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The current state of abandoned lands in the northern forest-steppe zone at the Republic of Bashkortostan (Southern Ural, Russia)

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El estado actual de las tierras abandonadas en la zona norte de la estepa forestal de la República de Bashkortostán (sur de los Urales, Rusia)
O estado atual de terras abandonadas na zona estepe florestal do norte na República do Bascortostão (sul do Ural, Rússia)

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ABSTRACT

This paper presents the results of the state of postagrogenic ecosystems (18-20 years after the land was taken out of crop rotation) in the northern forest-steppe zone, Republic of Bashkortostan (South Ural) where soil cover is represented by postagrogenic gray-humus soils (Regosols). Probably, the unfavorable physical and agrochemical soil properties were a limiting factor in obtaining a profitable crop yield, and it was a reason for the withdrawal of land from agricultural use. Eighteen to twenty years since agricultural fields were taken out of crop rotation, a diverse vegetation cover has formed on postagrogenic soils. Analysis of the NDVI (Normalized Difference Vegetation Index) showed that more than 50% of the territory is covered by average and high vegetation development (low-grass meadows and forest communities). The active renewal of natural vegetation is conducted in the studied territory, which develops under the influence of zonal type vegetation and is in the transition stage from ruderal communities to low-grass meadows and different-aged secondary forests with domination of broad-leaved and light-coniferous tree species. The low content of organic carbon and basic nutrients in postagrogenic soils, at this stage of restoration, does not influence the formation and diversity of vegetation cover. However, vegetation continues to suffer the consequences of long-term agricultural use (mainly mechanical impact), resulting in a well-defined mosaic of vegetation communities, the poverty of the floristic composition and the presence of perennial weed species occurring in high abundance. It is better to maintain the land abandoned to further improve soil properties and reduce erosion.

RESUMEN

Este estudio presenta los resultados del estado de los ecosistemas postagrogénicos (tras 18-20 años del abandono de la rotación de cultivos) en la zona norte de estepa forestal de la República de Bashkortostán (sur de los Urales), donde la cubierta del suelo está representada por suelos grises humíferos postagrogénicos (Regosoles). Probablemente, las desfavorables propiedades físicas y agroquímicas de los suelos eran un factor limitante para obtener un rendimiento rentable del cultivo, lo que constituyó una razón para la retirada de la tierra del uso agrícola. Tras 18-20 años a partir del momento en que los campos agrícolas fueron retirados de la rotación de cultivos, se ha formado una cubierta vegetal diversa en estos suelos postagrogénicos. El análisis de NDVI (Índice de Vegetación Diferencial Normalizada) mostró que más del 50% del territorio está cubierto por una vegetación promedio elevada (prados de bajo pasto y comunidades forestales). En el territorio estudiado se está produciendo la renovación activa de la

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vegetación natural, desarrollada bajo la influencia de vegetación zonal que se encuentra en la etapa de transición de comunidades ruderales a prados de hierba baja y bosques secundarios de diferentes edades con dominancia de planifolios y aciculifolios. El bajo contenido en carbono orgánico y nutrientes básicos en los suelos postagrogénicos, en esta etapa de restauración, no influye en la formación y diversidad de la cubierta vegetal. Sin embargo, la vegetación continúa sufriendo las consecuencias del uso agrícola a largo plazo (principalmente el impacto mecánico), lo que resulta en un mosaico marcado de comunidades vegetales, un empobrecimiento en la composición florística y la abundante presencia de especies de herbáceas perennes. Se aconseja mantener la tierra abandonada para mejorar aún más las propiedades del suelo y reducir la erosión.

RESUMO

Este artigo apresenta os resultados do estado dos ecossistemas pós-agogênicos (18 a 20 anos após a retirada da terra da rotação de culturas) na zona estepe-floresta do norte, República do Bascortostão (Ural do Sul), onde a cobertura do solo é representada por cinza pós-agogênica. solos de húmus (regossóis). Provavelmente, as propriedades físicas e agroquímicas desfavoráveis do solo foram um fator limitante na obtenção de um rendimento rentável das culturas e uma razão para a retirada de terras do uso agrícola. Após 18 a 20 anos a partir do momento em que os campos agrícolas foram retirados da rotação de culturas, uma cobertura vegetal diversificada se formou em solos pós-agrogênicos. A análise do NDVI mostrou que mais de 50% do território é coberto pelo desenvolvimento médio e alto da vegetação (prados de capim baixo e comunidades florestais). A renovação ativa da vegetação natural é observada no território estudado, que se desenvolve sob a influência do tipo de vegetação zonal e está em fase de transição das comunidades ruderais para os prados de gramíneas baixas e florestas secundárias de diferentes idades com dominação de folhas largas e espécies arbóreas luz-coníferas. O baixo teor de carbono orgânico e nutrientes básicos em solos pós-agrogênicos, nesta fase de restauração, não influencia a formação e diversidade da cobertura vegetal. No entanto, a vegetação continua a sofrer as consequências do uso agrícola a longo prazo (principalmente impacto mecânico), resultando em um mosaico bem definido de comunidades de vegetação, na pobreza da composição florística e na presença de espécies perenes de ervas daninhas que ocorrem em alta abundância. É melhor manter a terra abandonada para melhorar ainda mais as propriedades do solo e reduzir a erosão.

KEY WORDS
Postagrogenic soil (Regosols), revegetation, geomorphometric analysis, soil properties.

PALABRAS CLAVE
Suelo postagrogénico (Regosoles), revegetación, análisis geomorfométrico, propiedades del suelo.

PALAVRAS-CHAVE
Solo pós -agrogênico (regossóis), revegetação, análise geomorfométrica, propriedades do solo.

