Monitoring of agro-landscapes of Stavropol region that are subject to the combined effects of water and wind erosion

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Abstract. The article presents the results of research and monitoring of agricultural landscapes exposed to the combined effects of water and wind erosion in the context of the administrative regions of the Stavropol territory. This problem is significant for the region and timely detection of negative processes in agricultural landscapes allows you to respond appropriately to protect the land involved in agricultural turnover. Mapping of erosion processes is a significant problem for agriculture and the use of modern tools for monitoring agricultural landscapes contributes to the solution of this problem.

1. Introduction
Every year, more and more agricultural land is exposed to the combined effects of water and wind erosion, which leads to a rapid deterioration of the quality of these lands. The development of joint negative processes is typical for many regions of Russia, which includes the entire North Caucasus Federal district and, of course, the Stavropol territory [1]. Mapping monitoring of degradation processes is a complex problem for all regions of Russia, especially in areas where the intensity of erosion is increasing [2].

The result of water and wind erosion is an intensive reduction of the upper fertile soil layer and a decrease in humus and nutrients. In other words, it is no longer possible to get high yields and high-quality products in eroded areas. In addition, because of the development of erosion, the physical, biological and chemical properties of soils deteriorate sharply [3].

The natural causes of both water and wind erosion are primarily terrain, Geology, climate, soil, and the density and character of vegetation [4]. There are also anthropogenic or as they are also called socio-economic reasons for the occurrence and development of erosion. These include a large ploughed area, an increase in sowing of row crops, a decrease in perennial grasses, non-compliance with pasture turnover, that is, not rational use of agricultural land [5].

2. Materials and methods
Work to identify degraded land in the Stavropol territory was carried out in 2000-2017. The basis for their implementation was the "Methodological recommendations for the identification of degraded and polluted lands" (1995). In accordance with these recommendations, there are 5 degrees of land degradation:
- 0 - not degraded (undisturbed);
I - weakly degraded;
II - medium-graded;
III - highly degraded;
IV - very highly degraded (destroyed) [6].

Monitoring of land subject to erosion is carried out by continuous and polygon methods. Forms of monitoring of eroded land:
- large-scale soil survey;
- monitoring the development of erosion processes at stationary sites [7].

The objects of monitoring are agricultural land that is affected by water and wind erosion, waterlogging, waterlogging, salinization and stony conditions [8].

3. Results
As a result of monitoring of land exposed to the combined effects of water and wind erosion, we have established a stable increase in the area of degraded land. In 2000-2017, the total area of eroded agricultural land increased by 77,404 ha, or 40%. This is a very high intensity of degradation of highly productive land. The area of weakly degraded land is the maximum in 2017 (143,827 ha), and the minimum is observed in 2012 (82,089 ha). The same situation applies to land with an average degree of degradation.

Table 1. Dynamics of areas of agricultural landscapes exposed to combined effects of water and wind erosion

| Year | Eroded land | Agricultural land | Arable | Deposit | Perennial plantings | Hayfields | Pastures |
|------|-------------|-------------------|--------|---------|--------------------|-----------|----------|
|      | Total       | 123,830           | 84,936 | -       | 48                 | 510       | 38,336   |
| 2000 | Weakly      | 100,364           | 75,835 | -       | 48                 | 510       | 23,971   |
|      | Medium      | 20,752            | 8,911  | -       | -                  | -         | 11,841   |
|      | Strongly    | 2,308             | 169    | -       | -                  | -         | 2,139    |
|      | Very much   | 406               | 21     | -       | -                  | -         | 385      |
|      | Total       | 180,434           | 109,985| 624     | 540                | 5,856     | 63,429   |
| 2006 | Weakly      | 129,219           | 89,049 | 624     | 201                | 3,596     | 35,770   |
|      | Medium      | 43,471            | 20,787 | -       | 338                | 1,840     | 20,506   |
|      | Strongly    | 6,904             | 149    | -       | 1                  | 420       | 6,334    |
|      | Very much   | 840               | 21     | -       | -                  | -         | 819      |
|      | Total       | 108,379           | 79,019 | 1075    | 489                | 2,207     | 25,589   |
| 2012 | Weakly      | 82,029            | 67,916 | 972     | 212                | 70        | 12,859   |
|      | Medium      | 19,970            | 9,071  | 103     | 277                | 1,122     | 9,397    |
|      | Strongly    | 5,832             | 1,915  | -       | -                  | 961       | 2,956    |
|      | Very much   | 548               | 117    | -       | -                  | 54        | 377      |
|      | Total       | 201,234           | 116,336| 97      | 431                | 7,732     | 76,638   |
| 2017 | Weakly      | 143,827           | 95,035 | 79      | 129                | 4,430     | 44,154   |
|      | Medium      | 47,887            | 21,141 | 18      | 302                | 2,098     | 24,328   |
|      | Strongly    | 8,411             | 160    | -       | -                  | 703       | 7,548    |
|      | Very much   | 1,109             | -      | -       | -                  | 501       | 608      |

