Assessment of anthropogenic load in Samara region when implementing environmental approach to spatial configuration land use

E V Samokhvalova¹, P V Klyushin², V B Troz¹, A L Rabochev¹, S V Obuschenko³

¹Samara State Agrarian University, 2, Uchebnaya str., Kinel, Samarskaya Oblast, 446442, Russia
²State University of Land Use Planning, 15, Kazakova str., Moscow, 105064, Russia
³Station of Agrochemical Service “Samarskaya”, 112B, Novo-Vokzalnaya str., Samara, 443081, Russia

E-mail: Samokhvalova_EV@ssaa.ru

Abstract. A spatial analysis of indicators of anthropogenic load on the environment and anthropogenic degradation of agricultural land in the Samara Region was carried out in order to assess both feasibility and regulation areas of the land use spatial configuration. The values of environment stability ratio of the territory were defined and the ecological hazard of agricultural land use were calculated. The regularities of their spatial distribution over the districts of the Region were investigated. It was established that the main factor of environmental instability in the Samara Region is the degree of ploughness of land. The influence of the environmental hazard factor of the land use in agricultural production on the rural population density in forest-steppe zones of the Region was shown. The results of spatial analysis of indicators of anthropogenic load on the environment and anthropogenic degradation of agricultural land indicate the advisability of regulating land use spatial configuration, increasing sustainability of production and territorial structures.

1. Introduction

The agrarian sector transformations that have been recently introduced are mainly causing the spontaneous land use development. During difficult economic situation some part of arable lands as well as ploughed ‘virgin’ lands that did not have high fertility or lost it due to depleting agriculture is transferred to pastures and hayfields because of the unprofitable agricultural activities. As a result of urbanization and city growth, the intensive development of certain sectors of economy (mining, for example), a dangerous tendency has emerged for the local withdrawal of farmland from agricultural land. It is clear that spontaneous solution is unacceptable, taking into account the resource consumption regarding preparation and preservation of agricultural land as well as strategic importance of the agricultural sector as a whole, [1–3].

Currently the main task of researchers, when the above tendencies are outlined, is a clear management of land resources, determination of the purpose and protection status of lands in accordance with their potential and value [4–6]. This methodological approach is based on the concept of an “ideal image of territories” [7], which implements the idea of positive environmental management, taking into account the interests of all departments engaged in the exploitation of natural resources of a given
territory. On the basis of physical and landscape functional zoning (resource, environment-forming, environmental protection and others) the action of environmental, production and economic, residential, infrastructural and other factors is superimposed, which provides a joint analysis of natural and anthropogenic frameworks of the territory [8].

With regard to agriculture, it can be argued that the natural agricultural potential (NAP) determines the economic feasibility of the land use, and the distribution of social and economic resources, i.e. the possibility and potential efficiency of their use. At the same time, social and economic resources must be sufficient to ensure the economic processes of using NAP.

One of the necessary conditions for ensuring such a balance is the correspondence of population density to the NAP value. However, in the real distribution of population density, along with the potential of the territory and the economic attractiveness of the Region, environmental safety and comfort of living are of great importance. There is a need to substantiate spatial configuration regulation of agriculture from an environmental point of view.

The main objective of this work is a spatial analysis of indicators of anthropogenic load on the natural environment and anthropogenic degradation of agricultural land followed by an assessment of feasibility and regulation areas of spatial configuration of the land use in the districts of the Samara Region.

2. Materials and Methods
The indicator of population density in the administrative districts of the Region was used as a criterion for the need for regulation [9]. To ensure data homogeneity involved into study of the influence of environmental factors on settlement, the values of the population density in the districts are brought to uniform conditions of production efficiency by normalizing normative yield to the corresponding values.

