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Influence of local vegetation on soil properties in riparian habitats along the Iskar River in the region of Sofia, Bulgaria

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Abstract

The aim of the present study is to trace the correlation between major types of local riparian vegetation and soil properties under their slope in a section along the Iskar River. The objects of study were Alluvial Fluvisols spread on the territory between Plana and Lozenska Mountains in the area of Kokalyane village, Sofia region. In order to investigate the influence of vegetation on soil properties, 3 representative sample plots were defined with vegetation in the initial stage, composed respectively of annual grass communities in SP-1, in an advanced stage composed of perennial grass communities in SP-2 and in the final stage – a tree community with a distinct tree floor in SP-3. The obtained data show a significant soil properties alternation depending on the specifics of plant communities. The increase of soil organic matter under the different types of vegetation follows the natural successional order – from an initial stage with annual grass communities to stable tree communities with a clearly defined floor structure. The content of soil organic matter, total N and plant available water capacity are the most reflective indicators showing the importance of plant communities for the formation and changes of soil fertility. The statistically proven differences in the values of these indicators point out the role of vegetation in soil formation processes.

Key words: C:N ratio, Fluvisols, pH, plant available water capacity, plant communities, soil organic matter.

Introduction

Riparian soils and vegetation are important factors influencing the biodiversity and biogeochemical processes of river ecosystems (Zhao et. al. 2020). Vegetation along river banks not only protects soil from erosion, but at once affects both changes in soil and river indicators and properties (Dosskey et al. 2010). Studies of riparian ecosystems in different parts of the world report correlation between soils characteristics and type of vegetation established on them.

Investigation of Rhoades et al. (2001) on Mountain Alder (*Alnus viridis* Chaix subsp. *crispa*) influence on soils in ecosystems of the Agashashok River valley, northwest Alaska, shows that the Alder significantly increases exchangeable soil

N in each ecosystem. Jiao et al. (2014) have registered changes in soil nutrients content and soil structure under different vegetation types in the Yellow River Delta (China). Results from the assessment of changes in vegetation structure and soil properties, following riparian restoration, show that floods redistributed organic matter, with this effect depends on the vegetation also the probability of organic matter retention was positively correlated with groundcover and stem density of plants (Halea et al. 2018). In the study of riparian soils and their response to environmental factors (need space and height of trees, shrubs and grass, distance to river and altitude), Zhao et. al. (2020) found that soil properties like clay content, soil organic carbon and nitrate nitrogen in riparian zones were significantly affected by vegetation type.

Bulgarian studies analysing specifically the correlation between changes in vegetation along river banks and changes in soil indicators are relatively few in number. As a result of a study by Kachova et al. (2020) on the riparian soils in a section of the Iskar River and their correlation with the distribution of *Impatiens glandulifera* Royle localities, 4 types of localities of this invasive alien species have been identified. Research by Georgieva (2021) on the dynamics and growth of *I. glandulifera* in riparian habitats proves the positive correlation between soil organic matter, plant's height and fruit capsule length. More studies are focused on areas with artificial anti-erosion forest stands on eroded terrains along the Arda, Badinska and other Bulgarian rivers, which establish their role in improving soil fertility, soil physical properties and reducing surface water runoff (Velizarova 2008, Pavlova-Traikova et al. 2018).

Intense rainfalls and extreme flooding are very common in the riparian zone of Bulgaria. They have a negative impact on the environment and are also a disaster from a social and economic point of view. Analysing the interactions between soil and vegetation is a basis for determining the possibilities for restoration, protection and improvement of soil fertility and the development of vegetation as a condition for biodiversity protection, increasing the productivity of plant communities and rational use of natural resources.

The aim of the present study is to investigate the correlation between major types of local riparian vegetation and soil properties under their canopy within the area along the Iskar River.

Material and Method

The objects of the study were Alluvial Fluvisols (Penkov et al. 1992) occurring on the territory between Plana and Lozenska Mountains in the Kokalyane village area, Sofia region (Fig. 1).

