Application of artificial intelligence technologies to select the optimal cotton crop root scheme

D. T. Muhamediyeva, M. Rahmonova, M. E. Shaazizova

D. T. Muhamediyeva, M. Rahmonova, M. E. Shaazizova, "Application of artificial intelligence technologies to select the optimal cotton crop root scheme," Proc. SPIE 12637, International Conference on Digital Transformation: Informatics, Economics, and Education (DTIEE2023), 1263712 (27 April 2023); doi: 10.1117/12.2680673

Event: International Conference on Digital Transformation: Informatics, Economics, and Education (DTIEE2023), 2023, Fergana, Uzbekistan

Application of artificial intelligence technologies to select the optimal cotton crop root scheme

D. T. Muhamediyeva*[a], M. Rahmonova[b], M. E. Shaazizova[b]
[a]"Tashkent Institute of Irrigation and Agricultural Mechanization Engineers" National Research University, Tashkent, Uzbekistan; [b]Tashkent University of Information Technologies named after Muhammad al Kharezmy, Tashkent, Uzbekistan

ABSTRACT

The optimal organization of the territory of crop rotation fields and arrays allows you to choose the optimal scheme of cotton crop rotation. An analysis of the current level of development of crop rotations in the object under study showed that the agrotechnical foundations of cotton crop rotations have been studied quite fully, and specific recommendations have been developed for individual soil conditions of the region. At the same time, the organizational and economic substantiation of crop rotations has been little studied, taking into account the production and economic conditions of individual farms. This is especially true for the choice of crop rotation system, crop rotation and assessment of the yield of crop rotation fields, as well as linking the placement plan and crop rotation. Implementation allows you to determine in which field a particular crop should be sown. To solve this problem, a genetic algorithm is used. A computational experiment was carried out.

Keywords: Artificial intelligence, space optimization, genetic algorithm, computational experiment

1. INTRODUCTION

As you know, land is the main means of production in agriculture and a source of expanded reproduction. The most important property of the earth is fertility [1].

With the development of agronomic and economic science, a doctrine was created about the system of crop rotation, by which a person influences the earth and improves its fertility in order to create favorable conditions for the development of cultivated plants. At present, crop rotations, together with the factors of intensification of agricultural production, are a powerful agrotechnical method for increasing the productivity of fields and increasing the efficiency of all agricultural production. Crop rotations create favorable water, food, air conditions of the soil, ensure the fight against weeds and diseases of cultivated plants, i.e. are the basis for increasing soil fertility and farming culture [2].

According to the accepted classification, crop rotations are divided into several types - field, fodder and special. These types are in turn subdivided into types. Field crop rotations include grain-grass, grain-flax-grass, grain-grass-rowed, grain-rowed, cotton-alfalfa, cotton-alfalfa-corn, etc. Forage crop rotations are usually divided into near-farm and hay-mowing-pasture, which cover grass-rowed, grass-field, multi-field, etc. Special crop rotations include vegetable, vegetable-forage, rice, tobacco, fruit-nursery, etc. In the conditions of irrigated agriculture in Uzbekistan, cotton, rice, vegetable-forage and tobacco crops ¬ companies, and in the conditions of rainfed agriculture - grain-row, grain-fallow-fallow and grain-fallow crop rotations [3, 4].

In the system of agriculture of the Republic of Uzbekistan, a special place belongs to the cotton crop rotation. The role of cotton crop rotation is invaluable in the development of cotton growing, increasing its productivity and combating wilt, as evidenced by many years of experience in cotton growing farms.

*dilnoz134@rambler.ru

International Conference on Digital Transformation: Informatics, Economics, and Education (DTIEE2023), edited by Gulchekhra Khalmatjanova, Arthur Gibadullin, Proc. of SPIE Vol. 12637, 1263712 · © 2023 SPIE · 0277-786X · doi: 10.1117/12.2680673

2. MATERIALS AND METHODS

Statement of the problem and the economic and mathematical model for choosing the optimal cotton crop rotation scheme can be formulated as follows [5-6].

