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APPLIED PROBLEMS OF ARID LANDS DEVELOPMENT

Succession of Flooded Soils of Coastal Area of the Caspian Sea in Periods of Drying and Aridization

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Abstract—Oscillations of the Caspian Sea level and regular alternation of land flooding and drying enable the observation of rare natural processes: the succession of sea ecosystems, their replacement by land biogeocenoses, and the regular appearance of new formations. Regularly dried and flooded coastal lands are characterized by high biological activity and represent a battlefield of land and sea ecosystems (Soldatov, 1956; *Kaspiiskoe more*, 1990). The variation in the features of land and subaquatic soil formation and their manifestation rate depend on the duration of the drying period and on the contact of the surface with the atmosphere. The goal of this work is to reveal specific features of soil succession (salinization, swamping) at drying stages of different duration in the western Caspian Sea region.

Keywords: flooding–drying cycles, meadow solonchaks, light-chestnut calcareous solonetzic soils, level regime of the Caspian Sea, hydromorphic and automorphic soils

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MATERIALS AND METHODS

The properties of soils are changed after their flooding upon sea transgression and then after the beginning of the land stage of soil formation at sea regression. These cycles result in the formation of a new spatial pattern and vertical profile of soils. Based on these regularities, we studied the newly formed soils with consideration of their altitudes and the length of flooding–drying cycles. The investigations were performed at the experimental station in the Tersko-Kumskaya lowland, where the areas of soil types at the land stage are related to the altitudes of the area. The soils at the transitional stage from the littoral to the land formation are located at the altitudes of 26.0–27.5 m below zero. This area lowers towards the coastal line, and the differences in microfeatures of the topography (the range of the relative altitudes is 0.2–0.5 m) and soil varieties related to them become more pronounced in this direction. At the transition to the land regime, the cycles of formation of new soil varieties from the flooded soils are characterized by different lengths, and solonchakous, boggy, or meadow-boggy processes are developed. This makes it possible to determine the age of posthydrogenic soils and their properties under modern soil-forming conditions (Zalibekov et al., 2011).

RESULTS

Calcareous light-chestnut soils, meadow solonchaks, meadow solonetzic soils, and solonetzic-solonchakous meadow-chestnut soils predominate the soil cover of the Tersko-Kumskaya lowland. Each soil type is characterized by the particular duration of formation cycles after sea regression and by age. The longest functioning (the highest age) is typical for solonetzic calcareous light-chestnut soils (Table 1). The age and functioning period of soils become smaller, contrary to their hydromorphism rate, which is related to the level regime of the Caspian Sea. The relatively small age and regular flooding–drying cycles are typical for boggy soils and river plavni, which are formed in the mouths of the Terek and Kuma Rivers. The given data on the age of some soil types are evidence of its correlation with the altitude of the area.

The cycles of soil successions were specified by the flooding–drying stages of a particular duration. The period of time necessary for the formation of the differences in the spatial pattern and the profiles of soils and nonsoil formations was conventionally taken as a basis (Zalibekov, 2000). With consideration of the wide variation in cycle durations, the predominating variants were characterized according to the period of time necessary for a change of the aforementioned soil types in the particular area.

The **weekly cycle** (Table 2) of flooding–drying lasts up to 6–7 days and contributes to ground drying to different degrees and a slight compaction of the 0- to

Table 1. Successions of soil types at different cycles of flooding–drying (according to Zalibekov, 2000)

Soil types	Altitude, m	Duration of cycles	Soil transformation
Light chestnut	–20.0 and higher	Half a century, century	Automorphic light-chestnut into semihydromorphic meadow-semichestnut
Meadow-chestnut	–20.0 to –26.0	Many years	Meadow-chestnut into slightly and medium saline meadow solonchakous
Meadow	–26.0 to –27.0	Many years	Meadow solonchaks, meadow-boggy
Meadow-boggy	–27.0 to –27.5	from 3–5 years to moderate number of years	Meadow-boggy into boggy
Boggy	–27.0 and lower	Seasonal	Marshy (bogs)

10-cm-thick soil layer. The surface of the sea bottom undergoes a sharp alternation of the littoral and land regimes of soil formation. The flooded areas characterized by biological activity of sea organisms transform into areas with a land regime of functioning. The drying is accompanied by the infiltration of stagnant seawater (and its short-term confluence with groundwater), which results in the formation of a free porous space in the aeration zone 0- to 10-cm thick.

