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SYSTEMATIC STUDY OF ARID TERRITORIES

Diagnostics of Desertification with the Use of Water Retention Curve of Soils

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Abstract—Based on a study of processes developed upon desertification (salinization, solonetzization, and sand accumulation) in the soils of the Caspian Sea Lowland, it is shown that soil's water retention capacity may be used as an integral parameter of all desertification trends. It is characterized by the water retention curve (WRC). The physical sense of the use of the WRC to characterize desertification consists in the fact that it shows the capability of soil to retain moisture and soil moisture mobility and availability for plants and thus characterizes the main edaphic factors, which limit biological productivity in natural ecosystems and the agroecosystems of arid regions. The soil WRC is a constant value without seasonal fluctuations, and this makes it universal in comparison with other soil parameters that undergo seasonal variations, thus making determination of the desertification rate difficult.

Keywords: desertification, main hydrophysical parameter of soils, diagnostics, moisture availability
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Desertification is one of the most urgent ecological problems in arid regions. The reasons and manifestations of this process in different components of ecosystems are numerous in Russia and all over the world (Kust and Andreeva, 2012), which makes its diagnostics difficult. This complicated phenomenon manifests itself in changes in soils, plant and animal communities, the status of local water resources and the surface, and ecological and hydrological processes within the land bioproductive system (*United Nations...*, 1996).

Desertification is mainly indicated by the status of vegetation, which is characterized by projective cover, total biomass and productivity, and various vegetation indexes (NDVI, PVI, DVI, WDVI, RVI, SAVI, and others) (Cherepanov, 2011) or (more seldom) by the composition of plant communities (Kust and Novikova, 2006; Gunin et al., 2010; Gunin et al., 2014). In any case, the characteristics of the vegetation status are the most pronounced and important indicators of desertification, because they show the actual and potential (as a result of dynamics) bioproductivity of lands.

Nevertheless, plants do not always reliably indicate desertification. This, for example, is the case for agricultural lands, where natural vegetation is absent and the trends of productivity dynamic may differ, as well as for some natural ecosystems that undergo strong climate fluctuations. Therefore, soil indicators may and should be used as the main ones under such conditions and should supplement and confirm the data obtained with the use of plant indicators.

In any case, the use of soil indicators is more difficult. For small-scale mapping, the most useful indicators are usually represented by the percentage (in the composition of nonuniform soil cover) of low-productive soils (solonchaks, solonetzes, eroded and scalped soils, and others). These may be also the soils, which undergo corresponding degradation processes (water and wind erosion, salinization, solonetzization, and technogenic contamination in some cases (Kust et al., 2002; Slavko et al., 2014). That is to say, the use of these indicators is an indirect implementation of the principle of determination of the potential biological productivity of particular lands. For a medium-scale survey, the consideration of transitional soils in the soil cover (intermediate in the dynamic and evolution series of soils at desertification) is also informative (Kust, 1999).

These approaches cannot be applied in a large-scale survey or in target characterization of small areas, and this makes it difficult to determine desertification and requires specific soil indicators. It is reasonable to use evidence of soil degradation processes: the salt content and features of solonetzisity, compactness, and erosion, which are determined for each soil pit or soil (Kharin et al., 1987, 1992; Bananova, 1986). Nevertheless, the application of these parameters results in a loss of the sense of desertification as land degradation. A decrease in the biological and economic productivity of lands in general is not taken into consideration, but attention is paid to particular manifestations of soil degradation. A reasonable question arises: what is the purpose of the replaced of the well-known phenomena of salinization or erosion of soils by the new generalized term desertification? Maybe this idea is close to pseudoscience? This problem becomes especially urgent when desertification development is explained by its allocation to arid, subarid, and dry subhumid regions (where the ratio between the mean annual precipitation and potential evapotranspiration varies within 0.05–0.65). Beyond these areas, the process is not recognized as desertification, and only particular types of land degradation are specified. This is inconsistent speculation.

In this work, we try to determine if there is any physical sense in using the terms erosion, salinization, and others instead of desertification. May we use the term desertification for soils but not for lands in general? How may it be related to a decrease in their biological and economical productivity or their loss? Can it be justified to speak of the concept of "soil" desertification, especially if there are proposals in the literature to introduce the notions of climatic desertification (Zolotokrylin, 2003) and biological desertification (Gunin et al., 2015)? The proposal to include land status in the system of global indicators, together with the parameters of land cover and land productivity, as well as soil parameters in particular soil carbon (*United Nations*..., 2015), makes this problem more urgent.

MATERIALS AND METHODS

The main methodological approach to the investigation is based on the hypothesis (Kust and Andreeva, 2012) that, despite the numerous manifestations of soil desertification (salinization, solonetzization, erosion, compaction, and others), the role of soils in this process may be considered to be the preservation and regulation of available plant moisture, which determines the realization of bioproductivity potential. That is to say, the heterogenic properties that determine insufficient moistening (soil aridity) are formed in soils under particular conditions, which are often related to soil degradation.

