Monitoring and protection of deflated agricultural landscapes of the central caucasus

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Abstract. The purpose of our work is to analyze the results of monitoring agricultural landscapes exposed to wind erosion and develop recommendations for their protection and further use, depending on their quality condition. Monitoring data allows us to assess the state of agricultural land and make recommendations for their further use. During the research, modern methods of territory survey were used, such as remote sensing of the earth using satellite images and unmanned aerial vehicles, as well as ground-based methods for detecting deflated land. Deflated areas of agricultural landscapes were identified, the area, the degree of their degradation, the causes of their occurrence and the percentage of increase in the area relative to previous surveys were determined. The results of monitoring of agricultural landscapes show that the area of land subject to wind erosion tends to increase, and in addition, there is an increase in the area of land with a medium, strong and very strong degree of degradation. The obtained research results give an idea of the current state of agricultural landscapes that have undergone deflation, and also allow us to propose a number of measures aimed at their improvement and preservation. It should also be noted that not taking urgent measures to correct the current situation will lead to the loss of large areas of agricultural land in all administrative districts of the region.

1. Introduction
The problem of deflation of agricultural landscapes is characteristic of many regions of our country, but its most active development is observed in the leading agricultural regions, where large areas of land are arable land. Also, a significant factor affecting the development of wind erosion is the natural and climatic conditions of a particular region. The territory of the Stavropol Territory is characterized by a complex terrain and the presence of a large number of wind corridors. The average maximum wind speed is 15 m/s, but in different parts of the region, the wind speed can increase to 26-30 m/s. In such conditions, the risk of deflation is maximum, which has led to the fact that the area of deflation-prone land in the region is about 4.5 million hectares [1].

The region under study is also characterized by such a phenomenon as dust storms, which can occur almost at any time of the year. They cause great damage to agriculture and, especially, to crops and soils. Dust storms are repeated every 3-20 years, carrying away up to 15-20 cm of the surface layer of the soil, but in the 1970s, in some areas, dust storms blew up to 1 m of soil. Large particles of soil move over short distances, lingering at various obstacles and in the depressions of the terrain. The smallest soil particles in the form of an air suspension can move for tens, hundreds, and even thousands of kilometers [2]. There is also everyday deflation, which is more slowly but regularly eroding the soil. It manifests itself in the form of riding erosion and snowdrift.
2. Monitoring of deflated agricultural landscapes

Monitoring of deflated agricultural landscapes is not systematic and therefore the problem of conservation, use and protection of such lands is important for modern agricultural land use. On the territory of the studied region, more than 92% of the land fund belongs to agricultural land, of which about 90% is agricultural land. Thus, the use of agricultural landscapes is very intensive, which in turn leads to the development and strengthening of deflation processes. Issues of monitoring of deflated land and its protection should be addressed in a timely manner to avoid deterioration of the quality of the land and its further loss [3].

The area of deflated agricultural land during the study period increased by more than 100 thousand hectares and at the same time the area of land with a weak degree of degradation decreased, but the area of land with a medium, strong and very strong degree of degradation significantly increased.

More than 58% of the deflated land is arable land and about 40% is pasture. The remaining area is represented by hayfields (0.68%), perennial plantings (0.48%) and fallow (0.14%). Of all the lands subject to deflation, more than 47% are medium-drained and about 42% are low-drained. The area of heavily ventilated land is 83 thousand hectares and during the analyzed period it increased by more than 26 thousand hectares. The area of very heavily deflated land has also increased by 2115 hectares. The maximum area of deflated agricultural land was recorded in 2006. (820,507 ha), which is reduced by 64,000 ha by 2012 and increased by 34,000 ha by 2017.

The area of deflated land in the Stavropol Territory in 2017 is 854.2 thousand hectares (table 1).