For the purpose of environmental assessment of lands, the score of anthropogenic load on the territory was determined. According to the definition, anthropogenic load is a characteristic of anthropogenic and technogenic impact on the environment as a result of the introduction or movement of matter and energy, changes in the spatial structure [8, 10]. It is assessed for each type of agricultural land use according to the degree of change in the properties of the territory on a five-point scale. The highest score (5 points) is established for arable land and areas of rural infrastructure (yards, roads, buildings). The anthropogenic load score is 4 on the plots with perennial plantations (gardens, forest belts), where various agrotechnical measures and earthworks are carried out. Pastures and hayfields are assigned 3 and 2 points, respectively. The lowest score (1 point) is assigned to complexes with natural vegetation (forests, meadows). The total load score is determined by taking into account the area share of each land use.

To assess the degree of impact of anthropogenic load on the territory, the environmental stability ratio ($K_{es}$) was calculated:

$$K_{es} = \frac{\sum_{i=1}^{n} F_{st}}{\sum_{i=1}^{m} F_{unst}},$$

where $F_{st}$ are the areas occupied by stable elements of the territory that have a positive impact on the environment (forests, perennial crops and plantations, natural meadows, water bodies, nature reserves); $F_{unst}$ are the areas occupied by unstable elements that have a negative impact (arable, reclaimed, disturbed land, building plots, roads, swamps, quarries). In accordance with the scale [8], at $K_{es}$ values less than 0.5, the instability is well pronounced; 0.5-1.0 is an unstable state; 1.0-3.0 is conditionally stable; 3.0-4.5 is a stable condition; 4.5 and more denote that stability is well expressed.

To assess the degree of land degradation, there were used the data [9] on the area and degree of the land damage in the administrative districts of the Region under the influence of erosion processes, disturbances in the water-salt balance of soils, and contamination of fields with stones. The average degradation score under the influence of a complex of factors was calculated taking into account the
area of damage, caused by each of them, as weight coefficients. The ecological hazard coefficient $K_{eh}$ was calculated as a geometric mean of the features:

$$K_{eh} = \frac{100 \cdot \prod_{i=1}^{n} K_i}{n},$$

where $K_i$ is an indicator of productivity losses in the area under the influence of the $i$-th factor, $n$ is the total number of factors. The assessment of losses was carried out according to the data on the area and degree of soil damage [9], taking into account the coefficients of productivity decline [11] and was calculated as the product of the corresponding ratios for the types of degradation.

3. Results and Discussion

In accordance with the above methodology, the total score of anthropogenic load was calculated for each district of the Samara Region taking into account the area of land use as weight coefficients. In all districts, it was in the range of 4-5 (Table 1), which indicates a high and very high level of anthropogenic load. At the same time, the calculation of the ratio of ecological stability showed that instability is well pronounced in all districts of the Samara Region ($K_{es}$ less than 0.5). Only in Syzran and Isaklinsky districts the value approaches the threshold value.

It should be noted that among all the factors of instability, the contribution of the level of ploughing of the territory to the anthropogenic load is several times greater than the effect of others (correlation ratio is 0.997). Based on the classification the following is obtained: less than 50% is a permissible load, 50-70% is an increased load, 70% and more is a high load [8], in most districts of the Samara Region ploughing provides anthropogenic load on the territory on the verge of increased and high. Moreover, in the Khvorostyansky and Bogatovsky districts it exceeds 80%. The share of the area of other unstable elements of the territory does not go beyond 50% and characterizes the effect of factors as permissible.

Everything mentioned above suggests that in order to improve the comfort of living in the Samara Region the level of ploughing of agricultural lands should be gradually brought to the recommended limits (less than 40% [8]), changing the purpose of a number of sites in favor of stable elements of the territory (hayfields and pastures, primarily) or removing part of arable land from agricultural use to ensure normal functioning of natural ecosystems and recreational zones (according to world standards, it is 10% of the area or more).

At the same time, the solution of environmental problems by reducing the area of arable land should be justified so that there are no “bends” and a decrease in the economic attractiveness of the territory. The solution to these issues should be carried out locally and should be based on suitability analysis of agricultural land, assessment of their ecological state and danger of agricultural use.

