INSTRUMENTS FOR ASSESSING THE BIOLOGICAL DIVERSITY APPLIED TO SOCIO-ECONOMIC SYSTEMS. CASE STUDY: ROMANIAN REGIONS OF DEVELOPMENT

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Abstract. When referring to environmental diversity, the components (the variety of ecological systems and species, the genetic diversity, and the heterogeneity of anthropized and anthropic systems) vary at different spatial scales. This study proposes a method for assessing the latter component, based on a correlation between its spatial levels and the territorial statistical units. Consequently, Shannon-Wiener's informational entropy index, its associated measure of evenness, and Simpson's measure of dominance are used to characterize three components of the ethno-cultural diversity in Romania: ethnic, religious, and territorial. The results indicate that the three components exhibit lower values than natural systems, suggesting the possibility of assimilating them to young systems, and display a heterogeneous spatial distribution varying in time and across components influenced by administrative and political changes, which seem to control anthropic systems.

Key words: biodiversity, geodiversity, ethno-cultural diversity, Shannon-Wiener index, Simpson's index.

1. Introduction

One of the defining characteristics of systems, regardless of being territorial, ecological or socio-spatial is diversity (or, synonymously, heterogeneity or variability). Diversity is understood in statistics quantitatively as scatter around a central tendency (Dragomirescu, 1998) and qualitatively as different number of elements with different abundances (evenness of distribution) - Dragomirescu, 1998; Magurran, 1998; Dragomirescu and Petrişor, 2009, and in ecology as variety of structure, relationships between components and functions (Vădineanu, 1998; Petrişor, 2008a). Based on the discipline, diversity is called in geography geodiversity, in ecology bio- and eco-diversity and in spatial planning cultural diversity. The analyses of definitions indicate that geodiversity and biodiversity coincide (Musilla *et al.*, 2005; Santucci, 2005), even though some authors believe that geodi-

versity includes biodiversity (Hakala, 2005), while others claim the opposite (Vădineanu, 1998).

The concept of **geodiversity** is disputed by two disciplines. In geography, geodiversity is the heterogeneity of "*geological elements (rocks, minerals, fossils), geomorphologic (landforms, processes) and pedological (soils), including their assemblies, relationships, properties, interpretations and systems*" (Gray, 2004). In geology, geodiversity is defined as expression of the "*geology of a region, including rocks, minerals, fossils or geological structures open by natural or anthropic means*" (Popa, 2007).

Biodiversity and **eco-diversity** are defined at several levels. Structurally are defined: (1) the diversity of ecological systems as life-support systems (including ranks superior to the species, integrated in the biological organizational hierarchy – biocoenose, biome, biosphere) and hydro-geomorphologic units (including habitats) – eco-diversity, (2) the diversity of species and levels of the taxonomic hierarchy (ω diversity) – biodiversity, (3) genetic diversity of population and sources (including the human species) and (4) ethno-cultural diversity of socio-economic systems (Vădineanu, 1998). The first three components reflect the diversity of the natural capital, while the last pertains to the created capital. Functionally, biodiversity is reflected by the variety of food niches and subunits of the biocoenose, defined based on their role in trophy: tropho-dynamic modules, guilds, trophy levels etc. (Popeascu, 2009).

The spatial viewpoint differentiates: (1) α diversity – ecosystem (most often measured based on diversity indices - Magurran, 1998), (2) ß diversity – micro-regional complex of ecosystems, (3) γ diversity – regional complex of ecosystems, *e .g*, eco-regions or European biogeographical regions, (4) δ diversity – macro-regional complex of ecosystems, *e .g*, global biogeographical regions, (5) ε diversity – life environments (oceanic, terrestrial), and (6) ω diversity – global phylogeny (included even though the approach is structural) - Magurran, 1998; Petrişor, 2008a, 2009; Pusceddu, 2008.

