



## Forest species diversity in river watersheds of the Left-Bank Forest-Steppe of Ukraine

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Species diversity of forests in basins of the rivers Sula, Vorskla, Psel, and Seversky Donets and their tributaries (on the territory of Ukraine) are analyzed. The research aimed to identify forest species diversity in 109 watersheds of the rivers Sula, Vorskla, Psel, and Seversky Donets and determine the share of forests in the origin and composition of plantations in the river basins. To delineate the boundaries of 109 catchment areas of the Sula, Psel, Vorskla, and Seversky Donets rivers, the *MapInfo Professional 12.5* and a vector map of Ukraine were used. After defining the boundaries of 109 river basins, a vector layer of forest stands (which are subordinated to the State Forest Resources Agency of Ukraine) was applied, and the distribution database of these rivers was formed. It was determined that 63 species of trees were identified in the study region, the most common of which are common oak and Scots pine. The distribution of several tree species on 109 river basins is analyzed. Thus, the most significant number of tributaries (50%) has concentrated from 11 to 20 species of trees, slightly less number of tributaries (24 and 22%) represented 1-10 and 21-30 species, and the smallest number of tributaries (6 and 2%) represented 31-40 and 41-50%, respectively. Mixed plantations dominate (61% of the total forest area) in the river basin; pure plantations are the rest (39%).

**Keywords:** tree species, Sula River, Psel River, Vorskla River, Seversky Donets River

### Introduction

Forest has a positive effect on climate, soil, and conditions of surface runoff formation. Its development produces an organic mass, which performs many valuable functions: it accumulates solar energy, produces oxygen, helps retain moisture in fields, regulates water levels in rivers, filters water, and prevents floods (Ostapenko and Tkach, 2002).

Species diversity of forests depends on the composition, structure of plantations, and forest type (Bengtsson et al. 2000; Van Calster et al., 2008; Vacek et al., 2016), and forestry activities (Bílek et al., 2011; Vild et al., 2013; Sjölund and Jump, 2015; Chudomelová et al., 2017), which directly affected a living -ground cover (Vacek et al., 1999; Mölder et al., 2008; Vild et al., 2013; Bílek et al., 2014).

In the studies of some scientists (Von Oheimb and Brunet, 2007; Bartha et al., 2008; Hédl et al., 2010), there a loss of species diversity in hornbeam-oak, oak forests are already noted. Therefore, studies of species diversity of forests (Vacek et al., 2019) in river basins are relevant, especially in climate change conditions.

A study of natural regeneration, productivity determination, pests, and diseases of common oak (Tkach et al. 2019, 2020, Niccoli et al., 2020), Scots pine (Garmash, 2019; Conte et al., 2018; Sharma et al., 2020), common ash (Beyer et al., 2013; Davydenko et al., 2019), black alder (Buhaiiov et al., 2019; Deptuła et al., 2020), silver birch (Tyschenko, 2018; Álvarez-López et al. 2020) was performed in many scientific papers. However, research on the determination of species diversity, distribution, and origin in the river basins of the Left-Bank Forest-Steppe of Ukraine has hardly been conducted (Tkach, 1999; Bondar et al., 2020).

The research aimed to identify the species diversity of forests in 109 catchment areas of the Sula, Vorskla, Psel, and Seversky Donets rivers and determine the share of forests of various origin and compositions in the river basins.

## Materials and methods

The Sula, Psel, Vorskla, and Seversky Donets rivers and their tributary basins were separated using *MapInfo Professional 12.5* and a vector map of Ukraine. The catchment area boundaries were determined by watershed lines passing through the points from which the slope lines diverged in different directions. These points are located in places of the most extraordinary bending of horizontals. Watersheds ran along the lines of ridges through the peaks and saddles. After defining the boundaries of 109 river basins, a vector layer of forest plantations (which are subordinated to the State Forest Resources Agency of Ukraine) was applied, and a river basins' distribution database was formed.

