Improvement of the modeling system of mineral fertilizer use efficiency in agriculture

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Abstract. Chemical preparations used in agriculture and their effects are studied in the article. Also, the effect and composition of mineral fertilizers on the growth of food production was analyzed. At the same time, the interdependence of all the factors used in the production process was determined and evaluated in the evaluation of the additional productivity obtained due to the use of mineral fertilizers. At the same time, the impact of mineral fertilizers used in agriculture on climate change has been scientifically evaluated. It is necessary to take into account that the productivity of agricultural crops is influenced not only by mineral fertilizers, but also by the type of crops, soil fertility, geographical location, and the knowledge and experience of farmers.

1 Introduction

Today, the impact of global climate change is observed not only in the agricultural sector, but also in all sectors of the economy. Naturally, the sharpest changes in climate will have the greatest negative effects on agriculture, which is primarily related to the natural-climatic conditions of production. Although the productivity of production in the agricultural sector is not as high as that of industrial enterprises, it is precisely in the agricultural sector that food security and the production of high-quality raw materials for industry are ensured. Intensification of agriculture, i.e. increasing production, not increasing the consumption of factors, but reducing the amount of consumed resources without changing, is one of the urgent issues.

In this way, the intensification of chemical fertilizers used in agriculture, that is, increasing the efficiency of their use, on the one hand, increases the volume of production in agriculture, and on the other hand, stabilizes the volume of production of mineral fertilizers. It should be noted that the environment is significantly damaged during the production of mineral fertilizers. Therefore, the effective use of mineral fertilizers in agriculture, on the one hand, reduces the impact of industrial enterprises on the environment, and on the other hand, it offsets the expenses in the process of fertilizing crops, and lays the groundwork for the reduction of product prices.

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In fact, effective use of mineral fertilizers in agriculture depends not only on the process of fertilizing crops, but also on the composition of mineral fertilizers. Therefore, when determining the effectiveness of mineral fertilizers, it is necessary to take into account such factors as the level of richness in macroelements in the composition of fertilizers, the biological characteristics of the plant, that is, the level of acceptance of given fertilizers.

2 Methods and Results

Feeding plants in agriculture is a complex process, and it is a complex process to determine the time of feeding them with mineral fertilizers and to what extent the spent mineral fertilizers contribute to the growth of productivity. Because additional yield at the expense of spent mineral fertilizers depends on a number of factors:

- Climate change, plants receiving enough heat for feeding with mineral fertilizers during the vegetation period.
- Technology of feeding with mineral fertilizers.
- It is related to the presence of sufficient macroelements in the composition of mineral fertilizers.

According to the results of the research, the highest efficiency is achieved when all factors of the macro and micro level are fully covered in the feeding process in order to achieve high productivity in the feeding of plants with mineral fertilizers in agriculture . It is also important to give the applied mineral fertilizers on time to increase productivity. Because 4-5 types of mineral fertilizers were used at different times of the vegetation period in the cultivation of one cotton. This means that a change in the time of application of one type of fertilizer will affect the effectiveness of other fertilizers. Therefore, it is necessary to take into account the interdependence of all factors when evaluating the additional productivity obtained from mineral fertilizers.

According to the researcher Smil and his colleagues, as a result of the development of agricultural production and the increase in the use of mineral fertilizers, the increase in food production by 40% in the last 50 years is directly related to the effectiveness of nitrogen fertilizers . Therefore, due to the high importance of nitrogen fertilizer in increasing the productivity of crops in agriculture, in most cases productivity is analyzed depending on nitrogen fertilizer. In the post-nitrogen fertilizer analysis, in most cases, attention is paid to the soil quality.

Due to the low negative impact of nitrogen fertilizer on the environment and its use in all types of agricultural crops, it is appropriate to use this type of fertilizer in the evaluation of the effectiveness of mineral fertilizers.

In our opinion, in addition to mineral fertilizers, factors such as plant type, soil fertility, annual rainfall, vegetation period, and annual heat capacity (S) should be taken into account when increasing the productivity of agricultural crops. Accordingly, a number of approaches have been created for crop yield modeling in agriculture, i.e., forecasting expected changes in the future by analyzing factors affecting yield.

At the beginning of the 20th century, many economists, in the analysis of crop productivity, conducted research on determining the effect of soil fertility on plant productivity, and several mathematical approaches were developed by Mitscherlix.

