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A New Focus on Research Strategies in Determining the Structure of the Motivational Field of Scientific and Pedagogical Staff of Agricultural Universities

Yury A. Pichugin [a], Valentina A. Ivashova [b, *], Vadim N. Goncharov [c], Olga U. Kolosova [d]

[a] Saint-Petersburg State University of Aerospace Instrumentation, Saint Petersburg, Russian Federation
[b] Stavropol State Agrarian University, Stavropol, Russian Federation
[c] North Caucasus Federal University, Stavropol, Russian Federation
[d] Stavropol Branch, Krasnodar University of the Ministry of Internal Affairs of Russia, Stavropol, Russian Federation

Abstract

The article presents new research technologies that determine the features of motivational field structure of scientific and pedagogical staff (SPS) in the system of higher agricultural education in Russia based on mathematical statistics tools. Theoretical review of publications confirms the high relevance of the study of the motivational field by new tools: using mathematical apparatus based on principal components, estimates of structural similarity and amount of information. In the empirical part of the study, a comparative analysis of the motivational field structure of young scientific and pedagogical employees of agrarian universities (age group under 30) and the older generation (over 50) was conducted. For young workers the value of satisfaction from professional activity is defined due to qualitative improvement of labor processes and in general organization of labor on the basis of optimal ratio of labor costs and wages with preservation of good relations in labor collective. For the older age group – the value of constant increase in knowledge and interest in professional development with an active deterrent of the relationship with the immediate supervisor and the predominance of interest in work over wages.

The new research strategy increases the objectivity of the conclusions and the high interpretability of the results of sociological research.

* Corresponding author
E-mail addresses: yury-pichugin@mail.ru (Yu.A. Pichugin), vivashov@mail.ru (V.A. Ivashova), vgn1968@rambler.ru (V.N. Goncharov), kolosova.07@mail.ru (O.U. Kolosova)

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1. Inroduction

Higher education is an important social institution in Russian society. In recent decades, it has been undergoing permanent institutional changes, which has not always had a positive effect on the motivation of scientific and pedagogical staff to work. The situation in the higher agricultural education system is complicated by the fact that despite the actively developing segment of the economy – the agricultural sector, for which agricultural universities of the country train personnel. There are still difficulties with student recruitment, changes in FSES, insufficient funding of the research sector and many other things that generally do not give stability to the staffing situation in agricultural universities. The importance of the study of the motivational field also increases because the training of scientific and pedagogical staff, capable of conducting both teaching and research activities, taking into account the continuity of scientific practices, takes a long time: about 10-12 years, taking into account the levels of higher education: bachelor, master (in some cases specialist's degree) and postgraduate studies. The requirements to work as scientific and pedagogical staff are currently high, which against the background of relatively low salaries of young teachers, hurts the motivation to work and professional development. Accordingly, there is a negative trend in the dynamics of human resources potential not only in higher education in agriculture (the potential of those who teach) but also in the agricultural sector (those who are taught), which has now made a serious bid for success and active development in Russia, including in the field of new technological breakthroughs and digitalization.

Studies of the motivational field of employees of enterprises and organizations, including scientific and pedagogical workers of higher agricultural education, are usually carried out using quantitative methods, particularly the questionnaire survey method. However, at present, sociologists' arsenal of mathematical statistics tools available in the specialized software programs Statistica, SPSS and others do not fully solve the problem of assessing the structure of quantitative information of the survey database and the objective selection of the critical influence factor.

2. Materials and methods

The task of this study is to propose and test a new method of mathematical statistics based on principal components, assessment of structural similarity and amount of information to characterize the structure of motivational field of scientific and pedagogical employees of Stavropol State Agrarian Education, as a typical representative of higher agrarian education in Russia.

