Geoinformation Modeling of Knowledge Spillovers as an Innovative Development and Agricultural Efficiency Factor

Nosonov, A.,[1] Letkina, N.[2] and Nosonova, V.[3]
[1]National Research Mordovia State University, Department of Physical and Socio-Economic Geography, Russia, E-mail: artno@mail.ru
[2]Department of English for Professional Communication, Faculty of economics, Department of Public and Municipal Administration, Russia, E-mail: letkinanv@mail.ru
[3]Saransk, Russia, E-mail: vartno@mail.ru

Abstract
The article is devoted to the study of spatial regularity of knowledge spillovers in agriculture as an innovative development factor based on the use of geoinformation modeling methods. The spatial localization of patents development in the agricultural sector and the main regions of their citations have been analyzed which characterizes the secondary effects of knowledge dissemination. It was found that references to agricultural patents at the initial stage in most cases coincide with the areas of new knowledge generation. During the subsequent period this narrow localization of citations disappears and their distribution area expands significantly. The use of GIS technologies and geoinformation modeling allowed us to visualize the process of knowledge spillovers in the agricultural sector and to reveal the spatio-temporal patterns of agricultural innovative knowledge dissemination in various regions of Russia. The influence of knowledge spillovers in agriculture on the efficiency of agricultural production has been analyzed for the first time. We have discovered the dependence of patent activity in agriculture on the general level of regions innovative development. A typology of Russian regions on innovative functions based on the ratio of registered and used patents in agriculture was carried out. In accordance with this three types of regions have been distinguished – creative, acceptor-creative and acceptor. Within the identified types of regions, differences in the efficiency of agriculture were revealed that testify their close dependence both on the ratio of creative and acceptor functions and on the general level of regions innovative development.

1. Introduction

The current stage of society development is characterized by the formation of an economy based on knowledge, skills and technology as a result the high level of economic development of the world leading countries is largely determined by the effective integration of science, education and business. Currently, successful development of any country is determined by the level and the degree of use of the results of scientific activities implemented on the market in new equipment and technologies i.e. the commercialization of the innovation results (Baburin and Zemtsov, 2017 and Zamyatina et al., 2020). The production and new knowledge spillovers, the results of scientific research from a social resource turn into an element of market relations, into the mechanism of the country's competitive struggle for leadership in the field of innovative development. In this sense, science is realized as part of the economy innovative component (Makar and Nosonov, 2017).

In Russia at the present stage of development agriculture is aimed at a more efficient use of the territory natural agricultural potential, socio-economic factors, institutional conditions which can be achieved only on the basis of innovative development. Reserves of extensive agricultural growth were depleted in the late 1950s. Subsequently the entire increase in agricultural production was achieved only through intensification which is based on the use of new equipment and technologies, genetics development, breeding and genetic engineering, the expansion of melioration and farmland chemicalization, organizational and managerial innovations, and the improvement of human potential in the agricultural sector. Nowadays the threat of ensuring food security of the country has increased as a result of changes in the main areas of foreign economic trade policy in the field of agro-food products under the sanctions of a number of countries supplying agricultural products and agricultural machinery products. This generates a need for adjustments to the national agricultural policies in the direction of expanding their own food production on an innovative basis. State and private financing can provide food import substitution aimed at increasing and qualitative improvement of means of production and equipment, at developing the production and social infrastructure and human resource development. The implementation of the Food Import Substitution Federal Program over the past four years has significantly improved country's food security which was critical in a number of areas. At the present moment, Russia has fully ensured its food security for most types of food which is no less important than military-strategic or economic stability. From 2013 to 2018 the ratio of imports and exports of food products and agricultural raw materials has significantly changed. Over this period, food exports increased from $16 billion in 2013 to $25 billion in 2018, the import rate of these products decreased from $43 billion in 2013 to $30 billion in 2018 (Regions of Russia, 2018).

The study of agricultural innovation development trends based on the research of innovation diffusion as well as including the analysis of intra-industry knowledge spillovers is an understudied problem, the significance of which increases significantly in the conditions of mobile and dynamic exchange of scientific, technical and technological information between regions and countries.

2. **Methodology**

2.1 Literature Review

At present, there is a tendency to increase the number of scientific studies devoted to identifying and studying the factors of countries and regions innovative development which is considered to be the main source of their economic growth. Knowledge and its dissemination in time and space, i.e., knowledge spillovers take an important place among these factors. The knowledge spillovers is understood as the process of transferring knowledge created in one company or research center to another company free of charge or with little compensation, much less than the cost of knowledge itself (Zamyatina et al., 2020 and Romer, 2015). According to Japanese scientists the transformation of knowledge is a process of interaction between individuals in the course of which there is a conversion of implicit knowledge into explicit and vice versa (Figure 1) (Nonaka and Takeuchi, 1995). Implicit knowledge is the most significant for innovation. This is informal knowledge which represents individual knowledge, skills and professional experience and can only be transmitted verbally through personal contacts in a very limited epistemological community, for example, the transfer of knowledge from a teacher to a student. Explicit (codified) knowledge is a formalized and systematized knowledge that is easily transmitted by using paper and electronic media in the form of books, scientific articles, formulas, etc.

