ISSN 1068-3674, Russian Agricultural Sciences, 2015, Vol. 41, No. 1, pp. 40–44. © Allerton Press, Inc., 2015.
Original Russian Text © El Sayed said Mohamed Mohamed, A.V. Shuravilin, M.U. Lyashko, Abdel-Nasser Rashash, 2014, published in Doklady Rossiiskoi Akademii Sel'skokhozyaistvennykh Nauk, 2014, No. 6, pp. 37–40.

SOIL SCIENCE

Assessing Changes in Soil Properties in the Eastern Part of the Nile Delta over a Long-Term Period

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Received March 24, 2014

Abstract—The properties of alluvial soils eastern part of Nile delta based on geomorphological zones are studied. Water characteristics, soil physical and chemical properties were studied during 24–40 years. The results showed that the highest soils quality of alluvial zone are located in young terraces. In a zone of coastal plain the salinization processes are active. On the other hand old terraces are dominated by aeolian processes.

Keywords: Nile delta, properties of alluvial soils, geomorphological zone

DOI: 10.3103/S1068367415010115

According to ample data, the soils in the Nile Delta are the most fertile, and they characterized by a wide variety of differentiated soil layers [1]. The combined natural and anthropogenic impact on these soils leads to certain changes in their basic properties and makes these soils less productive [2]. However, there is a lack of studies dedicated to changes in the regimes and properties of the soils in this region and their resistance to anthropogenic action in intensive farming use.

The goals of this work were to study the change detection of soil proprieties East of the Nile Delta and to find regularities in their resistance to anthropogenic action.

METHODS

The study is conducted in the area of the city of Ismailiya. The climate conditions during 2010–2013 were little different from average long-term observations. The annual air temperature was 21.4–21.8°C, and it was 16.2–16.6°C in December–May. The total precipitation in the years of survey ranged between 35.0–38.6 mm and 24.1–27.0 mm in December–May.

The geomorphological zone and the types of alluvial soils are given in the table of the experimental arrangement. The attained data were compared with the surveys conducted in 1970, 1979, and 1987 on the same types of soils by researchers from Cairo and Ismailia Agricultural Universities [3–5].

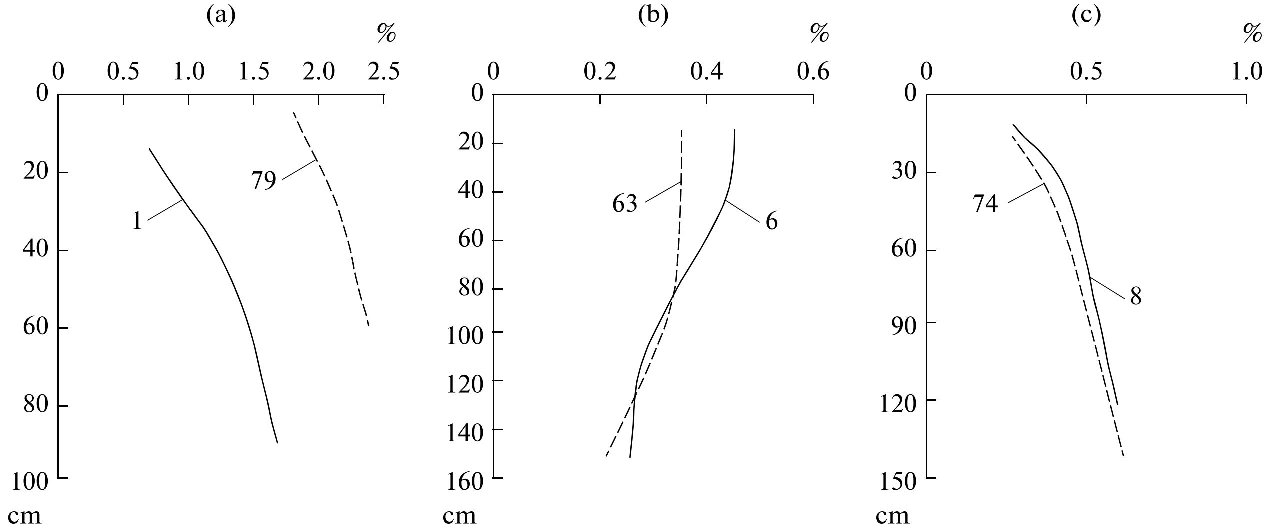
Both standard and modern methods of survey were used [6]. The physical and water physical properties of the soils were determined by already known methods [6]. Soil texture was determined according to [7]. The chemical properties of the soils, ground, and irrigation waters were analyzed using the methods expounded in [8, 9–11].

