ADDRESSING SOCIETAL CHALLENGES IN THE BLACK SEA CATCHMENT THROUGH INNOVATIVE EARTH OBSERVATION SYSTEM OF SYSTEMS

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Key-words: GEOSS, Societal Benefit Areas, Black Sea, Danube, data sharing, spatial data infrastructure.

The Black Sea catchment is internationally known for its historical and cultural diversity and richness, but unfortunately also for its ecologically unsustainable development and inadequate resource management, which has led to severe environmental, social and economic problems. The EU FP7 enviroGRIDS project (Lehmann et al. 2014) addresses these issues by bringing several emerging information technologies that are revolutionizing the way we are able to observe our planet. The Global Earth Observation System of Systems (GEOSS: http://www.earthobservations.org) is building a data-driven view of our planet that feeds into models and scenarios to explore our past, present and future. EnviroGRIDS aims at building the capacity of scientist to assemble such a system in the Black Sea Catchment, the capacity of decision-makers to use it, and the capacity of the general public to understand the important environmental, social and economic issues at stake.

EnviroGRIDS is built around several pilot studies addressing several of the nine societal benefit areas proposed by GEOSS: water, weather, climate, ecosystem, biodiversity, agriculture, energy, health and disasters. The objective of this special is to show how current developments in environmental data sharing can help addressing new environmental and societal challenges. The outputs of these pilot studies were themselves made available as web services on the enviroGRIDS data portal (www.envirogrids.cz/pilots) through a dedicated spatial data infrastructure (SDI) (Giuliani et al. 2013).

In the first paper, Constantinescu et al. (this issue) are predicting the shift of Alpine grasslands according to climate changes by comparing two different methods to predict ecosystem distribution (MAXENT et BIOCLIM). The obtained distribution maps indicate vulnerability areas with higher biodiversity loss that are of particular interest and should be monitored. The output of the models are contributing to the Black Sea catchment Observation Systems to be further accessible to scientists, decision-makers and the general public.

The second paper by Gastescu et Grigoras (this issue) reviewed the morphological changes on the coast of the Danube Delta in Romania. To identify portions of advancement and retreat, and setting the corresponding annual rates, existing topographic map series for a period of over 150 years, hydrographic measurements for 30 years and series of satellite images starting from 1975 were used.

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In a very similar paper, Gazyetov et Sizo (this issue) followed the Ukrainian coastline dynamics of the Northern arm of the Danube. Long-term trends were assessed based on original Landsat remote sensing data with spatial resolution of 30 m and time interval of 4 to 7 years. The relevance of original information and advantages of modern GIS-technologies allowed obtaining new information about long-term delta processes that are useful for the management of the Delta.

Dumitraşcu et al. (this issue) are assessing the occurrence, development and spread the main Invasive Terrestrial Plant Species (ITPS) in the Romanian protected areas. They developed a model of ITPS potential distribution in protected areas within the different biogeographical regions of Romania. This approach should support measures to eradicate or prevent the introduction of invasive species and control their already existing habitats. It represents the most cost-effective means to avoid or reduce the risk of long-term ecological, economic and social costs of their invasion.

In a fifth paper, Gonca Bozkaya et al. (this issue) are monitoring land use change in the Igneada forest of Turkey from multitemporal Landsat images. As a result of the land use/cover change and human activities, environmental degradation affected especially the forest areas between 1984 and 2010. Therefore, in order for the Igneada region to keep the sustainability of natural life resources, effective management strategies should be followed. Especially human activities should be planned carefully.

The next paper by Makarovskiy and Zinych (this issue) is assessing wind energy potential over Ukraine. The proposed methodology has numerous advantages: a simple algorithm, a minimum set of input data, and highly reliable results. According to the obtained results, the southern and eastern parts of Ukraine have outstanding wind potential.

In Cheroy et al. (this issue), the results of field observations on the dynamics of the marine edge of the Danube Delta in 2011–2012 is described. The results describe the littering of the sea edge of the Danube Delta with plastic waste, the registration of the dead dolphins, as well as description of the vegetation changes. The greatest impacts are due to the reduction of the Danube sediment runoff, the redistribution of the water flow between the different Danube arms, as well as the rise of the Black Sea level.

Snigirov (this issue) present an ichtyological study of the Dniester Delta to assess its biodiversity and species rarity. Decrease in fish species composition has been shown, as well as the disappearance of some native reophilic and lithophilous fish species as the result of the Dniester River discharge regulation.

Finally, in Mitrică (this issue) a demographic study is presented on the changes of urban population in Romania during the post-communist period. The results show how during this period the demographic structures changed with an increase in female population, a decrease in the young population, and an increase again in mature and elderly people.

Two other special issues were published on the enviroGRIDS project. The first one was published in the International Journal of Advanced Computer Science and Applications (IJACSA) and is describing all the technical aspects developed to build the Black Sea catchment observation system (editorial: Giuliani et Gorgan, 2013). The second special issue was prepared for Environment Sciences and Policy (editorial: Lehmann et al. 2014) to present the main outcomes of the project such as climatic, demographic and land use scenarios, as well as hydrological modelling, sustainable energy potential, or coastal erosion.

This entire set of publications gathered in three special issue represent the main scientific outputs of the enviroGRIDS project. While some progresses were made in order to improve the use of Earth observation on different societal benefit areas in the Black Sea region, a lot of work is still needed to transform the mentality of scientists, decision makers, politicians and the general public. The necessity to better share the observation on our environment remains a prerequisite to any sustainable development.

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ASSESSMENT OF ROMANIAN ALPINE HABITATS SPATIAL SHIFTS BASED ON CLIMATE CHANGE PREDICTION SCENARIOS

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Key-words: Climate Change, MAXENT, DIVA-GIS, ecosystems distribution, high priority habitats, data sharing, enviroGRIDS.

Shifts in the ecosystems distribution as the result of climate change are of interest for decision-makers in biodiversity conservation at local and European level. This paper presents the use of modeling technique, Maxent (Maximum entropy modeling) and BIOCLIM (environmental envelope model), to estimate the impact of climate change on the Alpine bioregion of Continental Europe for improving the management policy in support of stopping biodiversity loss. The European Union priority habitat 6230 occurring in mountain areas and sub-mountain areas of the Carpathians was selected for modeling being of high priority conservation status in the Natura 2000 network of protected area.

Maxent and BIOCLIM were used to create spatial distribution models for Mesophilous oligotrophic mountain pasture and Subalpine oligotrophic pastures. Models were run with 1950–2000 averaged bioclimatic data and double atmospheric CO_2 concentration scenario in perspective of the year 2050. In our analyses we have included once all 6320 mapped habitat with Nardus grasslands. Under 1950–2000 climate scenario, both models exhibited high AUC values (> 0.9). The predicted geographical distribution of Mesophilous oligotrophic mountain pasture and Subalpine oligotrophic pastures coded as VNG and PON habitat modeled by Maxent and BIOCLIM shows differences between the modeling approaches, with Maxent predicting smaller areas (12% less) of suitable habitat than BIOCLIM. For the future climate scenario (double CO_2) the surface with PON+VNG decreases by 31% for Maxent and 26% for BIOCLIM. However both models show significant shifts of the *Nardus* habitat due to climate change.

The distribution maps obtained indicate vulnerability areas to biodiversity loss and of interest to be monitored. The output of models will contribute to the Black Sea Catchment Observation Systems to be further accessible to scientists, decision-makers and the general public.

1. INTRODUCTION

Prediction and mapping of potential suitable habitat for threatened and endangered species is critical for monitoring and restoration of their declining native populations in their natural habitat, artificial introductions, or selecting conservation sites, and conservation and management of their native habitat (Gaston, 1996, Guisan et al., 2002, Overton et al., 2002, Thuiller, 2004). Predictive species distribution modeling is a valuable tool for decision-makers in biodiversity conservation, invasive species monitoring and other natural resources management fields. Over the last three decades, warming has had a discernible influence at the global scale on observed changes in many human and natural systems (EEA, 2010). Mountain areas face substantial challenges including

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reduced snow cover, potential negative impacts on winter tourism and extensive species loss (EEA-JRC-WHO, 2008). It is envisaged that dedicated adaptation measures by Europe is urgently needed to build resilience against climate impacts (EC, 2009^{c}). However, the EU White Paper on adaptation recognizes that limited knowledge is a key barrier and calls for a stronger knowledge base. The creation of a European clearinghouse on climate change impacts, vulnerability and adaptation with the aim to enable and encourage the sharing of information and good adaptation practices between all stakeholders is foreseen (EEA, 2010). The EEA report also concluded that improving monitoring and enforcement of sectoral and environmental policies will (i) ensure that environmental outcomes are achieved, (ii) give regulatory stability, and (iii) support more effective governance.

The aim of our work is to contribute to a better understanding of the stability and dynamics of alpine habitats, together with filling the need for knowledge and data in support of adequate conservation planning, monitoring and management. Our goal was to estimate the extent of the *Nardus* habitat in the Alpine region of the Carpathians, its spatial trend, and its vulnerability under changing climate. We produced occurrence and prediction maps that may be of use to be further integrated into a broader and holistic analysis of such vulnerable habitats. Species-rich *Nardus* grasslands was selected for modelling, being of high priority conservation status of Natura 2000 network of protected areas. This is one of the most widespread habitats in the EU, occurring in 24 Member States and 6 different bioregions. This habitat includes a huge variety of sub-types, which may be found in very different ecological situations (Galvánek D. & Janák M., 2008). An major proportion of its area is located within the Alpine bioregion (Alps, Pyrenees and the Carpathian).

The estimated surface of *Nardus habitat* in the Natura 2000 sites of the Alpine Bioregion of Europe is 80,703 ha (Galvánek D. & Janák M., 2008.), showing no data for Romania. Here it was estimated that the grassland area, dominated by *Nardus* stricta L., covers 200,000 ha (Samuil Costel & Vîntu Vasile, 2012). From our mapping inventory under the PIN MATRA (Programme International Nature Management, Dutch Ministry of Agriculture, Nature and Food Quality and Ministry of Foreign Affairs) and *Nardus* projects (Sârbu et al., 2004 and Hanganu et al., 2010) species-rich *Nardus* grasslands is covering 28,841 ha, most of them located in the Natura 2000 areas of the Carpathians, out of which 5,634 ha in the high Alpine area (over 1,800 m a.s.l.). In this habitat were found 123 plant species with high conservation status. As not all area were covered by the inventory, the real occurrence of the high Alpine *Nardus* habitat was assumed to be much larger. In the study we describe here, we are trying to assess the potential of this habitat now and under climate changes. We are testing two well-known methodologies (BIOCLIM and MAXENT) to model habitat potential distribution.

2. MATERIALS AND METHODS

2.1. Modeling techniques

For predicting of the potential distribution of "Species-rich *Nardus* grasslands" due to climate changes we use the Maximum Entropy Distribution Modeling Approach (MAXENT, software http://homepages.inf.ed.ac.uk/s0450736/maxent.html) that estimates the probability distribution for a species occurrence based on environmental constraints. We used also an environmental envelope model (BIOCLIM) using DIVA-GIS (Hijmans et al., 2012). We predicted the future habitat distribution based on a doubling of atmospheric carbon dioxide levels, which was made using an atmospheric general circulation model designed for climate research (CCM3) developed by USA National Centre for Atmospheric Research, Colorado (Govindasamy S. et al., 2003).

Maxent (Phillips et al., 2006, Pearson 2007) is a maximum entropy distribution modeling approach that estimates the probability distribution of species (described by present field database) based on environmental constraints. BIOCLIM using DIVA-GIS software is an environmental envelope model which built a climatic envelope within which a species is likely to be found. The climatic envelope is made using the occurrence of minimum and maximum species values for each climatic variable. The models are using biodiversity data (grassland alliances) and environmental data (bioclimatic variables). Model outputs give pixel values in percent and percentiles, where higher values are more suitable habitat. These models do not specify at what output threshold values probability a pixel becomes a suitable habitat. Therefore, a threshold of model prediction was used at which true positives and negatives are maximized while false positives and negatives are minimized.

2.2. Biodiversity data

Our input biodiversity dataset showing the occurrence of grassland alliances polygons was extracted from GIS Grassland database of Romania that was built from the national grassland inventory (PIN MATRA, 2004, NARDUS, 2010). The area mapped within the two projects covers 650,000 ha distributed by four Black Sea basin bioregions (Alpine, Continental, Pontic and Steppic) and includes 151,149 plant species records. Species-rich *Nardus* grasslands pastures (Habitat 6230) cover 28,841 ha on the mapped alpine area, and include 123 plant species with high conservation status. *Nardus* grasslands consist of two sub-types: Mesophilous oligotrophic mountain pasture and Subalpine oligotrophic pastures coded as VNG and PON, respectively (Sarbu et al., 2004). The range of PON+VNG field observation data starts from 500 m and goes up to 2,500 m. Habitats over 1,800 m a.s.l. are considered primary habitats that host a high number of endemic and threatened plant taxa that are particularly sensitive to climate change. In our analyses we have included both all 6320 mapped habitat (Fig. 1) and, separately, *Nardus* grasslands occurring at over 1,800 m a.s.l. (Table 1).

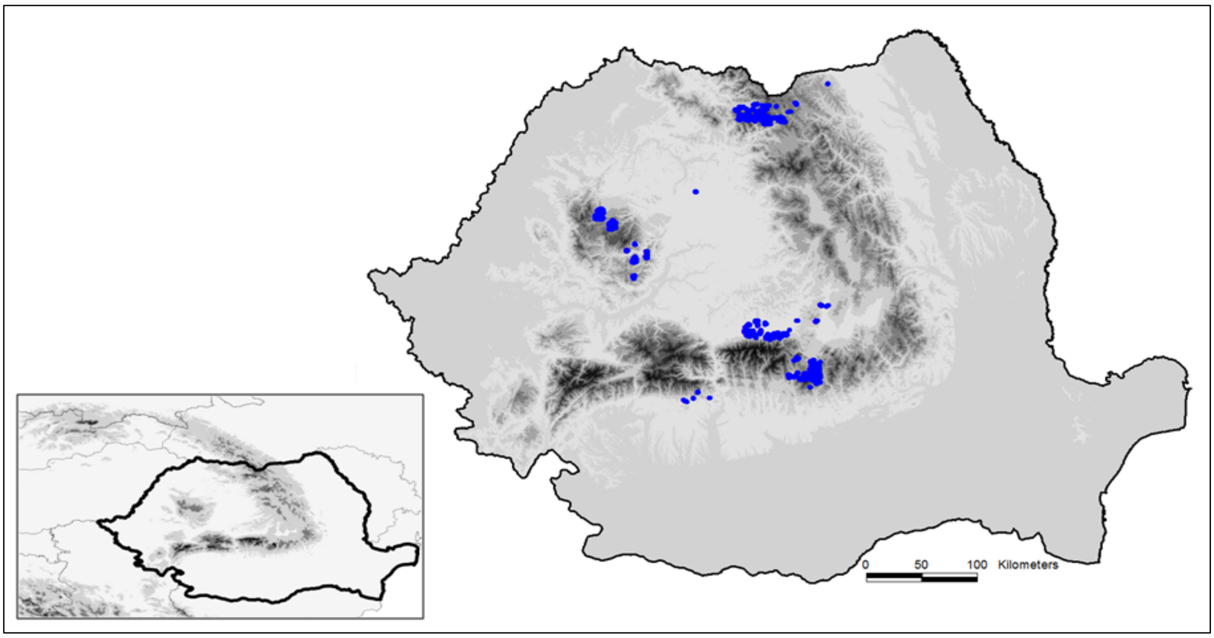


Fig. 1 – Spatial distribution of Mesophilous oligotrophic mountain pasture and Subalpine oligotrophic pastures (VNG+PON) observation data.

Table 1

Distribution of high altitude *Nardus* grasslands (field observation data)

Altitude (m)	Surface (ha)	Proportion
1,800 – 1,900	2,142	38%
1,900 – 2,000	1,179	21%
2,000 – 2,100	639	11%
2,100 – 2,200	639	11%
2,200 – 2,300	468	8%
2,300 – 2,400	423	8%
2,400 – 2,500	144	3%
Total	5,634	100%

2.3. Environmental data

The environmental datasets (Table 2) include 19 bioclimatic variables and four environmental layers (ESRI grids, 30 arc-seconds, ~ 1km2), digital terrain model (30m) , slope (30m) , soil map (100m) and Corine Land Cover 2006 (100 m). Present and future climate data sources of the climate data were provided by Worldclim dataset (Hijmans[a] et al., 2005), at: http://www.worldclim.org/current for current conditions (1950–2000) and http://www.worldclim.org/CMIP5 for future conditions (2000–2050 scenario) corresponding to a doubling of CO_2 emissions (Hijmans[b] et al., 2005). For Romania this future scenario corresponds to an average increase of annual mean temperature of 2.60°C (22%) and an average reduction of annual precipitation with 35 mm (6%).

Table 2

List of environmental variables (ESRI grids, 30 arc-seconds resolution, ~ $1km^2$)

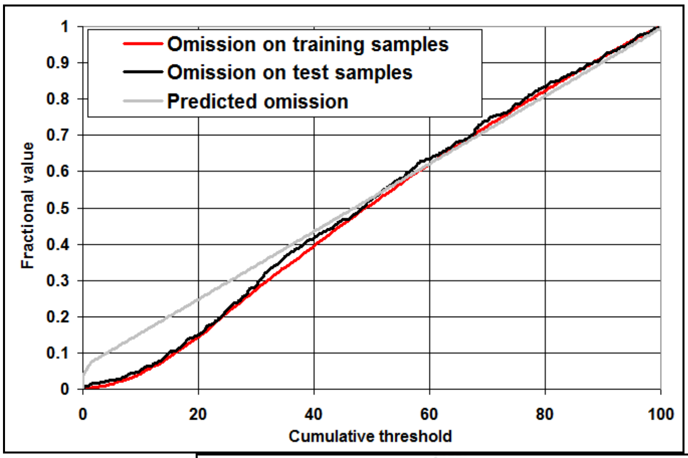
BIO1	Annual mean temperature	**BIO12**	Annual Precipitation
BIO2	Mean diurnal range (max temp – min temp)	**BIO13**	Precipitation of Wettest Period
BIO3	Isothermality (BIO1/BIO7) * 100	**BIO14**	Precipitation of Driest Period
BIO4	Temperature Seasonality (Coefficient of	**BIO15**	Precipitation Seasonality (Coefficient
BIO5	Max Temperature of Warmest Period	**BIO16**	Precipitation of Wettest Quarter
BIO6	Min Temperature of Coldest Period	**BIO17**	Precipitation of Driest Quarter
BIO7	Temperature Annual Range (BIO5-BIO6)	**BIO18**	Precipitation of Warmest Quarter
BIO8	Mean Temperature of Wettest Quarter	**BIO19**	Precipitation of Coldest Quarter
BIO9	Mean Temperature of Driest Quarter	**DTM**	Romanian digital terrain model
BIO10	Mean Temperature of Warmest Quarter	**SLOPE**	Romanian slope model
BIO11	Mean Temperature of Coldest Quarter	**SOIL**	Romanian soil map

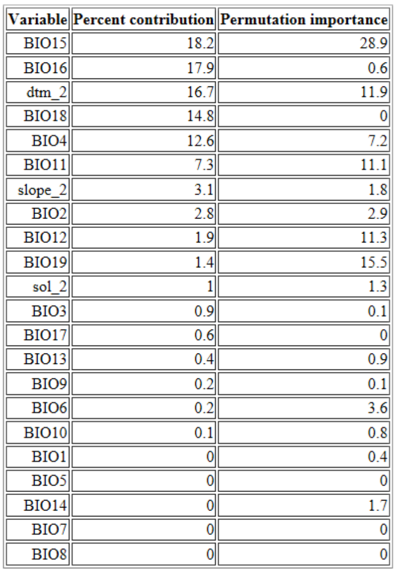
3. MODEL VALIDATION

The Area Under the Receiver Operating Characteristic Curve (AUC) was used to examine the accuracy of models. AUC is calculated by plotting the true-positive fraction (sensitivity) against the false-positive fraction (1-specificity) for all test points across all possible probability thresholds (Fielding and Bell, 1997). The curve goes from (0.0) to (1.1) and a model that produces a curve with a high true-positive fraction at low values of the false-positive fraction is considered good. This is commonly quantified by calculating the area under the curve (AUC). AUC ranges from 0 to 1 where a value of 0.5 indicates that a model is no better than random and a value of 1 indicates that the model can discriminate perfectly between the presence and absence records. Model outputs give pixel values in percent and percentiles, where higher values are more suitable habitat. These models do not specify at what threshold probability a pixel becomes a suitable habitat. Therefore, we used a threshold probability at which true positives and negatives are maximized while false positives and negatives are minimized.

Testing or validation is required to assess the predictive performance of the models. The ideal way to estimate the models performance is to use an independent set of data. In many cases this is not possible, therefore the most usual approach is to split the data into two partitions, a training set (2,235 records, 70%) and a test set (957 records, 30%) in order to have a quasi-independent data for model testing. Background points were randomly sampled from the full area.

The omission rate and predicted area for VNG+PON as function of cumulative threshold and the analysis of variable contribution using Maxent is shown in Fig. 2. The omission rate is calculated both on the training presence records, and on the test records. The environmental variable with highest gain when used in isolation is BIO16, which therefore appears to have the most useful information by itself. The environmental variable that decreases the gain the most when omitted is BIO15.





Variable	Percent contribution	Permutation importance
BIO15	18.2	28.9
BIO16	17.9	0.6
dtm_2	16.7	11.9
BIO18	14.8	0
BIO4	12.6	7.2
BIO11	7.3	11.1
slope_2	3.1	1.8
BIO2	2.8	2.9
BIO12	1.9	11.3
BIO19	1.4	15.5
sol_2	1	1.3
BIO3	0.9	0.1
BIO17	0.6	0
BIO13	0.4	0.9
BIO9	0.2	0.1
BIO6	0.2	3.6
BIO10	0.1	0.8
BIO1	0	0.4
BIO5	0	0
BIO14	0	1.7
BIO7	0	0
BIO8	0	0

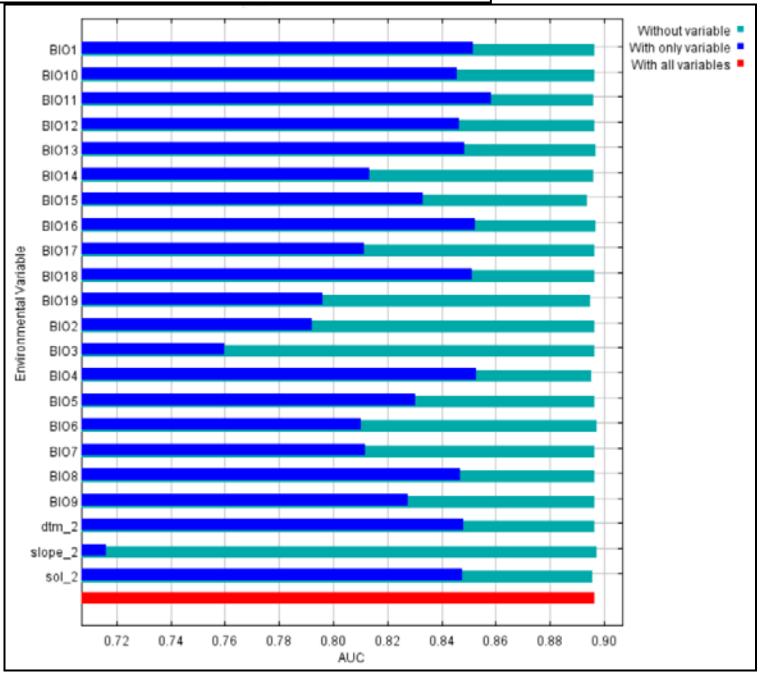


Fig. 2 – Maxent statistical outputs.

The Kappa correlation with threshold using DIVA-GIS is presented in Fig. 3.

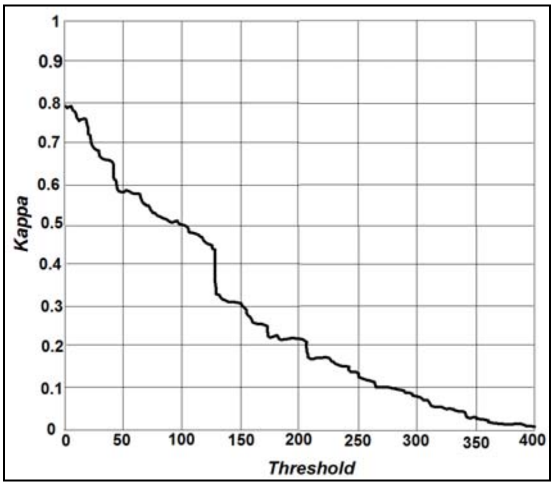


Fig. 3 – BIOCLIM (DIVA-GIS) statistical output.

4. RESULTS

Both modeling methods yielded high values of AUC under the ROC curve (Fig. 4) for predicted mesophilous oligotrophic mountain pasture PON) + subalpine oligotrophic pastures (VNG . (BIOCLIM = 0.926 and MAXENT = 0.901).

Present and future predicted geographical distributions of all PON+VNG habitats using Maxent (Fig. 5) and BIOCLIM (Fig. 6) show differences between the modeling approaches. Maxent predict smaller areas (12% less) of suitable habitat than BIOCLIM for present distribution. For the future climate scenario the surface with PON+VNG decreases by 31% with Maxent and by 26% with BIOCLIM (Figs 7 and 8).

Dynamics of changes show that both modeling techniques predict *Nardus* grasslands to be negatively affected by climate warming. The lost surface of the *Nardus* grassland habitat related to altitude for the double CO_2 scenario shows that MAXENT approach predicted higher values than BIOCLIM especially for alpine and sub-alpine areas above 1,750 m (Fig. 9, Table 3).

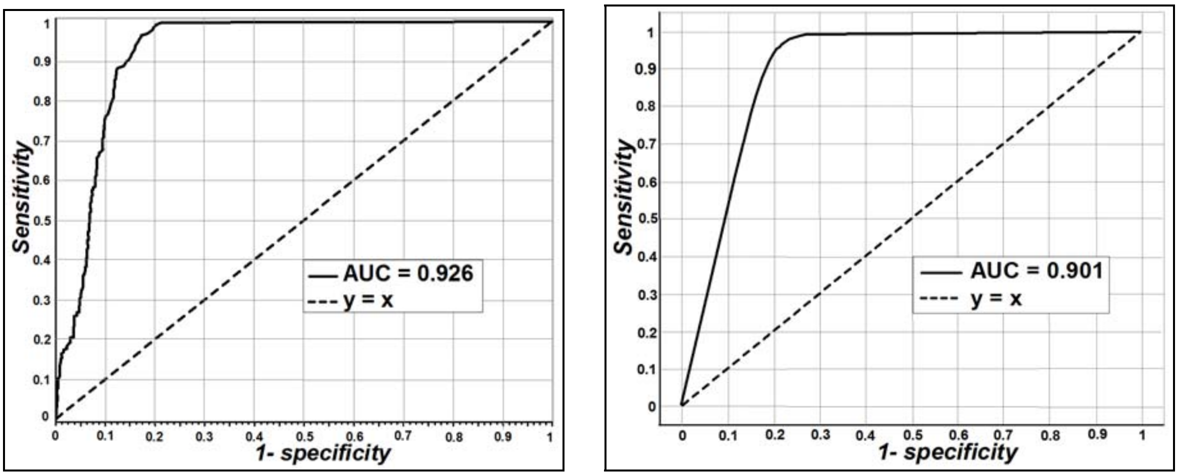


Fig. 4 – AUC values for BIOCLIM and Maxent.

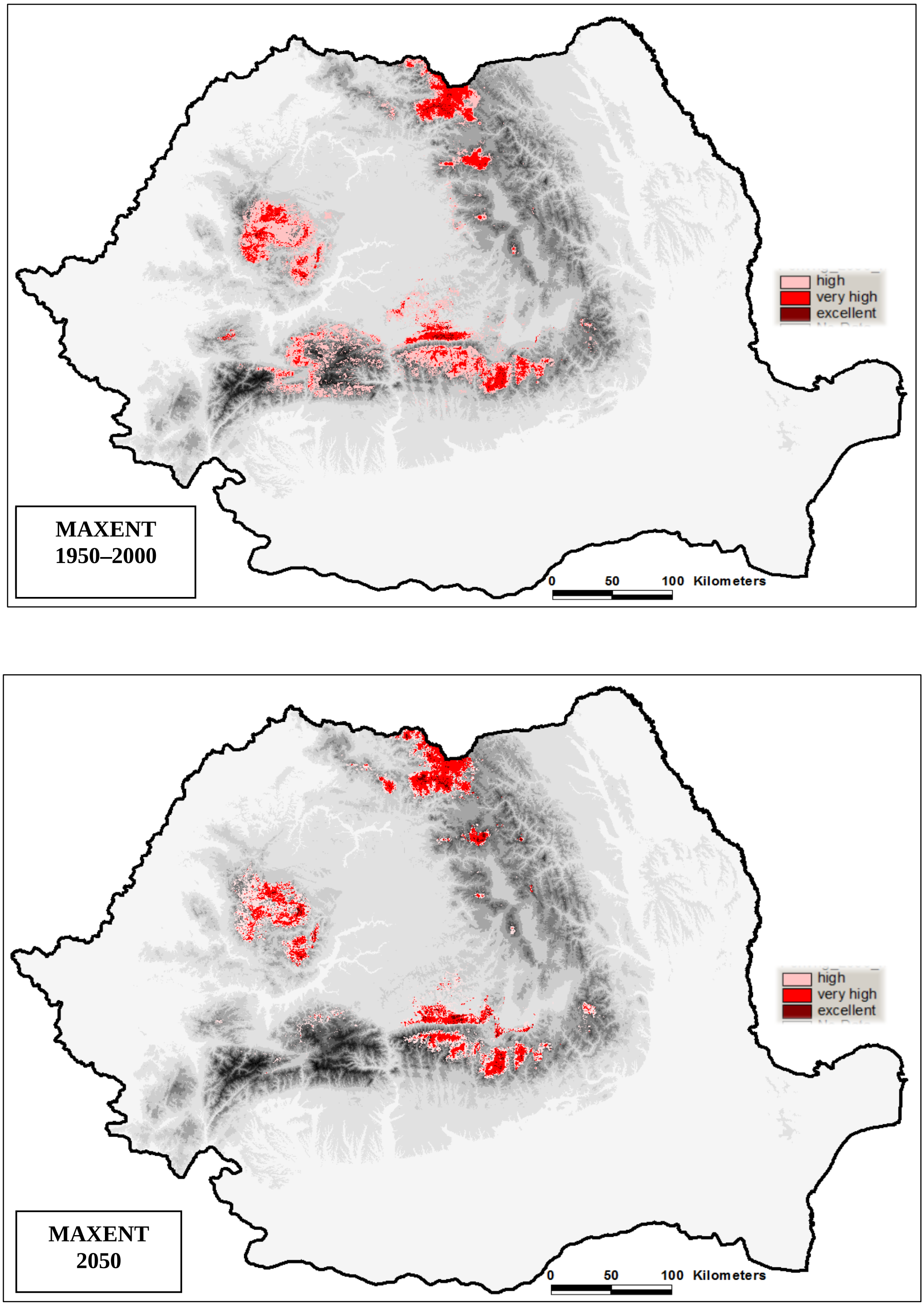


Fig. 5 – Present and predicted spatial potential distribution of PON+VNG habitats predicted by Maxent.

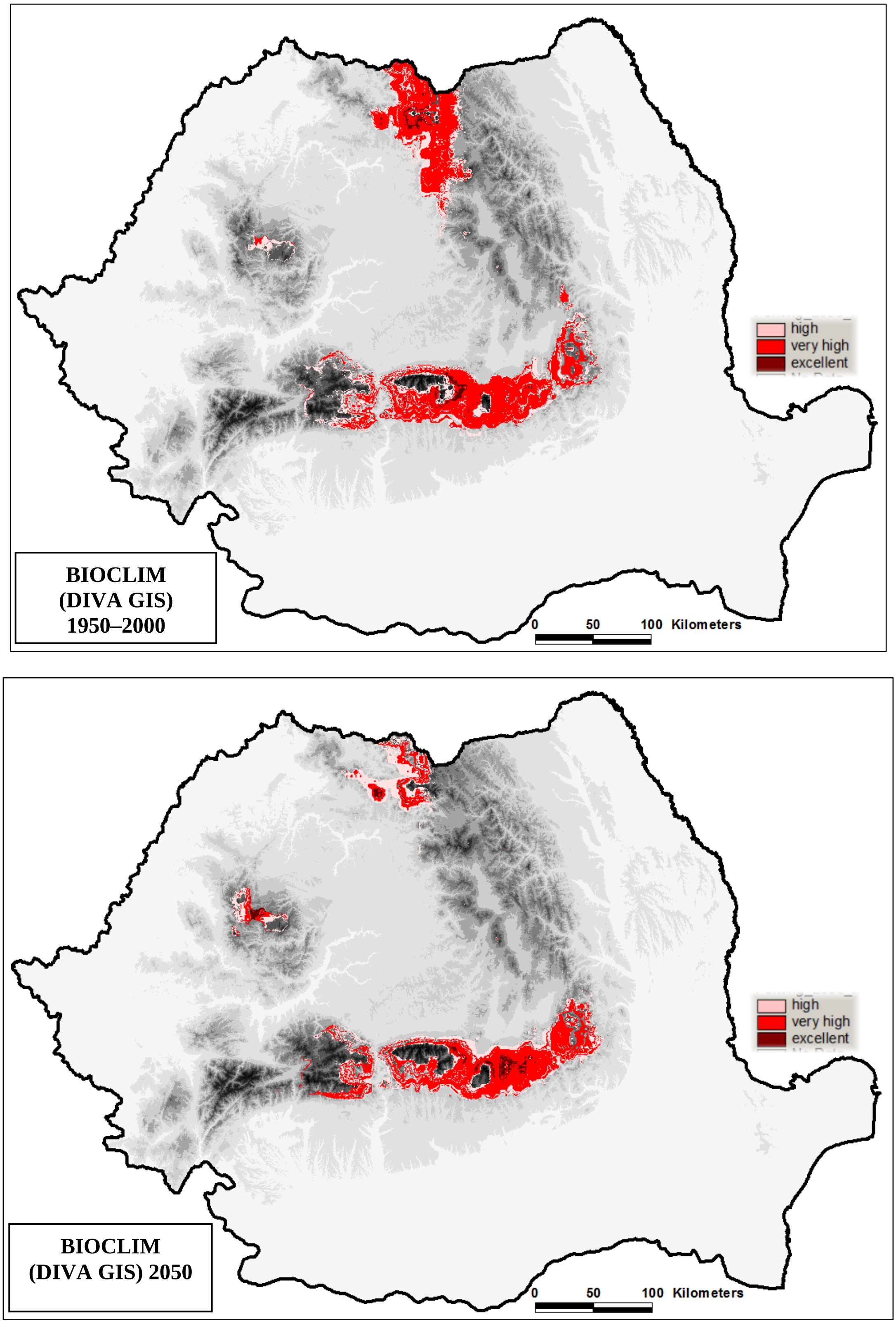


Fig. 6 – Present and predicted spatial potential distribution of PON+VNG habitats predicted by BIOCLIM.

Because model performance cannot be tested under future scenarios, it is not possible to say which modeling approach is performing better. Therefore, we combined the two results (lost areas layers for future scenario) into one spatial layer representing, with high probability, the lost surface for *Nardus* grassland habitat (Fig. 10).

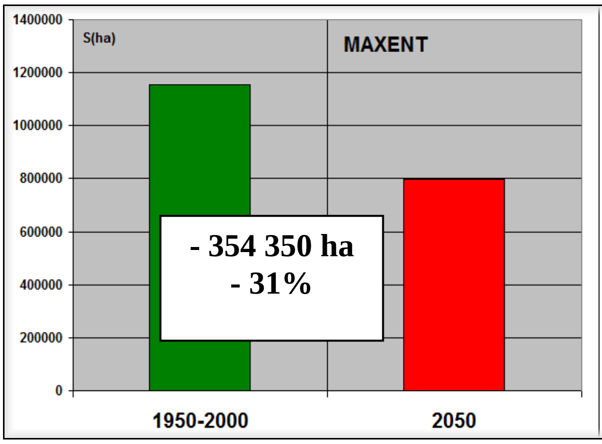


Fig. 7 – Decrease of PON+VNG surface for future climate scenario.

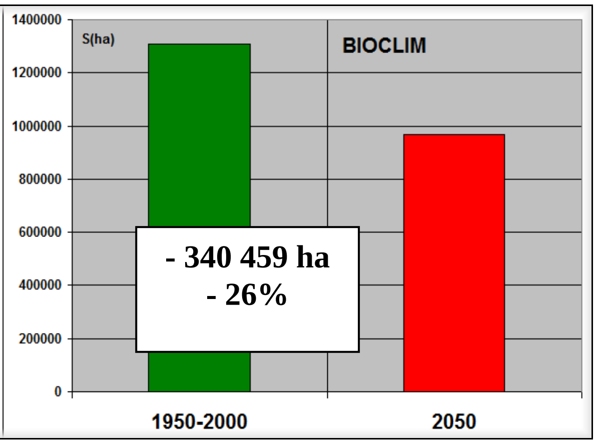


Fig. 8 – Spatial distribution of PON+VNG lost surface for future climate scenario.

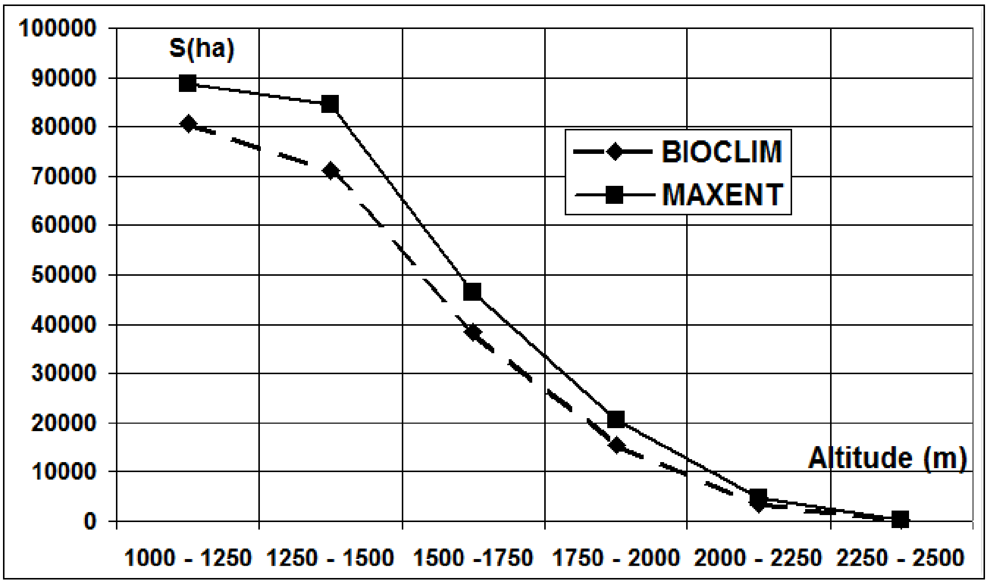


Fig. 9 – Lost surfaces of Nardus habitat (BIOCLIM and MAXENT) related to altitude.

Table 3

Lost surfaces of *Nardus* habitat (BIOCLIM and Maxent) related to altitude

	BIOCLIM	**MAXENT**	
Altitude (m)	**S(ha)**	**S(ha)**	**Difference MAXENT (%)**
1000 - 1250	80655	88703	9.07%
1250 - 1500	71240	84588	15.78%
1500 -1750	38515	46511	17.19%
1750 - 2000	15540	20396	23.81%
2000 - 2250	3433	4812	28.66%

5. DISCUSSION

5.1. Habitat distribution

It is known that the optimum condition for the *Nardus* grassland is the low trophic status of the substrate. Hence, it is believed that climate change should not cause total destruction of the habitat (Daniel Scherrer* and Christian Körner, 2011) as alpine terrain is, in fact, for the majority of species, a much safer place to live under conditions of climate change than is flat terrain which offers no short-distance escapes from the novel thermal regime. However, climate change may lead to substantial changes in the species composition of different subtypes. Sub-types in transition from wet grasslands, and those occurring in high-altitude mountainous areas, especially chionophile types, are probably the most vulnerable (Galvánek D. & Janák M., 2008). Alpine species should be at higher risk of local extinction than subalpine species or species distributed down to lower elevations, as the latter have a wider elevation tolerance and thus a lower risk of local extinction (Antoine Guisan & Jean-Paul Theurillat, 2001). Pauli et al., 2007 reported a slow shift of the species of alpine communities into nival and subnival habitats. Experiments by Herben et al., 2003, in the Krkonoše (Czech Republic), demonstrated that the weather may strongly influence competition among species on mountainous *Nardus* grasslands, and thus changes in weather resulting from climate change could lead to changes in species composition. At the level of the year 2050, our results show a decrease of the area occupied by Mesophilous oligotrophic mountain pasture and Subalpine oligotrophic pastures of 27% by MAXENT and 77% by BIOCLIM.