This hypothesis is based on the idea proposed by V.A. Kovda (1998–1999) that the soil aridity (not the climatic) determines the distribution pattern of vegetation and bioproductivity of ecosystems. Saline soil moisture is unavailable for most nonhalophyte plants, and some salts (gypsum, mirabilite, and others) may form crystalline compounds with some part of soil water. Salinization results in insufficient soil moisture, which causes plant death (Kovda, 1977).

According to a similar idea by Rozanov and Zonn (1981), the aridization rate of soils may be quantitatively evaluated by parameters of water-physical properties and the water regime.

This idea may be developed with study of the processes, which directly or indirectly decrease the content or (and) availability of soil moisture (water and wind erosion, crust formation, sand accumulation, formation of carbonates, intrasoil salt accumulation, gypsum deposition, loss of structure, solonetzization, compaction, a lower role of biological processes in soil formation, and others). The mechanisms of these processes are evident (Table 1), but the possibility of evaluating the desertification rate by particular water-physical soil properties is not realized in practice; there are many issues, though, in which the tendency of successions of soil properties at desertification is shown.

Our investigation is based on the calculation, construction, and analysis of the WRC of soils as an alternative to direct measurement of soil moistening and other water-physical and chemical parameters of soils that determine the availability of soil moisture for plants. This approach was used by us, because the data from direct measurements of soil moistening and physical properties are reliably comparable for the evaluation of soil desertification and degradation only under similar conditions of soil formation and functioning (Kust et al., 2008). No soil properties, such as compactness, moisture content, structural status, granulometric and microaggregate composition, and others, can be used as a unified parameter for the evaluation of soil degradation rate by conditions determining insufficient plant moisture.

It should be reminded that the WRC is a quantitative parameter of the water-retention capacity of soils. This property may be determined as the capability of soil to keep moisture by capillary-sorption force; the WRC is soil moistening at a particular pressure. The higher this parameter is, the greater is the water-retention capacity of soil (Shein, 2005). As the dependence of the capillary-sorption potential (pressure) of soil moisture on moisture content, the WRC is an integral parameter of the physical status of soil, its water retention capacity, and moisture availability for plants (Voronin, 1984; Smagin, 2003). Thus, it may be used as a comparative integral parameter of the aridization rate of soils and as a diagnostic criterion of desertification. It is obviously more correct to use a combination of the WRC and THP (the total hydrophysical parameter, which shows the dependence of the total pressure, not only the capillary-sorption pressure) on soil moistening. The total pressure includes the osmosis component, limiting the availability of soil moisture at salinization. The use of this combination of parameters was proposed for the characterization of physical status and water retention in soil in general (Smagin, 2003). Nevertheless, the WRC is very dynamic because of the extreme mobility of easily soluble salts, and this approach requires more frequent monitoring

Table 1. Brief description of concepts of the reasons for "soil drought" caused by soil degradation processes

Process	Mechanism of decrease in plant moisture availability
Water erosion	Erosion of the top structured soil horizon with high water-retention capacity results in an outcrop of layers with lower water-retention capacity, which causes a greater expenditure of moisture of atmospheric precipitation for side run-off and/or penetration through large cracks into ground beyond the main root zone
Wind erosion (deflation)	Blowing of fine earth from the surface structured soil horizons and transportation far away causes soil depletion of granulometric fractions of clay and fine silt (valuable for high water retention capacity) and organic and organic-mineral particles. The process often results in sand accumulation (described below)
Crust formation	Crust prevents moisture penetration deep into the soil and creation of moisture reserves. Evaporation from the crust surface is more intensive than from deeper soil layers
Surface fissuring	Moisture in deep cracks does not enter the root zone and does not saturate it in the dry period
Sand accumulation	Sandy soils are characterized by a lower water-retention capacity and high infiltration in comparison with loamy and clay soils; sand accumulation in the root zone results in a considerable decrease in moisture reserves in them
Accumulation of carbonates	Calcium carbonates cork soil pores and cement soil mass at a particular depth and thus prevent deep moisture penetration; with drought, moisture above the carbonate-bearing horizon quickly evaporates
Salinization	Salinization increases the osmotic pressure of soil solution and makes moisture unavailable for plants. A decrease in the adsorption potential of soil colloids is accompanied by a decrease in their hydration rate. Some salts are physiologically toxic
Gypsum accumulation	Gypsum is hygroscopic and actively bonds moisture, especially upon its deficit in a drought. The effect of gypsum impregnations is often similar to that of carbonate accumulation
Structure loss	The loss of agronomic valuable soil structure is related to the decrease in active pore space, which is a reservoir of soil moisture
Compaction	Compaction may be formed as a result of structure loss (described above). The formation of different heterogenic barriers in soil prevents the penetration of excessive moisture deep into the soil and the creation its reserves for droughts and excessive moisture expenditure for evaporation. It may also prevent moisture supply from deeper layers to root zone at quick rise in temperature of soil surface and wind velocity
Solonetzization	The combined effect of cracking, compacting, and structure loss is sometimes accompanied by a toxic effect of sodium ions in soil solutions
Decreased biological activity	Soil structure degradation (see structure loss) is indirectly favored as a result of decreased biological loosening and structuring of soil mass and the smaller size of organic polymers adsorbing moisture

