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Original Research Paper

Bio-Ecological Characteristics of Suaeda Forsk and Salsola L Species Distributed in the Aydar–Arnasay Lakes System

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Key Words

Aydar-Arnasoy lakes system, Mirzachul, Kyzylkum, Suaeda Forsk, Salsola L genus, Species, Amaranthaceae, Family, Flora, Fauna.

Abstract

This article provides scientific information about the formation and current state of the Aydar-Arnasoy lakes system, along with its geographical structure. It extensively discusses the ecological and morphological-biological characteristics of species belonging to the Amaranthaceae family, particularly the Suaeda Forsk and Salsola L genera, which are widely distributed in the region. Additionally, the study examines the reasons for the reduction of the Aydar-Arnasoy lakes system, its impact on the flora and fauna today, and presents theoretical considerations on preserving this ecologically and locally significant lake.

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Introduction

Biological diversity holds a significant place in the world, with plants forming the foundation of all life. According to A. Hamidov, there are more than 4,000 plant species in Uzbekistan, with over 1,200 species recorded in the Jizzakh and Navoi regions (Hamidov et al., 1987). The Aydar-Arnasoy lakes system stands out as an important region due to the diversity and unique characteristics of its plant life.

Currently, the Aydar-Arnasoy lake stretches up to 300 km in length, with a width ranging from 2 km to 40 km and a total water surface area of 3,702 km². Its water volume averages 44.1 km³, and the water level rises to 275 meters above sea level. These figures naturally fluctuate over the years depending on precipitation levels and the volume of water flowing into the lake.

Notably, over 325 species of higher plants grow within the Aydar-Arnasoy lakes system. Today, these plants are utilized for various purposes, including food, fodder, medicinal, dye-producing, essential oil extraction, and ornamental applications (G‘o‘dalov, 2019).

The Aydar-Arnasoy lakes system is bordered by desert and foothill landscapes, with its main part directly adjoining two major deserts Eastern Kyzylkum and Mirzachul. According to P.Q. Zakirov's work *"Nurata Vegetation Cover"*, the foothill areas of Nurata mainly consist of Paleozoic deposits, while the mountain slopes are composed of Mesozoic and Cenozoic deposits. The soil in the region includes gypsum-containing gray-brown dunes, white-gray and clayey soils in the lower foothills, and extensive sandy deposits. The climate exhibits sharp continental characteristics typical of the Kyzylkum Desert (Zakirov, 1969).

The average annual precipitation in the region ranges from 200 to 300 mm, with an average annual temperature of 14-16°C. The minimum temperature drops to -28°C to -30°C, while the maximum temperature fluctuates between 44°C and 49°C.

Aydarkul, an artificial lake, was formed in 1969 due to the discharge of excess water from the Chardara reservoir. The emergence of Aydarkul led to the creation of a new natural-territorial complex (NTC) in the Kyzylkum Desert, forming a unique landscape with its own evolutionary pattern (Mavlonov & Qodirov, 2019).

Currently, the Aydar-Arnasoy lakes system is the largest water body in the country after the Aral Sea. This lake was formed through two main processes:

1. The accumulation of wastewater and drainage water.
2. The influx of freshwater from rivers and the Chardara reservoir.

Initially, the area where the lake now exists was known as Aydar Sho'rxok—a salt marsh that experienced water accumulation during rainfall, followed by evaporation in the summer, leaving behind saline soils. The vegetation in this area mainly consisted of annual representatives of the Chenopodiaceae (now included in Amaranthaceae) family.

Objective

The objective of this study is to describe the bio-ecological characteristics of Suaeda Forsk and Salsola L genera, which are among the rare taxa of the Amaranthaceae family, forming the main vegetation cover in the Aydar-Arnasoy lakes system area.

