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THE INVENTORY AND TYPOLOGY OF THE WETLANDS AND DEEP WATERS FROM THE MOLDAVIAN PLATEAU (ROMANIA)

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Abstract : The Moldavian Plateau is positioned in the east of Romania, between the Eastern Carpathians in west, the Romanian Plain to the south, the Ukrainian border to the north and Prut Valley (border with the Republic of Moldavia) in east. Although the Moldavian Plateau is situated in the driest region of Romania (mean annual rainfall of 500-700 mm and average temperatures of 8-10^{0}C), the majority of the wetlands and of the low discharge rivers is found here. The existence of numerous wetlands, respectively small ponds, is due to the human activity and the lack of water resources. The impermeable clayey substratum favored the occurrence and survival of a large number of wetlands. Most of them are found in the Moldavian Plain (north), and the fewest to the south, in the Covurlui Plateau. The disappearance of wetlands from the region's south was caused by the accelerated erosion (determined by the human activity, through deforestations and inadequate tillage), that induced an intense sediment transportation, with effects on the valley floor aggrading phenomena. The most important wetlands are those developed along the two main rivers – Prut and Siret. Unfortunately, Siret's floodplain has been in most of its part dammed, and the wetlands entered the agricultural use. The map with the repartition of the wetlands is a product obtained through field investigations, through the consultation of the 1:50000 topographic maps, of aerial photos and satellite images' interpretation (LANDSAT TM7) from the years 2000-2005. For the interpretation of the satellite images we appealed to the Corine Land Cover 2000 methodology.

Keywords: *wetlands, inventory, typology, deep waters*.

1.Introduction

The Moldavian Plateau is the most extended and representative tableland of Romania. It occupies the eastern part of the country, being neighbored by Obcinele Bucovinei, the Moldavian Sub-Carpathians, the north-east of Romanian Plain, Prut and Danube valley (Romanescu et al., 2008) (fig.1).

The unit is a part of the large area of the hilly regions, being characterized by a landscape included in the Carpathian-Danube space. It has a total surface of 25,000 km^2, meaning over 10% of the Romanian territory.

From a morpho-structural aspect, the largest part of the plateau is identified with the Moldavian Platform, while the southern sector corresponds to the Bârlad Depression (Băcăuanu et al., 1980).

The geologic units are formed of a complex of clays and marls with alternations of sands, to which are added thin horizons of sandstones, limestone, conglomerates, gravels, andesitic cinerites etc. At their upper part, along the valleys or in the lacustrine areas are deposited thin Quaternary loess-like deposits and loamy-sandy-clayey alluvial deposits (Brânzilă, 1999).

The present landscape bears the imprint of the monocline structure, of the lithology and the external modeling factors represented by the hydrographic network and slope processes. In this case the hilly summits or the extended plateaus repeat on large areas, having altitudes of 350-500m in the central and western sector and of 200-300m to east and south (Băcăuanu et al., 1980).

Figure 1 : *Geographical position of Moldavian Plateau on Romania's territory*

The most extended landforms are those conditioned by the monocline structure: hills and valleys oriented mainly NW-SE, cuesta alignments, structural plateaus and so on. The frequency and development of landslides, as well as of other slope processes, makes up a characteristic feature on almost the entire area of the Moldavian Plateau

The climate of the Moldavian Plateau, due to the extra-Carpathian position, is of the temperate-continental type with excessive nuances. Towards west and north-west it interferes with the temperate continental climate characteristic to the continental west. The most characteristic are the eastern European influences, imprinted by the domination of the cold air masses during winter and of the hot and dry ones in the summer (Erhan, 2001).

The mean annual temperatures have values of 7.5-10^{0}C, with increasing variations on the north-south direction. Rainfall quantities are of 500-700mm, with lower values in the low or southern sectors.

The hydrographic characters are linked to the climatic and geomorphologic conditions. The surface waters are weakly represented and come from the Carpathians: Siret with its right-side tributaries and Prut. The alochtonous rivers are numerous, but of small dimensions and reduced discharge rates. Sometimes they present an intermittent character. The lakes are relatively numerous, but they have anthropic origin, mainly in the Moldavian Plain (Pantazică, 1974; Romanescu, 2006).

There may be separated a Moldavian province, with variable or deficient humidity, drained by rivers with moderate rainfall alimentation in the higher areas from the central and north-western parts and rainfall-snow melt alimentation in the lower altitude sectors. There may also be mentioned a moderate underground alimentation (Ujvári, 1972).

