A Spatial Regional Reference Framework for Sustainability Assessment in Europe

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Abstract

A Spatial Regional Reference Framework (SRRF) has been produced which will allow an efficient assessment of sustainability impact indicators across Europe. In order to achieve this goal, it was necessary to define relatively homogeneous regions, in terms of both biophysical and socio-economic characteristics. The major objective was the integration of these dimensions into European regions that were as uniform as possible. Therefore, in order to retain comparability, it was necessary to use consistent European databases. The spatial framework consisted of three levels, which were necessary to incorporate data on different tiers of spatial aggregation: (1) the INSPIRE Reference Grid, (2) a newly established NUTSx classification, which is a trade-off between administrative European NUTS2 and NUTS3 regions, and (3) the construction of SRRF cluster regions. The last were produced by using a statistical cluster analysis based on a restricted set of important biophysical and socio-economic parameters. 27 cluster regions resulted, which provided a flexible tool for further impact assessment at regional level.

Keywords

European cluster regions, statistical clustering, NUTSx classification, LANMAP2, Spatial Regional Reference Framework (SRRF), primary landscape structure, secondary landscape structure, regional impact assessment

1 Introduction

1.1 Background

Since the late 1980s, sustainable development has become a keynote in EU planning and policy. In general, three main policy dimensions are associated with sustainable development: economic, environmental and social. In order to assess the policy impact within the three dimensions, indicators and guidelines have been developed to provide the basis for in-depth analysis of sustainability impact assessment (CEC 2005). The SENSOR project seeks to identify regional sustainability thresholds, by considering regional differences in the socio-economic and biophysical settings. The analysis required regions that were comparable both in biophysical and socio-economical factors, and at a consistent spatial scale that is practical for European impact assessments. As a consequence, there is a need to identify and delineate spatial units which are relatively homogeneous, in order to be able to assess sustainability impact issues. Previous stratification approaches have mainly been based on biophysical parameters, although they had the potential for including landmanagement and selected socio-economic factors into the frameworks. Some of these classifications are highlighted below and were important sources for meeting the final goal:

- European Landscapes Map described by Meeus (Meeus, 1995): this pan-European landscape typology describes 30 European landscapes. The map integrates not only land form, soil and climate and but also regional culture, habits and history. Its spatial accuracy is not high since it is based mainly on expert-knowledge.
- Environmental Zones (Mücher et al. 2003, Metzger et al. 2005): this classification is derived from climatic, altitude, latitude, slope and oceanity variables. The resulting 84 environmental strata have been aggregated into 13 Environmental Zones. They are useful strata for stratified random sampling of ecological resources.

- LANMAP 2 (Mücher et al. 2003, Mücher et al. 2006): this is a European Landscape Classification that was produced in parallel with the Environmental Classification. LANMAP2 is hierarchical and has four levels. The first level is determined by climate (Environmental Classification) and has eight classes (aggregated), the second level uses climate and topography and has 31 classes, and the third level also includes parent material and has 76 classes. The database contains more than 14,000 mapping units and the minimum unit is 11 km^2. The fourth and final level is determined by climate, topography, parent material and land cover and has 350 landscape types. LANMAP2 already has many applications in the field of environmental stratification, indicator reporting and analysis of changes at the landscape level.

While classical environmental assessment builds upon purely biophysical research at the ecosystem or biogeographic level, most socio-economic studies are based mainly on demographic, economic or policy information. However, landscape scientific research, which once had a purely ecological perspective, is broadening to include wider socio-cultural domains (Naveh & Lieberman 1994; Wascher 2005). The interdependencies that exist between landscape character and the socio-economic context have also been stressed (Peterseil et al. 2004; Wrbka et al. 2004). Therefore, it seems to be a logical step, when defining European regions, to consider socio-economic factors that will help to provide the background for assessing sustainability, sensitivity to change and multi-functionality in the landscape. It is on this basis that an integrated approach for identifying homogenous regions in Europe has been selected. Both bio-physical and socio-economic parameters have been combined into a spatial stratification of land, which is an innovative concept because it is designed to overcome the methodological fragmentation of most current approaches.

1.2 Objective

In the current analysis, the objective is to establish a Spatial Regional Reference Framework (SRRF) for Europe, by stratifying the European land surfaces into relatively homogeneous regions, integrating biophysical, socio-economic and regionally specific characteristics The underlying rationale for conducting a more in-depth regional characterisation is to quantify the high degree of cultural and natural diversity that exists between European regions (Wascher 2005; Mücher et al. 2003). The approach is based upon the following assumptions:

1. regional characteristics determine the scale and scope of impacts on sustainability that have resulted from policy-induced land use changes;
2. environmental and socio-economic profiles are independent of administrative boundaries and define regional coherence and differences across the entire EU;
3. taking regional characteristics into account will facilitate expert assessments (e.g., for the identification of regional thresholds) and stakeholder participation;
4. understanding and addressing these regional characteristics will greatly improve the interpretation of impacts with regard to their likely environmental and socio-economic effects.

