UDK 630*261 (001)
https://doi.org/10.31298/sl.144.1-2.5

IMPROVED CHARACTERISTICS OF *POPULUS SP.* ECOSYSTEMS BY AGROFORESTRY PRACTICES

POBOLJŠANJE ZNAČAJKI EKOSUSTAVA *POPULUS SP.* AGROŠUMARSKIM SUSTAVOM GOSPODARENJA

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SUMMARY

Agroforestry is a multifunctional, environmentally-friendly and modern system of land use by which we can reach economic, environmental and social benefits for the society. This is confirmed by this study on poplar plantations along the Danube River in the region of Vidin (Bulgaria) where agroforestry was practiced by intercropping cultivation of vegetable crops. Productivity of poplars is improving by applying agroforestry. The average diameters and the average heights of trees in the areas with agroforestry are high for the correspondent age. Thus the 10 years old plantation with agroforestry has DBH = 9.9 cm and Hav = 7.44 m whereas the same aged control has worse dendrometric characteristics (DBH = 8.7 cm ; Hav = 7.04 m). The other sample plot (SP1) near Novo selo village with 2 years old plantation where are currently planted corn has DBH = 2.7 cm and Hav = 2.67 m. The sample plot (SP3) near Vidin with 3 years old plantation where before 1 year has been planted corn has DBH = 1.6 cm and Hav = 2.55 m. The creation of agroforestry systems also leads to improvement of soil properties. Total soil humus content is higher in poplar ecosystems with agroforestry (varied from 4.3% to 2.5%) in comparison with the control (2%). Regarding the composition of organic matter, the control has the smallest content of stable humic acids (0.20%) in comparison with the other three agroforestry systems which have humic acids contents from 0.78% to 0.49%. At the same time control has the highest content of fulvic acids (0.62%) which is more mobile and less stable in comparison with humic acids. The content of fulvic acids in the other plots (with agroforestry) varied from 0.46% to 0.05%. At the same time the control has the highest content of "aggressive" fulvic acids (0.05%). This gives as reason to recommend agroforestry systems as appropriate in growing Populus sp. in Vidin region on Fluvisol.

KEY WORDS: silvoarable systems, organic matter, poplar growth, humus composition

INTRODUCTION
UVOD

Agroforestry systems that combine woody perennials with agricultural use and / or grazing livestock on one and same parcel can be a good method and an opportunity to improve the forest plantations growth and soil quality where it is practiced (Alexandrov *et al.*, 1996; Yakimov *et al.*, 2003; Stancheva *et al.*, 2004; Rivest *et al.*, 2013; Fonte *et al.*, 2010; Huber *et al.*, 2018). The development of agroforestry systems in agrarian lands increases the overall quantity of microbial biomass and the amount of sequestered organic carbon in soils and thus helps to combat climate change (Lagerlöf *et al.*, 2014; Wang *et al.*, 2017; Mosquera-Losada *et al.*, 2017). Agroforestry systems are well combined with such approaches as „intelligent land resource management" and „smart farming" one of the leading in modern agribusiness and policies. The development of agroforestry systems leads to an increase in crop and tree productivity

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while promoting other ecosystems servises (Nair and Garrity, 2012). Vital, productive, sustainable and adaptive ecosystems are formed (Mosquera-Losada *et al.*, 2012), including on degraded lands (Brumec *at al.*, 2013). The established agroforestry systems frequently mimic the natural systems, and in most cases an appropriate combination of tree, shrub and grass species with agricultural crops are observed. Nevertheless, the reducing competition and increasing complementarity and compatibility of species used in agroforestry remains the main challenge facing science and practice. Tree species and agricultural crops are being defined, which are well combined and complementary each other's in structuring agroforestry systems. Poplar is such tree species particularly suitable for the construction of silvoarable and silvopastoral agroforestry systems (Fakirov, 1972; Vassev, 2013; Newman, 1997). It is a fast-growing species and provides accelerated growth especially on typical habitats such as riparian lands (Dobrev and Bodgakov, 1971; Zahariev *et al.*, 1975). In Bulgaria the cultivation of agricultural crops between rows of young poplar trees has been practiced for a long time and successfully (Marinov *et al.*, 2003). Between tree rows is grown: sunflower, cabbage, corn, pepper and eggplant; melon and squash, cauliflower, wheat, beans etc. (Yakimov *et al.*, 2003). The accumulation of waste green organic mass from agricultural plants supports the development of young poplar saplings, and agrochemical care (hoeing, irrigation, fertilizing, etc.) has a beneficial effect on their growth and development (Yakimov *et al.*, 2003). At the same time, improved biodiversity in agroforestry systems, along with increased biomass accumulation in the soil, leads to an improvement in soil quality and fertility (Silva *et al.*, 2012; Nair and Garrity, 2012; Tsonkova *et al.*, 2012).

