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Marta Ortega [a] , Marc J. Metzger [b] , Robert G.H. Bunce [c] , Thomas Wrbka [d] , Anna Allard [e] , Rob H.G. Jongman [c] & Ramón Elena-Rosselló [a]

[a] Escuela de Ingenieria Forestal y Medio Natural, Universidad Politécnica de Madrid, Ciudad Universitaria s/n, 28040 Madrid, Spain

[b] Centre for the Study of Environmental Change and Sustainability (CECS), School of GeoSciences, University of Edinburgh, Drummond Street, Edinburgh, EH8 9XP, United Kingdom

[c] Alterra Wageningen University and Research Centre, PO Box 47, 6700 AA Wageningen, The Netherlands

[d] Institute of Conservation Biology, Vegetation Ecology and Landscape Ecology, University of Vienna, Althanstrasse 14, Vienna, 1090, Austria

[e] Department of Forest Resource Management, Skogsmarksgrand, SE-901 83 Umea, Swedish University of Agricultural Science, Upsala, Sweden

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The potential for integration of environmental data from regional stratifications into a European monitoring framework

Marta Ortega[a], Marc J. Metzger[b], Robert G.H. Bunce[c], Thomas Wrbka[d], Anna Allard[e], Rob H.G. Jongman[c] and Ramón Elena-Rosselló[a]*

[a]*Escuela de Ingenieria Forestal y Medio Natural, Universidad Politécnica de Madrid, Ciudad Universitaria s/n, 28040 Madrid, Spain;* [b]*Centre for the Study of Environmental Change and Sustainability (CECS), School of GeoSciences, University of Edinburgh, Drummond Street, Edinburgh EH8 9XP, United Kingdom;* [c]*Alterra Wageningen University and Research Centre, PO Box 47, 6700 AA Wageningen, The Netherlands;* [d]*Institute of Conservation Biology, Vegetation Ecology and Landscape Ecology, University of Vienna, Althanstrasse 14, Vienna 1090, Austria;* [e]*Department of Forest Resource Management, Skogsmarksgrand, SE-901 83 Umea, Swedish University of Agricultural Science, Upsala, Sweden*

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The development of a co-ordinated system for monitoring European biodiversity that can provide policy makers with information to underpin the management of ecological resources requires an appropriate environmental stratification to facilitate sampling and data analysis. This paper quantifies the similarities between the European Environmental Stratification (EnS) and four regional stratifications to test whether the EnS is able to distinguish locally important environmental gradients. The results show that in general the EnS is comparable with regional stratifications, and resolves border effects where divergent environmental conditions are combined into dominant strata. However, some regional gradients are not discerned, illustrating the value of national stratifications to provide local detail within continental monitoring strata.

Keywords: environmental stratification; map comparison; Kappa statistic; monitoring; biodiversity observation network

1. Introduction

Policy commitments to maintain biodiversity and mitigate environmental change, both within the European Union (EU) and internationally, require pan-European strategies and supporting research for managing natural resources (Metzger *et al.* 2010). Reliable monitoring data are also required from large areas in order to make informed decisions on ecosystem management (Parr *et al.* 2002, 2003, Pereira and Cooper 2006). However, despite the existence of several regional habitat monitoring programmes across Europe, the collection of ecological data is only co-ordinated at the national level, following country or regional specific methods, classifications and priorities, without EU or international co-ordination (Bunce *et al.* 2008, Lengyel *et al.* 2008, Schmeller 2008, Metzger *et al.* 2010). It is therefore increasingly evident that standardised frameworks and methods at continental and global scales are

*Corresponding author. Email: ramon.elena.rossello@upm.es

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required in order to enable countries to integrate data for ecological monitoring and assessment (GEOSS 2005, Evans 2006, Bunce *et al*. 2008).

Consistent classifications or stratifications[1] of land into relatively homogeneous environmental strata provide a robust framework for comparison and analysis of environmental data and sampling ecological resources over large geographic regions (Bunce *et al*. 1996a, 1996b, 1996c, Metzger *et al*. 2005, Jongman *et al*. 2006). Furthermore, statistical inference requires sample data to be representative of defined population (Cochran 1977). Within a stratum, or subpopulation, changes or effects can, as far as possible, be analysed separately from environmental heterogeneity by using standard statistical procedures (Bunce *et al*. 1996a, Cochran 1977). It is essential, however, that any environmental stratification has a sufficiently fine spatial resolution and is derived statistically in order that the strata are determined unambiguously. The stratification is then reproducible and, as far as possible, independent of personal bias. This is of particular importance where large-scale continuous gradients are involved over hundreds of kilometres, and clear boundaries between zones are often not present. Statistical analysis provides robust divisions based on the balance between the environmental variables underpinning the stratification (Metzger *et al*. 2005).

Many countries have adapted quantitative environmental stratifications to support environmental management and planning, e.g. Australia (Mackey *et al*. 1988), Spain (Elena-Rosselló *et al*. 1997), Austria (Wrbka *et al*. 1999), New Zealand (Leathwick *et al*. 2003), Senegal (Tappan *et al*. 2004), Sweden (Esseen *et al*. 2006), and Norway (Bakkestuen *et al*. 2008). The Great Britain Countryside Survey[2] provides one of the best documented examples of a national monitoring scheme designed to assess stock and habitats and vegetation, providing decadal surveys since the 1970s (Firbank *et al*. 2003, Sheail and Bunce 2003). Other countries with similar monitoring schemes include Spain (Elena-Rosselló *et al*. 2005), Austria (Peterseil *et al*. 2004), and Sweden (Ståhl *et al*. 2011).

