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Mires of Serbia – distribution characteristics

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ABSTRACT: The goal of this paper is to provide the first complete insight into the distribution of mires in Serbia and to give an assessment of their size. For these reasons, a Serbian Mire Database and accompanied GIS Serbian mire distribution map have been developed. We estimated the distribution and total area of mires in Serbia since the last published records in 1979. Compared with the current estimation of about 3000 ha with histosols (peaty soils) in Serbia, mires were found to persist on about 1250 ha or 0.014% of the total Serbian territory, from analysing 155 mires and mire complexes. Nineteen of them are recorded and presented for the first time. Some notes on the minimum, maximum and average peat thickness as well as pH range are also discussed. A short overview on mire-related terminology and classification problems in Serbia with some suggested solutions is presented. This study also refers to the classification system for mires established by Jovan Cvijić in 1896, practically forgotten in Serbia and almost unknown outside Serbia. Finally, all relevant literature on Serbian mires is given.

Keywords: mire, peatland, peat, distribution, Serbia

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INTRODUCTION

The Balkan Peninsula represents the southernmost distribution limit of mires in Europe. Here, mires are generally characterized with numerous scattered localities of very small total size. They are important centers of plant diversity, especially of boreal flora. Unfortunately, they are also among the most threatened and vulnerable habitat types of the Balkan Peninsula. Many Balkan countries like Serbia, Macedonia, Montenegro and Bosnia and Herzegovina still do not have finalized "mire cadastres" and mire distribution maps. Considering all this, we focused our attention on presenting the first overview of all known mires on the territory of Serbia accompanied with the first Serbian mires distribution map. Patterns of their distribution according to different ecological factors are also considered.

Study area. The Republic of Serbia lies in the central part of the Balkan Peninsula and has a total land area of 88361 km^2. Because of its complex geological history, it has a great variety of geological and lithological substrates that, combined with orographic and climatic factors, lead to a complex pedological structure. Vojvodina region in the north belongs to the Pannonian basin and generally lies at elevations between 60-100 m with the highest peak at 540 m. The rest of Serbia is characterized by hills and high mountains. It includes sections of the Dinaric Arc, Carpathians, Balkanides, Rhodopes and Scardo-Pindic groups of mountains, with the highest mountains being: Mt. Stara Planina (2169 m), Mt. Besna Kobila (1923 m), Mt. Kopaonik (2017 m), Mt. Golija (1833 m), Mt. Tara (1544 m), Mt. Prokletije (2656 m) and Šar planina (2651 m). Most of Serbia has a temperate continental climate. A continental climate prevails in the mountains, while the climate in the Serbian southwest borders is influenced by the Mediterranean subtropical and continental climate type (Republic Hydrometeorological Service of Serbia www.hidmet.gov.rs).

Historical overview. For the preparation of a Serbian Mire Database and accompanied Serbian mire distribution map,

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all available references were used. A historical overview of Serbian mires research and list of references are presented concisely, with all relevant references for this topic.

Scientific research on Serbian mires starts with the famous Serbian botanist Josif Pančić and his floristic works. He visited many Serbian mires during the period from 1847 to 1880, some of them on more than 10 occasions (Tešić *et al.* 1979). These floristic data were published in "Flora Principatus Serbiae" (Pančić 1874) and "Additions to the Flora Principatus Serbiae" (Pančić 1884).