| Year | Deflated land | Agricultural land | Arable land | Fallow | Perennial plantings | Hayfields | Pastures |
|------|---------------|------------------|------------|--------|---------------------|-----------|----------|
| 2000 | Total, including | 754178 | 404670 | 1098 | 836 | 2894 | 344680 |
|      | weak | 544079 | 336282 | 1065 | 388 | 2039 | 204305 |
|      | medium | 147030 | 57522 | 33 | 448 | 782 | 88245 |
|      | strong | 56788 | 7406 | - | - | 73 | 49309 |
|      | very strong | 6281 | 3460 | - | - | - | 2821 |
| 2006 | Total, including | 884284 | 581936 | 347 | 3254 | 4255 | 294492 |
|      | weak | 372795 | 222459 | 347 | 881 | 2722 | 146386 |
|      | medium | 419914 | 316727 | - | 2337 | 1129 | 99721 |
|      | strong | 82427 | 36908 | - | 36 | 365 | 45118 |
|      | very strong | 9148 | 5842 | - | - | 39 | 3267 |
| 2012 | Total, including | 820507 | 509339 | 621 | 3578 | 3965 | 303004 |
|      | weak | 376424 | 207874 | 579 | 1134 | 2464 | 164373 |
|      | medium | 364955 | 267019 | 42 | 2425 | 1038 | 94431 |
|      | strong | 71140 | 29417 | - | 19 | 411 | 41293 |
|      | very strong | 7988 | 5029 | - | - | 52 | 2907 |
| 2017 | Total, including | 854232 | 501382 | 1238 | 4139 | 5792 | 341681 |
|      | weak | 357141 | 160758 | 1137 | 1548 | 3660 | 190038 |
The area of deflated arable land is more than 501 thousand hectares, of which 298.5 thousand hectares have an average degree of degradation and more than 160 thousand hectares are weak. More than 7% of the land exposed to wind erosion is deflated to a strong degree and about 1% is very severely degraded. During the research period, the total area of deflated arable land increased by 97 thousand hectares, but at the same time, the area of land with a weak degree of degradation sharply decreased and the number of lands with medium, strong and very strong degrees of deflation increased [4].

Analyzing the graph, it can be concluded that in 2006 the area of deflated arable land reached a maximum (581.9 ha) and after that there is a gradual decrease in the total area of land subject to wind erosion. It is also possible to note a constant decrease in the area of land with a weak degree of degradation, and an increase in the number of land with an identified medium and strong degree of deflation. This fact indicates an increase in the intensity of deflationary processes on arable land and the deterioration of their condition.

Pasture lands are less prone to deflation, but on sloping lands and in areas where there is no dense grass, favorable conditions are created for the development of negative processes. More than 341 thousand hectares of deflated land have been identified in pastures, of which 190 thousand hectares are slightly deflated and 103 thousand hectares are medium-deflated. More than 45 thousand hectares of pastures are already deflated to a strong degree and more than 3 thousand hectares are very strongly deflated. During the analyzed period, the deflated area did not significantly decrease.

The dynamics of deflated pasture lands shows that their total area for 2000-2017 remains more or less stable, but there are significant changes in the areas of land where a weak and medium degree of deflation is detected [5].

On such lands as fallow, perennial plantings and hayfields, the total amount is not much more than 10 thousand hectares of deflated land, and only on hayfields were identified areas with a strong (603 ha) and very strong (81 ha) degree of degradation. The monitoring of deflated agricultural land was carried out in the context of administrative districts and taking into account specific natural conditions, topography and intensity of agriculture. Over 10 years, the total area of deflated land has decreased by 30 thousand. this reduction was due to the area of arable land (-80554 ha), but during this period the area of deflated pasture land (+47189 ha), hayfields (+1537 ha), perennial plantings (+885 ha) and fallow land (+891 ha) increased.

According to the monitoring results, a catastrophic situation was identified in the Georgievsky, Krasnogvardeysky, Kursk, Levokumsky and Neftekumsky districts. The total area of deflated land in these areas is 600 thousand hectares, that is, in each district it exceeds 100 thousand hectares of actually degraded land. In such districts as Blagodarnensky, Georgievsky, Grachevsky, Ipatovsky, Kirovsky, Krasnogvardeysky and Petrovsky, more than 90% of deflated land falls on arable land, and in most other districts this figure is about 50%. There are exceptional cases, for example, in Levokumsky, Kursk, Neftekumsky and Shpakovsky districts, the main land on which deflation is detected is pasture land [6].

When monitoring deflated land, we also calculated the percentage of land subject to deflation over a ten-year period (table 2).
Table 2. Dynamics of deflated areas of agricultural landscapes.