This study relies on the principle according to which ethno-cultural diversity, consisting of ethnic, linguistic and religious diversities (Petrişor, 2008a), represents a component of biodiversity (Vădineanu, 1998). The diversity of man-created systems, such as strongly-anthropized territorial systems (Ianoş, 2000) such as human settlements (urban and rural ecosystems - Petrişor, 2008a) can be added at a higher spatial level (ß or γ - Petrişor, 2008b). Administratively, socio-spatial systems are grouped by the levels of the Nomenclature of Territorial Units for Statistics (NUTS). The correspondence between the NUTS levels, geo-, bio- and eco-diversity is displayed in **Table 1**.

To analyze completely the Romanian diversity (including abiotic and biotic components at several spatial scales), it is enough to list its constituents: (1) five types of landform – floodplain, plain, hill or plateau and mountain (Cazan *et al.*, 2004; Mâra, 2007), (2) 900 Carpathian mineral species (Papp and Szakáll, 1996), (3) 10 classes and 39 types of soil (MMDD, 2008), (4) five of the eleven European biogeographical regions – alpine, Black Sea, continental, pannonian and steppic (Petrişor, 2008a), (5) 22 level 1 and 57 level 2 eco-regions (Cogălniceanu and Stanciu, 2001), (6) over 3700 de superior plant species and over 33802 animal species (Vădineanu *et al.*, 2003), (7) 783 types of habitats identified and

characterized in 261 areas analyzed in CORINE Biotopes (MMDD, 2007) and (8) ethno-cultural diversity reflected by 20 ethnic groups and 18 religions identified in the 2002 census (INS, 2008).

This study aims to employ statistical methods characteristic to the analysis of biological diversity to look at ethno-cultural and territorial diversity of Romania, hypothesizing that socioeconomic systems exhibit a lower diversity and can be assimilated to young (immature) ecological systems.

Table 1. Spatial approach of diversity based on NUTS classification

Diversity	*NUTS levels*			
	1 (national)	*2 (region of development)*	*3 (county)*	*5 (administrative unit)*
Hydro-geomorphologic units	x	x	x (by case)	
Biogeographical regions	x	x		
Eco-regions	x	x	x (by case)	
Types of ecosystems and/or habitats	CORINE I	CORINE I/II	CORINE II	CORINE III

x – indicates conformity between the approach and spatial scale

2. Materials and methods

The study compared ethno-cultural diversity of level II NUTS units (regions of development) using the methodology currently employed in ecology to compare the diversity of two ecosystems, biocoenoses, habitats etc. (Petrişor, 2000) based on Shannon-Wiener's index of diversity (informational entropy) - Magurran, 1998 computed for three datasets, referring to: (1) the administrative national organization, reflecting territorial diversity, (2) population by ethnic group at the 2002 census, reflecting ethnic and linguistic diversity, and (3) population by religion at the 2002 census, reflecting religious diversity (INS, 2008).

A similar generalization is proposed in Magurran (1998) to compare, based on data presented in Batten (1976), the number of standard territories occupied by 20, respectively 14 bird species in native oak woods from Ireland and Swedish plantations (Magurran, 1998). Ianoş (2000) proposes a generalized interpretation of the formula for territorial systems:

$$H = \sum_{i=1}^{s} P_i \log P_i$$

where $\mathbf{P_i}$ is the proportion of **i**-th category, and **s** the number of categories.

The study of sample entropy **h** indicates an asymptotically Normal distribution; if **s** > 30, the distribution of **h** approaches the Normal one, and the average value of **h** is (Hutcheson, 1970):

$$M(h) = -\sum_{j=1}^{s} p_j \ln p_j - \frac{s-1}{2n}$$

while its standard deviation is [13]:

$$D = \sqrt{\operatorname{var}(h)} = \sqrt{\left[\frac{\sum_{j=1}^{s} p_j \left(\ln p_j\right)^2 - \left(\sum_{j=1}^{s} p_j \ln p_j\right)^2}{n} - \frac{s-1}{4n^2}\right]}$$

Several authors present variations of the last term of the formula (**Table 2**).

Table 2. Computational formula of the standard deviation of sample entropy.