Recently, the EU has initiated the EBONE[3] project (European Biodiversity Observation Network), which aims to provide a method to produce sound scientific estimates of stock and change in European biodiversity at species and ecosystems levels. Coherent data collection, data harmonisation and integration between field and earth observations are important elements in the project, which is designed to provide policy makers with basic information to underpin their planning and management activities. EBONE has formal links to the Group on Earth Observations Biodiversity Observation Network (GEO BON), the biodiversity arm of the Global Earth Observation System of Systems (GEOSS), which is recognised by the Parties to the Convention on Biological Diversity (CBD 2010).

Within EBONE, the recently developed Environmental Stratification of Europe (EnS, Metzger *et al*. 2005) is used to provide the sampling framework. Although the EnS is the most relevant available dataset and has been used in numerous studies (Hazeu *et al*. 2011), there is still a degree of environmental heterogeneity within strata, especially in regions with complex regional gradients, e.g. the stratum ALS1 (Alpine South one) covers a range of altitudes from mountain valleys at 630 m to summits at 4453 m. It is therefore important to assess how accurately the EnS represents recognised regional environmental divisions (Bunce *et al*. 2002).

This paper presents a statistical comparison of similarities of mapped environmental features among maps of differing scales, themes and purposes. Four national environmental stratifications from different geographic regions in Europe (i.e. Great Britain, Sweden, Austria and Spain) are compared with the EnS, using three statistical measures: Kappa (Monserud and Leemans 1992), Delta (Martin and Femia 2004) and a consistency index S. The analyses were designed to demonstrate whether a continental stratification such as the EnS provides sufficient detail for the integration of environmental data at a European level from regional studies.

This paper does not include accuracy assessments of the classifications. However, these have been carried out previously by Bunce *et al.* (1996a) and Metzger *et al.* (2005), confirming the validity of the stratification using independent data.

2. Environmental stratifications

2.1. The Environmental Stratification of Europe (EnS)

The EnS identifies relatively homogeneous regions suitable for strategic random sampling of ecological resources through the selection of sites for representative studies across the continent (Metzger *et al.* 2010), and the provision of strata for modelling exercises (Verboom *et al.* 2007, Metzger *et al.* 2008). The EnS provides a generic classification that can be adapted for a specific objective, as well as providing suitable zoning for environmental reporting (Hazeu *et al.* 2011).

The EnS was created using tried-and-tested statistical clustering procedures on primary physical environment variables, and covers a 'Greater European window' (118W–328E, 348N–728N), 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.* 1996d). 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 Components Analysis (PCA) was used to compress 88% of the variation of these 20 environmental characteristics into three dimensions, which were subsequently clustered using an ISODATA clustering routine. The classification procedure is described in detail by Metzger *et al.* (2005).

The EnS comprises 84 strata, aggregated into 13 Environmental Zones (EnZ). 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).

2.2. The Countryside Survey (CS) Land Classification of Great Britain

The Countryside Survey (CS) is a monitoring project that has recorded stock and change of features, such as land cover, habitats and vegetation by means of a stratified random series of 1×1 km squares in 1978, 1984, 1990, 2000 and 2007.

The land classification (Bunce *et al.* 1996a, 1996b, 1996c) was initially developed using multivariate TWINSPAN analysis (Hill 1979) of environmental variables. Climatic, topographic, geological and anthropogenic data were recorded from 1200 out of the 240,000 1×1 km squares of the National Grid of Great Britain (GB) laid out at the intersections of a 15 km square grid. Logistic regression and discriminant functions were subsequently used to assign all the remaining squares to the original classes but also to reassign the squares from the initial grid sample. Field surveys of ecological parameters have been used to provide independent data for testing the classification, to characterise the classes and to provide national estimates of habitats and vegetation (Barr *et al.* 1993). Since CS2000 (Haines-Young *et al.* 2000, Firbank *et al.* 2003), the policy requirement was for Scotland to be kept separate from the rest of the UK led to 40 classes (Figure 1(a)) being derived from the initial 32 classes according to their presence in the two regions.

2.3. *The National Inventory of Landscapes in Sweden (NILS) stratification*

The main objective of the NILS programme is to provide and perform data analyses of environmental conditions and ecological processes at the landscape scale (Allard