The average altitude of the studied section is 650 m. The area is characterized by relatively mild winters, low annual temperature amplitudes and two rainfall maxima during the year (Georgieva 2021). The maximum average month temperature in July is 21.5 °C and the minimum in January is 1.5 °C. The predominant direction of the wind is northwest, and winter winds are strongest in December, January, February and March. The average annual rainfall is 590.7 mm with a maximum in May and a minimum in December. A second rainfall maximum is observed in June, and a second minimum in August. The duration of the snow cover is usually from the end of November to the end of March (Sabev and Stanev 1963, Topliyski 2006). Vegetation development

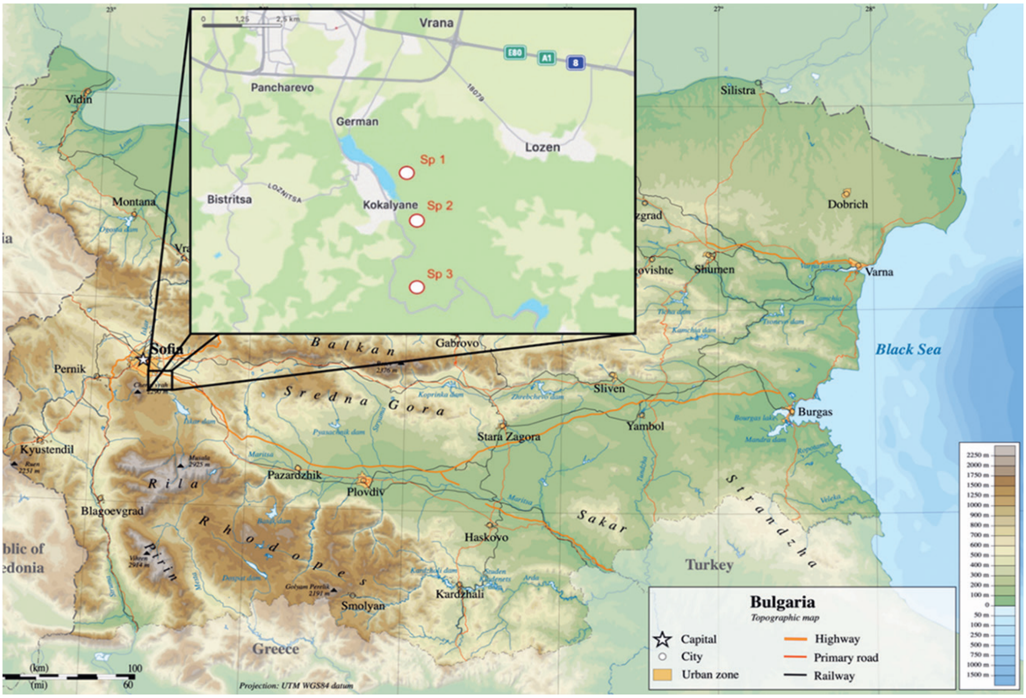

Fig 1. Location of sample plots (SP-1–3) in the study area.

limits surface runoff and erosion processes in the study area.

The characteristics of the soils correspond to those of the soil group Fluvisols in World reference base for soil resources (IUSS … 2015). At the next lower taxonomic level in the same classification model, the main qualifiers for the studied soils are Skeletic and Leptic.

The research site is part of Protected Area BG0000613 under NATURA 2000 and includes habitat 91E0 Alluvial forests with *Alnus glutinosa* (L.) Gaertn. and *Fraxinus excelsior* L. (Glogov 2021).

In order to investigate the influence of vegetation on soil properties, 3 representative sample plots (SP) were defined with vegetation in the initial stage, composed respectively of annual grass communities (AC) in SP-1, in an advanced stage composed of perennial grass communities (PC) in SP-2 and in the final stage – a tree community with a distinct tree floor (TC) in SP-3 (Table 1). The classification of plant communities in the sample plots is in accordance with the results of the studies of Glogov and Georgieva (2021) and Georgieva (2021).

Soil samples have been taken from five profiles in each plot from the layers 0–10 cm and 10–20 cm. The following methods were used to analyse the soil samples:

• Soil organic matter (SOM, %) by the Turin method;

• Total N (%) content, with a modified version of the classic Kjeldahl method;

• C:N ratio – calculation method;

• Soil acidity (pH in water extraction) – measured potentiometrical;

• Plant available water capacity (PAWC, mm), by a laboratory method,

Table 1. Sample plots data.

