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GEOMORPHICAL MESO-ENTITY SEMBERIJA LOWLAND PLAIN

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SUMMARY

In this paper, it was necessary to prove that Semberija is in the geomorphological sense, the southern part of the Pannonian Basin, which is in contact with the Dinaric mountain system. Its done on the basis of the geomorphological analysis of the terrain, primarily morphotectonic, morphological and morphogenetic similarities with the plain terrain of Pannonia. This was the basis for a complex geomorphological regionalization which included added similarities and connections with the Pannonian Basin in climate, pedogeography and biogeography sense. Thus, after the complex geomorphological regionalization, it was determined that Semberija is a meso-entity, a subunit of the geomorphological macroregion Sava Basin, ie the southernmost part of the geomorphological megaregion Pannonian Basin.

Key words: Complexed geomorphological regionalization, geomorphological meso-entity Semberija lowland plain, Pannonian Basin, Bosnia and Herzegovina.

1. INTRODUCTION

Semberija is the lowest, northeastern part of Bosnia, whose area according to J.Đ. Markovic (1988) with surface is about 300 km2. The boundaries of Semberija, which resemble an isosceles triangle, are very clearly - neotectonically, lithologically, geomorphologically and hydrologically determined.

The structural boundary of this lowland in the north is the Sava tectonic trench through which the Sava river flows. In the east, the border stretches along the Drina primary fault through which the Drina river meanders on the stretch from Janja to the confluence with the Sava. The southwestern border is structurally expressed by the local fault Crnjelovo Gornje - Janja. On this stretch, the border of Semberija between North Majevica hills and the Brčko plateau is morphologically clearly expressed in the surrounding relief. (OGK 100, Interpreter for Brčko) (See Figures: 2 and 3). De facto, it is also a morphotectonic boundary filled with proluvial-deluvial deposits that lithologically build holocene fans formed at the fault contact of the low flat surface of the Semberija plain with the surrounding low slopes of north Majevica hills.

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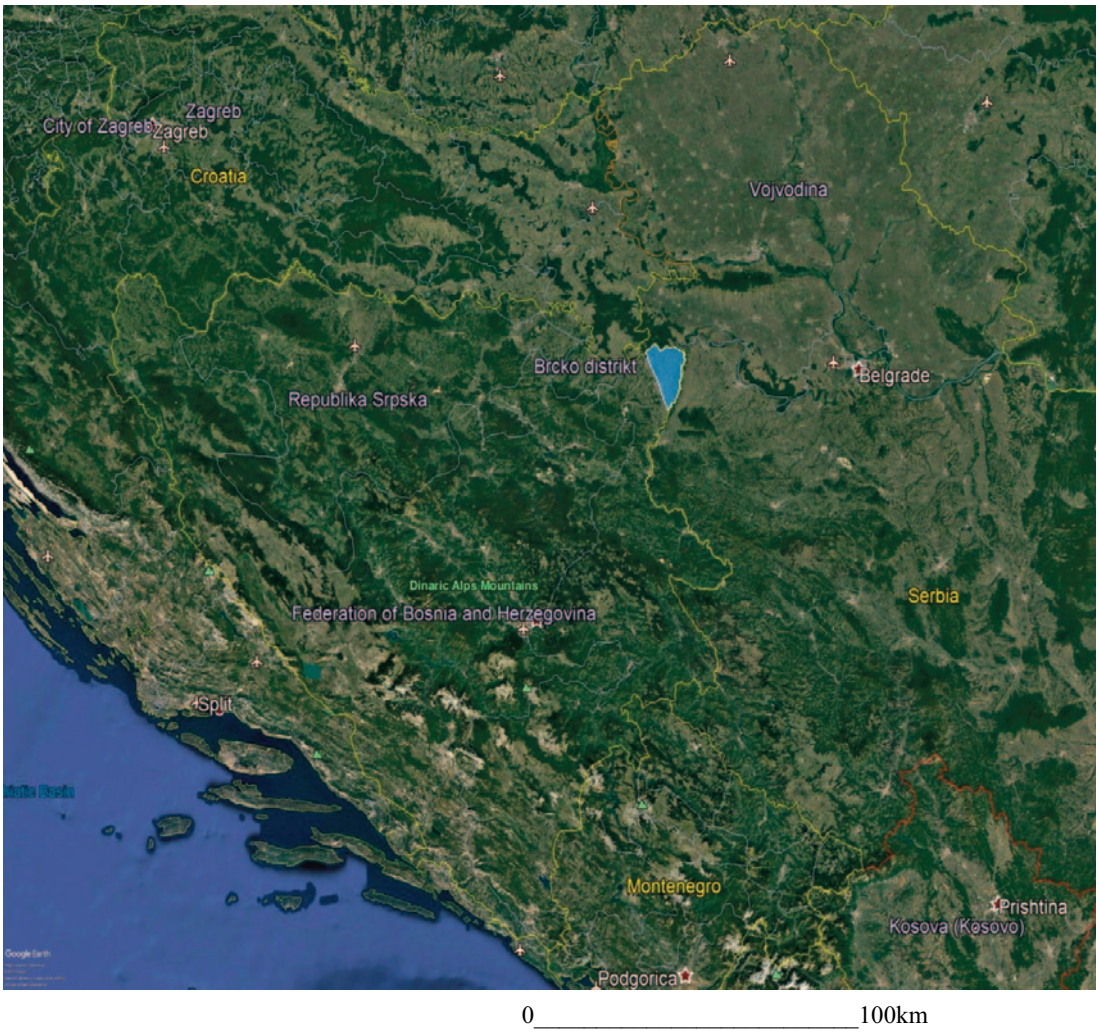


