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DYNAMIC OF ECOSYSTEMS AND THEIR COMPONENTS

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DYNAMIC CHANGES IN THE AREA WITH SURFACE-CARBONATE SOILS OBSERVED ON REMOTE SENSING DATA IN THE VOLGOGRAD REGION

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We studied the dynamics of changing area of surface-carbonate soils with the help of satellite images over a 30-year period of irrigation in 3 key areas that belong to different natural zones of the Volgograd Region: 1) the Northern Yergeni Upland (“Chervlenoye” massif), 2) the Caspian Depression, Khvalynsk Clay Plain – Northern Sarpa Lowland (Svetloyarsky massif), 3) the Caspian Depression, Khvalynsk Clay Plain – Sarpa Gully (Duboovrazhny massif). All 3 sites are located in the dry-steppe zone with an initial soil cover of light-chestnut solonetzic complexes. They differ in elevation, relief, parent and underlying rocks, groundwater levels, alkalinity, soil salinity, and the history of anthropogenic impacts associated with field planning, groundwater level rise, methods of plowing and irrigation, and crops. All sites have surface-carbonate soils, which were additionally confirmed by our fieldwork and laboratory data. We used Landsat-5 and Landsat-8 OLI satellite images for the period of 1985-2018 with a ground resolution of 30 m. Individual fields in the images were selected where surface patches were most evident, formed by the carbonates in the arable soil horizon (0-30 cm). The patches were analyzed for 3 different years, with intervals of 5-18 years. When processing images, we identified surface-carbonate soils visually, interactively, and by unsupervised image classification that uses the IsoData method in the ENVI software package. These methods yielded different results, with a similar trend of growing areas of patched over the years, which may be caused by the following reasons: 1) the spreading of carbonates across the field during annual plowing, 2) the settling of carbonates that come from carbonate-saturated soil solutions during evaporation and water use by plant roots, 3) the incorporation of carbonate horizon into plow layer as a result of the erosional loss of a portion of the topsoil. According to the image classification method, the greatest increase in area is observed in the fields of the “Chervlenoye” (12.6 ha) and Svetloyarsky (11.0 ha) massifs over 23 and 33-year periods, respectively. In the fields of the Duboovrazhny massif, the increase was 4.2 ha over 11 years, since the planning of the fields during the construction of the irrigation system there was insignificant, and the period under consideration was shorter (11 years).

Keywords: light chestnut soils,Haplic Kastanozems, irrigation, soil carbonates, field planning, space imagery classification, soil cover heterogeneity.
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In the Volgograd Region, certain factors, such as water and wind erosion, soil salinization, limit the fertility of agricultural soils. Additionally, there has been observed a formation of surface-calcareous soils, which also negatively affects agricultural crops. This process is caused by anthropogenic impact of land reclamation and irrigation.

The accumulation of carbonates in the upper soil horizons occurs due to plowing (Rozanov, 1992; Sizemskaya, 2013; de Soto et al., 2017; Khitrov et al., 2021), deep land reclamation (Amit, Harrison, 1995; Lyubimova, Degtyareva, 2000), the burrowing activity of animals (Abaturov, 2001), irrigation (Baranovskaya, Azovtsev, 1981; Prikhodko, 1996; Wu et al., 2008; Gorokhova, Pankova, 2017), field leveling (Kornblum, Myasnikov, 1982; Balabko et al., 2018), the infusion of carbonates by plants with soil solutions (Zamanian et al., 2016), and soil erosion (Kuznetsov et al., 1989; Tregubov, Averyanov, 1987; Khitrov et al., 2024).

In the FAO publications “Calcareous Soils” (1972) and “Soil Survey Investigations for Irrigation” (1979) it is noted that carbonates contribute to the formation of stable, large-pored aggregates. However, the presence of more than 2% dispersed carbonates in the surface horizons creates challenges for agriculture, which is particularly common in irrigated soils. For example, when soils rich with surface carbonates dry out after the irrigation or rain, a dense crust forms, which hinders moisture infiltration and crop germination (Levy, 1980; Khitrov et al., 2021, 2025). Furthermore, finely dispersed carbonates reduce the availability of essential plant nutrients (Zamanian et al., 2016).

The most significant anthropogenic impact on the soil cover is field leveling carried out during the construction of irrigation systems. At the start of it, the surface horizons are stripped away to remove the micro- and meso-relief elevations, and piled in mounds. The created depressions are then filled with the excavated soil, and the mounds are spread across the surface of the leveled field. Consequently, the resulting soils differ fundamentally in structure and properties from the original material, creating in many cases an artificial mosaic with complex profiles (Kornblyum, Myasnikov, 1982).

Extensive field leveling brings the natural carbonate-accumulation horizon of chestnut soils and solonetzes closer to the surface, while plowing incorporates this carbonate material into the arable horizon. A significant quantity of such material creates a heterogeneous, patchy pattern across the fields, which then can be easily identifiable both in the field studies (Zimovets, 1981) and satellite imagery (Khitrov et al., 2021; Gorokhova, Khitrov, 2023). The goal of our research is to analyze the dynamics of surface-carbonate soil patches over more than 30 years, using long-term satellite imagery of irrigation systems of the Volgograd Region. We aim to determine whether the area covered by these surface carbonates increases over time or remains constant. Furthermore, if these areas undergo any changes, we aim to evaluate the history of such changes in time and space. For this study, fields with the most pronounced patches of surface carbonates were selected within each irrigation area.

Materials and Methods

The objects of our study are irrigated areas of the dry-steppe zone in the Volgograd Region (the main irrigation region). According to the zoning proposed by A.G. Doskach (1979), these areas are located in different natural regions: 1) the Northern Yergeni upland – “Chervlenoye” massif; 2) the Caspian Depression, Khvalynsk Clay Plain, Northern Sarpa lowland – “Svetloyarsky” massif; 3) the Caspian Depression, Khvalynsk Clay Plain, Sarpa Gully – “Duboovrazhny” massif (Fig. 1).

1) The Northern Yergeni Upland (“Chervlenoye” irrigated area) extends into the Volgograd region with its northern part, characterized by wavy watersheds and gentle slopes of river valleys and ravines. Its surface elevations range from 150 to 180 m above sea level. Its groundwater typically has a depth of 30-40 m, decreasing to 1 meter only in the ravines (Volgograd Region …, 2011).