2 Methods

2.1 Building up the framework

The smallest spatial unit available for a European-wide assessment of socio-economic and regional administrative aspects is the NUTS2 or 3 level (Official Journal of the European Union, 2003). The Nomenclature of Territorial Units for Statistics (NUTS) was established by Eurostat more than 25 years ago, in order to provide a single uniform breakdown of territorial units for the production of regional statistics for the European Union (http://ec.europa.eu/comm/eurostat/ramon/nuts/introduction_regions_en.html). This information is only meaningful at the level of spatial aggregation, in contrast with the majority of the biophysical aspects, which can be up- or downscaled more easily. Hence, it is necessary to take these NUTS levels into account as the smallest spatial units when looking for homogeneous regions, although there are obvious limitations.

The framework is made up of three levels (Figure 1): Grids with available biophysical information, NUTS regions as the spatial level of available socio-economic information and SRRF clusters which combine all these data. Together, all three levels create an interrelated spatial framework with grid cell level as the smallest unit.

In order to derive homogeneous regions, it is necessary to take into account both spatial integration of biophysical aspects and also how NUTS regions can be used for threshold analysis. Cluster analysis of NUTS regions into SRRF regions is the most appropriate statistical approach, considering the fact that the resultant classes will always be heterogeneous to some degree. The result of the statistical clustering procedure was intended to provide the basis for environmental and socio-economic profiling by identifying relevant and important variables for sustainability assessment.

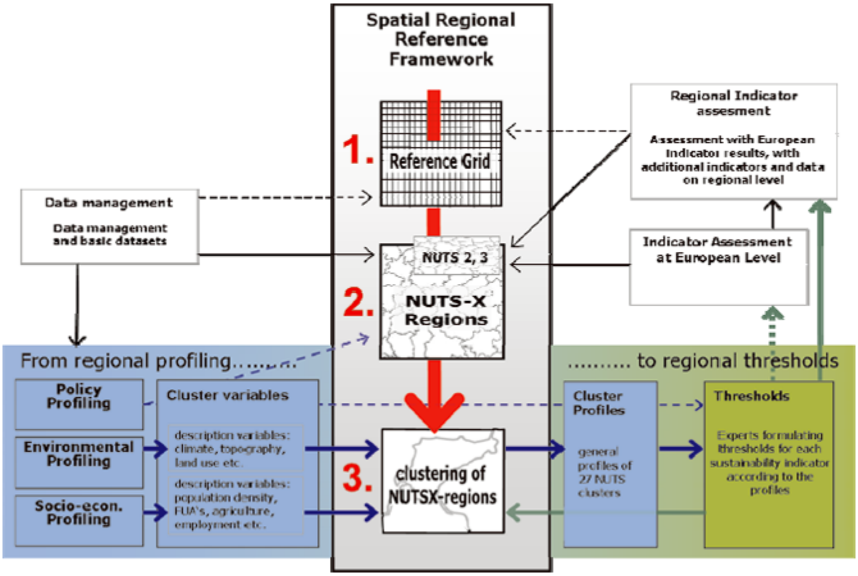

Fig. 1. The three main levels of the Spatial Regional Reference Framework: 1. Reference grid, 2. NUTS-regions and 3. SRRF clusters, creating a related spatial framework with its applicability in the regional assessment.

2.2 Deriving a comparable level of NUTS-regions: the NUTS-X map

It is essential for the NUTS regions to have comparable landscape areas in order to achieve reliable clustering with a degree of homogeneity. In addition, administrative boundaries should be taken into account to ensure that units are comparable for statistical procedures. In order to derive data compatibility between the different variables, the EU common standard of geographical sample grids of the European Environment Agency (EEA) was adopted; using the INSPIRE standards (INSPIRE 2002). The result is termed a NUTSx map and is a selective composition of NUTS2 and 3 units on the basis of the IRENA methodology (EEA 2005).

However, the IRENA project involved only 15 countries, whereas the SENSOR project covers all 27 EU countries, plus Norway, Iceland and Switzerland. Therefore, it was necessary to define the NUTSx level for the additional 12 countries.

Proposals were made on the basis that the chosen level should be comparable to the size of the IRENA regions as regards area, population size and administrative status.

For some of these 12 countries it was difficult to find the appropriate trade-off between the NUTS2 or 3 levels. For example, in Hungary, the Czech Republic and Slovakia, NUTS2 is appropriate on the basis of area or NUTS3 because of population size. In Hungary the choice of NUTS3 could also be made on the basis of its administrative status: the Megyek is the traditional regional division in Hungary, whereas NUTS2 regions are only for statistical purposes. Using the same logic, the opposite choice could be made in Poland. For both countries, the area and population size that are closest to an IRENA region would fall between NUTS2 and NUTS3.

