PLANNING, ARCHITECTURE, SEISMIC, CONSTRUCTION AND ENERGY-RELATED CRITERIA FOR SUSTAINABLE SPATIAL DEVELOPMENT IN THE DANUBE DELTA BIOSPHERE RESERVE AREA

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Abstract. The Danube Delta Biosphere Reserve represents a complex of ecosystems embedding a biome that had been included on UNESCO World Heritage list due to its global environmental importance. The outstanding natural diversity, including ecosystems, habitats and species situated at the top of European and International conservation lists, is mixed with an equally rich and important cultural (ethnic and religious) diversity of the human communities inhabiting the area. According to the guidelines of the Man and the Biosphere Programme of UNESCO, the biosphere reserves including human settlements should be managed such that they could constitute an example for what sustainable development means. Starting from the spatial dimension added to the traditional socioeconomic, ecological and cultural pillars of sustainable development, the paper examines planning, architecture, seismic, construction and energy-related criteria that could substantiate a sustainable development model applicable to the Danube Delta, and counter the effects of clime change in the area. The results suggest that the traditional practices of the inhabitants could offer sustainable solutions and help preserving the natural and cultural diversity of the region.

Key words: Danube Delta, land cover, land use, cultural diversity, constructions, planning.

1. Danube Delta Biosphere Reserve: Geographical, Administrative, and Ethnic Particularities

The Danube Delta is situated in the East of Romania, the last of the ten European countries crossed by the Danube (Germany, Austria, Slovakia, Hungary, Croatia, Serbia, Bulgaria, Moldova, Ukraine, and Romania), second longest river after the Volga. The Danube Delta marks the confluence between the river and the Black Sea (Fig. 1), with elevations ranging from 0 to 75 m, higher in the north of the area (Fig. 2).

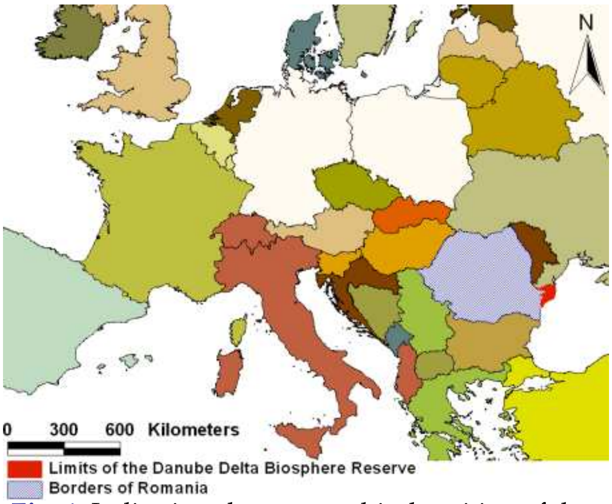

Fig. 1. Indicating the geographical position of the Danube Delta Biosphere Reserve.

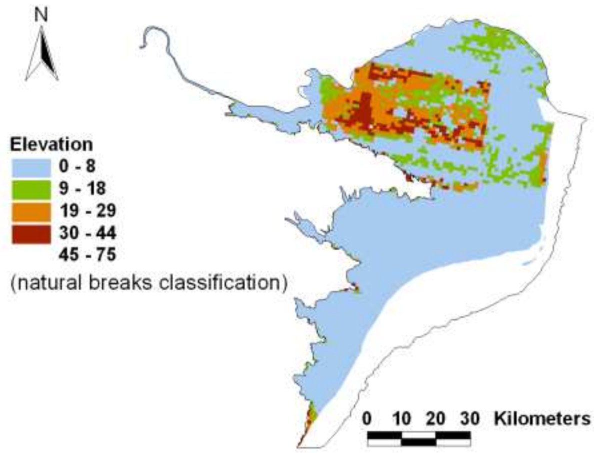

Fig. 2. Indicating the elevation of the Danube Delta Biosphere Reserve.

From an administrative standpoint, the territory of the Danube Delta Biosphere Reserve spans, according to the classification of the Statistical Office of the European Communities (EUROSTAT), over two NUTS (Nomenclature of Territorial Units for Statistics) level 3 units (in Romania, counties), namely Constanța and Tulcea, including 4 and, respectively, 26 NUTS level 5 units (in Romania, base administrative units - cities and communes), covering a total area of 580000 hectares (Fig. 3), making it the second largest wetland and the first Biosphere Reserve with respect to the size (Petrişor, 2007, 2010).

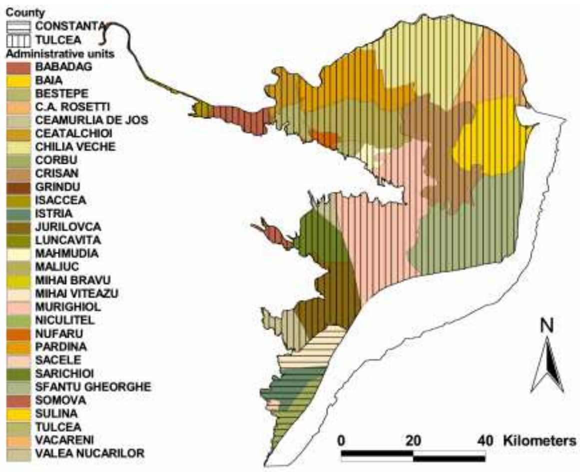

Fig. 3. Displaying the territorial units in the Danube Delta Biosphere Reserve (based on NUTS Classification, Statistical Office of the European Communities, levels 3 - counties and 5 - base administrative units).

The territory is inhabited by a population totaling 14583 at the 2002 census, with a very high ethnic diversity, including Romanians, Lipovans (Russians), Ukrainians, Roma people, Greeks, Turks, Hungarians, Bulgarians, Germans, Armenians, and other ethnic groups - Fig. 4 (Danube Delta Biosphere Reserve Authority, 2011). If Shannon's informational entropy index is computed for the ethnic data displayed in Fig. 4, its value is 0.5, while for the different Romanian regions of development (NUTS 2 units), the values range between

0.1 and 0.8 (Petrişor and Ianoş, 2010). The result underlines that the area is characterized by a high diversity of the human population, due to its ethnic structure.

