Line conditions of different-age arable soils of landscape catens of central forest-steppe

Elena Kovalyova*, Alexander Akinchin, Sergej Linkov, Ekaterina Kotlyrova and Irina Orazaeva

Belgorod State Agrarian University named after V. Y. Gorin, Belgorod, Russia

* E-mail: umat_05@mail.ru

Abstract. The study of acid-alkaline conditions of arable soils in different terms of agricultural use was carried out in the Belgorod region on a key site corresponding to the meadow-steppe zone landscape of the forest-steppe. As a result of field studies, 32 incisions were studied in the meadow-steppe section (6 incisions on background catens and 12 incisions on open catens). Each incision was provided with layered values of morphometric indicators of soil horizons. For background steppe soils, shade slopes are characterized by more alkaline conditions, in comparison with southern slopes. For 140-year-old arable land, the situation is opposite: shadow slopes have a more acidic reaction of the medium, in comparison with insoluble ones; for 240-year-old arable land, alkaline-acid conditions on the slopes of opposite exposures do not significantly differ. In the first 140 years of plowing, acidification of the soil profile occurs; the difference in the pH value between the background and arable land values of 140 years of age on the slope of the northern exposition reaches 1.6 on the surface, gradually decreasing to 0.2 at depth. Further plowing leads to alkalization of the soil profile by 0.6-0.9 pH units, however, the initial, background level is not achieved.

1. Introduction
The essence of the catenary approach to the analysis of soil regularities is reduced to the identification in any locality of one or several model geomorphological profiles (chains) running from the highest place of the territory to the lowest one. The profile is graded along the relief by individual factors (humidity, temperature, etc.) or by a set of landscape features. The upper parts of the chain are the driest part of the catena, the lower parts are the wettest. From top to bottom of the catena most of the factors change consistently and smoothly, i.e. in a gradient manner. Therefore, the catena serves as a mechanism for identifying the ecological capabilities of different species of plants, animals, microorganisms, their assemblages and ecosystems as a whole. As noted in the literature [9], changes in many biological parameters (abundance, diversity, biomass of organisms, biological productivity, etc.) along a number of biogeocenoses of one geomorphological profile (catena) are described by bell-shaped curves.

The catena is attractive because it represents the middle unit of the landscape structure, intermediate between the elementary cell of the biosphere - biogeocenosis - and such a large unit as a landscape. It is a polygon where soil evolution, vegetation and animal population succession take place [4,13].

It should be noted that the concept of "catena" (translated from the Latin language means "chain") entered the scientific lexicon thanks to the works of East African soil researcher Joffrey Milne, who made an invaluable contribution to the knowledge of tropical soils [11]. Having studied in detail the soil
cover of many areas of Africa, he found that there is no continuous, zonal distribution of one type of soil, but there are their regular combinations. He called these combinations catena. It was he who established how the individual soils, the links in this chain, are linked together through surface and intra-soil water runoff.

In Russian-language literature, the definition of a catena differs significantly from the Western European one in the clear development of the concepts of eluvial (absence of substance inflow except for atmospheric precipitation) and accumulative (absence of substance removal) elementary landscapes as characteristic initial and final elements of a catena [12]. M.A. Glazovskaya (1983) supplemented this concept with the notion of "transit landscapes", which are located linearly between the eluvial and accumulative landscapes and differ in different ratios of substance input and output.

The Western European concept of catena allows recognition of any arbitrarily chosen part of the slope, whereas the concept presented in the Russian language literature allows considering only the entire slope as a catena, as there is only one eluvial and one accumulative landscape on it. The remaining landscapes are transit landscapes between them. If the slope has a complex relief, a catena of the first order can be distinguished on it, and within it - catenas of the second order, each of which has its own eluvial and accumulative elementary landscapes. Examples of studying soil catenas in the south of the forest-steppe from the perspective of the Russian concept approaches are available in the works of a number of scientists [7, 17, 18]. It is their experience that we applied in this work.

A very great influence on rainwater absorption by soil on slopes has an agrotechnical effect. The essence of agrotechnical measures on slopes is reduction of slope runoff. Ploughing across the slope reduces spring runoff by about 3 times compared to longitudinal ploughing. The degree of moisture redistribution is influenced by the exposure, length and shape of slopes, as well as the amount and intensity of precipitation [5].

The acid-base state of the soil determines many features of the behavior of elements in the soil. The reaction of soil solution also has a direct effect on crops [6]. Soil reaction is a mobile indicator of soil fertility, reflecting the state and dynamics of the ecosystem.