The aim of this study is to investigate the growth of saplings of *Populus sp.* and the composition of soil organic matter in agroforestry systems established on typical habitats along the Danube.

MATERIAL AND METHODS
MATERIJAL I METODE

The region of Vidin is in the Missian forest vegetation zone with moderate continental climate. It has low January temperatures, high July temperatures and annual precipitation sums of 500-600 mm. Along the river Danube there were established 3 sample plots (SPs) and one control (K) located in Vidin Forestry Estate – the most north-western part of Bulgaria. SP1 is near the village of Novo selo. It has an area of 3.4 ha, with altitude of 30 m, eastern exposure, flatly, and plantation of the "Agathe" poplar clone at the age of 2 years. In SP1 between poplar rows is planted corn. Next to this SP is located the SP2 with an area of 2.4 ha, altitude 30 m, northwestern exposure, flatly, plantation of "mnBL" clone, 10 years old. When the tree plantation was 2-3 ears old there were planted corn and water-melon. The other two SP are located near the town of Vidin in eastern direction near the petrol station "Fantige". SP3 has an area of 3.7 ha, altitude of 40m, eastern exposure, flatly, and plantation of "Agathe", 3 years old. The last year between tree rows there were corn crop. Next to this SP is located the control – SP4, where no agricultural crops were grown – without agroforestry. SP4 has an area of 1.1ha with eastern exposure, flatly and plantation of "Agathe","mnBL" and "I 214", 10 years old. All SPs lies in the zone of Nature 2000 and located in the Danube River's defensive line. The soils are alluvial (*Alluvial Fluvisols*) developed on loess.

Dendrometrical indicators were determined by in situ measurements. The mean diameter breast height (DBH) was determined by the arithmetic basal area – formula (1):

$$DBH=SQRT(1.274*G)$$

where

$G=\Sigma g_i / n$ - is arithmetic basal area in sample plot (m^2);
Σg_i – the sum of basal area of all trees in sample plot (m^2);
n - is number of trees in sample plot.

The mean height (Hm) was calculated as the weighted average in terms of basal areas of Lorey's formula (2):

$$Hm = (h_1 g_1 + h_2 g_2 + \ldots\ldots.. + h_n g_n) / (g_1 + g_2 + \ldots\ldots\ldots + g_n)\ (m) = \Sigma h_n \cdot g_n / \Sigma g_n \quad (2)$$

where

$h_{1,2\ldots n}$ – is a arithmetic height of each degrees of thicknes (m);
$g_{1,2\ldots n}$ – the basal area of all trees according to the relevant degree of thickness (m^2);

Caliperring of older plantations (SP2 and SP4) was made by programme product FET 1.11 (Demo) (Evangelov, 2012), through option "Sorting of whole standings" which uses mathematical model of adopted by practice tables of high-stem poplar (Nedyalkov *et al.*, 2004)

Statistical processing with the software product Statistica 12 was performed.

For soil analyses an average sample of 5 soil samples were taken from the 0-5 cm soil layer. In determining the total carbon, we used the Thurin method, and for the determination of the total nitrogen, the Keldal method was applied (Donov *et al.*, 1974). We studied the composition of humus in soils by Kononova-Belchikova method (1961) which comprises the following steps: total content of humic and fulvic acids with a mixed solution of 0.1N $Na_4P_2O_7$ and 0.1M NaOH; free and bound to the sesquioxides (R_2O_3) with 0.1M NaOH; aggressive fulvic acids with 0.05M H_2SO_4. The soil-to-solution ratio is 1:20 for all three extracts.

