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ORIGINAL ARTICLE

The methodology resource suggestion with environmental criteria for rationality agricultural systems estimation

Yu.P. Manko, O.A. Tsyuk, L.V. Tsentulo, O.V. Shemetun

Department of Agricultural Science, National University of Life and Environmental Sciences of Ukraine, Kyiv, Ukraine.
E-mail: tsyuk@ukr.net
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Methodical resource for an integrated estimation of the rationality experimental agricultural systems as a multifactorial and multidimensional object has been created. The research aim was attained by the theoretical (analysis, synthesis, alternative, inversions, judgments, dialectics, statistical examination) and experimental (laboratory, field) methods. In the course of conducting research, according to its programs, the following tasks were performed: 1) 10 criteria for the four bases of the agricultural system: economic, energy, economic and environmental efficiency and scale for values its indicators estimation were worked out; 2) original version of the cluster analysis was elaborated. It makes possible to contain information on the observed criteria indicators of the set investigated agriculture systems characteristics in a single digit compared to the identified scale; 3) an approbation of the proposed methodical complex is carried out on the the comparative estimation example of the 12 variants of the agricultural system: according to the results of 16-year observations in a stationary field experiment.
Keywords: Methodical resource; rationality of the agricultural system; criteria; cluster analysis; economic; energy; economic; ecological efficiency

Introduction

Modern agricultural systems are intended to be the most important anthropogenic deterministic part of natural ecosystems, directing the dominant influence on food and ecological well-being of the humans existence. Its positive influence was always the purpose of agricultural systems, and its reality depends on its rationality.

The objective content of the farming system concept is a way of space and terrestrial organic energy transformation into photosynthesis generated energy by crops that combines organizational and agronomic measures their cultivation to achieve secured resource, energy and productivity feasibility studies for fertility restoration soil and environmental safety of the environment and cultivated products (Manko, 2015).

Meaning of rationality in farming systems, logistics input field, indicating the activities related to economically and environmentally efficient land resources using in the national interest, the local communities' interests and the private interests of individuals (Tretiyak, 2013). Arguments of rational use are its natural properties, relief, climatic and hydrographic conditions, social, economic and environmental conditions, the lands structure, legal relations. The Land Code of Ukraine obligates landowners to ensure the rational use and lands protection. Irrational lands use leads to its degradation with erosion signs, salinization, pollution, waste production and pollutants, excessive drying or flooding, compression, level of humus declining, and as a result is its fertility reducing.

An important condition for the successful research of agricultural systems is the methodological supports availability for effectiveness estimation. The multidimensionality of this research object determines the set of integrated evaluation criteria. The science and practice of agriculture worked out the separate autonomous criteria indicators for effectiveness of agricultural systems estimation. Particulary, the following criteria were cultivated crops productivity, arable lands productivity, the humus balance and soil nutrients, economic efficiency, energy efficiency, environmental safety (Kaminskiy, 2012; Kaminskiy, 2013; Tanchik et al., 2017). However, it remains unworked methodological resource for determining the rationality of the agricultural system estimation, with the participation of all the most important criteria. Such problems state is the reason to choose the purpose of the study with involving formation of methodological resource for integrated estimation rationality experimental farming systems as a multifactorial and many dimensional object.

Research objective: To create a methodical resource to estimate the agricultural systems rationality, which combines its criteria proposals and its indicators scale. Based on the approbation of methodological complex and concluded comparative zonal systems evaluation of rationality agriculture.