observations of this parameter, for example, with the use of conductometric measurements (Smagin et al., 2006). Since these investigations were not planned by us, we only represent the base evaluation with the use of the WRC as the most stable and informative diagnostic criterion for the determination of desertification by the water-retention capacity of sols.

The goal of this work is to verify the assumption that the WRC may be used as an integral parameter of desertification, reflecting moisture availability for plants independently of the causes and types of desertification.

The experimental data for the construction of the water-retention curve were obtained by the approach of equilibrium centrifuging (Smagin et al., 1998). Ordinates on the WRCs are represented by pF- units according to Scofield calculated as a common logarithm of the module of capillary-sorption pressure of soil moisture given in centimeters of water column (Voronin, 1984): $pF = \log(PcmH_2O)$.

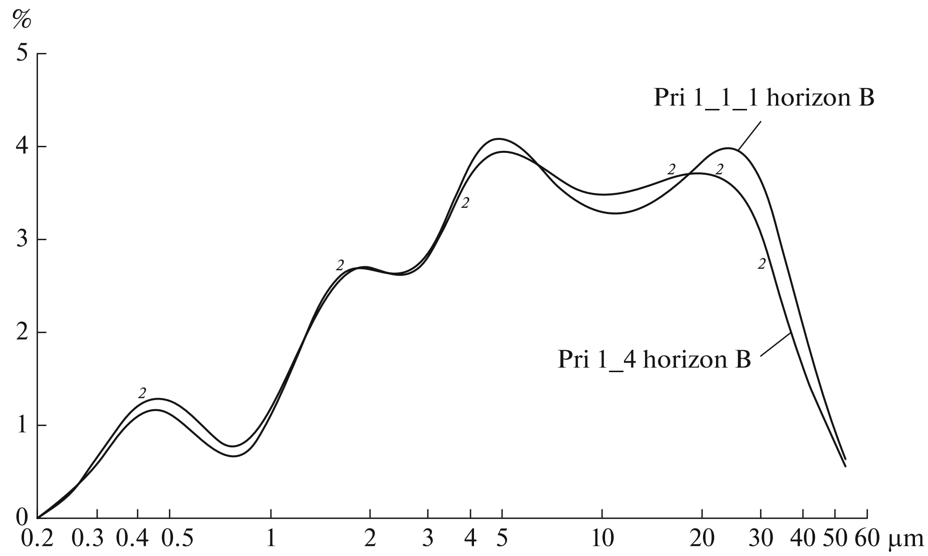

Fig. 1. Differential curves of size of soil particles (soil pits Pri 1_1_1 and Pri 1_4 and B horizons).

The objects of study were soil samples taken on various test plots of the Volgograd and Astrakhan oblasts. The desertification/degradation rate in sampling places was evaluated by earlier elaborated parameters (Andreeva and Kust, 1998; Kust, 1999; Slavko et al., 2013). The sites and brief descriptions of the test plots (TPs) are given in the text. The study objects on the TPs were selected such that the soil-forming conditions, which potentially exert an effect on the water-retention capacity of soils, were similar for all the objects, except for the one studied condition with a particular gradient of values. For example, all of the parameters except for salinization are similar for the objects of Salinization Plot. The objects for the evaluation of sand accumulation were chosen within the same area of light-chestnut, solonetzic, medium-thick soil. Since it is difficult to analyze all of the data in one article, we will show the differences in the WRCs by the most typical examples for each pair of the compared objects. The characteristics of the studied objects are given in Table 2.

RESULTS AND DISCUSSION

Differences in WRCs with salinization. The differences in the WRCs with salinization were evaluated on the Pri Test Plot located 3 km to the southwest of the El'ton Lake (Pallasovsk district, Volgograd oblast). The Pri 1_1_1 and Pri 1_4 pits characterize fallow soils now used for pasture. The soil of the Pri 1_4 pit is assigned to solonchakous soils by a number of characteristics (electric conductivity and morphological features) (Table 2), contrary to the nonsaline soil of the Pri 1_1_1 pit. Other features of the chosen pair of objects (in particular granulometric composition of the B horizons of the studied soils) are similar (Fig. 1), which enables a comparison of the salinization of these soils and an evaluation of the role of the salinity of soil solution in the behavior of the WRC.

