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## 1. Introduction

The Digital Map of European Ecological Regions –DMEER- delineates and describes ecological distinct areas in Europe, on the basis of updated knowledge of climatic, topographic and geobotanical European data, together with the judgement of a large team of experts form several European nature related Institutions and the WWF. The map of ecological regions in Europe is aimed at showing the extent of areas with relatively homogeneous ecological conditions, within which, comparisons and assessments of different expressions of biodiversity are meaningful (Painho *et al*, 1996).

To implement ecosystem management, it is needed basic information about the nature and distribution of ecosystems. In order to improve European efforts to assessing, monitor, plan and share ecological data, this map will help to evaluate inherent capabilities of land.

This document describes the methodology followed in the production of the Digital Map of European Ecological Regions. This map is based on two existing maps that characterise Europe on two major ecosystem components – the vegetation and the climatic conditions.

Although the core classification was automatically performed by data analysis, large adjustments were subsequently made to incorporate the comments and the decisions of biogeography experts.

## 2. Information Sources

The DMEER maps draw on information sources of potential vegetation – Map of Natural Vegetation of Europe (Bonn, 1994)- and topographic and climate data –The European Land (Bunce, 1995).

Vegetation reflects many physical factors found at a site, such as climate, soil, type, elevation, and aspect. It is also the ecosystem's primary production and it serves as habitat for the animal community. Vegetation acts as an integrator of many of the physical and biological attributes of an area, and a vegetation map can be used as a surrogate for ecosystems in conservation evaluations (Specht 1975, Austin 1991). A vegetation map, therefore, provides the foundation for our assessment of the distribution of the ecological regions (Painho *et al*, 1996).

As important as vegetation to the definition of an ecosystem, are the natural physical data as climate, topography and soils. The ecosystem is defined as the set living beings, physical factors and their relationships, found at a particular place.

### *2.1 The Map of Natural Vegetation of Europe*

The potential vegetation map (Figure1) was produced in Germany by the Institute für Bundesamt für Naturschutz - BfN (Bonn, 1994).

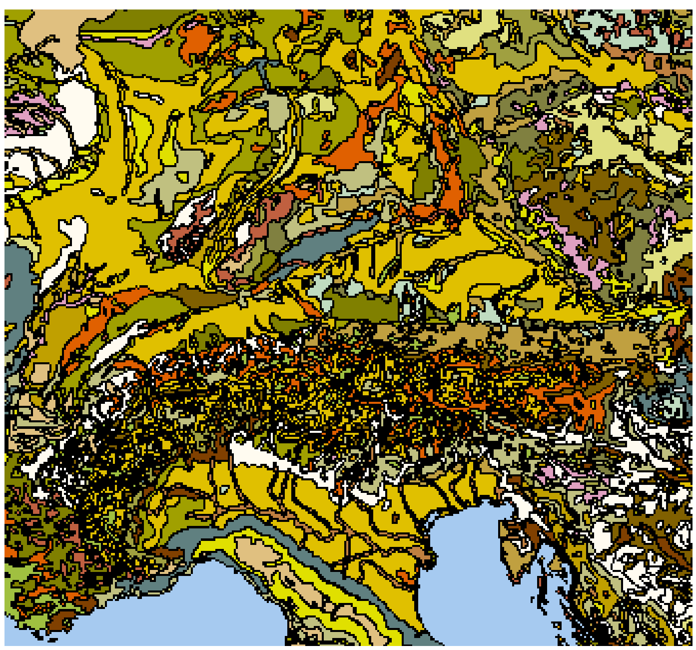

**Figure 1**- Detail of The map of natural vegetation of Europe, the Alps.

This vector map illustrates the distribution of natural dominant plant communities and their complexes, which are adapted to existing climatic and edaphic conditions, excluding - as far as possible- human impact. It is divided into 19 fisiognomically and ecologically characterised formation- complexes, which are further, differentiated according to floristic, edaphic, climatic and phytogeographical criteria. Altogether the legend comprises 650 mapping units, from which 580 were used in the data classification (Bonn, 1994).