Soil fertility is largely determined by its physical and chemical properties. The reaction of the soil environment according to the totality of system relations is considered as one of the leading properties. It determines the direction and intensity of almost all soil processes, providing nitrogen, phosphorus and potassium regimes, as well as the availability of nutrients, including trace elements. Despite the fact that the chernozem soils of the Central Black Earth Region (CCR), occupying 70.7% of its territory, are among the most fertile in Russia, they are, at the same time, largely prone to various types of degradation. To date, the soil cover of the Central Black Earth region is characterized by a high proportion of acidic soils [21].

In Belgorod region the value of this indicator is 44.3%, in Voronezh region - 28.2%, in Kursk region - 68.0%, in Lipetsck region - 73.8%, in Tambov region - 76.0%. Since the first rounds of the agrochemical survey (1964-1970), their number has increased to the greatest extent in the Tambov (by 30.4 %), Belgorod (by 21.5 %), and Kursk (by 6.2 %) regions [8, 19].

The lowest share of acidic soils (22.9%), including moderately acidic soils (1.5%) in Belgorod oblast was recorded in 1976-1983. In 1984-1989 despite the rather high liming volumes the share of acidic soils increased by 4.1%, including moderately acid by 2.3% and strongly acidic by 0.2%. During the period from 1990 to 2004 these indices were within the limits of 33.5...36.4 %, 7.1...8.2 % and 0.2...0.5 %, correspondingly. [10].

In 2005-2014, the share of acid soils increased to 45.8 %, including moderately acid soils to 12.6 %. In 2015-2018, for the first time in the entire observation period, a significant decrease in the share of acidic soils was observed, to 35.5 %, medium acidic soils to 5.8 %, and highly acidic soils were practically absent [20].

It is known that physiographic zoning of territories is based on the system of relationships between soils and soil-forming factors, among which climatic conditions play the leading role. At that, difference between precipitation inflow and evaporation has the greatest influence on profile formation [1, 3]. The factors of arable soil acidification include protonation of the soil environment associated with the vital
activity of plants and microorganisms, redox reactions, the use of physiologically acidic mineral fertilizers, as well as losses of alkaline earth elements due to removal with crop harvest and leaching with surface, subsurface and groundwater runoff [16]. Factors of anthropogenic influence weaken or strengthen the natural processes, which, nevertheless, remain dominant. Since total runoff is one of the main specific factors of soil evolution with direct and independent impact, the observed trends of changing climatic conditions [14, 15] are capable of shifting the dynamic equilibria in soils as well.

The most necessary elements of arable soil monitoring are assessment of possible changes in its acidity during intensification of agricultural use and development of decision support systems for regulation of economic activities and management of soil fertility.

2. Materials and research methods

For site selection we needed materials of the Russian State Archive of Ancient Acts (RGADA, Moscow), on the basis of which the age of agricultural tillage of the soils studied in the meadow-steppe key research area was established. The age of the young arable land was 140 years and the old arable land was 240 years.

The field study of soils at the selected key sites involved the following types of work: laying of soil sections, description of the structure of soil profiles, photographing of the front walls of soil sections, determination of soil density using steel rings; taking soil samples for laboratory analyses. Soil samples for analyses were taken within 2 meter soil profile in every 10 cm up to 40 cm depth and in every 20 cm from 40 cm depth up to 200 cm. Each soil sample was a mixed mass of soil that was collected at several locations within the transect at similar depths. Soil profiles were described according to the traditional soil transect description technique. At each point at a known depth, steel rings of known volume were sampled in triplicate and then the average density (bulk mass) was determined.

As a result of field studies, 32 transects in the meadow-steppe area were studied (6 transects on background catenas and 12 transects on plowed catenas each). Each transect was provided with layer-by-layer values of morphometric indicators of soil horizons and the depth of carbonate occurrence. Laboratory soil analysis methods included determination of stacking density (volume weight), granulometric composition (including silt fraction content) by the Kachinsky method, total humus by Tyurin, and CO2 carbonate content by Tyurin in the Simakov modification. A total of 321 samples from the Kurasovka plot were analyzed. All the above analyses for each sample were performed in duplicate to avoid errors in determining the indicators.

The key study area named "Kurasovka", corresponding to the meadow-steppe forest-steppe landscape, is located on arable lands to the south-east of Kurasovka settlement of Ivnyansky District, and the background areas are in the vicinity of Safonovka and Pokrovsky settlements of the same district of Belgorod Region.

