PEDOGEOGRAPHICAL CHARACTERISTICS OF TUZLA

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The research results of pedogeographic characteristics of Tuzla city are shown in this paper. The detailed analyse of represented soil types, their condition, the way of usage, degradation, devastation, contamination and pollution was made. The naturalgeographic characteristics of the area were also a subject of the research. The analysed pedological factors (geological structure, relief, climate, hydrogeographic characteristics) indicated the uniqueness sensitivity of this area. Arable and productive soils are less represented than unproductive soils. Devastation process is especially expressed on the most quality soils which are appropriate for agricultural production. Potentially the most productive soils in Tuzla municipality, which are located alongside Jala river, are covered with buildings, traffic, industrial and other urban infrastructure.

Keywords: soil, pedogenetical factors, pedogeographic researches, devastation, agricultural production, Tuzla city.

INTRODUCTION

For the development and formation of soil, the geological basis is of greatest importance. The geological soil basis is the rock surface from which, under the influence of a number of factors, the soil is created and developed. Soil material can be provided by any rock if it´s on the surface and susceptible to physical, chemical and biological influences that cause its surface layer to decay (Ćirić, 1991). For a longer period of time, the area of the city and the wider surrounding area of Tuzla is characterized by processes of urbanization and deruralization, industrialization and deagrarization, which have largely contributed to soil pollution, degradation and devastation (Stjepić Srkalović, 2016).

One of the biggest problems in pedogeographic research in our country is the lack of recent professional and scientific literature related to the study area. The former soil researches are carried out from the acpect of geoecology or agricultural land, while the distribution, genesis and evolution of soils are ignored. The financial problems and the lack of specific standards for testing the presence of heavy metals in soil samples (ICP OES method) should also be mentioned.

In addition to the thoroughly analyzed pedogenetic factors, the soil distribution on the territory of the Tuzla and the soil usage, the paper also analyzes the soil quality, i.e. its fertility, quality and pollution, which represents a contribution to previous and future researches. However, the territory of the city of Tuzla should be thoroughly analyzed in detail (physical and chemical characteristics of soil, depth of solum, parent substrate), because compared to previous studies of this kind in the period 1969-1972, they are now anthropogenized, polluted, devastated and some completely modified.

The data needed for the research was obtained from the scarce available literature, and expanded by terrain and laboratory research.

GEOGRAPHICAL POSITION AND PHYSICAL-GEOGRAPHICAL CHARACTERISTICS OF TUZLA

Location and relief. The relief is an important pedogenetic factor, which in conjunction with other factors directs pedogenetic processes and causes the appearance of different pedosystematic units in space. The relief influences a number of pedogenetic processes such as erosion, morassing, eluviation, salinization, alkalization and other (Ćirić, 1991). The territory of the city of Tuzla geographically belongs to the region of northeastern Bosnia, more precisely to the subregion of the Spreča-Majevica region. Tuzla is located in the valley of the Jala River. In the northeast, the teritory is surrounded by the mountain morphostructure of Majevica, and in the south by the Spreča valley.

The urban area of Tuzla is located between 18°56' and 18°79' E and 44°48 'and 44°60' N, at an altitude from 202 and 480 m. The area of Tuzla city covers about 303 km^2 and is located on the northern slopes of the Dinarides mountain system and is generally mildly tilted towards the Gornja Spreča valley (Stjepić Srkalović, 2015). There are about 110,979 inhabitants living in 66 settlements in this area (Census, 2013).

Administratively and geographically, the city of Tuzla is surrounded by municipalities: Čelić in the north, Srebrenik in the northwest, Lukavac in the west, Živinice in the south, Kalesija in the southeast and Sapna in the east. It borders with Republic of Srpska in the northeast. The city of Tuzla is the administrative center of the Tuzla Canton (Stjepić Srkalović, 2015).

Geological structure. The substrate provides the material basis from which the soil is formed (sometimes more than 90%). Therefore, the nature of the parent substrate greatly influences soil properties and development, often reflecting on the entire soil evolution (Ćirić, 1991). The oldest structures belong to the Tuzla's lower Miocene formations in which organogenic limestones are prevailing ("slavinovićki" limestones and dolomites) with sporadic marls. Above them, the clasts were deposited with characteristic reddish coloring sandstones and conglomerates, building the "red" series. The continuation of sedimentation cycle is made of a "trakasta" series, where the salt formation with accompanying dolomite, anhydrite and tufts are developed.The organogenic limestones, clays, marly clays, sands and subsidiary conglomerates are belonging to the youngest Miocene products. The development of the lower Pliocene is characterized by the deposition of several seams of lignite (main, base and top seams). Vertical development of the Pliocene formation has the characteristics of rhythmicity: quartz sand, clays (slate and alevrite) and lignite. Quaternary formations were developed along the streams in the form of proluvial depositions (debris) and as precipitated terrace and alluvial sediments (sand and pebbles) (Fig. 1) (Čičić, 1988).