The Natural Vgeteation map from BfN includes the most important features of latitudinal and longitudinal vegetation regularities, azonal vegetation types and their differentiation as well as the edaphic, geographical and floristic varieties of the natural plant cover. The vegetation of Europe is subdivided into 19 formation units, which are sorted according to their physiognomic and structural features, dominant species and florist composition into lower units.

### *2.2 The Map of European Land Classification*

The Map of European Land Classification, in Figure 2 made by the Institute of Terrestrial Ecology, United Kingdom provides the topographic and climate information.

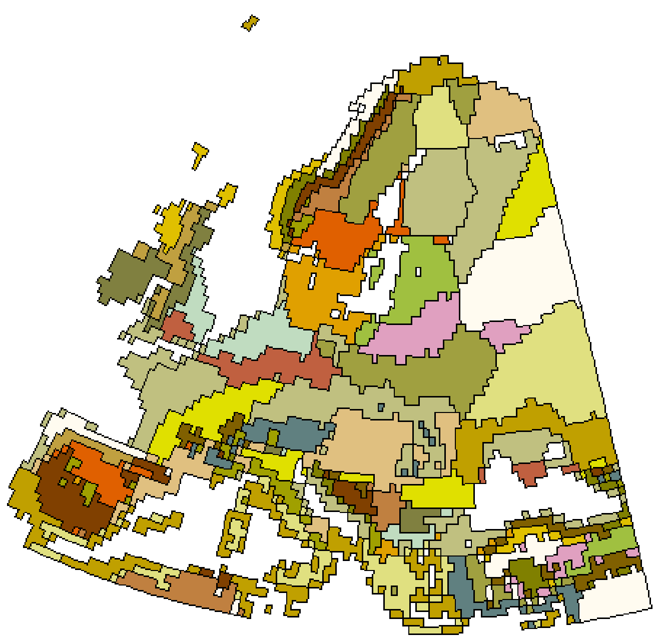

**Figure 2 -** The Map of European Land Classification, at 1:30 M scale

This map that cover the whole Europe, West Russia and North Africa, is based on a statistical analysis of climate, altitude and locational data for ½ x ½ degree cell (Bunce, 1995). This statistical analysis of 76 variables produced a basic classification of 64 distinct land classes in the area covered by the map.

## 3. Methodology

Ecological regions imply earth locations. A basic principle of ecology is that everything must be somewhere. To manage the multiple layers of information required to characterise an ecological region would be impossible without a Geographical Information System (GIS). The strength of a GIS is its ability to integrate data from a variety of sources using a common frame of reference (Painho et all, 1996).

To derive ecological gradients, and understand patterns of ecology, a cluster analysis was performed. Cluster analysis is a classification technique for placing similar entities or objects into groups or "clusters". The cluster analysis model was used to place similar samples into clusters, which are arranged in a hierarchical treelike structure called a dendrogram. These clusters or classes of sorting objects represent different ecological regions, and depending on their position on the dendrogram, or the level of aggregation, they represent homogenous sub-ecological regions, inside the primary ecological regions.

To produce DMEER, two software systems were used: ARCINFO® to perform the geographical information analysis, as a GIS, and SAS® to produce the hierarchical classification.

### *3.1 Overlay of Information Sources*

The first step to perform the overlay of the two information sources, was to generate the ArcInfo covers from the original files.

The land classification map was transformed into a polygon vector map. The natural vegetation cover already produced added the geographical position. The land class values were assigned to polygons. Finally, a dissolve instruction merged adjacent polygons of the same land class, resulting in the map in Figure 2, above.

In order to combine the information sources, it was first necessary to reassemble the two maps to the same map projection. Both maps were transformed in the Albers Projection.

In the Albers Projection the area is preserved although shape, distance and direction suffer some distortion.

A combination map was produced, as a result of overlaying the BfN map with the ITE vector transformed map. Due to the different geographical area cover, the two maps do not coincide in their outside boundaries. These mismatched areas were manually eliminated (Figure 3).

Considering the DMEER intended scale of 1:2,5 M, all polygons smaller than 20 $Km^2$ (3 $mm^2$ on the map) were absorbed by their neighbours with whom they shared the largest border.