During the analysis of the forest fund of forestry enterprises in the basins of the Sula, Psel, Vorskla, and Seversky Donets rivers and their tributaries, the electronic distribution database of VO "Ukrderzhlisproekt" (Ukrainian State Project Forestry Production association) was converted from ".vff" to ".mdb" format with MS Access software using NewUnPackOHOTA program, developed in the Laboratory of New Information Technologies in Ukrainian Research Institute of Forestry and Forest Melioration (Kharkiv, Ukraine). The sample of data required for further calculations was exported to the ".xls" format of Microsoft Excel (Vedmid et al., 2006) as of 01.01.2011.

The research was conducted on the territory of Poltava, Kharkiv, Sumy, Chernihiv, Kyiv, and Cherkasy regions of Ukraine. Geographical coordinates of the extreme points of the study region: North 33°42'58", 51°08'31", South 34°10'05", 48°56'46", West 31°32'59", 50°46'47", and East 38°05'37", 49°49'56" (Fig. 1). The river centroid coordinates are as follows: Sula 33°04'11", 50°21'29", Psel 34°16'42", 50°05'13", Vorskla 34°58'10", 49°05'15", and Seversky Donets 36°45'59", 49°55'19".



**Fig. 1.** Catchment areas of the river Sula (1), Psel (2), Vorskla (3), and Siversky Donets (4) (from Bondar et al., 2020)

The total area of forests studied was 502.0 thousand hectares, which are at the disposal of the State Forest Resources Agency of Ukraine. The largest share of the forest is concentrated in the catchment area of the Seversky Donets (176.9 thousand hectares), slightly less in the catchment areas of the Psel (137.8 thousand hectares) and the Vorskla (119.2 thousand hectares), and the smallest in the Sula basin, respectively (68.1 thousand hectares).

## Results

Sixty-three species of trees were identified as part of the plantations of the studied river basins. Within individual catchment areas, the number of tree species was slightly smaller. Thus, in the Psel basin, plantations were formed by 51 tree species, Seversky Donets – 49, Sula, and Vorskla – 48 species.

Common to the analyzed catchment areas is the predominance of common oak (*Quercus robur* L.) and Scots pine (*Pinus sylvestris* L.) plantations, but the composition of plantations in these areas differs slightly (Table 3.1). Thus, the share of oak plantations in the catchment area of the Seversky Donets is 65%, of the Vorskla – 51%, the Sula – 49%, and the Psel – 44%.

**Table 1.** Distribution of plantation areas in river basins by predominant tree species

Species	Sula	Psel	Vorskla	Siversky Donets
<i>Betula pendula</i> Roth.	5	2	1	1
<i>Alnus glutinosa</i> (L.)	12	5	4	1
<i>Quercus robur</i> L.	49	44	51	65
<i>Acer platanoides</i> L.	2	2	1	1
<i>Tilia cordata</i> Mill.	4	2	1	1
<i>Populus tremula</i> L.	2	2	1	2
<i>Pinus sylvestris</i> L.	13	31	33	24
<i>Fraxinus excelsior</i> L.	2	6	4	2
<i>Robinia pseudoacacia</i> L.	4	1	1	1
Others	7	5	3	2

Area of stands of black alder (*Alnus glutinosa* (L.) Gaerth.), common ash (*Fraxinus excelsior* L.), silver birch (*Betula pendula* Roth.), aspen (*Populus tremula* L.), Robinia (*Robinia pseudoacacia* L.), small-leaved linden (*Tilia cordata* Mill.), Norway maple (*Acer platanoides* L.) is from 1 to 4% of the total area covered with forest vegetation. The area of plantations of other tree species is only 4% of the total.

These differences in the species diversity of forests in different river basins are associated with certain features of the typological structure of the forest fund, the peculiarities of forest management, and forest vegetation conditions.

For a detailed description of the distribution and determination of the number of tree species within the catchment areas of the Sula, Psel, Vorskla, and Seversky Donets rivers, their tributaries were grouped into separate groups according to the number of tree species. There were five groups: the first – with the 1-10 number of species; the second – 11-20; the third – 21-30; the fourth – 31-40, and the fifth – 41-50 species (Table 1).