Innovations arise in the process of transforming different types of knowledge. The following stages of knowledge transformation are distinguished as a result of their transfer (Nonaka and Takeuchi, 1995 and Fischer, 2001):

1. from implicit to explicit knowledge (externalization). This is the process of creating new conceptual models by codifying implicit knowledge.
2. from explicit knowledge to implicit (internalization). This is a first-hand training based on formal instructions.
3. from implicit to implicit knowledge (socialization).
4. from explicit to explicit knowledge (combinations). This is a systematic approach to the creation of new knowledge on the basis of heterogeneous types of codified knowledge, which is used in training new employees, as well as during monitoring visits and instructions.

There are several approaches to the analysis of knowledge spillovers (Feldman, 1999):

Modified Production Function of Knowledge: taking into account the territorial scope and characteristics of the created innovations (Griliches, 1992 and Jaffe, 1989).

$$I_{si} = IRD_{si} * UR_{si} * \varepsilon_{si}$$

Equation 1

	into implicit knowledge	**into explicit knowledge**
from implicit knowledge	socialization (knowledge exchange)	externalization (codification of knowledge)
from explicit knowledge	internalization (training)	combination (data processing)

Figure 1: Four main transforming knowledge processes (Nonaka and Takeuchi, 1995)

where *I* - innovative return; *IRD* – private expenditures of corporations on research and technological development (RTD); *UR* – University RTD expenses.

Analysis of Patent Activity and Patents Citation: Some economists believe that it is impossible to trace the «paper traces» of knowledge spillovers (Krugman, 1991). However, Jaffe et al., (2000) have developed an approach that involves the analysis of patents with its references to other patents (i.e. patent citation), which is the basis for the analysis of both territorial and temporal aspects of knowledge spillovers (Jaffe et al., 1993 and 2000). The relationship between the patent's place of creation and the territories of its citation can be used to identify spatial knowledge spillovers. A spatial pattern has been revealed that the number of references to patents (as an expression of explicit (codified) knowledge) significantly decreases with increasing distance, which indicates the decisive role of spillovers of implicit knowledge.

The Intellectual Capital of the Region (Ideas Embodied In People): Many studies show that the main mechanism for disseminating knowledge at the local level is the transfer of scientists, engineers, and innovation managers both between companies and between firms and universities, research institutes and vice versa. Currently, the dissemination of knowledge is mainly due to personal contacts and the mobility of innovators. The main carriers of knowledge are people who are as a rule familiar, trust each other and share acquired knowledge. There is also an indirect transfer of knowledge through scientific articles and as a result of scientists views exchange the scientific conferences (Breschi and Lissoni, 2001).

Innovations implemented in goods and services and Related to International Trade (Ideas Embodied in Goods): This is manifested in international RTD spillovers and high technologies transfer. The dissemination of knowledge in this case is carried out through the patents sale, obtaining licenses for inventions and useful models, and the supply of high-tech equipment and technologies.

In this study we have used a methodology to analyze patent activity and citation of patents. We have also used the IDW interpolation method for the first time to visualize the process of knowledge spillover. That method is widely used in geo-information modeling of geographical objects, phenomena and processes due to its high efficiency. The effectiveness of the method in the spatial analysis of discrete processes and phenomena is especially high when the set of points with the initial spatial data is dense enough to reveal the degree of local change in the displayed surface. Considering that the IDW interpolation is used to study the following phenomena and processes:

- geo-ecological problems associated with the pollution of point objects (Matějíček et al., 2006, Anjusha et al., 2020 and Meng, 2020).
- designing of digital elevation models (Pellitero et al., 2016, Soleimamani and Modallaldoust, 2008).
- research of negative social phenomena (Ansari and Kale, 2014 and Achu and Rose, 2016).
- spatial analysis of emerging infectious diseases (Blanco et al., 2019, Samadzadeh et al., 2019 and Belief, 2018).
- analysis of climatic indicators (Earls and Dixon, 2007 and Wang et al., 2010).

Despite the widespread use of spatial interpolation methods in the study of natural, economic, social and environmental problems, their insufficient use for the analysis of innovative processes and phenomena should be eliminated. However, the possibilities of spatial interpolation methods, in particular IDW interpolation, can effectively solve such problems of innovative development of countries and regions as the study of innovations diffusion and the spillover of knowledge, identify factors stimulating innovation, conduct a typology of regions on innovative functions, etc. Similar studies are necessary for organizations and decision makers to justify managerial impacts on socio-economic systems in order to increase the efficiency of their functioning.

