

RESEARCH ARTICLE

Ecological Situation of Poplar Species in the Aral Sea Region of Kazakhstan

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Abstract: The study was conducted in response to the deteriorating environmental conditions in the Aral Sea region of Kazakhstan, characterized by the degradation of natural ecosystems, loss of biodiversity, and the disappearance of valuable tree species. Of particular importance is the investigation of the current status of populations of *Populus pruinosa* Schrenk and *Populus diversifolia* Schrenk, relic tree species of the desert regions of Kyzylorda Region that play a crucial role in maintaining the stability of tugai and floodplain ecosystems. The aim of the study was to determine the current distribution range of *Populus pruinosa* and *Populus diversifolia* in Kyzylorda Region and to assess the condition of their coenopopulations and reproductive potential. To achieve this objective, 12 key sites across the region were surveyed. A comparative analysis of the historical and current distribution ranges of the species was carried out using distribution maps developed by S. Ya. Sokolov (1951), P. P. Besschetnov and L. M. Grudzinskaya (1981), as well as original maps prepared by the authors in 2024. Field studies included assessments of population density, projective cover, morphological characteristics of the plants at different stages of vegetation, and their potential for both sexual (seed) and vegetative reproduction. The collected data were processed using Microsoft Excel. The results demonstrated a significant reduction in the distribution ranges of both species within Kyzylorda Region. In several areas, particularly within the Aral and Kazaly districts, some populations have disappeared completely. Experimental investigations revealed a low rate of natural regeneration by seed, whereas propagation through root suckers showed high potential for producing planting material. The study concludes that urgent measures are required to conserve and restore the natural populations of *Populus pruinosa* and *Populus diversifolia*. The findings can be applied in programs aimed at restoring tugai forests, conserving the biodiversity of the Aral Sea region, and establishing nurseries for the artificial propagation of rare tree species under arid ecosystem conditions.

Keywords: Desert Area, Turanga Bunge, *Populus pruinosa*, *Populus Diversifolia*, Rare Species

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Introduction

The Kazakhstan part of the Aral Sea region, including the North Aral Sea and the lower Syrdarya River basin in the Kyzylorda Region, remains one of the most environmentally vulnerable areas in Central Asia [1, 2]. Despite ongoing

restoration efforts, the region continues to face severe ecological challenges associated with water scarcity, soil degradation, and vegetation loss [3, 4].

Populus pruinosa Schrenk and *Populus diversifolia* Schrenk are distributed from the Aral Sea desert region to the Balkhash–Alakol Depression in southwestern Kazakhstan. These species occur in former river channels, along riverbanks, in interdune depressions, and occasionally in saline habitats. They are characterized by thick trunks and broad hemispherical crowns, reflecting their adaptation to arid desert environments [5].

Populus pruinosa Schrenk is listed as a declining species in the Red Data Book of the Republic of Kazakhstan. These species are among the principal broad-leaved trees of desert riparian (tugai) forests in Central Asia. Their natural distribution extends across Central Asia, southern Kazakhstan, Iran, and western China [6-8].

The taxonomic classification and phylogenetic relationships of *Populus species*, particularly those belonging to the section Turanga, remain a subject of scientific debate. Nevertheless, most authors agree that these species belong to the willow family (Salicaceae Mirbel), with Turanga Bunge recognized as a taxonomic section (or subgenus, depending on the classification) within the genus *Populus* [8-10].

While some authors recognize only two species within the section Turanga, namely *Populus pruinosa* Schrenk and *P. euphratica* Oliv., others propose a more detailed classification based on morphological and ecological characteristics. In particular, Dode recognized *P. diversifolia* and *P. ariana* as separate species occupying different habitats and also described *P. litwinowiana* as a distinct species. According to this classification, *P. diversifolia*, *P. ariana*, *P. litwinowiana*, and *P. transcaucasica* Yarm. Ex Gross belongs to one taxonomic group, whereas *P. pruinosa* Schrenk and *P. glaucicomans* Dode are assigned to another [11].

Populus euphratica was first described by Oliver in 1807. Later, Schrenk (1848) distinguished two closely related species, *Populus diversifolia* Schrenk and *Populus pruinosa* Schrenk.

In Kazakhstan, three representatives of the section Turanga have been reported: *Populus diversifolia* Schrenk, *Populus pruinosa* Schrenk, and *P. litwinowiana* Dode. Their distribution, biology, and ecology have been investigated by several authors [12, 13].

The botanical history of *Populus species* dates back many centuries, as they represent a biologically distinctive group within the willow family.

Among the first researchers to investigate Turanga species was Schrenk, who conducted botanical studies along the banks of the Ili River in 1845. Subsequently, numerous authors continued these investigations [8, 11]. These studies provide detailed descriptions of the morphology, pollination biology, geographical distribution, and vegetative and generative reproduction of Turanga species.

The height of *Populus diversifolia* is reported to be 11–16 m [14]. However, some studies [15, 16] report heights of 30–38 m.

The height of *P. diversifolia* (*Populus euphratica* Oliv., Euphrates poplar) varies depending on habitat conditions, while the trunk diameter ranges from 30–40 cm to 90–100 cm, depending on the age of the trees. The leaves vary considerably in shape, ranging from broad to narrow, a characteristic that gave rise to the species name *diversifolia*. The leaf blades are typically characterized by deep lobes or grooves near the apex [17].

However, leaves of different shapes may occur on the same individual plant [8]. As these species are adapted to arid desert environments, numerous studies have investigated their photosynthetic characteristics, physiological adaptations to adverse environmental conditions, growth rates, and tolerance to abiotic stress [18, 19]. The fruits are capsules that mature approximately 90–100 days after flowering [19].

Populus pruinosa Schrenk is generally shorter than *P. diversifolia* Schrenk, typically reaching 9–10 m in height, although individuals may occasionally attain heights of 15–20 m [18, 19]. Rapidly growing shoots exhibit considerable variation in leaf morphology, a characteristic that is also observed in other species of the section Turanga. *Populus litwinowiana* Dode is morphologically similar to other deciduous *Populus species* but can be distinguished by several specific morphological characteristics. The ecological and economic importance of these species is largely associated with their high tolerance to drought, elevated temperatures, and soil salinity.

For example, during the summer period, the daily water loss through leaf transpiration reaches 548.1 L in willow (*Salix*), whereas in turanga (*Turanga*) it amounts to only 68.9 L. These findings indicate a lower transpiration intensity in turanga under hot conditions, representing one of its key adaptations to arid environments [19].

The salt concentration in the cell sap of *Populus pruinosa* Schrenk ranges from 10.4–10.6% at a height of 2.5 m above the ground to 12.6–12.8% in branches located approximately 12 m above the ground. In *Populus diversifolia* Schrenk, the corresponding value reaches 15.0–15.2% [6].

According to [20], these species are light-demanding and exhibit low tolerance to low temperatures. Their resistance to high temperatures is associated with several morphological and anatomical adaptations, including a thick cuticle, a well-developed double-layered epidermis composed of small cells, and photosynthetic tissues distributed on both sides of the leaf blade. In addition, their drought tolerance is enhanced by reduced water loss through leaf transpiration. The adaptation of *Populus diversifolia* Schrenk to arid environmental conditions is based on the efficient use of available resources, contributing to the stability and functioning of desert ecosystems [21].

According to previous studies, one of the important practical applications of poplar is its ability to lower groundwater levels through intensive transpiration. A 15-year-old tree can evaporate up to 20 tons of water during a single growing season; therefore, poplars can be used as a form of biological drainage [22].

Populus species also propagate effectively through root suckers and exhibit high tolerance to periodic flooding, making them suitable for stabilizing riverbanks. Their wood is light-colored, lightweight, and relatively low in density and mechanical strength. It has a low calorific value and emits an unpleasant odor when burned.

Based on these characteristics, the wood of *Populus species* is generally considered unsuitable for structural construction. However, [18] reported that it is widely used in the manufacture of high-quality furniture and other wood products.

