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SOIL DISTRIBUTION IN STRUMICA RIVER BASIN AND ITS IMPORTANCE FOR AGRICULTURAL PRODUCTION

SUMMARY

This paper is a result of many years of field and laboratory research of the soils in Strumica river basin, spread out on 148.124,02 ha, ranging from 150 to 1540 m above the sea level in order to gain a better understanding of the productive capacities of the soils and measures for their improvement. The filed research of the soils has been done according to methods described by (Markoski et al., 2014).

In laboratory, the following analyses have been carried out on the soil samples: hygroscopic moisture; mechanical composition; pH of the soil solution; humus content and total nitrogen; content of carbonates; available nutrients P_2O_5 and K_2O. The mechanical composition and chemical properties of the soils have been determined by standard methods described by (Belić et al, 2014), (Mitrikeski & Mitkova, 2001); (Resulović et al., 1971), (Džamić et al., 1996). This area is very heterogeneous, with numerous relief forms, with different expositions and inclinations, and with great differences of altitude.

Additionally, there are several geological formations of a very heterogeneous petrographic-mineralogical composition and climate-vegetation zones. Long-term effects from human involvement should also be noted. The vast diversity of the factors required for soil formation in this area is the reason for the formation of many different soil types as well as the lower taxonomic units. These types of soils are characterized by different properties (chemical, physical, and physical-mechanical, productive). Therefore, they have varied effects on agricultural production.

There are 14 (fourteen) different soil types distributed in the Strumica river basin together with a considerable amount of subtypes, varieties and forms. Mountain soils are prevalent in this river basin: 79.337,6 ha, or (53.56%) of the whole. Soils of lake terraces and of undulated hilly relief cover 30.507,42 ha, (20.59%), whereas soils of colluvial fans occupy 18.739,6 ha (12.65%) of the area. Finally, soils of the plains occupy 17.784,4 ha (12.01%) and Urbisol 1.755,57 ha (1.18%).

Key words: soil types, Strumica river basin.

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INTRODUCTION

The Strumica river basin is 1.649 km^2 that is 6.4% of the territory of the Republic of Macedonia. The major part of the total watershed (75%) is in Macedonia, while the remaining is in Bulgaria and Greece. River Strumica takes its source from the Plackovica Mountain at an altitude of 1.540 m asl running south in a deep valley and known as the Stara Reka (Popovska et al., 2014). It then enters the Radoviš valley and runs through the eponymous Radoviš. Afterwards the river runs southeast through the Strumica valley passing through the town of Strumica and turning east to enter Bulgaria south of Zaltarevo. The main tributaries are Turija, Vodocnica, Radoviška and Podareška. The annual average discharges of Strumica River for the from both sides of the Strumica River there are a large number of tributaries mostly mountainous streams with permanent water flow.

River outflow Macedonian border southeast of Novo Selo and inflow Struma River in Bulgaria at an altitude of 186 m asl. It is the Struma's largest tributary. Total length of Strumica River is 114 km out of which 81 km in Macedonia and 33 km in Bulgaria.

This area (Strumica river basin) is very heterogeneous, with numerous relief forms, with different expositions and inclinations, and with great differences of altitude. Additionally, there are several geological formations of a very heterogeneous petrographic-mineralogical composition and climate-vegetation zones. Long-term effects from human involvement should also be noted. The vast diversity of the factors required for soil formation in this area is the reason for the formation of many different soil types as well as the lower taxonomic units.

The soils in the area also appear in the complexes that are presented on the soil (pedological) map. These types of soils are characterized by different properties (chemical, physical, and physical-mechanical, productive). Therefore, they have varied effects on agricultural production.

In this paper are presented the main aspects of the soil geography. The agro technical and meliorative measures are determined based on the properties and processes of the various soil types found in this area with the goal of improving their productive capacity to further increase agricultural production.

MATERIAL AND METHODS

The filed research of the soils has been done according to methods described by (Mitrikeski and Mitkova, 2006). In laboratory, the following analyses have been carried out on the soil samples: hygroscopic moisture; mechanical composition; pH of the soil solution; humus content and total nitrogen; content of carbonates; available nutrients P_2O_5 and K_2O.