The surface of the Northern Yergeni Upland is covered by a thick layer of Scythian red-colored deposits and loess-like loams, upon which the light-chestnut solonetzic soil complexes have developed, containing varying portions of alkali soils. Among these light-chestnut soils, solonetzic variants are predominant. The heterogeneity of the soil cover there is additionally increased by meadow and meadow-chestnut soils found in shallow depressions, saucer-shaped hollows, and by numerous small mounds created by burrowing animals (Degtyareva, Zhulidova, 1970).

The “Chervlenoye” irrigated area is located south of the Volga-Don Canal. From the 1980s through the 1990s, secondary soil salinization was widespread in this area. In 1988, the groundwater was generally at 2.0-2.5 m, and at 1.5 m in some locations, with its mineralization levels of 3-10 g/L, and a sodium-chloride composition. After 1992, irrigation and crop cultivation effectively ceased there, or were limited to 1-2 fields for 15-18 years. Due to a drop in the groundwater level to more than 5 m, many significant changes have occurred in the area.

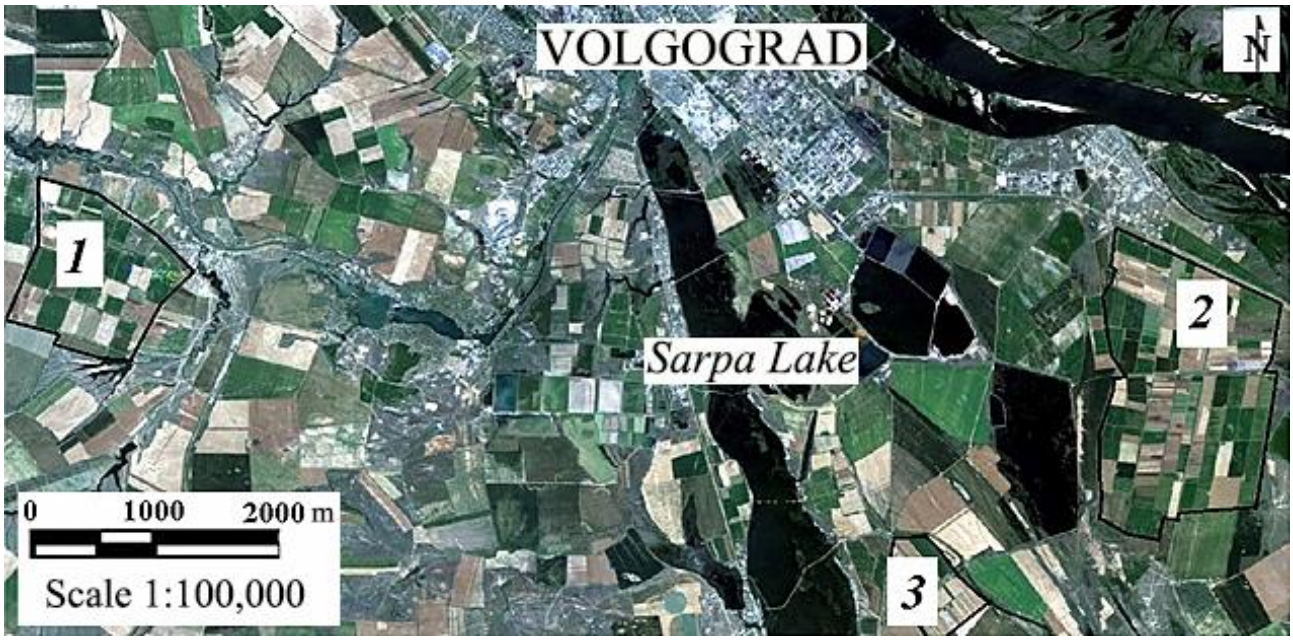

Fig. 1. Irrigated areas with studied fields that have patches of surface carbonates, on a Landcat-8 OLI image (26/05/1989).

Having no drainage system, the area has been and still is irrigated by the Volga-Don Canal, which mineralization level is 0.5-2 g/L. At first, the chosen method of irrigation was a surface one, but since the 2000s, sprinkler irrigation has been used (Novikova et al., 2009).

During the construction of the irrigation system, the fields underwent a severe land leveling. Therefore, in areas where soil has been excavated or filled, the surface exhibits effervescence when treated with a 10% HCl solution.

In 2017-2019, field surveys were conducted in the area (Fig. 2; Table 1).

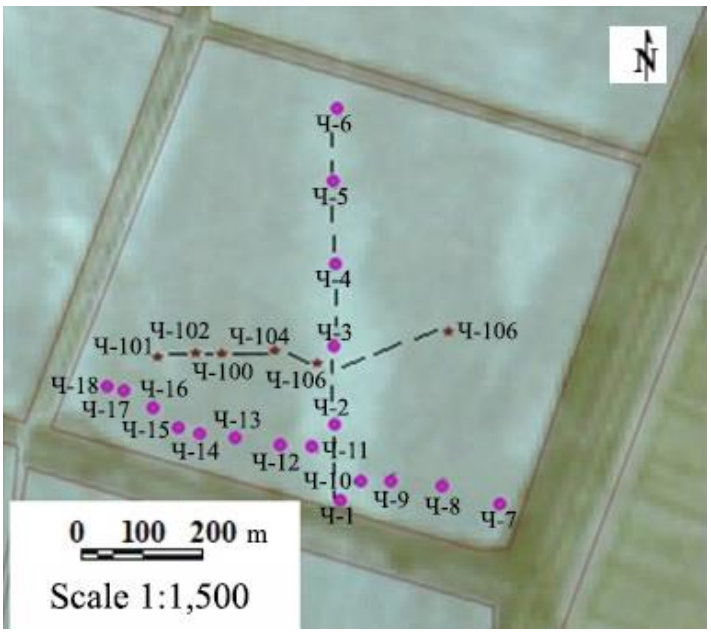

Fig. 2. A field of the “Chervlenoe” irrigated area with sampling points on a Kanopus-B image (August 2015).

Table 1. $CaCO_3$ content (%) in the arable soil layer at sampling plots (2018) in the field of the "Chervlenoe" irrigated area.