2. Danube Delta Biosphere Reserve: Ecological Characterization

At the scale of a landform unit such as the Danube Delta, the best ecological characterization is provided by its reference to major biogeographical and ecological units (Fig. 5-6), as well as to the land cover and use (Petrişor, 2008) - Fig. 7. Land use shows how man uses land; land cover indicates what lies on that surface, from a biophysical viewpoint (Jensen, 2000).

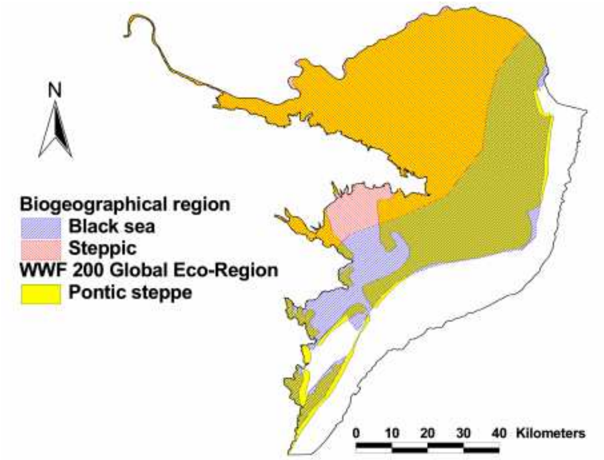

Fig. 5a. Presenting the biogeographical and ecological regions in the Danube Delta Biosphere Reserve (based on 2005 data from the European Environment Agency and 2000 data from the World Wide Fund For Nature).

When using the CORINE (Coordinated Information on the European Environment) data to analyze land cover and use, land cover is reflected by the first level of CORINE classification: artificial areas, agricultural regions, forests/semi-natural areas, wetlands, water), while land use is reflected more or less detailed by the last two CORINE levels which indicate the designation of each parcel based on the type of geosystem, i.e., "natural use" in natural or less anthropized systems that preserved their structure in time, and socioeconomic use for medium/strongly anthropized systems (Petrişor *et al.*, 2010; Ianoş *et al.*, 2011).

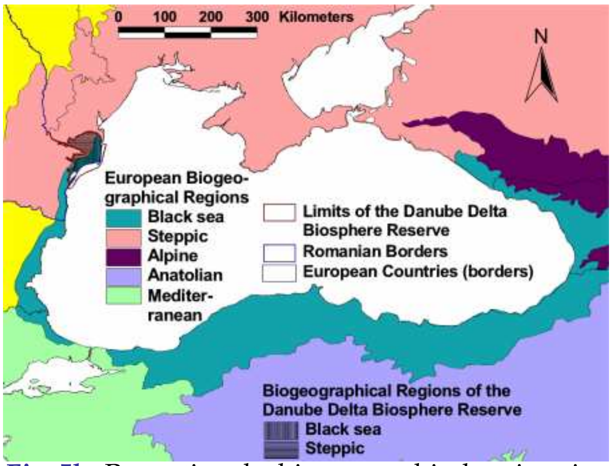

Fig. 5b. Presenting the biogeographical regions in the Danube Delta Biosphere Reserve compared to their continental distribution (based on 2005 data from the European Environment Agency).

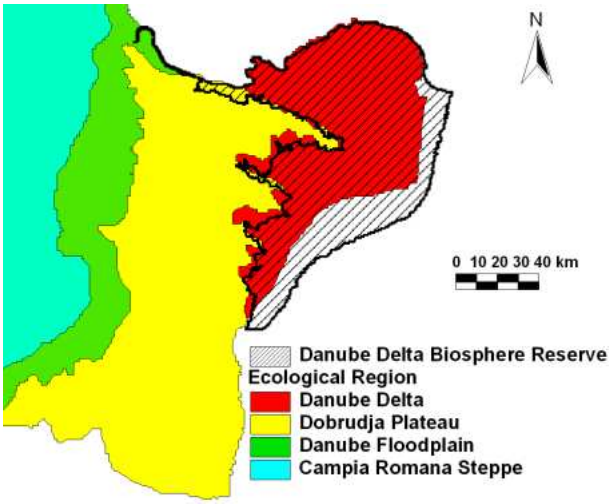

Fig. 6. Showing the ecological regions in the Danube Delta Biosphere Reserve based on the Romanian classification.

The situation displayed in the figures depicting land cover and use is summarized in Table 1. It can be seen that most land is covered by wetlands and water bodies, covering almost 80%, followed by agricultural and natural areas, each covering around 10%. When detailing the classification, inland marshes represent almost 50% of the total land, followed by coastal lagoons (15%), water bodies (10%), and non-irrigated arable land (10%).

CORINE data can be used to monitor long-term environmental changes reflected by land cover and use (Petrişor *et al.*, 2010). Land cover changes tend to cover lesser areas, but have more impact, while land use changes are more frequent, but have lesser impact (Petrişor, 2009). Fig. 8 displays both 1990-2000 and 2000-2006 changes in the Danube Delta Biosphere Reserve, focusing on the area where changes exhibited a higher density. Most of these changes are due to the urbanization, but some are due to the abandon of agricultural crops and forestry practices.

In addition to these changes, provided that in a broader context the ecosystems within the area were connected to the lakes of the floodplain of Danube, their reclaiming for agriculture in the beginning of the Communist regime in Romania (the 50's) resulted into the loss of many species in the Danube Delta and a decline of the fish harvest (Brezeanu and Cioboiu, 2010). In reverse, their ecological restoration in the 90's seems to have led to a positive trend, however still slowly increasing.

Table 1. Presenting the land cover and use in Danube Delta Biosphere Reserve based on CORINE Land Cover and Use data, 2006, European Environment Agency

