A raster-vector approach to GIS modelling: Natural Quality cartography

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The Surveying Department and the Transport Research Centre of the Polytechnic University of Madrid (TRANSyT) co-operated on a research project where the generation of a Natural Quality map for the Peninsular Spain and Balearic Islands was one of the main outcomes. The main purpose of this cartography is to assist on the development of Environmental Reports for Strategic Environmental Assessments procedures.

Some local, regional, national and international organizations have been consulted in order to obtain suitable GIS thematic databases, including the recent Spanish infrastructure of spatial data (IDEE), the European Environmental Agency and the Spanish nature data bank.

The methodology begins with integration and normalization processes of data format (ESRI coverage), data accuracy (100 m), projection and datum (Lambert Azimuthal Equal Area – European Terrestrial Reference System 1989) with the aim of homogenising spatial data sets.

The generation of this Natural Quality map implies the combination of a significant number of maps, finally 12. This high number of variables resulted in a very complex methodology, which forced researchers to work with raster data instead of vector. Raster combination of data has proved to be an efficient way of simulating a vector approach for a high number of datasets. This resulted in a raster map which attribute data was a vector comprising information from 12 environmental variables.

Finally, a synthetic map was yielded through reclassification of the vector previously obtained. This map was assessed for consistency using various protected areas. The developed methodology, based on the used of GIS, has demonstrated the viability of implementation and convenience for future analysis.

INTRODUCTION

The Surveying Department and the Transport Research Centre of the Polytechnic University of Madrid (TRANSyT) co-operated on a research project where the generation of a Natural Quality map for the Peninsular Spain and Balearic Islands was one of the main outcomes. The main purpose of this cartography is to assist on the development of Environmental Reports for Strategic Environmental Assessments procedures.

The generation of this Natural Quality map implies the combination of a significant number of maps. The methodologies involved in the process of integration of distinct variables into one value are based on Multicriteria Evaluation, part of Decision Theory (Malcewski, 1999; Barredo, 1996).

Finally, a synthetic map was yielded through reclassification of the vector previously obtained. This map was assessed for consistency using various protected areas. The developed methodology, based on the used of GIS, has demonstrated the viability of implementation and convenience for future analysis.

In this short communication, some vector and raster methods to yield the cartographic combination of the twelve maps are described, reporting the success achieved in each of them.

METHODOLOGY

Cartographic data

Three main groups of sources have been consulted in order to localize and purchase cartographic data:

- Consultation to the Spanish Spatial Data Infrastructure (IDEE, 2004)

- Consultation to some Spanish institutions and organisms, previously known as cartographic sources (IGME, 2004; DGCN, 2004a)

- Consultation to European Environment Agency Data Service (EEA, 2004) and other international organizations.

The first group of sources did not provide any significant information, probably due to the limited number of Spanish institutions integrated in the IDEE database. The second group provided very valuable data, though its success depends on the researchers' expertise. The European Environment Agency and other international organizations offer cartographic data of broader extent, though in general, at lower scales.

Layer	Organism	Metadata
Soil Type	Food and Agriculture Organization of the United Nations (FAO)	Scale 1:1.000.000 Projection: UTM, zone 30 Datum: ED-50 Digital format: Arc/Info Export (e00)
Protected figures: national, regional, natural parks; RAMSAR, Natura 2000...	DGCN	Scale : 1:50.000 Projection : UTM, zone 30 Datum: ED-50 Digital format: Arc/Info Export (e00) and ArcView Shapefile
Habitat map	DGCN	Scale: 1:50.000 Projection: UTM, zone 30 Datum: ED-50 Digital format: Arc/Info Export (e00)
Digital Elevation Model	SRTM project (NGA, NASA)	Horizontal precision: 60 m (90%) Vertical precision: 16 m (90%) No projection Datum: WGS-84; geoid model: EGM96 Digital format: non-standar ASCII
Landscape: Atlas of Spanish landscapes	Spanish Environment Ministry	Scale: 1:200.000 Projetion UTM, zone 30 Datum: ED-50 Digital format: Arc/Info coverage
Corine Land Cover	European Environment Agency	Precision: 100 m RMS

