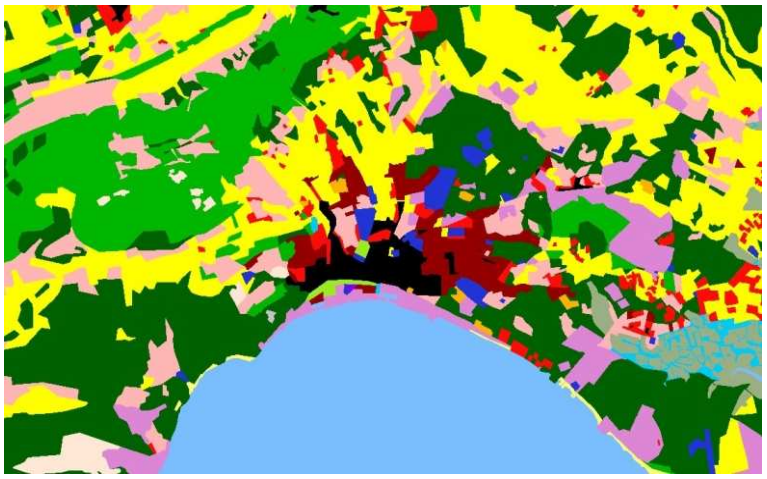

Figure 7. Shows an illustration of Setúbal City as an example, and later on all the Lisbon Metropolitan Area will be presented.

4. RESULTS

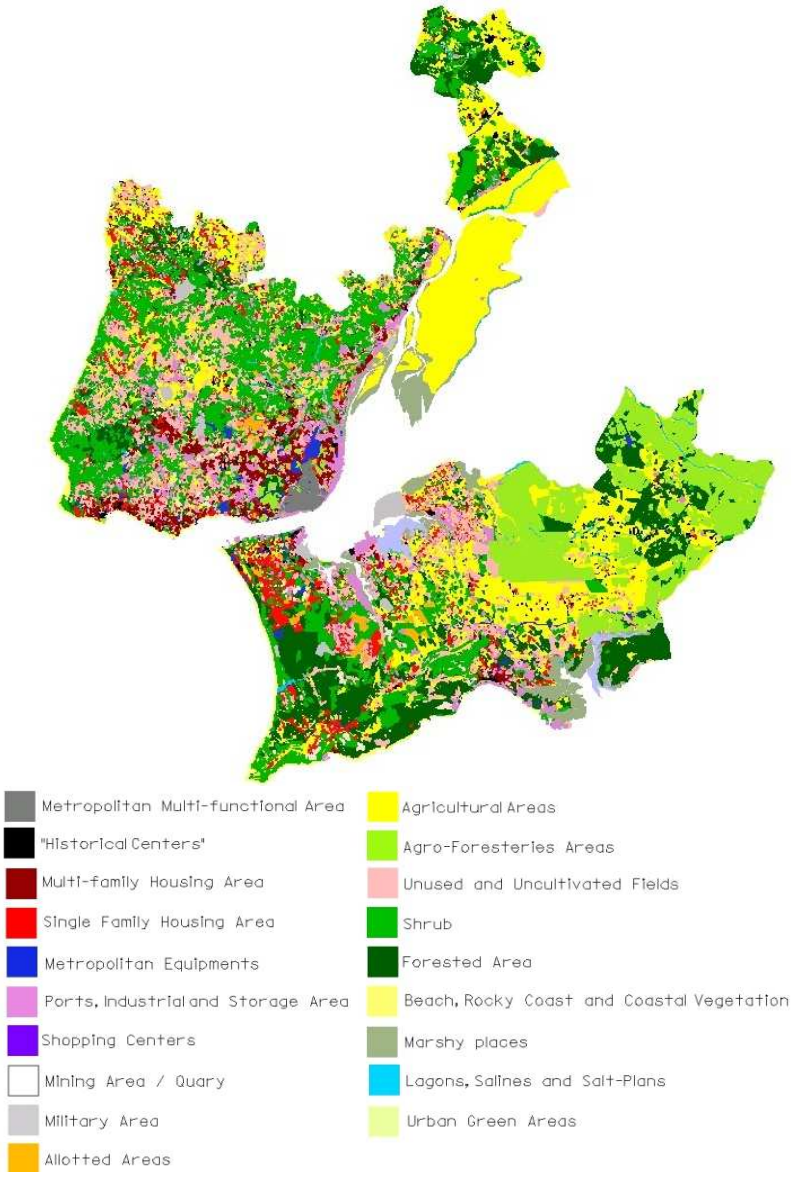

Figure 8. Land Use Map for Lisbon Metropolitan Area

In a final phase all polygons were geometrically corrected with the ortophoto maps (from 1995) accomplishing in this way a not so notorious difference.

At this moment the land use map is being updated using 1998 ortophoto maps (283 orthofoto maps at a 1:10 000 original scale), covering all the metropolitan territory.

Soon it will be possible to compare the two moments (1990 and 1998) detecting, in this way, modifications occurring on the territory, and to compare land use area values change so we shall be able to show how the tendencies can be modified.

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[1] The Team working on the project is: José António Tenedório (coordinator), (CEGPR of New Univesity of Lisbon), José Carlos Ferreira, Paulo Morgado Sousa, Jorge Rocha, Saudade Pontes, Gizela Mota, Carla Gomes (CEGPR of New University of Lisbon and Metropolitan Area of Lisbon) and Maria Manuel Lira (Metropolitan Area of Lisbon).