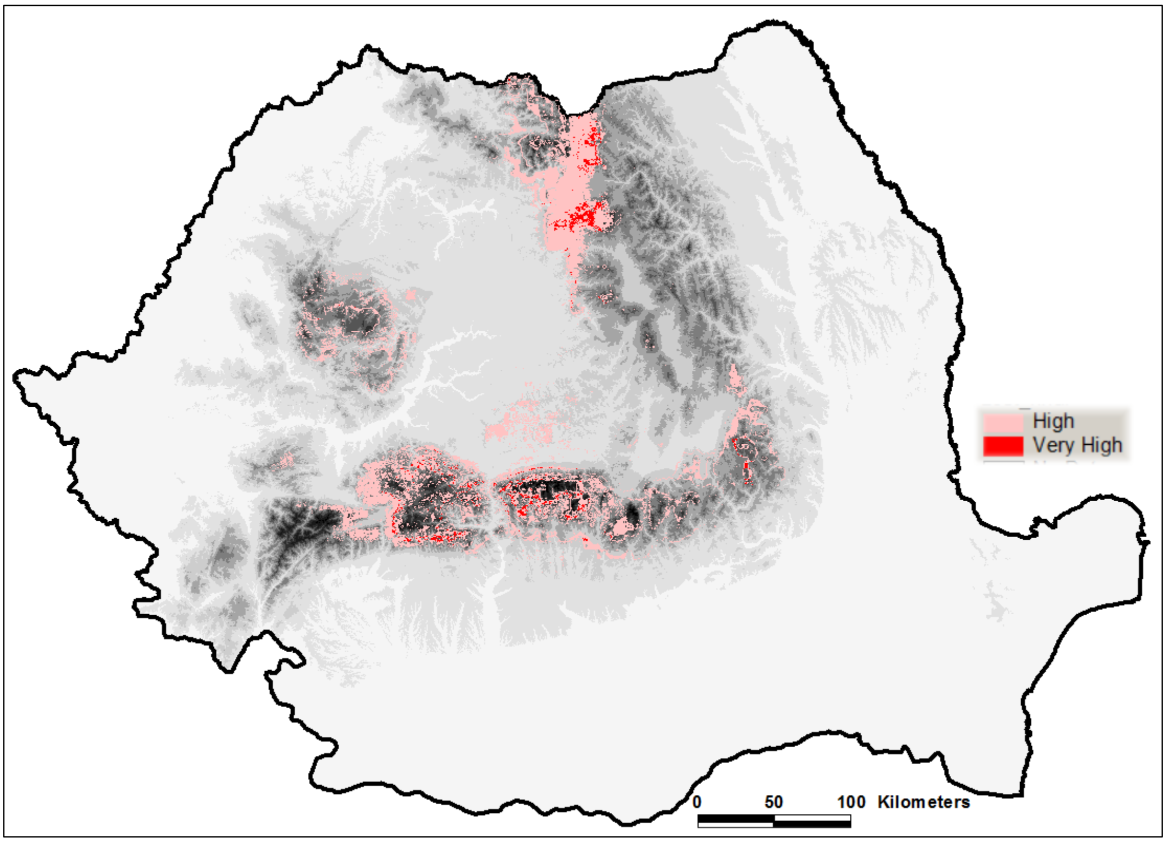


Fig. 10 – Lost surface of Nardus grassland habitat (combined Maxent and BIOCLIM).

5.2. Choice between BIOCLIM and MAXENT

Maxent predicts smaller areas of studied suitable habitat than BIOCLIM (DIVA-GIS) model does. Also, the lost surface of the *Nardus grassland* habitat related to altitude for the future scenario (double CO_2) shows that the Maxent approach predicted higher values than BIOCLIM especially for alpine and sub-alpine areas. Maxent, with a higher model strength, can be considered to have a higher likelihood of occurrence in all suitable habitat areas. In other words, the confidence in the prediction of suitable habitat is greater with all Maxent models (Elith et al., Alan, 1997). Model uncertainty can lead to choose ensemble forecasting like Biomod (Thuiller et al., Ecography 2009). Future improvements are necessary for calibration and validation of the models. The main issue is to get available *in situ* data for the species and habitats.

6. POLICY ASPECTS

Recognizing the importance of the species-rich *Nardus* 6230 habitat the European Commission (DG ENV B2) commissioned the Management of Natura 2000 network. The report (Galvánek D. & Janák M., 2008) has identified several stress factors on this habitat: eutrophication, inappropriate grazing practices, land abandonment, low management intensity, afforestation, tourism and skiing activities, and climate change effects. It is supposed that high alpine *Nardus* natural habitats do not require management measures while all other *Nardus* grassland semi-natural need active management measures mainly by adequate grazing, mowing and most importantly the ban on fertilization. In Romania, the grassland area, dominated by Nardus *stricta* L., covers 200,000 ha (Samuil & Vintu, 2012). Our estimates of high altitude *Nardus* grassland is 29,863 ha by BIOCLIM and 74,324 ha by MAXENT. The perspective of climate change for 2050 shows important reduction of Mesophilous oligotrophic mountain pasture and Subalpine oligotrophic pastures (habitat 6230) to 6`987 ha by BIOCLIM and 54`578 ha by MAXENT. In Romania *Nardus* stricta is mainly influenced by Ca++ concentration in soil litter (Bărbos & Sima, 2008). The disappearance or degradation of *Nardus* habitat is through change in soil pH indirectly driven by inadequate management such as overfertilization, overgrazing, and land abandonment (N. Ştefan, 2013 pers. Com.). This results in loss of species, grazing resources and landscape attractiveness. Active management such as stopping fertilization, overgrazing, or maintenance by adequate grazing and mowing can prevent degradation of semi-natural *Nardus* habitat.

We have also found that climate change may reduce the area of the high Alpine natural habitat but in this case the loss can be tackled only by global measure to prevent or reduce climate change induced by human activities. However, the trend of biodiversity is to decline globally despite a few encouraging achievements and increased policy action (CBD, 2010) (Stuart et. al., 2010). Composite Report on the Conservation Status of Habitat Types and Species as required under Article 17 of the Habitats Directive (EC, 2009[a]) enforces that "Protecting biodiversity is a priority for the European Union and for our policies to be successful we must have a comprehensive and reliable measure of the status of our biodiversity".

Key policy instruments are the EU Birds and Habitats Directives (EC, 2009[b]) (EC, 2010.) that aim at a favourable conservation status for selected species and habitats. The second main strand of policy action is the integration of biodiversity concerns into sectoral policies for transport, energy production, agriculture, forestry and fisheries. This is aimed at reducing the direct impacts from these sectors, as well as their diffuse pressures, such as fragmentation, acidification, eutrophication and pollution (OECD, 2006). Dedicated adaptation by Europe is urgently needed to build resilience against climate impacts. Adaptation (EC, 2009[c]) "is a first step towards an adaptation strategy to reduce vulnerability to the impacts of climate change, and complements actions at national, regional and even local levels". It has to be integrated in the policy of nature and biodiversity protection.

However, the EU White Paper (EC, 2009[c]) on Adaptation recognizes that limited knowledge is a key barrier and calls for a stronger knowledge base. To address related gaps, the creation of a European clearinghouse on climate change impacts, vulnerability and adaptation is foreseen. This aims to enable and encourage the sharing of information and good adaptation practices between all stakeholders. Our finding, mainly forecast distribution maps of *Nardus* habitat, may be of use to highlight sensitive areas at threat by climate changes warning to further take adequate measure to the negative effect of climate evolution as it is now. The results are seen to be of interest to policy decision-makers. Disseminations of the results and maps via the EnviroGRIDS portal, for example, is key for further reporting to Environmental Agencies for requesting stronger action to reduce the human impact on climate change.

7. CONCLUSIONS

Maxent and BIOCLIM were used to create spatial distribution models for Mesophilous oligotrophic mountain pasture and Subalpine oligotrophic pastures. Models were run with 1950-2000 averaged bioclimatic data and double atmospheric CO_2 concentration scenario for the perspective of the year 2050. In our analyses we have included once all 6320 mapped habitat with Nardus grasslands. Under 1950 - 2000 climate scenario, both models exhibited high AUC values (> 0.9). The predicted geographical distribution of PON+VNG habitat modeled by Maxent and BIOCLIM shows differences between the modeling approaches, with Maxent predicting smaller areas (12% less) of suitable habitat than BIOCLIM. For the future climate scenario (double CO2) the surface with PON+VNG decreases with 31% for Maxent and 26% for BIOCLIM. However both models show significant shifts of the *Nardus* habitat due to climate change.

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THE DELTA COASTLINE DYNAMICS FOR THE DANUBE NORTHERN ARM OVER THE PERIOD 1986–2011

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Key-words: Danube Delta, Black Sea, coastline dynamics, remote sensing, GIS-analysis, enviroGRIDS.

The research was implemented in the framework of EnviroGrids international project. Long-term trends in the dynamics of the delta coastline at the Ochakiv Arm (Ukraine) were assessed based on original LANDSAT remote sensing data with spatial resolution of 30 m and time interval of 7 and 4 years. The relevance of original information and advantages of modern GIS-technologies allowed to obtain new information about long-term delta processes. It is established that during 26 years the area of the Danube delta at the Ochakiv Arm, in general, increased by 1.335 sq.km. However, it was found that in different parts of the delta and in different time periods, not only accumulative but also erosion processes were dominant, leading both to the increase of the new land area and to the sea intrusion. Also, long-term changes in the geometric shape of the delta coastline were found. Some assumptions about the causes of the observed morphological changes were made. The information received is important from a scientific point of view as well as for the management and implementation of economic activities in the Danube River Delta.

1. INTRODUCTION

Long-term dynamics of the Black Sea level and continuous deposition of suspended sediments in the river delta form a coastal zone, and in particular, coastline location and type of the delta vegetation coverage. River deltas are known as indicators of natural and anthropogenic drivers of changes in the river runoff and sea level (Mikhailov *et al.*, 2006). Intensive economic activity can have a significant impact on the character and rate of geomorphological changes in deltas (Nikiforov *et al.*, 1963, Mikhailov *et al.*, 1981, Mikhailov *et al.*, 1999, Mikhailov *et al.*, 2010).

LANDSAT satellite data provide objective temporal data, and modern GIS techniques provide a comprehensive set of tools for analysing the changes.

The study-area is located in the south-west of Ukraine near the Romanian border in the Danube River Delta. The location of the coastline in the year 2010, and the main hydrographical objects of the Ochakiv Arm of the Danube are shown in Figure 1: Prirva Arm, Potapovske Arm, lakes and bays in the delta. Figure 1 is based on the aerial imagery web mapping service (Bing 2013). A total area of the studied pilot area was approximately of 62 sq. km.

The Ochakiv is the northernmost arm of the Danube and simultaneously a branch of the Danube's most water-abundant arm – the Kilia Arm. In 2001–2003, the Kilia arm water volume was 52% of the total Danube runoff (*Hydrology of the Danube Delta*, 2004). From the 1950s to 1998, the USSR and Ukraine used branches and canals of the Ochakiv Arm as a main Danube shipping route. However, after 1998, the Bystre Arm was decided to be used instead as a navigation waterway, because the Ochakiv Arm was shallowing and the unreasonable costs required for its dredging.

The main task of this work is to analyse the dynamics of the marine coastline and area of vegetation coverage in the Ochakiv Arm of the Danube using up-to-date GIS and remote sensing technologies.

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In this paper we made an attempt to evaluate trends of delta-formation processes driven by natural or anthropogenic factors in the study-area over the last 26 years based on remote sensing data.

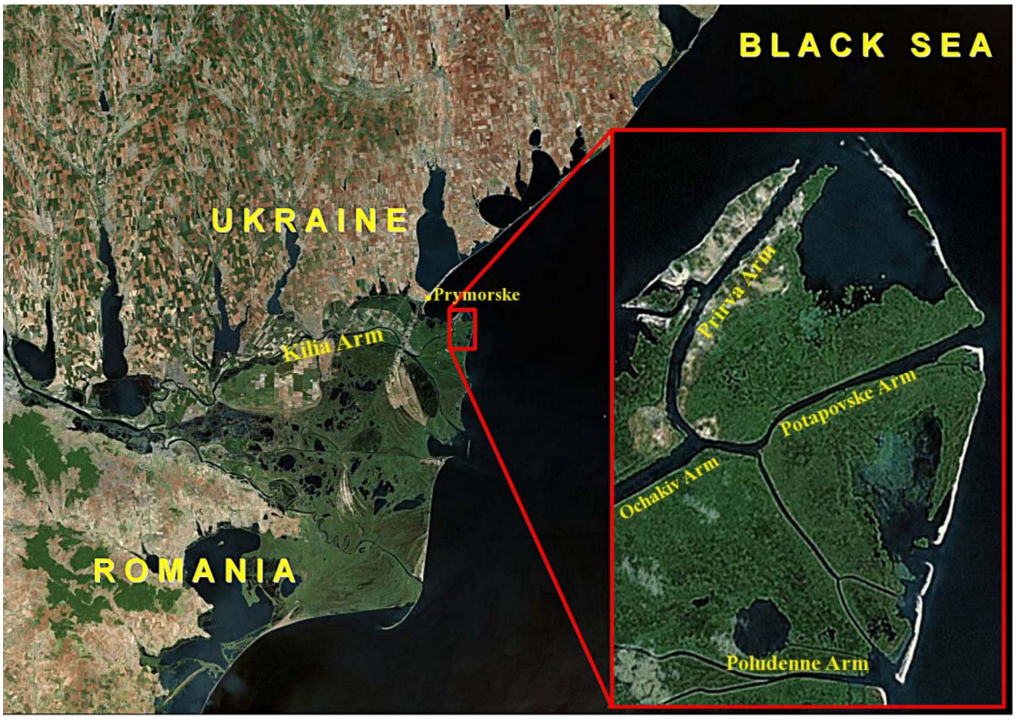

Fig. 1 – Location of the arms in the northern part of the Danube Delta.

2. INPUT DATA AND METHODOLOGY

2.1. Input data

Mapping the Ochakiv Arm coastline was done based on LandSat 5TM space imagery in the spring seasons of 1986, 1993, 2000, 2007 and 2011. The original information is available on open access at a website of the Earth Resources Observation and Science Center (EROS Center 2012). The spatial resolution of original satellite images is 30 m (15 m in panchromatic range).

The sea level is one of the most important factors to form a configuration of the coastline, islands and spits. Sizeable lowland areas of the delta can arise or disappear during short periods of time due to changes in the sea level, synoptic situation and wind tide processes. To minimize the error caused by short-term sea level fluctuations, we chose satellite images taken at dates with similar sea level values. Information on the sea level is based on measurements of the Prymorske hydrometeorological station, 10 km from the studied-area (Fig. 1). Sea levels for the dates of satellite images were kindly provided by the Danube Hydrometeorological Observatory (DHMO).

2.2. Methodology

Multichannel satellite images were processed by ArcGIS 10 and ERDAS IMAGINE 2011.

To identify the distribution of water and of land areas we used a combination of spectral channels LandSat 5TM – “7-5-3” as being most suitable for this purpose (GIS-Lab 2005).

The processing procedure of satellite images includes the merging of channels 7 and 5 and 3 of the image (Stack function of ERDAS IMAGINE 2011) and further the creation of a multichannel image (pseudo-RGB). ERDAS IMAGINE has been selected for the creation of space pseudo-colour images of the Danube River Delta because this software is one of generally accepted leaders for correct processing of the remote sensing information.

Supervised classification, transfer raster to vector and further processing of the vector maps were carried out in ArcGIS 10, which provides a wider range of tools for working with vector objects. The vector version of the maps has been chosen given the need to work with a significant number of small, often "unreal" objects, which appear during the classification of remote sensing data. The authors considered it more convenient to remove such objects or their merger into the larger ones in ArcGIS environment. The interactive supervised classification was done with ArcGIS on the basis of the significant number (30–40) of matching signatures being characteristic of water types of the underlying surface. Everything other than bodies of water was classified as land and/or vegetation. Then, from the whole set of received objects, 'land' was extracted using the 'Extraction' function of the 'Spatial Analyst' module of ArcGIS 10 and consequently processed with other functions of the 'Spatial Analyst' to remove occasional objects and make final maps. To accelerate the processing of a great amount of objects, obtained as a result of half-automatic classification, a set of ArcGIS 10 functions was used for the spatial processing of vector maps.

As a result, thw processing of time-dynamic raster images series of vector maps for the coastline of the studied area over the above-mentioned interval of time were composed. To reveal changes in the delta, the maps of the same scale were compared pairwise for the years as follows: 1986–1993, 1993–2000, 2000–2007, 2007–2011, 1986–2011. Also a toolset of the spatial operations module 'Analysis Tools' from ArcGIS 10 was used to compare vector maps and calculate the size of changed areas.

Thus, a series of vector maps was produced, showing the dynamics of a form and location of the marine delta coastline of the Ochakiv Arm for the above-mentioned periods (Figs. 2, 3, 4, 5, 6).

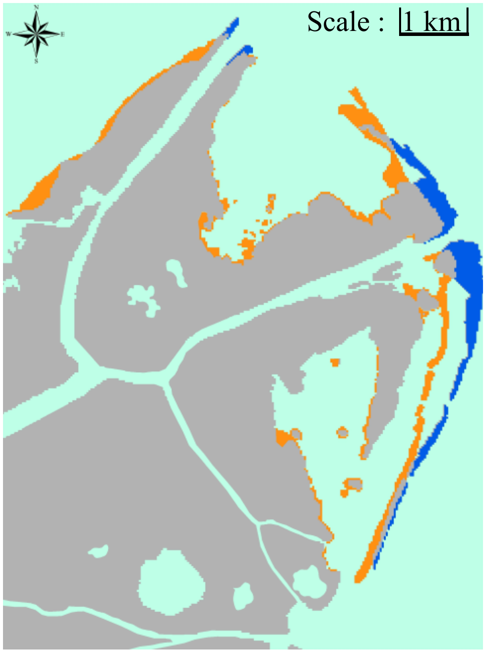

Fig. 2 – Coastline dynamics of the Ochakiv Arm in 1986–1993.

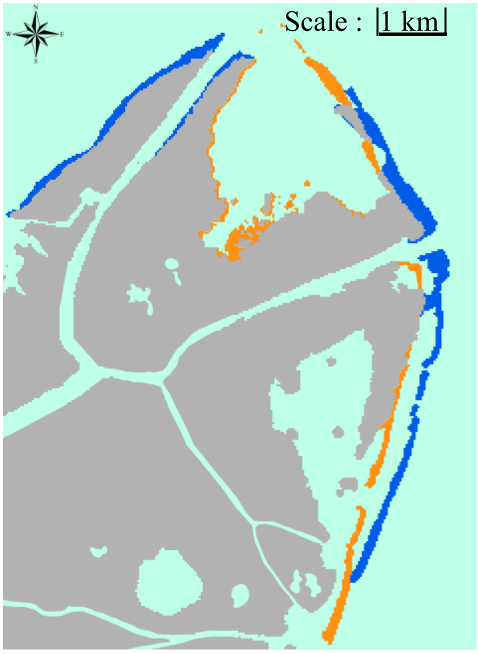

Fig. 3 – Coastline dynamics of the Ochakiv Arm in 1993–2000.

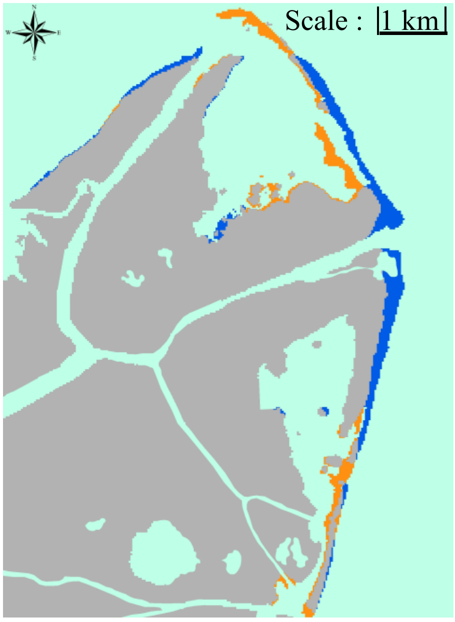

Fig 4 – Coastline dynamics of the Ochakiv Arm in 2000–2007.

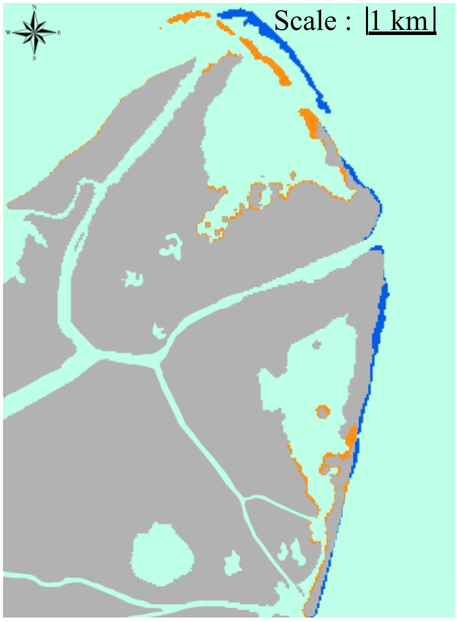

Fig. 5 – Coastline dynamics of the Ochakiv Arm in 2007–2011.

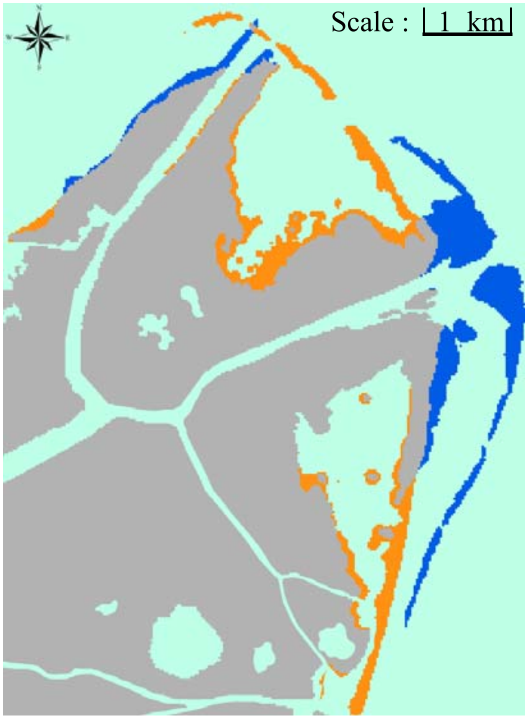

Fig. 6 – Coastline dynamics of the Ochakiv Arm in 1986–2011.

A map legend is identical for all the coastline dynamics maps: grey color indicates location of delta objects in the initial year of each period; blue ones are areas of the sea encroachment for the last year of each period; orange – areas of newly appeared land.

Assessment of reedbeds dynamics was carried out by the method as follows: using the 'Unsupervised Classification' function of ERDAS IMAGINE 11 we obtained the classes associated to different types of water surface, and different types of reedbeds and sand. Then, with the 'Spatial Analyst' module of ArcGIS 10, the raster was reclassified and three classes obtained: reed, sand and open water. For each of the three classes a size of the area was calculated that showed the reedbeds area dynamics from 1986 to 2011.

3. RESULTS AND DISCUSSIONS

Long-term trends of open water and lands distribution were evaluated with this pilot study of the Ochakiv Arm of the Danube Delta. Additionally, time periods were determined for the prevalence of active delta accumulative processes and formation of new land areas.

Maps of morphological dynamics of the coastal zone based on images of the 1986–2011 period (Fig. 6) revealed the following directions of the Danube delta changes:

- abrasion (sea encroachment) of spits and cones at the Prirva Arm and Potapivske Arm, where a land strip up to 800 m wide has disappeared (at a confluence point of the Potapivske Arm);
- accumulation, formation of new land areas (spits up to 280 m wide) to the west (toward the Continent) of formerly existing ones;
- trend of closure of extensive water areas of the sea near the marine coastline by alluvial spits;
- growth of reedbed areas with newly-formed reed fields as wide as up to 380 m (between the Prirva Arm and Potapivske Arm).

Comparative GIS-analysis of the delta coastline morphology over the last 26 years at the Ochakiv Arm has shown time dynamics as follows (Fig. 7):

The most intensive processes of land formation were recorded during 1986–1993 and 2007–2011 (land formation prevailed over abrasion by 1.7 times). The 1993–2000 and 2000–2007 intervals showed an opposite situation: erosion prevailed over accumulation of sediments and land-forming processes by 1.5 times.

In general, as for the Ochakiv Arm coastal zone in the 1986–2011 period, we can ascertain a balance between accumulation and abrasion activities. Tectonic subsidence of 1.5 mm/year (Shmuratko, 1982) in this region is negligible because for all the investigated interval of time this subsidence equaled about 4 cm in total.

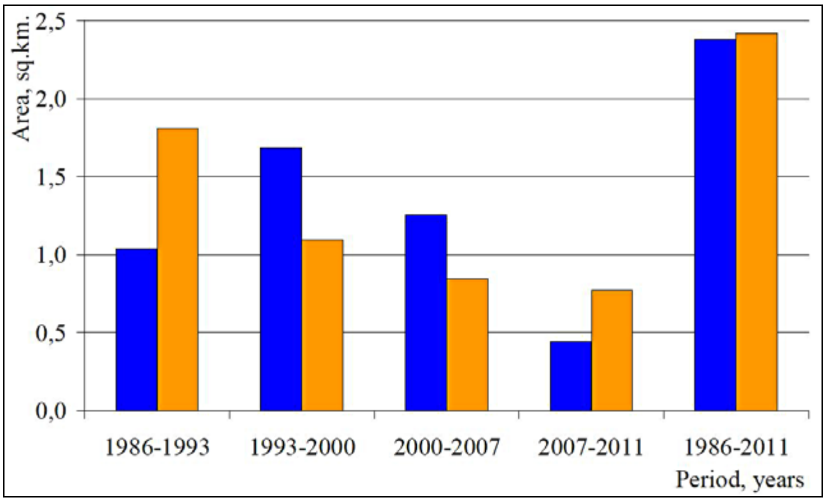

Fig. 7 – Dynamics of changes in the areas of the Ochakiv Arm coastal zone in 1986–2011 (blue – abrasion; orange – accumulation).

4. CONCLUSIONS

The pilot research of long-term changes in the region of the Ochakiv Arm of the Danube River, based on remote sensing services, has shown trends of radical delta changes, straightening of a cone-shape form of the Ochakiv Arm, and development of new closed lagoons in which accelerated overgrowing with reed is observed.

From 1993 to 2011, a general weakening trend of either abrasion or accumulation processes was observed in the study-area. Compared to 1986–1993, the 1993–2011 period demonstrated 2.6 less intensity of abrasion and accumulation processes. One of the reasons is the end of active economic use of the Ochakiv Arm with intensive dredging works (until 1998) aimed at improving a ‘Danube-Black Sea’ transit shipping route conditions.

The conclusions reached in the course of this pilot research correspond to the results of long-term observations and field studies of hydro-morphological processes in the Danube Delta provided by DHMO experts in co-operation with the Geographic Faculty of the M.V. Lomonosov Moscow State University (*Hydrology of the Danube Delta*, 2004).

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MORPHOLOGICAL CHANGES ON THE DANUBE DELTA BIOSPHERE RESERVE COAST – ACTUAL SYNTHESIS

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Key-words: coastal zone, Black Sea, abrasion, accumulation.

The Romanian Black Sea coastline covers 245 km. In terms of genesis and morphology, this coastline can be roughly divided into two sectors: accumulation of marine levees in the north, from Musura Stream at the Ukrainian border to Cape Midia (166 km); abrasion in the south with high cliffs, from Cape Midia to Vama Veche; the Bulgarian border (79 km). The article analyzes the northern sector corresponding to the delta front (Danube Delta Biosphere Reserve coast). This sector was created as a result of accumulation processes, the north-south coastal marine currents, moving the river alluvia blocked the river mouth forming the Danube Delta and Halmyris lagoon, the whole becoming Razim-Sinoie Lake Complex. This marine shore sector, due to the contribution of river alluvia, is characterized generally by the advance in the marine space, but the current conditions (reducing the volume of sediments from the Danube, marine minitransgression and anthropogenic interventions (by the dams raised at the mouth of the Sulina branch and Cape Midia) generate shoreline retreat in some areas. To identify portions of advancement and retreat, and setting the corresponding annual rates, existing topographic map series for a period of over 150 years, hydrographic measurements for 30 years and series of satellite images starting from 1975 were used.

Changements morphologiques de la côte d'accumulation de la Mer Noire dans le Delta du Danube. Le secteur roumain de la Mer Noire s'étend sur 245 km. Sous l'aspect génétique et morphologique, ce secteur peut être divisé, en grand, en deux sections, respectivement d'accumulation au nord (166 km) et d'abrasion au sud (79 km). Dans cet article, on analyse la section nordique qui correspond au front deltaïque du Danube. Bien que cette section se soit formée à la suite du processus d'accumulation qui a fermé les deux golfes – du Danube et d'Halmyris – pourtant, à présent ont lieu des processus d'accumulation qui déterminent un avancement dans l'espace marin, ainsi qu'une abrasion avec la retraite du rivage, au détriment de la terre ferme continentale. Pour identifier les sections d'avancement et de retraite du rivage, avec les taux annuels correspondants, on a utilisé les cartes topographiques existantes pour une période de plus de 150 ans et les mesurages faits aux bornes hydrographiques pour une période de 30 ans, aussi l'images satellites.

1. INTRODUCTION

The Black Sea coastal zone in Romania stretches over ***245 km***, between the secondary delta of Chilia in the North (frontierline with the Ukraine) and Vama Veche locality in the South (border point with Bulgaria).

Insofar as genesis and morphology are concerned, the coastline ca be divided into two sectors: lower, of accumulation in the North, in front of the Danube Delta Biosphere Reserve, extending along ***166 km*** formed of strandwalls and beaches, and a higher sector, in the South, long of ***79*** km, formed mainly of cliffs.

Coast morphology is an important characteristic of deltas. The Danube Delta Biosphere Reserve has a complex pattern of changes in time and space. The marine currents and waves, as well as the sediment fluxes of the river arms generated a complex dynamics along the coast.

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The actual coast is a result of a combination between ***natural factors*** and ***human intervention***. If human intervention in the 19th century had a small impact on coast changes, in the late 20th century this impact became very important.

The ***northern sector*** is characterised by an alternation of ***accumulation*** and ***abrasion*** processes, both in space (depending on the presence and orientation of different coastal sectors against the mouths of the Danube area) and in time (related to yearly seasonal variations of the Danube's solid discharge, sea level, direction and intensity of winds) (Gâştescu, P., Driga, B., 1986).

Since 1962, measurements have been made at the beach poles (landmarks) placed between Cape Midia and Sulina harbour in order to establish changes of distance on the shoreline. These measurements have provided a general picture of the evolution of this sector, affording quantitative assessments and estimates of annual coastline ***retreat (abrasion)*** or ***advance (accumulation/ accretion)***.

This abrasion is caused by a marine ***minitransgression***, drastic ***reduction of the sediments transported by the Danube*** and ***changes in the pattern of sea currents circulation*** in the wake of coastal engineering works.

Therefore, one can find abrasion, ***retreating sectors*** alternating with sectors of reduced ***accumulation (accretion)***. Sometimes, a ***relative temporal equilibrium*** between the two set in. Accumulation sectors occur as a rule right South of the Danube arms (Fig. 1, Table 1).

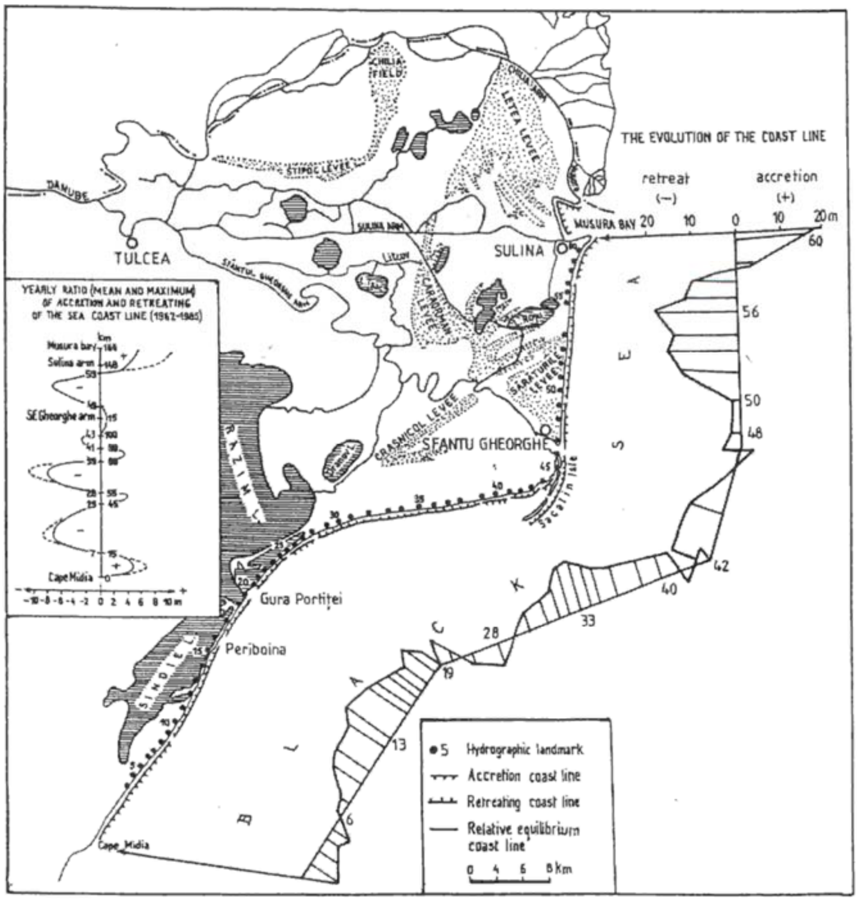


Fig.1 – Evolution of the accumulation Black Sea coast in front of the Danube between Sulina and Midia over 1962–1985 (Gâştescu, P., Driga, B., 1986).

Table 1

Quantitative assessments of accumulation and abrasion processes of the Romanian Black Sea coast (1962–1985)

Sector	Length (km)	Type of process (km)			Affected area (ha/year)		
		Accumulation	Abrasion	Equilibrium	Accumulation	Abrasion	Balance
Sulina-Midia	134	25	89	20	+34	112	+/- 72

At present, coastal ***abrasion*** in the studied area is by far more extended ***(109 km)*** than ***accumulation (57 km).*** Accumulation takes place largely in front of the three main Danube mouths: Chilia, Sulina and Sfântu Gheorghe.

Satellite data available from 1975 cover the majority of hydrological works in the Danube Delta Biosphere Reserve. Using the data, changes in costal morphology patterns was observed in correlation with major hydrological works (Grigoraş, I. 2008).

Using the series of satellite images on the Danube Delta coast, six major areas where morphological changes are significant were identified:

- two are deposit area,
- four are erosion areas.

The most affected abrasion area in the Danube Delta is the coast near Lake Roşu. The abrasion rate was increasing between 1990–1996 by 12 ha/year, and between 1996–2000 by 25 ha/year (Figs. 2, 3, 4).

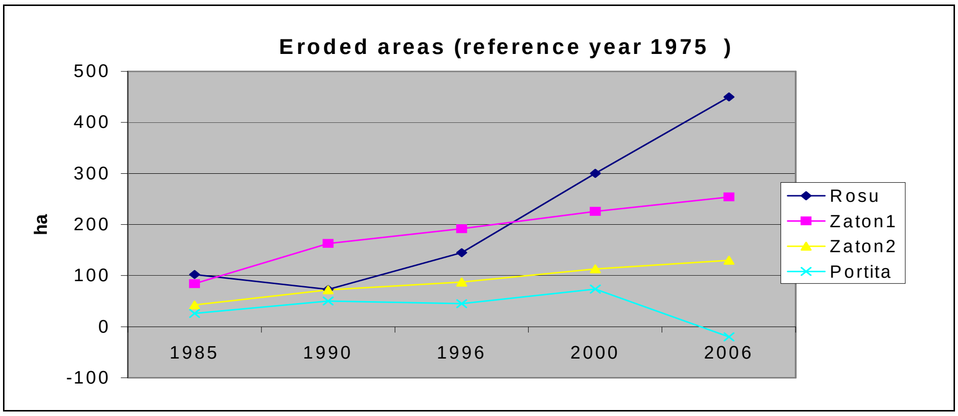


Fig. 2 – The areas affected erosion/abrasion (Grigoraş, I., 2008).

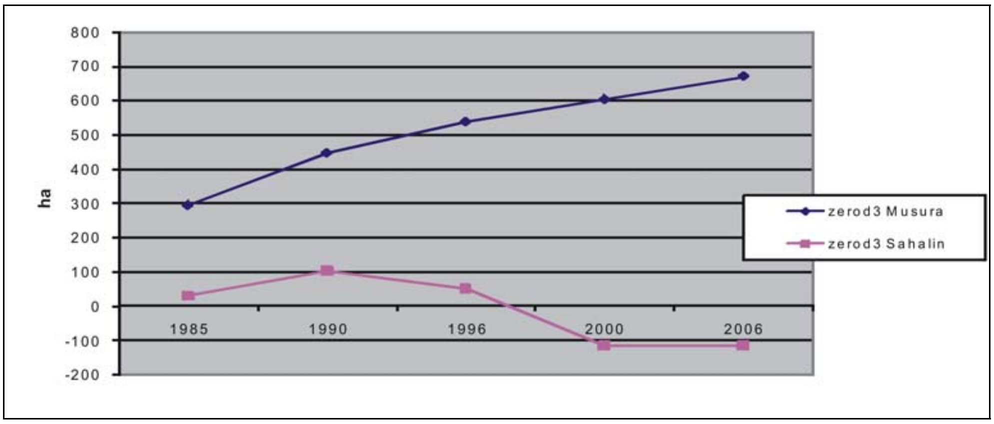


Fig. 3 – The areas affected by accumulation/deposit Grigoraş, I., 2008).

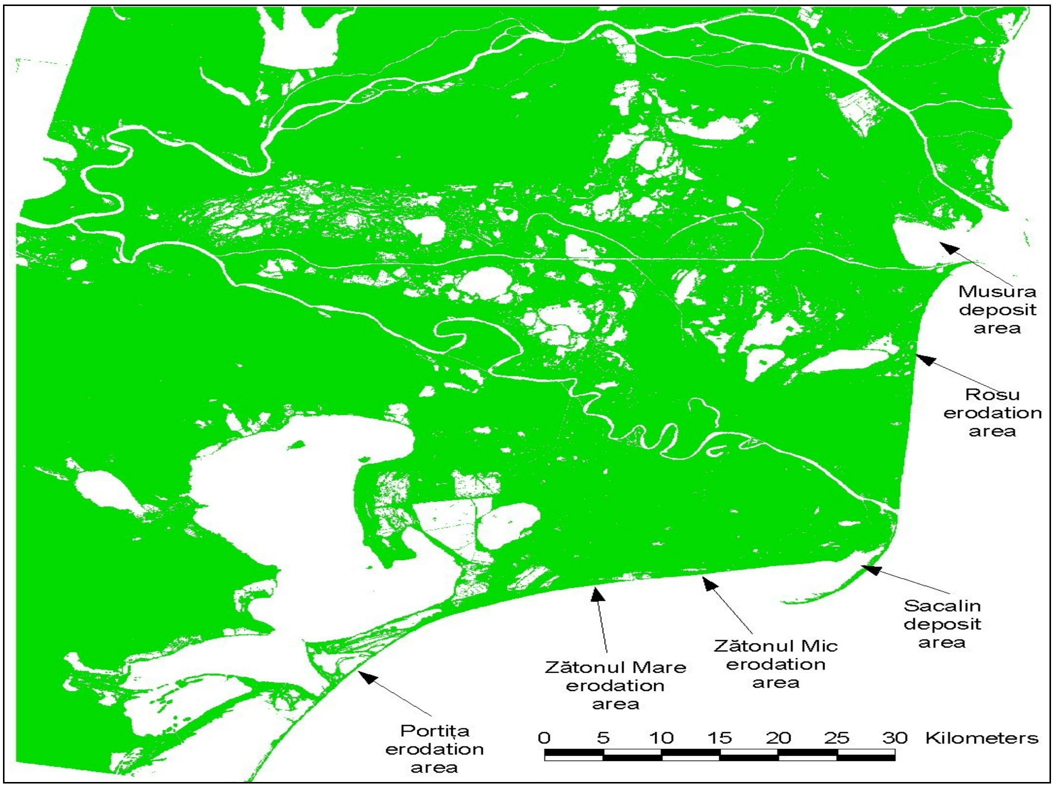


Fig. 4 – The position of the areas affected by erodation and deposit (Grigoraş,I., 2008).
The coastal sectors with a special evolution.

