

Spatial Analysis of Innovations Diffusion in the Agricultural Sector

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Abstract — The article presents the results of spatial analysis of innovations diffusion in the agriculture of the Russian Federation regions based on the use of GIS technologies. The research includes traditional and mathematical methods as well as geoinformation-cartographic modeling.

This paper presents various aspects of innovative development and innovative processes in the regions of Russia by constructing and analyzing geoinformation-cartographic models of various complexity. To illustrate innovations diffusion a series of analytical base and resulting maps have been obtained. Additionally, the results of GIS mapping are presented in the form of animated maps and cartographic animations reflecting the territorial distribution of innovations.

The spatial geoinformation-cartographic analysis of innovations geographical distribution as well as the direction of their diffusion processes reveals a number of objective patterns of their distribution. Primarily, in the space-time continuum of country's agricultural sector innovations shift from nuclei and sub-nuclei to innovative sub-periphery and peripherals. Geographically it happens in the direction from the largest cities that are at the same time the leading scientific and technical centers as well as from the areas of intensive agriculture, towards mostly eastern and northern regions of the European part of Russia, Siberia and the Far East.

In addition, GIS technologies allowed to form cartographic and attribute databases that are key indicators of innovative development, to construct and analyze geoinformational and cartographic models of territorial innovative agricultural systems at the regional level and reveal the processes of innovations diffusion.

Keywords: *innovation, diffusion of innovation, agriculture, regions of Russia, GIS technology, spatial analysis*

I. INTRODUCTION

The most important fundamental and relevant interdisciplinary problem in modern Russia is the need for scientific evidence of the best options for national and regional agricultural policy. The main way to solve it is to develop conceptual frameworks and methods for studying cyclical genetic patterns of regional agricultural systems formation and functioning. It includes mechanisms of their innovative development (genesis, development, innovations dissemination) based on the use of new methods of mathematical and geoinformation modeling.

Innovation or new developments most often refer to an introduced or already introduced innovation demanded by the market, contributing to the efficiency growth of various processes and/or improving product quality [1-3], introduction of a new or significantly improved product, item of goods, service, process, sales method, marketing or implementing organizational method in business practice, work place arrangements or in external relations [2; 4]. It is always the result of intellectual activity, creativity, discoveries, inventions and rationalization [3].

The concept of “innovation” appeared in the 19th century and at the beginning of the 20th century it received a new life in the works of J. Schumpeter [2; 5-7]. Developments or new developments that increase the effectiveness of the current system to a remarkable degree are recognized as innovations.

The most common and generally accepted points of view define the diffusion of innovations as a theory aimed at explaining the causes, essence, direction and speed of new ideas and technologies dissemination across different cultures.

The concept, first studied at the end of the XIX century by G. Tarde [3; 7], F. Ratzel [3; 7; 8] and L. Frobenius [3; 7], was embodied in the theory and popularized in the second half of the XX century by E. Rogers and T. Hagerstrand [3; 7; 9; 12]. They defined *innovation* as a special idea, a practical activity or an object perceived by an individual or by another so-called implementation unit as something new, and diffusion of innovations as a process that determines the transfer and implementation of innovations (new messages, ideas, processes, products, technologies, etc.) through communication channels (transmission media) among members of social systems - individuals (from one to another) and organizations during a certain period of time [9; 12].

In relation to the research issue and problems of our study - the diffusion of innovations in agriculture means their movement in the space-time continuum from innovative nuclei and sub-nuclei to innovative sub-periphery and periphery [1; 10; 11].

While investigating stochastic innovation processes mostly used are statistical and economic-geographical approaches. There are new and not yet widely accepted methodological approaches in agriculture which include simulation and optimization modeling of economic and innovative processes and phenomena, mathematical methods (structural and parametric identification, bidimensional integral and integro-partial differential Fredholm-Voltaire equations, spectral analysis, spline functions, Green functions, Monte Carlo method, etc.), creation of innovative development simulation models, taking into account the influence of various factors [1; 10; 11].

Our study shows that the development, creation and practical application of mathematical and geoinformation-cartographic modeling of innovation cycles, diffusion processes and the spatio-temporal dynamics of innovations based on geoinformation systems and GIS technologies are effective [10; 11; 13-16]. At the same time, a complex of tasks is solved by using them, among them, first of all, identification of the territorial differentiation of Russian regions by innovative functions and innovative potential of agricultural production, as well as their typology according to the degree of susceptibility to diffusion processes of innovations [1; 10].

Traditional actions performed while working with databases (hereinafter referred to as DB) (primarily search queries and statistical analysis of information) are combined with the advantages of overlay operations and full-fledged graphical visualization, and spatial analysis of the results [10; 14; 16; 17].