RESULTS AND DISCUSSION

According to the data of the morphological description obtained in the comparison of our surveys with the results of the previous surveys, the soil profiles did not undergo major structural changes in the

Table 1. Experimental Arrangement

Geomorphological zone	Soil
Coastal plain	Alluvial meadow, carbonate, shallow, of medium loamy grain texture on clay alluvium (**Al**)
Old Delta plain (old river terrace)	Alluvial soddy, carbonate (desertified), of light grain texture on alluvial sands (**As**)
Recent terrace of the Nile	Alluvial soddy meadow, clay, medium thick, on clay alluvium (**Asm**)



Total salts (%) in (a) Al, (b) As, and (c) Asm soils. The numbers along the curve are the numbers of cuts.

elapsed long-term period. Their particles size distribution remained resistant to outside action and did not change much over the 24–40 years of intensive use. The only differences consisted in some changes in particle-size fraction content and shift in the depth of the surveyed layers. In the Al soil (see the survey arrangement), Gleyzation phenomenon was observed at 50–80 cm in depth at shallow groundwater occurrence (90–120 cm). In 1971–2011 the groundwater level decreased from 50–60 cm to 0.9–1.3 m, whereas the gleying limit went down from 0.5 to 0.9 m, which resulted from the water horizon decrease in Lake Manzala. In the As soils, no groundwater level was observed until down to 3.5 m in depth, and no significant soil changes were registered either. In the Asm soils, the groundwater level was observed at 160–180 cm in depth with roughly the same level being detected in 1987 (1.4–1.6 m). The soil profiles did not undergo any major morphological structural changes either.

In the indicated 24–40 years, there were no major changes in the consistence density and porosity of the top and most distended layer of the alluvial soils. The greatest changes occurred in the subsurface soil. In the layer of 30–60 cm, the consistence density increased on average by 5–6% in all the soils: it increased from 1.3 to 1.38, 1.62 to 1.7, and 1.33 to 1.40 g/cm^3, respectively, in the Al, AS, and Asm soils. The porosity of each of the three soils decreased from 49.1–50.9 to 46.0–48.7%, from 38.2 to 35.1%, and from 51.9 to 48.9%, respectively. At the same time, there were no major changes in the consistence density and porosity of the deeper layers. The highest aggregation was observed in the Asm soils, where the totality of healthy aggregates was 64.1%, while that in the As soils was 54%. The Asm soils also have the highest level of water stability, whereas the As soils have the poorest water resistance: the respective figures are 59.8 and 21.2%. The amount of healthy aggregates in the topsoil layer was lower than in the Asm and As soils by 3.1–3.6 and 1.6–2.2-fold, respectively. Thus the As soils have the best physical properties in terms of density, porosity, amount of structural aggregates, and water stability; the properties of the Al soils are not so good, while the As sandy soils have the poorest properties of all.

The As soil in the zone of old delta plains has the lowest moisture capacity and insignificant wilting percentage and effective moisture content. In the long-term period, the lowest moisture capacity of these soils remained almost unchanged: 7.6–10.2% of volume in 1979 and 2011 alike. The Asm soil has the most favorable properties. In the long-term period, its lowest moisture capacity and productive moisture content tended to decrease due to dewatering. Compared with the alluvial soddy soil, its water property indexes were approximately 4–5 times as high. The lowest moisture capacity in the Am soils in the coastal zone of lake Manzala was 15–18% of the total volume, and the productive moisture content in the soil layer 0–90 cm in depth was 85 mm. With increasing distance from the lake, we observed that the lowest moisture capacity and the productive moisture content naturally increased 2.5-fold and twofold, respectively. Both indexes were much lower as compared with the figures from the previous surveys (1.05–1.2-fold and 1.1–1.4-fold, respectively).