Figure 1. Geographical position of the Semberija lowland plain (blue color), Source: Google Earth 2013.

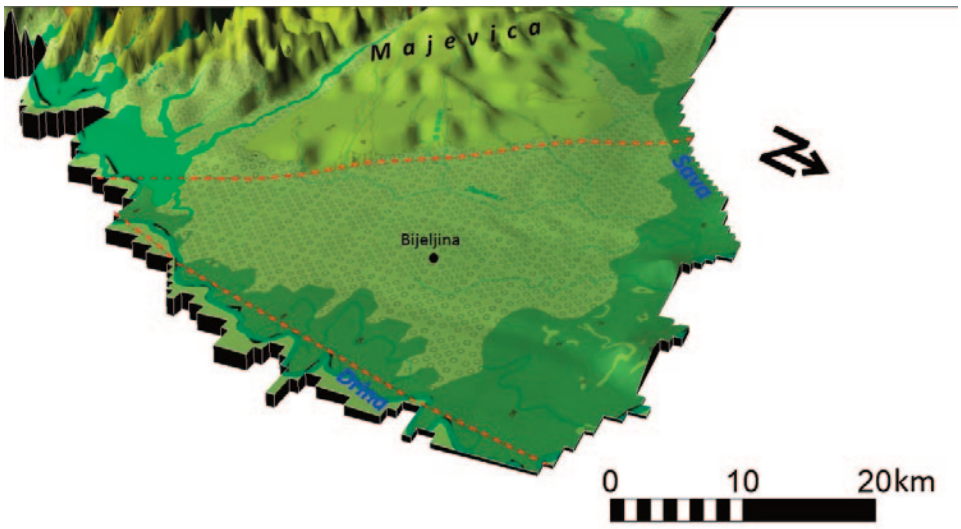


Figure 2. Semberija; The Drina River (east border) and the Sava River (north border). In the wide bank of these rivers you can see a higher floodplain (dark green), a terrace plain covering more space (light green with circles). The Crnjelovo-Janja fault (red dashed line, above of Bijeljina City) can be clearly seen as the morphological and morphotectonic boundary of the Semberijas terraces plain with the slopes of the North Majevica hills. (DEM: Dado Srkalović, 2019)

In the regional sense, Semberija has been treated as a part of the Pannonian or Peripannonian space in most of the physical-geographical and geomorphological works presented so far. This refers to the works of Yugoslav geographers: B.Ž. Milojević (1952), R. Petrović (1957), S. Ilešić (1961), J. Đ. Marković (1970, 1988), V. Rogić (1973, 1987) and others. The relief of the mentioned lowland mesoregion, considered geotectonically, was formed in the Sava zone, the youngest structural unit of the Inner Dinarides (Andjelković 1984). It is a zone of horsts and trenches (K. Petkovic, 1960) (Figure 3). The Pannonian Basin covers parts of the Pannonian structural complex and the Inner Dinarides (Supradinaric) (M. Herak 1990). Wrenching and tectonic inversion: NE-SW striking system of the dextral strike slip faults during Oligocene-Miocene was followed byNW-SE striking wrenching in Early and Middle Miocene, affecting South Pannonian Basin, Western thrust belt and Adriatic foreland. It is reflected as tectonic inversion in Mid-Bosnian Schists Vranica Mts. and as the system of the right-lateral strike and oblique slip faults, creating the large Sava and Drava depressions of the South Pannonian Basin. To the N and NE, Dinarides units were overprinted by tectonic processes controlling the evolution of the petroliferous Neogene Panonian Basin (V.Tari 2002.).

