Research Article

Algorithm for the implementation of management decision support in agricultural production

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Article History: Received: 10 January 2021; Revised: 12 February 2021; Accepted: 27 March 2021; Published online: 20 April 2021

Abstract— The article application the implementation of an algorithm for making management decisions on alternative options for solving the two-criterial ecological-economic model of location and specialization of agricultural production.
Keywords— Effective solutions; Pareto set; decision-making; normalized matrix; ecological-economic model.

1. Introduction

Today, mathematical methods are used to develop the agricultural industry and the rational use of natural resources, and the scientific foundations for the design, management and optimization of agricultural production are being created. One of the important issues in the implementation of management and use of natural resources on irrigated lands, taking into account the environmental requirements of the tasks is the agricultural production distribution. At the same time, it is necessary to develop environmental models and algorithms for solving the problems of agricultural production distribution.

2. ecological and economic model of agricultural production

In the work [4], a qualitative analysis of the two-criterial ecological-economic model of the placement and specialization of agricultural production was considered. In other work [6] the criteria for the ecological and economic model of agricultural production is formulated.

In this work uses an algorithm for the practical implementation of managerial decision-making in agricultural production based on the results of the two-criterial ecological-economic model.

Formulation of a model of a two-criterion problem of location and specialization of agricultural production with a maximum production and a minimum water consumption for crop and livestock products in the following form:

$$F_1(x,y,z)=\left\{ \min_{j\in J_1^i} \frac{\sum_{i\in I}(\sum_{k\in K_i} a_{ijk}x_{ijk}-y_{ij})}{A_j},\ \min_{v\in J_2^i}\frac{\sum_{i\in I} z_{iv}}{B_v} \right\} \to \max \quad (1)$$

(Maximization in Agricultural Production);

$$F_2(x,y,z)=\left\{ 0,\ \max_{i\in I} \frac{\sum_{j\in J_1^{ii}}\sum_{k\in K_i}\beta_{ijk}x_{ijk}+\sum_{v\in J_2^i}\bar{\beta}_{iv}\, z_{iv}}{Q_i} \right\} \to \min \quad (2)$$

(minimization of water consumption);

$$\sum_{j\in J_1^i} b_{ij}^k x_{ij} - \sum_{j\in J_1^i} q_{ij}^k y_{ij} + \sum_{v\in J_2^i} d_{iv}^k z_{iv} \le T_i^k,\ ,i\in I, k\in \overline{1,L} \quad (3)$$

(Resource constraints).

The two-criterion problem (1)-(3) is reduced to a parametric linear programming problem, the optimum of which is attained at the extreme points of the polyhedron [4].

Pareto set for effective solutions to the two-criterial ecological-economic model of the location of agricultural production are given in table 1, calculations were obtained in work [5].

Table-1

Pareto set for effective solutions based on the results of the ecological-economic model

N	Alternatives					
	1	2	3	4	5	6
α_1	0,37	0,4	0,62	0,72	0,83	0,95
α_2	0,63	0,6	0,38	0,38	0,17	0,05
F_1	1,01	1,02	1,03	1,04	1,05	1,06
F_2	0,33	0,34	0,35	0,38	0,42	0,68
F_A	F_{A1}	F_{A2}	F_{A3}	F_{A4}	F_{A5}	F_{A6}

Here $F_A=(F_{A1},F_{A2},F_{A3},F_{A4},F_{A5},F_{A6})$ is the decision support weighting coefficient for the decision maker. In the next step, we will consider algorithms for finding a weighting coefficient F_{Ai} - $i \in \{1,2,3,4,5,6\}$ to support decision making.

3. ALGORITHMS FOR FINDING THE OPTIMAL SOLUTION OF AGRICULTURAL PRODUCTION

From this given table, we will adopt the criterion of minimization of water consumption in agricultural production as the 1st level criterion, and the criterion of maximizing the production of agricultural production as the 2nd level criterion due to the current water shortage situation of the region. Two main criteria, obtained for comparison: the options of the minimum water consumption $Q=(q_1;q_2;q_3;q_4;q_5;q_6)=F_2=(0,33;0,34;0,35;0,38;0,42;0,68)$ and the maximizing the agricultural production $Z=(z_1;z_2;z_3;z_4;z_5;z_6)=F_1=(1,01;1,02;1,03;1,04;1,05;1,06)$ are obtained.