Level 1 class	Level 2 class	Level 3 class	Area (ha)	Area (%)
Artificial surfaces (383.24 ha, 0.91%)	Urban fabric	Discontinuous urban fabric	272.73	0.65
	Industrial, commercial and transport units	Industrial or commercial units	43.67	0.10
		Port areas	13.20	0.03
	Mine, dump and construction sites	Mineral extraction sites	14.32	0.03
		Dump sites	15.26	0.04
		Construction sites	5.08	0.01
	Artificial, non-agricultural vegetated areas	Sport and leisure facilities	18.99	0.05
Agricultural areas (4462.07 ha, 10.61%)	Arable land	Non-irrigated arable land	4170.26	9.92
	Permanent crops	Vineyards	4.26	0.01
		Fruit trees & berry plantations	3.27	0.01
	Pastures	Pastures	240.96	0.57
	Heterogeneous agricultural areas	Complex cultivation patterns	11.15	0.03
		Land mainly agricultural, with significant natural vegetation	32.18	0.08
Forest and semi natural areas (4522.66 ha, 10.76%)	Forests	Broad-leaved forest	1858.37	4.42
	Scrub and/or herbaceous vegetation associations	Natural grasslands	1756.83	4.18
		Transitional woodland-shrub areas	368.91	0.88
	Open spaces with little or no vegetation	Beaches, dunes, sands	535.96	1.27
		Sparsely vegetated areas	2.60	0.01
Wetlands (20806.10 ha, 49.48%)	Inland wetlands	Inland marshes	20297.87	48.27
	Maritime wetlands	Salt marshes	508.24	1.21
Water bodies (11872.32 ha, 28.24%)	Inland waters	Water courses	939.96	2.24
		Water bodies	4285.06	10.19
	Marine waters	Coastal lagoons	6228.25	14.81
		Sea and ocean	419.05	1.00

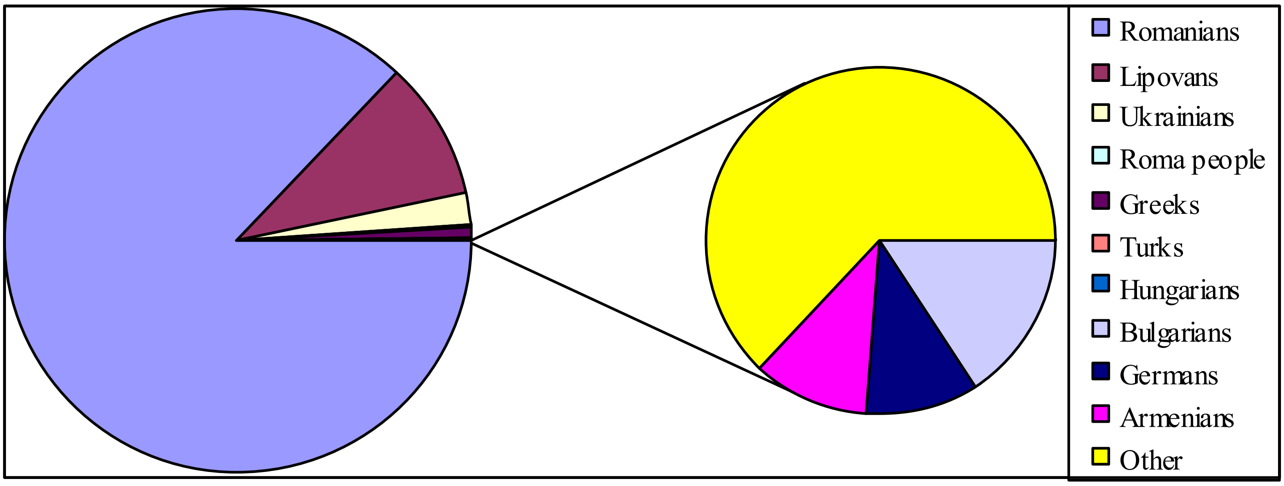

Fig. 4. Showing the ethnic structure of the population of Danube Delta Biosphere Reserve (based on 2002 census data from the Administration of the reserve).

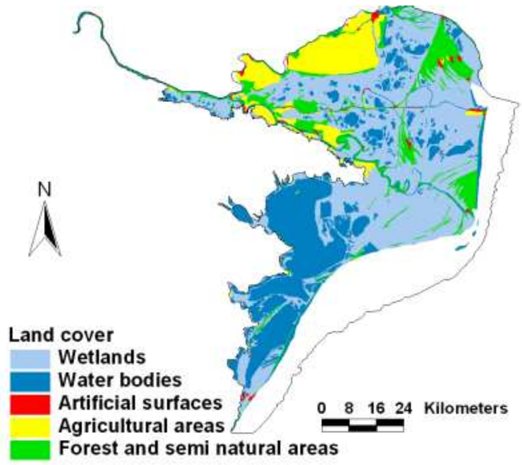

Fig. 7a. Displaying land cover in the Danube Delta Biosphere Reserve (based on CORINE Land Cover and Use data, 2006, European Environment Agency, level 1).

In addition to land cover and use, the biological diversity of the Danube Delta Biosphere Reserve was investigated by looking at the habitats and species within the natural protected areas within. While the total area is designated as a Biosphere Reserve, several sites were included in other categories (Fig. 9), either according to the Romanian and European Union classifications or to the categories established by the International Union for the Conservation of Nature (IUCN). The studies developed within these areas, especially the NATURA 2000 sites (SCI - Romanian acronym for Areas of Special Conservation Interest and SPA - Romanian acronym for Special Protection Areas), revealed the presence of 29 habitats, out of which 7 of communitarian interest, and 119 Red List species (Table 2).

3. Danube Delta Biosphere Reserve: Climate Change

Climate data were downloaded from the DIVA-GIS project developed by Robert Hijmans, freely available from http://www.diva-gis.org in a format readable by a Geographical Information Systems (GIS) application called DIVA-GIS. The program can be downloaded from the same webpage and used free of charge. In addition, the software is compatible with other GIS-type products (Hijmans *et al.*, 2001), including ESRI ArcView 3.X used to change the spatial projection was from WGS-1984 to the Romanian National System, STEREO 1970 and clip a subset for Romania using the Geoprocessing Wizard. The actual clime data set described by Hijmans *et al.* (2005) includes two subsets, referring to temperatures and precipitations, computed for a 2.5^0 longitude × 2.5^0 latitude grid and covering the period 1950-2000; predicted climate data for 2100, described by Govindasamy *et al.* (2003), are based on 2×CO_2 concentration and CCM3 model, and use SSTs based on those from NCAR coupled model, Climate System Model (CSM), computed for a 2.5^0 longitude × 2.5^0 latitude grid. In addition, the differences between current and predicted values were computed. The results are displayed in Fig. 10 as maps depicting each time five classes, defined using the "natural breaks" option in ArcView, based on applying Jenk's optimization formula to minimize the variability of each category (ESRI, 1996).