Layer	Organism	Metadata
		Projection: Lambert Azimuthal Equal Area Datum: ED-50 (assumed) Digital format: BIL (ráster) and Arc/Info export (e00) (vector) 1990
Vegetation: Spanish Forestry Map	DGCN	Scale: 1:50.000 Projection: UTM, zone 30 Datum: ED-50 Digital format: Arc/Info Export (e00)

Table 1: Map layers used in the Natural Quality model

Data normalization

In order to integrate all map layers, it is necessary to harmonize the cartographic information. Lambert Azimuthal Equal-Area projection was selected as it is recommended by European organization Eurogeographics (Eurogeographics, 2004). This projection advantages other projections used in Spain, Lambert Conformal Conic and Extended zone 30 UTM, in terms of area and length precision. Later projection consists on the use of zone 30 for the whole Spanish peninsula, even though east and west territories should be projected using zones 29 and 31.

A previous statistical analysis was performed based on 11.380 arcs from a road map and 3.090 polygons form the soil map. This arc and polygon samples were projected using the usual projections in Spain and compared to that projected using UTM zones 29, 30 and 31. Polygon areas and arc lengths were computed for all features. Stating the later values (UTM correctly used) as true for comparison purposes, Lambert Azimuthal Equal-Area resulted in the best choice for area calculations and extended zone 30 UTM for length calculations.

95% Precision	Extended zone 30 UTM	LAEA	LCC
Length	±0,27%	±0,88%	±2,60%
Area	±0,84%	±0,23%	±5,32%

Table 2: Area and length precision comparison depending on projection method.

European Terrestrial Reference System – 1989 Datum (ETRS-89) was selected as recommended by Eurogeographics. As most cartographic data in Spain has been created on the European 1950 datum, datum transformations are a common step in harmonization processes. Again, Eurogeographics reports what type of transformation should be used detailing the needed parameters (7-parameter Helmert transformation).

All layers were imported to a unique digital format. For procedural reasons, the digital formats chosen were Arc/Info coverage for vector data and ESRI Grid for raster layers.

Scale was discarded as a normalization objective, being part of precision harmonization. Considering the precision of source layers and future uses of this cartography, precision was established in 100 m RMS and the minimum cartographic unit in 1 ha. These values cannot be reached by the integrated Natural Quality map because some sources exceed these requirements. A fuzzy logic approach should be considered in order to obtain a valid estimation of precision.