The area of agricultural land subject to a strong degree of erosion (+6103 ha) is increasing rapidly. In 2017, more than 1 thousand hectares of very heavily degraded land were identified, of which approximately equal shares are occupied by pastures and hayfields. In contrast to deflated land, the main area of land degraded by erosion and deflation is slightly degraded (71.5%), but also significant areas of the region are classified as medium-eroded (23.8%).
The combined development of erosion and deflation is more typical for the Eastern plains and foothill areas with complex terrain. The Eastern regions suffer from large areas of clean vapors, dust storms, and torrential rains. The results of monitoring by year and by type of agricultural land are presented in Table 1.

The main areas of eroded land are arable land (57.8%) and pasture (38.1%). The trend of distribution of degraded arable land according to the degree of erosion is the same as in General for agricultural land. Weakly degraded land is predominant (81.7%), medium-graded land accounts for 18.2% of arable land, and strong-graded land accounts for 0.1%. At the same time, there are no areas that are very heavily degraded by water and wind.

The area of eroded pasture land in 2017 is more than 76.5 thousand hectares and during the research period it has increased by more than 38 thousand hectares, that is, by a factor of two. This is a very high rate of soil erosion, as there is a growth of weakly, medium and highly degraded pastures. Since 2006, the area of highly degraded land has decreased (- 211 ha), which is associated with the activation of landslides in pasture areas and the transfer of these lands to other unused land.

In 8 districts of the Stavropol territory, land eroded jointly by water and wind erosion is conditionally absent, but there is no guarantee that they will not appear in the near future, since there are areas that are subject to degradation separately by water erosion and deflation.

Degraded pasture areas were identified in fifteen districts, and during the research period, all districts showed an increase in the area of eroded pastureland, except for the Mineralovodsky district, where there are no eroded pastures as of 2016. The largest area of pastures subject to joint water and wind erosion is located in Kochubeyevsky (33752 ha), Levokumsky (16069 ha) and Blagodarnensky (6208 ha) districts (Table 2, Fig. 1).

The maximum areas of eroded agricultural land were found in such areas as Kochubeyevsky (65,440 ha), Levokumsky (43,229 ha), Blagodarnensky (22,707 ha), Georgievsky (15,650 ha) and Ipatovsky (12,603 ha). At the same time, in the Levokumsky, Blagodarnensky, Ipatovsky and Georgievsky districts, the main area of degraded land is represented by arable land, and in the Levokumsky district, more than 51% of eroded areas are identified in pastures and more than 10% in hayfields. In addition, Kochubeyevsky district is the only one where areas of degraded deposits were identified, but during the analyzed period, this area decreased by 527 hectares [9].

As of 2006, in 4 districts of the Stavropol territory, plots of land of perennial plantings were found eroded by water and wind erosion (540 ha), but as of 2017, such plots remained only in the Georgievsky (248 ha) and Kochubeyevsky (183 ha) districts.

Hayfields eroded by water and wind erosion in the region occupy a total area of 7,732 ha and are identified in 3 districts. The maximum area is found in the Kochubeyevsky district (6693 ha), followed by the Alexandrovsky (805 ha) and Shpakovsky (234 ha) districts.

The table analysis shows that more than 35% of agricultural land has already been degraded by the combined manifestation of water and wind erosion in the Kochubeyevsky district. In addition, this type of land erosion is widespread in Levokumsky (10.38%), Blagodarnensky (10.08%), Georgievsky (9.67%) and Novoselitsky (5.85%) districts.