Let's give a determining of the comparison matrix A of one of the alternatives cited in terms of the solution options of the two-criterial ecological-economic model of the placement of agricultural production.

Let's start with the general hierarchical level, taking into account these conditions, and in it the minimum of water consumption Q and the criteria of maximum production Z are considered. From the decision-maker’s point of view, the criterion of water consumption minimum Q is much more important than the criterion of maximum production Z. So it gives a 5 value to the element (1,2) of the Matrix A $a_{12}=5$. This automatically defines that $a_{21}= 1/ a_{12}=1/ 5$.

$$A = \begin{array}{c c} & \begin{array}{cc} Q & Z \end{array} \\ \begin{array}{c} Q \\ Z \end{array} & \begin{pmatrix} 1 & 5 \\ \frac{1}{5} & 1 \end{pmatrix} \end{array}$$

Elements of the pair comparison matrix of the A_Q-water consumption minimum and A_Z-maximization agricultural production criteria are determined by the decision of the decision maker based on the advantages of the two-criteral ecological-economic model of the placement of agricultural crops and based on the methodology presented in [1].

$$A_Q = \begin{array}{c c} & \begin{array}{cccccc} q_1 & q_2 & q_3 & q_4 & q_5 & q_6 \end{array} \\ \begin{array}{c} q_1 \\ q_2 \\ q_3 \\ q_4 \\ q_5 \\ q_6 \end{array} & \begin{pmatrix} 1 & \frac{1}{4} & \frac{1}{4} & \frac{1}{3} & \frac{1}{5} & \frac{1}{6} \\ 1 & 1 & 1 & \frac{1}{2} & 1 & \frac{1}{3} \\ 4 & 1 & 1 & 1 & \frac{1}{2} & \frac{1}{3} \\ 3 & 2 & 1 & 1 & 1 & \frac{1}{2} \\ 5 & 1 & 2 & 1 & 1 & \frac{1}{2} \\ 6 & 3 & 3 & 2 & 2 & 1 \end{pmatrix} \end{array}$$

$$A_Z = \begin{array}{c} \\ z_1 \\ z_2 \\ z_3 \\ z_4 \\ z_5 \\ z_6 \end{array} \begin{array}{c} \begin{array}{cccccc} z_1 & z_2 & z_3 & z_4 & z_5 & z_6 \end{array} \\ \begin{pmatrix} 1 & 1 & 1 & \frac{1}{2} & \frac{1}{2} & \frac{1}{3} \\ 1 & 1 & 1 & \frac{1}{2} & \frac{1}{2} & \frac{1}{3} \\ 1 & 1 & 1 & 1 & \frac{1}{2} & \frac{1}{3} \\ 2 & 2 & 1 & 1 & 1 & 1 \\ 2 & 2 & 2 & 1 & 1 & 1 \\ 3 & 3 & 3 & 1 & 1 & 1 \end{pmatrix} \end{array}$$

The next step is to calculate the vector of advantages over the given matrix. In the mathematical term, it denotes the calculating the main private vector, and since it is normalized, it becomes a vector of advantages. Comparative weight coefficients are taken into account as the average value of the corresponding paths of the normalized Matrix N elements, and its elements are determined from the ratio of the sum of the elements of each column of the matrix to the comparison of the pairs.

For this matter, we find the comparative weight coefficients of the matrix of comparison of pairs. The comparative weights of the criteria Q and Z can be determined by the sum of the elements of each column in the same column by the ratio. Therefore, to normalize the matrix A, it will be practical to divide the elements of column 1 into the value of $1+\frac{1}{5}=\frac{6}{5}$, the elements of Column 2 into the value of 1+5=6. Then the matrix

$$A = \begin{array}{c} \\ Q \\ Z \end{array} \begin{array}{c} \begin{array}{cc} Q & Z \end{array} \\ \begin{pmatrix} 0,833 & 0,833 \\ 0,167 & 0,167 \end{pmatrix} \end{array}$$

will be formed. It is necessary to find the required comparative weight coefficients w_Q and w_Z, these issues are considered to be the average value of the elements of the normalized Matrix A rows. Further, the average values of the path elements are calculated:

$$w_Q = (0,833 + 0,833)/\ 2 = 0,833,\ w_Z = (0,167 + 0,167)/\ 2 = 0,167$$

will be equal, as a result we get following: $W_A = (w_Q; w_Z) = (0,833; 0,167)$.

