SOLONETZS AND SOLONETZIZED SOILS OF REPUBLIC OF MOLDOVA: REMEDIATION METHODS

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Abstract

Alkaline and alkalis soils are present in all soil provinces, but the most important areas are located in the central (Ciuluc hills, at the border of Codri plateau) and southern (Southern Moldova Plain) part of the country. In world practice for alkali soil improvement, the usual method is gypsum application in common with organic fertilization. In the Republic of Moldova these amendments are missing and their purchasing requires considerable amount of money. Created situation generates the necessity to replace gypsum with other calcium materials. Investigations were carried out on two pilot areas. To assess the state of soil quality there were described soil profiles and taken soil samples from genetic horizons. Within investigations on chemistry and quality indicators of surface water there were taken samples from water bodies of the study areas.

Key words: agriculture, soil improvement, solonetz, solonetzized soils, Republic of Moldova

Solonetzs substantially increase the complexity of soil cover and decreases massively land productivity by 40-60% (Сувак П.А., 1986). Previous researches and studies revealed that automorfe solonetzs are formed and evolve on deposits of Neogen salty clay. Fine texture, excessive compactness, and high degree of dispersion and peculiarities of structural composition attribute to these soils highly unfavorable physical, chemical and mechanical proprieties (Sandu Gh., 1984).

It was also established that amended solonetzs restore their defective characteristics in 7-10 years, thus this is a defined pedogenetic process, the intensity of which depends largely on natural conditions and human impact.

Considering the climatic conditions, the Republic of Moldova belongs to a region of insufficient and unstable humidity. This makes the country's agriculture to develop in conditions of increased risk. It has been established that the main natural limiting factor that largely determines the size of plant productivity is the degree of soil insurance with available water (Andrieș A., 2007).

Thus, optimization of soil moisture by irrigation application results in droughts mitigation and plant productivity improvements. It should be mentioned that irrigation is an anthropogenic intervention with various effects on soil, in particular, on chernozems. Multiple researches show that extension of irrigated areas in the steppe zone has generated a major problem related to water quality (Крупеников И.А. *et al.*, 1978).

In the Republic of Moldova chernozems make up over 74% of soil suitable for irrigation. Change of moisture regime of chernozems from natural to irrigated one, even when using high quality water, leads to structure degradation, compaction of upper horizons, worsening of the chemical and physico-chemical properties (Крупеников И.А. *et al*, 1978; Подымов Б.П., 1976). Utilization of water from local sources (internal rivers, lakes, ponds) for irrigation needs, which, in general, is characterized by high degree of mineralization, alkaline reaction and chemically unfavorable composition, leads to accelerated development of salinization process and, in particular, of secondary solonetization of chernozems (Filipciuc V. *et al*, 1995). Prevention or mitigating the negative effects can be achieved by application of a system of agro-pedo-ameliorative measures and strict regulation of water quality indices. Performance of these activities constitutes the main purpose of the project.

MATERIAL AND METHOD

To achieve the first phase of the project, calendar plan includes the following tasks:

- selection of the pilot area;

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- collection relevant information on the pilot area;
- determination of initial state of soil and water quality through collection of archival materials and analysis of soil and water samples collected in the field;
- geospatial analysis of soil cover and river system to assess the terrain quality in 3D.

Investigations were carried out on two pilot areas. For assessment of calcium amendments impact on automorphic solonetzs there was selected a catchment of the Middle Ciuluc river, placed in the Central part of the country within the Cozesti commune, Singerei district. The effect on irrigation and chemical amendment on chernozems proprieties was studied at the polygon from Lebedenco commune, Cahul district, located in the southern part of the republic. Research methods were those in field, in laboratory and office. Performed analyzes and determinations correspond to usual methods and/or adopted ISO.

The research started with the assessment of natural conditions and delimitation of soil units borders. For mapping the comparative-geographical method of V.V. Dokuchaev was used, which allows the establishment of natural bonds between soils and soldering factors. Utilization of geographic information system (GIS) and mapping modern equipment during research activities were carried out within the territory of the pilot areas. The researches were conducted in 2016-2017 by the working team.