$+\frac{s-1}{2n^2}$	Botnariuc and Vădineanu, 1982, pp. 382; Hutcheson, 1970, pp. 152; Magurran, 1998, pp. 35
$-\frac{s-1}{2n^2}$	Magurran, 1998, pp. 148, in the formula, citing Batten, 1976
$-\frac{s-1}{4n^2}$	Magurran, 1998, pp. 148, in effective computation, citing Batten, 1976. The latter was preferred due to its use in computing **D** based on real data in both Batten, 1976 and Petrişor, 2000.

To compare two empirical entropies, use a **t** (Student) test (Magurran, 1998):

$$t = \frac{h_1 - h_2}{\sqrt{\operatorname{var}(h_1) + \operatorname{var}(h_2)}}$$

If the null hypothesis is true, the test has a **t** (Student) distribution, with the number of degrees of freedom (Magurran, 1998):

$$df = \frac{\left[\mathrm{var}(h_1)+\mathrm{var}(h_2)\right]^2}{\frac{\left[\mathrm{var}(h_1)\right]^2}{n_1}+\frac{\left[\mathrm{var}(h_2)\right]^2}{n_2}}$$

In addition to Shannon-Wiener index, in order to cross-validate the results and facilitate their comparison, other two indices were computed: the evenness based on informational entropy and Simpson's measure of dominance (Magurran, 1998).

The evenness measures the ratio between computed value of entropy and maximum possible value, using the formula (Magurran, 1998):

$$E = \frac{H}{H_{\max}} = \frac{H}{\ln s}$$

where **s** is the total number of species.

Simpson's dominance measure, denoted by **D**, starts from modeling diversity as the probability for two randomly selected individuals to belong to the same species. Denote: $\mathbf{n_i}$=number of individuals from the **i**-th species, **N**=total number of individuals=$\mathbf{\Sigma n_i}$.

Simpson's index is (Dragomirescu and Petrişor, 2009): $\mathbf{D=1-\Sigma p_i^2=1-\Sigma(n_i/N)^2}$. For finite communities, a continuity correction applies and changes the formula to (Magurran, 1998):

$$D = \sum_{i=1}^{s} \frac{n_i(n_i-1)}{N(N-1)}$$

3. Results

Results were grouped in two tables, based on the systems compared: using data on 2002 ethnic and religious structure of population and 2005 territorial organization, the reference consisted of overall national values (**Table 3**). Since data for territorial systems were available for 1990, 1995, 2000 and 2005, comparisons for each region of development and nationwide were displayed in **Table 4**.

Table 3. Comparison of ethnic, religious and territorial diversity based on Shannon-Wiener's index, its evenness, and Simpson's dominance.

Region	Ethnic diversity			
	H	p	Evenness	Simpson
Romania	0.46	Ref.	0.15	0.19
North-East	0.13	<0.001***	0.04	0.04
South-East	0.27	<0.001***	0.09	0.09
South	0.15	<0.001***	0.05	0.06
South-West	0.14	<0.001***	0.05	0.05
West	0.62	<0.001***	0.21	0.25
North-West	0.76	<0.001***	0.25	0.40
Center	0.81	<0.001***	0.27	0.48
Buc.-Ilfov	0.16	<0.001***	0.06	0.05
Region	**Religious diversity**			
	H	p	Evenness	Simpson
Romania	0.65	Ref.	0.22	0.24
North-East	0.47	<0.001***	0.16	0.19
South-East	0.25	<0.001***	0.09	0.08
South	0.15	<0.001***	0.05	0.04
South-West	0.10	<0.001***	0.03	0.03
West	0.84	<0.001***	0.29	0.35
North-West	1.16	<0.001***	0.40	0.51
Center	1.22	<0.001***	0.42	0.55
Buc.-Ilfov	0.25	<0.001***	0.08	0.07
Region	**Territorial diversity**			
	H	p	Evenness	Simpson
Romania	0.57	Ref.	0.39	0.31
North-East	0.54	0.010**	0.36	0.28
South-East	0.59	0.171	0.41	0.33
South	0.60	0.026*	0.41	0.33
South-West	0.53	<0.001***	0.36	0.28
West	0.58	0.509	0.40	0.31
North-West	0.57	0.928	0.39	0.31
Center	0.58	0.810	0.39	0.29
Buc.-Ilfov	0.81	0.001***	0.39	0.31