In terms of *climate*, the city belongs to the moderate continental climate and according to the Köppen classification belongs to the Cfb climate (moderately warm humid climate with warm summers). The climate is a pedogenetic factor whose effect is exerted by the influence of solar radiation and the dynamic processes in the atmosphere that transmit moisture and heat. The soil exchanges thermal energy, water and various gases with the atmosphere. In addition to its direct impact on soil formation, climate also acts indirectly, conditioning the distribution of different biocenoses, which may have quite different microclimates (Ćirić, 1991).

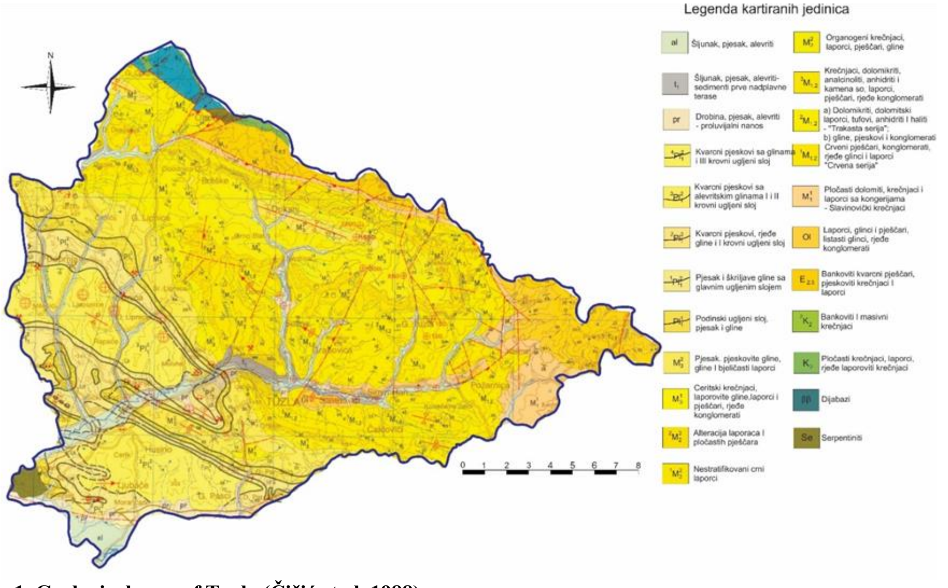

Fig. 1. Geological map of Tuzla (Čičić et al, 1988).

Hydrographically, this area belongs to the basin of the Jala River (37 km), which flows into the Spreča River near Lukavac. The river network is one of the factors of soil formation, because with watercourses, due to the constant presence of water, hydromorphic soils are most commonly formed: fluvisols (eluvial soils), eugleys, deluvial-alluvial soils, fluvial-alluvial soils, etc.

In *biogeographical* sense, the city of Tuzla is entirely in the Peripanonian area, the North Bosnian ecological and vegetation region, characterized mainly by oak lowland forests of *Carpinion betuli, Alno-Quercion, Alnion glutinosae, Salicion albae* and *Quercion robori-petreae* forests. A special phytogeographic feature of this area is represented by beech forests, i.e. beech and fir trees in the small areals at Majevica (Stefanović, et al, 1983). The biocenoses are exchanging matter and energy with the parent substrate and thus have a direct impact on soil formation. The biocenoses also modify climate impacts and thus exert indirectly influence on soil formation (Resulović, et al, 2010).