Even though making harder a comparison between different features (*e.g.*, the pattern displayed by the differences between current and predicted values of either temperature or precipitations is not obvious when examining the distribution of current and predicted values separately), the images underline some patterns. While temperatures (actual and predicted) tend to increase from the northeast to the southwest and precipitations from east to the west, the differences between current and predicted temperatures increase from south to the north, and precipitation differences show a circular pattern with the highest temperatures in the center, located in the north. These patterns do not appear to be influenced by the elevation, perhaps excepting for the differences between actual and predicted precipitations, where high differences (indicating more precipitations in the future) correspond somewhat to higher altitudes. This configuration suggests, in conjunction with the trends revealed by land cover and use changes possible adverse effects over the functions of ecosystems (Dale *et al.*, 2011).

Table 2. Important habitats and species in the Danube Delta Biosphere Reserve, according to data from studies developed within the NATURA 2000 sites

1. Habitats (bold indicates priority habitats)
1. Natural dystrophic lakes and ponds
2. Pannonic sand steppes
3. Calcareous fens with *Cladium mariscus* and species of the *Caricion davallianae*
4. Riparian mixed forests of *Quercus robur, Ulmus laevis and Ulmus minor, Fraxinus excelsior* or *Fraxinus angustifolia*, along the great rivers (*Ulmenion minoris*)
5. Southern riparian galleries and thickets (*Nerio-Tamaricetea* and *Securinegion tinctoriae*)
6. Sandbanks which are slightly covered by sea water all the time
7. Annual vegetation of drift lines
8. *Salicornia* and other annuals colonizing mud and sand
9. Mediterranean salt meadows (*Juncetalia maritimi*)
10. Pannonic salt steppes and salt marshes
11. Embryonic shifting dunes
12. Fixed coastal dunes with herbaceous vegetation ("grey dunes")
13. Dunes with *Hippophaë rhamnoides*
14. Humid dune slacks
15. Oligotrophic to mesotrophic standing waters with vegetation of the *Littorelletea uniflorae* and/or of the *Isoëto-Nanojuncetea*
16. Natural eutrophic lakes with *Magnopotamion* or *Hydrocharition*-type vegetation
17. Water courses of plain to montane levels with the *Ranunculion fluitantis* and *Callitricho-Batrachion* vegetation
18. Rivers with muddy banks with *Chenopodion rubri* pp.p. and *Bidention* pp.p. vegetation
19. Ponto-Sarmatic steppes
20. *Molinia* meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)
21. Mediterranean tall humid grasslands of the *Molinio-Holoschoenion*
22. Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
23. Alluvial meadows of river valleys of the *Cnidion dubii*
24. Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*)

25. Hard oligo-mesotrophic waters with benthic vegetation of *Chara* spp. **26. Coastal lagoons** 27. *Salix alba* and *Populus alba* galleries **28. Ponto-Sarmatic deciduous thickets** 29. Eastern white oak woods	
2. Species	
Mammals	*Mustela eversmannii, Vormela peregusna, Spermophilus citellus, Lutra lutra, Mustela lutreola*
Birds	*Accipiter brevipes, Alcedo atthis, Anser erythropus, Aquila clanga, Aquila heliaca, Aquila pomarina, Ardea purpurea, Ardeola ralloides, Aythya nyroca, Botaurus stellaris, Branta ruficollis, Burhinus oedicnemus, Buteo rufinus, Charadrius alexandrinus, Chlidonias hybridus, Ciconia ciconia, Ciconia nigra, Circaetus gallicus, Circus aeruginosus, Circus cyaneus, Circus macrourus, Circus pygargus, Coracias garrulus, Cygnus columbianus bewickii, Cygnus cygnus, Dendrocopos medius, Dendrocopos syriacus, Dryocopus martius, Egretta alba, Egretta garzetta, Emberiza hortulana, Falco cherrug, Falco columbarius, Falco naumanni, Falco peregrinus, Falco vespertinus, Gallinago media, Gavia arctica, Gavia stellata, Gelochelidon nilotica, Glareola pratincola, Haliaeetus albicilla, Hieraaetus pennatus, Himantopus himantopus, Ixobrychus minutus, Lanius collurio, Lanius minor, Larus genei, Larus melanocephalus, Larus minutus, Limosa lapponica, Lullula arborea, Melanocorypha calandra, Mergus albellus, Milvus migrans, Numenius tenuirostris, Nycticorax nycticorax, Oenanthe pleschanka, Oxyura leucocephala, Pandion haliaetus, Pelecanus crispus, Pelecanus onocrotalus, Phalacrocorax pygmeus, Phalaropus lobatus, Philomachus pugnax, Picus canus, Platalea leucorodia, Plegadis falcinellus, Pluvialis apricaria, Porzana parva, Porzana porzana, Porzana pusilla, Puffinus yelkouan, Recurvirostra avosetta, Sterna albifrons, Sterna caspia, Sterna hirundo, Sterna sandvicensis, Sylvia nisoria, Xenus cinereus*
Amphibians and reptiles	*Bombina bombina, Testudo graeca, Emys orbicularis, Vipera ursinii, Triturus dobrogicus*
Fish	*Gobio albipinnatus, Aspius aspius, Rhodeus sericeus amarus, Misgurnus fossilis, Sabanejewia aurata, Cobitis taenia, Gymnocephalus schraetzer, Zingel streber, Pelecus cultratus, Zingel zingel, Alosa pontica, Gobio kessleri, Gymnocephalus baloni, Alosa tanaica, Umbra krameri*
Invertebrates	*Lycaena dispar, Osmoderma eremita, Theodoxus transversalis, Ophiogomphus cecilia, Morimus funereus, Arytrura musculus, Catopta thrips, Colias myrmidone, Coenagrion ornatum*
Plants	*Marsilea quadrifolia, Aldrovanda vesiculosa, Centaurea jankae, Centaurea pontica, Echium russicum*

