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Prevailing forest types in the river catchments within the Left-Bank Forest-Steppe zone, Ukraine

Oleksandr Bondar[1], *Maksym Rumiantsev*[1], *Liudmyla Tkach*[2], *Iryna Obolonyk*[1] ✉

[1] Ukrainian Research Institute of Forestry and Forest Melioration named after G.M. Vysotsky, Pushkinska 86, 61024 Kharkiv, Ukraine, phone: +380503008864, e-mail: obolonik@uriffm.org.ua

[2] O.M. Beketov National University of Urban Economy in Kharkiv, Marshal Bazhanov 17, 61002 Kharkiv, Ukraine

Abstract

The aim of the study was to determine the distribution of prevailing forest types within the catchment areas of the biggest rivers in the north-east of Ukraine. During the allocation of the catchment areas of the studied rivers, the MapInfo Professional 12.5 program and the vector map of Ukraine were used. The research covered the forest area (more than 502,000 ha) of the state forest enterprises managed by the State Forest Resources Agency of Ukraine. The studied area located on the tributaries of the Sula, Psel, Vorskla and Siversky Donets rivers within the Poltava, Kharkiv, Sumy, Chernihiv, Kyiv and Cherkasy administrative regions of Ukraine. The analysis of the forest fund was carried out based on the electronic subcompartment database of the Ukrderzhlisproekt Production Association, using the application software and geoinformation technologies. It was revealed that a large variety of forest types in the tributaries of the Sula, Psel, Vorskla and Siversky Donets rivers as well as the prevalence of fresh fertile maple-lime oak and fresh fairly infertile oak-pine forest types (in 75 tributaries of Psel, Vorskla and Siversky Donets rivers) and fresh fertile maple-lime oak and fresh fertile hornbeam oak forest types (in 20 tributaries of the Sula River) are due to the relief, hydrological and soil-climatic conditions of the studied area, as well as anthropogenic factor. Assuming homogeneous natural conditions, an insignificant number of forest types are formed (up to five). For a large variety of natural conditions, there are at least six forest types that should be taken into account during forest management, along with the characteristics of the catchment areas of tributaries. The analysed data on the total number of forest types in the catchments of rivers would be appropriate to use in the future when creating a single list of forest types for the Left-Bank Forest-Steppe zone of Ukraine. The prevalence of certain forest types within the catchment areas of tributaries of the Sula, Psel, Vorskla and Siversky Donets rivers directly depends on the soil and climatic conditions, geomorphological structure, relief and anthropogenic influence in the forests. The results should be used in forest management activities to preserve and restore the species diversity of forests within the river catchments.

Key words

catchment area, tributary, forest mensuration database, Sula River, Psel River, Vorskla River, Siversky Donets River

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Introduction

Forest typology is the theoretical basis for forests science, forestry, classification and monitoring of forests (Flanagan et al. 2015; Vaz et al. 2015; Corona 2016; Valbuena et al. 2016). Forest typology has been studied by many research schools and centres around the world, whose investigations have been the basis for the organisation and planning of relevant forest management practices (De Cáceres et al. 2019). The most famous forest-typological classifications were the following: Franco-Swiss phytosociological classification by Brown-Blanket (1964), Zurich physiognomic-ecological classification by Meusel (1943), German physiognomic-ecological classification by Drude (1890), Finnish structural and physiognomic classification by Cajander (1949), Anglo-American ecologically-dynamic classification by Clements (1916) and Ukrainian forest-ecological classification developed by Pogrebnyak and Vorobyov and Ostapenko and Tkach (by Furdychko et al. 2010). The object of forest-ecological direction in the Ukrainian forest typology is the forest as not only an area with growing trees but also the areas not occupied and occupied by stands earlier, which are subject to reforestation and afforestation. Forest-ecological typology has a clearly stated purpose: it is the classification of forest areas and the grouping of stands into types for the needs of forestry, which defines the scope of scientific and practical application (Tkach 2012).

At the present stage, the European forest typology based on the application of geographic information system technologies is closely related to the findings of Barbati et al. (2010).

At present, there is some decline in the forest and ecological research in the Ukrainian forest typology. Only individual scientists, in particular, Tkach, Pasternak and Migunova, continue to study types of forest. At the same time, in general, a significant number of scientific works are devoted to the study of the characteristics of forest stands. However, in modern conditions, under increasing human pressure on forests (Barbati et al. 2007, 2014), the application of the knowledge on forest typology is increasingly relevant for rational use of forest resources and maximum conservation of forest landscapes (Melniichuk and Chabanchuk 2016; Bondar 2018).

The aim of our study was to reveal peculiarities of the distribution of prevailing forest types within the catchment areas of the large rivers in the Left-Bank Forest-Steppe zone of Ukraine (Sula, Psel, Vorskla and Siversky Donets), taking into account natural conditions.

Material and methods

During the allocation of the catchment areas of the studied rivers, we used the MapInfo Professional 12.5 program and the vector map of Ukraine. The boundaries of the catchment areas were determined by the watershed lines that passed through the points from which the slope profiles spread in different directions. As a rule, these points were located in the places with the greatest culmination of the terrain contours. Watershed divides passed along the ridges through the peaks and saddles.

The streams of the Sula, Psel, Vorskla and Siversky Donets rivers within the Left-Bank Forest-Steppe zone were conditionally divided into parts. Sectioning of stream parts in the water catchments was carried out as follows: we determined the total length of the river and conditionally divided it into the following three parts of equal length: upstream, midstream and downstream.

Tributaries were listed starting with those nearest to the mouth of the river and ending with those nearest to the source of the river. We used the arrangement of tributaries (streams) in a hierarchy of first, second, third and higher orders, with the first-order tributary being typically the largest in size.

For a more detailed description of the distribution of prevailing forest types, the tributaries were grouped into categories depending on the proportion of the forest type area in the total forest area within separate catchments of large rivers. Five categories were generally identified. The first category included the tributaries with 0–20% proportion of a prevailing forest type; the second category included those with the proportion of 21–40%, the third category included those with 41–60%, the fourth category included those with 61–80% and the fifth category included those with 81–100%.