Let from S - cotton farms know l - soil differences ($l=1,2,...,L$) and K - recommended crop rotation patterns ($K=1,2,...,K$) for l - soil, A_l - square of l - and soil difference. At $K>1$ for an array l - th soil, a multivariate problem arises of choosing a cotton crop rotation scheme for it, taking into account the combination of fodder crops. In this case, some initial conditions must be met:

- Limited land, labor costs and production resources.
- The need to maintain a balance between the production and use of feed.
- The number of livestock should be determined taking into account the possible volume of fodder production from the fodder wedge of the farm.
- The selected scheme and combination of fodder crops (type) should ensure the highest yield of cotton and other products and increase the economic efficiency of agricultural production on the farm.

The foregoing statement allows one to perform a mathematical formalization of the conditions of the problem. The model is developed on the basis of the general linear programming problem [7-11].

Mathematical model of the problem.

It is required to find the extremum of the linear function:

$$F(x)=\sum_{k=1}^{K}\sum_{l=1}^{L}\sum_{j=1}^{J_0}c_{lj}^{k}x_{lj}^{k}+\sum_{j\in J}\sum_{l=1}^{L}c_{lj}y_{lj}+\sum_{t=1}^{T}\sum_{j=J_0+1}^{J_1}c_j^t z_j^t \to \max \quad (1)$$

Under the following conditions (restrictions):

The area of crop rotation arrays with the -th scheme should not exceed the area of land by l - th soil:

$$F(x)=\sum_{k=1}^{K}\sum_{l=1}^{L}\sum_{j=1}^{J_0}c_{lj}^{k}x_{lj}^{k}+\sum_{j\in J}\sum_{l=1}^{L}c_{lj}y_{lj}+\sum_{t=1}^{T}\sum_{j=J_0+1}^{J_1}c_j^t z_j^t \to \max \quad (2)$$

Sowing area j - th crop in crop rotation arrays must have the dimensions provided for by the crop rotation scheme:

$$x_{lj}^k-\alpha_j^k x_l^k=0, \quad (3)$$

Areas of repeated crops in a crop rotation are determined by the ratio:

$$\sum_{k=1}^{K}\sum_{j=1}^{J_0}x_{lj}^k-\sum_{j\in J}y_{lj}\geq 0 \qquad l=\overline{1,L}, \quad (4)$$

Number of livestock or birds is determined by the ratios:

$$z_j\leq B_j; \qquad j=J_0+1,...,J_1; \qquad -\sum_{t=1}^{T}z_j^T+\beta^{\upsilon}\cdot z_j\geq 0; \qquad \beta_j^{\upsilon}<1; \quad (5)$$

Area of pastures and hayfields used for fodder purposes should not exceed the required

$$\overline{x}^1\leq A^1; \qquad x^z\leq A^z, \quad (6)$$

Volume of production of cotton and other types of commercial products of crop and livestock production should not be less than established from above:

$$\text{a)} \sum_{k=1}^{K}\sum_{l=1}^{L} u_{lj}^{k} x_{lj}^{k} + \sum_{l=1}^{L} u_{lj}^{0} y_{lj} \geq Q_j; \qquad j = 1,2,...,J_0 \tag{7}$$

$$\text{b)} \sum_{t=1}^{T} u_j^t z_j^t \geq Q_j; j = J_0 + 1,...,J_1 \tag{8}$$

If $Q_j = 0$, that decision itself determines the volume of production;

Between the production (including purchased) and the use of feed for fattening livestock and birds, a balance must be maintained:

$$\sum_{j=1}^{J_0}\sum_{k=1}^{K}\sum_{l=1}^{L} v_{lj}^{ik} x_{lj}^{k} + \sum_{j=1}^{J_0}\sum_{l=1}^{L} v_{lj}^{i} y_{lj} + \sum_{\lambda=1}^{z} \overline{v}^{\lambda} \overline{x}^{\lambda} - \sum_{t=1}^{T}\sum_{j=J_0+1}^{J_1} q_j^{it} z_j \geq D_i, \tag{9}$$

$i = \overline{1,m}$, where i - feed type number; the volume of labor resources used should not exceed their availability; in the most stressful periods of the year, it is envisaged to attract them from outside:

$$\sum_{k=1}^{K}\sum_{j=1}^{J_0}\sum_{l=1}^{L} h_{lj} x_{lj}^{k} + \sum_{l=1}^{L}\sum_{j=1}^{J_0} h_{lj}^{0} y_{lj} + \sum_{t=1}^{T}\sum_{j=J_0+1}^{J_1} h_j^t z_j^t + \overline{h}\overline{x}^1 - W \leq T^*, \tag{10}$$