1. Introduction

During the last three decades, economic changes formed a tendency of land abandonment in Eastern Europe. There are numerous key reasons why agricultural lands in huge territories became abandoned, such as: i) the changes of landowners and land users (Morano and Tajani 2018; Visockiene et al. 2019), ii) related changes in land use, the social, legal and economic constraints (Abolina and Luzadis 2015), iii) the development of soil degradation and erosion (Sorokina 2010; Ivanov and Kudeyarov 2015; Gabbasova et al. 2016), and iv) the decrease in soil ecological functions and related ecosystems services and consequently of crop yields as a result of the prolonged intensive agricultural use (Löw et al. 2015; Baude et al. 2019). It should be noted that in Russia the reduction of agricultural lands began in the 1990s during the economic collapse. Arable lands of more than 40 million hectares were withdrawn from agricultural use, which is comparable to the crop areas of France, Italy and Germany (Shutkov 2017).

After the withdrawal of land from agricultural use, the postagrogenic stage of transformation in soil cover begins, which is related to the zonal processes of soil formation, peculiar for every natural bioclimatic zone. The biogeochemical cycles in soil in abandoned areas change under the influence of several factors, like morphological differentiation of soil profile, soil structure and organic matter composition/ input (Litvinovich and Pavlova 2010; Kechaikina et al. 2011; Erokhova et al. 2014; Ryzhova et al. 2014; Telesnina et al. 2016; Baeva et al. 2017; Hu et al. 2018; Funes et al. 2019; Kukuls et al. 2019), nitrogen and phosphorus (Shang et al. 2019; Song et al. 2019), enzymatic and biological activity (Vladychenskii et al. 2013; St-Denis et al. 2017; Raiesi and Salek-Gilani 2018), greenhouse gases emissions (Lyuri et al. 2013). Postagrogenic changes in soil are also accompanied by natural revegetation or afforestation (Jõgiste et al. 2013), or, in some conditions further development of erosion is possible (Arévalo et al. 2016; Komissarov and Gabbasova 2017; Rodrigo-Comino et al. 2018; Zethof et al. 2019). Also the natural revegetation and afforestation influences biogeochemical cycles, which in turn forms a feedback as changes in biogeochemical soil properties influence the vegetation cover (Arévalo et al. 2017; Segura et al. 2020).

In this context, the aim of our research was to assess the state of soils that were withdrawn from agricultural use about 18-20 years ago in the northern forest-steppe zone of the Southern Urals under conditions of natural regeneration cover renewal. In accordance with the purpose of the research, the following tasks were carried out: i) geomorphometric analysis of the territory on the plots withdrawn from agricultural use; ii) determination of soil physico-chemical, agrochemical and agrophysical properties; iii) estimation of the condition of vegetation using the Normalized Difference Vegetation Index (NDVI); and iv) identification of the character of restorative succession and the degree of influence of soils on the formation of natural vegetation.

2. Materials and Methods

The soil-geobotanical studies and assessment of postagrogenic soils state were conducted in the Birsk region of the Republic of Bashkortostan, Russia at middle August of 2017. Two locations were selected: Verkhnelachentau and Romanovka (**Figure 1**).

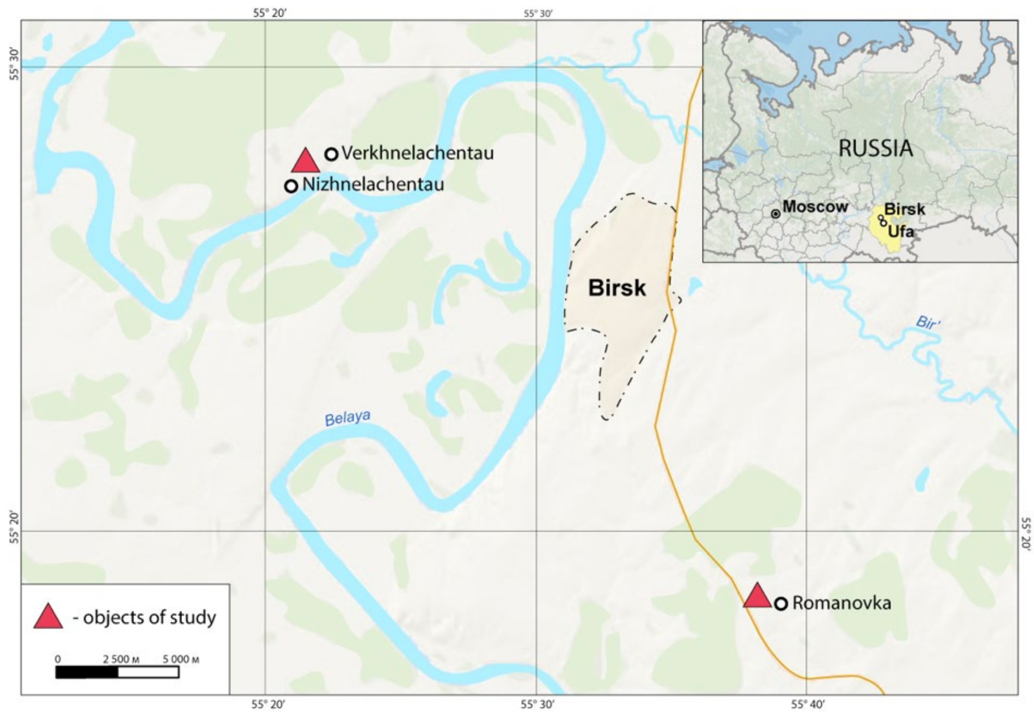

Figure 1. Map of the study area (image source: www.google.com/intl/ru/earth).