Soil and climatic resources of the territory provide a sufficiently high productivity of agricultural crops. The assessment of bioclimatic potential of the Samara Region based on modeling of the production rate of grain crops [12], and the subsequent appraisal of agricultural land shows that land in all areas of the Region (in general, without detailing by fields and plots) can be attributed to the first degree of suitability (bonitet - 36-84 points) [13].
At the same time, the microclimate of the territory and the ecological state of the land create a variety of conditions in certain areas of the territory and fields, some of which are suitable only for fodder land or are not suitable for agricultural land in their natural state resulting in the need for allotment for other types of use.

There was also assessed the environmental state of agricultural land in the Samara Region with an assessment of degradation degree caused by a complex of negative factors and the coefficient of environmental hazard of land use in agricultural production (Table 2). In this case, the degree of degradation under the influence of certain negative factors was scored taking into account the area and severity of damage [14].

Table 1. Assessment of indicators of anthropogenic load on the territory of the Samara Region

| Administrative region         | Arable land | headquarters for construction | headquarters for roads | bogs | disturbed lands | other | reclamation | construction | gardens | forest | pastures, hayfields | anthropogenic load, score | ecological stability ratio |
|-------------------------------|-------------|-------------------------------|------------------------|------|-----------------|-------|-------------|--------------|---------|--------|---------------------|--------------------------|---------------------------|
| Chelnovershinsky             | 75.1        | 6.6                           | 1.5                    | 0.4  | 0.0             | 0.7   | 1.0         | 1.7          | 1.9     | 16.7   | 4                   | 0.26                     |
| Shentalinsky                 | 72.4        | 0.9                           | 0.8                    | 0.4  | 0.0             | 0.7   | 0.1         | 5.0          | 0.0     | 19.3   | 4                   | 0.33                     |
| Klyavinsky                   | 69.3        | 0.2                           | 1.4                    | 0.1  | 0.0             | 0.6   | 0.0         | 1.5          | 4.2     | 22.5   | 4                   | 0.40                     |
| Koshkinsky                   | 74.3        | 0.2                           | 1.5                    | 0.7  | 0.0             | 0.4   | 0.5         | 1.6          | 0.6     | 19.9   | 4                   | 0.29                     |
| Sergievsky                   | 70.0        | 0.2                           | 1.1                    | 0.9  | 0.0             | 0.7   | 0.0         | 2.8          | 2.3     | 21.4   | 4                   | 0.37                     |
| Isakinski                    | 64.9        | 0.5                           | 0.8                    | 0.3  | 0.0             | 0.7   | 0.0         | 1.6          | 3.3     | 27.8   | 4                   | 0.49                     |
| Kamyslynsky                  | 69.2        | 0.2                           | 1.3                    | 0.3  | 0.0             | 0.7   | 0.0         | 1.7          | 3.3     | 23.1   | 4                   | 0.39                     |
| Elkhovky                     | 73.1        | 0.2                           | 1.3                    | 0.3  | 0.0             | 0.8   | 0.0         | 1.1          | 1.3     | 21.3   | 4                   | 0.32                     |
| Povhistevsky                 | 71.7        | 0.9                           | 0.7                    | 0.3  | 0.1             | 0.7   | 0.2         | 1.3          | 3.1     | 20.5   | 4                   | 0.34                     |
| Syzransky                    | 63.1        | 0.2                           | 1.8                    | 0.5  | 0.0             | 1.5   | 0.5         | 1.6          | 6.6     | 23.8   | 4                   | 0.48                     |