2. THE COSTAL SECTORS WITH SPECIAL EVOLUTION

The Chilia Arm secondary delta. Chilia Arm, the youngest and most active Danube branch in terms of discharge and sediment transport (ca. 58 %), has in time built three successive up-to-downstream secondary deltas (Pardina, Roşca-Buhaiova, and the current evolving delta).

The set of delta maps produced between 1830 and 1883 (Map of the Russian Military Headquarters, 1930; Hartley's Map, 1871; Lambert's Topographic Map Projection, 1883; Gauss-Krüger's Topographic Map Projection, 1971), have been used to determine the rate of delta accretion (m/year) along three main directions – Oceakov, Ankudenov and Staro Stambul, as well as the surface-area increase rate (sqkm/year) (Table 2, Figs. 5, 6, 7, 8) (Gâştescu, P., 1977).

Table 2

Accretion/accumulation rates and mean value (m/year) of the Chilia Arm secondary delta along three directions (arms) (Gâştescu, P., 1977)

Directions (arms)	1830	1856	1871	1883	1971	1830 – 1971
Chilia-Oceacov	As from this year the delta area stared growing at different accretion rates	23.0	45.7	70.7	63.8	50.8
Chilia-Ankudinov		43.3	36.6	82.5	47.0	52.3
Chilia-Stambulul Vechi		130.0	88.0	92.0	94.7	101.2
Mean value		65.4	56.8	81.7	68.5	68.1

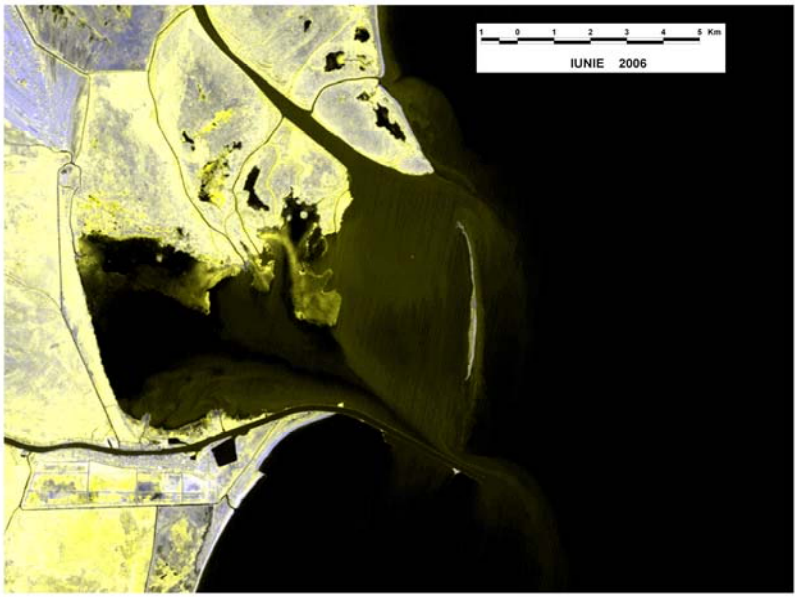


Fig. 5 – Musura Bay in 2006.

Fig. 6 – Evolution of the Chilia Arm secondary delta over 1830–1971 and satellite image 2003 (Gâştescu, P., Ştiucă, R., 2008).

New technologies available now enable a more accurate study of coastal morphologies. For the new island that is developing in front of Musura Bay, LIDAR data from 2011 can be used. Using this technology, the volume of new sediments above the water can be computed.

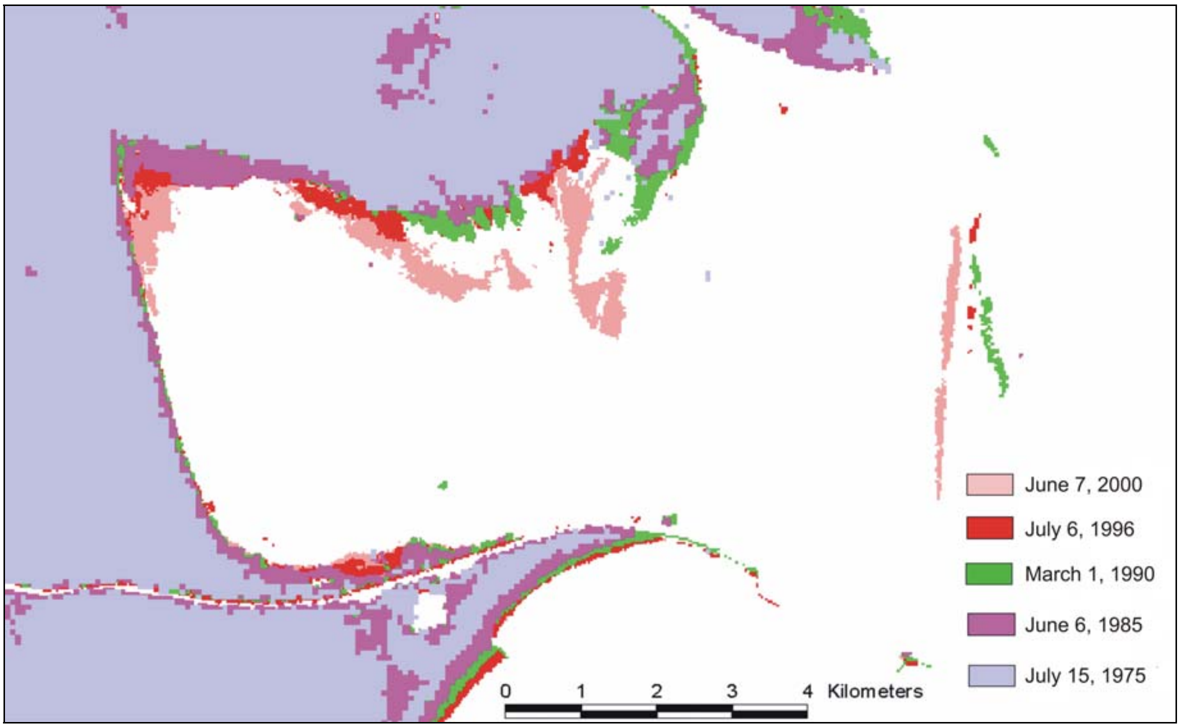
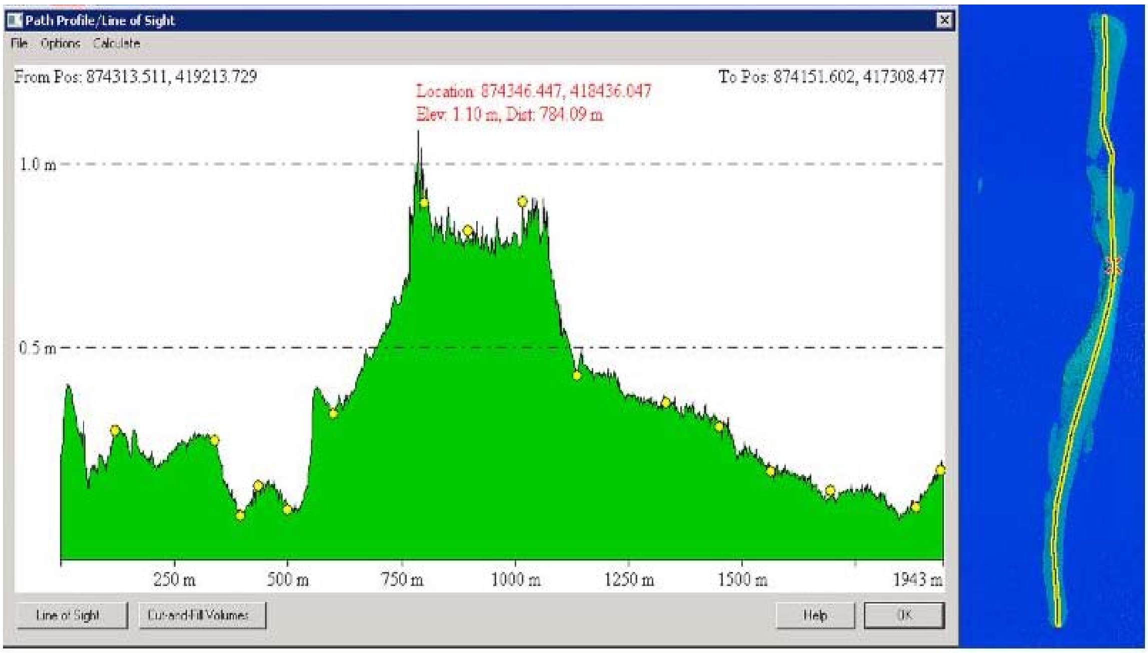


Fig. 7 – Musura Bay deposit area over 1975–2000 (Grigoraş, I., 2008).



From Pos: 874313.511, 419213.729

To Pos: 874151.602, 417308.477

Location: 874346.447, 418436.047
Elev: 1.10 m, Dist: 784.09 m

Fig. 8 – New island inner Musura Bay (Grigoraş, I., 2008).

The Sulina mouth. Reported problems in navigation on the Sulina Arm date back to the latter half of the 19th century, after the Paris Treaty of 1856, when the European Danube Commission (EDC) was established and assigned the surveillance of navigation along the Danube arms and the execution of works to enable high-tonnage sea vessels to reach the river ports of Galați and Brăila. Ever since Sulina mouth was chosen as a route for maritime navigation, the alluvia that keep depositing are forming a submerged bar that necessitates a lot of dredging and protection for that deep navigable channel flanked by two parallel piers; these piers have extended over 9 km if measured from the old lighthouse.

The sediments deposited in front of the channel are derived from the Sulina Arm, with many incomings from Staro Stambul, Sulina's most active branch situated in the North. Some smaller quantities of alluvia are carried by the coastal currents along a NE–SW direction.

Sulina South (3 km long) lies in the "shade" of the Sulina navigable channel piers. One finds here an accumulation of wave-eroded detritus carried by the western branch of the circular current that comes form Gârla Împuțita (Fig. 9.) (Gâştescu, P., 1977).

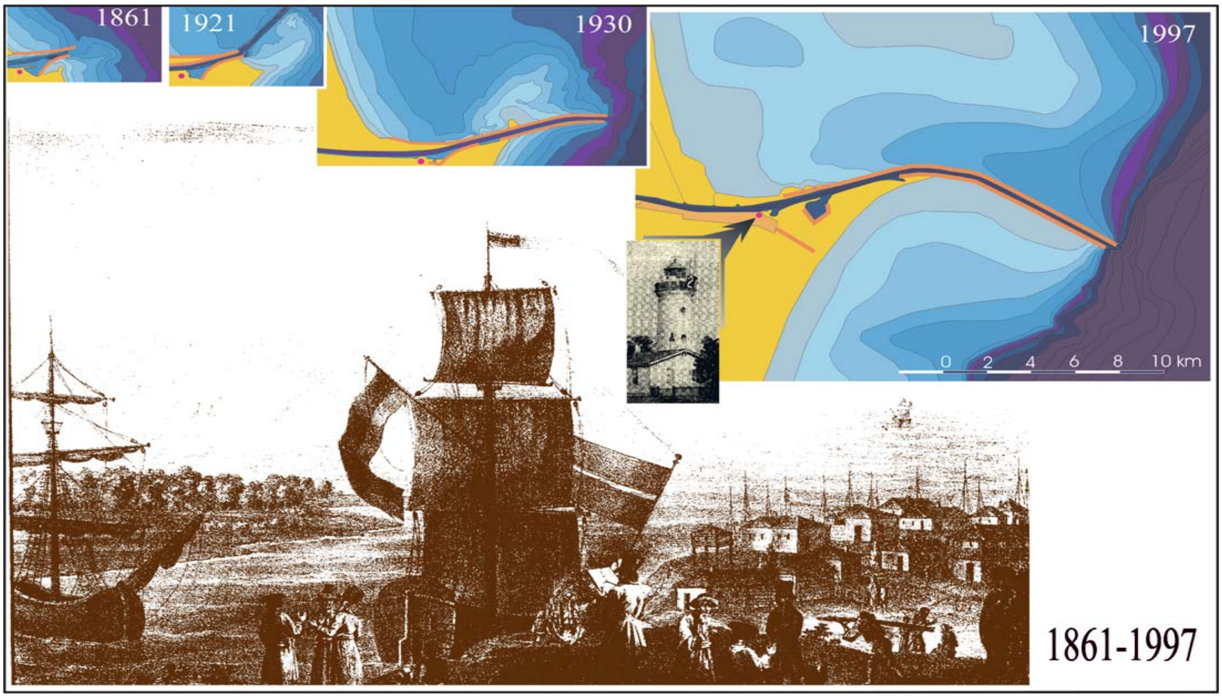


Fig. 9 – Evolution of the Sulina Arm/Canal over the 1861–1997 period
(Gâştescu, P., Ştiucă, R., 2008).

The mouth area of the Sfântu Gheorghe Arm. Relative stability in front of Sărăturile levee, with early accumulation both on the submerged ridge (Sacalin Peninsula today) and through the ***secondary deltas*** in front of the Gârla de Mijloc and Gârla Turcească (secondary arms protected to the East by the alignment of the Sacalin Peninsula) (Figs. 10, 11) (Ionescu-Dobrogeanu, M., 1938, Gâştescu, P., 1979, Gâştescu, P., Driga, B., 1986).

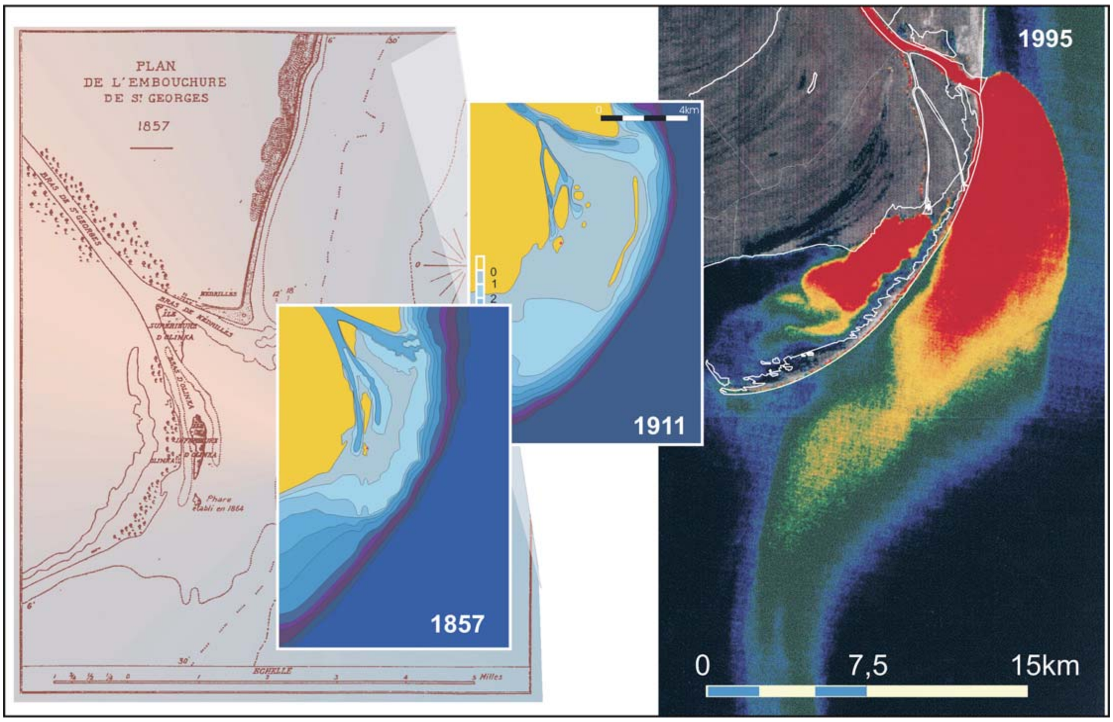


Fig. 10 – Evolution of the Sacalin Island/Penisula over the 1857–1995 (Gâştescu, P., Ştiucă, R., 2008).

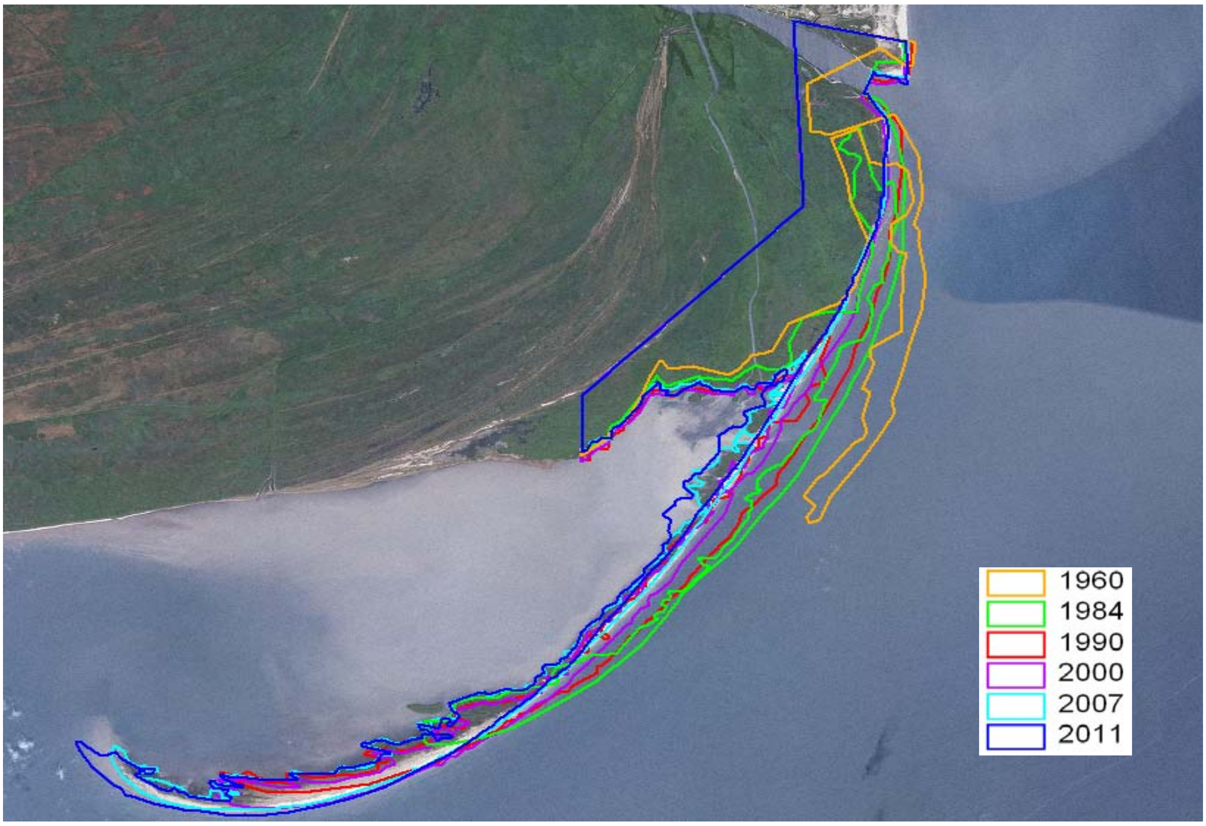


Fig. 11 – Evolution of the Sacalin Island/Peninsula over the 1960–2011 (Grigoraş, I., 2008).

3. CONCERNING THE EVOLUTION OF THE SACALIN ISLAND/PENINSULA

The changes in the tendencies of natural processes became important after 1990. This is the year when a big transportation project was finished. It consisted in cutting six meanders of the Sfântu Gheorghe Arm. These works affected three closest deposit/erosion areas:

- according to analyses, till 1990 the Sacalin area was dominated by the process of deposition. After that year, the dominant process was erosion.
- if in 1990 the Peninsula's surface-area reached 670 ha, in 1996 it decreased to 620 ha and to 450 ha in 2000. The erosion rate between 1990–1996 was of 8.3 ha/year. That rate increased to 42.5 ha/year between 1996–2000 (Grigoraş, I., 2008).
- in the 1990–2000 interval, in the most active Sacalin area, the coast was retreating by 350 m. If the actual erosion rates remain, in 10 years' time this peninsula will disappear, and what remains will be only an island in the southern part dominated by deposition.

Processing techniques of satellite images and GIS can be used for understanding the natural morphological processes. It is also useful in observing and quantifying the disturbance caused by human activity in these processes.

The study of the Danube Delta coast morphology is very important because here are the clean brackish water habitats, essential for the survival of sturgeons and other endangered species that live and feed here when young.

Now, in the Romania Danube Delta Biosphere Reserve we have only two areas with brackish habitat: between the Sacalin Peninsula and the Danube Delta coast -Musura Bay.

Both are now in the process of undergoing a change of status. The Sacalin Peninsula will disappear so that the habitat will become a marine one. The Musura Bay will be close to the island which is growing fast and becoming a fresh water habitat

4. CONCLUSIONS

Coast morphology is an important characteristic of deltas. The Danube Delta has a complex pattern of changes in time and space. The fluxes of marine and river branches generate a complex dynamics along the coast. The actual coast is the result of a combination between natural factors and human intervention. If human intervention in the 19th century had a small impact on coast changes, in the late 20th century this impact became very important. Satellite data available from 1975 cover the majority of hydrological works made in the Danube Delta Biosphere Reserve. Using these data, changes in costal morphology patterns were observed in correlation with major hydrological works.

Using remote sensing techniques morphological changes can be analysed at low cost and good accuracy. Analysing the current morphological processes of the Romanian Black Sea it appears that the coastal accumulation zone shows a slow sea level uplift at a rate of ca 2 mm/year; a sharp quantitative decrease of the Danube-derived sediments, deposited at the seaside; the dominance of wave action over current action; man's intervention on the coast by the construction and extension of the Sulina mouth piers.

As regards the Sacalin area, graphs show a change in the patterns of costal morphology. If until 1990, the dominant process was deposition, between 1990–2006 it was erosion. After 2006, deposition processes became again dominant. The lake-forming process, by the merging of the Sacalin Island with the coast, continues even if the island is now a peninsula (split). Morphological changes on the coast seem to indicate the possible location of the future junction. The high rate of morphological changes is related to the meanders cut in the Sfântu Gheorghe Arm, which was finished in 1990.

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Therefore coastal abrasion in the studied area is by far more extended (109 km) than accumulation (57 km). Accumulation takes place largely in front of the three main Danube mouths: Chilia, Sulina and Sfântu Gheorghe.

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INVASIVE TERRESTRIAL PLANT SPECIES IN THE ROMANIAN PROTECTED AREAS. A GEOGRAPHICAL APPROACH

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Key-words: Invasive Terrestrial Plant Species (ITPS), protected areas, FP7 enviroGRIDS project, Romania.

The current paper is aiming to present some of the most significant scientific results developed in the framework of ***FP7 enviroGRIDS project – Building Capacity for a Black Sea Catchment Observation and Assessment supporting Sustainable Development***, in terms of assessing the occurrence, development and spread the main Invasive Terrestrial Plant Species (ITPS) in the Romanian protected areas. Taking into consideration the intensification of the human-induced influences in various habitats, the authors undertook an in-depth analysis of selected ITPS (*Amorpha fruticosa, Acer Negundo*, *Ailanthus altissima, Fallopia japonica, Impatiens glandulifera*) in relation to the key environmental driving forces in some protected areas considered as case-studies for each biogeographical region in Romania: Maramureş Mountains Natural Park (Alpine region), Mureş Floodplain Natural Park (Pannonic region), Comana Natural Park (Continental region), Măcin Mountains National Park (Steppic region) and Danube Delta Biosphere Reserve (Pontic region). Based on the complex assessment of spatial and statistical data as well as field surveys an ITPS potential distribution model (ITPS-podismod) was also developed. Additionally, some relevant biological indicators (abundance, frequency and ecological significance) in relation to its key environmental driving forces (both natural and human-induced) have been calculated.

1. INTRODUCTION

Under the current global changes, biological invasions ranks among the most critical ecological threats to biodiversity and ecosystem services, especially since the *Convention on Biological Diversity's 2011–2020 Biodiversity Target* has stimulated global initiatives to quantify the extent of biological invasions, their impact on biodiversity and the related policy responses (McGeoch *et al.,* 2010). As a consequence, are often categorized as economic, environmental, or social threats (Charles and Dukes, 2006, Bailey *et al.,* 2007; McGeoch *et al.,* 2010), thus becoming key components of global change (Shea and Chesson, 2002; Arim *et al.*, 2006) through their high adaptive capacity enabling them to penetrate natural geographic barriers or political boundaries (Richardson *et al.,* 2000; Anastasiu and Negrean, 2005; Anastasiu *et al*., 2008; Andreu and Vila, 2010; Dumitraşcu *et al*., 2010, 2011a).

As a result, ITPS have become successfully established over large areas in Europe causing significant environmental socio-economic damages (Pysek and Hulme, 2005; Lambdon *et al.,* 2008, Dumitraşcu *et al.,* 2012) and, under the increasing trade and travel means the threat they produce is likely to increase (McGeoch *et al.,* 2010). In protected areas, in particular, biological invasions are disturbing drivers for the ecosystem functioning and structure, as well as for species, species communities or habitats (De Poorter *et al.,* 2007).

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In order to exchange information and knowledge on invasive species and assure the bridging the gaps between research, policy and practice, in 1994 the *Invasive Species Specialist Group (ISSG)* was set up as a global network in the framework of *Species Survival Commission (SSC)* of the *World Conservation Union (IUCN).* This structure is assuming an important role in fighting against invasive species by reducing the threats they stress upon to natural ecosystems and the native species they contain (Dumitraşcu *et al.*, 2010).

Prior to the EU-FP6 project *Delivering Alien Invasive Species In Europe (DAISIE)*, the assessment of ITPS at European level mainly consisted in scattered regional studies. Afterwards, a valuable and comprehensive database was created comprising 5,798 alien plant species in Europe, out of which 2,843 are alien to Europe (of extra-European origin) and 2,671 of European origin (Lambdon *et al.*, 2008) (Fig. 1).

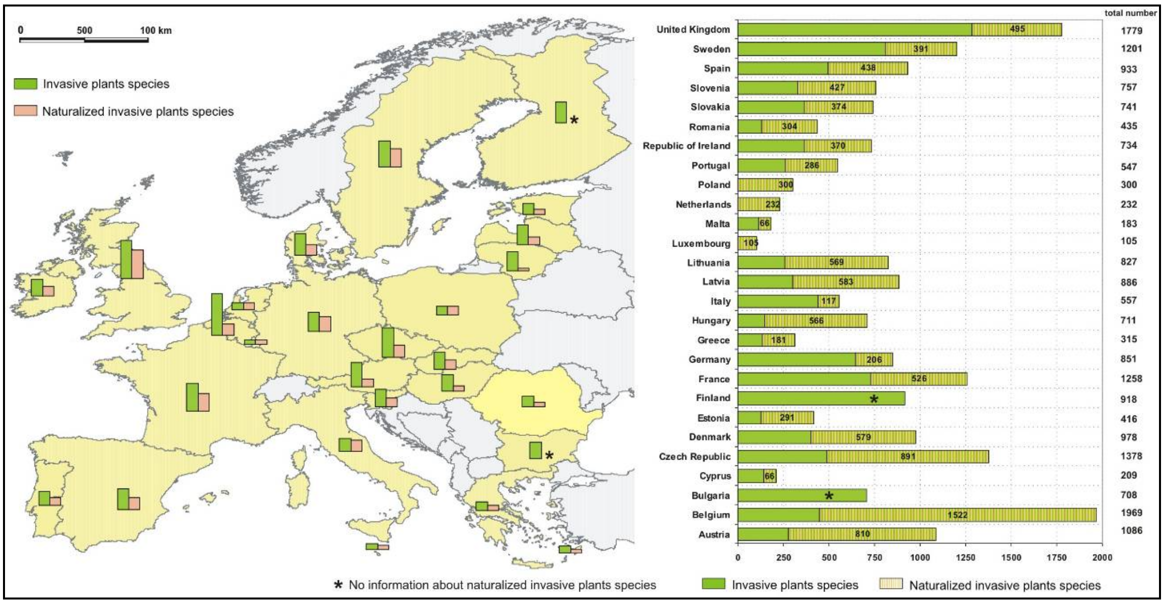

Fig. 1 – Invasive plant species in the EU countries (processed and adapted after FP6 – Delivering Alien Invasive Species Inventories for Europe – DAISIE and Lambdon *et al.,* 2008; Dumitraşcu *et al.*, 2010)

Under the global context of increasing biological invasions, the damage caused by alien species (both animals and plants) in the EU sums up to over 12 billion Euros every year (BirdLife Europe, 2013). As a result, the *New Strategic Plan of the Convention on Biological Diversity – Aichi Biodiversity Targets for 2011–2020* is proposing, among its strategic goals and targets (*Target 9*), to diminish direct pressures on biodiversity through identifying, controlling or eradicating invasive alien species and pathways as well as adopting measures to manage pathways and prevent their introduction and establishment (UN CBD, 2010; GEO BON, 2011).

2. INVASIVE TERRESTRIAL PLANT SPECIES IN THE ROMANIAN PROTECTED AREAS

Under the global environmental changes, the role of protected areas in conserving biodiversity and landscape becomes increasingly important. Under the given circumstances, the growing surface of protected areas, creating corridors link between them and reducing human impact are just some of the needs for ensuring an adequate management (Geacu *et al*., 2012).

Currently, protected natural areas in Romania cover 1,798,782 hectares, that is, 7.55% of the national territory. An increased surface of protected areas was a priority of Romania's over the accession to the European Union, thus having to reach a 17% protected surface of the national territory (from 7% as it had previously been before EU accession, in 2007) by means of other important conservative tools, such as "Natura 2000" European Network (Bălteanu *et al.,* 2009; Dumitraşcu *et al.,* 2010). As a consequence, a series of decisions taken by the Romanian Government during 2004–2010 led to the extension the number of protected areas to 998 (79 scientific reserves – I; 13 national parks – II; 230 natural monuments – III; 661 natural reserves – IV; 15 parks – V) (Fig. 2). Regarding Natura 2000, in 2011 Romania totalised 54,067 km^2 (39,952 km^2 SCI and 35,542 km^2 SPAs) which represent 22.68% of the national territory (Bălteanu *et al.,* 2009; Geacu *et al.,* 2012).

In Romania the first invasive plants species have been reported at the beginning of 18th century and, significant information having a systematic and floristic character (Anastasiu and Negrean, 2005) was regularly displayed ever since. Consequently, an increased number of invasive species were identified and further mentioned in several scientific works or floristic lists which were synthesized in "Flora României" vol. 1–13, (1957–1972) and more recently in "Flora Ilustrată a României" (2000) and "Plante adventive în flora Românei" (2011) (Dumitraşcu *et al.,* 2011b).

At present, over 400 species (13.87% of the Romanian flora) are considered biological invasions (Anastasiu and Negrean, 2005; Sîrbu and Oprea, 2008). According to the third National Report of Biological Diversity Convention (2005), some of the most important invasive alien tree species in Romania are: *Acer negundo, Ailanthus altissima, Amorpha fruticosa, Fraxinus americana* etc. (MODIS, 2007).

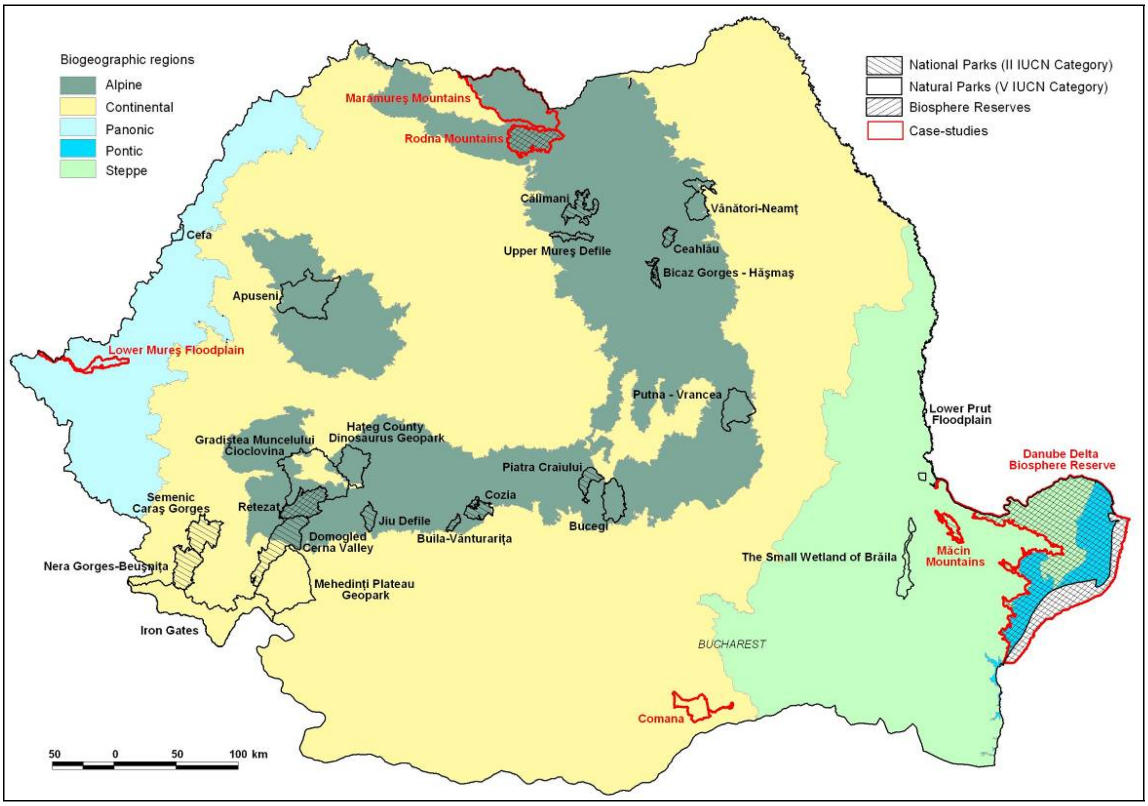

Fig. 2 – Selected case-studies in the Romanian natural protected areas.

Although Romania endorsed the Convention of Biodiversity (Rio de Janeiro, 1992) through law 58/1994, up till now there were no important steps undertaken, especially in terms of implementation of article 8, with respect to alien invasive species (Dumitraşcu *et al.,* 2011a). Thus, the complex assessment of ITPS species, both qualitative and quantitative, is crucial in estimating their potential spread and evolution pathways.

The assessment of the Terrestrial Invasive Plant Species was focused on some significant case-studies, one for each biogeographical region in Romania: Maramureş Mountains Natural Park (Alpine region), Mureş Floodplain Natural Park (Pannonic region), Comana Natural Park (Continental region), Măcin Mountains National Park (Steppic region) and (Danube Delta Biosphere Reserve (Pontic region) (Figs. 2, 3).

3. INTEGRATED DATA AND METHODS

The study developed in the framework of ***FP7 enviroGRIDS project – Building Capacity for a Black Sea Catchment Observation and Assessment supporting Sustainable Development***; ***WP5 – Impacts on Selected Societal Benefit;*** *Sub-task 5.6.2: Terrestrial Invasive Plant Species Areas* had in view to assess the occurrence, development and spread of ITPS in relation to their main environmental requirements and, ultimately, their potential distribution in the Romanian protected areas. In view of that, the authors relied on the comprehensive cross-referencing of the geographical and biological scientific literature, the complex assessment of spatial (GIS processing of the most relevant cartographical materials: topographical, geological, hydrogeological, soil, vegetation, aerial photographs, etc.) and statistical data, as well as field surveys.

In important step in assessing ITPS is relating them to the driving forces of change in order to in understand the causal relationships between them, to identify their habitat requirements, spreading territory and, ultimately to develop accurate prediction models (Kucsicsa *et al.,* 2013). For that reason, the scientific literature refers to some large-scale geographical factors able to explain the role of environmental driving forces in the distribution of invasive species in some European countries: ***climatic*** (mean annual precipitation, mean annual temperature, temperature amplitude), ***geographical*** (latitude, longitude and area) and ***economic*** (population density, Gross Domestic Product and roads density) (Lambdon *et al.*, 2008). On a regional scale (for the Romanian protected areas) the authors propose as key environmental drivers responsible for the introduction and spread of the ITPS two main categories ***natural*** and ***human-induced*** rearranged into smaller categories (Dumitraşcu *et al.,* 2010, 2011a, 2012; Kucsicsa *et al.,* 2013) (Table 1).

Table 1

The main environmental driving forces responsible for the introduction and spread of the ITPS in the Romanian protected areas

Major driving forces		**Consequent driving forces**
NATURAL	**soil**	soil type, texture
	relief characteristics	altitude, slopes exposure, declivity, geomorphic features
	vegetation	dominant vegetation types, fragmentation
	water bodies, wetlands	lakes, rivers, ponds, marches
	climate	air/soil temperature, precipitation, air humidity, wind, climate change signals
	extreme events	flooding, wind and snow felling, heavy rains
HUMAN INDUCED	**planting invasive species**	for ornamental/ recreation, forestry purposes
	agricultural practices	crop type, land abandonment, excessive fertilizers
	forest exploitation	deforestation/forest fragmentation, forest infrastructure
	grazing	pastures and land degradation
	urban development	waste deposits, transport network (roads, railways etc.), building sites

Source: Dumitraşcu *et al.*, 2010, 2011a, 2012; Kucsicsa *et al.,* 2013

ITPS mapping and database elaboration relied on different GIS-based procedures (editing, storing and processing) useful for summarizing large datasets for modeling habitat quality and distribution of invasive species (Holcombe *et al.,* 2007; Kucsicsa *et al.,* 2013).

Fig. 3 – *Fallopia japonica* (A, B) and *Impatiens glandulifera* (C) in Maramureş Mountains Natural Park; *Ailanthus altissima* (D) in Măcin Mountains National Park; *Amorpha fruticosa* in Mureş Floodplain Natural Park (E) and Comana Natural Park (F) (Kucsicsa *et al.,* 2013).

For the Romanian protected areas the ITPS was carried out using topographical maps scale 1:25000 and orthophoto images, scale 1:5000. Additionally, in order to achieve more accurate information, GPS measurements were conducted, as well. For each analysed protected area, the authors computed key biological indicators (abundance, coverage, frequency and ecological significance) and collected soil samples with the aim to highlight certain soil characteristic relevant in identifying the ecological requirements of the species at stake: the heavy metal (Zn, Cu, Kd, Mn, Pb, Hg etc.), humus and salts content, pH values etc. The information was stored using polygon (e.g. *Fallopia japonica, Amorpha fruticosa, Ailanthus altissima*) and point spot-like (e.g. *Impatiens glandulifera, Acer negundo*) geospatial data (Kucsicsa *et al.,* 2013).

Based on the primary ITPS assessment (data gathering, mapping, understanding its habitat requirements etc.) a ***GIS-based model (PODISMOD–ITPS)*** was developed. The focal aim of the model is to identify similar ecological requirements of species in different habitat types (other than in the areas where the species was originally found) in order to assess the distribution potential in a certain region (Fig. 4).

Depending on ITPS ecological requirements, ***thematic maps*** displaying the main driving factors which cause species development and spread were elaborated. Besides the general thematic maps taken into consideration for this investigation (soils, climatic parameters, land use etc.), the Digital Elevation Model (DEM – 30 m resolution) was considered, as well. The latter constitutes itself into essential information in ITPS assessment, out of which layers regarding local relief particularities were generated (hypsometry, slope declivity and slope exposure). Therewith, in the case of some ITPS the distance to certain driving factors is critical.

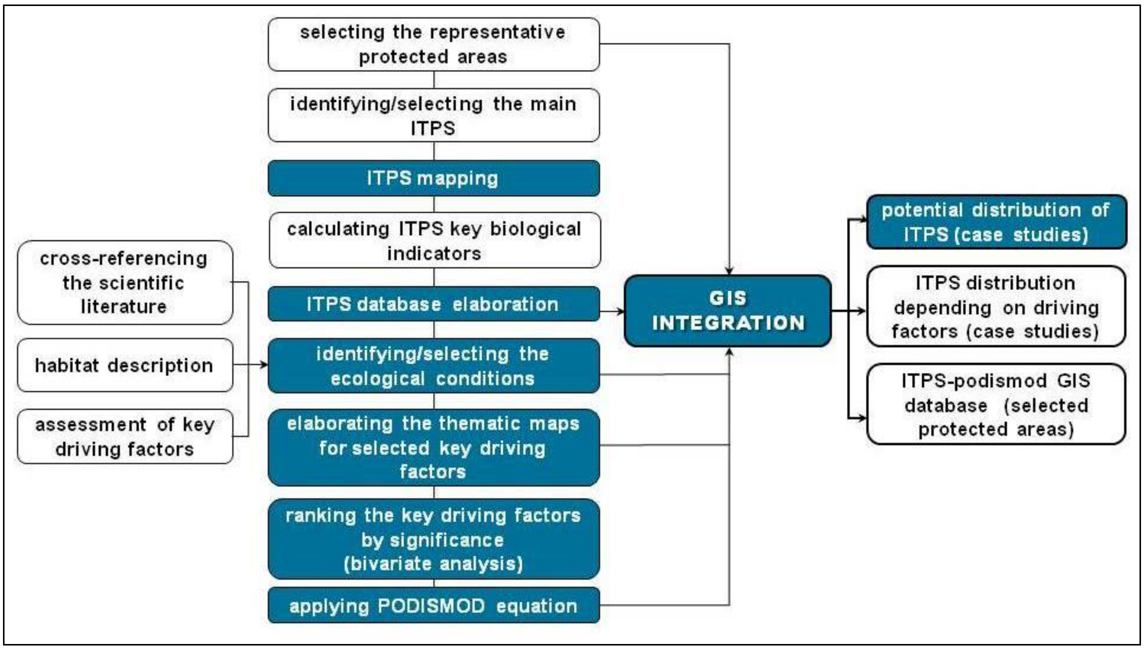

Fig. 4 – ITPS podismod scheme.