The analysis of the forest fund within the catchment areas of the Sula, Psel, Vorskla and Siversky Donets rivers was carried out using the electronic subcompartment database of the Ukrderzhlisproekt Production Association. The data were converted from '.vff' format to '.mdb' format of the MS Access software using the

NewUnPackOHOTA program developed in the laboratory of new information technologies of the Ukrainian Research Institute of Forestry and Forest Melioration. The retrieving data necessary for further calculations were exported to .xls format of the Microsoft Excel software (Vedmid et al. 2006). For the analysis of the research data, appropriate software applications, as well as geoinformation technologies, were also applied.

The electronic subcompartment database is a collection of taxation subcompartments in stands. Each subcompartment contains a detailed description of the growth conditions (a type of forest site conditions, forest type, forest functional category and area) as well as mensuration characteristics of the stands themselves (age, years, stand composition [%], diameter [cm] height [m], density, site class and growing stock [m^3 ha^{-1}]).

Following the formed databases, we analysed the distribution (by area) of the dominant forest types in the catchments of the rivers within the Left-Bank Forest-Steppe of Ukraine, namely, Vorskla, Psel, Sula and Siversky Donets.

Typological analysis of forests was conducted in accordance with the main methodological provisions of the forest-ecological (Ukrainian) school of forest typology (Pogrebnyak 1955; Ostapenko and Tkach 2002). Pogrebnyak and Vorobyov identified the following main taxonomic units in the Ukrainian typology: forest site type, forest type and type of forest stand.

The forest site type (or similar names: edatope, type of habitat conditions, type of forest area and type of edaphic conditions) is a combination of forested and non-forested areas having similar soil and hydrological conditions and a close forest site capacity.

Each section of a forest has a certain degree of soil fertility and soil moisture and is, at the same time, both a trophotope and a hygrotope. The combination of soil fertility and moisture forms the forest site type. Thus, an individual cell in the edaphic grid of Alekseev-Pogrebnyak (Tab. 1) represents the first and the largest unit of forestry and ecological direction of forest typology – a forest site type.

Following the location within the edaphic grid, a forest site type gets a binary (double) name, which consists of words indicating the fertility group (trophotope) and the moisture group (hygrotope), and has its identification. When indexing forest site types, the following letters of the Latin alphabet are used to indicate the trophotope: A (infertile sites), B (fairly infertile

Table 1. Edaphic grid of Alekseev-Pogrebnyak

Hygrotopes	Trophotopes			
	A Infertile pine site type	B Fairly infertile pine site type	C Fairly fertile (usually hardwood) site type	D Fertile (usually hardwood) site type
0 Very dry	A_0 Very dry infertile pine site type	B_0 Very dry fairly infertile pine site type	C_0 Very dry fairly fertile site type	D_0 Very dry fertile site type
1 Dry	A_1 Dry infertile pine site type	B_1 Dry fairly infertile pine site type	C_1 Dry fairly fertile site type	D_1 Dry fertile site type
2 Fresh	A_2 Fresh infertile pine site type	B_2 Fresh fairly infertile pine site type	C_2 Fresh fairly fertile site type	D_2 Fresh fertile site type
3 Moist	A_3 Moist infertile pine site type	B_3 Moist fairly infertile pine site type	C_3 Moist fairly fertile site type	D_3 Moist fertile site type
4 Damp	A_4 Damp infertile pine site type	B_4 Damp fairly infertile pine site type	C_4 Damp fairly fertile site type	D_4 Damp fertile site type
5 Wet or swamp	A_5 Wet infertile pine site type	B_5 Wet fairly infertile pine site type	C_5 Wet fairly fertile site type	D_5 Wet fertile site type

sites), C (fairly fertile sites) and D (fertile sites), and the following Arabic numerals for the hygrotopes: 0 (very dry), 1 (dry), 2 (fresh), 3 (moist), 4 (damp) and 5 (wet). For example, dry infertile site type is referred to as A_1, fresh fairly infertile site type as B_2, moist fairly fertile site type as C_3, damp fertile site type as D_4 and so on.

The forest type is the main taxon of forest typology. It includes forested and non-forested areas that are similar in soil, hydrological and climatic conditions. The main features to distinguish particular forest types are the dendrological composition of the primary stands, their structure and productivity and, from the subsidiary features, topographical (relief) and soil conditions of the sites.

Formation of forest types occurs under the influence of climatic factors (the temperature, continentality and humidity of the climate and the length of the growing season). In each forest site type, depending on whether it combines climatically homogeneous or different sites, one or several forest types can be formed. The principal attribute of the classification of forest types is the different response of tree species to climatic factors. Wood species are considered as indicators of climatic conditions, and the classification of forest types reflects the diversity of soil and hydrological conditions, which are similar in forest growth capacity. In the forest-ecological (Ukrainian) classification, the forest type is considered as a climatic variant of forest site types (edatopes). The given concept explains, for example, why, in the fresh fertile site type (D_2) within the Left-Bank Forest-Steppe zone of Ukraine, both fresh maple-lime fertile oak forest type and fresh ash-lime fertile oak forest type are prevalent.

In Ukrainian forest management, the forest type is the main production unit and the scientific basis for planning, designing and implementing all activities relating to forestry.

The type of forest stand is the smallest and most specific classification unit of the forest-ecological direction in the forest typology. The type of forest stand combines forest stands that are homogeneous in the composition of the tree layer and site conditions. Un-

Figure 1. The location of the catchment areas of the Sula (1), Psel (2), Vorskla (3) and Siversky Donets (4) rivers

like the forest community, only the tree layer is taken into account during the identification of the forest stand type, and the compositions of the shrub and grass layers are not considered.

The study covered the forests within the Poltava, Kharkiv, Sumy, Chernihiv, Kyiv and Cherkasy administrative regions of Ukraine.

Geographical coordinates of the extreme points of the research area were the following: 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″. The coordinates of the centroid of the rivers were the following: Sula, 33°04′11″, 50°21′29″; Psel, 34°16′42″, 50°05′13″; Vorskla, 34°58′10″, 49°05′15″; and Siversky Donets, 36°45′59″, 49°55′19″. The total area of the forests surveyed was more than 502,000 ha. The forests are managed by the State Forest Resources Agency of Ukraine.