The results of spatial interpolation of knowledge spillovers are the basis for identifying the types of regions according to the ratio of creativity and acceptance. There are many approaches to highlight the level of regions creativity. According to Schumpeter (2003) the indicator of community creativity is the share of innovators (inventors, entrepreneurs) in it (Schumpeter, 2003). A classical approach is that proposed by Richard Florida which is based on the identification of employment areas. R. Florida unites people engaged in creative professions under the general term "creative class" or the class of creative professionals. These include scientists, engineers, architects, programmers, educators, and designers, representatives of the arts, entertainment, sports and mass media (Florida, 2002, 2005 and 2006). The creative class makes the maximum contribution to the GDP growth of developed countries (Florida, 2002). The greatest concentration of creative professionals is characteristic mainly in developed Western countries, as well as in the capitals and major cities of developing countries and countries with economies in transition. According to R. Florida (Florida, 2006) the creativity of the regions is determined by the share of the creative class concentration, inventive activity and the diversity of the local community. He developed a creativity index based on the concept of three "T": talent, technology and tolerance. An approach based on a modification of the methodology of Florida (2002) was used in the studies of Pilyasov and Kolesnikova (2008). The approach is based on the assumption that the more talented, technological, and tolerant a community is, the more creative it is. The indicators of creativity index are similar to those proposed by R. Florida (Florida, 2005); for those absent in Russian statistics, the equivalents are used: the share of employees with higher education, the number of researchers per 1 million inhabitants, the share of R&D expenses in GRP, the number of patents granted per million inhabitants and others. Common to these approaches is the determination of regions creativity by the concentration of the creative class in them, including innovators and inventors.

Baburin (2010) and Baburin and Zemtsov (2017) proposed two approaches for determining the level of creativity of regions. The first approach takes into account the dependence of the number of connections and innovations on the size of the urban population and the density of cities. The higher the density of cities and the urban population, the higher the innovative and creative potential of the region. The second approach is based on different creative and acceptor abilities of the community, depending on different ages in the demographic structure. Younger people (0-25 years old) most actively accept information. In the future, at the age of 25-50, they become the main reinventors and innovators supporting and disseminating social and technological inventions. In their 50s people become a conservative element of society, giving it stability. Based on a generalization of these two approaches, all regions of the country can be attributed to the regions that create new technologies (creative «donors») and the regions that consume technologies («acceptors»). To assess the first factor, an indicator of the number of patents per 100 thousand urban residents is used, as a second indicator - ratio of the share of embedded patents to created ones. In accordance with this, Baburin (2010) identified the following types of regions in terms of creativity: creative (using inventions much less than they are created); sub-creative (using inventions less than they produce; with a higher average density of innovations); acceptor-creative (with a higher average generation of innovations, but with a high share of inventions used, exceeding 100%); strong acceptors (with a relatively low generation of innovations, but with a very high share of inventions used, exceeding 100%); weak acceptors (with low generation of innovations and with the share of used inventions above the average level, but less than 100%); innovation periphery (with extremely low rates) (Baburin, 2010).

2.2 Methodology and Research Methods

GIS technologies are not sufficiently used in the study of spatial knowledge spillovers which allow you to visually display the distribution of knowledge in the form of patent citations across the territory. Currently, two main approaches are applied to the integration of geographic information technologies and models of socio-economic (including innovative) processes in order to create a spatially distributed modeling system (Kapralov et al., 2008, Lurie, 2008 and Teslenok et al., 2014). The first one uses the GIS package software as an additional block of the computer model of the process providing the formation of input data arrays and the presentation of simulation results performed by traditional methods (Manju et al., 2019). The second approach involves full integration of GIS and a process profile model implemented by the capabilities of the GIS software package.

The source of information for the study of knowledge spillovers in agriculture was the bibliometric data on the number of patents and their citations for agriculture, which are contained in the databases of the Scientific Electronic Library eLIBRARY.RU for 2010-2019. (12,670 patents and 51248 citations) (Scientific electronic library, 2019). Design work on the possible options and the development of their database structure based on GIS ArcView GIS by ESRI, Inc. has been carried out and it became the basis for geoinformational modeling and mapping. Based on the nature of the initial statistical data the number, general list, names and attribute tables field parameters of the designed GIS have been determined.

After creating the corresponding new project in the GIS ArcView the themes (layers) outlined at the design stage have been formed, the project and its layers have been configured, the fields with previously defined parameters have been formed in the attribute tables of the respective topics. The source data for inclusion in the GIS database are presented in Excel format (*.xls). Preliminary, the files (books) with data in the context of the territorial entities of the Russian Federation had been created in Microsoft Excel for each of the analyzed indicators. Then, the active sheets of all books were saved in *.dbf (DBF 4 (dBASE IV)) format in order to provide the possibility of further work with them in ArcView GIS since the shapefile attributes are stored in this format.