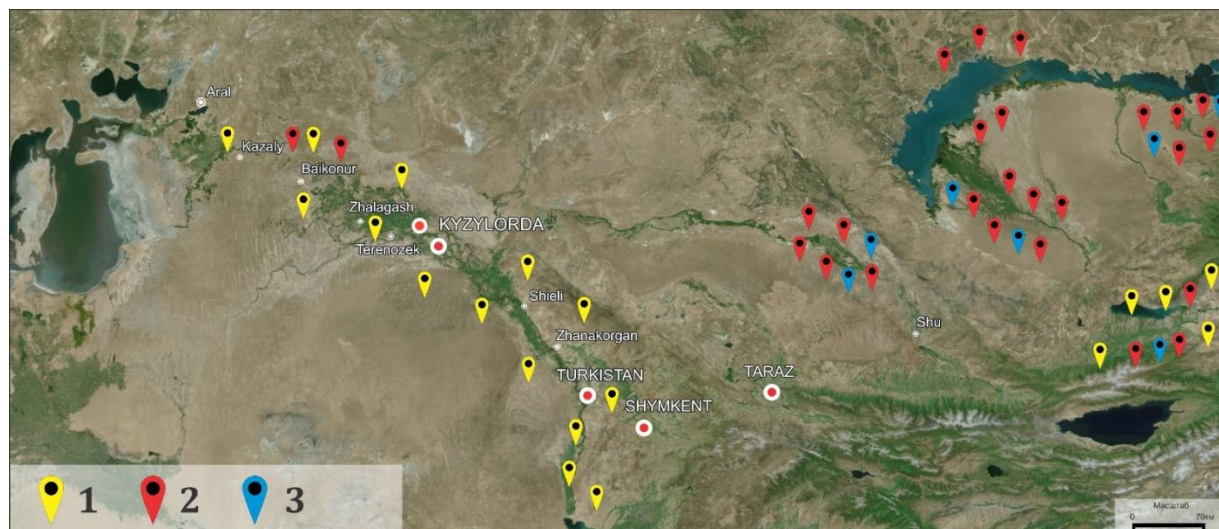
Populus species also have medicinal value [6], and natural dyes extracted from their tissues can be used to produce brown and yellow colors for textile dyeing [23].

In recent years, *Populus species* have attracted considerable attention from researchers investigating the flora of Kazakhstan. Numerous studies have focused on their distribution in the Turan Lowland, the dried bed of the Aral Sea, and the lower reaches of the Syrdarya River. These species have also been recognized as rare components of the desert flora [24] and have been proposed for use in the phytomelioration of the dried Aral Sea bed [9].



1- *Populus diversifolia*; 2- *Populus pruinosa*; 3- *Populus litwinowiane*

Fig. 1: Distribution area of poplar poplars in Kazakhstan (according to [25])



1- *Populus pruinosa*; 2- *Populus diversifolia*; 3- *Populus litwinowiana*

Fig. 2: Distribution area of poplars by [26]

Previous studies have demonstrated that *Turanga* species used in urban landscaping exhibit high resistance to atmospheric pollution caused by vehicle exhaust emissions.

Historically, the distribution range of *Turanga* poplars in Kazakhstan was considerably broader than it is today. Several studies have documented the historical distribution of *Turanga* species. In particular, the distribution map published by [25] illustrates the former extensive distribution of *Populus diversifolia* and *Populus pruinosa* (Figure 1).

According to this map, the historical distribution of *Populus diversifolia* extended across much of Kazakhstan, covering an approximate distance of 3,000 km from the border with China in the east to the Caspian Sea in the west.

In contrast, the historical distribution of *Populus pruinosa* was largely confined to the Syr Darya River basin. Its range extended from the border regions with Uzbekistan and Kyrgyzstan to the Turkestan and Kyzylorda regions of Kazakhstan, covering an estimated distance of approximately 450–500 km.

The distribution of *Populus litwinowiana* was considerably more restricted, being limited to the Ili River valley within the Almaty and Zhetysu regions of Kazakhstan.

Figure 1 illustrates the historical geographical distribution of *Turanga* species in Kazakhstan as reported by [25].

The distribution map presented in more recent studies (Figure 2) indicates that *Populus pruinosa* is currently distributed along the Syr Darya River as far as the Kazaly District, whereas the range of *Populus diversifolia* has become considerably more restricted. In addition, no records of *Turanga* species are shown for the areas surrounding the Aral Sea. This pattern suggests a substantial contraction of their distribution in the region, which may be associated with major environmental changes, including the reduced discharge of the Syr Darya River, desiccation of the Aral Sea, increasing aridity, and progressive soil salinization [26] (Figure 2).

Recent studies employing Geographic Information Systems (GIS) and remote sensing have identified the main habitats of *Turanga* species in the lower reaches of the Syr Darya River. In the Kyzylorda Region, *Turanga* populations are primarily distributed along the Torangasay and Zhaskairat canals and in the vicinity of the Tuschybas, Kamystybas, Zhaltyrkol, Kokshekol, Makpalkol, Raimkol, and Zhalanashkol lakes, as well as the Kobekti and Taldy-Aral wetlands and the Kuli, Kayazdy, Zhyngyldy, and Laikol rivers. These observations indicate that the current distribution of *Turanga* species is considerably more restricted than in the past.

In addition to ecological factors, socio-economic measures and environmental education play an important role in the conservation of these species. Raising public awareness and engaging local communities through environmental education and participatory conservation programs can contribute to the long-term protection and sustainable management of *Populus pruinosa* Schrenk and related *Turanga* species in the region [27].

Materials and Methods

Research Sites and Sampling

The study was conducted in the Kazakh part of the Aral Sea region within the Kyzylorda Region, where natural populations of two *Populus* species (*Populus pruinosa* Schrenk and *Populus diversifolia* Schrenk) are still preserved. The study objects were coenopopulations of these species occurring under different ecological conditions in the alluvial floodplains of the Syr Darya River and in sandy desert landscapes.

The preparatory stage included a comprehensive review of scientific literature, herbarium collections, and electronic databases related to the morphology, developmental biology, ecology, distribution, and economic significance of the studied species [28, 29, 30-32]. Based on published data, diagnostic morphological traits used for species identification and assessment of ontogenetic stages were determined [6, 9, 17, 22, 28]. The classification of ontogenetic stages of *Populus pruinosa* and *Populus diversifolia* was based on the concept of discrete plant ontogeny described in *Plant Coenopopulations* (1976). The following developmental stages were distinguished: seeds (sm), seedlings (p), Juvenile (j), Immature (im), Virginile (v), young generative (g1), mature generative (g2), old generative (g3), Subsenile (ss), Senile (s), and dying individuals (sc) [6, 21, 24].

For field investigations, twelve key study sites were selected to represent the main areas of the current distribution of the studied species: Korgantogai (No. 1), Bekman Togai (No. 2), and Sausakol (No. 3) in the Zhanakorgan District; Baigekum (No. 4), Tartogai (No. 5), and Sulutobe (No. 6) in the Shieli District; Shirkeyli (No. 7) and Baiten (No. 8) in the vicinity of Kyzylorda City; Kargalym (No. 9) and Koshshynyrau (No. 10) in the Syrdarya District; and Kamyshlybash (Nos. 11–12) together with adjacent territories near the Aral Sea (Figure 3).

Geobotanical and coenopopulation surveys were conducted within homogeneous plant communities. At each study site, three replicate plots measuring 40×40 m (1,600 m²) were established. Each plot was further subdivided into 10×10 m quadrats to estimate population size and density. The values obtained from the quadrats were averaged across the three replicate plots.

During field surveys, habitat characteristics were recorded, projective vegetation cover was estimated, and the abundance of individuals representing different ontogenetic stages was determined. The ontogenetic structure of each coenopopulation was assessed by constructing ontogenetic spectra, which describe the relative proportion of individuals at each developmental stage within the population [9, 13, 33].

The coenopopulations were classified as invasive (expanding), normal, or regressive according to the classification system proposed by [34-36].

The age of *Turanga* trees (*Populus diversifolia* and *Populus pruinosa*) was determined using a Pressler increment borer. Within each coenopopulation, 25–30 representative trees were randomly selected to ensure uniform coverage of the study site and representation of different diameter classes. Increment cores were extracted at breast height (1.3 m above ground level; Diameter at Breast Height, DBH) perpendicular to the stem axis.

After drying and polishing, the increment cores were examined under a stereomicroscope, and tree age was determined by counting annual growth rings. When the extracted core did not reach the pith, the total tree age was estimated by extrapolating the missing portion of the stem radius. The resulting data were used to characterize the age structure of each coenopopulation [37, 38].

The scientific names of all plant species were verified using the International Plant Names Index (IPNI) and cross-checked against the Plantarium database to ensure taxonomic consistency.

To assess long-term changes in species distribution, the current distribution data obtained during field surveys were compared with historical distribution maps published by [25, 26]. Based on the field surveys conducted in 2024, updated distribution maps of *Populus pruinosa* and *Populus diversifolia* in the Kyzylorda Region were developed, allowing an assessment of changes in the distribution ranges of both species over time [25, 26].

Statistical analyses were performed using Microsoft Excel. For quantitative variables, the arithmetic mean, Standard Deviation (SD), and Coefficient of Variation (CV) were calculated. The results are presented in tables and distribution maps.

Results

Population Density and Age Spectrum

Habitat characteristics and population structure were investigated in twelve plant communities representing the current distribution of *Populus pruinosa* and *Populus diversifolia* in the Kyzylorda Region. The study sites were distributed across five administrative districts: three sites in the Zhanakorgan District, three in the Shieli District, two in the vicinity of Kyzylorda City, two in the Syrdarya District, and two near the Aral Sea.