After Pančić, another famous Serbian scientist, geographer Jovan Cvijić studied mires, predominantly in E Serbia (Cvijić 1896). He suggested the first classification system of Serbian mires. Cvijić divided mires, depending on the altitude at which they are located, into two simple groups: low (Serbian *niske*) in the lowlands and high (Serbian *visoke*) in the mountains. In particular, Cvijić (1896) established some kind of microtopographic or microstructural (microformes) classification pattern of mires, complementary with "hummoc-hollow" series (Rydin & Jeglum 2005) or "hummock-lawn-carpet-mud bottom-pool" series (Sjörs 1948). Exploring the large mire complex on Vlasina plateau (SE Serbia) he uses the term "*žmiravac*" for hummock - a raised island of vegetation surround by open water, either rooted or floating, that deviates and sinks when stepping onto it. "*Žmiravac*" can also be developed as a bank zone between open water and land. The term "*vedarce*" is used for small hollow, filled with water colored brown or dirty blue by organic substances. Larger and deeper hollows he called "*bistrice*" (German *Seefenster*) and special types of hollow with underwater springs he called "*toplici*". A complex based on "*žmiravac*" accompanied with other structures ("*bistrice*", "*toplici*") was definded as a mire ("*tresava*") (Cvijić 1896). In the same paper Cvijić used the term <*livadska tresava*> meaning meadow mire. The mire classification system and terminology established by Cvijić (1896) was used immediately after the publication and for next few decades, and after that it was slowly abandoned with very sporadic usage later.

Several important mire-related studies and articles were published before the Second World War in the field of geobotany (Košanin 1908, 1910), phytogeography and paleobotany (Katić 1910; Černjavski 1931-1932, 1938). Many more mire-related paleobotanical and botanical articles were published after World War II: Nikolić (1955); Gigov (1956a, 1956b, 1969, 1972, 1973); Gigov & Nikolić (1954); Gigov & Milovanović (1963); Marković-Marjanović & Gigov (1971) and Gajić *et al.* (1989-1990). Numerous multidisciplinary mire-related studies were started within the Faculty of Agriculture in Zemun and later supported by the Serbian Academy of Art and Science during the period 1959-1979. These studies were carried out by several groups of authors: Antić *et al.* (1965), Bogdanović *et al.* (1963, 1972a, 1972b, 1973a, 1973b, 1982, 1987), Bogdanović & Stojanović (1968), Gigov *et al.* (1972), Tešić *et al.* (1962, 1969, 1979), Tešić (1972). A summary of their work, beside the collection of scientific facts, was the exploitation potential of Serbian peatlands. In recent times their work has been supported by Vukčević *et al.* (2008), Perović *et al.* (2010) and Kuzmanović *et al.* (2010). Phytocoenological, floristic and mire habitat research studies were published by: Stjepanović-Veseličić (1953), Marinković & Gajić (1956), Čolić & Gigov (1958), Jovanović-Dunjić (1962, 1971, 1979, 1981, 1986, 1988), Čolić (1965), Lakušić & Grgić (1971), Mišić *et al.* (1978), Petković (1983), Ranđelović & Redžepi (1984), Tatić *et al.* (1985), Gajić (1989), Karadžić & Janković (1989), Janković & Karadžić (1991), Jovanović & Jovanović (1991), Gajić *et al.* (1992), Lakušić (1993, 1995), Topalović *et al.* (1994, 1997); Petković *et al.* (1996); Blaženčić (1997); Blaženčić & Blaženčić (1997); Ranđelović *et al.* (1998); Papp & Sabovljević (2002); Ranđelović (2002); Amidžić (2003); Lazarević *et al.* (2004, 2008); Papp *et al.* (2004); Lakušić *et al.* (2005); Papp & Erzberger (2005); Petrović *et al.* (2007); Lazarević (2009a, 2009b); Momčilović-Petronijević *et al.* (2009); Miladinović *et al.* (2010); Puzović (2010); Ranđelović & Zlatković (2010).

MATERIAL AND METHODS:

The database of Serbian mires and mire complexes was made on the basis of all available both published and unpublished literature data and personal field investigations. The mire database is part of the Institute for Nature Conservation of Serbia information system. For each mire site, the database contains the following data: distribution (GIS layers), assessed cover area, altitude, geological substrate, mean annual temperature, mean annual precipitation, and relevant references. For many of the mires, other relevant data are also included: vascular plant and moss cover, syntaxonomical units, peat characteristics (thickness, pH) and protection status (protected or not, degree of protection). Climatic characteristics such as average annual precipitation, average annual temperature and relief structure were considered according to Ducić & Radovanović (2005).