Additionally, the authors applied relevant ***biological indicators*** in order to complete the ITPS complex assessment in some protected areas. The surface areas chosen for the comparative research regarding the phenology data were of 10 m² for pastures and reed-covered areas and of 100 m² for the forest and brushwood communities. The quantitative biological indices taken into consideration for the current approach (coverage, abundance, frequency and ecological significance) were computed in several test-areas in the analyzed case-studies (Dumitraşcu *et al.,* 2013a, 2013b). Based on this in-depth analysis the authors were able to relate biological indicators with relevant key natural and human-induced driving forces.

4. RESULTS AND DISCUSSIONS

Over the last century natural ecosystems were massively transformed by human activity trough different practices such as: deforestation, overgrazing etc. and replaced with secondary meadow and scrub associations, strongly affecting the floristic structure and composition. Following the in-depth analysis of the most significant ITPS in some selected Romanian protected areas, the authors were able to obtain useful and accurate information regarding species' spreading area, habitat requirements as well as predicting potential distribution depending on selected dependent and independent driving forces. Therefore, the complex investigations undertaken over the last four years (2010–2013) revealed that the ITPS with the highest impact on local habitats are in the Romanian protected areas are: ***Amorpha fruticosa*** (the desert false indigo or the indigo bush), ***Ailanthus altissima*** (Chinese sumac or the tree of heaven), ***Fallopia japonica*** (Japanese knotweed), ***Acer negundo*** (Box-elder or Ash-leaved Maple) and ***Impatiens glandulifera*** (Himalayan balsam).

Amorpha fruticosa is an ITPS originating from the south-eastern part of North America. It was introduced in Romania in the first half of the last century for decorative purposes. Subsequently it penetrated the natural *Populus* and *Salix* forests along the Danube River (Fig. 5).

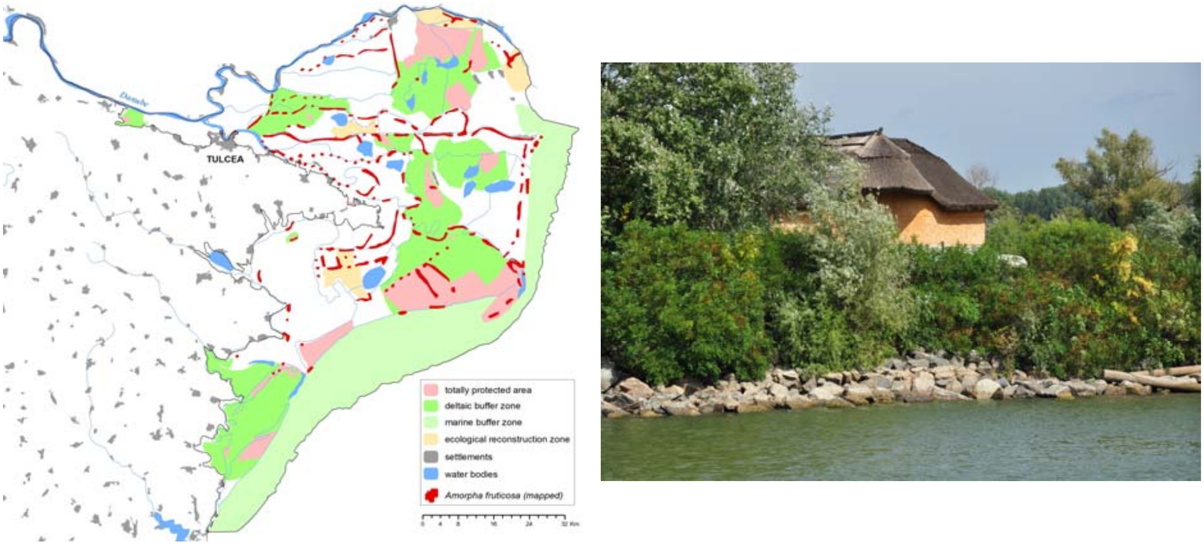

Fig. 5 – Danube Delta Biosphere Reserve. The distribution of *Amorpha fruticosa* (Dumitraşcu *et al.,* 2013 processed after Doroftei, 2009a; 2009b) and species' specific habitat along Danube's branches.

After 1985 it has spread upon broader areas proving a high capacity of widening its habitat (Stănescu *et al.,* 1997; Dumitraşcu *et al.,* 2011a, 2011b). Currently, the plant is adapted to all types of environment, but it prefers especially the wetlands from Danube Flodplain and Danube Delta (Anastasiu and Negrean, 2005; Anastasiu *et al.,* 2008, Dihoru, 2004; Doroftei, 2009a, 2009b) or Mureş Floodplain Natural Park (Dumitraşcu *et al.,* 2013). It can also be adapted to reduced soil moisture which characterise the sylvosteppe soils (e.g. Comana Natural Park).

Although *A. fruticosa* mainly prefers riparian ecosystems, due to the particularities of the habitats they develop one can identify slight differences in terms of the several quantitative and qualitative parameters. For instance, the calculation of some biological indicators in tree wetland areas (Danube Delta Biosphere Reserve, Comana Natural Park and Mureş Floodplain Natural Park) has revealed different abundance, frequency, coverage index values (Table 2).

Table 2

Abundance – coverage scale according to Braun – Blanquet system (Cristea *et al.,* 2004) and the ecological significance index values

Class	**Coverage interval (%)**	**Class value (%)**	**Ecological significance index (%)**	
5	75–100	87.5	>2	characteristic
4	50–75	62.5	10–20	complementary
3	25–50	37.5	5–10	associate
2	10–25	17.5	1–5	accessory
1	1–10	5.5	0,1–1	accidental

Thus, Danube Delta Biosphere Reserve shows higher abundance and coverage rates while the frequency seems lower as compared to the other two study-areas. On the other hand, Comana Natural Park displays higher frequency rates while Mureş Floodplain Natural Park the species records rather even abundance and frequency values and lower coverage as compared to the other protected areas at stake (Dumitraşcu *et al.,* 2013a, 2013b).

The ecological significance, seen as the relationship between frequency and abundance, shows values ranging between 2 and 12 for certain key areas which were taken into consideration in the

Danube Delta Biosphere Reserve and Comana Natural Park and rates which does not exceed 9 units in the Mureş Floodplain Natural Park. The average values points Danube Delta Biosphere Reserve first in terms of ecological significance followed by Comana Natural Park and Mureş Floodplain Natural Park. In all studied areas, the species is considered associate species (Table 2, Fig. 6).

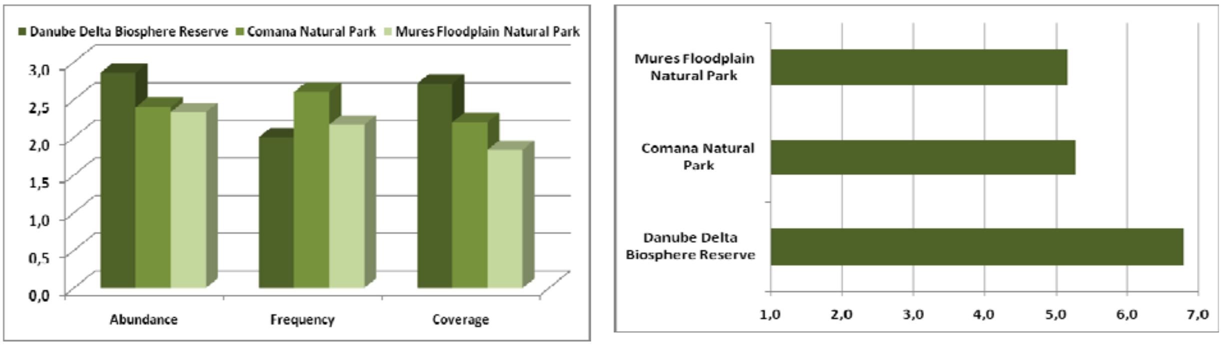

Fig. 6 – Average class values of the key biological indicators for *Amorpha fruticosa* in the Danube Delta Biosphere Reserve, Comana Natural Park and Mureş Floodplain Natural Park.

Additional studies state that *A. fruticosa* develops very well on metal-contaminated soils (lead, zinc, copper, nickel, etc.), on tailing ponds as incipient species together with other fast-growing non-native and native species or on fertilized terrains (Li, 2006; Seo *et al.,* 2008; Marian *et al.,* 2010; Xiang, 2011). This explains species' largest spread along railways and major roads, especially non-electrified routes in Comana Natural Park (Dumitraşcu *et al.,* 2011). The multiplication and spread are made by means of seeds, rarely by sprouts or layering which explains its high dissemination capacity.

The complex assessment of *Amorpha* (habitat requirements, the relationship with each environmental driving factor, the outcomes of the key biological indicators etc.) has allowed the authors to predict its potential distribution by means of the ITPS-podismod. The model reveals index values which highlight a certain dependency of the potential distribution areas to species main preferred habitats. Thus, over 6% of Park's area displays high and very high potential distribution, mainly favoured by the vicinity of wetlands and by the spoiled soils located along the railroad which connects Comana and Mihai Bravu.

Medium values cover roughly 17% of Park's area, largely favoured by the soil type and texture as well as by the characteristic habitats (shrubs and grasslands). In the rest of the study-area, the low representation of its favourable habitat conditions and the prevalence of Cernisols with sandy and sand-loamy texture under forests and open agricultural areas as restrictive factors, determines low and very low potential (67%) (Fig. 7). Furthermore, in order to validate the model, the authors related the potential distribution areas with species' mapped territory, thus identifying a very good match between *Amorpha* highest frequencies and the very high and high potential (82%), as well as medium potential (18%) regions.

Ailanthus altissima (Chinese sumac or the three of heaven) is an invasive toxic pioneer species (Burch and Zedaker, 2003) ranking among the most destructive in Europe as it penetrates native flora and irreversibly changes its structure. It is a deciduous three native to China introduced into Europe in the late 18th century as an ornamental species. In Romania *Ailanthus* was introduced both for ornamental purposes and for the protection of degraded areas or sliding slopes. Species' spreading capacity is given by its fast propagation (up to 350,000 seeds/year) and rapid growth (up to 3 cm/day). Its well known toxicity (through pollen, bark and leaves) restrain the establishment of other plant species in its vicinity (Feret, 1985; Lawrence *et al.,* 1991) and the root system roves to be aggressive enough to cause damage to different underground works. *Ailanthus* can tolerate different kind of environments from abandoned fields to railroad embankments, roadsides, waste grounds, and other disturbed sites (Landenberger *et al.,* 2006), as well as a wide range of pH conditions (Feret, 1985). The species is also drought resistant which made its broad expansion possible (Trifilo *et al.,* 2004.).

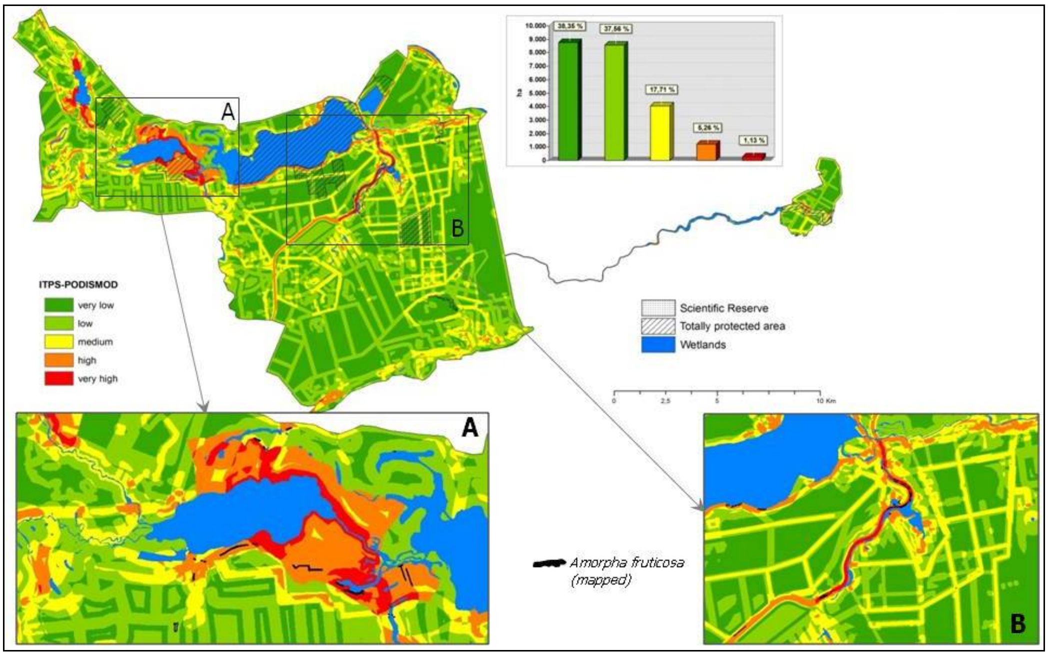

Fig. 7 – Potential distribution of *Amorpha fruticosa* in the Comana Natural Park (ITPS-podismod).

In the Măcin Mountains National Park, the tree of heaven mainly affects the grasslands, forest skirts, river banks, mining and disturbed sites etc. by competing and displacing the native vegetation (Sîrbu and Oprea, 2011). The field surveys carried out so far allowed the authors to identify and map over 120 ha covered by *A. altissima* mainly located in the Pricopan Ridge (north-western part of the Park area), an area entirely included into the *totally protected area* category, thus indicating a higher impact on native valuable ecosystems (Fig. 8).

In the study-area *A. altissima* tolerates different environmental conditions ranging from brightness (shinny and semi-shinny slopes) to open areas (scrub and/or herbaceous vegetation associations) but also prefers some specific soil types (litosoils and kastanozeoms) and textures (loamy and clay loam) with a high mineral content, thus proving species' preference for spoiled and degraded terrains. Moreover, field researches revealed that *Ailanthus* is very well developed on the upper half of the slopes with declivities of over 5^0 (over 95 %) at altitudes of 50 m – 200 m (over 90 %).

Unfortunately, the control of this species is rather difficult because the mechanical eradication methods are not always efficient, therefore they must be completed with other mechanical and even chemical techniques (Meloche and Murphy, 2006).

Fallopia japonica (Japanese knotweed), also known as *Polygonum cuspidatum* or *Reynoutria japonica* is a clonal, herbaceous, fast-growing perennial plant (Aguilera *et al.,* 2010), inhabiting riparian ecosystems and causing serious damages to native flora (NB II, 2005; Barney*,* 2006). The specie is broadly regarded as one of the most invasive plant species in Europe, also listed by the World Conservation Union and FP6-DAISIE project as one of the top one hundred invasive species of global concern (Lowe *et al.,* 2000 cited by Kabat *et al.,* 2006; DAISIE, 2005–2008; Lambdon *et al.,* 2008). *F. japonica* is native to eastern Asia (Pysek, 2006) whence, since the end of the 19th century, gradually invaded increasingly wider areas in Europe, North America and Australia (Tiébré *et al.,* 2007, 2008;

Aguilera *et al.,* 2010; Moravcová *et al.,* 2011; Sîrbu, 2011), thus becoming one of the most prevalent and destructive alien species. The species is a strongly growing, herbaceous adventive plant which can grow up to 3 m in height (Kabat *et al.,* 2006). In Romania, *F. japonica* was mentioned as sub-spontaneous specie for more than seventy years (Paucă, 1940; Ţopa, 1947 cited by Oprea and Sîrbu, 2011), currently being spread in more than 90 settlements from all over the country (Sîrbu, 2011).

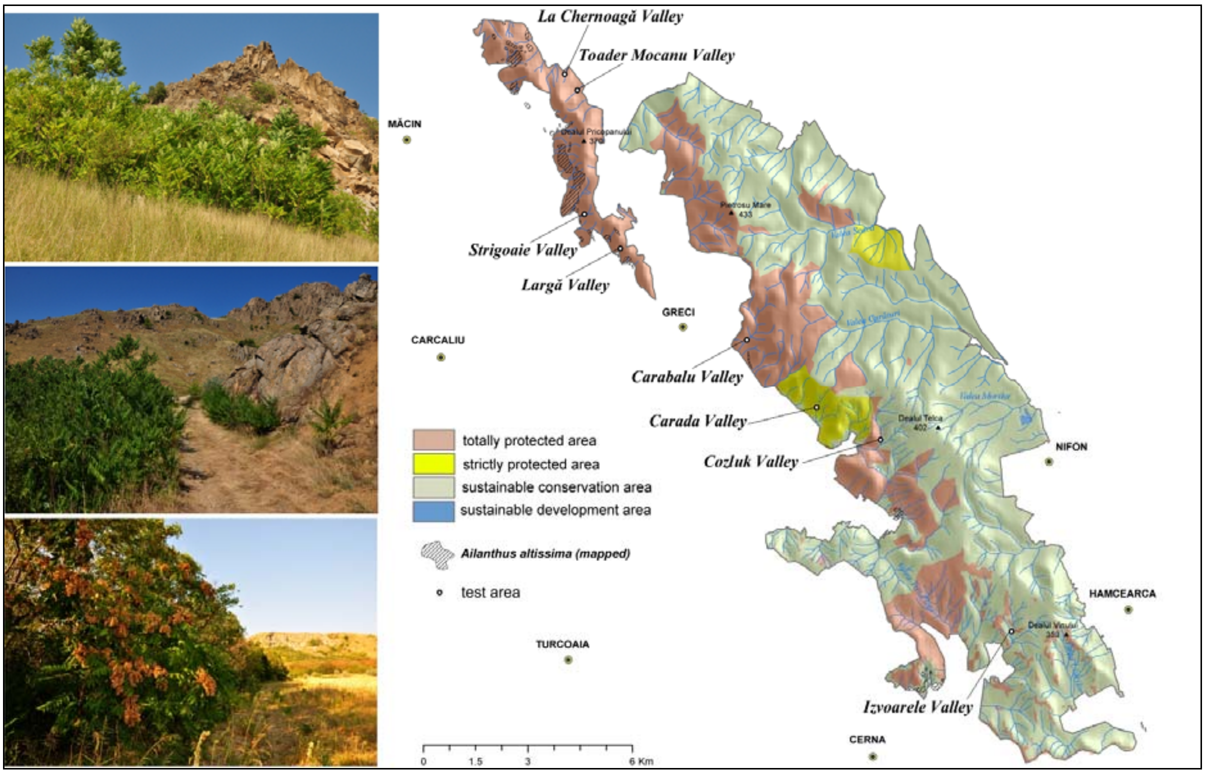

Fig. 8 – *Ailanthus altissima* in the Măcin Mountains National Park.

The Japanese knotweed can usually tolerate a wide variety of environmental conditions ranging from high shade, high temperatures (even drought) to high salinity. It frequently occurs in riparian habitats (e.g. along river banks) whence it spreads rapidly, turning into dense monoculture structures. When coupled with its capacity of generating huge amounts of rhizomes, the species seriously affects river protected structures, penetrates and displaces foundations, walls, and drainage works (Beerling, 1991), thus triggering significant damages to the riverbanks and, ultimately enabling floods. It also tolerates disturbed habitats, such as railroad tracks and roadsides (Forman and Kesseli, 2003; NB II, 2005).

Among the analysed protected areas, the widest spread of this species was encountered in the Maramureş Mountains Natural Park. Here, large areas were identified in the western (Vişeu River floodplain) and central parts (Ruscova River floodplain and upstream Repedea village on the Frumuşeaua and the Vaser Rivers). *F. japonica* was also found close to the southern limit of the park area in Borşa town on Rodna Piedmont along the Pietroasa flow. The entire mapped surface sums up to approx. 88 ha and indicates areas most invaded by this invasive species mainly on the river banks. Dense areas with Japanese knotweed we also found along the modernized roads, the railway connecting towns of Valea Vişeului and Vişeu de Jos and the flood protection dams along the Vişeu River (Fig. 9 and Fig. 11). In terms of spatial distribution, the species mainly prefers lower altitudes (under 500 m), open spaces (free of coexisting species), tending to invade grasslands, croplands and even courtyards (e.g. in the Vişeu River floodplain), thus seriously affecting native vegetation (Dumitraşcu *et al.,* 2012).

The current assessment on *F. japonica* in the Maramureş Mountains Natural Park in relation to the species' habitat requirements and key environmental features is essential in establishing the relationship between species diversity and invasive success on one hand and the physical extrinsic factors (environmental features) on the other (Shea and Chesson, 2002) in order to provide valuable future predictions through GIS-based modelling techniques. Thus, applying ITPS-podismod the authors were able to identify areas most prone to species future development and spread. Over 32% of the analysed territory for the model displays high and very high potential distribution, while over 33% displays moderate rates which indicates that floodplain areas are the most exposed to *F. japonica's* spreading potential in the Maramureş Mountains Natural Park, widely overlapping the areas in which the species was mapped during the field campaigns (Fig. 9).

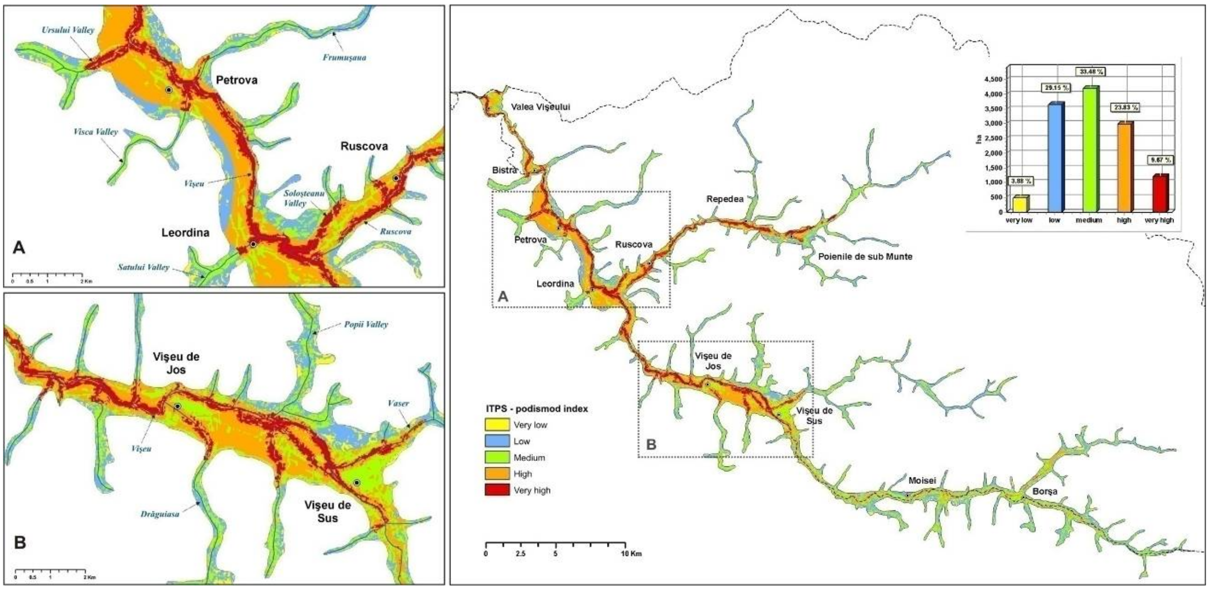

Fig. 9 – Potential distribution of *Fallopia japonica* in the Maramureş Mountains Natural Park (ITPS-podismod).

Acer negundo (Box-elder or Ash-leaved Maple) is a tree native to eastern North America whence it was firstly introduced to England in 1688 (Favretti and DeWolf, 1971), the Netherlands (1690) and Germany (1699), and subsequently to other European countries (Medrzycki, 2007). In Romania, the specie was introduced in forest plantations, anti-erosion forest belts, as well as in parks, gardens or alongside streets as ornamental tree.

Given its high and constant fruit production, which can be easily wind borne, its sprouting ability, and the tolerance to different habitat types, the Box-elder easily spreads from its cultivation sites, thus invading the neighbouring open lands, especially ruderal spaces, road sides, railway embankments, vineyards, wetlands in the plain or hilly areas etc. As a result, there is no longer recommended to perform new plantations with this species (Dumitriu-Tătăranu, 1960; Oprea and Sîrbu, 2011).

In the Mureş Floodplain Natural Park the specie is rather weakly developed, being mapped in two main areas along Mureş River Floodplain: one in the south of Pecica locality, in the Raţa Vaida Forest and the other south of Şeitin locality, on alluvial protosoils with mixed texture at 90–100 m altitude (Fig. 10).

Fig. 10 – The distribution of ITPS *Amorpha fruticosa, Acer negundo* and *Fallopia japonica* in the Mureş Floodplain Natural Park.

Impatiens glandulifera (Himalayan balsam) is a species native to the western Himalayas where it grows from 1800 to 4000 m altitude from where was introduced to Europe in the first half of the 19th century as an ornamental plant, shortly after being reported as escaped from culture (Helmisaari, 2010). Currently, the species is considered invasive in the most part of Europe. *I. glandulifera* becomes accustomed to different habitats, but it thrives best on moist and nutrient rich habitats, especially along rivers banks. It can be also frequently found in human influenced habitats such as grasslands, shrubs, dikes, channels, roadsides etc. (Kurtto 1996).

The species invades the herbaceous perennial vegetation of river banks, floodplain forests and wet meadows tolerating a variety of soil types. Apart from the other ITPS investigates in the current study, in Europe *I. glandulifera* is frost intolerant (Helmisaari, 2010), which means it prefers environments characterised by positive temperature values all year round.

I. glandulifera has been introduced in Romania as an ornamental plant, subsequently escaping gardens. The species was identified for the first time as subspontaneous in Transilvania (1882) (Balogh, 2008), whence it was expanded, however not yet reported in Banat, Oltenia and Dobrogea (Oprea and Sîrbu, 2011).

This ITPS is largely spread in the Maramureş Mountains Natural Park, especially along the floodplains of Vişeu River and its tributaries Ruscova and Ţâsla. The species grows along river banks, often on waste covered terrains (resulting from constructions or wood processing), and sometimes associated with *Falopia japonica*.

The species was mapped at altitudes of nearly 400 m (Vişeu River floodplain, near Leordina locality) to 860 m (Borşa Turistic Complex on Vişeuţ River), especially on cvasi-horizontal terrains with southern and south-western sun exposure, on alluvial soils and alluvial protosoils with mixed texture. Thus, the main areas the Himalayan balsam was largely found are: Poienile de sub Munte (Cvasniţa River valley); Ruscova River floodplain (Ruscova locality), Vişeu River floodplain (close to Vişeu de Jos, Moisei and Borşa localities), Ţâsla River floodplain (near Băile Borşa locality).

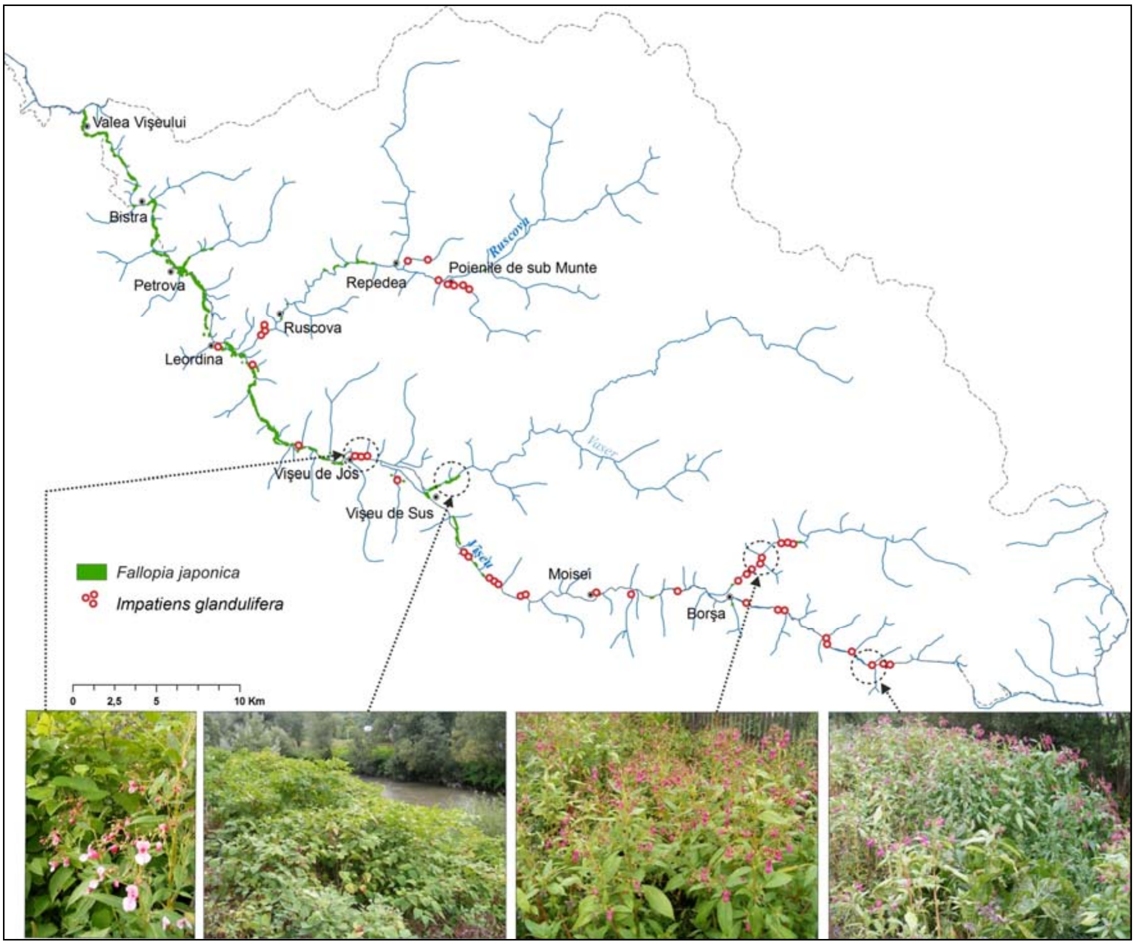

Fig. 11 – The distribution of ITPS *Amorpha fruticosa* and *Impatiens glandulifera* in the Maramureş Mountains Natural Park.

5. CONCLUSIONS

The assessment of ITPS in the Romanian protected areas is an important research direction especially since biological invasions have become increasingly dynamic in native ecosystems. Given the intensification of the human-induced influences in various habitats, the complex assessment of the occurrence, spread and potential distribution of the main ITPS becomes essential task in developing early warning services.

Moreover, a comprehensive geographical assessment of ITPS distribution and spread in relation to their main natural and human-induced driving factors through GIS-based investigations and integrated spatial analysis is particularly useful in identifying the potential distribution of the invasive species. Furthermore, this could support sustainable measures to eradicate or prevent the introduction of invasive species and control their already existing habitats as the most cost-effective means to avoid or reduce the risk of long-term ecological, economic and social costs of their invasion.

Consequently, promoting integrated research assessment, monitoring key pathways, developing early detection and early warning systems and outreach activities that addresses the issues of spreading invasive species into native habitats requires strong cooperation between researchers, foresters, stakeholders, environmental agencies, local authorities worldwide.

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SATELLITE-BASED MULTITEMPORAL CHANGE DETECTION IN IGNEADA FLOODED FORESTS

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Monitoring land use/land cover changes is a very important component for sustainable management of sensitive regions. Because of their ecological, biological, environmental and economic importance, Igneada flooded **(longos)** forests have a multiple role in the landscape. This study is conducted to detect and monitor land use and land cover changes of Igneada region using multi-temporal remotely sensed data. For this purpose, Landsat 5 TM satellite data were used, including four scenes acquired from 1984 to 2010. Change detection methodology of land use/land cover has four main stages: 1) Preprocessing of satellite images, 2) Classifying images using maximum likelihood method, 3) Accuracy assessment of the classification, 4) Comparing classified images in GIS environment and 5) Change detection.

1. INTRODUCTION

"Flooded (longos/alluvial/floodplain) forests are forests in which the water table is usually at or near the surface, and the land is covered periodically or at least occasionally with shallow water" (Čermák et al. 2001, Pivec 2002, Tepley et al. 2004, Paal et al. 2007, Kavgaci et al. 2011). Because of their ecological, biological, environmental and economic importance longos forests have a multiple role in the landscape (Kavgaci et al. 2011). These forests are one of the most fragile and threatened ecosystems in the world. Typically, these types of ecosystems have high biological diversity, high productivity, and high habitat dynamism (Hughes et al. 2003). There are limited numbers of these areas in the world and Igneada Longos Forest is one of the largest longos forest in Europe (Özyavuz 2008). Igneada and the surrounding environment have unique characteristics; these types (Igneada Longos Forests) of wild forest in other parts of Turkey and in Europe have been damaged due to anthropogenic effects (Özyavuz, Yazgan 2010, Bektas Balcik et al. 2011) such as excessive and irrational use of resources, natural or consciously fires, unconscious hunting, agricultural activities, residential development and population growth. Accurate detection of these changes is important for the development of protection strategies for the area. For monitoring and determining the types and extent of environmental changes of sensitive areas, change detection techniques can be applied widely with a repetitive satellite image acquisition as a reliable and cost effective approach (Bektas, Goksel 2005, Balik Sanli et al. 2008).

Many remote sensing change detection methods have been developed (Coppin et al. 2004, Lu et al. 2004, Jin et al. 2012) to identify and observe an object at different times (Singh 1989). Land use/cover change (LUCC) detection is a rapidly growing scientific field because land use change is one of the most important ways that humans influence the environment (Marsik et al. 2011). LUCC is a dynamic, wide-spread and accelerating process, mainly driven by natural phenomena and

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anthropogenic activities, which in turn drive change that would impact the natural ecosystems (Serra et al. 2008). Hence, LUCC detection for spatial patterns is essential for a better understanding of landscape dynamics over a given period of time for sustainable management.

Human induced effects such as uncontrolled and unplanned development of urbanization, unconscious hunting and agricultural activities have become serious problems of Igneada. The main objective of this study is to assess and detect temporal land use/cover changes that have occurred between the years of 1984 and 2010 by using maximum likelihood supervised classification change detection method to protect natural life resources such as mixed forest areas, wetlands, flooded forests, sand dunes and flora and fauna of the region using multi temporal Landsat 5 TM data set.

2. STUDY AREA

Igneada, located on the Black Sea coast 15 km from the Turkish-Bulgarian border, lies in an area that is approximately 5,757 ha between the northern latitudes $41^{o}44^{'}43^{''}$ and $41^{o}58^{'}27^{''}$ and the eastern longitudes $27^{o}44^{'}52^{''}$ and $28^{o}39^{'}17^{''}$ (Fig. 1). In the classification stage, for the 1984, 1990 and 2010 dated images, 653, 640, 638 and 670 training areas respectively were determined. Igneada Flooded Forest is one of the most important protected areas of Turkey. Longos forests with associated aquatic and coastal ecosystems include freshwater and saline lakes, coastal dunes, freshwater and low salinity marshes, and mixed forests of deciduous tall trees (Özhatay et al. 2003). Igneada Longos Forest and its surrounding environment are very valuable and recognized both for its protection of regional biodiversity and for contributions to scientific research (Kavgaci 2007, URL 1). Igneada was classified by Conservation International as one of the world's top 25 biodiversity hotspots, and named by the World Wildlife Fund (WWF) as one of its Global 200 ecoregions (Bozkaya 2013).

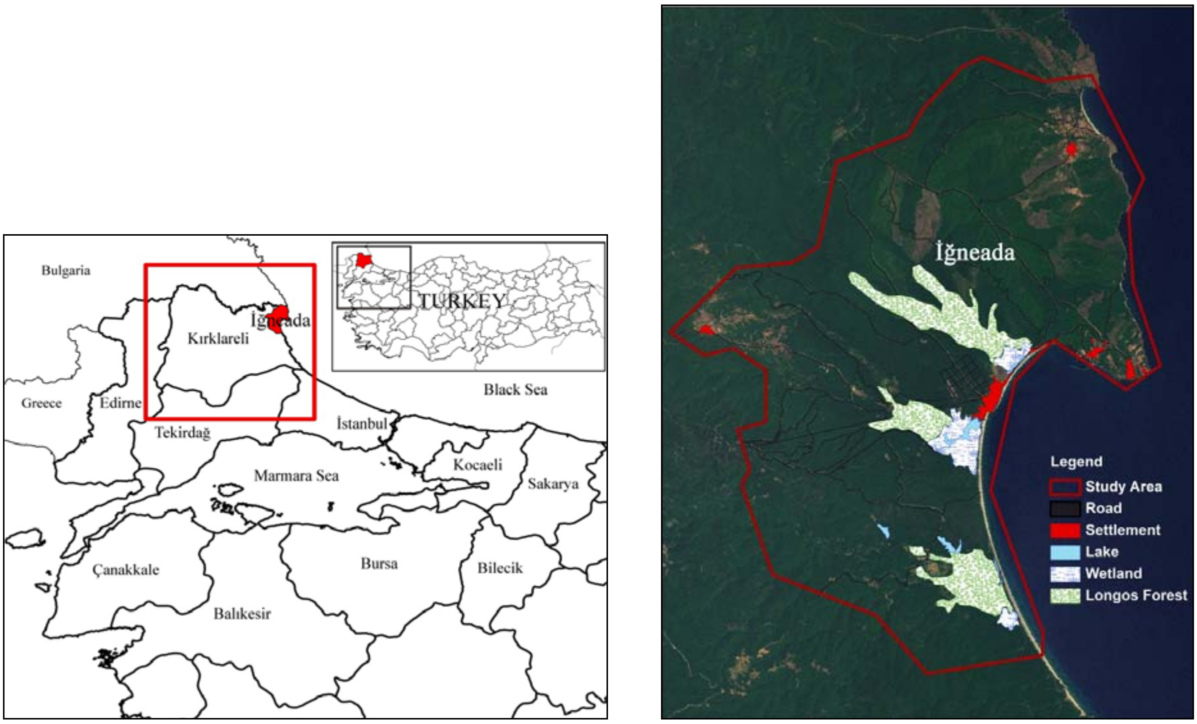

Fig. 1 – Study area in Igneada, Turkey.

The area hosts different kinds of ecosystems and a wide range of biodiversity; some parts of it have previously been protected as Nature Protection Park, Natural Site, and Wildlife Protection Area. The Igneada Longos Forest is confirmed as a very important plant richness center, and was already designated as National Park in 2007 (URL 2). These areas are home to several rare and endemic plant species and are sensitive to human use. Despite its ecological sensitivity and importance, Igneada has been under serious threats, as was the project of supplying drinking water to Istanbul using upstream water sources. Upstream forests and water resources are critical to maintain the delicate balance of the alluvial forest and wetland ecosystem of Igneada.

3. DATA

Landsat 5 TM images used in the study were acquired on September 7th 1984, August 7th 1990, August 18th 2000, and September 15th 2010 to examine land use/land cover changes in Igneada. Landsat 5 TM sensor acquires data in 7 spectral bands that cover a wavelength range from 450 nm–2350 nm with a spatial resolution of 30 m. In addition, topographic maps at the scale of 1: 25 000 and field collected hand hold GPS data, 2003 dated IKONOS images and 2009 dated Aster images were used for pre-processing and accuracy assessment of the derived thematic information.

4. METHODOLOGY

Image pre-processing steps were conducted to eliminate atmospheric distortions, sensor problems and geometric distortions. The original digital numbers (DN) of Landsat 5 TM images were converted to exo-atmospheric reflectance based on the methods provided by Chander and Markham (2003) and the Landsat 7 Science Data Users Handbook (2006). The widely used Dark Object Subtraction (DOS) atmospheric correction method was used to minimize contamination effects of atmospheric particles (Chavez 1988, Liang 2004). After atmospheric correction, multi-temporal Landsat images were geometrically registered to the Universal Transverse Mercator (UTM) projection system (ellipsoid WGS 84, datum WGS 84, and zone 35) by using ground control points, primarily highway intersections, evenly distributed across the image. A first-order polynomial model was used for the rectification with nearest neighbour resampling method. The Root Mean Square (RMS) errors were less than 0.5 pixels (15 m) for each of the four images. Figure 2 gives the flowchart of the study to derive land use/land cover categories of 4 different years.