Results

The inventory data on the forest distribution throughout the river catchments within the Left-Bank Forest-Steppe zone in Ukraine indicated the largest forested area in the catchments of the Siversky Donets (176,900 ha) and Psel (137,800 ha) rivers. A somewhat smaller area of forests was identified in the catchment of the Vorskla River (119,200 ha), and the smallest one was estimated for the Sula River catchment (68,100 ha).

Within the catchment areas of the largest rivers in the Left-Bank Forest-Steppe zone, water catchments for 118 tributaries of smaller rivers were allocated. Accordingly, 36 tributaries were allocated to the Sula River, 35 tributaries to the Psel River, 24 tributaries to the Vorskla River and 23 tributaries to the Siversky Donets River (Fig. 1). For 109 tributaries, electronic subcompartment databases of forests were formed.

The analysis of the databases revealed that the forests within the Left-Bank Forest-Steppe zone were generally formed in 62 forest types, including 49 forest types in each of Sula and Psel catchments, 46 forest types in the Vorskla catchment and 32 forest types in the Siversky Donets catchment. The most common forest type was the fresh fertile maple-lime oak forest (Tab. 2).

Its proportion in the total forested area within individual catchments was the largest in the catchment area of the Siversky Donets River (54%); it was slightly lower

Table 2. Distribution of area of the most common forest types in the river catchments within the Ukrainian Left-Bank Forest-Steppe zone (numerator, thousand hectares; denominator, the percentage from the total forested area)

Name of forest type	Sula	Psel	Vorskla	Siversky Donets
Dry infertile pine forest	<0.1/<1	3.0/2	1.1/1	1.6/1
Fresh infertile pine forest	<0.1/<1	6.3/5	7.3/6	6.3/4
Fresh fairly infertile oak-pine forest	5.8/9	26.8/20	23.3/20	28.6/16
Fresh fairly fertile maple-lime oak forest	0.4/1	2.0/2	1.0/1	–
Fresh fairly fertile lime-oak-pine forest	1.3/2	11.6/8	10.9/9	5.6/3
Moist fairly fertile maple-lime oak forest	1.2/2	0.4/<1	0.2/<1	0.3/<1
Moist fairly fertile lime-oak-pine forest	0.1/<1	2.6/2	1.2/1	0.4/<1
Wet fairly fertile alder forest	3.8/6	2.2/2	1.8/2	0.7/<1
Dry fertile maple-lime oak forest	0.2/<1	1.7/1	3.3/3	24.5/14
Fresh fertile hornbeam oak forest	13.3/20	1.0/1	0.5/<1	–
Fresh fertile maple-lime oak forest	17.6/26	61.7/45	55.8/47	96.2/54
Moist fertile hornbeam oak forest	0.9/1	0.2/<1	0.3/<1	–
Moist fertile elm-field maple floodplain oak forest	1.0/1	1.2/1	1.0/1	3.0/2
Moist fertile maple-lime oak forest	1.0/2	2.0/1	0.6/1	0.4/<1
Wet fertile alder forest	2.6/3.8	3.2/2	1.0/1	0.5/<1
Other forest types	18.7/28	12.2/9	9.9/8	8.8/5
Total	68.1/100	137.8/100	119.2/100	176.9/100

in the Vorskla and Psel river catchments (47% and 45%, respectively). Although this type of forest prevailed in the Sula catchment area, however, its proportion was much lower, only 26%.

There is also a large area of fresh fairly infertile oak-pine forest in the region. The largest areas of this forest type were found in the catchments of Psel and Vorskla rivers (20% each); its proportion was slightly lower in the Siversky Donets catchment (16%) and the smallest in the Sula River catchment (9%) (Tab. 2). Almost one-third of the total catchment area of Sula is occupied by stands growing in the hornbeam complex of forest types, namely, in fresh fertile hornbeam oak forest, fresh fairly fertile hornbeam oak forest, fresh fairly infertile hornbeam-oak-pine forest and others. That is because the boundaries of this catchment are directly adjacent to the Right-bank Forest-Steppe zone with fresh fertile hornbeam oak forest as the zonal and predominant forest type. A large variety of forest types in the catchment areas of the rivers and their tributaries causes some difficulties during forest management.

Prevalent forest types

For the rivers in the Left Bank Forest-Steppe zone, the distribution of two most frequent forest types was analysed within catchments. The types were chosen to occupy the largest areas in the forests of the region. The investigated types were fresh fertile maple-lime oak forest and fresh fertile hornbeam oak forest in the catchment areas of Sula's tributaries and fresh fertile maple-lime oak forest and fresh fairly infertile oak-pine forest in the catchment areas of the tributaries of the Psel, Vorskla and Siversky Donets rivers.

The most widespread forest types distinguished within the catchment areas of the tributaries of the Sula, Psel, Vorskla and Siversky Donets rivers are described below.

Fresh fertile maple-lime oak forest type is spread within the Left-Bank Forest-Steppe and the Northern Steppe zones of Ukraine. Topographic position included flatlands, slopes of various expositions (except southern ones). Soils found included grey forest soil and light-grey forest soil, mesopodzol and telopodzol. Stand composition was *Quercus robur* L. and sometimes *Betula pendula* Roth. in the first layer and *Tilia cordata* Mill., *Acer platanoides* L., *Acer campestre* L., *Ulmus glabra* Huds, *Pyrus communi*s L. and *Malus sylvestris* Mill. in the second layer. Indicator plants in the forest live ground cover are *Aegopodium podagraria* L., *Carex pilosa* Scop., *Asarum europaeum* L., *Viola reichenbachiana* Jordan ex Boreau, *Pulmonaria obscura* Dumort., *Lathyrus digitatus* (L.) Bernh and *Asperula graveolens* Bieb ex Schult et Schult.