In order to solve the task a survey of scientific and pedagogical employees of Stavropol State Agrarian University was organized. To compare the structure of motivational field two age categories were selected: under 30 years old and over 50 years old, which characterizes such an important parameter of research and teaching activities as preservation of continuity and professional traditions in the field of agricultural education. Thus, the general population was defined by three target characteristics:

- first feature – belonging to the number of scientific and pedagogical employees of Stavropol State Agrarian University, as a typical higher educational institution of higher agrarian education of Russia;
- the second feature – employment contract on the permanent basis;
- the third feature – belonging to the age group "up to 30 years old" and "over 50 years old".

The sample was built taking into account the organizational structure of the university and included representatives of all faculties: agrobiology and land resources, biotechnology, veterinary medicine, mechanization of agriculture, socio-cultural service and tourism, ecology and landscape architecture, economics, accounting and finance, and electric power. The total number of scientific and pedagogical staff with permanent labor contracts at the university is 119 people in the age group "up to 30 years" and 159 people in the age group "over 50 years" among the scientific and pedagogical staff of all faculties. Since there were 401 full-time scientific and pedagogical employees in the university in 2020 (i.e. the size of the general population is up to 500 people) stratified sampling was used in the study of the structure of motivational field. Identified strata: belonging to the age group "under 30 years" and "over 50 years" and participation of at least 80 % of scientific and pedagogical employees of each of these age groups in the university departments.

A total of 95 scientific-pedagogical workers of the age group "up to 30 years" and 127 respondents of the age group "over 50 years" took part in the survey conducted by the method of handout individual questionnaire. At a confidence level of 95 %, the general population of 401 people, comparable to the sample of 222 people, the error of the results of the study is about 4.0 %.

To develop the questionnaire the interpretation of the concept of labor motivation was carried out, indicators characterizing 8 significant characteristics were developed: interest to work, achievements in work, relationship with employees, relationship with management, pretensions in professional activity, preference of work for high wages, working conditions and general satisfaction with work. These characteristics are disclosed in the research toolkit (questionnaire) in 19 indicators:

Indicator 1: What I do at work interests me;
Indicator 2. In recent years, I have made progress in my profession;
Indicator 3. I have good relationships with people in my team;
Indicator 4. Job satisfaction is more important than earning a high salary;
Indicator 5. My job title does not match my abilities;
Indicator 6. What I like about my job is that I get to learn new things;
Indicator 7. From year to year, I feel my knowledge and skills are improving;
Indicator 8. People with whom I work respect me;
Indicator 9. There are often situations in life where you can't do all the work you're asked to do;
Indicator 10. My bosses have been very satisfied with my work recently;
Indicator 11. The job I do cannot be done by someone with lower qualifications;
Indicator 12. I enjoy doing my job;
Indicator 13. I am not satisfied with the organisation of work in our team;
Indicator 14. I often have disagreements with my colleagues at work;
Indicator 15. I am rarely rewarded for my work;
Indicator 16. Even if I was offered a higher salary, I would not change my job;
Indicator 17. My line manager often doesn't understand or doesn't want to understand me;
Indicator 18. Good working conditions at my company;
Indicator 19. I set and achieve goals in my work.

The 19 indicators of job satisfaction at the University were rated from -5 to +5, where -5 is total dissatisfaction; +5 is total satisfaction.

To characterize and comparatively analyze the structure of motivational field of scientific and pedagogical employees we will use a mathematical apparatus based on principal components, estimates of structural similarity and amount of information.

Structural similarity coefficient and assessment of age-related changes

The original observations for each age group is a sample matrix (table) $\mathbf{Y}$ of dimension $m \times n$, where m = 19 is the number of questions and n is the number of respondents. For the first group, under 30, n = 95, and for the second group, over 50, n =127. We denote the elements of the sampling matrix by y_{ij} (i = 1, 2, ..., m; j = 1, 2, ..., n) respectively. Based on these data, a correlation matrix $\mathbf{R}$ of dimension $m \times m$ and an orthogonal matrix $\mathbf{Q}$ of dimension $m \times m$, converting the matrix to a diagonal form, are calculated for each group using the SPSS Statistics package. Thus the following equation is fulfilled