For study development, there were used the following materials: maps of territorial organization of communes from the pilot areas at scale of 1:10000; soil maps at 1:10000; topographic plans at 1:10000; digital map of soil cover of Moldova at 1:10000; remote sensing materials "orto-photo" at 1:5000 of Land Relations and Cadastral Agency (LRCA); "Digital Elevation Model (DTM)" of LRCA. Mentioned materials were connected to the national reference system MoldRef-99. Subsequently thematic layers ("Hydro", "Terrain", "Settlements", "Soil", etc.) as well as structure of the database parameters were formed. Next step consisted in digitization of soil and territories with vineyards and orchards plantations polygons that can be used in irrigation. A digital model of the elevation was developed at a scale of 1:1000 and attributive information for each area was introduced. There were performed field research activities for actualization of soil, infrastructure and land degradation polygons which were estimated digitally in the office from geospatial remote sensing materials. The works were made in the MapInfo (2D) and ArcGIS (3D) software and in accordance with "Instructions on soil survey to attribute of land for state and public needs" approved in 1991, "Regulation on the content of general Land Cadastral documentation "approved by the Republic of Moldova Government Decision no. 24 of 11.01.1995. To assess the state of soil quality there were described soil profiles and taken soil samples from genetic horizons. Within investigations on chemistry and quality indicators of surface water there were taken samples from water bodies of the study areas. Soils physical, physico-chemical, chemical indices, as well as chemical composition and water for irrigation were determined in laboratory.

All field and office materials were commonly analyzed and studied as a system [13]. Later they were used to compile up-to-date information. As a result of cartographic work, development of set of thematic digital maps of study area components was performed.

RESULTS AND DISCUSSIONS

The impact of calcium amendment and ameliorative fertilization on automorphic solonetzs was studied in the limits of a catchment with total area of 2702.4 ha situated in the south of the Singerei district. By its geographic location, study area is included in II soil-climate zone with insufficient humidity (Ursu A., 2011). The average annual air temperature is 9.0 – 9.5ºC; sum of temperatures over 10ºC makes up 3000 - 3200ºC; vegetation period with temperatures greater than 10°C is in between 177-182 days. The cold period (with temperatures below 0ºC) is 174-188 days. Sunny days last 290-320 per year. For study area there were analyzed materials on monthly climatic indicators for 1950 - 2016. The lowest average temperature was recorded in January 1963 which was equal to -14.3ºC and the highest average temperature was registered in July 1989 which was 23.7ºC. The average annual temperature is equal to 8.9ºC (*Figure 1*). From the chart it is noted that the minimum average temperature during the year corresponds to January, - 3.7ºC and maximal - to June, reaching up to 19.96ºC.

In Moldova the assurance of plants with water is quite variable during the years; from normal to critical periods. According to multiannual data for study area average annual precipitation is 500-600 mm, and during periods when temperatures exceed 10ºC, these constitute 380-400 mm. The number of droughts alternates from 1 to 3 within 10 years period. Value of hydro-thermic coefficient is from 0.6 to 0.8 and indicates insufficient humidity during the plants growing period. Processing of climate data for the period 1950 - 2016 showed that monthly maximum average precipitations were registered in June 1985 with amount of 246 mm. The minimum value was recorded in September 1963 with no precipitation. Month average for 64 years is 44 mm. Over the years 1950-2016 precipitations had a non-uniform trend. Amount of precipitation varied from 337 mm in 1954 to 741 mm in 1996. The annual average is 513 mm. Monthly average precipitations over the years range from 27 mm in October to 77 mm in June.

The Republic of Moldova topography was formed as a result of the interaction of tectonic movements of the crust and denudation processes in contemporary conditions which took place in late Neogene. From geomorphological point of view, study area belongs to Region II of North Moldavian Plain, Ciuluc Hills district (Урсу А.Ф., 1980). Topography of catchments is characterized by a fragmented relief and deep valleys. Here long hillsides with steep slopes prevail that favor the emergence and development of soil degradation forms represented by erosion and landslides. General catchment direction is south.

For study area the *Digital Elevation Model* was developed that includes specific indicators, such as hill shades, slope classes, aspect and altitude. From the GRID materials (picketing DEM) with 27479 points the hill shades - DEM was formed (*Fig. 2*) with a very high resolution 1*1 m. In case of geo-referenced keystone of the territory, it has been identified a minimum of 59.2 m, a maximum of 257.0 m, average altitude being 122.2 m. Thus, there is elevation amplitude of 197.8 m (*Fig. 2 and 3*).

Elevation classes were formed and evaluated with an interval of 40 m (*Table 1*). From obtained data there can be observed predominance of class heights ranging between 80-120 m, occupying 49.4 % and those of 120-160 m with 30.9 % of the territory. In the range of 80 - 160 m elevation land share is 80.3 %.