The vegetation, fauna and soils meet the characters that derive from the relief's reduction in altitude from the Carpathian unit towards the exterior and by some interference of the central and east European elements, with local differences according to the climatic and geomorphologic conditions.

Human activity has radically influenced the occurrence of the biotic and soil cover elements.

2. Materials and methods

For the wetland inventory from the Moldavian Plateau we appealed at the analysis of satellite images. The interpretation of satellite images, an analysis method that comes to complete the field research, represents a modern instrument modern of terrain study under its spatial and economic aspects. The methodology of satellite interpretation is in an incipient stage, especially for the Romanian scientific community. Its necessity comes in the help of the spatial natural and anthropic phenomena, facilitating the laboratory analysis of the study area, with later field verification.

Satellite images represent a reflex of the geographic reality and are obtained with the help of sensors sensible to the reflectance of the organisms and systems from the Earth (placed on satellites with defined orbits). The recording of the reflection is done for different wavelengths, thus being obtained several images (spectral bands) for different wave length intervals (table 1).

After the delineation of the wetlands on these images have been conducted expeditionary field surveys for the sampling needed and the precise

classification of the wetlands to the respective typology. The field surveys have been conducted during summer, and the samples have been taken during noon.

For the creation of the wetland map we have used as information sources both Landsat TM 7 satellite images from 2000-2005 (INCDD, 2000-2005), as well as a series of topographic maps scaled 1:25,000 and 1:50,000 (IGFCOT, 1978).

Table 1 Radiometric features of the Landsat satellite

Satellite	Spectral resolution (μm)	Band	Spatial resolution (meters)
Landsat 1 – 3	**MSS**		
	Band 4: 0.50 - 0.60	Green	79
	Band 5: 0.60 – 0.70	Red	79
	Band 6: 0.70 – 0.80	Near IR	79
	Band 7: 0.80 – 1.10	Near IR	79
Landsat 4 – 5	**MSS**		
	Band 4: 0.50 – 0.60	Green	82
	Band 5: 0.60 – 0.70	Red	82
	Band 6: 0.70 – 0.80	Near IR	82
	Band 7: 0.80 – 1.10	Near IR	82
	TM		
	Band 1: 0.45 – 0.52	Blue	30
	Band 2: 0.52 – 0.60	Green	30
	Band 3: 0.63 – 0.69	Red	30
	Band 4: 0.76 – 0.90	Near IR	30
	Band 5: 1.55 – 1.75	Medium IR	30
	Band 6: 10.4 – 12.5	Thermal	120
	Band 7: 2.08 – 2.35	Medium IR	30
Landsat 7	**ETM+**		
	Band 1: 0.450 – 0.515	Green	30
	Band 2: 0.525 – 0.605	Red	30
	Band 3: 0.630 – 0.690	Red	30
	Band 4: 0.760 – 0.900	Near IR	30
	Band 5: 1.550 – 1.750	Medium IR	30
	Band 6†: 10.40 – 12.5	Thermal	60
	Band 7: 2.080 – 2.35	Medium IR	30
	Band 8: 0.52 – 0.92	Panchromatic	15

† Band 6 for Landsat 7 is divided in high and low

The applied methodological norms are found in the technical guide of the Corine Land Cover 2000 program (elaborated by the European Environment Agency experts). These norms establish minimum dimensions from which are taken into account some characteristics, the polygons' inclusion, aggregation and delineation rules.