A total of 8 soil profiles pits were excavated: 4 located at Verkhnelachentau and 4 at Romanovka (**Figure 2**). At each study location, 1 basic profile pit (3 m in length, 1 m in width, and 1 m in depth) and 3 small soil pits (1 m in length, 0.5 m in width, and 1 m in depth) were made. The basic soil profile pits were made for soil diagnostic and classification. Small ones were dug as replications and for extra soil sampling. The basic soil profile pit at the Verkhnelachentau site was named 1B-2017 (**Table 1, Figure 2a-d**), and at Romanovka – 2B-2017 (**Table 2, Figure 2e-h**). Soil classification, diagnostics of the soil profile and genetic horizons ware carried out taking into account the substantive genetic classification (Shishov et al. 2004) based on an assessment of soil profile as a diagnostically equivalent system of genetic horizons, which allows taking natural and anthropogenically transformed soils into a unified classification. The resulting soil name is duplicated in accordance with the World Reference Base for Soil Resources (IUSS Working Group WRB 2015). Soil samples were collected from each soil pit from every genetic horizon over a width of the soil profile, there are total 32 soil samples were taken: 16 from Verkhnelachentau (4 soil pits and 2 horizons) as well at Romanovka (**Table 3**). The soil samples were air dried, grounded and passed through a 1 mm sieve. Agrochemical analyses were carried out using standard methods reported in Arinushkina (1970) and Sokolov (1975): the carbon content, using the Tyurin method with termination according to Orlov and Grindel (Arinushkina 1970); alkaline hydrolysable nitrogen, according to Cornfield (Sokolov 1975); available phosphorus and exchangeable potassium, according to Chirikov (Sokolov 1975); exchange cations Ca^{2+} and Mg^{2+} by the trilonometric method (Arinushkina 1970); soil reaction by potentiometry (Arinushkina 1970).

Field soil moisture content was determined by using Soil Moisture Sensor SM 150 (Delta-T Devices Ltd, UK), soil penetration was measured from the soil surface to a depth of 45 cm in 2.5 cm intervals by using Soil Compaction Meter FieldScout SC 900 (Spectrum technologies, Aurora, USA) equipped a metal rod with a cone (size 1/2 inch).

The geomorphometric analysis of the territory was carried out using QGIS geographic information system based on a digital elevation model with a resolution of 30 m – NASA's Shuttle Radar Topography Mission (SRTM) (https://www2.jpl.nasa.gov/srtm) using Google Earth Planet satellite images (www.google.com/intl/ru/earth). For calculation of the NDVI the satellite images from Sentinel 2a satellite with a spatial resolution of 10 m were used, satellite date – 07.25.2018 (https://scihub.copernicus.eu/dhus/#/home). The radiometric and atmospheric image correction preliminary was made. The total studied surface with the satellite images was approximately 150 hectares (~70 ha at Verkhnelachentau and ~ 80 ha at the Romanovka site).

Moreover, the geobotanical description was performed on plots where soil pits were located. Geobotanical releves and classification of vegetation was done according to the Braun-Blanquet (Westhoff and van der Maarel 1978) and Kopecký and Hejný (1974) approaches. The syntaxon names follow the International Code of Phytosociological Nomenclature (Weber et al. 2000). The names of plant species are given in accordance with the species list of Czerepanov (1995). The statistical analyses were performed by using MS Excel 2007 (v. 12.0) (Microsoft Corp., Redmond, WA, USA).

According to the geographical regionalization of the Bashkortostan republic, the research area belongs to subzone of the northern forest-steppe and is a part of the Right-Bank Pribelsky subregion. This subregion is characterized by the development of rigged and hilly plains with absolute elevations from 65 to 300 m above sea level. The climate at study area characterized as moderate continental with average humidity or as warm-summer humid continental (Dfb) by the Köppen climate classification (Beck et al. 2018). The average annual air temperature varies from 1.7 to 2.8 ºC, the average January temperature is -16.2 and -14.3 ºC; the average July temperature is 18-19.3 ºC. The winter is characterized by steady frosty weather with snowfalls and rare thaws. The average thickness of the snow cover in the end of winter reaches 45-55 cm. The summer is warm with occasional rainfall. The average annual precipitation of 450-550 mm, the prevailing part of them falls in warm season. The forested area is 20-35% and trees are located mainly on steep slopes and on tops of watersheds and presented by an association dominated by *Tilia cordata* Mill., *Quercus robur* L., *Acer platanoides* L., *Ulmus glabra* Huds., *Ulmus laevis* Pall., *Betula pendula* Roth and *Populus tremula* L. The natural vegetation cover is represented by grass and forb steppes and meadows, but the areas without forests are mostly plowed.

The gray soils (Shishov et al. 2004; IUSS Working Group WRB 2015) are ubiquitous in this area, in some places the sod-podzolic (Retisols (IUSS Working Group WRB 2015)), sod-calcareous (Calcisols), chernozemic (Chernozems) and clayey-illuvial chernozem (Umbric Luvisols) dominates the drained positions, while in the valleys of the Belaya, Tanyp, Bir, Ufa, Sim rivers alluvial soils can be found. Agricultural presence of the territory is 50-60%, arable land prevails in the structure (about 70% of agricultural land) and more than half of the arable land area is subject to varying degrees of erosion or faced essential erosion risks (Kadilnikov 1964; Khaziev 1995).

3. Results

The morphological description of the studied soils is given in **Table 1 and 2.**

Table 1. Description of soil profile 1B-2017 (Verkhnelachentau site)

Profile Name		**1B-2017**
Location		55° 27' 48.17" N; 55° 20' 59.57" E
Area Description		Abandoned field located 1.2 km north-west from the village of Verkhnelachentau, Birsk District, the Republic of Bashkortostan
Altitude		Varies within 93-141 m above sea level
Slopes		0-5 degrees occupies 71%, 5-10 degrees – 7%, 10-15 degrees – 8%, 15-20 degrees – 7% and 20-25 degrees – 5% (Figure 2)
Horizon	AY	0-44 cm – gray, unstructured, sandy loam, crumbly, wet, silica coatings on peds, the transition is sharp in color
	C	44-64 cm – reddish gray, structureless, light loamy, crumbly, wet, small dark-red spots, silica coatings on peds
Soil Name		Gray-humus postagrogenic (Regosols)

Table 2. Description of soil profile 2B-2017 (Romanovka site)