Slopes classes were extracted from digital elevation model (DEM) according to elaboration methodology for soil studies showed in figure 6. A third part of the study are (29.81 %) is located on 3-5º slopes,1-3º slopes occupies 24.38% of the catchment, while rolling ones (5-7º) -17.48 % (*Figure 4*). In the flood plains, a terrain with slope up to 1º prevails. The weighted average degree of slope is 5.1º (Canarache A., *et al.* 1987).

Slopes aspects area constitute following specifications: South-Vest - 23.98%, North-East- 18.04%, East – 14.02%, Vest – 13.96%, South - 11.73%. Average aspect of study area is 158˚, which represents domination of south slopes (*Fig. 5*).

Aspect is classified in four classes. First class called *shaded* includes north and northeast aspect. Such land occupies the area of 619.7 ha. Second class called *semi-shaded* incorporates eastern and north-western slopes with an area of 487.21 ha. Third class corresponds to *sunny* one with southern and southwestern aspects covering 964.89 ha. Last class – *semi-sunny* - with western and south-eastern slopes covers an area of 630.6 ha.

Table 1

Elevation classes

Elevation, m	Area, ha	% of total area
40-80	189.94	7.03
80-120	1333.55	49.35
120-160	835.25	30.91
160-200	234.46	8.68
200-240	104.20	3.86
240-280	5.00	0.19
TOTAL	**2702.40**	**100**

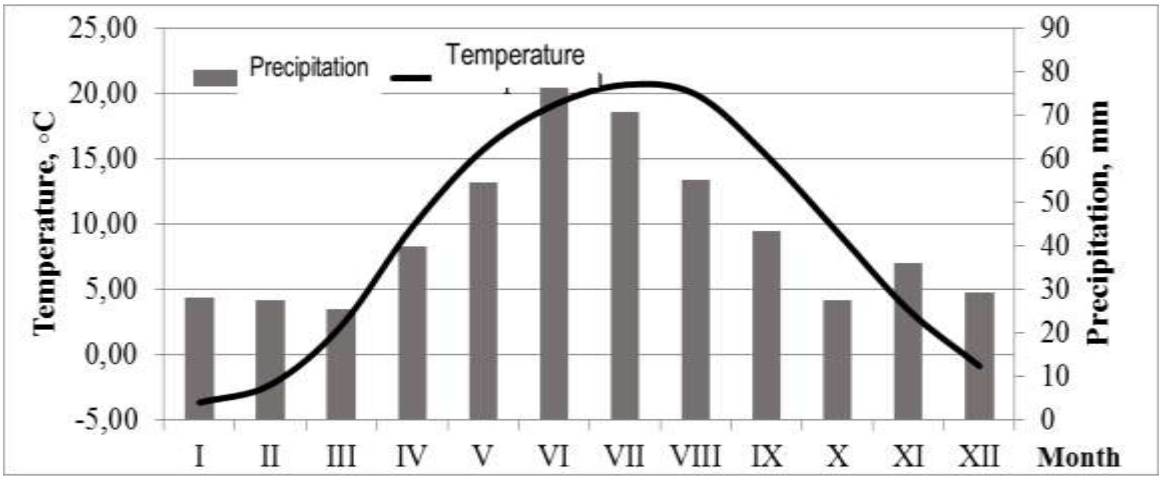
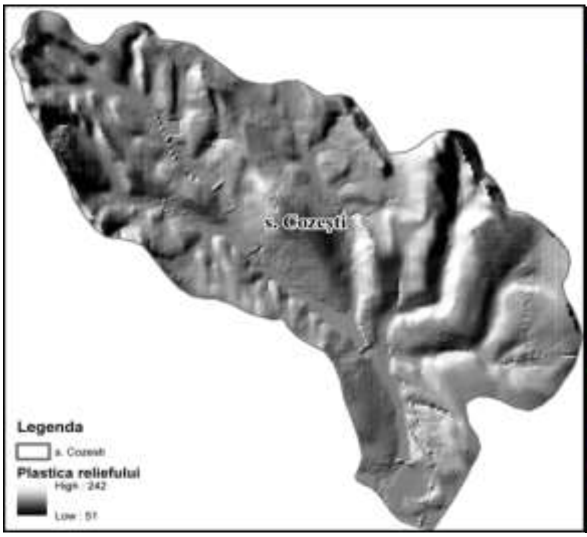