| Shigonsky                    | 75.2        | 0.8                           | 0.6                    | 0.1  | 0.0             | 1.1   | 0.0         | 6.0          | 16.1    | 1.5    | 5                   | 0.29                     |
| Stavropol                    | 73.2        | 0.6                           | 1.6                    | 0.9  | 0.0             | 0.9   | 0.2         | 3.7          | 0.1     | 14.1   | 4                   | 0.29                     |
| Krasnoyarsk                  | 68.1        | 0.4                           | 1.3                    | 1.2  | 0.0             | 1.3   | 0.2         | 4.1          | 0.0     | 23.0   | 4                   | 0.38                     |
| KinelCherkassky              | 72.8        | 1.1                           | 0.3                    | 0.5  | 0.0             | 0.7   | 0.0         | 2.1          | 1.0     | 21.0   | 4                   | 0.33                     |
| Privolzhsky                  | 77.5        | 0.8                           | 0.9                    | 3.1  | 0.0             | 0.5   | 0.7         | 0.8          | 3.1     | 11.9   | 5                   | 0.20                     |
| Bezhenchuksky                | 64.3        | 0.2                           | 1.0                    | 8.4  | 0.0             | 0.6   | 0.1         | 3.0          | 0.1     | 20.9   | 4                   | 0.34                     |
| Volzhsky                     | 67.2        | 0.4                           | 1.6                    | 2.0  | 0.1             | 0.5   | 0.2         | 3.5          | 0.0     | 22.8   | 4                   | 0.39                     |
| Kinelsky                     | 67.9        | 0.3                           | 1.5                    | 1.2  | 0.0             | 1.4   | 0.5         | 3.3          | 0.0     | 22.6   | 4                   | 0.37                     |
| Bogatovsky                   | 83.5        | 0.1                           | 1.4                    | 0.7  | 0.0             | 0.3   | 0.2         | 1.0          | 1.7     | 10.2   | 5                   | 0.16                     |
| Borsky                       | 75.3        | 0.1                           | 1.2                    | 0.3  | 0.0             | 0.7   | 0.0         | 3.8          | 0.2     | 18.1   | 4                   | 0.29                     |
| Khvorostyansky               | 81.6        | 0.3                           | 0.8                    | 0.1  | 0.0             | 0.3   | 0.0         | 1.6          | 0.9     | 14.1   | 5                   | 0.20                     |
| Krasnaorveysky               | 78.5        | 0.1                           | 1.1                    | 0.1  | 0.0             | 0.3   | 0.0         | 1.7          | 0.4     | 17.1   | 5                   | 0.25                     |
| Neftegorsk                   | 77.5        | 0.6                           | 0.4                    | 0.1  | 0.0             | 0.2   | 0.1         | 1.8          | 0.0     | 18.7   | 4                   | 0.27                     |
| Alekseevsky                  | 75.4        | 0.3                           | 1.2                    | 0.0  | 0.0             | 0.6   | 0.0         | 2.0          | 0.0     | 19.9   | 4                   | 0.29                     |
| Pestravsky                   | 76.8        | 0.4                           | 0.9                    | 0.2  | 0.0             | 0.5   | 0.1         | 2.3          | 0.0     | 17.5   | 4                   | 0.27                     |
| Bolsheglushitsky             | 77.7        | 0.5                           | 0.7                    | 0.1  | 0.0             | 0.7   | 0.0         | 2.7          | 0.0     | 16.7   | 5                   | 0.25                     |
| Bolschechnigovskiy           | 73.3        | 0.4                           | 0.7                    | 0.3  | 0.0             | 0.4   | 0.0         | 2.1          | 0.0     | 21.5   | 4                   | 0.33                     |
| Region as a whole            | 73.0        | 0.4                           | 1.1                    | 0.9  | 0.0             | 0.7   | 0.1         | 2.5          | 1.0     | 19.4   | 4                   | 0.32                     |
Table 2. Scale of indicators of anthropogenic load on the territory and degradation of agricultural land in the Samara Region (%)

