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European environmental stratifications and typologies: An overview

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ABSTRACT

A range of new spatial datasets classifying the European environment has been constructed over the last few years. These datasets share the common objective of dividing European environmental gradients into convenient units, within which objects and variables of interest have relatively homogeneous characteristics. The stratifications and typologies can be used as a basis for up-scaling, for stratified random sampling of ecological resources, for the representative selection of sites for studies across the continent and for the provision of frameworks for modeling exercises and reporting at the European scale.

This paper provides an overview of five recent European stratifications and typologies, constructed for contrasting objectives, and differing in spatial and thematic detail. These datasets are: the Environmental Stratification (EnS), the European Landscape Classification (LANMAP), the Spatial Regional Reference Framework (SRRF), the Agri-Environmental Zonation (SEAMzones), and the Foresight Analysis for Rural Areas Of Europe (FARO-EU) Rural Typology. For each classification the objective, background, and construction of the dataset are described, followed by a discussion of its robustness. Finally, applications of each dataset are summarized.

The five stratifications and typologies presented here give an overview of different research objectives for constructing such classifications. In addition they illustrate the most up to date methods for classifying the European environment, including their limitations and challenges. As such, they provide a sound basis for describing the factors affecting the robustness of such datasets. The latter is especially relevant, since there is likely to be further interest in European environmental assessment. In addition, advances in data availability and analysis techniques, will probably lead to the construction of other typologies in the future.

1. Introduction

Integrated assessments have become increasingly important to explore the state and trends of the European environments by identifying threats, evaluating existing policy targets and supporting future policy development (Tol and Vellinga, 1998). The classification of knowledge and data is essential for the analysis, summary and communication of the complexity of ecological and socio-economic systems. Furthermore, spatial stratifications can be used as basis for up-scaling, for stratified random sampling, for the selection of representative sites for studies across the continent, and for the provision of frameworks for modeling exercises (Metzger et al., 2005a). Such stratifications have been developed for this purpose in a range of countries (e.g., Great Britain (Bunce et al., 1996a,b), Spain (Elena-Rosselló, 1997), New Zealand (Leathwick et al., 2003), Austria (Peterseil et al., 2004), and Norway (Bakkestuen et al., 2008)).

At the European scale, classification and mapping of the environment have been carried out since the Nineteenth Century. The original methods for spatially classifying environmental differences relied upon the intuitive interpretation of observed patterns, based on personal experience. Recent examples include maps of European landscapes (Meeus, 1995), Biogeographic Regions Map of Europe (Roekaerts, 2002) and the Potential Natural Vegetation map (Bohn et al., 2000). These classifications provide descriptions of environmental regions, but are not suitable for sampling stratification or up-scaling, since class divisions depend on subjective judgment and cannot be reproduced independently.

There were also early quantitative approaches. Firstly, there are the climatic vegetation classifications (cf. Köppen, 1900), and biome

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classifications used in dynamic global vegetation modeling (cf. Prentice et al., 1992). However, they distinguish only a few classes for Europe which is not sufficient to enable a suitable stratification (Metzger et al., 2005a). Secondly, statistical approaches in the construction of environmental stratifications have also been developed. Jones and Bunce (1985) defined 11 classes on a 50 km grid for Europe. More than a decade later, improved data availability, software, and computing power allowed the classification of 64 classes on a 0.5° grid (Bunce et al., 1996c). Although this latter classification was used in a range of studies (e.g., Duckworth et al., 2000; Petit et al., 2001), its coarse resolution limited its application. Since then, a range of new European stratifications and typologies has been produced, stimulated by the increased availability of spatial environmental datasets, rapid advances in spatial data processing, and motivated by the requirements of European Union projects.

Five of these datasets, constructed for different objectives, are discussed and compared in this paper: (1) The Environmental Stratification of Europe (EnS; Metzger et al., 2005a; Jongman et al., 2006) was developed to provide generic strata for sampling, reporting and modeling, following the earlier work by Bunce et al. (1996c). (2) Mücher et al. (2006, 2010) developed the European Landscape Classification (LANMAP) to provide a consistent delineation of European Landscapes for sampling, reporting and modeling. (3) The Spatial Regional Reference Framework (SRRF; Renetzeder et al., 2008) was developed to assess the sustainability of administrative regions. (4) The Agri-Environmental Zonation (SEAMzones) (Hazeu et al., 2006, 2010) was constructed to provide a framework for integrated modeling of European agriculture. Finally, (5) the Foresight Analysis for Rural Areas Of Europe (FARO-EU) Rural Typology was developed to provide a consistent definition of variability in European rural regions. Table 1 provides a summary of the mentioned datasets, while Fig. 1 shows maps of the stratifications and typologies for the Iberian Peninsula.