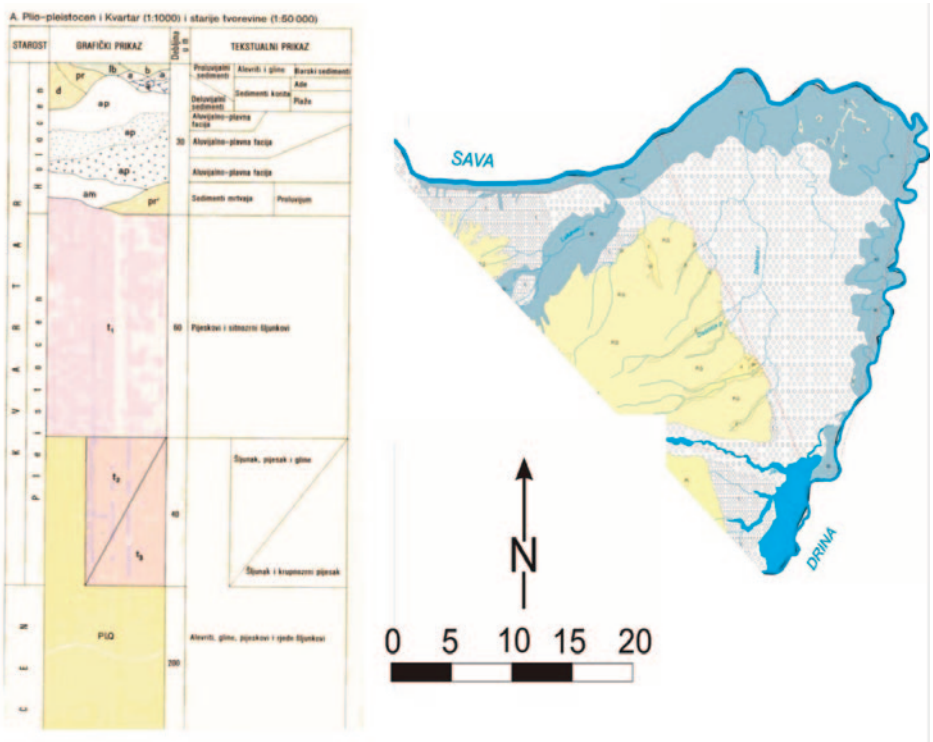
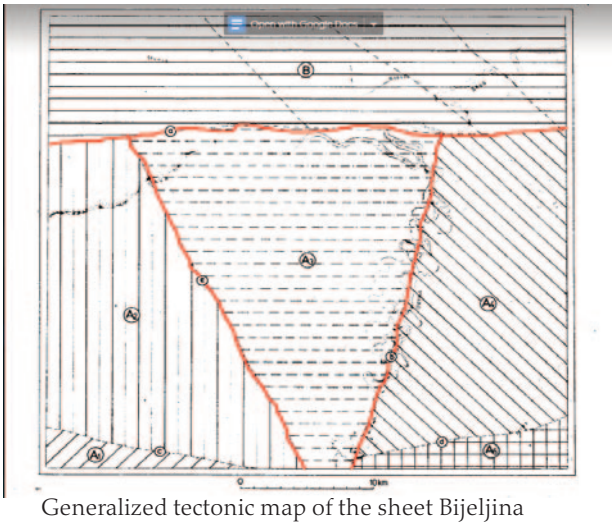