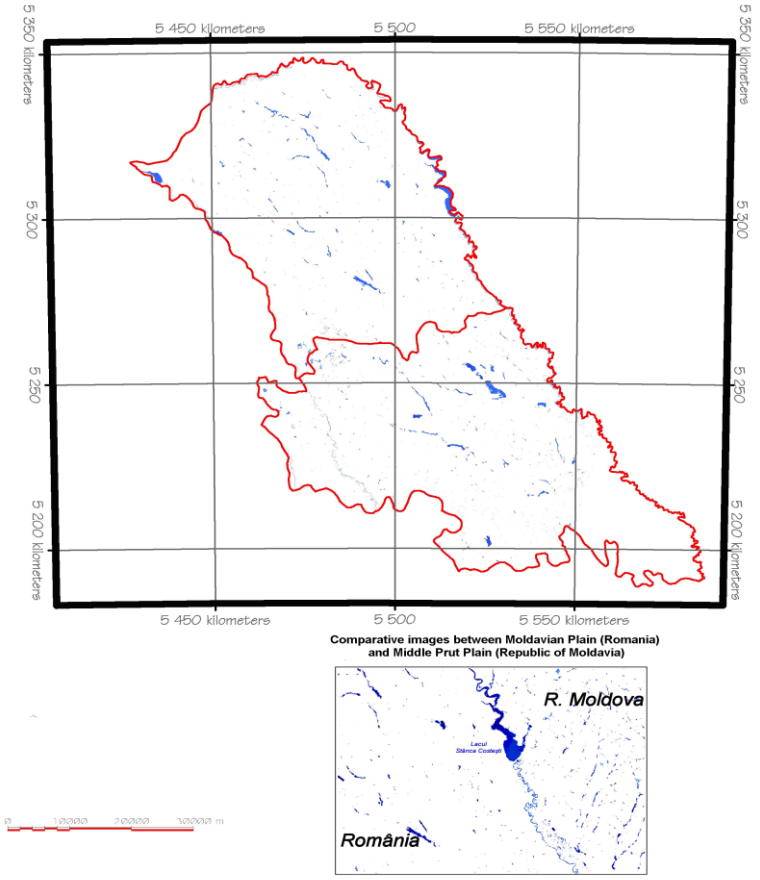

Figure 2 : *Kauth's Tasseled Cap wetness index applied in the identification of wetlands in the Moldavian Plateau*

The combination of the spectral bands that stood at the base of the photo-interpretation is TM4, TM5, TM6. This is the combination used and in the CLC 2000 technical guide, proving to be useful in the identification of the hygrophyte and hydrophile vegetation.

These methodological norms establish a series of polygon identification, delineation, aggregation, inclusion, etc criteria.

To refine the results obtained through satellite images interpretation was used and the wetness index (fig.2).

The operation, known as Kauth's Tasseled Cap, calculates three Kauth biophysical indices (greenness, brightness and wetness) departing from Landsat images, and uses six spectral bands: TM1,TM2,TM3,TM4,TM5,TM7.

Wetness = 0.13929* TM1+ 0.22490* TM2+ 0.40359* TM3+ 0.25178* TM4-0.70133* TM5- 0.45732* TM7.

This index evidences wetlands, including the water included in the vegetal biomass, reason for which the forested surfaces are a mapping error source.

The wetland map has been realized in vector format, using the TNTmips 6.9 GIS software (Margarint, 2004).

In this context we have chosen the most important sectors with typical and diverse wetlands, or those where from the satellite image couldn't have been drawn a clear conclusion regarding their classification.

For the wetland typology of the Moldavian Plateau was used a special scheme, adapted to the Romanian reality, where these are classified according to the system, sub-system, class, subclass, water regime, chemistry, pH, soil type, evolution of the protection level and perspectives. For the wetland typology was held in mind the evidencing of the water chemical regime, the analysis of the organic and inorganic matter, the realization of drills for the determination of the thickness of the moist-affected strata, the determination of the grain size distribution and of the solid material type, the mapping of the indicator plant species and the evidencing of the floristic associations (Romanescu, 2005, 2008).

3. Results and discussions

To detail the studies conducted in the Moldavian Plateau was consulted a large body of American and European domain literature, from which have been extracted the most important directions and ideas to be reported to the local realities (Adamus et al., 1987; Barbier et al., 1996; Barbault, 1997; Barnaud, 1998; Barnaud, Dausse, 2000; Bendjoudi, Fustec, 1996; Bernard, 1994; Brinson, 1993; Brinson et al., 1998; Carter, 1996; Goode, 1974; Gowardin et al., 1979; Devillers et al., 1991; Florea et al., 1972; Fustec, Frochot, 1996; Hurt, Carlisle, 2001; Kentula, 1996; Lefor, Kennard, 1977; Mitsch, Gosselink, 1993; Mulholland, Kuenzler, 1979; Smith, 2001; Spencer, 1994; Sprecher, Warne, 2000; Stewart, 1996; Tiner, 1999; Wentworth et al., 1988; Wilen et al., 1996; Report EPA, 1983; Report Y-87-1, 1987; Office of Wetlands Protection, 1988;

FICWD, 1989; La Documentation Française, 1994; National Water Summary on Wetlands Resources, 1996 etc.).