The search for sites within the meadow-steppe forest-steppe landscape represented the identification of combinations of arable soils of southern and northern exposure slopes with slope parameters that are most characteristic of southern Central Russia.

In the catenas identified for the study, the average length of the slopes was 500-550 m. They are convex in shape and have a steepness from 0-20 at the top to 4-60 at the bottom. On each of the four ploughed rangelands (two polar exposures on the recently developed (140 years of ploughing) and on the old ploughland (more than 230 years of ploughing), 6 soil transects were laid. All the points of these transects on each catena were chosen on the assumption that they would have positional analogues on the opposite slope and on the slopes of the catena of a different plowing age (Figure 1).
Figure 1. Profiles of the catenae on which the field research was carried out and the satellite image superimposed on the topographic basis of the research area (the Kurasovka site).

It was difficult to find the background caten due to the significant development of the territory, and it was not easy to find untouched areas of soil cover by ploughing, as well as by other economic activities. Nevertheless, such soil cover areas were identified in the vicinity of Safonovka and Pokrovskiy villages. Plots that were as similar as possible in morphometric and morphological features to their arable counterparts were found.

Three transects were created on the two background catens of northern and southern exposures, the top of which corresponded to a completely flat watershed (a close analog of the locations of transects 1 and 2 on arable land), the middle transect corresponded to the positions of transects 3 and 4 on arable land, and the lowest transect corresponded to the locations of transects 5 and 6 in the lower parts of the studied slopes on arable land. The distance between the studied profiles of the soils of the background rims was 180-200 m. The limitation of the study points of the background rims was determined by weather conditions of the study period, which did not allow us to study them in detail (by laying 6 soil transects on each background rims).

The background areas of the studied meadow-steppe landscape soil catenas are characterized by the following features of the morphological structure of soil profiles.

In the catena of northern exposition from watershed to lower part of the studied slope there is a regular change of soils by relief elements.

At point 1 with a surface steepness of 0 degrees, the soil is identified as typical black earth; thick, medium loamy, on carbonate medium loess-like loam (Figure 2).
Figure 2. Photographs of soil profiles in the Kurasovka meadow-steppe landscape background area of the northern exposure.

At location 2, a typical chernozem was studied at a 2-3° steep surface; thick, medium-loam, on carbonate medium loess-like loam. A more detailed soil characteristic of this location is given below.

The width of the watershed plateau between the side slopes of the escarpment is 30 m. A0 +9-+5 cm. Brownish-yellow felt of semi-decomposed remains of last year's grasses.

A0 0-5 cm. Yellowish-grey turf of densely intertwined grasses.

A1' 5-22 cm. Dark grey; fresh; coarse-grained with clumpiness; medium-loam; compacted; many coprolites; densely interwoven with roots; transition prominent; boundary faintly undulating.

A1'' 22-45 cm. Dark gray, slightly brownish in lower part; fresh; granular-lumpy; medium-loam; compact; many worms and coprolites; visible number of roots; gradual transition; margins slightly undulating.

A1Bca 45-57 cm. Brownish-dark gray; fresh; nutty-lumpy; medium-loam; compacted; contains sparsely scattered thin whitish carbonate tubes 0.5 mm thick and 1 pc/cm2 abundant; worms and coprolites occur in appreciable quantity; in some places torn by yellowish-brown burrs; contains rare roots; transition is gradual; boundary is wavy.

BA1ca 57-82 cm. Greyish-brown; fresh; clumpy-rusty with granularity, size of nutty aggregates 2-4 cm; medium-loam; compacted; whitish carbonate tubes in the main mass of the horizon have an abundance of 1-2 pcs. per 2 cm2; whitish mycelium of carbonates with abundance of 3-6 veins per 1 cm2 appears in brownish-yellow gaps; interspersion with yellow-brown and brownish-gray gaps leaves 50 % from area of horizon; worm passages and coprolites are found in places; contains rare roots; transition is gradual; boundary is wavy.

Vs. 82-130(146) cm. Inhomogeneous because of strong tearing by burrows; from grayish-brown with yellowish to yellowish-brown with grayish; fresh; lumpy to coarse-rind; compacted to dense; whitish mycelium of carbonates with abundance of veins from 3 to 10 units/cm2, thickness of veins to 1 mm is expressed everywhere; carbonates are not visually expressed in brownish-gray weakly boiling fillings of some mole holes; in other dark-colored mole holes with loose fillings, a weak whitish carbonate mold overgrowth is detected; mole-ratios occupied more than 70 % of area of horizon; color of mole-ratios yellow, yellowish-brown, brownish-gray with yellowishness; hollow worm passages, rare coprolites and rare roots are found; transition is visible; boundary is strongly undulating and pockets on mole-ratios.