Sample plot	Geographic coordinates	Altitude, m	Soil type	Type of vegetation	Plant communities
SP-1	42°34’58.674’’ N 23°25’39.212’’ E	600	Fluvisols	Annual herbaceous communities (AC)	Ass. *Calystegio sepium-Impatientetum glanduliferae* Hilbig 1972, All. *Senecionion fluviatilis* Tüxen ex Moor 1958, Ord. *Convolvuletalia sepium* Tüxen 1950 ex Mucina in Mucina, Grabherr & Ellmauer 1993 and Cl. Galio-Urticetea Passarge ex Kopecký 1969
SP-2	42°33’35.6” N 23°25’21.4” E	650	Fluvisols	Perennial herbaceous communities (PC)	Ass. *Melilotetum albo-officinalis* Sissingh 1950, All. *Dauco carotae-Melilotion* Görs ex Rostański et Gutte 1971, Cl. *Artemisietea vulgaris* Lohmeyer et al. ex von Rochow 1951
SP-3	42°34’04.5” N 23°25’42.7” E	610	Fluvisols	Tree communities (TC)	Ass. *Stellario nemorum-Alnetum glutinosae* Lohmeyer 1957, All. *Alnion incanae* Pawłowski et al. 1928, Ord. *Fagetalia sylvaticae* Pawlowski in Pawlowski et al. 1928 and Cl. *Querco-Fagetea* Br.-Bl. et Vlieger in Vlieger 1937

with the calculation of field capacity and permanent wilting point.

The results of the soil properties study were statistically analysed using Statistica 12 and SPSS programmes. Mean, minimum (Min) and maximum (Max) values, standard deviation (SD) and coefficient of variation (CV) were determined. LSD Post-Hoc analysis (IBM SPSS 26.0 for Mac) was applied to prove statistically significant differences between indicators in individual sample areas. A significance level of $p < 0.05$ was chosen.

Results and Discussion

The field soil survey showed that the soils in all three test areas – with vegetation in the initial stage with annual grass communities (AC), in the advanced stage with perennial grass communities (PC) and in the final stage with tree communities (TC) have, in general, similar morphological structure of the soil profile, which is typical of class Fluvisols (Ilinkin et al. 2017, 2018). Genetic horizons have not been formed due to the periodic deposition of new sediments. The soil profile is composed of separate layers and a poorly formed surface humic horizon, which is in initial phase of development.

It was found that the chemical and physical properties of soils, as well as their morphological features, were changed because of the vital activity of plant communities, and the changes depend on their type. Above all, the formation of an organic O horizon with a low depth (between 2 and 4 cm) is observed in the soil under the tree community (TC). Two layers were distinguished in its morphological structure – a fresh undecomposed plant litter and a humified layer, which is composed of amorphous humic substances and has a direct correlation to soil fertility, because it determines the content of soil organic matter.

A major source of organic matter in the soil under tree vegetation is the plant litter, which consists of leaves, twigs, bark, etc., and forms the organic O horizon in forest soils. In turn, it contributes to the accumulation of humus in the forest soils. The differences in the content of soil organic matter and total N depending on the nature of the plant cover are clearly expressed, both in the upper (0–10 cm) and in the lower (10–20 cm) soil layer. The mean content of soil organic matter in the soil in annual grass communities (AC) is 1.41 % in soil layer with depth 0–10 cm and 0.88 % in depth 10–20 cm (Table 2).

Table 2. Soil properties.