RESULTS AND DISCUSSION
REZULTATI I DISKUSIJA

Poplars are the main species used in the afforestation of the lands around Vidin, as the afforestation with poplars here dates back to 1890 (Mitsov, 1963).

General characteristics of the plantation of all SPs are given in table 1.

The calculated values of the average diameter DBH (for SP1 = 2.7 cm and for SP3 = 1.6 cm) and average height Hav (for SP1 = 2.67 m and for SP3 = 2.55 m) show that, although one year younger (at 2 years of age) the plantation in SP1 in which maize is currently sown has better base dendrometrical indicators. Growth characteristics depend heavily on the clone of poplar (Vassev, 2013), but definitely the hoeing care used in crop cultivation as well as the residual green mass in the system have a beneficial effect on the growth of poplars in these typical habitats. This defines the advantages of implementing agroforestry system from the very beginning of the planting life. At this early age, there is still no differentiation with respect to the average diameter and all trees of Agathe poplar clone in both studied plantations (SP1 and SP3) fall into one degree of thickness (2 cm). The comparison between the older plantations SP2 and SP4 (at 10 years of age) shows that the plantation at which agroforestry was applied (SP2) by sowing corn and bostan at ages 2 and 3 is already significantly superior in terms of average diameters and heights (DBH = 9.9 cm; Hm = 7.44 m) compared to those in which no implementation were performed (SP4) (DBH = 8.7 cm; Hm=7.04) m. This is also confirmed by caliperring of the trees in the two sample plots, where in SP2 there is a concentration of 0.8960 m^3 (89.6 m^3 / ha), and in SP4 0.7145 m^3 (71.45 m^3 / ha) of the standing stock. At this age in SP2 (with applied agroforestry), there is already a differentiation of trees from “mnBL” popular clone according to diameter into two degrees of thickness (8 cm-4 and 10 cm-26). On the other hand, in the area without agroforestry (SP4), the trees are located in a broader range with respect to the average diameter (for a degree of thickness of 2 cm – 1 number, for 6 cm – 1 number, for 8 cm-14 numbers and for 10 cm – 14 numbers).

From the statistical analysis, the values of some statistical parameters characterizing the diameters and heights are obtained (Table 2). The values of the arithmetic mean for diameters are almost no different from the calculated weighted averages ones (+0.04, 0.00, +0.03 and -0.15 for SP1 to 4 respectively). The small variation in diameters at this early age is also confirmed by the variance values. The largest number of diameters are centered on the arithmetic mean of the young SP1 and SP3 plantations where the values of the standard deviation are the smallest (0.15 cm). Forestry science and practice also need values of the coefficient of variation of the diameter (Ustabashiev and Ferezliev 2013). Values of the variation coefficients in SP1, SP2 and SP3 fallen in the interval up to 10% show a slight alteration of the diameters, while in SP4 is defined an average alteration of the indicator (19.6% in the interval of 11 to 25%) (Lakin, 1990). In all four cases, the variation of diameters is characterized by negative (left) asymmetry. In SP1, SP2, and SP3 empirical variations deviate insignificantly from the normal curve, which classifies asymmetry as „small“ (with Kurtosis values below 0.5). In the first two cases, the distribution is performed on a curve exceeding minimally the highest part of the normal curve, and in the third case by a curve decreasing to a very small extent the curve of the normal distribution. In the control (SP4) the distribution of the diameters is performed on a curve exceeded relatively more significantly the normal distribution curves in its highest part (the variation curve has a sharp Kurtosis values +12.40).

In a statistical check of height growth, we ascertained that the average values are almost no different from the weighted averages calculated by the Lorey formula (Lorey, 1878) - Table 2.