WSa 130(146)-177 cm. Brownish-pale; fresh; clumpy-prismatic; medium-loam, close to heavy-loam; dense; finely porous; contains fine whitish mycelium and whitish tubes of carbonates; the mycelium is mainly concentrated in the upper part of the horizon, to a depth of 150 cm, forming whitish pockets 3-4 cm in size, where mycelium abundance reaches 8-11 strands per cm2; deeper than 150 cm microzones of mycelium clusters are less often expressed; the horizon is evenly saturated with whitish tubes of carbonates, the abundance of which varies within 1-4 pc. per 1 cm2 with a thickness of 0.6-2
mm; there are small iron-manganese admixtures of 3-6 pcs/cm² in abundance; in the upper part of the horizon there are sprues; contains single roots. Soil is typical chernozem; thick, medium-loam, on carbonate medium loess-like loam.

The next, lowest transect in the background area was laid on the surface with a steepness of 5-6°. The soil surface was covered by steppe felt.

Soil profile description.

A0 +7-+4 cm. Brownish-yellow felt consisting of dried remains of the previous year's grasses.

Ad +4-0 cm. Brownish-grey turf of densely intertwined grass roots.

A1 0-16(20) cm. Dark gray; fresh; clumpy-grained (granular aggregates are difficult to crush when pressed); medium-loam; loose in 0-10 cm layer, compacted below 10 cm; horizon full of worm and coprolite passages; gradual transition, margins slightly undulating.

A1BCa 16(20)-45(49) cm. Greyish-brown; fresh; granular-lumpy with indistinct nuttiness; medium-loam; compacted; foci of whitish carbonate mycelium occur from a depth of 29 cm; mycelial foci 4-6 cm in size; worm burrows and coprolites present in significant numbers; yellow-brown and brownish-grey gnat holes in lower part; contains small grass roots; transition visible; boundary wavy.

B1ca 45(49)-66(70) cm. Inhomogeneous due to overgrowth by burrowing; grayish light brown in the main mass, gray-brown and yellowish brown in places; fresh; cloddy-rusty; medium-loam; compacted; whitish mycelium of carbonates expressed everywhere, veins up to 1 cm, abundance 6-7 units. per 1 cm²; whitish efflorescence of carbonate mold on chambers and worm passages; in grayish-brown filling of gaps, boiling is weaker than in the rest of the horizon, carbonates in these gaps are not visually traceable; horizon overgrown by gaps 30% of horizon area; there are often vertically oriented hollow worm passages; coprolites are found in places; grass roots are present; transition is gradual; boundary is undulating.

B2ca 66(70)-98(101) cm. Heterogeneous yellowish-brown, in some places with grayish, in general darker than the overlying horizon; fresh; lumpy-rich with prismatic; medium-loam; compacted; prismatic margins covered with brown organomineral matt films and thin whitish discolorations of carbonate mold; whitish carbonate mycelium present everywhere, with the same size and abundance as in the overlying horizon; contains brownish-gray with yellowish, gray-brown and yellow-brown mole holes, occupying about 60% of the horizon; whitish carbonate mold overgrowth is well expressed in brownish-gray mole holes with loose filling; hollowed worm holes, which in some places contain coprolites; the walls of some worm holes are dark gray humus covered; from a depth of 72 cm in the main mass of the horizon, besides mycelium of carbonates, small (0.3 mm) iron-manganese admixture in abundance of 3-4 pcs per 1 cm²; sparse roots; transition noticeable in color; boundary wavy.

VCsa 98(101)-175 cm. Brownish-pale, in some places yellow-brown; fresh; coarse-grained with clumpiness; compacted, in some places dense; thinly porous; in the upper part of horizon, along hollow worm passages whitish carbonate mold, whitish carbonate mycelium with increasing tendency to occur everywhere on faces of nutlike parts, mycelium abundance in intraaggregate mass varies from 1 pc. per 1 cm² to 3-4 pc. per 1 cm²; from a depth of 101 cm, dirty yellow crustaceans with a dense nucleus are found, some crustaceans have a dense nucleus and loose periphery, crustacean size is 1-2.5 cm, abundance from 1 pc per 6 dm² to 1 pc per 1 dm²; a combination of whitish carbonate mycelium and small dark brown and black iron-manganese admixes, the size and abundance of which are the same as in the overlying horizon, is clearly expressed on the smooth scraped horizon; it is interrupted by gray-brown and brownish-gray burrs (the area under burrs is 20-25% of the horizon); there are rare roots.