Methods

For research objectives realization, the following tasks were accomplished: 1) a methodical complex that unites logistically integrated criteria and scale of the indicators of their indicators, oriented to assess the rationality of agricultural systems was created; 2) the original version of the cluster analysis for the statistical experimental data examination in researches of agricultural systems was obtained, in order to calculate the integral rationality estimation; 3) an approbation of the created methodological complex during the comparative rationality determination of the three agricultural systems. Its based on the long-term results (2001-2017) experimental study of its efficiency in a stationary field experiment.
The methodological substantiation the researches was the agricultures laws: the indispensability and equivalence of plant life factors (Manko et al., 2008; Tanchik et al., 2015), the limiting factor (Libykh, 1936), the combined factors effect (Williams, 1936), return to soil plants fertility that were taken out by plants (Libykh, 1936).
Objective influence on the choice of the object and subjects investigations also made special laws of the agriculture system development: biotechnological priority, determination of the actual productivity of arable land by a specific agro-landscapes ecological potential, adequacy of agriculture and livestock development, the enhanced reproduction of soil fertility as an objective prerequisite for a stable intensification industry, the limiting technological investments (Primak et al., 2010).
The importance and actuality of the investigations problem is a methodological provision for an objective assessment of the agricultural systems rationality due to a significant change in the modern objects paradigm, which determines its future development in the ecologization direction (Shikula et al., 2000). The theoretical methods of research: analysis, synthesis, alternatives, inversions, dialectics, judgments, statistical examination were used to create methodological complex. The criteria of agricultural systems rationality are elaborated according to the following principles: 1) systems suitability of criteria for comparative evaluation of zonal adaptive farming systems. The obvious need for zonal differentiation of the criteria package. 2) the presence of normative values of the criteria and scale for their assessment with an interval between the gradations, adequate, probable the smallest significant difference between them in terms of significance (5%). The recognized axiom of the difference values in agronomic studies, for their good accuracy, is the triple value of the latter (t × Sd%=10%), used by the authors in processing the scales of the proposed criteria, 3) in accordance with the principle of systemicity when working out the variant of cluster analysis, optimal for the statistical estimation of the experiment data used way to convert a multidimensional indicators package of observed features in one-dimensional, expressed as a percentage of average values of those attributes (Manko et al., 2016).

Results

Multifactority and multidimensionality of the researches object (agriculture system), determines criterias for its rationality estimation. The result of our investigations was the package of criteria elaborated in four groups of the basic features of this rationality and its definitions methodology:

1. The economic (productive) efficiency of the agricultural industry is expressed by two criteria. The first is the adequacy criterion (K_a) for the actual productivity of arable land (P_a, feeds units) of its resource-secured value (P_r, feeds units), is calculated from the model: $K_a=P_a/P_r$.

The actual hectares productivity for arable land in the farm (P_r) is calculated by dividing the amount of the main crop production, expressed in feed units (f.u), on the growing area (ha). A hectare productivity of arable land in the economy (P_r) is determined by the existing methods by the share of the amount of the main crop yield expected the production expressed in feed units (t), under the conditions of actual resources available to plants moisture in the root (1 m) layer of soil and digestible nutrients in a layer of 0-30 cm and in fertilizers. Scale of economic efficiency estimation of agriculture by coefficient of adequacy (K_a) determines high adequacy for its value ≥ 0.9; average ≥ 0.7-0.8; low <0.7 (Manko, 2018).
The second criterion of agricultural systems' economic efficiency shows the stability of arable lands productivity in time, determined by the model:
K_s=100-V, where
K_s - coefficient of stability, %
V - coefficient of variation, calculated by variational analysis of actual productivity data for arable land during research years,%.
The scale of stability of arable lands productivity estimation determines high stability with its coefficient Ks ≥ 90%, mean - 80-90%, low <80%.

2. The energy efficiency of the agricultural system is estimated by two criteria. The first of these BAE (accumulation of biological energy agro-ecosystems) equal to the amount of energy accumulated during the year in the main and secondary crops products (Ec) and soil humus energy(Eg): BAE = Ec+Eg │3│

The first component (Eu) is calculated by multiplying mass of the harvest on its normative energy intensity, and the second on the annual balance of humus and its specific energy intensity of 16.7 GJ/t.
The scale of this criterions evaluation defines it low for the BAU module <50 GJ / ha, the average 50-100 and high 100 GJ/ha.
The second criterion is the energy efficiency of farming systems is energy efficiency ratio (Kee), expressed as the ratio of power products consumption grown (Ec, GJ/h) to the non-renewable energy costs of its production (Ez, GJ/ha) by model:
Kee=Ec/Ez│4
The proposed scale for assessing the energy efficiency of the agricultural system determines that it is ineffective in terms of quantity, low-efficiency Kee<2-4, medium-effective Kee = 4-6, highly effective and highly effective Kee 6-8 and >8.

3. The criterion for the economic efficiency of agricultural systems is the sector intensity (Ki), calculated on the ratio of the value of basic products (Bp, UAH/ha) to the cost of man-made costs for its production (Bc, UAH/ha).