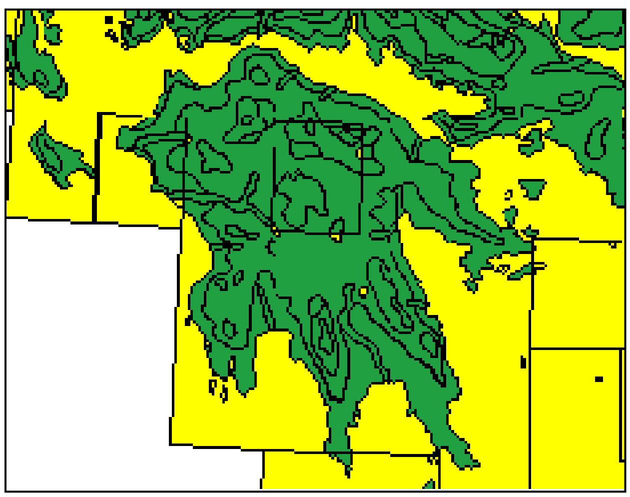

**Figure 3** – South of Greece, in yellow all the polygons that were eliminated from the combination map: the mismatch areas and polygons smaller than 20 $Km^2$.

The result is a map covering about 10,5 M $Km^2$, with 15991 polygons, each one with a potential vegetation code –BfN- and a land classification value-ITE.

### *3.2 Automatic Classification*

The combination map has a table of attributes, which already includes information from both sources, describing for each portion of the map the potential vegetation unit and the land class.

This table was exported to SAS (Statistical Analysis Software) and cross-tabulated with land classes in column headings (ITE), natural vegetation units as row headings (BfN), and each cell of the matrix containing the total area of co-occurrence of a single potential vegetation BfN and land class unit ITE (Figure 4).

SAS

File Edit Data View Customize Globals Options Window Help

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| | CODE | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | A1 | 0 | 0 | 0 | 1.4267E8 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | A2a | 0 | 0 | 0 | 1.1695E8 | 0 | 0 | 6.0203E8 | 0 | 1.613E8 | 0 |
| 3 | A3 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | A4 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1.3589E8 | 0 |
| 5 | B12 | 0 | 0 | 0 | 0 | 0 | 5.3159E8 | 0 | 0 | 0 | 0 |
| 6 | B13 | 0 | 0 | 0 | 0 | 0 | 31616188 | 0 | 0 | 0 | 0 |
| 7 | B20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 8 | B21 | 1.1064E8 | 3.9416E8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 9 | B22 | 0 | 0 | 0 | 38915044 | 0 | 1.0505E8 | 0 | 0 | 0 | 0 |
| 10 | B25 | 0 | 1.1031E8 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 11 | B31 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 56061552 | 0 | 0 |

**Figure 4** – The cross-tabulated matrix. The number column headings are the codes of the European land classification ( ITE )

From the resultant matrix areas containing azonal vegetation, and areas with no vegetation (lakes, glaciers, etc.) were excluded. This matrix has 499x57 dimension and became the original data matrix for further analysis

From this rectangular matrix, a square matrix of 580x580 was calculated to evaluate de Lance and Williams distance – *Dlw* - between potential vegetation units, according to the area they shared in the land class:

$$Dlw= \Sigma BfNij-BfNik|/ \Sigma ( BfNij+BfNik)$$

Over this distance matrix, hierarchical clustering non-overlapped methods were performed, being the Unweighted Arithmetic Average the selected one (with the highest cophenetic correlation coefficient =0,92047).

The resulting dendrogram was then split in five parts according with their own Euclidean distance: from 0,0 minimum aggregation, than 0,5; 0,6; 0,7; 0,8 and 0,9 the maximum aggregation level (Figure 5).