Classification is a process of grouping pixels that have similar spectral values to transfer data into information for determining earth resources (Balik Sanli et al. 2008). In this study, Maximum Likelihood supervised classification method was used to derive land use/cover categories. Supervised classification is a technique that is based on the statistics of training areas representing different ground objects selected subjectively by users on the basis of their own knowledge or experience (Liu, Mason 2009). In the classification stage, for the 1984, 1990, 2000 and 2010 dated images, 653, 640, 638 and 670 training areas were determined respectively. The nine spectrally separable, different land cover classes identified by Maximum Likelihood were: i) water surfaces, ii) forest areas, iii) flooded (longos) forest, iv) wetland / bulrush, v) plantation area, vi) agriculture / bare ground / grassland, vii) sand dunes, viii) artificial surfaces, and ix) cloud (Fig. 3). The statistical results of the classification are given in Fig. 4. The classified data were compared with ASTER and IKONOS images of the study area to determine the identity and informational value of the spectral classes.

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Many methods for assessing the accuracy of classification have been assessment discussed and used in remote sensing (Foody 2002). Confusion or error matrix is the most widely mentioned and conducted method for accuracy assessment by using reference data, such as aerial photographs and field collected data. Different measures can be calculated from confusion matrix to examine classification accuracy, including errors of omission and commission, producer's and user's accuracies and the KAPPA coefficient (Foody 2002).

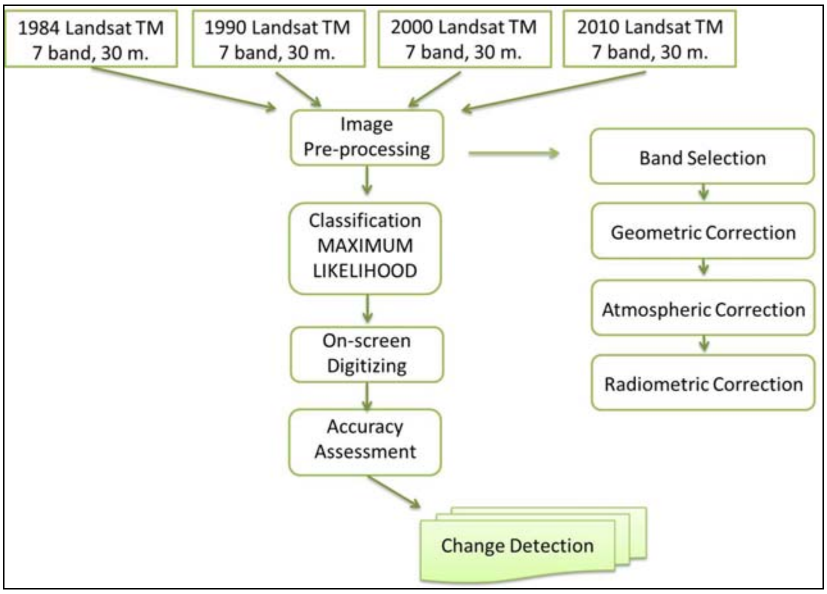

Fig. 2 – Flowchart of methodology.

Totally 1,216 random points were selected for nine classes to assess the accuracy of the four classified images. The overall accuracy and a KAPPA analysis were used to perform classification accuracy based on error matrix (Table 1). The results show that there is a mixed pixel problem between land cover categories such as flooded forest – forest, settlement – agriculture – bare ground – grassland and road in the study area. Because of the mixed pixel problems, the accuracy of the resultant images needs be improved. On-screen digitizing method was conducted in order to solve the mixed pixel problem and improve the accuracy rates. Digitized data combined with classification results lead to an overall accuracy of classified images for the years 1984, 1990, 2000 and 2010 of: 96.57%, 96.24%, 83.33%, and 90.74%, respectively.

Change detection was applied by comparing these base maps using **from-to** analysis. According to the change matrix, the rate of change in residential areas is the highest. A simultaneous analysis of multi-temporal data (i.e. an image-to-image comparison) was applied. The comparison was done between the years of 1984 and 2010. The results showed that major changes occurred on settlement and agricultural areas of the Igneada (Table 2).

The change statistics below gives an explanation on the question of where land use/cover changes are occurring (Table 2). Forest and flooded forest of the study region were changed to agriculture / bare ground, grassland as a result of economic development. As seen from the post classification change processing 1,158 ha areas changed from forest to plantation area, 1,206 ha area changed from forest to agriculture / bare ground, grassland, 278 ha area changed from flooded forest to agriculture / bare ground, grassland and 152 ha area changed from sand dune to agriculture / bare ground, grassland (Table 2).

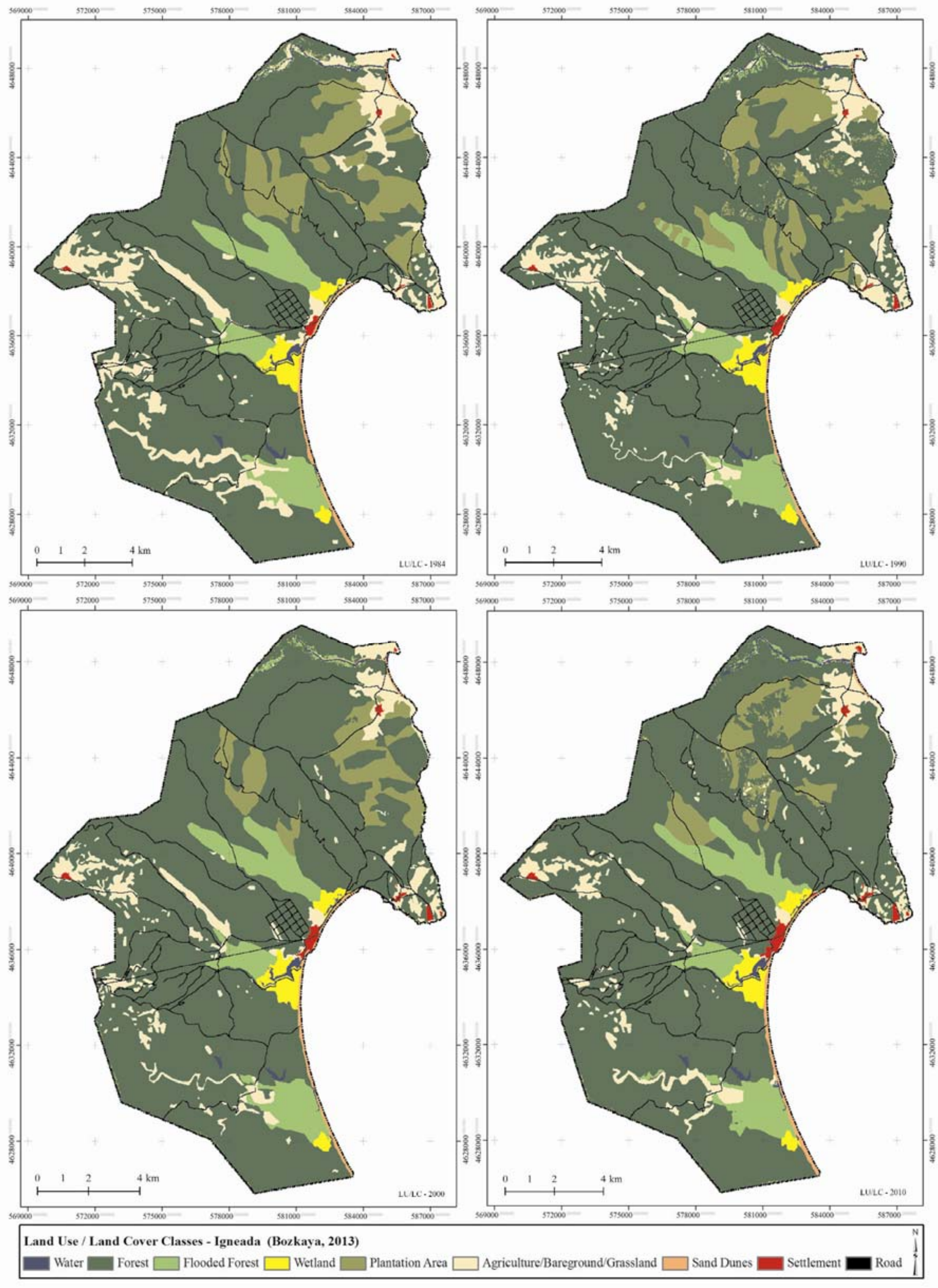

Fig. 3 – Results of the supervised classification using Maximum Likelihood method:
a) 1984, b) 1990, c) 2000, d) 2010.

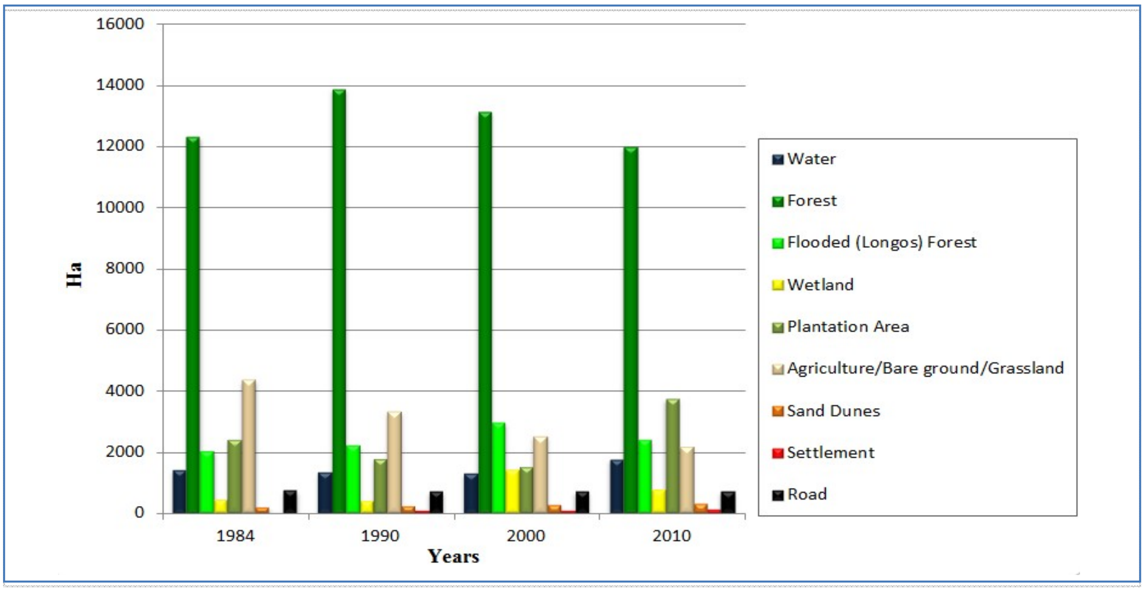

Fig. 4 – Supervised classification results in hectare for the year 1984, 1990, 2000 and 2010.

Table 1

Assessment of the Classification Accuracy.

Year	1984	1990	2000	2010
Overall classification accuracy	96,57%	96,24%	83,33%	90,74%
Overall Kappa statistics	0.9614	0.9576	0.8126	0.895834

Table 2

Area of nine major land covers on the Igneada, from-to changes for the year 1984 and 2010

Year	1984 (ha)											
2010 (ha)	***LU / LC Classes***	1	2	3	4	5	6	7	8	9	∑	**%**
	1	**1,279**	234	29	17	22	165	17	1	1	1,764	23
	2	60	**9,123**	401	27	1,158	1,206	0	0	5	11,979	-7
	3	15	1,126	**929**	11	39	278	0	0	1	2,399	63
	4	21	128	8	**325**	107	183	4	1	1	778	79
	5	11	1,981	38	27	**954**	719	0	0	10	3,742	53
	6	31	229	66	19	146	**1,663**	7	5	7	2,174	-50
	7	12	21	1	7	24	77	**152**	3	4	302	60
	8	0	1	0	1	0	71	9	**59**	0	142	104
	9	0	0	0	0	0	1	0	0	**709**	711	-4
	∑	1,430	12,843	1,472	435	2,452	4,363	189	70	738	23,991	

LU: Land use, LC: Land cover, 1: Water, 2: Forest, 3: Flooded (Longos) Forest, 4: Wetland, 5: Plantation Area, 6: Agriculture / Bare ground, Grassland, 7: Sand Dunes, 8: Settlement, 9: Road.

5. RESULTS AND CONCLUSION

The results showed that Landsat 5 TM images could be used to produce land use/cover maps and statistics. General pattern and trajectories of land use and land cover in the Igneada area were evaluated through the years 1984, 1990, 2000 and 2010.

Land use/cover maps were produced with an overall accuracy of over 83.30% by using Maximum Likelihood supervised classification method. The magnitude of change was calculated and "from–to" change information derived from classified images. The results showed that major damage occurred on bare ground/grassland/agriculture areas of the selected region. The area was 2,532 ha in 1984 and 1,584 ha in 2010. The area of flooded forest was 497 ha in 1984 and 1,589 ha in 2010 because of new plantations in the region. Mixed forest and flooded forest categories converted to bare land and plantation area. The result shows that approximately 7% decreased over the 26-year period. These results and analyses can be used for sustainable natural resource management. To keep sustainable management under control, this kind of monitoring should be done in certain periods. As a result of the land use/cover change and human activities, environmental degradation affected especially the forest areas between 1984 and 2010. Therefore, in order for the Igneada region to keep the sustainability of natural life resources, effective management strategies should be followed. Especially human activities should be planned carefully.

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WIND ENERGY POTENTIAL ASSESSMENT OF UKRAINE

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Key-words: enviroGRIDS, wind energy, theoretical wind power potential, technically achievable wind power potential, methodology, wind power potential of Ukraine.

The article presents a methodology for theoretical and technically achievable wind power potential assessment, developed in the framework of EnviroGRIDS Black Sea Catchment project. The methodology has considerable advantages: it contains a simple algorithm, minimum set of input data, at the same time it provides highly reliable results and allows adequately assess wind power potential of investigated area. Developed methodology was tested on wind power potential of Ukraine.

1. INTRODUCTION

The utilization of renewable energy in the Black Sea countries is increasing, driven by promotion measures adopted by the governments of these countries. The utilization of biomass, solar and hydro energies is growing. There are a lot of international projects in support of international research and innovation cooperation. One of such projects is EnviroGRIDS Black Sea Catchment project which is intended for information potentialities of modeling and forecasting the situations, concerned with climate change, and their impacts on Societal Benefit Areas.

The rise of Renewable Energy Sources (RES) development (particularly wind and solar energy) is becoming one of the major factors of sustainable development. It is caused by the fact, that energy is a basic sector of the economy. The strategic goal of the economic development of any country is to maximize the share of energy in its energy balance, produced by the country's own energy resources.

The energy resources of Ukraine consist of three main branches: nuclear power, thermal power and hydropower. All the above-mentioned areas of energy in industrialized countries are unpromising and environmentally unsafe. The intensive use of thermal power plants led to a number of environmental problems [1]. During the last decades, the issues related to the development of renewable energy in the world and in Ukraine are extremely relevant because of the scarcity and limitedness of energy resources and environmental deterioration.

Wind power is a very attractive field. Wind technologies have grown in scope, and in various places wind is becoming a feasible source of energy. This kind of natural resource is vulnerable to weather conditions, but in certain locations, mainly in coastal offshore areas and at high altitudes, there is a steady stream of wind.

Wind power is harnessed through the use of wind turbines, which are turned by the wind to produce electricity. Wind energy is reliable and efficient. Unlike other power plants, wind energy systems require minimal maintenance and have low operating expenses.

Ukraine currently uses only 0.2% of its wind capacity. At present the total installed capacity of the wind power plants in Ukraine amount to 146.515 MW. Most of the wind power plants have been constructed within the framework of the "State Complex Program for Construction of wind power plants in Ukraine".

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Most of currently known methodologies for wind power potential assessment are complicated by a large quantity of input data and labour-intensive calculations. In respect of the importance of this issue, the simplified methodology for wind power potential assessment has been developed in the framework of EnviroGRIDS project, which allows to adequately assess wind power potential of investigated area using a minimum set of data.

The corresponding information services for RES potential assessment of Black Sea Catchment area are scheduled; such services are oriented at wind and solar energy potential forecasting as easily accessible and non-polluting energy sources.

2. THEORETICAL WIND POWER POTENTIAL ASSESSMENT

Renewable energy potential assessment includes assessment and analysis of the theoretical and technical potential of renewable energy [2]. The theoretical potential represents all the natural resources of RES. The technical potential is that part of the theoretical potential of renewable resource whose energy use is limited by technical (technology) and non-technical terms (financial, legal and others).

It is exactly the technical potential of renewable energy that is the potential which is important and necessary for the selection of specific technology for renewable energy conversion.

For estimating the wind energy potential of Ukraine, the following statistic parameters were calculated:

2.1. Vertical wind speed gradient

The wind speed at the surface is zero due to the friction between the air and the surface of the ground. The wind speed increases with height most rapidly near the ground, increasing less rapidly greater the height. The vertical variation of the wind speed, the wind speed profile, can be expressed by different functions. One of the most common functions which have been developed to describe the change in the mean wind speed with the height is Power Exponent Function [2]:

$$V(z) = V_r \cdot \left(\frac{Z}{Z_r}\right)^{\beta}$$

where Z is the height above ground level (m); V_r is the wind speed (m/s) at the reference height Z_r above ground level (m); $V(z)$ is the wind speed (m/s) at height Z (m); β is an exponent which depends on the roughness of the terrain, can be calculated in approximation by using the formula:

$$\beta = \frac{1}{\ln \frac{Z}{Z_0}}$$

The parameter Z_0 for different types of terrain is shown in Table 1.

Table 1

Roughness lengths and roughness classes for various surface characteristics [2]

Z_0 (m)	Types of terrain surfaces	Roughness class
1.00	City	III
0.80	Forest	
0.50	Suburbs	
0.30	Built-up terrain	

Table 1 (continued)

0.20	Many trees and/or bushes	II
0.10	Agricultural terrain with a closed appearance	
0.05	Agricultural terrain with an open appearance	
0.03	Agricultural terrain with very few buildings, trees, etc.	I
0.02	Airports with buildings and trees	
0.01	Airports, runway	
0.005	Meadow	
$5 \cdot 10^{-3}$	Bare earth (smooth)	0
10^{-3}	Snow surfaces (smooth growth)	
$3 \cdot 10^{-4}$	Sand surfaces	
10^{-4}	Water surfaces (lakes, seas, etc.)	

2.2. Average wind speed

Wind speed is the most important constituent for assessing the wind energy potential of investigated area. The wind speed measurement period must be long enough to cover all meteorological conditions in that region with a sufficient amount of data. In order to obtain the stable value of mean wind speed, the observation period should cover no less than 10 years [3]. For obtaining wind frequency data, the observation period has to be longer (about 25 years).

In order to assess the wind potential of Ukraine, the USRIEP team has obtained an averaged climatic data from the State Hydrometeorological Service of Ukraine, the measured at 187 meteorological stations of Ukraine. Meteorological stations are uniformly distributed all over Ukraine and the distance between them does not exceed 50–100 km (Fig. 1). The observation period covers 30 years.

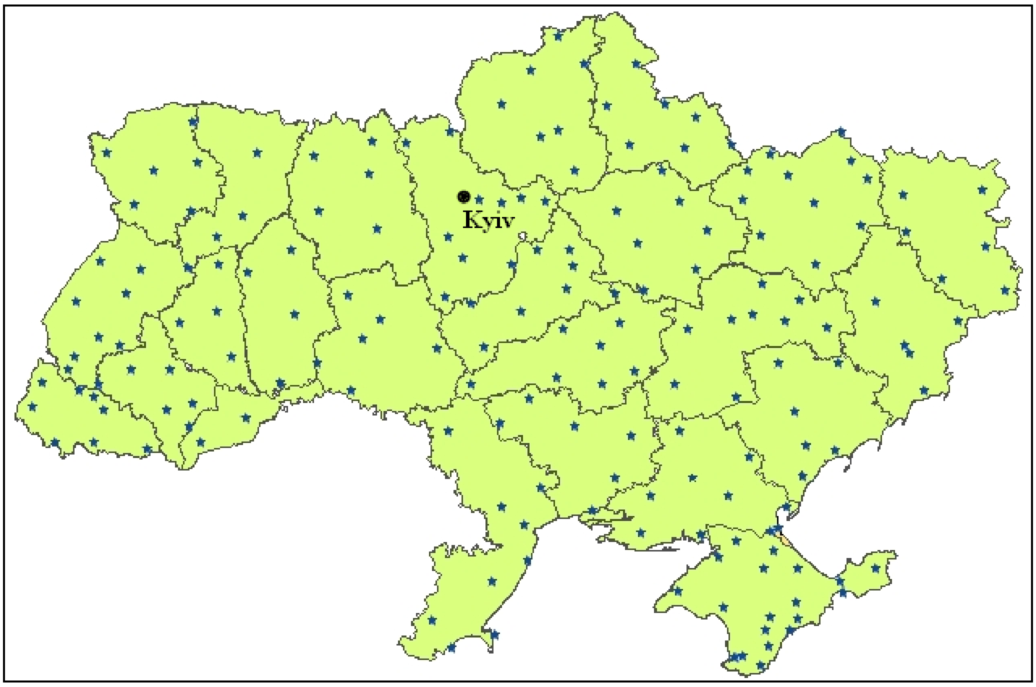

Fig. 1 – Location of hydrometeorological stations.

Obtained data includes:

- Averaged wind speed values for 30 years (m/s), measured at 10 meters above ground level;
- Wind speed frequency (%) for the following wind speed ranges:
    - 0–1 m/s;
    - 2 5 m/s;
    - 6–9 m/s;
    - 10–15 m/s;
    - 16–20 m/s;
    - 21–24 m/s;
    - 25–28 m/s;
- Annual calm period (%).

All the above-mentioned meteorological parameters are included in the standard list of measurements for each Ukrainian meteostation.

Mean wind speed (V_c), as the most commonly used indicator of wind production potential, is defined as [4]:

$$V_c = \frac{\sum_{i=1}^{n} \Delta V_i \cdot P_i}{\sum_{i=1}^{n} P_i}$$

where ΔV_i is a middle of i^{th} wind speed range; P_i is the wind speed frequency of i^{th} wind speed range; n is a number of wind speed ranges.

The averaged values of wind speed measured at 10 m above ground level were analyzed and mapped in GIS environment (Fig. 2).

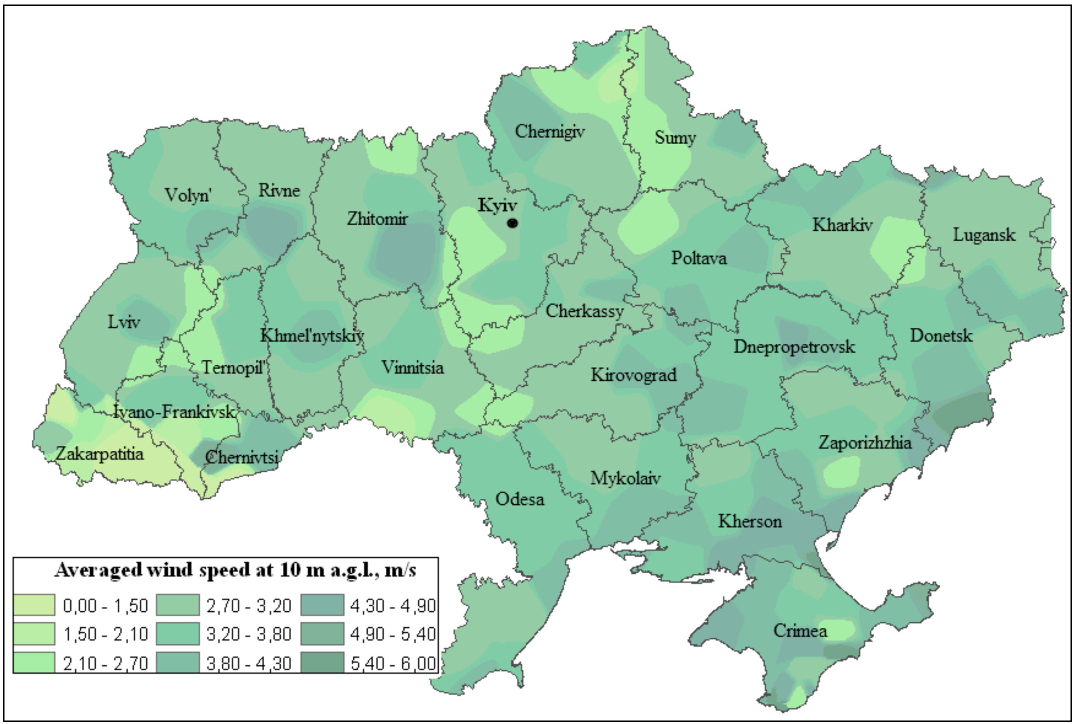

Fig. 2 – Averaged wind speed at 10 m a.g.l.

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2.3. Standard deviation

Standard deviation is a widely used statistic measurement of variability or diversity. The standard deviation of wind speed is an indicator of the turbulence level and atmospheric stability.

$$\sigma = \sqrt{\sum_{i=1}^{n} (\Delta V_i - V_c)^2 \cdot P_i / \sum_{i=1}^{n} P_i}$$

2.4. Coefficient of variation

The coefficient of variation (C_v) is a normalized measure of dispersion of a probability distribution. The coefficient of variation is defined as the ratio of the standard deviation to the mean wind speed:

$$C_v = \sigma / V_c$$

2.5. Full medium cube of a wind speed

To achieve lasting results, such parameter as medium cube of a wind speed, required for wind-power density assessment, should include statistic parameters as well:

$$\overline{V_c^3} = (V_c)^3 \cdot (1 + 3 \cdot C_v^2 - 0,9 \cdot C_v^3 + 2,9 \cdot C_v^4)$$

where $\overline{V_c^3}$ is a medium cube of a wind speed (m^3/s^3).

The value of the full medium cube of a wind speed should be calculated for each meteostation at the reference height. Usually, wind speed measures at 10 m height above ground level and average height of a wind turbine is about 70–80 meters. Therefore, in this article, the cube of wind speed is calculated for 75 m above ground level. The distribution of the wind speed at 75 m a.g.l. across the territory of Ukraine is shown in Fig. 3.

2.6. Wind power density

Wind power density is generally considered as a better indicator of the wind resource than wind speed, so, it is the amount of wind power available per unit of area perpendicular to the wind flow. Wind power density (WPD) should be calculated at the height of expected wind turbine (here it is assumed that the height is 75 m a.g.l.). WPD (W/m^2) can be calculated using the following equation:

$$WPD = \frac{1}{2} \rho \cdot \overline{V_c^3}$$

where ρ is an air density (kg/m^3); $\overline{V_c^3}$ is the full medium cube of a wind speed (m^3/s^3) at the height 75 meters.

2.7. Annual specific wind power density:

Annual specific wind power density WPD_{annual} is calculated by the following formula:

$$WPD_{annual} = WPD \cdot 24 \cdot 365 \cdot (1 - F/100)$$

where WPD_{annual} is an annual specific wind power density (Wh/m^2); F is an annual wind calm period, %.

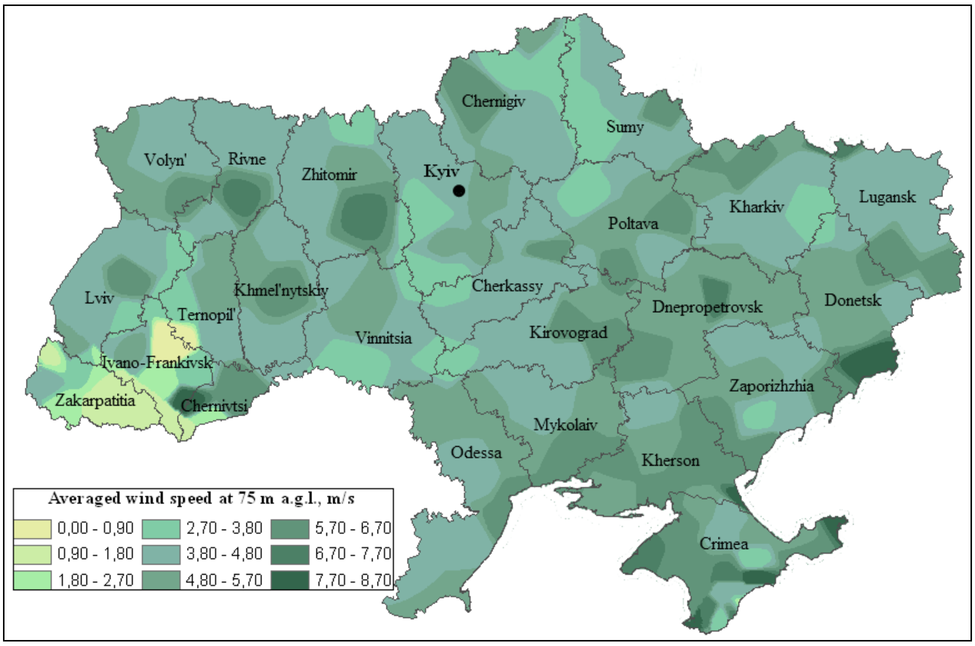

Fig. 3 – Averaged wind speed at 75 m a.g.l.

3. TECHNICALLY ACHIEVABLE WIND POWER POTENTIAL OF UKRAINE

Wind farms require large sites, potential wind farm sites are preferably open areas of flat land or on top of hilly areas. Obviously, the sites should be known to be windy, with high and recurrent wind resources. A considerable percent of the Ukrainian area is unsuitable for wind turbine placing. For technically achievable wind power potential assessment the following areas, unsuitable for wind turbine placing, were chosen and excluded from the calculations:

- urbanized areas;
- roads, highways and railways; and 300 m of buffer zone around each side of the road;
- forests;
- water body surfaces;
- cultivated areas.

The total area unsuitable for wind turbine placement was calculated using GIS software, the results are shown in Table 2.

Wind turbines operate over a limited range of wind speeds. If the wind is too slow, they would not be able to turn, and if it is too fast, they shut down to avoid being damaged. To make wind farms profitable enough, annual average wind speed should not be under 6 m/s, otherwise wind farm placing at low wind speed sites is not reasonable.

The mutual distance between the wind turbines has to meet the requirements of the manufacturers. If the wind turbines are too close together output may be reduced. Another, more serious, consequence may be damage to primary structural parts caused by the wake of wind turbines sited upwind. The minimum distance depends on the placing with regard to the prevailing wind direction. For turbines sited perpendicular to the prevailing wind direction, the mutual separation distance has to be at least four, and preferably, five times the rotor diameter. In this report, the methodology for wind power potential assessment takes as its foundation the Technical report on Europe’s onshore and offshore wind energy potential [5], so technically achievable wind energy potential is calculated assuming the use of 2 MW wind turbines onshore with a view to prospects for 2030. Regarding average wind energy production potential per square kilometer, it is considered that five 2 MW wind turbines can be sited per square kilometer onshore within the area suitable for wind turbine placing [6], and for the average turbine of 2 MW, the related rotor diameter would be 80 m.

Table 2

Areas excluded from calculations, suitable area for the wind turbines placing

Region name	**Total area of the region, km^2**	**Urbanized area, km^2**	**Forest-lands, km^2**	**Roads, railways + buffer zone, km^2**	**Water bodies surface, km^2**	**Cultivated area, km^2**	**Total area suitable for the placing of wind turbines, km^2**
Kherson	28,500	230.9	1324	3022	1096.7	11341	11,485.43
Crimea	27,000	225.8	3087	4032,4	8.6	6819	12,827.3
Donetsk	26,500	1,097.4	1855	4915,7	203.9	11944	6,483.99
Zhytomyr	29,900	367.9	9890	5197,2	111.8	4549	9,784,18
Chernihiv	31,900	324.1	6566	4688,6	251.9	7571	12,498.4
Luhansk	26,700	746.3	2829	3547	64.7	8513	11,000.07
Odesa	33,300	305	1953	5025,6	1311.2	16388	8,317.15
Rivne	20,100	98.1	7317	3086,7	88.5	3236	6,273.74
Dnipropetrovsk	31,900	777.2	1528	5605,6	1038.6	16884	6,066.59
Mykolaiv	24,600	262.3	949	2949,3	354	13720	6,365.38
Kharkiv	31,400	578.9	3727	5830,9	371.6	13838	7,053.56
Volyn	20,200	118	6324	3784,5	180.1	2972	6,821.34
Sumy	23,800	330.6	4038	4445,1	88.7	7820	7,077.61
Poltava	28,800	248.7	2362	5394,4	880.8	14502	5,412.18
Ivano-Frankivsk	13,900	163.8	5767	2539,7	121.1	1465	3,843.39
Zaporizhzhia	27,200	336.1	1054	4257,6	2386	14759	4,407.24
Kyiv	28,900	394.9	6322	5183,1	2005.7	8496	6,498.27
Lviv	21,800	396.2	6264	5087,9	68.3	3158	6,825.57
Khmelnytskyi	20,600	215.7	2627	4356,5	210.5	7552	5,638.33
Kirovohrad	24,600	243.2	1588	3995,7	388.9	14585	3,799.21
Chernivtsi	8,100	92.4	2378	1751,5	151	1658	2,069.11
Vinnytsia	26,500	213.6	3514	5811,3	234.8	12024	4,702.2
Zakarpattia	12,800	68.6	6529	2033	68.2	891	3,210.18
Cherkasy	20,900	281.4	3193	3735	544	9772	3,374.6
Ternopil	13,800	125.4	1924	3091	59.9	6178	2,421.7
TOTAL	**603,700**	**8242.3**	**94,909**	**103,367.4**	**12,289.6**	**220,635**	**164,256.72**

It was mentioned above that areas with an annual average wind speed lower than 6 m/s are unsuitable for wind farm placing, so, such areas should be excluded from the calculations. An annual average wind speed of the main part of Ukraine is 6.3–6.8 m/s; but wind speed in some regions is exceeding the range of 7–8 m/s. Obviously, such territories are more attractive for the building of wind farms. Also, it can be expected that at such windy sites the number of wind turbines per square kilometer might be somewhat more than five on average (for example seven). Generalizing the developed concept, the territories of Ukraine, suitable for wind farms placing, with an average wind speed of 3 different ranges (<6 m/s; 6-7 m/s; >7m/s) were calculated and presented in Table 3.

The wind power capacity of each region of Ukraine $W_{capacity}$ was calculated using the following equation:

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$$W_{capacity} = \sum_{i=1}^{n} S_i \cdot N_{i\,turb} \cdot P_{turb}$$

where S_i – area with respective wind speed range, km^2; $N_{i\,turb}$ is a number of wind turbines per square kilometer corresponding to wind speed range; P_{turb} is the power of wind turbine (2 MW); n is the number of ranges (note that one of the ranges has been excluded, so, calculations perform only for two left ranges). The results of calculations are shown in Table 3.

Table 3

Results of wind power potential assessment of Ukraine

Region name	**Annual averaged specific wind power density, kWh/m^2**	**Total area suitable for the placing of wind turbines, km^2**	**The area of average wind speed**			**Wind power capacity for the areas of the following wind speed ranges, GW**		**Total technically achievable wind power capacity, GW**
			<6 m/s	**6-7 m/s**	**>7m/s**	**6-7 m/s**	**>7m/s**	
Kherson	3236.77	11485.43	8843.78	2297.09	344.56	22.97	4.82	27.79
Crimea	1420.52	12827.30	4489.56	6413.65	1924.10	64.14	26.94	91.07
Donetsk	1308.42	6483.99	4992.67	518.72	972.60	5.19	13.62	18.80
Zhytomyr	711.07	9784.18	7533.82	782.73	1467.63	7.83	20.55	28.37
Chernihiv	524.68	12498.40	9998.72	624.92	1874.76	6.25	26.25	32.50
Luhansk	549.73	11000.07	8800.06	2200.01	0.00	22.00	0.00	22.00
Odesa	687.39	8317.15	7069.58	1247.57	0.00	12.48	0.00	12.48
Rivne	840.24	6273.74	5018.99	501.90	752.85	5.02	10.54	15.56
Dnipropetrovsk	848.87	6066.59	4489.28	1213.32	364.00	12.13	5.10	17.23
Mykolaiv	745.16	6365.38	5410.57	954.81	0.00	9.55	0.00	9.55
Kharkiv	618.71	7053.56	5995.53	1058.03	0.00	10.58	0.00	10.58
Volyn	560.80	6821.34	6139.21	682.13	0.00	6.82	0.00	6.82
Sumy	523.39	7077.61	5662.09	1415.52	0.00	14.16	0.00	14.16
Poltava	626.33	5412.18	4329.74	1082.44	0.00	10.82	0.00	10.82
Ivano-Frankivsk	826.83	3843.39	3420.62	115.30	307.47	1.15	4.30	5.46
Zaporizhzhia	706.73	4407.24	3658.01	749.23	0.00	7.49	0.00	7.49
Kyiv	463.16	6498.27	5523.53	974.74	0.00	9.75	0.00	9.75
Lviv	427.94	6825.57	5801.73	1023.84	0.00	10.24	0.00	10.24
Khmelnytskyi	507.75	5638.33	4510.66	1127.67	0.00	11.28	0.00	11.28
Kirovohrad	739.27	3799.21	3039.37	759.84	0.00	7.60	0.00	7.60
Chernivtsi	1044.61	2069.11	993.17	931.10	144.84	9.31	2.03	11.34
Vinnytsia	438.04	4702.20	4231.98	470.22	0.00	4.70	0.00	4.70
Zakarpattia	583.25	3210.18	3049.67	160.51	0.00	1.61	0.00	1.61
Cherkasy	448.25	3374.60	3138.38	236.22	0.00	2.36	0.00	2.36
Ternopil	504.57	2421.70	2058.45	363.26	0.00	3.63	0.00	3.63
TOTAL		**164,256.72**	**128,199.16**	**27,904,77**	**8,152.80**	**279.05**	**114.14**	**393.19**

In accordance with the obtained results, the technically achievable wind power capacity has been assessed and mapped (Fig. 5).

The actual power will be somewhat less than the calculated one, because available power cannot be totally extracted by any wind machine. The maximum extractable power from any wind machine is limited by the famous Betz relation which assigns a power co-efficient Cp=16/27 for the maximum performance of a wind machine [1]:

$$WP(Max.ExtractablePower) = \frac{1}{2} \cdot \rho \cdot C_p \cdot A \cdot \overline{V_i^3}$$

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where WP is maximum extractable power (W); A is the rotor swept area, (m^2); $\overline{V_c^3}$ is the cube of the wind speed at the reference height, expressed as m^3/sec^3.

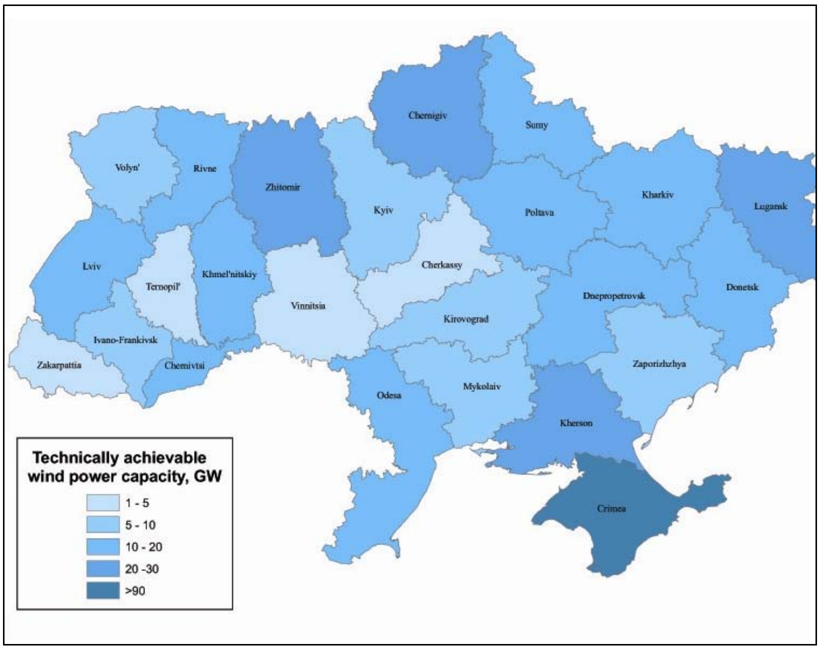

Fig. 5 – Technically achievable wind power potential.

According to the obtained results, the southern and eastern parts of Ukraine have outstanding wind potential, particularly the Autonomous Republic of Crimea, Kherson, Donetsk and Lugansk regions.

As for annual specific values of wind power potential, the existing data indicate a promising wind potential around the Autonomous Republic of Crimea, Kherson, Donetsk, Chernigiv, and Zhitomyr regions. For these areas the average annual wind speed varies between 5 to 8 m/sec at 75m a.g.l.