The observations and analyses conducted in the Moldavian Plateau were deployed in the summers of 2000-2005, and the water samples were taken during the day, between 10-18 hours.

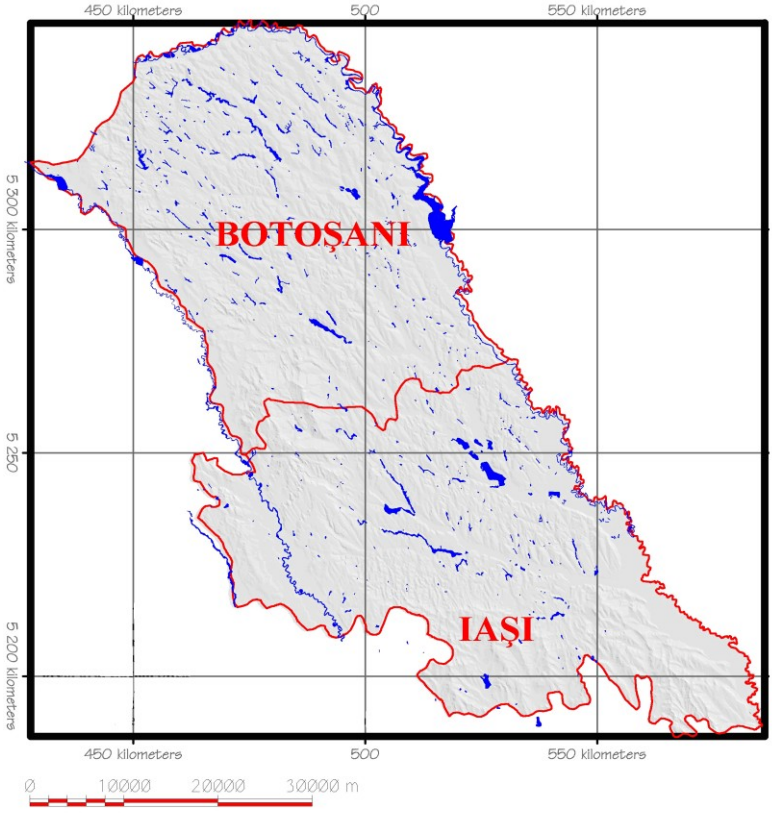

Figure 3 : *The distribution of wetlands and deep waters on the Iasi and Botosani counties territory*

Although on the territory of the Moldavian Plateau (Iaşi and Botoşani counties) the climatic conditions (temperature, evapotranspiration, rainfall etc.) do not favor the occurrence of large and numerous wetlands, they have a quite high number and as percentage occupy an important place in the area's geography (fig.3, 4). The number and surface are due to the existence of a relatively low relief, with large and fine textured (clayey) floodplains. In consequence the geology and relief morphology have favored the extension of

these wetlands on a relatively important area. The majority of wetlands and deep water basins are met in the rivers' floodplains (e.g: Jijia, Başeu, Bahlui, Bahluieț, Miletin, Bodeasca etc.) and rarely on structural surfaces (very rare in the Moldavian Plain).

In the northern part of the Moldavian Plateau, especially in the Botoşani and Iaşi countries, are met the most extended wetlands and deep waters. This situation is due firstly to the occurrence of lakes (even from the times of Stefan the Great, in the 14^{th} – 15^{th} centuries) and then to the clayey rocks that deny a fast infiltration (Baican, 1996). The fewest wetlands and deep waters are met in the southern part of the tableland, mainly in the Tutova hills and Covurlui Plateau areas (fig.5).

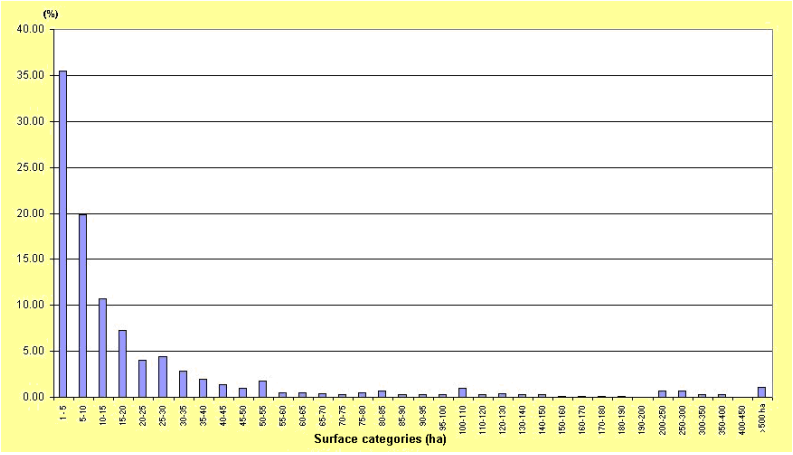

Figure 4 : *The distribution of wetlands and deep waters on surface categories in the Iaşi and Botoşani counties*

