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Taxonomic and ecological analysis of vascular plants of the pine forest of the Irtysh Region

The article presents a taxonomic, biomorphological, geographical analysis of the biodiversity of the flora of herbaceous species of pine forests of the Irtysh region, which is represented by 168 plant species belonging to 116 genera and 42 families. Analysis of the largest flora families of herbaceous species shows that the dominant communities are *Artemisia* L. — *Festucaria* Heist. ex Fabr. and *Artemisia* L. — *Poaceae* Barnhart (*Artemisia* L., *Festuca* Heist. ex Fabr., *Stipa capillata* L.) phytocenoses. In all the studied sites, the following plant species are dominant or codominant: *Festuca rupicola* Heuff., *Agropyron cristatum* (L.) Gaertn., *Stipa capillata* L., *Artemisia vulgaris* L., *Carex supina* Willd. ex Wahlenb., *Spiraea hypericifolia* L. The flora is based on angiosperms, including dicotyledons — 137 species (81 %); monocotyledons — 28 species (16.6 %). Gymnosperms are represented by two species of *Pinus sylvestris* L., *Juniperus sabina* L., and there is also one species of *Egisetum arvense* L. horsetail. The richness of the flora is also emphasized by some quantitative indicators of its taxonomic composition: the average species saturation of one family is 4, the maximum is 36. There are 9 rich families with the number of species above the average (21.4 % of the total number of families), and 22 the poorest, single — species families (52.3 %). The top ten leading families contain 71 % of the total floral diversity. The high level of floristic diversity of the studied territory is due to the variety of ecological conditions of plant habitats (the valley of the Irtysh River with a high variation in moisture and salinity, a variety of rocks of the adjacent riverside uplands) and anthropogenic activities leading to an increase in weed and adventitious plant species.

Keywords: pine, ecology of vascular plants, forest, flora, taxonomy, ecosystem.

Introduction

Distribution of coniferous forests in Kazakhstan is limited. There are four groups of pine forests within the Republic of Kazakhstan: pine forests of Kazakh uplands; Kalba upland pine forests; ribbon pine forests on alluvial sands in the Turgai trough; ribbon pine forests on alluvial sands of the Irtysh region.

We studied the species composition and ecology of vascular plants in the pine forest of the Irtysh region. Pine Forest is located in the region of the Irtysh depression, it is the south-eastern edge of the West Siberian lowland, extends a wide part on both sides of the Irtysh from the western borders of the region almost to the Char and Shulbinka river mouths. In the south, it is bounded by the uplands, in the east — by the foothills of the Altai, in the north — by the Priobsky plateau, and in the west it goes beyond the region [1].

At its base, the basin is composed of Paleozoic rocks, above which underlie tertiary deposits, covered with a thick bed of layered ancient alluvial mainly light geologic material — sand, sandy loam. The relict pine forest of the Irtysh region is the most productive ecosystem in our natural conditions. This priceless gift of nature was created by the last Zyryanov glaciation in the Holocene period [1–3].

The Irtysh pine forest is classified into four types according to the types of relief: dry forests of high hills, dry forests of gentle hills, dry forests of medium hills, plain forests [3].

We studied the species composition of vascular plants in the above-mentioned four types of pine forest. During 2018–2020, we conducted floral surveys in various ecotopes of the pine forest within the Irtysh region. In the area of the study, we laid a network of routes that intersect the main landforms.

Experimental

The collections of the herbarium fund of Department of “Biology” of the Shakarim University of Semey and the plants of various ecotopes of the pine forest within the Irtysh region identified during the floral survey of 2018–2020 served as the material for research.

Various methods of studying vascular plants were used and several test sites with a size of 10000 m² (100×100 m) were laid to study the aspect, species composition and their biological and ecological features,

in each area under study, for a more detailed identification of the floristic composition when describing large areas in them, several small areas 1×1 m in size were laid, the areas may have the shape of a square or a circle. The geographical coordinates of the studied areas were determined by the GPS device. Expedition research was carried out on 7 sites in the vicinity of villages: the Staraya Krepost (2 sites), Kashtak, Polovinki, Talitsa, Mikhailovka, Borodulikha (Fig. 1).