Fresh fertile hornbeam oak forest type is spread within the Forest-Steppe zone of Ukraine. Topographic position included high plain and slopes of ravines. Soils found included sod-podzolic loamy soil on loess, grey forest soil on loessial loams, podzolic chernozems. Stand composition was *Q. robur* L. mixed with *Fraxinus excelsior* L., *U. glabra* Huds., *B. pendula* Roth. and *Cerasus avium* (L.) Moench in the first layer and *Carpinus betulus* L., *T. cordata* Mill., *A. platanoides* L., *A. campestre* L., *P. communis* L. and *M. sylvestris* Mill. in the second layer. Indicator plants in the forest live ground cover are *C. pilosa* Scop., *Stellaria holostea* L., *Hepatica nobilis* Mill., *A. podagraria* L., *Urtica dioica* L., *Galium odoratum* (L.) Scop and *Geum urbanum* L.

Fresh fairly infertile oak-pine forest type is the most common and productive forest type in fairly infertile pine sites within Ukraine. Topographic position included flat or slightly undulating areas of the middle plain or slightly raised river terraces and depressions between sandy hills. Soils found included sod cryptopodzolic and mezopodzolic argillo-arenaceous or sandy loam soils on water-glacial sandy sediments; mature sod cryptopodzolic argillo-arenaceous soils on ancient alluvial sediments; sandy soils with clay loamy layers. Stand composition: *Pinus sylvestris* L. mixed with *Q. robur* L., *B. pendula* Roth., *Populus tremula* L. and *P. communis* L. However, a separate second layer of *Q. robur* L. is possible. Indicator plants in the forest live ground cover are as follows: *Peucedanum ruthenicum* M. Bieb., *Genista tinctoria* L., *Pteridium aquilinum* (L.) Kuhn, *Betonica officinalis* L., and *Polygonatum odoratum* Mill.

The Sula River

Within the Sula tributaries, the percentage of the fresh fertile maple-lime oak forest from the total forested area in the catchment was the highest in the Olava tributary (93%) and the smallest in the Sliporid tributary (3%) (Fig. 2).

The study on prevailing forest types in Sula River catchment indicates that Vilshanka-1, Kremiana, Bo-

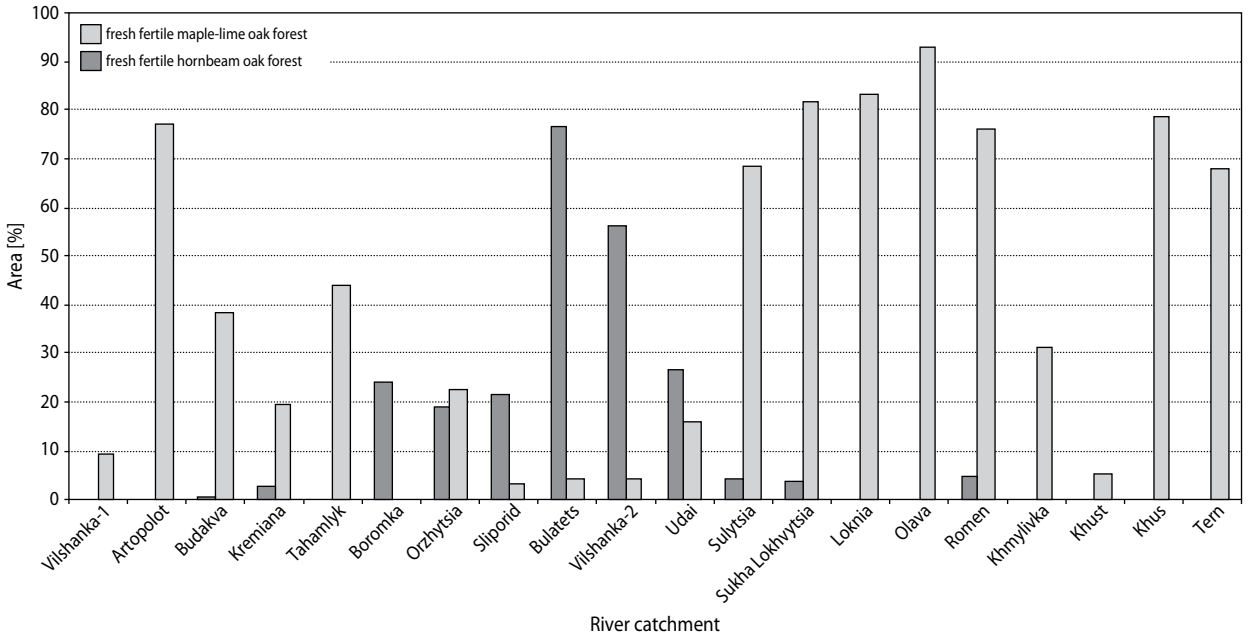

Figure 2. The proportion of the area of fresh fertile maple-lime oak forest type (light grey) and fresh fertile hornbeam oak forest type (grey) in the catchment areas of the tributaries of the Sula River

romka, Sliporid, Bulatets, Vlishanka-2, Udai and Khust tributaries belong to the first category with the fresh fertile maple-lime oak forest proportion of up to 20% of the total forest area (Fig. 2). The Budakva, Orzhytsia and Khmylivka tributaries belong to the second category (21–40%); the Tahamlyk tributary falls into third category (41–60%). The Artopolot, Sulytsia, Romen, Khus and Tern tributaries are in the fourth category (61–80%), and the Sukha Lokhvytsia, Loknia and Olava tributaries are in the fifth category (81–100%).

The largest proportion of the area of fresh fertile hornbeam oak forest was found in the Bulatets tributary (77% of the total forested area), whereas the smallest one was in the Budakva tributary (below 0.1%). In nine tributaries – Vlishanka-1, Artopolot, Tahamlyk, Loknia, Olava, Khmylivka, Khust, Khus and Tern – fresh fertile hornbeam oak forest type was not found.

By the area proportion categories, the Kremiana, Orzhytsia, Sulytsia, Sukha Lokhvytsia and Romen tributaries belong to the first category, with the proportion of area up to 20%; the Boromka, Sliporid and Udai tributaries belong to the second category (21–40%); Vilshanka-2 falls into the third category (41–60%); and the Bulatets tributary belong to the fourth category (61–80%).