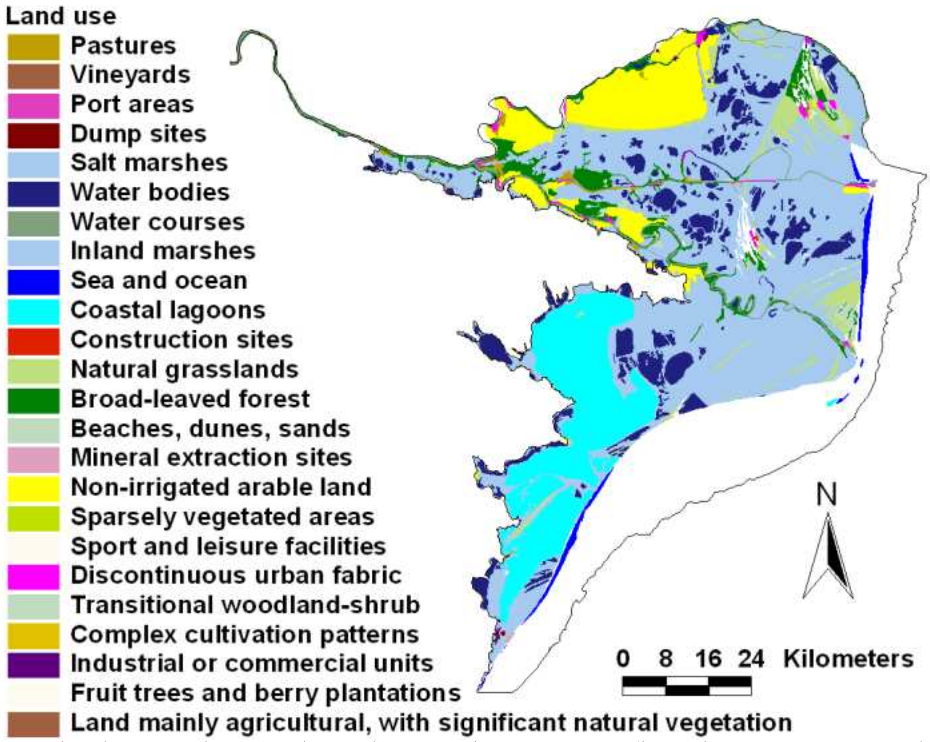

Fig. 7b. Displaying land use in the Danube Delta Biosphere Reserve (based on CORINE Land Cover and Use data, 2006, European Environment Agency, level 3).

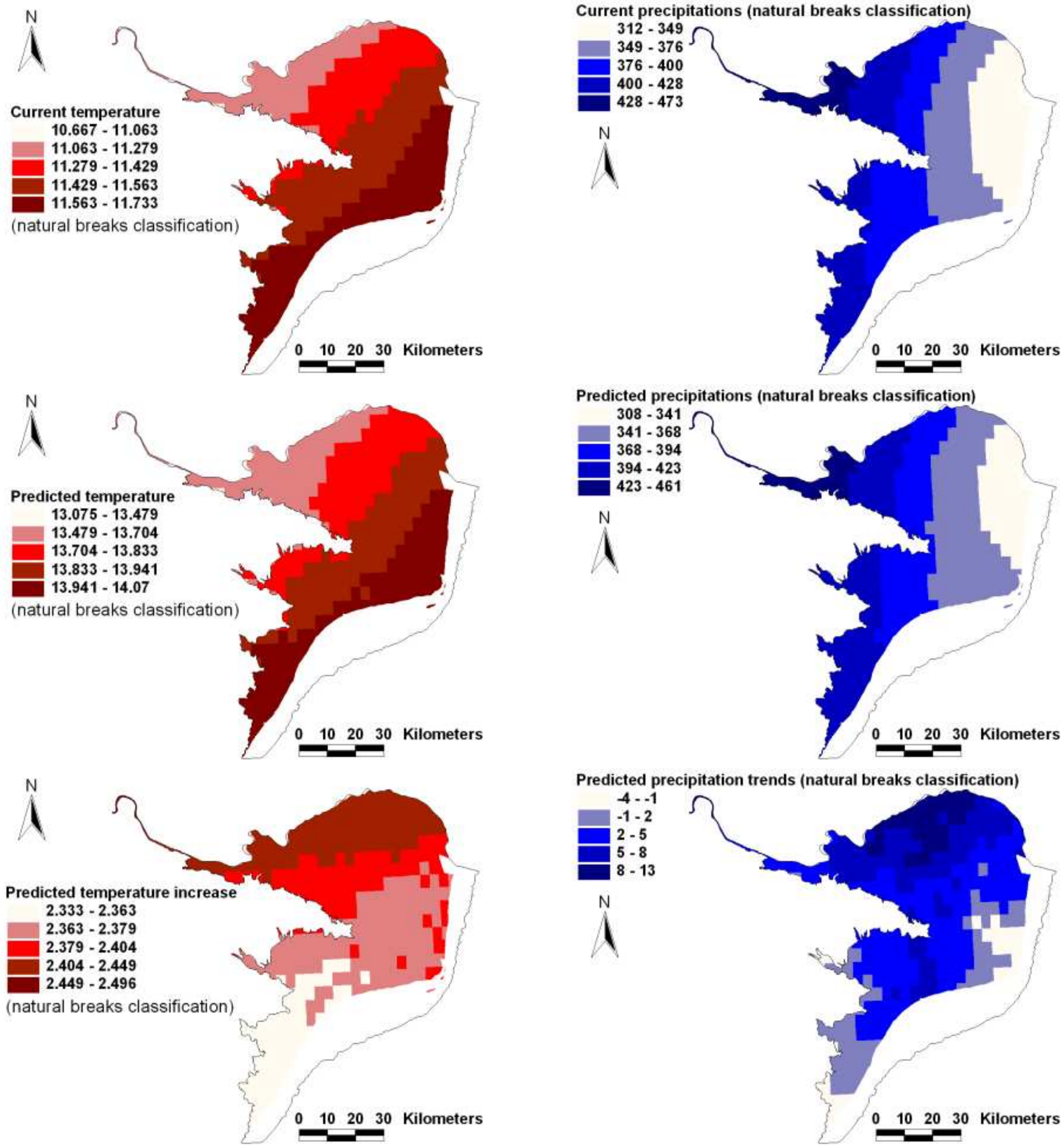

Fig. 10. Presenting actual and predicted temperatures and precipitations, and clime change based on the difference between current and predicted values in the Danube Delta Biosphere Reserve (present situation based on data from Hijmans *et al.*, 2005 and prediction based on data from Govindasamy *et al.*, 2003).