Figure 3. Geological map of Semberija

The active uplifting of the horst anticlinorium of Majevica took place simultaneously with neotectonic subsidence, which affected the surrounding paleodepression of the Semberija (Fig. 3 and 6.). Vrhovčić J. Buzaljko R. and M. Mojičević M. Mojičević (1986), (authors OGK 100, sheet Bijeljina, for SR BiH) state that the investigated mesoregion in the stratigraphic-structural sense enters the unit of Posavina and Semberija where it belongs entirely to the Dvorovi tectonic microblock (Fig.3 and 4). The modern Holocene period is marked by the activity of shear faults - the system of the Sava graben and the Drina fault and the secondary fault Gornje Crnjelovo - Janja (Fig. 3 and 4). The recent runoff directions of the Sava and the lower course of the Drina are neotectonically directed by subhorizontal wing displacements, strike-slip faults of the Sava and Drina trenches (A. Lepirica 2013) (Fig. 3 and 4).



Generalized tectonic map of the sheet Bijeljina

A - Unit of Posavina - Semberija: A_1 - block of Ugljevik, A_2 - block of Dragaljevac, A_3 - block of Dvorovi, A_4 - block of Mačva, A_5 - block of Lešnica;
B - Unit of Srem. Faults: a - Sava fault, b - Drina fault, c - Modrane fault, d - Lešnica fault and e - Crneljevo - Janja fault

Figure 4. F. Horváth, (1985b) in his work: "Thickness of Neogene Quaternary basin fill [Pannonian Basin system]", includes Semberija in the Pannonian Basin which is visible along the border with the Vardar zone and clearly represented by a blue dashed line (Fig. 5).

The fault neotectonic movements significantly determined the morphoevolution of the relief of this macroregion. With the uplifting of mountain elevations (altitude over 500 m above sea level) and the regression of Paratethys (or Pannonian Sea) in the pont, the morphoevolution development of the landforms of northern Bosnia and Semberija begins (Fig. 6).

In the analysed area, the average thickness of the continental crust is about 25 km. Semberija, from the lithological point of view, is characterized by heterogeneous lithofacial complexes (Fig. 3). It is mainly dominated by thick deposits of marine and lake sediments, genetically related to Paratethys and Paleogene and Neogene northern Bosnian basins. (Čičić, S., 2002) (Fig.2 and 3).

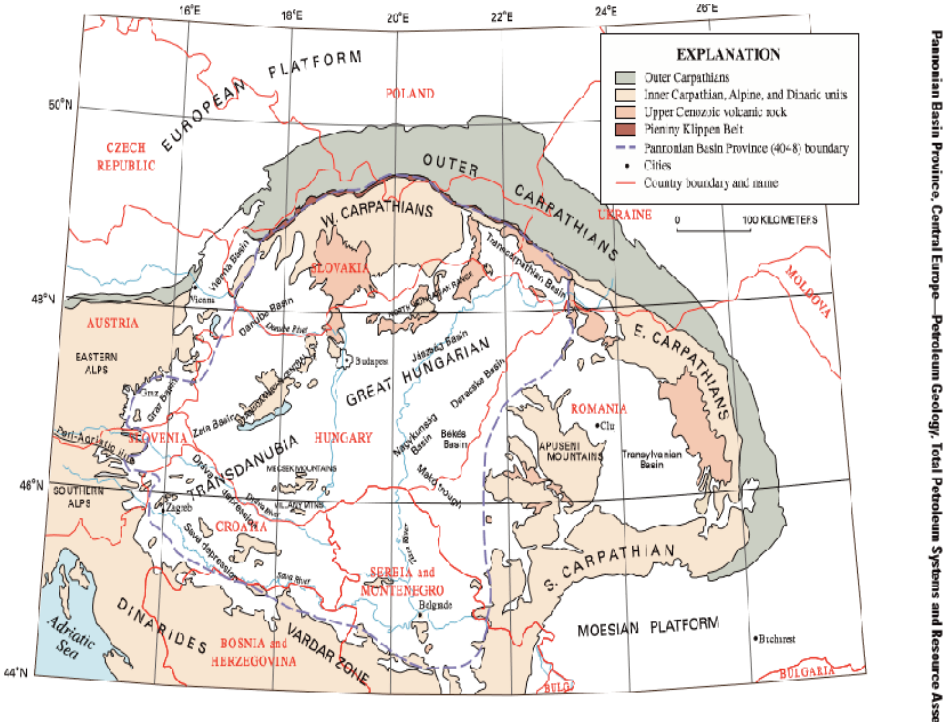


Figure 5. Horváth, F., 1985b, The Pannonian Basin, (Retrieved from: A study in basin evolution: American Association of Petroleum Geologists Memoir 45, map 1.)