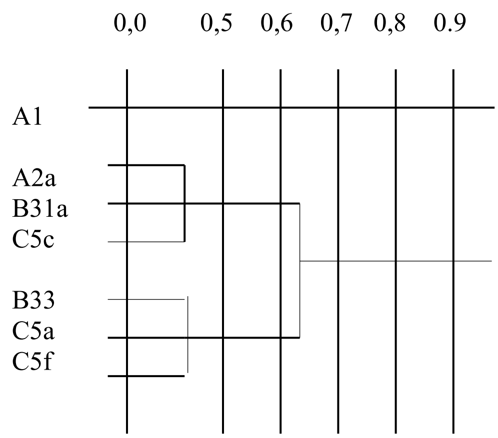


**Figure 5** - depicts the first three clusters formed in hierarchical classification, by Euclidean distance in the dendogram. The letters on left are the potential vegetation codes of BfN, and the numbers on the top are the Euclidean distances on the clusters tree or dendrogram.

This classification was transformed in a table, and added to the ArcInfo identity map table. Again in Arcinfo, the classification maps were created by dissolving the boundaries of neighbour polygons with the same cluster classification.

### 3.2.1 Results from Automatic Classification

The methodology described above, lead to 6 experimental DMEER maps, ranging from 46 to 183 DMEER classes, each one representing a different aggregation level, summarized on Table 1.

The increasing level of desegregation affects different regions on the map. Some features as the Mediterranean mountains, and the classes over 60ºN latitude, are defined at the first two levels of aggregation, and keep their form until maximum desegregation level. In Central Europe, after 67 classes, the ecological regions spread in small polygons, depicting unique combinations of land class over natural vegetation, that are too small to be represented in the map.

Table 1, below summarises basic features of the six maps

| Maps | Average area by cluster ($Km^2$) | Average number of polygons by clusters |
|---|---|---|
| 40clusters | 163025 | 82 |
| 67 clusters | 97328 | 60 |
| 91 clusters | 71659 | 53 |
| 107 clusters | 60380 | 49 |
| 130 clusters | 50550 | 45 |
| 153 clusters | 42901 | 41 |