In general, the area of land eroded by water and wind in the Stavropol territory increased by 0.37% and as of 2017, 3.56% of agricultural land has already been eroded.
Table 2. Dynamics of areas of agricultural landscapes exposed to combined effects of water and wind erosion

| No.  | District         | Area of agricultural land, 2006 | Area of land subject to joint water and wind erosion, 2006 | Area of agricultural land, 2017 | Area of land subject to joint water and wind erosion, 2017 |
|------|-----------------|---------------------------------|-----------------------------------------------------------|---------------------------------|-----------------------------------------------------------|
| 1.   | Alexandrovsky   | 175,561                         | 2,641 1.5                                                | 175,561                         | 2,494 1.42                                                |
| 2.   | Andropovsky     | 199,286                         | - -  -                                                   | 199,285                         | - -  -                                                   |
| 3.   | Apanasenkoisky  | 315,889                         | - -  -                                                   | 315,889                         | - -  -                                                   |
| 4.   | Arzgirsky       | 297,766                         | 1,458 0.49                                               | 297,754                         | 2,069 0.69                                               |
| 5.   | Blagodarnensky  | 225,355                         | 19,736 8.76                                             | 225,269                         | 22,707 10.08                                             |
| 6.   | Budenovsky      | 269,828                         | 6,909 2.56                                              | 269,807                         | 7,722 2.86                                               |
| 7.   | Georgievsky     | 161,867                         | 13,954 8.62                                             | 161,863                         | 15,650 9.67                                              |
| 8.   | Grachevsky      | 160,242                         | 1,632 1.02                                              | 160,182                         | 2,141 1.34                                               |
| 9.   | Izobilnensky    | 160,402                         | 3,208 1.99                                              | 160,276                         | 4,908 3.06                                               |
| 10.  | Ipatovsky       | 362,557                         | 10,257 2.83                                             | 362,551                         | 12,603 3.47                                              |
| 11.  | Kirovsky        | 119,719                         | 220 0.18                                               | 119,305                         | - -  -                                                   |
| 12.  | Kuchubeyevsky   | 185,819                         | 63,853 34.36                                           | 184,715                         | 65,440 35.43                                             |
| 13.  | Krasnogvardeysy | 195,753                         | 1,022 0.52                                             | 195,675                         | 1,701 0.87                                               |
| 14.  | Kursky          | 314,029                         | - -  -                                                   | 314,029                         | 1,358 0.43                                               |
| 15.  | Levokumsky      | 416,486                         | 40,613 9.75                                             | 416,482                         | 43,229 10.38                                             |
| 16.  | Mineralovodsky  | 120,223                         | 198 0.16                                              | 119,597                         | 527 0.44                                                 |
| 17.  | Neftckumsky     | 326,903                         | - -  -                                                   | 326,893                         | 2,018 0.62                                               |
| 18.  | Novoalexandrovsky | 174,006                     | - -  -                                                   | 173,796                         | - -  -                                                   |
| 19.  | Novoselitsky    | 158,262                         | 8,841 5.58                                             | 158,210                         | 9,266 5.85                                               |
| 20.  | Petrovsky       | 239,633                         | 2,557 1.06                                             | 239,575                         | 2,948 1.23                                               |
| 21.  | Predgorny       | 157,386                         | - -  -                                                   | 157,159                         | - -  -                                                   |
| 22.  | Sovetsky        | 181,493                         | - -  -                                                   | 181,361                         | - -  -                                                   |
| 23.  | Stepovsy        | 169,995                         | - -  -                                                   | 169,995                         | - -  -                                                   |
| 24.  | Trunovsky       | 150,037                         | 791 0.53                                              | 150,367                         | 1,332 0.88                                               |
| 25.  | Turkmensky      | 239,240                         | - -  -                                                   | 239,240                         | - -  -                                                   |
| 26.  | Shpakovsky      | 181,843                         | 2,544 1.4                                              | 182,298                         | 3,121 1.71                                               |

**Total by edge** | 5,659,580 | 180,434 | 3.19 | 5,657,352 | 201,234 | 3.56
4. Conclusion
Monitoring of land affected by combined water and wind erosion is necessary, since the area of eroded land is constantly increasing [10]. This situation is typical for most administrative districts of the Stavropol territory. The development of water erosion and deflation occurs in the direction of increasing degradation across all land, which can lead to the loss of large areas of arable and pasture land in a short period of time.

5. Acknowledgments
The research was carried out in accordance with a State contract with the Ministry of agriculture of the Stavropol territory.

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