The comparative weights of the alternatives indicated in the solution variants of the two-criterial ecological-economic model of the placement of agricultural production, are calculated in the framework of the criteria Q and Z, using the two comparison matrices.

The sum of the elements of the values of water A_Q consumption is (23; 8,25; 8,25; 5,83; 5,7; 2,83) according to the columns of the matrix as the main criterion of the 1st degree. From this, a normalized private vector $W_Q = (w_{q_1}, w_{q_2}, w_{q_3}, w_{q_4}, w_{q_5}, w_{q_6})$ is calculated:

$$w_{q_1} = (0,043 + 0,03 + 0,03 + 0,057 + 0,035 + 0,059)/\ 6 = 0,043,$$

$$w_{q_2} = (0,174 + 0,121 + 0,121 + 0,086 + 0,175 + 0,118)/\ 6 = 0,133,$$

$$w_{q_3} = (0,174 + 0,121 + 0,121 + 0,171 + 0,088 + 0,118)/\ 6 = 0,132,$$

$$w_{q_4} = (0,130 + 0,242 + 0,121 + 0,171 + 0,175 + 0,176)/\ 6 = 0,17,$$

$$w_{q_5} = (0,217 + 0,121 + 0,242 + 0,171 + 0,175 + 0,176)/\ 6 = 0,184,$$

$$w_{q_6} = (0,261 + 0,364 + 0,364 + 0,343 + 0,351 + 0,353)/\ 6 = 0,339$$

is equal, and as a result, we get a following normalized private vector:

$$W_Q = (0,043, 0,133, 0,132, 0,170, 0,184, 0,339).$$

As a 2-level criterion, the sum of the elements of the evaluation matrix of production maximization A_Z is equal to (10; 10; 9; 5; 4,5; 4) by columns. From this, the normalized private vector $W_Z = (w_{z_1}, w_{z_2}, w_{z_3}, w_{z_4}, w_{z_5}, w_{z_6})$ is calculated as following, and it is equal to

$$w_{z_1} = \left(0,1 + 0,1 + 0,111 + 0,1 + 0,111 + 0,083\right)/\ 6 = 0,101,$$

$$w_{z_2} = \left(0,1+0,1+0,111+0,1+0,111+0,083\right)/\ 6 = 0,101,$$
$$w_{z_3} = \left(0,1+0,1+0,111+0,2+0,111+0,083\right)/\ 6 = 0,118,$$
$$w_{z_4} = \left(0,2+0,2+0,111+0,2+0,222+0,25\right)/\ 6 = 0,197,$$
$$w_{z_5} = \left(0,2+0,2+0,222+0,2+0,222+0,25\right)/\ 6 = 0,216,$$
$$w_{z_6} = \left(0,3+0,3+0,333+0,2+0,222+0,25\right)/\ 6 = 0,268$$

and as a result, we get a following normalized private vector:

$$W_Z = (0,101, 0,101, 0,118, 0,197, 0,216, 0,268)\,.$$

Based on this, the presented W_Q and W_Z vector values give the water consumption minimum as 1-level prime criterion, and the corresponding weight coefficients from the point of maximizing the production as the 2-level criterion.

If the values of the elements of the normalized matrix by the columns are the same, then the given comparison matrix will be adequate. If the given comparison matrix is not adequate, then the adequacy index is calculated for it and it provides information about the failure level of adequacy.

Let's look at the calculations of the consistency coefficient of the comparison matrix by sequence.

Conveniently, the matrix A coincidence condition is given as following. The matrix A is coincident, only if it is

$$AW = nW$$

here W -normal vector column is calculated for the comparative weight coefficients w_i.

A matrix is approximated by the average value of *i*- line elements of the normalized matrix N of the comparative weight wt in the case of non-adequacy. It is possible to indicate the following condition processing by defining calculated price as $\overline{w}$

$$A\overline{w} = n_{\max}\overline{w}$$

Here $n_{\max} \geq n$. In this case, if the value $n_{\max}$ is close to *n*, the comparison matrix A will be adequate to it.