Figure 1 **Average monthly temperatures and precipitation in the study area**



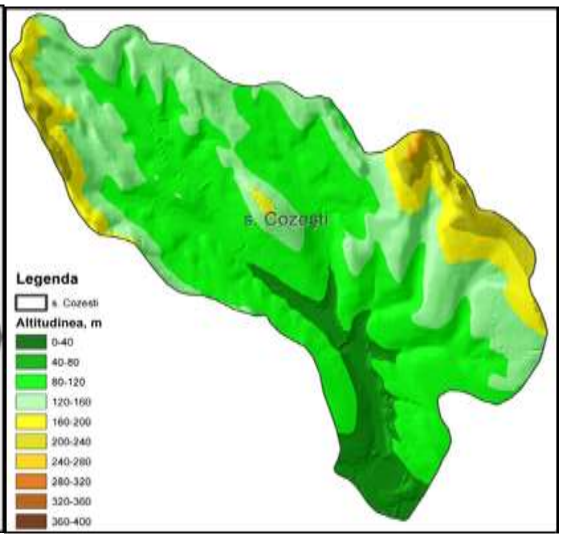
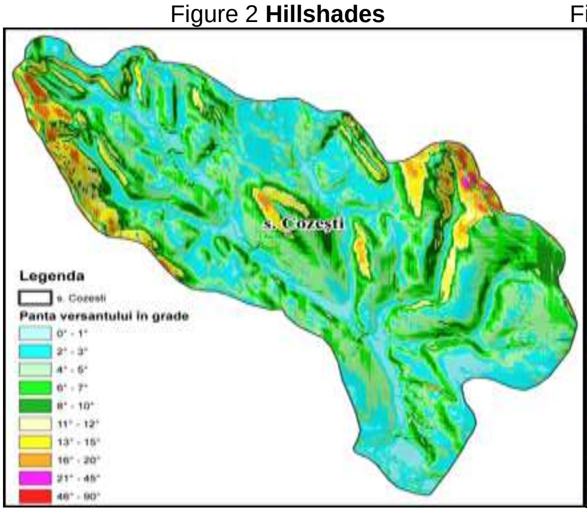


Figure 2 **Hillshades** Figure 3 **Digital elevation model of the study area**



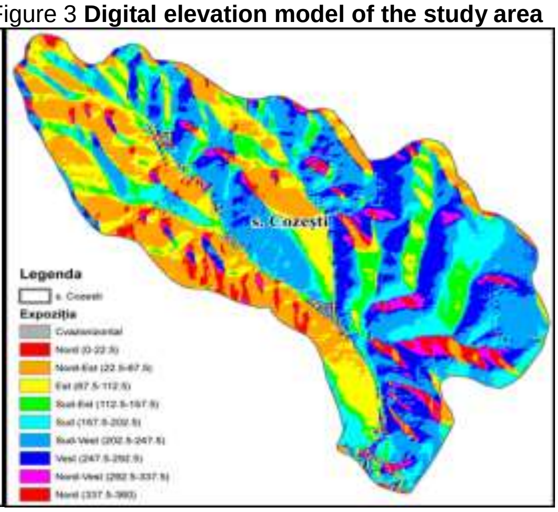


Figure 4 **Slopes, degree** Figure 5 **Aspect of the study area**

According to pedo-geographical regionalization, study area is included in first pedo-geographical Zone of Hilly Silvo-steppe of Northen Moldavian Plateau; district II of chernic and leached chernozems of Northen Plain Steppe, rayon III of Steppe of Balti Plateau, district on IIIa of Steppe of Ciuluc Hills with chernic and solonetized chernozems.

For the study area, soil cover map at 1:10000scale was developed in digital format. In the limit of the area there were found 135 polygons (*Figure 8*) covering an area of 2576.44 ha. The structure of the soil cover is formed by about 64% chernozems where the calcic prevails with 28.4%, widespread at altitudes of 67-257 m and the average slope of 6.07º. Ordinary chernozem with a share of 28.1% is located within altitudes of 63-224 m with an average slope of 4.4º. Chernic chernozem can be found between altitudes of 78 m to 252 m, with the average slope degree of 4,58º and with area 7.8% of total soils area (*Fig. 6*). On the second place solonetzs and saline soils are situated (14.8 %). Chernozem soils occupy about 11 %. Share of alluvial soils is 7.8 %, landslides constitute 2.1 %. Weighted average bonitet (system of land fertility appraisal) is 62 points.