The classification of Russia territorial entities by the number of patents granted and their citations and visual presentation of the results in the form of cartograms were performed using the GIS legend editor ArcView GIS and the type of legend «color scale», when changing the values of the attribute data of the theme objects is represented by the range of the spectrum of one color scale with the initial and final colors.

By default, the capabilities of the base GIS ArcView GIS allow automatic classification of mapped objects using the «color scale» legend type in four ways (natural boundaries, equal intervals, fractiles, standard deviations) according to a numerical attribute – a field with an analyzed indicator.

The method (type of classification) of natural boundaries (intervals) is used by default in ArcView GIS. It defines the boundary points between classes (the so-called breakpoints) using the statistical Jenk’s optimization formula. The method is based on minimizing the sum of values deviations within each class which allows to group data close in values. Classification by the method of equal intervals (equidistant) divides the general range of attribute values into equal-sized subranges on which theme objects are then distributed. The method of quantiles (uniform, equal) allows you to include the same number of objects in each class and is most suitable for linearly increasing data that does not have a disproportionate number of objects with the same values. In the above mentioned classification methods the possible sequence of colors of the legend scale from initial to final when constructing it is determined by the order of the colors in the continuous spectrum (red, orange, yellow, green, blue, blue, violet). In this study the method of equal intervals (equal to intermediate) turned out to be optimal using which all values were divided into three equal-sized groups in accordance with the value of the analyzed indicator: high, medium and low.

In the future for better visual perception, greater visibility and ease of use when analyzing the results of classification also using the legend editor, the colors of the intervals of values of each class can be selected and a color ruler (color change scale) with a transition from dark colors of one gamma corresponding to high the level of the indicator to light, indicating a low level of the parameter. Given the potential need for further frequent use, the legends obtained can be saved in the corresponding files (*.avl). To study the main directions of spatial spillovers of agricultural knowledge, the interpolation method between the centers for creating patents and the regions of their citation was applied. For these purposes the Inverse Distance Weighted Interpolation (IDWI) method was used based on the weighting of points in such a way that the influence of a known value decays with increasing distance to an unknown point, the parameters of which must be determined. Weighing is assigned by the source centers with a different number of patents using a weighting coefficient that estimates how the influence of the parameter will decrease with increasing distance to it. The higher the value of the weighting coefficient the less will be the effect exerted by the point. As the coefficient increases the value of the unknown point will approach the value of the nearest point with a known value.

To study the main directions of spatial flows of agricultural knowledge, we have applied the interpolation method between the centers for creating patents and the regions of their citation. For these purposes we have usedthe inverse-distance weighting (IDW) method. This method is based on the weighting of points in such a way that the influence of a known value decays with increasing distance to an unknown point, the parameters of which must be determined. Weighing is assigned by the source centers with a different number of patents using the weighting coefficient, which estimates how the influence of the parameter will decrease with increasing distance to it. The higher the value of the weighting coefficient, the less will be the effect exerted by the point. As the coefficient increases, the value of the unknown point will approach the value of the nearest point with a known value. IDW interpolation is used when the mapping phenomenon (process) is characterized by localization at individual points and their quantitative characteristics naturally decrease when moving from the center to the periphery. The phenomenon being mapped (knowledge spillovers) fully complies with these requirements.

ESRI ArcVIEW defaults to 12 interpolation methods: Inverse Distance to a Power; Kriging Minimum Curvature; Modified Shepard’s Method; Natural Neighbor; Nearest Neighbor; Polynomial Regression; Radial Basis Function; Triangulation with Linear Interpolation; Moving Average; Data metrics, Local Polynomial. During the research all 12 interpolation methods were tested. The specificity of the spatial data used and the analysis of the results obtained made it possible to select the most optimal method, Inverse Distance to a Power, using the expert evaluation method.

At the final stage of the study a typology of the regions of Russia on their creative and acceptor functions was carried out, based on the ratio of issued and used patents for inventions and useful models in the agricultural sector which reflects innovative functions of country's regions. When performing this typology we have used the methodology proposed by Baburin (2010) which was modified and adapted as applied to agriculture. The main classification feature is the number of patents and their citations, as well as the ratio of invented and used patents. The following indicators were used as additional indicators: the general level of region's innovative development, the ratio of developed and used production technologies, internal costs of scientific research and development in agricultural sciences, the graduation of bachelors and masters of agricultural specialties, number of personnel engaged in agricultural research and development (including those with a PhD degree), etc. In accordance with this three groups of regions are distinguished: *creative*, in which much less inventions are used than are created; *acceptor*, which are characterized by low generation of innovations and a high proportion of inventions and utility models used; *acceptor-creative*, occupying an intermediate position. A separate group consists of regions in which all indicators of innovative development are extremely low - *the innovation periphery*. Within the selected types a comparative analysis of the main indicators of agricultural efficiency was carried out to identify the impact on these parameters of patent activity and knowledge spillovers in the agricultural production system.