Most of the water courses from these areas are of small dimensions and often drain (e.g: Berheci, Tutova, Geru, Drăguşeni, Perişani, Jeravăț, Horincea etc.). The slopes' forest cover degree is almost zero, and erosion, in all conditions, inclusively wind erosion, manifests very intensely. The aridization phenomenon is accentuated by the global climatic changes.

The disappearance of the wetlands from the southern Moldavian Plateau is also duet o accelerated erosion (determined by human activities through deforestations and tillage) that induced an intense alluvial transport with repercussions on the valley floor aggrading. Most of the torrential organisms and hydrographic basins suffer a strong aggrading in their downstream sectors, where the sedimentation is extremely strong during floods. Some water courses don't have a floodplain in their downstream sectors, and the rest of the course is

over-elevated and doesn't intersect the phreatic level no more. As a consequence of the alluvial material depositions directly in the major floodplain, rill erosion cannot face aggrading and the water course is isolated from the phreatic level, the river transforming from permanent to temporary. Unfortunately this is not an isolated case, but quite frequent in Covurlui Plateau. The river drying phenomenon is accentuated and by the high permeability of the loess-like deposits, with high thicknesses on almost all the main valleys.

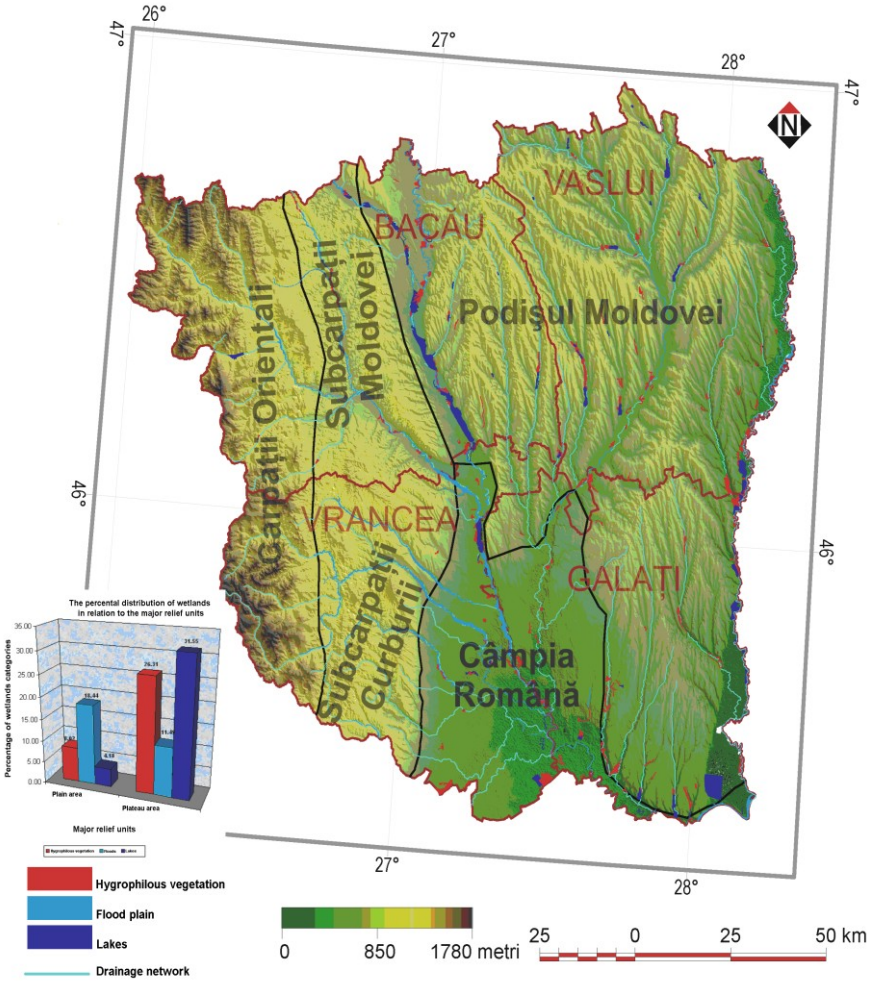

Figure 5 : Wetland repartition in the southern part of the Moldavian Plateau (Vaslui, Bacău, Vrancea and Galați counties)

As a consequence of the fact that agricultural activities develop in an alert rhythm, and tillage is practiced up and downhill, especially during the last years, it is certain that a large part of the wetlands, mainly the small ones, will disappear in the near future.