Sample plot No.	Soil horizon depth, cm	Average carbonates in a horizon, %
Ч-1	0-10	7.21
Ч-2	0-10	7.6
Ч-3	0-10	6.8
Ч-4	0-10	–
Ч-5	0-10	6.21
Ч-6	0-10	5.0
Ч-7	0-10	1.59
Ч-8	0-10	0.0
Ч9	0-10	0.41
Ч10	0-10	2.0
Ч11	0-10	6.21
Ч12	0-10	1.0
Ч-13	0-10	0.0
Ч-14	0-10	0.0
Ч-15	0-10	1.0
Ч16	0-10	0.0
Ч17	0-10	2.0
Ч18	0-10	0.59
Ч101	0-10	–
Ч102	0-10	–
Ч103	0-10	–
Ч104	0-10	2.41
Ч105	0-10	13.21
Ч106	0-10	1.0

2) The Caspian Depression, Khvalynsk Clay Plain, Northern Sarpa Lowland (Svetloyarsky irrigated area) is located in a triangle between the Volga River and the Sarpa Lakes. Absolute elevation ranges from 50-40 m above sea level in the north to 30-15 m in its central part. The region is poorly drained. Its prevailing landscape consists of a complex of loamy dry steppe and semi-desert, with pronounced strips of meadows in depressions and swales. Surface moisture is scarce and highly uneven, occasionally provided by heavy rains, while its primary source is melting snow. The soils are represented by the light-chestnut solonetzic complexes, with varying proportions of solonetzes. In the depressions, the soils are of meadow-steppe or meadow, with varying desalinization degrees (Doskach, 1979).

The parent materials of the Sarpa Lowland consist of sediments from the Khvalynsk Sea, such as clays and loams with a high concentration of readily soluble salts, underlain by highly saline chocolate clays. When the chocolate clays occur closer to the surface, they become the parent material themselves. The leveled terrain together with the low permeability of the clays, results in a naturally high groundwater level of 7-10 m, or 5-7 m in some areas (Degtyareva, Zhulidova, 1970).

In the early 1990s (after 20-25 years of irrigation) its groundwater level was at 3-5 m. Soil salinization was occasional and only within the 1st meter of the former alkali and solonetzic soils, with the salinity degree ranging from low to moderate. Over the last 10-15 years, the irrigation was

reduced which has led to a gradual decline in the groundwater level, now situated at more than 5 m. For alfalfa, irrigation is carried out via surface methods, while winter cereals receive pre-sowing irrigation.

During our fieldwork at the site, we found out that the upper part of the solonetz profile that was located on protuberant landforms had been removed during field leveling. As a result, in an area with 25-50% solonetzes and solonetzic soils prior to the construction of the Svetloyarsk irrigation system, there are no more solonetzes. Most of these horizons were destroyed during the leveling. In the areas where the soil was removed, the carbonate horizon is now lying at the surface, and a deposited carbonate arable horizon has formed in former depressions (Gorokhova et al., 2018).

Our field studies in the irrigated area were conducted in 2015-2016 (Fig. 3; Table 2).

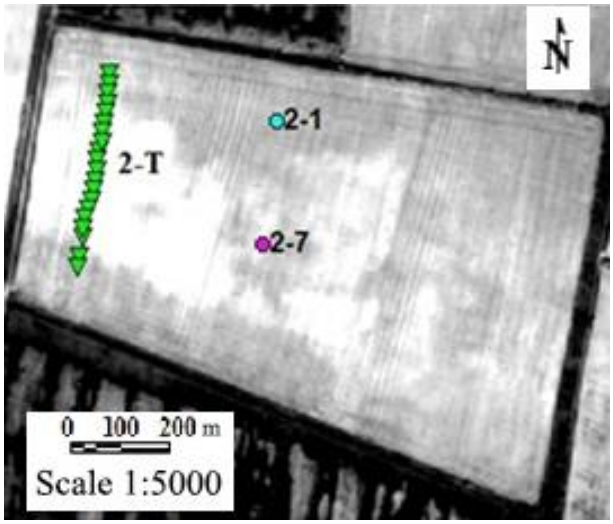

Fig. 3. A field in the Svetloyarsky irrigated area with sampling points and transect 2-T, which included regular sampling in 2015-2016, on a Pleiades image (20/05/2015).

3) The Caspian Depression, Khvalynsk Clay Plain, Sarpa Gully (Duboovrazhny irrigated area). In the northern part of the gully, there is a chain of deep freshwater lakes and a system of occasionally flooded limans. Near the Volga River, the gully is deep, down to 10 m, but it becomes shallower toward the southwest and south, merging with the surrounding landscape. The gully is incised into the saline marine (Khvalynsk) sandy-clay deposits, which, in their turn, are covered by alluvial-marine loams. In its northern section, there are 1-2 narrow Late-Khvalynsk and Post-Khvalynsk terraces, composed of loamy alluvium with low humus content, similar to that of the Volga alluvium. Its groundwater is down at 2.5-3 m, with mineralization varying at 3-10 g/L. Beneath the lake hollows, the water is desalinated (Doskach, 1979).

Before the Volgograd Reservoir was constructed, the Sarpa Gully used to be flooded annually by high water that was filling the limans and lakes. These days, the flooding is done only by the sparse spring runoff from the Yergeni Upland and, to a lesser extent, by snowmelt. The bottom of the gully is a floodplain undergoing desertification, with varying degrees of waterlogged, saline liman meadows and diverse cover of forbs. Its elevated areas are steppe-like, forming a complex semi-desert with an alternation of solonetzes and light chestnut soils (Doskach, 1979).

In summer, most of the Sarpa lakes dry up. Groundwater is typically found in the alluvial sands at 16 m; near the lakes, it occurs at 1-3 m. Its mineralization is up to 10 g/L, motley, predominantly sodium-bicarbonate and sodium-chloride (Degtyareva, Zhulidova, 1970).

In the 1990s, the "Duboovrazhny" massif was in a favorable state of land reclamation. Its groundwater was at 3-5 m, rising to 1.5-2 m only in the north, in a small area. Its mineralization

was 3-5 g/L, of a sodium-magnesium-chloride or sodium-chloride composition, with no secondary soil salinization. A residual solonetz-like salinity was 5% and 5-10%, being a result of field leveling during the construction of the irrigation system, and field leveling itself was minimal.

Currently, this massif functions as a farm on a ridge-and-hollow mesorelief, growing tomatoes, watermelons, carrots, pumpkins, onions, mustard, and cotton. Drip irrigation is employed in the fields. The primary factors that limit irrigation are the relatively shallow occurrence of Khvalynian chocolate clays (100-250 cm) which contain significant amounts of toxic salts and act as an impermeable layer hindering the drainage, as well as a high carbonate content in the soil, reaching the surface in some areas (Kravchenko et al., 2021).

Table 2. $CaCO_3$ content (%) in the upper soil layer at sampling plots (2015-2016) in the field of the Svetloyarsky irrigated area.