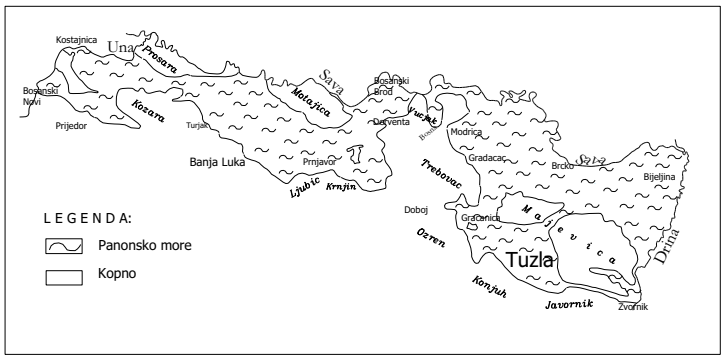


Figure 6. Paleogeographic map of northern Bosnia in Baden (Vrabac, S., Ferhatbegović, Z. & I., Đulović I., 2006)

2. MATERIALS AND METHODES

Thus, we used the method of complex geomorphological regionalization according to A. Bognar (2001). So we were primarily based on morphotectonic, lithological, morphological and morphogenetic similarities with the Pannnonian Basin. In the other hands, using the methodology of modern geomorphological regionalization, we took it into account additional, climatic, hydrological, pedological and biogeographical characteristics that resulted in the regional geomorphological determination of the Semberija.

The morphotectonic analysis have included: of the relations between relief, lithological substrate and neotectonic structures were analyzed.

The types and river network density were made by morphotectonic analyses using primary the topographic maps scale 1:25 000 and Google Earth satellite map.

The morphological analysis were included:of the orographic structure, hypsometric relations, slope inclinations and energy relief were made.

We used topographic maps scale 1:25000, 1:50000 and 1:100000, geological maps 1:25000, 1:100000, digital map Adria topo 2.10, and the Google Earth satellite map. In the terrain researches and analyses, we used a GPS (Garmin, Montana 600) for the observations of the microlandforms, in situ. Afterwards, the base of morphometric data was made, which was processed in the GIS using the Map Info Professional 9.5 application, and for creating the thematic maps and we used digital elevation model (DEM) and Satelit imagery google 2017.

Thus, the goal of this research is to determine the geomorphological position and regional hierarchy of the Semberija plain.

3. RESULTS AND DISCUSSION

In a strictly geomorphological sense, Semberija expresses in relief the northeastern part of the geomorphological macroregion "Mountains, hills, valleys and valleys of northern Bosnia" (Lepirica 2009).

From the aspect of geomorphological regionalization, it represents a mesoregion. It is a smaller, south-eastern part of the geomorphological macroregion of the Sava Basin. Semberija with the neighboring Mačva is the largest macro-flood in this part of Sava drainage system.

Figure 7. Photo: Ervin Lepirica, View of the low plain Semberija from Majevica from Bilalić (Teočak); on the left side of the picture on a flattened Sember terrace, in the distance, you can see a part of the town of Bijeljina.

It is part of the Pannonian Plain south of the Sava according J. Đ. Marković, 1988. Neotectonic subsidence of Semberija, 2-4 mm / year, active during the Quaternary (according to the map of vertical movements of the lithosphere crust, P. Jovanović, 1971) stimulated increased fluvial accumulation and lateral erosion of river flows. Geomorphologically, this was reflected in the development of floodplain and terrace plains (See Fig. 3).

Thus, fault neotectonic movements, but also climatic fluctuations during the Pleistocene and Holocene, significantly determined and directed the Quaternary fluvial and fluvio-marsh morphoevolution of the Semberija relief. The relief structure of Semberija is represented predominantly by flattened fluvial terrace landforms and elongated floodplains of the rivers Drina, Sava and their smaller tributaries. (Fig. 7).

From the hypsometric aspect, the lowest, lowland belt (0-200 m above sea level) is the most common in this mentioned area. The highest terrains extend of about 115 m A.S.L., at the contact of the terrace plain with the slopes of the North Majevica hills, southwest of Bijeljina.

