INTERNATIONAL JOURNAL OF BUSINESS

MANAGEMENT AND ACCOUNTING

International Journal of Business, Management and Accounting

Volume 2, No.3, June 2022

Internet address: http://www.ejournals.id/index.php/IJBMA/issue/archive
E-mail: info@ejournals.id
Published by ejournals PVT LTD
Issued Bimonthly
DOI prefix: 10.52325
Potsdamer Straße 170, 10784 Berlin

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MATHEMATICAL MODELING OF THE PLACEMENT OF VEGETABLE CROPS IN THE FIELD OF THE FARM

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Abstract: The article considers and investigates the structure of production of vegetable farms, the size and number of on-farm production units and develops scientific results on the introduction of mathematical modeling of the placement of vegetable crops in the fields of the farm.
Keywords. Vegetable growing, agriculture, fertilizers, transportation, storage, soil fertility, land relations, crop placement, marketable products

The large-scale transformations and qualitative changes carried out during the years of independence of Uzbekistan in the field of agro-industrial complex, the comprehensively balanced policy implemented to optimize sown areas and zoning of agricultural crops have not only increased yields, but also significantly raised the standard of living of the population. The implementation of systemic measures in the agricultural sector made it possible to achieve not only qualitative, but also very tangible quantitative results. Thus, the industry demonstrates stable positive growth rates exceeding 6-7% per year. During the years of independence, the volume of agricultural production has increased in general by more than 2 times.

Vegetable growing in the irrigated zone is one of the most intensive and labor-intensive branches of agriculture. It requires increased expenditures of labor and funds for irrigation, the use of fertilizers, the mechanization of cultivation and harvesting, the transportation and storage of finished products.

The most important task of this industry today is to increase the growth of production and improve quality.

This is significantly influenced by the level of reproduction of soil fertility and the technology of growing crops.

Research institutions of the irrigated zone carry out significant work to substantiate measures that ensure the reproduction of soil fertility. Among them are the development of the scientific foundations of crop rotations and recommendations for improving the culture of farming.

At the same time, in the new economic conditions, the structure of production of vegetable farms, the size and number of on-farm production units are changing, and land lease relations are being introduced. Under such conditions, vegetable crop rotations should be considered as a dynamic system with an annual refinement of the placement of crops in the fields. This is especially important in diversified vegetable farms, where several types of marketable products are cultivated.

