

Original Research Paper

Current Growth Conditions of *Populus Diversifolia* Schrenk and *Populus Pruinosa* Schrenk in the Syr-Darya Valley

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Abstract: In the context of urbanization of territories and the intensification of agriculture, the biological diversity of animals and plants in their habitats is degrading. The purpose of the study is to determine the edaphic factors affecting the growth of *Populus diversifolia* Schrenk and *Populus pruinosa* Schrenk, as well as anthropogenic factors affecting their conservation in the Syr-Darya valley (Kazakhstan). For identifying the range of edaphic growing conditions, the analysis of soil samples gathered in different phytocenoses with the dominance or participation of Turanga was carried out. The following results were presented: Physical and chemical analyses of soil samples for the content of humus, mobile forms of easily hydrolyzable nitrogen, phosphorus, and potassium; pH aqueous solution; type, and degree of salinization. Among the 6 sections studied, 4 belong to alluvial-meadow tugai salt marsh soils, 1-to meadow salt marshes, and 1-to alluvial-meadow strongly salt marsh soils. *Populus diversifolia* has been found to prefer mild (sandy) and fewer saline conditions than *Populus pruinosa*. Among the negative anthropogenic impacts on the Turanga groves were: Regulation of the runoff of the Syr-Darya, felling of trees, fires, and grazing. The identified cenoflora was represented by 103 species of higher vascular plants. Among them, *Chenopodiaceae* (18), *Asteraceae* (18), and *Brassicaceae* (12) were leading. The indicative role of Turanga was based on its connection to the places of groundwater occurrence.

Keywords: Turanga Woodlands, Species Composition, Soil Samples, Salinization, Indication

Introduction

The exhaustion of natural resources is one of the most pressing problems of our time. For Kazakhstan, whose significant part of the territory is located in the desert zone, first of all, water is such a resource. In desert regions, water is a limiting factor for living organisms. The exhaustion of water resources will entail the inevitable loss of the biological diversity of animals and plants.

Since in desert areas people's life is confined to rivers as the main sources of water, so far in the river valleys one can find the greatest human population density and, as a result, a high level of anthropogenic influence (Vesselova *et al.*, 2017a, b; Vesselova and Kudabayeva, 2017).

The largest water artery of Kazakhstan, also passing through the Kyzylorda area, is the Syr-Darya River. A unique type of vegetation, tugai forests containing woody

forms of plants that are rarely found on the plaques of the desert zone, is confined to the Syr-Darya valley (Vesselova *et al.*, 2017a).

There are relict light woodlands containing two dominant species *Populus diversifolia* Schrenk and *P. pruinosa* Schrenk of the Turanga sub-genus in tugai forests. These species are fairly widely distributed: *Populus diversifolia* with Kazakh-Turan, and *P. pruinosa*-Iranian-Central Asian-Dzungar-Kashgar areas. Being vicarian species and replacing each other in the territory of Turan they occupy a narrow ecological niche confined to modern and ancient river valleys (SPCK, 2013). At the same time for the desert territories of the Kyzylorda region, turanga light woodlands are an azonal type of vegetation.

There are studies on turanga forests in Kazakhstan (Rakhimzhanov *et al.*, 2021) but the turanga valley forests in the Syr-Darya River are not studied enough. This also applies

to the species composition of turanga groves of the Ile valley flora (Stikhareva *et al.*, 2021), as well as the modern state and protection of the turanga forests of the Ile-Balkhash basin (Thevs *et al.*, 2017). A rather detailed analysis of the turanga groves of Mangistau deserts is contained in articles by Imanbayeva *et al.* (2014), etc.

Poplars have long been used by the local population for fuel, which became one of the reasons for their rarity. Such a circumstance of the regular and prolonged destruction of poplars, along with such threats as the development of irrigation, agricultural changes in the environment, etc., led to decreasing their number and restricting their natural area (Thomas and Lang, 2021). For example, in the Syr-Darya Delta, tugai forests with turanga dominance almost completely disappeared.

The same situation was found during the following studies carried out (Aishan, 2016) on degraded tugai forests under rehabilitation in the Tarim riparian ecosystem, Northwest China. It was reported that large areas that were originally *P. euphratica* riparian forests were being disappeared, with the remaining areas in critical condition. It was reported that the greatest threats over the past few decades were the rising water consumption in the upper and middle reaches and massive construction of embankments and dams in the development of uncultivated land including the direct clearance of forests for cotton production. Such a situation led to widespread destruction of the natural ecosystems, particularly in the lower river reaches where about 320 km of the floodplain forests were either highly degraded or dead as the result of nearly 30 years of river desiccation. The consequence of these deteriorations became the expansion of aggravated land desertification in the region.

Earlier researchers also presented one of the main criteria for the assessment of vitality of *P. euphratica* forests by estimating the defoliation level, and analyzed forest structure, and determining the height-diameter relationship of trees in different vitality classes (i.e., healthy, good, medium, senesced, dying, dead and fallen). Their results had let to differentiate degraded *P. euphratica* trees from healthy trees utilizing determining the height-diameter correlation coefficient, and the coefficient would be a new parameter for detecting degradation and assessing sustainable management of floodplain forests in arid regions. To make an accurate height-diameter model for tree height prediction it is necessary to take into account tree vitality (Aishan *et al.*, 2015).

In 2007 the need to preserve turanga poplars as an important component of tugai forests led to the inclusion of *Populus pruinosa* into the International Red Book (Participants of the FFI/IUCN SSC Central Asian regional tree Red Listing workshop, 2006; UCN Standards and Petitions Committee, 2019), the Red Book of Kazakhstan (Grudzinskaya and Nelina, 2014) and the Red Book of the Kyzylorda region (Sitpaeva, 2014).

Nowadays great importance is attached not only to the *in-situ* protection but also to the microclonal reproduction of turanga poplar as one of the most significant elements of tugai forests. Given the important environment-forming, soil-strengthening, and reclamation role of turanga forests in regulating the relationships of the components of the coastal-aquatic ecosystem, research on microclonal reproduction of Turanga is very promising. The development of this area of research, for example, is actively engaged by the botanists of China (Zheng *et al.*, 2016).

For instance, there were investigated changes in soil physical and chemical factors before and after flooding and the effects of such changes on the clonal regeneration of *Populus pruinosa* Schrenk (Gai *et al.*, 2020). The results demonstrated a complex of factors influencing the clonal growth of *P. pruinosa* before and after flood overtopping: The soil moisture content, field water capacity, soil organic matter content, and alkaline nitrogen had the greatest direct effect on the clonal growth of *P. pruinosa* before flood overtopping; soil porosity, available phosphorus and potassium had the greatest direct effect after flood overtopping. The flooded woodland was noted to be conducive to clonal growth of *P. pruinosa*, but too long flood overtopping resulted in increased soil bulk density, decreased porosity, and increased soil salinity having hindered clonal growth. Scientists suggested the implementation of flood diversion measures in flooding woods to ensure normal post-flooding clonal growth.