Sample plot No.	Soil horizon depth, cm	$CaCO_3$ content, %
2.1	0-20	1.80
2.7		8.00
2T1	0-33	2.41
2T6	0-26	2.00
2T11		4.41
2T16	0-22	11.42
2T20	0-22	13.21
2T25	0-20	13.41
2T30	0-24	10.60
2T40	0-20	11.60
2T45		11.21
2T50		12.41
2T55		12.00
2T60	0-30	11.80
2T65		10.80
2T70		10.80
2T75	0-20	10.21
2T80		5.00
2T85	0-30	2.41
2T90	0-20	не опр.
2T95		4.80
2T100		3.20

In August 2018, we made 29 soil excavations at the key site and collected over 200 samples, most of which are presented in this paper (Fig. 4; Table 3).

Thus, all 3 study sites are located in the dry-steppe zone of the Volgograd Region, in different natural areas with varying elevation, terrain dissection, parent and underlying rocks, groundwater levels, soil salinity and alkalinity. They all have distinct history of anthropogenic impact, such as field leveling, rising groundwater, plowing techniques, irrigation methods, and crop types. A feature they share is the presence of surface-carbonates soils, which was confirmed by our fieldwork and analyses.

We used satellite imagery from the Landsat-5 – Landsat-8 OLI, from 1985 to 2018. Then we picked those fields that had a distinct surface patchiness due to the presence and shallow (0-30 cm)

occurrence of carbonate soils. Such patches are clearly visible in images of bare soil, as well as in areas covered by mature grains or fodder.

We analyzed these patches across 3 different years, with intervals of 5-18 years. The reason for such irregular intervals was due to no imagery in which the patches were visible across all selected fields for the same years; in some instances, the fields were obscured by clouds or a dense crop cover. During image processing, we identified the surface-carbonate soils through manual interactive interpretation and through unsupervised image classification, the IsoData algorithm within the ENVI software. The automated classification helped us to avoid the subjectivity inherent in manual identification.

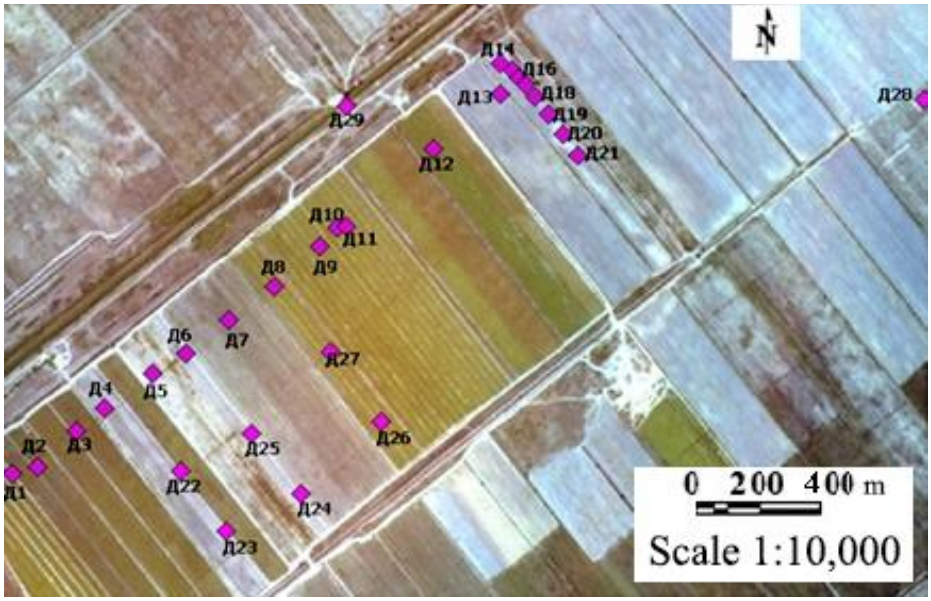

Fig. 4. Fields in the Duboovrazhny irrigated area with sampling points on a Resurs-P image (August 2018).

The IsoData performs clustering of satellite imagery based on its spectral characteristics, requiring a preset number of clusters. We set the number of clusters to 5, which captured spectral reflectance both within and around the fields. Then, the algorithm divided the values into groups and found the center of each. Mean values were put into the center of each class, with clustering based on the minimum distance to the centers. After that, each pixel was assigned to a specific group based on the criterion of the shortest Euclidean distance to that group's center.

Results and Discussions

The areas of patches of surface-carbonate soils on the satellite imagery, identified and calculated by the interactive and automated methods, are shown in Figures 5-7. The applied methods yielded different results, but had the same consistent trend of a carbonate area increasing from year to year (Fig. 5-8).

Differences in the areas were due variations in the contrast of the satellite images, caused by differing filming conditions across the years, thus affecting the spectral signatures that serve as the basis for our classification. Additionally, these discrepancies can be caused by the presence of crops in the fields that are clearly visible in the images and have a masking effect.

Based on the values obtained from image classification, the largest area increase occurred in the fields within the "Chervlenoye" (12.6 ha) and "Svetloyarsky" massifs (11.0 ha) over 23 and 33 years.

Table 3. $CaCO_3$ content (%) in the arable soil layer or effervescence presence on the soil surface at sampling plots (2018).

Sample plot No.	Soil horizon depth, cm	$CaCO_3$ content, %
Д2	0-30	no effervescence
Д3		
Д4		2.38
Д5		5.36
Д6		no effervescence
Д7		2.82
Д8		0.18
Д12		2.80
Д13		low effervescence
Д14		2.80
Д15		0.09
Д16		0.44
Д17		7.56
Д18		7.48
Д19		0.87
Д20		9.32
Д21		3.25
Д22		no effervescence
Д23		
Д24		
Д25		12.23
Д26		0.52
Д27		2.70
Д28		no effervescence
Д29		

In the “Duboovrazhny” massif, the increase was 4.2 ha over 11 years due to a smaller scale of field leveling during the construction of the irrigation system, and the overall period being shorter compared to the other massifs. The rate of area increase of surface-carbonate soils is most pronounced in the “Chervlenoye” (7.0 ha) for 1995-2000. In the “Svetloyarsky”, the patches of carbonates increased by 6.9 ha over 15 years (1985-2000). After 2000, there was a much slower increase: 6.6 ha in the “Chervlenoye”, and 4.1 ha in the “Svetloyarsky” massifs.

In the fields of the “Duboovrazhny” irrigated area, the increase in 1995-2000 was 0.6 ha, and 2.1 ha in 1989-1995. The total area of its patches is significantly bigger than in other two massifs due to the larger field (105 ha, 53.2 ha and 41.3 ha respectively), while the rate of area increase is lower due to the abovementioned scale of leveling (Fig. 8).

The shape and arrangement of the patches vary across the fields.