PEDOGEOGRAPHICAL CHARACTERISTICS

On the pedological map (R = 1: 50 000) of the Tuzla's urban area, there are 26 (mostly automorphic) soil types (Ćirić, 1991; Stjepić Srkalović, 2015) (Fig. 2). On the Tuzla city territory, the following soils are distinguished from the automorphic group: brown degraded soil on clays and loams, vertisols, yellow-brownish soils on sands, yellow-brownish soils on sandstones, brown medium and deep carbonate soils, gray carbonate and non-carbonate soils on shale, brown soils on shales, pelosols, lithochromatogenic red and purple soils, lithochromatogenic red soils on claystones, brown soils on serpentinites, brown carbonate soils on limestones, brown degraded and podzol soils on claystones, brown podzol soils on clays, brown soils on mixed carbonate debris, gray carbonate and non-carbonate soils on marls, podzol pseudogley terraced soil, podzol pseudogley soils on slopes

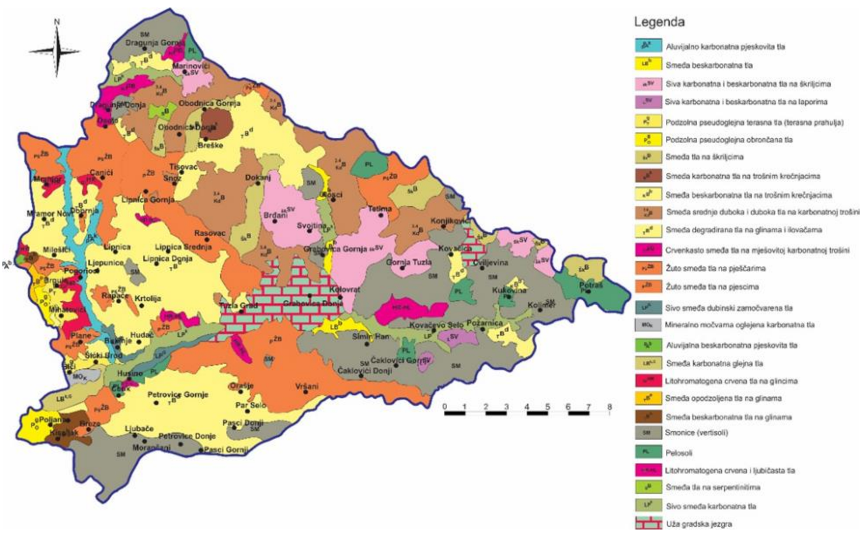

Fig.2. Pedological map of Tuzla (Pedological map of Jugoslavija, 1969.)

In the area of Tuzla, the following soils are distinguished from the group of hydromorphic (valley) soils: gray-brown carbonate soils, alluvial-carbonate sandy soils, alluvial-non-carbonate sandy soils, brown non-carbonate soils, gray-brown deeply-marshed soils, mineral marshed soils and brown non-carbonate gley soils. It should be noted that a large part of these soils is covered by urban infrastructure and is not used for agricultural purposes (Stjepić Srkalović, 2015).

RESEARCH METHODS

Various methods were used during the preparation of this paper, such as analysis of previous research results, defining the concept of work and the order of research, field research, preparation of samples for laboratory tests and the preparation of thematic maps and tables, etc.

The fieldwork involved the collection of soil samples (10 samples) from 303 km^2 area (within the borders of the city of Tuzla). The samples were collected according to a composite sampling scheme, i.e. 5 sub-samples collected from the corners and center of the square make 1 sample. The samples were taken from a depth of about 30 cm and stored in PVC bags with the noted ordinal number, location and geographical coordinates. Soil sampling was performed according to the instructions of the Geochemistry Expert Group (The Urban Geochemistry Project (URGE)) (Ottesen, 2008).

Preparation of soil samples for laboratory analysis (sowing, drying, milling, weighing) was carried out at the Faculty of Mining, Geology and Civil Engineering, University of

Tuzla, where laboratory analysis was performed using the ICP-MS method (Inductively Coupled Plasma – Mass Spectrometry). Graphic processing of the results was performed in Golden software Surfer 12 software package.

RESULTS AND DISCUSSION

Field studies implied that in the class of automorphic soils, brown degraded soils on clays and sandstones, vertisols, yellow-brownish soils on sands and sandstones, brown carbonate and non-carbonate soils on shales and pelosols are the most represented, while grey-brownish carbonate soils are the most present in the class of hydromorphic soils.

Table 1. Soil use in Tuzla city area

Use	Area in km^2	Area in %
Forests	137,821	45,48
Urban and non-urban areas	122,12	40,3
Road infrastructure	13,63	4,49
Slag and ash landfill	2,62	0,8
Desetine Landfill	0,21	0,07
Par Selo Landfill	0,69	0,22
Tetima Salt Mine	4,06	1,33
Quartz sand exploitation	6,59	2,17
Coal basins	24,13	7,96
Inactive mines	1,55	0,51
Landslides	40,75	13,44
Labile slopes	29,97	9,89
Special Purpose Areas	0,26	0,08
Subsidence zones	3,12	1,02
State land	10	3,3
Mined areas (forests)	10,79	3,56
Mined areas (soil)	3,76	1,24

Source: Spatial plan of Tuzla municipality (2006-2026); Google Maps

It should be noted that the urban area of Tuzla occupies almost one third of the city's surface. Some of the most fertile soils are located in this area, mainly along the stream of the Jala River, but are inaccessible due to urban infrastructure (Figures 2, 3, Table 1).