**Figure 6** shows the Iberian Peninsula across levels of disaggregation.

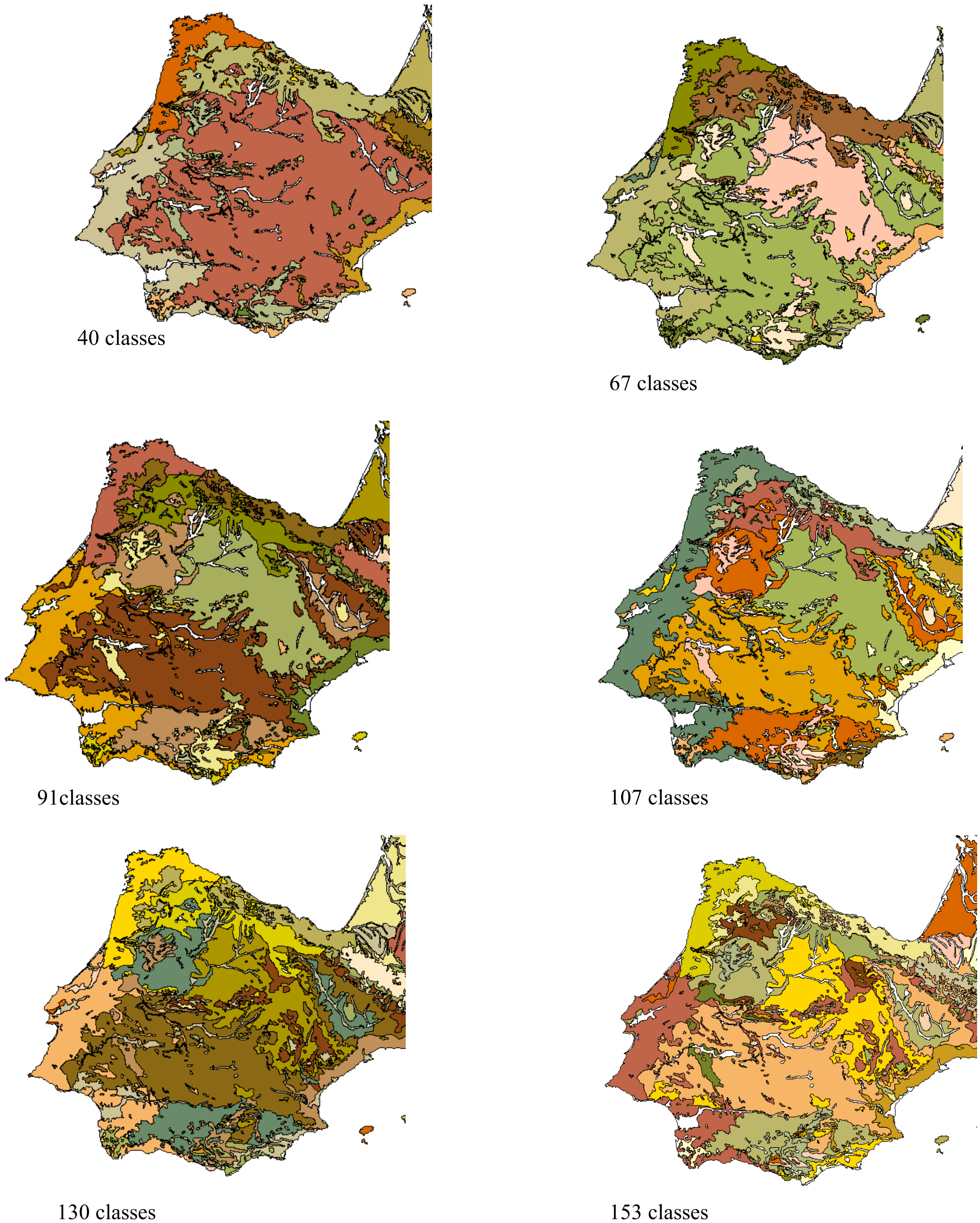


**Figure 6** Iberian Peninsula across the increasing levels of desegregation

### *3.3 Incorporation of Experts Comments*

Based on the intermediate maps, biogeography experts interactively decided, for each location, which level of the dendrogram, better translated the ecological characteristics of that same location.

In Figure 7, the coloured areas represents some ecological regions accepted by the experts, at the 40 classes map.

In the first level of agregation, 40 classes, all the Mediterranean mountains are classified. This is probably because at low latitude, the hight of the site is very important to climate, and therefore to living conditions. In Figure 7, the coloured areas represent some ecological regions accepted by the experts, at the 40 classes map. There are the Alps, the Pyrenees together with the Dinaric Alps, the Balkan Mountains, and the Cantabric Mountains. At this level it were also delineated the Ukrainian steppes, and the subartic nemoral lands of Norway

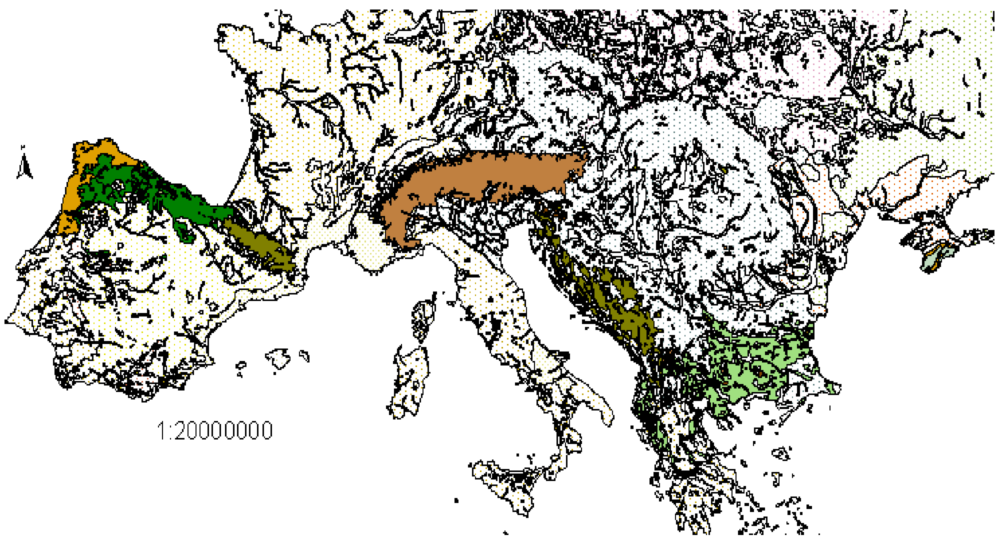


**Figure 7**– At the 40 classes map most Mediterranean Mountains are depicted by the classification scheme.

In the second level of aggregation (67 classes), all the classes in Central Europe and Scandinavia were accepted.