Assessment of original Layers

Several assessments of original datasets were made within the framework of this project. A number of multicriteria assessment methods were used (Barredo, 1996; Malczewski, 1999), choosing the Euclidean distance from the origin as the final method for the integration of different valuations. This method can be solved with layer algebra (ESRI, 2004), although the intention was to get a vector were all previous assessments are represented. For instance, vector (2, 3, 1) represents values from 3 variables.
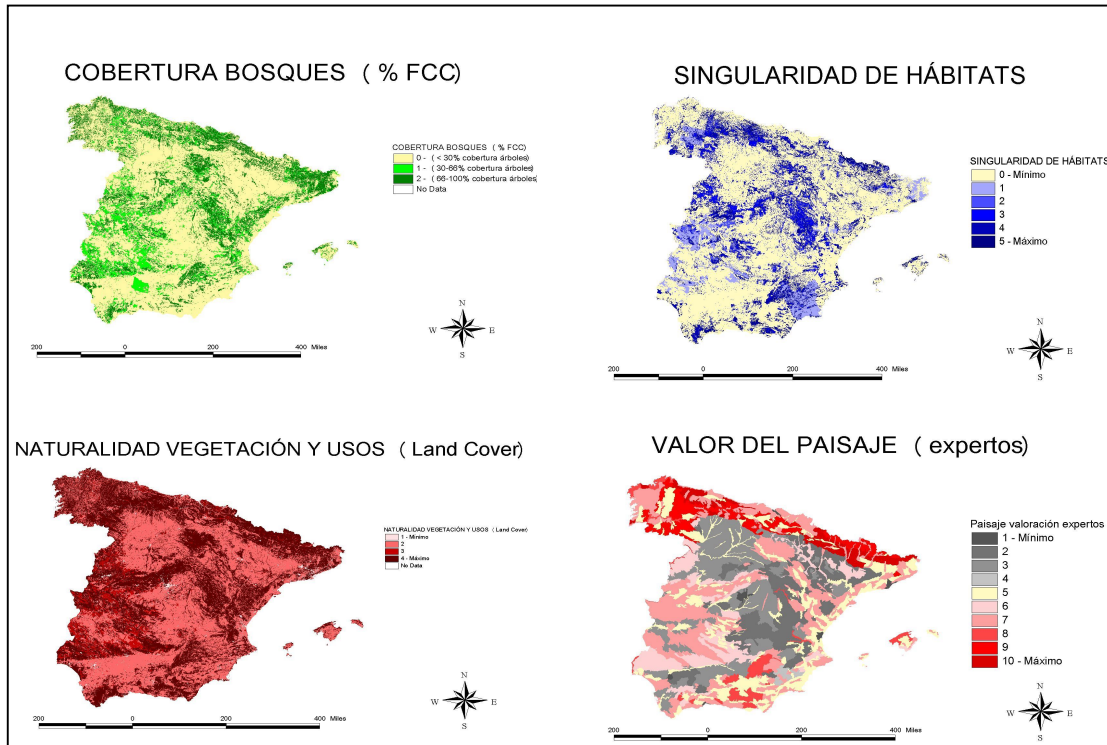
Figure 1: Four of the 12 layers that are integrated in the Natural Quality model

Final Integration

Four different methodologies were evaluated in order to obtain pursued objectives:

- Vectorial Union of all layers using a non-topology format (shapefile)

- Vectorial Union of all layers using a format (Arc/Info coverage and Arcgis personal Geodatabase)

- Vectorial Union of all layers using an external database (Arcgis + ArcSDE + Oracle 9i corporate Geodatabase)

- Raster combination of all layers.

RESULTS

Those three vector methodologies were unsuccessful. The wide territorial extension (500.000 km^2) along with the high number of layers involved caused numerous procedural errors that prevent the whole cartographic union.

Raster layers combination methodology was successful, allowing the union of all layers in a reduced time using a standard PC.