The largest percentage of the soils of the territory of Tuzla is under forests, 45.48%, then under urban infrastructure 40.3%, transport infrastructure, exploitation fields, landfills and landfills of slag and ash, as well as protected areas. Almost 2/3 of the soil of Tuzla is endangered by landslides (Table 1). The devastation of soil by anthropogenic destruction is especially visible in the area of active and inactive mines, landfills, slag and ash landfills, which is the most severe form of land destruction. The soil of the city of Tuzla is developed on slopes of 12° - 40°, which makes them susceptible to erosion. During the humid season, the slopes are intensely denuded by torrents, ravine, washing and landslides.

The presence of calcium carbonate in the soil and the presence of heavy metals (Ar, Ba, Cd, Co, Cu, Cr, Mo, Mn, Ni, Pb, V, Zn) were determined and calculated by laboratory methods. Of the 10 samples collected on an area of about 25 km^2 (potentially fertile soil), only two samples did not show heavy metal contamination (Mihatovići-Plane and Ljubače) (Figure 4, tables 2 and 3).

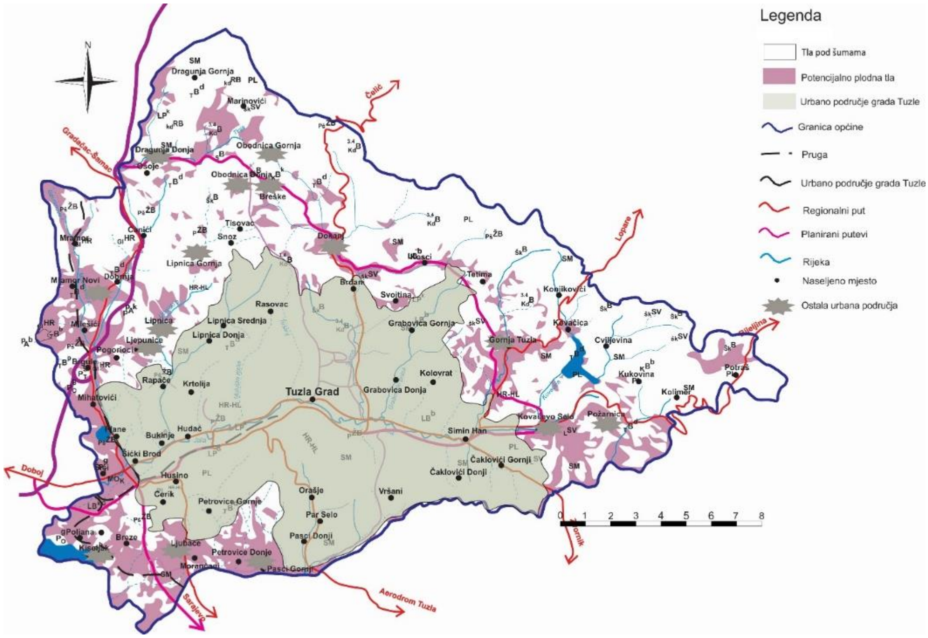

Fig. 3. Potentialy fertile soils in Tuzla's area (Google Maps, 2015; Spatial plan of Tuzla municipality 2006-2026.)

Table 2. Heavy metals in soil samples

Heavy metals	Limiting values* mg/kg	Sample No									
		1	2	3	4	5	6	7	8	9	10
Arsen	30	0	0	0	0	3	0	0	0	0	0
Barij	80	49,27	21,47	15,63	30,5	50,73	39,1	24,73	101,4	36,8	37,7
Kadmij	1,5	0,07	0,17	2,67	0	1,53	0,57	0,53	0	0	0
Kobalt	60	11,27	5,63	8,8	14,87	20,53	11,13	7,9	24,57	12,57	12,2
Bakar	80	10,83	0	0,47	9	11,13	6,63	0,27	19,63	11,2	7,83
Krom	100	43,74	11,97	11,07	34,63	64,47	31,27	14,3	50,1	48,93	55,7
Molibden	10	0	0	0	0	0	0	0	0	0	0
Mangan	850	534,33	254,9	205,33	382,33	10000	687,67	374,67	10000	456,33	298,3
Nikl	50	99,03	9,27	53,5	70,83	107,57	58,8	12,9	138,1	142,47	148,07
Olovo	100	8,23	8,5	6,2	8,1	13,07	16,63	10,93	17,23	8,63	4,17
Vanadij	40	14	9,27	3,67	12	23,3	18,4	9,7	18,73	13,33	8,67
Cink	200	33,23	16,8	20,47	32	32,9	27,37	16,53	31,97	37,9	24,7