In the Zhanakorgan District, investigations were conducted in the Korgantogai:

- (1) Bekman Togai
- (2) Sausakol
- (3) Coenopopulations

All three sampling plots at Korgantogai (Site 1) were located on alluvial meadow soils adjacent to the Syr Darya River. The ontogenetic structure of the *Populus pruinosa* coenopopulation was dominated by generative individuals, indicating a stable population with ongoing natural regeneration. Regeneration occurred through both seed reproduction and vegetative propagation by root suckers. A relatively high abundance of juvenile individuals and root suckers was recorded, suggesting successful recruitment and good regeneration potential. The predominance of healthy generative individuals indicates that the population is currently maintained under the existing environmental conditions.

The tree layer of the Korgantogai community was dominated by *Elaeagnus oxycarpa* L., *Tamarix ramosissima* Ledeb., *Populus pruinosa* Schrenk, and *Populus diversifolia* Schrenk. The herbaceous layer was composed primarily of *Glycyrrhiza glabra* L., *Aeluropus litoralis* (Gouan) Parl., and *Phragmites communis* Trin.

The *Populus pruinosa* stand consisted predominantly of closely spaced trees aged 15–25 years. Natural regeneration was intensive and occurred through both seed reproduction and vegetative propagation by root suckers. Dense clusters of juvenile seedlings were observed on sandy and sandy-loam substrates exposed after the seasonal recession of the Syr Darya River floodwaters. Within the 1,600 m² sample plots, the mean number of juvenile individuals (j) was 87, representing 26% of the population, with heights ranging from 0.5 to 1.4 m. Although regeneration was satisfactory, approximately 90–95% of the trees exhibited symptoms of stem and foliar diseases. The trees reached heights of 4–6 m and trunk diameters of up to 25 cm. The population density and ontogenetic structure are presented in Table 1.

A well-developed coenopopulation of *Populus diversifolia* was also recorded at this site, with individuals representing all ontogenetic stages. The population was dominated by Virginile and Generative individuals (v–g). Within the 1,600 m² sample plots, the mean numbers of Juvenile (j), Immature (im), Virginile and Generative (v–g), and Senile (s) individuals were 95 (13%), 123 (18%), 134 (65%), and 32 (4%), respectively. Regeneration of *P. diversifolia* occurred through both seed reproduction and vegetative propagation (Table 1).

The Bekman Togai study site (Site 2) is located on the right bank of the Syr Darya River in the Zhanakorgan District and is characterized by meadow soils. The tree layer was dominated by *Populus pruinosa* Schrenk, *Tamarix ramosissima* Ledeb., *Lycium ruthenicum* Murr., *Elaeagnus oxycarpa* L., and *Salix wilhelmsiana* M. Bieb., whereas the herbaceous layer consisted primarily of *Asparagus persicus* Baker, *Limonium otolepis* (Schrenk) O. Kuntze, *Taraxacum officinale* F.H. Wigg., and *Zygophyllum fabago* L. Most *P. pruinosa* trees were relatively young (15–17 years old), reaching heights of 6–7 m and trunk diameters of 30–35 cm. The canopy was well developed and nearly closed. Symptoms of foliar diseases were observed in approximately 20–25% of the trees. Seedlings originating from seeds reached heights of 1.5–6 cm during their first year of growth. The ontogenetic spectrum was dominated by virginile individuals. Within the 1,600 m² sample plots, juvenile (j), Immature (im), and Virginile and Generative (v–g) individuals averaged 89 (28%), 119 (37%), and 112 (35%), respectively. Regeneration of *P. pruinosa* occurred through both seed reproduction and vegetative propagation (Table 1).

The Sausakol study site (Site 3) is located on the right bank of the Syr Darya River in the Zhanakorgan District and is characterized by meadow soils. The tree layer was dominated by *Populus diversifolia* Schrenk, *Halimodendron halodendron* (Pall.) Voss, *Lycium ruthenicum* Murr., and *Elaeagnus oxycarpa* L., whereas the herbaceous layer consisted primarily of *Zygophyllum fabago* L., *Limonium otolepis* (Schrenk) O. Kuntze, *Alhagi pseudalhagi* (M. Bieb.) Fisch., *Dodartia orientalis* L., *Glycyrrhiza glabra* L., *Trachomitum lancifolium* (Russanov) Pobed., and *Euphorbia jaxartica* Prokh. *Populus diversifolia* trees

reached an average height of 11.5 m and trunk diameters of approximately 25 cm. Vegetative regeneration occurred throughout the population, whereas no seed-derived regeneration was observed. Juvenile individuals were relatively scarce, with a mean abundance of 68 individuals (14%) per 1,600 m² plot. A total of 478 individuals were recorded, of which virginile and generative individuals (v-g) accounted for 295 (62%), while senile individuals represented 29 trees (6%) (Table 2).

The Baigekum study site (Site 4) is located in the Shieli District. The tree layer was dominated by *Haloxylon persicum* Bunge ex Boiss. & Buhse, *Haloxylon aphyllum* (Minkw.) Iljin, *Tamarix hispida* Willd., *Halimodendron halodendron* (Pall.) Voss, and *Tamarix ramosissima* Ledeb., whereas the herbaceous layer consisted primarily of *Suaeda acuminata* (C.A. Mey.) Moq., *Alhagi pseudalhagi* (M. Bieb.) Fisch., *Zygophyllum fabago* L., and *Chenopodium album* L. *Populus diversifolia* occurred in small, scattered stands throughout the site. The population was dominated by virginile and generative individuals, which accounted for 204 trees (72%). Tree height ranged from 4 to 7 m, trunk diameter from 25 to 32 cm, and crown diameter from 3.5 to 7 m. No seed-derived regeneration was observed, whereas vegetative regeneration through root suckers was limited (Table 2).

Table 1: Spatial and Age Structure of *Populus pruinosa* Coenopopulations

Plant community	Study site	Mean abundance and percentage (%) of <i>P. pruinosa</i> individuals by ontogenetic stage				Number of individuals per 1,600 m ² sample plot
		j	im	w- g	s	
<i>P. pruinosa</i> Schrenk - <i>Elaeagnus oxycarpa</i> L- <i>P. diversifolia</i> Schrenk - <i>Tamarix ramosissima</i> Ledeb+ <i>Aeluropus litoralis</i> (Gouan) Parl.+ <i>Phragmites communis</i> Trin	1	<u>87</u> 26	<u>95</u> 28	<u>156</u> 46	-	338
<i>P. pruinosa</i> - <i>Tamarix ramosissima</i> Ledeb + <i>Lycium ruthenicum</i> Murr+ <i>Elaeagnus oxycarpa</i> L- <i>Salix wilhelmsiana</i> Bieb+ <i>Limonium otolypis</i> (Schrenk) O. Kuntze, <i>Taraxacum officinale</i> Wigg	2	<u>89</u> 28	<u>119</u> 37	<u>112</u> 35	-	320
<i>P. pruinosa</i> + <i>P. diversifolia</i> - <i>Ammodendron Conollyi</i> Bunge + <i>Tamarix ramosissima</i> Ledeb + <i>Elaeagnus oxycarpa</i> L+	5	<u>0</u> 0	<u>112</u> 39,1	<u>174</u> 60,9	-	286
<i>P. pruinosa</i> + <i>P. diversifolia</i> - <i>Ammodendron Conollyi</i> Bunge	6	<u>0</u> 0	<u>90</u> 23,4	<u>294</u> 76,6	-	384
<i>P. pruinosa</i> + <i>P. diversifolia</i> + <i>Salix wilhelmsiana</i> Bieb+ <i>Salix alba</i> L+ <i>Salix triandra</i> L+ <i>Elaeagnus oxycarpa</i> L	7,8	<u>74</u> 20,1	<u>100</u> 27,2	<u>193</u> 52,5	-	367
<i>P. pruinosa</i> + <i>Salix alba</i> L- <i>Haloxylon aphyllum</i> (Minkw.)+ <i>Halimodendron halodendron</i> (Pall.)Voss+ <i>Calligonum commune</i> (Litv.) Mattei+ <i>Tamarix ramosissima</i> Ledeb	9	<u>0</u> 0	<u>0</u> 0	<u>48</u> 100	-	48
<i>P. pruinosa</i> - <i>Haloxylon aphyllum</i> (Minkw.)- <i>Halimodendron halodendron</i> (Pall.)Voss	10	0 0	0 0	<u>15</u> 100	-	15

Note: Values above the line indicate the number of individuals per 1,600 m² sample plot; values below the line indicate their percentage (%) of the total population