$$\mathbf{Q}^T\mathbf{R}\mathbf{Q} = \mathbf{\Lambda} = \mathrm{diag}(\lambda_1, \lambda_2, \ldots, \lambda_m), \quad (1)$$

provided the spectrum is ordered in descending order $\lambda_1 \geq \lambda_2 \geq \ldots \geq \lambda_m$, where T is the transposition operator. SPSS Statistics automatically selected the first k (k = 5) spectral values (the central part of the spectrum) to which the first k columns of the matrix $\mathbf{Q}$ correspond. Table 1 shows the full spectrum $\{\lambda_1, \lambda_2, \ldots, \lambda_m\}$ (2nd column, the main part in bold) and the first five columns of the orthogonal matrix $\mathbf{Q}$ (from 3rd to 7th columns of Table 1) for the first age group. Table 2 presents similar results of the statistical analysis for the second age group. Hereafter, membership in the second group is indicated by a wavy line $(\tilde{\mathbf{R}}, \tilde{\mathbf{Q}})$.

Table 1. The spectrum of the correlation matrix **R** and first five columns of the orthogonal transformation matrix **Q** for the first age group

№ *i*	Matrix **R** spectrum(λ_i)	The first five columns of the matrix **Q**				
1	**6,207**	0,314	0,112	0,045	0,087	0,135
2	**2,187**	0,226	0,121	-0,371	-0,100	-0,124
3	**1,601**	0,296	-0,158	0,074	0,242	0,280
4	**1,366**	0,177	0,090	0,264	-0,472	0,389
5	**1,07**	-0,190	0,212	0,232	-0,083	-0,134
6	0,88	0,154	0,221	0,423	-0,175	-0,203
7	0,8	0,252	0,130	-0,163	0,068	-0,144
8	0,75	0,297	-0,010	0,064	0,325	0,147
9	0,719	-0,048	0,335	0,312	0,384	-0,192
10	0,647	0,170	0,235	-0,288	0,105	-0,077
11	0,582	0,149	0,371	-0,375	-0,027	-0,057
12	0,47	0,313	0,083	0,319	0,027	-0,066
13	0,412	-0,204	0,229	-0,058	0,101	0,588
14	0,35	-0,152	0,436	-0,047	0,036	-0,170
15	0,281	-0,179	0,322	0,159	0,262	0,040
16	0,245	0,188	0,257	0,045	-0,524	-0,006
17	0,204	-0,220	0,313	-0,124	-0,026	0,426
18	0,14	0,322	0,034	0,144	0,195	0,164
19	0,089	0,288	0,071	-0,175	0,012	0,031

Table 2. The spectrum of the correlation matrix $\tilde{\mathbf{R}}$ and first five columns of the orthogonal transformation matrix $\tilde{\mathbf{Q}}$ for the second age group

№ *i*	Matrix $\tilde{\mathbf{R}}$ spectrum ($\tilde{\lambda}_i$)	The first five columns of the matrix $\tilde{\mathbf{Q}}$				
1	**5,052**	0,265	0,122	0,288	-0,337	0,082
2	**2,806**	0,259	0,302	0,009	-0,066	-0,167
3	**1,621**	0,237	-0,093	-0,038	-0,346	0,415
4	**1,17**	0,213	0,163	-0,434	0,075	0,257
5	**1,121**	-0,195	0,342	-0,063	0,097	0,326
6	0,892	0,148	0,135	0,280	0,424	0,312
7	0,851	0,243	0,279	0,229	-0,250	-0,202
8	0,801	0,207	0,115	0,270	0,116	0,356
9	0,732	-0,259	0,082	0,311	0,025	-0,110
10	0,702	0,137	0,183	-0,338	0,246	-0,229
11	0,673	0,035	0,368	-0,257	-0,165	-0,142
12	0,554	0,258	-0,014	-0,025	-0,066	0,303
13	0,474	-0,291	0,190	-0,168	-0,246	0,195
14	0,357	-0,264	0,283	-0,005	-0,084	0,035
15	0,307	-0,184	0,281	0,225	0,306	0,141
16	0,282	0,179	0,318	-0,256	0,204	-0,051
17	0,252	-0,290	0,325	0,185	-0,057	-0,062
18	0,186	0,269	-0,078	0,116	0,411	-0,209
19	0,166	0,264	0,222	0,222	-0,152	-0,267