The effect of easily soluble salts on the water-retention capacity of soils, plant moisture availability, and its mobility depends on some factors with a predominating role of the dispersion rate (Smagin, 2003; Shein, 2005). For example, the salinization of coarse-disperse (sandy) soils does not exert a significant effect on the WRC; only the module of total potential increases, resulting in a higher water-retention capacity of soils. This is especially the case in dry soils, where salts precipitate because of their hygroscopic properties. The mobility of liquid moisture remains stable, and the plant availability drops to the status of complete absence with a rise in the concentration and osmotic pressure of the pore solution (Smagin, 2012). The effect of salinization in fine-dispersed soils and grounds is mainly related to the ion-electrostatic barrier, which prevents the coagulation of fine particles and makes possible the participation of their surface energy in moisture fixation (Smagin, 2003; Shein, 2005). The width of this barrier (λ) is in adverse correlation with the square root of the product of the solution concentration (C) by the square of charge (valence) of ions (z) (Smagin, 2003): $\lambda \sim \frac{1}{\sqrt{Cz^2}}$. Therefore, a rise in the solution concentration and cation charge results in the narrowing of the barriers (diffusive layer of ions), the inter-coagulating fine particles eliminate their surface energy (the main factor of the disjoining pressure), and their capability for moisture retention decreases in comparison with that prior to coagulation. As a result, the WRC is shifted to the left, i.e. the equilibrium moisture decreases at a constant moisture pressure, or the pressure module drops at

Table 2. Some characteristic properties of studied soils

Diagnostic parameters	Designations of some soil pits used for comparison					
	Koch_1	Bul_3	Pri 1_1_1	Pri 1_2	Pri 1_3	Pri 1_4
Soil name	Chestnut residual-solonetzic medium thick light loamy	Dark-chestnut slightly-solonetzic thick medium-loamy	Light-chestnut solonetzic medium-thick medium-loamy	Light-chestnut solonetzic medium-thick light-loamy	Light-chestnut solonetzic thin light-loamy	Light-chestnut solonchakous solonetzic thin light-loamy
Parameters of biological productivity						
NDVI	0.29	0.307	0.15	0.13	0.03	0.01
Projective cover, %	45	80	60	60	20	5
Morphological parameters						
Salinization features and depth of appearance of neoformations	Absent	Absent	Absent	Absent	Absent	At a depth of 30 cm or deeper as veins and white spots (salt crystals)
Features of solonetzization	Abundant humus-clay cutans on sides of structural units in the B horizon, compactness of the B horizon	Rare humus-clay cutans on sides of structural units in the B1 horizon	Nut-like–prismatic structure of the B1 horizon, humus-clay cutans on sides of structural units in the B1 horizon	Absent	Absent	Blocky–nut-like structure in the B horizon, humus-clay cutans on sides of structural units
Granulometric composition of the A horizon	Light loam	Medium loam	Light clay	Heavy loam	Medium loam	Heavy loam
Granulometric composition of the B horizon	Medium loam	Medium loam	Heavy loam	Heavy loam	Medium loam	Heavy loam
Structure, A horizon	Compacted	Loose	Compacted	Compacted	Loose	Compact
Structure of humus horizon	Blocky-crumbly-powdery	Granular-crumbly (beads along roots)	Granular-crumbly-powdery	Blocky-crumbly-powdery	Crumbly-powdery	Blocky-crumbly-powdery
Structure of horizon with solonetzization features	Small-prismatic–large nut-like	Nut-like–crumbly	Nut-like–prismatic	–	–	Blocky–nut-like–powdery
Boundary of effervescence with 10% HCL, cm	35	65	from the surface	from the surface	from the surface	from the surface
Physicochemical parameters						
EC (A horizon), μSm/sm	48	193	107	580	350	348
EC (B horizon), μSm/sm	99	120	800	112	125	4000
pH (A horizon)	7.38	7.61	9.35	8.6	8.22	9.39
pH (B horizon)	8.9	8.77	9.61	8.65	9.1	8.37
pNa	3.64	3.75	2.41	3.8	3.47	2.56
Carbon content in humus horizon, %	1.31	3.8	0.94	0.69	0.30	1.85
Water stability of aggregates according to Andrianov (A horizon)	30.5	99.75	76.75	59.75	12.25	28