Table 1. Main characteristics of plantations
Tablica 1. Glavne značajke nasada

iSP *Pokusna ploha*	**Tree species** *Vrsta drveća*	**Location** *Mjesto*	**Age** *Dob*	**Mean Brest High Diameter** (DBH) *Prosječan promjer (DBH)* cm	**Mean Height** (Hav) *Prosječna visina (Hav)* m
1	Agathe	N44.1449° E22.8190°	2	2.7	2.67
2	mnBL	N44.1458° E22.8195°	10	9.9	7.44
3	Agathe	N43.9358° E22.8483°	3	1.6	2.55
4 (K)	Agathe; mnBL; I-214	N43.9347° E22.8472°	10	8.7	7.04

Table 2. Values of the statistical parameters characterizing the mean diameters and mean heights in the sample plots
Tablica 2. Vrijednosti statističkih parametara koji karakteriziraju promjere i visine u uzorcima

SP *Pokusna ploha*	Number of trees *???*	Mean *Prosječna vrijednost*	Range *Opseg*	Variance *Varijacija*	Std. Dev. *Standardno odstupanje*	Coef. Var.(%) *Koeficijent varijacije*	Standard Error *Standardna pogreška*	Skewness *Asimetrija*	Std. Err. Skewness *Standardna pogreška asimetrija*	Kurtosis *Kurtosis*	Std. Err. Kurtosis *Standardna pogreška kurtosis*
Values of the statistical parameters characterizing the trees diameters *Vrijednosti statističkih parametara koji karakteriziraju promjere*											
1	28	1.74	0.60	0.23	0.15	8.6	0,29	-0,86	0.44	0.35	0.86
2	30	9.90	2.54	0.41	0.64	6.5	0.12	-0,87	0.43	0.28	0.83
3	28	1.63	0.52	0.02	0.15	9.2	0.03	-0.85	0.44	-0.35	0.86
4	30	8.55	8.90	2.84	1.68	19.6	0.31	-3.05	0.43	12.40	0.83
Values of the statistical parameters characterizing the heights *Vrijednosti statističkih parametara koji karakteriziraju visine*											
1	28	2.67	0.64	0.41	0.20	7.5	0.04	-0.32	0.44	-0.86	0.86
2	30	7.42	2.60	0.32	0.57	7.8	0.10	0.19	0.43	0.69	0.83
3	28	2.54	1.42	0.08	0.29	11.4	0.05	-1.64	0.44	4.97	0.86
4	30	7.10	1.80	0.30	0.55	7.7	0.10	0.31	0.43	-0.45	0.83

The difference between the maximum and minimum values of the measured heights is the highest in SP2 (2.60 m). The variation of this indicator in relation to the average height is significantly smaller (the variance has values in the range of 0.08 - 0.41). In the four case studied, the greater number of heights are centered around the arithmetic mean, with standard deviation values in the range 0.20 - 0.57 m. Values of the variation coefficient (Vh) do not exceed 11.5%. Its variation is from slight and almost equal in SP1 (7.5%); SP2 (7.8%) and SP4 (7.7%) to moderate for SP3 (11.4%). The variation of heights in the sample plots with younger plantations (SP1 and SP3) differs with negative (left) asymmetry, whereas the older plantations (SP2 and SP4) with positive (right) asymmetry. Deflection of variation curve versus normal height distribution curve is characterized by the rises and falls (due to positive and negative Kurtosis), with the highest elevation in SP3 (Kurtosis 4.97).

Essential for the development of saplings is the quality of soils. There are studies that confirm the existence of a direct relationship between the height of tree plants and soil conditions (Duhovnikov *et al.,* 1975). Land use type can influence soil properties (Göl and Yilmaz, 2017) and in this respect is interesting to analyse soil properties under agroforestry practices.

Table 3 presents the main characteristics of soils: pH, C/N ratio and the stock of C and N - recalculated in t/ha in 1 cm of soil with an average bulk density taken as 1.5 g / m^2. Stocks are calculated using the formula:

$$X = A * H * Q * K$$

where:

A = C% or N%; H = 1 cm; Q = 1.5 g / m^2; K = coefficient for relaying the soil skeleton (= 0.95 in 3% skeleton).

According to the scale of Geliaskov (Donov, 1993) the soils from the SPs fall into the range of slightly acidic soils (pH = 5.7 - 6.5). Only the soil from control (SP4) is within the range of neutral soils. It can be assumed that the planting of vegetable crops implies weakly acidifying of the soils in the area. The calculated carbon and nitrogen stocks in the soils show that the soils in the area are poorly stocked. Organic content is low, the lowest is in the control (SP4).