Table 3. Principles of urbanism and ecological construction in the Danube Delta Biosphere Reserve (Meiță, 2003)

Needs	**Construction requirements**
Environmental protection	(1) Integration in the natural environment, (2) integration in the built environment
Functionality	(1) Surface, (2) volume
Safety	(1) Structural, (2) fire, (3) utilization
Hygiene	(1) Clean air, (2) clean water, (3) solid waste elimination, (4) waste water sewerage
Comfort	(1) Acoustic, (2) hygro-thermal, (3) visual, (4) anthropo-dynamic
Adaptation to its use	(1) Heating, (2) ventilation, (3) power
Optimization of power consumption	(1) Thermal insulation, (2) energy consumption

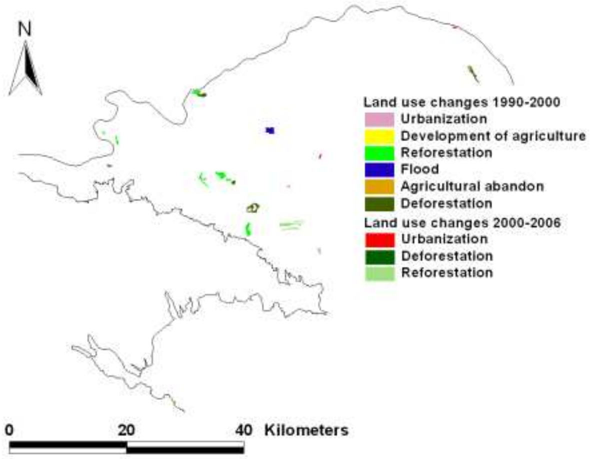

Fig. 8. Showing land cover and use changes in the Danube Delta Biosphere Reserve between 1990 and 2006 (based on CORINE Land Cover and Use Changes data, 1990-2000 and 2000-2006, European Environment Agency). The image displays the area with most changes.

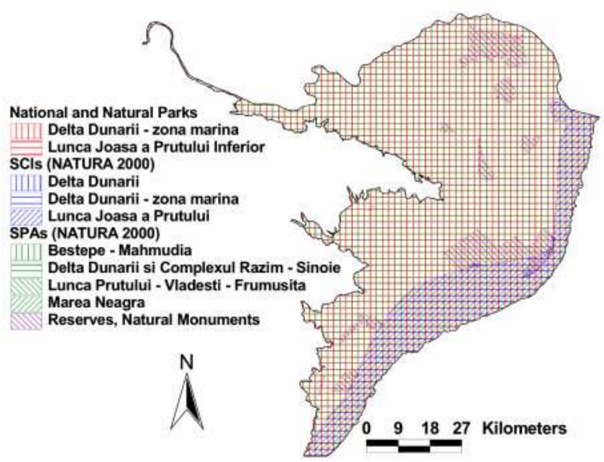

Fig. 9. Displaying the natural protected areas within the Danube Delta Biosphere Reserve (based on data from the Romanian Ministry of the Environment and Forests, 2011, excluding local reserves with a total area less than 5 hectares).

4. History of Socio-Cultural Development in the Danube Delta Biosphere Reserve and the Human Pressure

Given its natural assets and geographic position, the Danube Delta played always an important economic, politic, and strategic role. The area has called for the presence of people through the diversity of relief, productive soil, mild climate and varied natural richness. The products were known and sought for in the farthest areas, since the maritime and river routes intersected the terrestrial ones, helping out the trading activities. Moreover, the Danube Delta and its adjacent floodplains (Brăila and Ialomița) also represented final destinations for transhumant shepherding (Meiță, 2010).

For a long time, the pressure induced by the humans was not felt, since resources were used in traditional manners by a reduced population.

– *The first significant impact* occurred in the end of the 19th century, when Sulina Canal became available for navigation. The cutting of meanders and consolidation of banks broke the unity of the Danube Delta and change the flow regime.
– *The second significant impact* was started by Grigore Antipa in the beginning of the 20th century in order to increase the productivity of fisheries and consisted of cutting canals totaling several tens of kilometers to ensure the circulation of water between the arms of Danube and shallow lakes.
– *The third significant impact* occurred during 1950-1970 and was caused by the exploitation of reed. Dikes were raised, new canals were cut, and pumping stations were built to control the level of water in the areas circled by dikes. At the entrance of Sulina Canal, the dikes protecting the entrance advance 250-300 m per year, determining changes in the seaside area. The nesting colonies of pelicans, shags and herons were destroyed and hundreds of thousands of birds shot. If in the beginning of the 20th century there were some 10-15 million birds, only some 7 million remained at the end of World War II, and 500,000 in the 70's. Very aggressive human activities affected the entire area in this period, leading to the most intense transformations from its history.

– *The fourth significant impact* took place in the 80's, when the large polders Sireasa and Pardina, as well as other 22 areas covering 53,505 ha, were surrounded by dikes and de-watered. The creation of other fisheries or forestry exploitations imposed the construction of new dikes, increasing the total area surrounded by dikes within the Danube Delta to 103,385 ha (Meiță, 2003).

5. The Local Seismic Culture concept for a sustainable living in Danube Delta Biosphere Reserve

The Danube Delta, as well as the surrounding area, can be subjected to two types of earthquakes:
- large magnitude (M_w ≥7.2) Vrancea intermediate depth earthquakes (h≥60km), originating at some 150-200 km, at the curvature of Carpathian Mountains;
- shallow earthquakes (crust) earthquakes, originating at local faults.

Dobrudja area belongs to an older geologic block and four significant faults are considered to have played a major role in the tectonic evolution of Dobrudja area. The northern Adjud-Sfantu Gheorghe Fault is in fact along the Sfantu Gheorghe Branch of Danube and justifies the interest for its possible seismic activity.

The Tulcea earthquake of 13 November 1981 (M 5.2) occurred in the area Tulcea-Mahmudia-Bestepe, at 11 km depth, and caused local damage mostly in Tulcea with an intensity of VI-VII on Mercalli scale. While several brittle engineered buildings sustained heavy damage, the vernacular architecture houses, with solid walls made of local clay / earth behaved almost without cracks (Georgescu, 1982, 1986, 1997). It seems that the solid earth walls had an acceptable strength and shock damping capacity even under near-field earthquakes.

This peculiar case is in line with the analysis of vulnerability which proved that, as a general trend, the earthquake disasters were not a rule on Romanian territories; the inhabitants have built adequate houses using local materials, mostly wood, stone and earth, and, later on, bricks. The life preserving qualities of those houses under earthquake motions is obvious and the vernacular architecture is still proving this pattern nowadays. If one takes an ethnographic map of construction materials, there is a very good agreement of all construction elements with the seismic zoning map of Romania. The height, stiffness, placing of heavy and light materials are well correlated to the seismicity of each zone and the available materials and this is an overall measure of the Local Seismic Culture (LSC) level achieved in Romania (Georgescu, 1982, 1997).