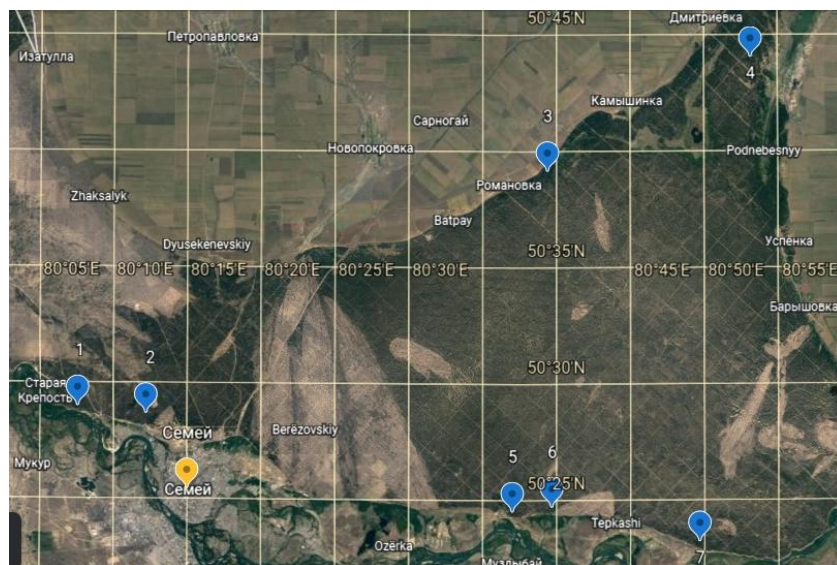


Figure 1. Cartographic diagram of the location of the studied sites

When studying vascular plants of the pine forest of the Irtysh region, we used various classical methods developed by prominent foreign and local scientists:

The methods of studying the aspect are the appearance of the plant community; it highlights the distinctive features and consists of the most noticeable traits of the composition and structure of plant associations [4].

Methods of studying the ecological features of the site are described with an indication of the terrain, soil type, salinity, moisture content, and other distinctive features that characterize a particular site. Among the main life forms, their ecological types are distinguished in relation to light, water and soil conditions [5, 6].

The main methods by which the floral and species composition of plants was studied were generally accepted classical methods of botanical and floristic research: in the field areas, the traditional route-reconnaissance method was used. Specimens of woody, shrubby and herbaceous plants were collected in herbarium folders with descriptions of collection sites (recorded using GPS), dates and collector. Collection and processing of herbarium material were carried out according to the generally accepted methodology of A.K. Skvortsov [7]. In the process of defining the herbarium, multi-volume summaries were used as sources “Flora of Kazakhstan I, II” [8]. To clarify the species and generic names, the latest reports of S.K. Cherepanov [9], M.S. Baitenov [10], S.A. Abdulina [11], A.L. Takhtajyan [12] were used.

Special attention is paid to the presence of rare, endangered, and endemic plant species in the model plots. The phytoprotective status was assessed in accordance with the IUCN categories [13, 14]; the inclusion of species in the Red Book of Kazakhstan was taken into account [15, 16].

The study of the floristic and species composition of plants was guided by the data of early studies on the region by N.Sh. Karipbaeva, V.V. Polevik [17–19].

Methods of studying the life form of plant species, that is, plant species that are similar in shape and method of adaptation to the environment, are determined by adult flowering specimens. Moreover the structure of vegetative and generative shoots, the duration of their life; the ratio of the perennial and annual parts of the shoots; the location of the plant renewal buds; the time and duration of flowering; the nature of the root system is considered. According to the classification of I.G. Serebryakov [20], there are various types of life forms, namely trees, shrubs, semi-shrubs, semi-prostrate shrubs, perennial and annual herbaceous plants.

The projective cover of the soil by plants was determined by eye measurement. It is expressed as a percentage from the area surface. 100 % of the total coverage means that the surface of the soil is completely

covered with plant projections, and 70 % means that 30 % remains uncovered (visible when viewed from above) [21].

Results and Discussion

Ribbon forests of the Irtysh region were historically formed on the territory of Kazakhstan in harsh soil and climatic conditions among treeless steppe spaces. They perform important climate-regulating, soil-protecting, and water-protecting functions.

Within the “Semey Ormany” National forest nature reserve, the ribbon forests are located on an area of 595,929 ha [21].

Pine forests of the Irtysh region are herbaceous forests, mostly xerophyticised. The areas of the pine forest studied by us are represented by several associations: wormwood — forb pine forest, forb — reed pine forest, wormwood — feather grass pine forest, etc. The grass cover of each association is composed depending on the ecological conditions of growth.