By studing soils from the Danube, Mihaylov (1988) also found very low and low organic carbon content in these soils (<2%), which shows that this is a characteristic feature of the Danube soils in Bulgaria. We find one exception for SP1 soils that are medium stocked with organic matter. In this sample plot, maize is currently grown, and it can be concluded that this favors the organic stock in this soil. With regard to the total nitrogen content it is very low everywhere - below 1 t / ha. High summer temperatures and low summer rainfall in the region are one of the reasons for

Table 3. Main characteristics of soils
Tablica 3. Glavna svojstva tla

SP *Pokusna ploha*	pH	Store of C *Zaliha ugljika* t/ha	Store of N *Spremište N* t/ha	C/N	Humus *Humus* %
1	6.1	3.56	0.13	27	4.3
2	5.9	2.07	0.10	21	2.5
3	6.5	2.74	0.11	23	3.3
4 (K)	6.8	1.64	0.09	18	2.0

low levels of humus and active mineralization of plant residues in the soils along the Danube (Kirilov *et al.,* 2015). The climatic factor is basic in relation to soil organic matter (Zhiyanski *et al.*, 2012). The ratio of C / N in soils, which is an indicator of the rate at which mineralization of organic matter in the soil occurs, is low to moderate and confirmed by other authors (Kirilov *et al.*, 2015). Most quickly is carried out the mineralization of the organic substance in the soils of the control.

Table 4 shows the composition of organic matter in soils, which is highly sensitive through management applied and widely is used as an indicator of soil quality (Thomazini *et al.,* 2015). We separate two types of organic acids - humic and fulvic acids. The humic acids are stable carboxylic acids which dissolve in NaOH but do not dissolve in HCl. Their higher content is associated with higher soil organic matter stability and a stronger bonding of organic carbon to the mineral soil and better sequestration in the soil. On the contrary, fulvic acids are taken as the more mobile part of soil organic matter. They are with lower molecular weight and dissolve in NaOH and HCl. The results show that in control there is the lowest percentage of humic acids, which is accompanied by the highest percentage of fulvic acids and especially high percentage of the most reactive part of organic matter so called "aggressive fulvic acids". These data support the view that the organic substance in the control is the most unproductive and with lower carbon sequestration ability in soil. There are the other studies that found that trees provides continuous input of liable organic matter by litterfall and there were observed higher content of liable and soluble carbon in agroforestry systems and native forest in comparison with agricultural systems (Thomazini *et al.,* 2015). Obviously, in our study agricultural crops play an role of enhancing the recalcitrant form of carbon in the system. The practice of agroforestry is a good tool to improve the content and composition of the soil organic matter in the system of poplar plantations. For all soils studied, organic acids are 100% linked to sesquioxides and do not bounded with Ca. The data confirm those of Mihaylov (1988) who claim that the carbonate horizon of these soils is down from 190 cm. Summarizing the results leads us to conclusion that agroforestry enhances soil fertility. This is in comply with other studies of the other authors (Neupane and Thara, 2001; Tsonkova *et al.*, 2012; Chen *et al.,* 2019). Our study confirms the statement that agroforestry systems supplies sustainable nutrient security and long term soil productivity (Schwab *et al.*, 2015)

CONCLUSION
ZAKLJUČCI

Agroforestry is a multifunctional, environmentally-friendly and modern system of land use. We achieved good results in the establishment of agroforestry systems in growing *Populus sp.* along the Danube concerning enhancing their productivity and improving soil quality. Planting agricultural crops among tree saplings is a good method to increase their dendrometrical indicators as average diameter and average height. As a modern form of land use, agroforestry is also a tool to enhance soil organic matter content. Agroforestry practices is especially good to improve soil organic matter composition – the amount of carbon which is bounded in recalcitrant part is increase and