At the “Chervlenoye”, the patches are elongated and oriented in a nearly meridional direction. The central patch extends across the entire field. Over the observed period, the length-to-width ratio of this patch, measured at its narrowest and widest points, decreased from 4.0-9.0 to 3.2-3.6, indicating that its width has expanded. In the 0-20(30) cm soil horizon, the carbonate content increases from north to south, ranging from 10.8% to 12.0%; near the patches it is 2.4-10.8%, rising closer to the patch. In the smaller, isolated patches, the carbonate content sometimes reaches 17.2%.

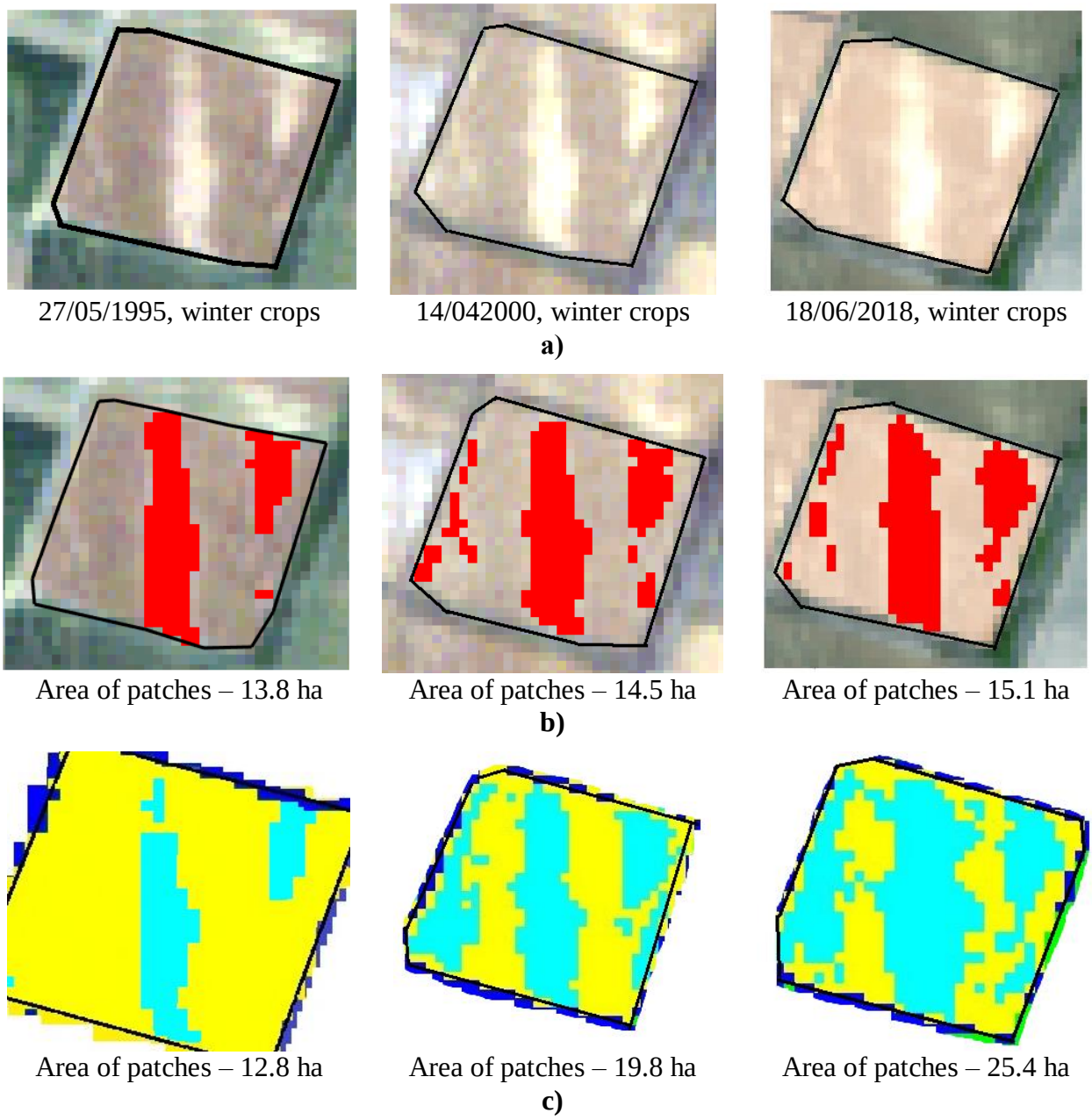

Fig. 5. Multi-temporal RGB satellite image of the studied field in the "Chervlenoe" irrigated area obtained from the Landsat-8 OLI satellite (a), interactive (b) and automatically classified (c) images of surface patches of carbonates. Area calculation was done using the image itself, scale 1:10,000.

At the "Svetloyarskoye", the central patch is elongated and oriented in a nearly latitudinal direction. Its length-to-width ratio decreased from 10.2-3.4 to 5.1-3.1, which means that its width has expanded as well. In the 0-20(30) cm horizon, the carbonate content is 1.8% outside the patches, 2.4-5.0% along the patches, and 10.6-13.4% inside the patches.

In the "Duboovrazhnoye", there is a cluster of patches, each significantly smaller than the central patches at the other sites. They gradually merge into narrow strips following the axis of the ridge. The length-to-width ratio of the central strip decreased from 76.0 to 57.0, which means that the width of this strip has expanded. The carbonate content in the 0-30 cm is 2.8-12.3% inside the large patches, 2.3-5.36% inside the small patches, and 0.09-0.87% between the patches (Fig. 9; Tables 1-3).