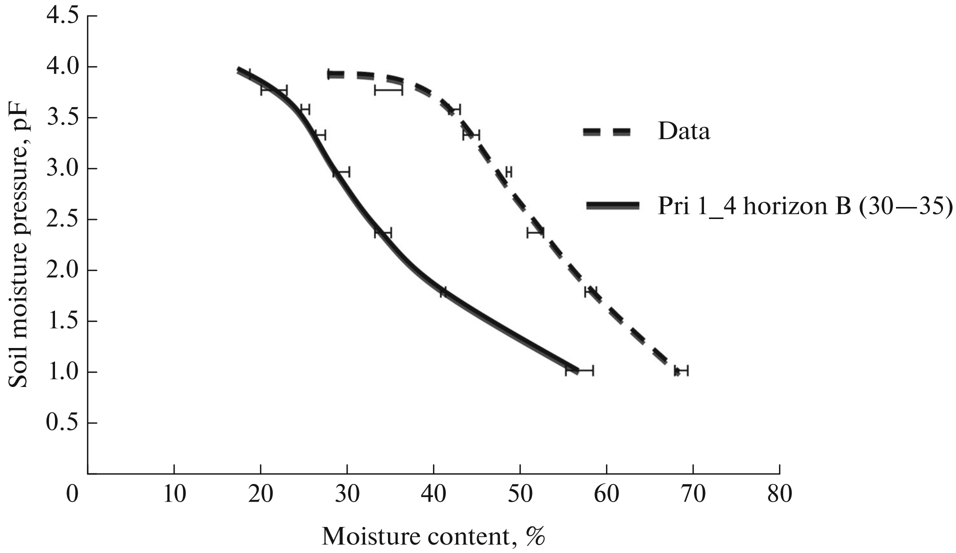

Fig. 2. Curves of water retention for B horizons (soil pits Pri 1_1 and Pri 1_4).

constant moistening (Smagin, 2003). The regularity of moisture availability is similar: it rises in fine-dispersed soils under the effect of salt solutions (the effect of salt leaching of solonetzes, which is widely used in amelioration, is based on this phenomenon). The WRC shows that plant moisture availability rises contrary to water-retention capacity, but this is not the case in reality, because moisture is saline and may not be available for plants due to high osmotic pressure. Under these conditions, desertification determination by the WRC should be supplemented with the THP, which was mentioned above.

Analysis of the obtained experimental data shows that the WRC of the B horizon in the Pri 1_4 soil is shifted to the left when compared to the Pri 1_1 soil (Fig. 2). Since both horizons are characterized by a similar heavy loamy texture, a fivefold rise (calculated as 4000 μSm/sm/ 800 μSm/sm) in the concentration of easily soluble salts should result in a drop in the water-retention capacity (the content of equilibrium moisture fixed by fine soil particles) by no more than $\sqrt{5} = 2.2$ times (according to the above given equation) if the composition of the solution remains similar. This is confirmed by Fig. 2, where the twofold drop is the greatest. Moisture availability under these conditions rises. For example, when the moisture content is equal to 50%, the equilibrium pF drops from 3 to 1.5 units, i.e. the moisture potential or the work against capillary-sorption forces, which should be performed in order to extract this water amount from soil, decreases by $10^{1.5}$ =32 times. Nevertheless, the moisture is saline (4000 μSm/sm = 4 dSm/m is the lower limit of slight salinity) and may result in a drop in productivity by 50% or more, even in death of plant species that are intolerant of saline soils (Leguminosae, Umbelliferae, bulbiferous plants, and fruit trees) (Smagin et al., 2006, Smagin, 2012).

Evaluation of WRC differences with solonetzization. The variations in the WRC with solonetzization were compared for the objects of the Koch and Bul test plots. The former is located 6 km to the east of the Limannyi settlement of the Volgograd oblast, and the site of the latter is at a distance of 20 km, to the northeast of the Bulukhta Lake. These plots are representative for the most part of the Caspian Sea Lowland. Their topography is formed by local drainageless depressions (small and large limans) in combination with flat, slightly undulated plains. The soil cover is formed by chestnut and dark-chestnut soils of the plains, their solonetzic varieties on the slopes, and meadow-chestnut solodized soils in depressions. The soils of the Bul plot differ from those of the Koch plot by a less pronounced morphological solonetzisity in the similar geomorphologic positions despite the heavier texture (Fig. 3), higher humus content, and greater projective cover of vegetation. These differences are obviously related to long-term fallow (since 1988) on the Bul plot and its use for hays, which is well determined by retrospective cosmic photographs. The Kock plot was intensively plowed prior to 2005 and is now actively used for grazing.