Unfortunately, some of the terminology used to describe the datasets can be confusing. The most generic term, *classification* is defined as *the act or system of putting in classes* (Chambers dictionary). However, when classes are not meant as descriptive units, but specifically designed to divide gradients into relatively homogeneous subpopulations we prefer to use the statistical term *stratification*. By contrast, a *typology* tends to refer to distinct entities that have well-marked characteristics. Although we try to adhere to these subtle differences throughout the manuscript, in practice classification, stratification and typology are often used interchangeably.

In the following sections the objectives, background, and construction of the classifications are described for each dataset, followed by a discussion of their robustness. The latter considers the reliability of the input data, a comparison with other classifications, and a discussion of the residual heterogeneity within the strata. Finally, applications of each dataset are summarized. The paper concludes with a comparison of the five classifications and their robustness.

2. European environmental stratifications

2.1. The environmental stratification of Europe

2.1.1. Objectives and background

The Environmental Stratification of Europe (EnS) was developed to provide a high-resolution stratification of the principal European environmental gradients. In existing maps (e.g., for Biogeography (Roekaerts, 2002) or Eco-Regions (Olson et al., 2001)), classes were not defined statistically, but depend on the experience and judgment of the originators and rely upon the intuition of the observer in interpreting patterns on the basis of personal experience. These classifications, while important as descriptions of environmental regions, are not suitable for statistical stratification (Metzger et al., 2005a).

The EnS aimed to identify relatively homogeneous regions suitable for strategic random sampling of ecological resources, the selection of sites for representative studies across the continent, and the provision of strata for modeling exercises. The dataset provides a generic classification that can be adapted for a specific objective; as illustrated in this paper; as well as providing suitable zonation for environmental reporting.

2.1.2. Construction

The EnS was created using tried-and-tested statistical clustering procedures on primary biophysical variables, and covers a 'Greater European window' (11°W–32°E, 34°N–72°N), extending into northern Africa. This wider extent was needed to permit statistical clustering that could distinguish environments whose main distribution is outside the European continent. Data were analysed at 1 km^2 resolution.

Twenty of the most relevant available environmental variables were selected, based on those identified by statistical screening (Bunce et al., 1996c). These were (1) climate variables from the Climatic Research Unit (CRU) TS1.2 dataset (Mitchell et al., 2004), (2) elevation data from the United States Geological Survey HYDRO1k digital terrain model, and (3) indicators for oceanicity and northing. Principal Component Analysis (PCA) was used to compress 88% of the variation into three dimensions, which were subsequently clustered using an ISODATA clustering routine. The classification procedure is described in detail by Metzger et al. (2005a).

The EnS comprises 84 strata, aggregated into 13 Environmental Zones (EnZs). These were constructed using arbitrary divisions of the mean first principal component score of the strata, with the exception of Mediterranean mountains, which were separated on altitude. Within each EnZ, the EnS strata have been given systematic names based on a three-letter abbreviation of the EnZ to which the stratum belongs and an ordered number based on the mean first principal component score of the PCA. For example, the EnS stratum with the highest mean principal component score within the Mediterranean South EnZ is named MDS1 (Mediterranean South one).

2.1.3. Robustness

Input data for the EnS were selected on the basis of previous experience (Bunce et al., 1996c) and are consistent with the accepted scientific understanding that at a continental scale of climatic factors are main determinants of ecosystems patterns (Klijn and De Haes, 1994). Although the data used in the present study have limitations, e.g., in deriving climate surfaces from the spatial interpolation of weather stations, they are recorded consistently across Europe and are the best data currently available.

Bunce et al. (2002) have shown that statistical environmental classifications have much in common, identifying the major gradients and assigning classes in similar locations despite differences in statistical clustering techniques or input datasets. Kappa analysis of aggregations of the EnS strata shows a 'good comparison' (Monserud and Leemans, 1992) with other European classifications (Metzger et al., 2005b). In addition, the EnS shows strong statistical correlations with European environmental datasets (e.g., for soil, growing season and species distributions (Metzger et al., 2005a) and habitats (Bunce et al., 2008)).

Despite distinguishing 84 strata there can still be considerable environmental heterogeneity with a stratum, especially in regions with many regional gradients, e.g., in topography or soil types. For example, the stratum ALS1 (Alpine South one) covers a range of altitudes from mountain valleys at 630 m to summits at 4453 m. In such cases, regional subdivisions can be constructed based on ancillary datasets such as altitude and soils (Jongman et al., 2006).