The transects in the Kurasovka background area of the southern exposure are analogous to the northern exposure in terms of the morphological characteristics of the slope (Figure 3).

Section 1. Watershed surface with steepness of about 1°. Soil surface 0+4 cm - rags of stems and leaves of herbaceous plants, loose, dry, covering 80-90% of soil surface area, 4-year old, plant stems charred in places

A description of the soil profile in the soil section is provided below.
Ad 0-8 cm. Grey, to dark grey in some places; compacted; medium-loam; granular with powderiness 3-4 mm in diameter; there are coprolites and numerous pores; abundantly penetrated by roots and stems of herbaceous plants in average 20% of horizon, in places up to 40%; transition gradual in structure and reduction of root penetration; boundary wavy with increase on cereal tussocks.

A1' 8-27 cm. Dark grey, with brownish tinge in places on cut; fresh close to dry; strongly compacted; medium loamy; cloddy-grained with aggregates from 1 cm to 5 mm in diameter; average number of worm and insect passages, pore-chambers; high coprogenicity; light sand grains visible on faces of structural units; vertical cracks observed, beginning at 6 cm and ending at 40 cm: large cracks (about 1 cm thick) occur at 50 cm spacing, cracks 1 mm in diameter at 10 cm spacing; average number of herbaceous roots, mostly thin, up to 2 mm in places, especially visible along large cracks; transition gradual structure, boundary weakly wavy.

![Figure 3. Photographs of soil profiles on the background of the Kurasovka meadow-steppe landscape of the southern exposition.](image)

A1" 27-55 cm. Dark gray, with a brownish tint in places, especially on slice; fresh; compacted; heavy loam; granular-lumpy with prismatic, average aggregate size 1 cm -0.6 cm; single blindfolds with yellowish-brown mottled filling measuring 6 cm; numerous coprolites; abundant pore-walks, even more than in the overlying horizon; network of cracks without a pronounced vertical component; cracks of desiccation on the section wall 1 mm thick occur every 5 cm; light sand grains along faces of structural separations; beads along roots; medium to small number of roots - thin 1 mm or less, 6 mm thick roots occur occasionally; transition in structure and color is noticeable; boundary is weakly wavy.

A1B 55-68 cm. Inhomogeneous: brownish-dark gray background, patches of gray-brown about 20% of horizon (blind-spotted in brown), moist; lumpy-nutty with prismatic; walnut prisms 3-4 cm in size when pressed disintegrate into clumps about 1 cm or less; medium-loamy; compacted; abundantly fine-porous, average number of pores - worm passages; frequent light mineral grains along faces of structural separations, shiny in the sun, less than 0.5 mm in size; rare coprolites, rare roots 2 mm or less in size; transition in color and structure gradual, boundary weakly wavy.

BA1 68-82 cm. Unhomogeneous: gray-brown to grayish-brown in lower part, dark gray sliver spots in number about 10% of horizon, measuring about 8 cm; fresh; strongly compacted; medium-loam; close to wetted; prismatic-rich with clumpiness; sparse coprolites; single thin glossy clay film on faces of structural units; light sand grains much less frequent than in the overlying horizon; roots sparse, pores
of average number, numerous thin pores; transition noticeable by color, in places by boiling, boundary weakly wavy.

Bca 82-110 cm. Yellowish-light-brown, brownish-whitish when dry; fresh; nutty, with lumpiness and prismatic elements; medium-loamy sandy; strongly compacted; ramulus 60%, of which dark grey 5%; pseudomycelium rare by faces of aggregates, about 1 pc per cm2, almost not found on slice, two species: Pale pseudomycelium (old) and very young - faded along fine pores, more mycelium along blindfolds; carbonate film along coarse faces in lower part of horizon (almost completely overlaps faces), under it - clay film; rare fine roots; abundantly porous; blindfolds boil up less violently, transition is gradual in structure and color, boundary is weakly undulating.

BCca 110-150 cm. The background is yellowish-light brown, grayish-brown mottled slopes occupy 40% of the horizon slice area; they also occur with lighter, uniform brownish-pale fill, boiling more roughly than the main background, wetter and less opaque than the main mass of the horizon. The horizon itself is fresh, in places to wet; coarse-rhombic with prismatic; medium-loam; compacted; abundant carbonate whitish overlying a thinner clay film along the vertical facets (this horizon accounts for the maximum clay film and overlay); pseudomycelium is sparse in the upper part of the horizon; thin-porous, pore abundance is medium, thin roots are rare; transition is gradual in decreasing number of slopes and carbonate plaque; along the left wall, slopes with brownish-pale filling and brown-gray ringing; boundary is weakly wavy.