The **monthly cycle** is characterized by less saturation with water and short-term drying of the surface layers. Seawater infiltrates to a depth of 0–50 cm. A crust with small fissures forms on the surface of the bottom deposits. Within the coast of the Kizlyar Gulf (the western part of the Caspian Sea), the monthly drying areas stretch over 300–500 m along the coastal line. The emerged area is characterized by a slightly pronounced inclination towards the Caspian Sea. In the vertical profile, the section established after a monthly cycle is marked by an unclear horizontal stratification and variegated texture. Evidence of the formation of land vegetation is absent, which is explained by an insufficient period of the functioning of the emerged area under land conditions.

The **annual cycle** is determined as the average interval of a three-year-long period. The functioning of dried areas for a period up to 1 year is determined by onshore–offshore winds and natural oscillations of the sea level determined by global and regional factors. These areas are spread in the northern part of the coast, in the Biryuchek Kizlyar Sea Reserve and near the Novoterechnyi settlement. The area emerged from the sea is favorable for the development of physical, chemical, and biological processes, which initiate soil formation. The deposit is characterized by a dried horizon 40- to 50-cm thick and a drop in the groundwater level by 1 m. In areas with clay-loamy deposits, salts are accumulated on the surface. The moistening rate of the soil profile rises downward (dry → fresh → wet); the deposits involved in soil formation are characterized by a slightly compact top layer and well-pronounced aeration zone. The differences are also related to salt accumulation in the 0- to10-cm-thick layer and the presence of remains of hygrophilous plants. The climatic conditions of the area cause a rise in the temperature of the emerged bottom surface, and its regime becomes close to that of the semidesert climatic zone (Alisov, 1990).

The **perennial cycle** lasts 4–10 years. The bottom deposits transform into land soil cover with specific parameters. A 10- to 20-year-long period of the contact of sea deposits with the atmosphere (after sea regression) results in the leading role of the time factor and the formation of a biologically active layer. The soil profile is differentiated, and humus horizons are formed. The soil is characterized by a slight differentiation of the A + B horizons and their morphological parameters (color, texture, the transition between the horizons, and inclusions). A pronounced differentiation of gleying, water permeability, and humus accumulation is seen. Structural formations typical for solonetzic soils and semidesert conditions appear. The plant cover is composed of meadow and meadow-steppe communities with the corresponding species composition and diversity.

The **half-a-century drying cycle** is a stage of the first period of soil succession. The land ecosystems are characterized by some stability and particular functional parameters of their components, including the soil cover. The succession of soil-forming conditions at this stage depends on the effect of natural land factors. The predominating soil types are represented by poorly formed meadow soils of various salinization and meadow-chestnut slightly and moderately saline soils (Zonn, 1983; Dobrovolskiy et al., 1986; Kerimkhanov, 1979). Light-chestnut soils are formed on elevated mesoelements of the topography and on rocks of light texture. Their typical features (except for the pronounced differentiation of the A + B horizons) are still formed and include the presence of carbonate-alluvial horizon, alkalinity, etc. The area of the half-a-century flooding-drying cycle is situated closer to the continental zone at the altitudes of 20–25 m below zero. The plant cover is formed by meadow communities with rich species composition (Chilikina, 1960; Yarulina, 1983).

The century cycle of drying is a conventional complete cycle of the formation of hydromorphic and

Table 2. Soil formation in the periods of the drying of flooded areas

Soil formation in periods of the drying of flooded areas

Stage	**Processes**	**Features**
Weekly	Down filtration	Ground slightly saturated with water, 0- to 20-cm thick
Monthly	Surface drying, filtration of a 0- to 20-cm-thick layer	Slightly differentiated moisture content in the soil profile
Seasonal, year	Surface drying, runoff of seawater and groundwater	The start of crust formation, fissures on the soil surface
Many-year	Evaporative precipitation, drainage	Differentiation of A+B horizon
Half-a-century 25–50	Biological drying, transpiration	Differentiation of the profile, the start of degradation of automorphic soils
Century 50–100	Atmospheric drying, transpiration	Full-profile soils undergo degradation