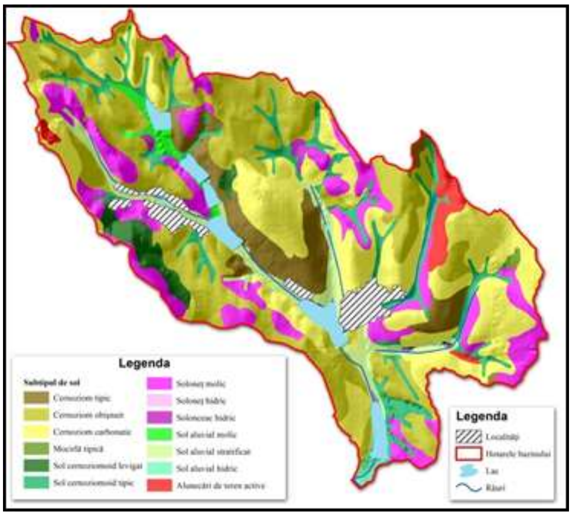


Figure 6 **Soil map**

Types of soil degradation are very different in the catchment area (*Figure 7*). Approximately 32.6% (841.07 ha) of land are subject to holomorphic processes.

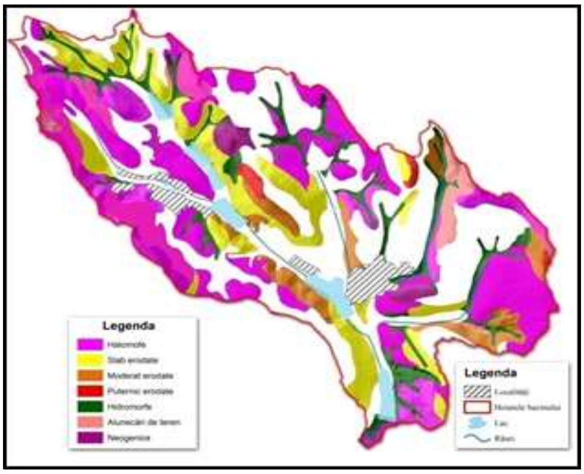


Figure 6. **Soils degradation types**

Water erosion extends on about 25% of the total area. Chernic, ordinary and calcic chernozems are eroded at 55.7 %, 41.7 % and 23.8 % respectively. Leached chernozem soils are eroded at about 87 %. The total area of soils with different erosion degrees is 643.68 ha. Slightly eroded soils prevail with a share of 59% formed at an average altitude of 116 m, with average slope degree of 5.75º. Moderately eroded soils with a share of 37 % are located at an average altitude of 137 m, with average slope degree of 7.85º. Strongly eroded soils occupy only 3.6 % and spread at an average elevation of 171 m and slope degree of 9.44º. Soils subject to hydro-morphic processes occupies 31.15 ha or 1.21 % of area. Within the catchment area there are highlighted 590.93 ha (22.94%) of soils formed on Neogene salty parental rocks which generates formation and developments of solonetzs and salty soils. Total area of different types of degraded soils makes up 1459.05 ha of the total area equal to 2576.44 hectares, which constitute 56.6 %.

Description of chernozem automorphic solonetzs profile:

Ah (0-30 cm) – arable humic layer, low solonitized, dark-grey, compact, massive structure, fine pores, cracks, plant debris, horizons clearly distinguished.

Btna (30-50 cm) – sodium clay-illuvial horizon, dark-gray with brown hues, and massive structure with prismatic slitizate (vertic) formations, very compact, fine pores, semi-decomposed small roots, fine clay, and horizons clearly distinguished.

Bkz (50-70 cm) – transitional horizon, yellow with brown hues, nonhomogeneous, humus tongues, unstructured, compact, fine pores, veins and crystals of gypsum with carbonate, fine clay, and gradual transition.

BCkz (70-100 cm) – horizon of transition to soil formation rock, yellow with humus accumulation through the cracks, unstructured, compact, weak gleyzation, stagnant, rare *bieloglaska*, fine pores, spots of carbonates and gypsum crystals, fine clay.

Performed researches showed that the experimental field soil is characterized by ”great” share (4.79%) of organic matter on 0-30 cm depth. Sodium clay-illuvial horizon (Btna) contains 3.26% of humus and falls in the ”middle” class. The underlying horizons amount of humus is ”low” to ”very low” (Canarache A. *et al*, 1987).

Distribution of organic matter within soil profile is characteristic for given subtype of soil and is manifested by a sudden reduction of its content from the upper to deeper horizon. Thus, the difference in humus content in the topsoil and subsoil constitutes 1.53 %.