Cca150-180 cm. Yellow-brown, moist, coarse-grained, medium-loamy, close to light loamy, sandy, sandy grains up to 1 mm wide in places, they are shiny, abundantly finely porous, rare admixture (2-3 units per cm2), single roots and inclusions of dead roots. Pseudomycelium is not expressed, but there is brightening around thin pores, single and very weak film on the edges of aggregates.

Soil: Typical, moderately thick, close to thick, moderately loamy, on thin medium carbonate loess-like loam.

Section 2. Point on unploughed southeastern exposition slope, steepness less than 20. Frequent fresh outcrops of burrows. Felt +3 cm, dry, predominantly of Tipchak, soil surface coverage - about 60%.

Ad 0-5 cm. Grey, to dark grey; dry; granular with powderiness, beads along roots; loose; medium-loamy; proportion in volume of roots of herbaceous vegetation - about 20%, maximum values - 30-40%; rarely mold (fungus); coprogenous; transition clear by number of roots, border wavy.

A1 5-34. Dark grey, fresh, cloddy-grained, with elements of angularity (average size of aggregates 6 mm), compacted, medium-loam, beads on roots everywhere. Average number of worm holes, average number of roots also (1 mm in size, single up to 3 mm. Vertical cracks, 3 mm wide, occur at 30 cm spacing. Coprogenic, on all faces of structural separations sand grains 0.5 mm in size, angular, Transition gradual in structure and color, border wavy.

A1B 34-51 cm. Dark gray with brownish, browner on cut, fresh, wetter than overlying horizon, nutty-crust with granularity, strongly compacted, medium-loamy, many worm holes, germplasm with material of AB and BA horizons, rarely repeated germplasm (filling of A horizon, ringing of horizon B), coprolites (including brown), medium amount, single humus films, thin, on vertical faces, sandy on faces of structural detachments, less light than in overlying horizon, on faces of aggregates are found everywhere. Roots thin, few in number. The transition is gradual in color, strongly wavy facies.

BA1 51-60 cm. Inhomogeneous, background grayish-dark brown, spots yellowish-brown and brownish-dark gray (50%), fresh close to wetted, nutty with prismatic and clumpy elements, compacted, medium-loamy, sparse pseudomycelium, clumps with intensity 2 pc/cm2 in places, these clumps occupy about 10%. There are scattered matte clay-humus films along the vertical faces of aggregates. Worm passages are rare, coprolites are few. Faint boiling begins at 49 cm. Thin pores abundant, thin roots rare. Transition is gradual in color, boundary is strongly wavy.

Bca 60-95 cm. Yellowish-brown, moist, nutty with prismatic, compacted, medium-loam, strongly overgrown by mole-rats (about 80% of horizon), speckled. Preserved moles are dark brown, yellow-brown, they are often enclosed in each other. Pseudomycelium is 3 pc/cm2, friable, whitish, concentrated in the form of clumps. Whitish carbonate efflorescence is observed in loose molehills. When drying, there is a whitish carbonate film in the lower part of the horizon along the vertical faces
of structural separations. Under it there is a clay film. In some places there is lighter carbonate staining (diffuse carbonates) on drying, the roots are sparse and thin. Transition is gradual in coloring and degree of tearing, the border is strongly wavy.

BC ca 95-115 cm. Yellowish-light brown; moist; compacted; medium-loam; clumpy-rich; there are carbonate films on faces of structural units, on large faces they overlap clay films, rarely there are clusters of pseudomyceum and carbonate efflorescence at drying; weakly contrasting mottles up to 60%, predominantly old, fresh mottles about 5% of the area of the entire horizon; color of fresh mottles is brownish-dark gray, old mottles to grayish-brown; mottles rarely have light spots boiling up from carbonates; rare thin roots; rare quartz grains up to 1 mm (less frequently up to 2.3 mm) in size. Occasionally there are pore-tubes with carbonate ringing. The transition is gradual in coloration; the boundary is strongly wavy.

C ca 115-180 centimeters. Rapidly boiling. Yellowish-brown, darker than overlying horizon, moist, compacted, indistinctly clayey. Medium-loamy, clay film along vertical faces of large structural units. Abundantly thinly porous. Single sparse slopes (spotted, with a greyish tint) about 3% in area. Single carbonate efflorescence along small pores. Single thin roots.