Biomorphs are represented by the following groups: trees, shrubs, semi-shrubs, prostrate shrubs, semi-prostrate shrubs, perennial and annual herbaceous plants. A group of herbaceous plants prevails. The grass cover of pine forests is fragmentary, thinned, xeromorphic, the total projective cover is 20–30 %, inside the spots 50–60 %. The dominants *Poaceae* Barnhart (*Leymus* Hochst., *Stipa* L., *Chrysopappus* Takht., *Scorzonera* L., *Spiraea* L. etc.), *Amaranthaceae* Juss (*Ceratocarpus arenarius* L., *Bassia prostrata* (L.) A.J. Scott) and *Brassicaceae* Burnett (*Alyssum alyssoides* L., *Barbarea vulgaris* R. Br., *Erysimum cheiranthoides* L.) grow in groups of several square meters; within them, representatives of other species are scattered, and sometimes isolated. The horizontal composition of the layer is uneven, related to a change in the microrelief, the projective density is from 10 to 30 %.

Ribbon forests of the Irtysh region consist of *Pinus sylvestris* L., which forms mainly clear-boled forests with numerous glades overgrown with dry–steppe, steppe, meadow–steppe vegetation.

The high level of floristic diversity of the studied territory is due to the variety of ecological conditions of plant habitats (the valley of the Irtysh River with a high variation in moisture and salinity, a variety of rocks of the adjacent riverside uplands) and anthropogenic activities leading to an increase in weed and adventitious plant species.

The main forest-forming species are Scots pine *Pinus sylvestris* L., *Betula pendula* Roth and *Populus tremula* L. The grass layer is dominated by sod grasses — *Stipa pennata* L., *Festuca valesiaca* Schleich. ex Gaudin, *Artemisia marschalliana* Spreng.

In the course of our research on the territory of the Irtysh region, we conducted a taxonomic ecological analysis, discovered and identified 168 plant species belonging to 115 genera and 42 families (Table 1). The flora is based on angiosperms, including dicotyledons — 137 species (81 %); monocotyledons — 28 species (16.6 %). Gymnosperms are represented by two species of *Pinus sylvestris* L., *Juniperus Sabina* L. and there is also one species of *Equisetum arvense* L. horsetail.

According to the data of early studies of the territory, the flora of higher plants of the pine forest of the Irtysh region is represented by 344 species from 201 genera and 61 families. The flora is based on angiosperms — 340 species, including dicotyledons — 80.59 % (274 species), monocotyledons — 19.41 % (66 species). The presence of rare species was noted: *Pulsatilla patens* (L.) Mill. (category 3R), *Stipa pennata* L. (category 3R).

The richness of the flora is also emphasized by some quantitative indicators of its taxonomic composition: the average species saturation of one family is 4, the maximum is 36. There are 9 rich families with the number of species above the average (21.4 % of the total number of families), and 22 the poorest, single-species families (52.3 %). The top ten leading families contain 71 % of the total floral diversity (Table 1).

The species saturation of genera on average is 2.76, and the maximum is 23. The proportion of genera with the number of species above the average (3–23) is 8.6; single — species genera are the vast majority — 68, or 58.6 %.

The higher plants of the surveyed territory are represented by various life forms. According to the classification of I.G. Serebryakov (1962), 6 groups are distinguished, they are united into three major types: woody (trees, shrubs, prostrate shrubs); semi-woody (semi-shrubs, semi-prostrate shrubs); grasses (perennial, annual and biennial). A special feature of this territory is *Pinus sylvestris* L., a low proportion of shrubs-only 7.14 (12 species) (Table 2). Among them the most noticeable are *Spiraea hypericifolia* L., *Rubus idaeus* L., *Rosa canina* L., *Rosa majalis* Herrm., *Rosa acicularis* Lindl. and *Caragana arborescens* Lam.

Table 1

Dominant families of the Irtysh pine forest

Family	Number of genera	Number of species	Percentage of the total number of species, %
<i>Poaceae</i> Barnhart	9	12	7.14
<i>Polygonaceae</i> Juss	3	5	2.97
<i>Caryophyllaceae</i> Juss	6	8	4.76
<i>Ranunculaceae</i> Juss	4	4	2.38
<i>Brassicaceae</i> Burnett	6	10	5.95
<i>Rosaceae</i> Juss	9	17	1.11
<i>Fabaceae</i> Lindl	12	17	10.11
<i>Lamiaceae</i> Martinov	4	5	2.97
<i>Scrophulariaceae</i> Juss	4	6	3.57
<i>Asteraceae</i> Bercht. & J.Presl	23	36	21.4
Total:	80	120	71.43
Other families	39	53	31.5

Table 2

Spectrum of the main life forms of higher plants

Life form	Number of species	
	Absolute	Percentage of the total number of species, %
Shrubs	12	7.14
Semishrub	2	1.19
Semi-prostrate shrubs	4	2.38
Wood and sod	5	2.97
Perennial herbs	113	67.26
Annual and biennial herbs	32	19.04

Mass species, which are dominant and subdominant to plant communities, play a crucial role in the life of the ecosystem. They create a special background, often throughout the growing season, produce the main mass of organic matter, create a food base, places of refuge and breeding for wild animals, insects, etc. In the area of study, 67 background species from 23 families were recorded, i.e. 39.8 % of the total floral diversity of the territory. The maximum relative proportion (50 %) of background species is found in the *Asteraceae* Bercht. & J.Presl family, primarily *Chrysopappus* Takht., *Artemisia* L. and *Bojeria* DC.

