The influence of adverse natural phenomena, anthropogenic factors on the efficiency of land users (regional aspect)

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Abstract. The efficiency of land users depends on weather conditions, which significantly affect the results of agricultural production. Recently, there has also been a general trend of some natural phenomena unpredictability. It can worsen or negate the operating profits of land users in the agricultural production field, therefore it is essential to study the nature of negative natural phenomena typical for the Central Black Earth region.

The Central Black Earth Region is characterized by a high degree of reclamation and ploughing of lands. With the high ploughing of agricultural land in the region, the ecological potential of natural land protection has sharply decreased. This problem requires significant costs and public funding. Therefore, it is necessary to provide conditions for maintaining, and then improving the environmental sustainability of agricultural landscapes and reliable soil protection from erosion processes. The conditions for addressing these issues are formed in the process of creating sustainable land use. In this case, local wind circulation is especially important. The analysis showed yearly average dominance of south-west (15.0%), south-east (14.3%) and west (13.7%) winds in the region, which means that the wind blows with a certain stability from all sides. Therefore, when establishing protective forest belts, it is necessary to take into account various aspects of the agro-ecological environment and climate. Protective forest belts and bush plantings are one of the main levers for controlling the microclimate formation of a given land use territory.

1. Introduction

The influence of natural and anthropogenic factors on the formation of sustainable land use is great. It is caused by such basic conditions as: geographical location of the territory, fertile soils availability, climate and environmental conditions, and many others. If climatic conditions determine the favourable cultivation and growth of crops, while the temperature and atmosphere precipitation have a huge impact, then soil conditions affect crop yields and agricultural land productivity. Water resources availability in the territory, allowing to regulate the moisture deficit of soil is also important [1]. These factors have a direct impact on the production direction choice of a farming, which means that they directly affect the efficiency of land users and the place of the region in the territorial division of labor.

2. Materials and methods

Undoubtedly, the efficiency of land users depends on weather conditions, which significantly affect the results of agricultural production. Recently, there has also been a general trend of some natural phenomena unpredictability. It can worsen or negate the operating profits of land users in the
agricultural production field.

Many works of domestic and foreign scientists on the issue of natural phenomena adversely affecting agricultural production have been published. These works provide insight into the essence of atmospheric circulation processes and help to plan measures against them [2, 3]. Agricultural specialists did not pay much attention to these issues earlier, often approaching them mechanically, using certain aspects of certain developments in various projects.

3. Results

For a deeper and comprehensive investigation of this issue, it is necessary to study the nature of adverse natural phenomena typical for the Central Black Earth Region. The analysis revealed that almost one year out of three is dry, and sometimes such conditions are formed for several years running [4], negatively affecting the agricultural production, and hence the efficiency of land users. The economic damage caused by such adverse natural phenomena, resulted in absolute shortfall in agricultural production, is constantly growing [5].

It is revealed that one of the main reasons for the frequency of adverse natural phenomena, extended duration of their effect, the growth of shortfall in agricultural production, is an imbalance in the stability of agricultural land use: on the one hand, the anthropogenic load on land use is constantly growing; on the other hand, the climate is becoming more arid.

Drought is a significant change in the water balance of plants under unfavourable combination of hydrothermal conditions, leading to wilting, which means a significant shortfall in agricultural production or the complete death of cultivated plants [6]. A certain combination of agrometeorological conditions against the background of an environmentally unstable agricultural landscape with a low-developed farming system can be manifested through atmospheric, soil or joint drought. When analyzing the frequency of droughts in the European part of Russia, we see that one year out of three is arid, and sometimes a drought can occur two or three years in a row.

Droughts are often accompanied by dry winds and high air temperatures, which leads to a significant reduction in crop yields [3]. Great damage is caused by the joint soil and atmospheric drought, when prolonged lack of rain and insufficient spring moisture reserves have a negative impact on the development of plants.

Drought nearly always depends on vegetation air temperatures, rainfall and evaporation. Various parameters and indicators estimate the influence of droughts, but, unfortunately, scientists have not come to a single generally accepted indicator according to the criteria for assessing drought. In our opinion, the yield of grain crops is an indicator characterizing drought. Often, drought estimation occurs through a decrease in the yield of spring wheat as a percentage of its average value over a certain period. To this effect, the following scale should be used: weak drought – decrease in yield by 20%, strong – by 20-50 %, and extreme -more than 50%.