The Psel River

The Rybytsia tributary had the largest percentage of fresh fertile maple-lime oak forest (90%), whereas Muzheva tributary had the lowest one (3%). By the area proportion categories, the Lyhan, Vilshanka, Budylka, Bobryk, Vepryk, Liutenka, Muzheva, Hnylytsia, Rudka and Vovnianka tributaries belong to the first category, with the proportion of the forest type area of up to 20%; the Omelnyk and Manzhaleia tributaries belong to the second category (21–40%); the Udava, Hrun-Tashan, Hovtva and Sumka tributaries fall into the third category (41–60%); the Syrovatka, Khorol, Hrun and Oleshnia tributaries fall into the fourth category (61–80%); and Rybytsa and Hriaznyi tributaries belong to the fifth category (81–100%) (Fig. 3).

The area of forest stands growing in the fresh fairly infertile oak-pine forest type was almost twice less than that in the fresh fertile maple-lime oak forest type (Tab. 2). The largest percentage – 67% – of the fresh fairly infertile oak-pine forest was recorded in the Vepryk tributary. The smallest percentage – below 0.1% – occurred in the Rybytsia tributary. The above-mentioned forest type was not found in Udava, Hriaznyi and Vovnianka tributaries.

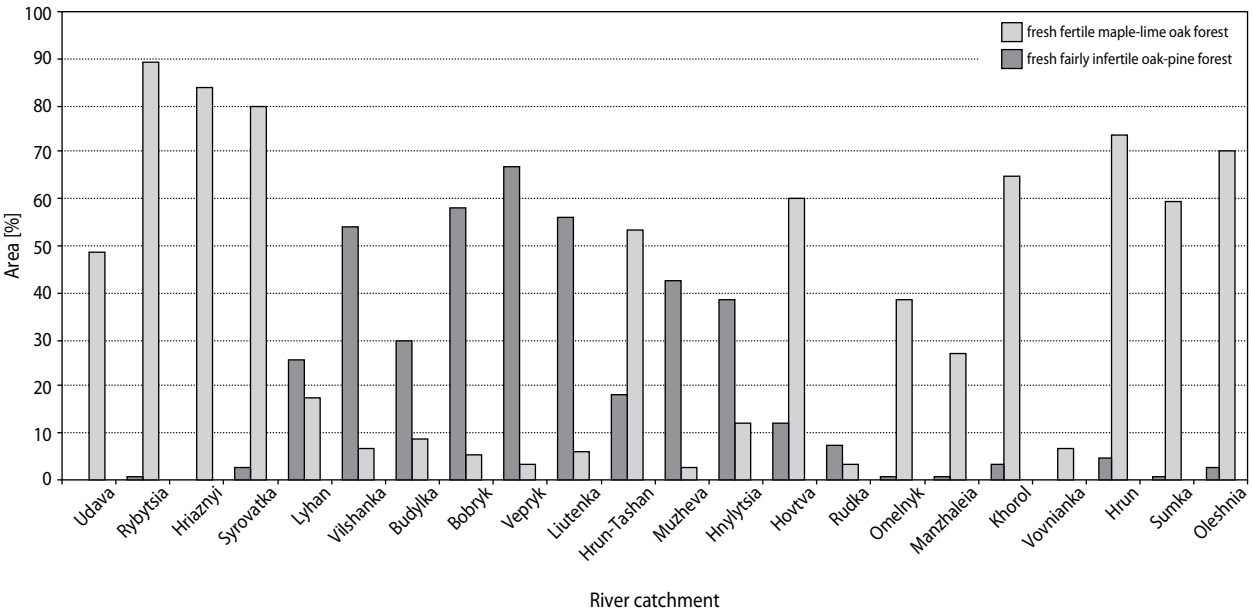

Figure 3. The proportion of the area of fresh fertile maple-lime oak forest type (light grey) and fresh fairly infertile oak-pine forest type (grey) in the catchment areas of the tributaries of the Psel River

By the forest type area proportion categories, the Rybytsia, Syrovatka, Hrun-Tashan, Hovtva, Rudka, Omelnyk, Manzhaleia, Khorol, Hrun, Sumka and Oleshnia tributaries belong to the first category (0–20%). The Lyhan, Budylka and Hnylytsia tributaries belong to the second category (21–40%). The Vilshanka, Bobryk, Liutenka and Muzheva tributaries fall into the third category, and Vepryk tributary falls into the fourth category (61–80%) (Fig. 3).

The Vorskla River

In the Vorskla tributaries, the proportion of the fresh fertile maple-lime oak forest type from the total forested area was the highest in the Riabyna tributary (96%) and the smallest in the Krynychka tributary (less than 0.1%) (Fig. 4). In four tributaries – Ivany, Husynka, Okhtyrka and Oreshnia – this forest type was not found.

The percentage of area distribution of fresh fertile maple-lime oak forest type indicated that the Krynychka, Tahamlyk and Kustolova tributaries fall into the first category (the area proportion is up to 20%), whereas the Khukhra and Svynkivka tributaries belong to the third category (41–60%). The Haivoronka, Poluziria and Boromlia tributaries are in the fourth category (the area proportion is 61–80%), and the Bratenytsia, Riabyna, Oleshnia and Vorsklytsia tributaries are in the fifth category (81–100%) (Fig. 4).

Within the Vorskla tributaries, the largest percentage of fresh fairly infertile oak-pine forest type was identified in the Krynychka tributary (79%) and the smallest one in the Poluziria tributary (1%). In three tributaries, Haivoronka, Bratenytsia and Riabyna, this forest type was not found. By the forest type area proportion categories, the Oreshnia, Poluziria, Oleshnia, Boromlia and Vorsklytsia tributaries belong to the first category (0–20%). The Khukhra, Merla, Svynkivka, Tahamlyk and Kustolova tributaries belong to the second category (21–40%), and the Ivany, Husynka and Krynychka tributaries fall into the fourth category (61–80%) (Fig. 4).