Ukraine is one of the more promising wind markets of the world. The Law on “green” tariff adopted in 2009 and other similar incentives aimed at promoting and stimulating renewable energy development in the country have begun to bear fruit in the commissioning of new wind and solar power plants with advanced international technology and equipment.

In accordance with key principles of the EU green paper, the long-term renewable energy development in Ukraine should be based on the economic competition with other energy sources, with the state providing support to renewable energy sources advanced technologies which reflect public interest as regards enhancing the energy security level, environmental cleanness and combating global climate change.

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ECOLOGICAL STATE OF THE MARINE EDGE OF THE KILIA DANUBE DELTA IN 2011–2012

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Key-words: dynamics of marine edge, Danube Delta, eco-polygon, species of plants, enviroGRIDS.

The results of observations of the dynamics of the marine edge of the Danube Delta in 2011–2012 describe the main trends in the individual sections, taking into account the factors of their formation. Also, the results of observations of littering the sea edge of the Danube Delta with plastic waste, the registration of the dead dolphins, as well as botanical research are reported herein.

1. INTRODUCTION

The marine edge of the Danube Delta (MED) and the seaside of its mouth are areas of intensive transformation. Natural factors that form the MED include the following: the carry-over of sediments by the river, currents and associated with them the transportation of marine sediments, and deformations caused by sea roughness. Changes in the ratio of the river and of marine factors provoke growth, erosion or relative stability of avandelta areas [1]. Current dynamical processes at the marine delta edge depend on the reduction of the Danube sediment runoff, flow redistribution between Tulcea Arm and Kilia Arm, and the rise of the Black Sea level.

The MED is a unique biological object where newly-developed accumulative forms are covered with pioneer vegetation. Farther from the seashore to inland, you can trace the evolution of flora closely connected with the relief formation of the area. In addition to natural biological stuff, the surf and the wind bring to the seashore various wastes, mostly polymers (plastic bottles, plastic foam, cellophane, etc.). A substantial increase of plastic waste inflow into the MED happened in the mid-1990s.

2. ANALYSIS OF RECENT STUDIES AND PUBLICATIONS

Due to their uniqueness, the MED and some of its areas are the object of geodesic, ecological, hydrological, hydrobiological and other geographical surveys [1–8]. These surveys are essential for the management of nature conservation activity within the Danube Biosphere Reserve. Interesting is the description of vegetation species which appear under intensive changes of abiotic factors in the MED area. Studies on the contamination of the MED area with waste are unique of the kind. Dead dolphins found within the MED were also registered. Therefore, **the goal of the studies presented** herein is to determine and analyze current trends in changes of the Kilia Danube Delta marine edge, to make assessments of contamination with waste and to give a description of vegetation and of the registration of dead dolphins within the MED area.

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3. MATERIAL AND METHODS

To observe the dynamics of the Kilia Delta, the Danube Hydrometeorological Observatory (HMO) has set benchmarks and defined azimuths for permanent surveying profiles. Since the 1970s, the MED measurements are made in summer almost annually: geodesic surveys, measurement works, and the setting of new benchmarks if necessary.

In the framework of the international project 'Building Capacity for a Black Sea Catchment Observation and Assessment System Supporting Sustainable Development' (enviroGRIDS Black Sea Catchment), carried out in 2009–2013, two of the project partners, Danube HMO and Melitopol Pedagogical University, signed a co-operation agreement. The aim of it was to expand opportunities of local co-operation between these two partners, and to provide joint expeditions for integrated studies in the Danube Delta. In 2011–2012, the Danube HMO organized hydroecological expeditions which the authors of this paper took part in. These expeditions continued observations of the marine edge dynamics, defined ecological study plots (eco-polygons) and their spatial co-ordinates, made botanical description of eco-polygons and an inventory of waste on their borders.

Works on integrated ecological observations included the following:

1. Studies on the marine edge dynamics (Fig. 1), (geodesic observations on surveying profiles, measurement of coastal waters). Locations of surveying profiles were defined by benchmarks and an optical theodolite, in some cases – with geodesic GPS unit (Trimble R3). Levelling was made with an optical levelling instrument, depth mesurment near the coast was done by wading in water with a pole, and up to 5-m isobath – by an echo-sounder. Distance on land was measured with a measuring tape, and in the sea – with the GPS unit. When surveyed profiles of previous years were compared, all heights were cut to a unified system. Location of the 'Ptashyna Kosa' Spit was identified by marking particular points at the water's edge – with GPS unit.

2. Inventory of agents of anthropogenic garbage in fixed study plots (Fig. 1) – registration, marking, description of plastic and other agents.

A plot to observe contamination (eco-polygion) was marked by a benchmark and the sea water edge. The left and right borders of the plot were as far as 20 m from the observation profile and are parallel to it. A theodolite and measuring tape was used to lay out the plots.

3. Botanical description of profiles and eco-polygons (species composition, vegetation projective cover and age of plants).

4. Search and registration of dead dolphins within the MED area.

Methods of research: geodesic, hydrological and statistical graphical analysis, and botanical description. An analysis of surveying profiles, geographical maps, and satellite images was also made.

4. RESULTS AND ANALYSIS

Morphological changes. Summarized results of preceding studies on the dynamics of the marine edge of the Kilia Danube Delta are presented in the monograph "Hydrology of the Danube Delta" printed in 2004 [2]. Later, several other works were published [4–6]. The results of new studies for recent years presented are below.

Processes of growth and wave erosion of the marine edge of the Kilia Delta for short-time intervals (1–2 years) are often reversible and very changeable – strong storms change the position of young accumulative forms and cause their deformation. It is quite difficult to set correlations between relief changes and some hydrometeorological parameters [4]. The difficulty of finding these correlation links is related to rather rare studies of the MED morphological parameters, and the absence of surveys "before" and "after" the phenomena responsible for abrupt qualitative changes. The annual (once a year) survey at the MED gives us an integrated index of changes determined by several storms, hydrograph, wind rose of this particular year, occurrence of strong eastern winds, etc.

It is necessary to distinguish between short-time often reversible deformations of the marine edge caused mainly by some particular storm, strong wind or ice phenomena and long-term changes driven by perennial fluctuation of water drainage, changes in the runoff of river sediment, or runoff redistribution processes. In a separate group we should include changes induced by a direct anthropogenic impact on the marine edge: the construction of dykes and dredging works.

Based on the expedition studies of 2011–2012 we have identified major trends in the principal sections of the MED as follows (Fig. 1):

The coast of Zhebrianska Bay. From the southern part of the dyke of Sasyk Liman to the Badyk Bay the marine edge is represented by broad and mainly clean beaches, occasionally covered with *Elaeagnus sp.*, tamarisk and annual grasses. The marine edge is substantially changing there: spits are formed, then joined to the coast and after that eroded. Deepening and shallowing of the coastal zone can occur several times a year. In some areas the marine edge shifts by more than 50 m within one year. Last years Perebiina Spit (Fig. 1) was eroded and shifted toward the coast. At the mouth of the Polunochne Arm the coast is predominantly made up of shells of the sand gaper (*Mya arenaria*), lower layers consist of broken shells followed by black mud. Marine surf brings shell to shallows of the bay. The coast is eroded there, which is proved by lots of remnants of grass roots at the depth of 40–60 m up to 30 m from the coastline.

Spits in the area of the Polunochnyi Kut Bay (Durnyi Kut), at the mouth of the Shabash Arm, and at the western bank of the Shabash Island are eroded by waves and shifted southward. Taranova Spit is intensively transformed and has several breaches along its length. Satellite images from 2006 show that a drowned immobile cutter boat was situated inside the bay (near Prorvin Island and Taranova Spit), having been moved out in 2012 as far as 25 m toward the sea.

The area between the Potapovske and the Poludenne mouths. The coast at the mouth of the Potapovske Arm is washed out [2], and for the 2010–2011 period 55 m of the coast was eroded at the observation profile. The benchmark was destroyed and the distance was identified by GPS unit. A new benchmark was placed in 2011 south of the Potapovske Arm, 27 km offshore. In 2012, the distance from the sea water edge to this benchmark was reduced to 7 m.

Products of strong wave erosion of the mouth bar of the Potapovske Arm have formed a long and rapidly growing New Potapovska Spit (Fig. 1 shows the southern part of Potapovska Spit). For the period 1990–2011 an above-water part of the spit increased by 540 m. However, in the last years the spit growth rate decreased. In 2010–2012 the spit was washed out by 20 m at azimuth of observations. The southern end of the spit is currently stabilized and, under increasing deficit of sediments, it will be eroded from seaward.

The area between the mouths of the Poludenne and the Bystre Arms. Being protected by the New Potapovske Spit in the area of the right mouth spit of the Poludenne Arm, the MED started growing seaward. The wave erosion in 1975–1982 substituted by the growth of the coast. For the period 1992–2001 the spit growth amounted to 95 m. For the next 3 years the MED was stable, and then retreated a bit. In 2005–2008 the spit location was stable. In 2009–2012 the spit expanded by 25 m southward. According to a surveying profile, located to the north of the former mouth of the Seredne Arm (Fig. 1), during 1984–2009 the coast expanded by 160 m, growing by an additional 30 m in 2010–2012.

The strongest expansion of the coast occurred directly to the north of the mouth of the Bystre Arm. There, on the left mouth spit, formed of sediments of the Bystre Arm and products of wave erosion, the MED grew by more than 500 m over 1975–1985, with an abrupt jump in 1983–1984. Prior to 2002, the marine edge in this area periodically retreated or expanded, and since 2002 the coast has been intensively growing [1, 2, 4]. In 2008–2009, a stone dyke was constructed on the left spit of the Bystre Arm. It connected the left bank of the arm and a ‘German’ dyke built in 2004. The dyke protects a shipping route from muddying by sediments which are carried from north and south. According to our observations, since the very moment of its existence the dyke, encouraged more intensive development of new accumulative forms from its northward side. Observations at an old azimuth were stopped in 2011, followed by the setting of a new benchmark and defining a new azimuth.

In 2011–2012, the marine edge retreated there as far as 18 m. The sand, accumulated near the left side of the dyke is loose and forms sand dunes. When the north wind blows the dunes move, partially run over the dyke and fall into the canal. To all appearances, this process will soon stop, due to fixation of the sand spit and dyke by delta vegetation. Generally, this area, under increasing deficit of sediments, will stabilize or even be eroded.

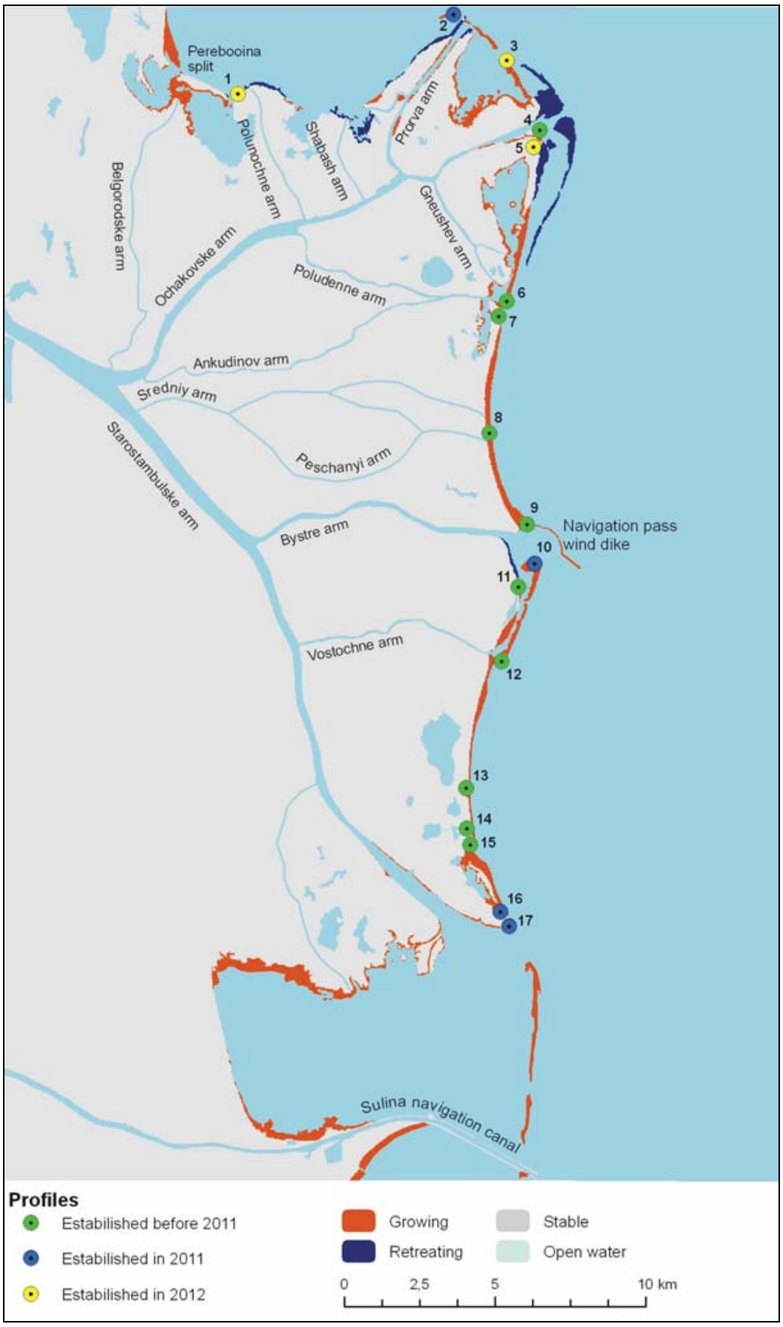

Fig. 1 – Skeleton map of location of profiles and eco testing grounds at the marine edge of the Kilia Danube Delta.

Location:

1. Profile of the left bank of the Polunochne Arm
2. Profile of the left spit of the Prorva Arm
3. Profile on the Taranova Spit
4. Profile of the right bank of the Potapovkse Arm
5. Profile in the north of the Potapovska Spit
6. Profile of the Potapovska Spit
7. Profile of the right spit of the Poludenne Arm
8. Profile of the left bank of the Seredne Arm
9. Profile of the left bank of the mouth of the Bystre Arm
10. Profile in the north of the Ptashyna Spit
11. Profile between the mouths of the Vostochne Arm and the Bystre Arm
12. Profile of the left bank of the Vostochne Arm (in the south of the Ptashyna Spit)
13. Profile of the left bank of the former Zavodnynske Arm
14. Profile of the left bank of the Tsyhanske Arm
15. Profile of the right spit of the Tsyhanske Arm
16. Profile between the Tsyhanske Arm and the Starostambulske Arm
17. Profile of the left spit of the Starostambulske Arm

The area between the mouths of the Bystre and the Starostambulske arms. In this MED area the most essential changes are recorded south of the mouth of the Bystre Arm (Fig. 1). The right mouth spit of the Bystre Arm, deprived of sand sediments from the arm, was strongly eroded by the sea roughness during 1977–2002 (north-eastern and eastern waves passed over Ptashyna Spit and reached the coast). Observations over the last years show a relative stabilization of the coast on the left spit of the Bystre Arm.

Farther to the south, between the mouths of the Bystre and the Vostochne arms, the MED was growing. In 1975–1995 it expanded almost by 200 m. The following years the coast was slightly eroded by waves. In 1997–1998, according to the observation profile, the above-water spit appeared (it was called ‘Ptashyna’ [English: Bird’s Spit]), and the MED made an abrupt jump growth into the sea. Between old and new marine edges a lagoon developed (local: *kut*) 1.1–1.2 m deep and 600–800 m wide. As for 2011–2012, the spit approached the ‘bedrock’ coast as far as 50 m in some places. Now the lagoon is 100–300 m wide and about 0.5–0.6 m deep.

In 2002–2003 the southern end of the Ptashyna Spit approached the mouth of the Vostochne Arm. After that, the spit stopped growing, being prevented by water drainage of the Vostochne Arm. In the last years, a general trend of spit shifting closer to the coast was recorded. The northern part of the spit is the most resistant one. In the near future the spit will join the coast, obviously it will be a southern part of the spit where the minimal width of the lagoon was 50 m in 2012.

North and south of the Vostochne Arm the MED was generally more or less stable and showed some trend of expanding. In this area the bank is intensively overgrown with woody plants.

Farther south the MED is recorded to grow. The left mouth spit of the Tsyhansky Arm has a growing trend, the same as the seaside. In this section the MED grew by 90 m during 1990–2012.

At the profile between the mouths of the Tsyhanske and the Starostambulske Branch arms the MED growth amounted to 30 m over the 2005–2012 period.

The MED also expanded in the area adjacent to the left mouth spit of the Starostambulske Arm. Last year it grew by 5–10 m. Also, the marine edge of Tsyhanka Island and the northern part of Nova Zemlia Island is observed to rebuild.

Inventory of agents of anthropogenic garbage. Within the defined eco-polygons (Fig. 1) investigations were carried out of the morphological structure of anthropogenic inclusions, i.e. visual identification of different wastes the so-called anthropogenic agents. The amount of the same agents was calculated, and they were marked and weighed. It should be noted that there is no recreation activity in the study area and the agents are brought by water or wind.

The inflow of these agents into the MED has an interesting mechanism. Eastern winds and accompanying currents bring plastic to the coast. Then, depending on wind force and an agent’s properties (weight and size) it can be carried deep into the territory of the coast and stay there. The west wind usually does not provoke a reverse outflow of the agents because a surface west wind at the

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seaside is almost completely cancelled by delta vegetation and it cannot move the agents. In the northern part of the Kilia Delta these winds come from the north (bringing the agents) and south. It means that both the growth and retreat of the marine edge will accumulate mainly plastic on fore delta.

The analysis of *in situ* observation results allows to conclude that a main type of waste in the eco-polygons are plastic bottles of different size – 89% in number and 82% in weight of all waste (Fig. 2). In addition, remains of plastic containers and packages, disposable tableware, plastic foam, etc. were also found. So, the main type of waste in the MED area is rubbish consisting of polymeric material: polyethylene terephthalate, polyethylene, polypropylene, polystyrole ethylene vinyl, and cellophane. It is because of the properties of polymeric materials: they can be easily carried by water or wind and have a low level of biodegradation. It should be noted that in some cases it is impossible to make a precise visual identification of polymeric material. Further, for more accurate identification, studying the burning reaction of these agents would be advisable.

In addition to polymeric materials, metal and glass waste was also found (also resistant to biodegradation) but they did not exceed 2.5% of all waste items found in the eco-polygons. However, further detail observations of the morphological structure of waste are required because different components are not equally dangerous for the environment.

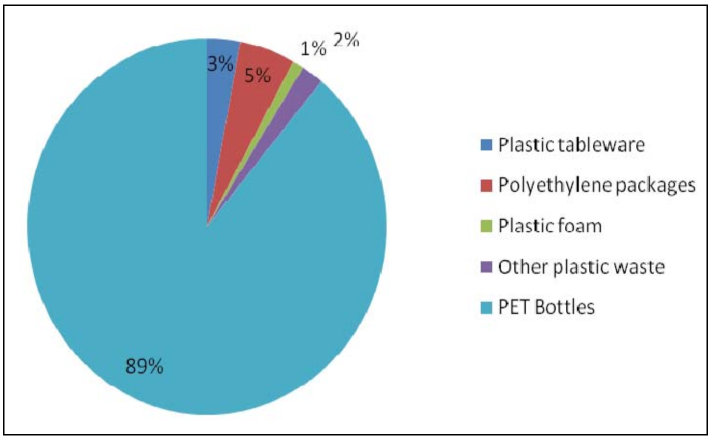

Fig. 2 – Distribution of different types of polymeric waste (by number).

The main danger of polymeric waste is that being chemically and microbiologically inert they litter the coastal zone, can provoke death to animals, put obstacles to the normal functioning of ecosystems, and produce unaesthetic visual contamination. An additional factor, intensifying the impact of this waste, is the contents of boxes, bottles or packages – various building materials, chemical solutions, detergents, etc.

Observations of the number of plastic bottles in 9 eco-polygons enables the assessment of a summarized amount of this type of waste for the whole MED area. To make this assessment all the MED area was divided in sites, each of them relating to a particular eco-polygon (Fig. 1), i.e. the conditions for accumulation of this type of plastic waste in a particular site are identical to those observed in the representative eco-polygons.

As the plastic waste is inert, the accumulation level existing in the study territory has been formed during a long period of time, parallel to changes in the MED area. Taking into account that a sharp increase in the production and consumption of plastic bottles goes on since 1995, we took the estimated period from 1995 to 2011 to calculate a summarized inflow of plastic bottles into the MED. Then we made an assumption that for that period the MED evenly expanded seaward proportionally to the growth of the total Kilia Delta area. Thus, according to our estimation, the current mean rate of the delta growth is of 0.22 km a year and, therefore from 1995 to 2011 (16 years) the delta area expanded by 3.52 km. The length of the active edge is 32.24 km which means that the mean expansion of the MED equalled 109 m. Table 1 shows the average amount of plastic bottles in 8 MED sites. As one can see from the table, the amount of plastic waste varies quite significantly in different eco-polygons. The highest amount occurs in the eco-polygons of the Potapovske and the Tsyhanske arms, the lowest amount of plastic is seen in the northern islets and spits of the Kilia Delta. Based on our assessment, we conclude that for the years 2011–2012 the Ukrainian part of the MED holds about 2.5 tons of plastic bottles and about 0.5 tons of other synthetic waste.

Botanical research. In the course of our work we studied all the territory of the forming seashore from the northernmost part (the Polunochne Arm Mouth) to the end of the Tsyhanka Island in the south of the Danube Biosphere Reserve. In the study area, 110 species of plants were found which make up 11.4% of all the higher plants of the Danube Biosphere Reserve (966). The plants in the coastal part of the Kilia Danube Delta include 12 species (10.9%) of trees and shrubs, and 98 species (89.1%) of grass. The latter consists of 36 species (32.7 %) of perennial grasses, 2 (1.8 %) of biennial and 60 species (54.6 %) of annual grasses. The high percentage of perennial plants including tree-shrub species (48%) is not typical of the primary syngenesis of isolated natural formations like the Danube Delta [7, 8]. In the Kilia Danube Delta, a powerful water flow, especially during floods, brings a huge amount of vegetative propagating plants (reed, willow, poplar, etc.) which are able to fix on the substrate and then participate in the pioneer vegetation on new coastal formations.

Table 1

Assessment of the amount of plastic bottles in the MED area

Site	Length of site	Amount of plastic bottles, g/m^2	Overall weight of bottles, kg
Prorva-Potapovske	5	0.108	58.86
Potapovske – south of Potapovska Spit	5.52	1.611	969.31
south of Potapovska Spit– Seredne	4.33	0.696	328.49
Seredne – north of Ptashyna	4.78	0.592	308.44
north of Ptashyna Spit – south of Ptashyna Spit	3.4	0.586	217.17
south of Ptashyna Spit – Zavodnynske	4.43	0.753	363.60
Zavodnynske – Tsyhanske	1.73	0.708	133.51
Tsyhanske – Starostambulske	3.05	0.662	220.08
Total			2599.46

The analysis of species occurrence has revealed that only one species, *Xanthium strumarium L.*, was present in each of the 12 profiles; it is an adventive annual plant with wide ecological amplitude. Six species of plants occurred in 11 profiles: *Chenopodium rubrum L., Juncellus pannonicus L., Salsola soda L., Leymus sabulosus Tzvel., Phragmites australis (Cav.) Trin. ex Steud., and Tamarix ramosissima Ledeb*. More than half the profiles had only 20 species of plants, or 18.2% of the total analyzed flora. These 20 species are typical coenosis-forming plants of coastal new formations of the Kilia Danube Delta. Among the rest of the plants, 44 species (40%) occur only in one of the profiles; these are species which are recorded mostly on the edge of ecotopes and found only as solitary specimens.

In the process of the research it was established that the most intensive growth of the delta and formation of the vegetation cover occur in the southern part – the end of the Tsyhanka Island, to the left from the starting point of the Starostambulske Arm. In this area, the soil is represented by sand alluvial (marine) and muddy alluvial (river) deposits. There, the whole site, inwashed by the last year or the past two years, has 90 species out of the 110 mentioned above. However, the profile itself (a section from the benchmark to the water) holds only 38 species of plants. Therefore, the analysing the flora only within the profiles cannot reflect a complete picture of the syngenesis process on the marine edge of the Kilia Danube Delta.

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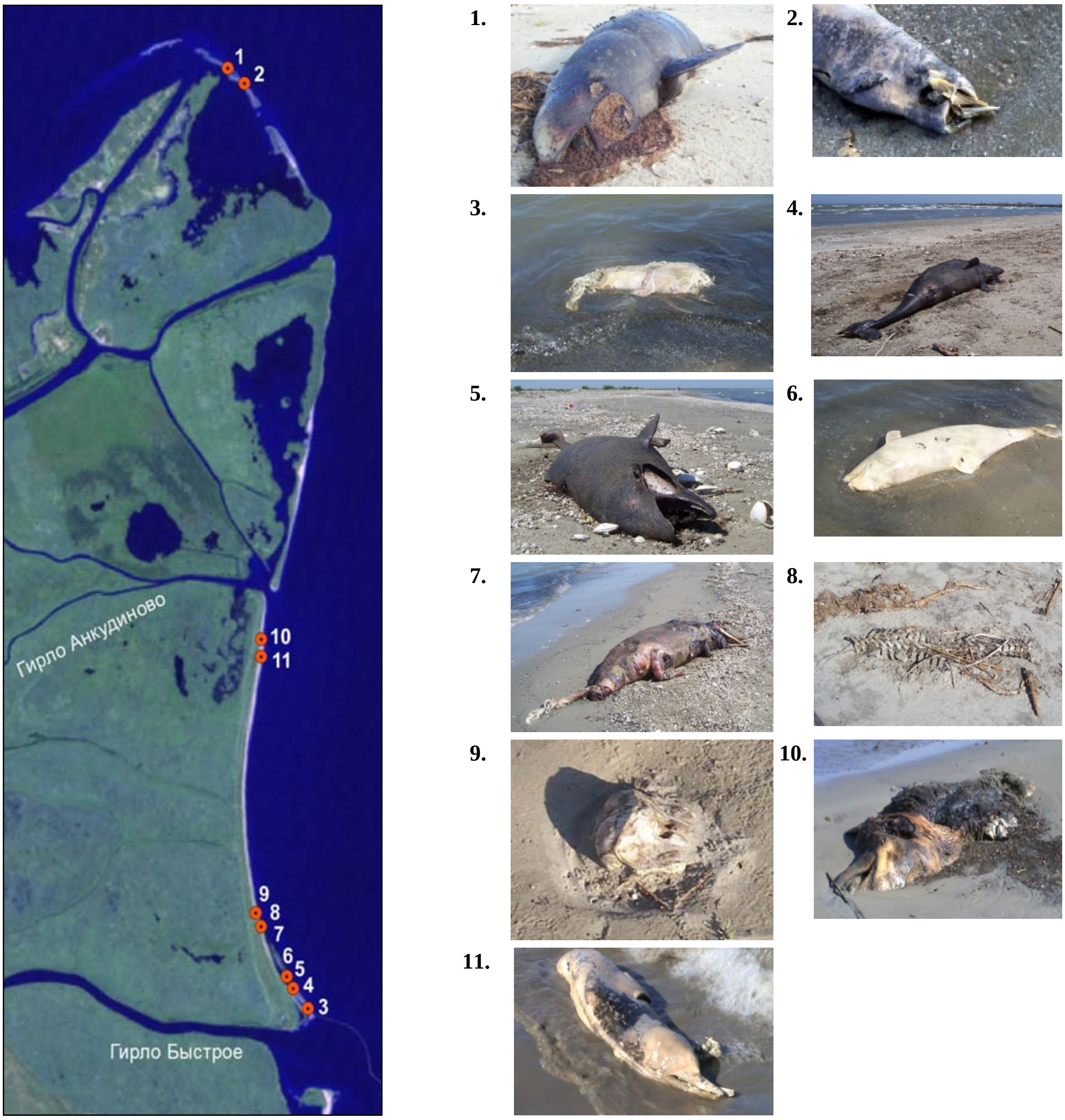
Registration of dead dolphins was carried out throughout the outer part of the MED during the expeditions of 2011 and 2012. The majority of dead dolphins were registered in 2012. It was established that 9 out of the 11 remains belonged to the harbour porpoise (*Phocoena phocoena*) (Nos 1–9, Fig. 3), one was the Black Sea bottlenose dolphin (*Tursiops truncatus ponticus*) (No. 10, Fig. 3), and one was the short-beaked common dolphin (*Delphinus delphis*) (No. 11, Fig. 3).

The first dead harbour porpoises were found on the 26 July, 2012 to the right of the Prorva Arm Mouth on the Taranova Spit (Nos 1, 2, Fig. 3).



1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11.

Fig. 3 – Dolphins and porpoises found on the 26th and the 28th of July, 2012 during an expedition the MED.

Other dead bodies of harbour porpoises in various stages of decomposition were found on the 28th of July, 2012 in the section 7.5 km long between the Poludenne and the Bystre Arms. That very

day in this section we also found a large bottlenose dolphin (No. 10) and a short-beaked common dolphin (No. 11). A White-tailed Eagle was feeding on the corpse of a large bottlenose dolphin.

Such a great number of dead dolphins and porpoises in a similar stage of decomposition was obviously connected with a prolonged storm which had prevented fishermen from coming to the sea and check their nets. When the storm was over, all dolphins and harbour porpoises were thrown from the nets into the sea. The majority of harbour porpoises is also an indirect evidence that death was caused by fishing nets (the harbour porpoise has the highest mortality percentage in fishing nets, chiefly those for turbots, spiny dogfish or sturgeons).On the other part, if dolphins die in fishing nets their caudal fins are typically absent. In our case, only one specimen of the harbour porpoise (No. 7) had not a caudal fin (not taking into account a skeleton and a skull of the porpoise (Nos 8 and 9). According to Internet data, registered the mass death of dolphins in 2012 in the Black Sea at the seaside of Sochi City (Russia) and in the Crimea (Ukraine) was not related to their being caught in fishing nets. Therefore, we can assume that in our case a part of the dolphins died from natural causes, such as diseases.

The expedition of 2011 found the remains of two harbour porpoises and one large Black Sea bottlenose dolphin in the same area, between the Poludenne and the Bystre Arms. A case of devourment of the dead bottlenose dolphin by a wild boar was recorded.

According to fishermen, a large shoal of porpoises was observed in Zhebrianska Bay in mid July, a week prior to the start of the 2012 expedition.

According to visual observations the abundance of dolphins close to the coast in June–July 2012 along the north-western Black Sea seashore from the Danube Delta to Odessa City was much higher than in the same period of 2011. It was due to sea currents which caused the fish shoals to come closer to the coast. If such conditions will recur (because of climate change) the number of dolphins and porpoises in the catches of local fishermen can substantially increase.

The results of observations, including the skeleton map and photo materials, were given to the Danube Biosphere Reserve, which is a focal point of the Ukrainian National Net for the Cetaceans Monitoring and Conservation (NNCC), and also to Brehm Laboratory (Simferopol, Ukraine) which is a co-ordination centre of the NNCC (http://www.dolphin.com.ua/).

The Danube Delta, including the territory of the Danube Biosphere Reserve, is very important for the NNCC activity, and the DHMO staff also provides registration of dead dolphins during annual expeditions. We would therefore recommend to extend an ecological component of the MED survey and include in it dolphin observations and cases of their death at the seashore or in fishing nets. The results of these observations will be submitted to the NNCC focal point in Vilkovo City, i.e. to the Office of the Danube Biosphere Reserve. Then they will be entered in a common database, also available on-line to supplement it with new data. These data are required to monitor the animal mortality rate and mortality causes.

A special attention should be paid to a section of the Kilia Danube Delta from the Poludenne Arm to the Bystre Arm. There, a dam, recently constructed for navigation in the Bystre Arm, buldges 2.5 m in the direction of the sea that a situation apparently creates the conditions to catch dead bodies of dolphins and porpoises that the waves had tossed up.

5. CONCLUSIONS AND PERSPECTIVES FOR FURTHER RESEARCH

1. The greatest impact on current MED-forming processes is due to the following factors: reduction of the Danube sediment runoff of, redistribution of the water flow between the Tulcea Arm and the Kilia Arm, and the rise of the Black Sea level. In the last years, the drainage of the Ochakovske Arm reduced the flow of sediments to the utmost. It was caused by a decrease of the water content in the Kilia Arm and the termination of dredging work in the Prorva Arm and its Soedinitelnyi Canal (2007). It obviously leads to a deficit of sediments in the northern part of the Kilia Delta, especially in dry years. In 2011–2012, erosion processes accelerated in the area of the northern spits of the Kilia Delta, at the mouth of the Potapovske Arm. The northern and southern parts of the Kilia Delta are not so much affected by sediment deficit owing to the relative stability of the Starostabmulske Arm.
2. The accumulation of polymeric waste, coming to the marine edge of the delta from the outside, is an ongoing process both in the growing and retreating parts of the MED.
3. As for 2011–2012, the Ukrainian MED holds about 2.5 tons of plastic bottles and about 0.5 tons of other synthetical waste.
4. The formation of pioneer vegetation in the Kilia Danube Delta depends on the composition of soil-forming structures, soil salinity and the development rate of the area. In the Danube Biosphere Reserve, 110 higher plant species participate in covering new coastal formations, which is a great number of plants for primary syngenesis.
5. Measures for dolphin protection in the Black Sea countries should be intensified. The Danube Hydrological Observatory (Izmail, Ukriane) is recommended to extend an ecological component of the MED survey programme and include in it dolphin observations and cases of their death at the seashore or in fishing nets.
6. Integrated monitoring of the marine edge of the Danube Delta should be continued and expanded, by involving Romanian experts as well.

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BIODIVERSITY OF ICHTHYOFAUNA IN THE DNIESTER DELTA

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Key-words: ichthyofauna, Lower Dniester, species composition, structure of catches, enviroGRIDS.

The List of current Lower Dniester fishes comprising 65 fish species belonging to 12 orders, 17 families and 52 genera is presented in the paper in a comparative approach. Analysis of the Lower Dniester and the Dniester Liman ichthyofauna structural characteristics has been carried out under conditions of regulated discharge, increasing pollution and spawning grounds degradation. Decrease in fish species composition has been shown, as well as the disappearance of some native reophilic and lithophilous fish species as the result of the Dniester River discharge regulation. Data about rare species found in the Dniester River and the Dniester Liman are presented, including *Benthophiloides brauneri* Beling et Iljin, 1927, which has not been recorded in the Lower Dniester before. The dwindling of catches of the main commercial fish species is also shown.

1. INTRODUCTION

According to current knowledge, the Dniester River and the Dniester Liman are among the most studied water-bodies of Ukraine. The first brief information about the Dniester water-bodies have been presented in papers by D. Kantemir, A.D. Nordman, I.M. Wiedhalm, N.Ya. Danilevskiy (Vinogradov, 1958). More significant information on the Dniester ichthyofauna is contained in the works of K.F. Kessler, was the first to present the fauna list of the Dniester fish, underlining the reophilic character of the river ichthyofauna (Kessler, 1874). It was K.F. Kessler, who divided his Dniester segment studies into parts comparing the ichthyological composition of catches – medium part from Galicia border to Dubossary town and the lower part (from Dubossary to the river mouth). His concepts are valid to this day (Kessler, 1874). The ichthyofauna of the Dniester River was studied and the Dniester Liman fisheries described at the beginning of the 20th century by prominent zoologists and hydrobiologists S.A. Zernov, F.F. Eherman, A.K. Makarov, E.K. Suvorov, A.A. Brauner (Brauner, 1887; Vinogradov, 1958). The full list and important information on the Dniester ichthyofauna were presented by Academician L.S. Berg in the 1920 (Berg, 1949). Systematic comprehensive fish studies in the Dniester were continued in the post-war period by ichthyologists V.L. Grimalskiy, M.S. Burnashev, B.C. Chepurnov, V.N. Dolgiy and many others (Burnashev et al., 1954; Vinogradov, 1958; Yaroshenko, 1957). Important data were reported in papers by I.I. Puzanov, A.R. Prendel, F.S. Zambriborsh (Vinogradov, 1958; Zambriborsch, 1953). At the end of the last century faunisitc lists of fish are found in papers by the hydrobiologists of Kiev gathered in the monograph edited by L.A. Sirenko and N.B. Evtushenko (Sirenko et al., 1992); in publications of ichthyologists V.A. Tkachenko and N.I. Goncharenko (Tkachenko et al., 1998). More recent data on ichthyofauna and fish-husbandry of the Dniester were generalized in the works of E.D. Vasileva (Vasil'eva, 2003), L.I. Starushenko and S.G. Bushuev (Starushenko et al., 2001; Bushuev et al., 2013), I.D. Trombitskiy, V.V. Lobchenko, T.D. Sharpanovskaya (Lobchenko et al., 2001) and many other ichthyologists, hydrobiologists and ecologists, not only Ukrainian or Moldavian, but also Russian.

As can be seen, within a period of 150 years a number of comprehensive surveys were carried out and a significant volume of factual material collected, which enabled researchers to receive

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principally new knowledge on the structural and functional characteristics of the Dniester ichthyofauna.

According to the results of those numerous studies, the decrease in the number of dominant ichthyofauna species, depauperation of fish fauna and changes of ichthyocoenoses are the immediate consequences of a wide range of anthropogenic factors that impact the Dniester River and the Dniester Liman ichthyofauna (Bushuev et al., 2013; Sirenko et al., 1992; Starushenko et al., 2001). The most vivid changes in fauna and biocoenoses were caused by river flow regulation – hydro-engineering transformation of the ecosystem.

After the construction of the Dubăsari dam (1954) and Novodniester Hydroelectric Station (1981) the Dniester River runoff was significantly decreased. In 1965–1971 it made at average of 12 km^3, in 1982–1987 – 10.4–6.5 km^3 (Sirenko et al., 1992). Nowadays, it does not exceed 7.0 km^3. On the other hand, the construction of the navigation channel to Belgorod-Dniester port via Tsaregradskaya Arm (1970) led to increased turnover between the liman and the sea. The annual volume of marine (salty) water, entering the liman, increased from 3.7 km^3 to 4–4.5 km^3 (Sirenko et al., 1992). Decreasing river flow, intensive development of the floodplain, above all bonding of meadows and floodplains for agricultural lands, salinization of the southern part of the liman, have led to the degradation of more than 40 thousand hectares of wetlands, including spawning grounds of phytophilous species of fish (Bushuev et al., 2013).

As a result of the intensification of fishing and frequent cases of poaching the volume of fish catches in the Dniester River and the Dniester Liman was reduced twofold or threefold compared to the 1990s. The number of commercial fish species declined from 21 to 16 (Starushenko et al., 2001; Bushuev et al., 2013). General and local water pollution, anthropogenic eutrophication, accidental or purposeful introduction of aggressive non-indigenous species influenced negatively the ichthyofauna (Bushuev et al., 2013; Sirenko et al., 1992; Starushenko et al., 2001). Changes of structure of the Dniester River and the Dniester Liman fish coenoses, as well as decrease in fish productivity of those watercourses have caused a stringent need to study the ichthyofauna current state comprehensively. The aim of this study is to evaluate the current state of the fish fauna of the Lower Dniester basin reservoirs, the species composition and abundance of the main representatives of the fish fauna, including endangered species.

2. MATERIALS AND METHODS

The results of the author's studies carried out in the Dniester Delta with financial support from the EU TACIS Project «Technical Assistance for the Lower Dniester River Basin Management Planning» in 2006–2007, the data received in the studies of the Dniester River ichthyofauna in the framework of the Research Project of the Ministry of Education and Science of Ukraine (2006–2013), as well as with support from the OSCE / UNECE / UNDP Project «Trans-boundary Cooperation and Sustainable Management of the Dniester River: Phase III – Implementation of Action Programme» («Dniester – III») and the ENVIROGRIDS Project of FP7 programme (2009–2012) were used in the paper. Besides, fishery statistics (Bushuev et al., 2013; Starushenko et al., 2001). and the data collected during analyses of commercial catches of the «Kalkan» private enterprise, as well as anglers' catches in 2007–2013 were used in the work. During the surveys fish was caught using small mesh size fingering trawl (30.0 m long, 1.5 m high, mesh 6–8 mm); fyke-nets (mesh 6–8 mm); research multi-mesh gillnets; gillnets (mesh size 13, 30 and 65–70 mm, length 30, 100 and 750 m, respectively); small mesh size fingering trawl (10 m long, 1.2 m high, mesh size 6.0–8.0 mm), dredge (width 1.1 m, height 0.5 m) and throw net according to standard methodologies (Romanenko et al., 2006; Pryahin et al., 2008). The scheme of research catching is attached (Fig. 1). Altogether 900 different catches have been analysed.

