



## Cluster models of households' agrarian production development

**Abstract.** The article is dedicated to economic substantiation of agricultural development with the use of artificial neural networks. The major goal of this research is to present new models for a regional clusterisation by means of an analysis of the general and specific natural and relative indicators of crop and animal production in Ukraine. The NXL Clusterizer Toolbox of MS Excel has been applied to conduct the calculations. The adequacy of the proposed approach has been illustrated by example of 3 clusters created for the households of Ukraine by regions using 8 main agricultural indicators as for 01.01.2015. The received profiles have defined clusters in order to support the foremost achievements, improve positive results and overcome negative tendencies of the agricultural production in the national households.

**Keywords:** Agriculture; Agribusiness; Family Farms; Households Development; Cluster Models; Artificial Neural Network; Grain Production; Crop and Animal Production

**JEL Classification:** C45; O13; Q12

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#### Кластерні моделі розвитку аграрного виробництва в господарствах населення

**Анотація.** Статтю присвячено обґрунтуванню економічного розвитку в сільському господарстві за допомогою штучних нейронних мереж. Головною метою дослідження була розробка моделей регіональної кластеризації засобами аналізу загальних та специфічних натуральних і відносних показників виробництва у рослинництві та тваринництві. Для проведення обчислень застосовано інструментарій NXL Clusterizer електронної таблиці MS Excel. Адекватність запропонованого підходу проілюстровано на прикладі створення трьох кластерів для господарств населення України. Одержані профілі дозволили визначити кластери підтримки передових досягнень, вдосконалення позитивних результатів та подолання негативних тенденцій аграрного виробництва у вітчизняних господарствах населення.

**Ключові слова:** сільське господарство; розвиток господарств населення; кластерні моделі; штучна нейронна мережа; рослинництво і тваринництво.

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#### Кластерные модели развития аграрного производства в хозяйствах населения

**Аннотация.** Статья посвящена обоснованию экономического развития в сельском хозяйстве с помощью искусственных нейронных сетей. Основной целью исследования была разработка новых моделей региональной кластеризации посредством анализа общих и специфических натуральных и относительных показателей производства в растениеводстве и животноводстве. Для проведения расчетов использован инструментарий NXL Clusterizer электронной таблицы MS Excel. Адекватность предложенного подхода проиллюстрирована на примере создания трех кластеров для хозяйств населения Украины. Полученные профили позволили определить кластеры поддержки передовых достижений, усовершенствования позитивных результатов и преодоления негативных тенденций аграрного производства в отечественных хозяйствах населения.

**Ключевые слова:** сельское хозяйство; развитие хозяйств населения; кластерные модели; искусственная нейронная сеть; растениеводство и животноводство.

### 1. Introduction

The cluster development of regions and different branches of the economy provides a modern mechanism to increase the effectiveness of economic activities. A definition of the business cluster presents it as an agglomeration of enterprises and anchoring institutions united by the joint goal of competitive benefits in the common field of production. It results in a positive concentration and accelerated spread of innovative technologies, an emergence of the effects of a large-scale production and joint sales, an enhancement in marketing, an improvement in management, a reduction of the cost of raw materials, a development of human resources by a mutually beneficial exchanges of the relevant professional knowledge and experience, a synergetic enhancement the quality of the produced and proposed goods and services, etc.

Agriculture also belongs to the sphere of cluster development. Under the influence of the internal and external crisis conditions the agrarian sector of the Ukrainian economy has shown the most financial stability and saved its own export positions. Agricultural enterprises and rural households are known to be agrarian producers in Ukraine. Agricultural enterprises are capable of developing their own technical and financial bases. To-

day's Ukrainian laws provide households with the possibility to work properly without establishing a legal entity at the land plots up to 2 ha because this is not considered to be an entrepreneurial activity. Being highly motivated, the households choose a labour intensive agrarian production in conditions of strong natural and market risks. In such a case the major goal is, in the first place, to provide demands of the members of households by means of production, processing and consumption of agricultural products and, in the second place, to sell their surplus.