Soil: typical black earth, medium thickness, medium loamy, on medium carbonate loess-like loam.

Section 3 is laid on a slope with a surface steepness of 5-6°.

Ad 0-4 cm. Grey-brown turf of densely intertwined roots.

A1 4-23 cm. Dark gray; fresh; granular-lumpy; heavy loam, close to medium loam; compacted; many coprolites and roots; gradual transition; margin slightly wavy.

A1B 23-37 cm. Greyish-brown; fresh; granular-lumpy with nuttiness; medium-loamy, close to heavy-loamy; compact to compact; yellowish-brown and brownish-dark-grey gnarls in places; contains rare roots; many worm holes filled with grey humusy loam and coprolites, sometimes there are hollow worm holes; transition gradual; boundary slightly undulating.

B 37(42)-68(72) cm. Light brown with yellowish; fresh; lumpy-rich; heavy loam; dense; thin brown films with dull, glossy luster on faces of nutty aggregates; contains small dark brown and black ferruginous-manganese admixtures sized 0.2 mm and an abundance of 5-8 pc/cm2; dark gray humusy filling along fine fissure network; rare worm holes, walls of some holes covered with dark gray humusy overlay; rare brownish-gray gadflakes; transition gradual in color; boundary wavy.

BCg ca 68(72)-133 cm. Inhomogeneous due to overgrowth by burrs; from bluish-yellow with reddish to brownish-blue with greenish and greyish; fresh; coarse-rich clumps with prisms; heavy loam; from dense to compacted; from a depth of 80 cm, whitish carbonate mycelium and whitish crustaceans 1-2 cm in size are found; some crustaceans are destroyed when pressed with a knife; abundance of crustaceans varies from 1 pc/dm2 to 4 pc/dm2; abundance of carbonate mycelium is 3-4 veins/cm2; in relatively loose filling of some dark-colored slopes, whitish exudations of carbonate mold are observed in ochreous-reddish areas of gleying, there are large accumulations of iron-manganese primasols up to 1 mm in size and up to 11 pcs/cm2; in light-colored grayish areas, the size and abundance of primasols decreases; area occupied by mole-ratings is 60 % of area of horizon; mole-ratings are brownish-dark gray, grayish-brown, reddish-brown, yellowish-gray; sparse roots are found; transition is marked by color; boundary is wavy.

Dgca 133-177 cm. Reddish-brown with yellowish; fresh; clumpy; heavy loam, sandy loam; dense; upper part contains whitish tubes of carbonates in abundance from 1 pc/-3 cm2 to 2 pcs./1 cm2; along the main vertical fractures, dirty yellow carbonate crusts and chains of dirty yellow crusts 1-3 cm in size, with frequency of occurrence of 1 pc per 5-10 cm along vertical fracture strike; iron-manganese admixes occur in appreciable abundance, with average size 0.5 mm (up to 2 mm in some cases), abundance 3-5 pcs/cm2; interrupted by rare grayish-brown and glaucous-yellow mole crusts.

Fragmentary boil-up on mudflats starts from the depth of 72 cm, continuous - from the depth of 86 cm, rapid - in the layer 96-135 cm, deeper the boil-up weakens. From the depth of 155 cm, boiling becomes fragmentary and weak.

Soil - leached, sparse-pitched, soil-gleyey, on heavy carbonate clay loam underlain by gleyed variegated sandy loam heavy loam.
3. Results and their discussion

Acid-alkali conditions of the studied soils are characterized by the following features (Figures 4-6).

Values of pH values by catenas show that soils of young arable land of northern exposition are characterized by the lowest values (Figure 5). On the contrary, soils under steppe vegetation of the northern exposure slope are characterized by the highest pH values (Figure 4).

Accordingly, during the first 140 years of plowing, acidification of the soil profile occurs; the difference in pH values between the background values and those of the 140-year-old plowing on the slope of northern exposition reaches 1.6 at the surface, gradually decreasing to 0.2 at the depth. Further plowing, leads to alkalinization of soil profile by 0.6-0.9 pH units, however at that initial, background level is not reached.