Since most of the calculations were done by hand, the probabilities of the obtained results were very low, and the calculation process was also complicated. Later, the development of information technologies, the development of new forecasting programs significantly eased the productivity forecasting process, and made it possible to calculate the interrelationship between soil quality, plants and mineral fertilizers.

As a result of the improvement of information technologies, it is possible to analyze not only the effectiveness of mineral fertilizers according to the condition of the soil, but also the technology of applying mineral fertilizers and determine its effectiveness.

As a result of the widespread use of mathematical models in the field, most of the used models are single-factor, that is, focused on the analysis of the effect of only one factor on the studied outcome factor.

Currently, rather than this method, new trends in modeling are calculated by differential equations that are continuous functions. Modeling is essential for predicting differential functions with respect to any desired level of the considered parameter. Also, the transition from a unifactorial model to a bifactorial model and then to a multifactorial model is a common trend in agricultural research . In this regard, Harmsen and his teammates conducted the most research and developed a method of using these equations in agriculture.

Optimizing mineral fertilizers in agriculture required constant scientific research. Because the technology of growing products in agriculture is constantly changing under the influence of objective and subjective factors. It will be possible to determine the interrelationship between the fertilizers used for cotton cultivation and the level of productivity, and on this basis, to develop mechanisms for the effective use of mineral fertilizers in the future.

According to our research, it is appropriate to use the methodology proposed by Cooke and his colleagues in the mathematical modeling used in the assessment of the relationship between the fertilizer used in agriculture and the level of productivity.

In the duration of research, in order to determine the most optimal fertilization option for cotton, in the development of mathematical models for the assessment of the dependence of mineral fertilizers on productivity, fertilization experiments with different doses were carried out on the same crop fields. The obtained results are used to evaluate the effectiveness of mineral fertilizers.

As mentioned above, the effect of nitrogen fertilizer, the most widely used in agriculture, was evaluated as a single nutrient factor together with three different levels of phosphorus, potassium and applied suspensions.

The optimal dose of fertilizer application in cotton production is evaluated, first of all, from a technical economic point of view, and then from the point of view of maximum benefit. Because productivity in cotton farming directly depends not only on mineral fertilizers, but also on other natural factors (soil quality, natural and climatic conditions, geographical location of the cotton field). The study was conducted mainly in Angor district, which is located in the southern region of Surkhandarya region. During the study, priority was given to the yield dependence of more nitrogen fertilizers. Because the most widely used mineral fertilizer in our republic is nitrogen fertilizer (statistical data are presented in Table 2.2.1 of paragraph 2.1). On the one hand, the price of nitrogen fertilizer is cheap compared to other mineral fertilizers, and on the other hand, it is the mineral fertilizer that has the greatest impact on productivity. Therefore, it is appropriate to give high priority to nitrogen fertilizer in the assessment of mineral fertilizers that affect the level of productivity.

When assessing the dependence of mineral fertilizers on productivity, the cotton variety should be selected correctly. That is, Surkhan 14 and Surkhan 16 varieties, which are the most cultivated in the republic, were selected. These varieties are suitable for the southern regions of the republic, and its vegetation period is 130-140 days on average. These varieties yield an average of 35-40 centners per hectare. How much of this yield was obtained as a result of mineral fertilizers, that is, represents experimental coefficients useful for designing a structured mathematical model.

Although this research takes a lot of time, it is important to evaluate the efficiency of the applied mineral fertilizers and to forecast cotton yield in the future.

In the mathematical model, as a result factor, productivity and changes in the soil score and mineral fertilizers are included in the variables. The best estimate of productivity dependence on fertilization is made using the ratio given by Mitscherlich.

$$f(x) = f(0) + a(1 - e^{-bx}) \quad (1)$$

Here: $f(0)$-yield level without mineral fertilizer salting; a -and b - are fixed constants, and the results are determined by the method of least squares by comparing the experimental data.

The model proposed by Mitscherlich was developed with more accuracy and high probability in estimating the relationship between fertilizers and yield. This model makes it possible to estimate the benefit or loss of optimization of cotton fertilization.

Determining the obtained coefficients and obtaining the results in a graphic form was carried out using the STATA program, and the data were statistically analyzed.