The mechanical composition and chemical properties of the soils have been determined by standard methods described by: (Belić et al., 2014); (Mitrikeski and Mitkova 2006); (Resulović et al., 1971; Džamić et al., 1996).

RESULTS AND DISCUSSION

Geography of soils

Distribution of soil types and complexes.

The formation, the distribution and the soil properties in this area are in close co-relation with the environmental conditions, i.e. the soil genesis conditions, such as the geographical position and the relief, the hydrography, the parent material, the climate, the vegetation, the time period and the human factor. The soil (pedologic) map (picture 1), (picture 2 and 3) together with Table 1 on the distribution of the soil types, differentiates the following properties in the geography of soils. In the catchment area of the Strumica river, there are 14 (fourteen) soil types and a number of subtypes, varieties and forms. The total area of this region is 148.124,02 ha. Depending on the dominant influence of individual soil forming factors, most part of the areas are covered with soils that also demonstrate climate – vegetation zoning (Chromic Luvisols on saprolite, Cambisols, Humic Eutric and Umbric Regosols, Albic Luvisols), which is also combined with the influence of other soil forming factors (parent material, relief). Some of the soils demonstrate strong lithogenous character (Leptosols, Regosols, Humic Calcaric Regosols, Vertisols), whereby the influence of other factors (relief) is also significant. Some of the soils have topogenous – hydrologic origin, related to the consequences of the erosion processes (Fluvisols, Gleysols, Fluvisols-Colluvial Soils). Lately, due to the newly planted seedlings (orchards, vineyards), some of the soils also have antropogenous origin (Aric Regosols). The papers of (Markoski et al., 2015) and (Filipovski, 2015), address these conditions in details.

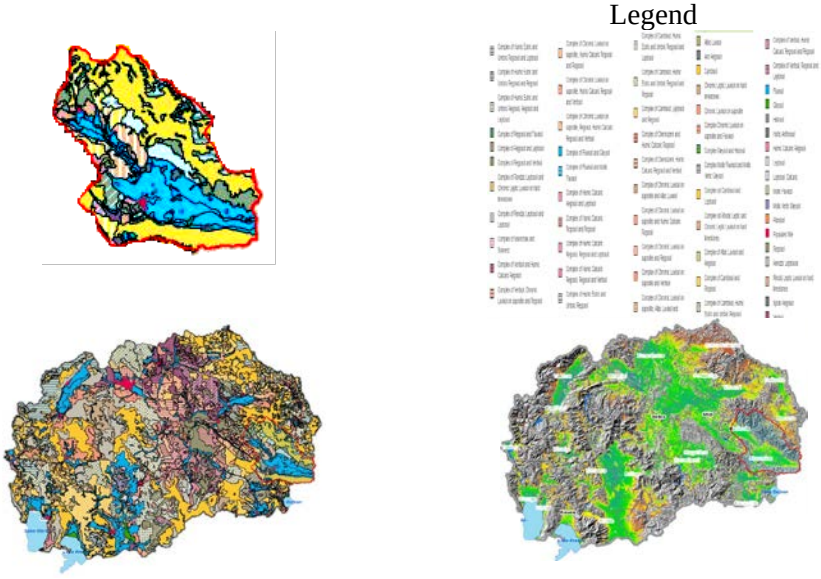

Chart 1. Soil map - Soil types and complexes distribution in the catchment area of the Strumica river (http://www.maksoil.ukim.mk/masis/)

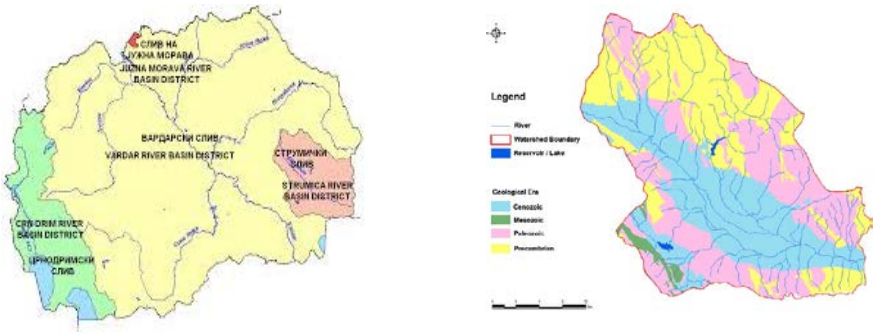

Chart 2. Geological eras of Strumica river basin

Table 1. Soil types and complexes distribution in the catchment area of the Strumica River (ha and %)