Researchers continue to study poplar forests and attribute them to indicators of salinity of groundwater, and also study the relationship of leaf area with other morphological and physiological indicators. As it is known along Central-Asian rivers in arid regions, groundwater level lowering constitutes a major threat to the riparian forests containing *Populus euphratica*. Some of these fragile ecosystems are supplied with additional ('ecological') water for protection and conservation. There were studied interrelationships among groundwater distance, stand structure and above-ground wood production (at the tree and the stand level) in *P. euphratica* stands along a groundwater gradient (distances of 2.0-12.0 m) that also included a plot supplied with 'ecological water' (Thomas *et al.*, 2017a).

For instance, *Populus euphratica*, a constitutive tree species of the Central-Asian riparian forests, form extremely heterophyllous leaves. There were tested gradients of salinity and water supply from the soil in arid regions of NW China, and also there were tested whether Specific Leaf Area (SLA), a pivotal plant functional trait, was related to other morphological variables and the productivity of the trees as well as to important physiological variables (foliar concentrations or ratios of sodium (Na⁺), nutrients and stable isotopes of Carbon ($\delta^{13}\text{C}$) and Oxygen ($\delta^{18}\text{O}$). Data of this study were evaluated at the leaf, tree, and stand levels (Thomas *et al.*, 2017b).

Researchers also reported that riparian forests in the Tarim Basin (northwest China), mostly composed of poplar species *Populus euphratica* and *Populus pruinosa*, were phreatophytes being dependent on access to groundwater. And groundwater, in turn, undergoes a large anthropogenic load (Thomas and Lang, 2021). Such poplar forests perform recreational and food roles. But they are threatened by the excessive use and constant decline of groundwater due to the excessive use of groundwater in agriculture. As a result, over the past decade, the area of poplar forests sharply decreased. A set of measures (moderate extent of wood harvesting by pollarding and continuous and sufficient water supply) was proposed to promote vegetative and seed reproduction of poplar forests (Thomas and Lang, 2021).

For accelerating the restoration of degraded riparian forest ecosystems in extremely arid areas and enhancing the resistance of those ecosystems to drought the researchers selected the lower reaches of the Tarim River in China to analyze monitoring data on vegetation and hydrology spanning 16 years, and a 100-year data record of tree rings in *Populus euphratica*. The results let suggest that ecological water conveyance can restore degraded desert riparian forest ecosystems: in the early stages of restoration, the interval between two overflows should not be longer than 3 years. Intermediate disturbance (1–2 overflows a year, each lasting 21–30 days) conducted to the formation of a diverse and stable plant community supporting the intermediate disturbance hypothesis. According to this hypothesis, the intermediate water disturbance (in the form of the overflow of surface water and changes in the depth of groundwater) may help to accelerate the restoration of degraded riparian forest ecosystems in extremely arid areas and enhance the resistance of those ecosystems to drought. It is known that *P. euphratica* and *Tamarix chinensis* adopted suitable strategies for using groundwater from different depths to adapt to drought. Using these results, appropriate disturbance modes related to both surface water and groundwater were proposed for the restoration and conservation of desert riparian forest ecosystems under varying intensities of drought. These modes offered scientific guidance on more efficient use of water and ecosystem management in similar areas around the world (Ling *et al.*, 2019).

The researchers continued studying the riparian vegetation in the lower reaches of the Tarim River is an irreplaceable natural resource for its ecosystem, and also a guarantee for transportation safety in this area. There were analyzed different plant influences on soil erosion and evaluated the main ecosystem service functions served by the riparian vegetation for the research area. It was demonstrated that the total amount of sand fixation in the study area was 4.14×10^{13} t and that *Tamarix chinensis* produced a greater influence on wind speed and sediment transport than *Populus euphratica*. *Tamarix chinensis* was recommended as a suitable plant for wind erosion protection measures. It also can provide a scientific basis for the optimization of

vegetation matching and a reasonable allocation scheme for ecological construction in arid areas. The total ecosystem service value was calculated and it was $\$11.03 \times 10^{11}$. Riparian vegetation primarily served as sand fixation. Results demonstrated that this research was identical, and the construction of shelterbelts was important for the promotion of wind and sand control measures. Such findings highlighted the need for further research on how vegetation acts as windbreak and sand fixation (Mamat *et al.*, 2019).

Desert poplars *Populus pruinosa* and *P. euphratica* are characterized by extreme adaptation to salt stress. *P. trichocarpa* and *P. tomentosa* are their salt sensitive congeners. Researchers identified the adaptations to salt stress that were common to each type of these poplars; they compared transcriptome changes in the four poplar species after exposure to continuous salt stress (Luo *et al.*, 2017).

Using the advances and capabilities of molecular biology, the researchers set out to understand what led to the genomic divergence between the four lines that make up the complex species of desert poplars that have salt resistance and are involved in the formation of vegetation cover and landscape in the arid regions of the planet (Ma *et al.*, 2018).

Based on the literature review, it can be concluded that poplar trees in the arid regions of the planet are the subject of great interest to researchers involved in the conservation of biodiversity and the restoration of natural resources.

The study aimed to determine the edaphic factors affecting the growth of *Populus diversifolia* Schrenk and *Populus pruinosa* Schrenk, as well as anthropogenic factors affecting their conservation in the Syr-Darya valley (Kazakhstan).

Materials and Methods

Scientific research was carried out in the Syr-Darya valley within the Kyzylorda area during the expeditionary trips of the 2020-2021 years.

During our research classical botanical (route reconnaissance; ecological-systematic; ecological-geographical) and geo-botanical methods including methods for assessing the disturbance degree of the indigenous community were applied.

Observations and collection of the primary material in various districts of the Kyzylorda region were carried out at 54 points (Fig. 1). several sections were chosen to demonstrate the modern state of turanga woodlands confined to the modern channel of the Syr-Darya and those located at a significant distance from it (Fig. 2). In places of significant concentration of turanga-tugai forests (vicinity of Kyzylorda city) the soil sections were laid to determine the type of soils and their physicochemical characteristics. Remoted areas of relict turanga rare forests were confined mainly to sands which is why soil research was not planned for them.