The modern solonetzization is slightly developed in the studied soils (pits Koch_1 and Bul_3), which is evidenced by relatively low sodium activity at a rather high alkalinity of illuvial horizons. Despite this fact, the physical properties of these soils show that solonetzization in the Koch_1 soil pit is better pronounced, which is particularly reflected in the formation of less agronomic valuable structure of the humus horizon and greater eluvial-illuvial differentiation of the soil profile with respect to the granulometric com-

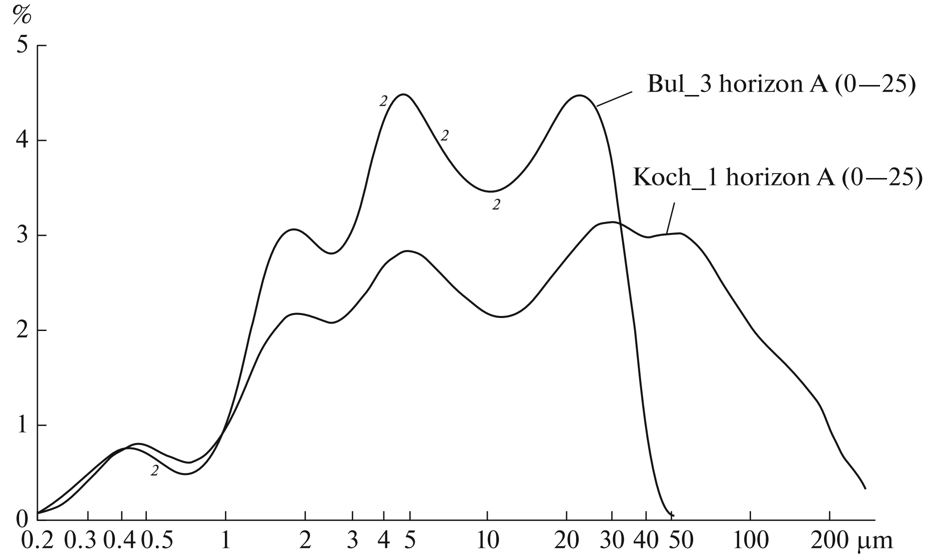

Fig. 3. Differential curves of the size of soil particles (soil pits Koch_1 and Bul_3 and humus horizons).

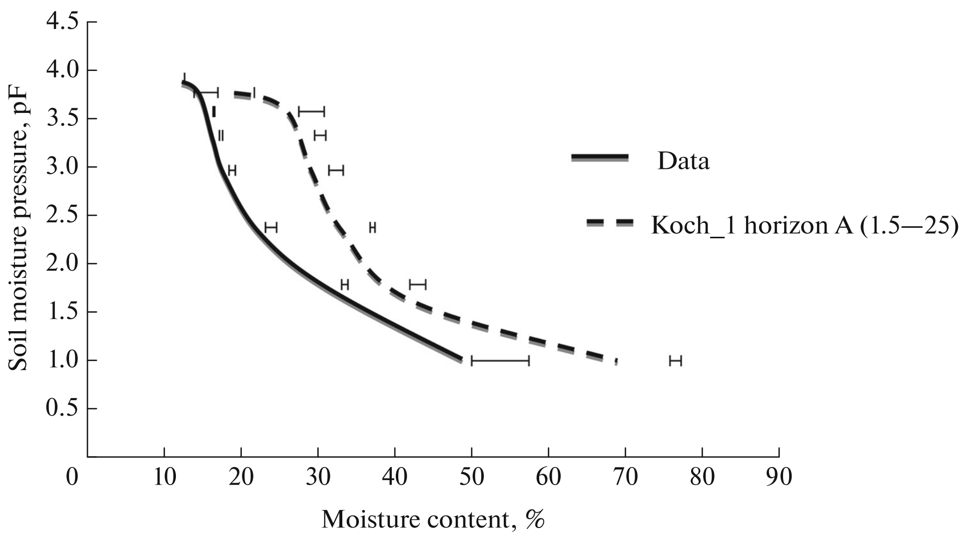

Fig. 4. Water retention curves of humus horizons (soil pits Koch_1 and Bul_3).

position. For example, the parameter of water stability of aggregates by Andrianov is 99.75% for the humus horizon of the Bul_3 pit with a good granular-crumbly structure and high humus content and is only 30.5% for the Koch_1 pit.

The obtained data generally confirm the idea (Smagin et al., 2004) that the destruction of organic matter of soils results in the inevitable degradation of their physical status, which is determined by a number of parameters: compactness and consolidation, disaggregation, the loss of water stability of structure, poorer water retention capacity, and slighter capability of soil to conduct moisture and gaseous substances.

Comparison of the WRCs of the humus horizons of the studied soils (Fig. 4) confirms these conclusions: the shift of the WRC of the humus horizon of the Koch_1 pit to the left is evidence of the lower water-retention capacity, which is obviously due to the lower content of amphiphilous organic substances (humus) and higher content of coarse soil particles as a result of aeolian transportation related to solonetzization. Therefore, the WRC is an integral characteristic of the effect of several interrelated factors: the granulometric composition, organic matter content, and structure status at solonetzization. In further studies, a detailed substantiation of the initial lithological similarity of the compared objects and its variations under the given process is required, but, at the present time, this