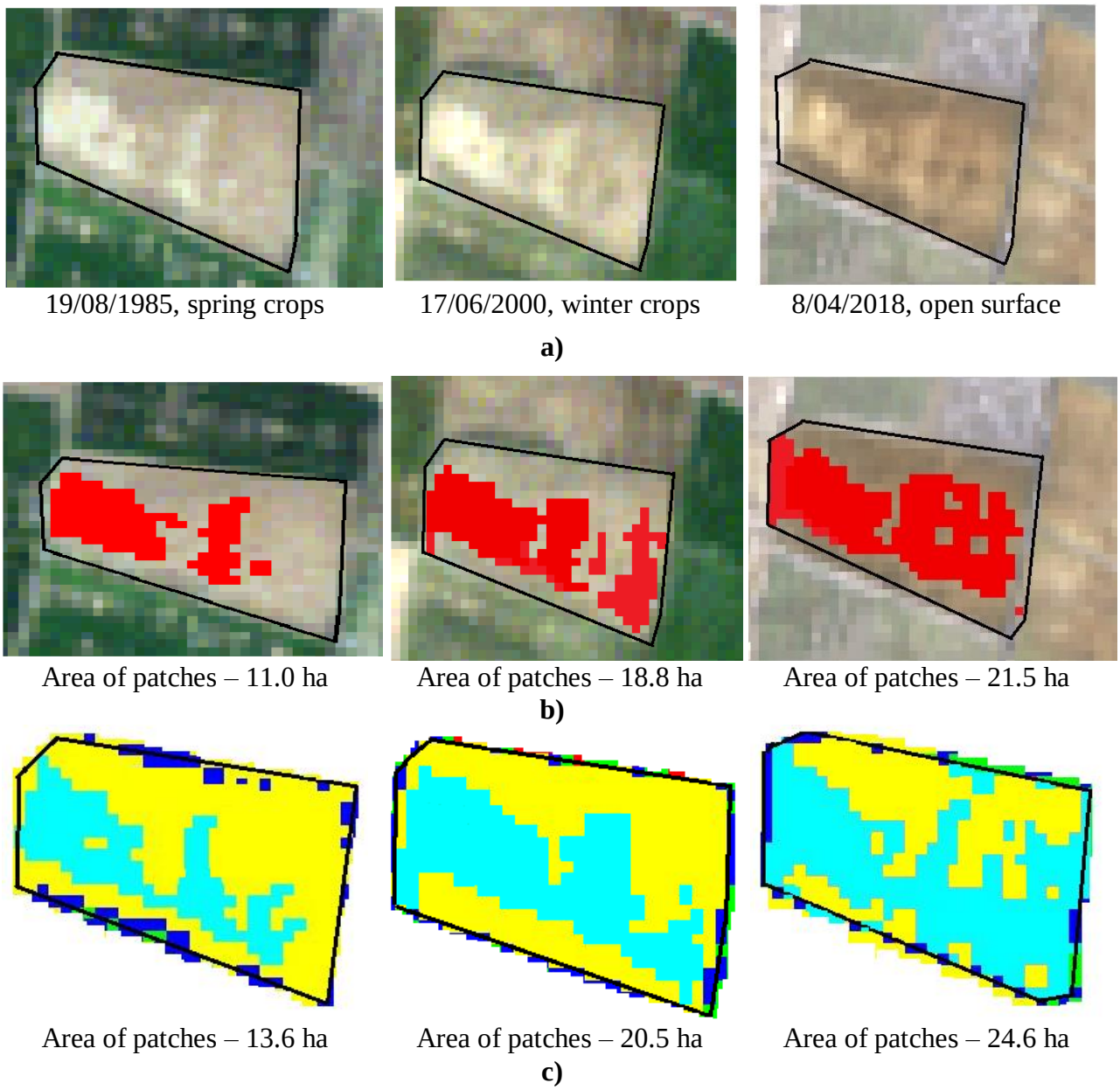

Fig. 6. Multi-temporal RGB satellite image of the studied field in the Svetloyarsky irrigated area obtained from the Landcat-8 OLI satellite (a), interactive (b) and automatically classified (c) images of surface patches of carbonates. Area calculation was done using the image itself, scale 1:10,000.

The growth of carbonate areas on the soil surface can be attributed to several factors: 1) the redistribution of carbonate material across a field during annual plowing; 2) the infusion of carbonates from the carbonate-saturated soil solutions as water evaporates or is brought up by plant roots; 3) the incorporation of deeper carbonate horizons into the arable layer as the topsoil gradually removed erodes away.

Research into the formation of surface-carbonate soils in the irrigated or severely eroded agricultural lands of arid zones began a while ago and continues to this day (Baranovskaya, Azovtsev, 1981; Amit, Harrison, 1995; Lyubimova, Degtyareva, 2000; Khitrov et al., 2024, 2025). This process is linked to anthropogenic activities, most notably land reclamation and irrigation.

Furthermore, the leveling of fields during the construction of irrigation systems can bring natural, carbonate-rich soil horizons closer to the surface, resulting in patchy, light-colored patterns across the fields.