The first group (1–10 species) includes 22 rivers, most of which are tributaries of the Sula (rivers Vilshanka 1, no title (2, 3, 4, 5, 7, 9), Bobryk, Kremiana, Tahamlyk, Rudka, Boromka) – 54 %, and the most minor – tributaries of the Vorskla (rivers Ivany, Husynka, Okhtyrka, Poluziria) – 18 %, the Psel (rivers Udava, Vovnianka, no title 7), and the Seversky Donets (rivers no title 4, Hnylytsia 1, Sukhyi Burluk) – 14 % each, respectively.

The second group (11–20 species) includes 55 rivers, most of them are tributaries of the Sula (rivers Antropoloh, Budakva, Sliporid, Bulatets, Sulytsia, no title (1, 6, 8, 10, 11), Sukha Lokhvytsia, Loknia, Olava, Romen, Khmylivka,, Khust, Khus, Tern) – 33 %, slightly less are the ones of the Psel (rivers Hriaznyi, Vilshanka 1, Budyłka, Bobryk, Vepryk, Hnylytsia, Hovtva, no title (1, 2, 3, 4, 6), Omelynk, Manzhaleia, Sumka) – 27 %, and the tributaries of Vorskla (rivers Haivoronka, Bratenytsia, Riabyna, Krynychka, Khukhra, Oreshnia, Tahamlyk, Kustolova, no title 2, Kobyliačka, Oleshnia) and the Seversky Donets (rivers Babka, Tetliha, Byshkiv, Shcherbynka, Milova, no title (1, 3, 4), Povna, Khotimlia, Hnylytsia 2) are at 20% respectively.

**Table 2.** Distribution of the number of tree species in river catchment areas, pcs.

River basin	Number of tree species on river tributaries				
	1-10	11-20	21-30	31-40	41-50
Sula	12	18	2	-	1
Psel	3	15	13	1	-
Vorskla	4	11	2	4	-
Siversky Donets	3	11	7	1	1
Total	22	55	24	6	2

The third group (21-30 species) includes 24 rivers, most of them are tributaries of the Psel (rivers Rybytsia, Syrovatka, Lyhan, Liutenka, Hrun-Tashan, Muzhva, no title (5, 8, 9, 10), Rudka, Hrun, Oleshnia) – 55 %, slightly less – of the Seversky Donets (rivers Homilsha, Vovcha, Velykyi Burluk, no title (2, 5) Voloska Balakliika, Oskil) – 29 %, and the least – of the Sula (rivers Orzhysia, Vilshanka) and Vorskla (rivers no title 1, Vorsklytsia) – 16% respectively.

The fourth group (31–40 species) includes six rivers, the largest of them are the tributaries of the Vorskla (rivers Merla, Svyknivka, no title 3, Boromlia) – 67%, and the most minor – tributaries of the Psel (Khorol River) and the Seversky Donets (Mozh River) – 33%.

The fifth group (41-50 species) includes only tributaries of the Sula (Udai River) and the Seversky Donets (Uda River).

After analyzing the number of tree species in river basins, it was determined that the most significant number of tree species was concentrated in the second group (50% of the total number of tributaries), twice less in the third (22%) and first (20%) group and the least represented the fourth (6%) and the fifth group (2%).

Plantations are divided by composition into pure and mixed. Pure plantations are formed by one tree species, and mixed – by two or more tree species. In general, mixed plantations (61% of the total area covered by forest vegetation) dominate in the river basins of the Left-Bank Forest-Steppe of Ukraine, and pure plantations (39%) are much less represented.

The largest share of pure plantations is concentrated in the Vorskla catchment area (43%), slightly smaller in the Seversky Donets one (42%), and the smallest in the Psel (37%) and the Sula (30%). This is due to the peculiarities of soil and climatic conditions, geomorphological structure, and human economic activity in river basins.