| n/a | District          | Area of agricultural land, 2006. ha | Area of deflated land, 2006 ha | Area of agricultural land, 2017. ha | Area of deflated land, 2017. ha |
|-----|-------------------|-------------------------------------|-------------------------------|-------------------------------------|-------------------------------|
| 1   | Alexandrovsky     | 175561                              | 12400                         | 7,06                                | 175561                         | 11651                         | 6.63 |
| 2   | Andropovsky       | 199286                              | 3746                          | 1.88                                | 199285                         | 3205                          | 1.61 |
| 3   | Apanasenkovsky    | 315889                              | -                             | -                                   | 315889                         | -                             | -    |
| 4   | Arzgirsky         | 297766                              | 10375                         | 3.48                                | 297754                         | 9691                          | 3.25 |
| 5   | Blagodarnensky    | 225355                              | 17667                         | 7.84                                | 225269                         | 16844                         | 7.48 |
| 6   | Budennovsky       | 269828                              | 12898                         | 4.78                                | 269807                         | 11327                         | 4.19 |
| 7   | St. George's      | 161867                              | 138004                        | 85.26                               | 161863                         | 134915                        | 83.35 |
| 8   | Grachevsky        | 160242                              | 37608                         | 23.47                               | 160182                         | 19441                         | 12.13 |
| 9   | Izobilnensky      | 160402                              | -                             | -                                   | 160276                         | 19441                         | 12.13 |
| 10  | Ipatovsky         | 362557                              | 15337                         | 4.23                                | 362551                         | 14008                         | 3.86 |
| 11  | Kirovsky          | 119719                              | 13751                         | 11.48                               | 119305                         | 13049                         | 10.94 |
| 12  | Kochubeevsky      | 185819                              | 18830                         | 10.13                               | 184715                         | 17690                         | 9.58 |
| 13  | Krasnogvardeysky  | 195753                              | 133157                        | 68.02                               | 195675                         | 129268                        | 66.06 |
| 14  | Kursky            | 314029                              | 108940                        | 34.69                               | 314029                         | 106743                        | 33.91 |
| 15  | Levokumsky        | 416486                              | 115328                        | 27.69                               | 416482                         | 114014                        | 27.37 |
| 16  | Mineralovodsky    | 120223                              | 6621                          | 5.51                                | 119597                         | 5496                          | 4.59 |
| 17  | Neftekumsky       | 326903                              | 115338                        | 35.28                               | 326893                         | 113022                        | 34.57 |
| 18  | Novoaleksandrovsy | 174006                              | 6                             | 0.003                               | 173796                         | -                             | -    |
| 19  | Novoselitsky      | 158262                              | 14335                         | 9.06                                | 158210                         | 13503                         | 8.53 |
| 20  | Petrovsky         | 239633                              | 64090                         | 26.74                               | 239575                         | 62857                         | 26.24 |
| 21  | Foothill          | 157386                              | 1707                          | 1.08                                | 157159                         | 1901                          | 1.21 |
| 22  | Soviet            | 181493                              | 48                            | 0.03                                | 181361                         | 39                            | 0.02 |
| 23  | Stepnovsky        | 169995                              | -                             | -                                   | 169995                         | -                             | -    |
| 24  | Trunovsky         | 150037                              | 5091                          | 3.39                                | 150367                         | 4118                          | 2.74 |
| 25  | Turkmen           | 239240                              | 9704                          | 4.06                                | 239240                         | 8643                          | 3.61 |
| 26  | Shpakovsky        | 181843                              | 8618                          | 4.74                                | 182298                         | 7706                          | 4.23 |
|     | Total by edge     | 5659580                             | 884284                        | 15.62                               | 5657352                        | 854232                        | 15.1 |

The reduction in the area of deflated arable land is associated with increased attention to arable land and the use of anti-erosion measures, but the qualitative state of natural forage lands and perennial plantings is ignored [7].

The smallest areas of deflated land were found on the territory of the Sovetsky (39 ha), Foothill (1901 ha) and Andropovsky (3205 ha) districts. And within the boundaries of the Apanasenkovsky, Novoaleksandrovsy and Stepnovsky districts, no land subject to wind erosion was found during the research period.
The total area of land subject to deflation in the Stavropol Territory decreased by 0.5% during the analyzed period. The maximum share of agricultural land subject to deflation of various degrees, with the majority of them falling on arable land, is noted in the Georgievsky district (more than 83%). In the Krasnogvardeysky district, 66% of the land is eroded. In some areas, about a third of the land has signs of deflation: Neftekumsky (34.57%), Kursk (33.91%), Levokumsky (33.91%) and Petrovsky (26.24%).

Monitoring of land subject to wind erosion has shown that the development of these processes tends to reduce the area of arable land, and on other types of agricultural land to increase. And this situation is absolutely typical for most of the administrative districts of the Stavropol Territory. The development of deflation depends on many factors, and to reduce the intensity of its development, urgent measures are needed to preserve and protect agricultural landscapes [8].

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