Table 2: Spatial and Age Structure of *Populus diversifolia* Coenopopulations

Plant community	Study site	Mean abundance and percentage (%) of <i>P. diversifolia</i> individuals by ontogenetic stage				Number of individuals per 1,600 m ² sample plot
		j	im	w- g	s	
<i>P. diversifolia</i> + <i>P. pruinosa</i> - <i>Elaeagnus oxycarpa</i> L+ <i>Tamarix ramosissima</i> Ledeb	1	<u>95</u> 13	<u>123</u> 18	<u>134</u> 65	<u>32</u> 4	384
<i>P. diversifolia</i> + <i>Elaeagnus oxycarpa</i> L+ <i>Halimodendron halodendron</i> (Pall.)Voss, + <i>Lycium ruthenicum</i> Murr	3	<u>68</u> 14	<u>86</u> 18	<u>295</u> 62	<u>29</u> 6	478
<i>P. diversifolia</i> + <i>Haloxylon aphyllum</i> (Minkw.)+ <i>Tamarix ramosissima</i> Ledeb + <i>Halimodendron halodendron</i> (Pall.)Voss	4	<u>16</u> 6	<u>64</u> 22	<u>204</u> 72	-	284
<i>P. diversifolia</i> + <i>P. pruinosa</i> + <i>Ammodendron Conollyi</i> Bunge + <i>Tamarix ramosissima</i> Ledeb + <i>Elaeagnus oxycarpa</i> L	5	<u>0</u> 0	<u>49</u> 23	<u>147</u> 69	<u>18</u> 8	214
<i>P. pruinosa</i> + <i>P. diversifolia</i> + <i>Ammodendron Conollyi</i> Bunge	6	<u>77</u> 17	<u>201</u> 44	<u>154</u> 34	<u>24</u> 5	456
<i>P. pruinosa</i> + <i>P. diversifolia</i> + <i>Salix wilhelmsiana</i> Bieb+ <i>Salix alba</i> L+ <i>Elaeagnus oxycarpa</i> L	7,8	<u>36</u> 14	<u>63</u> 24	<u>162</u> 62	-	261

Note: Values above the line indicate the number of individuals per 1,600 m² sample plot; values below the line indicate their percentage (%) of the total population

The Tartogai study site (Site 5) is located in the Shieli District and is characterized by sandy soils. The tree layer included *Populus pruinosa* Schrenk, *Populus diversifolia* Schrenk, *Ammodendron conollyi* Bunge, *Tamarix ramosissima* Ledeb., *Tamarix hispida* Willd., and *Elaeagnus oxycarpa* L. *Elaea* Rare Species gnus *oxycarpa* formed dense stands throughout the study area. Most Turanga trees were relatively old, with an average age of 55–60 years. Tree height ranged from 12 to 15 m, crown diameter from 6 to 9 m, and trunk diameter from 35 to 70 cm. Vegetative regeneration was well developed throughout the population. In the *Populus pruinosa* population, no juvenile (j) or senile (s) individuals were recorded. Immature individuals (im) accounted for 112 trees (39.1%), whereas virginile and generative individuals (v–g) comprised 174 trees (60.9%) (Table 1). The *Populus diversifolia* population also lacked juvenile individuals. Immature plants (im) accounted for 49 individuals (23%), virginile and generative individuals (v–g) for 147 (69%), and senile individuals (s) for 18 (8%). Regeneration at this site occurred exclusively through vegetative propagation (Table 2).

The Sulutobe study site (Site 6) is in the Shieli District and supports populations of both *Populus pruinosa* and *Populus diversifolia*. Compared with the previously described populations, the Turanga trees at this site were younger, ranging in age from 30 to 45 years. Tree height varied between 8 and 12 m, crown diameter between 4 and 5 m, and trunk diameter between 35 and 46 cm. Neither seed-derived seedlings nor vegetative shoots were observed during the survey. In addition, many trees exhibited symptoms of disease and pest damage. Most individuals were at the mature generative stage (g_2). In the *Populus pruinosa* population, neither juvenile (j) nor senile (s) individuals were recorded. Immature individuals (im) accounted for 90 trees (23.4%), whereas virginile and generative individuals (v–g) comprised 294 trees (76.6%) (Table 1). The *Populus diversifolia* population included 77 juvenile individuals (17%), 201 immature individuals (44%), 154 virginile and generative individuals (34%), and 24 senile individuals (5%) (Table 2).

The Shirkeyli (Site 7) and Baiten (Site 8) study sites are located near Kyzylorda City. Compared with the previously described sites, the tree and shrub vegetation was considerably denser. Both Turanga species (*Populus pruinosa* and *Populus diversifolia*) were well represented, together with several *Salix* species, including *Salix alba* L., *Salix triandra* L., and *Salix wilhelmsiana* M. Bieb., as well as *Elaeagnus oxycarpa* L. and *Halimodendron halodendron* (Pall.) Voss. The herbaceous layer consisted of a diverse assemblage of herbaceous species. Most Turanga trees were between 15 and 25 years old, although scattered individuals aged 40–45 years were also present. The riparian woodland extended along both banks of the Syr Darya River, forming a belt approximately 60 m wide. In the *Populus pruinosa* population, the ontogenetic structure comprised 74 juvenile individuals (20.1%), 100 immature individuals (27.2%), and 193 virginile and generative individuals (52.5%) (Table 1). Tree height ranged from 6 to 11 m, while trunk diameter varied between 23.5 and 48 cm. Both seed reproduction and vegetative propagation were observed. The *Populus diversifolia* population included 36 juvenile individuals (14%), 63 immature individuals (24%), and 162 virginile and generative individuals (62%), whereas senile individuals were absent (Table 2).

The Kargalym study site (Site 9) is located in Compartment No. 68 of the Torangylsai Nature Reserve in the Syrdarya District. The terrain is flat and lies along the former channel of the Zhanadarya River. The soils are alluvial meadow and sandy. The natural tree layer consists of *Haloxylon persicum* Bunge ex Boiss. & Buhse, *Haloxylon aphyllum* (Minkw.) Iljin, *Calligonum commune* (Litv.) Mattei, *Tamarix ramosissima* Ledeb., *Elaeagnus oxycarpa* L., and *Halimodendron halodendron* (Pall.) Voss. Introduced tree species included *Salix caspica* Pall., *Salix caprea* L., and *Populus nigra* L.

The canopy of *Populus pruinosa* was relatively open, and the species occurred only sporadically within the 1,600 m² sample plots. No juvenile individuals were recorded, and the population consisted entirely of old generative trees (g_3). Tree height ranged from 26 to 38 m, trunk diameter from 36 to 42 cm, and crown diameter from 4 to 5 m. Most trees exhibited extensive dead branches and reduced leaf size. Virginile and generative individuals (v–g) accounted for all recorded trees (48 individuals; 100%), whereas no other ontogenetic stages were observed (Table 1).

The Koshshynyrau study site (Site 10) is located approximately 15 km from Kargalym in Compartment No. 70 of the Torangylsai Nature Reserve. The terrain is flat and characterized by solonchic and sandy soils. The upper tree layer was dominated by *Populus pruinosa* Schrenk (7–8 m in height), whereas the shrub layer consisted mainly of *Halimodendron halodendron* (Pall.) Voss (1.5–2.0 m) and *Tamarix hispida* Willd. (2.5–3.0 m). Herbaceous vegetation was sparse, and species diversity was lower than that recorded at the Kargalym study site. Among the tree species, only *Populus pruinosa* was present. Natural regeneration was extremely limited. Only a small number of root suckers was observed, most of which were at the immature stage. Virginile and generative individuals (v–g) accounted for all recorded trees (15 individuals; 100%), whereas no other ontogenetic stages were observed (Table 1).

The Kamyshlybash study sites (Sites 11 and 12) and adjacent areas near the Aral Sea were also surveyed. According to [26], *Populus pruinosa* and *Populus diversifolia* formerly occurred in this region. However, no living individuals of either species were recorded during the present survey. During soil sampling, a Turanga stump containing 17 annual growth rings was discovered at a depth of approximately 70 cm, confirming the former presence of Turanga populations in the area.

Based on the ontogenetic structure of the investigated populations, *Populus pruinosa* coenopopulations were classified as expanding (Sites 1, 2, 7, and 8) or regressive (Sites 5, 6, 9, and 10). Likewise, *Populus diversifolia* populations were classified as expanding stable (Sites 1, 3, 4, 6, 7, and 8) or regressive (Site 5).

The results indicate that the current reduction in the distribution range of Turanga species is primarily associated with insufficient water availability and increasing anthropogenic pressure.