In automorphic solonetzs improvement practice content of $CaCO_3$ and maximum accumulation depth play an important role. From presented data it can be seen that amount of calcium carbonate is insignificant in the first 50 cm. In the subsoil and parental material $CaCO_3$ content increases significantly (7.1 %) and is included in the ”middle” class. Great depth location of carbonic acid salts excludes the possibility of agro-biologic improvement which consider involving calcium compounds reserves in Btna horizon through soil improvement works.

Water capacity corresponds to useful water reserve that the soil can yield plants. Those measurements show that the shallow soil horizon is ”low” (10.4%). The soil and rock underlying horizons have WITH ”very small” (3.3 - 6.8%).

Wilting capacity (Plant available water) corresponds to water resources that soil can yield to plants. The measurements show that in surface layer of soil horizon CU is ”low” (10.4%). Underlying horizons and soil formation rock have CU ”very low” (3.3-6.8%).

It is known that alkali soils are characterized by a defective structure. In the unchanged alignment, automorphic solonetzs structure is strictly differentiated in genetic horizons (Герасимов И.П., *et al.* 1960). Elluvial horizon has lamellar structure with reduced hydro-stability. Structure of clay-illuvial sodium horizon (Btna) is prismatic-column. Structural aggregates have an extremely compact alignment, and their porosity is low and fine. The underlying soil horizons, soil is nonstructural with massive formations.

Structural soil composition of experimental polygon is dominated by aggregates larger than 10 mm, whose content varies between 49 and 57 %. The micro-aggregates (< 0.25 mm) are contained in small amounts of 1-4 %. Structural aggregates with agronomic value (Σ 10 to 0.25 mm) comprise 41-48 % and according to the Dolgov-Bakhtin scale structure are assessed to be ”satisfactory”.

CONCLUSIONS

Intrazonal subtype of (steppe) chernozem automorphic solonetzs and zonal soils complexes with different degrees of alkalinity, in general chernozems, are widespread in all pedo-geographic provinces of Moldova. It should be mentioned that spatial distribution of these soils is very scattered and is determined by lithological and geomorphologic conditions. An important role in formation, development and spatial distribution of chernozem automorphic solonetzs is played by soil formation rocks.

The largest areas of automorphic solonetzs and the largest participation in the composition of the soil cover, is recorded in Ciuluc - solonetzs Hills and Central Moldavian Plateau. These soils are widespread in the Codri borders, in Southern Moldavian Plain and the Tigheci Hills.

According to soil survey study results, total area of chernozem automorphic solonetzs is 26.9 thousand hectares. In most cases these soils are located on the territories of elluvial and trans-accumulative (transition) landscapes. It is widely accepted that in mentioned landscapes, predominantly located in interfluves and related hillsides with gently undulating slopes, a regime of slowed migration of several elements and substances in the soil, including soluble salts is installed. Chernozem automorphic solonetzs is formed and evolved in these types of landscape only in conditions when the soil formation rocks were presented by salty clay deposits, generally of Neogen, located in small depth of 0.5-1.0 m. These clays contain considerable amounts of soluble salts (1.5-2.5%), sulfate prevailing in their composition; they are characterized by fine texture with predomination of clay with a share of 40-47% in its composition.

On watersheds, there can be often meet solonetzs with crust or columns at the top of the surface. Solonetzs with medium depth columns occupy slopes with south, southwest and west aspect. Automorphic solonetzs with great depth columns are located on gently undulating slopes of northern, northeastern and eastern aspect. In trans-accumulative landscapes automorphic solonetzs often form complexes with semi-hydromorphic solonetzs.

Main peculiarity of chernozem automorphic solonetzs distribution consists of formation of small island areas distinctively outlined. These soils, diffused in the highly productive terrains, substantially increase the complexity of soil cover and reduce their productive capacity by 40-60%. A significant participation of automorphic solonetzs both as number of contours as well as surface share (5-8% of arable land) is recorded in the districts located in the Ciuluc – solonetz Hills. The largest share of solonetzs is located in Singerei district, this constituting 8.49% or 4634 ha.

For assessment of ameliorative state of salty soil in terms of application of agro-pedo-ameliorative works soil profiles were placed on chernozem automorphic solonetzs from where samples for chemical and physical analysis were taken. Within field and laboratory work, physical hydrological, physico-chemical and physico-mechanical properties of soil were determined. Soil profile morphology and morphometric are characterized below.

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