* significant (0.01<p≤0.05); ** highly significant (0.001<p≤0.01); *** very significant (p≤0.001)

The results can be synthesized as follows:

1. Ethno-cultural and territorial diversities of Romania seem to be low. The values of Shannon-Wiener index rarely exceed 1, meaning that Romania seems to exhibit ethnic and religious homogeneity, due to the presence of a dominant group (Romanian ethnic group, the Orthodox religion, and communes).

2. The diversity exhibits high spatial variability. All regions differ from the national situation with respect to their ethnic and religious diversity, and four of the eight regions with respect to their territorial diversity as well.

Table 4. Comparison of the dynamics of territorial diversity in 1990, 1995, 2000 and 2005 based on Shannon-Wiener's index, its evenness, and Simpson's dominance.

Region	**1990** (Ref.)			
	H	**p**	**Evenness**	**Simpson**
Romania	0.50	Ref.	0.36	0.28
North-East	0.57	Ref.	0.41	0.33
South-East	0.57	Ref.	0.41	0.33
South	0.50	Ref.	0.36	0.28
South-West	0.56	Ref.	0.40	0.31
West	0.54	Ref.	0.39	0.31
North-West	0.54	Ref.	0.39	0.29
Center	0.66	Ref.	0.47	0.41
Buc.-Ilfov	0.54	Ref.	0.39	0.31
Region	**1995**			
	H	**p**	**Evenness**	**Simpson**
Romania	0.54	0.741	0.39	0.31
North-East	0.50	0.936	0.36	0.28
South-East	0.57	0.928	0.41	0.33
South	0.58	0.873	0.42	0.33
South-West	0.50	0.968	0.36	0.28
West	0.56	0.849	0.40	0.31
North-West	0.55	0.928	0.39	0.31
Center	0.54	0.865	0.39	0.29
Buc.-Ilfov	0.66	1.000	0.47	0.41
Region	**2000**			
	H	**p**	**Evenness**	**Simpson**
Romania	0.54	0.575	0.39	0.31
North-East	0.50	0.936	0.36	0.28
South-East	0.57	0.857	0.41	0.33
South	0.58	0.865	0.42	0.33
South-West	0.51	0.912	0.36	0.28
West	0.56	0.772	0.40	0.31
North-West	0.55	0.897	0.39	0.31
Center	0.54	0.697	0.39	0.29
Buc.-Ilfov	0.68	0.757	0.49	0.42
Region	**2005**			
	H	**p**	**Evenness**	**Simpson**
Romania	0.57	<0.001***	0.41	0.32
North-East	0.54	0.001***	0.39	0.31
South-East	0.59	0.246	0.43	0.34
South	0.60	0.101	0.43	0.35
South-West	0.53	0.057	0.38	0.30
West	0.58	0.171	0.42	0.32
North-West	0.57	0.107	0.41	0.32
Center	0.58	0.025**	0.42	0.31
Buc.-Ilfov	0.81	0.098	0.58	0.46

* significant ($0.01<p\leq0.05$); ** highly significant ($0.001<p\leq0.01$); *** very significant ($p\leq0.001$)