Objects and Methods

The research focuses on plant communities forming the vegetation cover of the Aydar-Arnasoy lakes system, specifically rare genera of the Amaranthaceae family, including the following species from the Suaeda Forsk and Salsola L genera:

Species of the Suaeda Forsk Genus

1. *Suaeda acuminata* (C.A. Mey.) Moq
2. *Suaeda altissima* (L.) Pall
3. *Suaeda arcuata* Bunge
4. *Suaeda dendroides* (C.A. Mey.) Moq
5. *Suaeda heterophylla* Bunge ex Boiss
6. *Suaeda linifolia* Pall
7. *Suaeda paradoxa* (Bunge) Bunge

Species of the Salsola L Genus

1. *Salsola arbuscula* Pall
2. *Salsola arbusculiformis* Drobow
3. *Salsola collina* Pall
4. *Salsola dendroides* Pall
5. *Salsola foliosa* (L.) Schrad. ex Schult
6. *Salsola iberica* Sennen & Pau
7. *Salsola leptoclada* Gand
8. *Salsola micranthera* Botschantz
9. *Salsola orientalis* S.G. Gmel
10. *Salsola paletzkiana* Litv
11. *Salsola paulsenii* Litv
12. *Salsola richteri* (Moq.) Kar. ex Litv
13. *Salsola sclerantha* C.A. Mey
14. *Salsola turkestanica* Litv
15. *Salsola vvedenskyi* Iljin & Popov

The research was conducted between 2018 and 2024 within the territory of the Aydar-Arnasoy lakes system in Uzbekistan. During the study, classical and geobotanical methods were used, along with the following widely accepted methodologies:

- Plant phenology analysis based on I.I. Beydeman (1969).
- Ontogenesis studies in experimental plots following T.A. Rabotnov (1983).
- Investigation of underground plant parts using the method of S.G. Golovchenko (1971).
- Comparative biomorphological and other analytical methods.

Soil samples from the Aydar-Arnasoy lakes system were analyzed using the neutron activation method. The research findings identified the chemical composition of soil samples collected from Bomurod settlement and Arnasoy district (Omon Keldi), revealing the presence of 31 macro- and microelements (Beydeman, 1983, Rabotnov, 1983) (Table 1).

Table 1: Chemical Element Composition of Soil Samples from the Aydar-Arnasoy Lakes System

Element	Boymurod Settlement Soil Sample (µg/g)	Arnasoy District Soil Sample (µg/g)
As	2.9±0.31	3.7±0.39
Au	<0.001	<0.001
Ba	310±28	480±42
Br	70±5.1	2.8±0.33
Ca	93500±8900	68300±6400
Ce	22±1.9	27±2.1
Co	3.9±0.28	4.9±0.31
Cr	21±1.7	62±5.9
Cs	1.7±0.22	1.9±0.21
Eu	0.38±0.041	0.57±0.048
Fe	10100±1300	13200±1200
Hg	n/o	n/o
K	9700±850	6500±710
La	12±1.3	16±1.4
Lu	0.19±0.015	0.13±0.012
Mn	217±21	80±9.2
Mo	3.8±0.41	1.0±0.089
Na	42800±3300	6600±580
Nd	11±1.3	6.2±0.75
Ni	<10	<10
Rb	35±2.7	66±5.1
Re	<1.0	<1.0
Sb	0.50±0.048	0.50±0.052
Sc	4.0±0.38	4.7±0.45
Se	n/o	n/o
Sm	1.8±0.15	1.8±0.17
Sr	1200±110	290±31
Ta	0.32±0.029	0.38±0.037
Tb	0.26±0.024	0.3±0.028
Th	3.2±0.35	5.2±0.48
U	3.5±0.32	1.5±0.18
Yb	1.2±0.13	1.3±0.15
Zn	35±2.9	36±3.1

Results

According to the results of neutron activation analysis of the samples, the most abundant chemical elements in the soil composition are Ca (Calcium), Na (Sodium), K (Potassium), and Fe (Iron).

The Aydar-Arnasoy lakes system desert ecosystems, despite their harsh ecological conditions, dry and extremely hot climate, stand out for their rich and diverse flora and fauna. Throughout historical evolutionary development, many species (biodiversity) have adapted to these conditions.

As mentioned above, more than 325 plant species have been identified in the ecosystems along the Aydarkul shoreline, and their systematic and biomorphological spectrum has been analyzed (Imomova & Imomova, 2021; Esanov et al., 2019; Imomova & Imomova, 2021).

The majority of the plant species distributed in the region belong to genera and species of the Amaranthaceae family.