Table 1. - Overview of final NUTS-X regions for the SRRF

Nr	Code	EU 27 + 3	IRENA coverage	Member EU	Average NUTS-X size (km2)	Final Sensor NUTS-X-level	Number of NUTS-X regions	Number of NUTS-2 regions	Number of NUTS-3 regions	NUTS-2 / NUTS-3 ratio	NUTS-2 (km2)	NUTS-3 (km2)	COUNTRY (km2)
1	LU	Luxembourg	Yes	Yes	2565	3	1	1	1	1.0	2565	2565	2565
2	BE	Belgium	Yes	Yes	2752	2	11	11	43	3.9	2752	704	30273
3	NL	Netherlands	Yes	Yes	2920	2	12	12	40	3.3	2920	876	35039
4	DK	Denmark	Yes	Yes	2835	3	15	1	15	15.0	42527	2835	42527
5	IE	Ireland	Yes	Yes	8662	3	8	2	8	4.0	34647	8662	69295
6	AT	Austria	Yes	Yes	9239	2	9	9	35	3.9	9239	2376	83150
7	PT	Portugal	Yes	Yes	13306	2	7	7	30	4.3	13306	3105	93139
8	GR	Greece	Yes	Yes	10280	2	13	13	51	3.9	10280	2620	133642
9	UK	United Kingdom	Yes	Yes	6529	2	37	37	133	3.6	6529	1816	241576
10	IT	Italy	Yes	Yes	14341	2	21	21	103	4.9	14341	2924	301167
11	FI	Finland	Yes	Yes	17083	3	20	5	20	4.0	68333	17083	341667
12	DE	Germany	Yes	Yes	8608	2	41	41	439	10.7	8608	804	352909
13	SE	Sweden	Yes	Yes	21506	3	21	8	21	2.6	56452	21506	451620
14	ES	Spain	Yes	Yes	10208	3	50	17	50	2.9	30024	10208	510402
15	FR	France	Yes	Yes	5681	3	96	22	96	4.4	24788	5681	545340
16	MT	Malta	No	Yes	323	2	1	1	2	2.0	323	162	323
17	CY	Cyprus	No	Yes	9499	3	1	1	1	1.0	9499	9499	9499
18	SI	Slovenia	No	Yes	1678	3	12	1	12	12.0	20135	1678	20135
19	EE	Estonia	No	Yes	8982	3	5	1	5	5.0	44910	8982	44910
20	SK	Slovakia	No	Yes	6060	3	8	4	8	2.0	12121	6060	48484
21	LV	Latvia	No	Yes	10643	3	6	1	6	6.0	63858	10643	63858
22	LT	Lithuania	No	Yes	6405	3	10	1	10	10.0	64050	6405	64050
23	CZ	Czech Republic	No	Yes	5566	3	14	8	14	1.8	9741	5566	77925
24	HU	Hungary	No	Yes	4611	3	20	7	20	2.9	13174	4611	92218
25	BG	Bulgaria	No	Yes	3966	3	28	6	28	4.7	18506	3966	111039
26	RO	Romania	No	Yes	5642	3	42	8	42	5.3	29622	5642	236974
27	PL	Poland	No	Yes	6839	3	45	16	45	2.8	19235	6839	307763
28	CH	Switzerland	No	No	5778	2	7	7	26	3.7	5778	1556	40448
29	IS	Iceland, Island	No	No	104253	3	1	1	1	1.0	104253	104253	104253
30	NO	Norway	No	No	17242	3	19	7	19	2.7	46799	17242	327596
		Average			**11133**		**19**	**9**	**44**	**4.5**	**26311**	**9229**	**159459**
		Total					**581**	**277**	**1324**				

It was decided that for these countries the NUTS3 level should be used in SENSOR.

Choosing NUTS3 prevents dilution of available information by keeping the spatial regionalisation at the most detailed level. If necessary (e.g., if there were to be a change in the availability of information), the NUTSx level could be changed. Table 1 gives an overview of the final NUTSx level used in the cluster analysis.

2.3 Development of SRRF regions

Conceptual Approach

The methodology for developing and profiling homogeneous regions was guided by the hierarchical concept of "primary – secondary – tertiary landscape structure" (O'Neill et al. 1986, Ružicka & Miklos 1990), an approach which tries to assign systematically any landscape attribute to three domains: the biophysical (Primary Landscape Structure or PLS), the land-management / socio-economic (Secondary Landscape Structure or SLS) and planning / policy which is the Tertiary Landscape Structure, or TLS (see Figure 2).

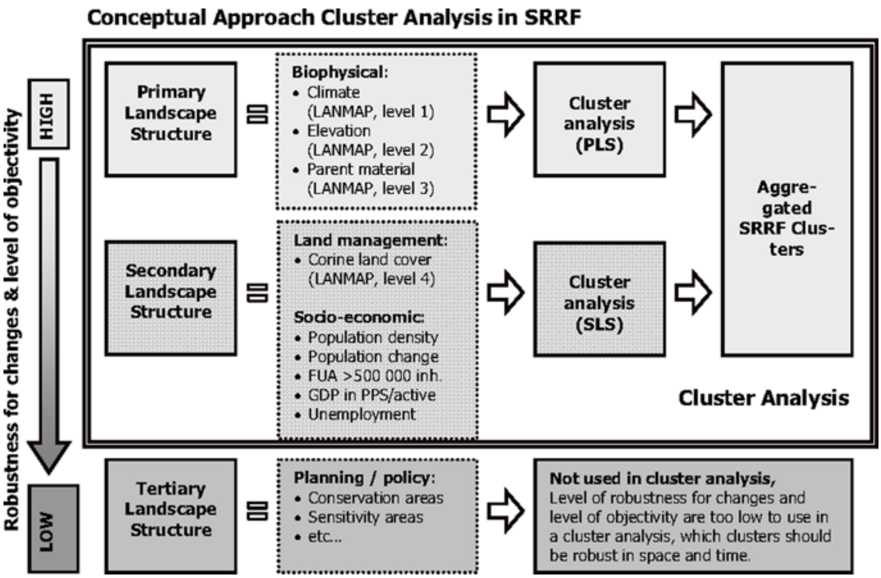

Fig. 2: Conceptual approach for establishing clusters in the Spatial Regional Reference Framework; (FUA = Functional Urban Area, GDP in PPS/active = GDP per worker (active population) in 1999 in purchasing power standards (PPS)

In this concept, parameters which cannot be altered; e.g., climate, topography and bedrock; are the main drivers of land cover and are therefore assigned as PLS.