Determination of fish has been done in the field using Keys (Berg, 1949; Kottelat et al., 2007; Movchan et al., 1980–1983; Zambriborsch, 1968). Taxonomy of fishes is presented in accordance with checklist (Kottelat et al., 2007; Bogutskaya et al., 2004). Environmental characteristics of species are presented according to (Movchan et al., 1980–1983). The appurtenance to faunistic complexes is shown in line with (Nikolskiy, 1980).

The following categories have been chosen for quantitative assessment of the values of fish occurrence: rare species (separate specimens of the fish were observed during the entire period of studies), common and dominant species (more than 100 specimens for a year of studies).

To assess the level of species composition similarity between the Middle Dniester and the Lower Dniester in successive associated periods from 1930 to 2013, Sorensen-Chekanovskiy Index *(I_{CS})* and Shimkevich-Simpson Index *(I_{SzS})* were used (Pesenko, 1982). Alterations of species composition were assessed from relative occurrence, appurtenance of fish to different ecological groups: by habitats, breeding. Index of changes (Titlyanova et al., 1993) was calculated as ratio of disappeared and emerged species at present time to the number of species found before hydro-engineering transformation of the Dniester (the fish species list was taken from the paper by L.S. Berg (Berg, 1949). Dynamics of commercial catches was presented according to (Starushenko et al., 2001; Bushuev et al., 2013).

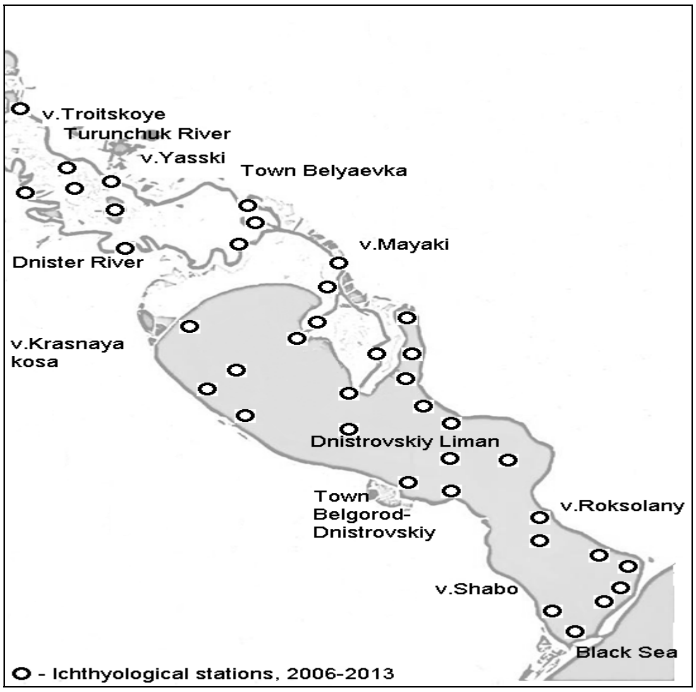

Fig. 1 – Scheme of Ichthyological Stations in the Lower Dniester, 2006–2013.

3. RESULTS AND DISCUSSION

3.1. Dynamics of the Dniester Ichthyofauna Structural Characteristics

Based on generalising the results received by the author from analyses of research catches in the Lower Dniester in 2006–2013, 65 fish species belonging to 12 orders, 17 families and 52 genera were revealed (Table 1).

Table 1

Taxonomic Composition of the Dniester River Ichthyofauna and Occurrence of Species.

Taxa	**Data According to Berg, 1949**	**Data According to Zambriborsch, 1953**	**Data According to Sirenko et al., 1992**	**Data of 2006-2013***	**Protection Status of Species**
1	**3**	**4**	**5**	**6**	**7**
Petromyzontiformes					
Petromyzontidae					
Eudontomyzon mariae (Berg, 1931)	+	-	+	-	RBU, IUCN
Acipenseriformes					
Acipenseridae					
Acipenser gueldenstaedtii Brandt & Ratzeburg, 1833	+	+	+	-	RBU, IUCN, EL, BC
Acipenser nudiventris Lovetsky, 1828	r	r	-	-	RBU, IUCN, EL
Acipenser ruthenus Linnaeus, 1758	+	+	+	-	RBU, IUCN, EL, BC
Acipenser stellatus Pallas, 1771	+	+	+	r	RBU, IUCN, EL, BC
Huso huso (Linnaeus, 1758)	+	+	+	r	RBU, IUCN, EL, BC
Atheriniformes					
Atherinidae					
Atherina boyeri Risso, 1810	+	+	+	+	
Beloniformes					
Belonidae					
Belone belone (Linnaeus, 1761)	-	+	-	-	
Gasterosteiformes					
Gasterosteidae					
Gasterosteus aculeatus Linnaeus, 1758	+	+	+	+	
Pungitius platygaster (Kessler, 1859)	+	+	+	+	
Mugiliformes					
Mugilidae					
Liza aurata (Risso, 1810)	-	+	-	+	
Liza saliens (Risso, 1810)	+	+	-	-	
Liza haematocheila (Temminck & Schlegel, 1845)	-	-	-	i, +	
Mugil cephalus Linnaeus, 1758	+	+	-	-	
Perciformes					
Centrarchidae					
Lepomis gibbosus (Linnaeus, 1758)	-	r	+	+	
Gobiidae					
Benthophiloides brauneri Beling et Iljin, 1927	-	-	-	r	RBU, IUCN
Benthophilus nudus (Berg, 1898)	+	+	-	+	
Gobius niger Linnaeus, 1758	-	-	-	r	
Gobius ophiocephalus Pallas, 1814	r	+	-	-	
Knipowitschia caucasica (Berg, 1916)	-	+	-	-	
Knipowitschia longecaudata (Kessler, 1877)	-	+	-	+	
Mesogobius batrachocephalus (Pallas, 1814)	r	+	+	r	
Neogobius eurycephalus (Kessler, 1874)	-	-	-	r	
Neogobius fluviatilis (Pallas, 1814)	+	+	+	+	
Neogobius gymnotrachelus (Kessler, 1857)	+	+	+	+	
Neogobius kessleri (Gűnther, 1861)	+	+	-	r	
Neogobius melanostomus (Pallas, 1814)	+	+	+	+	
Neogobius syrman (Nordmann, 1840)	-	+	-	-	
Proterorhinus marmoratus (Pallas, 1814)	+	+	-	+	
Percidae					

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Table 1 (continued)

Gymnocephalus acerina (Gmelin, 1789)	+	+	+	-	RBU, IUCN
Gymnocephalus cernua (Linnaeus, 1758)	+	+	+	+	
Perca fluviatilis Linnaeus, 1758	+	+	+	+	
Percarina demidoffii Nordmann, 1840	r	+	+	r	RBU, EL
Sander lucioperca (Linnaeus, 1758)	+	+	+	+	
Sander volgensis (Gmelin, 1789)	+	r	-	-	RBU, IUCN, BC
Zingel zingel (Linnaeus, 1766)	+	+	+	r	RBU, IUCN, BC
Pomatomidae					
Pomatomus saltatrix (Linnaeus, 1766)	-	+	-	r	
Sparidae					
Diplodus annularis (Linnaeus, 1758)	-	+	-	-	
Pleuronectiformes					
Pleuronecthidae					
Platichthys flesus (Linnaeus, 1758)	+	+	+	+	
Scophthalmidae					
Psetta maxima maeotica (Pallas, 1811)	-	+	-	-	
Scorpaeniformes					
Cottidae					
Cottus gobio Linnaeus, 1758	+	-	+	-	
Cottus poecilopus Heckel, 1837	+	-	+	-	
Syngnathiformes					
Syngnathidae					
Nerophis ophidion (Linnaeus, 1758)	+	+	-	-	
Syngnathus abaster Risso, 1827	+	+	-	+	
Syngnathus typhle Linnaeus, 1758	r	+	-	r	
Anguilliformes					
Anguillidae					
Anguilla anguilla (Linnaeus, 1758)	r	r	+	r	EL
Clupeiformes					
Clupeidae					
Alosa tanaica (Grimm, 1901)	r	-	+	-	
Alosa maeotica (Grimm, 1901)	+	+	+	+	
Alosa immaculata Bennett, 1835	+	-	-	+	EL
Clupeonella cultriventris (Nordmann, 1840)	+	+	+	+	
Engraulidae					
Engraulis encrasicolus (Linnaeus, 1758)	-	+	-	-	
Cypriniformes					
Balitoridae					
Barbatula barbatula (Linnaeus, 1758)	+	-	+	-	
Catostomidae					
Ictiobus cyprinellus (Valenciennes, 1844)	-	-	+	-	
Cobitidae					
Cobitis rossomeridionalis Vasil'yeva & Vasil'ev, 1998	+	+	+	+	
Misgurnus fossilis (Linnaeus, 1758)	+	+	+	+	
Sabanejewia aurata (De Filippi, 1863)	-	-	+	r	
Cyprinidae					
Abramis ballerus (Linnaeus, 1758)	+	+	-	-	
Abramis brama (Linnaeus, 1758)	+	+	+	+	
Abramis sapa (Pallas, 1814)	+	+	+	r	
Alburnoides bipunctatus (Bloch, 1782)	+	-	+	-	
Alburnus alburnus (Linnaeus, 1758)	+	+	+	+	
Aspius aspius (Linnaeus, 1758)	+	+	+	+	
Barbus barbus (Linnaeus, 1758)	+	r	+	r	RBU, IUCN
*Barbus carpathicus*Kotlik, Tsigenopoulos, Rab et Berrebi, 2002	+	-	-	-	

Table 1 (continued)

Blicca bjoerkna (Linnaeus, 1758)	+	+	+	+	
Carassius gibelio (Bloch, 1782*)*	+	-	+	+	
Carassius carassius (Linnaeus, 1758)	+	+	+	r	RBU, IUCN
Chondrostoma nasus (Linnaeus, 1758)	+	+	+	r	
Ctenopharyngodon idella (Valenciennes, 1844)	-	-	+	+	
Cyprinus carpio Linnaeus, 1758	+	+	+	+	EL
Gobio gobio (Linnaeus, 1758)	+	+	+	r	
Romanogobio kesslerii (Dybowski, 1862)	+	-	+	r	RBU, IUCN, BC
Hypophthalmichthys molitrix (Valenciennes, 1846)	-	-	+	+	
Hypophthalmichthys nobilis (Richardson, 1846)	-	-	+	+	
Leucaspius delineatus (Heckel, 1843)	+	+	+	+	
Leuciscus cephalus (Linnaeus, 1758)	+	+	+	r	
Leuciscus idus (Linnaeus, 1758)	+	+	+	r	
Leuciscus leuciscus (Linnaeus, 1758)	+	+	+	-	RBU, IUCN
Petroleuciscus borysthenicus (Kessler, 1859)	+	r	-	r	
Pelecus cultratus (Linnaeus, 1758)	+	+	+	r	
Phoxinus phoxinus (Linnaeus, 1758)	+	-	+	-	
Pseudorasbora parva (Temminck & Schlegel, 1846)	-	-	+	+	
Rhodeus amarus (Bloch, 1782)	+	+	+	+	
Rutilus frisii (Nordmann, 1840)	+	+	+	r	RBU, IUCN, BC
Rutilus rutilus (Linnaeus, 1758)	+	+	+	+	
Scardinius erythrophthalmus (Linnaeus, 1758)	+	+	+	+	
Tinca tinca (Linnaeus, 1758)	+	+	+	r	
Vimba vimba (Linnaeus, 1758)	+	+	+	r	
Siluriformes					
Siluridae					
Silurus glanis Linnaeus, 1758	+	+	+	+	
Lotidae					
Lota lota (Linnaeus, 1758)	+	-	+	-	RBU
Esociformes					
Esocidae					
Esox lucius Linnaeus, 1758	+	+	+	+	
Umbridae					
Umbra krameri Walbaum, 1792	+	+	+	r	RBU, EL, BC
Salmoniformes					
Salmonidae					
Oncorhynchus mykiss (Walbaum, 1792)	-	-	+	-	
Salmo labrax Pallas, 1814	+	+	+	-	RBU, IUCN
Thymallus thymallus (Linnaeus, 1758)	+	-	+	-	RBU, IUCN, BC
Altogether species:	**74**	**71**	**67**	**65**	**23**

Notes: * – author's own data and results of the Lower Dniester ichthyofauna studies in the framework of the OSCE / UNECE / UNDP Project «Trans-boundary Cooperation and Sustainable Management of the Dniester River: Phase III – Implementation of Action Programme» («Dniester – III»);

- – species not found; + – common species; r – rare species; i – introduced species;

RBU – Read Book of Ukraine (2009); IUCN – List of International Union for Conservation of Nature (2001, 2004); EL – European Red List (IUCN Red List Status – Ex-Nt) (2011); BC – list of fish species from the Protocol of the Bern Convention on the Conservation of European Wildlife and Natural Habitats (1979).

Analysis of taxonomic composition dynamics of the Lower Dniester ichthyofauna from 1930 to 2013 has shown that no significant changes have generally taken place in the taxonomic structure of the Dniester fish coenoses. For example, the number of fish species registered in the river at present is only 1.2 times lower than the number presented in the list of species by L.S. Berg, who had been studying the Lower Dniester ichthyofauna early last century, before artificial regulation of the river flow began.

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Reduction of the Dniester ichthyofauna species composition during the period of studies, caused by disappearance of such native species as *A. nudiventris*, *C. chalcoides*, *A. ballerus*, *S. volgensis*, *Z. zingel*, *A. bipunctatus* and some other, was compensated due to the introduction into the Dniester water-bodies of some new species: *C. gibelio*, *H. molitrix*, *C. idella*, *P. parva*, *L. haematocheila*, *L. gibbosus*. As a result, the number of the Dniester fish species stayed relatively stable for the past 70–80 years. Besides comparing the quantity of species, common for the two periods practically no changes, varying from 48 to 61.

Relative similarity of fish populations of the Dniester in different periods of time between 1930 and 2013 is confirmed by the results received from the calculation of the Sorensen-Chekanovskiy and the Shimkevich-Simpson indices of species similarity. The values of these indicators stay practically unchanged not only in cases of comparison between lists of species for successive associated periods, but also in the cases of studies separated by significant periods of time (Table 2).

Table 2

Species similarity indices of the Dniester River Ichthyofauna by Comparison of Different Studies from 1930 to 2013

Period of Studies	**Period of Studies**			
	1930–1940 (Berg, 1949)	1950–1960 (Zambriborsch, 1953)	1983–1989 (Sirenko et al., 1992)	2006–2013 (Our own data)
Sorensen – Chekanovskiy Index of Species Similarity*				
1930–1940 [1]	X	0,47	0.46	0.44
1950–1960 [26]	0.47	X	0.43	0.45
1983–1989 [19]	0.46	0.43	X	0.45
2006–2013 (Our own data)	0.44	0.45	0.45	X
Shimkevich-Simpson Index *				
1930–1940 [1]	X	0.48	0.47	0.46
1950–1960 [26]	0.48	X	0.44	0.46
1983–1989 [19]	0.47	0.44	X	0.45
2006–2013 (Our own data)	0.46	0.46	0.45	X

Note: * calculating similarity indices of lists of the species observed in different segments of the river, specific features of the Lower Dniester ichthyofauna have been taken into account and the species characteristic of the Upper and the Middle Dniester were ignored and so were the marine species found only in the Dniester Liman and difficult to spot, for example: *B. belone*, *B. brauneri*, *K. longecaudata*, *D. annularis*, *P. saltatrix*, *T. thymallus* and other species.

However, it should be pointed out that while the taxonomic structure of ichthyofauna in general stayed relatively stable during the discussed period, the situation with many separate species in the Lower Dniester changed significantly, which evidences more global transformation of the Lower Dniester water-bodies' structural characteristics. For example, the share of species characterised by a high number and included into the category of "common species" has by now shrunk to 33.8% of the total number of species found, while in mid-20th century over 85% of the found species could be referred to as 'common' (Table 3). Besides, the number of rare species grew by now 3–4 times, the number of very rare increased by an order of magnitude, including the extinct species that inhabited the river before its hydro-engineering transformation.

Table 3

Number of Introduced and Native Species (%) of Separate Categories of the Lower Dniester Relative Ichthyofauna Abundance for the Period 1930–2013

No. of Species, %	**Period of Studies**			
	1930–1940 (Berg, 1949)	1950–1960 (Zambriborsch, 1953)	1983–1989 (Sirenko et al., 1992)	2006–2013 (Our own data)
Common	87.8	85.9	70.2	33.8
Rare	8.1	8.5	10.4	38.5
Very rare and extinct	1.4	4.2	6.0	15.4
Introduced	2.7	1.4	13.4	12.3
Altogether species, absolute units	**74**	**71**	**67**	**65**

So, if we consider the state of ichthyofauna by taking into account the abundance of separate species, significant restructuring of the Lower Dniester ichthyocoenoses' structural elements becomes evident. As a result, more than 1/3 of the species registered at present have the status of increased risk and 1/6 of species are in danger of extinction.

Under ever higher anthropogenic pressure on the Dniester, disturbance of hydrology and flow regulation, destruction of spawning grounds by sand and gravel extraction, as well as floodplain development, the transformation of ichthyofauna will progress, which will end in significant shrinking of the fish species list.

Analysis of the data collected enables us to single out from the current ichthyofauna of the Dniester River and the Dniester Liman representatives of four main faunistic complexes. Introduced species (13.3% of the species found) have been combined for convenience into one general group. Dominant complex is the Ponto-Caspian marine complex (34.0%), which comprises the brackish water and sea species widespread in the lower part of the Dniester Liman that became significantly more saline as a result of the hydro-technical changing of the ecosystem (Table 4).

The significance of limnophilic and reo-limnophilic species within the ecological groups has increased, which is characteristic of a decreased flow speed and increased turbidity.besides the number of reophilic, lithophilous and psammophilous species has decreased. On the contrary, the number of introduced species has increased significantly (index of changes 3.0).

Table 4

Dynamics of Composition of Separate Ecological Groups of Ichthyofauna in the Dniester River in the period 1930 – 2013

Ecological Groups	**No. of Species, Absolute Units**		**Index of Changes**
	Data acc. To L.S. Berg, 1949	Data of 2006–2013	
Fresh water	44	42	0.1
Brackish water	25	20	0.2
Marine	5	3	0.4
Migratory	8	5	0.4
Demersal	36	33	0.1
Pelagic	7	7	-
Bottom-pelagic	31	25	0.2
Lithophilous	20	15	0.3
Psammophilous	3	2	0.3
Phytophillous	21	20	0.1
Pelagophyls	13	12	0.1
Ostracophils	1	1	-
Depositing eggs in 'nests'	13	13	-
Carrying eggs	3	2	0.3
Introduced	2	8	3.0

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3.2. Dynamics of the Lower Dniester Commercial Ichthyofauna

Against the background of the Lower Dniester ichthyofauna characteristics changes in general, reduction of commercial species composition are also observed, though, as mentioned previously, the Lower Dniester ichthyofauna has been enriched with new commercial species, such as *H. molitrix*, *H. nobilis, C. idella*, *L. haematocheila*. Similarly, from the 1990s till now statistics of catches does not reflect Acipenseridae, *T. tinca*, *R. frisii*, *P. cultratus*, *V. vimba*, *P. demidoffii* and some other species, which evidences that those species either have disappeared completely or occur in the Lower Dniester very seldom.

According to statistics of catches, only 18 commercial species were found in the yields of 2012–2013. Total yield size in the Lower Dniester and the Dniester Liman is relatively stable for the past 5 years and varies between 448.9 and 509.6 tons per year. Catches consist mainly of *A. brama* (31.4% of average annual size of total yield) and *C. gibelio* (23.7%). The share of other fish in commercial catches is smaller: *H. molitrix* (depending on stocking quantities) – 9.8%, *R. rutilus* – 5.9%, *Alosa gen. sp.* – 5.3%, *B. bjoerkna* – 5.1%, *P. fluviatilis* – 4.9%, *S. lucioperca* – 3.9%, Gobiidae – 3.5%, *C. carpio* – 2.7%. Even smaller in the yields are the shares of *E. lucius* (0.7%), *S. glanis* (0.4%), *A. aspius* (0.4%), *S. erythrophthalmus* (0.3%), *L. haematocheila* (0.1%). Average annual yields of *C. cultriventris*, *A. boyeri* and some other species do not exceed 1.6%.

According to the data collected, as well as to commercial statistics (Starushenko et al., 2001; Bushuev S.G. et al., 2013) compared to the 1990s catches from the Dniester River and the Dniester Liman have decreased 2.0–3.0 times (Fig. 2). Keeping in mind that part (40 to 80%) of the catches has always been concealed by fishermen and consequently not included in the statistics of commercial yields, the data on the decrease of commercial catches presented above are, probably, not reliable enough. Taking into consideration oral information from the fishermen of the Dniester River and the Dniester Liman we may conclude that the quantity of fish caught decreased for the past 25 years by 4.0–5.0 times.

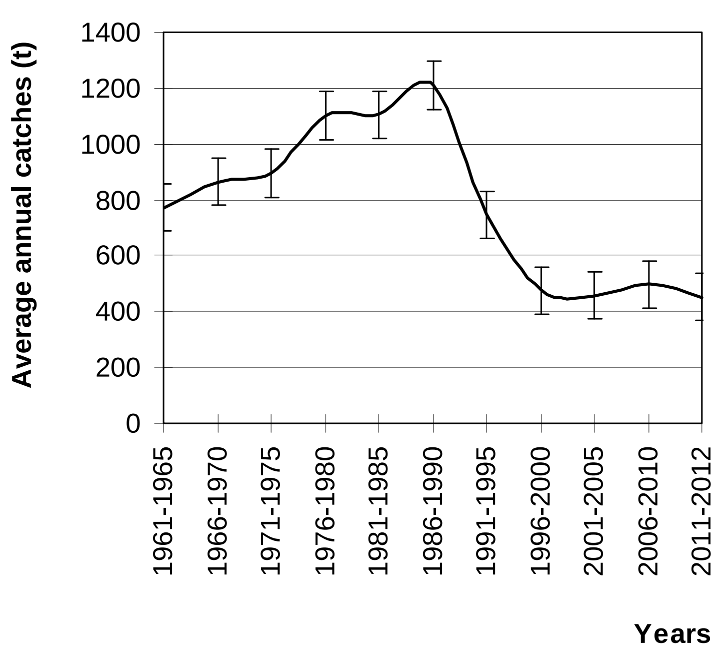

Fig. 2 – Average annual catches (t) of the main commercial fish species in the Lower Dniester, 1961–2012.

Analysis of average annual catches of some species also shows that the decrease in fishery yields in the Dniester Liman is more significant. According to statistics of commercial yields the catches of *S. lucioperca* in the Liman have decreased 9.1 times compared to the 1990s, catches of *R. rutilus* – 8.7 times, *C. carpio* – 6.3 times, *A. brama* and *C. gibelio* – 2.6 and 2.5 times, respectively (Fig. 3). While decrease in the catches of more important species like pike-perch, carp and roach could to a certain extent be connected with the fact that fishermen conceal a greater share of yields, the decrease in catches of *A. brama* and *C. gibelio* is no doubt the result of conditions for fish deteriorating in the Dniester Liman.

At present, more than enough has been said about the reasons for decreasing yields in the Lower Dniester. Noteworthy probably most of it was formulated back in 1887 by A.A. Brauner in his paper «Sketchbook on Fishery in the Dniester River and the Dniester Liman within Odessa Region». According to the observations made by this prominent scientist, over a 20-year period from the 1860s to 1887, catches from the Lower Dniester water-bodies decreased because of fine-meshed fishing gear and, as a result, much fry as by-catches; catching during spawning-run and during spawning; development of riparian land.

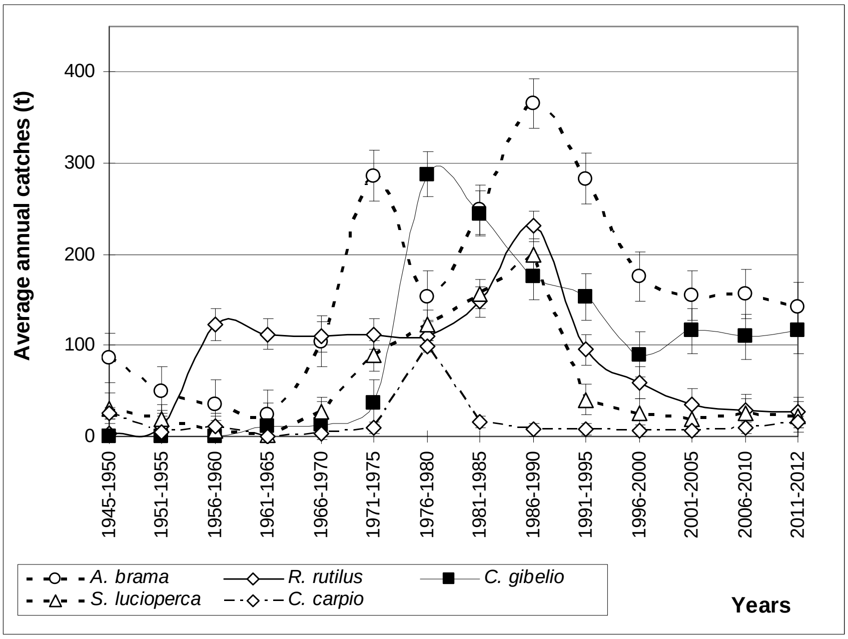

Fig. 3 – Average annual catches (t) of five main commercial fish species in the Lower Dniester in 1961–2012.

At present, with the significant increase of the catching capacity of fishing gear, first of all fine-meshed gillnets of angling line, catching of fry has increased in total to 50–75% of the general yield when nets with mesh size 30–32 mm is used. Illegal fishery, especially with electric rods, is widespread in the Dniester and damages ichthyofauna irreversibly. Uncontrolled fishery during spawning periods goes on. The unsatisfactory hydrological regime of the Lower Dniester, illegal development of riparian land on the banks of the river and the liman, uncontrolled sand and gravel extraction have caused significant shrinking of spawning and feeding areas of most fish species in the Lower Dniester. Under these conditions we have to expect further reduction of species composition and decrease of catches in the Lower Dniester.

Thus, at present in the catches from the Lower Dniester and the Dniester Liman are dominated by such species as *A. brama* and *C. gibelio*, and also, but to a lesser extent, *B. bjoerkna*, *R. rutilus*,

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C. carpio, *H. molitrix*, *S. lucioperca*, *E. lucius*, *S. glanis* and *P. fluviatilis*. Non-commercial fish species, whose size is insignificant, are abundant: *N. fluviatilis*, *N. melanostomus*, *N. gymnotrachelus*, *P. marmoratus*, *A. alburnus*, *R. amarus*, *P. parva*, *L. gibbosus*. Those species are quite widespread in the Lower Dniester and are common.

Other species are found in the Lower Dniester much more seldom. There are many reason for the decrease in their number, among which are, first of all, regulation of the river flow, significant shrinking of spawning grounds, anthropogenic eutrophication and general pollution of the Dniester water-bodies. For example, individual specimens of psammophillous fish (*G. gobio*, *R. kesslerii*) and of almost all the lithophilous species (*A. stellatus*, *H. huso*, *P. demidoffii*, *Z. zingel*, *S. aurata*, *B. barbus*, *C. nasus*, *L. cephalus*, *V. vimba*) are at present registered mainly in the middle part of the river, while before the hydro-engineering changes of the Dniester, *V. vimba*, for example, was one of the main commercial species. Catches of this fish totalled 180 tons per year or around 25% of the total yield in the Dniester Liman. Catches of *P. demidoffii* exceeded 200 tons per year – 42% of the total yield. Average annual catches of Acipenceridae in the Dniester Liman equall 3.8 t (Starushenko et al., 2001). During studies over 2006–2013, some phytophilous species (*A. sapa, C. carassius, R. frisii*, *T. tinca*) were very seldom registered in catches, though before catches of, for example, *C. carassius* and *T. tinca* in the Dniester Liman totalled 10 tons per year (Starushenko et al., 2001). According to the results of studies, significant changes have taken place in the Dniester River from 1930 to the present day. Species composition has decreased 1.2 time. *A. nudiventris*, *S. volgensis*, *Z. streber*, *B. barbatula, A. ballerus, C. chalcoides* have disappeared or are considered extinct. Many fish species that used to be widespread in the Dniester water-bodies and considered common have become rare now. The number of introduced species has increased. Commercial catches have decreased 2–3 times.

4. CONCLUSIONS

1. During studies in the 2006–2013 period, 65 fish species belonging to 12 orders, 17 families and 52 genera were registered in the Dniester River and the Dniester Liman.
2. Out of the 65 species, 11 are listed in the Red Book of Ukraine, 8 – in the IUCN List, 6 – in European Red List, and 6 are protected under the to Bern Convention. In 2007, in the middle part of the Dniester Liman the *B. brauneri* Beling et Iljin, 1927 was found – first registration in the Dniester Liman.
3. Increased anthropogenic pressure on the Dniester River and its water-bodies has resulted in the transformation of ichthyofauna: decrease of fish species composition 1.2 time, 2.3 times decrease of rare indigenous fish species, decrease in the number of reophilic, lithophilous and psammophilous fish species.
4. In connection with species composition negative transformation and a 2.0–3.0 time decrease of commercial catches in the Dniester River and the Dniester Liman calls for urgent measures to strengthen the protection of fish resources, restoration of stock and improvement of the Lower Dniester ecosystem's environmental health in general.

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CHANGES IN THE DYNAMICS AND DEMOGRAPHIC STRUCTURES OF THE ROMANIAN URBAN POPULATION. AN OVERVIEW OF THE POST-COMMUNIST PERIOD

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Key-words: urban population, changes, demographic size, population structures, Romanian towns enviroGRIDS.

In the present period Romania's urban system is undergoing a process of restructuring, the urban phenomenon acquiring new dimensions and characteristics. Thus, the industrial town – the representative type of urban settlement, has largely been replaced by the polyfunctional and services type, a trend that met the country's major economic and social-political targets, set early in the Third Millennium, in line with Romania's integration into the European urban system. Another trend, this time in rural-urban evolution, was to raise communes, viewed as local polarisation cores, to town status. Consequently, between 2003 and 2011, a number of 53 settlements (out of the 60 given town rank after 1989) were raised to this position. Although in the post-war period and up to the last 20th-century decade the share of Romania's urban population/total population was steadily growing (55% in 1997), yet the annual average growth rate was gradually declining, the numerical increase of townspeople slowing down. Since in the 1990–2011 interval, the urban population would even decrease, also the level of urbanization was slightly dropping (54%). The demographic structures themselves suffered some changes in that the female population increased, the young one decreased, while mature and elderly people became evermore numerous.

1. INTRODUCTION

Until mid-20th century, Romania continued to be a rural-agrarian country, with a low urbanisation level (23.4% in 1948). The geographical features of its territory and the turbulent history of this part of Europe made the Romanian society maintain its dominantly rural traits.

In the inter-war period, as industrialisation was progressing, urban development was boosted, the number of towns increasing from 119 in 1912 to 142 in 1930 and 152 in 1948. As a result, the town population grew by 1.8 times, at an annual average rate of 45,000 persons between 1912 and 1948, that is from 16% in 1912 to 23% in 1948.

In the second half of the 20th century Romania's economic and social development policies led to radical changes in these fields. There were two major transition periods, 1950–1960/1962 that marked the passage from the capitalist economy to the highly centralised plan-based socialist system, and the post-1989 period, when the socialist economy began being replaced by the market system. Between 1950 and 1989, Romania, like other Central-European socialist countries, opted for the extensive industrialisation model associated with explosive urbanisation and with territorial planning schemes. In the 7th, 8th and 9th decades, the creation of a balanced county structure helped strengthening the national urban system. As a result, by 1986, more than half the population of Romania lived in town.

It might be said that the aim of the post-war industrialisation and urbanisation policy was largely attained through gradual transition from the traditional rural-agrarian society to the urban-industrial society of the 1990s. It was a stagewise evolution that took on different forms, had a dynamics of its own, and in the course of urbanisation, developed specific socio-cultural features.

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2. URBAN POPULATION DYNAMICS AND URBANISATION LEVEL

One of the evolution trends in the rural-urban interface manifest on the vertical plane this time, is the increasing transformation of communes, viewed as local polarisation cores, into towns (*Law No. 351/2001, annex II-6.1.* designated 17 zones, with no town within a radius of 25–30 km, which were to develop urgently into localities with inter-communal servicing role). In this way, the Romanian urban system was enlarged (2003–2010) with 53 out of the 60 settlements raised to town status after 1989 (Săgeată R, 2012).

The consequence of this increase was, among other things, the strengthening of the county urban networks and their better balanced distribution within the national territory. The average number of towns/county rose from 3 in the early half of the 20th century to 7.8 in 2010, the majority of counties (over four-fifths from the total) listing between 4 and 9 towns (Table 2), more numerous in the counties of Suceava (16), Prahova and Hunedoara (14), Maramureş (13), and Constanța (12), with Giurgiu (3) and Bistrița-Năsăud, Brăila, Galați and Sălaj (4) standing at the bottom of the table.

Table 1

Counties grouped by town number in 2011

No. of towns	No. of counties	List of counties by number of towns
3	1	Giurgiu
4	4	Bistrița-Năsăud, Brăila, Galați, Sălaj
5	10	Buzău, Călăraşi, Covasna, Iaşi, Mehedinți, Neamț, Teleorman, Tulcea, Vaslui, Vrancea
6	2	Cluj, Satu Mare,
7	5	Argeş, Botoşani, Dâmbovița, Dolj, Ialomița
8	4	Bacău, Caraş-Severin, Ilfov, Olt
9	2	Gorj, Harghita
10	4	Arad, Bihor, Braşov, Timiş
11	4	Alba, Mureş, Sibiu, Vâlcea
12	1	Constanța
13	1	Maramureş
14	2	Hunedoara, Prahova
16	1	Suceava

In 1990, Romania boasted a historic number of inhabitants – 23,206,720 persons. As of 1991, external migration getting momentum, natural growth declining (to negative in 1992), as did female fertility, and demographic ageing increasing, the country registered a numerical decrease of its population. In early 1992, the natural growth rate adding to external migration led to more than two million and six thousand fewer inhabitants between 1990 and 2011.

The ***numerical evolution of the urban population*** mirrors the growing level of urbanisation and, at the same time, the proportion of townspeople within Romania's total population throughout the 20th century, from a mere three million at the beginning of the century to 11.4 million in 2002 (Fig. 2). The absolute increase between 1912 and 2002 was of 9,371,338 inhabitants at an annual average of over 104,126 persons. Within the interval spanning the two censuses, the urban population fell from 11,435,080 in 2002 to 10,858,790 persons in 2011 that is by 576,290 fewer people, at an annual decrease of 64,032 inhabitants.

Although the share of urban population per total population had steadily increased in the post-war period, up to the 55% in 1997, by the end of the 1990s, the gradual diminution of the annual average growth suggests a slowdown of this process, and even an annual average numerical decrease of townspeople (by 97,700 persons up to 2002). As from 1999, this trend materialised in a slight decrease of the urbanisation level (54.8%) (Fig. 1). After 2002, the urban population growth (by 479,263 people in 2007) was the result of new towns emerging rather than a positive population dynamics. In 2007, the urbanisation level of 55.2% represented the maximum value ever recorded in

Romania, however, since in-between the last two censuses the number of urban population decreased, the level of urbanisation fell to 54.0%.

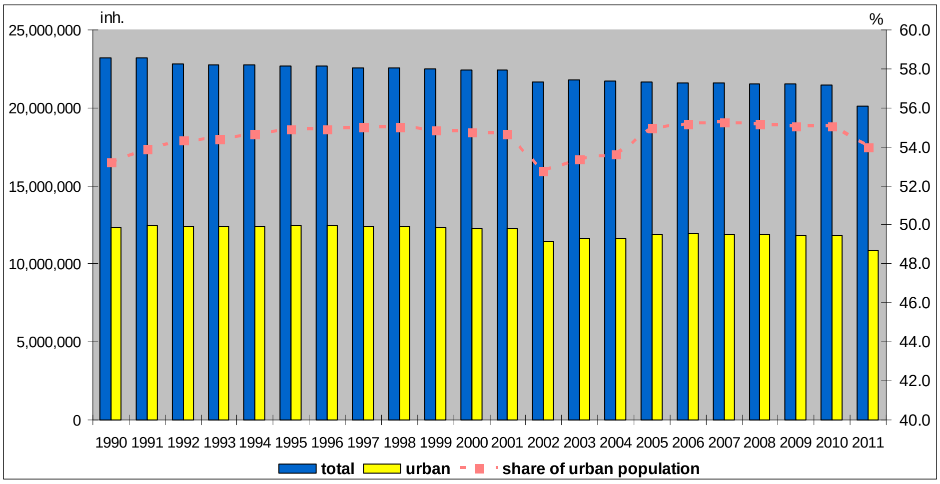

Fig. 1 – Urbanisation dynamics, 1990–2011.

Between 1992 and 2002, the permanent urban population dropped by 1.6%, compared to the rural one, in all counties, less so in Ilfov County where the number of townspeople increased by 11,166 persons (57.6%), steepest decreases being registered in Teleorman (-14.2%), Neamţ (-13.4%), Caraş-Severin (-13.3), Satu Mare (-12.8%), Bacău (-12.1), Braşov (-11.0%), Vaslui (-10.7%) and Hunedoara (-10.3%).

Compared to 2002, the permanent urban population ratio rose (by 1.3%) to the detriment of the rural one. The number of counties which registered increases is almost equal tot that with a decrease record. In the former category are the counties of Suceava (8.0%), Vâlcea (5.1%), Ialomiţa (4.9%), Maramureş (4.9%), Arad (4.7%), Botoşani (4.0%) and Gorj (3,2%). A special case is Ilfov County, in which the town attracted over 136,500 persons, this raising its percentage by 32.8% as against the 2002 census data. However, Bucharest's permanent residents dropped by 2.2% more than in the former census, one of the reasons being the City population migrating to neighbouring settlements in Ilfov County. Over 2002–2011, the lowest value of permanent populatyion ratio had Bacău and Covasna counties (2.8% and 2.3%, respectively). Highest negative values compared to 2002 had the countryside (9.6% to 5.0% in the urban area). While in the majority of counties decreases affected both the urban and the rural environments, the situation in Cluj County shows that the permanent town population fell by 14,000 people and the village one by 2,600 people. On the other hand, a reverse situation is seen in the counties of Arad, Botoşani, Ilfov, Suceava, Timiş and Vâlcea, that is, greater numbers in town than in the countryside.

In 2011, highest urban population percentages had the counties of Hunedoara (75.0%), Braşov (72.3%), Constanţa (68.8%), Cluj (66.3%), Sibiu (66.2%), Brăila (62.5%) and Timiş (61.8%). The closset difference between the permanent inhabitants of municipia, towns and communes registered Mureş, Bihor and Prahova (50.2%, 49.2% and 49.1%, respectively were town-dwellers). A number of 11 counties in Romania, had a town population below two-thirds of the county's permanent dwellers. It is the case of Dâmboviţa (28.9%), Giurgiu (29.2%), Teleorman (32.4%), Neamţ (36.0%), Vrancea (36.2%), Călăraşi (36.2%), Bistriţa-Năsăud (36.7%), Buzău (38.6%), Vaslui (38.7%), Olt (39.1%) and Sălaj (39.3%).

The pace of *urban demographic growth* in the latter half of the 20th century differed with each category of town and stage, in line with the objectives set by the central power to balance the county urban network by increasing the number of new towns. It also reflects the economic and social level attained by the urban system in various development stages.

Analysing the number of inhabitants is based on the rate of population growth in-between the 1992 and 2011 censuses surveys. The findings show that the average value of that interval was of -15.6%, with extreme returns for the towns of Bălan (59.3%) and Bragadiru (202.6%). Also, 90% of the 290 towns registered a demographic decline, with the exception of 30 towns, most of them situated in Ilfov County (the metropolitan area of Bucharest City), which had an increase record.

Urban centres with a positive or negative demographic growth record are listed below (Fig. 2):

a) Towns with big decrease (-59.3 – -30.1%). This category includes 37 towns (11.6%) located in the centre of Romania (Sinaia, Buşteni, Ştei, Cugir, Agnita, Tălmaciu, Făgăraş, Victoria, Cisnădie, Azuga), in the west (Anina, Moldova Nouă, Bocşa, Gătaia, Ciacova, Vulcan and Hunedoara – in the counties of Caraş-Severin, Timiş and Hunedoara), in the east (Solca, Milişăuți, Roman, Buhuşi, Oneşti, Bicaz, Broşteni – Moldavia Province) and in the south Sulina, Măcin and Turnu Măgurele.

b) Towns with moderate decreases (-30.0% – -1.1) are 249 (77.8% in the overall urban network), being relatively evenly spread in the territory.

c) Towns with stagnant evolution (-1.0 – 1.0%), no more than 6 (1.9% in the overall urban network): Şomcuta Mare, Seini, Eforie, Berbeşti, Turceni şi Nucet.

d) Towns with moderate increases (1.1 – 30.0%, 19 towns – 5.9% of the urban network) can be grouped into four categories: the presence of an industrial or services unit (Năvodari, Băbeni, Odobeşti, Salcea, Vicovu de Sus, Podu Iloaiei); location in the vicinity of a large town (Ungheni, Buftea), tourism (Techirghiol, Amara), and positive natural balance (Bolintin-Vale, Mihăileşti, Ştefăneşti, Topoloveni, Ulmeni, Tăuții-Măgherăuş, Fundulea).