The Siversky Donets River

Within the tributaries of the Siversky Donets River, the proportion of the fresh fertile maple-lime oak forest type was the highest in the Tetliha tributary (99%) and the smallest in the Khotimlia tributary (1%). In the Sukhyi Burluk tributary, this forest type was not recorded (Fig. 5). By the forest type area proportion categories, the Povna, Khotimlia, Hnylytsia, Hnylytsia-1 and Voloska Balakliika tributaries belong to the first category (up to 20%), whereas the Byshkiv, Velykyi

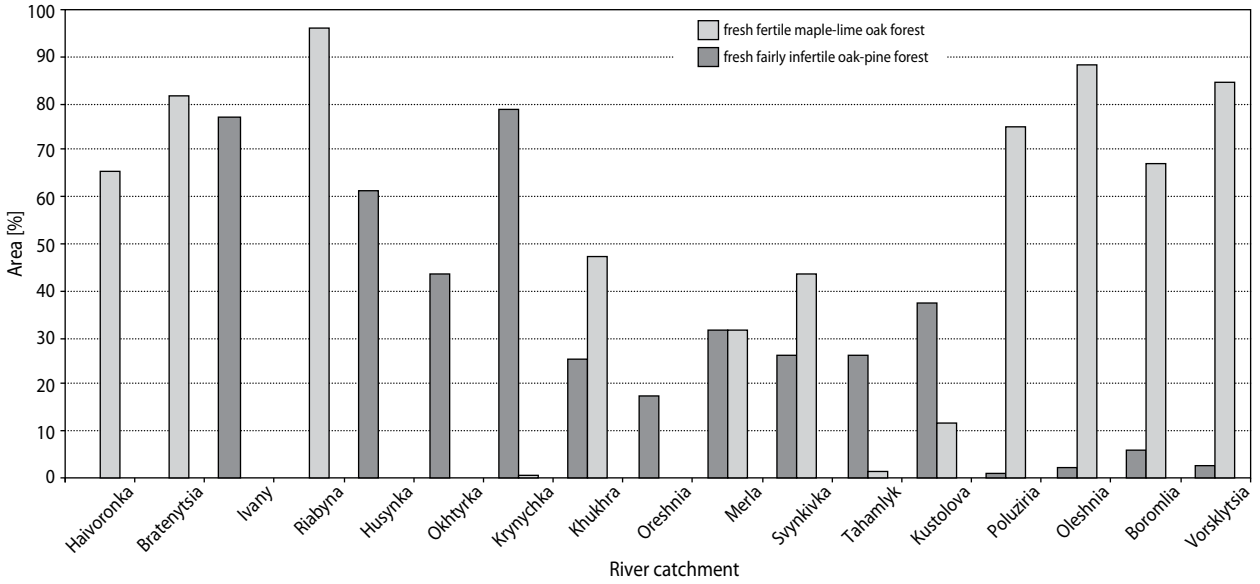

Figure 4. The proportion of the area of fresh fertile maple-lime oak forest type (light grey) and fresh fairly infertile oak-pine forest type (grey) in the catchment areas of the tributaries of the Vorskla River

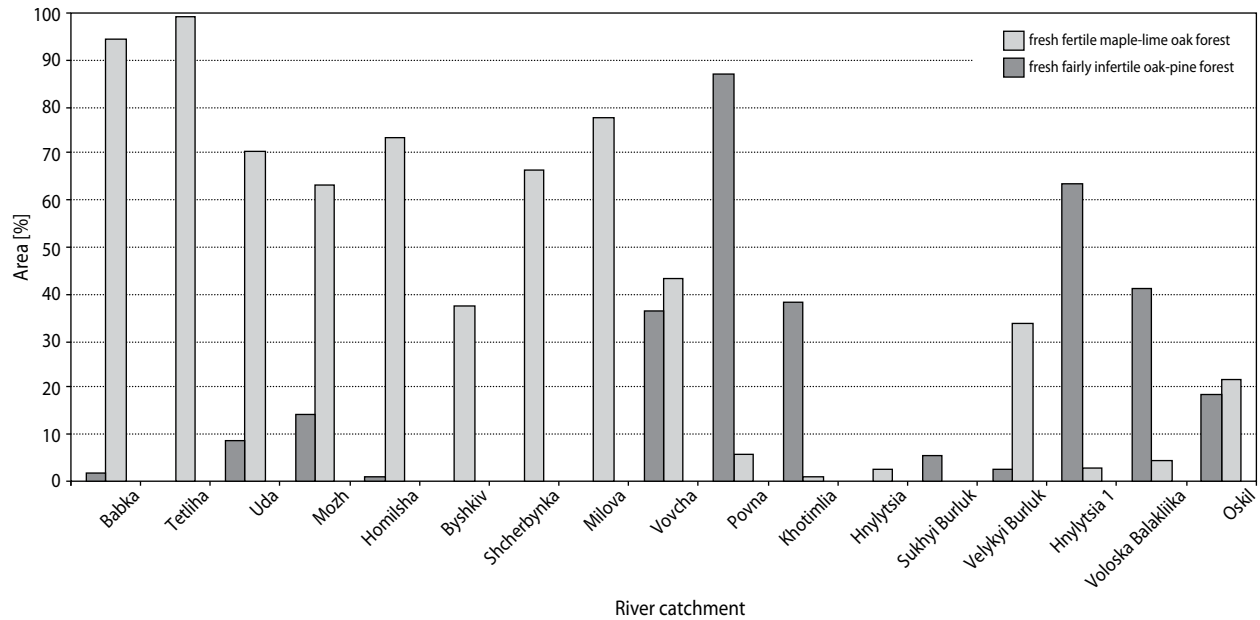

Figure 5. The proportion of the area of fresh fertile maple-lime oak forest type (light grey) and fresh fairly infertile oak-pine forest type (grey) in the catchment areas of the tributaries of the Siversky Donets River

Burluk and Oskil tributaries fall into the second category (21–40%). The Vovcha tributary belongs to the third category (41–60%); the Uda, Mozh, Homilsha, Shcherbynka and Milova tributaries are in the fourth category (61–80%), whereas the Babka and Tetliha tributaries fall into the fifth category (81–100%) (Fig. 5).

Amongst the Siversky Donets tributaries, the largest area of the fresh fairly infertile oak-pine forest type was recorded in the Povna tributary – 87% of the total

area covered with forest vegetation – and the smallest in the Homilsha tributary – 1%. This forest type was not found in the Tetliha, Byshkiv, Shcherbynka, Milova and Hnylytsia tributaries (Fig. 5). By the forest type area proportion categories, the Babka, Uda, Mozh, Homilsha, Sukhyi Burluk, Velykyi Burluk and Oskil tributaries belong to the first category (the area proportion is up to 20%). The Vovcha and Khotimlia tributaries fall into the second category (21–40%). Voloska Balakliika tributary falls into the third category (41–60%), whereas the Hnylytsia-1 tributary belongs to the fourth category (61–80%) and Povna to the fifth category (81–100%).