As mentioned above, the analysis of the dependence of only fertilizers on productivity in cotton farming, that is, the relationship between fertilizers and productivity is one factor, and the ratio of mineral fertilizers to the mathematical relationship between cotton productivity is the most optimal, and is calculated by Mitscherlich's formula (1).

It was analyzed the influence of mineral fertilizers on cotton productivity based on mathematical modeling using Mitscherlich's formula at the farm "Angor Sardorbek Daler" in Angor District, Surkhandarya Region (Table 1).

Table 1. Effect of mineral fertilizers on cotton yield at the farm "Angor Sardorbek Daler" in Angor district (as of 2022).

N	**N0**		**N50**		**N100**		**N150**	
PK	**c/ha**	**%**	**c/ha**	**%**	**c/ha**	**%**	**c/ha**	**%**
P0 K0	15.8	100	18.7	100	21.9	100	20.3	100
P60 K60	20	126.6	22	117.6	24.7	112.8	28.3	120.4
P70 K70	24	120.0	26.1	118.6	29.3	118.6	33.1	117.0
P80 K80	27	112.5	29.4	112.6	32.9	112.3	37.3	112.7

In this case: PK - phosphorus and potassium fertilizers used for plant nutrition; N - is spent nitrogen mineral fertilizer.

Also, in Table 1, the change in productivity as a result of a change in one type of fertilizer was analyzed. In this case, it is appropriate to use the following dependence model when evaluating the dependence of the change in the amount of fertilizer on the yield:

$$f(x) = f(0) + a * \tanh(bx) \quad (2)$$

In this case, the difference between profit and cost is calculated to calculate profitability. When determining the maximum level of profit, the derivative of the above formula is calculated. It should be remembered that if two or more mineral fertilizers are used, the profitability is calculated based on the following formula:

$$f(x,y) = f(0,0) + \frac{a_1 tanh(b_1 x) + a_2 tanh(b_2 y) + a_3 tanh(b_1 x)\tanh(b_2 y)}{1 + tanh(b_1 x)\tanh(b_2 y)} \quad (3)$$

Here: $f(0,0)$ - is the level of productivity when the factors do not change; a_1b_2 - represents the change in the volume of added fertilizers.

So, as a rule, if 400 kg of ammonium nitrate is applied to one hectare of land (for cotton), the yield can be increased by applying additional fertilizer as follows. In this case, the studied farm area is considered to have the same credit score. When assessing the effect of mineral fertilizers on productivity, all factors were considered constant, and the results obtained as a result of changes in the consumption of mineral resources were analyzed.

In the analysis, when the participation of several factors is observed, the ANOVA test is used to evaluate whether the resulting factor depends only on one type of factors (mineral fertilizers). Because the expected error in such analyzes is high and the possibility of achieving the expected result is limited even when all factors are fully analyzed. That is, the influence of natural factors is high. Therefore, it is appropriate to use the ANOVA test when assessing the dependence of only mineral fertilizers on productivity . Also, the ANOVA test is based on statistical analysis such as the accuracy of monographic observations, the accuracy of the collected data, and the relative closeness of the variance between the factors.

The results in Table 3.2.1 were calculated by ANOVA test of the effect of mineral fertilizers on productivity. Also, the difference in productivity is significant, with the difference between the results being equal to $a = 0.005$ (Table 2).

Table 2. Two-way analysis using the ANOVA test in the cultivation of cotton at the farm "Angor Sardorbek Daler" in Angor District.

Sources of change	SS	Df	MS	F	P-value	F-critical
PK the results of row	1.9670197	3	38.69	43.53	3.48E-07	11.7018
N the results of column	5.41169	3	1.80	21.61	1.23E-04	11.7018
Standard error	127079	7				
Total	20338445	13				

In the ANOVA evaluation of the data in the above table, the proportionality of the studied data was checked based on the Siminov and Levene statistics.

The correlation of the selected data was equal to 0.05 for 4 cases (Table 1), respectively. That is, the risk probability of the obtained results is 5 percent.

Here: SS (Sum Of Squares) is the mean square sum of the amount of mineral fertilizers affecting productivity in the analysis; Df (Degrees of freedom) - the number of groups participating in the statistical analysis; MS (Mean square) – deviation calculated as sum of squares of statistical analysis; F (Statistic) - mutual ratio of variances of factors in the analysis; P-value is the probability that the null hypothesis is correct; F-critical is the value of F (Statistic) at the threshold probability of rejection of the hypothesis.