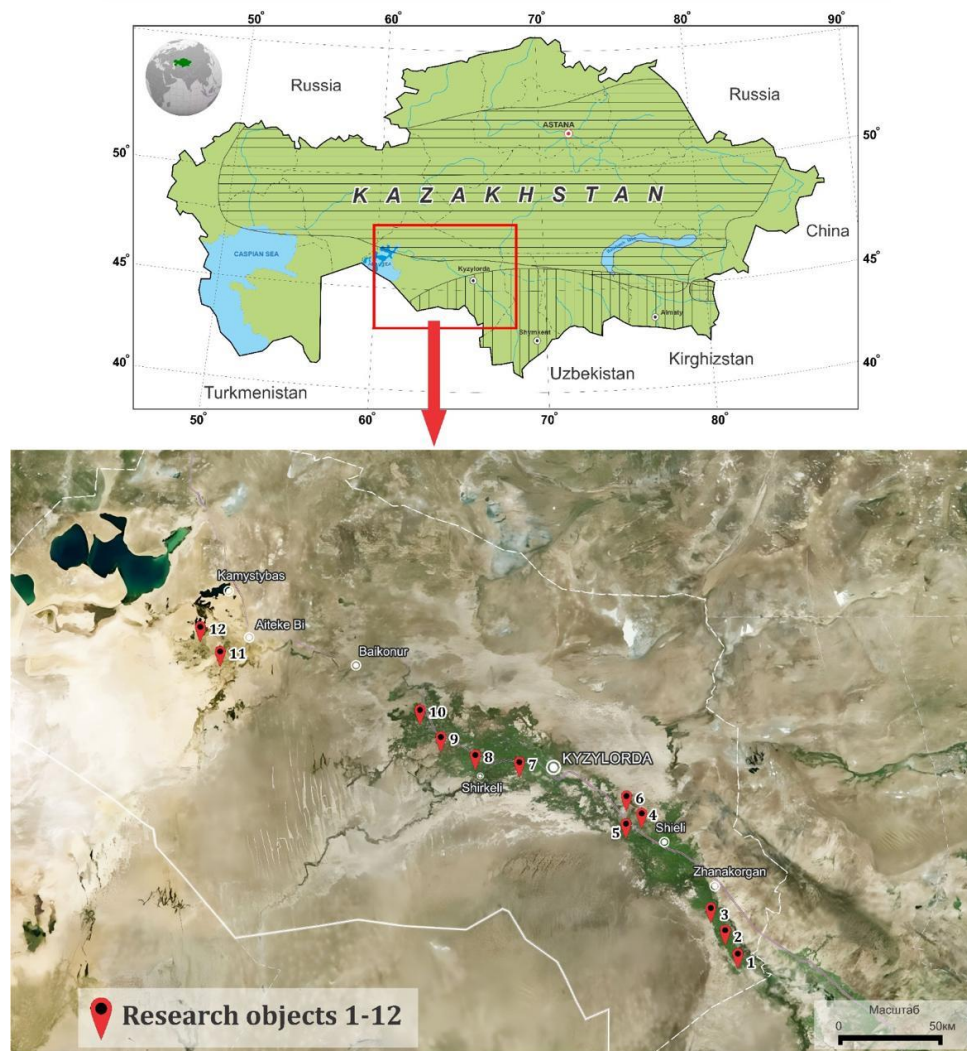


Fig. 3: Location of the study sites in Kyzylorda Region (2023–2024)

Ontogeny of Turanga Species (*Populus diversifolia*, *Populus pruinosa*)

Laboratory and field observations were conducted to investigate the early developmental stages and growth dynamics of Turanga species.

Latent period Seeds (sm): *Populus diversifolia* Schrenk begins seed dispersal in late May and early June. The seeds are covered with silky hairs that are approximately three to four times longer than the seeds themselves, facilitating long-distance wind dispersal. Under favorable moisture conditions, the seeds rapidly absorb water after reaching the soil surface. According

to the observations, seed germination began within 3–4 h at temperatures of 35–38°C. The apical part of the embryo is covered with hairs that facilitate attachment to the soil surface. During the initial stages of germination, one primary root and three lateral roots develop. The hypocotyl is thick and succulent and bears two prominent cotyledons at its apex.

Latent period Seeds (sm): *Populus pruinosa* Schrenk begins seed maturation between 10 and 20 June. The seeds are 0.7–0.9 mm long and 0.4–0.6 mm wide and are orange-gray in color.

One end of each seed is covered with hairs measuring 2.6–3.0 mm in length, which facilitate wind dispersal after seed maturation. Following dispersal, the seeds readily absorb moisture from the soil and begin to germinate within 4–6 hours at temperatures of 35–38°C. Under laboratory conditions, germination was observed after 3–4 hours at 40–45°C. Depending on temperature, rupture of the seed coat occurred within 7–10 hours after water uptake.

The apical region of the embryo is covered with fine hairs that anchor the seedling to the soil surface during early development. The primary root develops first, followed by the formation of three lateral roots, indicating that seedlings of *Populus pruinosa* establish a taproot system with three secondary roots. The hypocotyl is thick and succulent and bears two prominent cotyledons, which are unequal in thickness. Approximately 15–18 hours after germination, rapid cell division beneath the rhizoderm initiates the differentiation of vascular tissues. True roots become fully developed and anchored in the soil within 22–26 hours. The shoot apex appears after approximately 5–8 days, after which rapid elongation of the stem begins in response to geotropic growth. The first true leaves emerge within 10–15 days after germination.

Pregenerative Stage

Seedling Stage (pl)

***Populus diversifolia* Schrenk**

Populus diversifolia Schrenk seedlings produce their first true green leaves approximately 10–20 days after germination. These leaves remain functional throughout the first growing season. During the first 30–40 days of development, the primary root grows rapidly, reaching a length of 6–7 cm and extending to 15–18 cm by the end of the growing season. At this stage, the aboveground shoot reaches a height of 4–5 cm, while the hypocotyl diameter ranges from 1.0 to 1.5 mm.

During the first year of development, two to three primary lateral roots are formed, whereas the main components of the root system continue to develop during subsequent years. In the second year of growth, new shoots develop from the apical buds, and the leaves become lanceolate, resembling those of willow species.

***Populus pruinosa* Schrenk**

Approximately 15–18 days after germination, the first leaves of *Populus pruinosa* seedlings become smaller than the leaves produced during subsequent stages of development.

During the first 1.5–2 months, the root system develops rapidly, reaching a length of 7–12 cm. After approximately 2.5 months, the growth rates of the aboveground and belowground organs become more uniform. Overall, the seedling growth rate of *P. pruinosa* is lower than that of *P. diversifolia*. The first leaves are broad, with leaf blades averaging 1.5 ± 0.873 cm in length and approximately 0.5 cm in width.

Juvenile Stage (j)

***Populus diversifolia* Schrenk**

Juvenile individuals of *Populus diversifolia* originate from both seeds and root suckers. The aboveground shoots reach a height of 7–10 cm. The depth to the compact soil layer restricting root penetration ranges from 9 to 15 cm. By the end of the growing season, each shoot bears approximately 15–18 leaves. The shoots are cylindrical, the root collar is slightly inclined, and the stem is light pink in color.

Seasonal flooding in early spring exposes the hypocotyl by removing up to 15 cm of the upper soil layer. Vegetative regeneration occurs through horizontal roots located at a depth of 60–65 cm (Figure 6).

***Populus pruinosa* Schrenk**

Juvenile individuals of *Populus pruinosa* originate from seeds. The aboveground shoots reach a height of approximately 15–22 cm. By the end of the growing season, each shoot bears 15–18 ovate leaves. At this stage, the plant develops a single

vegetative shoot. The hypocotyl and primary taproot are 7–10 cm long. The juvenile stage lasts approximately 1–3 years (Figure 4).

Immature Stage (im)

Populus diversifolia Schrenk

Immature individuals of *Populus diversifolia* are typically three years old, reaching an average height of 16 cm, a crown diameter of 12 cm, and a stem diameter of 0.48 cm. As the root collar and hypocotyl become buried to a depth of 1.5–12 cm, secondary buds develop, stimulating root and shoot branching.

Seasonal increases in the water level of the Syr Darya River during spring and autumn may adversely affect immature individuals aged 3–4 years. Prolonged flooding damages the lateral roots and suppresses growth at the root apex. Aboveground shoots subsequently regenerate from dormant buds. At this stage, four-year-old individuals attain a height of approximately 10 cm, while the root collar diameter reaches 0.63 cm.

Repeated flooding promotes further burial of the hypocotyl, resulting in thickening of the root collar. Root branching in four-year-old plants remains relatively weak until secondary lateral roots become fully established.

In five-year-old immature individuals growing in areas where the groundwater table occurs at a depth of 170–220 cm, the underground portion of the root system branches to approximately 35 cm. The aboveground shoot reaches a diameter of about 2.5 cm, whereas the root collar diameter averages 1.1 cm. The basal portion of the primary root bends downward, extending obliquely for approximately 12 cm before penetrating the sandy-clay substrate to a depth of 220 cm. Secondary roots develop from dormant buds on the underground shoots, resulting in the formation of a well-developed branched root system.

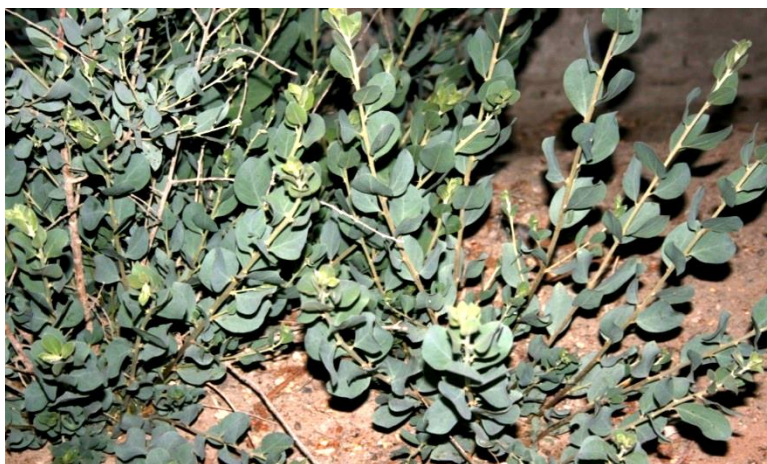


Fig. 4: *P. pruinosa* juvenile (j) period



Fig. 5: *P. pruinosa* virginil (w) stage

***Populus pruinosa* Schrenk**

Immature plant (im) of *Populus pruinosa* are typically four years old and attain a height of 12–18 cm. As the root collar and hypocotyl become buried to a depth of 2–10 cm, secondary buds develop, promoting increased branching of the immature plant.