Profile Name		**2B-2017**
Location		55° 18' 29.56" N; 55° 38' 20.88" E
Area Description		Abandoned field located 700 m west of the village of Romanovka, Birsky District, the Republic of Bashkortostan
Altitude		Varies within 167-192 m above sea level
Slopes		0-5 degrees occupies 67%, 3-6 degrees – 26%, 6-9 degrees – 6% and 9-12 degrees – 1% (Figure 2)
Horizon	AY	0-38 cm – chocolate gray, unstructured, sandy loam, crumbly, wet, silica coatings on peds, the transition is sharp in color
	C	38-90 cm – light gray, unstructured, sandy loam, crumbly, wet, silica coatings on peds
Soil Name		Gray-humus postagrogenic (Regosols)

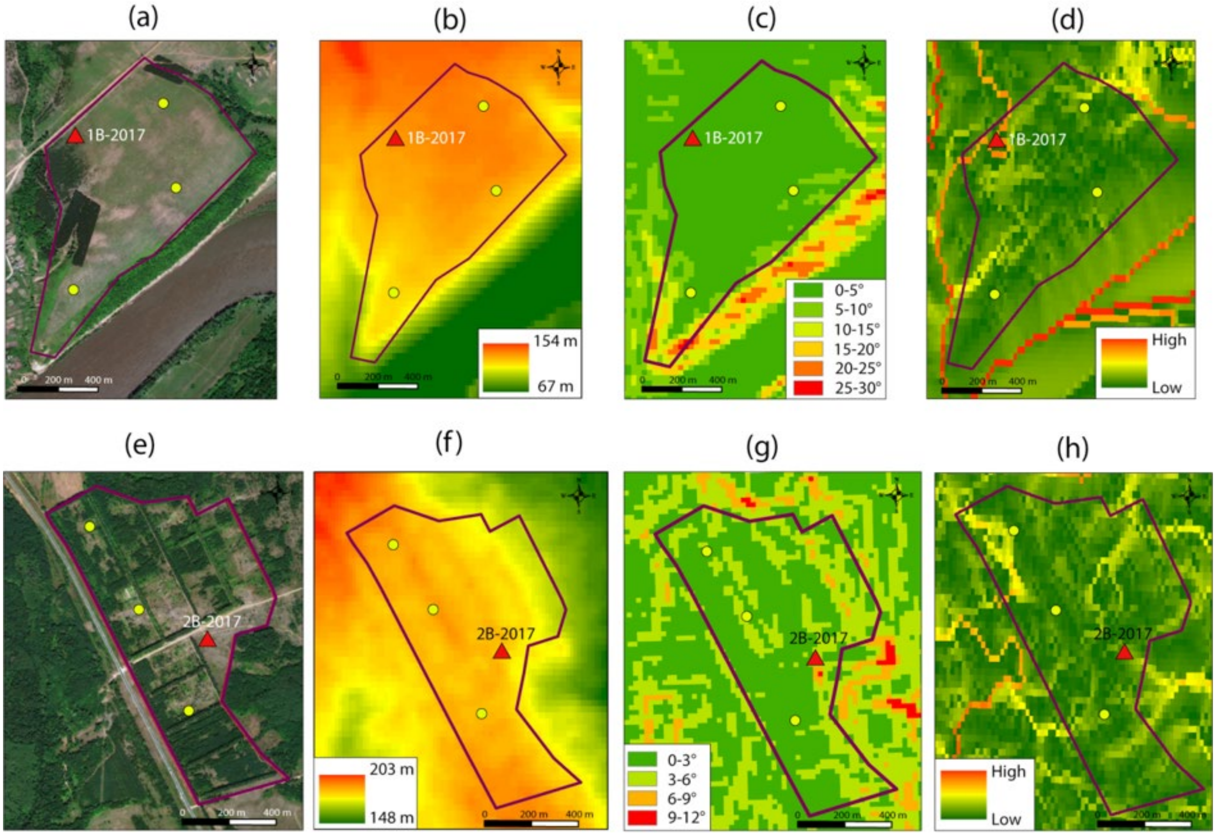

Figure 2. Geomorphometric analysis of the territory. (a) general view of Verkhnelachentau site; (b) elevation map in meters above sea level of the Verkhnelachentau site; (c) slope in degrees of the Verkhnelachentau site; (d) soil erodibility (K factor) at the Verkhnelachentau site; (e) general view of Romanovka site; (f) elevation map in meters above sea level of the Romanovka site; (g) slope in degrees of the Romanovka site; (h) soil erodibility (K factor) of the Romanovka site. Note: the basic soil pits are shown as triangles, the small soil profiles as circles.

Geomorphometric analysis of the territory showed that the area of soil profile 1B-2017 (near the village of Verkhnelachentau) is a flattened surface with absolute altitudes 93-141 m, the slopes lower than 5 degrees are predominance and constitute about 71%. The area of the soil profile 2B-2017 (near the village of Romanovka) also represents by flattened surface with absolute levels of 167-192 m, the slopes lower than 3 degrees is dominant and constitute about 67%.

The studied soils in the humus-accumulative horizon are characterized by a neutral reaction (pH in H_2O - 5.9-6.9), loamy texture, lack of soil structure, low organic carbon content (13.8-14.4 g kg^{-1} soil), alkaline hydrolysable nitrogen (21-32 mg kg^{-1} soil), mobile phosphorus (41.1-48.9 mg kg^{-1} soil) and exchangeable potassium (22-25 mg kg^{-1} soil). The amount of adsorbed cations is 9.1-12.8 $cmol_{(+)}$ kg^{-1}, among which a slight excess of Ca^{2+} over Mg^{2+} is noted. With increasing depth in the parent rock, the studied parameters changed slightly (Table 3). According to soil resistance data, the plough pan most likely formed at a depth 20-35 cm.

The vegetation in Verkhnelachentau (the area of soil profile 1B-2017) is represented by low-grass pasture meadows, and now the tree species there are actively renewed and assigned to the basal community *Agrostis tenuis-Pinus sylvestris* [Cynosurion/Aconito-Tilion]. The tree stand is represented by the young growth of *Pinus sylvestris* L. with a height of 3-5 m and their coverage is 20-40%. The age of trees ranges 10-16 years.