Sample plot	Depth, cm	Indicator	SOM, %	Total N, %	C:N	pH	Depth, cm	PAWC, mm
AC	0–10	Min	1.24	0.024	20.4	6.06	0–20	-
		Max	1.59	0.044	30.5	7.18		-
		Mean	1.41	0.035	24.4	6.54		-
		SD	0.16	0.008	4.2	0.52		-
		CV	0.11	0.229	0.2	0.08		-
	10–20	Min	0.77	0.016	21.1	6.21		27.0
		Max	0.98	0.027	28.4	7.29		32.0
		Mean	0.88	0.021	25.0	6.77		29.8
		SD	0.10	0.004	3.3	0.53		1.9
		CV	0.11	0.190	0.1	0.08		0.1
PC	0–10	Min	2.92	0.125	8.1	6.98	0–20	-
		Max	3.44	0.240	11.9	7.32		-
		Mean	3.26	0.208	9.2	7.20		-
		SD	0.20	0.048	1.6	0.15		-
		CV	0.06	0.230	0.2	0.02		-
	10–20	Min	1.49	0.092	7.9	6.91		46.0
		Max	2.17	0.135	11.3	7.48		56.0
		Mean	1.77	0.115	9.0	7.08		50.2
		SD	0.25	0.017	1.4	0.23		3.6
		CV	0.14	0.149	0.2	0.03		0.1
TC	0–10	Min	3.42	0.255	7.5	7.14	0–20	-
		Max	4.31	0.316	8.7	7.47		-
		Mean	3.81	0.281	7.9	7.32		-
		SD	0.36	0.023	0.5	0.12		-
		CV	0.09	0.082	0.1	0.02		-
	10–20	Min	2.00	0.120	8.6	6.98		50.0
		Max	3.45	0.210	10.2	7.36		63.0
		Mean	2.40	0.149	9.4	7.24		56.2
		SD	0.61	0.038	0.7	0.15		5.3
		CV	0.25	0.260	0.1	0.02		0.1

Note: SOM – soil organic matter, PAWC – plant available water capacity, AC – annual grass communities, PC – perennial grass communities, TC – tree community.

The mean content of soil organic matter in perennial grass communities (PC) is significantly higher in both layers, 3.26 % and 1.77 %, respectively. The increase in soil organic matter content in sampling site with tree vegetation (TC) is even greater. The mean value reaches 3.81 % in 0–10 cm soil layer and 2.40 % in layer 10–20 cm (Table 2).

The content of total N alters according to soil organic matter content. While in annual grass communities (AC) its mean value is 0.035 % in 0–10 cm soil layer and 0.021 % in 10–20 cm layer, in the perennial grass communities (PC) it increases in both soil layers to 0.208 % and 0.115 %, respectively, and even more increases in the tree community (TC) – 0.281 % and 0.149 %, respectively (Table 2). The predominant cover of *Melilothus officinalis* (L.) Pall., which is a species from the legume family (Fabaceae) is an additional factor of the higher nitrogen content in soils under perennial grass phytocoenoses (PC) compared to annuals (AC) (Van Riper and Larson 2009).

The obtained data show a difference in the ratio of the amount of total carbon to the amount of total nitrogen (C:N) in the soil depending on the type of plant communities. The ratio C:N expresses the degree of soil organic matter decomposition and helps to clarify the nature of the soil processes. Simultaneously high carbon and low nitrogen content is an indicator of slow organic matter mineralization, and conversely, in cases of faster decomposition of organic matter, the carbon content decreases and nitrogen content increases.

The values of the C:N ratio in the tree community (TC) and in the perennial grass communities (PC) were significantly lower compared to the soil in annual grass communities (AC), both in the upper 0–10 cm soil layer and in the lower 10–20 cm layer. The mean values in both soil layers in the tree community (TC) were 7.9 and 9.4 respectively, and in the sample area with perennial grass communities (PC) – 9.2 and 9.0, respectively (Table 2). The higher mean value of the C:N ratio in the lower soil layer in the tree community (TC) indicates that mineralization proceeds more slowly, and at the same time, that the humus is poorer in nitrogen. On the other hand, the insignificant difference of values in both soil layers in the perennial grass communities (PC) might be a consequence of more intensive flushing of the soil profile, in which mobile fulvic acids were transported to depth together with their associated nitrogen-rich compounds (Bogdanov 2022).

The significantly higher values of the C:N ratio in annual grass communities (AC) – 24.4 in 0–10 cm soil layer and 25.0 in 10–20 cm layer (Table 2), are an indicator of the lower intensity of the processes of organic matter mineralisation. This is in conformity with the differences in the microbiological activity of the studied soils in the tree vegetation and perennial grass communities, on the one hand, and in the annual grass vegetation in an initial stage on the other, which are determined by the influence of the microclimate on the vital activity of soil microorganisms.