Table 4. Humus composition
Tablica 4. Sastav humusa

SP *Pokusna ploha*	**Total C%** *Ukupno C%*	Organic C% Extracted with 0.1 M $Na_2P_4O_7$ + 0.1MNaOH *Organski C% Ekstrahira se s 0,1 M $Na_2P_4O_7$ + 0,1 M NaOH*			Organic C% Fractions of humic acids *Organski C% Frakcije humusnih kiselina*		Non extracted organic C% (humin) *Neekstrahirani organski C% (Humin)*	**"Aggressive" fulvic acids** *„Agresivni" fulvske kiseline*
		Total C extracted with 0.1 M $Na_2P_4O_7$ + 0.1M NaOH	Humic acids *Huminske kiseline*	Fulvic acids *Fulvske kiseline*	Free or bounded with R_2O_3 *Slobodan ili ograničen s R2O3*	Bounded with Ca *Ograničen s Ca*		
	1	*2*	*3*	*4*	*5*	*6*		*7*
1	2.50	0.82	0.78	0.05	100	0	1.68	0.02
2	1.45	0.95	0.49	0.46	100	0	0.50	0.01
3	1.92	1.00	0.85	0.15	100	0	0.92	0.02
4 (K)	1.15	0.82	0.20	0.62	100	0	0.33	0.05

P.S. column 1, 2, 3, 4, 5, 6, 7 are given as a % to the weight of soil sample the amount of liable part (fulvic acids) is decrease especially this concerning "aggressive" fulvic acids. The results obtained give as reason to recommend agroforestry systems as appropriate in growing *Populus sp*. along the Danube.