Extreme conditions of temperature and humidity, wind and its energy cause serious damage to agricultural production. It is impossible to predict or cancel them. The solution to this problem is in the future and does not eliminate the possibility of their manifestation. It is necessary to create a sustainable agricultural landscape of land use to adverse natural phenomena. This is workable objective for modern environmental science.

The natural conditions of the Central Black Earth Region are characterized not only by an unstable climate and the presence of a wide variety of soil differences, but also by a complex terrain [7]. If climatic conditions are subject to significant fluctuations and their influence is quite difficult to identify and link to certain results of human economic activity, then the terrain of the agricultural enterprise territory refers to permanent factors. It determines the nature of land use and imposes certain restrictions to ensure the rational and efficient use of the land fund territory. For our region, the terrain is one of the main determining factors in organizing the use and arrangement of the agricultural enterprises territory.

In studying the regional characteristics of the influence of natural and anthropogenic factors on the formation, organization, and arrangement of land use territory, it was revealed that the main reasons
for the manifestation of a number of negative natural and anthropogenic processes came along with the climatic conditions of the considered territory, also the high plowing of the land, its strong fragmentation by a valley-ravine network, pollution and other factors that negatively affect the state of land [8].

Thus, the Central Black Earth Region is characterized by a high degree of reclamation and ploughing of lands. The share of agricultural land from the total land fund of each region is 5.5-6 times higher than the average for the Russian Federation.

The largest area of plowed land is observed in the Kursk region - 64.8 %, less in the Lipetsk region - 64.4%, in the Belgorod and Tambov regions - 60.9 and 60.1%, respectively. Voronezh region is at a lower position compared to other regions - 58.6 %.

With the high ploughing of agricultural land in the region, the ecological potential of natural land protection has sharply decreased. Systematic soil covering cultivation determined the development of soil degradation processes and, as a result, a decrease in the humus horizon. The main reason for the reduction of humus level in soils is directly related to the removal of nutrients, by increasing crop yields and the introduction of row crops with complete capture of the soil horizon zone, due to the peculiarities of the root system [9].

Modern agricultural production requires cultivated plants to obtain significant yields, and therefore more nutrients for biomass formation. Over time, this leads to nutrients reduction in the soil system [10].

Intensive exploitation of flat land is gradually changing the humus level in arable land due to anthropogenic influence.

On slope lands, this trend in change of nutrients stocks occurs for a shorter period of time.

Nutrient stocks depletion largely determines the treatment of necessary doses of mineral and organic fertilizers, which increases the cost of agricultural production.

Long-term plowing of lands and its intensive agricultural use is accompanied not only by soil dehumidification, but also activates the processes of acidification, salinization, and compaction of the arable layer, worsening the physical and agrochemical soil parameters, which, ultimately, leads to the degradation of arable land [11].

Over the century, humus reserves decrease reached more than 30%, the humus level in the upper horizons decreased by 1-3%. Humus mobility increased on ploughed chernozems [12]. Activation of dehumidification processes has led to a loss of humus to 2 - 2.5 % over the last three-four decades.

As for the Central Black Earth region, the share of arable land on slopes with a steepness of up to 3° is 37% from the total region's area, a significant percentage - 62 on slopes from 3 to 7° and over 7° - about 0.7%. Furthermore, the largest land masses on inclined surfaces are located in the Kursk region.

Erosion is the main process that worsens the stability of the agricultural landscape in the Central Black Earth region and the state of its ecosystem. As for the Voronezh region, more than 80% of its territory is subject to erosion processes. The main reason is the excess energy of spring surface runoff. Storm erosion is rarely observed. For 25 years of observations in the Stone Steppe (1958-1981), only in 1963 and 1976, there was erosion from heavy rains.

Sufficiently high intensity of erosion processes in the Voronezh region is determined by a complex range of natural and climatic factors, a significant variety of landscape and environmental factors - precipitation, soil, topography, and, most importantly, irrational human production activities.

Land exploitation was accompanied by intensive development of erosion processes, which ultimately worsened the conditions of agricultural production. The anthropogenic influence increased in the land-use ecosystem every year, and its disturbed natural balance became less resistant to adverse events. Realizing that the soil can not be replaced by anything, determines the need for the formation of rational land use.