automorphic soils in the emerged areas. The soils are characterized by a well-formed profile and parameters typical for the corresponding classification units. Automorphic soils on elevated topography elements acquire features of zonal soils (calcareous or solonetzic light-chestnut soils in the studied area). They are formed in the higher parts of previously flooded areas. The soil-forming rocks are saline and stratified, and their granulometric composition is nonuniform (Kryshchenko et al., 2006). Semihydromorphic and hydromorphic soils are formed on clay, and heavy-loamy deposits and are characterized by a considerable content of easily-soluble salts. The groundwater 0.5–1.5 m deep is mineralized. In summer, its level drops to a depth of 2 m, but the capillary fringe is preserved in the entire soil profile. This evolutionary stage of semihydromorphic and hydromorphic soils is represented by meadow-chestnut, meadow, meadow-boggy, and boggy soils of various salinization rates. A considerable part of the area is occupied by sulfate-chloride solonchaks of mainly clay and heavy-loamy texture (Kapustyanskaya, 1959). The soils are characterized by drying and aridization related to climatic conditions, but the rates of these processes are differentiated with respect to the soil type.

Light-chestnut soils undergo aridization with dehumification, wind erosion, and a rise in the compactness of the subhumus horizon. The novelty of the data consists in the fact that the sharp changes in soil properties within short time periods are related to natural factors.

Semihydromorphic (meadow-chestnut) soils in dry years undergo degradation related to wind erosion of the humus horizons, drying of the 0- to100-cm-thick soil layer, and a slight compaction of the subhumus horizon. The degradation processes here are damped in the years when the precipitation is equal to or higher than the mean annual amount. It should be mentioned that the degradation of semihydromorphic soils is reversible and depends on the frequency and duration of draughts (Rozanov, 1984).

The hydromorphic regime results in the formation of meadow, meadow-boggy, and boggy soils, and their saline variants occupy more than 50% of their area. Meadow solonchakous soils, meadow solonchaks, and crusty solonchaks represent a considerable part of hydromorphic soils. Typical solonchaks are most exposed to degradation due to the erosion of pastures and secondary salinization. An overly strong pasture load, even in small areas, results in enhanced salt accumulation and a greater instability and smaller productivity of plant communities. For the optimum load, the stocking rate should be up to one livestock unit per 1 ha.

At a sea transgression higher than –27.5 m, the succession of the soil cover in the deltas of the Kuma and Terek rivers begins. The flooded part of the accumulative sea plain within Dagestan comprises about 50% of the total submerged area of the coastal landscapes of the western Caspian Sea region. Greater hydromorphism of the area causes soil succession and the development of gleying, humification, and other processes. On the elevated topography elements in the adjacent areas, the subsidence processes cause a change in the micro- and mesoelements of topography. In the flooded areas, including those that have undergone sea surge variations, hydromorphic processes and salinization of ground and soil-forming rocks predominate.

CONCLUSIONS

The coastal area of the Caspian Sea Lowland having undergone alternative flooding and drying is characterized by a specific regime of soil formation and sharp changes in the environmental conditions related to the regime of the Caspian Sea level. Changes in the profiles and spatial distribution pattern of soils under semidesert climatic conditions are short-term and are not related to the anthropogenic impact.

(1) The duration of periods of fluctuations of the soil cover in the coastal areas depends on the oscillations of the Caspian Sea level. The age of soil types depends on the altitude of the area and lithological composition of the soil-forming rocks.

(2) The cycles are determined on the base of flooding-drying stages and the period of time necessary for the formation of the soil cover pattern and soil profile. We have determined the historical periods of cycles, within which soils of different stages are formed. These data are used to determine the age of the morphological features and genetic horizons of the soil profile.

(3) Weekly, monthly, and annual cycles contribute to the differentiation of physical soil properties in the 0- to 30-cm–thick layer: the compactness, aeration zone, water permeability, and groundwater drainage. Multiyear and half-a-century cycles cause evaporative precipitation and the settlement of some hygrophilous plant species. The drying of the root zones and features of humus formation are seen.

(4) The century cycle—the final stage of the flooding–drying processes—determines the differentiation of the A + B soil horizon by color and structure and the amount of carbonate and iron neoformations. The newly formed features of the soil profile are typical for clay and heavy loamy texture of fine-earth deposits. Their parameters may be used to determine the age of particular soil properties and to predict their evolution under conditions of aridization and desertification. The formation of soil properties typical for modern soils of the delta areas requires stable soil functioning for five or six century cycles.

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