REFERENCES
LITERATURA

- Alexandrov, A., D. Velkov, K. Genov, E. Asparuhova, 1996: Current Problems of the Agroforestry as an international direction, In Proceedings: Scientific reports at International scientific-technological session "Kontact 96", 36-40 pp., Sofia (in Bulgarian).
- Brumec, D., Č. Rozman, M. Janžekovič, J. Turk, Š. Čelan, 2013. An assessement of different scenarios for agroforestry environment regulation of degraded lands using integrated simulation and a multi-decision model – a case study, Shumarski list, 3-4: 147-161.
- Chen, C., W. Liu, J. Wu, X. Lang, X. Zhu, 2019. Can intercropping with the cash crop help improve the soil physico-chemical properties of rubber plantations?, Geoderma, 335: 149–160.
- Dobrev, D., P. Bodgakov, 1971: Our experience with fast-growing tree species, Zemizdat, 139 p., Sofia (in Bulgarian).
- Donov, V., 1993: Soil Science, 430 pp., Sofia (in Bulgarian).
- Donov, V., Sv. Gencheva, K. Yorova. 1974: Guidance on Soil Analyzes. C., 220 pp., Sofia (in Bulgarian).
- Duhovnikov, I., A. Iliev, V. Donov, 1975. Quantitative bound between height of white pine, spruce and fir and soil conditions, Gorskostopanska nauka, XII, 4: 38-45 (in Bulgarian).
- Evangelov, E., 2012: Forestry Estimation Tool (FET 1.11 Demo), Programme for cubing and sorting, version 1.11 (demo).
- Fakirov, V., 1972. Growth and productivity euroamerican poplar plantations in different density of planting on dried Danube sites, Gorskostopanska nauka, IX, 2: 3-17 (in Bulgarian).
- Fonte, S. J., E. Barrios, J. Six, 2010. Earthworms, soil fertility and aggregate-associated soil organic matter dynamics in the Quesungual agroforestry system, Geoderma 155: 320–328.
- Göl, C., H. Yilmaz, 2017. The effect of land use type / land cover and aspect on soil properties at the Gökdere catchment in northwestern Turkey, Shumarski list, 9-10: 459-468.
- Kirilov, I., E. Filcheva, M. Teoharov, 2015. Comparative characterization of the humus state in sandy soils from the Bulgarian Black Sea coast and those from the Danube valleys, Soil Science, Agrochemistry and Ecology, XLIX, 2: 16-25 (in Bulgarian).
- Kononova, M., N. Belchikova. 1961. Rapid method of mineral soil humus composition. Ускореные методы определения состава хумуса. Pochvovedenie, 10: 75-85, Minsk (in Russian).
- Lagerlöf, J., L. Adolfsson, G. Börjesson, K. Ehlers, G. Palarès-Vinyoles, I. Sundh, 2014. Land-use intensification and agroforestry in the Kenyan highland: Impacts on soil microbial community composition and functional capacity, Applied Soil Ecology, 82: 93–99.
- Lakin G.,1990: Biometrics, Higher School, 352, Moscow (in Russian).
- Lorey, T., 1878. Die mittlere Bestandeshöhe, Allgemeine Forst- und Jagdzeitung, 54: 149–155 (in German).
- Malézieux, E, Crozat Y, Dupraz C, Laurans M, Makowski D, Ozier-Lafontaine, B. Rapidel, S. De Tourdonnet, M. Valantin-Morison, 2009: Mixing plantspecies in cropping systems: concepts, tools and models. A review, In: Agronomy for Sustainable Development, Springer Verlag/EDP Sciences/INRA, 2009, 29 (1), 43-62 pp.
- Marinov, I., V. Stiptsov, G. Rafailov, 2003: Status and Perspectives of Agroforestry in Bulgaria, Bulgarian - Swiss Forest Fondation and SilvicaFondation, 63 pp., Sofia (in Bulgarian).
- Mihaylov, M., 1988: Genesis, diagnosis and classification of soils developed on beams in the Danube valleys, Dissertation, ISSAPP "N. Pushkarov, 170 p., Sofia (in Bulgarian).
- Mitsov, S., 1963. Afforestation with Poplars in the region of Vidin, Gorsko stopanstvo, 11: 38-40 (in Bulgarian).
- Mosquera-Losada, M. R., G. Moreno , A. Pardini , J. H. McAdam,V. Papanastasis, P. Burgess , N. Lamersdorf, M. Castro , F. Liagre ,A. Rigueiro-Rodríguez, 2012: Past, Present and Future of Agroforestry Systems in Europe, In: P.K.R. Nair and D. Garrity (eds.), Agroforestry - The Future of Global Land Use, Advances in Agroforestry 9, DOI 10.1007/978-94-007-4676-3_16, Springer Science+Business Media Dordrecht.
- Mosquera-Losada, M. R., R. Borek, F. Balaguer, G. Mezarrala, M. E. Ramos-Font, 2017: Agroforestry as a mitigation and adaptation tools, In: EPI-AGRI Focus Group, Agroforestry, 1-9 pp.
- Nair, P., D. Garrity, 2012: Agroforestry — the future of global land use, Dordrecht: Springer; 514 pp.
- Nedyalkov, K, Cv. Naydenova, V. Fakirov: 2004: Volume and sorting table for high-stem popular. In. Krastanov, K., R. Raikov, Reference book in dendrobiometer, Bulprophor, Bulgaria, 312-320 pp., Sofia (in Bulgarian).
- Neupane, R., G., Thara, 2001. Impact of agroforestry intervention on soil fertility and farm income under the subsistence farming system of the middle hills, Nepal, Agric. Ecosyst. Environ. 84 (2): 157–167.
- Newman, S. M., 1997. Poplar agroforestry in India, Forest Ecology and Management, 90: 13- 17.
- Rivest, D., M. Lorente, A. Olivier, C. Messier, 2013: Soil biochemical properties and microbial resilience in agroforestry systems: Effects on wheat growth under controlled drought and flooding conditions, Science of the Total Environment, 463–464: 51–60.
- Huber, J. A., M. Matiu, K. J. Heulsbergen, 2018. First-rotation growth and stand structure dynamics of tree species in organic and conventional short-rotation agroforestry systems, Heliyon, e00645. doi: 10.1016/j.heliyon.2018.e00645
- Silva, G., H. Lima, M. Campanha, R. Gilkes, T. Oliveira, 2012. Soil physical quality of *Luvisols* under agroforestry, natural vegetation and conventional crop management systems in the Brazilian semi-arid region, Geoderma, 167-168: 61–70.
- Stancheva, J., K. Petkova, S. Bencheva, S. Bencheva, M. Broshtilova, K. Broshtilov, N. Tsvetkova, 2004: Agroforestry, 239 p., Sofia (in Bulgarian).
- Schwab, N., U. Schickhoff, E. Fischer, 2015. Transition to agroforestry significantly improves soil quality: A case study in the central mid-hills of Nepal, Agriculture, Ecosystems and Environment, 205: 57–69.
- STATISTICA 12 (data analysis software system), 2004. StatSoft, Inc. www.statsoft.com.
- Thomazini, A., E.S.Mendonça, I.M. Cardoso, M .L. Garbin, 2015. SOC dynamics and soil quality index of agroforestry systems in the Atlantic rainforest of Brazil, Geoderma Regional, 5: 15–24.