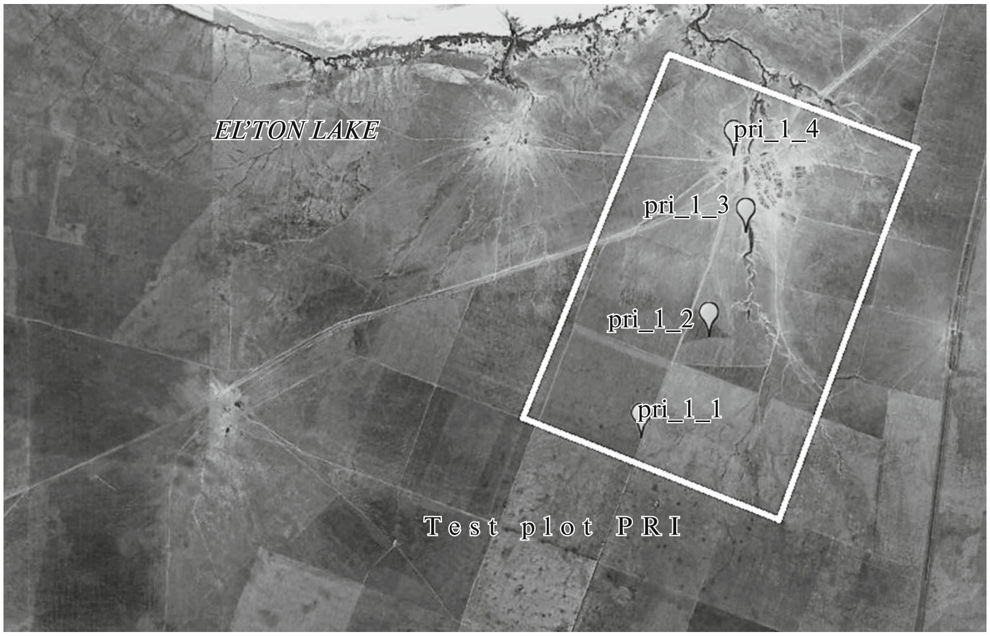

Fig. 5. Test plot Pri (satellite image "Spot," date October 1, 2012. Source: Google Earth. 12-year-old fallow soil, despite the clear field lines).

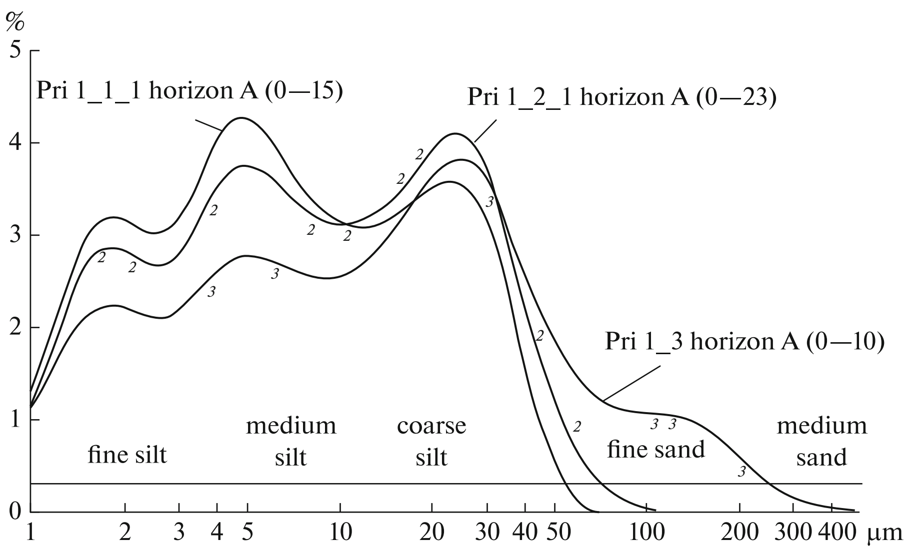

Fig. 6. Differential curves of soil particle size (soil pits Pri 1_1—Pri 1_2—Pri 1_3 and humus horizons).

hypothesis is already confirmed by similar properties of the B horizons, including the granulometric composition (Table 2).

Evaluation of WRC differences with sand accumulation. Differences in sand accumulation were studied on a transect 6 km long on the Pri test plot. Soil pits were set on the transect at different distances from the cattle pan. Sand accumulation can be seen well on cosmic photographs (Fig. 5), and the descriptions of soils of plots at different stages of pasture degradation are comprehensively described in the published works, in particular in relation to the distance from the sites of stock watering or pans (Dobrovolsky et al., 1991; Mozharova and Fedorov, 1990; Huanga et al., 2007).

The data given in Table 2 show that the projective cover decreases as much as 12 times with the approach to the cattle pan, which is confirmed by a 15-fold decrease in the vegetation index. Similar tendencies are seen in the carbon content (except for the pit Pri 1_4, which is subject to the effect of animal wastes), which decreases by a third in the soil series Pri 1_1—Pri 1_2—Pri 1_3.