SOIL TYPES AND COMPLEXES (WRB Soil Classification)	Symbol	ha	%
I. SOILS OF THE PLAINS			
1. Fluvisol	J	17533.8	11.84
2. Gleysol	G	213.22	0.14
3. Solonetz+ Solonchak	Z/S	37.33	0.03
Total		**17.784,4**	**12.01**
II. SOILS OF COLLUVIAL FANS			
1. Fluvisol (Colluvial Soils)	K	**18.739,1**	**12.65**
III. SOILS OF LAKE TERRACES AND OF UNDULATED HILLY RELIEF			
1. Regosol	R	9896.73	6.68
2. Complex of Regosol and Leptosol	R/E	2870.31	1.94
3. Humic Calcaric Regosol	Rz	1818.39	1.28
4. Complex of Humic Calcaric Regosol, Regosol and Leptosol	Rz/R/E	647	0.44
5. Aric Regosol	ATa	1295.71	0.86
6. Chromic Luvisol on saprolite	Lc	3976.81	2.68
7. Complex of Chromic Luvisol on saprolite, Humic Calcaric Regosol and Regosol	Lc/Rz/R	571.21	0.39
8. Complex of Chromic Luvisol on saprolite and Regosol	Lc/R	7795.97	5.26
9. Vertisol	V	1246.88	0.84
10. Complex of Humic Calcaric Regosol and Regosol	Rz/R	264.32	0.18
11. Albic Luvisol	La	124.09	0.08
Total		**30.507,4**	**20.59**
IV. MOUNTAIN SOILS			
1. Leptosol	E	6724.81	4.54
2. Complex of Cambisol and Regosol	B/R	9255.01	6.25
3. Cambisol	B	51691.95	34.90
4.Complex of Humic Eutric and Umbric Regosol	Lm/R	9699.55	6.55
5. Chromic Leptic Luvisol on hard limestones	Lvd	71.79	0.04
6.Rendzic Leptosols	Eh	145.17	0.09
7.Complex of Humic Eutric and Umbric Regosol, Regosol and Leptosol	Lm/R/E	1529.38	1.03
8.Complex of Humic Eutric and Umbric Regosol and Regosol	Lm/R/R	219.92	0.14
Total		**79.337,6**	**53.56**
1.Urbisol	Urb	**1.755,57**	1.18
Total area of this region		**148.124,02**	**100**

Table 1 contains data on the soil types and complexes distribution according to the relief forms in the catchment area of the Strumica River in ha and %. It can be seen from the Table that the soils spread on mountainous terrains dominate in the catchment area and cover an area of 79.337,6 ha, or 53.56% of the area, followed by the soils spread on lake terraces and of undulated hilly relief with 30.507,4 ha, or 20.59%. The soils on sloping terrains (colluvial fans) and plains cover small areas (18.739,1 ha or 12.65% and 17.784,4 ha, or 12.01% and of the area).

The plain terrains are mostly covered by Fluvisols (17.533,8 ha or 11.84%), while the percentage of other soils is under 1%. The sloping terrains are mostly covered by Fluvisols (Colluvial Soils) (18.739,1ha or 12.65%). The undulating-hilly terrains and the lake terraces are mostly covered by Regosols (9.896,73 ha or 6.68%), followed by Complex of Chromic Luvisol on saprolite and Regosol (5.26%), Chromic Luvisol on saprolite (2.68),Complex of Regosol and Leptosol (1.94%), as well as Humic Calcaric Regosol (1.28%). Most of the mountainous terrains are covered with Cambisols (51.691,95 ha or 34.90%) and Complex of Humic Eutric and Umbric Regosol (9.699,55 ha or 6.55%), and Complex of Cambisol and Regosol (9.255,01ha or 6.25%) as well as Leptosol with 6.724,81ha or 4.54%. The erosion processes, i.e. the human factor are strongly reflected in the geography of the soils in the area. The area of soils that occurred from erosion processes (Leptosols, Regosols, Fluvisols-Colluvial Soils and their complexes) is more than 25% of all areas and unfortunately, the spreading process for these areas is still active.