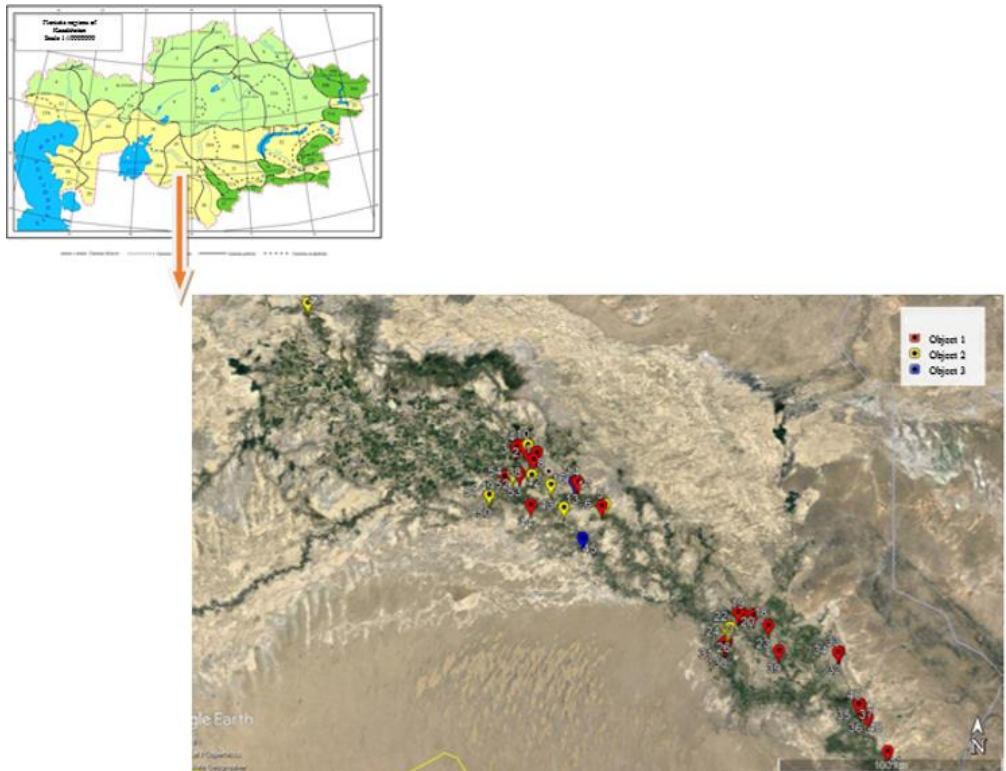


Fig. 1: Diagram of floristic regions of Kazakhstan and map of the Syr-Darya valley with an indication of all study points

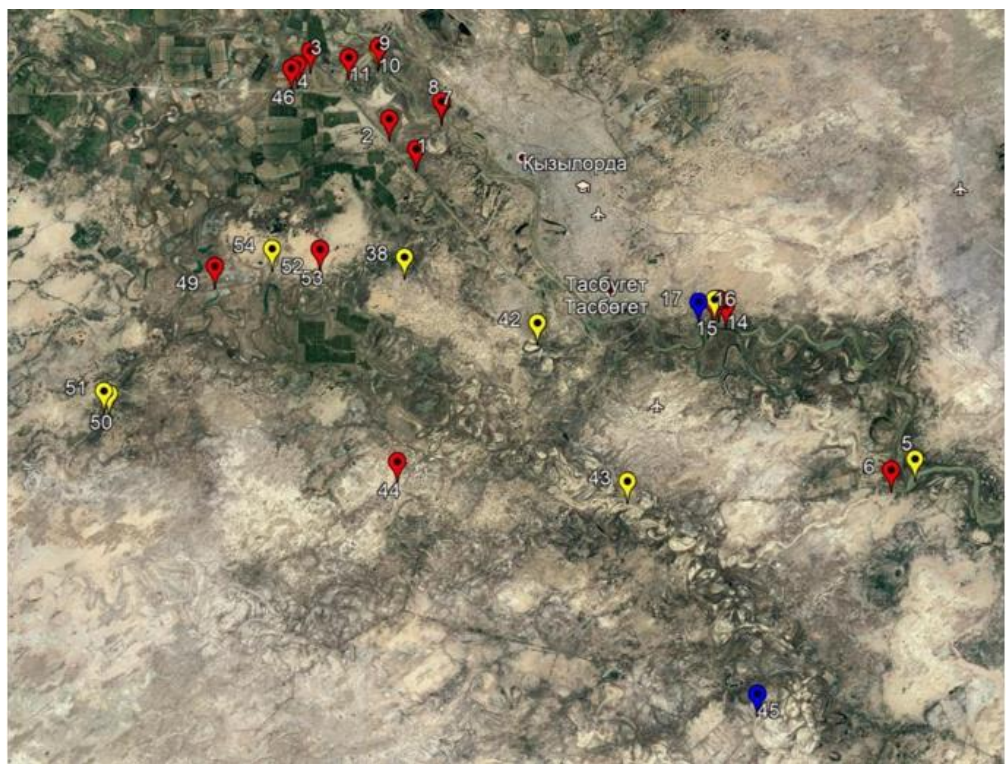


Fig. 2: Map of the Syr-Darya valley with an indication of research points in the vicinity of Kyzylorda city Note: Red color: *Populus pruïnosa*; yellow color: *Populus diversifolia*; blue color: Co-growing *Populus pruïnosa* and *P. diversifolia*

Study Species

When studying turanga-woodlands, the following types of studies were carried out: Floristic, edaphic (taking into account the peculiarities of phytocenotic composition of communities), and environmental.

Identifying the plants, and determination of species affiliation was carried out using fundamental floristic reports: "Flora of Kazakhstan", "Illustrated determinant of plants of Kazakhstan" and "Determinant of plants of Central Asia". The nomenclature of taxa was verified according to S.K. Cherepanov.

As instructional and methodological documents the following were used: Instructions for large-scale soil surveys of the lands of the Republic of Kazakhstan; a Systematic list and main diagnostic indicators of soils in the plain territory of the Republic of Kazakhstan.

Chemical analyses of soil samples were carried out in the certified Laboratory "Chemical Analyses" of LLP "Kazakh Scientific Research Institute of Soil Science and Agrochemistry named after U.U. Usanov," which has licenses to carry out such a type of investigation.

Study Area

The Syr-Darya is one of the largest rivers in Kazakhstan, which has the greatest variety of ecosystems. Its valley is a location of concentration of tugai forests in the Kyzylorda region. The high river floodplain or the so-called "tugai terrace" has a width of up to 15 km. Along the Syr-Darya and its ducts, old rivers, partly currently turned into watering channels, the alluvial plains of the ancient delta are situated.