For this, the following main conditions should be taken into account.

The discussion is evaluated by the following formulas with the coincidence index (coincidence index) or relation of coincidence (compliance ratio):

$$CI = \frac{n_{\max} - n}{n-1}, \qquad RI = \frac{C(n-2)}{n}, \quad CR = \frac{CI}{RI}$$

Here: CI – relation of coincidence; RI – homogeneous relation; CR –coincidence index; C- the average value of the homogeneous index of matrix randomly formed of the pair comparison, or the value of table amount with the uniformity of the input parameter matrix [2].

To check the coincidence of A comparison matrix the evaluation of the coefficient *CR* is used. If it is $CR < 0,1$, the level of coincidence is considered acceptable. On the contrary, the level of inconformity is high, in which the rules of the expert opinion is considered to have violated during the filling of the Matrix or seriously considering, the decision-maker is advised to check and re-examine the elements of the Matrix A [3].

The value $n_{\max}$ is calculated based on the Matrix equation $A\overline{w} = n_{\max}\overline{w}$, here *i*- equation is in the following form:

$$\sum_{j=1}^{n} a_{ij}\overline{w} = n_{\max}\overline{w},\ i = 1,2,\ldots,n.$$

From this if we consider $\sum_{j=1}^{n} w_j = 1,$ it will be equal to

$$\sum_{i=1}^{n}\left(\sum_{j=1}^{n} a_{ij}\overline{w}\right) = n_{\max}\sum_{i=1}^{n}\overline{w}.$$

Now, we will calculate the coincidence index because the elements of the columns of the normalized matrixes of the matrixes A, A_Q and A_Z are not identical.

1) We calculate the coincidence index for the matrix A:

$$A*W_A = \begin{pmatrix} 1 & 5 \\ \frac{1}{5} & 1 \end{pmatrix} * \begin{pmatrix} 0,833 \\ 0,167 \end{pmatrix} = \begin{pmatrix} 1,708 \\ 0,341 \end{pmatrix},\quad n_{\max} = 2,05\,,\ CI = \frac{\lambda_{\max} - n}{n-1} = \frac{2,05-2}{2-1} = 0,05 < 0,1\,,\ RI = 0\,,$$

$$CR = 0 < 0,1$$

which satisfies the basic conditions and continues the next calculation process.

2) In our experience, the matrix A_Q doesn't match because the elements N_Q of its columns don't match. Matrix consistency A_Q needs to be investigated. We calculate the value $n_{\max}$. So,

$$A_Q * W_Q = \begin{pmatrix} 1 & \frac{1}{4} & \frac{1}{4} & \frac{1}{3} & \frac{1}{5} & \frac{1}{6} \\ 4 & 1 & 1 & \frac{1}{2} & 1 & \frac{1}{3} \\ 4 & 1 & 1 & 1 & \frac{1}{2} & \frac{1}{3} \\ 3 & 2 & 1 & 1 & 1 & \frac{1}{2} \\ 5 & 1 & 2 & 1 & 1 & \frac{1}{2} \\ 6 & 3 & 3 & 2 & 2 & 1 \end{pmatrix} * \begin{pmatrix} 0,043 \\ 0,133 \\ 0,132 \\ 0,170 \\ 0,184 \\ 0,339 \end{pmatrix} = \begin{pmatrix} 0,259 \\ 0,819 \\ 0,812 \\ 1,050 \\ 1,135 \\ 2,100 \end{pmatrix}$$

From this we get

$$n_{\max} = 0,259 + 0,819 + 0,812 + 1,05 + 1,135 + 2,1 = 6,176 .$$

Then we get n=6.

$$CI = \frac{n_{\max} - n}{n - 1} = \frac{6,176 - 6}{6 - 1} = 0,035, \quad RI = \frac{1,24(n-2)}{n} = \frac{1,24 * 4}{6} = 0,826,$$

$$CR = \frac{CI}{RI} = \frac{0,035}{0,826} = 0,042 \cdot$$

From this, the consistency of the matrix A_Q corresponds to the requirement because of $n_{\max} = 6,14645$, $CI = 0,035 < 0,1$, $CR = 0,042 < 0,1 \cdot$