Agrostis tenuis Sibth., *Festuca pratensis* Huds., *Poa pratensis* L., *Fragaria viridis* (Duchesne) Weston predominate in the herb layer. *Achillea millefolium* L., *Elytrigia repens* (L.) Nevski, *Festuca pratensis* Huds., *Trifolium arvense* L., *Taraxacum officinale* F.H. Wigg are present with

Table 3. Chemical properties (mean ± standard deviation, n = 8) of gray-humus postagrogenic soil

Horizon, depth, cm	pH H_2O	C_{org}	Ca^{2+}, exchangeable	Mg^{2+}, exchangeable	Nitrogen, alkaline hydrolysable	Phosphorus, available (P_2O_5)	Potassium, exchangeable (K_2O)
		g kg^{-1} soil	$cmol_{(+)}$ kg^{-1}		mg kg^{-1}	mg kg^{-1} soil	
Verkhnelachentau site							
AY, 0-44	6.9±0.05	14.4±1.1	7.3±0.4	5.5±0.2	32±1.10	48.9±0.52	22±0.2
C, 44-100	6.9±0.05	12.4±0.9	6.7±0.3	5.1±0.2	14±0.08	52.8±0.61	18±0.1
Romanovka site							
AY, 0-38	5.9±0.02	13.8±1.0	4.8±0.3	4.3±0.1	21±0.41	41.1±0.51	25±0.3
C, 38-90	6.2±0.04	10.2±0.7	5.2±0.3	4.1±0.1	14±0.09	54.0±0.58	22±0.2

high coverage. There are, also, ruderal species of the classes *Artemisietea vulgaris* Lohmeyer et al. ex von Rochow 1951 and *Stellarietea mediae* R. Tx. et al. ex von Rochow 1951 (*Artemisia absinthium* L., *A. vulgaris* L., *Echium vulgare* L., *Carduus crispus* L., *Cichorium intybus* L., *Convolvulus arvensis* L., *Agrimonia asiatica* Juz., *Euphorbia virgata* Waldst. & Kit., *Capsella bursa-pastoris* (L.) Medikus, *Fallopia convolvulus* (L.) Á. Löv, and *Galeopsis bifida* Boenn).

The projective cover of the herb layer is 60%, where the average height of herbage is 30 cm. The low-grass pasture species have high constancy in their floristic composition (e.g., *Amoria repens* (L.) C. Presl, *Leontodon autumnalis* L., *Plantago major* L., *Potentilla anserina* L., and *Taraxacum officinale* F.H. Wigg.) which indicates a high anthropogenic (grazing or recreational) pressure. This basal community belongs to the alliance *Cynosurion* R. Tx. 1947 (order *Arrhenatheretalia* R. Tx. 1931, class *Molinio-Arrhenatheretea* R. Tx. 1937). According to the floristic composition (with the exception of the renewal forest stand), the community is the closest to the association *Loto corniculati-Agrostietum tenuis* (Yamalov 2005), which are distributed on floodplains of the rivers Inzer, Belaya, Zilim in forest-steppe and deciduous forests.

The vegetation in Romanovka (the area of soil profile 2B-2017) (community *Elytrigia repens-Dactylis glomerata*) is characterized by a poor floristic composition. The herb layer is dominated by species such as *Elytrigia repens* (L.) Nevski, *Dactylis glomerata* L., *Bromopsis inermis* (Leyss.) Holub, *Poa pratensis* L. and *Phleum pratense* L. The core herbage constitutes *Achillea millefolium* L., *Artemisia absinthium* L., *Crepis tectorum* L., *Chamaenerion angustifolium* (L.) Scop., *Senecio Jacobaea* L., *Centaurea scabiosa* L., *Potentilla erecta* (L.) Raeusch., *Geum urbanum* L., and *Equisetum arvense* L. The herb layer cover ranges 50-65% with average height of 60 cm. The presence in the floristic composition of a large group with species of pastures low-grass can attribute to the alliance *Cynosurion* R. Tx. 1947 (order *Arrhenatheretalia* R. Tx. 1931, class *Molinio-Arrhenatheretea* R. Tx. 1937).

Moreover, there is an active renewal of tree species on neighboring sites. The tree stand is represented mainly such species as *Pinus sylvestris* L. and native young growth by *Tilia cordata* Mill., *Ulmus glabra* Huds., *Betula pendula* Roth. and *Populus tremula* L. with a height of 3-8 m and cover range of 5-60% with trees average age of 10-16 years. The herbage is sparse under the canopy of tree stand, and represented mainly by low-herb meadows of the community *Elytrigia repens-Dactylis glomerata*.

The assessment of state and pattern of vegetation were made by using the NDVI vegetation index. The NDVI index has been long established as a simple quantitative indicator of the amount of photosynthetically active biomass (le Maire et al. 2011; Fern et al. 2018; Grădinaru et al. 2019; Valle Júnior et al. 2019). Analysis of NDVI (**Figure 3**, soil profile 1B-2017) showed that sparse weed-meadow vegetation occupies about 45% of the abandoned field near the Verkhnelachentau village. The rest of territory is occupied by low-grass meadows, where pine is renewed by self-seeding from light-coniferous nemoral forest (alliance *Aconito lycoctoni–Tilion cordatae*) which is located on the western part of abandoned fields. The Romanovka site is characterized by a more developed vegetation (**Figure 3**, soil profile 2B-2017). The forestry vegetation with a predominance of young growth of small-leaved and broad-leaved species, such as *Betula pendula* Roth. and *Populus tremula* D., *Tilia cordata* Mill. and *Ulmus glabra* Huds., is distributed on the 50% of the territory. The low-grass meadows occur on the 25% of territory. In the southern part of the territory, there are massifs of pine cultures.