According to the research findings, 67 plant species from the Amaranthaceae family have been identified in the area. Among them, Suaeda Forsk and Salsola L are considered the most promising genera. The Suaeda Forsk genus includes 7 species, while the Salsola L genus consists of 15 species, all of which are considered highly prospective species (Table 2).

Table 2: Genera and Species of the Amaranthaceae Family in the Aydar-Arnasoy Lakes System

Family Name	Genus	Species
Amaranthaceae	Amaranthus L. – Gultojixo‘roz	Amaranthus albus L
Amaranthaceae	Amaranthus L. – Gultojixo‘roz	Amaranthus deflexus L
Amaranthaceae	Amaranthus L. – Gultojixo‘roz	Amaranthus retroflexus L
Amaranthaceae	Chenopodium L. – Sho‘ra	Chenopodium album L
Amaranthaceae	Chenopodium L. – Sho‘ra	Chenopodium botrys L
Amaranthaceae	Chenopodium L. – Sho‘ra	Chenopodium chenopodioides (L.)
Amaranthaceae	Chenopodium L. – Sho‘ra	Chenopodium glaucum L
Amaranthaceae	Chenopodium L. – Sho‘ra	Chenopodium rubrum L
Amaranthaceae	Chenopodium L. – Sho‘ra	Chenopodium vulvaria L.
Amaranthaceae	Spinacia L. – Ismaloq	Spinacia turkestanica Iljin
Amaranthaceae	Atriplex L. – Olabuta	Atriplex aucherii Moq
Amaranthaceae	Atriplex L. – Olabuta	Atriplex dimorphostegia Kar. & Kir
Amaranthaceae	Atriplex L. – Olabuta	Atriplex flabellum Bunge
Amaranthaceae	Atriplex L. – Olabuta	Atriplex ornata Iljin
Amaranthaceae	Atriplex L. – Olabuta	Atriplex tatarica L
Amaranthaceae	Ceratocarpus L. – Ebalak	Ceratocarpus arenarius L
Amaranthaceae	Camphorosma L. – Qoramatov	Camphorosma monspeliaca L
Amaranthaceae	Bassia All. – Bassiya	Bassia eriophora (Schrad.) Asch.
Amaranthaceae	Bassia All. – Bassiya	Bassia hyssopifolia (Pall.) Kuntze
Amaranthaceae	Kochia Roth. – Koxiya	Kochia iranica Bornm
Amaranthaceae	Kochia Roth. – Koxiya	Kochia prostrata (L.) Schrad
Amaranthaceae	Kochia Roth. – Koxiya	Kochia scoparia (L.) Schrad
Amaranthaceae	Corispermum L. – Qandalaurug‘	Corispermum lehmanninum Bunge
Amaranthaceae	Agriophyllum M. Bieb. – Qumajriq	Agriophyllum lateriflorum (Lam.) Moq
Amaranthaceae	Kalidium Moq. – Shoxilak	Kalidium caspicum (L.) Ung.-Sternb
Amaranthaceae	Halopeplis Bunge – Xalopeplis	Halopeplis pygmaea (Pall.) Bunge ex Ung.-Sternb
Amaranthaceae	Halostachys C.A.Mey. – Qorabarak	Halostachys belangeriana (Moq.) Botsch
Amaranthaceae	Halocnemum M. Bieb. – Sarsazan	Halocnemum strobilaceum (Pall.) M. Bieb
Amaranthaceae	Salicornia L.– Qorasho‘ra, qizilsho‘ra	Salicornia europaea L.
Amaranthaceae	Suaeda Forsk. – Qorabargo‘t	Suaeda acuminata (C.A. Mey.) Moq
Amaranthaceae	Suaeda Forsk. – Qorabargo‘t	Suaeda altissima (L.) Pall
Amaranthaceae	Suaeda Forsk. – Qorabargo‘t	Suaeda arcuata Bunge