Numerous immature individuals propagated through root suckers were observed in the Kyzylorda Region. Under favorable groundwater conditions, root suckers produce abundant buds, resulting in the development of shrub-like immature plants.

In four- to five-year-old immature individuals growing in areas where the groundwater table occurs at a depth of 170–220 cm, the root system branches to a depth of approximately 35–40 cm, while the aboveground shoots reach a diameter of 18–25 cm. The basal portion of the primary root bends downward, extending obliquely for approximately 12 cm before penetrating the sandy-clay substrate to a depth of 220 cm. Secondary roots arise from dormant buds on the underground shoots, together with the primary root forming a well-developed branched root system.

Morphologically, *P. pruinosa* is similar to *P. diversifolia* but differs in stem coloration and leaf morphology.

Virginile Stage (v)

Populus diversifolia Schrenk. Virginile plants are fully developed vegetative individuals that have not yet reached the reproductive stage. This ontogenetic stage includes individuals originating from both seeds and vegetative propagation, with no significant biomorphological differences observed between the two groups. However, individuals produced vegetatively generally develop a greater aboveground biomass. At approximately seven years of age, plants reach 115–120 cm in height, with a crown diameter of 85–90 cm and a root collar diameter of about 2 cm. The basal portion of the stem is buried approximately 5 cm below the soil surface. A well-developed taproot extends horizontally for 40–45 cm before penetrating vertically toward the groundwater table.

Populus pruinosa Schrenk. Virginile plants closely resemble mature trees in overall morphology but have not yet entered the reproductive phase. Branching of the main stem is intensive, and the leaves are broadly ovate in shape. Under natural conditions, the virginile stage generally lasts from 6 to 9 years (Figure 5).

III. Generative stage. Generative plants (g). *Populus diversifolia* Schrenk: Adult trees of *P. diversifolia* are capable of producing flowers and seeds; however, the duration of their reproductive period has not yet been clearly established. Under normal coenotic conditions, some individuals may continue vegetative growth for up to seven years before entering the flowering stage.

g_1 subgroup. Young generative plants: These are relatively weakly growing plants. The leaves on the generative shoots are broadly ovate, with a broad triangular toothed apex and two to four lateral teeth. Leaves on the vegetative shoots are lanceolate, with entire or occasionally serrated margins. Vegetative buds are orange-grey, whereas generative buds are orange. The flowers are arranged in catkins.

g_2 subgroup. Mature generative plants: This subgroup consists of vigorous, fully developed trees with abundant flowering. Under favorable environmental conditions, they are capable of vegetative propagation through root suckers (Fig. 7).

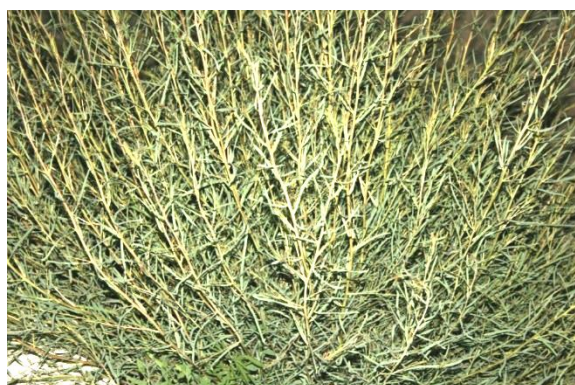


Fig. 6: The leaves are bloody *Populus diversifolia* juvenile (j). Stage



Fig. 7: *Populus diversifolia* generative stage (g2)

g_3 subgroup. Old generative plants: This subgroup includes aging trees with partially dead branches and reduced shoot vitality. Flowering and seed production remain abundant. Bud break occurs later in spring than in younger mature trees, and the leaves are smaller.

III. Generative stage. Generative plants (g). *Populus pruinosa* Schrenk: Adult trees of *P. pruinosa* begin producing generative shoots and viable seeds at approximately 9–10 years of age.

The above results were obtained from long-term observations of natural coenopopulations of *Populus diversifolia* and *Populus pruinosa*.

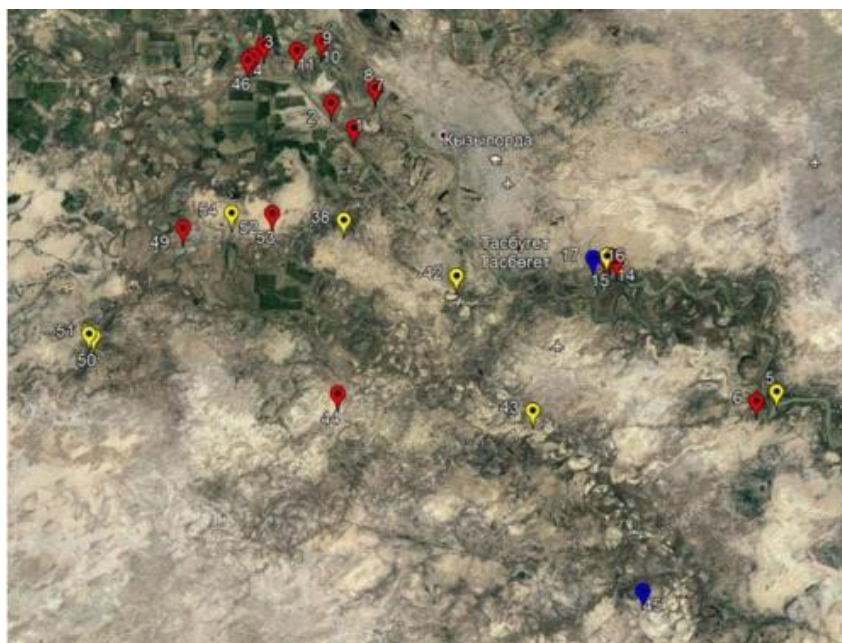
Discussion

The research was conducted in Kyzylorda Region, Republic of Kazakhstan. Kyzylorda Region is known for its environmental problems associated with the Turan Depression, the Aral Sea, and the Baikonur Cosmodrome. Field expeditions were carried out in six districts of Kyzylorda Region (Shieli, Zhanakorgan, Syrdarya, Karmakshy, Kazaly, and Aral) as well as in Kyzylorda City. Collectively, these territories constitute the lower reaches of the Syr Darya River.

Among the Turanga species occurring in Kazakhstan are *Populus diversifolia* Schrenk, *Populus pruinosa* Schrenk, and *P. litwinowiana*. Two of these species, *Populus diversifolia* Schrenk and *Populus pruinosa* Schrenk, occur in Kyzylorda Region. The distribution, biology, and ecology of these species in Kazakhstan have been studied by [25]. [25, 26]. In previous centuries, Turanga poplars occupied much larger areas in Kazakhstan than they do today. Several researchers have mapped the historical distribution of Turanga species. According to [25], *Populus diversifolia* and *P. pruinosa* were distributed across southern, northern, eastern, and western Kazakhstan (Figure 1). According to [26], Turanga species had a much wider distribution and higher productivity in Kyzylorda Region than they do at present. Their map shows that Turanga populations were widespread in the southern part of Kyzylorda Region, whereas their distribution gradually decreased toward the Kazaly and Aral districts in the west (Figure 2).

Using modern geographic information systems and remote sensing methods, the main vegetation communities of artificial reservoirs in the lower Syr Darya River were investigated. Turanga species were recorded in the Torangysay and Zhaskairat canals of Kyzylorda Region. However, no Turanga populations were found in the Aral Sea region, including the areas of Tushchybas, Kamystybas, Kokkol, Zhaltyrkol, Kokshekol, Makpalkol, Raimkol, Zhalanashkol, Kobekty Marsh, Taldyral Marsh, the Kuli, Kayazdy, Zhyngyldy, and Laikol rivers (Figure 3). These findings indicate that the distribution range of Turanga species has considerably contracted, primarily as a consequence of the substantial reduction in the flow of the Syr Darya River.

For the coenopopulation study of Turanga species, ten study sites were selected. According to the data presented in Table 1, Juvenile individuals (j) were recorded at four sites, whereas they were absent at the remaining six sites. This pattern may be explained by two factors: drought conditions during the initial stage of the study and a low groundwater level. In addition, Senile individuals (s) were absent or occurred only rarely in the coenopopulations examined at all study sites (Table 1). This indicates that the coenopopulations of Turanga species in the study area are dominated by younger age classes and remain capable of regeneration.