Ki=Bp/Bc │5│

Very low intensity expresses the value of the criterion index Ci<1; low-Ci=1; average-Ki=1.1-1.2; and high-Ki=1.3-1.4; very high-Ki 1.5. In addition to the estimation of basic characteristic, the criterion of profitability (P,%), calculated by the ratio of profit value (P, UAH / ha = Bp-Bc), is added to the its receipt cost.

P%=P 100/Bz│6│

The statistically low profitability should be considered <10%, the average-10-50%, high ->50%.

As an integrated energy-efficiency criteria farming systems (EEC) offered a number of power units payback costs of energy production (Kee - energy efficiency ratio) per unit cost payback production process costs (Ki - intensity factor):

EEC=Kee/Ki │7│

Estimation of energy-economic efficiency of the agricultural system is carried out according to the scale of the criteria EEE values: ineffective branch - <2; low efficient industry - 2-3; medium-effective 4-5; highly effective - 5-6; very effective ->6.

4. Indicators for the environmental estimation of the agricultural system are proposed. Index greening field (Ie), the content of which is arable land saturation industrial fertilizers, calculated by the ratio of the amount of chemical fertilizers in active substance (ΣNPK, kg / ha) to total physical mass made of organic fertilizers (ΣO t/ha):

Ie = ΣNPK, kg/ha / ΣO, t/ha │8│

According to this index all system can be divided in industrial agriculture (Ie=>15), ecological (Ie=>0 ÷ ≤ 15) and biological (organic) (Ie = 0).

The content of the second criterion of environmental friendliness in the agricultures field is the level of pesticide loading on the agrolandscape, expressed by the agroecotoxicological index (AETI), it magnitude is determined by the model (Manko et al., 1998):

AETI=10 × $V(1+v)^3/(1+V)^4$+5000 │9│

V-pesticide pollution of the landscape during the season, taking into account their dose, kg / ha and ecotoxicological danger:

V=De/Q × Ic │10│

De-ecotoxicological dose, expressed by the pesticides load on the entire territory of the holding, kg/ha (D=M/S, where M is the total weight of all pesticides (kg) used on the total area of the farm, S-general area, ha);

Q-the average weighted level of ecosystem polution by pesticides (Q=∑(Co × m), where Co is the normative level of ecotoxicological polution of each applied pesticide, which combines information about its toxicological and ecotoxicological properties, conditional units (Manko et al., 1998);

m-the weight of each pesticide is used for the growing area, kg (m=g × s, where g-each preparation dosages, kg/ha; s-areas treated with each preparation, ha. Ic-zonal regulatory indices of the territories capacity to self-purify from pesticides (Manko et al., 1998);

5000 is the constant of the dynamics curve of enzyme processes, which correctly reflects the process of pesticides' destruction in the natural environment.

Estimating the calculated index of AETI, the level of territories pollution with pesticides, uses the four-step scale of danger: if its value is in the range of 0-1, this indicates a low risk, 1-4-medium, 5-7-high, 8-10-large.

Important to estimate the environmental rationality of the agricultural system should be environmental safety criteria and cultivated products. The integral criterion of ecological environments safety is the annual balance of soil humus, expressed by the relative magnitude in dynamics.

Significant negative annual soil humus balance should be considered to reduce its content by ≥ 10%, simple reproduction-no change over the course in the year, extended reproduction-increase of maintenance on ≥ 10%.

Environmental criteria for rational estimation of agricultural systems for the plant products content in economically valuable ingredients, designed to be statistically reliable (t × Sx=10%) relative changes in their content in the experimental system, compared with the recommended variants of zonal agriculture systems.

The same methodological approach should be applied during the comparative evaluation of technological changes caused by the content changes in crop production toxic residues of pesticides, metabolites of mineral fertilizers, heavy metals, and radionuclides.

The demonstration of the application of the worked out methodological complex for the practical evaluation of the agricultural systems' rationality was carried out on the basis of experimental data of observations in the multi-year (2002-2017) stationary field experiment conducted at the NUBiP Agronomic Research Station of Ukraine in the conditions of the natural-agricultural province of the Right Bank Forest-steppe of Ukraine. The objects of the study were 12 variants of the fruit-changing system of agriculture, compiled for three resources gradations support and four gradations of basic cultivation of soil in crop rotation (Table 1).

The subjects of the study-10 functional criteria of agricultural systems' rationality: 1) productivity of arable land; 2) resource adequacy of arable land productivity (Ca); 3) intensity (Ci); 4) stability (Cs); 5) energy efficiency (Cee); 6) profitability (P); 7) biological accumulation of energy (BAE); 8) annual balance of humus; 9) agroecotoxicological index (AETI); 10) the content of heavy metals in samples of plant products.