On the basis of these data, Serbian mire distribution maps with accompanying graphic analyses have been produced. According to the soil classification system adopted at the national level (Ćirić 1984; Protić *et al.* 2005), histosols (min. 30 cm peat layer, at least 30% organic matter) have been mapped excluding peatlands without preserved hydrological regime and characteristic mire vegetation

cover. On the other hand, all mires in the syntaxonomical sense (only vegetation from class. *Scheuchzerio-Caricetea fuscae* R. Tx. 1937 as class. *Oxycocco-Sphagnetea* Br.-Bl. et Tüxen ex Westhoff et al. 1946 is not recorded in Serbia) have been mapped, including those without the defined 30 cm peat thickness. Some mire complexes with huge amounts of peat submerged below the water surface (Obedska Bara Marsh, Zasavica Marsh) are also mapped.

Mire polygons represent individual mires or mire complexes which contain a mosaic of small mires scattered over a certain restricted area. Topographic maps (1:25000), satellite maps (http://maps.google.com/), available sketches and drawings were used for drawing polygons. In the cases of personal research, data from a hand-held GPS device were used. Drawn polygons often cover a somewhat larger territory than targeted mires, including water bodies or non-mire areas that persist within mire territories. Generally, the accuracy of these polygons is quite satisfactory for this purpose. In Serbia, there are no national maps of recent vegetation or habitat types that could serve as additional background, while the pedological maps often exclude peatlands. Statistics included logarithm and exponential regression analysis (Microsoft Office Excel 2007).

RESULTS

The first problem related to Serbian mires was to clearly define the term *mire*. Inconsistency of terminological units, classification systems and definitions well known for problematic mires was also obvious for Serbia. The term *mire* in this paper was interpreted in the broader sense to include all peaty areas with preserved characteristic peat-forming vegetation whose rooting system was functionally related to peat. Indeed, mires were considered according to Rydin & Jeglum (2006) as peat-forming wetlands that could be divided into minerotrophic fens, ombrotrophic bogs (not recorded in Serbia) and transitional mires (poor fens). The term *peatland* means peaty areas with or without peat forming vegetation.

The English terms *mire*, *peatland*, *bog*, *fen*, etc., have only one equivalent word in the Serbian language – "tresava" (meaning something that shakes) with accompanying, mostly archaic synonyms: *blato*, *jezerina*, *živobara*, *mlaka*, *glib*, *pištoljina*, *drhtulja*, etc., in recent times out of use). The term *mire* may partly refer to the Serbian "močvara" (marsh), especially for lowland mires, and "močvara" also includes wetlands without a peat layer. Different Serbian authors have different understanding of the term mires based either on the syntaxonomical or pedological sense. The generally-accepted classification of Serbian mires is pedological (Ćirić 1984), with division into flat (planhistosol), transitional (planoacrohistosol) and raised (acrohistosol) mires. Before World War II, German mire terminology and classification was commonly used in Serbia: *Flachmoore*, *Neidermoore* for fens, *Übergangsmoore* for transition mires, *Hochmoore* for raised bogs, but also the terms: *Rohrsümpfe*, *Weisenmoore*, *Sphagnummoore* and *Hangmoore* (Cvijić 1896, Košanin 1908, Katić 1910, Černjavski 1932). The mire classification system established by Cvijić (1896) was used immediately after its publication during the next few decades and after that it was slowly abandoned. In recent times, the National habitat classification system was produced (Lakušić *et al.* 2005), based on the EUNIS habitat classification, and its improved version in the form of the Rule Book was legally adopted in 2010.

In consequence, there has been a wide range of problems and misunderstanding of terminology interpretation and mire classification in Serbia recently. Thus, as a rule, the term "tresava" (mire) is translated as *peat bog*, the term "ravna tresava" (flat mire (fen)) is confused with the term *blanket bog*, the Serbian terms for low and high mires are somewhere used in the sense of altitude and elsewhere in the morphological sense, being confused with *raised bogs*.

For this reasons, the following English/Serbian translations are suggested here: mire – *tresava*; peatland – *tresetište*; fen – *minerotrofna tresava*; rich fen – *bogata tresava*; bog – *ombrotrofna tresava*; transitional mire (poor fen) – *prelazna (siromašna) tresava*; blanket bog – *pokrovna tresava*; raised bog – *izdignuta tresava*.