The climate of the studied area is determined by its significant distance from the water basins, the latitudinal location, and mainly the plain nature of the surface. Its distinctive feature is an extreme hydrothermal regime caused by increased solar radiation. The average annual temperature of the studied district ranges from +11.1 to +6.8°C. The amount of precipitation during the year according to weather stations ranges from 156 to 91 mm. Mostly the vegetation type depends on precipitations' distribution depending on the seasons.

According to the current soil zoning of Kazakhstan, the described territory is situated in the subzone of typical deserts with gray-brown, light brown, and associated soils. Salt marshes, takirs, and takir-like soils are widespread in the studied territory.

The location of the study site in the floodplain of the Syr-Darya caused the predominance of intra-zonal floodplain alluvial-meadow soils in the soil cover. Therefore, the vegetation cover is presented, as a rule, by various types of meadow (meadow-tugai) and tugai communities, some of which are halophytic. In so doing the meadows are located in the valley in separate massifs or complexes and combinations with communities of other types of vegetation.

On the right bank of the Syr-Darya, as well as along the riverbeds and flow channels meadow-swamp soils were formed. Along the left bank of the river takir-like soils and takirs were widespread. Zonal gray-brown soils of the typical deserts in the surveyed territory were not found.

Data Collection

Collecting the primary material (plant samples for herbarium; soil samples) was carried out during expeditionary trips to the research area corresponding to the 24th floristic region of Kazakhstan. The points of the description of turanga-groves' composition and sample collecting are presented in the diagram (Fig. 1 and 2).

For diagnosing soils, and determination of their morphological and physical-chemical properties, 6 soil sections were laid; the description of the morphological properties of the soil profile was also given. The coordinates of the sections were determined by the "GPS map 76S Garmin" device. For comparing the properties of floodplain meadow tugai soils and the properties of floodplain meadow soils formed under herbal vegetation, the control section 25/11-K1 was laid on the site with similar soil formation conditions.

From the sections, 26 soil samples were selected for chemical analyses. The values of the following indicators were determined: The humus content; the content of mobile forms of nitrogen, phosphorus, and potassium; the pH of the aqueous suspension; the cationic-anionic composition of the aqueous extract.

Results

Floristic Research

The revealed floristic composition of the turanga communities of the studied territory demonstrated 103 species of higher vascular plants. Among them, such families as Chenopodiaceae, Asteraceae, Brassicaceae, Poaceae, and Fabaceae made up 61.2% of the total number of species (Fig. 3).

In the composition of the flora of the Syr-Darya valley the number of representatives of Chenopodiaceae, as a rule, much exceeds the participation of other families (including the species of Asteraceae family); in the considered cenoflora, all these families demonstrated the same number of species.

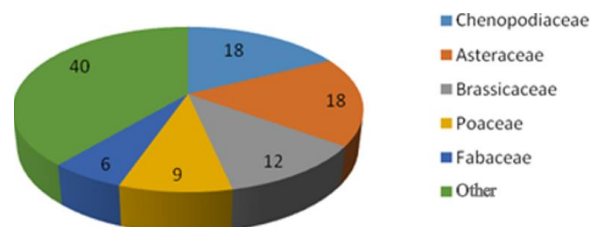


Fig. 3: Spectrum of leading families composing the coenoflora

Table 1: Results of physical and chemical analyses of soils

Section No.	Depth of genetic horizons, cm %	Depth of sampling, cm	Humus (organic matter)	Mobile forms, mg/kg				Salinization			
				Easily hydrolyzed nitrogen	Phosphorus	Potassium	Aqueous Ph	Salinization type *	Sum of salts, %	Sum of toxic salts, %	Degree of salinization
24/11-1	0-120	0-120	2.96.00	30,8.0	40	2000	8.42	S + Sod, CaS	3.152	2.126	Very strong
	12-470	20-300	0.21.00	16.8	6	320	8.59	S, MgS	0.643	0.482	Midrange
	47-760	50-600	0.14.00	19.6	2	40	8.64	S, MgCa	0.264	0.158	Weak
	76-100	90-100	0.07.00	19.6	0	20	8.98	S, SMg	0.128	0.106	Nonsaline
24/11-2	0-140	0-140	1.08.00	28.0	10	840	8.61	XC + Sod, MgS	0.953	0.759	Strong
	14-390	20-300	0.31.00	33.6	3	440	8.85	S, CaS	0.493	0.300	Midrange
	39-710	50-600	0.10.00	22.4	2	70	8.09	S, CaS	0.118	0.077	Nonsaline
	71-100	90-100	0.00.00	30.8	0	20	8.95	S, CaS	2.165	1.294	Strong
25/11-3	0-100	0-100	1.25.00	25.2	40	1180	8.28	S + Sod, MgS	2.811	1.873	Very strong
	10-210	10-210	0.73.00	30.8	6	290	8.21	S, MgS	0.965	0.722	Strong
	21-500	21-500	1.11.00	30.8	5	200	8.33	S, MgS	0.782	0.619	Strong
	50-100	60-700	0.03.00	16.8	3	30	9.04	S, CaS	0.106	0.067	Nonsaline
26/11-4	0-140	0-100	3.48.00	33.6	20	1560	8.41	S + Sod, SMg	0.123	0.091	Nonsaline
	14-330	20-300	0.21.00	30.8	5	630	8.74	S, MgS	5.358	4.243	Very strong
	33-600	40-500	0.10.00	19.6	3	490	8.70	CHS, MgS	1.450	1.082	Very strong
	60-880	70-800	0.03.00	25.2	3	90	8.91	CHS + Sod, MH	0.594	0.391	Midrange
26/11-5	88-105	90-100	1.91.00	22.4	0	110	8.37	CHS, MgS	1.356	0.921	Strong
	0-700	0-700	5.46.00	25.2	225	1800	7.34	S, MgS	0.749	0.609	Strong
	7-500	20-300	0.45.00	25.2	6	1100	8.68	CHS, MgS	0.979	0.689	Strong
	50-830	60-700	0.34.00	22.4	3	100	8.78	S, CaS	0.865	0.602	Strong
25/11-K1	83-113	90-100	0.38.00	19.6	0	70	8.37	CHS, CaMg	0.597	0.171	Weak
	0-260	0-100	0.87.00	22.4	33	400	8.14	S, Sca	1.341	0.588	Strong
	26-560	30-400	0.34.00	19.6	6	70	8.26	S, CaS	1.280	0.678	Strong
	56-660	56-660	0.10.00	22.4	3	30	8.25	S, MgCa	0.270	0.118	Nonsaline
66-100	80-900	0.14.00	25.2	2	30	8.28	S, MgCa	0.314	0.168	Weak	

* - by anions: S – sulphatic; S+Sod – sulphatic + soda; CHS – chlorine-sulphatic; CHS + Sod – chlorine-sulphatic + soda; - by cations: CaS – calcium-sodium; MgS – magnesium-sodium; Sca – sodium-calcium; MgCa – magnesium-calcium; SMg – sodium-magnesium; CaMg – calcium-magnesium

The high position of Brassicaceae in the structure of the turanga cenoflora was provided by the annual synanthropic species of the family found in human-disturbed open woodlands. In general, in the flora of the Syr-Darya valley, the representatives of the Brassicaceae family usually occupy the 4th or 5th positions.