The value of variables must not be negative:

$$\left(\left\{x_{lj}^k\right\},\left\{x_l^k\right\},\left\{y_{lj}\right\},\left\{z_j\right\},\left\{z_j^t\right\},\left\{\overline{x}^1\right\},\left\{\overline{x}^2\right\}\right) \geq 0. \tag{11}$$

Accepted designations in the model: $l = 1,2,...,L$ - numbers of types of soil differences; $j = 1,2,...,J_0$ - numbers of types of cash crops; $j = J_0 + 1,...,J_1$ - livestock and bird species numbers; $k = 1,2,...,K$ - numbers of crop rotation schemes; $i = 1,2,...,m$ - numbers of feed or nutrient types; $t = 1,2,...,T$ - level of productivity of livestock and birds; x_{lj}^k - sowing area j - cultures on lands with l - soil difference at K - th crop rotation scheme; x_l^k - crop rotation area with K - and scheme placed on the lands with l - and soil difference; y_{lj} - replant area j - and cultures on lands with l - and soil difference; z_j - total livestock j - th type of livestock or poultry; z_j^t - livestock j - th type of livestock or poultry with a level of productivity t; $\overline{x}^1$ - searched area of hayfields; $\overline{x}^2$ - desired pasture area; c_{lj}^k - value of gross output from 1 ha j - th crop cultivated on l - th soil difference under the K th crop rotation scheme; c_j^t - the value of gross output received from one head of livestock or poultry j - type at the level of productivity t; u_{lj}^k - productivity j - th culture on l - and soil difference at K - th crop rotation scheme; u_{lj}^0 - productivity j - th culture on with l - and soil difference during re-sowing; u_j^t - productivity j - th culture livestock IF bird level t; $\overline{v}^1$ - hay yield per 1 ha of hay; $\overline{v}^2$ - yield of green mass from 1 ha of pasture; v_{lj}^{ik}, v_{lj}^{k} - feed yield i - species (or nutrients i - th species) with I hectares of crops j - and crops on soils l - and soil difference at K - th crop rotation scheme or re-sowing; q_j^{it} need for one structural head of cattle j - type in i - th feed or nutrient at the production level t; h_{lj} and h_{lj}^0 - labor cost standards per I ha j - and culture cultivated on l - th soil difference, respectively, during primary and re-sowing; $\overline{h}$ - labor costs per I ha of hay; h_j^t - labor costs per I hectare of livestock j - type at the level of productivity t; W - number of attracted labor resources; T^* - availability of labor resources; D_i - the amount of purchased feed; β_j^v - share v - th sex-age group of livestock in the total livestock j - th type of livestock.

To solve the optimization problem, we use a genetic algorithm with artificial selection [3].

Operation of such an algorithm is formed by the sequence of the following steps:

- Creation of an initial population formed $P(0)$ individual chromosomes - the vertices of the complex.
- Crossbreeding operation with population increase $P_{CR}(0) > P(0)$.
- Mutation operation $P_M(0) > P_{CR}(0)$.
- First selection (determination of the worst individuals) without population reduction $P_{SEL1}(0) = P_M(0)$;
- Operation of choice is to replace the values with the best in the whole population.
- Operation of reflection with removal P the worst individuals $P_M(0) < P_{SEL1}(0)$.
- Stretching operation without increasing the population $P_E(0) = P_R(0)$.
- Compression operation without increasing the population $P_I(0) = P_E(0)$.
- Second selection with removal $P_W(0)$ worst individuals $P_{SEL2}(0) = P_I(0) - P_W(0) = P(1)$ and the formation of the population of the next iteration of the P(1) algorithm.