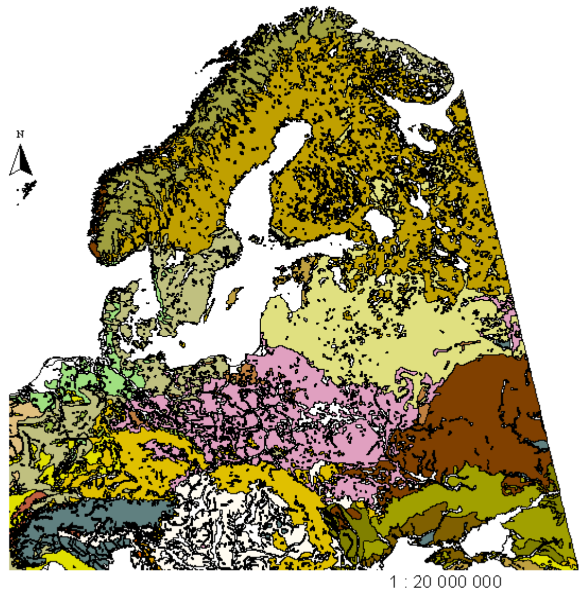


**Figure 8-** North and central Europe at DMEER 67 classes

For all but about 4 classes the cluster tree was followed down towards aggregation, until a readily interpretative map unit was reached. The convenient aggregation was found at Euclidian distances between 0,6 and 0,9, for 34 classes of the 38 total classes.

In 4 cases, classes were separated according to their biogeographical affinities, which were in all situations distinct, e.g. West- and East-Mediterranean. That was the case of Pyrenees that were automatically classified in the some ecoregion as the Dynaric Alps, but separated in two distinct ecoregions by expert decision, and Carpathians automatically classified with Hercynian, that were also separated.

For the edition of the resulting map (auto classification plus experts decision, were established the following steps:

1. To assign to every polygon the ecoregion decided by the experts, except for the polygons with azonal vegetation codes that were classified as one ecological region.

2. Merge the polygons according with the new classification.

3. Eliminate all the polygons smaller than 2000 $km^2$.

4. Include azonal vegetation polygons in the mapped class they were placed

5. Where necessary cut manually long linear features of azonal vegetation crossing more than one class.

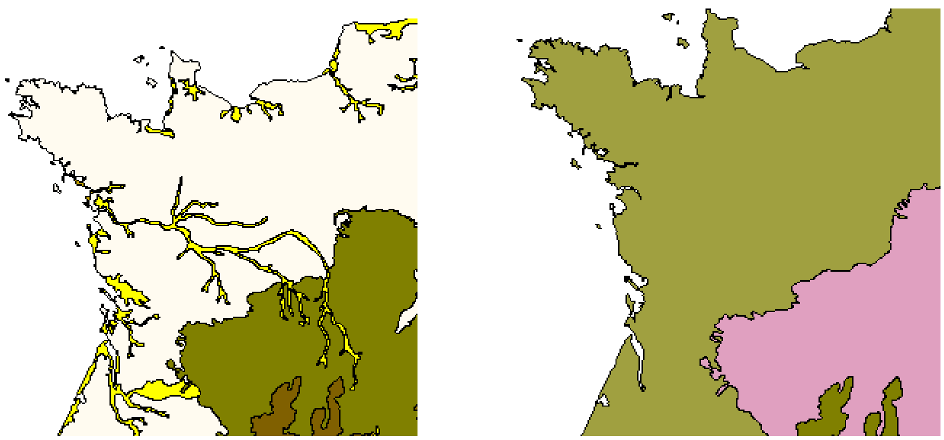

**Figure 9** – The elimination of long linear features of azonal vegetation.

As a result of the experts decisions, the map classifies Europe in 39 Ecological Regions, and was generalised for polygons smaller than 2000 $Km^2$ - Figure 10 – The ETC/NC Digital Map of European Ecological Regions.