A methodological vector variant implemented through aml language programming (ESRI, 2004) consisted in a split process (split) in different sublayers, union of all maps by sublayers (union) and final combination (append) of sublayers. This process was indeed successful, although it should be taken into consideration that several processing days and programming knowledge are needed.
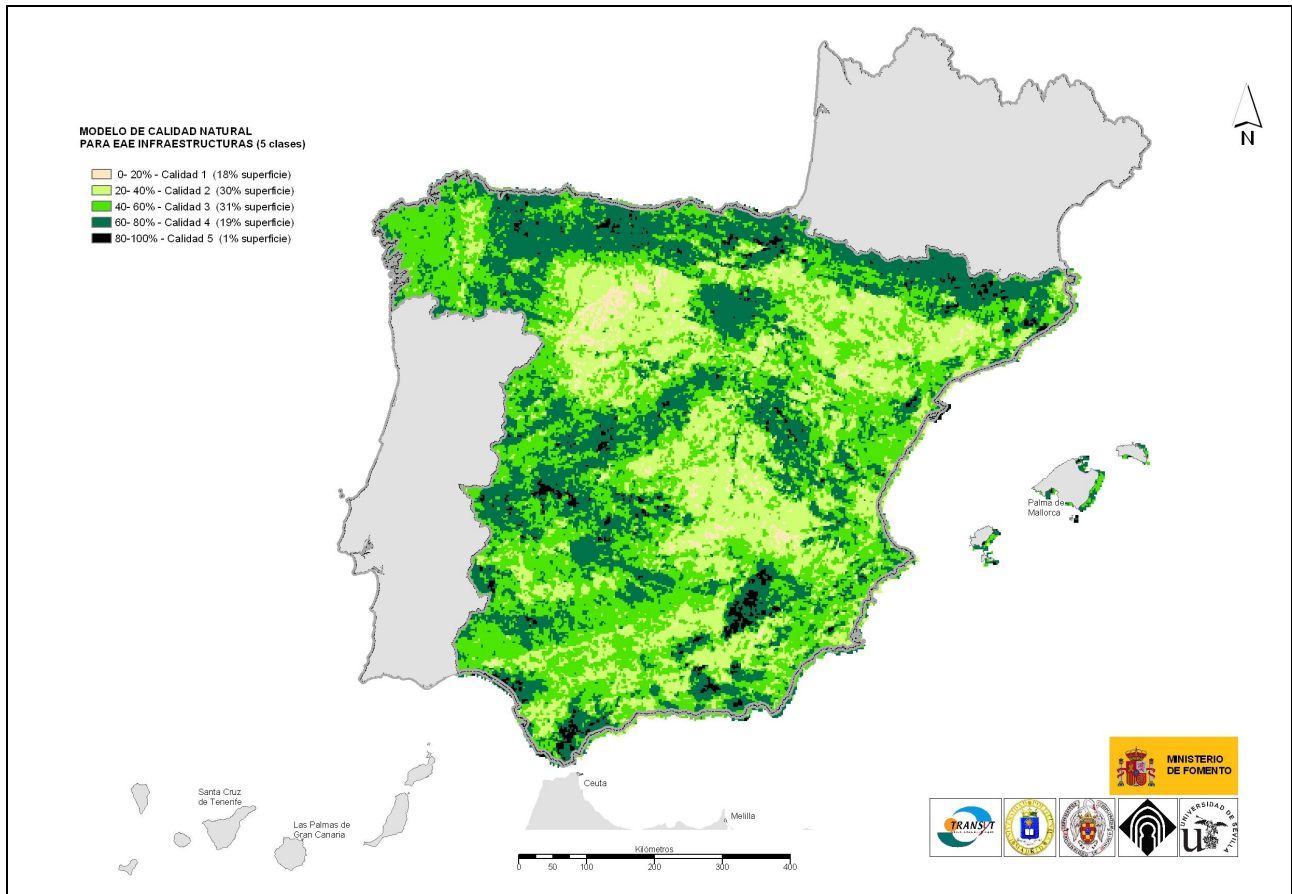
Figure 2: Natural Quality Map for Spain (5 classes)

CONCLUSIONS

In spite of current GIS development, there are large technical limitations in obtaining complex cartographic results using vectorial methodologies. The wide territory considered in this study (500.000 km^2) and the number of layers involved in the model (12) has made technically unfeasible the integration in vectorial format, except by applying programming methods. Experiments have been made using products from just one commercial trade, ESRI, although results in those conditions are important due to the widespread use of such as products, very common both in national and international administrations.

Raster methodology handling simulating vectorial methodologies (raster layers combination) is a suitable solution

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BIOGRAPHY

Dr. Santiago Mancebo, Forestry Engineer and PhD, he teaches GPS and GIS on both graduate and postgraduate levels and researches on environmental and physical assessment and planning in addition to GPS precision and efficiency. He has published 9 books or chapters of books; 9 scientific articles and reports; and 6 posters and brief communications in conferences and congresses, being half of them related to transport planning focusing on environmental issues. Though his recent doctoral thesis lecture, he has researched in 5 projects including *Analysis of impacts caused by land transport as defined in the infraestructure plan of 2000-2007. Connection between spanish and transeuropean networks; Environmental-based Land Planning in Spain and Latin America: application bases; Impact assessment of traffic atmospheric pollutants on people, buildings and urban parks.* His skills in programming and creating model algorithms resulted in 5 software patents, being remarkable the GIS extension *santitools.*