A high level of representation of background species (50 % each) is also characteristic of four more families: *Scrophulariaceae* Juss, *Lamiaceae* Martinov, *Brassicaceae* Burnett, *Caryophyllaceae* Juss.

Also the most numerous are the following families: *Poaceae* Barnhart (7,14 %), *Rosaceae* Juss (10,11 %), *Fabaceae* Lindl (10,11 %).

In a single chain of problems, the preservation of the biodiversity of any region or a particular site, preservation of rare and unique plants is the most important. On the territory of the Relict Pine Forest of the Irtysh region, 29 species of various categories of rarity are noted, which is 17.2 % of the entire flora of the forest. Plants of The Red Book are leading in this group (2.38 %): *Pulsatilla patens* (L.) Mill. (category 3R), *Stipa pennata* L. (category 3R), *Allium caespitosum* Siev. ex Bong. & C.A. Mey. (category 2V), *Tulipa patens* C.Agardh ex Schult. & Schult.f (category 3R).

Pine forest plants that can tolerate overheating and dehydration 74 (44.04 %) species of xerophytes, 79 (47.02 %) species of mesophytes and 15(8.92 %) species of xeromesophytes were identified in the studied territory according to ecological groups in relation to water.

Conclusions

Plant communities are mainly represented by perennial drought — and frost — resistant herbaceous plants with a strong root system. The main edifiers are *Elymus* L., *Stipa* L., *Festuca* Tourn. Ex L., *Chrysopappus* Takht., *Artemisia* L., *Scorzonera* L., *Tragopogon* L., etc., the vegetation cover is mosaic.

In the vegetation cover of shrubs, there is one species of *Spiraea* L., it grows among the sandy hills of the pine forest, that is, in the depressions of the relief, with relatively close ground waters.

The richness of the flora is also emphasized by some quantitative indicators of its taxonomic composition: the average species saturation of one family is 4, the maximum is 36. There are 9 rich families with the number of species above the average (21.4 % of the total number of families), and 22 the poorest, single-species families (52.3 %). The rich families are: *Asteraceae* Bercht. & J.Presl— 36, *Poaceae* Barnhart — 12, *Fabaceae* Lindl — 17, and *Rosaceae* Juss — 17 species.

Mass or background species are dominant to plant communities and play a crucial role in the life of ecosystems. They create a special background, often throughout the growing season, produce the main mass of organic matter, create a food base, places of refuge and breeding for wild animals.

The dominant communities are *Artemisia* L. — *Festucaria* Heist. ex Fabr. and *Artemisia* L. — *Poaceae* Barnhart (*Artemisia* L., *Festuca* Heist. ex Fabr., *Stipa capillata* L.) phytocenoses. In all the studied areas, the following plant species are dominant or codominant: *Festuca rupicola* Heuff., *Agropyron cristatum* (L.) Gaertn., *Stipa capillata* L., *Artemisia vulgaris* L., *Carex supina* Willd. ex Wahlenb., *Spiraea hypericifolia* L.

The plants of the pine forest of the Irtysh region are represented by various life forms. According to the classification of I.G. Serebryakov (1962), we have identified 6 groups: trees — 5 (2.97 %); shrubs — 12 (7.14 %); semi-shrubs — 6 (3.57 %); perennial — 113 (67.26 %); biennial and annual grasses — 32 (19.04 %) species.

In relation to moisture, pine forest plants are divided into xerophytes — 74 (44,04 %), 79 (47,02 %) mesophyte species and 15 (8.92 %) xeromesophyte species, among the xerophytes a special place is occupied by ephemera — ephemeroïds, the flowering time of which begins in late April and until mid — May (*Adonis* L., *Pulsatilla* Mill, *Tulipa* L., *Gagea* Salisb etc.).

In recent years, the development and anthropogenic impacts on the territory of the pine forest of the Irtysh region lead to a reduction or deterioration of biodiversity, causes irreversible processes of degradation of the population of *Pinus sylvestris*, and, in natural geocomplexes, plant cenoses with historically established communities are the most vulnerable.