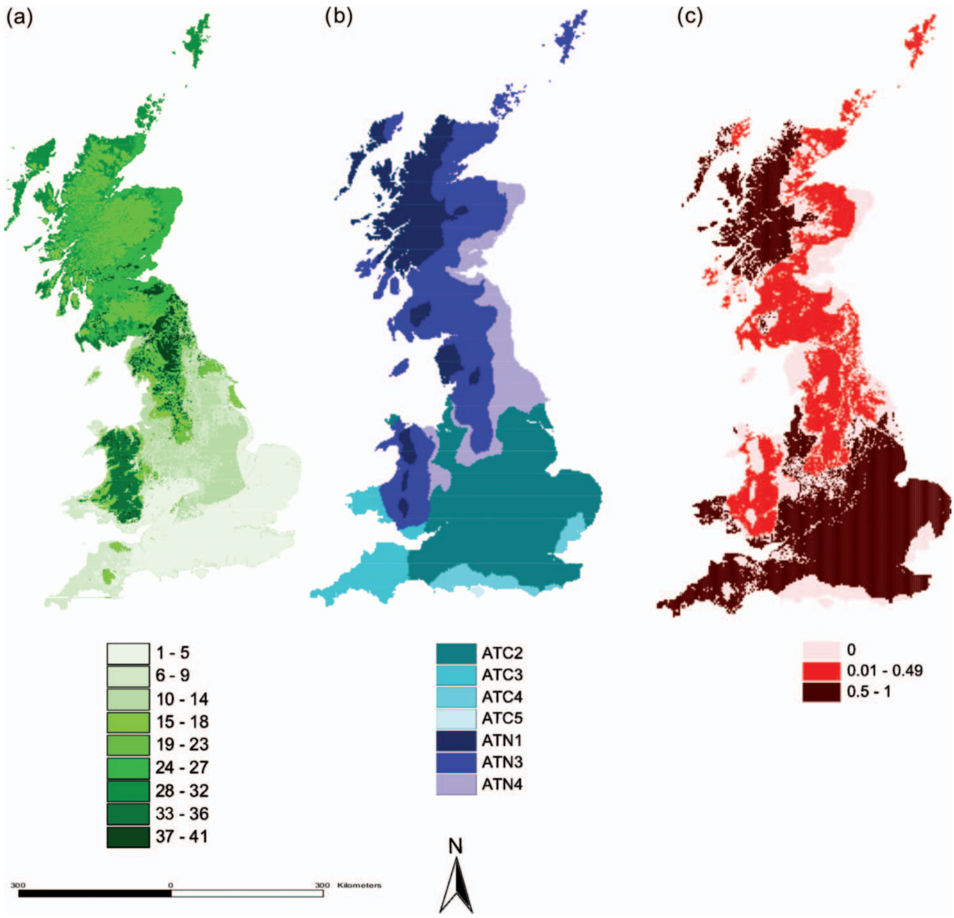

Figure 1. Comparison of the environmental stratification of Great Britain with the Environmental Stratification of Europe (EnS): (a) Countryside Survey (CS) Land Classification (Bunce *et al.* 1996a, 1996b; Barr *et al.* 1993). The 40 land classes were reduced to nine classes in order to show the main distribution patterns. (b) The seven strata of the EnS (Metzger *et al.* 2005) and (c) Map of consistency between (a) and (b).
Note: Please see online colour version for full interpretation.

et al. 2003, Esseen *et al*. 2006, Ståhl *et al*. 2011). NILS provides national statistics on land cover, land use and landscape structure for all terrestrial biotopes in Sweden, as well as providing an infrastructure for other monitoring and/or research exercises. NILS was launched in the summer of 2003, and by the end of the 2007 season all plots in the five-year sample had been inventoried.

The environmental stratification was based on a 5 km grid that was divided into 10 strata based on natural as well as sociological/cultural factors. In southern and middle Sweden the distribution is based on agricultural yield areas, defined by the Swedish Board of Agriculture. This means that the yield areas 1–6 form the strata 1–6 in NILS. In northern Sweden, the alpine areas and the alpine forests are assigned to a special stratum according to a nature conservation boundary defined by the Swedish Society for Nature Conservation (SYNC). In northern Sweden agricultural land mostly occurs below the Highest Coast Line (HCL) along the east coast. To be able to capture this agricultural land, the coastal area is assigned to a specific stratum based on the HCL. In most of the cases, the HCL and the border of the agricultural land coincide. However, sometimes the HCL is located far inland in forested areas. Therefore, the border of this stratum has been modified slightly compared to the HCL. The inland of Norrland is divided into two strata; the border goes between the provinces of Jämtland/Ångermanland and the county of Västerbotten (Figure 2(a)).

2.4. *The Spatial Indices for Land Use Sustainability (SINUS) stratification*

SINUS is a project designed to develop reliable, operational and spatially explicit indicators of practical use in long-term monitoring and assessment of ecological sustainability of Austrian cultural landscapes (Peterseil *et al*. 2004). In 1997, land use data and hemerobiotic character were recorded in 182 1×1 km squares with a stratified sampling using a design based on Austrian Landscape Classification (Wrbka *et al*. 1999).

The SINUS classification provides a framework for the description of the natural preconditions of agricultural land use in Austria. The classification was based on geo-morphological features, historical land-use patterns and preliminary coarse landscape types. The methodology used was the intersection of three thematic maps (altitudinal zones, geological land units and land use type) and classification with an isoclustering algorithm. Approximately 16,000 individual landscapes were delineated for the whole Austrian territory and then classified into 12 first-order landscape-type series and 42 second-order landscape-type groups. This final segregation has been used to compare with EnS in this paper (Figure 3(a)).

2.5. *The Spanish Rural Landscape Monitoring System (SISPARES) Biogeoclimatic Land Classification*

SISPARES is an ongoing project designed to study the ecological value and dynamics of rural landscapes in Spain, including their characterisation and classification (Elena-Rosselló *et al*. 2005). The initial stage was the establishment of a representative Spanish Rural Landscape Network (*REDPARES*) that has 206 4×4 km squares derived from a stratified simple random sampling. All the squares were surveyed using aerial photographs at four dates (1956, 1984, 1998 and 2008) to derive measurements of 11 major habitats.