At present, Ukrainian households do not attract investors and are incapable of an independent agricultural production corresponding to the international quality standards. In other words, maintenance of an effective activity of households is a socially important task of the national economy, as its ignorance may pose a threat to Ukraine's food security. The cluster approach to the development of households by similar regional agricultural profiles gives a relevant solution to this problem. The positive features of the household clusters are combinations of microeconomic interior improvements of management mechanisms with macroeconomic exterior advantages from a balanced saturation of the territorial agrarian markets. According to their current production

results, a justification of the household clusters needs an application of mathematical simulation methods and informative technologies. It composes the goal and the actual task of the separate scientific research with the calculated illustrations of the obtained results for the Ukrainian agrarian sphere.

## 2. Brief Literature Review

The Cluster Concept started from M. Porter. He defined three key competitive cluster externalities: an increase in productivity of the members of an association, innovative modernisation of their activity and expansion of the market scopes [1-2]. The cluster approach in the agrarian sphere in the Western world sustains agricultural gross domestic products (GDP) with fluctuations less than a few per cent per year. According to H. O. Hansen, the Cluster Concept confirms its practical effectiveness in the largest agricultural and food European clusters of the Netherlands, Germany, France, Spain, Belgium, Italy, Great Britain and Poland [3]. Clusters enable scientists to convert short-term cooperative benefits into long-term competitive advantages that are illustrated by P. W. B. Phillips, J. Karwandy, G. Webb, and C. D. Ryan for Saskatoon oilseeds cluster (Canada), Connecticut Corn and Fruit Bioscience Cluster, St. Louis Corn and Soybean BioBelt, San Diego Fruit and Vegetables Cluster (USA) [4]. The cluster model in China defines the mainstream of its agro-food development. In the opinion of M. Yu, J. Calzadilla, J. Lopez and A. Villa, it involves not only growth of productivity, but also employment of human resources and modernisation, as well as innovative commercial cooperation [5]. But even being non-optimised in scale and structure, Chinese clusters in agriculture, farming and husbandry, and food production bring the largest quantities of grain crops, potatoes, vegetables, fruits and berries, meat and eggs in the world [6]. The modern methods of spatial dynamics and network analyses are used to get rational characteristics of agricultural and agro-food clusters in the countries with a long history of the adaptation of clusters. Namely, in France assessing and balancing geographical and organised proximities calculated by K. Daniel, N. B. Arfa, F. Fontaine, S. Amisse enhanced the effect of collaboration in cereals, field crops, market gardening, vegetables, meat, milk and dairy products clusters [7]. Polish scientists U. Bronisz and W. J. M. Heijman proposed to measure rivalry within regional agricultural clusters by competitive index based on significant economic and social factors, including investment attractiveness and export potential [8]. Together with Dutch researcher A. Looijen, W. J. M. Heijman gave a tool for the identification of cluster specialization in local economies by Types of Farming and Gross Value Added [9]. The general database for comparing economies of agglomeration in terms of Star Clusters Rating has been conducted by the European Cluster Observatory launched and managed by the Stockholm School of Economics since 2007. Once more, agriculture confirms its status of the locomotive economic sector in many countries, especially under crisis conditions in Spain, Greece and Bulgaria [10-12].

Agriculture in Ukraine also needs improving by means of cluster development [13]. The segments of beef, poultry meat and milk production have been unprofitable for the past 20 years. Such a problem cannot be solved separately. The positive closely linked examples are demonstrated by B. Hansen, J. Mousing, L. V. Sorensen, and L. Langkilde, as well as by A. Franz, I. Deimel, and A. Spiller for animal husbandry clusters in Denmark and Germany [14-15]. The abovementioned scientists recommend uniting opportunities of global growth with benefits of new and existing specialised agri-businesses, multi-disciplinary synergy and collaboration between economics and biology. But the main element of success in the cluster development is connected with its construction on the base of a detailed substantiation.

**3. The purpose** of this research is to propose mathematical models of forming clusters in order to support the foremost achievements, improve positive results and overcome negative tendencies of agricultural, crop and animal production in the national households.