Amaranthaceae	Suaeda Forsk. – Qorabargo‘t	Suaeda dendroides (C.A. Mey.) Moq
Amaranthaceae	Suaeda Forsk. – Qorabargo‘t	Suaeda heterophylla Bunge ex Boiss
Amaranthaceae	Suaeda Forsk. – Qorabargo‘t	Suaeda linifolia Pall
Amaranthaceae	Suaeda Forsk. – Qorabargo‘t	Suaeda paradoxa (Bunge) Bunge
Amaranthaceae	Salsola L. – Sho‘rak	Salsola arbuscula Pall
Amaranthaceae	Salsola L. – Sho‘rak	Salsola arbusculiformis Drobow
Amaranthaceae	Salsola L. – Sho‘rak	Salsola collina Pall
Amaranthaceae	Salsola L. – Sho‘rak	Salsola dendroides Pall
Amaranthaceae	Salsola L. – Sho‘rak	Salsola foliosa (L.) Schrad. ex Schult
Amaranthaceae	Salsola L. – Sho‘rak	Salsola iberica Sennen & Pau
Amaranthaceae	Salsola L. – Sho‘rak	Salsola leptoclada Gand
Amaranthaceae	Salsola L. – Sho‘rak	Salsola micranthera Botschantz
Amaranthaceae	Salsola L. – Sho‘rak	Salsola orientalis S.G. Gmel
Amaranthaceae	Salsola L. – Sho‘rak	Salsola paletzkiana Litv
Amaranthaceae	Salsola L. – Sho‘rak	Salsola paulsenii Litv
Amaranthaceae	Salsola L. – Sho‘rak	Salsola richteri (Moq.) Kar. ex Litv
Amaranthaceae	Salsola L. – Sho‘rak	Salsola sclerantha C.A. Mey
Amaranthaceae	Salsola L. – Sho‘rak	Salsola turkestanica Litv
Amaranthaceae	Salsola L. – Sho‘rak	Salsola vvedenskyi Iljin & Popov
Amaranthaceae	Climacoptera Botsch. – Baliqko‘z	Climacoptera crassa (M. Bieb.) Botsch
Amaranthaceae	Climacoptera Botsch. – Baliqko‘z	Climacoptera intricata (Iljin) Botsch
Amaranthaceae	Climacoptera Botsch. – Baliqko‘z	Climacoptera lanata (Pall.) Botsch
Amaranthaceae	Climacoptera Botsch. – Baliqko‘z	Climacoptera longistylosa (Iljin) Botsch
Amaranthaceae	Halothamnus Jaub. & Spach – Cho‘g‘on	Halothamnus glaucus (M. Bieb.) Botsch.
Amaranthaceae	Halothamnus Jaub. & Spach – Cho‘g‘on	Halothamnus subaphyllus (C.A.Mey.) Botsch.
Amaranthaceae	Girgensohnia Bunge – Girginsoniya, Sog‘on	Girgensohnia oppositiflora (Pall.) Fenzl
Amaranthaceae	Girgensohnia Bunge – Girginsoniya, Sog‘on	Girgensohnia diptera Bunge
Amaranthaceae	Girgensohnia Bunge – Girginsoniya, Sog‘on	Gamanthus gamocarpus (Moq.) Bunge
Amaranthaceae	Anabasis (Schrenk) Benth. – Biyurg‘un	Anabasis eriopoda (Schrenk) Paulsen
Amaranthaceae	Anabasis (Schrenk) Benth. – Biyurg‘un	Anabasis salsa (Ledeb.) Benth. ex Volkens
Amaranthaceae	Haloxylon Bunge – Saksovul	Haloxylon ammodendron (C.A. Mey.) Bunge ex Fenzl
Amaranthaceae	Haloxylon Bunge – Saksovul	Haloxylon persicum Bunge
Amaranthaceae	Halocharis Moq. – Quyonjun	Halocharis hispida (Schrenk) Bunge
Amaranthaceae	Halimocnemis C.A.Mey. – Xardandon	Halimocnemis mollissima Bunge
Amaranthaceae	Halimocnemis C.A.Mey. – Xardandon	Halimocnemis villosa Kar. & Kir