| Administrative region     | Anthropogenic degradation, score | Environmental hazard |   |
|---------------------------|----------------------------------|----------------------|--|
|                           | erosion | violation of water-salt balance | stone clogging | stability ratio, size free | level assessment, score |
| Chelnovershinsky          | 2       | 1                                  | 0               | 0.44                           | 3                        |
| Shentalinsky              | 2       | 0                                  | 0               | 0.55                           | 3                        |
| Klyavlinsky               | 2       | 0                                  | 0               | 0.47                           | 3                        |
| Koshkinsky                | 2       | 1                                  | 0               | 0.47                           | 3                        |
| Sergievsky                | 3       | 1                                  | 0               | 0.71                           | 4                        |
| Isakinsky                 | 2       | 1                                  | 0               | 0.73                           | 4                        |
| Kamyshlinsky              | 4       | 0                                  | 1               | 0.72                           | 4                        |
| Elkhovky                  | 2       | 0                                  | 0               | 0.39                           | 2                        |
| Pohvistnevsky             | 4       | 0                                  | 1               | 0.72                           | 4                        |
| Syzransky                 | 2       | 0                                  | 0               | 0.52                           | 3                        |
| Shigonsky                 | 3       | 0                                  | 0               | 0.52                           | 3                        |
| Stavropol                 | 1       | 0                                  | 0               | 0.35                           | 2                        |
| Krasnoyarsk               | 1       | 1                                  | 0               | 0.45                           | 3                        |
| KinelCherkassky           | 3       | 0                                  | 0               | 0.49                           | 3                        |
| Privolzhsky               | 0       | 1                                  | 0               | 0.19                           | 1                        |
| Bezenchuksky              | 0       | 1                                  | 0               | 0.40                           | 2                        |
| Volzhsky                  | 1       | 1                                  | 0               | 0.45                           | 3                        |
| Kinelsky                  | 1       | 1                                  | 0               | 0.37                           | 2                        |
| Bogatovsky                | 0       | 0                                  | 0               | 0.22                           | 2                        |
| Borsky                    | 1       | 0                                  | 0               | 0.32                           | 2                        |
| Khvorostyansky            | 0       | 0                                  | 0               | 0.16                           | 1                        |
| Krasnoarmeyskhiy         | 2       | 0                                  | 0               | 0.48                           | 3                        |
| Netfegorsk                | 1       | 0                                  | 0               | 0.29                           | 2                        |
| Alekseevsky               | 2       | 0                                  | 0               | 0.42                           | 3                        |
| Petravsky                 | 2       | 0                                  | 0               | 0.43                           | 3                        |
| Bolsheglushitsky          | 1       | 0                                  | 0               | 0.36                           | 2                        |
| Bolshechemigovsky         | 3       | 1                                  | 0               | 0.95                           | 5                        |
| Region as a whole         | 2       | 0                                  | 0               | 0.48                           | 3                        |

The classification of districts by the $K_{eh}$ value was applied: for values less than 0.2 1 point is scored, 0.2-0.4 - 2 points, 0.4-0.6 - 3 points, 0.6-0.8 - 4 points, 0.8 and more - 5 points. As a result, one district with the greatest total effect of the processes was identified, with a score of 5 points, i.e. Bolshechemigovsky district ($K_{eh} = 0.95$), a group of districts with a score of 4 points among which are Pohvistnevsky, Kamyshlinsky, Sergievsky, Isakinsky. Two districts are marked with a score of 1 point, i.e. Privolzhsky and Khvorostyansky. In most areas, however, the coefficient of environmental hazard corresponds to 2 and 3 points.

The ratio of variation $K_a$, and the degree of ploughing by districts is 25%, the correlation with the population density turned out to be weak. This means that the influence of the factor of environmental stability of the territory is practically not traced. The ratio of variation of $K_a$ by districts is 38%, the correlation with the population density in the forest-steppe zone was -0.43 and, therefore, the
environmental state of lands cannot be excluded from the number of factors that determine the settlement of people. In the regions of the steppe and dry-steppe zones, the connection turned out to be insignificant.