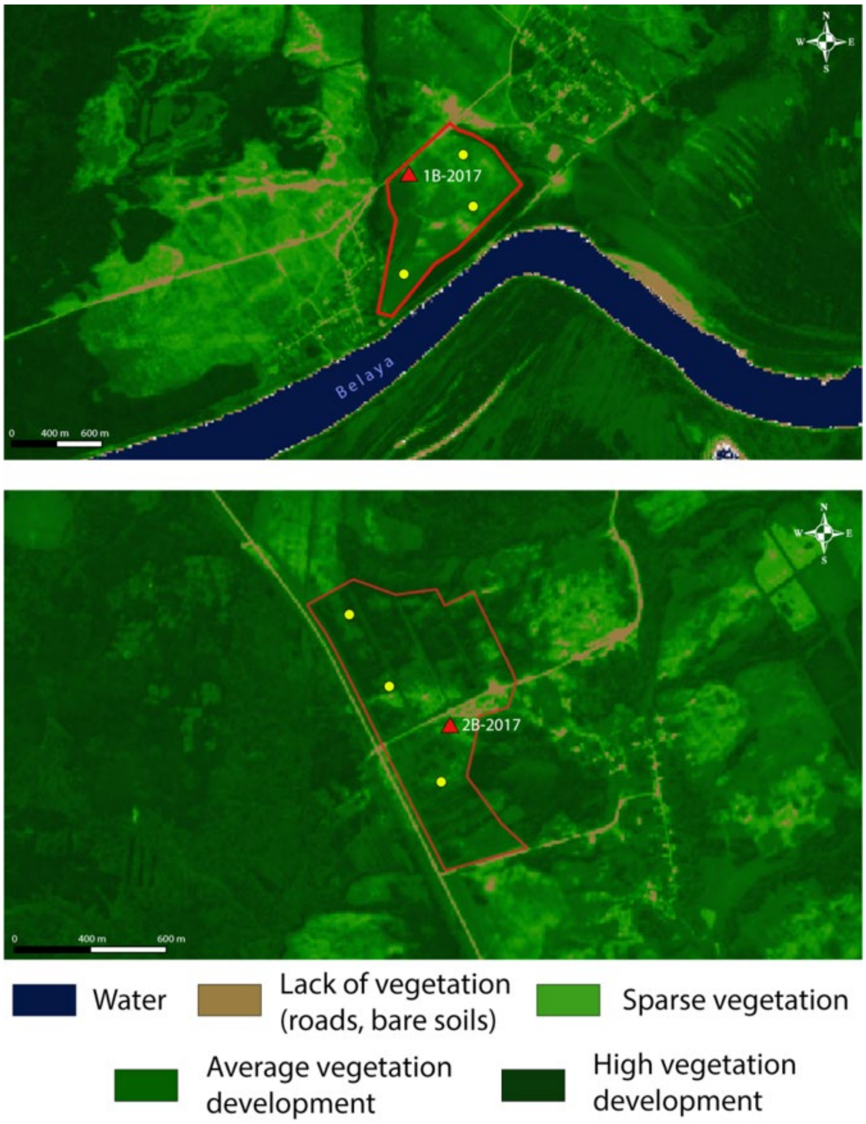

Figure 3. Vegetation analysis using the NDVI index.

Analysis of soil morphological and chemical properties showed that gray-humus postagrogenic soils have formed on substrates with light particle size distribution; the thickness of the humus-accumulative horizon is 38-44 cm. This horizon is structureless, crumbly, characterized by a slightly acidic pH, the organic carbon content is about 13.8-14.4 mg kg^{-1} and the nutrient contents: alkaline hydrolyzable nitrogen 21-32 mg kg^{-1}, mobile phosphorus 41.1-48.9 mg kg^{-1} and exchangeable potassium 22-25 mg kg^{-1}. The amount of adsorbed ions is small and amounts to 9.1-12.8 $cmol_{(+)}$ kg^{-1}, among which the calcium is slightly predominant. The studied parameters change insignificantly with depth in C horizon (**Table 3**).

Analysis of soil density data obtained by determining soil resistance using rod penetration tests showed that in the upper part of the soil profile the pressure force was 70-800 kPa, then it increased to about 5000 kPa at a depth of 20-35 cm and decreased again in the profile down to 1500-3000 kPa (**Figure 4**). The field moisture in the soil profile at the moment of penetration resistance measurement survey was 9-13% (**Figure 5**).