## 4. Results

Agglomerations of households present regional, horizontal and sectoral clusters in agriculture. An average size of land shares and rented plots of Ukrainian households equals to 3 ha, though the part of those over 5 ha is 43% at present. O. M. Karamushka notes that only 17% of the households have their own machinery

and equipment. Besides, 93% of the households apply a manual labour for some operations of land cultivation. The use of fertilizers in the households ranges from 58% of chemical to 83% of organic ones, while around 85% of the households apply pesticides [16]. According to O. V. Honcharenko, Ukrainian households demonstrate a low level of effective husbandry keeping, including 25% of regional adapted sorts of agricultural crops, 58% of crop rotation, 49% of veterinary checks, 21% of sanitary control of milk quality and so on [17]. Nevertheless, the official statistics shows almost the same average productivity by types of agricultural holdings in Ukraine. It is explained by the facts that the households get competitive advantages due to their lower dependency on the increasing prices of technical resources, fuel and electricity in comparison with agricultural enterprises [18].

Even in the current conditions the national households provide almost 45%, 41% and 55% of the shares of the gross agricultural, crop and animal productions, respectively. They dominate at the markets of potatoes, vegetables, fruits and berries, and milk products with the corresponding shares over 96%, 86%, 83% and 76%, respectively, and they occupy more than one third of meat and eggs markets and the fifth part of the grain production in Ukraine [19]. Though the households cannot be the key segment of the prominent innovative agriculture in Ukraine in the long-term, their development according to their current economic positions is an important short-term strategy [17]. This can be clarified by the fact that the international practice has numerous positive examples of successful agricultural practices at small land areas, e.g. in Japan or the Netherlands. In the social sphere the households maintain the main employment on the rural territories. An improvement of ecological aspects of the agricultural production in the households will make it possible to perfect the quality of their products and to use natural resources in a balanced way. In the opinion of O. P. Velychko, the agglomeration process of the households is reflected in the creation of branch service cooperatives [20-21]. Thus, the Cluster Concept will give an additional stimulating support for the agricultural development in Ukraine.

The creation of cluster models of agricultural development in households is based on the idea of their agglomeration by similar productivity levels reflecting the key directions of the regional agricultural specialisations. In such a way, it enables scientists to allocate the leading, average and failing producers to clusters with the strong, medium and weak results of agricultural activities. The clusters simulation being complete, the common management mechanisms focused on the balanced sustainable increase would be clarified at the micro- and macroeconomic agricultural levels.

Artificial neural networks give a modern mathematical tool for solving the clusterization problem. The NXL Clusterizer Toolbox, added to the spreadsheet MS Excel, performs model calculations at input data, consisting of some economic indicators for a set of items distributed into several clusters. Taking into account the principal differences in the agricultural, crop and animal production in the Ukrainian households, it would be methodically correct to create 3 separate cluster models in terms of artificial neural networks, where input data represent shares and gross domestic regional productions (% or million UAH), as well as structural parts of products and sales by agricultural branches in Ukraine (% or thousand tons).

Following the simulation by means of the Toolbox NXL Clusterizer, the constructed artificial neural network attaches every item to its cluster. The output characteristics of clusters are their weights as shares (in %) of items belonging to each cluster, as well as the minimum, maximum, average and weighted average values for all indicators in all the clusters. According to the official information of the State Statistics Service of Ukraine, this research considered data by 24 Ukrainian regions in 2014 [22]. The input items were distributed into 3 clusters in order to support the foremost achievements, improve positive results and overcome negative tendencies of agricultural, crop and animal productions in the national households.

To create the cluster model of the agricultural production's development in the households, 8 indicators were chosen, in particular: 1) the gross agricultural production in the households (million UAH); 2) their share in the total gross agricultural production of Ukraine (%); 3) the gross crop production in the house-

holds (million UAH); 4) their share in the total gross crop production of Ukraine (%); 5) the structural part of the crop production in the agriculture of households (%); 6) the gross animal production in the households (million UAH); 7) their share in the total gross animal production of Ukraine (%); 8) the structural part of the animal production in the agriculture of households (%). Following the simulation the following clusters and their profiles were defined by means of the constructed artificial neural network.