Soil and Phytocenotic Research

Analysis of soil samples demonstrated three types of soils involved in studies: Tugai alluvial-meadow, alluvial-meadow, and salt marshes meadow.

For studying the peculiarities of the edaphic conditions of turanga growth (*Populus pruinosa* and *P. diversifolia*) in the middle flow of the Syr-Darya in sites with different species composition and phytocenotic structures of turanga groves 6 soil sections were. Sections 24/11-1 (Fig. 2, point 1), 24/11-2 (Fig. 2, point 3), 25/11-3 (Fig. 2, point 5), 26/11-5 (Fig. 2, point 10) are confined to tugai alluvial-meadow strongly salt-marsh soils. Section 26/11-4 (Fig. 2, point 9) corresponds to meadow salt marshes, and the control section corresponds to alluvial-tugai meadow strongly salt marsh soils (Table 1).

The most interesting soil characteristics were section 26/11-5 (description point No. 10 with coordinates: N 44°53'8130"; E 65°21'9370"; h-123 m). This site is located near the Taldyral village; its vegetation was represented by a turanga grove with the specimens of *Populus diversifolia* placed sufficiently close to each other. At a site of 300 m², there were noted 55 trunks of turanga; so, the wood stand density at point No. 10 was 0.18 × 1 m². It should be noted that the bulk of the Turanga thickets were old-growth trees, the height of the largest trees was 12-15 m. The average diameter of the trunks was 20.5 cm, and their circles ranged from 13-73 cm.

Description of soil section 26/11-5 corresponds to tugai alluvial-meadow strongly salt-marsh sandy soil (Fig. 4).

0-7 cm. Dry over-rotten plant fall, dark gray with a brown tint, white veins and accumulations of salts, sandy, the transition is abrupt.

7-50 cm. Light chestnut, fresh, sandy, dense, structureless, whitish-colored veins, clusters of salts, and plant roots, the transition is noticeable.

50-83 cm. Light fulvous, wet, sandy, slightly compacted, structureless, points and veins of salts, plant roots, clear transition.

83-113 cm. Light fulvous with rusty and bluish spots of R₂O₃, moist, sandy, weakly compacted, structureless, rare dots and veins of salts, plant roots.

The upper horizon was a semi-decomposed mass of plant residues mixed with dusty sand. The content of organic substances in this layer reached 5.46%. The content of mobile forms of phosphorus and potassium was 225 mg per kg and 1800 mg per kg, respectively (very high levels). The medium reaction of the surface layer was slightly alkaline, pH = 7.34.

In the underlying layers, the amount of humus was very low, making 0.45-0.34%. The content of easily hydrolyzable nitrogen was very low throughout the soil profile, 25.2-19.6 mg/kg. The amount of mobile phosphorus also corresponded to a very low level, less than 6 mg/kg. The very low potassium content was noted in sandy layers of soils located deeper than 50 cm, where the alkaline reaction of the medium was noted, pH 8.37-8.78.

The soil profile was saline; the content of water-soluble salts was 0.949-0.597% (0.689-0.171% toxic). Salinity chemism was sulphatic and chloride sulphatic. Sodium prevailed in the composition of cations; magnesium was rare. The salinity degree was strong, but for the 83-113 cm layer, it was weak.



Fig. 4: Section 26/11-5. Tugai alluvial-meadow strongly salt-marsh sandy soil



Fig. 5: Section 24/11-1. Tugai alluvial-meadow strongly salt-marsh middle loamy soil 0-12 cm

The features of the described site also included a significant thickness of the plant litter; it was represented by the fall of turanga leaves and cow droppings. The constant presence of cattle in the described turanga grove was also evidenced by multiple violations of the bark integrity of the trees.

Section 24/11-1 also refers to tugai alluvial-meadow strong salt-marsh soils but differs from the previous point in the mechanical composition of the ground. If section 26/11-5 has a sand composition, then section 24/11-1 is characterized by a middle-loamy composition.

The vegetation of this site (description point No. 1 with coordinates: N 44°50'3930''; E 65°23'8410''; h-120 m) located between the road and the water canal when leaving Kyzylorda in the western direction, was represented by the turanga grove composed by *Populus pruinosa*. At the site of 300 m², there were noted 94 turanga trees with an average diameter of 14.3 cm; the trunk circles ranged from 5 to 98 cm.

The species composition of tree-shrub species, in addition to *Populus pruinosa*, included *Elaeagnus angustifolia* L., and *Tamarix ramosissima* Ledeb. and *Halimodendron halodendron* (Pall.) Voss. The herbaceous species were represented only by *Zygophyllum fabago* L.

The humus amount in the upper horizon of section 24/11-1 was 2.96%, which corresponded to a low content level. In the underlying horizons, the humus content dropped sharply to 0.2-0.1% (a very low level).

According to the humus content, the amount of mobile (easily hydrolyzable) nitrogen also corresponded to a low and very low level. The content of mobile phosphorus in the upper horizon was 40 mg/kg (increased level), in the underlying horizons its content dropped sharply to 6 mg/kg and less (very low level). In the upper horizon, the amount of mobile potassium varied very widely from 2000 mg/kg (very high level) to 20 mg/kg (very low level). The reaction of the soil aqueous medium was alkaline, pH in the soil profile was 8.42-8.98 units.

The number of water-soluble salts varied within 3.152-0.128% (2.126-0.106% of toxic salts), reaching maximum values on the surface horizon. Salinity chemism was sulphatic, in the surface horizon, it was sulphatic with the participation of soda. Sodium prevailed in the composition of cations in surface horizons, and calcium and magnesium prevailed lower in profile. The degree of salinization of the surface horizon was very strong. Down the profile, the number of salts was significantly reduced. Below 76 cm the sandy layers of the soil were not salted, the sum of toxic salts was only 0.106% (Fig. 5).

Dark gray, loamy, dry, dusty-lumpy, layered, compacted, with many white veins and accumulations of salts, many small roots, semi-decomposed leaves, and roots, the transition was sharp.

12-47 cm. Light fulvous with a grayish tint, light loamy, fresh, fragile-lumpy, layered, compacted, veins, and spots of salts, plant roots with a diameter of 1-2 cm, the transition were noticeable.

