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Components of Anthropogenically Transformed Landscapes of South of Russia Interaction

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***Abstract*— The objects of the study were the southern dry steppe and agricultural objects located within it with a spatial combination of agrobiocenosis and elements of anthropogenic impact on the territory of South of Russia. As a result of the research it was found that the intrusion impact on agrobiocenosis is comprehensive and mainly negative. Intrusion with projective cover (PC) less than 50% to a small extent affects the adjacent agrocenosis, when covering 70% or more – leads to quite pronounced changes in the adjacent areas of the agrocenosis. It also influences to the trophic structure of ecosystem and the nature of the links between its components. The creation of a stable "core" community consisting of productive perennial plants adapted to the conditions of the southern dry steppe is a general trend of plant interaction in the studied phytocenoses. A design of the database for information storage and systematization on the basis of the consort relationships between the main participants of biogeocenoses was developed. In future, it will allow to build a prognostic model for faster and more reliable screening of impacts on natural communities within the necessary environmental measures' framework.**

Keywords: anthropogenic ecosystems, phytocenoses, man-made intrusions, ecosystem components, consortia connection

I. Introduction

Currently, the ecological system approach to the management of agrocenoses is the most relevant approach in the development of the agro-industrial complex [1-3]. An adapted, focusing on the regulation of biocenotic relations in ecosystems, approach to the optimization of agricultural systems is neededsince these systems can contain both fully artificial and semi-artificial biocenoses. It is possible to modify this approach using biotechnological solutions in particular management by implementing agro-ecosystem of new elements – biotic (bacteria and fungi) or abiotic (chemical) [4; 5].

II. Materials and Methods (Model)

Scientific approaches used in the development of environmentally oriented optimization of biotechnology of arid anthropogenic ecosystems of the South of Russia suggest practical sampling and sample preparation representative samples (of soil, plants, microorganisms, etc.) and identification of key characteristics (species diversity, population numbers of key participants, spatial and trophic organization, etc.) of anthropogenic ecosystems with regard to typical regional variant (the combination of grain farming, shelterbelts and transition strips of ecotone). To develop a system of agrobiocenosis management using environmental tools, it is necessary to create a unified database containing information about the features of interaction between elements of natural, anthropogenic biocenoses and tightly controlled agroecosystems. The use of such a database will ensure the reduction of undifferentiated chemical pressure, will put into practice an individual approach to the management of biotic interactions in the community by modulating physical, chemical and biotic factors [5 - 7].

The need to establish regularities characterizing adaptive and regressive changes in agricultural and natural ecosystems and the formation of a data set as a basis for bioinformatics analysis, mathematical modelling and metabolomics of anthropogenic ecosystems of the South of Russia with the aim of predicting the behavior of the ecosystem in relation to its key elements when subjected to known external influences and to optimize its condition led to the implementation of the work on the state task "Development of environmentally oriented optimization of biotechnology of arid anthropogenic ecosystems of the South of Russia on the basis of the achievements of physico-chemical biology and bioinformatics" (project No. 40.7534.2017/8.9)".

In 2017 objects of study were the sites of the southern dry steppes and located within agricultural facilities – agricultural lands (barley mainly) in Volgograd region (Svetloyarskiy, Gorodishchensky districts), as well as within the city of Volgograd, in the Soviet district. In 2018-2019, the total number of test sites surveyed was expanded to eleven, with 2-3 intrusion sites each. Thus, the total number of intrusions was 28, which made it possible to make the necessary generalizations about their impact on the adjacent agrocenosis and rank them according to the degree of this impact [8]. Five sites were located in the Volgograd region, two - in the Astrakhan region, two - in the Republic of Kalmykia and two - in the Stavropol Krai. When choosing a site, we were guided by the presence of a spatial combination of agrobiocenosis and elements of technogenic impact (communications associated with oil and gas transportation systems, power lines, zones of passage of agricultural machinery) [9].

The main approach for obtaining objective information about the studied phytocenoses was the method of spectral decomposition of actual high-resolution satellite images. The software package ArcGISPro and the online platform USGS Earth Resources Observation and Science, which allows Landsat multispectral satellite images downloading, were used for spectral analysis of the selected sites. To obtain the data, open access multispectral satellite images downloaded from the USGS platform were used. The original high-resolution scale is 1: 500,000. Within the framework of this project, an original method for remote determination of anthropogenic transformation of phytocenoses using the vegetation index IPVI = (NDVI+1)/2 was developed. The following approach was indirect integral assessment of the species diversity and phytophases composed of man-made intrusions on the basis of dynamic shooting it with the side view at an angle from 20 to 45 degrees. This method allows to integrally assess the biodiversity and phenophase heterogeneity of the intrusion with sufficient accuracy with minimal complexity, as shown by expert assessments on the ground. Indicators over 60% of the maximum spread and above were assessed as high heterogeneity (which corresponded to high intrusion activity), indicators in the range from 35 to 60 – as average, below 35 – as low. In this case, it was possible to predict a slight impact of the intrusion on the adjacent agrocenosis. In addition, for the studied objects, studies were carried out in four main directions: geobotanical, entomological, microbiological and soil-ecological. Subsequently, the array of primary data was used to identify links between the main participants of biogeocenoses. The relationship was detected for the following subsystems: "phytocenosis–species-edificators", "soil-phytocenosis ", "the species-edificatory - entomocomplex (phytophages/entomophages)", "phytocenosis–microflora (pathogens /symbionts)", "soil–typical representatives of the microbiota," etc. The obtained results formed the basis for compiling the database, in relation to entities, their descriptive properties and hierarchy of relations.