To assess overall age-related changes, we calculate the structural similarity coefficient (see [1])

$$s = \max_{\varphi(i)} \frac{\sum_{i=1}^{k} \sqrt{\lambda_i \tilde{\lambda}_{\varphi(i)}} \left| \mathbf{q}_i^T \tilde{\mathbf{q}}_{\varphi(i)} \right|}{\sqrt{\sum_{i=1}^{k} \lambda_i \sum_{i=1}^{k} \tilde{\lambda}_i}}, \quad (2)$$

where $\mathbf{q}_i$ stands for the i-th column of the matrix $\mathbf{Q}$, the wave, as above, marks the columns and values belonging to the second age group, and the maximum is taken by all possible permutations (φ) of elements of the set number {1, 2, ..., k}, k being five in our case (k = 5, see above). $\{\mathbf{q}_i\}_{i=1}^{k}$ is the basis of the principal components.

To calculate the structural similarity coefficient, let us compose two matrices $\mathbf{A} = \left(\sqrt{\lambda_1}\mathbf{q}_1, \sqrt{\lambda_2}\mathbf{q}_2, ..., \sqrt{\lambda_k}\mathbf{q}_k \right)$ и $\tilde{\mathbf{A}} = \left(\sqrt{\tilde{\lambda}_1}\tilde{\mathbf{q}}_1, \sqrt{\tilde{\lambda}_2}\tilde{\mathbf{q}}_2, ..., \sqrt{\tilde{\lambda}_k}\tilde{\mathbf{q}}_k \right)$. As we see, these matrices are made up of the columns of the orthogonal matrix $\mathbf{Q}$ and $\tilde{\mathbf{Q}}$, multiplied by the square roots of the corresponding eigenvalues. Then we have

$$\mathbf{A}^T\tilde{\mathbf{A}} = \begin{pmatrix} \mathbf{5,304} & 0{,}588 & 0{,}273 & -0{,}131 & 0{,}072 \\ -0{,}714 & \mathbf{2,171} & 0{,}087 & 0{,}221 & -0{,}027 \\ -0{,}097 & -0{,}419 & 0{,}399 & 0{,}549 & \mathbf{0,858} \\ -0{,}442 & -0{,}310 & \mathbf{0,843} & -0{,}177 & 0{,}014 \\ -0{,}094 & 0{,}131 & -0{,}241 & \mathbf{-0,271} & 0{,}323 \end{pmatrix}.$$

By selecting one number from each column and each row so that the total sum of the modules is maximal, we obtain the numerator of formula (2). In our case it equals 9,446 (the result of selection is marked in bold). Further, by dividing by the denominator, which in our case is 12,096, we obtain the value of structural similarity coefficient s = 0,781. As shown in (Pichugin, 2018), if the regression relation between the numerator elements, with a corresponding permutation (φ) and a change of sign of some columns ($\tilde{\mathbf{q}}_{\varphi(i)}$, see above), does not have a free term, then we can test hypothesis $H: s = 0$. Checking the above condition showed that the required condition can be considered satisfied since the t-statistic for its verification gives a value of 1,221 versus the critical value of $t_\nu^{\alpha/2}$ = 2,779, at α=0,05. This allows hypothesis H to be tested by means of t-statistics (see (Pichugin, 2018))

$$\gamma = \frac{s\sqrt{mk-1}}{\sqrt{1-s^2}},$$

Which gives the value γ =12,121, which significantly exceeds the critical value and at significance level α =0,01, i.e. hypothesis H is firmly rejected (the number of degrees of freedom in both cases is $\nu = mk - 1 = 94$). See below for a discussion of this result.

