Intellectual assessment of staff sufficiency for innovative development of the sustainable regional agro-industrial complex

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Abstract. The paper is devoted to the problems of assessment of staff sufficiency for regional economy agroindustrial sector's innovative development. The proposed approach is based on the application of models and methods of expert assessment and digital intelligent technologies. The share of employees who are ready (professionally) to use innovations from the total number of employees was chosen as the main evaluation characteristic. At the same time, the indicators of staff sufficiency of subsystems and the sustainable regional agro-industrial complex as a whole are formed on the basis of statistical data provided by enterprises, expert judgments and knowledge about the subject area represented by a system of fuzzy production rules. The developed hierarchy of indicators reflects the structure of the regional agro-industrial complex (subcomplexes, reproduction and functional components, categories of enterprises). The transition to indicators of a higher tier of the hierarchy is realized based on the indicators of the previous tier, using weighted summation and/or fuzzy logical inference, which allows taking into account not only the relative importance of individual subsystems (components), but also the high level of uncertainty characteristic of the agro-industrial economy. At the same time, evaluation indicators of various tiers of the hierarchy can be used to make managerial decisions. Preliminary results of the application of the developed hierarchy of evaluation indicators of staffing of the sustainable regional agro-industrial complex and the proposed procedure for determining the values of these indicators may indicate the effectiveness of the proposed approach.

1. Introduction

The enterprises of the agro-industrial complex serve as the economic basis for the development of rural areas [1]. The concept of sustainable development [2] in relation to the agricultural sector of the economy involves the biologization of agriculture (production of environmentally friendly products [3], soil regeneration [4], reduction of agrogenic pollution [5], the use of renewable energy sources [6,7]). One of the important factors hindering the introduction of modern innovative agricultural technologies (along with insufficient scientific study, low economic efficiency and significant risks, as well as

technical and technological unavailability) is the lack of qualified personnel. The planning of the activities of the regional vocational education system (within the framework of regional programs to support the development of the agro-industrial complex) should be based on the results of a comprehensive analysis of data monitoring the state of the labor market and the level of provision of enterprises with qualified specialists.

The purpose of this study is to create a procedure for assessing the staff sufficiency of innovative development of the sustainable regional agro-industrial complex based on current monitoring data, expert judgments and knowledge reflecting the specifics of agricultural production in a particular region. The complexity of the assessment is based on the use of a hierarchical system of indicators that take into account the relative importance of individual components (subcomplexes). The proposed combination of the ideology of hierarchy analysis with the methodological apparatus of fuzzy linguistic analysis is due to the high level of uncertainty (characteristic of the agricultural sector) and is designed to formalize expert judgments. The use of modern intellectual (knowledge-oriented) digital technologies to assess the level of staffing of the sustainable regional agro-industrial complex will contribute to the timely adoption of management decisions that increase the effectiveness of the system of training (retraining, advanced training) of specialists.

2. Materials and methods

As the main characteristic of agro-industrial complex components's staff sufficiency, we will use the *Ind* indicator, measured in the range from 0 to 1, and reflecting the share of specialists with the required qualifications from the total number of specialists. However, using the numerical value of this indicator does not make it possible to show how significant this value is for an enterprise (sub-sector, industry). The level of significance can be determined by experts at the verbal level using the terms *low*, *medium*, *high*. Thus, a transition is realized from the numerical characteristic *Ind* to the linguistic variable *LingInd*, formally described in accordance with [8] by following assembly:

$$LingInd = <NameLingInd, UnInd, TbaseInd, GInd, MInd> \quad (1)$$

where *NameLingInd* is the name of the linguistic variable (the name corresponds to the name of the component of the agro–industrial complex); *UnInd* is a universal assembly of linguistic variable in the general case containing all possible measured numerical values *Ind*, and in the case under consideration, representing the segment [0,1]; *TbaseInd* = {*low*, *medium*, *high*} is the basic set of terms for the values under consideration; *GInd* is a set of syntactic rules that allow generating term names from the names of *TbaseInd* elements (which leads to the formation of a set of terms *TIND*, *TbaseInd* $\subset$ *TInd*); *MInd* - semantic rules that establish correspondences between terms from *TInd* and fuzzy subsets of the universal set *UnInd*. The membership functions of these sets can have, in particular, a trapezoidal type, as shown in figure 1.