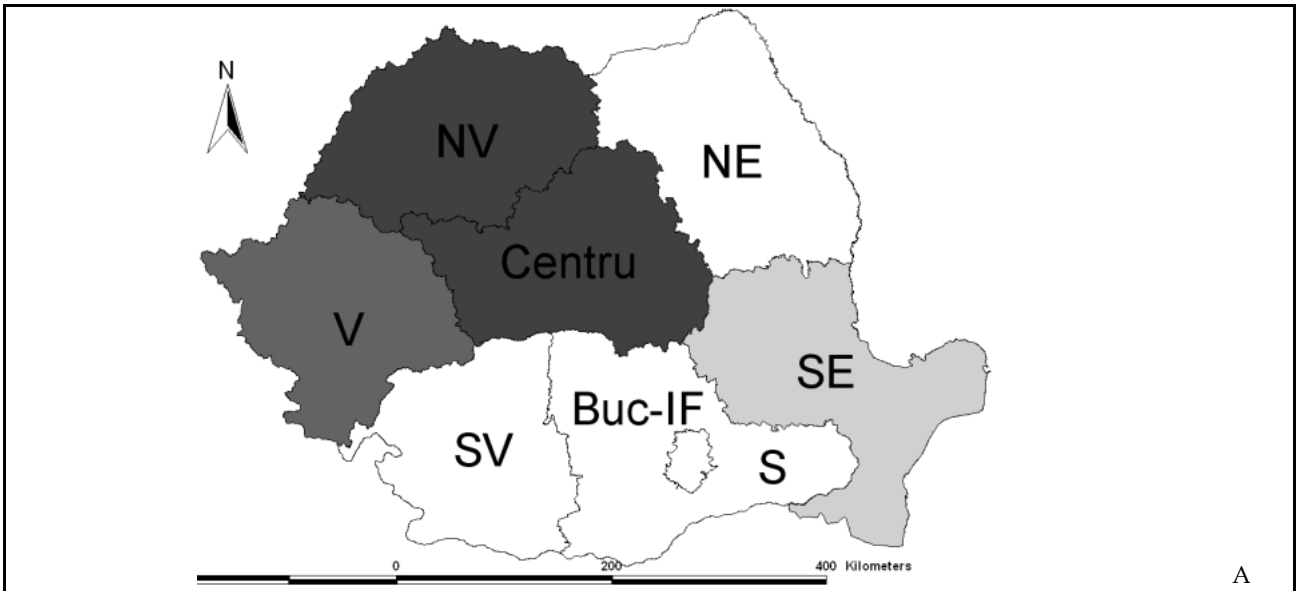
3. The dynamics of territorial diversity has a similar pattern in the regions of development: a slight decrease (not significant statistically) during 1990-1995, almost unchanged values during 1995-2000 (with slight regional increases), and an increase in 2005 compared to 1990, significant nationwide and also in two regions of development.

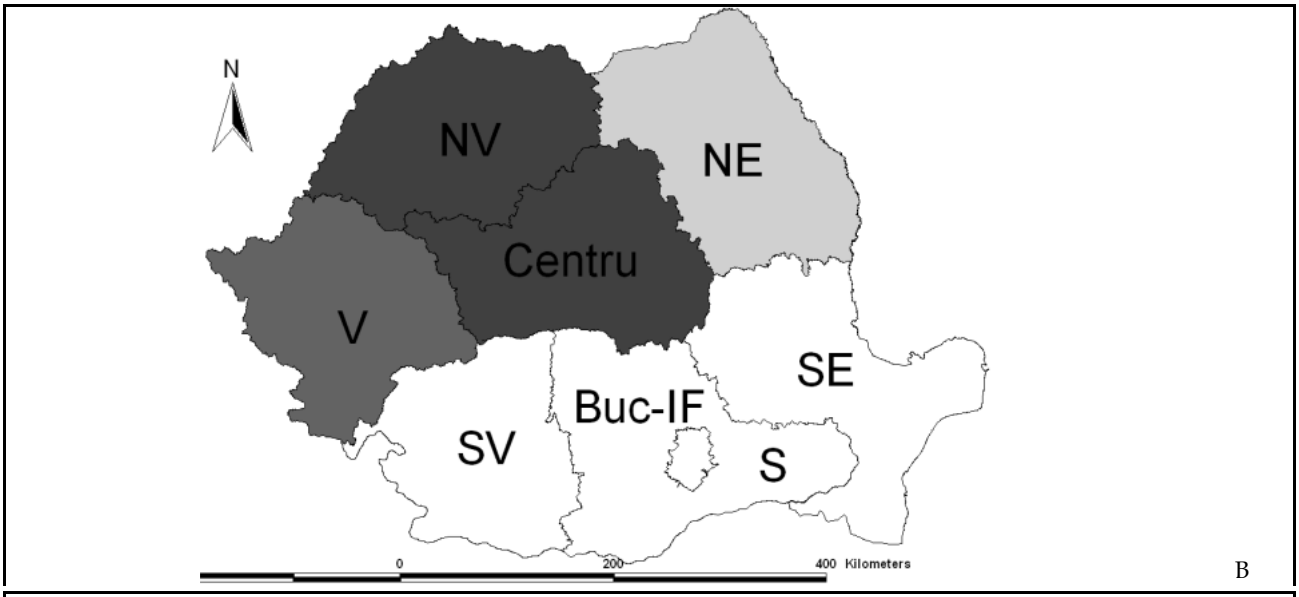
The results can also be interpreted based on a comparison with the "broken stick" model, the best in this case. The comparison confirms the hypothesis that socioeconomic systems are young (immature) with respect to their diversity – Cooke, 1967; Neuschatz, 1973; Petrişor, 2008a.