The lowest humus content is registered in the alluvial soddy (As) soils but the humus content in the top layer increased by 13% on average over 32 years (1979–2012), which is seemingly conditioned by annual fertilization. The highest humus content is reg-

Table 2. Chemical composition of alluvial soils

Cut No., soil, year of analysis	Depth, sm	Humus content, %	C, %	N, %	C/N	$CaCO_3$, %	Plaster, %
1, Al, 2011	0–25	1.62	1.042	0.100	10.42	7.2	0.68
	25–50	0.89	0.455	0.046	9.89	7.6	2.14
	50–90	0.61	0.305	0.034	8.97	7.4	3.17
3, Al, 2011	0–20	1.42	0.861	0.084	10.25	9.8	0.23
	20–60	0.94	0.552	0.056	9.86	7.2	0.46
	60–130	0.53	0.463	0.048	9.65	7.8	0.79
79, Al, 1971	0–5	1.38	0.717	0.057	12.58	9.9	0.74
	5–25	0.72	0.410	0.390	10.51	8.2	2.87
	25–60	0.51	0.305	0.032	9.53	7.4	3.08
10, Al, 1971	0–20	1.28	0.841	0.074	11.36	9.6	0.45
	20–50	0.76	0.458	0.043	10.65	8.8	0.77
	50–120	0.55	0.416	0.043	9.67	7.7	1.56
6, As, 2011	0–30	0.73	0.482	0.047	10.26	14.6	–
	30–45	0.62	0.354	0.036	9.83	12.9	–
	45–105	0.42	0.216	0.023	9.36	12.2	–
	105–150	0.21	0.113	0.012	9.42	7.5	–
63, As, 1979	0–30	0.54	0.282	0.025	11.28	12.14	–
	30–85	0.32	0.122	0.013	9.38	11.32	–
	85–150	0.23	0.146	0.016	9.12	9.65	–
8, Asm, 2011	0–25	2.34	0.825	0.078	10.58	4.2	–
	25–60	1.43	0.309	0.034	9.09	3.8	–
	60–120	0.48	0.201	0.023	8.74	3.9	–
74, Asm, 1987	0–25	1.79	1.090	0.100	10.94	2.45	–
	25–70	1.26	0.573	0.030	3.67	1.87	–
	70–140	0.47	0.515	0.052	8.85	1.81	–

istered in the Asm soils. The comparison of the results has shown as well that the humus content in the top layer increased by 0.54% or 1.3-fold in the 24 years (1987–2011). With the increasing distance from Lake Manzala, the humus content in the top layer of the Al soil gradually decreased from approximately 15 to 1.38%, which was conditioned by the decrease in organic matter content in kind of lake sediments with increasing distance from the coastal line. In 40 years (1971–2011), the humus content in the top soil layer near and far away from the lake increased 1.23-fold and 1.11-fold, respectively. This was conditioned by the kind of soil use and organic fertilization.

In the 32-year period, the C/N ratio in the top layer of the As soil decreased by 8% on average, whereas it remained almost unchanged during the 24-year period in the same layer of the Asm soil. However, this index tends to decrease with increasing distance from Lake Manzala. In the 40-year period, the carbon and nitrogen content in the top soil layer in the coastal zone near the lake increased 1.71-fold and twofold, respectively, whereas the increase in more remote areas was

1.02-fold and 1.14-fold, respectively. These differences were determined by the improved reclamation conditions due to dewatering. All the surveyed soils have very low absolute carbon and nitrogen content. At the same time, the C/N ratio was favorable.

We have determined the equations to express the relation among the humus content, ooze content, and lowest moisture capacity:

$$U = 0.493 + 0.031X; \quad R^2 = 0.88;$$

$$U = 0.368 + 0.035X_1; \quad R^2 = 0.70,$$

where U is the humus content, %; X is the ooze content, %; and X_1 is the lowest moisture capacity, % of volume.

The highest carbonate content is detected in the As soil; it was 12.1% in the top layer and decreased twofold depthwise. Similar results were obtained in 1979. This distribution of carbonates in soil layers is conditioned by their specific properties and by their ingress due to eolian processes widely spread in the surveyed zone. It should be noted that carbonates accumulate due to regular irrigation with mineralized bicarbonate calcic drainage wastewater and underwater. The carbonate content in the Asm soils is much lower: 2–3%. In the 24-year period, the carbonate content tended to increase, which was possibly due to it being added as mineral fertilizer. In the 40-year period, the carbonate content in the Al soil was virtually unchanged.