The results of the research show that at present there is a need to create nature reserves within the pine forest of the Irtysh region, especially in places where rare, endangered, valuable plants grow, with the subsequent regulation of all domestic activities. In this regard, it is necessary to develop effective measures and recommendations for the protection and reproduction of populations.

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Ертіс өңірінің қарағайлы орманының түтікті өсімдіктеріне таксономиялық және экологиялық талдау

Мақалада Ертіс өңірінің қарағайлы ормандарының өсімдік түрлерінің биоалуантүрлілігіне таксономиялық, биоморфологиялық, географиялық талдау келтірілген, онда 42 тұқымдас, 116 туысқа жататын өсімдіктердің 168 түрі ұсынылған. Шөптесін өсімдіктер флорасын талдаудың нәтижесінде ең басым қауымдастықтар *Artemisia* — *Festuca* және *Artemisia* — *Poaceae* (*Artemisia*, *Festuca*, *Stipa capillata*) фитоценоздары екенін көрсетті. Барлық зерттелген аудандарда өсімдіктердің келесі түрлері доминанттар немесе кодоминанттар болып табылады: *Festuca rupicola*, *Agropyron pectinatum*, *Stipa capillata*, *Artemisia vulgaris*, *Carex supina*, *Spiraea hypericifolia*. Флораның негізін ангиоспермдер құрайды, оның ішінде: қосжарнақтылар — 137 түр (81%); даражарнақтылар — 28 түр (16,6%). Жалаңаш тұқымдылар *Pinus sylvestris*, *Juniperus sabina* екі түрімен ұсынылған, сонымен қатар *Equisetum arvens* бір түрі бар. Флораның байлығы оның таксономиялық құрамының кейбір сандық көрсеткіштерімен ерекшеленеді: біртұқымдастың орташа қанықтылығы — 4, максимум — 36. Түрлердің саны орташадан жоғары тұқымдастар — 9 (тұқымдастардың жалпы санының 21,4%), түрлері ең аз тұқымдастардың саны (дара түр) — 22 (52,3%). Жетекші отбасылардың алғашқы ондығында барлық флористикалық әртүрліліктің 71%-ы кездеседі. Зерттелетін аумақтың флористикалық алуан түрлілігінің жоғары деңгейі өсімдіктер мекендейтін жерлердің экологиялық жағдайларының алуан түрлілігімен (аумақты суландыру мен тұздандудың жоғары вариациясы бар Ертіс өзенінің алқабы, өзен маңындағы ұсақ шоқыларға іргелес түрлі тау жыныстары) және қар құрсауының және арамшөптердің көбеюіне әкелетін антропогендік ықпалға байланысты.

Кілт сөздер: қарағай, тамырлы өсімдіктер экологиясы, орман, флора, таксономия, экожүйе.

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Таксономический и экологический анализ сосудистых растений соснового бора Прииртышья

В статье приведен таксономический, биоморфологический, географический анализ биоразнообразия флоры травянистых видов боров Прииртышья, которая представлена 168 видами растений, относящихся к 116 родам и 42 семействам. Анализ крупнейших семейств флоры травянистых видов показал, что доминирующими сообществами являются *Artemisia–Festuca* и *Artemisia–Poaceae* (*Artemisia*, *Festuca*, *Stipa capillata*) фитоценозы. На всех исследованных участках следующие виды растений являются доминантами или кодоминантами *Festuca rupicola*, *Agropyron pectinatum*, *Stipa capillata*, *Artemisia vulgaris*, *Carex supina*, *Spiraea hypericifolia*. Основу флоры составляют покрытосеменные растения, в том числе двудольные — 137 видов (81%); однодольные — 28 вида (16,6%). Голосеменные представлены двумя видами *P. sylvestris*, *Juniperus Sabina*, а также здесь встречается один вид хвощей *Equisetum arvense*. Богатство флоры подчеркивается и некоторыми количественными показателями ее таксономического состава: средняя видовая насыщенность одного семейства — 4, максимальная — 36. Богатых семейств с числом видов выше среднего — 9 (21,4% от общего количества семейств), беднейших, одновидовых — 22 (52,3%). Первая десятка ведущих семейств содержит 71% от всего флористического разнообразия. Высокий уровень флористического разнообразия изучаемой территории обусловлен многообразием экологических условий местообитаний растений (долина р. Иртыш с высокой вариацией увлажнения и засоления территории, разнообразные горные породы

прилегающего приречного мелкосопочника) и антропогенной деятельностью, приводящей к увеличению заносных и сорных видов.

Ключевые слова: сосна, экология сосудистых растений, лес, флора, таксономия, экосистема, экологические условия местообитания растений.

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