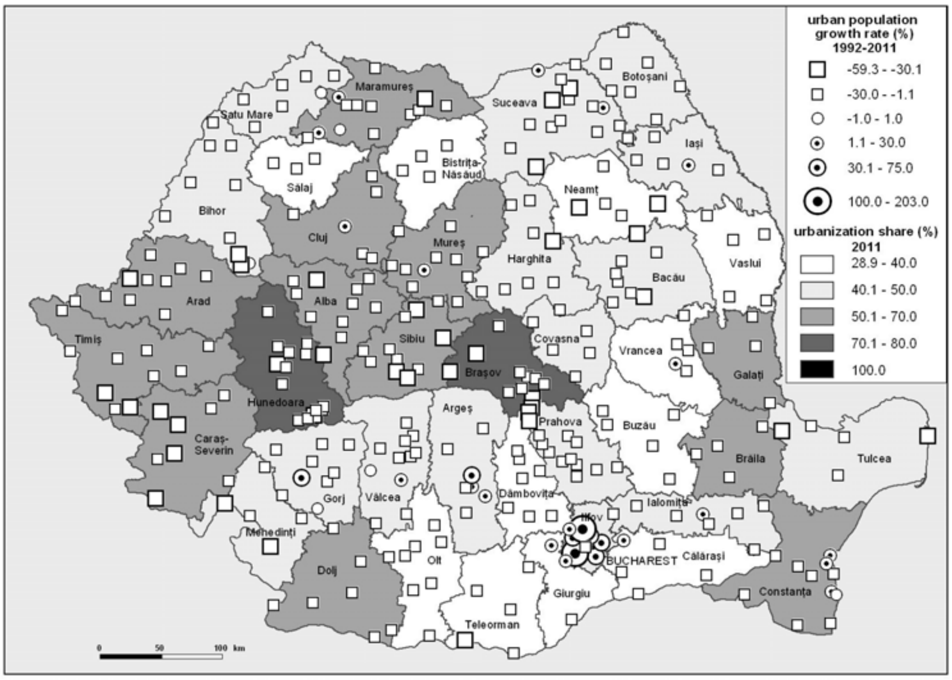

Fig. 2 – The territorial distribution of urbanisation in Romania, 1992–2011.

e) Towns with a big increase score (30.0 – 75.0%, 7 towns – 2.2% of the overall urban network) are concentrated in Ilfov County – Pantelimon, Popeşti-Leordeni, Voluntari, Chitila, and Măgurele. Once given town status, numerous Bucharest residents have developed new residential areas, thus adding to the local population. An obvious phenomenon in Romania's large cities is migration from the centre to the outskirts and from blocks-of-flats to one-family dwellings, or to new residential districts (Stănculescu and Berevoiescu, 2004, Grigorescu et al., 2012). Generally speaking, residential suburbanisation is changing the spatial distribution of population according to its socio-economic status, thus reversing the traditional socio-spatial pattern of the socialist city characterised by the socio-economic status of population declining with distance from the centre (Sykora and Ourednicek, 2007, Grigorescu et al., 2012).

On the other hand, the population of Mioveni (Argeş County) grew owing to the presence of Renault-Dacia Car Factory. In the case of Rovinari (Gorj County), it was the development of a new district Vârț and the inclusion of Poiana Village administrative area into that town.

f) Highest values registered the town of Otopeni (100.5%) and Bragadiru (202.6%), both within the influence area of Bucharest Municipium.

The growth of the urban population was the outcome of a number of factors, such as natural increase, rural inflows into the town, urban status granted to some communes and the inclusion of some villages into the administrative perimeter of towns. The extent to which these factors contributed to the numerical growth of the urban population and to the urbanisation of townspeople's life depends on the geographical region and the type of town. Although the ratio between these factors registered temporal changes, yet the high proportion of villagers adding to the urban population growth was a constant of the 6th–9th decades of the 20th century.

3. TOWN HIERARCHY BY DEMOGRAPHIC SIZE

Romania's urban network includes mainly small and medium-sized towns (under 100,000 inhabitants) which represent 9/10th of the total town number, with more than 2/3 of this group having under 20,000 inhabitants (Fig. 3). Their share within the total urban population is quite significant, but their relative weight has continually declined over the past 50 years. Concomitantly with the numerical extension of the urban network in the territory, the role of large cities with over 100,000 inhabitants each was being consolidated. Over the 1966–2002 interval, the number of these cities doubled and they acquired a higher demographic rank, 8 of them counting 200,000–325,000 inhabitants in 2011 (Cluj-Napoca, Timişoara, Iaşi, Constanța, Craiova, Brăila, Galați, and Ploieşti); Bucharest alone jumped at about two million, being the only very large city in this country (Fig. 4). However urban-rural migration and urban sprawl left Bucharest with fewer than 2 million inhabitants in 2011 (1,883,425 inh.).

There are few ***large cities*** with over 100,000 inhabitants (24 in 1992, and 19 at the 2011 census – therefore decreasing from 9.2% of the urban network in 1992 to 5.9% in 2011) (Fig. 3). These towns represented a distinct size-category within the national urban system in the post-war period. At present, this category includes part of the county-seats, important industrial and services centres, major national transport knots, university and cultural centres. An obvious demographic regress in the number of towns with over 300,000 inh., from 7 in 1992 to 2 in 2011 (Cluj-Napoca and Timişoara).

The geographical distribution of large cities is fairly uniform and they exert a greater or smaller influence over the activities discharged by the surrounding zones in larger or smaller areas. In terms of the economic basis and geographical expansion, large cities represent actual urban agglomerations with a distinct impact on the country's social and economic evolution. They are first-rank growth poles (Iaşi, Constanța, Cluj-Napoca, Timişoara, Braşov, Craiova, Sibiu, Galați, Brăila, Baia Mare) which have a strong influence on space organisation, modernisation of localities and urbanisation dynamics, balancing disparities between residential environments. The large Romanian cities have developed rapidly, simultaneously with the upsurge of the production forces across the country. Every second town-dweller and every fourth inhabitant of Romania is a large city-dweller. Their population dominates the urban settlement system and the territorial structure of the national economy.

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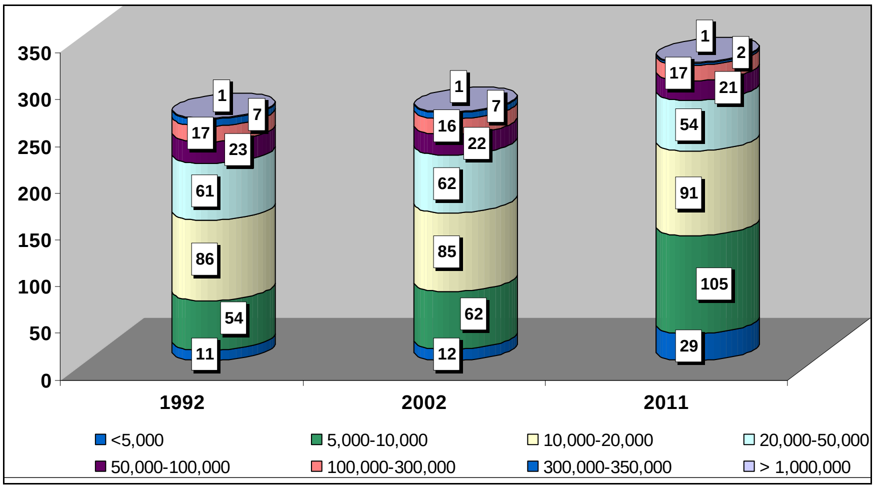

Fig. 3 – Towns grouped by demographic size, 1992–2011.

Medium-sized towns (75, 23.4% of the urban network in 2011 versus 84, 32.3% in 1992) number between 20,000 and 100,000 inhabitants. They play a major role in the national urban structure, given that 21 towns function as county-seats and are assigned the administrative co-ordination of the territory. The development of medium-sized towns goes back to Antiquity and the Middle Ages and was boosted by the 20th century industrial upsurge (Cugir, Codlea, Petroşani, Făgăraş, Reşiţa, Hunedoara, Mioveni and Săcele). But the massing of gigantic industrial units and the lack of functional flexibility makes this category of towns highly vulnerable, their future evolution depending on their ability to correlate industrial restructuring with the development of the tertiary sector.

This demographic category won either new county-seat municipia from the category with over 100,000 inh. (6 towns), or towns which in 1992 listed into the under 20,000 inh. category (3 towns).

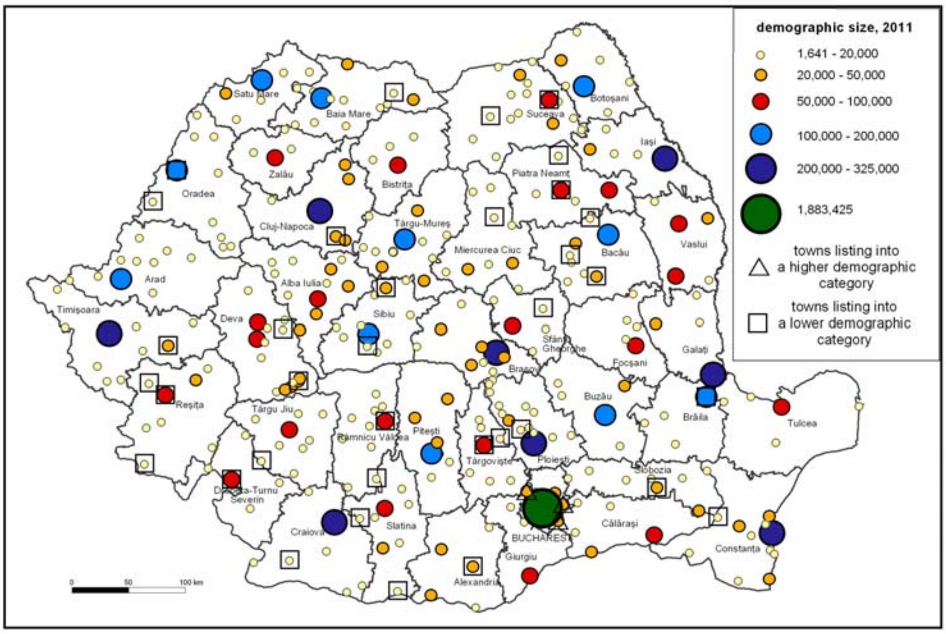

Fig. 4 – Towns grouped by demographic size, 2011.

Small towns (225, 70.3% of the urban network in 2011 versus 151, 58.1% in 1992) have a low demographic potential (under 20,000 inhabitants). This category, which has proved to be the most stable one in time and space, includes numerous new towns, as well as towns (20) with a long history documented in ancient or feudal times. During the socialist period, the 128 rural settlements assigned town status, would increase this demographic category. In the 20th century, despite absolute numerical growth, the share of small towns within the total urban population gradually decreased, from 33% in 1930 to 14.7% in 1980 and 14.4% in 2002. Since the settlements risen to town status after 2002 fell into the small-town category (except for Voluntari), they came to represent 19.3% of the overall urban population in 2010. It follows that small towns, inhabited by every seventh urban-dweller, hold a special place within the urban hierarchy, forming the base of the urban pyramid and discharging organisational functions within the national economy. The generic name of small towns comprises a huge variety of functional types: industrial, agro-industrial, spas and health resorts, the majority of them occupying a central position within the rural areas. The numerical growth of this category of towns over 1992–2011 was the outcome of some middle towns falling into this category and of low-demographic settlements being given town status.

Unlike the other two categories of town, small towns, left at the periphery of industrial and social progress, had to cope with many hardships in the course of their development. As a result, they are a pool of migrants for large cities. The difficulties of small towns reside in the irrational use of labour, the limited possibilities to use labour resources, the disproportionate sex structure of the workforce given the profile of the industrial centres (mining or textile), and the absence of a modern infrastructure, especially in the regions where the urban network is sparse. A special situation have the small industrial centres specialised in one branch alone. Here, there is a marked disproportion between the use of labour (by sex) and the mining centres based on exhausting resources, centres in which the population is on the decrease. Boosting their activity would require either to set up some complementary branches, or to strengthen their central role within the local systems.

Between 1992 and 2011, several towns (38) used to change their demographic category, but only three passed into a higher rank category (Popeşti-Leordeni, Pantelimon and Buftea in Ilfov County). The category of towns that declined to lower rank include the following: a) from 200,000 – 325,000 inh. to 200,000 inh. (Oradea and Brăila); from 100,000 – 200,000 inh. to under 100,000 inh., the case of county-seat municipia Târgovişte, Suceava, Piatra Neamț, Râmnicu Vâlcea, Reşița, Drobeta-Turnu Severin; from 50,000 – 100,000 inh. to under 50,000 inh. – these are either county-seat municipia (Alexandria and Slobozia), or former industrial towns under communism (Petroşani, Oneşti, Turda, Mediaş); from 20,000 – 50,000 to under 20,000 inh. – Drăgăşani, Buhuşi, Salonta, Moldova Nouă, Cernavodă, Târgu Secuiesc, Moreni, Băileşti, Gheorgheni, Orăştie, Vişeu de Sus, Târgu Neamț, Balş, Corabia, Băicoi, Cisnădie, Câmpulung Moldovenesc, Comăneşti, Bocşa, Motru, towns discharging generally industrial or mixed functions.

4. CHANGES IN THE DEMOGRAPHIC STRUCTURES

The dynamics of the population's sex and age structure is particularly important, it determining the evolution of the human communities and having profound demographic as well as social and economic implications.

The sex structure of the population, the outcome of the combined action of several factors (sex ratio of live newborns, distinctively different mortality between the two sexes, the population age structure) indicates the slight dominance of the female-to-male population, especially in town (Table 4). The evolution of the population's sex structure over the past 20 years revealed that, unlike in 1966 and 1977, the last three census data show a higher female ratio among the town population than the female ratio generally, irrespective of residential milieu (urban or rural, women are more numerous than men).

Table 4

Female population ratio to total population, census data over the 1992–2011 interval

Year	Total Romania	Urban
1992	50.8	51.2
2002	51.2	52.0
2011	51.4	52.2

In 1992, the urban population numbered 6,344,034 females (51.2%) versus 6,047,785 (48.8%) males. The increase of the female population over the 1992–2011 period compared to the male one accounts for the greater number of women per total urban population. The 2011 census data show 5,673,154 (52.2%) females to 5,185,636 males in the urban area, a situation found in all of Romania's counties. Bucharest Municipium tops the list in this respect (53.7%), another 15 counties standing between 52.0% and 53.0%. the same in 1992, in most counties, the urban female population representing over 50%, lest Gorj (49.8%) and Hunedoara (49.9%) specialised in the heavy industry (extractive, iron-steel), braches that generally require a male workforce.

Even through the male population ratio/total urban population was lower than the female one, yet it was the dominant element in a number of 57 towns (eg. Târgu-Ocna, Aiud, Rovinari, Mioveni). In 2002, only 21 towns, again heavy industry ones, had a similar record (Rovinari, Uricani, Vulcan, Borşa, Baia de Arieş, Vlăhiţa), as well as those raised tot town status after 2003.

The age structure of the urban population and of Romania generally, passed through significant mutations, owing mainly to severe demographic aging as the number and share of adults and elderly people, especially those aged 60 and over, would increase while the population under 15 years of age was decreasing. Compared to 1992, the 2002 ratio of the 0–14 year-group per total urban population fell from 24.3% to 15.9% simultaneoesly with the increase of the 15–59 group of adults from 64.1% to 69.3%.

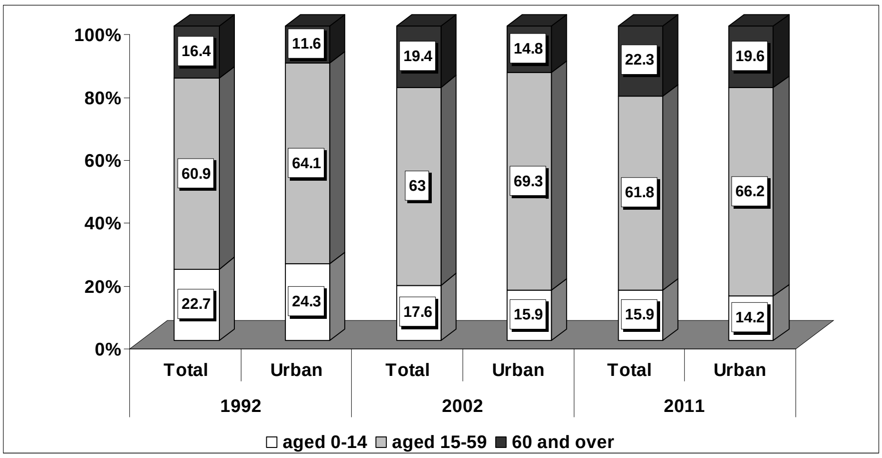

Fig. 5 – Age-group structure, census data 1992–2011.

In 2011, the ratio of the urban population aged 0–14 years/total permanent urban population was of 14.2%, the majority falling into the 15–59 age-group (66.2%), the 60s and over amounting to 19.6%, that is a nearly 5% rise compared to 2002 (Fig. 5). So, looking at the distribution of the permanent urban population by age-group comparatively with 1992 and 2002, it is quite clear that the urban population was ageing.

The distribution of the ***urban population by religious belief*** (1992–2011 census data) indicates that the overwhelming majority of the population are Orthodox Christians, yet from 86.9% in 1992, only 79.8 per cent were being registered in 38 counties and Bucharest Municipium in 2011. Compared

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to 1992, slightly more people would declare themselves Pentecostals, Baptists, Adventists and Muslims, while Roman-Catholics, Reformed, Graeco-Catholics and Evangelicals were on the decrease. The proportion of atheists, or of no religion respondees rose by 0.1% and 0.2% against 1992 and 2002, respectively. Noteworthy, ever more people did not state their religious belief (0.1% in 2002 and 8.4% in 2011).

More than 97.0% of the total Orthodox permanent urban population was recorded in the counties of Argeş (93.2%), Gorj (92.8%), Vâlcea (92.7%), Buzău 92.2%), Dolj (91.7%), Prahova (91.6%), Dâmboviţa şi Brăila (91.1%) and Mehedinţi (90.2%). At the other end of the spectrum stood Harghita (16.2%), Covasna (21,8%), Satu-Mare (43.2%), Bihor (51.7%), Mureş (52.3%) and Sălaj (63.9%).

Roman-Catholics (4.0% of the total urban population in 2011) represented the majority in Harghita County (55.9%) compared to 34.9% in Covasna, 20.1% in Satu-Mare, 10.3% in Bihor and Mureş counties.

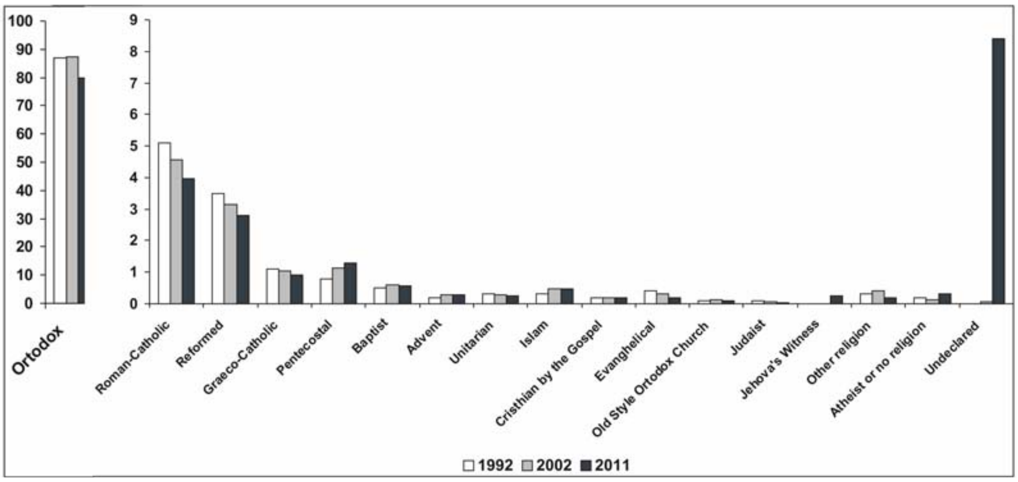

Fig. 6 – The religious structure of the urban population (1992–2011 census data).

In terms of the ***urban population nationality structure and number*** (2011 census data) the overwhelming majority are Romanians (8,974,284 persons, 82.6%) of all urban inhabitants. Looking at the previous census data, the number of Romanian nationals per total population dropped by 2,139,270 (7.1%) and by 1,326,777 (7.5%) versus 2002 (Table 5). This decrease, quite significant, matches the national trend, and is the result of external migration and of people who did not state their ethnicity (897,310). The ethnical distribution of population shows that Romanians are the majority in Bucharest Municipium (97.3%) and in the towns of 39 counties (between 93.7% in Argeş and 52.8% in Satu Mare), and of over 80% in 32 of the 39 counties.

Beside the 8.9 million Romanian town-dwellers (2011), nearly one million people belonged to other ethnical minorities.

Thus, the 2011 census registered town inhabitants of Hungarians (Magyar) nationality (631,670, 5.8% of the urban population), a figure higher than the national average, but by 282,000 (30.9%) fewer than in 1992. This nationals form the majority in Harghita (76.9%) and Covasna (71.5%) counties, with elevated ratios in Mureş (35.3%), Satu Mare (34.9%), Bihor (28.5%) and Sălaj (18.6%).

In 2011, the number of respondees declaring themselves of Roma (Gypsy) origin was of 230,670 (2.1% of the total urban population), by 28% more than at the 1992 census survey (1.3%). The numerical increase of this nationality is the result of higher fertility which is specific to this ethnicity and of more numerous Gypsies declaring their nationality. Their territorial distribution is relatively even, varying between 1.% in Argeş and 6.7% in Călăraşi counties.

Table 5

The ethnical structure of the urban population, 1992–2011 census data

	1992		**2002**		**2011**	
Total	12,391,819	%	11,435,080	%	10,858,790	%
Romanians	11,113,554	89.7	10,301,061	90.1	8,974,284	82.6
Hungarians	914,070	7.4	757,086	6.6	631,830	5.8
Roma/Gypsies	165,461	1.3	208,948	1.8	230,670	2.1
Germans	80,244	0.6	41,590	0.4	24,727	0.2
Ukrainians	10,682	0.1	8,832	0.1	5,683	0.1
Lippovan-Russians	16,231	0.1	15,540	0.1	9,644	0.1
Turks	23,481	0.2	24,934	0.2	21,213	0.2
Serbs	14,936	0.1	11,428	0.1	9,073	0.1
Tartars	17,525	0.1	17,298	0.2	14,557	0.1
Slovaks	8,290	0.1	7,007	0.1	6,100	0.1
Bulgarians	3,579	0.0	3,187	0.03	2,872	0.03
Jews	8,799	0.1	5,631	0.05	3,088	0.03
Croatians	516	0.004	873	0.01	560	0.01
Czechs	2,012	0.02	1,245	0.01	786	0.01
Poles	1,895	0.02	1,351	0.01	795	0.01
Greeks	3,490	0.03	5,152	0.05	2,601	0.02
Armenians	1,936	0.02	1,751	0.02	1,288	0.01
Italians	0	0.0	2,878	0.03	2,396	0.02
Chinese	0	0.0	2,229	0.02	1,675	0.02
Csangoes	0	0.0	491	0.0	577	0.005
Macedonians	0	0.0	0	0.0	1,016	0.01
Others	4,447	0.04	14,998	0.1	16,045	0.1
Undeclared	671	0.01	1,570	0.01	897,310	8.3

Source: data processed after 1992, 2002 and 2011 Censuses

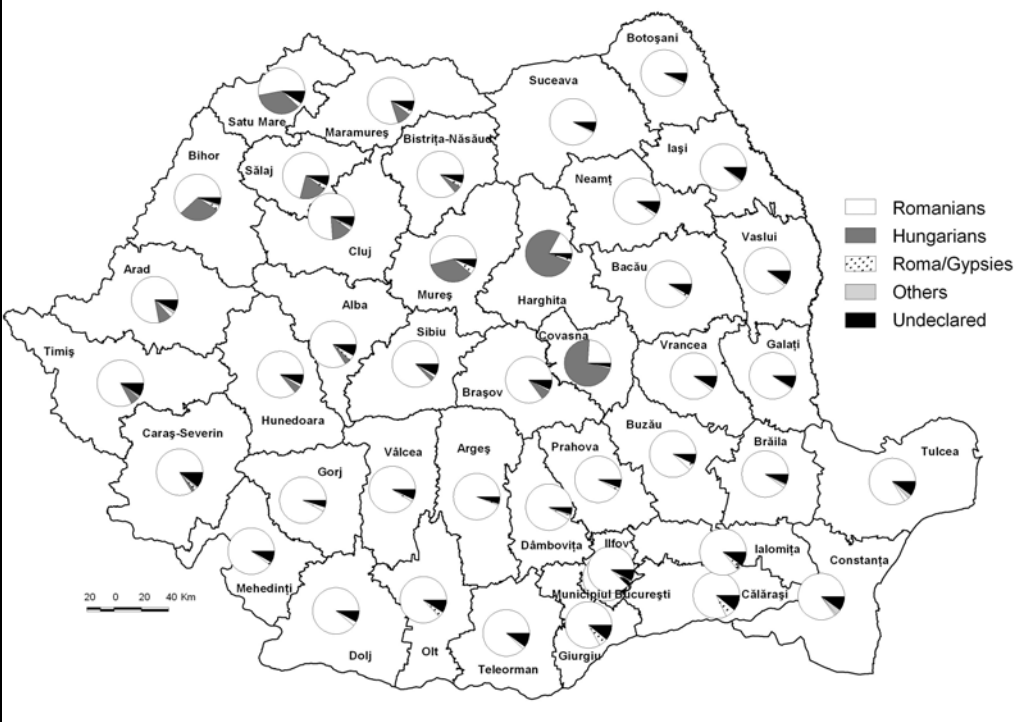

Fig. 7 – Ethnical structure of the urban population by counties, 2011.

The number of German nationals in town registered a steep decline, from 80,244 inhabitants in 1992 to only 24,727 in 2011, owing mainly to external migration. Nearly 70% are urban residents of Timiş (6,165 inh.), Sibiu (2,880 inh.), Caraş-Severin (2,374 inh.), Arad (1,989 inh.), Braşov (1,947 inh.) and Satu Mare (1,884 inh.) counties.

Speaking of the othert nationalities, it appears that the number of Italians, Chinese and Croatians was on the rise compared to 1992. In the case of all other nationals, census data indicate depleted figures, particularly steep decrease for Jews, Czecks, Poles, Ukrainians and Greeks.

The proportion of Magyars, Germans, Turks, Tartars, and more especially of Jews, Greeks and Armenians in the country's urban population tops the average cross-country value.

Quite interesting, 8.3% of all town-dwellers did not state their nationality, this category rising from 671 people in 1992 to 897,310 in 2011.

Counties in which numerous other nationals are town-residents: Constanța (Turks – 15.1 mii inh., Lippovan-Russians – 1.0 thou. inh., Tartars – 13.9 thou. inh.), Tulcea (Turks – 1.5 thou. inh., Lippovan-Russians – 2.1 thou. inh.), Timiş (Ukrainians – 1.3 thou. inh., Serbs – 5.9 thou. inh., Bulgarians – 1.3 thou. inh.), Maramureş (Ukrainians – 1.0 thou. inh.), Brăila (Lippovan-Russians – 1.9 thou. inh.), Caraş-Severin (Serbs – 1.8 thou. inh.), Arad (Slovaks – 3.6 thou. inh.), Bihor (Slovaks – 1.1 thou. inh.), Bucharest Municipium (Germans, Roma/Gypsies, Italians, Turks, Chinese and Jews).

5. CONCLUSIONS

Post-war urbanisation in Romania was an up-going process, from 54.3% at the beginning of 1990 to 55.1% in 2007 (the year of integration into the European Union), which is a remarkable percentage compared to the inter-war period (21.4% in 1930). After 1989, the new socio-political conditions led to indepth restructuring of the whole urban system, urbanisation itself acquiring new dimensions and particularities. The peak year of the 20th century – 1995 (54.9%) was followed by a slowdown of this process, the 2002 town population representing 52.7% of the country's total. As a large number of settlements (53) were given town status after 2002, urbanisation came to a record high of all times (55.2%) in 2007.

The towns' post-war functional profile was permanently changing, from the pre-war services-industrial and agrarian-services type to the industry-dominated type (specialised or diversified), or the mixed type (industrial-services, industrial agrarian) and the services type (specialised, or agrarian services). In the wake of the post-1989 economic and urban crisis and the functional destructuring of towns, the tertiary town model has become topical again.

One of the strategic objectives for 2013 inscribed in the National Strategy for Romania's Sustainable Development over 2013–2020–2030 is to support a balanced and sustainable regional economic and social development in order to meet each region's needs by creating urban growth poles. To this end, the provisions of the Regional Operational Programme shall be implemented, with highlight on enhancing the economic and social role of urban centres by a polycentric approach capable to create a better balanced regional development. Sixty per cent of the funds earmarked to urban development should be used to rehabilitate to town infrastructure and improve municipal services, inclusive of transport; 25% to modernise the social infrastructure and 15% to improve the business milieu.

In line with spatial development strategies, one of the national objectives scheduled for 2020 is the formation, at regional level, of the polycentric system of urban functional areas (urban agglomerations) and of urbanisation corridors along the transport routes of European interest (network polycentricity).

The urban network appears to be insufficiently developed in terms of number of towns versus the total population of Romania. In 2010, there were 320 towns, when 400–450 would have been necessary, which is what a European country the size of Romania is expected to have. There are many rural settlements whose economic basis, demographic strength and physiognomy are by far better than that of the towns granted this status in 1968 or before that date.

Planning and developing an extended network of urban and rural localities as a premiss for making Romania's regions dynamic, attractive and competitive, fully linked to the EU territorial management system, is a national objective for 2030. Orientative targets for urban centres have in view to raise the level of urbanisation up to 70% (by including some 650 rural localities into the town category) and providing for green-yellow belts around 2nd-rank towns (green area indicator: 35m^2/inh. in 1st– and 2nd-rank towns) (2006–2007, The Concept of Territorial Development of Romania and integration into the EU territorial structures, 2007–2030).

At present, the urban system is being restructured, the urban phenomenon acquiring new characteristics and dimensions. Town dynamics was seriously influenced by the December 1989 events and by some new elements, such as the elimination of administrative restrictions to people's settlement in urban centres, overemployment in the urban economy; at the same time, the supply of goods for the population was being improved.

Acknowledgements

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INTEGRATED RESEARCH IN THE DANUBE REGION SYMPOSIUM
FEBRUARY 24, 2014, BUCHAREST, ROMANIA

The third edition of this Symposium, held by the Romanian Academy and organized by the National Council for the Danube Region (SUERD), the National Committee for Global Environmental Change and the Romanian Academy's Institute of Geography, was attended by specialists from various Romanian and foreign research institutes and universities.

Within the context of the EU Strategy for the Danube Region, Symposium themes focused on the following problems: evaluation of the Danube future in a global change context (W. Mauser, Ludwig Maximilians University, Munich); presentation of a new integrated center for researches of the Black Sea – Danube Region (N. Panin, Geoecomar Institute, Bucharest); global water consumption in agriculture with perspectives for the Lower Danube Basin (Hong Yang, EAWAG Zürich); a multi-perspective research of the forests of Romania (I. Abrudan, Transilvania University, Braşov); assesment of water quality in the Lower Danube Basin (L. Georgescu et al., University of Galați); climate change and variability effects on Danube discharge (I. Sandu, E. Mateescu, National Meteorological Administration, Bucharest); presentation of the Danube Atlas - hazard and risk maps (M. J. Adler, National Institute of Hydrology and Water Management, Bucharest); interdisciplinary researches of sturgeon conservation in the Danube River Basin (C. Sandu, Institute of Biology, Bucharest) and cross-border co-operation for natural hazard management in the Lower Basin.

Discussions pointed out new possibilities for interdisciplinary co-operation research into the Lower Danube Basin in close correlation with economic, administrative and political stakeholders.

Dan Bălteanu

THE 28th SESSION OF THE UN GROUP OF EXPERTS ON GEOGRAPHICAL NAMES
NEW YORK, APRIL 28 – MAY 2, 2014

Proceedings of the 28th Session of the UN Group of Experts on Geographical Names were held in New York, USA, between April 28 and May 2, 2014. The event was attended by 160 delegates from 50 UN member-states and 6 international profile organisations who presented a number of 90 documents. The Session opened on April 28, 2014 with a plenary meeting that adopted the Session's agenda, continued with activity reports on behalf of the Chair of the Group of Experts, of the Secretariat and the 17 UNGEGN divisions. Session proceedings developed in plenary meetings, divisions or working groups. Romania is an active participant in the Romano-Hellenic and French-speaking Divisions, Working Group on Toponymic Data Files and Gazetteers, Working Group on Training Courses in Toponymy, Working Group on Country Names and Working Group on Geographical Names as Cultural Heritage.

Discussions held within the Working Group on Exonyms took up again the issue of changing the definitions of endonyms and exonyms formulated by Prof. Peter Jordan – Austria, the Working Group co-convener, as it emerged from the activity discharged since the previous Session, New York, August 2012, and the Meeting of the Working Group on Exonyms held in Corfu on May 23–25, 2013. Alongside Germany, Greece, Canada, and New Zeeland, Romania argued against new definitions, basically because ***geographical names in the official language of member states being excluded, the resulting exponential numerical increase of exonyms*** was in contradiction with the UN resolution adopted at previous conferences. Creating exonyms and endonyms within one and the same country means an upsurge of exonyms, which contravenes the idea of standardizing geographical names, which is the very purpose of this UN Working Group.

Discussions on the new definitions continued at the 16th meeting of the Hermagor Working Group, Austria (June 5–7, 2014), but eventually modifying them was given up.

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LAND USE-LAND COVER CHANGES AND LAND DEGRADATION (LUCC&LD) SYMPOSIUM
JUNE 23–26, 2014, BUCHAREST, ROMANIA

The 2014 IGU LUCC Regional Meeting "*LAND USE-LAND COVER CHANGES AND LAND DEGRADATION (LUCC&LD)*" was held in Bucharest, Romania on June 23-26. The event was organized by the Romanian Academy's Institute of Geography, the Romanian Space Agency – ROSA, and the University of Agronomic Science and Veterinary Medicine Bucharest. The Symposium focused on land use and land degradation related to soil erosion, landslides, desertification and climate change. The topics also included land-use transformations connected with economic, social and political changes.

The Symposium gathered nearly 40 researchers from the European countries (the Czech Republic, Bulgaria, Romania, Austria, Italy, and Russia) and Australia and the following institutions: *Al. I. Cuza* University of Iaşi, Department of Geography, Romania; *Charles* University, Faculty of Science, Czech Republic; Danube Delta National Institute for Research & Development, Romania; Esri Romania, Bucharest; Help Service Remote Sensing, Czech Republic; National Agricultural Research and Development Institute, Romania; the Romanian's Academy Institute of Geography, Romania; International Institute for Applied Systems Analysis (IIASA), Austria; Moscow State University, Faculty of Geography, Russia; National Institute of Geophysics, Geodesy and Geography, Bulgaria; Remote Sensing Application Center - ReSAC and Agency for Sustainable Development and Eurointegration – ASDE, Bulgaria; Romanian Space Agency – ROSA, Romania; Transilvania University of Braşov; University of Agronomic Science and Veterinary Medicine Bucharest, Romania; University of Bucharest, Faculty of Geography, Romania; University of New England, Australia.

The participants discussed problems of land use-land cover changes in Czechia, as well as along the Romanian Danube Valley, in the Oltenia Plain, in the Buzău County, in the Subcarpathian Watershed of the Argeşel River, in Regional Australia, and in the steppe region of Russia; agrolandscape methodology of LUCC study; assessment of the agricultural spatial-temporal patterns in the Romanian Flood Plain; land degradation in a salt mining area, the Curvature of the Central Moldavian Plateau, the Curvature of the Subcarpathian region; the dynamics of built-up areas in Bucharest Metropolitan Area.

After the Conference, a field trip was organized on June 23-26. The field trip represented a transect through the Romanian Plain, the Hilly Region of the Subcarpathians and the Carpathian Mountains. In the post-communist period these regions have registered transformations such us land use-land fragmantation, land abandonment, land degradation and deforestation. The field trip followed Land-use changes in the Bucharest Metropolitan Area, Agricultural land use in the Bărăgan Plain, Land use and soil erosion in the outer Subcarpathian area, Land use and cover changes in the Curvature Carpathians and Subcarpathians, Land use in the mountain area and mudflows, impacts on infrastructure, Land use and land degradation in the Buzău mountain area, Land use and deforestation/aforestation in the Braşov Depression.

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Maria Pătroescu, Cristian Iojă, Laurenţiu Rozylowich, Gabriel Vânău, Mihai Niţă, Iulia Pătroescu-Klötz, Annemarie Iojă (2012), *Evaluarea integrată a calităţii mediului în spaţii rezidenţiale* (Integrated assessment of environmental quality in residential areas), Editura Academiei Române, Bucureşti, 246 pages, 25 tables, 91 figs, refers., summary in English.

Elaborated by a team of specialists from the Centre for Environmental Research and Impact Studies, the work provides an interdisciplinary analysis of residential areas, a key component of a particularly dynamic society over the past few decades.

The volume stands out by the importance and topicality of the theme, observations, statistically-processed data, the direct measurements and mapping for case-studies being completed with an important theoretical and methodological approach, the outcome of a vast bibliographic documentation from the national and international specialist literature. Research has focused on the metropolitan area of Bucharest Municipium, where post-communist socio-economic and political-related transformations are most visible.

The seven chapters of this work could become an assessment model of environmental quality, applicable also to other residential areas in Romania.

Chapter One makes an analysis of urban expansion determined by socio-economic, technological and institutional factors, the direct and indirect relationship of residential areas with other urban structures, and forms of manifestation such as: compaction continuity in space, infill development, leap-frog expansion, urban corridor-like expansion, as well as landscape effects.

Chapter Two is devoted to the identification of methods necessary for the integrated assessment of environmental quality in residential areas, the authors considering that complex appraisal means several stagewise transdisciplinary investigations. A detailed presentation is made of environmental indicators and indexes as assessment modality and method, the role of direct observations and measurements, as well as questionnaires and statistical surveys, GIS techniques as a tool of processing and representation, and at the same time of identifying transfer vectors of different fluxes.

Furthermore, the state of sanogenesis and suitability of residential area locations is being discussed, bearing in mind vulnerability to natural and technological hazards, access to green areas, or to the area of manifestation of man-induced phenomena (urban heat island) (Chapter Three).

The population's consumption models in Bucharest Municipium (dwelling, energy, nutrition, hygiene, recreation, etc.) are viewed in connection with external degradation sources, key factors in assessing the quality of the environment in residential areas (Chapter Four).

The adequate functioning of residential areas enhances the pressure put by human settlements on the ecosystems, thereby generating environmental problems. Assessing the extent to which residential areas, through space consumption, exert their impact (Chapter Five) is made by determining the ecological footprint defined as the surface of productive biological terrain needed to meet the consumption demand of a population and take in all the wastes it produces. Calculating the ecological, physical, and energy footprint of Bucharest's metropolitan area is a very useful undertaking for practitioners, being at the same time an assessment model applicable also to other areas.

Chapter 6 expounds on the qualitative and quantitative variables characteristic of inner space quality (air, hygrothermal regime, luminosity, level of noise, etc.) which has a direct influence on the population's health state in residential areas. In the interval November 2008 – November 2011, hourly measurements monitored the quality of air in 24 dwellings of Bucharest Municipium, the results obtained being compared to WHO-recommended maximum values.

The last chapter discusses aspects of residential area adaptability to global environmental change, identifying priority action domains for the sustainable development of residential areas, which are being perceived both as determinant factor and as element affected by current global environmental change.

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A fundamental prerequisite for analysing environmental quality is integration of all the results obtained for each component within a unitary and coherent whole, with highlight on the causal connections between ongoing geographical processes and phenomena, on their weight and hierarchization in time and space, definitory features, short-medium-and-long-term evolution trends, vulnerability level to natural hazards and adaptability to global environmental change. The work succeeds in integrating all these aspects, pointing out the synergic effects of the interdependence of environmental components in residential areas. Apart from its methodological value for various categories of specialists, this volume is an important tool for planning out urban development programmes and policies in Bucharest Municipium and its metropolitan area.

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