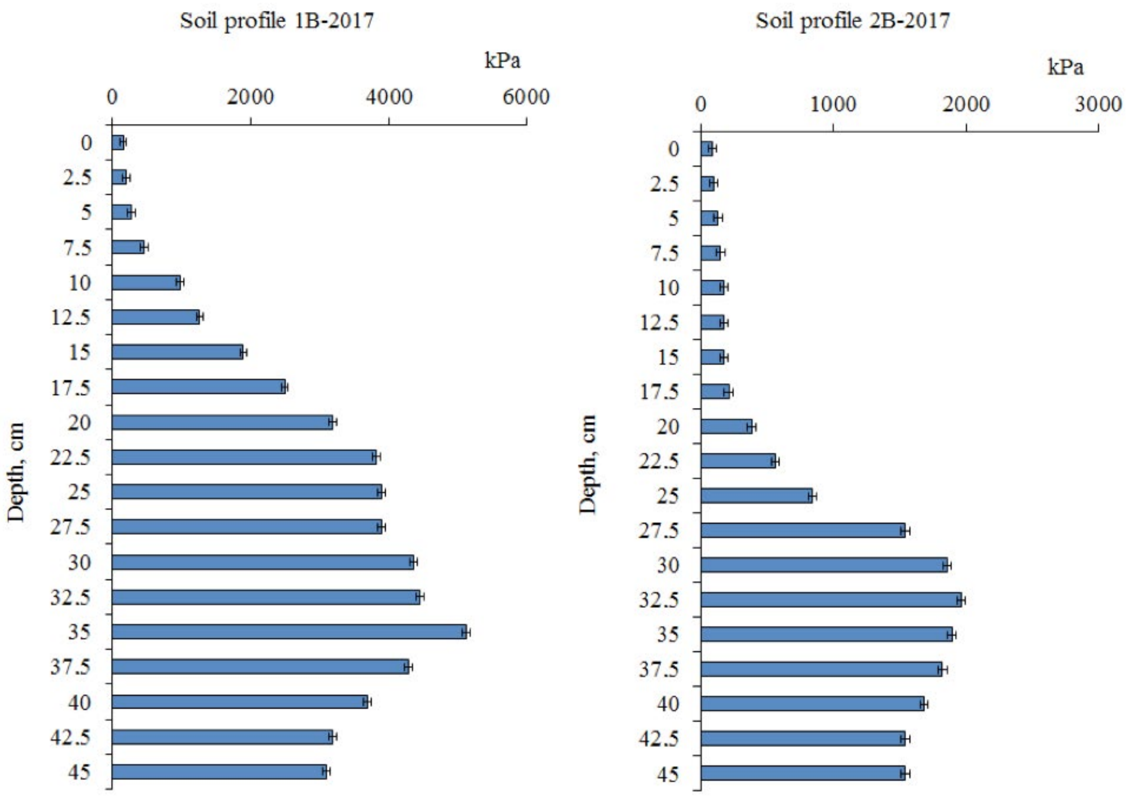

Figure 4. The penetration resistance of gray-humus postagrogenic soils.

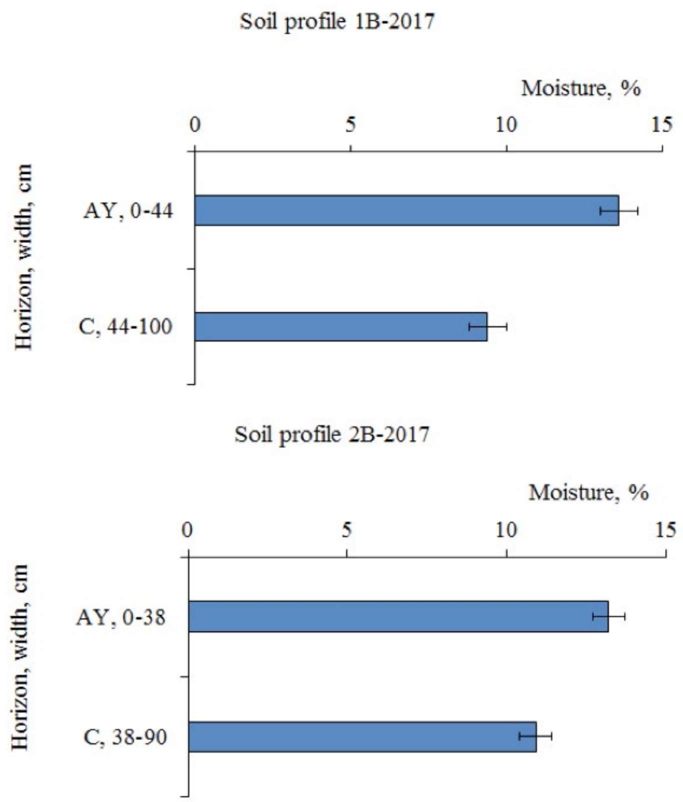

Figure 5. Field moisture of gray-humus postagrogenic soils.

4. Discussion

According to Shishov et al. (2004), the studied soils relate to the trunk of post-lithogenic soil formation, a division of organo-accumulative soils. These soils are characterized by a topsoil's humus horizon, which are formed on alluvial parent materials. The median horizon as an independent genetic formation is not expressed. These soils are formed under grassy plant communities or deciduous forests on unconsolidated substrates of any particle size and chemical composition. The formation of a complete profile is limited by topography, the duration of soil formation, climate, and the characteristics and composition of parent materials.

According to the Russian agrochemical classification (Kiryushin 1996), the content of organic carbon in studied soils is characterized as «low», the enrichment of soil in alkaline hydrolyzable nitrogen is «very low», mobile phosphorus and exchangeable potassium contents are also «low». The sandy texture, lack of structure, low cation exchange capacity and nutrient depletion contribute to the accelerated mineralization of organic matter and a low level of its stabilization. This results in a low content of organic carbon in the soil, which is a general characteristic of sandy textured soils. However, some studies have shown that over time, there is a tendency for a gradual increase in the content of organic carbon and nutrients in abandoned agricultural soils, subject to the development of processes of their self-growth and change of vegetation types (Shi et al. 2018; Hu et al. 2018; Zhang et al. 2018; Shang et al. 2019). Despite the poverty of the soil by organic and mineral elements in abandoned fields, an active renewal of natural vegetation is observed, as evidenced by high values of photosynthetically active biomass and well-defined mosaic of plant communities (**Figure 3**).

Since these soils were for a long time in agricultural use, most likely a plough pan was formed at a depth of 20-35 cm, which was present at the time of the survey of these sites. As noted in Medvedev (2011), the plough pan is formed due to the extremely high pressure of agricultural machinery in the zone of contact of the plow blade with the soil. This pan causes adverse environmental-genetic and agronomic consequences for the transformation and migration of substances, and in general for development and productivity of cultivated plants. Also, the plow pan leads to decreased soil drainage capacity, which under intense precipitation increases the surface runoff and consequently leads to water erosion (Verbist et al. 2007). Nevertheless, the disappearance of the compacted subsurface horizon (plough pan), for example, in the postagrogenic sod-podzolic soil was observed only after a 90-year period (Kechaikina et al. 2011).