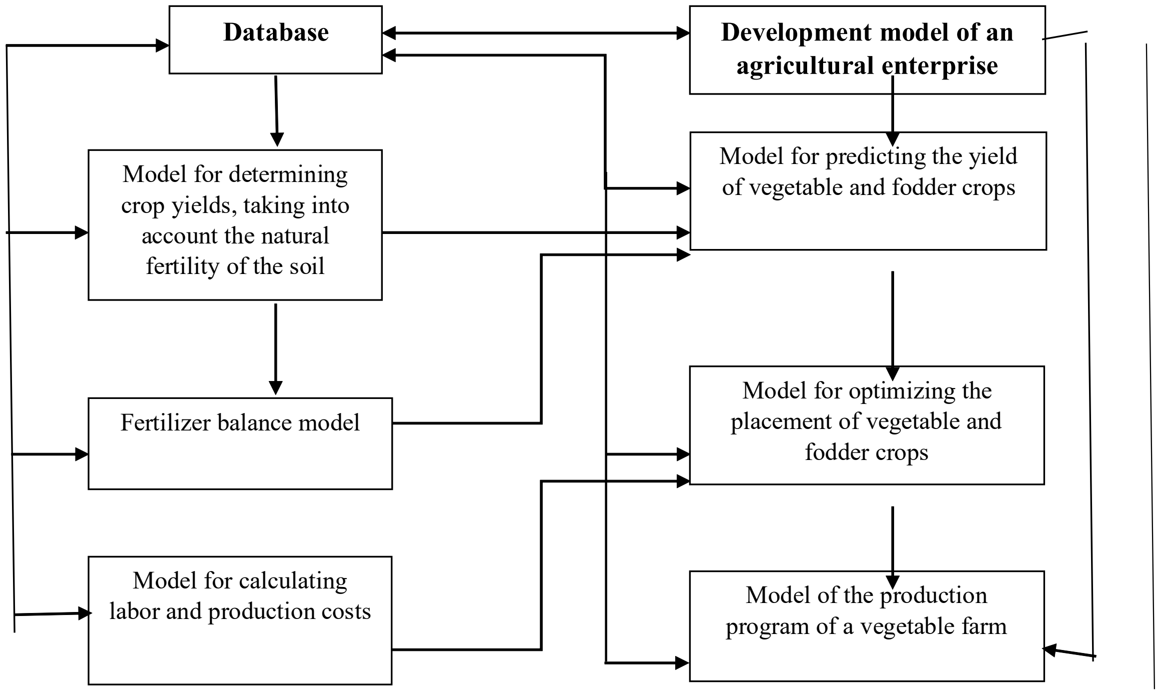

Fig. 1. Informational relationship of the complex of models of the vegetable crop rotation system

In this regard, one of the main tasks is to implement the location of production, taking into account the existing crop rotation scheme, so that approximately equal initial economic conditions are created for all on-farm subdivisions, i.e. by the level of profit or net income per 1 ha of vegetable crops. The complexity of this task lies in the fact that the land owned by on-farm subdivisions have unequal economic valuations. Hence the different costs of labor and funds for the production of a unit volume of the same crop production. Another reason is the lack of differentiated, taking into account these conditions, prices for certain types of agricultural products. Therefore, on-farm units are not interested in growing labor-intensive crops, prices for which are relatively lower than for other crops. It is impossible not to mention the stimulating role of differentiated prices for agricultural products, which is very important for determining the level of specialization of intra-economic units, from the point of view of coordinating their interests among themselves and each of them with the interests of enterprises.

Based on the foregoing, a set of models has been developed in the work: predicting the yield of vegetable crops; balance of mineral fertilizers; calculation of labor and material costs; optimization of the structure of sown areas and placement of vegetable crops in crop rotation [1].

The informational, logical and algorithmic relationship between the models of advanced production is shown in Figure 1.

In this complex, the crop yield model is implemented in two settings. The first is an assessment of the yield of vegetable crops with natural soil fertility. For this, information from the cadastral valuation of the land, average statistical data on the yield of fields is used. In the second formulation, the yield of vegetable and fodder crops is modeled, taking into account the factors of intensification of crop rotation.

Obtaining data on these models can serve as a basis for assessing the suitability of fields for sowing, placement of certain crops.

Models of placement of crops in the vegetable farm implements the problem in the statistical setting for the planned year. It has a block structure, where the requirements of vegetable crop rotation schemes are described in separate blocks. Placement models take into account the conditions for the formation of the structure of sown areas on the farm.

The paper investigates the issues of formation of the initial regulatory, reference, technological and other information, as well as the maintenance of vegetable crop rotations, which constitute the information base of the complex of models.

In the work, a large place is given to the development of yield models of crop rotation crops, taking into account the natural fertility of the soil [2]. To do this, the paper investigated the dependence of the yield of vegetable crops on the amount of fertilizer applied. With the help of the following model is obtained:

$$y = 195{,}5 + 7{,}5\,X_1 + 2{,}2\,X_2 + 0{,}7\,X_3$$

where: X1, X2, X3 - norms of nitrogen, phosphorus, potassium.

Then the yield of vegetable crops in different types of soils is determined. On the basis of the model: $У_{i\ell} = B_\ell \cdot Д_i$ where: B_ℓ – quality score of the ℓ-th soil type; $Д_i$ is the weight coefficient of the i-culture quality score. Here, the weight coefficient is understood as the size of crop yield per 1 bonitet point. It is determined on the basis of long-term statistical data on crop yields in the area under consideration.