Note: Red color: *Populus pruinosa*; yellow color: *Populus diversifolia*; blue color: Co-growing *Populus pruinosa* and *P. diversifolia* [6]

Fig. 8: Map of the Syr-Darya valley with an indication of research points in the vicinity of Kyzylorda city

Studies conducted in the Zhanakorgan and Shieli districts of Kyzylorda Region indicate that the reduction in the distribution of Turanga species is associated with the absence of spring flooding of the Syr Darya River, harvesting of trees for fuelwood, livestock grazing in tugai forests, high recreational pressure, and the occurrence of wildfires [39]. Furthermore, the distribution map compiled for Kyzylorda City (Figure 8) shows that Turanga species are concentrated mainly along the Syr Darya River. *Populus pruinosa* was found to be more common than *Populus diversifolia*, whereas mixed stands containing both *Populus pruinosa* and *P. diversifolia* were reported to be rare [6]. In contrast, our study frequently recorded mixed stands of *Populus pruinosa* and *P. diversifolia* in the Zhanakorgan and Shieli districts. Overall, our survey covered the entire Kyzylorda Region and demonstrated that Turanga species have disappeared completely from the Aral and Kazaly districts, whereas viable populations remain concentrated along the Syr Darya River in the Zhanakorgan, Shieli, Kyzylorda, and Syrdarya districts.

The phenological development of Turanga species remains insufficiently studied [39]. Previous studies have described the biometric characteristics of *Populus pruinosa* and *Populus diversifolia*, including leaf morphology and its seasonal variation [26, 28, 39, 40]. These studies demonstrated that leaf morphology varies considerably throughout the growing season. In the present study, the biometric characteristics of leaves were measured and documented photographically at each phenological stage during the growing season.

Conclusion

The present study showed that *Populus diversifolia* and *Populus pruinosa*, which belong to the Turanga section, are important rare relict components of the desert and tugai ecosystems of southwestern Kazakhstan. Their distribution is mainly confined to river floodplains, ancient riverbeds, sandy massifs, and saline areas extending from the Aral Sea region to the Balkhash-Alakol depression. Analysis of the literature and field observations confirmed that these species possess xerohalophytic traits that enable them to tolerate high temperatures, soil salinity, and prolonged drought. Their morphological and anatomical characteristics, water-use efficiency, and physiological stability indicate well-developed survival strategies under arid conditions.

Field studies conducted in 12 communities under different ecological conditions in the Kyzylorda Region revealed the current state and regeneration characteristics of the coenopopulations of *Populus pruinosa* and *Populus diversifolia*. The distribution of both species was found to be mainly associated with the floodplains and ancient channels of the Syr Darya River. Population stability depends on the hydrological regime, soil conditions, and the level of anthropogenic pressure. Expanding and normal coenopopulations were recorded at the Korgantogai, Bekman Togai, Shirkeyli, and Baiten sites, where

natural regeneration was relatively successful. In contrast, the populations at the Tartogai, Sulutobe, Kargalym, and Kosh Shyngyrau sites were classified as regressive, as the absence or very low number of juvenile individuals indicates weakened natural regeneration.

The results showed that the conservation prospects of Turanga populations in the Kyzylorda Region differ considerably between species and study sites. For *Populus pruinosa*, expanding coenopopulations were identified at sites 1, 2, 7, and 8, whereas regressive coenopopulations were recorded at sites 5, 6, 9, and 10. For *Populus diversifolia*, expanding and normal coenopopulations were recorded at sites 1, 3, 4, 6, 7, and 8, while a regressive coenopopulation was identified at site 5. In communities consisting mainly of mature individuals, the absence of natural regeneration increases the risk of further degradation. Therefore, the conservation of regressive populations requires comprehensive protection measures, including artificial restoration, propagation through seeds and root suckers, preservation of the hydrological regime, and the limitation of anthropogenic pressure.

Ontogenetic studies showed that the developmental cycle of *Populus diversifolia* and *Populus pruinosa* includes latent, pregenerative, and generative stages. Under favorable temperature and moisture conditions, the seeds of both species germinate rapidly, while the first years of development are characterized by intensive root system formation. This feature represents an important adaptive mechanism in desert floodplain ecosystems. Natural regeneration occurs through both seed reproduction and vegetative propagation by root suckers; however, its intensity depends largely on hydrological conditions, especially groundwater levels and spring flooding. *Populus diversifolia* enters the generative stage at approximately seven years of age, whereas *Populus pruinosa* reaches this stage at 9–10 years. Seed reproduction is possible only when male and female individuals grow together or occur in mixed populations, whereas under natural conditions vegetative reproduction through root suckers is more common.

The obtained results provide a scientific basis for developing conservation and restoration strategies for Turanga species in the Kyzylorda Region and for protecting rare tugai ecosystems under conditions of increasing aridization and anthropogenic pressure.

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Author's Contributions

Baikenzheyeva Ainur: Designed the study and supervised the research.

Rakhat Kurmanbayev: Coordinated the project and served as the corresponding author.

Toktaganova Gulzhas, Berdenkulova Almagul and Zharmenova Botagoz: Conducted field investigations and data analysis.

Childibayev Jumadil: Supervised laboratory experiments and methodological validation.

Bozshataeva Gulshatand Turabaeva Gulzat: Assisted in data processing and manuscript preparation.

All authors read and approved the final manuscript.

Ethics

The authors declare that there are no conflicts of interest regarding the publication of this manuscript. All research procedures were conducted in accordance with institutional and national ethical standards.

References

1. Rzymiski, P., Klimaszyk, P., Niedzielski, P., Marszelewski, W., Borowiak, D., Nowiński, K., Baikenzheyeva, A., Kurmanbayev, R., & Aladin, N. (2019). Pollution with trace elements and rare-earth metals in the lower course of Syr Darya River and Small Aral Sea, Kazakhstan. *Chemosphere*, 234, 81–88. <https://doi.org/10.1016/j.chemosphere.2019.06.036>