Presently, the inhabitants of most villages and even of some urban suburbs near Danube Delta use the earth as a building material for their one or two storied houses in two ways:
- as adobe bricks, made of local yellow earth / clay, with straw, dried at sun;
- as plastic lumps, made of the same mixture, but placed in walls in wet state layers; after drying, the next layer is put; some kind of sliding formwork is used in some places.

The earth which is able for building purpose was identified by each village and not confused with loess. There is a very innovative capacity of local communities and it is proved by the use of some crushed shells and sand mixture to plaster the walls against rain, as well as by wall foundations that are made of raw stone, while a collar beam of concrete is laid over the walls, under wood roof structure (Boştenaru Dan, 2004, 2005).

The recovery of vernacular techniques and combination with locally available materials may enhance the ecological pattern of future developments.

6. Principles for a Sustainable Socio-Economic Development in the Danube Delta Biosphere Reserve

Tourism. Its influence is due to:

- Circulation: mainly the general river transportation, and lesser tourism.
- Equipment: increased comfort assumes better water supply and distribution systems, water treatment, and leisure infrastructures. Their creation could lead to pollution and degradation of the local environment. Tourism infrastructure should be located far away from the wildlife and especially protected areas. Tourism-related activities must be organized and monitored.
- Water leisure and transport infrastructure: should include oar boats, hydro-bicycles, and motor boats with diminished impact.

Only organized tourism can valorize the natural potential without altering its quality, with benefits for its population; the economic independence and increased welfare could reduce the loss of rural population due to the migration to urban places offering better life standards (Meiță, 2010).

Urbanism. The following criteria must be accounted for:

- Placement: far from transportation, so that the places are not included in tourism circuits affecting the life of inhabitants by pressures and pollution;
- Living rules: educate future inhabitants on basic ecological principles;
- Information technology: allow the area benefit upon 21st century technology;
- Administration: good repartition of tasks for local authorities over the entire area;
- Circulation: designed to shorten distances and reduce impact on settlements;
- Water supply: cannot generalize or opt for individual vs. collective models; however, the latter presume sewerage and treatment of wastewaters;
- Forest: current European guidelines show that the trees within the settlements should be seen more as foresters than green spaces or leisure areas;
- Solid waste: managed and stored at the local level;
- Education: the curricula must reflect adaptation to the ecological habitat;
- Architecture: influenced by the local specific and materials should make it comfortable (Meiță, 2010).

Settlements should be designed in terms of location and materials to reduce the damage due to natural causes such as storms, floods, earthquakes, and land slides. Also, land should be used in a way leading to long-term benefits. In order to minimize conflicts and choose the most efficient compromises and options, social and economic development must be connected to the protection of the environment: first account for the protected areas, but also for the private property and rights of the indigenous population and other local communities, such as the Lipovans. The biological resources provide for food, habitat, medicine and spiritual nourishment are within natural ecosystems, such as forests (Letea), grasslands, pastures, open fields, lakes, river, and sea. The loss of biological diversity continues through the destruction of habitats, overexploitation of resources, pollution, and introduction of alien species. The loss of biodiversity is determined by people and constitutes a serious barrier against development. From the energy viewpoint, the Danube Delta, even though poor in classic energy (oil, coals, rivers), has many other natural sources (sun, wind, waves) able to provide for sustainable development (Meiţă, 2003).

Architecture. The key issue in designing constructions suitable for the Danube Delta area is the compliance of rural and urban rules with the local tradition and ecological principles, taking the sustainability principles from the local construction system, based on the idea that traditional houses specific to the rural areas were not designed by specialists, but built by local craftsmen. Houses should be thought and designed based on the principle according to which they are to be lived in by three generations (children, parents, and grandparents), in all respects concerning family life, education by older generation, and economy of resources. The connections between the urbanization of the area must be linked to the requirements for a sustainable development and technology, in a long-term thinking based on eco-technical criteria (based on ecology, economy, technology and social sciences):

- Use all the positive architectural traditions, including the efficient orientation and organization of houses;
- Identify all elements compatible with the protection of the environment;
- Promote new materials contributing to the sustainability of human settlements, resistance to floods, and compatibility with the Western living standards;
- Use energy produced by unconventional sources: wind, sun, gas, and water;
- Conceive settlements depending mainly on local resources;
- Design multifunctional constructions for education, culture, administration, and different services (Meiţă, 2010).

In time, constructors and architects considered the site and clime consequences as a natural feature due to many reasons, such as the slow pace of evolution, allowing for learning by attempts and errors, the local character of constructions and materials, and the need to use limited resources in the best way. The aesthetic quality can be achieved by simpler, natural, and sustainable means. Construction programs must be focused on local materials, energy efficiency, healthy and environmentally friendly materials and technologies based on manual works, creating more jobs. To reduce migration to larger cities, the government must improve the living conditions in rural areas and reduce the gap between rural and urban settlements. The environmental preference method, proposed by Chiel Boonstra, allows for selecting materials and products with a lower environmental impact compared to others designed for the same functions, for each element of the building separately (Anink *et al*., 1996).

Principles of ecological urbanism and architecture in the Danube Delta

In order to create a sustainable society, its people must live a sustainable life. The quality of life is more important than consumption. Sustainable life must be a part of the system where people, their homes, and effluents interact with green houses, gardens, animals, and fisheries, influencing their mind (Ianoş *et al*., 2009), lifestyle, environment, and economy. To achieve it, the development must meet the principles of ecological construction, listed below and summarized in Table 3.

1. Each existing element must be carefully assessed in terms of its contribution to increasing the quality of life.
2. Each problem contains its solution.
3. Sustainable development is the key for urbanism and ecological architecture. Landscape and architectural planning can be conceived to respect diversity, improving the life of all species, reducing the fear for insecurity and increasing the hopes for a better future.
4. Each element must have more functions, and each function must be carried on by more elements, increasing flexibility and stability. Should a certain element fail, the others will take over its role. Instead of maximizing the function of a single element, we should optimize the whole by increasing the connections, requiring new technologies or adopting the traditional ones in a modern context.
5. A sustainable system reunites fundamental human, material, and psychological needs: clean air and water, sufficient and healthy food, serenity, contact with vegetation, animals and other people, security, participation, expression of individuality, identity, freedom, love, and beauty. The needs must be fulfilled for all; resources should be used within the limits of sustainability and equity; even though the fundamental needs are present in each culture in every period, cultures differ by the manner of satisfying them.
6. A sustainable system must rebuild the natural cycles of production and composition.