We will briefly discuss the eco-biological characteristics of species belonging to the genus *Suaeda Forsk* of the family *Amaranthaceae*, which are distributed in the Aydar–Arnasay lake system.

According to the data provided by A. Hamidov and others, the bract leaves of representatives of the *Suaeda Forsk* genus are green, and during the fruiting period, the part of the floral bract that surrounds the fruit hardens and enlarges, meaning that the part of the fruit attached to the branch expands, forming five star-shaped depressions. The representatives of this genus are mainly forage plants and weeds in terms of significance (Hamidov et al., 1987; Tozhibaev et al., 2021; Imomova & Imomova, 2021). They form associations in the region.

Suaeda Acuminata (C.A. Mey.) Moq – Pointed-Leaved Suaeda (Сведа Заостренная – Qirrali Qorabarg‘O‘T)

A 10–50 cm tall annual herbaceous plant. Its stem usually grows upright. The leaves and branches are alternately arranged on the stem, linear, with pointed tips. The flowers are small, inconspicuous, bisexual, and clustered in groups, sometimes singly, in the axils of leaf-like branches. It blooms in August–September, and its fruits ripen in the second half of September. It reproduces only through seeds. It grows in saline marshes, sandy areas, abandoned places, rain-fed lands, and fields (Hamidov et al., 1987; Qodirov, 2008; Imomova et al., 2023; Imomova & Imomova, 2024]. Ecologically, it is a halophyte, and in terms of life form, it is an ephemeral.

Suaeda Altissima (L.) Pall – Tall Suaeda (Сведа Высокая – Novcha Qorabarg‘O‘T)

A 25–100 cm tall plant with fleshy, upright leaves. Its inflorescence is a pyramidal panicle. It blooms and produces seeds from July to September. It grows well in highly saline soils. It serves as a forage plant for sheep and camels. It is found in fallow lands, riparian forests, irrigation canals, and roadsides among crops. Its life form is an annual ephemeral, and ecologically it is classified as a halophyte.

Suaeda Arcuata Bunge – Curved-Leaved Suaeda (Сведа Дуголистная – Yoybargli Qorabarg‘O‘T)

A 10–100 cm tall ephemeral plant. Its leaves are fleshy, pencil-shaped, 1.6–4 cm long, and curved. It blooms and produces seeds from June to October. It grows in sandy areas of the desert and foothill zones, abandoned places, fields, and saline lands. It is an annual forage plant. Ecologically, it is a gypsophyte.

Suaeda Dendroides (C.A. Mey.) Moq – Tree-Like Suaeda (Сведа Древовидная – Daraxtsimon Qorabarg‘O‘T)

A forage plant that grows in saline marshes and along the shores of reservoirs. Its life form is a shrub, and ecologically, it is classified as a gypsophyte.

Suaeda Heterophylla Bunge Ex Boiss – Variable-Leaved Suaeda (Сведа Разнолистная – Har Xil Bargli Qorabarg‘O‘T)

An annual forage weed that grows in saline marshes, rain-fed lands, fields, roadsides, irrigation canal banks, sandy areas, and abandoned places. In terms of life form, it is an annual ephemeral, and ecologically, it is classified as a gypsophyte.

Suaeda Linifolia Pall – Linear-Leaved Suaeda (Сведа Линейнолистная – Qalamibargli Qorabarg‘O‘T)

A plant that grows in saline marshes, along reservoir shores, in fields, and in gypsum-rich soils. It is an annual forage weed. In terms of life form, it is an annual ephemeral, and ecologically, it is classified as a gypsophyte.

Suaeda Paradoxa (Bunge) Bunge – Strange Suaeda (Сведа Странная – G‘Alati Qorabarg‘O‘T)

An annual ephemeral forage weed that grows in saline marshes, sandy areas (Mirzachul, Kyzylkum), abandoned places, rain-fed lands, fields, and gypsum-rich soils (Hamidov et al., 1987; Tozhibaev et al., 2021, 11]. Ecologically, it is classified as a gypsophyte.

The *Salsola L.* genus belongs to the *Amaranthaceae* family and is also found in the Aydar–Arnasay lake system.

Salsola L. – (Saltwort – Солянка – Sho‘Rak)

This genus includes annual herbs, semi-shrubs, and tree-like species. The leaves are fleshy, needle- or scale-shaped. The flowers are in spike-like inflorescences, bisexual, with five floral parts, and the fruit has wings. In Uzbekistan, there are 48 species of this genus growing in saline and alkaline soils.