It could be accepted that the organic matter composition and the basic cations migration are the main factors influencing changes in soil acidity. The lowest pH values were found in the annual grass communities (AC) – 6.54 in 0–10 cm soil layer and 6.77 in 10–20 cm layer. This could be explained by the removal of a part of the basic cations due to more intensive surface and soil runoff in the annual grass communities (AC). In the perennial grass communities (PC) the mean pH values are 7.20 in 0–10 cm soil layer and 7.08

in 10–20 cm layer, and in the tree community (TC) – 7.32 and 7.34, respectively (Table 2).

The plant available water capacity depends on the soil texture and the amount of soil organic matter, which are related to the plant development and type of vegetation. The organic O horizon formation with high moisture content under the tree vegetation further helps to increase the value of plant's available water capacity. This has been confirmed by the results of the present study. The value of this indicator is lowest in the annual grass communities (AC) – 29.8 mm, while in perennial grass communities (PC) it significantly increases to 50.2 mm and is the highest in the tree community (TC) – 56.2 mm (Table 2).

The statistical analysis of the results showed statistically significant differences between the three trial areas in terms of soil organic matter (Fig. 2), total N (Fig. 3) and plant's available water capacity (Fig. 4). Therefore, these are the indicators that reflect the influence of individual plant communities on soil properties to the highest degree.

The statistically proven significant differences of these indicators, which are used to assess the fertility of forest soils (Donov 1993, Bogdanov 2022), emphasize the importance of the vegetation as a factor of soil formation.

The lack of statistical significance in pH changes shows that the influence of vegetation on this indicator is poorer compared to other factors, among which the soil forming rock probably plays a leading role.

The properties of the studied soils changed in a great extent under the influence of vegetation and depend on the type of plant communities. The enrichment of soils with organic substances under different types of vegetation follows the natural successional order – from initial stage with annual grass communities to stable tree communities with a clearly defined floor structure.

Independent of the fact that plant com-

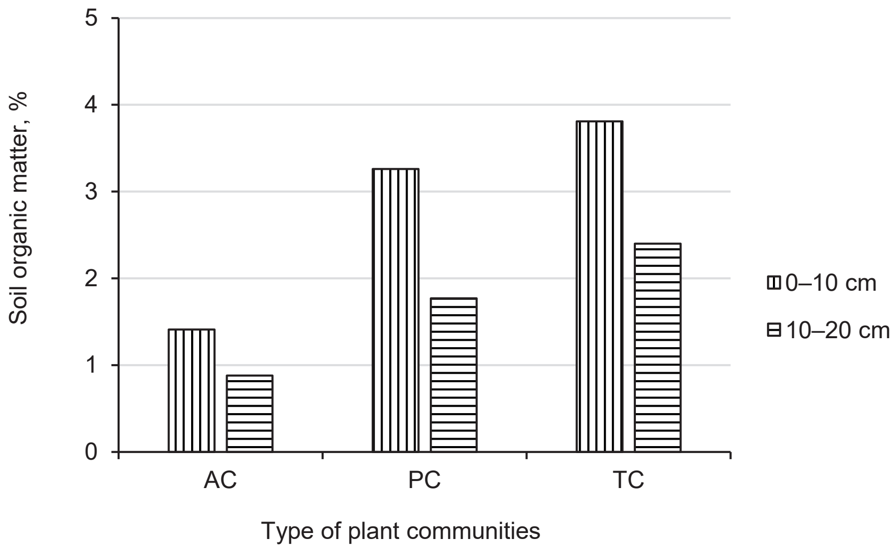

Fig. 2. Statistically significant differences (*p* = 0.024 < 0.05) in content of soil organic matter.