On the territory of each of the sites on the basis of the assessment of the degree of anthropogenic impact, the following key zones were identified: the zone of agrocenosis, the steppe zone in a quasi-natural state, as well as the zone of technogenic intrusion.

III. Results and Discussion

According to the results of field observations, it was revealed that, depending on the nature of the anthropogenic impact, technogenic intrusions can have a different spatial manifestation and form of the area: “insulated”, “invading”, “conterminal” [10]. According to the degree of intensity of the negative impact on the basis of expert assessments of the results of environmental and Botanical monitoring were identified intrusions with high, restrained and low degree of impact on the surrounding agrocenosis.

As a result of the conducted researches it is established that an intrusion influence on agrobiocenosis has complex, mainly negative character and is expressed in the following. At the periphery of the intrusion, there is a decrease in projective cover (PC) and, as a consequence, a decrease in the productivity of the cultivated crop. The intrusion zone enhances the anthropogenic migration of elements. Technogenic intrusion, as a rule, is associated with the formation of a special microrelief, which affects the conditions of surface and underground runoff and enhances the geochemical transport of pollutants with their subsequent accumulation in the "soil-plant" subsystem of agrocenosis. In addition, the intrusion zone affects the trophic structure and the nature of the connections between the elements of the agrobiocenosis.

In the course of the study on the territory, 3 key zones were identified on the territory of each site based on the assessment of the degree of anthropogenic impact:

- Agrocenosis zone as a completely artificial ecosystem;
- Zone of man-made intrusion;
- steppe zone, which is in a quasi-natural state.

In this case, man-made intrusion refers to biogeocenosis resulting from the interaction of artificial and quasi-natural ecosystems located in a territory, including the elements of technogenic impact.

According to the results of field observations, it was revealed that depending on the nature of anthropogenic impact, technogenic intrusions can have different spatial manifestation and shape of the area. Thus, on the territory of the studied areas, 3 main types of intrusions can be conditionally distinguished:

- the insular(Figure 1);
- invading (Figure 2);
- boundary (Figure 3).

Fig. 1. Technogenic insular intrusion

A distinctive feature of insular intrusions is their spatial manifestation, which is in most cases a chain of sites that resemble a biconvex lens. The reasons for the formation of lens intrusions may be the creation and maintenance on the territory of agrocenosis of man-made objects having a common linear direction and at the same time characterized by frequent disruption of continuity with formation of island long areas with own biocenosis. Examples of such facilities are the laying and maintenance of gas pipelines, power lines, etc.

Fig. 2. Technogenic invading intrusion

Invading-type intrusions are areas of anthropogenic impact, having the sum of the lengths of the sides bordering the agrocenosis, 2 or more times the length of the base (not bordering the agrocenosis). Invading intrusions can be formed when the border of agrocenosis located in close proximity to the existing linear transport communications (mainly underground), which, as a result of the complex impact in their maintenance and soil treatment by agricultural machinery, leads to the invasion of the man-made action in the zone of agrocenosis and the violation of the integrity of its borders.

Man-made boundary intrusion is due to the construction of a powerful and spatially extended anthropogenic factor that changes the chemism and granulometry of the soil, species diversity, general external characteristics of the territory. Intrusions of this type are widespread in the study area and are long in length, combined with a small and highly variable width.

The activity of technogenic intrusions in relation to the adjacent agrobiocenosis can be previously predicted by the degree of PC. It was found that intrusions with PC less than 50% have a small impact on the adjacent agrocenosis, when covering 70% or more-lead to sufficiently pronounced changes in the adjacent areas of agrocenosis to a depth of at least 40-50 m.