3. Results and Discussion

Modern agriculture is an extremely complex and poorly structured system therefore when studying the knowledge spillovers in this field it is necessary to apply scientific approaches and methods that take into account the following characteristics of that material production sphere:

– a significant impact on agriculture of natural conditions and territory resources and the presence of natural cyclicality;
– a longer period of using fixed assets compared to industry;
– the existence of long-term agrarian crises and a significant period of rehabilitation;
– significant dependence on organizational and production innovations (systems evolution of land use, degree of mechanization of production processes, reclaimed land area, mineral and organic fertilizer application, spillovers of technical, technological, organizational and managerial knowledge through diffusion of innovations, etc.);
– widespread of organizational and managerial innovations in the agro-industrial complex – foundation of agricultural holdings and other vertically oriented management structures. This type of innovation due to the high territorial concentration of labor, capital and cooperation is the focus of a wide range of innovations - technical, technological, marketing, social, etc. Promising innovations that are at the research and development stage are being tested in agricultural holdings: agricultural robots; closed ecological systems; genetically modified food; vertical farms. A special place in modern agrarian innovations is occupied by precision farming technology, which takes into account the peculiarities of the topsoil, microclimate and topography within the boundaries of individual fields. To determine and evaluate these local differences, high-tech methods are used – GLONASS global positioning, geo-information systems and technologies for remote sensing of the Earth, information technologies of agro-management, methods of technological standardization, etc.

In agriculture, increased costs on IRD and improving knowledge dissemination mechanisms are gaining great importance. An analysis of patent activity shows that four main centers have been formed in Russia with the largest number of created patents for inventions and utility models: Moscow and the Moscow Region, St. Petersburg, the North Caucasus and Chernozemye and the Middle Volga Region (Figure 2). This circumstance is due to the fact that a large number of both research institutes and agricultural centers, and agricultural higher education institutions is concentrated in these regions. Also in these constituent entities of the Federation work the most qualified specialists in the agricultural sector and there are opportunities (machinery and equipment) for doing research work in the high-tech spheres of the agricultural sector – genetics, breeding, agrobiotechnology, genetic engineering, and the production of nano- and composite materials.

The number of agricultural patents citations is geographically limited (Figure 3). Their largest number falls on the following regions of Russia: Moscow and Moscow Region (8784 citations), Ulyanovsk Region (5599), Ryazan Region (4796), St. Petersburg and Leningrad Region (4344), Krasnodar Territory (2917) and Stavropol Territory (2444). An analysis of the actual knowledge spillovers in agriculture (Figure 3) indicates their very limited localization within the main centers for generating agricultural innovations.

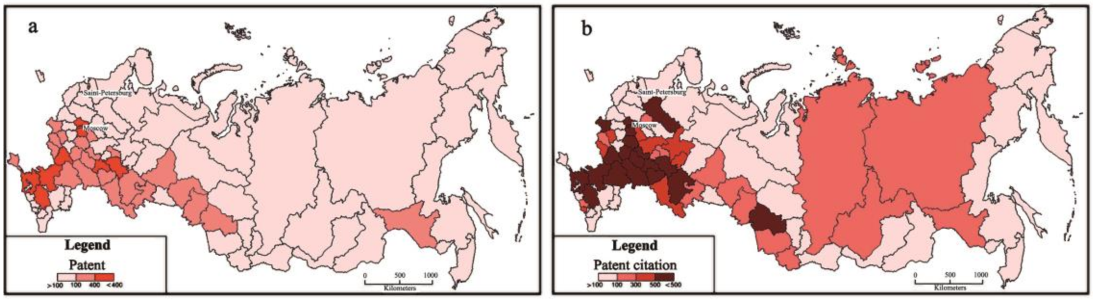

Figure 2: The number of patents in agriculture (a) and the number of patents citations in agriculture (b) registered in the Scientific Electronic Library in 2010-2019, units. *Compiled by* (Scientific electronic library, 2019)