Most of the water management works have been conducted on the majority of the water courses (presently well protected). Lakes with role of taking-over the water surplus have already been emplaced and most of them have reached their target. The torrential character of the creeks and rivers from the Moldavian Plateau manifests only on a fem small courses, that don't affect strongly wetland evolution.

The climate aridization in the eastern part of Romania, the anthropic activities and the natural evolution will lead to a reduction in surface of the wetlands, and in consequence will be needed a new orientation in their management, as well as an aggressive protection policy.

We must specify that the areas identified with the help of satellite images as being wetlands, according to the vegetation indices, water surface and floodplain geomorphologic conditions, do not meet all the criteria of being classified as so. We may meet hydrophile vegetation that does not enter the wetland because the floodplain has been dammed and the link with the water source is interrupted or limited. In this category enter the aspen, willow or alder forests. These species have adapted the new conditions of relative dryness and are met along the dammed floodplains.

The same case is specific to the floodplains. Not all the floodplains enter the wetland category. In Moldavia, on the main water courses have been conducted numerous dams, and a part of the major floodplains exit the normal circuit of discharge. Some floodplains are no longer affected by underground waters, because in some cases the minor floodplains have deepened and the influence of the aquifer strata disappeared.

There are major discrepancies in the wetland repartition in the two distinct areas of northern and southern Moldavia. If in the northern part dominates the clayey substratum that favors the local occurrence of wetlands, in the southern part dominate sandy deposits, and as consequence the strong infiltration does not favor the development of such areas. The hydrographic network from the south is more developed because the rocks are more friable, but the majority have either developed only the minor floodplain or the major one or strongly aggraded and doesn't intersect no more the aquifers. In this last case they have become alluvial plains suitable for intensive grazing.

At the same time the sandy-loamy substratum and the reduced river discharge didn't favored the emplacement of ponds (typical only for northern Moldavia).

The most important wetland from southern Moldavia is represented by Prut's floodplain and the Lower Siret Plain (mostly dammed). Unfortunately the Lower Siret Plain has been strongly modified during the last years, and most of the wetlands have been eliminated (fig.6). Following the 2005 catastrophic floods, when Siret registered a historical discharge rate of 5000-5500 m^3/s (discharge reconstructed at Cosmeşti and Movileni stations) (Romanescu, 2006), the attitude towards wetlands' importance may be revised and a part of them may re-enter their normal circuit.

At the same time may be remarked and a strong differentiation in the wetland development between the two dominant relief units: plateau and plain. In the tableland area, as a consequence of the development of a rich hydrographic network and of the higher rainfall, occurs a larger surface occupied by wetlands, while the plain areas are mostly lacking such water surfaces (also because of the terrain use in cereal crops).