The studied area has been influenced by agriculture for many years. In 2000 it became unused and now is mainly represented by abandoned agricultural land, of which meadow communities remain a part, and is currently in a state of natural revegetation. At this stage of natural restoration (18-20 years after withdrawal of fields from the crop rotation), the influence of the formation of meadow and forest communities at abandoned agricultural fields on the chemical and morphological properties of soils is not detected. Thus, the extra research aimed to compare the soil and vegetation properties at abandoned lands with current agricultural fields, virgin and forest sites is required in this study area. Meanwhile, other studies showed that some changes are occurring. For example, Baeva et al. (2017) found that on lands abandoned 6-30 years ago in the Moscow region, the carbon stocks in the upper 60-cm soil layer gained with an increasing period of abandonment, from 6.17 kg C m^{-2} on the arable land to 8.81 kg C m^{-2} in the forest soil. This represents the final stage of postagrogenic succession; the self-restoration of gray forest soils is accompanied by a reliable decrease in bulk density of the upper 10-cm layer from 1.31 ± 0.01 g cm^{-3} on the arable land to 0.97 ± 0.02 g cm^{-3} in the forest. Telesnina and Zhukov (2019) showed that in case of overgrowing of poor sandy agrosoddy-podzols at Kostroma Oblast, the changes in soil acidity and organic carbon content are adequately reflected by the proportion between different ecological groups of plants in the herb-dwarf-shrub layer. In the case of reforestation of former croplands, the organic carbon stock in biogeocenoses increases from 30-40 to 120 t ha^{-1} after 35-40 years. The restoration of forest vegetation on well-manured soils of private vegetable gardens with an initial carbon stock of 100-120 t ha^{-1} is retarded for a long time, and the organic carbon stock remains unchanged for at least 35 years. Li et al. (2019) showed in a study on the Loess Plateau (China) that soil microbial biomass C:N ratios had little change following natural vegetation restoration since farmland abandonment, and natural vegetation for more than 23 years had significantly enhanced the microbial biomass C:P and N:P ratios by 26.1-133.9% and 31.7-67.4%, respectively. Vegetation restoration for 30 years enhanced urease and alkaline phosphatase activities by 125.4% and 42.9%, respectively, which showed synchronous changes with N and P contents in microbial biomass. Soil fungi, urease and alkaline phosphatase were the drivers to the changes in microbial C:N:P stoichiometry. These authors suggest that although long-term vegetation restoration (more than 23 years) may aggravate microbial P limitation, at present soil microorganisms are maintaining the homeostatic regulation of stoichiometric ratios to mitigate P limitation.

Analysis of NDVI showed (**Figure 3**) that the vegetation of each abandoned field is characterized by high values of photo-synthetically active biomass and well-defined mosaic of plant communities. Thus, it can be noted that despite the relatively short term abandonments (18-20 years) and poverty of postagrogenic gray-humus soils, there is an active renewal of natural vegetation, which has a unidirectional successional character from ruderal communities (sparse vegetation) to low-grass meadows and forests (average and high vegetation development respectively). Recently abandoned fields provide suitable conditions for the renewal of tree species, which are sensitive to competition with perennial herbs and especially with grasses (Gill and Marks 1991; Coll et al.

2003). Also the analysis of NDVI showed that the restoration of natural vegetation in Romanovka site is faster than in Verkhnelachentau, despite the fact that they were abandoned in one time (1997-1999). We suggest that the speed forming of natural vegetation formation and its diversity on abandoned fields depend on the type of previous land use (arable field, meadow, pasture) and the presence of nearby seeding sources (Koerner et al. 1997; Prévosto et al. 2004; Shirokikh et al. 2017). Some researchers (Koerner et al. 1997; Dupouey et al. 2002; Dambrine et al. 2007) suggested that soil conditions, changed by previous land use, also could be responsible for the observed differences in vegetation.

The geomorphometric analysis of the territory using the USLE (Universal Soil Loss Equation) showed that the current soil erodibility (K factor) of abandoned land on each location is low (**Figures 2d, h**). We believe that this is due to the developed vegetation. It is well known that arable land has a low resistance to water erosion compared with grasses or forested areas (Feng et al. 2018). The Belaya river is close to the Verkhnelachentau site, thus our suggestion is not to plow this territory, in order to minimize lateral sediment transport into the river.

In general, the use of GIS tools in the identification of abandoned lands allows characterizing it more accurately and on larger areas than traditional field soil-geobotanical survey does. GIS tools also allow receiving and updating data, as well as monitoring changes (Suleymanov 2019) in abandoned agricultural land without high costs. With the advent of such data sets, the possibility of reconstruction of abandoned agricultural lands arises, which provides economic, social and environmental benefits and improves the landscape as a whole (Prishchepov et al. 2012; Löw et al. 2015; Grădinaru et al. 2019; Visockiene et al. 2019).

5. Conclusions

The studies conducted on abandoned agricultural lands (18-20 years) in the northern forest-steppe zone at the Republic of Bashkortostan (South Ural) showed that soil cover is represented by gray-humus postagrogenic soils. After 18-20 years from when the agricultural fields were taken out of crop rotation on postagrogenic soils, a diverse vegetation cover formed. The NDVI index analysis showed that more than 50% of the territory is occupied by average and high vegetation development (low-grass meadows and forest communities). On the studied territory the active renewal of natural vegetation takes place, which develops under the influence of the zonal vegetation type and is in the transition stage from ruderal communities to low-grass meadows and different-aged secondary forests with domination of broad-leaved and light-coniferous tree species.

The low organic carbon content and basic chemical elements in postagrogenic soils at this stage of restoration seem not to influence the formation and diversity of vegetation cover. However, vegetation continues to suffer the consequences of long-term agricultural use (mainly mechanical impact), resulting in a well-defined mosaic of vegetation communities, the poverty of the floristic composition, and the presence of perennial weed species occurring in high abundance.

Additional studies are desirable to compare the properties of soils and vegetation of abandoned lands with virgin soil, fallow and forest. The primary conclusion is that currently in Russia there is enough agricultural land, thus it is better to leave and not use the abandoned land, since it is assumed that the improvement in soil properties, replenishment of organic matter and nutrients in the soil and a decrease of erosion processes will occur.

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