The increase in soil erosion, its rate and size is a response. If soil scientists, agronomists do not enhance the sustainability of land use, do not adapt agriculture, the erosion processes will develop and lead to the fact that agricultural production will be problematic.
In our opinion, it is almost impossible to completely prevent erosion processes, but it is possible to bring them to acceptable values, in this regard it is necessary to develop ways of sustainable land use formation. This problem requires significant costs and public funding. Therefore, it is necessary to provide conditions for maintaining, and then improving the environmental sustainability of agricultural landscapes and reliable soil protection from erosion processes. Conditions for addressing these issues are formed in the process of sustainable land use formation.

The aim of the work is to create the necessary organizational and territorial conditions to reduce to acceptable parameters, and sometimes to prevent the negative impact of adverse natural phenomena and anthropogenic phenomena, the creation of sustainable agricultural landscapes with balanced agroecosystems and, against this background, ensuring rational land use in order to increase its efficiency.

Methodological provisions on the formation of environmentally sustainable agricultural landscapes were first presented in the works of M.I. Lopyrev [13]. It is worth mentioning the Federal target program "Improvement of soil fertility in Russia" which states: “Taking into account the experience of creating a modern model of ecological-landscape farming system in the Voronezh region, the Program provides the development of this system in ... 390 farms as a pilot project [14]. Important elements of the programme are land management schemes and projects taking into account specific land use conditions, its soil and climatic conditions, agricultural landscape of used lands and on this basis to differentially determine for each household a complex of interrelated balanced measures for the use and protection of land, improve soil fertility, the formation of environmentally sound land use.

The stated problem of addressing adverse natural phenomena is investigated on the agro-landscape basis. This is due to the fact that the basis for the successful protection from adverse events is laid in the process of territorial organization of land use [15], the formation of its ecological system, which ultimately determines the stability or instability of the land use territory. Increasing economic efficiency of any agricultural enterprise is impossible without solving landscape and environmental problems. This is identifying the causes of dry winds, droughts and other adverse natural phenomena and identifying ways to combat these phenomena in the system of measures for the sustainable land use formation.

Assessment of the current state of the Central Black Earth Region land resources characterizes their crisis state. The farming system is not adapted to the natural features of the territory, and the regimes of their ecosystems are not balanced, moreover, the negative consequences are aggravated by a high degree of ploughing of the territory, insufficient afforestation, protection and arrangement. As a consequence, modern land uses are not sufficiently sustainable [16].

The methodology of modern land use involves the formation on a calculation basis of ecologically sustainable agricultural landscapes, which will create conditions for the protection and rational use of the natural resource potential in the region.

A necessary condition for the development of targeted measures to address adverse natural phenomena is the awareness of the complex nature of their origin [17]. Their formation is a natural process of atmospheric circulation, and, unfortunately, adverse natural phenomena cannot be changed and difficult to predict. Thus, the wind regime determines the peculiarities of negative natural processes, and wind energy strengthening increases the damage from adverse natural phenomena. Wind energy can be reduced by a deeper study of the seasonal circulation of the prevailing wind directions. Wind is an important meteorological component that determines weather conditions. Air circulation occurs as a result of uneven heating of particular areas of the territory, and the wind reflects the transformation process of solar energy within the landscape. Wind energy is inexhaustible and often contributes to the strengthening of adverse natural processes for agriculture.

On the territory of the Central Black Earth region, there is a wide variability of wind movement directions in different periods of the year. Special attention has been given to the study of the prevailing winds directions on the territory of the Voronezh region in the context of natural and agricultural zones and microzones by seasons. The analysis was conducted at fourteen weather stations located in the Voronezh region (Nizhnedevitsk, Ostrogozhsk, Voronezh, Anna, Talovaya, Liski,
Borisoglebsk, Novokhopyorsk, Rossosh, Mitrofanovka, Boguchar, Buturlinovka, Pavlovsk, Kalach). The uniform arrangement of weather stations throughout the territory fully characterizes the natural features of the zones and microzones of the region. Based on the climate reference data, the prevailing wind direction was established for all weather stations of the region. According to the seasons and for the whole year, a group of monthly wind frequency was carried out. All fourteen weather stations of the region were studied in the context of natural and agricultural microzones. The study and analysis of the nature of wind directions in the Voronezh region showed that there is a process of changing the air flows movement over the seasons in a counterclockwise direction.

Local circulation is caused by changes in atmospheric pressure due to different inflow of solar radiation and determines the transfer of heat and moisture from one region to another. In General, seasonal wind circulation is also observed in the region. In winter, winds of the southern component blow more often than others: South-West (17.5 %) and South-East (17.3 %) directions. In spring, the winds of the South-Eastern (15.5 %) direction prevail. In the summer period, northwestern winds prevail (16.6%), which are close in frequency to the west (15.0%), north (14.9%) and north-east (14.5%) rumbas. In autumn, the most pronounced winds of the southwestern (17.5 %) and Western (15.6 %) sectors of influence [12].