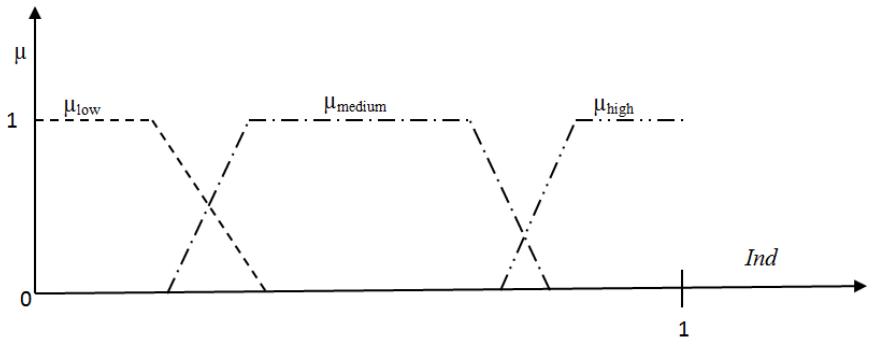

Figure 1. Graphs of membership functions μ_{low}, μ_{medium}, μ_{high}, defining the semantics of the terms *low*, *medium*, *high*.

Let's present a general system of indicators of staff sufficiency (starting from individual enterprises and up to the regional agro-industrial complex as a whole) in the form of a hierarchy as shown in figure 2.

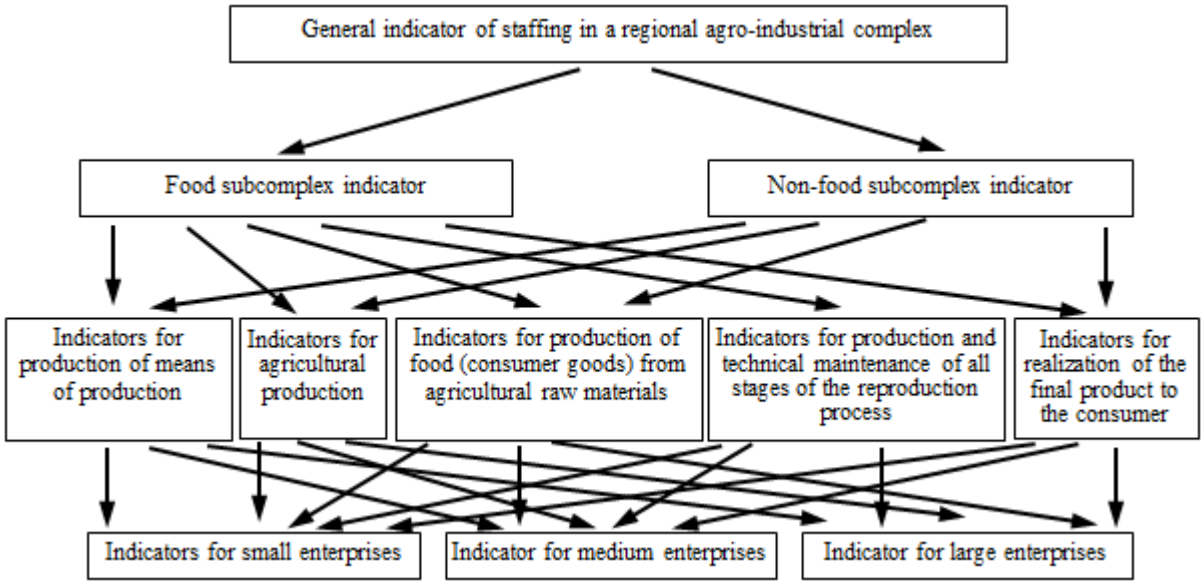

Figure 2. Hierarchy of staff sufficiency indicators, which reflects the structure of the regional agro-industrial complex.