Thus, the results obtained indicate a lower population density in areas where there is an increased level of environmental hazard. Since the environmental hazard of land use in agricultural production was assessed by the degree of their degradation, it can be assumed that a gradual decrease in the economic efficiency of production on damaged lands causes an outflow of the population from such areas. In the future, this will entail a disruption in the balance of natural, economic and labor resources and the emergence of an industrial crisis, especially in the areas of the forest-steppe zone, characterized by the highest agricultural potential.

4. Conclusion
The analysis of the environmental state of lands made it possible to identify the factors that determine the comfort of living of the rural population in the Samara Region and to assess the ecological danger of the development of soil degradation as a result of agricultural production. The results of spatial analysis of indicators of anthropogenic load on the natural environment and anthropogenic degradation of agricultural land indicate the advisability of regulating the spatial configuration of the land use. This will contribute to an increase in land capacity, the stability of production and territorial structures (economic complexes, crop rotations, fields, plots) and a balanced land use.

Acknowledgments
The work was carried out within the framework of the project Meteorological Substantiation of Agricultural Technologies and Agricultural Design (registration No. 116041210128 in the Unified state information system for recording research, development and technological civil works).

References
[1] Zhuchenko A A 2004 Resource potential of grain production in Russia (theory and practice) (Moscow: Agrorus)
[2] Loiko P F 2009 Some aspects of modern land policy in the agrarian sector of the world and Russia Land management, cadastre and land monitoring 1 16-29
[3] Dashkovsky I 2018 No soil underfoot. Land degradation deprives farmers of profits Agricultural engineering and technology 3. Retrieved from: https://www.agroinvestor.ru/analytics/article/29844-bez-pochvy-pod-nogami/
[4] Volkov S N 2006 Land relations as a basic factor for sustainable development of agriculture Economy of agricultural and processing enterprises 4 5-7
[5] Volkov S N, Komov N V and Khlystun V N 2015 How to achieve effective land management in Russia? International Agricultural Journal 3 3-7
[6] Kaim A, Cord A and Volk M 2018 A review of multi-criteria optimization techniques for agricultural land use allocation Environmental Modeling and Software 105 79-93
[7] Kagansky V L 2009 Cultural landscape: basic concepts in Russian geography Observatory of culture 1 62-70
[8] Tselovalnikov A S 2010 Monitoring of anthropogenic load and degradation processes of agricultural lands of the Stavropol Territory using geoinformation technologies: dissertation abstract (Moscow: FGOU VPO GUZ) 24 p
[9] Poroshina L N (ed) 2002 Atlas of lands of the Samara Region (Samara: Russian Research and Design Institute of Land Resources)
[10] Zaikanov V G, Minakova T B, Makhorina E I et al 1998 Comprehensive geoeconomic assessment of territories: Basic principles of the methodology Environmental Review: Overview (Moscow: VINITI) 2 62-80
[11] Ogleznev A K, Kupriyan T A, Norkina T E, Melnikov A V, Fadeev A A, Rodin A Z, Nosov S I, Bulgakov D S, Karmanov I I, Karmanova L A, Mikhailova O V, Overchuk A L and Miroshnichenko S G 2007 Assessment of the quality and classification of lands according to their
suitability for use in agriculture (Moscow: VISKHAGI)
[12] Samokhvalova E V 2017 Bioclimatic potential of the territory in the cadastral assessment of agricultural land (on the example of the Samara region) Meteorology and hydrology 4 102-112
[13] Nosov S I (ed) 2010 Handbook of agroclimatic assessment zoning of the constituent entities of the Russian Federation (Moscow: Maroseyka) 208 p
[14] Samokhvalova E V and Zudilin S N 2021 The analysis of spatial propagation of key degradation processes in the farmlands of Samarskaya oblast IOP Conf. Ser.: Earth and Environ. Sci. 720 012040