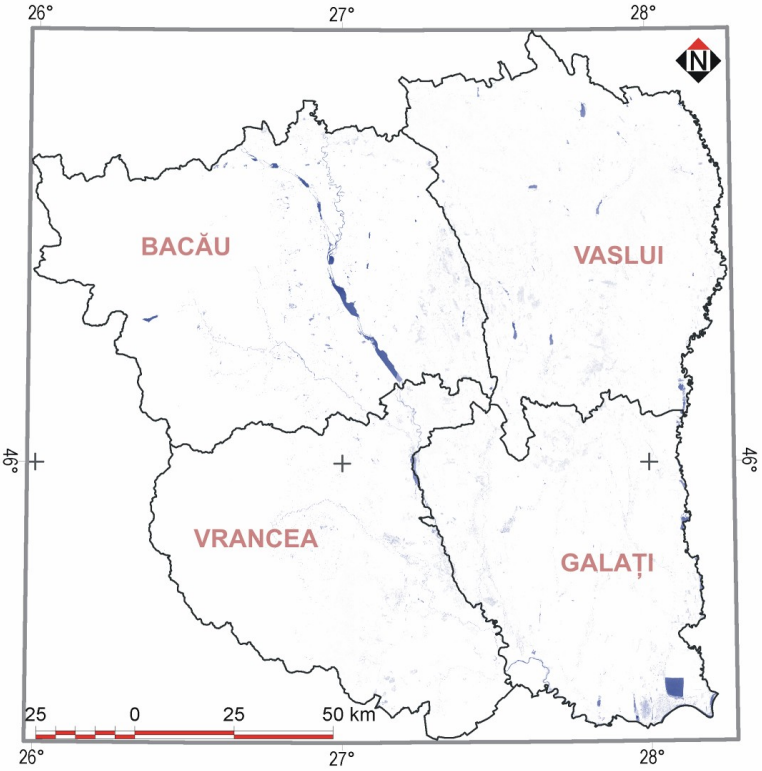

Figure 6 : *Wetland repartition in the southern part of the Moldavian Plateau (Vaslui, Bacau, Vrancea and Galati counties)*

The relief, through the morphology specific to the tableland units, allowed the maintenance of water surfaces, needed by the local economy. The plain lakes, except the floodplain ones, have almost completely disappeared because the need for agricultural terrains has been extremely high.

As it can easily be noted, the Moldavian Plateau, especially its southern part, has a low floodplain development in comparison to the alluvial units specific to the subsidence plains (Lower Siret Plain) (fig.7). Although the wetland vegetation should be more developed in the plains, it has disappeared after the terrains entered the agricultural circuit. In the plateau areas, these are better kept, especially in the areas affected by landslides or in the places where the clayey rocks, with local occurrence, are dominant.

After the realization of the vector wetland and hydrographic network (orders 4, 5, 6 and 7 in Horton system) strata, we proceeded to database interrogation, obtaining a series of statistical information regarding the wetlands, detailed on categories and regions (table 2).

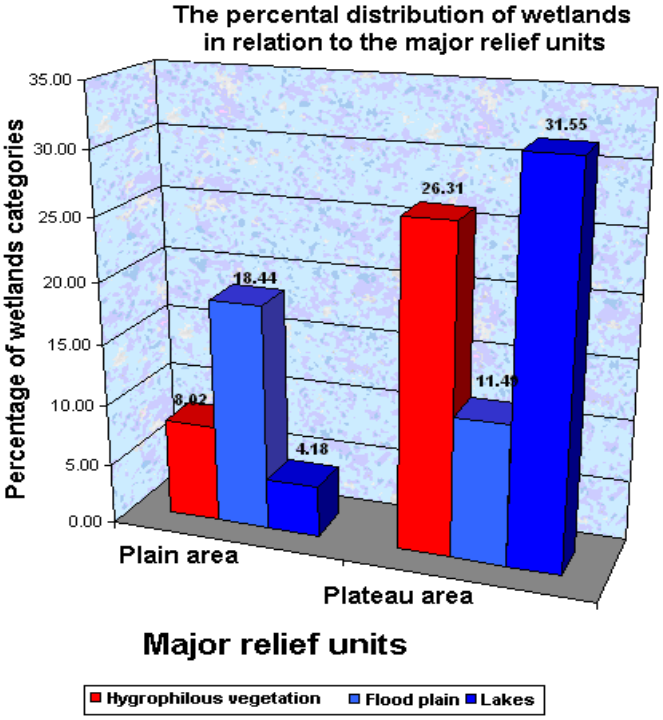

Figure 7 : *The percentage distribution of wetlands in relation to the major relief units (Vaslui, Bacau, Vrancea and Galati counties*)

Table 2 : *Wetland types on relief units*

The relief unit that holds the largest surface of wetlands is the Moldavian Plain (part of the Moldavian Plateau). The presence of these surfaces is favored by the relatively low altitudes, the existence of a clayey substratum and the tradition of pond emplacement (fig.8).

Through the interrogation of the database have been obtained a series of statistical data regarding the wetlands. Thus have been identified 745 polygons that represent wetlands and deep water surfaces, that occupy a total surface of 27,582.8 ha. Their average surface is of 37 ha, varying from 1ha (the minimum surface taken into consideration) to 4,315.75ha. Most wetlands and deep water surfaces are small, between 1-5ha. Through dimensions, they have the clear tendency of natural or following human intervention, disappearance. Most of them will probably included in the agricultural circuit.

