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REFORESTATION POTENTIAL OF TUGAI FORESTS IN THE FLOODPLAINS OF SYR DARYA AND ILI RIVERS IN THE TERRITORY OF KAZAKHSTAN

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SUMMARY

In the present era, assumptions on tugai forests consist of a complex floodplain ecosystem (reed-cattail thickets, gallery forests, halophytic shrubs, and grass biocenoses) of various ecological levels located from the water's edge to the upper floodplains and riverine shafts. Anthropogenic transformations disrupted the natural dynamics of the tugai ecosystem. The presented study sought to characterize the current state of tugai forests in different regions of Kazakhstan to conduct monitoring of forest entomology and determine the reforestation potential of tugai plants in the floodplains of the Syr Darya and Ili rivers of Kazakhstan. The recent work focused on vital aspects associated with reinstating tugai forests. Special monitoring of forest pests progressed for the timely detection of their reproduction bulk, foci development, and plan extinction measures. The forest entomology monitoring results revealed the destruction of plants due to leaf-gnawing and gall-forming insect pests. A laid out 27 test areas investigated the dynamics of the undergrowth in tugai forests. The reproductive capacity of the plants, viz., *Populus diversifolia*, *Elaeágnus angustifólia*, *Sálix acutifólia,* and *Salix wilhelmsiana, attained evaluation*. Natural renaissance under the main forest-forming rocks' characterization in tugai plantations was good.

Keywords: Tugai forests, floodplain ecosystem, forest entomology, leaf-gnawing and gall-forming insect pests, reforestation, Syr Darya and Ili rivers

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Key findings: In the floodplains of the Syr Darya and Ili rivers of Kazakhstan, an assessment based on the tugai forests and their entomology ensued. The results of the forest entomology monitoring revealed the thrash of plants by leaf-gnawing and gall-forming insect pests. The reforestation features of the main forest-forming species' validation also materialized.

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INTRODUCTION

In the arid zones of Kazakhstan, the forest lands, particularly the tugai forests, need the most restoration (Treshkin, 2000). Presently, the term 'tugai' not only refers to forest biocenoses, but it also includes the entire complex of floodplain ecosystems (reed-cattail thickets, gallery forests, halophytic shrubs, and grass biocenoses) comprising various ecological levels from the water's edge to the upper floodplains (Alpysbaeva, 2018; Zeng *et al.*, 2020). Tugai also performs a protective role and provides biodrainage in swampy floodplain areas (Sizemskaya *et al.*, 2021). Central Asia seemed to be the center of origin for the Tugai forests, and later they moved to the deserts of Dzungaria and Kashgaria areas of China (Rachkovskaya *et al.*, 2003; Thevs *et al*., 2008).

In the former USSR, tugai of various degrees of desertification (including shrubs and grasses) have been preserved in floodplains and deltas of rivers in Central Asia, such as Amudarya, Zeravshan, Tejen, Murgab, Sumbar, Vakhsh, Syr Darya, Arys, Ili, Chu, and Leps (Umurzakova *et al.*, 2020). In the global trend of reduction in floodplain forests, the disappearance of tugai is simply catastrophic. Today, in Central Asia, the tugai forest areas account for less than 10% of the area occupied by them in the 1960s (Sadygov, 2017).

Disruptions in the natural dynamics of the tugai ecosystem have resulted from anthropogenic transformations of a direct (logging, potting, and fires) and indirect (river flow regulation) nature. A sharp shift in the general direction of the dynamic process has pointed to halophitization and desiccation—the loss of indigenous tugai trees and shrub communities everywhere; not only do groups of associations disappear, but also wholly separate formations of tugai vegetation, and the replacement of tree-shrub tugai with various types of grasses and halophytic communities that previously did not have such a large distribution (Zhang *et al.*, 2020).