The first cluster includes Dnipropetrovsk, Donetsk, Kharkiv, Kherson, Kyiv, Poltava and Vinnytsya regions comprising 7 items or 29.2% of the total quantity. The first cluster is related to the regions with the most gainful agrarian sector in the households, according to the average gross agricultural production exceeding by 26.2%. In a relative dimension, the households give leadership to the agricultural enterprises, losing 14.4% in comparison with the average indicator within the country. The households of the first cluster work with a higher productivity in a crop production, obtaining by 41.2% more gross products than the national average. Yet their average gross animal production is almost equivalent to the one of the whole country. The positive strategic facts are the decreasing shares of the total gross crop and animal production in the households related to the first cluster by 5.8% and 31.8% in favour of the regional agricultural enterprises. The issue, which needs a foreground solution, is a negative tendency of worsening imbalances between the crop and animal branches in the households by 37.8% with respect to the general agricultural imbalances in Ukraine. It increases the dependency of the crop producers on natural risks and demands additional animal products for saturations of the inner regional markets.

The second cluster consists of Chernivtsi, Ivano-Frankivsk, Lviv, Rivne, Volyn, Trans-Carpathian, and Zhytomyr regions, which is 7 items or 29.2% of the total quantity. Their common features are the strongest shares of the agricultural, crop and animal productions in the households exceeding the same national average indicators by 41.7%, 43.9% and 26.8%, respectively. In terms of the total gross production their achievements are weaker by 4.5% and equal to 18.3% in the whole agriculture and its crop branch. Yet the gross animal production in the households of the second cluster is by 20.4% higher than the national average. One more positive aspect here is the best balance between the branches of the crop and animal production. It means that the agricultural development in the households of the second cluster does not need structural corrections, however it should be supported both financially and technically.

The third cluster brings together Cherkasy, Chernihiv, Khmelnytskyi, Kirovohrad, Luhansk, Mykolaiv, Odessa, Sumy, Ternopil and Zaporizhzhya regions, comprising 10 items or 41.6% of the total quantity. The households allocated to the third cluster are characterised by the least values of the gross agricultural, crop and animal production, which is 15.2%, 16.0% and 13.8%, respectively, with regard to the national average. However, their low shares of the animal and crop production with the deficits of 19.1% and 26.7%, respectively, in comparison with the national average, mean a positive domination of the advanced agricultural enterprises. The disproportion between agricultural branches and the structural part of animal production in the households forming the third cluster almost amount to the national average. Thus, to become important producers of the animal branch in the short-term future, the households of the third cluster are supposed to modernise and to facilitate technically their animal husbandry.

The key features of the national crop farming are great land areas in the Ukrainian agriculture, its profitability, as well as large volumes of production and export. The separate cluster model of the development of crop production by branches in the households is based on 12 indicators, in particular: 1-6) the shares of grain crops, sugar beet, sunflower, potatoes, vegetables, fruits and berries production in the households (%); 7-12) the volumes of sales' of the named crops by the households (thousand tons). Following the simulation, the next clusters and their profiles were defined by means of the constructed artificial neural network.

The first cluster includes Chernivtsi, Kherson, Ternopil, Vinnytsya, Volyn and Trans-Carpathian regions comprising 6 items or 25.0% of the total quantity. The core of the agricultural specialisation of the households forming the first cluster is indicated by the volumes of sales of sugar beet, potatoes, vegetables, fruits

and berries with the surpluses of 162.6%, 90.4%, 111.8% and 68.9%, respectively, against the similar values within Ukraine. Besides, the households of the first cluster have the strongest position by the share of grain production with the average surplus of 59.2% against the same indicator throughout the country. On the contrary, the volumes of their grain sales indicate the deficit of 57.5%. This implies the necessity of an innovative modernisation of the grain branch in the households of the first cluster.

The second cluster consists of Dnipropetrovsk, Donetsk, Kharkiv, Kirovohrad, Mykolaiv, Odessa, Poltava, and Zaporizhzhya regions, comprising 8 items or 33.3% of the total quantity. The households of the second cluster are brought together by the strongest export potential in the branches of the grain crops and sunflower seeds productions that are justified by their volumes of sales of the harvest exceeding the corresponding indicators throughout Ukraine by 130.2% and 165.9%, respectively. Nevertheless, these positive facts demand to strengthen control over ecological aspects of the sunflower seeds production in relation to the crop rotation and use of obligatory chemical fertilizers. The weakest positions of the households related to the second cluster are their volumes of sales of sugar beet, potatoes, vegetables, fruits and berries, which generate the necessity of an essential enhancement of productivity of the agricultural branches mentioned above.