From the data in the table, we can see that nitrogen fertilizers are more important than potash, phosphorus and nitrogen fertilizers in directly affecting productivity. That is, the results of the N (nitrogen) column are almost 3 times greater than the results of the PK (phosphorus, potassium) row. However, when all three fertilizers are fed by mutual fertilization, i.e. in combination, the possibility of obtaining additional yield is high. That is, in the future, when it is aimed to increase productivity by increasing the amount of mineral fertilizers, increasing the amount of potassium and phosphorus fertilizers to one requires increasing the amount of nitrogen fertilizers up to 3 times.

When analyzed by ANOVA test, we can see that SS is 1.9670197 according to row results and 5.41169 according to column results. Also, the average squares were equal to 386916667 in rows and 18038972 in columns. It can be concluded that it shows that $F_{column} > F_{row}$ (propositional writing).

Based on the soil score of cotton cultivation in the conducted research, it is appropriate to use the ANOVA test on a large scale to determine productivity in the future, to evaluate the effect of mineral fertilizers and soil fertility on productivity.

The results can be showed according to the following diagram.

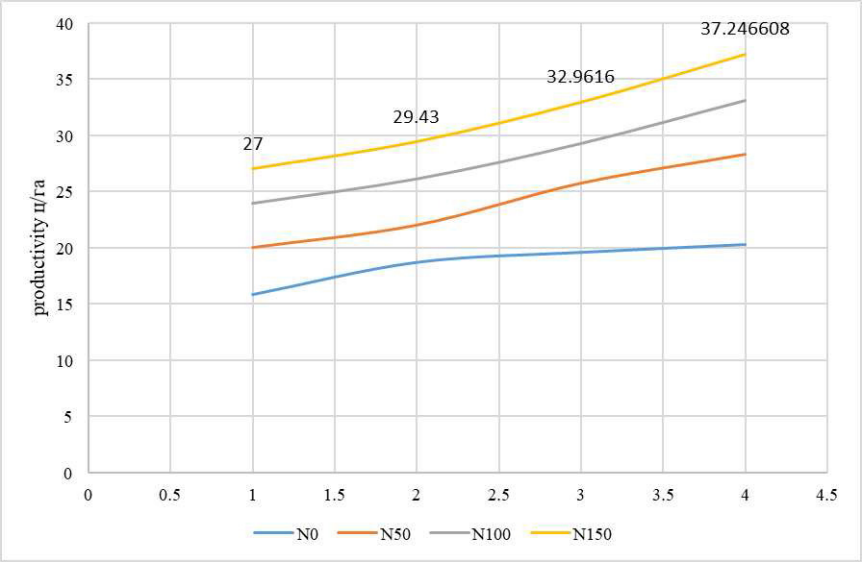

Fig. 1. The dependence of cotton productivity on changes in the amount of mineral fertilizers.

We can see from the picture that the average productivity is 15 centners per hectare without using mineral fertilizers. However, it is possible to increase cotton productivity up to 20 centners due to phosphorus and potassium fertilizers. Also, by increasing the nitrogen fertilizers, i.e., by giving additional nitrogen and phosphorus fertilizers, the productivity can be increased to an average of 37 centners.

Also, with the help of modeling the efficiency of mineral fertilizers use, it is possible to make appropriate planning, reliable forecasting, ensure correct decision-making, apply modern technologies in the field and develop efficiency criteria, evaluate factors for minimizing supply costs and solve other wide-scale issues from a practical point of view.

The most important aspect of modeling the effectiveness of the use of mineral fertilizers in agriculture is based on the possibility of researching a complex system, forecasting its main indicators, determining the level of interdependence of influencing factors, acceptance criteria and stability conditions, evaluating the effectiveness of all elements as a system, expressing the economic laws of development. .

3 Conclusion

In conclusion, the fact that the studied problem of the use of mineral fertilizers in agriculture has a general character at different levels makes it possible to solve it on the basis of the principle of territorial integration. This requires the development of a generalized algorithm of vertically integrated structures of various levels of natural-social, ecological-economic system regulation in the development of agricultural production in the region.

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