The above hierarchy of staff sufficiency indicators is based on the general structure of the agro-industrial complex, within which two main subcomplexes are distinguished:

- food subcomplex;
- a subcomplex of non-food products.

Each of these subcomplexes is divided according to the reproduction-functional structuring is divided into components that provide:

- production of means of production;
- agricultural production;
- production of food (consumer goods) from agricultural raw materials;
- production and technical maintenance of all stages of the reproduction process;
- realization of the final product to the consumer.

At the lower tier of the hierarchy are the staff sufficiency indicators for enterprises (divisions of enterprises) that provide the appropriate stages of the agro-industrial production process.

It is easy to see that although the values of the indicators of the higher tier of the hierarchy are determined on the basis of the indicators of the lower tier, however, the generalization procedure is not reduced to a simple summation. The quantitative contribution of indicators of the lower tier in the transition to more general indicators of the next tier may be non-linear in accordance with the views of experts on the relative importance of indicators, taking into account regional specifics. For example, the value of the staff sufficiency index of a large agricultural holding may have a more significant impact on the generalized indicator than formally the same value for a small enterprise, not only due to a larger number of employees and a greater contribution to the agroeconomics of the region, but also due to the possibility of an active personnel policy and the availability of its own system of professional development of employees. This makes it advisable (to avoid excessive detail) to group the agro-enterprises of the region by highlighting the categories of small, medium and large enterprises.

3. Results and discussion

The main result of the work is the building of a hierarchical information and linguistic model for assessing the staff sufficiency of the regional agro-industrial complex and the procedure for determining the values of the components of this model.

The lower tier of the model (the tier of indicators of enterprise categories) contains the components:

$$< ind, type\_ent, type\_func, type\_subcomp > \quad (2)$$

where *ind* is the value of the staffing index for a specific category of enterprises related to a specific reproduction and functional component of a specific subcomplex.

The remaining components of the information representation (2) provide the required concretization:

- *type_ent* – indicates the category of enterprises (*type_ent* ∈ { *small enterprises, medium enterprises, large enterprises*});
- *type_func* – indicates the reproductive-functional direction (*type_func* ∈{ *production of means of production, agricultural production, production of food (consumer goods) from agricultural raw materials, production and technical maintenance of all stages of the reproduction process, realization of the final product to the consumer*);
- *type_subcomp* – indicates the type of subcomplex (*type_subcomp* ∈{ *food subcomplex, non-food subcomplex*}).

Based on expert judgments regarding the significance of the numerical value of *ind* for specific values of *type_ent, type_func, type_subcomp*, a fuzzyfication, consisting in a transition to a set of values <(*low*,μ_{low}), *(medium,* μ_{medium}), *(high*,μ_{high})>, is performed.

The second tier of the hierarchical model (the tier of reproduction-functional structuring) consists of components:

$$< ind, type\_func, type\_subcomp > \quad (3)$$

The absence of an indication of the enterprise category is due to the fact that the transition to this tier from the lower tier involves the integration of the indicator across all types of categories. Integration is performed using knowledge about the subject area, represented by a system of fuzzy production rules [9], having (for example) the form:

If ((<ind - low, small enterprises, type_func, type_subcomp> or <ind - medium, small enterprises, type_func, type_subcomp>) and <ind - low, medium enterprises, type_func, type_subcomp>) and (4)

<ind - low, large enterprises, type_func, type_subcomp>) then <ind - low, type_func, type_subcomp>

If ((<ind - medium, small enterprises, type_func, type_subcomp> or <ind - high, small enterprises, type_func, type_subcomp>) and <ind - medium, medium enterprises, type_func, type_subcomp>) and <ind - medium, large enterprises, type_func, type_subcomp>) then <ind - medium, type_func, type_subcomp> (5)

If (<ind - high, small enterprises, type_func, type_subcomp> and <ind - high, medium enterprises, type_func, type_subcomp>) and <ind - high, large enterprises, type_func, type_subcomp>) then <ind - high, type_func, type_subcomp>. (6)

The specific type of fuzzy production rules (4-6) is determined by cognitologists in the field of personnel support of the agro-industrial complex, taking into account regional specifics.