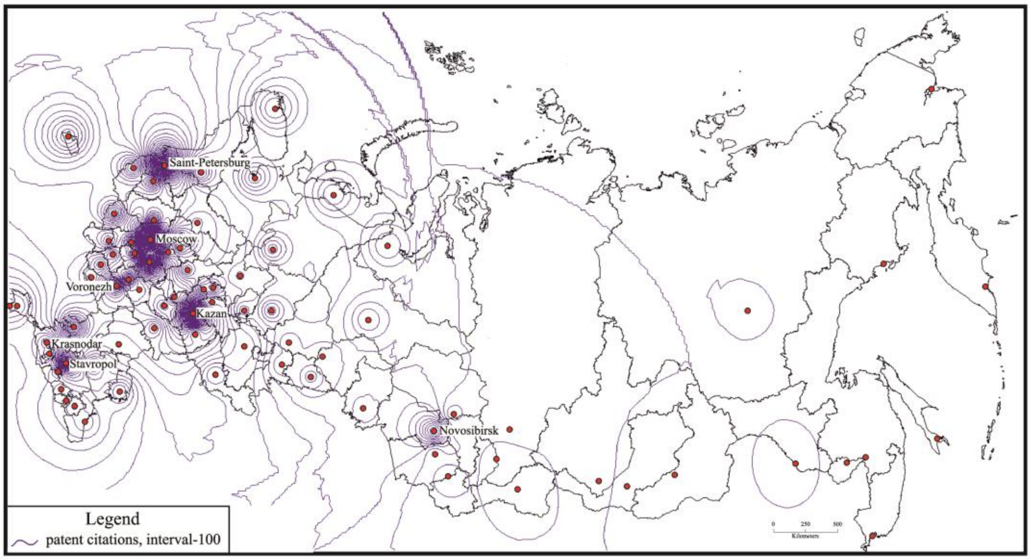

Figure 3: The interpolation by the inverse distance wights method of patents number in agriculture and their citations («knowledge spillovers»). *Compiled by* (Scientific electronic library, 2019)

Figure 4: Types of agricultural regions in terms of creativity: 1 -creative; 2 – acceptor-creative; 3 – acceptor. *Compiled by* the authors

There are only two large areas of knowledge spillovers – within Moscow and the Moscow region ,and in the North Caucasus within the Stavropol and Krasnodar territories. Less significant areas of knowledge flow in agriculture were also formed around St. Petersburg, Kazan, Penza, Ulyanovsk, Voronezh, Omsk and Novosibirsk.

On the territory of the Russian Federation, three types of regions are distinguished according to the ratio of creative and acceptor innovative functions of agriculture: creative, acceptor-creative and acceptor (Figure 4). The boundaries between the distinguished types generally correspond to gradations in the number of registered patents in agriculture, and are also well manifested on the map of knowledge spillovers (Figure 3). In nine regions of the creative type, 55% of patents were created in the field of agriculture from the all-Russian level and the proportion of their citations is 57%. This is more than in the remaining 74 regions of the country. The citation rates for patents are also high: from 2.9 citations per patent in acceptor regions to 4.2 in creative ones. Creative-type regions were formed under the influence of the following factors: firstly, high scientific and technical capacity and the availability of appropriate infrastructure for agricultural research (Moscow and Moscow Region, St. Petersburg); secondly, the high natural agricultural potential of the territory and a good supply of labor resources (North Caucasus and the Middle Volga region). In nine creative regions more than 80% of all agricultural research institutes and about 70% of higher education institutions conducting agricultural research the country are concentrated. Acceptor-creative regions are located within the main agriculturally developed territory of European Russia and are the main consumers of agricultural innovations generated in creative regions. Regions of an acceptor-type and innovative periphery occupy territories with low natural resource potential, insignificant labor supply and dominance in the sectoral structure of industrial production and services.

One of the study objectives was to analyze the differences in the efficiency of agricultural production in different types of regions depending on the general level of innovative development and patent activity (Table 1). The following indicators were used as criteria for the economic efficiency of agriculture: the balanced financial result of agriculture (profit-loss) (USD), agricultural profitability (%) and the value of gross agricultural output per 1000 ha of agricultural land (USD/ha). A regular decrease in the efficiency of agriculture during the transition from creative to acceptor regions was revealed.

4. Conclusion

Based on the results of the study we can draw the following conclusions.

1. The knowledge spillovers (especially explicit) in agriculture has not yet become a decisive factor in the industry innovative development. In the future this will be facilitated by the development of information technologies (the availability of computers and mobile devices, access to the Internet, the expansion of a range of electronic services provided, including social ones). Thus, specialists of the agricultural sector have increased opportunities for improving their level of qualification which is the basis for the quality growth of human potential as an important factor in innovative development.

Table 1: Key indicators by region type

Main characteristics	Types of regions		
	creative	**creative acceptor**	**acceptor**
Regional Innovation Index (by HSE rating)	**0,438**	**0,355**	**0,306**
The number of patents for inventions and utility models, units, total on average per region	 6922 769	 4426 192	 1322 26
The number of citations of patents for inventions and utility models, units total on average per region	 29320 3257	 18065 785	 3863 77
Balanced financial result of agriculture, *million* USD*	2645	1598	496
Profitability of agriculture,%*	10.3	9.4	1.6
Agricultural products per 1000 ha of agricultural land, thousand USD / ha*	43,4	22,0	17,3
Crop yield, cwt / ha*	41,8	23,5	19,8
Number of regions in type	9	23	50

Compiled by (Regions of Russia, 2018, Scientific electronic library, 2019, Abdrakhmanova et al., 2017) * average type

2. The highest patent activity in the agrarian sector is observed in the regions with developed and efficient agriculture (the North Caucasus and the Volga region) and in two «capitals» with adjacent areas – Moscow and St. Petersburg where a highly efficient agribusiness has been also formed.