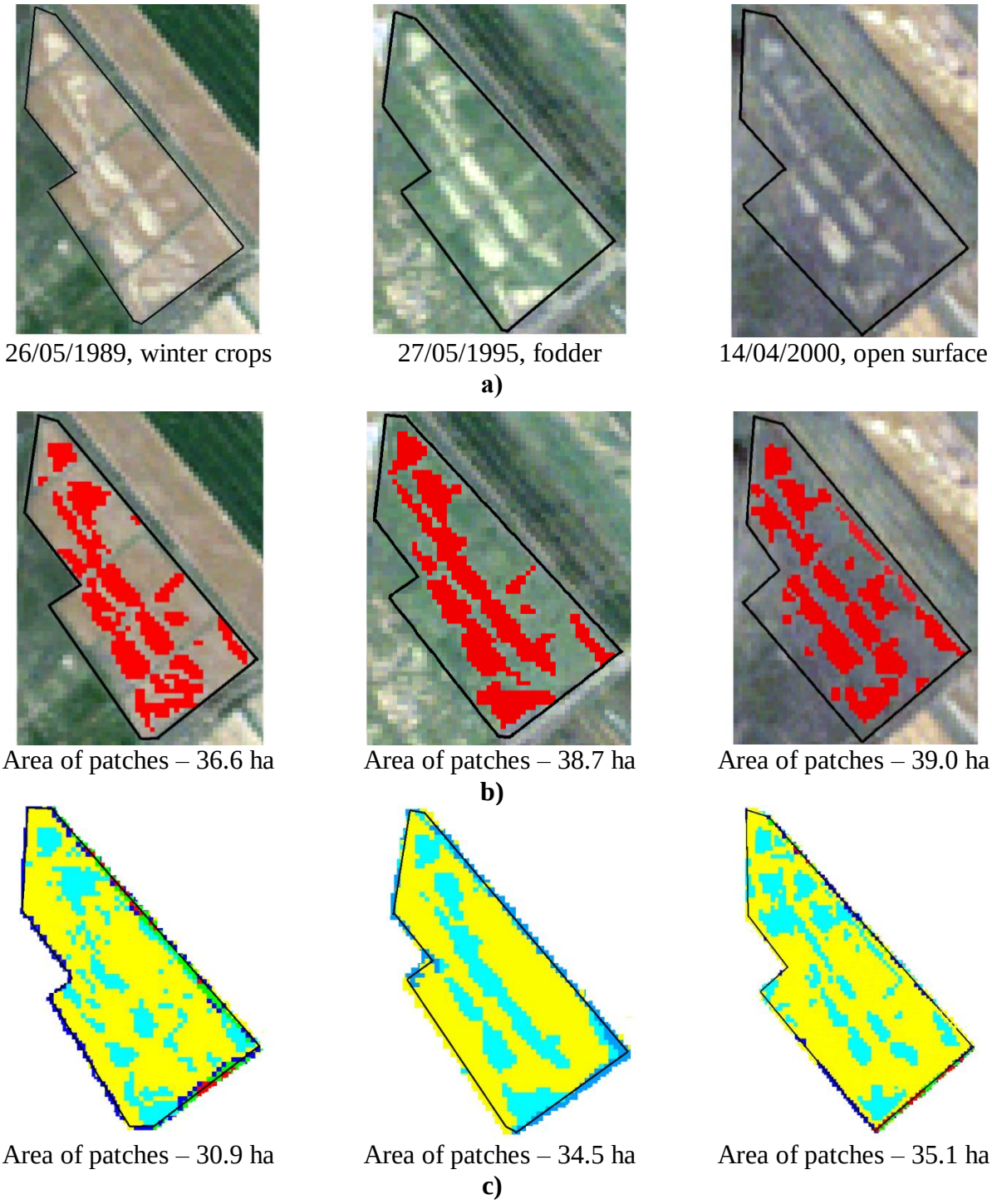

Fig. 7. Space-based multi-temporal RGB image of the studied field of the Duboovrazhny irrigated area obtained from the Landcat-8 OLI satellite (a), interactive (b) and automatically classified (c) images of surface patches of carbonates. Area calculation was done using the image itself, scale 1:10,000.

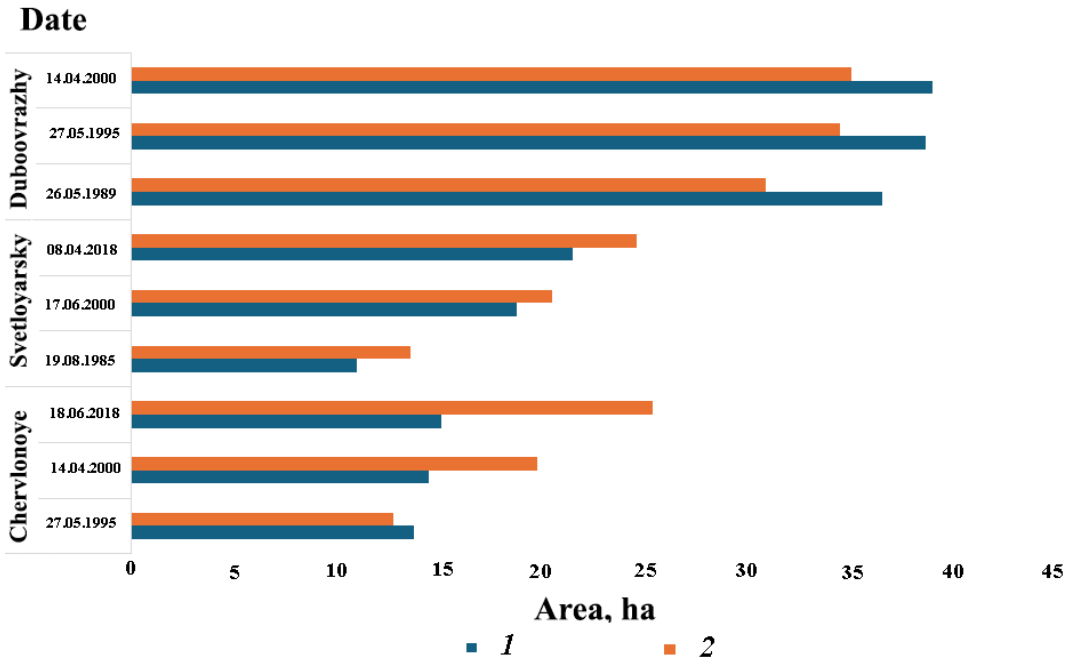

Fig. 8. Changes in the area of surface patches of carbonates over multiple years at 3 studied sites. *Legend:* 1 – area identified and calculated interactively, 2 –area identified and calculated by an automatic classification method.

The carbonate patchiness was noted by B.A. Zimovets (1991); other researchers identified it using remote sensing data (Zalibekova et al., 2011). The development of methods for processing large remote-sensing datasets and effective utilization of satellite imagery that covers more than 40 years to detect and record spatial heterogeneity of the soil cover is discussed by D.I. Rukhovich (2016), and D.A. Shapovalov et al. (2020).

In this article, for the first time the focus is on a trend observed in satellite imagery over a long period that shows an area increase of the carbonate patches. However, the lack of consistent imaging conditions and similar time intervals between them, and the variations in the soil surface (open soil surface, winter crops, fodder), make it very difficult to confirm the accuracy of our results. Therefore, our next objective is to acquire contemporary and simultaneous images of the study sites with open soil surfaces, to analyze them and substantiate our conclusions through further field researches.

Conclusions

By analyzing the dynamics of surface-carbonate soils over more than 30 years using satellite imagery, we identified a yearly increase in the area of such soils. Large, overly elongated, light-colored patches of surface-carbonate soils tend to expand laterally. We calculated the areas of these patches using both interactive and automated methods, and achieved varying results with the same general trend. Differences in the areas were due variations in the contrast of the satellite images, caused by differing filming conditions across the years, thus affecting the spectral signatures that serve as the basis for our classification. Additionally, these discrepancies can be caused by the presence of crops in the fields that are clearly visible in the images and have a masking effect.

In this article, we examined the expansion of surface-carbonate soil within the study sites, the shape and spatial distribution of their patches, and the carbonate content within and outside them. To precisely determine the cause of this rapid expansion that was observed in fields of the northern part of the Yergeni Upland and the Northern Sarpa Lowland—future research will require the

analysis of contemporary, concurrent satellite imagery captured when the soil surface is exposed. Additionally, these findings must be verified through field studies, which will be the focus of our future work.