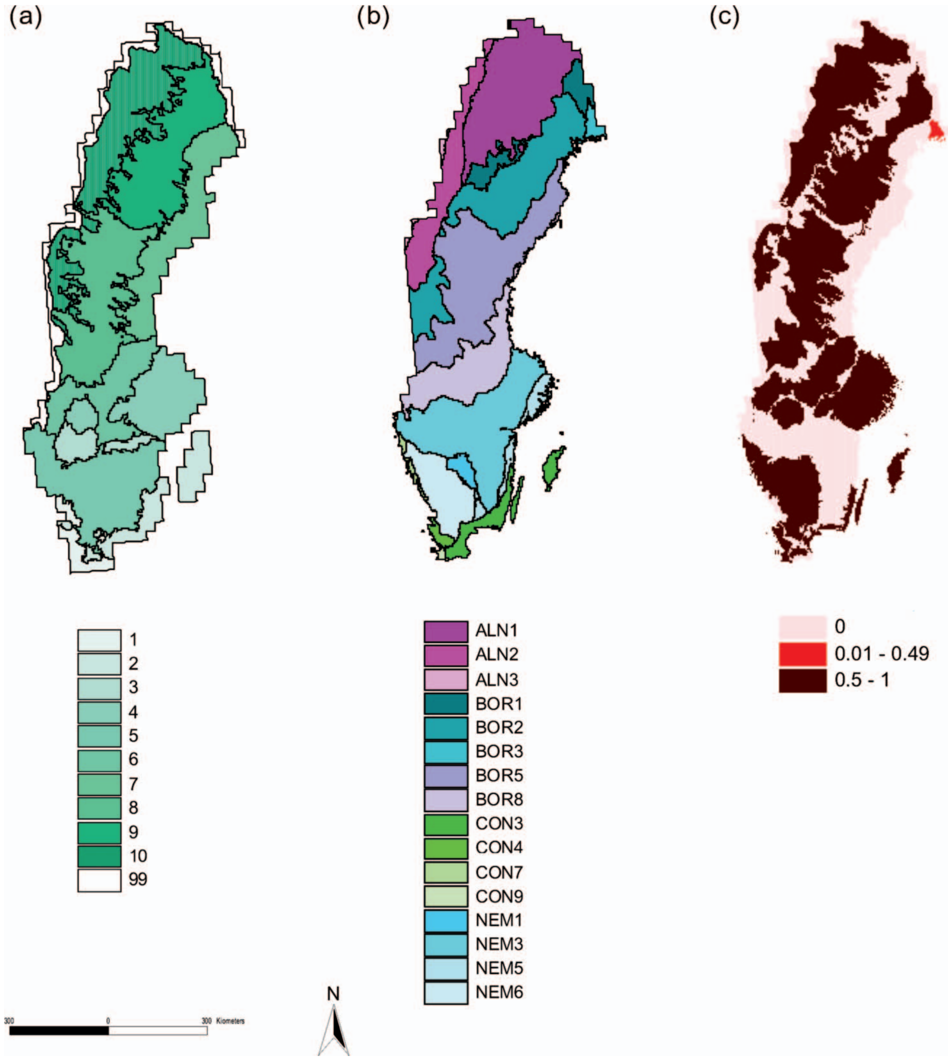

Figure 2. Comparison of the environmental stratification of Sweden with the Environmental Stratification of Europe (EnS) (a) The 10 classes of the National Inventory of Landscapes of Sweden (NILS) (Esseen *et al*. 2006, Ståhl *et al*. 2011). (b) The 16 strata of the EnS (Metzger *et al*. 2005) and (c) Map of consistency between (a) and (b).
Note: Please see online colour version for full interpretation.

The sampling design was based on the Biogeoclimatic Land Classification of Spain, known by its acronym CLATERES (Elena-Rossello *et al*. 1997), constructed using a divisive multivariate classification approach adapted from the CS land classification system (Bunce *et al*. 1996a, 1996b, 1996c), applied to climatic, physiographic and geological data. The construction was structured into two phases. First, the whole Spanish Peninsula and Balearic Islands were classified into 13 classes at 5 × 5 km resolution and then into 215 land classes with a greater resolution of 2 × 2 km. Soil type, vegetation class and land-use data were used for testing the ecological value of the classes. CLATERES was used to compare with EnS in this paper (Figure 4(a)).

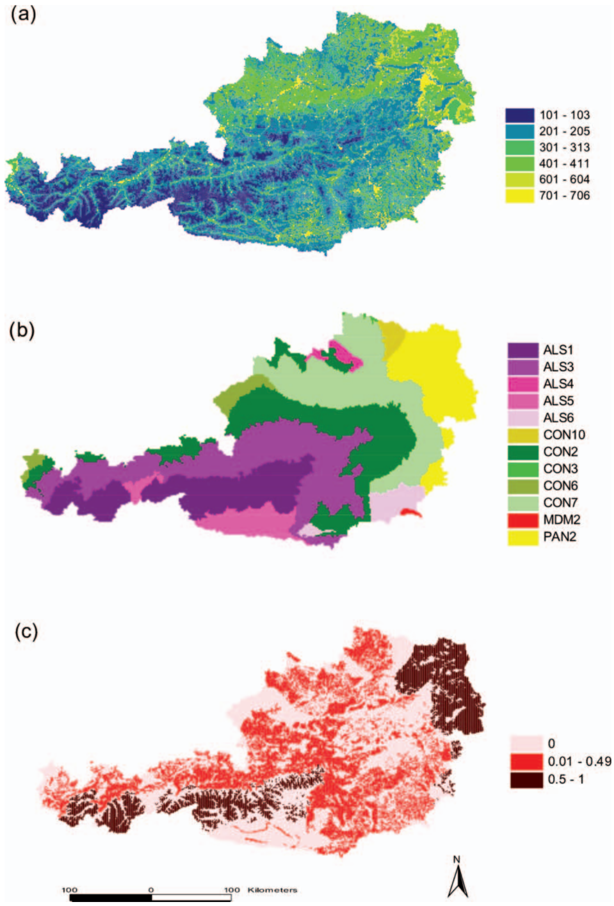

Figure 3. Comparison of the environmental stratification of Austria with the Environmental Stratification of Europe (EnS): (a) Spatial Indices for Land Use Sustainability (SINUS) (Peterseil *et al*. 2004). The 42 land classes were reduced to six classes in order to show the main distribution patterns. (b) The 12 strata of EnS (Metzger *et al*. 2005) and (c) Map of consistency between (a) and (b).
Note: Please see online colour version for full interpretation.