For artificial reforestation of tugai, it is necessary to apply special tools of community restoration, depending upon the degree and nature of salinization of degraded soils and watering possibilities (i.e., water use with different qualities, such as, a river or collector drainage, as well as, the use of various humidification regimes of territories: from minimal, rare initial irrigation with a lack of water to annual artificial flooding). With limited use of collector-drainage water of weak and medium degrees of salinity, it is possible to create only halophytic variants of tugai. However, at the same time, with the use of river water in sufficient quantities, it is also possible to restore typical tugai ecosystems even in highly and deeply saline (up to 2.5 m) soil conditions (Rüger *et al.*, 2005).

In the past, the establishment and reforestation of young tugai occurred due to the floodplain regime of the Amudarya River. Presently, due to no surface flooding, the natural formation of young tugai massifs has practically stopped, and the resumption is mainly overgrown. The emergence of an extensive network of collector-drainage runoff contributed to the formation of small young tugai communities, but due to the lack of surface flooding and instability of the groundwater level, these tugai populations were unable to form stable stands, thus, being assessed as desertification (Dukenov *et al.*, 2022).

In tugai forests, reforestation and affirmation occur due to renewal in the regrowth processes (Kuzmina and Treshkin, 2012; Thomas *et al.*, 2017; Lipka *et al.*, 2021). For successful seed renewal in tugai forests, the major requirement and condition is the surface flooding of the near-forest facies, which makes possible the formation of stable stands. Turangi and willow seed germination became possible only if the time of sediment formation coincided with the timing of the spread of ripe seeds (July – August) and was not overgrown with other plant species. The presented study aimed to characterize the current state of tugai forests in different regions of Kazakhstan, conduct monitoring of forest entomology, and determine the reforestation potential of tugai plants in the floodplains of the Syr Darya and Ili rivers of Kazakhstan.

MATERIALS AND METHODS

Study area

The Almaty branch of KazNIILHA named after A.N. Bukeikhan LLP implemented the research within the framework of the Scientific and Technical Program "Development of Scientific Foundations for the Conservation and Improvement of the Sustainability of Forest Ecosystems in the Regions of Kazakhstan" for 2021–2023, under the budget program 267 "Increasing the Availability of Knowledge and Scientific Research," under subprogram 101 "Program-targeted Financing of Scientific Research and Activities" for 2021–2023.

Monitoring of forest entomology

The monitoring of forest insect pests comprised a unique supervision to detect their mass reproduction on time, predict the development of foci, and plan the extermination measures. Surveillance of forest insect pests is divided into reconnaissance and detailed. Reconnaissance surveillance consists of ocular and visual, a method of detecting the mass of insects eating leaves and other plant parts, and their ocular accounting. During the reconnaissance survey, a selection of three plots with an area of at least 10 ha of the same tax structure ensued. Judging the presence of insect pests in plantings was with the most characteristic and simplest signs, i.e., the presence of insects at different stages of their development, the damage caused by them, and signs specific to individual species: nests, feces, and leaves.

However, accurate digital data on population dynamics can be accessible with detailed supervision. At the same time, selecting areas of plantings where reconnaissance supervision has detected increased pests is most advisable. The part of each allotment, homogeneous in nature, should be at least 10 ha. An allocation includes one permanent test area of at least 0.1 ha (20 m × 50 m). Considering the pest wintering in the litter/soil, researchers divided the test area into five parts of 200 m^2 (20 m × 10 m), with the succeeding part accounted for annually.

Based on litter/soil, the researcher carefully looks at the depth of the pest and chooses not only its individuals but also other detected pests, pupae, and cocoons. In pest detection, the droppings of their larvae are a distinct common sign. Counting of overwintering eggs also occurred on the entire test area, with the results recalculated and averaged per tree, then multiplied by the number of trees per sample. In the presence of pest damage, the assessment of a forest tree's resistance to insect pests and pathogens can proceed on the scale of Ogorodnikov (Ogorodnikov, 1968) as follows:

5 points – single or no damage (1.0)
4 points – damage to no more than one-fourth of the plants (0.8)
3 points – average, periodic damage, mainly covers vegetative organs (0.6)
2 points – severe damage to at least half of the plants (0.4)
1 point – the damage is very severe and covers at least three-quarters of the plants, inhibiting growth and development (0.2)
0 point –plants died (0).