The use of traditional and mathematical methods in the study of innovations diffusion in agriculture is supplemented by geoinformation-cartographic modeling. This allows creating a series of digital, electronic and computer maps reflecting the processes of agricultural development of the initial territory landscape structure, generation, establishing and development of agricultural

territorial systems at local and regional levels at different historical stages, spatio-temporal patterns of their productivity at different innovative development stages.

In the spatio-temporal aspect, the processes of innovations diffusion are graphically visualized and characterized: from innovative cores and sub-nuclei to innovative sub-periphery and peripherals; a typological classification of the Russian Federation's regions has been carried out according to the degree of susceptibility to them and the possibilities of their implementation, according to innovative functions and agriculture innovative potential [1; 10; 11]. At the same time, it becomes possible to forecast the processes of innovations diffusion in the agricultural sector of a particular region and country as a whole, scientifically justify the best options for agrarian management policy and solve a set of tasks to increase the efficiency of managing natural-social-production systems of different hierarchical levels and the stability of their functioning.

II. MATERIALS AND METHODS (MODEL)

The purpose of this study is to analyze geographically the diffusion of innovations in the agriculture of regions in Russia by means of geoinformation technologies and on this basis identify regional geospatial features of these processes.

The research is based on the study and analysis of the GIS mapping theory and methodology special aspects and modeling various spatial objects, phenomena and processes, the specifics of their application in geographical research presented in detail in works including innovative developments in the field of industry-specific thematic and integrated system mapping based on modern methodological and scientific and technological achievements, as well as the results of their practical use [13; 14 et al.].

Since the late 90s XXth century there have been carried out some well-known researches in the field of object-oriented analysis and modeling of complex dynamic systems (G. Buch, Yu. B. Kolesov); the use of GIS in the study of soils and land resources and the development of soil databases (R.A. Burrough, R.A. McDonnell, K.S. Teslenok et al., C. Le Bas, D. King, M. Jarnagne, J. Daroussin, B. Nicoulaud, M. Ngongo et al.); modeling GIS scenarios of changes in potential land productivity (I.Yu. Savin, E.Yu. Prudnikova, V.V. Sizov, L.G. Kolesnikova, E.V. Aleksandrova and others); optimization of geoinformation mapping (S.I. Myasnikova, A.K. Cherkashin, A.D. Kitov, I.V. Bychkov, et al. [17]), identifying by the results of geomorphometric analysis of digital elevation models of potential places where such processes as water and wind erosion, waterlogging, flooding, suffusion and etc. can develop (A. A. Glotov, K. S. Teslenok, S. A. Teslenok and others [16]); geoinformation analysis of land use structure and modeling of its optimality (K.S. Teslenok); geoinformation modeling and mapping of the natural resource potential of rapidly developing territories, etc. (V.S. Gruzinov, I.G. Zhurkin, L.N. Chaban, K.S. Teslenok).

A vast majority of studies by Russian scientists in the field of innovative development of agricultural production are focused on solving narrow regional issues of agricultural policy. The problems of development, creation, and

practical application of geoinformation-cartographic modeling of innovation cycles, diffusion processes and the spatio-temporal dynamics of innovations, the identification of territorial differentiation and typology of regions by their innovative functions and innovative potential of agriculture, spatial analysis of heterogeneity of Russian regions in terms of their susceptibility to innovations diffusion processes still remain not well studied [10; 13-15]. The main methodological problem, in this case, is the lack of specialized information on the innovative development of agriculture.

Information complexity, in this case, lies in the need to collect, analyze, record and process large quantities of spatially coordinated geographic data. Therewith the role and importance of the implementation and widespread use of geographic information systems and GIS technologies, geographic information modeling and mapping is beyond any doubt.

III. RESULTS AND DISCUSSION

At the first stage of research, the collection and primary processing of specialized statistical information was carried out as well as database creation on its basis to create a specialized geographic information system "Innovations in the regions of the Russian Federation" in order to implement subsequent geoinformation-cartographic modeling of innovations diffusion [1; 10; 11] and spatial geographic information analysis.

Then several options were designed and the database structure was developed on the basis of the target GIS software (ArcView GIS, ArcGIS, MapInfo Professional), which became the basis for geoinformation mapping of various aspects of agriculture innovative development in the states of the Russian Federation and the identification of the territorial specifics and regional geospatial features of innovation diffusion processes.

The nature of the initial statistical data determined the number, general list, parameters and fields names of the database attribute tables of the designed specialized GIS.

Then, geoinformation-cartographic models of varying degrees of complexity were constructed and analyzed by using the methods of geoinformation mapping. These models reflect both various aspects of innovative development in the regions of Russia and their innovative processes [1; 10; 11]. At the same time, innovative indicators having the longest time series were used.