It is tectonic trace of the Gornje Crnjelovo- Janja fault.

The terrain of Semberija is very pronounced, slightly, gradually sloping towards the erosion base - the riverbed of the Sava, which stretches to about 77.5 - 78 m A.S.L. Thus, the altitude in Semberija generally gradually decreases from southwest to northeast. The lowest values of vertical disintegration (0-5 m / km^2) and slope (0 ° - 2 °), (according to E. Hammond, 1964), predominantly characterize the terrains of the Semberija floodplains and terrace lowlands (See Fig.3 and 7).).

Therefore, in this lowland area, morphogenetically dominated by accumulation and fluvial lateral erosion (planning process) because this eastern part of the Sava Basin is neotectonically lowered between the Sava and Drina faults (Fig.2,3,5 and 7).

Semberija is mostly represented in relief by terraces and floodplains built by Quaternary alluvium and proluvium sediments deposits of the Drina (mostly) and the Sava, in the far north (according to the Interpreter of the Basic Geological map -100) (Fig.2).

Also in this lowland relief, the appearance of kilometer-long elongated swamp line depressions such as: Svora, Lukavača, Prugnjača, Popovača, Biogradska bara, Makova bara and others can be noticed. These are fragments of the former cut-off meanders of the Drina and Sava, which represent recent marsh. (See Fig 8).

Figure 8. Meandering of River Drina downstream from the Janjasettlement; IN the both sides in the picture you can see agricultural land of the terraced plains;floodplain s along the river flow (in the central part), the fragments of former riverbed (cut off meander) covered with hygrophilous vegetation, sandy-gravel bars with underwater hidrodynas, vegetation traces of former oxbow lakes (left) (Source: Google Earth 2011.)

The widest fluvial landform is a deep Sava riverbed, with an average width of 250-350 m, regulated for river navigation. A multi-kilometer long defensive embankment stretches above the Sava.

In these plain areas, the shallowly cut, unstable riverbed of the Drina, 170-300 m wide, is fulfilled with sandy-gravel deposits. Geomorphologically, Drinas meandering river bed it is marked by the braided channel patterns with dynamic development of fluvial microforms: river passages and channel bars with hydrodynes on bottom, accumulated point bars and opposite natural levees of the cut banks, river islands and oxbow lakes in initial phase on cut off meanders. On this part, of the lower Drina flow, the river islands are more than 1 km long as Buljuklića ada, Kolaričeva, Limanska ada, Nalića ada, Sitnjak ada and other numerous river islands, are covered by dense hygrophilous vegetation of willows and poplars.

The transition to the older phase of free meandering is marked by the moment when river currents, erosively cut the narrow meandering neck at higher flows. At the places where the meandering peaks are cut off, oxbow lakes are formed, filled with fine-grained muddy-clay sediments. With the subsequent intensification of organogenic-bar processes, the oxbow lake become swamp with further development, completely dry up with dense vegetation (Fig. 8).

Recent swamps, hundreds and thousands of meters away from the recent riverbeds of the Sava and Drina, indicate their former, wide, lateral migrations. During the colder winter months, they are often frozen. The concentration of oxbow lakes and swamps is mainly noticeable in the northeast part of area, around Velino Selo, where the fluvio-swampy lowland relief dominates. During the winter temperature minimums, the mentioned northern Bosnian river flows are partially frozen. It is a short time situation, expressed in places of slight falls of the longitudinal profiles, where the river flow are very slowly. The free meandering of the lower course of the Drina, through neotectonic subsided areas of Semberija and Mačva, formed a whole network of new and fossil river beds with channel bars, backswamps, abandoned river islands, fluvial beams and numerous oxbow lakes (See figure 8).