3. Statistical comparisons

The similarities between the different classifications were assessed using the Kappa statistic, as defined by Monserud and Leemans (1992), 'Equation (1)'. The same approach was used by Lugo *et al*. (1999) to 'verify and evaluate' their classification for the United States, and by Metzger *et al*. (2005) to compare the EnS with various global classifications. Monserud and Leemans (1992) suggested that values of $\kappa <$ 0.4 demonstrated 'poor' or 'very poor' agreement between raster maps, 0.4–0.55 'fair', 0.55–0.7 'good', 0.7–0.85 'very good' and $>$0.85 'excellent'.

$$\kappa = (\mathrm{Oa} - \mathrm{Ea})/(\mathrm{N} - \mathrm{Ea}), \tag{1}$$

where Oa is the observed count of agreement, Ea is the expected count of agreement, and N is the total number of respondent pairs.

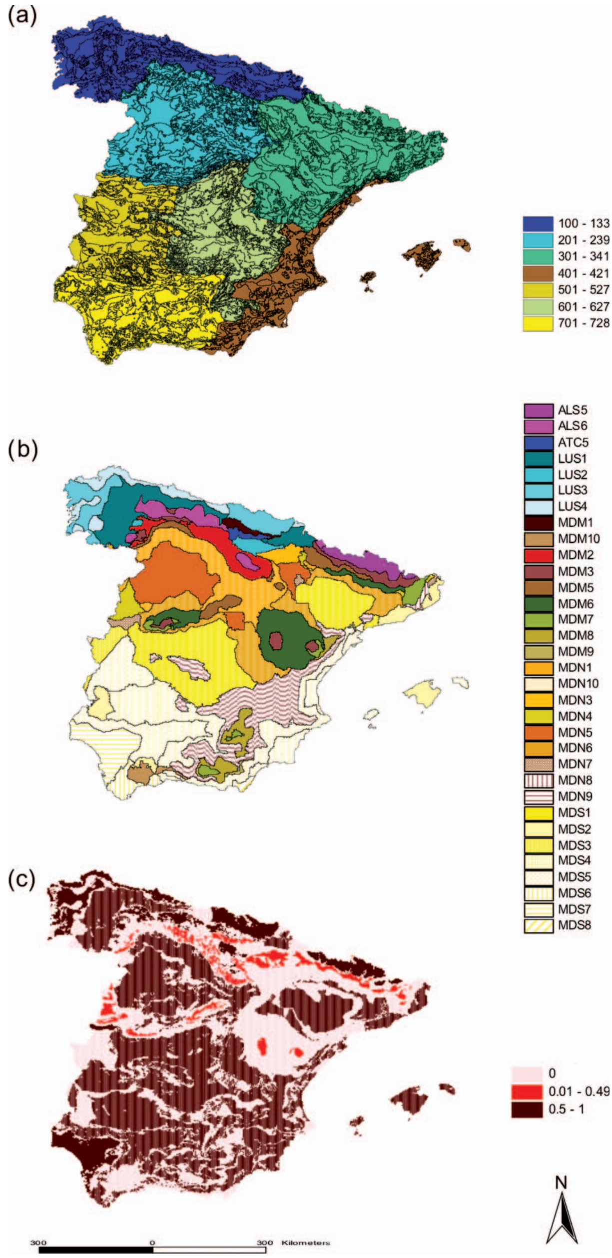

Figure 4. Comparison of the environmental stratification of Spain with the Environmental Stratification of Europe (EnS): (a) CLATERES Biogeoclimatic Land Classification (Elena-Rosselló *et al.* 1997) of the Spanish Rural Landscape Monitoring System (SISPARES) (Elena-Rosselló *et al.* 2005). The 215 land classes were reduced to seven classes in order to show the main distribution patterns. (b) The 33 strata of EnS (Metzger *et al.* 2005) and (c) Map of consistency between (a) and (b).
Note: Please see online colour version for full interpretation.

For the Kappa analysis, the datasets that are compared must have the same spatial resolution, and distinguish the same number of classes or strata. To meet these requirements, the national stratifications were resampled to the 1 km resolution of the EnS and contingency tables were constructed in two stages, as described by Bunce *et al*. (2002), to determine the classes on one map that corresponded with classes on the other map. These tables provided the area proportion of the national stratifications present in each of the EnS strata. The highest proportion of the squares of each national stratum determined the EnS stratum to which they were assigned. Some of the differences between classifications are likely to be due to this process of data generalisation.

Although the Kappa statistic is used widely, it performs poorly when the marginal distributions are unbalanced, in terms of the number of agreements of correspondent pairs between classes and hence it has been the subject of various critiques (Brennan and Prediger 1981, Agresti *et al*. 1995, Guggenmoos-Holzmann and Vonk 1998, Nelson and Pepe 2000). Therefore, a second measure of agreement, the Delta statistic, was used to assess agreement (Martin and Femia 2004). The Delta statistic 'Equation (2)' also refers to the total proportion of agreements that do not occur by chance. It is a valid option in the same cases as Kappa, being based on a probabilistic model. The Kappa and Delta statistics generally take similar values, except when the marginal distributions are strongly unbalanced, in which case the Delta measurement better reflects reality (Martin and Femia 2004).

$$\Delta = (\mathrm{kOa} - \mathrm{N})/\{(\mathrm{k} - 1)\mathrm{N}\}, \tag{2}$$

where k is the number of nominal classes, Oa is the observed count of agreement, and N is the total number of respondent pairs.

To analyse the agreement between stratifications separately for each class or stratum we also calculated an index based on Delta that is unbiased and asymptotically normal. The consistency index (S) Equation (3) measures separately the feasibility of an agreement between observers in a class when both of them are not *standard* (those with the right responses). The consistency index S can be mapped to give information on the spatial locations of the agreement between the two maps.

$$\mathrm{S_i} = 2\mathrm{r_i}\Delta_\mathrm{i}/(\mathrm{r_i} + \mathrm{c_i}), \tag{3}$$

where r and c are the observed count of agreement of the class i and Δ_i the coefficient Delta by class.