Presumably, the initial acidification is a consequence of leaching of dispersed carbonates from the upper part of the profile, which, in turn, occurs due to an increase in vertical moisture currents in the soil loosened by plowing tools, especially intense in the first decades of plowing chernozems. Further alkalinization can be caused by the action of a complex of processes. Erosion processes can lead to uplift of carbonate-saturated thickness to surface. Deterioration of the soil structure due to degumification (reduction of the adhesive function of humus) and the resulting compaction of soils can change the soil climatic regime. Due to the denser soil structure, moisture percolates less well and therefore more moisture is lost through evaporation. Also on soils with denser soil structure there is an increase in soil surface temperature when warming up on sunny days.

For background steppe soils, shady slopes are characterized by more alkaline conditions compared to southern slopes (Figure 4). For 140 year arable land, the situation is opposite: shady slopes have more acidic environment reaction as compared with insolated ones; for 240 year arable land (Figures 5, 6), alkaline-acid conditions on slopes of opposite exposures do not differ significantly.

![Figure 4. Distribution of pH in soils of background catens A of northern and B of southern exposures (Kurasovka).](image-url)
Figure 5. Distribution of pH in soils on arable land with the age of development 140 years A of northern and B of southern exposures (Kurasovka).
4. Conclusion
For background steppe soils, shady slopes are characterized by more alkaline conditions, compared with southern slopes. For 140-year arable land the situation is opposite: shady slopes have more acidic
reaction of environment, in comparison with insolated ones; for 240-year arable land alkaline-acidic conditions on slopes of opposite exposures do not differ significantly. During the first 140 years of plowing, acidification of the soil profile occurs; the difference in pH values between background values and those of 140-year-old plowing on the slope of northern exposure reaches 1.6 at the surface, gradually decreasing to 0.2 at the depth. Further plowing, leads to alkalinization of soil profile by 0.6-0.9 pH units, however at that initial, background level is not reached.

References

[1] Alyabina I O and Nedanchuk I M 2014 *Eur S Sc* 47(10) 968-979
[2] Glazovskaya M A 1983 Soils of the world (Moscow: Moscow State University Press) p 312
[3] Urusevskaya I S, Alyabina I O and Shoba S A 2015 *Eur S Sc* 48(9) 897-910
[4] Karavaeva N A 2005 *S Sc* 12 1518-1529
[5] Kashtanov A N and Zaslavsky M N 1984 Soil conservation farming (Moscow: ROSSELHOZIZDAT) p 12-14
[6] Kiryushin V I 2010 Agronomic soil science (Moscow: KolosS) p 82
[7] Kovaleva E V, Vagurin I Yu, Akincin A V and Kuzmina O S 2021 *Inn in agr comp: prob & pros* 1 (29) 100-107
[8] Kovaleva E V, Vagurin I Y, Akinchin A V, Kuzmina O S and Teteryadchenko A I 2021 *Agr Sc Jour* 7 16-20
[9] Kovaleva E V, Lopachev N A, Vagurin I Y, Akinchin A V and Kuzmina O S 2021 *Inn in agr com: prob & pros* 2 (30) 152-161
[10] Lisetsky F N 2020 Spatial and temporal organization of agrolandscapes (Belgorod: Publishing house of Belgorod State University) p 168
[11] Lukin S V 2011 *Agroch* 6 1-18
[12] Mordkovich V G 2014 Steppe ecosystems (Novosibirsk: Geo) p 112
[13] Chekmarev P A, Lukin S V and Siskevich Y I 2011 *Ach of Sc & Tech of Agr Com* 7 6-8
[14] Miln G 1936 Amani memoirs 22
[15] Polynov B B 1935 Weathering. Composition of Continental Sediments (Moscow: Publishing House of Academy of Sciences of USSR) p 27
[16] Ramensky L G 1938 Introduction to complex soil-geobotanical study of lands (Moscow: Selkhozgiz) p 34-36
[17] Chendev Y G, Lupo A R and Lebedeva M G 2015 *Eur S Science* 48(12) p 1279-1291
[18] Smirnova L G, Kukhuruk N S and Chendev Yu G 2016 *Eur S Sc* 49(7) 721-729
[19] Khomyakov D N 2000 *Agroch* 3 81-91
[20] Chendev Yu G, Gennadyev A N, Zhidkin A P, Koshovsky T S, Vagurin I Yu and Zazdravnykh E A 2017 Distribution of organic matter in soils of forest-steppe katen of different terms of agricultural development (Belgorod) p 274-280
[21] Chekmarev P A and Lukin S V 2017 *Intern Agr Jour* 4 41-44
[22] Litsukov S D 2021 IOP Conference Series: Earth and Environmental Science 839
[23] Litsukov S D 2021 IOP Conference Series: Earth and Environmental Science 677