The third cluster brings together Cherkasy, Chernihiv, Ivano-Frankivsk, Khmelnytskyi, Kyiv, Luhansk, Lviv, Rivne, Sumy and Zhytomyr regions, comprising 10 items or 41.7% of the total quantity. Their households have the average shares of the grain crops, sugar beet and sunflower production with the deficits of 37.3%, 15.2% and 75.1%, respectively, in comparison with the same indicators throughout Ukraine, whereas the shares of potatoes, vegetables, fruits and berries production approximately amount to the national average indicators. The volumes of the harvest sales (except for potatoes) are also by 69.7%, 41.0%, 84.3%, 50.1% and 16.1% less than the national average. These factors clarify the competitive advantages of the agricultural enterprises in the regions of the third cluster. Despite these facts, the households are the fundamental parts in the branches of potato, vegetable, fruits and berries production in Ukraine at present and in the short-term future.

The gainful properties of the animal husbandry are the whole year employment of the producers, their stable incomes and a smaller dependence on natural risks. The separate cluster model of the development of animal production by branches in the households applies 10 indicators, in particular: 1-5) the shares of beef, pork, poultry meat, milk and eggs productions in the households (%); 6-10) the volumes of sales of the named animal products by the households (thousand tons, except for million pieces of eggs). Following the simulation, the following clusters and their profiles were determined by means of the constructed artificial neural network.

The first cluster includes Kirovohrad, Lviv, Mykolaiv, Odessa, Rivne, Volyn, Zhytomyr, and Trans-Carpathian regions comprising 8 items or 33.3% of the total quantity. The households of the first cluster dominate by the shares of all considered kinds of animal productions, which exceed the similar average indicators throughout Ukraine by 16.8%, 35.1%, 49.9%, 14.3% and 56.1%, respectively. These results have a positive correlation with the prominent volumes of sales of beef, pork and eggs with the surpluses of 13.3%, 27.0% and 33.8% respectively, if compared with the national average. On the contrary, the volumes of sales of poultry meat and milk by the households forming the first cluster have deficits of 7.7% and 13.6%, respectively, with regard to the national average indicators. It should be noted that the poultry meat production in Ukraine has been staying unprofitable since 2007, whereas milk yield per cow in Ukraine is only half of the current figures in Canada, Denmark, Sweden and the USA [6]. Hence, Ukraine's animal production needs an active technological improvement in order to increase its effectiveness.

The second cluster consists of Chernivtsi, Dnipropetrovsk, Ivano-Frankivsk, Kherson, Khmelnytskyi, Luhansk, Ternopil and Zaporizhzhya regions, which is equal to 8 items or 33.3% of the total quantity. The key characteristics of the animal production in the second cluster are a principal domination of the agricultural enterprises in the poultry meat and eggs production. Namely, their



shares of beef and milk production have the surpluses of 15.0% and 10.6%, respectively, against the average indicators throughout Ukraine, whereas the structural part of the pork production is almost equivalent to the national average. However, the volumes of sales of beef amount to the same national average indicator. Furthermore, the volumes of sales of the listed products are by 6.7% and 21.4% less for pork and milk, respectively, than the national average. It should be noted that the production of meat and milk per capita in Ukraine (53 and 253 kg) are significantly lower than the internationally recommended nutrition norms for these products (85 and 390 kg respectively) [22]. Consequently, it is expedient to support and maintain an increase in effectiveness of the livestock production in the households of the second cluster.

The third cluster brings together Cherkasy, Chernihiv, Donets, Kharkiv, Kyiv, Poltava, Sumy and Vinnytsya regions, comprising 8 items or 33.3% of the total quantity. The households related to this cluster are characterised by the low shares of beef, pork, poultry meat, milk and eggs production with the deficits of 31.9%, 31.4%, 8.7%, 24.9% and 17.4%, respectively, in comparison with the national average indicators. The same negative results are demonstrated by the volumes of sales of beef, pork and eggs, which are by 16.5%, 20.3% and 21.6% less than the national average. The only positive achievements here are the essential volumes of sales of poultry meat and milk, which define the foreground direction of the agricultural development for the households of the third cluster.

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