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Soil Cover in the Eastern Part of the Dried Bed of the Aral Sea

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Abstract

The greatest environmental disaster in Central Asia—the drying up of the Aral Sea—has led to the formation of a new terrain, extending over 2.7 million hectares in Uzbekistan. This newly formed terrain is dynamically developing, with emerging soil formations replacing bottom sediments. This paper analyzes the results of a study on soil formation in the eastern part of the dried-up seabed, focusing on the influence of natural processes occurring there.

Keywords

Aral Sea, Environmental, Dried Seabed, Soil Cover

1. Introduction

Intensive desertification of the Aral Sea coastal area (Priaralie) is the main ecological consequence of the Aral Sea drying up. The processes of desertification, primarily anthropogenic amid global climate aridization, are noteworthy for their rapid progression. Processes that typically span centuries are now accelerated, unfolding within a single generation. Ignoring these processes could prevent understanding their trends, directions, and the nature of desertification, as well as nature's own fights for equilibrium and survival.

Surveys of the dried sea bottom and Priaralie were conducted from 2005 to 2023.

Key findings include the assessment of the Aral Sea's dried bed, classification of land cover, evaluation of degradation and desertification processes based on comprehensive field surveys of drought-resistant tree afforestation, and the development of soil, groundwater, and landscape maps for the area around the Aral Sea. These maps were then provided to authorities responsible for the artificial reclamation of the sea bed.

2. Method and Subject Investigation

Currently, the dried seabed of the Aral Sea encompasses over 5 million hectares, with 2.7 million hectares lying within Uzbek territory. The initial conditions of the seabed surface and the prolonged drying process have created a vast and quite heterogeneous land area.

The eastern part of the dried seabed is especially unique, as it was once an archipelago comprised of islands interspersed with lakes.

Focus on this island area is required when studying the sea drying process.

The studies of the dried Aral Sea bed primarily relied on field expeditions (on foot and by car) and semi-stationary research, which involved setting up key polygons for large-scale surveying, providing rough descriptions, analyzing data, and mapping the soil.

The field study encompasses the description of locality, selection of key sites, arrangement of soil profiles, morphological description of soil profiles across genetic horizons, and soil sampling. The soil was described using a standard model. Soil samples were sent to a laboratory to analyze their chemical and physical properties, salt content in full water extract, anionic and cationic composition, organic substance content, gypsum and carbonate content, and soil texture (granulometric composition) (Arinushkina, 1970; Shein, 2005).

Soil surveys in the Akpetky archipelago area were conducted during four expeditions in 2005, 2011, 2020, and 2023. Twenty-nine soil pits were dug during these expeditions.

Vegetation cover was characterized in parallel to the soil surveys.

3. Results Investigation

The eastern part of the dried seabed is occupied by the vast Akpetkinskiy massif, formerly an island system with significant elevation shifts. The complex seabed relief within this system led to a prolonged drying process, gradually exposing its various elements, which fostered the development of a diverse soil cover. Old sand deposits, previously islands reaching heights of 10 - 15 m, are now covered with saxaul and desert sedge (**Figure 1**). Unlike the conditions in 1990, large sources of soil erosion are rare, indicating that unfixed deflated sands are virtually absent (Sektimenko et al., 1991; Stulina & Sektimenko, 2004; Stulina, 2008; Löw et al., 2021). Desert-sandy island soils, sometimes covered by sand, are forming on slopes (**Table 1**).

The upper part of the profile is sandy non-saline; medium and high salinity is observed from a depth of 120 cm.

In the Akpetkinskiy massif, numerous large channel-shaped and inland depressions once housed small lakes. These vast depressions surrounding the lakes featured unique hydrogeological conditions that facilitated intense solonchak formation. Currently, almost all of these lakes have dried up, leading to the formation of solonchaks in their stead. Hydromorphic solonchaks form within these depressions, while semi-hydromorphic solonchaks develop along their peripheries. The prevalent type of salinity is chloride. We present the description of profile 4 (**Table 2**) hydromorphic solonchak (GWT 0.5 m) in the center of deep depression, and Profile 3—semi-hydromorphic solonchak (GWT 0.9 m) at a distance of 70 cm from the center of shor to periphery were cut.

Soils down to the groundwater table are sandy in texture. A notable characteristic of young solonchaks is the presence of a significant amount of organic matter in the profile, which is not morphologically apparent and exists in a bound state with salts, forming coarse humus and semi-decayed organic remains. Due to high evaporation, capillary flows move upward, leading to salt accumulation in the upper part of the profile; in surface horizons (profile), dissolved solids account for 7% - 12%, EC 28 - 35 dS/m. Soils are highly gypsumed in the entire profile, and gypsum content reaches 75%. The bottom of certain hollows is columnar and residual, resulting from the weathering of gypsiferous soils.