Landscape change resulting from human interaction with PLS can be rapid; e.g., from forest to pasture; and is therefore at the second hierarchical level. Landscape policy and / or planning and administrative boundaries are often dynamic, but in general their influence is not readily quantifiable. These aspects are assigned to the lowest level of the concept – the TLS.

This approach was chosen to keep the subsequent statistical procedures as simple and transparent as possible. However, it was also decided that the whole classification approach should allow flexibility for any necessary improvements by stepwise integration of additional variables and/or knowledge. Biophysical/socio-economic and land cover data have been clustered in two separate steps. This offers more transparency in separating the results for the biophysical variables from the relatively more dynamic socio-economic and land use management variables (see Figure 2).

The tertiary landscape structure level (the planning / policy domain) is not suitable for a cluster analysis, because the levels of resistance to change and the objectivity are too low.

The next stage was to aggregate the two resulting data sets to form reasonably homogenous clusters within Europe. A matrix of NUTSx regions was therefore constructed, comprising a combination of a PLS / SLS clusters (see Figure 3).

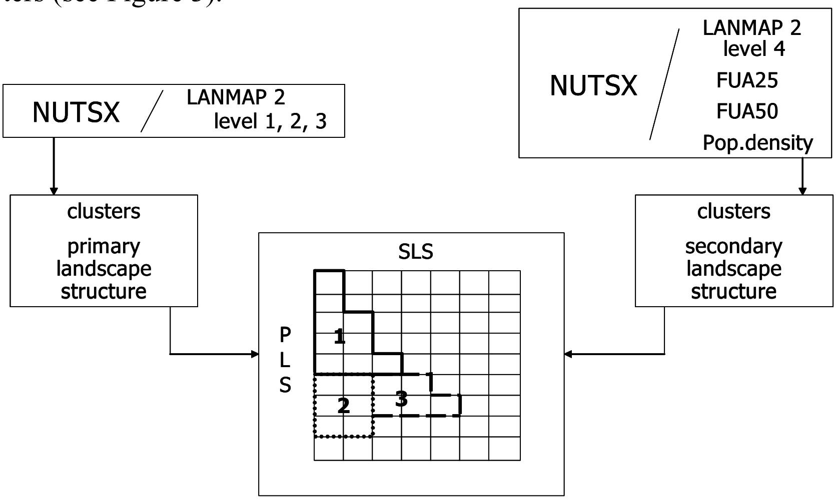

Fig. 3: Concept of aggregating PLS and SLS clusters to SRRF clusters; PLS = Primary Landscape Structure; SLS = Secondary Landscape Structure; SRRF = Spatial Regional Reference Framework

Aggregation of the two sets of clusters was carried out by building a matrix, arranging the clusters according to the relative distance between the cluster centres. Clusters with a small distance between each other, were merged with their neighbours, whereas clusters that were further apart, were grouped separately. In this matrix, columns and/or lines, which represent a given degree of similarity, were joined into one SRRF cluster, but there remained some options for generalising or further dividing some groups.

Methodological Implementation

Input data

To create a meaningful Europe-wide clustering of NUTSx regions, consistent data are essential, therefore only two accepted data sets were used. The biophysical data representing PLS were derived from LANMAP2 (Mücher 2005) and socio-economic data for the SLS were extracted from the ESPON and EUROSTAT database (http://www.espon.eu/; http://epp.eurostat.ec.europa.eu).

All levels of LANMAP2 were intersected in GIS with the NUTSx regions to calculate the percentages of area of the variables for each NUTSx. Since it is generally assumed that coastal influence is important, as is emphasised by many institutions; e.g., the Integrated Coastal Zone Management of the EU (http://ec.europa.eu/environment/iczm/home.htm); the length of coastline per NUTSx region was calculated and incorporated into the cluster input data.

The socio-economic data set, which was proposed by Briquel (2007), consisted of 16 variables which needed to be redefined and re-aggregated. Because several of these attributes showed strong correlations with each other, a selection had to be made. Therefore, the parameters were grouped according to their different information content (demography, GDP & (un-)employment and FUAs). Within each of the groups a Principal Components Analysis (PCA) (Jongman et al. 1995) was carried out, revealing the most significant parameters. The final selection was based on the highest correlation of variables with the resulting axes of the PCA; this is shown in Table 2, as input data for the cluster-analysis.

Because it proved impossible to obtain complete coverage of Europe, there are still gaps in the existing data concerning a few NUTSx regions[1].