- Tsonkova, P., C. Böhm, A. Quinkenstein, D. Freese, 2012. Ecological benefits pro-vided by alley cropping systems for production of woody biomass in the temperate region: a review, Agrofor. Syst., 85: 133–152.
- Vassev I., 2013: Poplur – save and effective investment, Editorial house at Forest University, 18 p., Sofia.
- Wang, J., C. Ren, H. Cheng, Y. Zou, M. Ahmed Bughio, Q. Li, 2017. Conversion of rainforest into agroforestry andmonoculture plantation in China: Consequences for soil phosphorus forms and microbial community, Science of the Total Environment, 595:769–778.
- Yakimov, M., V. Stiptsov, K. Kalmukov, E. Aleksandrova, I. Yonovska, 2003: Agricultural uses of forest area, In: Agroforestry, Bulgarian - Swiss Forest Foundation and Silvica Foundation, 22 p., Svishtov (in Bulgarian).
- Ustabashiev, F, A. Ferezliev, 2013. Dynamics of the growth indicators in relation to height structure of Austrian black pine (Pinus nigra Arn.) natural stands in the region of SGBS Chepino, Northwestern Rhodopes, Nauka za gorata, 1-2: 39-54 (in Bulgarian).
- Zahariev B., S. Iliev, T. Mitev, 1975. Growth and productivity of some Euro-American poplar clones in coastal and external dry sites in our country, Gorskostopanska nauka, XII, 2: 16-22 (in Bulgarian).
- Zhyianski M., M. Sokolovska, E. Filcheva, Y. Yordanov, 2012. Soil organic matter in urban forest parks, Ecology and Future, XI, 3: 27–31.

SAŽETAK

Agrošumarstvo je višenamjenski, okolišno povoljan i moderan sustav korištenja zemljišta kojim se mogu postići ekonomske, okolišne i socijalne dobrobiti za društvo. Ovom studijom se to potvrđuje na primjeru plantaža topola uz rijeku Dunav u regiji Vidin (Bugarska) u koje je uveden i uzgoj povrtlarskih kultura. Primjenom agrošumarskih metoda proizvodnost plantaža topola je povećana. Prosječni prsni promjeri i prosječne visine stabala u područjima u kojima je primijenjeno agrošumarstvo su veći u odnosu na plantaže bez primjene agrošumarstva iste dobi. Desetgodišnja plantaža uz primjenu agrošumarstva ima prosječni prsni promjer stabala od 8,70 cm i prosječnu visinu od 7,44 m, dok kontrolna ploha ima lošije dendrometrijske značajke (prsni promjer od 7,44 cm i prosječnu visinu od 7,04 cm). Uspostava agrošumarskog sustava također je dovela i do poboljšanja značajki tla. Sadržaj humusa u tlu je veći u plantažama s primijenjenim agrošumarskim sustavom (4,3-2,5%) u odnosu na kontrolnu plohu (2%). S obzirom na sastav organske tvari, kontrolna ploha ima najmanji udio huminskih kiselina (stabilni dio organske tvari) (0,20%) u usporedbi s agrošumarskim sustavom (0,78-0,49%). Ujedno, kontrolna površina ima najveći udio fulvo kiselina (mobilni dio organske tvari (0,62%) u usporedbi s agrošumarskim sustavom (0,46-0,05%) i najveći udio “agresivnih” fulvo kiselina (0,05%). Na temelju rezultata ovoga istraživanja, razložno je preporučiti agrošumarski sustav gospodarenja kao odgovarajući za uzgajanje plantaža topola na fluvisolima regije Vidin.

KLJUČNE RIJEČI: silikatni sustavi, organska tvar, rast topole, sastav humusa