Table 1 consist of the absolute values of the listed criteria indicators, calculates their relative values and determines the value of the indicators of the integrated criteria with the deviation from the control variant of the agricultural system.

The proposed methodological resource for multidimensional objects estimating by a set of their features, which are agricultural systems, differs from the known positive properties. Its positive was the possibility in the cluster analysis process mathematically simple transformation of this set of absolute values into relative one-dimensional quantities with the calculation of the terminal criterion, containing in one-digit comparable information about the indicators' observation of the criteria components of the set of characteristics of the investigated multifactorial agronomy objects. An important positive point is also the ability to determine the assessment of the objects under study by groups of their features through the given scales of indicators of individual criteria. Specifically, for cluster analysis of agricultural systems, the package of criteria for the four groups of the basic attributes of their rationality is proposed: economic, energy, economic and environmental efficiency. An important property of cluster analysis, applied in the proposed methodological complex, is the adequacy of the vector increasing the modules of observed indicators and increasing the positive effect of research objects. This property allows you to identify the best of their variants, which are characterized by more modules. All relative values of the specified criteria are accompanied by the "+" if they are issued positive effect on the estimation, or "-", if such an effect is negative (reverse dependence). These marks are taken into account when the terminal integral criterion calculating, expressed by the arithmetic average of all criteria, observable basic features of objects.

Table 1. Cluster analysis of functional criteria indicators of rationality investigated systems of agriculture in the experiment results (2002-2017).

Signs of system options agriculture		The values some rationality criteria indicators																						
		The main soil tillage in crop rotation	Productivity of arable land		Adequacy of productivity		Intensity		Stability		Energy efficiency		Profita-bility		BAE		Humus balance		AETI		The content of heavy metals		Integral criterion of rationality, Kr	
System name	Resource content		t/ha	% to the ave-rage	Ka	% to the ave-rage	Ki	% to the ave-rage	Ks	% to the ave-rage	Ke	% to the ave-rage	%	% to the ave-rage	GJ /ha	% to the ave-rage	t/ha	% to the ave-rage	Unit	% to the ave-rage	mg\kg	+% to the ave-rage	%	± to control %
Industrial (control)	Organic fertilizers 12 t / ha, mineral fertilizers 300 kg\ha NPK, ecological	1	11.4	115	1.3	108	1.8	106	84	101	5.3	84	70	91	193	109	0.48	48	0.1	-200	27.3	-113	45	0
		2	10.0	101	1.2	100	1.6	94	84	101	5.3	84	70	91	170	96	0.48	48	0.1	-200	27.3	-113	40	-11
		3	11.6	117.2	1.3	108	1.8	106	84	101	5.3	84	70	91	196	111	0.48	48	0.1	-200	27.3	-113	45	0
		4	10.1	102	1.2	100	1.6	94	84	101	5.3	84	70	91	172	97	0.48	48	0.1	-200	27.3	-113	40.3	-11
Ecological	Organic fertilizers 24 t / ha, mineral fertilizers 150 kg / ha, ecological index 6.25	1	10.9	110.1	1.3	108	1.8	106	82	98	6.2	98	80	104	202	114	1.5	151	0.06	-120	22.9	-94.6	67.4	+49.8
		2	9.9	100	1.1	100	1.7	100	82	98	6.2	98	80	104	185	104	1.5	151	0.06	-120	22.9	-94.6	64	+42.2
		3	11.2	113.1	1.3	108	1.9	112	82	98	6.2	98	70	104	206	116	1.5	151	0.06	-120	22.9	-94.6	68	+51.5
		4	9.6	97	1.1	92	1.7	100	82	98	6.2	98	80	104	180	102	1.5	151	0.06	-120	22.9	-94.6	62.7	+39.3
Biological	Organic fertilizers-24 t / ha, ecological index - 0	1	8.9	90	1.2	100	1.9	112	83	100	7.4	117	80	104	160	90	0.98	99	0	0	22.3	-92.1	72	+60
		2	8.1	81.8	1.1	92	1.7	100	83	100	7.4	117	80	104	148	84	0.98	99	0	0	22.3	-92.1	68.6	+52.4
		3	9.2	92.9	1.2	100	1.9	112	83	100	7.4	117	80	104	165	93	0.98	99	0	0	22.3	-92.1	72.6	+61.3
		4	7.8	78.8	1.0	83	1.7	100	83	100	7.4	117	80	104	143	81	0.98	99	0	0	22.3	-92.1	67.1	+49.1
Average absolute values			9.9		1.2		1.7		82.9		6.3		76.7		177		0.99		0.05		24.2		59.4	