Thus, the analysis showed a systematic seasonal change in the direction of the prevailing winds in a counterclockwise direction. On average, the winds of the South-West (15.0%), South-East (14.3 %) and West (13.7 %) directions prevail in the region. As we can see, the frequency of the prevailing winds has a small amplitude of deviation from the average value. This allows us to note that the wind blows with a certain stability from all sides.

The change in the directions of the prevailing wind flows over the seasons, their diverse amplitude within the Voronezh region represent their most complex nature and development of spatial and temporal transformation. All these features determine the complex and unpredictable nature of adverse weather processes, as well as the need to take them into account in addressing the main issues of environmentally sustainable land use formation. The complex nature of prevailing wind directions circulation was determined according to season. This obliges us to take a new approach to the territorial structure of land use. The main goal is to increase their sustainability under the conditions of adverse natural phenomena.

These phenomena are often interconnected with the winds of certain directions and occur in the corresponding time periods. So, the basic requirement for the perpendicular distribution of the main forest shelterbelts to the prevailing direction of dry winds is conditional. Dry winds appear cyclically in the period from early spring to late autumn while covering a wide range of directions. It is especially difficult to predict the wind of which particular direction and at what time it will have the maximum negative impact on the basic conditions of crop growth throughout the year.

Thus, when constructing ecologically sustainable land uses, it is not enough to use only the accounting for the directions of the prevailing dry harmful winds, since it is not known in what specific period of time a situation unfavorable for agricultural production may occur, therefore fields or arable lands should be reliably protected from winds of all directions.

Various conditions for the formation and occurrence of adverse natural phenomena necessitate a systematic approach to the development of a set of measures to assess them. The fundamental basis for addressing weather anomalies should be laid in the territory arrangement through the development of land use [18].

The theoretical and fundamental foundations of this approach were introduced by V. V. Dokuchaev. The past decades have confirmed its reliability and effectiveness, as well as the need for a systematic approach to the formation of the territorial organization on the agro landscape basis for agricultural production. V.V. Dokuchaev was the founder of the zonal approach in agriculture. It was based on the landscape-ecological approach. In his book "Our steppes before and now" V.V. Dokuchaev presented a system of measures to transform the natural resources of the steppe zone. He showed and proved that as a result of a violation of the agricultural landscape structure, namely predatory ploughing of the steppes and forests destruction, the natural resource potential of the territory can be lost.
He paid special attention to the issue of forest establishment and field-protective forestation. These elements and components of the agricultural landscape create the optimal temperature regime in its ecosystems, while the wind energy is reduced [19]. When establishing protective forest belts, it is impossible to limit be limited only to studying the prevailing direction of the harmful dry wind, because protective forest belts causing a wide range of effects on the surrounding agro-ecological environment.

4. Conclusion
Therefore, when establishing protective forest belts, it is necessary to take into account various aspects of the agro-ecological environment and climate. Protective forest belts and bush plantings are one of the main levers for controlling the microclimate formation of a given land use territory. The efficiency of land users directly depends on the degree of environmentally sustainable agricultural landscape, which is understood as the ability to withstand various adverse natural phenomena. Under the conditions of erosion and drought, cold and storms, the main goal in the land use formation is to provide an optimal environment with favourable conditions (nutrient, water, temperature and air, etc.) for crops. By creating an optimal agricultural landscape, the negative consequences will be reduced and the necessary prerequisites for improving the efficiency of land users will be created.

5. Acknowledgements
The presented provisions were tested in accordance with the resolutions of the Voronezh region administration. “On the introduction of environmental (ecological and landscape) farming systems in the region” No. 973 dated 26. 09. 1996. A list of 110 basic farms was approved for testing the theoretical and scientific - practical provisions of the methodology for the organization and arrangement of sustainable agricultural landscapes and the introduction of adaptive environmentally balanced farming systems. Regulation dated April 11, 1997 N 395-P "On creation of Coordination Council for the implementation of ecological and landscape agriculture systems". "PROGRAM concerning the implementation of ecological-landscape farming system project in the base farms of the Voronezh region" dated January 14, 1998 is approved.