For a detailed analysis of the distribution of pure plantations within the catchment areas of the Sula, Psel, Vorskla, and Seversky Donets rivers, their tributaries were divided into separate groups by the share of pure stands (Table 3). In total, the following five groups were identified: the first – with the share of pure plantations from 0.1 to 20.0% of the total area covered with forest vegetation; the second – 20.1-40.0%; the third – 40.1-60.0%; the fourth – 60.1-80.0%, and the fifth – 80.1-100.0%.

The first group (0.1–20.0%) includes 34 rivers, most of them are tributaries of the Sula (rivers Kremiana, Tahamlyk, no title (9, 11), Sliporid, Bulatets, Vilshanka, Sulytsia, Sukha Lokhvytsia, Olava, Romen, Khmylivka, Khust, Khus) – 41%, and the Psel (rivers Rybytsia, Hriaznyi, Syrovatka, no title (3, 7, 10), Hovtva, Rudka, Omelnyk, Manzhaleia, Vovnianka, Oleshnia) – 35 %; and the least respectively are tributaries of the Vorskla (rivers Bratenytsia, Kobyliačka, Oleshnia, Vorsklytsia) and Severskiy Donets (rivers Babka, no title 1, Shcherbynka, Hnylytsia 1) – 12% each.

The second group (20.1–40.0%) includes 33 rivers, mainly tributaries of the Psel (rivers Lyhan, no title (1, 2, 4, 5, 6, 9), Khorol, Hrun, Sumka) – 30%, then the Sula (rivers no title (4, 5, 10), Antropoloh, Budakva, Orzhysia, Udai, Loknia, Tern) – 28%, the Vorskla (rivers Haivoronka, Riabyna, Khukhra, no title (2, 3) Poluzir'ia, Boromlia) and the Severskiy Donets (rivers Tetliha, no title (2, 3), Uda, Homilsha, Byshkiv, Velykyi Burluk) – 21% each respectively.

The third group (40.1–60.0%) includes 13 rivers, most of them are tributaries of the Vorskla (rivers Ivany, Oreshnia, Merla, Svyntivka) and the Severskiy Donets (rivers Mozh, Milova, Vovcha, Oskil) – 31% each, slightly less – tributaries of the Sula (rivers Bobryk, Rudka, Boromka) – 23 %, and the least are the ones of the Psel (rivers Hrun-Tashan, Hnylytsia) – 15 %.

**Table 3.** Distribution of the share of pure plantations on tributaries of the river

River basin	Share of pure plantations on tributaries of the rivers, %				
	0.1-20	20.1-40	40.1-60	60.1-80	80.1-100
Sula	14	9	3	5	2
Psel	12	10	2	7	-
Vorskla	4	7	4	4	2
Siversky Donets	4	7	4	4	4
Total	34	33	13	20	8

The fourth group (60.1-80.0%) includes 20 rivers, most of them – tributaries of the Psel (rivers Vilshanka 1, Budyłka, Bobryk, Vepryk, Liutenka, Muzhva, no title 8) – 35 %, fewer ones – of the Sula (rivers Vilshanka 1, no title (1, 6, 7, 8)) – 25 %, and the Vorskla (rivers Krynychka, Tahamlyk, Kustolova, no title 1) and the Severskiy Donets (rivers Sukhyi Burluk, Hnylytsia 2, no title 5, Voloska Balakliika) are 20% each respectively.

The fifth group (80.1–100.0%) includes eight rivers, mostly tributaries of the Severskiy Donets (rivers Povna, no title (1, 4), Khotimlia) – 50 %, twice less the tributaries of Sula (rivers no title 2, 3) and the Vorskla (rivers Husynka, Okhtyrka) – 25% each.

Only in the catchment area of the river Udava (a tributary of the Psel) are all plantations mixed. The share of mixed plantations in the basins of Sula, Psel, Vorskla, and Seversky Donets will be directly opposite to the five groups of pure stands.