The first preliminary peatland distribution map with estimated areas for the former Yugoslavia was presented by Gigov & Bogdanović (1963), while Bogdanović *et al.* (1972a) published a distribution map for mires near Danube river. The most comprehensive review for Serbian peatland distribution was published in the paper "Peatlands of Serbia" (Tešić *et al.* 1979), though without any accompanying map.

On the basis of the Serbian mires database, a mires distribution map (Fig. 1) and distribution map with estimated mire size (Fig. 2) has been produced. The borders and size of polygons in Fig. 1 are slightly enlarged to be visible at the map scale used. In total, 155 mires and mire complexes were analyzed and presented, of which 19 were recorded for the first time by the author. The true number of all mires in Serbia is certainly much greater because some of the small mountain mires have been grouped into complexes and a certain number of small mountain mires still wait to be recorded. Beside mountain areas, some mires are hidden within vegetation units outside of class. *Scheuchzerio-Caricetea fuscae* R. Tx. 1937 and were not recognized as mires by Serbian scientists. On the other hand, some mire polygons, especially those around the town of Vranje, were not investigated and have not been confirmed recently. However, the number of mires

analysed with their accompanying data is sufficiently representative for this topic.

Considering their azonal and intrazonal character, Serbian mires are scattered around the whole territory. Mires of Serbian lowlands near large rivers, especially in the Pannonian basin (rivers Danube, Sava and Tisa) have been significantly reduced or destroyed during the past centuries. However their remnants are still among the largest mires and peatlands in Serbia. On the lowlands around Velika Morava river in central Serbia there are no data on existing mires. Southwards, lowland mires have also been recorded around Južna Morava river (localities: Malo Jezero, Lopardince, Crni Vir, Jezero-Medja), Kosovo valley (Batuse) and Metohija valley (localities: Piskote, Letike, Bara Fazlija, around Djurakovac), despite the influence of a certain Mediterranean climate in some parts of these areas. All these lowland mires are predominantly with typical marsh, swamp and water vegetation. As for the rest of Europe, agricultural development, amelioration, urbanization, transport infrastructure and other influences including peat extraction have drastically reduced the area of lowland mires. As expected, the number of mires is rising in mountain regions, especially in the silicate massifs (Mts. Šara, Prokletije, Kopaonik, Stara Planina). Unfortunately, mountain mires in Serbia nowadays are also threatened, especially by the development of tourism and ski resorts.

Currently, the largest mire territory in Serbia is lowland Obedska Bara marsh situated 75 m a.s.l. with an estimated peaty area of about 500 ha, with a mostly submerged peat horizon (Puzović 2010). Peštersko Polje on Pešter plateau (SW Serbia) is the other large mire complex with over 200 ha, situated at 1160 m (Miladinović *et al.* 2010). Taking into consideration only the mires with the strict vegetation sense (class. *Scheuchzerio-Caricetea fuscae* R. Tx. 1937), the largest is Vlasina Mire (SE Serbia). The peatland area on Vlasina Mire was estimated at ca. 350 ha (Cvijić 1896). Immediately after World War II, Vlasina Mire was converted to a hydro accumulation lake and today only about 30 ha has remained not submerged, together with 8-10 ha of floating peat islands (Momčilović-Petronijević *et al.* 2009).

Concerning the numbers of mires with their size (occupied area, mire area) together with the suggested