3. RESULTS

The results of solving the problem according to the first option showed that the most effective for the conditions of the region's farms is a 10-field cotton crop rotation with schemes 1:2:7; 2:4:1:3; 1:4:1:4; 2:8. At the same time, the share of cotton in the structure of crops of farms will fluctuate within 70-80%. In accordance with the decision, 16% of the area of irrigated arable land of cotton farms in the region should be occupied by crop rotation with schemes 1:2:7 and 2:4:1:3. On the rest (about 80% or about 170.0 thousand hectares) cotton crop rotation with schemes 2:8 and 1:4:1:4 should be placed. Only $4 of land or 8.5 thousand hectares should be occupied by other crop rotations with schemes 2:4:1:3, 2:6:1:3 and 2:4.

An analysis of the fulfillment of this condition after solving the problem showed the possibility of increasing the productivity of cows from 2000 to 2200 kg while maintaining the existing herd structure. This allows you to get an additional 1260 centners of milk with a cow productivity of 2200 kg. In addition, by increasing the feed rate, you can get an additional 45.2 (445.2-400) centners of cattle meat, 14.7 (114.7-100) centners of poultry meat. Accordingly, the production of grain and other crops will increase, which leads to an increase in the volume of sales.

4. CONCLUSION

With the deepening of economic specialization in the cotton growing zone and the concentration of agricultural production, a further increase in the efficiency of production and the yield of cotton and other crops depends to a large extent on the full development of cotton crop rotations. The urgent tasks of accelerating the pace of development of cotton crop rotations are the expansion of alfalfa, grain legumes and other fodder crops on the sown area of cotton farms, the adjustment of existing crop rotations in connection with the organization of crop rotation agricultural plots based on optimal schemes with bringing their number to a minimum, as well as improving the structure of sown areas of farms, taking into account the requirements of the cotton crop rotation.

REFERENCES

[1] Romanov, V. N., Ivchenko ,V. K., Ilchenko, I. O. and Lugantsev, M. V., Influence of methods of basic tillage in crop rotation on the dynamics of moisture and agrophysical properties of leached chernozem, Achievements of science and technology of the agro-industrial complex, 5, 32-34 (2018).

[2] Niyazaliev, B. I., Influence of organo-mineral composts on cotton productivity, Agrarian science, 2, 5-6 (2016).

[3] Hulugalle, N. R., McCorkell, B., Heimoana, V. F. and Finlay, L. A., Soil properties under cotton-corn rotations in australian cotton farms, Journal of Cotton Science, Papers 4(20), 294-298 (2016).

[4] Naqvi, R. Z., Zaidi, S. S. E. A. and Akhtar, K. P., Transcriptomics reveals multiple resistance mechanisms against cotton leaf curl disease in a naturally immune cotton species, Gossypium arboreum, Scientific reports, 15880, 7 (2017).

[5] Kazemeini, S. A., Moradi, R., Talebbeigi and Valizade, M., Effect of nitrogen and wheat residue on cotton (Gossypium hirsutum L.) yield and weed control, Archives of Agronomy and Soil Science, Papers 3(62), 395-412 (2016).

[6] Locke, M. A., Krutz, L. J., Steinriede, R. W. and Testa S., Conservation management improves runoff water quality: Implications for environmental sustainability in a glyphosate-resistant cotton production system, Soil Science Society of America Journal, Papers 2(79), 660-671 (2015).

[7] Zhang, D. M., Li, W. J. and Xin, C. S., Lint yield and nitrogen use efficiency of field-grown cotton vary with soil salinity and nitrogen application rate, Field crops research, 138, 63-70 (2012).

[8] Lofton, J., Haggard, B., Fromme, D. and Tubana, B., Utilization of poultry litter, tillage, and cover crops for cotton production on highly degraded soils in northeast Louisiana, Journal of Cotton Science, Papers 3(18), 376384 (2014).

[9] Pettigrew, W. T., Bruns, H. A. and Reddy, K. N., Growth and agronomic performance of cotton when grown in rotation with soybean, Journal of Cotton Science, Papers 4(20), 299308 (2016).

[10] Zhang, H., Liu, H. and Sun, C., Root Development of Transplanted Cotton and Simulation of Soil Water Movement under Different Irrigation Methods, Water, Papers 7(9), 503 (2017).

[11] Yang, G. Z., Tang, H. Y. and Nie, Y. C., Responses of cotton growth, yield, and biomass to nitrogen split application ratio, European journal of agronomy, Papers 3(35), 164–170 (2011).