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[1]The excluded regions are: Las Palmas, Tenerife, Andorra, Bjornoya, the Channel Islands, Cyprus, the Faeroe Islands, Gibraltar, the Isle of Man, Iceland, Jan Mayen, Liechtenstein, Monaco, the Azores, Madeira, San Marino and the Vatican City

Because of this, these regions have not been integrated into the clustering process.

Table 2. Selected variables for cluster-analysis

PLS		
LANMAP2	climate	Alpine North % area
		Alpine South % area
		Arctic % area
		Atlantic Central % area
		Atlantic North % area
		Boreal % area
		Continental % area
		Lusitanian % area
		Mediterranean Mountains % area
		Mediterranean North % area
		Mediterranean South % area
		Nemoral % area
		Pannonian % area
		Steppic % area
	topography	lowland % area
		hills % area
		mountains % area
		high mountains % area
		DEM alpine % area
	parent material	river alluvium % area
		marine alluvium % area
		glaciofluvial deposits % area
		calcereous rocks % area
		soft clayey materials % area
		hard clayey materials % area
		sands % area
		sandstone % area
		soft loam % area
		siltstone % area
		detrital formations % area
		crystalline rocks and migmatites % area
		volcanic rocks % area
		other rocks % area
		organic materials % area
		unclassified (urban/water/ice) % area
		coastline % perimeter

SLS		
ESPON / EUROSTAT		population density 2003
		population annual change rate % 1998-2003
		activity rate in %
		index of GDP in PPS/active in €
		unemployment rate 2003
		FUAs with > 500000 habitants population in thousands
LANMAP2	land cover	artificial surfaces % area
		arable land % area
		intertidal flats % area
		forest % area
		heterogeneous agric. areas % area
		open spaces with little or no vegetation % area
		pastures % area
		permanent crops % area
		shrubs & herbaceous vegetation % area
		waterbodies % area
		wetlands % area

Cluster Analysis

The aim of the cluster analysis was to generate groups of NUTSx regions to enable the development of sustainability profiles, and the calculation of regional indicators and thresholds.

The resulting NUTS groups were presented as maps (see Figures 4, 5 and 6). A stepwise clustering method, as described in the conceptual approach, delivered the best results and generated 27 clusters; with variance being kept as low as possible *within* clusters, and as high as possible *between* clusters.

Clustering PLS and SLS

The structure of the input data (building on experience from the draft calculations with SPSS 12.0) led to the conclusion, that K-Means clustering using Euclidean distance was the most appropriate clustering technique. This procedure is suitable for calculations with metric data. The main advantage, compared to the hierarchical method, is that objects which are part of one cluster can be removed and allocated to another in the following iterative step. Iteration is done as long as the optimal cluster solution is found and the sum of variation square is minimised within the clusters (Janssen & Laatz, 2005).

In this method, the number of clusters has to be specified beforehand. It was therefore necessary to run some trials in order to achieve a tenable result. A point was reached when it became unproductive to enlarge the number of clusters, because those with many NUTSx regions did not split up, but a significant number of single NUTSx regions were created that formed a cluster on their own. Based on the results of the trials, it was found that 25 PLS cluster and 20 SLS cluster satisfactorily represented heterogeneity at the European level. This resulted in the avoidance of isolated individual clusters with fewer than 3 NUTSx regions (spatial homogeneity), while retaining the ability to show differences at the highest possible level.

Aggregation to Spatial Regional Reference Framework Clusters

After clustering NUTSx regions according to their PLS and SLS, it was necessary to join them together and form relatively homogenous regions throughout Europe. Each NUTSx region combines two different clusters (one PLS, one SLS). The cluster results created the possibility of constructing a matrix with PLS in rows and SLS in columns (Figure 3).

Distances between the cluster centres show how strongly clusters are linked. Small distances indicate a greater similarity and they were therefore grouped next to each other, and clusters which differed more were arranged further apart. Some clusters have a connection with several groups and it was therefore necessary to use expert knowledge in order to find the appropriate allocation. Depending on what degree of detail the regional profiles required, it was possible to formulate around 100 regions (the number of existing combinations) or to generalise them if required. The first attempt defined 30 groups which appeared to show clear differences between regions, from the European perspective.

3 Results

3.1 Regional Clusters

Primary Landscape Structure (PLS)

Basically, 25 clusters could be identified from the analysis of PLS. In Figure 4, a map shows the classification of the NUTSx regions, based on biophysical variables. One result is the cluster centre values, which are the calculated mean of the variables of the NUTSx regions belonging to the cluster, and provide the basis for describing each one.