3. Results

Results of information ordering

As a result of information ordering, we have a sequence of values of the quantity of information I_j. In addition, it is convenient to consider a descending sequence of information

quantity increments an auxiliary $\Delta I_j = I_j - I_{j-1}$, (see below) sequence of information quantity ratios $\Delta I_{j+1} / \Delta I_j$ and (most importantly) a sequence of question numbers in descending order of information quantity increments $i = \mu(j)$ (j=1, 2,..., m).

Table 3 shows the results of the information ordering for the first age group. Table 4 shows similar values for the second age group. The graphical representation of the third columns of Tables 3 and 4 (information growth I_j) shows no significant difference. Most revealing are the fourth columns containing decreasing sequences of information increments (ΔI_j). These columns are graphically represented in Figure 1 and Figure 2, respectively. The last – fifth columns of Tables 3 and 4 are of an auxiliary nature and serve to clarify the boundaries of the most or least informative (important) questions for the age groups considered (see below).

Table 3. Results of information sequencing (first age group)

№ selection step j	№ question $\boldsymbol{\mu}(j)$	Amount of information I_j (%)	Increment of the amount of information ΔI_j (%)	Ratio of consecutive increments of the amount of information $\Delta I_{j+1} / \Delta I_j$
1	**12**	11,74	11,74	
2	**11**	22,03	10,28	0,88
3	**9**	32,22	10,19	0,99
4	**13**	41,86	9,64	0,95
5	**4**	51,09	9,23	0,96
6	**3**	59,47	8,38	0,91
7	16	65,05	5,58	**0,67**
8	17	69,65	4,59	0,82
9	8	73,96	4,31	0,94
10	2	78,10	4,14	0,96
11	6	82,11	4,01	0,97
12	14	85,63	3,51	0,88
13	18	88,38	2,75	0,78
14	15	91,06	2,69	0,98
15	10	93,55	2,49	0,93
16	*5*	95,37	1,82	**0,73**
17	*1*	97,14	1,77	0,97
18	*7*	98,68	1,54	0,87
19	*19*	100,00	1,32	0,86

Table 4. Results of information sequencing (second age group)

№ selection step j	№ question $\tilde{\boldsymbol{\mu}}(j)$	Amount of information $\tilde{I}_j$ (%)	Increment of the amount of information $\Delta \tilde{I}_j$ (%)	Ratio of consecutive increments of the amount of information $\Delta \tilde{I}_{j+1} / \Delta \tilde{I}_j$
1	**17**	11,54	0,46	
2	**7**	22,48	0,90	0,95
3	**4**	32,06	1,28	0,88
4	**6**	41,27	1,65	0,96
5	3	48,68	1,95	**0,80**
6	18	55,22	2,21	0,88
7	5	60,81	2,43	0,86

8	10	66,07	2,64	0,94
9	1	70,87	2,83	0,91
10	11	75,13	3,00	0,89
11	15	78,88	3,15	0,88
12	19	82,56	3,30	0,98
13	13	85,75	3,43	0,86
14	16	88,86	3,55	0,98
15	8	91,94	3,68	0,99
16	*9*	94,23	3,77	**0,74**
17	*2*	96,42	3,86	0,96
18	*14*	98,30	3,93	0,86
19	*12*	100,00	4,00	0,90