The quality score (B_ℓ) of one contour in the ℓ-th type of soil is determined by the formula:

$$B_\ell = (\Sigma B_{\beta\ell} \cdot P_{\beta\ell}) / \Sigma P_{\beta\ell}$$

where: $B_{\beta\ell}$ - bonitet score of the β-th soil difference in one contour; $P_{\beta\ell}$ is the area of the β-th soil difference in one contour of the l-th soil type.

The yields of crops found in this way are differentiated along the contours of the fields. In this case, the formula is used: $У_i^r = (\Sigma У_{i\ell}^r \cdot P_\ell^r) / \Sigma P_\ell^r$

where: $У_i^r$ – yield of the i-th crop in the r-th crop rotation field; P_ℓ^r – size of the area of the ℓ-th contour of arable land of the r-th crop rotation field; $У_{i\ell}^r$ is the yield of the i-th crop in the l-th contour of the r-th crop rotation field.

When placing crops on crop rotation fields, it is important to observe the ratio of nitrogen fertilizers to phosphorus and potassium. For this, the following formulas are used:

$$Ф_\ell = Э1_\ell \cdot N_\ell$$
$$K_\ell = Э2_\ell \cdot N_\ell$$

where: $Ф_\ell, K_\ell$ - application rates of potassium and phosphorus in relation to nitrogen per 1 ha of the ℓ-th circuit; $Э1_\ell$, $Э2_\ell$ - coefficients characterizing the ratio of norms of potassium, phosphorus to nitrogen;

N_ℓ - nitrogen application rates.

The above models and algorithms that implement informational tasks, the output information of which is the input for the crop placement model in the vegetable crop rotation, which is considered as coordinating.

The goal of implementing a coordinating model for crop placement across crop rotation fields is to find such a structure of production and the size of sown areas that would maximize the profit of the farm and each on-farm subdivision, subject to the requirements of crop rotation and other agro technical conditions. At the same time, additional conditions are the limited material, technical, labor and other resources of production, as well as maintaining the ratio of all commercial and non-commercial crops in the vegetable crop rotation.

To record the economic-mathematical model of the placement of crops in the fields of crop rotation in optimizing the structures of sown areas, we introduce the following notation [3,4]:

Indices: i - vegetable products, production resources, agrochemical and economic indicators; j - types of crops in vegetable crop rotation; s - types of crop rotation schemes; h - group of crops in crop rotation; r-number of crop rotation array;

Sets: N - vegetable crops; N_1 - vegetable products; N_2 - production resources; N_3 - agrochemical indicators; N_4 - economic indicators; S - types of crop rotation schemes; R - crop rotation arrays;

Symbols: X_j - sown area of j-crop; X_{hrs} - sown area h - group of crops, r-th array in the s-th crop rotation scheme; Z_i is the calculated amount of the i-th type of economic indicator; U_{ij} - yield j - crops for the production of the i-th product; a_{ij} - consumption rate of the i-th production resource for the j-th crop; W_{ijrs} - the rate of use of the i-th agrochemical indicator for the j-th crop of the r-th array of the s-th crop rotation scheme; P_j is the rate of return of the j-th crop per unit of sown area; K_{jhrs} - coefficient of the ratio of sown areas of the j-th crop in the h-th group of crops of the r-th array according to the s-th crop rotation scheme; Z_{ij} - coefficient of the i-th economic indicator per unit of sown area of the j-th crop; Q_i - the volume of guaranteed production of vegetable products; $\overline{B}_i$, $\overline{\overline{B}}_i$ - lower and upper limits of the use of the i-th production resource; W_{irs} - allowable volume of the i-th agrochemical indicator of the r-th array with the s-th crop rotation scheme; A_{rs} is the sown area of the r-th array of the s-th type of vegetable crop rotation scheme.