t × Sx	4.5	10

Notes: I-Productivity of arable land, expressed as the content of feed units, in the main and adding products, t\ha; II-Indicators of criteria with inverse influence on the rationality of the agricultural system are indicated with the sign "-"; III-The energy intensity of humus in the calculations of APE is 16.7 GJ/t, and the feed unit is 16.2- GJ/t; IV-The differences significance between the values of the integral criterion of agricultural systems rationality to be determined by the criterion (t × Sd)=10%. The main soil tillage in crop rotation options: 1) Differentiated tillage (control) recommended for Forest-steppe; 2) Nonmoldboard tillage; 3) Periodical plowing tillage under sugar beet and nonmoldbord tillage for other culture 4) Surface nonmoldboard soil tillage. Crops rotation scheme: 1.Perennial herbs; 2. Winter wheat; 3. Sugar beet; 4. Corne for silage; 5. Winter wheat; 6. Corne for grain; 7. Peas; 8. Winter wheat; 9. Sugar beet; 10. Barley.

Tables data shows the value of the integral criterions indicator of rationality for 12 agricultural systems (Kr), calculated on the 10 criterias basis, observed during 16 years (2002-2017) in a stationary experiment. Given the magnitude, the study of the agricultural system should be divided into 5 clusters. Within the limits of each claster, variants of farming systems by the size of Kr do not differ significantly between themselves, and there is a significant difference between clusters. The first cluster combines variants of farming systems with a minimum integral rationality criterion, 40 ÷ 40.3% (industrial model against a background of planar and surface basic soil cultivation). The determining influence on the rationality estimation of these options was their environmental negatives, expressed by the indicators of AETI and the heavy metals content in samples of green almonds. To the second cluster with the size of Kr 45% there were variants of industrial agriculture with differentiated and periodical plowing and non moldboard tillage, which is characterized by high productivity of arable land, but also environmental negatives. The third cluster (Kr=62.7 ÷ 67.4%), filled with variants of ecological and biological agriculture with surface different soil treatment, which is characterized by significantly less control of the productivity of arable land, but also less no ecological negatives. Up to 4 clusters include agricultural systems with the value of Kr=67.4 ÷ 71.9%, which belong to the ecological and biological model with high energy and economic efficiency and environmental safety. These signs became the determinant for variants of the biological system of agriculture with the participation of differentiated and periodical plowing and non moldboard tillage, which revealed the highest indices of the integrated rationality criterion (Kr=72.0 ÷ 72.6%), united in the fifth cluster. Attention is drawn to the significant differences absence between the boundary values of the ecological and biological farming systems, which provides grounds for considering the best rationality of the ecological agriculture option against the background of politsevo-bezpolitsey soil tillage, which has a significant advantage in arable land productivity, economic and energy efficiency, environmental safety of the environment and grown products.
For practical use of the planned integral criterion of the agricultural systems rationality, a scale of its values, created for use on the basis of the statistical norm of the probable presence of significant differences between experimental variants equal or greater than 10%, is used. Therefore, it is logical to consider the system of agriculture irrational if the value of the indicators of this criterion is less than 10%, the low rationality is 10-50%, the average is 50-80%, the high-more than 80%.

Conclusions

The result of the theoretical and experimental research was the creation of a methodological resource for rationality of agricultural systems estimation, which combines the proposals of its criteria and its indicators scales. For the removal of absolute values' multidimensionalness of great signs number of the agricultures systems, offered its unidimensional relative sizes expressed by percents to base. The base sizes at the comparative evaluation of operating the agriculture systems rationality become the actual averages of observant signs, and for the designed systems-resurs supply volums or norms of ecological admittances are expected. The created resource testing, with experimental data using, in a multi-year stationary field experiment, its suitability for comparative rationality of zonal agriculture systems estimation has shown. Beetwemn 12 variants, most rational ecology agriculture system with periodical nonmoldbosrd soil tillage every 4 years with integral criterion Kr=72.6 has been established.

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