Diversity: a sustainable system must be open and flexible, allowing for expressing individual and collective differences, and manage conflicts as an integrant and healthy component of each process. Every human being and group is unique and must be provided for the means and freedom to act responsibly at his own will. Our hope is to build merely cyclic than linear systems, heart and mind, joy instead of despair, green replacing the gray, fertile in place of the desert, life and not death, and balance instead of instability.

Note

The paper was initially published as: Meiţă V., Georgescu E.-S., Petrişor A.-I. (2011), *Sustainable spatial development in the Danube Delta Biosphere Reserve: Planning, architecture, seismic, construction and energy-related criteria*, ACSEE 2011. The Asian Conference on Sustainability, Energy & the Environment Proceedings, The International Academic Forum, Japan, pp. 53-70, and is reproduced with slight changes, with the permission of original publishers.

REFERENCES

Anink D., Boonstra C., Mak J. (1996), *Handbook of sustainable building: an environmental preference method for selection of materials for use in construction and refurbishment*, 176 pp., Earthscan, London, ISBN 978-1873936382.

Boştenaru Dan M. (2004), *Multi-criteria decision model for retrofitting existing buildings*, Natural hazards and earth system sciences **4(4)**:485-499.

Boştenaru Dan M. (2005), *Multidisciplinary co-operation in building design according to urbanistic zoning and seismic microzonation*, Natural hazards and earth system sciences **5(3)**:397-411.

Brezeanu G., Cioboiu O. (2010), *Grigore Antipa (1867-1944) the founder of ecological hydrobiology*, Oltenia. Studii şi comunicări. Ştiinţele Naturii **26(2)**: 313-315.

Dale, V. H., Efroymnson, R. A. & Kline, K. L. (2011), *The land use-climate change-energy nexus*, Landscape Ecology **26(6)**:755-773.

Danube Delta Biosphere Reserve Authority (2011), *Population*, http://www.ddbra.ro/en/population.php

Environmental Systems Research Institute - ESRI (1996), *Using ArcView GIS. The Geographic Information System for Everyone*, ESRI Press, Redlands, CA, USA.

Georgescu E. S. *et al*. (1982), *Seismological and engineering aspects of 13 November 1981 Tulcea, Romania earthquake*. Lecture Notes, The 9th Regional Seminar on Earthquake Engineering, 7-17 September 1982, Istanbul, Turkey.

Georgescu E. S. (1986), *State of the art of the earthquake behaviour specific to several types of traditional and new rural buildings in Southern Romania*, Proceedings of the 8th European Conference On Earthquake Engineering, Lisbon, Portugal, 7-12 September 1986.

Georgescu E. S. (1997), *Local Seismic Culture aspects in seismic zones of Romania in comparison with other Mediterranean countries*, Course Notes. The 7th Intensive Course on Local Seismic Cultures, CUEBC Ravello, Italy, 1997.

Govindasamy B., Duffy B., Coquard J. (2003), *High-resolution simulations of global climate, part 2: effects of increased greenhouse cases*, Climate Dynamics **21(5-6)**:391-404.

Hijmans R. J., Cameron S. E., Parra J. L., Jones pp. G., Jarvis A. (2005), *Very high resolution interpolated climate surfaces for global land areas*, International Journal of Climatology **25(15)**:1965-1978.

Hijmans R. J., Guarino L., Cruz M., Rojas E. (2001), *Computer tools for spatial analysis of plant genetic resources data: 1. DIVA-GIS*, Plant Genetic Resources Newsletter **127**:15-19.

Ianoş I., Peptenatu D., Zamfir D. (2009), *Respect for environment and sustainable development*, Carpathian Journal of Earth and Environmental Sciences **4(1)**: 81-93.

Ianoş I., Petrişor A.-I., Stoica I. V., Sârbu C. N., Zamfir D., Cercleux A. L. (2011), *The different consuming of primary eco-energies and their degradation in territorial systems*, Carpathian Journal of Earth and Environmental Sciences **6(2)**:251-260.

Jensen J. R. (2000), *Remote Sensing of the Environment. An Earth Resource Perspective*, Prentice Hall, Upper Saddle River, New Jersey, ISBN 978-0-13-489733-1, 544 pp.

Meiță V. (2003), *The architecture of Danube Delta habitat – an eco-technical and sustainable development perspective* [in Romanian], 117 pp., "Ion Mincu" University Press, Bucharest, Romania, ISBN 978-973-7999-06-1.

Meiță V. (2010), *Ecological materials for the constructions in the Danube Delta* [in Romanian], Urbanism. Arhitectură. Construcții **1(1)**:31-36.

Petrişor A.-I. (2007), *Environmental analysis applied to urban and landscape planning* [in Romanian], 89 pp., "Ion Mincu" University Press, Bucharest, Romania, ISBN 978-973-7999-85-6.

Petrişor A.-I., Toth G., Chicoş A., (2008), *Characteristics of areas vulnerable to climate change in the Romanian Tisa catchment area*, Romanian Review of Regional Studies **6(2)**:17-30.

Petrişor A.-I. (2009), *Spatial approach to the assessment of anthropic impact on biodiversity based on the Nomenclature of Territorial Units for Statistics (NUTS) applicable to Romania*, Oltenia. Studii şi comunicări. Ştiințele Naturii **25**:305-308.

Petrişor A.-I. (2010), *GIS analysis of wetland cover by NATURA 2000 sites*, Environmental Engineering and Management Journal **9(2)**:269-273.

Petrişor A.-I., Ianoş I. (2010), *Application of the Methods Used in the Study of Biological Diversity to Territorial Systems*, In: Ovidius University, *Biodiversity - present and perspectives. Anniversary symposium* [in Romanian], Ovidius University Press, Constanța, Romania, ISBN 978-973-614-552-0, pp. 86.

Petrişor A.-I., Ianoş I., Tălângă C. (2010), *Land cover and use changes focused on the urbanization processes in Romania*, Environmental Engineering and Management Journal **9(6)**:765-771.

Received: July 14, 2013 • **Revised**: July 19, 2013 • **Accepted**: July 22, 2013