47-76 cm. Fulvous, sandy, fresh, structureless, poorly compacted, salt stains, rare roots, single rusty spots R_2O_3 , clear transition.

76-100 cm. Fulvous with a gray tint, rusty and bluish spots R_2O_3 , moist, sandy, structureless, rare roots.

The next section was 24/11-2 (description point No. 3 with coordinates: N 44°53'7170"; E 65°18'6940"; h – 112 m); it was characterized by a light-loamy variety of tugai alluvial-meadow strongly salt-marsh soil. It was laid not far from section 26/11-5 on the western exit from Kyzylorda city.

The species composition of the plot included 12 species: *Populus pruinosa* (dominant), *Tamarix ramosissima*, *Halimodendron halodendron*, and *Halostachys belangeriana* (Moq.) Botsch., *Suaeda microphylla* Pall., *Petrosimonia sibirica* (Pall.) Bunge, *Aeluropus littoralis* (Gouan) Parl., *Cynanchum sibiricum* Willd., *Climacoptera lanata* (Pall.) Botsch., *Limonium otolepis* (Schrenk) Kuntze, *Glycyrrhiza glabra* L., and *Apocynum pictum* Schrenk. It should be noted that the described turanga grove consisted of young, close to each other (the average distance between trunks was about 1.5 m) trees of almost the same height.

The structure of the soil profile and morphological description were shown in Fig. 6.

0-14 cm. Gray, fresh, lightly loamy, dusty-lumpy, compacted, white veins and salt stains, small roots, clear transition.

14-39 cm. Fulvous-gray, fresh, sandy, fragile-lumpy, compacted, fewer salts, many small roots, gradual transition.

39-71 cm. Fulvous-gray, fresh, sandy, structureless, poorly compacted, many thick roots, rare rusty spots of R_2O_3 , gradual transition.

71-100 cm. Fulvous-gray with rusty and bluish spots of R_2O_3 , moist, sandy, structureless, weakly compacted, rare thick roots up to 4 cm in diameter.

Section 24/11-2 differed from the 24/11-1 in the light granulometric composition of the soil.

The humus amount corresponded to a very low (rarely just low) level of content: Even in the upper horizon where the humus content was maximum, its amount was only 1.08%. In the underlying horizons, the humus amount dropped sharply. The content of mobile forms of nitrogen and phosphorus also corresponded to a very low level. In humus horizons the amount of mobile potassium varied in the range of 840-440 mg/kg (very high content); in the underlying layers, it decreased to 20 mg/kg (very low level).

The reaction of soils was alkaline, the pH of the aqueous medium in the soil profile was 8.09-8.95.

The amount of water-soluble salts ranged from 2.165% (1.294% toxic) to 0.118% (0.077% toxic). On the surface horizon, the sum of the salts was 0.953% (0.759% toxic). The type of salinization was chloride sulfate with the

participation of soda, which indicated progressive salinization. Sodium and magnesium predominated in the composition of cations. The degree of salinization of the upper horizon was strong.

The salinization chemism of the underlying horizons was sulfatic, calcium-sodium; the salinization degree was medium and strong.

For soil section 25/11-3, a light-loamy mechanical composition was noted, characterizing the tugai alluvial-meadow high salt-marsh soil with a buried humus horizon of 21-50 cm. The plot with this section (description point No. 5 with coordinates: N 44°39'9790"; E 65°47'9140"; h – 128 m) was located 22 km east of Tasbuget village. This plot was characterized by the low woodland density of *Populus diversifolia* and *P. pruinosa*. The largest tree of *Populus diversifolia*, over 12 m, was seen here. At this plot, there were lots of open spaces and the species composition turned out to be the most diverse, at least 25 species (including pasture weeds) grew there: *Salix* sp. and *Elaeagnus oxycarpa* Schldl. (Acting as co-dominants), *Glycyrrhiza glabra* (dominant), *Alhagi pseudalhagi* (M. Bieb.) Fisch., *Clematis orientalis* L., *Leymus multicaulis* (Kar. & Kir.) Tzvelev, *Calamagrostis pseudofragmites* (Haller f.) Koeler, *Aeluropus littoralis* (Gouan) Parl., *Limonium otolepis*, *Lepidium obtusum* Basiner, *Xanthium strumarium* L. and *Pseudosiphora alopecuroides* (L.) Sweet. There were also representatives of such genera as *Erigeron*, *Salsola*, and *Gypsophila*.

This plot according to its vegetation composition was used as pasture.

Analysis of soil samples demonstrated that the size of humus horizons was 50 cm. At the same time, the humus amount in the upper horizon was 1.25%, and in the underlying horizons, the humus content decreased to 0.73-1.11%. Such a humus amount corresponded to a very low level of content.

The amount of mobile (easily hydrolyzable) nitrogen also corresponded to a low and very low level. The content of mobile phosphorus in the upper horizon was 40 mg/kg (hyper level), in the underlying horizons it dropped sharply to 6 mg/kg and less (very low level). The content of mobile potassium in the upper horizon reached 1180 mg/kg (a very high level). In the horizons below, up to 50 cm, its amount decreased to 200-290 mg/kg (high level). Below 50 cm, in sandy sediments, soils were characterized by a very low potassium content, 20-30 mg/kg. Morphological characteristics of this section are presented in Fig. 7.

Figure 7. Section 25/11-3: Tugai alluvial-meadow strong salt-marsh light-loamy soil

0-10 cm. Grayish light brown, dry, lightly loamy, dusty-lumpy, loose, white veins and spots of salts, small roots, clear transition.

10-21 cm. Brownish-gray, white-colored salts, dry, loamy, fragile-lumpy, dense, small roots, noticeable transition.



Fig. 6: Section 24/11-2. Tugai alluvial-meadow highly salt-marsh light-loamy soil



Fig. 8: Section 26/11-4: Meadow loamy salt-marshes



Fig. 7: Section 25/11-3: Tugai alluvial-meadow strong salt-marsh light-loamy soil



Fig. 9: Section 25/11-K1: Alluvial-meadow strong salt-marsh light loamy soil



Fig. 10: Factors of negative impact on turanga groves

21-50 cm. Gray, dry, loamy, fragile-lumpy, dots and veins of salts, poorly compacted, rare thick roots, sharp transition.

50-100 cm. Light brown with rusty and bluish spots of R_2O_3 , fresh, sandy, structureless, weakly compacted, rare thick roots.

The reaction of the soil aqueous medium was alkaline, pH in the soil profile was 8.2-9.0 units. The number of water-soluble salts varied within a very wide range of 2.811-0.123% (1.873-0.067% toxic salts).

The maximum salt values of 2.811% were determined on the surface horizon among them 1.873% were toxic salts. The type of salinization was sulphatic with soda. Sodium prevailed in the composition of cations. The degree of salinization of the upper horizon was very strong.