The work carried out in the Voronezh region has received support, approval and further development in accordance with the RF Government Regulation dated November 8, 2001. N 780 On the federal target program Improving the soil fertility of Russia in 2002 - 2005 which says: Based on the experience of creating a modern model of ecological-landscape farming system in the Voronezh region, the Program envisages the development of this system in the farms of the Voronezh region as a pilot project. Relevant activities and funding from the Federal budget, the regional budget and extra-budgetary sources are reflected in the regional program for improving soil fertility and are taken into account in this Program. It is planned to carry out on-farm land management taking into account the introduction of ecological-landscape farming system, changes in conditions for developing the crop rotation and the cultivated area structure. The corresponding works will be carried out in 390 farms". The planned work continued in accordance with the resolution of the Voronezh Region Administration “On Approving the Regulation on the Adaptive-Landscape System of Agriculture and Soil Protection” dated February 4, 2014.

References
[1] Langhammer J and Roedlova S 2013 Changes in water quality in agricultural catchments after deployment of wastewater treatment plant Environmental Monitoring and Assessment 185(12) 10377-10393
[2] Buchinsky I E 1954 Essays on the climate of the Russian plain in the historical era (Leningrad: Gidrometeoizdat)
[3] Sazonov B I 1991 Severe winters and droughts (Leningrad.:Gidrometeoizdat )
[4] Vysotsky G N 1905 The Steppes Of European Russia (Saint-Petersburg - The complete encyclopedia of Russian agriculture) 7 106
[5] Kotlyarova E G and Gritsina V G 2017 Productivity and economic efficiency of soybean varieties cultivation upon application of organic and mineral fertilizers *Journal of fundamental and applied sciences* **9** 1582-1602

[6] Kotlyarova E G, Gritsina V G, Titovskaya A I and Litsukov S D 2017 Formation of the symbiotic apparatus and yield of soy varieties depending on the level of fertilization *International Journal of Advanced Biotechnology and Research* **8**(4) 1156-1164

[7] Abdo M T, Vieira S R, Martins A L M et al. 2013 Gully Erosion Stabilization in a Highly Erodible Kandiustalf Soil at Pindorama, São Paulo State, Brazil *Ecological Restoration Journal* **31** 246-249

[8] Shein E V, Dembovetskii A V, Kiryushin V I, Korchagin A A, Mazirov M A and Il'in L I 2017 Assessment of agronomic homogeneity and compatibility of soils in the vladimir opolie region *Eurasian Soil Science* **50**(10) 1166-1172

[9] Kotlyarova E G, Ryazanov M N, Titovskaya L S, Nuzhnaya N A and Garmashov V M 2018 The effect of soil cultivation on contamination of sunflower crops in the result of technology intensification in the last 40 years in the central black earth region *Research Journal of Pharmaceutical, Biological and Chemical Sciences* **9**(5) 1261-1268

[10] Linkina A and Nedicova E 2016 Ways to preserve soil fertility based on agrolandscape *Agrofor International Journal* **1**(2) 112-118

[11] Bukhtoiarov N I 2019 Design of Environmental Technologies on Agricultural Land *AER - Advances in Engineering Research* **182** 365-368

[12] Chechin S D and Kharitonov A A 2000 The land Fund of the Voronezh region (landscape-ecological aspect) *Problems of regional nature management and methods of teaching natural Sciences in secondary school* 3-4

[13] Lopyrev M I, Postolov V D and Chechin D I 2008 Construction of environmentally sustainable agricultural landscapes – a new stage in the development of land management and agriculture *Land management, cadastre and monitoring* **3** 20 –25

[14] Approved by the RF Government Resolution № 780 of November 8 2001 Improvement of soil fertility in Russia for 2002-2005: Federal target program *Soping legislation of the Russian Federation* **48** 9928-9973

[15] Postolov V D and Kryukova N A 2008 The medium-forming role of agroforestry in the landscape ecosystems of the Central Chernozem region *Land management, cadastre and monitoring* **5** 65-70

[16] Kotlyarova O G 1990 *Soil protection system in intensive agriculture of the Central black earth zone* (Voronezh: Tsentral'nno-chernozemnoe knizhnoe IZDATEL'stvo)

[17] Dokuchaev V V 1948 *The teaching about the zones of nature* (Moscow: Geographies)

[18] Kiryushin V I 1997 Agroecological classification of lands as a basis for development of agricultural systems *Eurasian Soil Science* **30**(1) 67-73

[19] Chechin D Š and Kharitonov A A 1999 Technological features of the field agricultural landscape *Bulletin of the Voronezh Department of the Russian geographical society* **1**(1) 72