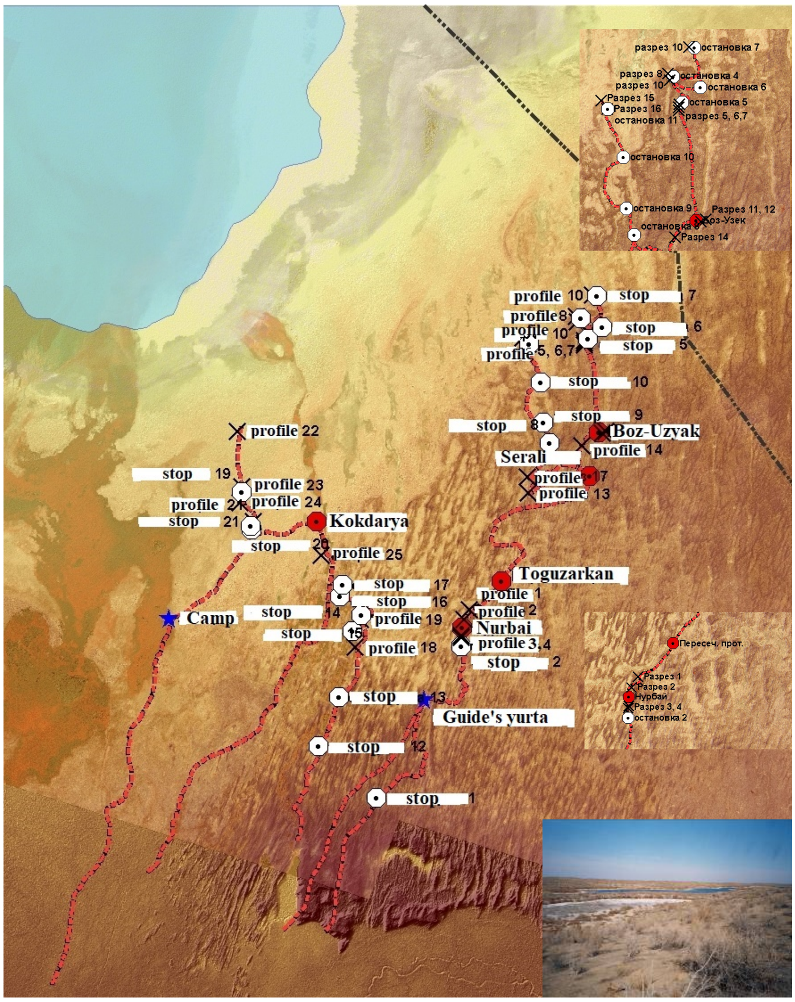

Figure 1. The profile on the hill slope was cut, revealing desert-sandy soils overlain by fixed sands.

Table 1. Description of the soil profile 2.

Schematic Breakdown of the Soil Section Profile	Horizon Thickness (centimeters)	Description of the section includes color, moisture, structure, density, texture, new formations, inclusions, nature of mixing, transition horizons, signs of waterlogging, salinity, alkalinity, and other features.
Profile 2 43˚43'35". 60˚42'00"	0 - 15	Pale gray sand, dry with a pronounced slaty structure, rooted. Visible transition observed.
	15 - 36	Pale gray, structureless, open-textured, and multiple fibrous roots, and sand. Visible transition by density observed.
	36 - 53	Open-textured sand but denser than the previous one
	53 - 117	Pale yellow, structureless, consolidated layer with some roots. Visible transition by the size of roots observed.
	117 - 134	Pale yellow open-textured sand, differing from the previous horizon by multiple decomposed roots. Visible transition observed.
	134 - 155	Pale horizon with a whitish tint, white spots of carbonates, and inclusions of 15 × 5 cm decomposed plant residues.
		Buried GWL > 10 meters

Table 2. Description of the soil profile 4.