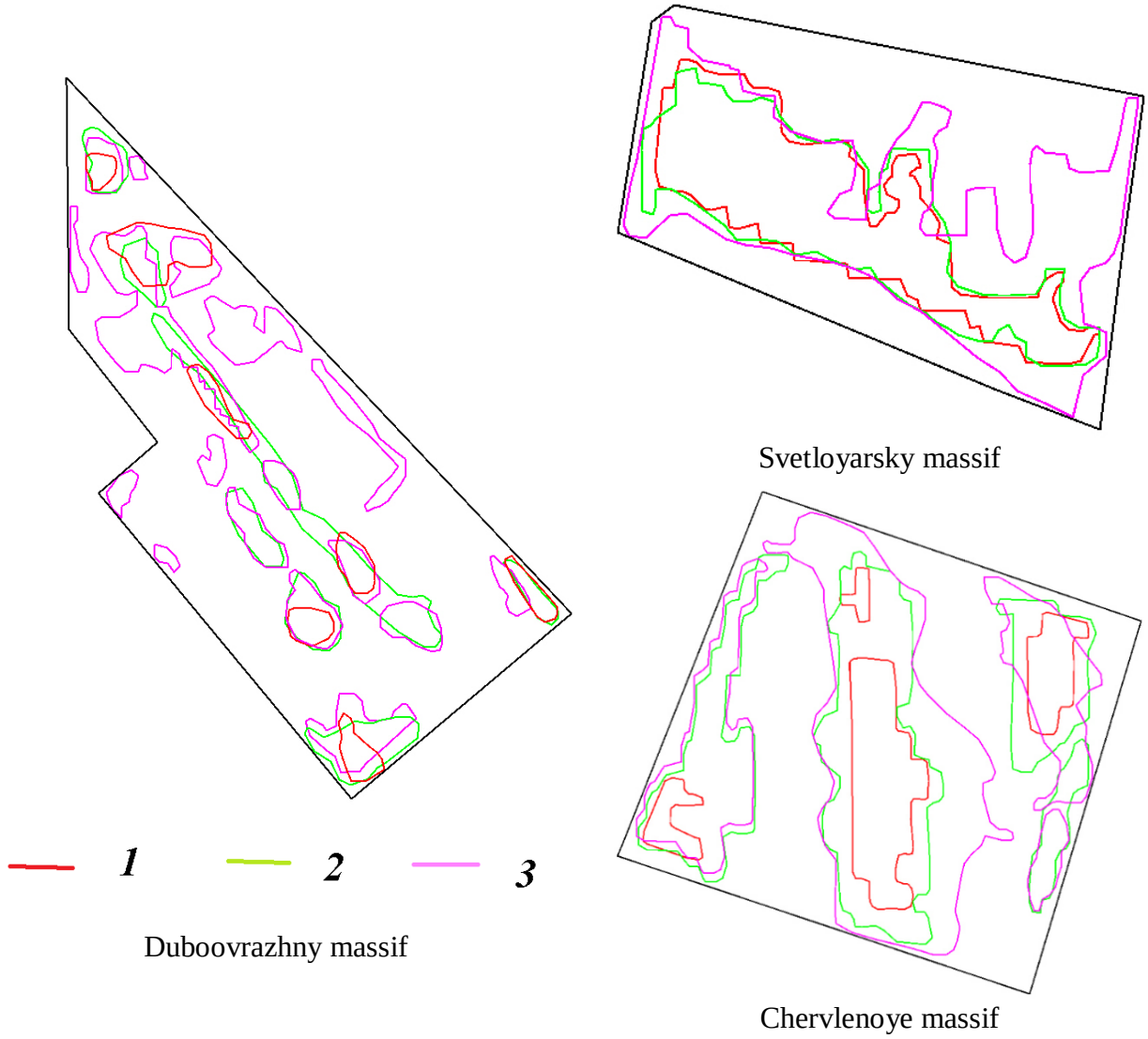

Fig. 9. Surface carbonate soils that were identified by automatic classification and displayed in vector format for a long-term period. *Legend:* 1 – first period, 2 – second period, 3 – third period.

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ДИНАМИКА ИЗМЕНЕНИЯ ПЛОЩАДЕЙ ПОВЕРХНОСТНО-КАРБОНАТНЫХ ПОЧВ ПО ДИСТАНЦИОННОЙ ИНФОРМАЦИИ В ВОЛГОГРАДСКОЙ ОБЛАСТИ

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Проведены исследования динамики изменения площади поверхностно-карбонатных почв по космическим снимкам за более чем 30-летний период орошения на территории 3 ключевых участков, расположенных в разных природных районах Волгоградской области: 1) возвышенность Северные Ергени (массив «Червленое»), 2) Прикаспийская низменность, Хвалынская глинистая равнина, север Сарпинской низменной равнины (Светлоярский массив), 3) Прикаспийская низменность, Хвалынская глинистая равнина, Сарпинская ложбина (Дубоовражный массив). Все 3 участка находятся в сухостепной зоне с исходным почвенным покровом, представленным светло-каштановыми солонцовыми комплексами. Они различаются отметками высот, расчлененностью рельефа, почвообразующими и подстилающими породами, уровнем грунтовых вод, солонцеватостью, засоленностью почв, историей антропогенного воздействия, связанной с планировкой полей, подъемом уровня грунтовых вод, видами вспашки, способами орошения, возделываемыми культурами. Для всех участков характерно наличие поверхностно-карбонатных почв, которое подтверждено полевыми работами и лабораторными данными. Использованы космические снимки со спутника Landsat-5 – Landsat-8 OLI за многолетний период (1985-2018 гг.) с разрешением на местности 30 м. На снимках были выбраны отдельные поля, где визуально просматривалась пятнистость поверхности, связанная с наличием карбонатов в пахотном горизонте (0-30 см). Пятнистость анализировали в 3 разных года, с интервалом 5-18 лет. При обработке снимков поверхностно-карбонатные почвы выделяли визуально в интерактивном режиме и при помощи классификации изображения без обучения методом IsoData в программном комплексе ENVI. Они показали разные результаты при одинаковой тенденции увеличения площади пятен год от года. Причинами увеличения площадей карбонатных пятен могут быть: 1) растаскивание карбонатного материала по полю при ежегодной вспашке, 2) осаждение карбонатов из подтягиваемых снизу почвенных растворов, насыщенных по карбонатам, при испарении и расходе воды корнями растений, 3) припашка карбонатных горизонтов по мере эрозионного сноса части пахотного горизонта. По методу классификации изображения снимка наибольшее приращение площади наблюдается на полях массивов «Червленое» и «Светлоярский» (12.6 и 11.0 га) за 23 и 33-летний периоды соответственно. На полях Дубоовражного массива приращение составило 4.2 га за 11 лет. Это связано с тем, что на массиве планировка полей при строительстве оросительной системы была небольшой, а рассматриваемый период составляет меньший срок (11 лет).

Ключевые слова: светло-каштановые почвы, орошение почв, почвенные карбонаты, планировка полей, классификация космического изображения, неоднородность почвенного покрова.
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