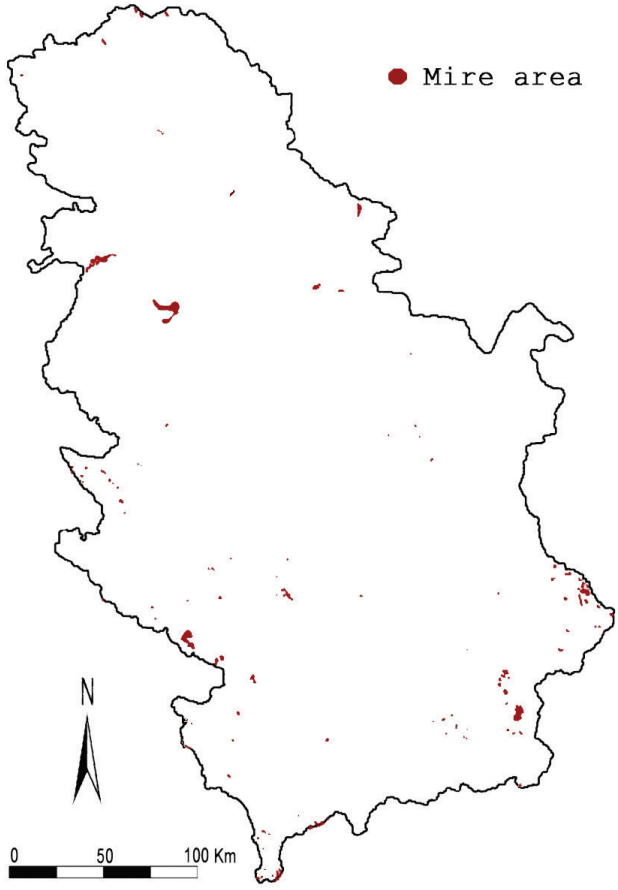

Fig. 1. Distribution of mires and mire complexes in Serbia.

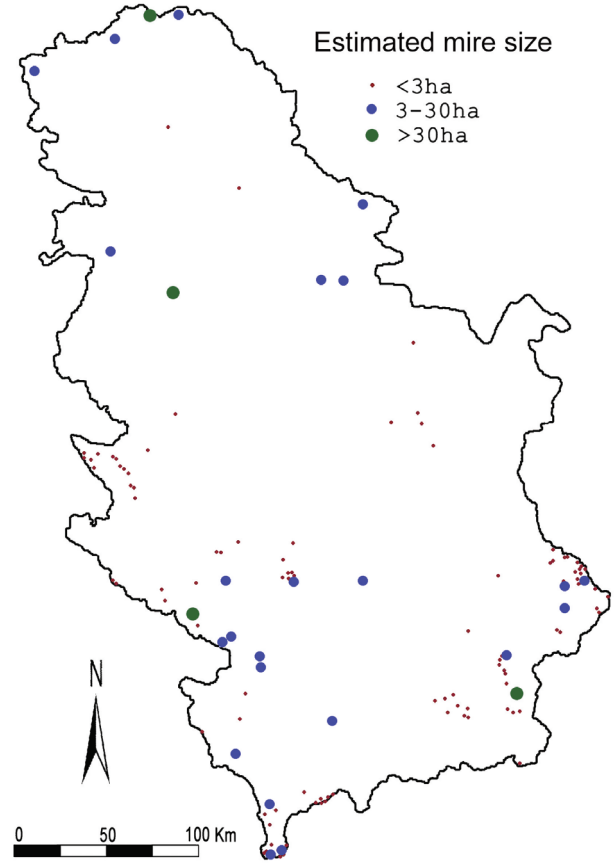

Fig. 2. Distribution of mires and mire complexes in Serbia according to gradient of their assessed size (<3 ha, 3-30 ha, >30 ha).