The average annual flows of this largest tributary of the Sava are 395 m^3 / sec. (Source: D. Dukić: Enciklopedija Jugoslavije, 1990.) Slightly curved meanders of smaller river flows Janja (a tributary of the Drina) and Dašnica (a tributary of the Sava) up to twenty meters wide intersect the Semberija terrace plain. "Active fluvial landforms include alluvial fans, terraces, deltas, and floodplains. The latter are often further subdivided into natural levees, channel bars, backswamps, infilled channels, and crevasse deposits" (P. F. Hudson 2017). The torrent Drina riverflow, which is in the upper course of the nival-pluvial river regime into the low Sava valley, flows from the high mountainous hinterland whose peaks often exceed altitudes of 2,200 m above sea level. The upper course of this mountain stream drains Dinarides mountain system of the southeastern Bosnia, northern Montenegro and Albania. The Drina at the confluence with the Sava, especially in the period of its very high water levels of the Drina, affects the characteristic occurrence of slowing water runoff, which is one of the causes of flooding of the surrounding plains and the formation of dynamic forms of low floodplains. Spatially, the largest alluvial plains, in Bosnia and Herzegovina, reshaped by the lateral planning of the Drina and Sava, are located in Semberija (Fig 2.). In the geomorphological sense, they represent higher alluvial planes formed 2-3 m above the rivers that are higher part of the riverbed. They express very high water levels of annual discharge in the lowland relief. Their flattened areas, kilometers wide, extend above the low river banks of the Drina and Sava. More alluvial lithologically are represented by alluvial-proluvial and marsh sediments on which alluvial and gley soils have developed. They are dominated by rounded, loose alluvial deposits (gravel, sand, fine-grained clayey sand, clays and sandy clays) (Fig 3.). Periodically flooded terrains of the northern Bosnian floodplains are marked by numerous smaller permanent wetlands, overgrown with reeds and sedges (Lepirica 2013). This lowland are hydrologically fed by flood, groundwater and precipitation waters. Micro-relief depressions of higher fields are often represented by oxbowlakes, traces of past, old riverbeds, channels and periodic swamps, recognizable by dense hygrophilous vegetation which, with the additional application of modern agro-technical measures, turned higher floodplains into fertile agricultural areas (Fig. 8).

J.Đ. Markovic (1970) states that Semberija is for the most part a fluvial macrofan of the Drina River, whose sediments from the Pleistocene to the present day have shifted the Sava river low to the north. Northeast of the confluence of the Drina and the Sava, there is a classic example of the movement of the Sava riverbed by about 5 km to the north. South of the current flow of the Sava, the entire old flow of the Sava has been preserved, in the abandoned meander of the flow of Resavica and Banovo polje (Tumač 1986.). Thus, in Semberija, in the morphogenetic sense, the fluvial relief of the terrace lowlands dominates (Fig 3.). As part of the terrace plains, sand, gravel, silt and clay, over 80 m thick, participate (Fig 2.). Those plains are dissected by meandering, unstable riverbeds. Partially denuded forms of the terrace lowlands of Semberija appear in three elevation levels. They extend above the alluvial-flood plains. They represent older, draining planar fluvial forms, sandy-gravelly-clayey composition. The morphoevolution of terrace

forms is marked by succession of lateral and deep fluvial erosion caused by neotectonic changes and climatic fluctuations.

The lowest first river terraces, cut by fluvial erosion in Quaternary sediments, were leveled by subsequent lateral erosion. The Semberijas part of the first Drina terrace is located 4 to 5 m above the normal level of the Sava and Drina rivers, and at altitudes of 80 to 100 m. It is situated between the Drina and the alluvial floodplains of the Sava (Interpreter of the Basic Geological Map 100, 1986). On the surfaces of the first river terrace, the Bijeljina City developed, as well as many other settlements. (See Fig.3) Spatially, the largest are morphoevolutionarily older, other Pleistocene river terraces (t2), are slightly inclined towards the bottom of the basins. They were formed at about 12-20 m, above the remains of the older, higher, third Pleistocene terrace (t3), they are fragmented. They are located above low fields, at altitudes of about 105-115 m A.S.L. Due to the mechanically more erodible Quaternary lithological composition, their terrace sections were denudation-destroyed. The edges of the higher terrace areas, in contact with the slopes of the low hills in the south, are covered with proluvial-deluvial deposits. Proluvial-deluvial fans landforms formed primarily by torrents and leaching from the surrounding slopes during rainfall and during periods of melting of the snow cover. In relief, they represent mainly the southwestern border with the North Majevica hills. They are formed in contact with the more flat terrains of the Semberija lowland, where the kinetic energy of torrents decreases sharply. Anthropogenic - technogenic relief is mainly concentrated around Bijeljina City where it is represented by the urban center of Bijeljina and numerous newly built satellite settlements not far from the city with supporting infrastructure (residential, industrial and energy facilities, asphalt roads, railways, canals, transmission lines). The settlement of Janja and other smaller rural settlements with agricultural areas belong to this genetic type of relief. It is important to point out that a large part of the fertile terrace of the Semberija lowland plain has been brought to agricultural use. Then, the ethno village "Stanišić", the infrastructure swimming-pool in Dvorovi and especially the technogenic relief are expressed by numerous canals (Dašnica, Drinica) and the defensive embankment along the Sava River.