The individual terrain forms differ from each other by their terrain, geological structure, their climate – vegetation and hydrographic conditions and by the degree of anthropogenization. This is reflected on the geography of soils and their properties, as well as on the degree of their utilization and the measures that need to be undertaken in the agricultural production of the area.

Common properties of the soils according to terrain (relief) forms

Common properties of the soils on the mountainous terrains. The soils spread on mountainous terrains cover 79.337,6 ha, or 53.56% of the area. These are: Leptosols, Humic Eutric and Umbric Regosols, Cambisols, as well as their complexes, in combination with Regosols. Their common properties are: a) very pronounced erosion processes; b) weak chemical weathering resulting in shallow solum over some substrates, and lack of deep regolith and poor clay content; c) absence of carbonate, pronounced acidification (weaker in the soils over acidic rocks than in the basic rocks); d) absence or very poor textural differentiation of the solum; e) clearly expressed changes in the soil properties and the intensity of some processes as the altitude increases; f) clearly expressed dependence of the soil properties from the substrate: soils over acidic rocks contain less clay, they are more acidic and are less texturally differentiated, unlike the soils formed over basic rocks, g) absolute domination of the silicate over the carbonate substrate.

Common properties of the soils from the lake terraces and of undulated hilly relief. The following soil types are present on this terrain form: Regosols,

Humic Calcaric Regosols, Vertisols, and Chromic Luvisols on saprolite and Albic Luvisols. The occurrence of these types of soils is in close co-relation with the substrate, the relief, the climate-vegetation conditions and the degree of erosion. The soils on this terrain (relief) form have the following common properties: a) very pronounced erosion (occurrence of Regosols and erosion of horizon A or part thereof, in the soils with A-C, A-(B)-C and A-E-B-C profile type); b) absence of compact rocks as substrate and soil genesis over clastic sediments, resulting in deep solum and physiologically active profiles; c) greater presence of clay resulting from the substrate or the argilogenesis within the profile; d) presence of smectites in some soils (Vertisols) arising mainly from the substrate and partially from the soil genesis, and in relation to that, deterioration of the physical properties of the soils; e) occurrence of textural differentiation at some soils (Vertisols and Albic Luvisols), and in relation to that, deterioration of the physical properties; f) greater presence of the silicate – carbonate substrate in the soil genesis, in comparison to the substrate of the mountainous terrains; g) relative dryness of the soils (which is lower at the lake terraces), caused from insufficient quantity of rainfalls, surface water flow and very deep underground water; e) insufficient quantity of humus and nutrients (especially N and P); f) relatively good chemical properties (the high content of carbonates of Humic Calcaric Regosols and the acidity of the Albic Luvisols are an exception).

Common properties of soils from sloping terrains. These terrains are covered with Fluvisols (Colluvial Soils), which are characterized by: a) horizontal and vertical (according to depth of profile) heterogeneity in the mechanical and mineral-petrographic composition; b) low content of clay, drainage, dryness, good aeration; c) poor humus content, insufficient stability of the aggregates; d) good chemical properties with insufficient nutrient elements; e) increasing the finer particles by descending to the lower parts of the cones ("fans"); g) short duration of soil genesis (the youth of the soils); h) unregulated water regimen (floods and sedimentation of coarse material).