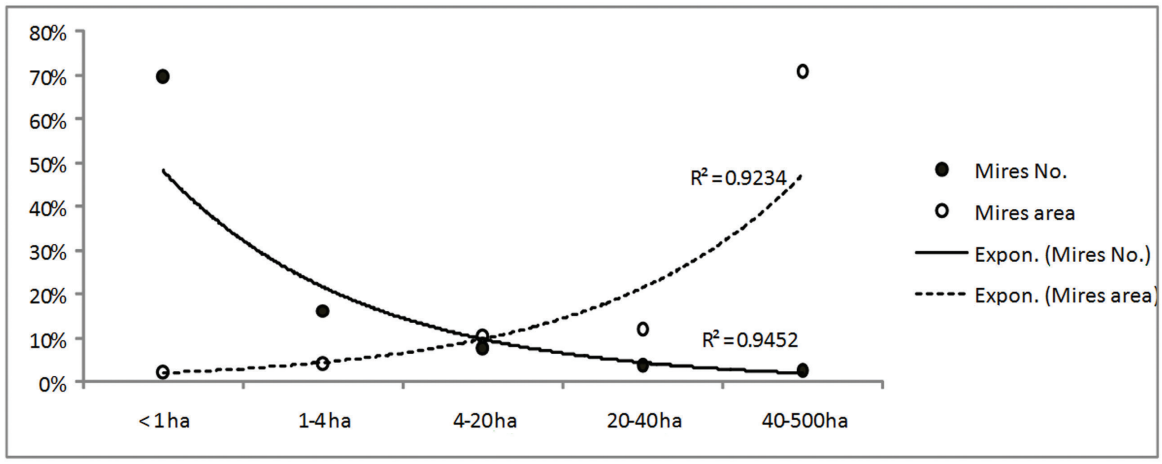

Figure 3. Proportions and exponential trends between number of mires and mire size (mire area) (in %) along a size gradient (< 1 ha, 1-4 ha, 4-20 ha, 20-40 ha, 40-500 ha).

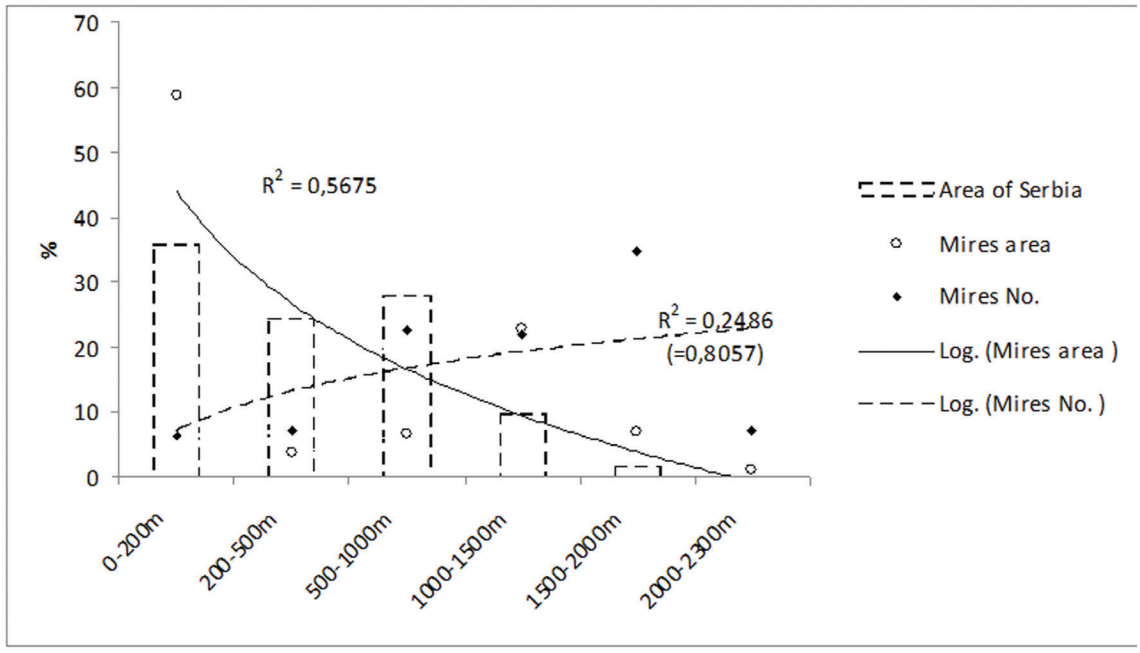

Fig. 4. Proportions and logarithmic trends between number of mires and occupied mire area (in %) along the hypsometrical structure of Serbian relief (m a.s.l.).

size gradient, they are disproportionate. This is noticeable across the gradient of five mire size categories: <1 ha, 1-4 ha, 4-20 ha, 20-40 ha, 40-500 ha (Figure 2).