3. Unlike the hierarchical mechanism of dissemination of innovation diffusion in most sectors of the economy, in agriculture this process has a more network nature. This is due to the lack of pronounced centers for the generation of agricultural innovations in the country and a significant territorial dispersal of their centers and regions.

4. The creation of various agricultural innovations is significantly affected by environmental conditions which determine the different nature of innovations (crop or livestock). The generation of high-tech innovations (in the field of genetics, breeding, genetic engineering, etc.) related to the fourth technological mode is concentrated in large innovation centers at the national level.

5. Large territorial entities in the agro-industrial complex (agricultural holdings) provide a real technological breakthrough by continuous updating of the material-and-technical part of agriculture and introducing innovations: high-tech information systems for agricultural management, advanced soil cultivation technologies, efficient use of mineral fertilizers and pesticides, information technologies for production management and GIS technology applications.

6. The obtained results show a significant impact on the agriculture innovative development of patent activity and the general level of regions innovative development which are currently the main factor in increasing the efficiency of agricultural production and increasing the production of food resources.

Acknowledgment
The study was carried out with support from the Russian Foundation for Basic Research within the research project № 19-05-00066.

References

Abdrakhmanova, G., Bakhtin, P., Gokhberg, L., Ditkovskiy, K., Islankina, E., Kindras, A., Kovaleva, G., Kovaleva, N., Vera, K., Kuznetsova, I., Kuzmin, G., Kuzminov, I., Kutsenko, E., Martynov, D., Martynova, S., Nechaeva, E., Ratay, T., Sagieva, G., Streltsova, E., Timofeev, A., Tochilina, E., Fridlyanova, S. and Fursov, K., 2017, Russian Regional Innovation Scoreboard/L. Gokhberg (ed.); National Research University Higher School of Economics. Issue 5, Moscow: HSE, 260.

Achu A. L., Rose, R. S., 2016, GIS Analysis of Crime Incidence and Spatial Variation in Thiruvananthapuram City, *International Journal of Remote Sensing Applications*, Vol. 6, 1-7.

Anjusha, K. V., James, A. M., Thankachan, F. A., Benny, J. and Hezakiel, V. B., 2020, Assessment of Water Pollution Using GIS: A Case Study in Periyar River at Eloor Region. *Green Buildings and Sustainable Engineering*. 413-420.

Ansari S. M. and Kale K. V., 2014, Mapping and Analysis of Crime in Aurangabad City Using GIS. *IOSR Journal of Computer Engineering*. Vol. 16(4), 67-76, DOI:10.9790/0661-16476776.

Baburin, V. L. and Zemtsov, S. P., 2017, Innovative Potential 0f Russian Regions. *Moscow: KDU*, 358.

Baburin, V. L., 2010, Innovation Cycles in the Russian Economy. *Moscow: KRASAND*, 216.

Belief, E., 2018, GIS Based Spatial Modeling to Mapping and Estimation Relative Risk of Different Diseases Using Inverse Distance Weighting (IDW) Interpolation Algorithm and Evidential Belief Function (EBF)(Case study: Minor Part of Kirkuk City, Iraq). *International Journal of Engineering & Technology*, Vol. 7(4.37), 185-191.

Blanco, I., Diego, I., Bueno, P., Fernández, E., Casas-Maldonado, F., Esquinas, C. and Miravitlles, M., 2019, Geographic Distribution of Chronic Obstructive Pulmonary Disease Prevalence in Africa, Asia and Australasia. *The International Journal of Tuberculosis and Lung Disease*, Vol. 23(10), 1100-1106.

Breschi, S. and Lissoni, F., 2001, Knowledge Spillovers and Local Innovation Systems: A Critical Survey, *Industrial and Corporate Change*. Vol. 10(4), 975-1005.

Earls, J. and Dixon, B., 2007, Spatial Interpolation of Rainfall Data Using ArcGIS: A Comparative Study. In *Proceedings of the 27th Annual ESRI International User Conference*. Vol. 31. 1-9.

Feldman, M. P., 1999, The New Economics of Innovation, Spillovers and Agglomeration: Areview of Empirical Studies. *Economics of Innovation and New Technology*. Vol. 8(1–2), 5-25.

Fischer M. M., 2001, Innovation, Knowledge Creation and Systems of Innovation. *The Annals of Regional Science*. Vol. 35(2), 199-216.

Florida, R., 2002, The Rise of the Creative Class: And How It's Transforming Work, Leisure, Community and Everyday Life. *Canadian Public Policy*, Vol. 29(3) 1-10.

Florida, R., 2005, Cities and the Creative Class. *City & Community*, Vol. 2(1), 3-19.

Florida, R., 2006, The Flight of the Creative Class: The New Global Competition for Talent. *Liberal Education*, Vol. 92(3), 22-29.