2. Klimaszyk, P., Kuczyńska-Kippen, N., Szeląg-Wasielewska, E., Marszelewski, W., Borowiak, D., Niedzielski, P., Nowiński, K., Kurmanbayev, R., Baikenzheeva, A., & Rzymiski, P. (2022). Spatial heterogeneity of chemistry of the Small Aral Sea and the Syr Darya River and its impact on plankton communities. *Chemosphere*, 307, 135788. <https://doi.org/10.1016/j.chemosphere.2022.135788>
3. Ge, Y., Wu, N., Abuduwalli, J., Kulmatov, R., Issanova, G., & Saparov, G. (2022). Identifying Seasonal and Diurnal Variations and the Most Frequently Impacted Zone of Aerosols in the Aral Sea Region. *International Journal of Environmental Research and Public Health*, 19(21), 14144. <https://doi.org/10.3390/ijerph192114144>
4. Ma, L., Abuduwalli, J., Smanov, Z., Ge, Y., Samarkhanov, K., Saparov, G., & Issanova, G. (2019). Spatial and Vertical Variations and Heavy Metal Enrichments in Irrigated Soils of the Syr Darya River Watershed, Aral Sea Basin, Kazakhstan. *International Journal of Environmental Research and Public Health*, 16(22), 4398. <https://doi.org/10.3390/ijerph16224398>
5. SIC ICWC. (2017). *Water Yearbook: Central Asia and Around the Globe. Section 2. Water management situation in the Aral Sea basin.* CAWater-Info / SIC ICWC Series.
6. Vesselova, P., Makhmudova, K., Makhmudova, K., Kudabayeva, G., Osmonali, B., & Mikhalev, V. (2022). Current Growth Conditions of *Populus Diversifolia* Schrenk and *Populus Pruinosa* Schrenk in the Syr-Darya Valley. *OnLine Journal of Biological Sciences*, 22(4), 425–438. <https://doi.org/10.3844/ojbsci.2022.425.438>
7. Klimov, A. V., & Proshkin, B. V. (2024). Origin and Evolution of the Genus *Populus* L. (Family Salicaceae) (Proiskhozhdenie i evolyutsiya roda *Populus* L. (semeystvo Salicaceae)). *Environment and Human: Ecological Studies (Sreda i Chelovek)*, 14(2), 205–238. <https://doi.org/10.31862/2500-2961-2024-14-2-205-238>
8. Liu, X., Wang, Z., Wang, W., Huang, Q., Zeng, Y., Jin, Y., Li, H., Du, S., & Zhang, J. (2022). Origin and evolutionary history of *Populus* (Salicaceae): Further insights based on time divergence and biogeographic analysis. *Frontiers in Plant Science*, 13, 1031087. <https://doi.org/10.3389/fpls.2022.1031087>
9. Dimeyeva, L., Islamgulova, A., Permitina, V., Ussen, K., Kerdyashkin, A., Tsyhuyeva, N., Salmukhanbetova, Z., Kurmantayeva, A., Iskanov, R., Imanalilova, A., & Kaliyev, B. (2023). Plant Diversity and Distribution Patterns of *Populus pruinosa* Schrenk (Salicaceae) Floodplain Forests in Kazakhstan. *Diversity*, 15(7), 797. <https://doi.org/10.3390/d15070797>
10. Klimov, V. A., Belozernov, B., & Ishmuratova, M. Y. (2019). Indigenous poplars of the Republic of Kazakhstan (Translated from Russian: Aborigenyye topolya Respubliki Kazahstan). *Botanical Research of Siberia and Kazakhstan*, 1(331), 32–41. <https://doi.org/10.32014/2019.2518-1629.5>
11. Tsarev, A. P. (2019). Biology-structural features and paleoorigin of the genus *Populus* L. (Review). *Forest Bulletin*, 23(132), 121–126. <https://doi.org/10.18698/2542-1468-2019-2-121-126>
12. Veselova, P. V., Kudabaeva, G. M., & Osmonali, B. B. (2021). To the study of coenoflora of Turangian relict light forests of the middle course of the Syrdarya river//*Bulletin of the Karaganda University. Bulletin of the Karaganda University. Biology. Medicine. Geography Series*, 103(3), 31–40.
13. Veselova, P. V., Kudabaeva, G. M., Osmonali, B. B., Shormanova, A. A., Nelina, N. V., Abdildanov, D. Sh., & Usen, S. (2023). Influence of disturbance factors on the composition and structure of vegetation in the desert part of the syrdarya river valley (kyzylorda region). *Experimental Biology*, 104(3), 125–138. <https://doi.org/10.26577/bb2025104310>
14. Turalin, B. A. (2023). Comparison of the anatomical structure of two populations of the relict species *Populus pruinosa* Schrenk (Salicaceae Mirb.), growing in the Aktobe region. *Bulletin of the Karaganda University "Biology Medicine Geography Series"*, 109(1), 135–142. <https://doi.org/10.31489/2023bmg1/135-142>
15. Hasanova, G., & Imanbaeva, A. (2024). Composition and structure of populations of *Populus diversifolia* Schrenk in Mangistau conditions. *Eurasian Journal of Applied Biotechnology*, 3S. <https://doi.org/https://doi.org/10.11134/symposium.7>
16. stikhareva, T., Ivashchenko, A., Kirillov, V., & Rakhimzhanov, A. (2021). Floristic diversity of threatened woodlands of Kazakhstan formed by *Populus pruinosa* Schrenk. *Turkish Journal of Agriculture and Forestry*, 45(2), 165–178. <https://doi.org/10.3906/tar-2006-70>
17. Mustafaeva, R. M., Baikenzheeva, A. T., & Sadanov, A. K. (2008). Biology, ecology and economic significance of Poplars piglets (review). *Bulletin of the National Academy of Sciences of the Republic of Kazakhstan Almaty*, 5, 103–105.
18. Mustafaeva, R. M., Erbolatov, N. N., Sadanov, A. K., & Baikenzheeva, A. T. (2008). Torangilsai Reserve and Flora Protection Bulletin of the National Academy of Sciences of the Republic of Kazakhstan Almaty. *Bulletin of the National Academy of Sciences of the Republic of Kazakhstan*, 5, 100–102.
19. Mustafaeva, R. M., & Baikenzheeva, A. T. (2019). Range and ecological phytocenological distribution of poplars TURANGA (Kyzylorda region). *Collection of Materials of the International Scientific and Practical Conference "The Role of Natural Sciences in Sustainable Development: Proposals, Theories and Technologies"* Atyrau, 162–164.
20. Mikhailenko, N., Turdiyev, T., Kentbaeva, B., Tuigunov, Z., & Kushnarenko, S. (2025). Adaptation of in vitro turanga-poplar plants to greenhouse conditions. *Fundamental and Experimental Biology*, 11830(2), 26–33. <https://doi.org/10.31489/2025feb2/26-33>
21. Hasanova, G. G. (2022). Study and prospects of the rare species *Populus diversifolia* Schrenk in arid conditions of Mangistau. *Proceedings of the International Scientific and Applied Conference «Study, Conservation and Rational Use of the Plant World of Eurasia»*, 286–289. <https://doi.org/10.37770/2712-7656-2021-3-5-19>
22. Sharma, S., Dobbal, S., Kumar, R., & Thakur, S. (2020). Morphological, physiological and molecular analysis of Line × Tester in *Populus deltoides* Bartr. *Plant Physiology Reports*, 25(1), 87–106. <https://doi.org/10.1007/s40502-019-00479-3>
23. Desert Poplar. (2017). *Desert Poplar (Populus pruinosa) LC.* Museum of Fine Arts, Boston. [https://cameo.mfa.org/wiki/Desert_Poplar_\(Populus_pruinosa\)_LC](https://cameo.mfa.org/wiki/Desert_Poplar_(Populus_pruinosa)_LC)
24. Rakhimzhanov, A., Ivashchenko, A., Kirillov, V., Aleka, V., & Stikhareva, T. (2021). Assessment of the current status of the turanga forests in the south-east of Kazakhstan. *Eurasian Journal of Ecology*, 67(2), 86–96. <https://doi.org/10.26577/eje.2021.v67.i2.09>
25. Sokolov, S. Ya. (1951). *Trees and shrubs of the USSR: Wild, cultivated and promising for the introduction of T.2. Angiosperms. 2.*
26. Besschetnov, P. P., & Grudinskaya, L. M. (1981). *Turanga Poplars of Kazakhstan.*
27. Dlimbetova, G., Kurmanbayev, R., Akimish, D., Toktaganova, G., & Zharmenova, B. (2023). The effectiveness of socio-economic mechanisms in environmental education of young people in Kazakhstan. *Economic Annals-XXI*, 203(5–6), 59–69. <https://doi.org/10.21003/ea.v203-07>

28. Grebenyuk, N. P., Sapozhnikova, T. F., & Kondratyeva, N. A. (2017). Phenological features of tree species of the genus *Populus* in the conditions of central Russia//Forestry. Forestry (Lesnoye Khozyaystvo / Lesnoe Khozâjstvo), 6, 19–13.
29. Sidorov, V. N., Lebedeva, M. S., & Akhmetov, I. F. (2020). Phenology of species of the genus *Populus* in North. Asian Regions//Siberian Ecological Journal, 3, 51–44.
30. Makhanova, A. K., & Musaev, K. B. (2019). Influence of climatic conditions on the growth and development of introduced tree species in the conditions of the south of Kazakhstan//Vestnik KazNU. Biological Series, 79(2), 70–64.
31. Zhai, J., Li, Z., Zhang, S., Han, X., & Li, X. (2022). Differences in the structural and functional traits of *Populus euphratica* and *Populus pruinosa* with tree height. Applied Ecology and Environmental Research, 20(4), 3597–3617. https://doi.org/10.15666/aeer/2004_35973617
32. Zhai, J., Zhang, X., Li, Z., Han, X., & Zhang, S. (2023). Differences in the Functional Traits of *Populus pruinosa* Leaves in Different Developmental Stages. Plants, 12(12), 2262. <https://doi.org/10.3390/plants12122262>
33. Chen, X. X., Gai, Z. S., Zhai, J. T., Wu, Z. H., & Li, Z. J. (2022). Phenotypic variation of natural *Populus pruinosa* Schrenk populations shaped by geographical and climatic factors. Applied Ecology and Environmental Research, 20(2), 1065–1083. https://doi.org/10.15666/aeer/2002_10651083
34. Uranov, A. A., & Zaugolnova, yudmila B. (1977). Tsenopopulyatsii rastenii (razvitie i vzaimootnosheniya) [Plant Coenopopulations: Development and Interrelationships.
35. Smirnova, O. V., Zaugolnova, L. B., & Ermakova, I. M. (1976). Tsenopopulyatsii rastenii: osnovnye ponyatiya i struktura [Plant Coenopopulations: Basic Concepts and Structure.
36. Mustafaeva, R. M. (2008). Density and age spectrum of lattices in the zones of the lower reaches of the Syrdarya River. Bulletin of the National Academy of Sciences of the Republic of Kazakhstan, 6, 85–87.
37. Zhivotovsky, L. A. (2001). Ontogenetic States, Effective Density, and Classification of Plant Populations. Russian Journal of Ecology, 32(1), 1–5. <https://doi.org/10.1023/a:1009536128912>
38. Fay, N., & Berker, N. de. (2018). A review of the theory and practice of tree coring on live ancient and veteran trees.
39. Ahataeva, A. D., Inelova, A. Z., Veselova, V. P., Kudabaeva, G. M., Osmonali, B. B., Satybaldieva, K. G., Zaparina, E. G., Ajtzhani, M. U., & Boros, E. (2025). Comparative analysis of the current state of *Populus pruinosa* Schrenk populations in the desert part of the Syrdarya River Valley. Bulletin of the ZKU, 2(98), 511.
40. Medvedeva, E. Y., & Srodnykh, T. B. (2014). Phenological development of poplars in ekaterinburg. Agrarian Bulletin of the Urals, 3(121), 56–59.