After analysing the distribution of the two most common types of forest in the catchment areas of Sula, Psel, Vorskla and Siversky Donets and their tributaries, it was ascertained that the same type of forest in individual catchments dominated the area, whereas others occupied a small proportion of the area or in general it was not found, for example, in the catchment of rivers of the third order. These features must be taken into account during the organisation and planning of certain economic activities in the catchment areas, as well as during the creation of new plantings.

Number of forest types within third-order streams

In the tributaries of the Vilshanka, Bobryk, Artopolot, Kremiana, Tahamlyk, Rudka, Boromka, Bulatets, Olava, Khmylivka, Khus, Udava, Griaznyi, Vovnianka, Sumka, Haivoronka, Ivany, Riabyna, Okhtyrka, Tetliha, Byshkiv, Milova, Hnylytsia and Sukhyi Burluk rivers, the total number of forest types did not exceed 10 (Tab. 3).

Table 3. Distribution of third-order stream catchments by number of the forest types within the large rivers in the Left-Bank Forest-Steppe zone

Number of forest types	River catchments				Total number of third-order streams
	Sula	Psel	Vorskla	Siversky Donets	
Up to 10	18	6	4	7	35
11–20	12	16	8	9	46
21–30	2	8	5	7	22
31–40	1	2	3	–	6
Total	33	32	21	23	109

From 11 to 20 forest types were identified in the Budakva, Orzhytsia, Sliporid, Sulytsia, Sukhha Lokhvytsia, Loknia, Romen, Khust, Tern, Rybytsia, Syrovatka, Budylka, Vepryk, Liutenkka, Hnylytsia, Hovtva, Rudka, Omelnyk, Manzhaleia, Oleshnia (Psel's tributary), Bratenytsia, Husynka, Krynychka, Khukhra, Kustolova, Kobyliachka, Poluziria, Oleshnia (Vorskla's tributary), Babka, Homilsha, Shcherbynka, Vovcha, Povna, Khotimlia and Velykyi Burluk tributaries.

From 21 to 30 forest types were detected during the forest inventory in the Vilshanka, Lyhan, Vilshanka-1, Bobryk, Muzheva, Hrun, Oreshnia, Tahamlyk, Boromlia, Vorsklytsia, Uda, Mozh, Hnylytsia-1, Voloska Balakliika and Oskil tributaries. The number ranged from 31 to 40 in the catchment areas of the Udai, Hrun-Tashan, Khorol, Merla, and Svynkivka river tributaries.

In the catchments of smaller rivers (third-order streams), the typological diversity of forests is much smaller (by the number of forest types) than in the Sula, Psel, Vorskla and Siversky Donets catchments; however, it has certain specificities. For example, from 109 studied river catchments, only 6 rivers (Udai, Hrun-Tashan, Khorol, Merla and Svynkivka) had more than 30 forest types, and for the other small rivers (103 catchments), the number of forest types did not exceed 20.

The distribution of the number of forest types along the river banks in the Sula, Psel, Vorskla and Siversky Donets catchments (Tab. 4) indicated that, on the right bank, when compared to the left one, the number of forest types was gradually decreasing from 45 (the Sula River) to 31 (the Siversky Donets River). The cause is the steeply sloping of the right banks of rivers resulting in a lower number of forest types in contrast to the left banks.

The largest number of forest types on the left bank was identified for the catchment areas of Psel (49 types) and Vorskla (42 types) and the smallest for the catchment of Siversky Donets (26 types). It was also revealed that the upstream of the Vorskla and Psel rivers was the areas with the largest number of forest types, 42 and 49 types, respectively, whereas the upstream of the Siversky Donets River had the smallest number, 26 types.

Within the midstreams and downstreams of the rivers, the largest number of forest types occurred in the Sula (42 and 36 types, respectively) and Psel (41 types each) catchment areas. The smallest number of forest types was identified in the Vorskla (36 types in middle

stream and 31 types in lower stream) and the Siversky Donets (31 types each) catchment areas.

Table 4. Distribution of the total number of forest types by banks and streams in the catchments of large rivers within the Left-Bank Forest-Step zone, Ukraine

River catchment	Bank		Stream		
	right	left	upstre-am	mid-stream	down-stream
Sula	45	36	28	42	36
Psel	42	49	35	41	41
Vorskla	41	42	39	36	31
Siversky Donets	31	26	30	31	31

Discussion

Different numbers of forest types in the Sula, Psel, Vorskla and Siversky Donets catchments are attributable primarily to the relief, hydrological, soil and climatic conditions of the area in which the studied forests grow, as well as anthropogenic factor. For example, under conditionally homogeneous environments, an insignificant number of forest types (up to five) is formed, and for a large diversity of environments, there are six or more forest types that must be taken into account during forest management according to the catchment principle.

The analysis of the distribution of the two most common forest types in the catchment areas of the Sula, Psel, Vorskla and Siversky Donets rivers and their tributaries confirmed the findings of Horoshko (2012) regarding the forest-typological characteristics of the catchments of the rivers in the Middle Siversky Donets basin. We found that the tributaries of Siversky Donets river significantly differed in the distribution of prevailing forest types, namely, fresh fertile maple-lime oak forest type and fresh fairly infertile oak-pine forest type. For example, seven tributaries were dominated by fresh fertile maple-lime oak forest type in area (≥50% of the total catchment area); in nine tributaries, this forest type occupied an area of below 50%, and it was not found in one tributary at all. Also, we did not find a significant difference in the total number of forest types by stream parts (upstream, midstream and downstream) in the Siversky Donets River. These specificities should necessarily be taken into account in management as well as when planting new stands in river catchments.