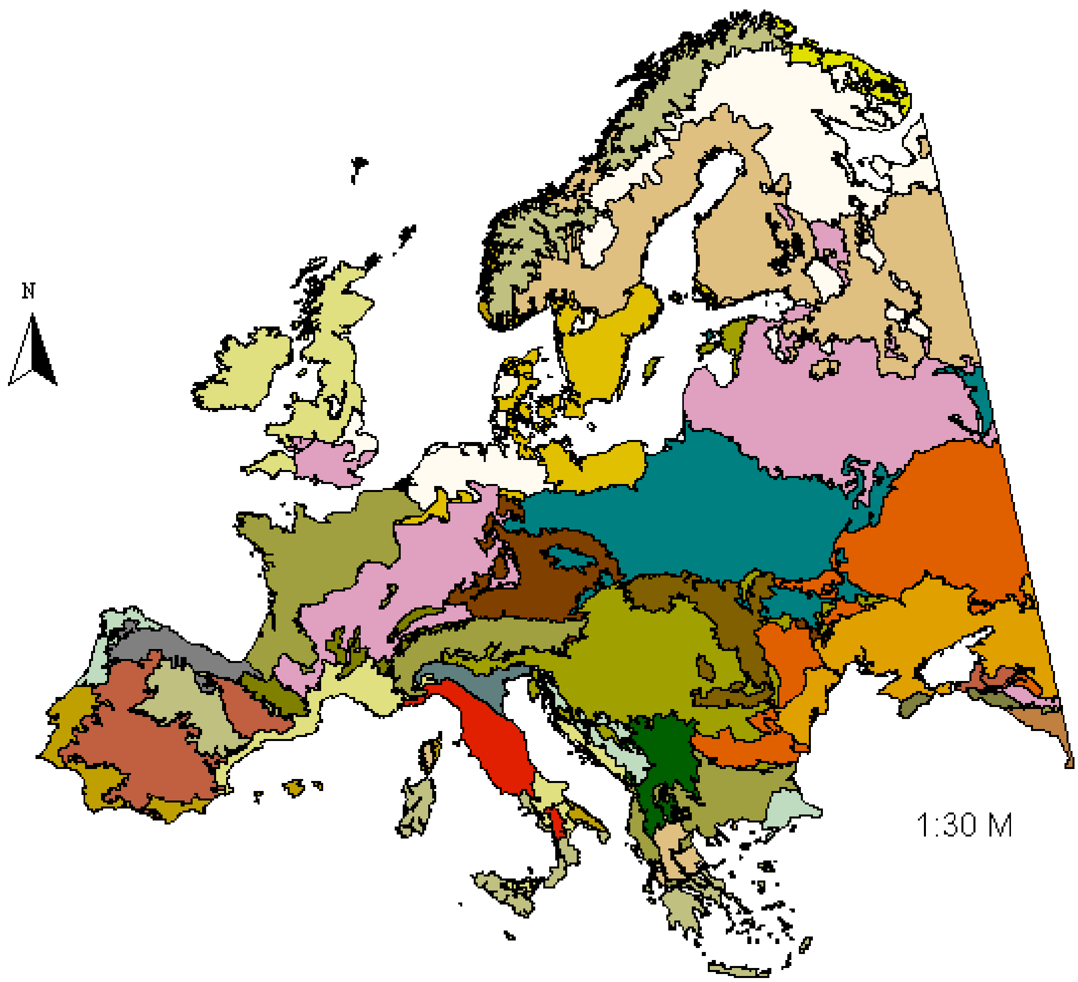


**Figure 10** – The EEA, ETC/NC map for Ecological Regions in Europe

## 4. The Agreement with World Wide Fund For Nature

Subsequently, an agreement between EEA, ETC/NC and WWF to come to two compatible maps of ecological regions for Europe, by EEA and by WWF, made necessary a series of compromises from both initiatives comprise the acceptance of DMEER lines and units on the WWF map, and the acceptance of WWF units on DMEER.