Taking into account the accepted notation, the mathematical formalization of the conditions of the problem looks like this:

Wanted to find $\boldsymbol{X_j, X_{hrs}, Z_i}$

at which the objective function reaches its maximum value:

$$\ell_{(x)} = \sum_{j \in N} P_j X_j$$

subject to the following restrictions and conditions:

1. Restriction on the size of labor and material and technical resources:

$$\sum_{j \in N} U_j X_j \geq Q_i \qquad (i \in N_1)$$

2. Restriction on the size of labor and material and technical resources:

$$\overline{B}_i \leq \sum_{j \in N} a_{ij} X_j \; \overline{\overline{B}}_i \qquad (i \in N_2)$$

3. Limitation on the size of agrochemicals for vegetable crops:

$$\sum_{j \in N} W_{irs} X_j \leq W_{rsi} \qquad (s \in S,\ i \in N_3,\ r \in R)$$

4.Restriction on the requirements for the placement of crops and compliance with the ratio of crops in the vegetable-forage crop rotation:

$$\sum_{h \in N} \sum_{s \in S} K_{jhrs} X_{hrs} - X_j = 0$$

$$\sum_{h \in N} \sum_{s \in S} X_{hrs} = A_{rs}$$

5. Restriction on determining the total values of economic indicators:

$$\sum Z_{ij} X_j - \overline{Z}_i = 0 \qquad (i \in N_4)$$

6. Conditions for non-negativity of variables:

$$\left\{ X_j, X_{hrs}, \overline{Z}_i \right\} \geq 0$$

The described mathematical model is implemented on a computer with a solution search method. As a result, the optimal options for the placement of crops in the fields of crop rotation, the size of sown areas, the volume of crop production, production costs and the amount of conditional profit were determined.

Calculations show that as a result of a change in the distribution of crops by crop rotations, the structure of the sown areas of the economy is changing. Particularly significant changes occur, according to computer calculations, in the structure of vegetable crops. The crops of tomatoes and cucumbers are noticeably increasing. Due to a slight reduction in the crops of potatoes, onions, carrots and other crops, this variant of the result is justified and this is due to the fact that the prices for early tomatoes and cucumbers are relatively high than for other types of products produced on the farm. With such ratios, in general, the requirements of crop rotation schemes and crop rotation are not violated.

As the calculation shows, as a result of the transition of the farm to the recommended crop structure, when the level of vegetable crop yield is reached, the cost of marketable products of the conditional profit of the farm increases by more than 20.3% compared to the actual data for 2020.

Thus, the analysis of the results of experimental calculations shows the practical applicability of a set of models, algorithms and software developed in the work to improve the structure of sown areas of suburban vegetable farms and ensures the preservation, reproduction of soil fertility and linking the indicators of the production program with the requirements of crop rotation.

Conclusions and offers. The study allows us to draw the following conclusions and suggestions:

1.The study of the processes of functioning of suburban farms in large cities showed that the development of the production program of farms does not take into account the basic economic and environmental conditions of farming, in particular, accounting for and assessing the natural fertility of the soil, the conditions for the production of environmentally friendly products.

2.The analysis of the structure of placement of crops in the fields of vegetable crop rotation showed that irrational placement of crops, violation of crop rotation requirements leads to a deterioration in land quality, affects the profitability of the economy and individual crops are absent in practice, sufficient, effective and convenient for specialists to use methods of scientifically based placement of crops in vegetable crop rotation and calculation of the structure of sown areas of the economy and their derivative units, taking into account the balance of fertilizers and assessment of soil quality.

3.The conducted research made it possible to determine the structure of the main functional tasks, to establish principles, to formulate the main requirements for the construction of a complex of economic and mathematical models, to develop and propose:

- Block economic-mathematical model for optimizing the structure of sown areas and optimizing the placement of crops in the vegetable crop rotation;

_ Models of soil scoring, fertilizer balance, calculation of labor and production costs, taking into account the peculiarities of the functioning of vegetable farms

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