Mathematical tutorial for building a regional cluster in the field of vegetable growing

A V Medvedev 1, L N Medvedeva 1,2, O Roiss 3 and Y G Onoprienko 1,4

1 All-Russian Research Institute of Irrigated Agriculture, 9 Timirjazeva St, Volgograd, 400002, Russian Federation
2 Volzhsky Polytechnic Institute (branch) of Federal State Budget Educational Institution of Higher Education Volgograd State Technical University, Volgograd, Russian Federation
3 GEO Roehren-und Pumpenwerk BAUER GmbH, Kowaldstrabe 2, A-8570 Voitsberg, Austria
4 Volgograd State Technical University, 28 Lenina Avenue, Volgograd, 400005, Russian Federation

E-mail: milena.medvedeva2012@yandex.ru

Abstract. The purpose of the research was the studying of development prospects of agro-industrial cluster in vegetable growing on the South of Russia, based on systematic approach. Statistical information in the area of public administration of agriculture, entrepreneurship development and vegetable growing, was used for analysis. The structure of sown areas was considered and the results of the gross harvest of agricultural products at the regional level were presented; a brief overview of the most significant enterprises, producing and processing vegetables was provided; the factors were shown and the tutorial of the formation of an agro-industrial cluster in vegetable growing was calculated. With the help of the methods of economical and mathematical modeling, the agro-industrial cluster tutorial for the South of Russia was developed. It was shown, that for the effective socio-economic development of the country, it is necessary to form clusters, use the mechanism of public-private partnership and support innovative agricultural entrepreneurship in the field of irrigated agriculture.

1. Introduction
The researches, which conducted in various countries in socio-economical systems are showing, that one of the promising forms of organizing entrepreneurial activity is the organization of regional clusters [1]. It should be noted that in most cases the cluster is considered as a voluntary association of geographically neighboring economic entities (private sector and government regulation sector), the joint complementary activities of which in a certain area provide competitive positions in the industry market due to the synergistic effect. Cluster initiators most often are financial and infrastructural institutions, business entities and government bodies, taking into account the territories and markets “assigned” to them.

To identify the potential of clustering of a region in the agro-industrial sphere, it is advisable to carry out a multivariate analysis of the competitive stability of enterprises of the industry in full. During the implementation of a quantitative analysis of the competitive stability of the agro-cluster at the regional level, the following coefficients (specialization, localization, production intensity in dynamics) are calculated [2].
The creation of clusters in the region becomes possible, if as a result of calculations, the final values of the indicators are bigger or equal. The qualitative analysis is aimed at identifying a set of the conditions of competitive stability and the composition of the resource base of the agricultural complex, and here it is assessed: degree of accessibility to production factors, demand in the domestic market, the presence and degree of activity of supplier organizations (professional non-profit organizations, scientifical research organizations, vocational education institutions), the degree of assistance from government agencies (preferences, subsidies, concessional lending). A quantitative and qualitative analysis of the factors, which is motivating the formation and development of a territorial cluster, involves an assessment of the strategic potential of the cluster [3].

The main evaluation criteria are most often statistical indicators, that make it possible to assess industry and cluster growth, and to determine the share of industry cluster products in the gross regional product. Consider the potential for the development of a regional cluster involving an assessment of the strategic potential of the cluster [3].

Investment projects are being implemented in the region for growing and processing vegetables into ecologically clean products; creation of new plots of irrigated land. In recent years, the volume of processing of agricultural products has almost quadrupled – from 70 thousand of tons to 315 thousand, and by 2021 it is planned to increase this figure to 500 thousand tons [5]. Effective growth of vegetable production is associated with the use of resource-saving technologies in a complex melioration system (drip irrigation, fertigation and integrated crop protection system), of high-yielding hybrids and varieties of a new generation. Such measures will allow to increase by 2024 not only the production of fruit and vegetable products by 34% (up to 1.2 million tons), but also to ensure export supplies of canned fruit and vegetables by 4.5 times (up to 50 thousand tons).
It is obvious that the Volgograd region has significant opportunities to strengthen the position of the agro-industrial complex through deep processing of agricultural products using innovative science-intensive technologies and the implementation of the principles of the cluster approach. The formation and development of the agricultural cluster should be carried out taking into account the geography of the region, the priority of the development of types of economic activity and state financial support in accordance with the legislation of the Russian Federation [6].

2. Results and Discussion
Agricultural companies, which are operating in the South of Russia have the opportunity to unite into an industry cluster in one or more types of activities through financial support from regional and federal structures.

A significant role in the formation of cluster education is assigned to universities and research institutes, such as the Volgograd State Agrarian University, FSBSI All-Russian Scientific Research Institute of Irrigated Agriculture, Federal Scientific Center of Agroecology of the Russian Academy of Sciences.

Executive authorities should of the regional cluster become important participants: committees for agriculture, industry and trade, economics and development of business structures, finance, land resources, as well as the Federal Statistics Service, insurance companies, banks and investment funds, logistics centers [7].

Their joint coordination of interactions, monitoring of industry enterprises that are significant for the region, control over the implementation of agro-technical solutions, and the provision of investment support will contribute to the intensive economical and innovative development of the region. In the future, it is advisable to form a larger integrated structure - the agri-food cluster (agro-cluster) of the South of Russia, which, first of all, will provide the domestic market with high-quality food products; secondly, it can become an important and effective tool for stimulating agricultural producers towards innovative development, as well as stimulating the socio-economic development of rural areas [8].

Ultimately, the formation and development of the agro-cluster in the future will contribute to the growth of regional capital, improve the well-being of the population, turn the agro-industrial complex into an environmentally friendly, economically efficient and competitive sector with a specialization in the field of vegetable growing. Regional cluster diagram in Figure 1.