Estimating the stability of the plant species is by the mass population and the degree of damage.

Renewal process of tugai plantations

Laying down accounting platforms of 2 m × 5 m (or 1 m × 10 m) in 10 pieces assessed the natural renewal under the canopy of the tugai stand diagonally on the test area. The division of the younger generation of the forest consisted of seedlings, self-seeding, and undergrowth. Seedlings are those plants that appeared in the year of registration, and their age may be up to two years. According to Melekhov (Melekhov, 1954), self-seeding refers to "a younger generation of the forest than the undergrowth formed from it." After the calculation of self-seeding and undergrowth, further division was made by breed, indicating the origin (growth and seed), condition, and age category. Self-seeding also has characteristics of qualitative state, such as, healthy, sick, and dry.

RESULTS AND DISCUSSION

The current state of tugai forests in Kazakhstan

The presented research began with the development of scientific foundations for improving sustainability, restoring tugai forests, and afforestation in the southern regions of Kazakhstan. As a result of the progressive research, it is a conjecture that the woody and shrubby vegetation on the territory of the floodplain is unevenly distributed, i.e., willow, loch, and turangi plantations grow along the riverbed, reeds, licorice, and cereals occupying large areas of riverbed terraces, with the spaces overgrown with shrubs. If someone follows the breed composition of the tugai forests in the direction from the riverbed to the second terrace, then at first glance, they might see a large mosaic in the arrangement of

Table 1. The total area of Tugai forests in Kazakhstan by region (2018).

No.	Region	The total area of tugai forests (000 hectares)	Covered with forest (000 hectares)
1	Almaty	126580	60264
2	Zhambyl	16368	4166
3	Turkestan	60935	39874
4	Kyzylorda	45681	24962
Total		249564	129266

Figure 1. Tugai forests of the Syr Darya and Ili rivers, Kazakhstan.

Table 2. Dynamics of changes in the areas of Tugai forests from 1979 to 2018.

No.	Area	By year (1000 hectares)	
		1979	2018
1	Total area of tugai forests	472.7	233.1
2	Forested area	179.6	125.1

Figure 2. Reconnaissance survey of Tugai forests of the Ili River floodplains, Kazakhstan.

the plantings. The results of the reconnaissance survey and analysis of the areas occupied by tugai plantations appeared as follows: on the southern region territory of Kazakhstan, tugai forests occupy a total area of 249,564 ha, of which 129,266 ha have forest coverings. The total area of tugai forests and various extents of said forests are in Table 1 and Figure 1, respectively.

In 2018, the total area of tugai forests in the southern region of Kazakhstan was 51.8% of the overall coverage (Table 1). Tugai forests occupy 47.6% of the Almaty region, 25.5% of the Zhambyl region, 65.4% of the Turkestan region, and 54.6% of the Kyzylorda region. A comparative analysis of the dynamics of changes in tugai forest areas continued in the Almaty, Turkestan, and Kyzylorda regions from 1979 to 2018. The data analysis appears in Table 2, wherein it shows a significant decrease in the area of tugai forests by 50.7% and the area covered by forests by 30.3%. Therefore, it was necessary to develop scientifically sound proposals and recommendations to increase the sustainability of tugai forests through reforestation and afforestation in the face of enhanced anthropogenic impacts on the environment.