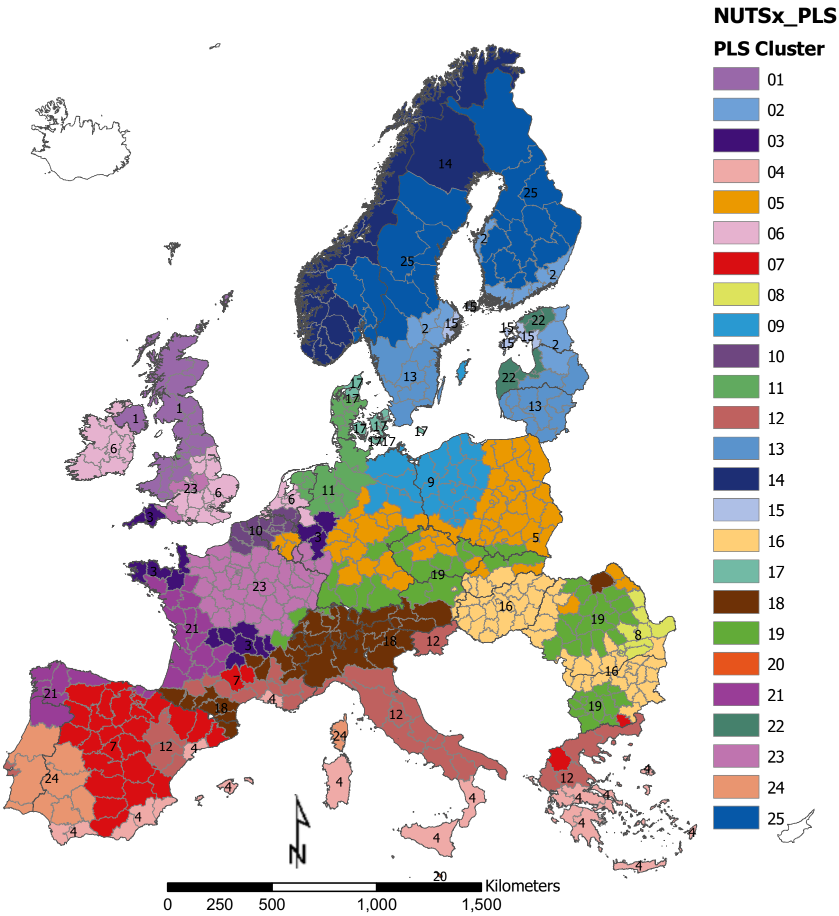

Fig. 4. PLS cluster regions of Europe

Table 3: ANOVA analysis of PLS clusters, variables which are significant in forming the clusters are highlighted in orange (higher significance) and blue (lesser significance)

		ANOVA				
		Cluster		Error		
		mean square	df	mean square	df	F
Climate	Alpine North	2,864.36	24	16.496	539	173.635
	Alpine South	4,387.63	24	83.952	539	52.264
	Arctic	0.144	24	0.095	539	1.523
	Atlantic Central	25,831.14	24	88.086	539	293.248
	Atlantic North	9,262.43	24	79.588	539	116.38
	Boreal	11,564.55	24	33.038	539	350.035
	Continental	26,076.77	24	181.415	539	143.741
	Lusitanian	6,162.97	24	40.137	539	153.548
	Med. Mountains	2,257.71	24	65.675	539	34.377
	Mediterranean North	4,553.53	24	112.339	539	40.534
	Mediterranean South	6,025.18	24	75.218	539	80.102
	Nemoral	8,648.57	24	27.826	539	310.808
	Pannonian	12,760.92	24	64.697	539	197.24
	Steppic	2,180.02	24	17.795	539	122.507
topography	Coastline	10,365.03	24	378.589	539	27.378
	intertidal flats	4.812	24	1.054	539	4.564
	hills	17,101.79	24	337.414	539	50.685
	lowland	21,717.98	24	269.544	539	80.573
	mountains	12,884.47	24	213.174	539	60.441
	high mountains	2,176.26	24	33.442	539	65.075
	alpine (DEM)	1.468	24	0.176	539	8.357
parent material	river alluvium	1,520.19	24	137.783	539	11.033
	marine alluvium	175.364	24	23.119	539	7.585
	glaciofluvial sediments	20,445.34	24	146.891	539	139.187
	calcareous	6,297.39	24	176.024	539	35.776
	soft clayey	988.273	24	132.27	539	7.472
	hard clayey	28.924	24	12.535	539	2.307
	sands	4,024.47	24	149.964	539	26.836
	sandstone	212.63	24	43.958	539	4.837
	soft loam	8,247.91	24	219.202	539	37.627
	siltstone	4.734	24	1.18	539	4.012
	detrital formations	67.408	24	28.359	539	2.377
	crystalline	10,267.62	24	273.085	539	37.599
	volcanic	55.303	24	21.708	539	2.548
	other rocks	176.62	24	35.033	539	5.042
	organic materials	85.299	24	14.061	539	6.066
	unclassified	3.757	24	0.824	539	4.559

The ANOVA analysis (Table 3) provides information about the significance of attributes for the classification. The high F-values indicate that climatic variables are the most important distinguishing feature on a broad scale. However, topography and parent material are discriminators for classifying regions within.

Secondary Landscape Structure (SLS)

On the basis of the input data, the NUTSx regions were assigned to 20 clusters. Figure 5 presents the European SLS clusters. The ANOVA analysis presented in Table 4 reveals that land cover is mainly responsible for creating clusters; other socio-economic variables play a less important role.