Graphical visualization of GIS DB information using appropriate software is usually carried out in the two most common ways: in the form of an electronic map on the video screen of a computer monitor or in the form of a computer map displayed on a printing device. This made it possible to prepare several options for cartographic visualization, having received a series of electronic and computer maps.

The most acceptable results at this stage of the research were shown by the regions classification and its visual presentation by using filled maps — a statistical method for cartographic images of average intensity of a particular indicator within individual territories.

Software tools of the used GIS software make it possible to classify mapped objects automatically in various ways: natural boundaries, equal intervals, quantiles, and standard deviations [10].

The method of equal intervals (equidistant) was recognized as the most optimal, using which all attribute values of the general range of the time series were divided into three or five equal-sized groups (sub-ranges) according to the value of the analyzed indicator (respectively: low, medium and high or low, below average, medium, above average and high).

The sequence of colors (from initial to final) in the scale of the legend of the resulting maps was determined by the order of the colors of the continuous spectrum (red, orange, yellow, green, blue, blue, violet) [10]. In order to improve visual perception to increase visibility and convenience while analyzing classification results, the colors of each class intervals value and color change scales (color bars) with a transition from dark green (high level), through yellow (medium) to dark red (low) have been applied.

As a result, a series of basic analytical and resulting maps was obtained. It reflects the essence and condition of various indicators, aspects and the actual changes in innovative activities, innovative potential and innovative development of agriculture in the regions of Russia over a number of years. Their variety shows the process of innovations diffusion in the agricultural sector of the country (Fig. 1, 2).

The results of geoinformation mapping were also presented as a series of animated maps and cartographic animations reflecting the territorial distribution of innovations through their diffusion.

Spatial geoinformation-cartographic analysis of geographical distribution of the innovations used in agricultural production in Russia as well as the direction of their diffusion processes performed by GIS tools reveals a number of objective patterns of their distribution.

The main one is that there is a movement of innovations in the country's agriculture in the space-time continuum in the direction from innovative nuclei and sub-nuclei to innovative sub-periphery and periphery. Geographically, this is primarily in the direction from the largest cities that are also the leading scientific and technical centers (St. Petersburg, Moscow, Kazan, Ufa, Yekaterinburg, Saratov, Barnaul, Novosibirsk, etc.), as well as areas of intensive agriculture (Leningrad, Moscow, Voronezh, Rostov regions, Krasnodar region, the Republic of Tatarstan and the Republic of Bashkortostan) mainly towards the eastern and northern regions of the European part of Russia, Siberia and the Far East.

Thus, the results of this study (as well as the analysis of relevant scientific publications) prove full compliance of the general level of region's innovative development with the degree of innovations development in its agriculture. Highly efficient agriculture in the Moscow region, Krasnodar region, the Republic of Tatarstan and the number of other regions of the country is largely determined by the appropriate level of their innovative development.

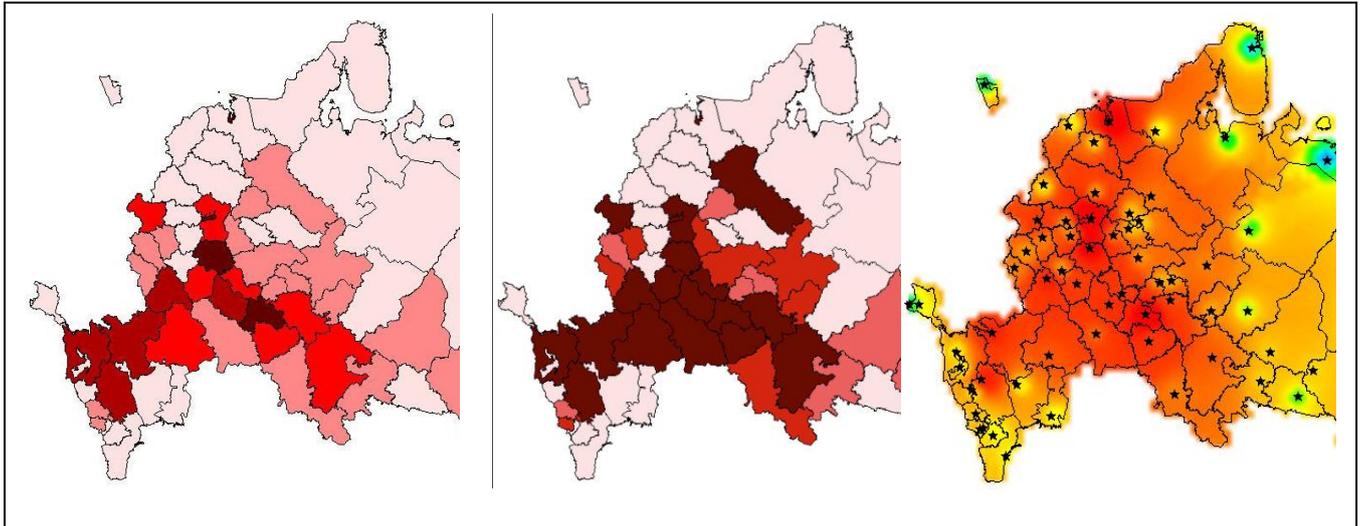


Fig. 1. An example of various map tile design showing the number of citations in the field of agricultural production by regions of the Russian Federation