Salsola Arbuscula Pall – Tree-Like Saltwort (Солянка Деревцевидная – Oq Boyalish Sho‘Rak)

A halophytic shrub, 50–80 (120) cm tall, with small, semi-curved, fleshy leaves. Wild populations of this plant are typically found in light-colored, gray-brown gypsum-rich soils. It forms associations in the region. Its leaves and young shoots are well consumed by sheep in autumn. The term "boyalish" refers to plants of moderate nutritional value. According to A. Li and D. Berkovich (1970), in spring, boyalish accumulates a high protein content (19.8% crude protein, 13.4% protein). It is a drought-resistant plant (Bobaeva & Rabbimov, 2018). Ecologically, it is a halophyte and has significance as a forage and dye-producing plant.

Salsola Arbusculiformis Drobow – Boyalish-Like Saltwort (Солянка Боялычевидная – Boyalishsimon Sho‘Rak)

A shrub 40–100 cm tall with a highly branched stem. The old branches are gray-brown or dark brown. The leaves are alternately arranged; the leaves on small branches of old twigs are gray-green, semi-meaty, 1–1.5 cm × 1–1.5 mm, slightly fleshy, with a slightly widened base. It blooms in August and fruits in late September. The seeds are thin and

elongated. It is a primary food source for sheep and camels. Ecologically, it is classified as a gypsophyte, and in terms of significance, it is a forage plant (Rakhimova & Rakhimova, 2022).

Salsola Dendroides Pall – Shrub Saltwort (Солянка Древовидная – Buta Sho‘Rak, Sho‘Rbuta)

A plant 75–100 (110) cm tall. It has a short woody caudex near the root, from which thick annual branches emerge. Its inflorescence is a broad panicle, blooming and fruiting from June to October. It is found in desert, foothill, and mountain zones, as well as in saline soils and among irrigated crops. This plant is significant as a forage and in forest reclamation projects. Ecologically, it is a halophyte, primarily found in saline soils.

Salsola Iberica Sennen & Pau – Iberian Saltwort (Солянка Иберийская – Ibiriya Sho‘Ragi)

A plant reaching 100 cm in height, with a dark green, branched stem. Its branches are rough. The leaf edges are also rough and ciliated, with sharp, spiny tips. It blooms and produces seeds from July to September. It primarily grows in sandy, clayey, and gravelly soils, saline marshes, desert lands, and weedy fields. In autumn, it forms a ball shape and rolls away due to wind. Ecologically, it is classified as a halophyte and serves as a forage plant.

Scientific research and expedition findings indicate that representatives of both genera are predominantly halophytes.

Discussion

Indeed, in recent years, the intensification of ecological changes in the Aydar–Arnasay lake system has been observed. The continuous reduction of the lake by several meters annually (50–75 m), leading to the transformation of the lakebed into dry land, has raised serious concerns. The water level has decreased by more than 2 meters, and salinity has increased from 5.1 g/L to 8.9 g/L over the past 10 years, reaching up to 14 g/L in the northern Boymurod section of the lake. The rapid increase in water mineralization has also impacted pastures and groundwater mineralization in the region.

As a result, the overall development of many medicinal and forage plants has been affected, leading to an increase in halophytic plant species with low economic significance in the area. The spread of toxic dust and salts has also been observed. If this trend continues, thousands of hectares of pastures surrounding the lake will deteriorate, negatively affecting desert livestock farming. Desertification will accelerate, land degradation will worsen, and the seed and vegetative reproduction of plants will decline. Consequently, the once-diverse plant cover of the Aydar–Arnasay lake system will become sparse (Gazeta.uz, 2021).

Conclusion

The vegetation spread across the Aydar–Arnasay lake system is of unique ecological significance. Today, the potential disappearance of the lake could lead to a repetition of the environmental catastrophe seen in the Aral Sea. The worsening water supply issue in the Aydar–

Arnasay lake system suggests that implementing the long-discussed project of diverting part of the Siberian rivers to Uzbekistan, planned 30–35 years ago, could be a viable solution. This project could be considered one of the most effective solutions to the escalating water crisis in the region.

In recent years, the ongoing crisis in the Aydar–Arnasay lake system requires state-level attention. The decline in the population and density of *Suaeda Forsk* and *Salsola L.* species, which have significant economic value, negatively impacts biodiversity and plant cover. A drastic reduction or complete disappearance of *Amaranthaceae* species in the region would severely disrupt ecological stability.

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