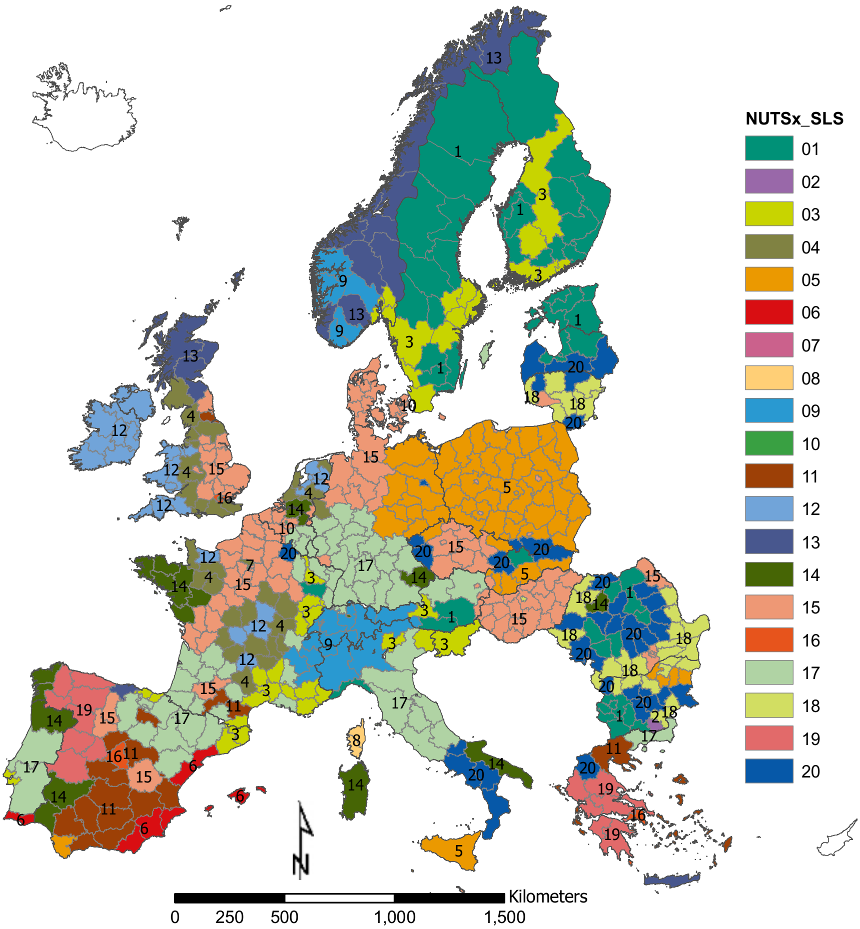

Fig. 5. SLS cluster regions of Europe

Table 4. ANOVA analysis of SLS clusters, variables which are significantly forming the clusters are highlighted in orange (higher significance) and blue (lesser significance)

ANOVA	Cluster		Error		
	mean square	df	mean square	df	F
pop.density	796.951	19	10.222	544	77.968
pop.change	9,455.269	19	178.736	544	52.901
activity rate	222.055	19	36.432	544	6.095
GDP	3,296.948	19	65.859	544	50.060
unemployment rate	5,188.289	19	103.909	544	49.931
FUA	1,300.655	19	112.421	544	11.570
artificial surfaces	2,056.768	19	10.620	544	193.670
arable land	30,142.035	19	166.882	544	180.619
intertidal flats	1.526	19	1.173	544	1.301
forest	23,136.604	19	127.593	544	181.331
heterogeneous agric. areas	3,513.123	19	76.378	544	45.996
open spaces (unvegetated)	2,523.869	19	17.245	544	146.352
pastures	11,369.805	19	43.295	544	262.615
permanent crops	136.243	19	19.706	544	6.914
shrubs & herbaceous vegetation	5,515.312	19	53.432	544	103.221
waterbodies	4.000	19	1.604	544	2.494
wetlands	5.201	19	1.379	544	3.772

Aggregation to SRRF clusters

Each NUTSx region belongs to one PLS and one SLS cluster. In total, there are 107 different combinations of clusters; those most alike are grouped next to each other. In the matrix, lines indicate where aggregations are statistically not feasible.

The method is flexible because it combines a statistical base and still allows for expert judgement. Depending upon which level of detail seems to be necessary, aggregation can be adjusted.

When working with the SRRF clusters in terms of applications, it was apparent that the first result of the "scientific" clustering had limitations, because policy makers require spatial coherence in order to reflect regional character. Therefore, in a second phase SRRF clusters were modified, using the PLS / SLS matrix based on the following pre-defined rules:

Individual or groups of identical SRRF clusters which lie more than 350 km apart were treated as follows:

- cluster regions with up to three NUTS regions were reallocated according to the matrix, or in exceptional cases to neighbouring classes ('changes with boundaries');

- if there were more than three NUTS regions then these were allocated to a separate cluster ('split-up');
- urban clusters, e.g. Paris, London, Berlin, Madrid, ('city rule') were allocated to surrounding clusters to keep consistency, because other significant conurbations were not included, e.g. Amsterdam;

Application of these rules resulted in 27 SRRF cluster regions (Figure 6). The reallocation of the outline of NUTS-X regions is improving the socio-economic cohesion, and is therefore easier to interpret and communicate to policy makers.