About 70% of the analyzed Serbian mires were small (<1 ha) and occupying only around 2% of total area of mires in Serbia. On the other hand, less than 3% of mires (larger than 40 ha) occupied 70% of the total mire area. Exponential regression analysis clearly confirmed a decreasing trend in the number of mires (r^2=0.9452) and increasing trend in their area (r^2=0.9234) along the suggested size gradient.

Comparison of the number of mires and their size (mire area) along the hypsometrical structure of the Serbian relief (Fig. 4) showed that the biggest part, 36% of Serbian territory lies in the range from 0 to 200 m, 25% from 200 to 500 m and 28% from 500 to 1000 m. This means that 89% of Serbia is situated at altitudes less than 1000 m. Further, 9% of Serbian territory is at 1000-1500 m altitude and less than 2% is over 1500 m.

Mire size partly follows this declining trend with rise in altitude (Figure 4). There is an exception at the range from 1000 to 1500 m where another peak of areas appears,

due to the existence of two large mires on Vlasina and Pešter Plateau. Logarithm regression analysis confirmed a decreasing trend in the size of mires with increasing altitude (r^2=0.5675). Regarding the hypsometrical structure of Serbian relief, 59% of the total area of mires occupy 36% of Serbian territory above 200 m altitude, while an additional 10% of total mire area is located on 53% of Serbian territory in the range between 200 and 1000 m altitude. Almost 70% of mires area are situated on 88% of Serbian territory below 1000 m altitude. The two large mires between 1000 and 1500 m give an additional 23% of mire area on 9.7% of Serbian territory. Finally, at altitudes above 1500 m, 8% of total mire area is found on less than 2% of Serbian territory.

Contrary to the situation with mire size, number of mires rises with altitude (Figure 3). This rising trend peaks from 1500 to 2000 m altitude, with 35% of total mire number on 1.6% of Serbia's territory. Above 2000 m the number of mires rapidly decreases. In consequence, logarithm regression analysis (r^2=0.2486) did not confirm an increasing trend in the number of mires with increase in altitude. As only 0.25% of Serbia's territory is above 2000 m, the analysis was repeated without data for these mires. This additional analysis clearly confirmed an increasing trend in the number of mires with increasing altitude (r^2=0.8057).

Comparison of mire density along the hypsometrical structure of Serbia gave interesting results. Around 88% of Serbian territory (situated under 1000 m altitude) contained 36% of all Serbian mires. The highest density, 35% of mires was recorded on 1.6% of Serbian territory (at 1500-2000 m). A relatively high number of mires (7%) were found on only 0.25% of Serbian territory (over 2000 m). Thus, 42% of all recorded mires are present on less than 2% of Serbian territory located at altitudes above 1500 m. In reality, this percentage (42%) is even higher as the real number of small (yet not recorded) mires will inevitably be higher. This analysis indicated that mountain regions above 1500 m are mire distribution centers in Serbia, especially for those from the class. *Scheuchzerio-Caricetea fuscae* R. Tx. 1937.

The lowest recorded altitudes of existing mires were at around 70 m in the Pannonian basin (localities: Vatinska Mire, Gajskodubovački Rit, Obedska Marsh etc.). Negotinski Rit was the lowest recorded mire in Serbia, at less than 40 m above sea level, though it is now essentially extinct because of land reclamation and burning. The highest recorded mire was below Crni Kamen Peak (Šara Mt.) at 2165 m. Nevertheless, it is likely that the highest mires reach around 2300 m altitude near the glacial lakes on Mt. Prokletije, below Djeravica peak (2656 m).

All Serbian mires belong to fens and transition mires with no exclusive dependence on precipitation (no true bogs). A combination of ecological factors such as rising average annual precipitation with increase in altitude and decline of average annual temperature has an obvious influence on the occurrence of mires, especially for small mires from class. *Scheuchzerio-Caricetea fuscae* R. Tx. 1937. These interdependences would be reflected in the expected upward trend of mire number with increasing wetter and cooler conditions on higher altitudes.