Source *: Rulebook on Determination of Permitted Amounts of Hazardous and Hazardous Substances in Soil and Methods of Their Testing, Official Gazette of the FBiH, No.72, 18.11.2009.

Table3. Sample location, geographic coordinates, soil type and percentage of $CaCO_3$ in sample

Sample No	Location	Lat	Lon	Elevation	Type of soil	% $CaCO_3$
1	Šićki B. - Poljana	44.514819	18.586985	200	Mok	10,946
2	Mihatovići - Plane	44.527196	18.588991	212	Pšžb	3,093

3	Obodnica	44.610165	18.633598	477	Kdb	1,006
4	Mramor 1	44.567822	18.564721	243	Tbd	1,29
5	Kovačevo Selo	44.530542	18.778930	296	Lsv	0,774
6	Gornja Tuzla	44.541123	18.754210	289	HrHl	6,76
7	Ljubače	44.498749	18.613826	233	SM	0
8	Mramor 2	44.566828	18.564506	230	Tbd	1,22
9	Breške	44.609711	18.653136	539	Kbk	21,27
10	Brđani	44.583699	18.697213	327	Šksv	0

Source: Field and laboratory research

On about 25 km^2 of potentially fertile soils, which are potentially suitable for agricultural production in the area of Tuzla and which are not covered by urban infrastructure, forests, roads, tailings and landfills, landslides and unstable slopes, ten soil samples were taken.

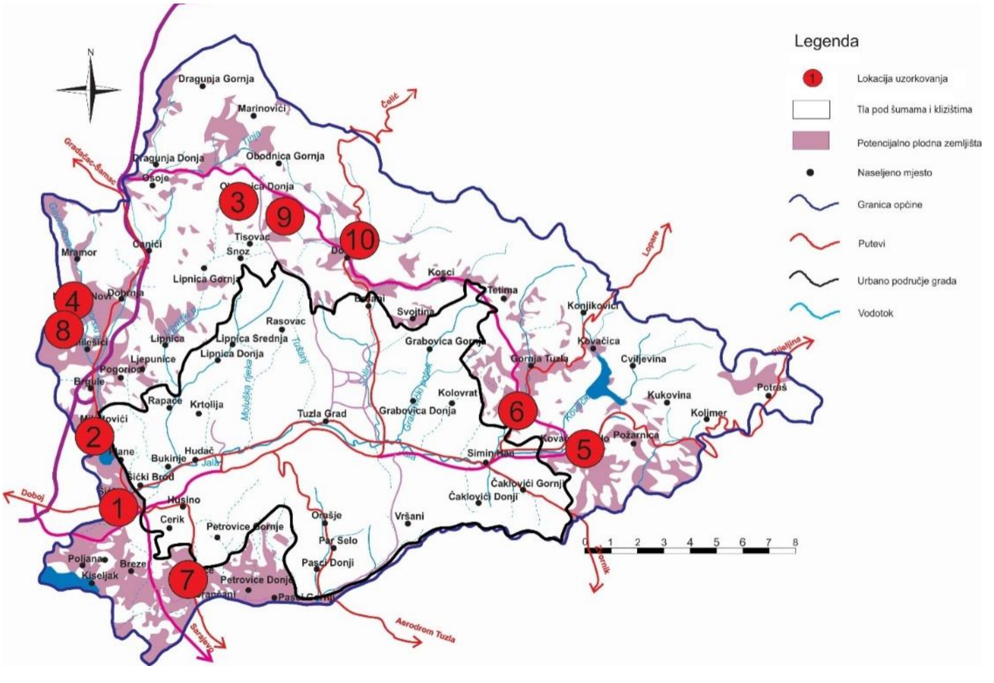

Fig. 4. Soil sampling locations (Terrain research; Google Maps, 2015; Spatial plan of Tuzla municipality 2006-2026.)

During the sampling, it was ensured that the samples are on sufficient distant from roads or other direct pollutants and that they belong to different soil types. The presence of heavy metals was determined at eight of the ten soil sampling sites.