Monitoring of forest entomology in tugai plantations

Forest entomology surveys and monitoring pressed on in the tugai forests of the floodplain of the Syr Darya and Ili rivers of Kazakhstan. A reconnaissance survey, which is a visual method of detecting mass leaf-eating insects and their accounting, went on in the territory of tugai forests in the Otrar State Institution for the Protection of Forests and Wildlife of the Turkestan region and the Bakanasky forestry of the Almaty region of Kazakhstan (Figure 2).
The reconnaissance survey continued on selected sites in plantings characteristic of the occurrence of foci of harmful forest insects, and by inspecting the route passages crossing such plantings (Babayan, 2022; Saimova *et al*., 2022). The investigations ran according to

Table 3. Results of reconnaissance forest entomology survey of Tugai forests of the floodplain of the Syr Darya and Ili rivers, Kazakhstan.

Route number	Examination method	Terms of examination	Survey results	Degree of damage
Otrarskoe, Route # 1	Ground, visual	May-September	Damage to trees by leaf-gnawing, gall-forming pests was found. There are dead-hardy trees.	4 points – damage to no more than ¼ of the plants (0.8)
Otrarskoe, Route # 2	Ground, visual	May-September	Damage to trees by leaf-gnawing, gall-forming pests was found. There are dead-hardy trees.	4 points – damage to no more than ¼ of the plants (0.8)
Bakanaskoe, Route # 3	Ground, visual	May-September	Damage to trees by leaf-gnawing, gall-forming pests was found. There are dead-hardy trees.	4 points – damage to no more than ¼ of the plants (0.8)
Bakanaskoe, Route # 4	Ground, visual	May-September	Damage to trees by leaf-gnawing, gall-forming pests was found. There are dead-hardy trees.	4 points – damage to no more than ¼ of the plants (0.8)

Figure 3. Forest entomology monitoring in the Tugai forests of the floodplain of the Syr Darya and Ili rivers, Kazakhstan.

the most characteristic signs indicating the presence of harmful forest insects, i.e., the presence of insects at different stages of their development, the damage caused by them, as well as the signs specific to the individual species, viz., nests, feces, larvae, and leaf cores. The basis for assessing the degree of damage to the population stand was the scale of the tree conditions.

The results of the reconnaissance forest entomology survey of the tugai forests of the floodplain of the Syr Darya and Ili rivers are available in Table 3. During the reconnaissance survey of tugai forests in the floodplain of the Syr Darya and Ili rivers, the damage caused by leaf-gnawing and gall-forming insect pests showed validation in the dry-hardy and dry-top trees.

Also, a detailed forest entomology examination transpired in the tugai plantations of the floodplain of the Syr Darya and Ili rivers. During the inspection, the accounting for leaf-eating insect pests for their wintering phase of development advanced with the determination of quantitative and qualitative traits of the outbreak used in the development of forecasts (weight of pupae, size, weight of egg clutches and nests, the ratio of males and female pests, and the presence of their parasites and diseases) (Figure 3). In "Litvinov's and

Figure 4. The laying out of test areas to assess natural regeneration under the canopy of a stand.

Raznolistnaya Turanga," recording of the leaf damage caused by leaf beetles and leaf blocks ensued. Damage caused by leaf-eating insects to the foliage also showed on the silver loch. Root-gnawing insect pests (crustaceans) were visible in small quantities (less than one piece per square meter) (Babayan, 2022; Saimova *et al*., 2022). Also, according to a detailed examination, the average degree of damage by leaf-gnawing and gall-forming insect pests of "Litvinov's and Raznolistnaya Turanga" and the narrow-leaved loch was more than 50%.

Based on the exploration and detailed forest entomology examination findings, the sanitary condition of the tugai plantations was satisfactory. No active foci of insect pests and diseases were notable. In tugai forests, carrying out forest-cultural and forestry measures, including sanitary logging, cleaning of clutter, selection of places for forest crops that most fully meet the favorable conditions for plant growth, fulfillment of agrotechnical settings for growing the crops, and creation of mixed and rapidly closing plants are recommendable. All these measures also enhanced the resistance of forest plantations to damage caused by insect pests (Borisova *et al.*, 2016).