A visual display of results is presented in **Fig. 1** (spatial distribution of ethnic, religious and territorial diversity) and **Fig. 2** (spatial distribution of territorial diversity in during 1990-2005). Darker shades indicate higher values, grouped in five classes of: reduced, relatively reduced, average, high, and very high diversity.

The results indicate that ethnic and religious diversities are higher in the north-west, as expected, due to the presence of German and Hungarian ethnics. Territorial diversity is greater in the South-East, especially around Bucharest, due to the presence of many small administrative units contributing to the high value of the index.

With respect to its dynamics, a drastic decrease can be seen during 2000-2005. The explanation of the phenomenon consists of the fact that, despite of the fact that many communes became cities and many cities municipalities, resulting into increased real diversity, due to the excessive fragmentation of the rural space (new communes) decrease the values of territorial diversity measured using Shannon-Wiener index.





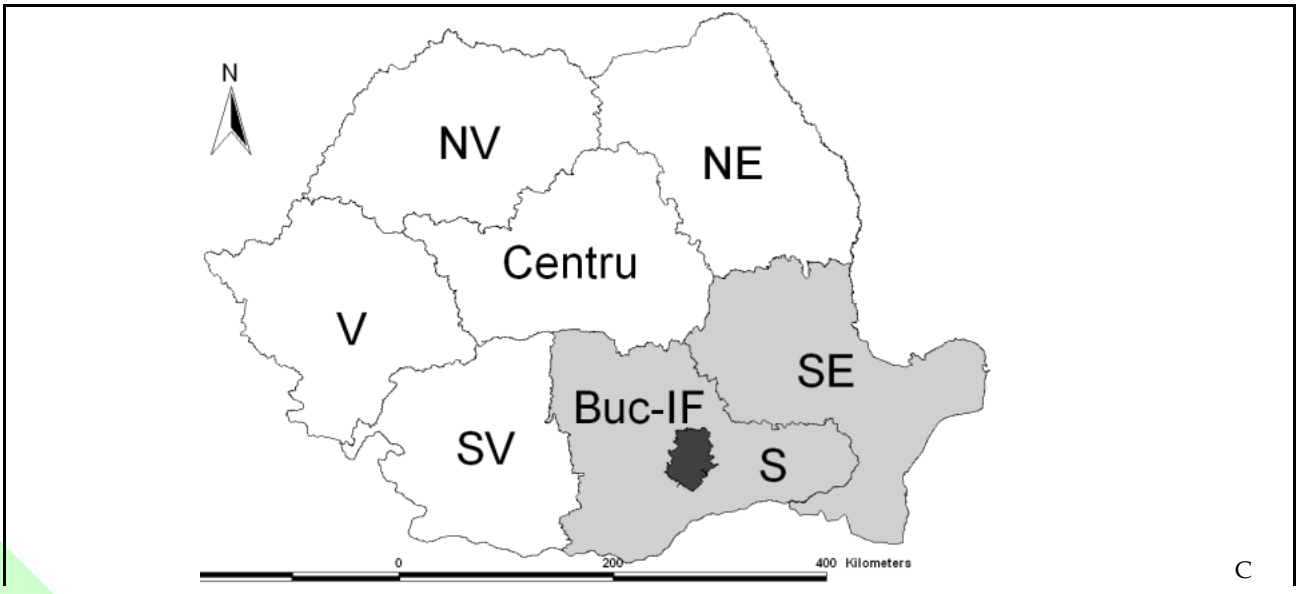


Fig. 1. Spatial distribution of ethnic (A), religious (B) and territorial (C) diversity in Romania. Darker shades indicate higher values.