The chemism of salinization of the underlying horizons (up to a depth of 50 cm) was sulfatic, magnesium-sodium. The sum of salts was 0.782-0.965%, among them 0.619-0.722% were toxic. The salinization degree was strong. Soil layers lying below 50 cm and represented by sandy alluvium were not salted. The sum of salts was 0.106-0.123%, among them 0.067-0.091% were toxic.

Section 26/11-4 was characterized by meadow loamy salt-marshes (description point No. 9 with coordinates: N 44°53'8860"; E 65°21'9680", h – 104 m). It was located at the plot near the Taldyarl village from the side of Kyzylorda city. At the time of the study, the described plot had 15 plant species with the dominance of *Populus pruinosa* and the

participation of other trees and shrubs that make up the upper tiers of this phytocenosis.

Among them: *Elaeagnus angustifolia* L., *Tamarix ramosissima*, *Halimodendron halodendron*, *Krascheninnikovia ewersmanniana* (Stschegl. ex Losinsk.) Grubov, *Halostachys belangeriana*, and *Suaeda microphylla* Pall. In the lower layer, represented by herbaceous grassland there were noted: *Zygophyllum fabago* (dominates), *Petrosimonia sibirica* (dominates), *Limonium otolepis*, *Clematis orientalis*, *Asparagus* sp., *Cynanchum sibiricum*, *Atripaltalis* Trin. ex Steud. A significant number 33.3% of representatives of the *Chenopodiaceae* family indicated a high salinization degree of the territory that was confirmed by the results of soil analyses and the most dangerous for the survival of tugai groves according to Treshkin (2011) is the “progressive process of halophytization of soil and plant cover,” initiated by a decrease in groundwater levels.

The humus content in the first soil horizon was 3.48%. Among the sections described, this was the second largest value. In the underlying layers, the humus amount dropped sharply to 0.2-0.03% (a very low level), and only at the depth of 88-105 cm (buried humus horizon) increased to 1.91%. The amount of easily hydrolyzed nitrogen in surface horizons at 0-14 cm and 14-33 cm was 30.8-33.6 mg/kg, which also corresponded to a low content level. In the underlying horizons, its content did not exceed 25.2 mg/kg (a very low level).

The level of mobile phosphates on the surface horizon was average, in the underlying layers, it was very low. The amount of mobile potassium varied widely from 490-1560 mg/kg in surface horizons (very high content) to 90-110 mg/kg in horizons below 60 cm (low and medium level).

The reaction of soil aqueous medium was alkaline; pH was 8.37-8.91 units.

Figure 8 demonstrates sections 26/11-4. The salinization degree of the soil profile to a depth of 60 cm was very strong, and the content of water-soluble salts was 5.358-1.450% (4.243-1.082% toxic). The salinization degree of the underlying layers was average and strong, salt content was 0.594-1.356% (0.391-0.921% toxic), respectively. Salinity chemism was sulphatic and chloride sulphatic (sometimes involving soda). The composition of cations was dominated by sodium and magnesium.

0-14 cm. Dark gray, dry, loamy, lumpy-dusty, layered, weakly compacted, white veins, clusters and spots of salts, rare small roots, clear transition.

14-33 cm. Brown with a gray tint, white-colored veins, and accumulations of salts, dry, light loamy, fragile-lumpy, compacted, less amount of roots, clear transition.

33-60 cm. Brown, fresh, sandy, fragile-lumpy, dots and veins of salts, weakly compacted, roots 1-2 cm in diameter, clear transition.

60-88 cm. Light fulvous with rusty and bluish spots of R_2O_3 , wet, sandy, structureless, weakly compacted, rare thick roots, sharp transition.

88-105 cm. Bluish-gray (buried humus horizon) with rare rusty spots R_2O_3 , light loamy, compacted strongly, structureless, wet, rare roots.

For control section 25/11-K1 the plot without turanga trees in plant cover was chosen (a point of description No. 6 with coordinates: N 44°39'5970"; E 65°46'7776"; h – 115 m); the plot was located east of Tasbuget village at 21 km. It was at a perennial fallow land currently occupied by a rare woodland of saxaul (*Haloxylon aphyllum* (Minkw.) Iljin) with the participation of *Halimodendron halodendron*. In addition to these species at this site, there were noted: *Tamarix ramosissima*, *Salsola arbuscula* Pall., *Climacoptera lanata* (Pall.) Botsch., *Peganum harmala* L., *Alhagi pseudalhagi*, *Aeluropus litoralis*, *Lepidium obtusum*, *Suaeda microphylla*, *Zygophyllum fabago* and *Haplophyllum obtusifolium* (Ledeb.) Ledeb.

This section characterizing the alluvial-meadow strong salt-marsh light-loamy soil (Fig. 9) demonstrated the lowest humus content (0.87%). In underlying soil horizons, the humus content decreased to 0.1-0.34%.

0-26 cm. Light gray-brown with light veins and spots of salts, dry, light loamy, weakly compacted, fragile-lumpy, white-colored veins and clusters of salts, plant roots, clear transition.

26-56 cm. Gray-brown, fresh, sandy, slightly compacted, lumpy-dusty, dots and veins of salts, plant roots, sharp transition.

56-66 cm. Fulvous, fresh, sandy, poorly compacted, structureless, loose, plant roots, sharp transition.

66-100 cm. Light fulvous, dry, light loamy, dense, lumpy, rare roots.

The amount of mobile (easily hydrolyzable) nitrogen also corresponded to a very low level (19.6 to 25.2 mg/kg). The content of mobile phosphorus in the upper horizon was 33 mg/kg (hyper level); in the underlying horizons, it dropped sharply to 2-6 mg/kg (very low level). Another distinctive feature of this section was a very high level of mobile potassium content in the upper horizon (400 mg/kg). In the lower horizons, its amount was reduced to 70 mg/kg (low) and 30 mg/kg (very low potassium content).

The reaction of the soil aqueous medium was alkaline, and the pH of the soil profile was 8.14-8.28 units. The number of water-soluble salts varied very widely from 1.341 to 0.270% (0.678-0.118% toxic salts). The maximum amount of salts was on the surface horizon.

The salinization type was sulphatic. Calcium salts prevailed in the composition of cations, rarely sodium. The salinization degree of the upper horizons of the soil profile, up to 56 cm, was strong. The underlying layers were not salted or had a low salinization degree.

Analysis of soil samples taken at turanga growth sites demonstrated that the salinity degree of soils under turanga forests in different horizons was not the same. Meanwhile, there was a general tendency to decrease the

salinization level of soils in the direction from surface horizons to deeper ones confirmed by specific digital data (Table 1). At the same time, in general, the decrease in salinization level on average began from a depth of 50 cm reaching a weak degree, and the absence of salinization in the soil layer up to 100 cm.