Reforestation of the major species in tugai forests and their natural renewal

As a result of active anthropogenic interference in the ecosystem, there have been noticeable variations toward the degradation of natural complexes, including tugai forests, characterized by a variety of different rich ecotypes and species of flora and fauna and having important hydrological, landscape, socioecological, economic, and biological significance. Therefore, over the past 60–70 years, the areas causing the depletion of biodiversity, soil degradation of adjacent territories, and intensification of the desertification process have significantly decreased. The reduction in the areas covered by forests also continues under the influence of abiotic and biotic stresses and anthropogenic factors because of insufficient natural renewal (Saparova, 2020).

The features of the natural regeneration underwent study under the canopy of the main forest-forming rocks. Assessing the natural renewal under the covering of the tugai population's stand on the diagonal of the test area laid out accounting platforms measuring 2 m × 5 m with 10 pieces (Figure 4). In the summer of 2021, employees

Table 4. Average biometric indicators and the amount of undergrowth under the main forest-forming species in Tugai plantations for 2021.

Variants	Breed / composition	Trunk length (cm)	Diameter of the barrel (cm)	Age	Number per 10 m^2 (pcs)	Total for 1 ha (pcs)
1	2	3	4	5	6	7
Ili River						
Riverside terrace						
1	*Populus diversifolia*	0.85 ± 0.07	0.62 ± 0.06	1	18	18000
2	*Populus diversifolia*	0.63 ± 0.04	0.42 ± 0.03	1	10	10000
3	*Populus diversifolia*	0.91 ± 0.06	0.53 ± 0.05	1	7	7000
Means		0.80 ± 0.057	0.52 ± 0.047	1	11.7	11667
1	*Elaeágnus angustifólia*	0.71 ± 0.06	0.22 ± 0.03	1	12	12000
2	*Elaeágnus angustifólia*	0.60 ± 0.07	0.30 ± 0.07	1	9	9000
3	*Elaeágnus angustifólia*	0.59 ± 0.07	0.25 ± 0.03	1	10	10000
Means		0.63 ± 0.67	0.26 ± 0.043	1	10.3	10334
1	*Sálix acutifólia*	0.62 ± 0.07	0.31 ± 0.03	1	6	6000
2	*Sálix acutifólia*	0.82 ± 0.11	0.36 ± 0.04	1	13	13000
3	*Sálix acutifólia*	0.86 ± 0.09	0.33 ± 0.03	1	9	9000
Means		0.77 ± 0.09	0.33 ± 0.033	1	9.3	9334
Central terrace						
1	*Populus diversifolia*	0.74 ± 0.06	0.52 ± 0.06	1	16	16000
2	*Populus diversifolia*	0.50 ± 0.04	0.32 ± 0.03	1	8	8000
3	*Populus diversifolia*	0.80 ± 0.06	0.44 ± 0.05	1	5	5000
Means		0.68 ± 0.053	0.43 ± 0.046	1	9.7	9667
1	*Sálix acutifólia*	0.86±0.04	0.30±0.02	1	8	8000
2	*Sálix acutifólia*	0.96±0.04	0.36±0.05	1	6	6000
3	*Sálix acutifólia*	0.81±0.05	0.36±0.05	1	7	7000
Means		0.88 ± 0.043	0.34 ± 0.04	1	7	7000
1	*Elaeágnus angustifólia*	0.63±0.06	0.24±0.04	1	7	7000
2	*Elaeágnus angustifólia*	0.76±0.04	0.30±0.05	1	5	5000
3	*Elaeágnus angustifólia*	0.70±0.06	0.31±0.05	1	8	8000
Means		0.70 ± 0.053	0.28 ± 0.047	1	6.7	6667
Syr Darya River						
Riverside terrace						
1	*Populus diversifolia*	0.66 ± 0.03	0.33 ± 0.03	1	7	7000
2	*Populus diversifolia*	0.77 ± 0.03	0.31 ± 0.02	1	10	10000
3	*Populus diversifolia*	0.58 ± 0.08	0.35 ± 0.06	1	11	11000
Means		0.67 ± 0.047	0.33 ± 0.037	1	9.3	9334
1	*Salix wilhelmsiana*	0.68±0.03	0.34±0.03	1	9	9000
2	*Salix wilhelmsiana*	0.63±0.06	0.25±0.04	1	7	7000
3	*Salix wilhelmsiana*	0.58±0.07	0.27±0.04	1	9	9000
Means		0.63 ± 0.053	0.27 ± 0.037	1	8.3	8334
Central terrace						
1	*Populus diversifolia*	0.47±0.09	0.48±0.18	1	12	12000
2	*Populus diversifolia*	0.91±0.13	0.72±0.11	1	9	9000
3	*Populus diversifolia*	0.48±0.07	0.60±0.11	1	6	6000
Means		0.62 ± 0.097	0.60 ± 0.13	1	9	9000
1	*Salix wilhelmsiana*	0.66±0.07	0.26±0.06	1	6	6000
2	*Salix wilhelmsiana*	0.54±0.07	0.24±0.05	1	7	7000
3	*Salix wilhelmsiana*	0.77±0.07	0.31±0.07	1	3	3000
Means		0.66 ± 0.07	0.27 ± 0.06	1	5.3	5334