Plaster was found only in minor amounts in the Al soils, although it increased in content depthwise. On the whole, the change in the chemical composition of the Al soils is closely related to the termination of inundation and accumulation of silt deposits in the delta associated with the construction of the Aswan Dam.

The lowest salt content is detected in the As sandy soils (figure). The top soil layer is little salinized, whereas the deeper layers are not saline at all. The highest fractions in anions and kations in the salt content belong to chloride ion and sulfate ion and Na and Ca or Mg, respectively. In the 32-year period, there was a certain increase in the water soluble salt content, which was 1.14-fold on average: this resulted from the specifics of irrigation regime, quality of irrigation water in use, and type of soil use in farming. At the same time, mineralized collector drainage water was used in irrigation, which heavily salinized all the soil profile.

The top layers of the Asm soil are not salinized, but the degree of salinization increases depthwise to reach the average level. This distribution of salts is mainly conditioned by irrigation, type of alluvial deposits accumulated during inundation processes, and specifics of irrigation equipment and technology. All these factors have affected salt movement and distribution. In terms of salinization, these soils belong to chloride sulfate and sulfate chloride types. In terms of cationic composition, the soil layer corresponded to the Mg–Ca salinization, whereas the deeper layers corresponded to Mg–Na salinization. In the 24-year period, the total salt content in the top layer remained almost unchanged. However, the salt content of the lower layers had a minor, 1.11-fold increase. Such differences are conditioned by consistent irrigation and income of salt to the soil from irrigation and ground water and from salinized soil forming rock. Since 1987, the Asm soils have shown signs of annual salt accumulation conditioned by intensive farming use, soil irrigation, and poor outflow of drainage water due to insufficient drainage of territory.

The most salinized soils are the Al soils in the zone of sea-coast terraces. Their salinization results from the influence of seawater flowing in underground from the Mediterranean Sea and Suez Channel and its accumulation in the soil stratum. Especially high salinization is typical of the soils in the littoral part of Lake Manzala. Prior to dewatering activities, those soils had been waterlogged, heavily salinized, and almost unused in crop growing. Due to the dewatering activities, the topsoil layer was a little demineralized and the soil turned from heavily salinized to medium salinized. With the increasing distance from Lake Manzala, the soils become less salinized. On the whole in the 40-year period, the average salinization in the three cuts in the Al soils decreased from 1.61–1.80 to 0.68% or 2.5-fold, whereas the salinization of the bottom soil layer decreased from 2.14–2.41 to 1.61% or 1.4-fold. The water-soluble content decrease resulted from the dewatering of soils ensuring gradual annual desalinization. In recent years, steps to lay drainage systems and leach excessively salinized soils have been taken. In addition, less mineralized water from the Al Salam Canal started to be used in irrigation works instead of drainage and discharged waters.

According to the experimental results, the dependence of the soil salinization on the irrigation water mineralization and groundwater level has been found:

$$U = -0.129 + 1.021X_1 - 0.081X_2; \quad R^2 = 0.98,$$

where U is the salt content in the meter-deep layer, %; X_1 is the irrigation water mineralization, g/L; and X_2 is the groundwater level, m.

Thus, gleying processes in the soils in the region considerably attenuated as a result of long-term farming use with irrigation. In the alluvial meadow soils, gleying moved from the top layers to the deeper horizons, and it almost ceased in the alluvial soddy meadow soils. The physical properties of the alluvial soils got much worse as a result of long-term anthropogenic action. In the 24–40 year period, the subsurface horizon became much denser, whereas the soil grain texture remained almost unchanged. The water properties of the soils did not change considerably. However, the dewatering activities decreased the lowest moisture capacity and productive moisture content of the alluvial meadow soils. In the 24–40-year period, the humus content in the alluvial meadow, soddy, and soddy meadow soils increased 1.0–1.2-fold, 1.13-fold, and 1.3-fold, respectively. The carbonate content did not change much. The plaster content somewhat decreased, seemingly because plaster had been dissolved and washed out by irrigation water. Considerable changes occurred to the water-soluble salt content.

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Translated by S. Kuznetsov