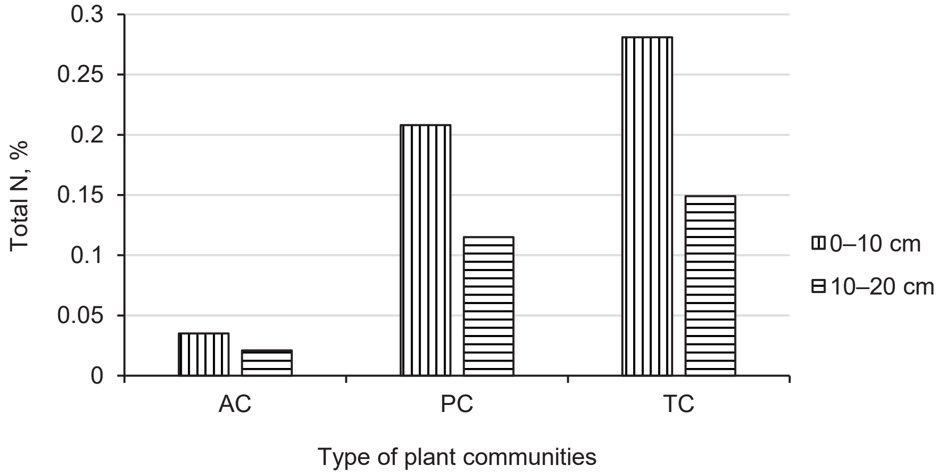

Fig. 3. Statistically significant differences (*p* = 0.028 < 0.05) in content of total N.

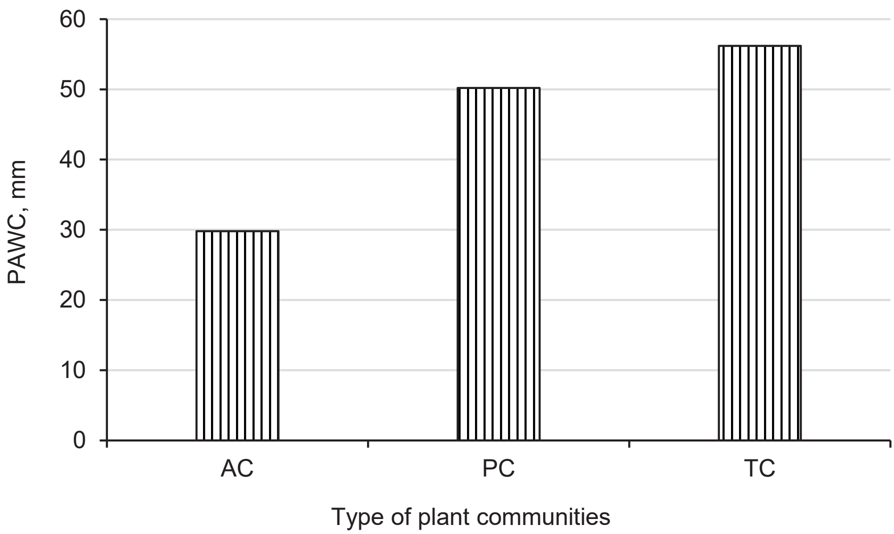

Fig. 4. Statistically significant differences (*p* = 0.004 < 0.05) in plant available water capacity (PAWC).

munities in all three trial areas are relatively young, and a large part of the nutrients entering the soil as a result of the synthesis and mineralisation processes of organic matter are spent on their growth and development, soil fertility improves in accordance with the stage of plant formation development. This largely depends on the organic matter accumulation in the surface horizon under the tree community and its transformation, which provides the reserves of soil organic matter, total N and plant's available water.

The positive influence of vegetation on

microclimate, depending on its characteristics, supports the vital activity of soil microorganisms, as a condition for intensive mineralisation of organic matter and synthesis of humic substances.

The changes in soil acidity (pH) reflect the influence of plant communities in accordance with their coverage and the composition of organic matter that they provide to the soil.

The content of soil organic matter, total N and plant available water capacity are the most reflective indicators showing the importance of plant communities for the formation and changes of soil fertility. The statistically proven differences in the values of these indicators point out the role of vegetation in soil formation processes.

Conclusion

The properties of the studied soils changed to a great extent under the influence of vegetation and depend on the type of plant communities. The enrichment of soils with organic substances under the different types of vegetation follows the natural successional order – from an initial stage with annual grass communities to stable tree communities with a clearly defined floor structure.

Independent of the fact that the plant communities in all three trial areas are relatively young, and a large part of the nutrients entering the soil as a result of the synthesis and mineralisation processes of organic matter are spent on their growth and development, soil fertility improves in accordance with the stage of plant formation development. This largely depends on the organic matter accumulation in the surface horizon under the tree community and its transformation, which provides the reserves of soil organic matter, total N and plant available water.

The positive influence of vegetation on microclimate, depending on its characteristics, supports the vital activity of soil microorganisms, as a condition for intensive mineralisation of organic matter and synthesis of humic substances.

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