The software to calculate Kappa, Delta and the consistency index S by stratum are available from http://www.urg.es/~bioest/Delta.exe.

4. Results

4.1. Great Britain (GB)

In GB, the contingency table of CS land classes compared with EnS strata produced five groups from the original 40 land classes to statistically compare with five EnS strata from the seven original strata that the EnS defines in Great Britain (Table 1). The strata ATC4 and ATC5 in the extreme south of England had no correspondence with any CS land classes, presumably because their affinity is with mainland Europe and hence cannot be identified when GB data alone are used (Figures 1(a), 1(b)).

Table 1. Contingency table showing the proportion ($\times 1000$) of the European Environmental strata (EnS) (Metzger *et al.* 2005) in each of the five combination of the 40 Countryside Survey (CS) land classes (Barr *et al.*, 1993, Bunce *et al.* 1996a, 1996b). The measure of consistency of each EnS stratum with groups of CS land classes is shown with their standard error.

CS/EnS	*ATC2*	*ATC3*	*ATN1*	*ATN3*	*ATN4*
1–4,8,9,11–13	291	7	3	10	19
5–7	10	49	0	6	2
18,21,23,24,29,30	0	0	100	46	0
14–17,19,22,25–28,31–40	6	6	42	236	57
10,41	25	0	0	9	39
Consistency ± S.E.	0.86 ± 0.02	0.75 ± 0.05	0.63 ± 0.04	0.46 ± 0.06	0.29 ± 0.06

Kappa and Delta indicated 'good' correspondence (k = 0.65 and D = 0.63). The values of consistency of CS vs EnS by class were higher than 0.50 for ATC2, ATC3 and ATN1 strata and lower than 0.50 for ATN3 and ATN4 strata (Table 1). Therefore, the map of consistency indicated that 44% of the total area of GB had high consistency (higher than 0.50), 27% had low consistency (lower than 0.50) and 28% had no consistency (Figure 1(c)). These latter areas are mainly situated in boundary zones.

4.2. *Sweden*

In Sweden, a contingency table of NILS land classes compared with EnS strata was created by grouping the EnS strata because the number of classes of NILS is lower than in the EnS. Table 2 shows the statistical comparison between these classifications. The NILS class 3 (Götland north plain district) had no analogue with any EnS strata, so the comparison was between nine classes of NILS and nine groups of EnS from 16 original strata of EnS (Figures 2(a), 2(b)).

Kappa and Delta, indicated a 'good' correspondence between NILS classes and groups of EnS strata (k = 0.61 and D = 0.63). The values of consistency by class were high (>0.50), except for class 7 (Norrland coast land) with BOR3 of EnS that was low (<0.50), but it covered less than 1% of the total area of Sweden. Therefore, 65% of the total area of Sweden had high consistency, 1% low consistency and 34% no consistency (Figure 2(c)). The difference in the number of classes in Sweden compared with the EnS is likely to have contributed to this lack of consistency.

4.3. *Austria*

In Austria, the contingency table of SINUS land classes compared with EnS strata produced seven groups of SINUS land classes that were identified with seven EnS strata from 12 original strata of EnS (Table 3). The five EnS strata that had no analogue with SINUS land classes are located near the Austrian state border. These classes are ALS4, CON3, CON6, CON10 and MDM2 (Figure 3(a), 3(b)).

Kappa and Delta indicated a 'fair' correspondence (k = 0.40 and D = 0.39, respectively). The consistency of EnS strata by class were high (>0.50) in the EnS strata ALS1 and PAN2 and low (<0.50) in ALS3, ALS5, ASL6, CON2 and CON7. The map of consistency of EnS strata vs. SINUS classes showed that 50% of the Austrian total area had no consistency, 33% had low consistency and 17% had high consistency (Figure 3(c)).

Table 2. Contingency table showing the proportion (x 1000) of the nine National Inventory of Landscapes of Sweden (NILS) classes (Esseen *et al*. 2006, Ståhl *et al*. 2011) in each of the nine combination of the European Environmental strata (EnS) (Metzger *et al*. 2005). The measure of consistency of each NILS classes with groups of EnS strata is shown with their standard error.

NILS/EnS	1	2	4	5	6	7	8	9	10
ALN1,ALN2	0	0	0	0	0	0	5	50	163
BOR1,BOR2	0	0	0	0	0	21	23	116	27
BOR5	0	0	0	0	1	55	131	4	1
BOR3	0	0	0	0	0	4	0	0	0
BOR8	0	0	4	0	57	15	16	0	0
CON7, NEM1,NEM6	4	1	0	70	0	0	0	0	0
NEM3, NEM5	0	1	77	53	25	0	0	0	0
CON3	3	23	0	9	0	0	0	0	0
CON4, CON9	6	1	0	1	0	0	0	0	0
Consistency $\pm$ *S.E.*	0.57 $\pm$ 0.12	0.75 $\pm$ 0.07	0.64 $\pm$ 0.04	0.66 $\pm$ 0.04	0.62 $\pm$ 0.05	0.08 $\pm$ 0.04	0.65 $\pm$ 0.04	0.55 $\pm$ 0.04	0.77 $\pm$ 0.03

4.4. Spain

In Spain, the contingency table grouped the 215 classes of the Spanish dataset into 27 groups of classes that corresponded with 27 EnS strata from 33 original strata of EnS (Table 4). Therefore, there were six EnS strata without correspondence and which were MDM9, MDM10, MDN8, MDN10, MDS3 and MDS8 (Figure 4(a), 4(b)). As in Austria and GB, these classes probably have their distribution centres outside of Spain and there were therefore insufficient squares to build a comparable Spanish class.