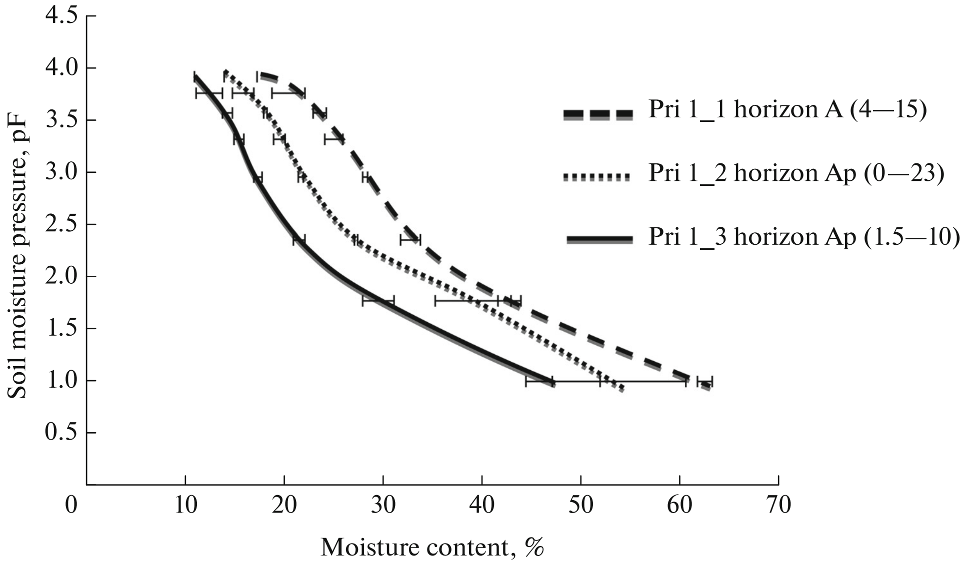

Fig. 7. Water-retention curves for humus horizons (soil profiles Pri 1_1—Pri 1_2—Pri 1_3).

The manifestations of sand accumulation in the soil series Pri 1_1—Pri 1_2—Pri 1_3 are as follows:

(1) the granulometric composition of the humus horizon in the studied soils becomes easier (light clay—heavy loam—medium loam);

(2) the compact structure of the humus horizons becomes loose;

(3) the water stability of aggregates in humus horizons (according to Andrianov) decreases by six times;

(4) the morphological features are evidence of a decrease in the structure quality.

Analysis of the differential curves of granulometric composition provides direct evidence of sand accumulation: the content of silt particles decreases and the amount of sand particles rises in the direction of the cattle pan (Fig. 6).

The comparison of the WRCs (Fig. 7) completely confirms the obtained data: the curve is gradually shifted to the left with sand accumulation, which points to a decrease in the water-retention capacity of humus horizons. Therefore, the amount of precipitated moisture remaining in the root zone will decrease contrary to sand accumulation on the transect. For example, the 10% difference in soil moistening, which remains between the extreme branches of WRC (Pri 1_1—Pri 1_3) over almost the entire range of the measured parameters, signifies a loss of water retention of 260—300 t of moisture per ha or 26—30 mm of precipitation (with consideration of the typical horizon thickness of 20 cm and compactness of 1.3—1.5 g/cm^3), while the day precipitation here seldom exceeds 5—10 mm. Under the conditions of a moisture deficit, this may become the leading factor of land productivity and desertification of the area.

CONCLUSIONS

Based on a study of the processes that develop with desertification (salinization, solonetzization, and sand accumulation) in the soils of the Caspian Sea Lowland, it is shown that the soil water-retention capacity may be used as an integral parameter of all desertification trends. It is characterized by a water retention curve (WRC) of soils. The physical sense of the use of the WRC to characterize desertification consists in the fact that it shows the soil's capability for moisture retention, soil moisture mobility, and plant availability and thus characterizes the main factors that limit biological productivity in natural ecosystems and the agroecosystems of arid regions.

The advantage of the WRC in characterization of the desertification process is that it may be successively used, even when several synergetic factors of degradation (desertification) are simultaneously revealed in soils and their rates are different, with differing initial background conditions (granulometric and mineralogical soil composition, geomorphological position, and others).

The soil WRC is a relatively constant value and does not undergo seasonal variations. This makes it universal in comparison with other soil parameters, which are subject to seasonal variability and make it difficult to determine the desertification rate.

It may be concluded that the term desertification may be used for soils. Its physical sense is that the combination of various degradation soil processes results in a decrease in the availability of soil moisture for plants, which may be determined by the WRCs. This enables the integration of individual diagnostic features of salinization, solonetzization, erosion, sand accumulation, and other degradation soil processes within a unified approach to the diagnostic of land desertification.

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