Climate significantly affects the characteristics and intensity of exogenous geomorphological processes. Most of northern Bosnia is dominated by a temperate-continental climate with more pronounced continental characteristics of thermal and pluviometric regimes. "The main maximum precipitation falls in spring or early summer and the secondary in autumn." (R.Milosavljević, 1984-85.)

Table1. Mean air temperatures and average values of annual precipitation in the period 1951-1970.

Weather station	**Altitude** (m)	**Medium per year** air temperature (^{0}C)	**Average annual precipitation** (mm)
Brčko	96	11,2	781
Bijeljina	90	10,9	751

(Source: Ecological-vegetation regionalization of Bosnia and Herzegovina.- Special editions no. 17, Faculty of Forestry, 51, Sarajevo, 1983).

The lowest average values of annual precipitation of 600 -750 mm characterize the low area of Semberija, in the northeast (See Table1). Vegetation in this basin area exists on fluvial, fluvio-swampy sediments soils such as predominant eugley, fluvisol, semigley.

Semigley soils are very high quality agricultural soils, and are found in Lijevče polje and Semberija (Ahmetbegović, S., Stjepić-Srkalović, Ž., Gutić, S., 2017). In the Sember lowland, from a pedological sense but also from a bioclimatic point of view, oak forests and other moist and semi-moist forests of alder, field ash, willow, poplar, shrub and shrub (Almion glutinosae, Almion incanae, Populion alba) are partially developed. (Source: Intrazonal forest vegetation in SFR Yugoslavia, Encyclopedia of Yugoslavia 1990)

4. CONCLUSION

Semberija is a part of the Pannonian Basin in the far south, as evidenced by works related to the scientific geological research of the F. Horvat (1985), M. Herak (1990). and V. Tari (2002). Therefore, the lowland plain of Semberija, in geomorphological sense belong the Pannonian Basin. There is no doubt that morphostructural and morpholitogenic elements are decisive for the regional differentiation of the state space (Bognar 1995). Apart from them, the predominant interference of other natural elements - climatic,

hydrological, pedological and biogeographical, which represent the principle of special spatial connections, was of great importance in the separation of regions in individual cases. The mentioned principle is often used in natural geographical - homogeneous regionalization, but also in modern geomorphological regionalization (Bognar, 1997, Lepirica 2009, 2013). A. Bognar (1995), regionalizing the territory of Croatia, singled out the Pannonian Megaregion of Croatia, the southwestern part of which tectonically belongs to the Inner Dinarides. Of course, a similar approach of homogeneous, physical-geographical and geomorphological regionalisation in this paper was applied to the Semberija. Therefore, on the basis of the performed geomorphological regionalization, it was determined that the geomorphological mesoregion of the Semberija Lowland Plain. It is the southeastern part of the Sava Basin macroentity. In the regional separation of the analyzed area, the criterion of specific spatial connections used in modern geomorphological differentiation of the area was strictly taken into account. Thus, complex geomorphological and physical-geographical analyses of the plain terrain obtained a very high degree of correlation or natural homogeneity with the geomorphological megaentityof the Pannonian Basin in relation to neotectonic subsidence, landforms(river terraces, alluvial plains, meandering riverbeds), morphology (lowland plain, relief energy, altitudes), climate (continental precipitation regime, mean annual precipitation height 600-700 mm.). Also, the complex analysis included general Pannonian hydrographic features (mechanisms of runoff of lower river watercourses).The Quaternary hydrodynamics of the Drina river flow reflected in the morphoevolution of two lowland plains - Semberija in the west and neighboring Mačva in the east.

These fluvial processes also directly affected on the pedogenesis of fluvial-marsh soils (eugley, fluvisol, semigley) and the vegetation features (oak, hornbeam, malt, poplar and willow) which confirms that Semberija is the southern part of the Pannonian Basin geomorphic megaunit.

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