Kappa and Delta indicated a 'good' similarity for Kappa and Delta indices (k = 0.64, D = 0.65). Therefore, 55% of the Spanish total area had a high correspondence, 4% of areas had low EnS strata and 41% had no concordance (Figure 4c). These final strata were mainly situated in boundary zones, such as in the mountain range of southern Spain, in the Ebro basin and to the west of Spain close to the border with Portugal.

5. Discussion

5.1. Does EnS distinguish regional gradients?

These results indicate that EnS distinguishes regional environmental gradients in the majority of cases, and that it can overcome the boundary effects that inevitably exist in national stratifications. However, some regionally important gradients are not identified because the scale of these variations is too small at a continental scale. Examples of national environmental gradients include the aridity gradient from north to south in Spain, the humidity gradient of the UK from west to east, and altitudinal gradients in mountain regions.

National and regional stratifications therefore help to expand the accuracy of EnS by identification of local environmental gradients. In some cases it will be necessary to divide the EnS strata in order to link them with national classifications. A good example is the stratum ALS1 present in Austria covering a range of altitudes from 630 m to 4453 m. The EnS strata correspond to two Austrian classes of SINUS: 'Rocks and glaciers of alpine highlands' and 'Seminatural and natural grassland of alpine highlands'. Subdividing EnS strata using factors such as soil type or altitude could add the necessary detail (Jongman *et al*. 2006, Hazeu *et al*. 2011) to resolve differences in the comparison.

5.2. Limitations to the statistical comparisons

Statistical map comparisons provide quantitative measures to help assess the similarities between maps. Here, these measures were used to assess the capability of the EnS to reflect regional gradients. However, there are a number of other factors that can lead to differences between the classifications.

National boundaries affect zones with contrasting environmental conditions near national borders, which are related to larger adjacent zones. Such regions are often not identified as separate strata in national datasets. Examples given above include southern England, which is more closely related to environmental conditions in France, and parts of Spain that share characteristics with Portugal and northern Africa. These boundary effects have been discussed by Parry *et al*. (1996) and Bunce *et al*. (2002) and strongly affect the similarity statistics.

Table 3. Contingency table showing the proportion (x1000) of the Environmental stratification of Europe (EnS) (Metzger *et al*. 2005) in each of the seven combination of the 42 classes of Spatial Indices for Land Use Sustainability (SINUS) stratification (Peterseil *et al*. 2004). The measure of consistency of each EnS strata with groups of SINUS land classes is shown with their standard error.

SINUS/EnS	*ALS1*	*ALS3*	*ALS5*	*ALS6*	*CON2*	*CON7*	*PAN2*
101,102	77	38	9	0	5	0	0
103,201,301,302,305	60	145	32	0	75	6	0
401	1	1	2	0	2	1	0
312,411,604	0	0	0	14	1	8	2
204,205,303,304,310,406,410	5	35	9	6	81	57	11
202,307–309,402,405,407,408,701,702,704	0	4	0	9	27	83	12
203,306,403,404,601–603,705	0	2	1	1	10	28	88
Consistency ± S.E.	0.51 ± 0.04	0.35 ± 0.05	0.04 ± 0.05	0.42 ± 0.08	0.14 ± 0.06	0.48 ± 0.04	0.71 ± 0.04

Table 4. The contingency table showing the proportion (x 1000) of the Environmental stratification of Europe (EnS) (Metzger *et al*. 2005) in each of the 27 combinations of the 215 classes of Biogeoclimatic Land Classification (Elena-Rosselló *et al*. 1997) of the Spanish Rural Landscape Monitoring System (SISPARES) (Elena-Rosselló *et al*. 2005). Kappa = 0.64, Delta = 0.64. The measure of consistency of each EnS strata with groups of SISPARES geoclimatic classes is shown with their standard error between brackets.

	LUS				*ATC*	*ALS*		*MDM*							*MDN*							*MDS*					
SISPARES/EnS (*Consistency* ± *S.E.*)	*1*	*2*	*3*	*4*	*5*	*5*	*6*	*1*	*2*	*3*	*5*	*6*	*7*	*8*	*1*	*3*	*4*	*5*	*6*	*7*	*9*	*1*	*2*	*4*	*5*	*6*	*7*
106,107,116–120,122,126,128,130, 131 (0.76 ± 0.05)	37	0	5	3	0	0	4	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
121, 219, 223 (0.57 ± 0.16)	0	4	0	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
102,104,105,111–115,127 (0.66 ± 0.07)	4	0	26	9	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
101,103,108–110 (0.53 ± 0.10)	0	0	5	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
124 (0.40 ± 0.20)	2	1	1	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
338–34n1 (0.89 ± 0.06)	0	0	0	0	0	12	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
132, 237, 238 (0.62 ± 0.11)	1	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
123,125 (0.50 ± 0.22)	0	0	0	0	1	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
229, 230, 232, 233 (0.37 ± 0.09)	0	1	0	0	0	0	3	0	10	2	4	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0	0
329, 335, 336 (0.47 ± 0.11)	0	0	0	0	0	0	0	0	0	8	3	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
234, 239, 337 (0.27 ± 0.11)	0	0	0	0	0	0	2	0	2	2	5	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0
207,231 (0.65 ± 0.06)	0	0	0	0	0	1	0	0	2	3	6	36	2	1	6	0	0	0	2	0	1	0	0	0	0	0	0
334, 527 (0.30 ± 0.17)	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0
404, 622, 627, 728 (0.61 ± 0.11)	0	0	0	0	0	0	0	0	0	0	0	0	2	8	0	0	0	0	0	0	0	0	0	0	0	0	0
215–218,220,222,224–228,625, 626 (0.64 ± 0.06)	0	0	0	0	0	0	0	0	5	0	1	0	0	0	35	0	0	8	0	0	0	0	0	0	0	0	0
315, 318 (0.47 ± 0.14)	0	1	0	0	0	0	0	0	0	0	1	1	1	0	0	5	1	3	2	0	0	0	0	0	0	0	0
202, 236 (0.46 ± 0.15)	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	4	1	1	0	0	0	0	0	0	0	0
201,203–206,209,211–214,221,618 (0.68 ± 0.05)	0	0	0	0	0	0	0	0	1	0	1	1	0	0	4	0	3	41	5	0	0	0	0	0	0	0	0
208,210,312,313,316,317,322,605,615–617, 619 (0.55 ± 0.06)	0	0	0	0	0	0	0	0	0	0	0	3	1	2	4	1	1	7	42	0	8	6	1	1	0	0	0
525 (0.50 ± 0.22)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2	0	1	0	0	0	0	0
319,401,406–408,524,604,608, 609,620,621,623,722, 723,726,727 (0.61 ± 0.05)	0	0	0	0	0	0	0	0	0	0	0	3	0	3	0	0	0	0	3	0	56	6	0	10	0	0	0
301–308,506,507,510–512,517,518, 521,522,526,601–603, 606,607,610–614,624 (0.78 ± 0.03)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	5	1	13	100	2	3	6	0	0