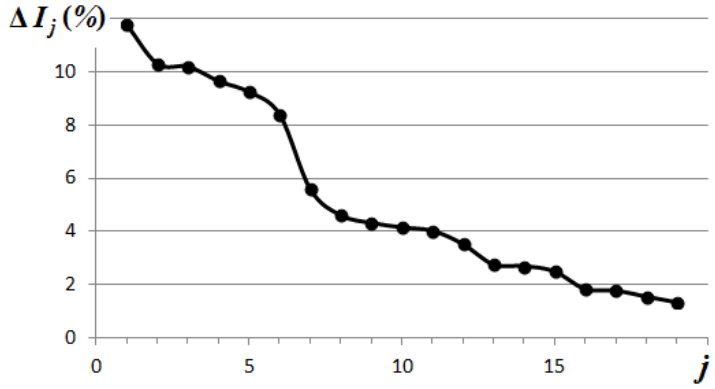

Fig. 1. Decreasing increments in the amount of information when a sequential selection of questions (age group 1)

Figure 1 shows the decrease in the increments of the relative amount of information in the sequential selection. Figure 1 shows that starting from the 7th selection step there is a noticeable decrease in the increments of the amount of information. In the last column of Table 3, a relatively low value $\Delta I_{j+1}/\Delta I_j$ = 0,67 corresponds to the boundary of this transition (this "step") (shown in bold). Consequently, for the first age group, the 6 questions are the most important (the numbers of these questions in the second column of Table 3 are in bold). On the other hand (see "tail" of the graph), it is possible to identify a group of four questions which the first age group considers unimportant. The relatively low value $\Delta I_{j+1}/\Delta I_j$ = 0,73 in the last column of Table 3 also serves as a boundary here (the numbers of irrelevant questions are in italics).

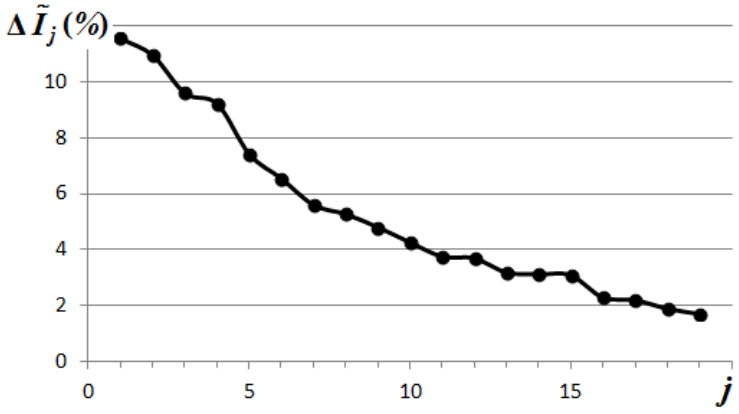

Fig. 2. Decreasing increments in the amount of information when a sequential selection of questions (age group 2)

Compared to the first age group, the second group (see Figure 2 and the last column of Table 4) does not highlight the most important questions so sharply (a relatively smoother drop in the graph). Their number is limited to four questions. However, the number of relatively little questions in the second age group is the same as in the first group, although the numbers of little questions are different (also highlighted in italics in Table 4).

Before turning to the substantive part of the results obtained, let us note the essential point of this research method's general ideology. In model (6), the components of the vector **z** are interpreted as intrinsic latent motives in numerical terms. Thus, the most informative questions identified in the above procedure are strongly related to intrinsic motivation. Mathematically, this means that from the test results for the most informative questions, we can more accurately (than for any other questions) estimate the components of vector **z**, for which, in turn, we can reproduce the test results for the remaining questions with the minor mistake (Pichugin,2019).

Sociological conclusions

Let us now consider the content side of selecting variables based on the results of information order. The data are presented in Table 5.