In some cases, strong salinization (section 26/11-5) was present in almost all soil horizons, and only to 100 cm deep, the number of salts decreased to a weak level. In other variants (section 26/11-4) with a very strong salinization degree of the entire profile only within 60-88 cm depth, the salinization level decreased to average and then increased again to a strong one.

Ecological Study

During the botanical survey of turanga groves, the main factors of influence on the soil and plant cover were identified. Negative effects include regulation of the runoff of the Syr-Darya for the needs of crop production; cattle grazing, vegetation being eaten, damaging the tree trunks, soil compaction; fires, total or partial destruction of vegetation including poplars (Fig. 10: A-D); felling for fuel and construction works; recreational load near cities and settlements.

Discussion

The root system of the turanga tree in addition to the main rod feeding root going deep forms two tiers of horizontal appendage roots extending more than 30 m. At the same time, less deeply lying radial roots located, as a rule, at a depth of up to 1 m, participate in the process of vegetative reproduction (Rakhimzhanov *et al.*, 2021). Thus, the concentration of turanga groves in the vicinity of Kyzylorda is explained by the low salinization degree of soils at the depth of up to 1 m, which makes it possible to maintain the population due to vegetative reproduction. However, natural seed reproduction of turanga and the formation of new populations is possible only if there is temporary flooding which guarantees the complete immersion of developing seeds in water (Gai *et al.*, 2020). Currently, in connection with the regulation of the runoff of the Syr-Darya flood spills are almost absent, and, therefore, there is no basic condition for the seed reproduction of turanga trees.

Our studies demonstrated that at a distance from open water sources (Zhanakorgan and Shieli study areas), turanga, as a rule, it is *Populus diversifolia*, is found exclusively on sandy soil, and in the vast majority of cases on the slopes and tops of hills, barkhans or ridges, less often at inter-barkhan declines. This is understandable from the point of view of the good water supply of the sands due to the capillary lifting of moisture from underground water sources.



Fig. 11: Deflation processes



Fig. 12: Turanga, dried tree tops. Not far from Shieli village, 2 km southwest of the highway, at the territory of the Zhanakorgan forestry (N 44°04'55.550"; E 67°04'59,405"; h – 116 m) (Fig. 1, point 34)



Fig. 13: Turanga grove (*Populus diversifolia*) near the lake within the protected natural area “Torangylsay” (N 44°41'9030"; E 65°9'2550"; h – 100.6 m) (Fig. 2, point 50)

Depending on the wind rose the process of development of the turanga poplar population on sandy soils can go according to 2 scenarios. In one case, when sand particles are accumulated around the trunks of the turanga, the sand mounds increase in size. In this case, the turanga acts as a relief-forming plant. Otherwise, the sand masses are blown out (deflation process) from under the turanga trunks, which leads to the bare of their roots (Fig. 11) It should be noted that the vital state of such Turanga populations, in this case, *Populus pruinosa*, approaches the senile stage, determined by such signs as the curved (curvature) trunks, dried tops and interrupting the trees.

As it is known to maintain the life of the turanga population growing on the sands, the maximum depth of groundwater should not exceed 7m. The optimal development of turanga populations corresponds to the depth of groundwater of up to 3 meters (Rakhimzhanov *et al.*, 2021).

Therefore, turanga trees can be bio-indicators not only of the groundwater presence but also indicators of groundwater depth. With a shallow occurrence of groundwater, turanga trees do not lose their habit features, including natural decoration (sufficient tree height, typical crown architecture, straight trunks) and growth intensity. The evidence of this is a clear difference in the living conditions of turanga populations growing at a distance (more than 8 km) (Figs. 11-12) and near (less than 1 km) (Fig. 13) the open water sources (river, lake). An example of the population of a good life state of turanga was the turanga grove of *Populus diversifolia* noticed by us near the lake, represented by middle-aged (about 30-40 years), relatively straight and evenly distributed trees.

Unfortunately, in general, the area occupied by turanga rare woodlands over the past 100 years has significantly decreased (in several places to 80%) (Rakhimzhanov *et al.*, 2021). This situation was mainly due to a shortage of water caused by its high consumption, primarily for rice cultivation. As a result of the decrease in river water debit groundwater level also decreases which catastrophically affects precisely the remote relict populations of turanga. Nowadays these populations exist exclusively due to vegetative reproduction, and the population that is repeatedly renewed in this way, which has existed for hundreds of years in itself, is a “living relic”.

Conclusion

According to the analysis of data obtained from studies of turanga groves of the Syr-Darya valley within the Kyzylorda region, the following conclusions were made:

- In the vicinity of Kyzylorda turanga forests and rare woodlands are formed mainly by *Populus pruinosa*. The concentration of turanga groves in this district is explained by the low salinization degree of soils at a depth of up to 1 m which makes it possible to maintain the population due to vegetative reproduction; at a distance from open water sources (Zhanakorgan and Shieli study districts), *Populus diversifolia* is predominantly found
- *Populus pruinosa* and *P. diversifolia*, confined to the Syr-Darya valley grow in saline soils - tugai alluvial-meadow strongly salt-marsh and at salt marshes meadow; soils can be of different (sandy, middle-loamy, light-loamy) mechanical composition. *Populus diversifolia* is more common in lighter soils, and *P. pruinosa* prefers to settle at heavier soil variants. Humus content in the upper soil horizon is influenced by the activity of using the territory for cattle grazing
- The species composition of turanga groves is influenced by the salinization degree of soils and the degree of anthropogenic impact. The high salinization degree which is a characteristic of meadow salt marshes is evidenced by a significant number of *Chenopodiaceae* representatives; the disturbance of communities is evidenced by the presence of synanthropic (weed) species
- Among the main negative factors affecting the condition of turanga groves, it should be noted the anthropogenic impact associated with the regulation of the runoff of the Syr-Darya, cattle grazing, felling the trees, and fires
- Turanga is a bio-indicator both of the groundwater presence and its depth. The living conditions of turanga populations are caused by the groundwater level
- According to the features of the nowadays distribution of turanga woodlands located at a significant distance from the modern channel of Syr-Darya, it is possible to restore the historical aspects of the formation of the river valley

The main practical result of the research carried out on the study of turanga groves of the Syr-Darya Valley is the determination of the main directions of further monitoring research necessary for the development of effective environmental protection measures.

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Author's Contributions

All authors equally contributed to this study.

Ethics

This article is original and contains unpublished material. The corresponding author confirms that all of the other authors have read and approved the manuscript and no ethical issues are involved.

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