The results (Nazarenko and Pasternak 2016) revealed that the forests of the Pridonetsk Sector of the Slobozhansky forest-typological area (southeastern part of the Left-Bank Forest-Steppe zone of Ukraine) belonged to 34 forest types. According to our data, the typological diversity of forests within river catchments in the Left-Bank Forest-Steppe zone is significantly wider (62 forest types). The catchment areas of the third-order rivers, territorially related to the northern part of the Left-Bank Forest-Steppe zone, have more forest types than those of the southern part of the zone. That can be explained by richer and wetter conditions for the growth of forest stands.

Forests within river catchments are unique and essential natural complexes. Floodplain forests growing in lower part of a catchment are the element of the entire catchment vegetation. Every year in spring they are periodically flooded for varying periods. As a result, a great typological diversity and specificity of both the forest conditions and the types of forest have occurred; in particular, the floodplain forest types are distinguished. This is consistent with the studies of Yin et al. (2009) and Lyle et al. (2018) in Mississippi River floodplain forests (USA), emphasizing a change in the species diversity of the forests under floods.

Forests in catchments play important ecological, protective and recreational functions (Tkach 1999; Fernandez et al. 2018). They have been the subject of active human intervention for a long time. Their current health (some weakening and mass dieback) results from the site conditions, specificities of forestry management in the past and anthropogenic influence at present, such as regulation of surface runoff, building of cascades of reservoirs, putting into operation water intakes and other water control structures (waste-water discharge into rivers, and ecologically unjustified economic activities in different sections of river catchments). All of these contribute to a significant change in forest site conditions, reduce the species diversity of forests, promote erosion processes and deteriorate the overall environmental status of both large and small river basins (Tkach 1999; Díaz-Redondo et al. 2018; Jobin et al. 2018).

In general, forests in Ukraine grow in 317 forest types (Tkach 2012). These are the types of forest allo-

cated during forest management. It should be noted that Ostapenko et al. (1998) described 82 forest types for the plain part of Ukraine and allocated 98 forest in total, including 8 types in infertile pine forests (A), 18 types in fairly infertile pine forests (B), 41 types in fairly fertile hardwood forests and 31 types in fertile hardwood forests. Herushynsky (1996) described 78 forest types for the Ukrainian Carpathians, and Posokhov (1971) described 97 forest types for the Mountain Crimea. More detailed lists of forest types now do not exist. In general, 257 forest types have been described in detail for Ukrainian conditions, and about 20–30 types were allocated without detailed description. The number is much less than that allocated by forest management (Tkach 2012). This results mainly from the analysis of the latest forest inventory data and the lack of uniform list (cadastre) of forest types for Ukrainian forests. So, during a regular surveying, forest types that were not previously described by scientists are allocated (Ostapenko and Tkach 2002). Now, there are significant uncertainties about the descriptions of forest types and objective assessment.

The need to develop cadastres of forest types within individual regions of the country is one of the priorities for further work in the field of forest typology (Ostapenko et al. 1998). The regional cadastre of forest types is a systematic list of forest types within a given area – for example, an administrative region – with their detailed characteristics, which allows assessing the forest type as a specific forest area, from different positions, including its functional significance. Regional cadastres of forest types will serve as a source of complete and accurate data on the diversity of forest ecosystems, or number of forest types, which will allow the organisation and implementation of both research and relevant forest management.

In the study region (Left-Bank Forest-Steppe), the largest number of forest types by administrative regions was found in the Sumy and Chernihiv regions – 39 types each in the catchments of the Vorskla, Psel and Sula rivers. A smaller number (36 types each) was registered in the Kyiv and Poltava regions in the catchments of the Vorskla, Psel and Sula rivers. In the Kharkiv Region, 35 forest types were allocated in the catchment area of the Siversky Donets River, and in the Cherkasy Region, 34 forest types were detected in the catchment of the Sula River. In total, 62 forest types were identified within the catchment areas of the large rivers in the Left-Bank Forest-Steppe zone.

Considering the particular growth of stands at the river catchments within Left-Bank Forest-Steppe in the prevailed forest types (fresh maple-lime fertile oak forest type, fresh fertile hornbeam oak forest type and fresh fairly infertile oak-pine forest type), we deem it appropriate to allocate the catchments as a subject of independent forestry activity. This will promote forest management on a soil-typological basis and targeted cultivation of forest stands, differentiated by forest types. Similar findings were made by Tkach (2012) when exploring floodplain forests in basins of large rivers. He considered that it is advisable to develop a forest management system following the prevailing forest types and their complexes for specific forest areas in river catchments. The allocation of forest landscapes within large catchment basins should be the basis for all forestry management.

The results of our research show that the catchment areas of the tributaries within the Left-Bank Forest-Steppe zone in Ukraine are significantly different in terms of the distribution of forest types. A different number of forest types occurred in different river banks (left and right) and in different parts of the stream (upstream, midstream and downstream). The relief of catchment areas and, accordingly, the formation of different soil types also affect the typological diversity of forests. All of these peculiarities should be used in planning, organising and implementing appropriate forestry activities to preserve and restore the species diversity of forests within the river basins (catchments) in the Left-Bank Forest-Steppe zone of Ukraine.

Conclusions

It the catchment areas of the large rivers within the Left-Bank Forest-Steppe zone in Ukraine, forest typological structure is quite diverse. The forests cover 0.5 million hectares and are represented by 62 forest types. The number of forest types varies considerably in different catchments (from 32 forest types within the Siversky Donets catchment to 49 forest types in the Sula and Psel catchments) because of the relief, hydrological, soil and climatic conditions of the area, as well as significant anthropogenic impact. Taking this specificity into account

would allow efficient forest management based on the catchment–landscape principle.

The prevailing forest type in the region of the study is the fresh maple-lime fertile oak forest type. It covers the area of more than 230,000 ha or 46% of the total area covered with forest vegetation. The proportion of this forest type is about half of the forested area within the catchments of the Psel (45% or 62,000 ha), Vorskla (47% or 56,000 ha) and Siversky Donets (54% or 96,000 ha) rivers. In the Sula River catchment, its proportion is much smaller, 26%, or 18,000 ha.

In the significant area of the Psel, Vorskla and Siversky Donets catchments, forests grow in fresh oak-pine fairly infertile forest type – 10,000, 9,000 and 8,000 ha, respectively. Within the Sula catchment, the large area of forests is of fresh hornbeam fertile oak forest type (9,000 ha).

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