Rules (4) make it possible, using the procedure of fuzzy logical inference (for example, the Mamdani algorithm [10]), to obtain fuzzy values of indicators of the second tier in the form of triples <(*low*,μ_{low}

), *(medium,* μ_{medium}), *(high,*μ_{high})>.. By defuzzification, numerical values of staffing in the range from 0 to 1 can be obtained from them, but these will be conditional shares of employees with the required qualifications, since when determining them, the difference in the contribution of small medium and large enterprises to the staffing of the reproduction and functional direction of the regional agro-industrial complex was taken into account (using a fuzzy production representation of knowledge). Thus, conditional shares are more informative and more useful in making managerial decisions.

The third tier of the hierarchy (the tier of reproduction-functional structuring) consists of components <*ind, type_subcomp*> characterizing the staffing of the food and non-food subcomplexes.

The last (fourth) tier represents the top of the hierarchy – a general indicator of the staffing of the regional agro-industrial complex < *ind* >.

The transition from the second tier to the third tier and from the third tier to the top of the hierarchy can be performed in the same way as the transition from the fourth tier to the third tier discussed earlier. However, excessive cumbersomeness of procedures can be avoided by using numerical values of conditional shares of employees of the required qualifications obtained after defasification. Then an approach can be used in which the generalized indicator is defined as a weighted sum of particular indicators [11]. For example, when moving from the tier of subcomplexes to the top of the hierarchy, the numerical value of the staffing index of the entire regional agro-industrial complex can be determined by the formula:

$$ind = w_{fsc}\, ind_{fsc} + w_{nfsc}\, ind_{nfsc} \qquad (7)$$

$$w_{fsc}, w_{nfsc} \geq 0,\ w_{fsc}, w_{nfsc} = 1$$

where ind_{fsc} , ind_{nfsc} are values of conditional indicators of staffing of food and non-food subcomplexes, w_{fsc}, w_{nfsc} are weight coefficients reflecting the relative importance of these subcomplexes for the agroeconomy of the region. The values of weighting coefficients determined on the basis of expert judgments (for example, by the method of paired comparisons [11]), in fact (as well as production rules) reflect the knowledge of experts regarding the subject area (agro-industrial sector of the regional economy).

It should be noted that the indicators of individual components (subsystems) of the regional agro-industrial complex determined within the framework of the proposed procedure, generally speaking (except for indicators of the lower level of the hierarchy), do not coincide with the shares of employees with the required qualifications from the total number of employees. However, the fact that these values are determined taking into account the role and place of these components in regional agroeconomics makes these indicators more useful in making managerial decisions. At the same time, it is necessary to investigate the sensitivity of solutions to possible small changes in expert judgments [12].

4. Conclusion

The widespread introduction of modern innovative agricultural technologies is impossible without a sufficient number of qualified specialists ready for this type of activity.

The paper is devoted to the problems of assessing the staffing of the agro-industrial sector of the regional economy. The proposed approach is based on the application of models and methods of expert assessment and digital intelligent technologies. Indicators of the staffing of subsystems and the sustainable regional agro-industrial complex as a whole are formed on the basis of statistical data provided by enterprises, expert judgments and knowledge about the subject area represented by a system of fuzzy production rules. The developed hierarchy of indicators reflects the structure of the regional agro-industrial complex (subcomplexes, reproduction and functional components, categories of enterprises).

Preliminary results of the application of the developed hierarchy of evaluation indicators of staff sufficiency of the regional agro-industrial complex and the proposed procedure for determining the values of these indicators may indicate the effectiveness of the proposed approach. It is planned to develop further research, applying the results obtained in the development of management decision

support systems in the field of regional educational and personnel policy (for example, using tools for modeling personnel processes [13,14]).

5. Acknowledgments

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