The changes EEA, ETC/NC map (Figure 11), were drawn manually over the Natural Vegetation of Europe map BfN 1:10 M. This caused some serious mismatch between these lines and the BfN 2,5 million, that is the base of DMEER, where EEA map lines were changed.

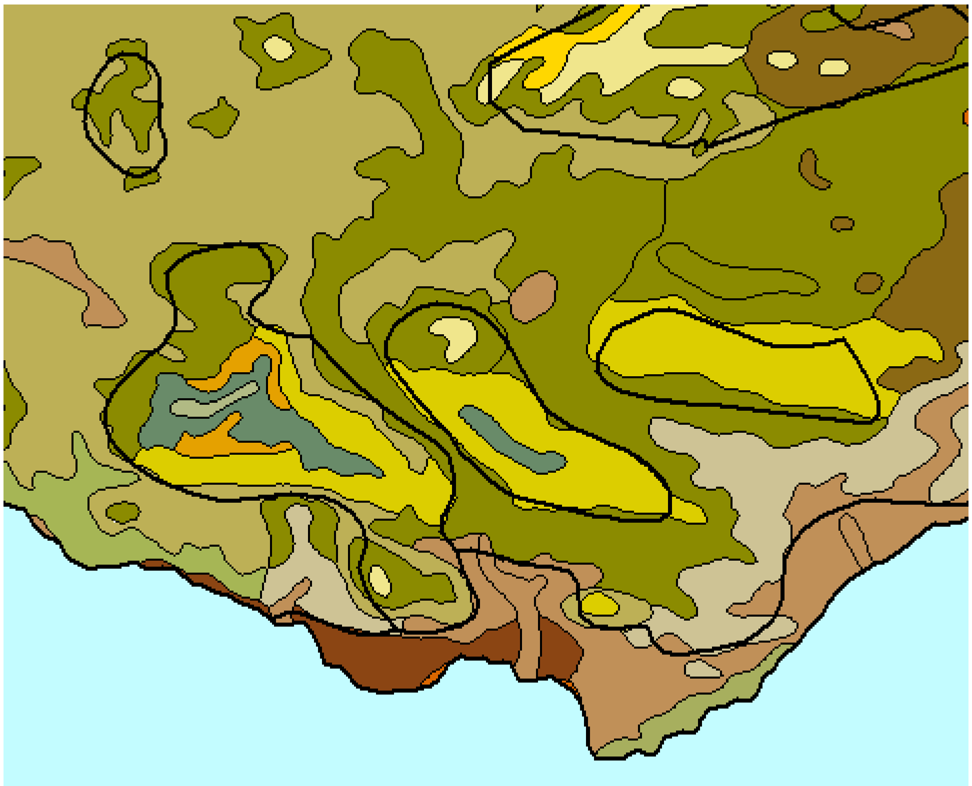

**Figure 11 -** shows some mismatch between the BfN 2,5 million and the hand-drawn lines of WWF in South of Spain at 1,5 million.

It was also decided to include in the Digital Map of European Ecological Regions, all the area covered by BfN map or ITE map, accepting the classes delineated by the experts of both EEA and WWF. That is why there is no information about the potential vegetation, or the landclass for some of the ecoregions.

The final steps in the production of the Digital Map of European Ecological Regions, comprised:

- To clean the hand drawn lines, towards the underlying BfN 1:2,5 mio classes. Because this is a time-consuming selection of lines on the screen, the way forward agreed was to start with the smallest units, where the relative error is highest.
- To split the WWF ecoregion "atlantic mixed forests into two regions on DMEER, according to EEA version. They were named "Northern temperate atlantic", and "Southern temperate atlantic".
- In the final version of DMEER, the minimum map unit was abandoned.
- This map contains 68 classes. Each class is described in the database according to its natural vegetation and climate parameters (Annex 1).

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