Schematic Breakdown of the Soil Section Profile	Horizon Thickness (centimeters)	Description of the section
Profile 4 43˚42'36" EL 60˚42'44"	0 - 3	Dark gray crust featuring white and yellow spots, gypsified, with multiple small shells and a visible transition in density.
Glistens	3 - 13	Dusty-white sand marked by dark gray and rust-colored spots, salt, some roots, and yellow-pale inclusions of light loam.
	13 - 24	White sand, sparsely dotted with rust-colored spots, loose, open-textured, and containing 1-cm shell deposits.
	24 - 35	Rust-colored, dense gypsum that crumbles in hand into nutty crystalline formations.
	35 - 48	Dusty-white sand with ochreous spots, open-textured, and aggregated ochreous separates.
	GWL 48 cm	

The soil cover from an altitude of 53 meters to the Togyzarkan flow path consists of solonchaks and desert-sandy soils, topped with sand. The solonchak complex includes brine and crust solonchaks primarily. Puffed solonchaks are found in shallow former lake hollows and are common at the edges of solonchak channel depressions, a relief typical for the area along the Togyzarkan flow path and northward, where depressions are milder. Desert-sandy plain soils are more saline than their counterparts in ridgy-hilly sands. The territory is characterized by self-overgrowth with minimal deflation. Water surfaces around self-discharged wells. Along the Toguzarkan flow path, a large massif of solonchaks on alluvial deposits was formed. The upper 15 cm consists of fixed sand with a large quantity of sea shells, medium saline, EC 2 dS/m; up to 30 cm is medium loam of blue-gray color, very highly saline, EC 17 dS/m, underlain by ochre heavy loam, very highly saline, EC 14 dS/m. Towards the periphery, crust solonchaks transition to puffed solonchaks. Water surfaces in the flow path. The complex of solonchaks with varying degrees of hydromorphy becomes a source of salt-dust transport as they dry up and thus need stabilization.

After crossing the Togyzarkan flow path towards the north and northeast, hills covered with saxaul are interspersed with semi-fixed sands. The area features a mix of depressions and hills. The depressions are flat, extensive shors with a unique soil cover pattern. In the center of a shor, excessively hydromorphic solonchaks (Profile 5, GWT 0.3 m) transition to hydromorphic (Profile 6, GWT 0.7 m), semi-automorphic, and automorphic soils towards the edges (Profile 7, GWT 1.8 m) (**Figure 2**).

Automorphic crust and puffed solonchaks are overgrown with saxaul, semi-hydromorphic and hydromorphic ones with saltwort. Salty crust in the central part of shor is not covered by vegetation; it is white but more often dark grey or dirty yellow, as over time it is overlain by sand or rarely by silt particles; from a depth of 30 cm the clay has a smell of hydrogen sulfide, while salinity in upper horizons amounts to 15 - 45 dS/m.

Profile 6 consists of sand, with the upper part featuring a salty, expanded crust. Salinity levels are 39 dS/m and 26 dS/m in the 0 - 10 cm and 10 - 30 cm layers, respectively. The presence of salty horizons in the middle and lower parts of the profile is typical for automorphic solonchaks. In Profile 7, the maximum salt content ranges from 17 - 29 dS/m at depths of 12 - 44 cm, with the displacement of the salty horizon due to salt leaching from precipitation. The lower salty horizon, with an electrical conductivity (EC) of 15 dS/m, is maintained by saline groundwater. Profile 9, bordered by deflated sands of profile 8, exhibits characteristics of desert-sandy soils. The surrounding vegetation includes saxaul and ephemerals, with the soil surface covered by moss. The entire depth of the soil profile is saline, with the upper 30 cm being medium to highly saline (EC 1 - 3 dS/m), indicating the onset of soil formation. The soil is enriched with humus (1.5% - 1.8%) from a depth of 50 cm due to a high amount of plant remains. The deflated sands in profile 8 create hillocks of blown sand around the vegetation.

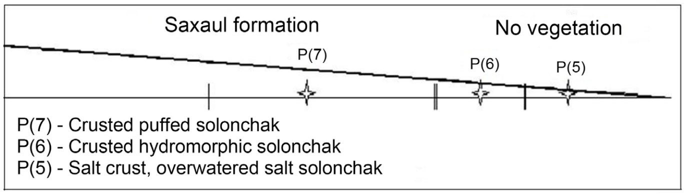

Figure 2. Changing soil types.

The territory extending from the Serali tract to the Boz-Uzyak tract, west to east, and northwards up to latitude 60˚54' and longitude 44˚14', requires development of plain solonchaks, with a focus on automorphic and semi-automorphic types. This is especially relevant for the landscape comprising lowland solonchaks dotted with small hillocks. The hillocks, covered with fixed sands and desert-sandy soils (profile 13), do not need development. Profile 13, situated mid-slope, has sandy, non-saline soil (EC 0.2 - 0.5 dS/m), contains 1.37% humus, and supports vegetation such as saxaul, ephemerals, and moss. Soil samples from the upper horizon towards the slope's edge, next to solonchaks, are non-saline. This area is relatively accessible, unlike landscapes marked by deep hollows with solonchaks (profile 17) and high hills, where solonchak coverage is minimal and natural reclamation is more evident.