Common properties of the soils of the plains. Fluvisols with varying degrees of gleyzation are present in the flat bottom deep in the profile and the Gley soils (Gleysols and Mollic Vertic Gleysols) have the following characteristics: a) the appearance of non-saline underground waters at different depths; b) the appearance of a physiologically deep profile; c) gleyzation at the bottom of the profile; d) a significant amount of organic matter (especially in Gleysols), where it is of hydromorphic origin; e) occurrence of unregulated water regimen (floods, riverbad erosion, deposition of coarse sediments, regeneration of fertility by application of fine sediment); g) absence of texture differentiation of the profile (no occurrence of (B) or Bt horizons); h) favorable physical and chemical properties.

The occurrence of Halomorphic soils (Solonchak and Solonetz) on small areas (total 37.33 ha or 0.03%) is characteristic of these terrains in the area. Their formation is related to the presence of salts in the sediments, drier climate conditions and relief-topographical conditions in which there are shallow and

saline underground waters. Soil significance according to relief forms for agricultural production in the area

The properties (mechanical composition and chemical properties) of individual soils formed in the area are described in detail in the papers of: (Markoski et al., 2015; Filipovski, 2015 and Filipovski 2015a). Here, together and according to relief forms, we will explain their significance for agricultural production in the area, the measures for improving their productive ability will be explained in the conclusions.

In mountain reliefs, part of the Humic Eutric and Umbric Regosols is under summer pastures, a smaller part under forests, and a small part is cultivated. Fields are mostly abandoned, and some produce potato and seed material for it, then rye and oats, and at lower altitudes some fruit trees are cultivated. As for the use of Cambisols, it can be said that they have the greatest significance for forestry, because they produce and then exploit most of the wood mass in our country. By deforestation some of these soils are converted into pastures or into now abandoned fields. A very small part is cultivated, used as fields, and a smaller part as pastures. Potatoes are most commonly cultivated field crops, some forage field crops can be successfully grown, as well as crops for green fertilization. Some of these soils can be successfully turned into artificial grasslands. Several fruit crops can be successfully grown (chestnut, walnut, plums, apples, pears, raspberries, blackberries, ribes).

Among the soils formed on lake terraces and of undulated hilly relief, Vertisols and Humic Calcaric Regosols are characterized by greater productivity in comparison with Regosols, Chromic Luvisols on saprolite and Albic Luvisols. Depending on the conditions for irrigation these soils have heterogeneous use. Field crops, vegetable crops, forage crops, industrial crops, vineyards, orchards are cultivated on them. Fluvisols (Colluvial Soils) are significantly less productive than Fluvisols (with which they border. They are less sorted, do not have a flat relief, have higher impact from drought, contain less nutrients, and do not supply water from groundwater.

In the plain terrains of the area, Fluvisols are of the greatest significance for agricultural production. This is due to the favorable physical and chemical properties, the deep solum, the provided conditions for irrigation and the presence of available forms of P_2O_5 and K_2O. They provide relatively high yields of all agricultural crops. Gleysols are potentially fertile. They have relatively good properties, but have shallow underground waters, occasional floods at some sites, anaerobic conditions and due to this, poor nitrification.

CONCLUSIONS

There are 14 (fourteen) different soil types distributed in the Strumica river basin together with a considerable amount of subtypes, varieties and forms. They are formed on four relief forms (plain terrains, sloping terrains, mountain terrains and undulating-hilly terrains and lake terraces) that have different significance

for agricultural production. In order to increase their productive ability, the following joint measures should be undertaken according to relief forms:

- Joint measures for soils from mountain terrains: (protection from erosion, fertilization with organic and mineral fertilizers, proper tillage, liming if necessary);

- Joint measures for soils from lake terraces and undulating-hilly terrains: (deep tillage, humization: organic fertilizers and phytomeliorations, intensive use of mineral fertilizers N and P_2O_5, and for plants that need potassium during the entire year and for obtaining much higher yields and K-fertilizers, anti-erosion measures, proper irrigation method);

- Joint measures for soils from sloping terrains: (anti-erosion protection measures, irrigation, humization, intensive use of mineral fertilizers);

- Joint measures for soils from plain terrains: (regulation of the water regimen, lowering of the level of underground water-drainage, tillage and creating a deep fallow, fertilization with mineral and organic fertilizers with previous soil fertility control, proper irrigation).

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