(*continued*)

Table 4. (*Continued*).

	LUS				*ATC*	*ALS*		*MDM*							*MDN*							*MDS*					
SISPARES/EnS (*Consistency* ± *S.E.*)	*1*	*2*	*3*	*4*	*5*	*5*	*6*	*1*	*2*	*3*	*5*	*6*	*7*	*8*	*1*	*3*	*4*	*5*	*6*	*7*	*9*	*1*	*2*	*4*	*5*	*6*	*7*
309–311,314,413,414,416 (0.61 ± 0.07)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	3	1	2	0	22	4	4	0	0
402,403,405,409–412,503, 504,505,514–516,519, 520,713,715,719–721,724,725 (0.65 ± 0.05)	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	12	1	5	65	12	0	0
415,417–421,501,508,509,513,703,710, 711,712,716–718 (0.70 ± 0.04)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	3	8	61	3	3
709,714 (0.55 ± 0.14)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	3
701,702,704–708 (0.79 ± 0.06)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	3	2	23

Differences in spatial resolution between two classifications also affect the similarity indices. When the resolution of the EnS (1 km) is coarser than the resolution of the national classification, then the loss of detail will lower the degree of similarity, which would then be underestimated. This is the case for SINUS (Austria), which has a 1 ha resolution. By contrast, in the reverse situation the similarity would be overestimated, as in the cases of Sweden (5 $\times$ 5 km resolution) and Spain (2 $\times$ 2 km resolution). Only the GB classification has the same resolution of 1 km as the EnS.

The aggregation of the classifications to achieve an identical number of strata in the Kappa analysis results in a simplification and loss of detail in the datasets that is not expressed in the Kappa and Delta statistics. For example, the high Kappa and Delta values in Spain ignore the fact that 215 national classes have been aggregated into 27 groups of classes, with obvious loss of information. However, the aim of this study is to illustrate that the national stratifications can provide additional detail to enrich the EnS.

Finally, differences in classification methods and the input data will influence the stratifications. The EnS is based on climatic variables, while in Sweden socio-economic factors were included and in Austria land use information. Therefore, there will be inevitable differences between the European and national datasets. However, Bunce *et al.* (2002) compared several national environmental classifications with an earlier European environmental classification and showed how the core of strata remained stable. These results are amplified by the further detail provided in the present paper which confirms that, although there are differences in detail, statistical stratifications have much in common even although different scales may be involved.

5.3. The potential for integration into a European monitoring framework

As outlined in the introduction, policy commitments and ecosystem management require reliable monitoring data from large areas to make informed decisions (Parr *et al.* 2002, 2003, Pereira and Cooper 2006). Integration of ongoing national and regional monitoring activities (Schmeller *et al.* 2006) is crucial to ensure cost-effectiveness and gain policy support among countries. This is especially important when patterns of change follow environmental gradients, as is the case with climate change (Gitay *et al.* 2002, Metzger *et al.* 2008).

Within EBONE, the EnS is used as a framework to integrate disparate sources of biodiversity data. These include connectivity and phenology analyses using remote sensing techniques, habitat information derived from statistically designed field surveys (Bunce *et al.* 2008), and information about species distributions. The result will provide a coherent picture of the current state of European biodiversity.

The similarity between the EnS and national stratifications presented in this paper support the possibility of integrating national monitoring activities within EBONE. Despite inevitable differences, the EnS recognised the broad patterns discerned by the national stratifications, and national samples can therefore be associated with European strata. The implication is that some regions could be over-sampled, but this effect will be minimised when linked to the strata. The EnS is envisioned as the geographic sampling and reporting framework for EBONE, and will underpin the formal sampling design allowing for integration with existing programmes, and meeting information requirements of end-users to support the successful management of biodiversity and ecosystem resources.

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Notes

1. When a classification is specifically designed to divide gradients into relatively homogeneous groups, the present paper uses the term 'stratification'.
2. See http://www.countrysidesurvey.org.uk/
3. EBONE (European Biodiversity Observation Network), a Framework Programme 7 aimed at developing a cost effective system for biodiversity data collection at regional, national and European levels. Available from: http://www.ebone.wur.nl/

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