In the study region, the distribution of the share of forests by origin is characterized by specific features. Thus, the largest share of natural plantations grows in the catchment area of the Seversky Donets (61%), slightly smaller in the catchment areas of the Sula (49%), Vorskla (45%), and Psel (44%).

For a detailed analysis of forests by origin within 109 river basins, they were grouped into separate groups by the share of origin of stands. In total, natural and artificial forests were grouped into five groups (Table 4): the first – with the share of plantations on tributaries up to 0.1-20.0% of the total area covered by forest vegetation; the second – 20.1-40.0%; third – 40.1-60.0%; fourth – 60.1-80.0%; and the fifth – 80.1-100.0%.

Thus, plantations of natural origin grow on 16 rivers of the first group (0.1–20.0%), most of them on tributaries of the Sula (rivers Vilshanka 1, no title (3, 5, 8), Kremiana, Rudka) – 38%, slightly less – on the Seversky Donets (rivers Povna, no title 4, Khotimlia, Sukhyi Burluk) and the Vorskla (rivers Ivany, Husynka, Okhtyrka, Krynychka) – 25% each, and the least on the tributaries of the Psel (rivers Vilshanka 1, Bobryk) – 12 %.

The second group (20.1-40.0%) includes 19 rivers, most of them are tributaries of the Psel (rivers Budyłka, no title (2, 8), Vepryk, Liutenka, Muzhva, Hnylytsia, Hrun) – 42 %, slightly less – the tributaries of the Seversky Donets (rivers Hnylytsia 1, Hnylytsia 2, no title (4, 5), Voloska Balakliika) – 26 %, and the least – of the Sula (rivers no title (2, 9), Olava) and the Vorskla (rivers Merla, Tahamlyk, no title 1) – 16% each.

The third group (40.1-60.0%) includes 41 rivers, mostly tributaries of the Sula (rivers Antropoloh, Boromka, no title (1, 4, 6, 7, 10), Sliporid, Bulatets, Vilshanka, Udai, Sulytsia, Sukha Lokhvytsia, Loknia, Romen, Khust, Khus, Tern) – 44 %, much less – tributaries of the Psel (rivers Rybytsia, Hriaznyi, Syrovatka, Lyhan, Hrun-Tashan, Khorol, no title (1, 6, 7, 9), Sumka, Oleshnia) – 29 %, and the Vorskla (rivers Bratenytsia, Khukhra, Oreshnia, Kolomak, Kustolova, no title 2, Oleshnia, Boromlia) – 20 %; and the lowest, respectively, are tributaries of the Seversky Donets (rivers Vovcha, Velykyi Burluk, Oskil) – only 7%.

The fourth group (60.1-80.0%) includes 24 rivers, most of them are tributaries of the Seversky Donets (rivers with no title (2, 3), Tetliha, Uda, Mozh, Byshkiv, Shcherbynka, Milova) – 33 %, slightly less – the Psel's ones (rivers Udava, no title (4, 5, 10), Hovtva, Rudka, Manzhaleia) – 29%, and the least – tributaries of the Vorskla (rivers Haivoronka, Riabyna, Poluziria, no title 3, Vorsklytsia), and the Sula (rivers Bobryk, Orzhysia, no title 11, Khmylivka) – 21 and 17% respectively.

**Table 4.** Distribution of the number of tributaries by share of forests of different origin

River basin	Share of forest origin from the total forest area, %					Total
	0.1-20.0	20.1-40.0	40.1-60.0	60.1-80.0	80.1-100	
Natural origin						
Sula	6	3	18	4	2	33
Psel	2	8	12	7	3	32
Vorskla	4	3	8	5	1	21
Siversky Donets	4	5	3	8	3	23
Artificial origin						
Sula	2	4	18	3	6	33
Psel	3	7	12	8	2	32
Vorskla	1	5	8	3	4	21
Siversky Donets	3	8	3	5	4	23

The fifth group (80.1–100.0%) includes eight rivers, most of them are tributaries of the Seversky Donets (rivers no title 1, Babka, Homilsha) and the Psel (rivers no title 3, Omelnyk, Vovnianka) – 33% each, and, respectively, the smallest of the Sula (rivers Budakva, Tahamlyk) and the Vorskla (Kobyliachka River) – 22% and 12%, respectively.