of the Almaty branch of KazNIILHA named after A.N. Bukeikhan LLP also laid out 27 test areas to study the dynamics of the number of undergrowth in tugai forests (Ili River – 15: 6 in Pruslovaya, 9 in Central; Syr Darya River – 12: 6 in Pruslovaya, 6 in Central), which determined the number and average biometric parameters of undergrowth under the canopy of the main forest-forming species with their exploration per unit area (Rakhimzhanov, 2022) (Table 4).

Table 4 shows that natural regeneration under the main forest-forming species in tugai plantations was good. The magnitude of undergrowth on the Ili River in the riverbed terrace varies from 9,334 pieces ha^{-1} (*Sálix acutifólia*) to 11,667 pieces ha^{-1} (*Populus diversifolia*). The number of *Elaeágnus angustifólia* was 10,334 pieces ha^{-1}. These characteristics in the central terrace decreased by 25.0% and 17.1%, respectively. The number of *Elaeágnus angustifólia* declined by 35.5%. In the floodplain of the Syr Darya River on the riverbed terrace, the number of plants under the canopy of the main forest-forming species varies from 8,334 pieces ha^{-1} (*Salix wilhelmsiana*) to 9,334 pieces ha^{-1} (*Populus diversifolia*). However, these species indicators in the central terrace decreased by 3.6% and 36%, respectively. There was also no natural renewal in *Elaeágnus angustifólia*. It might be due to poor fruiting and the influence of natural and anthropogenic factors.

CONCLUSIONS

Tugai forests have superior soil and water protection and shore-strengthening significance. Carrying out the reforestation of tugai requires exceptional preference given to the tugai species, i.e., *Populus*, *Elaeágnus,* and *Salix*, which have higher adaptation to the existing environmental conditions. Tugai forests can tolerate the harsh conditions of the desert climate with its dry air, extreme intensity of solar radiation, high summer temperatures, and strong winds, having an exceptionally high transpiration capacity and tolerating the significant salinization of the soil. The monitoring and assessment of the tugai forest's entomology in the floodplains of the Syr Darya and Ili rivers revealed the destruction of plants by leaf-gnawing and gall-forming pests. In addition, determining the features of reforestation of the main forest-forming species also transpired for future use. The evaluation of the reproductive capacity of plants was limited to four species: *Populus diversifolia*, *Elaeágnus angustifólia*, *Sálix acutifólia,* and *Salix wilhelmsiana.* In further studies, it is necessary to evaluate the reproductive capacity of other species.

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