On the territory of the Moldavian Plain (Iasi and Botosani counties) there are wetland and deep water surfaces usually between 1-55ha. Thus, they are of small dimensions, and most of them are lakes and ponds.

Interesting is the comparison between the Romanian sectors and those from the territory of the republic of Moldova. In this case wetland and deep waters density from the territory of the neighboring country is much higher. The drainage of this territory has been weak and the relief morphology allowed the occurrence and maintenance of a large number of wetlands (fig.2).

Conclusions

The inventory and classification of the wetlands and deep waters from Romania and especially of those from the Moldavian Plateau derived from the fact that these operations hasn't been approached yet and the used methodology was not sufficiently acquired by the specialist. This time the methodology used is taken over mostly from the American school and the European one (the parts regarding the pollution and management degree).

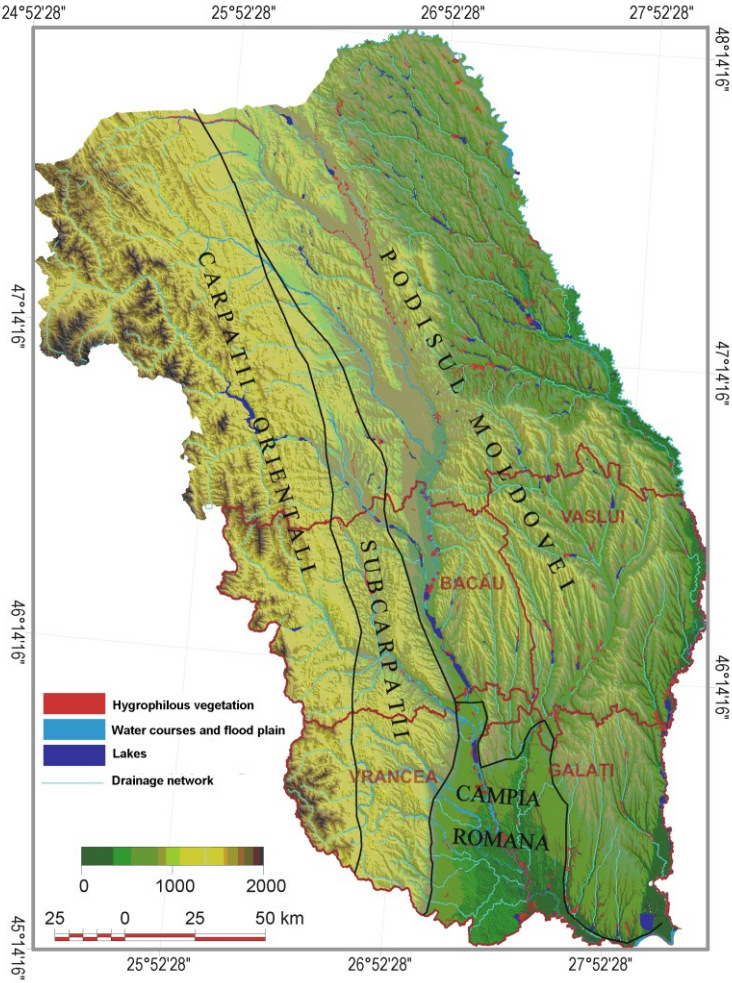

Figure 8 : *Wetland repartition in the area of the Moldavian Plateau and the mountainous areas of the component counties*

Although the Moldavian Plateau is situated in the east of Romania (relief unit with influences of the continental climate with excessive tendencies), on its surface are found most wetlands (and the largest ones) from the territory of our country (with the exception of the Danube Delta). The fact is due to the existence of an impermeable clayey substratum and to the pond emplacement tradition. In reality most of the wetlands and deep waters are of anthropic nature, because the population has been forced to construct such basins in this semiarid

climate.Wetland typology evidenced the existence of numerous genetic varieties specific to the relief units of medium and low altitudes. Unfortunately the largest part of the lacustrine wetlands is under the influence of the anthropic factor. The global climatic changes that lead to aridization or even desertification, also lead to the natural disappearance of the wetlands that are under the influence of aquifer strata or of the flood waters. Valley aggrading, especially in the southern part of the plateau, leads to a rapid disappearance of the wetlands from the main floodplains.

The most rapid and economically effective way to restore wetlands resumes to re-naturation, through dam breaking and supplementary water inputs for the restoration of the biological fund.

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