The share of artificial plantations in the catchment areas of the tributaries of the Sula, Psel, Vorskla, and Seversky Donets will be directly opposite to the five groups of natural forests.

## Discussion

Forests of Ukraine are formed by more than 30 tree species, among which dominates are Scots pine (*Pinus sylvestris* L.), common oak (*Quercus robur* L.), beech (*Fagus sylvatica* L.), European spruce (*Picea abies* L.), silver birch (*Betula pendula* Roth.), black alder (*Alnus glutinosa* (L.) Gaerth.), common ash (*Fraxinus excelsior* L.), common hornbeam (*Carpinus betulus* L.), and European silver fir (*Abies alba* Mill) (General characteristics of forests of Ukraine 2011, Forestry of Ukraine 2019). According to the results of our research, it was found that the predominant wood species in the Sula basin are common oak, Scots pine, and black alder, and in the Psel, Vorskla, and Seversky Donets catchment areas, there are common oak and Scots pine. The peculiarities of relief explain such a significant difference (in 30-31 species of trees) compared with the predominant species on the Ukraine territory, geomorphology, soils, and climatic indicators (Ostapenko - Tkach 2002).

The species diversity of forests on the territory of the Left-Bank Forest-Steppe is quite diverse and is represented by 70 tree species. The most common species represented by the following: common oak (46%), pine (31%), black alder (5%), common ash (3%), silver birch (3%), Robinia (2%), quaking aspen (2%), small-leaved linden (2%), Norway maple (1%), the rest are occupied by other tree species (4%). Our research confirmed the results of (Sydorenko, 2017) on the dominance of the nine tree species mentioned above. However, some fluctuations in the share of these species are possible, depending on the catchment areas of the rivers Sula, Psel, Vorskla, and Seversky Donets. This is due to the peculiarities of the terrain, geomorphology, soil and climatic conditions, and forestry.

Pure (oak or pine) plantations in comparison with mixed (oak-ash-maple, or pine-oak) in neighboring areas in the same forest vegetation conditions have lower forestry taxation indicators (Ngo Bieng et al. 2013; Petritan et al. 2014; Králíček et al. 2017; Pretzsch et al. 2015, 2016, Pretzsch and Schütze, 2015) and are less biologically resistant to pest spread (Jactel and Brockerhoff, 2007) and less productive (Río and Sterba. 2009; Bielak et al. 2014) mixed plantations. These studies were conducted in Europe. Compared to pristine forests, growing mixed forests increases resistance (Pretzsch and Rais, 2016; Zeller et al., 2017) and the diversity of natural habitats. This is especially relevant now, as in Ukraine, there is now a drying of pure pine plantations in Polissya and Forest-Steppe (Tkach and Mieshkova, 2019).

Despite the findings of previous studies, research on the species diversity of forests and their distribution by origin in the basins of the Sula, Psel, Vorskla, and Seversky Donets, and especially on the current climate change, remains relevant.

## Conclusions

Sixty-three species of trees represent forest species diversity in Sula, Psel, Vorskla, and Seversky Donets. Among them, the most common are oak and Scots pine.

The research object territory is dominated by mixed plantations (61%), pure plantations are slightly less (39% of the total forest area). Thus, the largest share of pure plantations grows in the catchment area of the Vorskla River (43%), slightly smaller in the catchment area of the Seversky Donets River (42%), and the smallest in the basin of the rivers Psel (37%) and Sula (30%), respectively.

In the study area, plantations of natural origin predominate – 51%, slightly less artificial origin – 49% of the total forest area. The largest share of natural forests grows in the basin of the Seversky Donets River (61%), slightly smaller in the catchment area of the Sula River (49%), Vorskla River (45%), and Psel River (44%), respectively.

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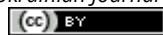
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