The presence of nickel, twice the amount of the permitted value was recorded on the sample taken from the Šićki Brod-Poljana site (sample no. 1). The sample taken from the Obodnica site (sample No. 3) recorded the presence of heavy metals of cadmium and nickel above the limited values. The sample taken from the site Mramor 1 (sample No. 4) had an elevated nickel content of 20.83 mg/kg, while the presence of cadmium, manganese and nickel was significantly higher than the limited values in the sample taken at Kovačevo Selo (sample No. 5). The sample collected in Gornja Tuzla (sample No. 6) had an elevated nickel content, while the sample collected at the site Mramor 2 (sample No. 8) had significantly higher values of barium, manganese and nickel than allowed. Samples collected at Breške and Brđani (samples Nos. 9 and 10) showed a three times higher presence of nickel than allowed. Excessive nickel concentrations cause developmental disabilities and have geno-toxic, neurological, reproductive and cancerogenic consequences. The deficiency of this element causes retardation during animal growth and metabolic disorders in humans. Nickel pollution is generated through industrial dust, waste, waste water and the combustion of fossil fuels (Halamić and Miko, 2009).

Manganese is an essential element for most plants and animals and is non-toxic under normal conditions. It activates many reactions that promote enzyme formation in plant metabolism. Manganese deficiency causes infertility in mammals. At higher concentrations, it is moderately toxic and accumulates in the liver and kidneys (Brevik and Burges, 2013).

Cadmium is toxic to humans and animals and is administered by inhalation or by food and drink. Soils with concentrations of this element greater than 5 mg/kg result in less yield. The major sources of cadmium contamination are metal smelters, and can also be reached by the application of urban waste as fertilizer, burning of fossil fuels, from lead and zinc mines, the decomposition of paints and protectants, composts and sludges and fertilization with phosphorous fertilizers (Johanneson, 2002).

Barium is moderately toxic to plants and almost non-toxic to mammals. However, water-soluble barium compounds are toxic. Toxicity is manifested through a disorder in the digestive and respiratory tract and mineralization in the bones. Barium also has cancerogenic properties. It is mostly introduced into the human body through vegetables, meat and beverages (Brevik and Burges, 2013).

From the ten collected samples, two did not record heavy metal contamination (sample No. 2 and 7, i.e. Mihatovići - Plane and Ljubače sites) (Figures 3, 4; Table 2, 3). On the site of Ljubače there are vertisols - heavy soils, which in addition to quality melioration can produce good yields. The vertisols at Ljubače site are poor in calcium carbonate and calcification of these soils is necessary. The Mihatovići - Plane site will soon be transformed into a recreation area.

CONCLUSION

The analyzed area is characterized by relatively favorable relief and climate characteristics, rich natural resources and significant demographic and urban changes, which is why this area is very interesting for geographical researches.

The conducted research and analysis show that the area of Tuzla is characterized by a diversity of pedological cover, which is largely exposed to negative anthropogenic influences. These are, first and foremost, devastation, change of usage and pollution of fertile and productive soil. The most productive soils are endangered, devastated and polluted with traffic, industrial and other urban infrastructure, facilities and anthropogenic processes. The most fertile soils that stretch along the stream of the Jala River have already disappeared due to the construction of urban infrastructure. The remaining areas of very good brown carbonate-free and gray-brown carbonate soils in the Jala valley are also under the city's roads, residential and commercial areas. Taking into account the constant expansion of the city center, construction of new roads, along with existing minefields, landfills and landslides, it is evident that the percentage of productive soils in the territory of Tuzla municipality is low. Therefore, it should be emphasized that an extremely small area of land is free and suitable for agricultural production, which means that we are largely deprived of man's one most important resources - the basis for food production.

In the area of Tuzla, forest land occupies slightly less than half of the total area of the municipality, 137,821 km^2, or 45.48%.

The presence of heavy metals was determined at eight of the ten soil sampling sites. Increased nickel content was recorded in samples no. 1, 3, 4, 5, 6, 8, 9, 10. Samples collected at Breške and Brđani (samples No. 9 and 10) showed three times higher values of nickel than allowed. Increased manganese content was recorded in samples No. 5 and 8, and increased cadmium content on samples No. 3 and 5. Sample no. 8, collected at Mramor 2, records an elevated concentration of barium.

There are no pedological potentials in the area of Tuzla for the development of intensive agricultural production on larger areas. Agricultural production is possible on smaller, fragmented estates, where the production of vegetable crops is recommended, but greenhouse production is the most suitable.

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