![Figure 1](image-url)  
Figure 1. Scheme of an agro-industrial cluster for processing vegetables in the region.

The tutorial of the mathematical model of the agrocluster in the form of a multi-parameter linear programming problem was built on the basis of taking into account the volume of investments, production, profitability and optimization of cash flows (income and expenses) of entrepreneurs [6].

A mathematical model was used to process the data in the form of a linear optimization problem; the discounted balance of financial flows was used as the main criterion for the efficiency of the cluster functioning. To construct a mathematical model of the agro-cluster, the following designations were used:
\[ y_k = \text{the volume of production by k-type of agricultural products on reclaimed land, thousand tons; } \\
 m_k = \text{the number of acquired fixed assets for the production of k-type agricultural products, units; } \\
 q_k = \text{forecast demand for products of the k-th type in value terms, rubles; } \\
 V_k = \text{design productivity of fixed assets in k-type; } \\
 T_k = \text{service life of k-type fixed assets, years; } \\
 P_k = \text{unit cost of k-type product, rubles; } \\
 T = \text{validity period, years; } \\
c_k = \text{the average annual cost of fixed assets of the k type of agricultural products, rubles} \\
\]

\[ x_k = c_k m_k \quad (k = 1, ..., n) \quad \text{– investments purchased in fixed production assets of the k-type, rubles;} \]

\[ x_{n+k} = P_k m_k y_k \quad (k = 1, ..., n) \quad \text{– proceeds from the sale of k-type products, rubles;} \]

\[ y_k = \frac{x_{n+k}}{P_k m_k} = \frac{c_k x_{n+k}}{P_k x_k} \quad (k = 1, ..., n) \quad \text{– output of k-type products, tons;} \]

\[ R = \sum_{k=1}^{n} P_k m_k y_k \quad (1) \]

\[ F = \beta R \quad (2) \]

\[ X = \text{total investments in the acquisition of fixed assets;} \]

\[ Am = \text{the amount of depreciation deductions for the entire planning period T for all types of fixed assets, rubles;} \]

\[ Am = T \sum_{k=1}^{n} c_k m_k \frac{T}{T_k} \]

\[ z = \text{total material costs, determined as a given percentage of the total costs of the agro-cluster, rubles;} \]

\[ \delta_k = \text{relative efficiency indicator for the k-type of fixed assets;} \]

\[ \gamma_k = \alpha_3 \frac{T}{T_k} - 1; \]

\[ \sigma_k = \alpha_3 \frac{T}{T_k} = \gamma_k + 1; \]

\[ \theta_k = T/T_k; \]

\[ \gamma = (1 - \alpha_2)(1 - \beta)(k = 1, ..., n). \]

The net profit (after tax) received by the entrepreneurs of the cluster is described by the following equation:

\[ W = (1 - \alpha_3)(R - (Am + F(1 + \alpha_4) + X + z)). \]

Where \( \alpha_3 \) – the rate of the single agricultural tax (UAT); 

\( \alpha_4 \) – the rate of deductions from the wage fund for compulsory insurance, or, taking into account the introduced designations,

\[ W = (1 - \alpha_3) \left[ - \sum_{k=1}^{n} \theta_k x_k + (1 - \beta) \sum_{k=1}^{n} x_{n+k} \right] \]

Own funds of the agri-food cluster can be represented as

\[ D_3 = Am + W \text{ or, taking into account the introduced designations:} \]

\[ D_3 = \sum_{k=1}^{n} \gamma_k x_k + \gamma \sum_{k=1}^{n} x_{n+k} \]

If the condition is satisfied that \( D_3 \geq 0 \), then the cluster is solvent. During constructing a mathematical model of an agrocluster, the following restrictions were introduced:

\[ 0 \leq P_k m_k y_k \leq q_k \quad \text{– the sales volume of products of the k-type does not exceed the demand for it;} \]

\[ 0 \leq y_k(t) \leq q_k, \quad \text{– the output of k-type products does not exceed the productivity of the OPF.} \]

The criterion for the efficiency of an agrocluster can be considered the net present value \( J \), which reflects the added value of the created integrated structure:

\[ J = -I + \frac{W + Am}{1+r} \]

(13)
where \( r \) – discount rate.

The proposed agri-food cluster will provide the population with quality products, become an important and effective tool for stimulating entrepreneurs in the agricultural sector [9]. One of the important areas of the agricultural cluster is the production of vegetables in greenhouses. In the Volgograd region there are 4 modern greenhouse complexes: LLC «Agrocomplex Volzhsky», LLC «Ovoshchevod», GUP VOSHP «Zarya», SEC «Teplichny». The «Botanica» project was implemented in 2014 and has become a well-known Russian brand. More than 20 billion rubles will be invested in the development of the greenhouse complex until 2021. In the future, the company plans to increase the area of greenhouses to 95 hectares, and the yield from 47,000 tons to 90,000 tons per year [10].

![Figure 2. Regional brand in the production of indoor vegetables “Botanica”.

3. Conclusion

The formation of clusters that ensure the development of socio-economic is possible in the field of agriculture, possibly taking into account the changing climate, natural conditions of the territories, the situation in the domestic and world markets, the availability of existing vegetable growing and processing farms that introduce innovative technologies, the integration of agricultural producers and scientific educational sector, as well as the functioning of the mechanism of state regulation and support.

Specialized regional clusters, for example, for the production and processing of vegetables, make it possible to implement strategic plans for the development of territories, provide the population with food with a short lag: the field is a counter, and most importantly, ensure the exchange of information between entrepreneurs and develop an innovative production culture.

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