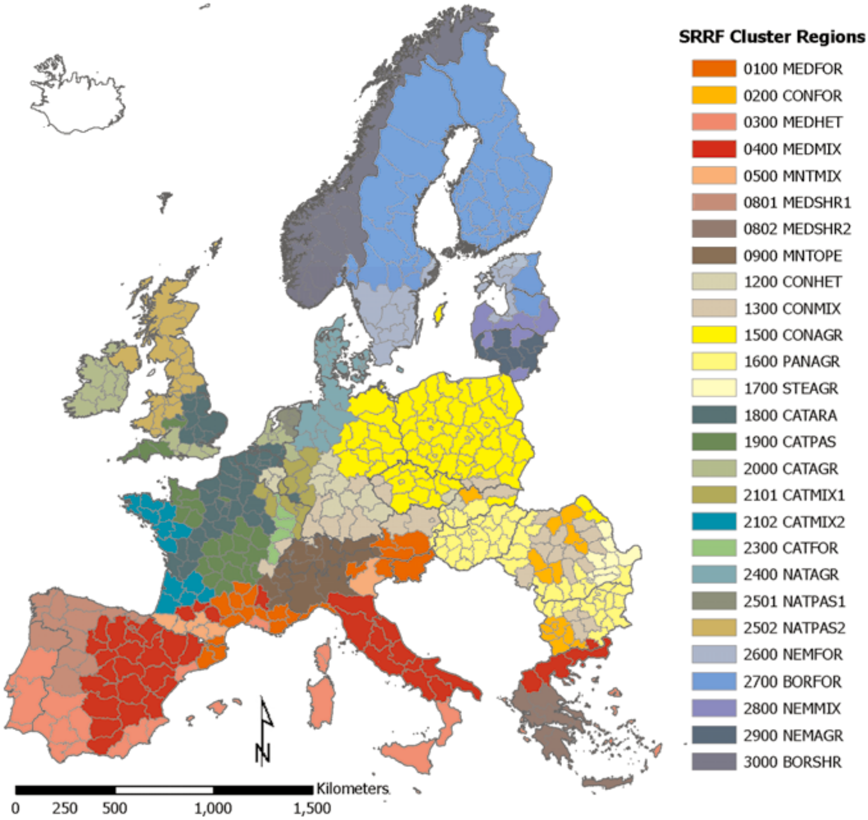

Fig. 6. Final SRRF cluster regions after implementing the post-processing procedure; identifiers and abbreviations of the SRRF cluster regions are presented in the adjacent legend.

4 Discussion

For the SENSOR project it is essential to find appropriate reference units for which thresholds and limits can be defined. As the impact assessment is based on three pillars of sustainability (economic, environmental and social), the development of these reference units has to be based on variables which represent all policy domains. Hence the approach described above.

Previously developed landscape classifications such as Environmental Zones (Metzger et al., 2005) and LANMAP2 (Mücher et al., 2006) are more appropriate for ecological investigations.

For a Europe wide classification it is important to rely on consistent data. Therefore the major data sources have been identified as LANMAP2 (Mücher et al. 2006) and the ESPON data base. Biophysical and land cover data were available on as grid or as vector data. But socio-economic parameters, e.g. GDP per capita, population density, unemployment rate etc., were in most cases available for administrative units (NUTS-regions). Therefore the interface of NUTS-X regions was developed in order to have the possibility to combine all data sets. This is one of the crucial points of the SRRF. On the one hand, NUTS-X show several limitations like different size, heterogeneity and different composition of land cover classes, but on the other hand, European projects and administrations are almost solely using these units (Official Journal of the European Union, 2003).

There remains a major constraint in that some socio-economic data from LANMAP for some NUTSx regions were not available for incorporation into the SRRF. A possible solution is to find other data-sources which offer comparable information and to integrate these data into the cluster regions. From a political and pragmatic point of view, this could be an administratively useful first step towards a classification system covering the whole of Europe. Other European institutions, e.g., the EEA may not find the SRRF as suitable, because environmental questions may need other spatial units.

The clustering and profiling for threshold analysis is based on primary and secondary landscape structure. Only the SLS is expected possibly to change in future, leaving the PLS as a robust basis of the current clustering method. In the timescale of the SENSOR project small administrative changes in NUTS boundaries will have limited effects on the clustering results. Major NUTS changes could influence the final clustering (e.g., new grouping of two NUTS regions, which are now in two different clusters). Since the original PLS and SLS values are known it is possible to regroup the new regions manually, with expert knowledge, as has been carried out in this version.

Another possible improvement would be to update the data. The ESPON data used covered the years 1999 / 2000, whereas land cover data were derived from CORINE 1990. Calculating a cluster-analysis with newer data may also result in slight changes. However, they are not expected to cause major re-arrangements of cluster regions since the change in land cover between the year 1990 and 2000 is relatively small (http://terrestrial.eionet.europa.eu/CLC2000/changes).

5 Conclusion

The SRRF can be considered as the first real attempt to integrate biophysical, socio-economic and regional specific characteristics into a robust spatial reference framework. It provides the basis for regional indicator assessment and acknowledges the heterogeneity of European geography and cultural identity. It is flexible and can be re-arranged if future generalisation, or major changes in boundaries and land use so require. Updating of input data and statistical improvements will be the main future tasks if the SRRF stays in use after the project-period of SENSOR.

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