4. Conclusions

The application of methods used to study natural systems to the territorial ones confirms the hypothesis according to which socioeconomic systems can be assimilated to young (immature) systems in terms of diversity. The main driving forces of the dynamics of their diversity are administrative and political activities. Ethnic, religious and territorial diversity exhibit an unequal spatial distribution, characterized by high values of ethnic and religious diversity in the North-West, and high values of territorial diversity in the South-East.

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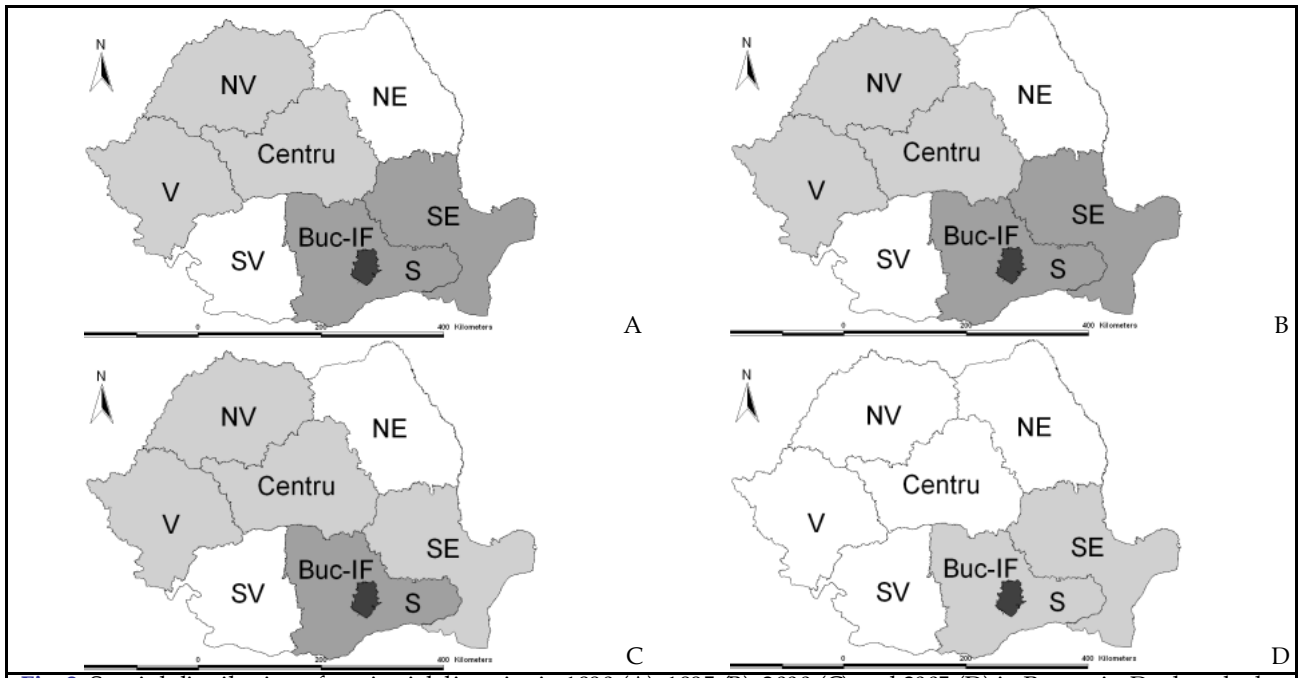

Fig. 2. Spatial distribution of territorial diversity in 1990 (A), 1995 (B), 2000 (C) and 2005 (D) in Romania. Darker shades indicate higher values.

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