Griliches, Z., 1992, The Search for R&D Spillovers. *Scandinavian Journal of Economics*. Vol. 94, 29-47.

Jaffe, A. B., Trajtenberg, M. and Fogarty M. S., 2000, Knowledge Spillovers and Patent Citations: Evidence from a Survey of Inventors. *American Economic Review*. Vol. 90, 215-218. DOI: 10.1257/aer.90.2.215.

Jaffe, A., 1989, The Real Effects of Academic Research. *American Economic Review*. Vol. 82(1), 363-67.

Jaffe, A., Trajtenberg, M. and Henderson, R., 1993, Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations. *Journal of Economics*. Vol. 63, 577-98.

Kapralov, E. G., Koshkarev, A.V. and Tikunov, V. S., 2008, Geoinformatics / Ed. by V. S. Tikunov. M.: Academy, 384 .

Krugman, P., 1991, *Geography and Trade. Cambridge*, MA: MIT Press, 85.

Lurie, I. K., 2008, *GIS Mapping. Methods of Geoinformatics and Digital Processing of Satellite Images*. Moscow: KDU, 424.

Makar, S. V. and Nosonov, A. M., 2017, Assessment and Spatial Regularities of the Innovative Activity Development in the Regions of Russia. *Economics, Taxes & law*, Vol. 10(4), 96-106.

Manju, K. P., Soraganvi, V. S. and Lingadevaru, D. C., 2019, Use of RS and GIS for Land Use/Land Cover of Historical Badami Town, Bagalkot District, India. *International Journal of Innovative Technology and Exploring Engineering (IJITEE)*, Vol. 8(11) , 2936-2938.

Matějíček, L., Engst, P. and Jaňour, Z., 2006, A GIS-Based Approach to Spatio-Temporal Analysis of Environmental Pollution in Urban Areas: A Case Study of Prague's Environment Extended by LIDAR Data. *Ecological Modelling*, Vol. 199(3), 261-277.

Meng, Y., 2020, Spatial Distribution Patterns of Chosen Chemical Elements with Different Spatial Scales in London Topsoils and Lake Taihu Sediments. *Taihu Sediments (Doctoral Dissertation, NUI Galway*. 133.

Nonaka, I. and Takeuchi, H., 1995, The Knowledge-Creating Company. How Japanese Companies Create the Dynamics of Innovation. New York, Oxford. Oxford University Press, 46-49.

Pellitero, R., Rea, B. R., Spagnolo, M., Bakke, J., Ivy-Ochs, S., Frew, C. R. and Renssen, H., 2016, GlaRe, a GIS Tool to Reconstruct the 3D Surface of Palaeoglaciers. *Computers & Geosciences*, Vol. 94, 77-85.

Pilyasov, A. N. and Kolesnikova, O. V., 2008, Evaluation of Creativity of the Russian Regional Communities, *Economic Issues*, Vol. 9, 50-69.

Regions of Russia, 2018, Socio-Economic Indexes: Stat. Digest, Moscow, 1162.

Romer, P. M., 2015, Mathiness in the Theory of Economic Growth, *American Economic Review*. Vol. 105(5), 89-93.

Samadzade, R., Habibzadeh, S., Mohammadshahi, J., Shokrollahi, M. and Moradi-Asl, E., 2019, Spatial Epidemiology of tuberculosis in Ardabil Province: Based on Geographical Information System, *Pakistan Journal of Medical and Health Sciences*, Vol. 13(3), 965-969.

Schumpeter, J., 2003, *Capitalism, Socialism and Democracy*. London & New York: Taylor & Francis e-Library, 460.

Scientific electronic library eLIBRARY.RU. 2019. Available: https://elibrary.ru/

Soleimamani, K. and Modallaldoust, S., 2008, Production of Optimized DEM Using IDW Interpolation Method (Case Study; Jam And Riz Basin-Assaloyeh). *Journal of Applied Sciences*, Vol. 8(1), 104-111.

Teslenok, S. A., Nosonov, A. M. and Teslenok, K. S., 2014, Geoinformation Modeling of the Diffusion of Innovations. *InterCarto/Intergis-20: Sustainable Development of Territories: Cartographic and Geoinformation Support*. Moscow, 159-169.

Zamyatina, N., Poturaeva, A., Pelyasov, A. and Goncharov, R., 2020, The Sandwich of Russian Space: How Different Spaces Differentiate Themes in Regional Science. *Regional Science Policy & Practice*. Vol. 12(4), 559-577.

Wang, X., Lv, J., Wei, C. and Xie, D., 2010, Modeling Spatial Pattern of Precipitation with GIS and Multivariate Geostatistical Methods in Chongqing Tobacco Planting Region, China. *International Conference on Computer and Computing Technologies in Agriculture*. Springer, Berlin, Heidelberg. 512-524.