3) We will check whether the matrix consistency corresponds to the requirement. We calculate the value

$$W_Z = (w_{z_1}, w_{z_2}, w_{z_3}, w_{z_4}, w_{z_5}, w_{z_6}) = = (0,101, 0,101, 0,118, 0,197, 0,216, 0,268) \cdot$$

Therefore,

$$A_Z * W_Z = \begin{pmatrix} 1 & 1 & 1 & \frac{1}{2} & \frac{1}{2} & \frac{1}{3} \\ 1 & 1 & 1 & \frac{1}{2} & \frac{1}{2} & \frac{1}{3} \\ 1 & 1 & 1 & 1 & \frac{1}{2} & \frac{1}{3} \\ 2 & 2 & 1 & 1 & 1 & 1 \\ 2 & 2 & 2 & 1 & 1 & 1 \\ 3 & 3 & 3 & 1 & 1 & 1 \end{pmatrix} * \begin{pmatrix} 0,101 \\ 0,101 \\ 0,118 \\ 0,197 \\ 0,216 \\ 0,266 \end{pmatrix} = \begin{pmatrix} 0,615 \\ 0,615 \\ 0,714 \\ 1,203 \\ 1,321 \\ 1,641 \end{pmatrix}.$$

From this we get

$$n_{\max} = 0,615 + 0,615 + 0,714 + 1,203 + 1,321 + 1,641 = 6,111 .$$

Then we will have the followings for n=6:

$$CI = \frac{n_{\max} - n}{n - 1} = \frac{6,111 - 6}{6 - 1} = 0,022; \quad RI = \frac{1,24(n-2)}{n} = \frac{1,24 * 4}{6} = 0,826;$$

$$CR = \frac{CI}{RI} = \frac{0,022}{0,826} = 0,026.$$

Now because of $CI < 0,1$, $CR < 0,1$, the consistency of the matrix A_Z corresponds to the requirements. Proceeding from this, the combined weight coefficient of the assessment of alternatives is based on the calculation of the using the following formula:

$$F_{A_i} = w_{k_1} \cdot w_{k_1 A_i} + w_{k_2} \cdot w_{k_2 A_i} + ... + w_{k_m} \cdot w_{k_m A_i} = \sum_{j=1}^{m} w_{k_j} \cdot w_{k_j A_i}, (i = \overline{1,n}).$$

Thus, we calculate the combined weight coefficient of each of the 6 solution variants of the two-criterial ecological-economic model of the placement of agricultural production.

$$F_A = \begin{pmatrix} 0,043 & 0,101 \\ 0,133 & 0,101 \\ 0,132 & 0,118 \\ 0,170 & 0,197 \\ 0,184 & 0,216 \\ 0,339 & 0,266 \end{pmatrix} \cdot \begin{pmatrix} 0,833 \\ 0,167 \end{pmatrix} = \begin{pmatrix} 0,052 \\ 0,127 \\ 0,129 \\ 0,174 \\ 0,189 \\ 0,327 \end{pmatrix},$$

$$F_{max}=max(F_{A1}, F_{A2}, F_{A3}, F_{A4}, F_{A5}, F_{A6})=0,327$$

From the alternatives presented on the two-criterial ecological-economic model of the placement of agricultural production, the selection of the alternatives $\boldsymbol{F_{A6}=0,327}$, $F_1=1,06$, $F_2=0,63$ will have the highest combined weighting factor, which would be the optimal choice.

4. Conclusion

In the indicators of the solution of the two-criterial ecological-economic model of the placement of agricultural production, there are 6 options, in the solution of results algorithm $F_{A_6} = 0,327$ is in the corresponding solution.

Then the overall production growth is expected to be

$$\nabla F_1 = \frac{F_1^6 - F_1}{F_1} * 100\% = \frac{1,06F_1 - F_1}{F_1} * 100\% = 6\%$$

6% and water consumption savings by

$$\nabla F_2 = \frac{F_2^6 - F_2}{F_2} * 100\% = \frac{0,63F_2 - F_2}{F_2} * 100\% = -37\%$$

37% compared to a unit measurement.

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