The territory east and north of the Boz-Uzyak tract features typical points, including profile 11 of desert-sandy soil on saxaul-wormwood formation, profile 12 of hydromorphic solonchak with reed vegetation, and profile 14 of desert-sandy soil on a wormwood formation. Desert-sandy soil (profile 11) is slightly saline with an electrical conductivity (EC) of 0.6 dS/m up to 70 cm, and a humus content of 0.5% - 0.7%. Below this layer, the soil becomes medium to highly saline, with an EC of 1.4 - 5 dS/m, following a similar salt distribution pattern as observed in the profile of desert-sandy soil (profile 2).

Solonchak, as described by profile 12, has very high salinity, with electrical conductivity (EC) reaching up to 43 dS/m, and increased organic content due to 3% organic remains in the salty crust, a characteristic noted in some solonchaks. This area, extending to the belt of semi-fixed sands in the north, is not considered critical in terms of deflation effectiveness.

The belt of deflated sands north of latitude 60˚54' and 44˚14', featuring scattered barkhans leading up to marshy coastal solonchaks.

Since ancient times, the islands of the Archipelago, characterized by mixed saxaul plant formations, have been used by locals as grazing lands for small livestock and camels. The vegetation primarily consists of communities of plants such as black saxaul (*Haloxylon aphyllum*), broomrape (*Tamarix*), saltbush (*Halostachys belangeriana*), candymum (*Calligonum caput-medusae*), cercaise plant (*Salsola dendroides*), seline (*Stipagrostis pennata*) and others. These plant communities have developed naturally and progressively, with dominant species that are mainly halophilous and some psammophilous, belonging to families like Chenopodiaceae, Tamaricaceae, Fabaceae, and Polygonaceae.

The distribution of plants varies with water level, salinity, soil type, and composition. Sandy terrains are predominantly inhabited by psammophytes (sandworts). In these soils, one can find plants such as candymum (*Calligonum caput-medusae*), sand acacia (*Ammodendron conollyi*), wormwood (*Artemisia diffusa Krasch*), astragalus (*Astragalus villosissimus*), and seline (*Stipagrostis pennata*).

Halophytes such as black saxaul (*Haloxylon aphyllum*), zhuzgun (*Calligonum aphyllum*), broomrape (*Tamarix*), sarsazan (*Halocnemum*), bassia plant (*Bassia*), saltbush (*Salsola*) thrive on saline soil. There is a close relationship between soil salinity and plant species. The distribution of these plants varies by the level of soil salinity: highly saline soil—sarsazan, saltbush, sea blite; on moderately saline soil—zhuzgun (*Calligonum aphyllum*), broomrape (*Tamarix*) and the most common representatives of annuals—saltbush (*Salsola*), and on slightly saline soil—karmak (*Karmak*), black saxaul (*Haloxylon aphyllum*) and various annual grasses. Afforestation efforts in Akpetki by IFAS, a GTZ project, and Karakalpakstan's forestry station include rows of old saxaul plantations, some with mechanical protection. The plants and herbs are in good condition, with heights of 1.5 - 2 m, average diameters of 0.8 - 1.2 m, and a density of 500 - 800 thousand plants per hectare. Plants are also observed between the tree rows.

In recent years, approximately 500,000 hectares have been afforested. Saxaul and tamarix trees were planted both manually and mechanically on sandy and sandy loam soils, which contain shells and are characterized by hillocky barchans. The plants are in good condition, with a rooting rate of 65% - 70%. The process of natural regeneration is well pronounced.

4. Conclusion

Monitoring the process of the sea drying up and changes in soil and vegetation covers from 2005 to 2023 allowed us to observe the unique formation of new soil and plant communities.

Recently, the Akpetkinskiy archipelago is known as a unique natural phenomenon, rich in various resources. Its vast area, along with the adjacent dewatering plain, offers potential for expanding pasture lands. However, given the area's unstable ecological condition—characterized by both negative (desertification, erosion, salt transport) and positive (desert soil formation, desalinization, natural vegetation) processes—it is necessary to regularly monitor and manage these processes. This approach will support nature's balance and self-sustaining tendencies. Establishing a national park on the Akpetkinskiy archipelago would be a prudent decision.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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