Floristic structure and composition of mire vegetation are significantly determined by the surrounding geological substrate with regard to its mineral content dissolved in water. There are still no specific studies of this interdependence in Serbia (for example, influence of water conductivity and pH on mire vegetation).

Existing data on peat characteristics (pH, mineral content, chemical and microbiological characteristics etc.) in Serbia are scarce, so relevant analysis could not be performed. Peat thickness starts from about 10-20 cm in high mountain mires (Lakušić *et al.* 2005), to up to 800 cm on Vežanja Mire - Tara Mt. (Gigov 1960). From the available, but insufficiently representative, data mainly from larger mires, the average maximum depth of Serbian mires is about 190 cm, somewhat deeper on limestone than on non-limestone geological substrate. Data that are particularly missing are those on the thickness of peat of smaller mountain mires. The range of peat acidity starts from pH 3.5 on Veljinbeški Rid – Šara Mt. (Ranđelović *et al.* 1998) to neutral or slightly alkaline (≤ pH 7.9) in lowlands mires (Gigov *et al.* 1972; Bogdanović *et al.* 1982).

Estimates of the area of Serbian mires have changed during the past 30 years. Tešić *et al.* (1979) estimated Serbian peatlands to occupy about 10000 ha or 0.11% of total Serbian territory (88361 km^2). This number, taken from the European Soil Database also occurred in a paper on peatland distribution in Europe (Montanarella *et al.* 2006), but on an accompanying peatland distribution map of Europe, Serbia was shown as a completely empty area. Protić *et al.* (2005) estimated Serbian histosols to occupy c. 3000 ha (0.03% of Serbia). In this paper, 155 mires/mire complexes were analyzed excluding 18 mires cited by Tešić *et al.* (1979) that have become extinct during the last 30 years. The total area of these 155 Serbian mires was assessed to be about 1250 ha or 0.014% of Serbian territory. Some of the analysed mire areas, especially in lowlands, do not have updated assessments on mire size and partly include peatlands (without preserved characteristic vegetation). Mires whose extinction is confirmed during the last 30 years occupied ca. 200 ha. Mires in the vegetational sense (*Scheuchzerio-Caricetea fuscae* R. Tx. 1937) was estimated on less than 100 ha (<0.001% of Serbian territory).

All this points to the continuing trend of disappearance of the already-small mire areas in Serbia caused by negative

anthropogenic factors or by natural successions. Further inventorying and monitoring of mires in Serbia with an estimation of their condition would be the basis and necessity for their involvement in appropriate programs of protection and restoration.

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Botanica SERBICA

REZIME

Tresave Srbije – karakteristike rasprostranjenja

Predrag M. Lazarević

Osnovni cilj ovog rada je da pruži prvi kompletan uvid u distribuciju tresava u Srbiji sa procenom njihove veličine. Iz tih razloga napravljena je GIS baza podataka o tresavama i njihovom rasprostranjenju u Srbiji. Procenjena je distribucija i ukupna površina tresava u Srbiji u odnosu na poslednje publikovane podatke iz 1979. U poređenju sa najnovijim procenama od oko 3000 ha pod histosolima (zatresavljena zemljišta) u Srbiji, utvrđeno je da 155 analiziranih tresava i tresavskih kompleksa zauzima oko 1250 ha ili 0.014% od ukupne teritorije Srbije. 19 od njih je evidentirano i po prvi put predstavljeno od stane autora. Neke napomene o minimalnim, maksimalnim i prosečnim debljinama tresetnih naslaga kao i krajnje pH amplitude treseta su takođe razmotrene. Dat je i kratak osvrt na probleme u vezi terminologije i klasifikacije tresava u Srbiji sa nekim predloženim rešenjima. U radu je takođe dat podsetnik na klasifikacioni sistem ustanovljen od strane Jovana Cvijića 1896 godine, danas praktično zaboravljen u Srbiji i gotovo nepoznat izvan Srbije. Konačno, prikazana je na jednom mestu i sva relevantna literatura u vezi razmatrane problematike.

Ključne reči: tresave**,** tresetišta, treset, rasprostranjenje, Srbija