Table 5. Content characteristics of the work motivation indicators in the young and older age groups of scientific and pedagogical staff (list ordered by statistical procedures)

Scientific and pedagogical staff up to 30	**Scientific and pedagogical staff over 50**
Indicator 12. I enjoy the process of working	Indicator 17. My line manager often does not understand or does not want to understand me
Indicator 11. Someone cannot do the work I do with lower qualifications	Indicator 7. Every year I feel my professional knowledge is growing
Indicator 9. There are often situations in life where you cannot do all the work assigned to you	Indicator 4. Job satisfaction is more important than earning a high salary
Indicator 13. I am not satisfied with the organisation of work in our company	Indicator 6. What I like about my job is that I get to learn new things
Indicator 4. Job satisfaction is more important than high salaries	–
Indicator 3. I have a good relationship with my co-workers	–

Summarising the internal, most significant motives for young scientific-pedagogical employees (up to 30 years old) makes it possible to formulate a vector of increasing motivation to work. Satisfaction from the professional activity is valued due to the qualitative improvement of work processes and, in general, organisation of work based on an optimal ratio of labour costs and wages while maintaining good relations in the work collective.

The structure of critical motives of the older age group (scientific and pedagogical employees over 50 years of age) includes the value of the continuous increase in knowledge and interest in professional development with the active deterrence of the relationship with the immediate supervisor, and the predominance of interest in work overpay.

Thus, the most informative issues highlighted through the above procedure of mathematical statistics, most strongly associated with intrinsic motivation, were aggregated into the critical values of scientific and pedagogical employees of higher agricultural education. This information can serve as an objective basis for making managerial decisions aimed at increasing the motivation of this category of employees to work (Pichugin, 2020).

4. Discussion

A review of the literature on research strategies for studying the motivational field of employees in companies and organisations exposes the relevance of finding new solutions.

Authors C. Gerhardt, N.K. Semmer, S. Sauter, B. Ulrich, A. Elfering conducted a meta-analysis of 557 studies and examined correlations between social stress factors and health and well-being outcomes (Gerhardt et al., 2021).The quantitative analysis of a large body of information, for which the tools of mathematical statistics are essential, is noteworthy. The study found that the most substantial effects were job dissatisfaction, emotional burnout and unproductive work behaviour. All of this harmed people's overall health and well-being. On the one hand, this study confirms the importance of exploratory analysis of the work sphere and job satisfaction. On the other hand, we see the need for mathematical, statistical tools, which are also in active development. These are essential arguments in favour of new research strategies and a specific proposed method for determining the structure of the motivational field of employees.

The issues of professional identity, job satisfaction, and burnout to change jobs have been addressed by Chinese researchers T. Zhang, J. Feng, H. Jiang, B. Pu, Y. Gang (Zhang et al., 2021). The study was conducted in China and analyzed data from a national survey of health care professionals conducted on a stratified multistage sample of 3,236 general practitioners. The proposed indicators of job satisfaction assessment had scale values to enable in-depth analysis of the data through mathematical statistics. This study also confirms the relevance of the methods used in our paper to study personnel satisfaction with work. The issues of job satisfaction are also discussed in the articles (Sung et al., 2021; Golob et al., 2021; Qu et al., 2021).

Questions of quality of work processes in the structure of personnel work satisfaction are raised by the authors F. Alazmani-Noodeh, K. Abdi, H. Ranjbar (Alazmani-Noodeh, 2021). The research results emphasize the significance of goal-setting of work activity in stressful situations. The same conclusions about the influence of an organization's goals and mission on the staff's satisfaction with work are presented in several publications (Javanmardnejad et al., 2021; Nurmeksela et al., 2021; Molina-Hernández et al., 2021; Bakeret et al., 2021).

It is essential to maintain an optimal balance between effort and reward of employees (Ge et al., 2021). This aspect of job satisfaction occupies an important place in Russian organisations and is articulated in other countries (Akuffo et al., 2021; Deng et al., 2021; Keku et al., 2021). In our study, this motivational factor was voiced both in young scientific and pedagogical workers of higher agricultural education and in the older age group. It was the only recurring factor in the structure of the motivational field of the compared categories of employees.

5. Conclusion

This work shows that the application of modern methods of multivariate mathematical statistics opens up entirely new possibilities in sociological research. These methods are undoubtedly objective, which, in turn, makes it possible to draw more valid conclusions from the research results. The overall interpretability of the results, which does not cause any difficulties, also supports the objectivity.

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