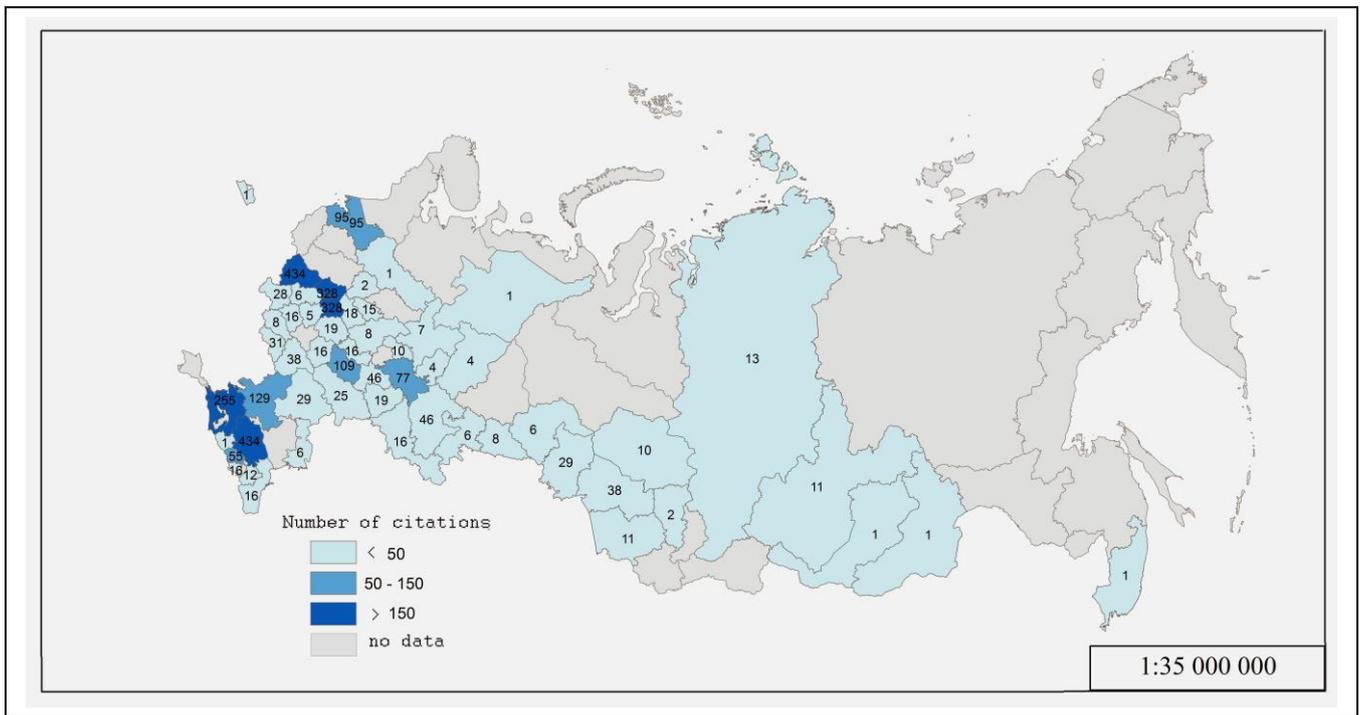


Fig. 2. An example of various map tile design showing the number of citations in the field of agricultural production by regions of the Russian Federation

IV. CONCLUSION

The use of geographic information mapping methods allowed us to perform the study that resulted in:

- formation of cartographic and attributive database of the main indicators of Russia's regions innovative development;
- construction and analysis of varying degrees of complexity of geoinformation-cartographic models of local agriculture innovation systems at the regional level, as well as the processes of innovations diffusion taking place there.

Geoinformation-cartographic models are the basis for the development of a socio-economic forecast for the

innovative development of regional agricultural systems and various options for their functioning and future development [11]. On their basis, work is underway to create an electronic GIS atlas “Innovative Development of Russian Regions”.

ACKNOWLEDGMENT

Implemented with the support of the Russian Foundation for Basic Research (project No. 19-05-00066 “Spatial-temporal patterns of innovative development of agriculture in the regions of Russia”).

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