Fig. 3. Technogenic boundary intrusion

Researches indicates the communities developing in the areas exposed to constant anthropogenic impact, are characterized by a high degree of explosiveness. At the same time, there are "random" species listed, preferably, by working personnel and technical means. At the same time, the initial successional processes of penetration of the surrounding areas flora into the technically altered space are observed. Most often they are representatives of xerophytic and halophilic flora belonging to the Asteraceae and Chenopodiaceae families. The general trend of plant interaction in the studied phytocenoses can be called the creation of a stable "core" community consisting of productive perennial plants adapted to the conditions of the southern dry steppe. With, the creation of species-poor "starting" communities, beginning to form the already mentioned "core", in irregular plowing of pipelines is observed. It should be noted the presence of stable pairs centerpieces-subdominant, represented by two allelopathic species – *Artemisia absinthium* and *Elytrigia repens*. Their interaction often leads to the existence of typical stable structures in which the basis of the material and energy balance is the competition between the dominant and the subdominant.

When entomological collecting in mixed grass-sagebrush association revealed a complex of insects, inhabiting associated with certain types of plants edificatory plant communities. It should be noted that on *Cichorium intybus* and *Melilotus officinalis* there is a significant accumulation of pollinators and insect parasites attracted for feeding by nectar and flower pollen. The motley-grass association noted richer with entomofauna than forb-sagebrush one.

From the biocenotic point of view, the solution of the problem of self-regulation of agrocenoses and management of their phytosanitary condition is impossible without environmental monitoring, the initial stage of which is the inventory of biotic components, including microfloristic populations.

The main part of aerobic bacteria in soils, according to microbiological studies, were non-spore-forming forms-fluorescent and pigment bacteria of the *Pseudomonas* genus. The number of aerobic saprophytes using soil organic nitrogen (in the 0-20 cm horizon) is 4.5 – 5.6 million cells/g

of soil. The dominant group is *Bac. мesentericus – Bac. мegaterium – Bac. subtiiis*, minor group – *Bac. idosus – Bac. megaterium*. The number of anaerobic bacilli is 25-29 thousand cells/g of soil, including 14-39% – spore-forming. The main representatives of the *Clostridium* genus in the studied soils were *Cl. acetobutilicum* (20-45 thousand/g of soil), to a lesser extent, *CI. pasteurianum* and *CI. butiricum* (no more than 5 thousand/g of soil). There was a slight increase in anaerobic bacteria in the arable areas. The bulk of actinomycetes is represented by light-colored species: *Act. albus*, *Act. priseus, Act. globisporus*. The total number of actinomycetes – 44-70 thousand cells / g of soil. Pigmented forms were more diverse in arable variants. Light chestnut soil is poor in nitrifying microorganisms. Cellulose-decomposing microorganisms are represented by species of the *Cytophaga* genus. The composition of cellulose-destroying fungi includes *Chaetomium* and *Dematium*, whose share in the utilization of cellulose is much higher than the contribution of bacteria.

The species affiliation of the identified predominant microorganisms and their ecological niche are still to be clarified in the course of further work.

One of the directions of the study was soil microflora, which was associated with plant species identified as printers. Morphological and cultural properties were determined for her.

Primary linkage analysis for the studied phytocenoses showed that the strongest relationship is that between the group of aerobic bacteria (*Pseudomonas*) and such cenosis-forming species as *Euphorbia helioscopia* and *Atriplex tatarica*. The situation is similar for the group of anaerobic bacteria *Cl. acetobutilicum* and *Artemisia lercheana*.

Species diversity of pathogenic microorganisms in the studied cenoses is represented by these fungi from the classes *Ascomycetes*, *Deuteromycetes* and *Basidiomycetes*. The *Septoria*, *Puccinia* genera also *Erysiphe* are the leading ones in terms of the number of species. The species composition of micromycetes of natural phytocenoses is more diverse in comparison with agrobiocenoses, but it is distributed separately on individual plants with greater amplitude in the development of the disease, which is associated with a diverse species composition of feeding plants and the specifics of their growth. The prevalence and high ecological plasticity of the causative agents of diseases such as powdery mildew and *Septoria* leaf spot on *Convōlvulus arvēnsis* determine their further study as candidates for biocontrol.

IV. Conclusion

An analysis of the primary data made it possible to identify stable patterns and make an assumption about possible consort relations between the main participants in biogeocenoses. On the basis of these data, for storing and systematizing the information obtained during the implementation of the work the design of the research database (DB) was developed. Based on the results of the field stages of the study, a data set was formed as a basis for bioinformatic analysis and mathematical modeling, metabolomics of agrobiocenoses of the arid zone. Obtaining or refining the quantitative and semi-quantitative characteristics of previously established relationships, will further go to the construction of a predictive model based on difference equations, the correction of which after testing on the test samples will develop an expert system of dynamic forecasting of ecosystem behavior in relation to its key elements when exposed to known external influences, which will open the possibility of a virtual analysis of the consequences of the use of the proposed methods of ecosystem change. It will allow faster and more reliable screening of impacts on natural communities within the framework of necessary environmental measures.

Filling in and testing such a DB is a matter for the future. We have also identified the term technogenic intrusion and attempted to classify the diversity of intrusions on the basis of spatial characteristics and origin.

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