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Development Planning and Forecasting Fleet of Tractors and Grain Harvesters of the Agro-Industrial Complex of the Republic of Kazakhstan

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Abstract

The methodological provisions on the justification and forecasting by the method of astrological modeling of the needs of the agro-industrial complex of Kazakhstan in agricultural machinery for plant growing on the basis of data of tractors and combine harvesters are given in the work. Prepared within the framework of the grant Project of the State Institution "Science Committee" of the Ministry of Education and Science of the Republic of Kazakhstan on topic No. AP19678876 "Effective system of macroeconomic instruments for state regulation of innovative development of the agro-industrial complex of the Republic of Kazakhstan".

Keywords: *Strategic Forecasting, Astrological Modeling, Time Series, Variability, Situational Model.*

Introduction

Today, agricultural production operates in a complex unstable environment. Along with this, the consequences of reforming production relations in the agro-industrial complex over the past 25 years require an adequate dynamic approach to the management system and planning of the reproduction process.

In these conditions, one of the effective management tools is strategic forecasting and planning based on an indicative approach, which makes it possible to anticipate problems and solve them in a timely manner, which will ensure the potential for future successful development, not to mention a number of other advantages outlined in the work [1].

When implementing state technical policy in the agro-industrial complex of the Republic of Kazakhstan, it is necessary to take into account the technology of the real state of strategic forecasting of the need for agricultural machinery. Since there is no single universal forecasting method.

Despite some experience in applying the system of strategic forecasting and planning in countries with market economies [1], in Kazakhstan this issue is at the initial stage of implementation due to an insufficiently developed methodology, especially in relation to the agricultural sector.

Due to the huge variety of predicted situations, there is also a large variety of forecasting methods (over 250), but despite this, issues related to forecasting the further development of agricultural sectors in market conditions remain imperfect to this day.

Fateful historical events and, in particular, fluctuations in key indicators of agricultural production in its stable development occur under the influence, mainly, of astrological phenomena [2, 3, …, 7]. In practice, few have yet attached due importance to this, with the exception of works [8 and 9].

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Indicators of climatic conditions are reflected in the long-term variation in the productivity of land. This variation is objectively inherent in the indicator of any crop and in each region [10 and 11].

Therefore, we can, with full justification, use the systematic component of the natural climatic factor in forecasting any indicator (SCNCF) (in agriculture). For example, the variability of arable lands by year of the horoscope (*Mouse, cow, leopard, hare, dragon, snake, horse, sheep, monkey, chicken, dog, boar*). The SCNCF with a cycle duration of 12 years.

To determine the need for the necessary tractors in crop production of the agro-industrial complex of the Republic of Kazakhstan, it is first necessary to forecast the development of the arable land area in the republic. For this purpose, guided by the developed methodology given in the works [8, 9, 10, 11, 12 and 13], calculations were carried out.

The work used data from the Agency of the Republic of Kazakhstan on Statistics and information resources of the Internet.

In solving the tasks set, various general scientific and statistical methods were used. The practical data were processed using a personal computer based on the STADIA 8.0 and Microsoft Excel 2010 application software packages.

During the study and research of the dynamic series, the principle of taking into account the peculiarities of the horoscope years was observed (Mouse, Cow, Leopard, Hare, Dragon, Snake, Horse, Sheep, Monkey, Chicken, Dog, Boar). Or, in other words, fluctuations in the levels of dynamic series, i.e. their deviations from the trend expressing the tendency of changes in levels - a process that occurs over the years of the horoscope, and therefore all changes in climatic factors are accumulated in these years [8, 9, 11, 12 and 13].

The purpose of the study of time series is to obtain its typical characteristics that would allow choosing the most adequate method for forecasting, i.e. pre-forecast analysis. The study began with the study of statistical materials on the development of arable land area.

To conduct further economic analysis in order to draw up a forecast of the arable land area in the Republic of Kazakhstan, it is necessary to establish the presence of a trend in the dynamics of dynamic series.

Due to the cumbersomeness of the upcoming calculations, a working program was developed in the MS Excel environment, where built-in functions of statistical indicators and the VBA language were widely used [14 and 15].

First of all, we will check for gross errors in the sample. We will evaluate this population for gross errors and find the usual and stable estimates of the arithmetic mean and variance using the method given in [16]. We will check them from the point of view of classifying them as gross errors. We will use the Smirnov-Grubbs criterion [16].

In our case, all calculated values of the Smirnov-Grubbs criterion turned out to be less than their tabular values, and the selected values of the studied population cannot be considered gross errors.

Next, the trend of the dynamics of volatility is studied and assessed. Note that deviations of the levels of the dynamic series from the trend are always called volatility. Fluctuations always occur in time; there can be no fluctuations outside of time, at a fixed moment. In our case, fluctuations are expressed in years of the horoscope.

We will test the hypothesis about the existence of a trend in the dynamic series of the area of arable land in the Republic of Kazakhstan.

By the years of the horoscope, we will determine the order of rank (number) of the arable land area in the ranked series P_{yi}, which will not always correspond to the ordinal number (ranks) P_{ti} of the year.

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For the period 2001-2022 in the Republic of Kazakhstan, the equation of the *tendentious trend* for the arable land area has the form:

$$y_{p_t} = 20717 + 442 \cdot t - 32{,}273 \cdot t^2 + 0{,}9994 \cdot t^3$$

and its coefficient of determination was: $R^2 = 0{,}96$.

In order to take into account the annual fluctuation of the area of arable land, i.e. the astrological phenomenon caused by the years of the horoscope and the planet Earth, in the equation we will correct the ordinal number of the year for the difference in ranks (d_i) equal to the studied series and ranks of years in the series, without changing its dynamics and the years of the horoscope. In this way we will estimate the magnitude of variability and model the features of the *i*-th year of the horoscope. As a result, we will obtain *a situational model* that adequately describes the annual variability of the arable land area by the years of the horoscope, i.e.:

$$y_{p_t} = 20717 + 442 \cdot (t_i - d_i) - 32{,}273 \cdot (t_i - d_i)^2 + 0{,}9994 \cdot (t_i - d_i)^3$$

where $d_i = P_{ti} - P_{yi}$; there P_{ti} - year ordinal number in the sample; P_{yi} - horoscope rank.

Regardless of the type and method of constructing this kind of mathematical model, the question of the possibility of its application for the purposes of analyzing and forecasting an economic phenomenon can be resolved only after establishing *adequacy,* i.e. the correspondence of the model to the process or object under study. Therefore, the main goal of studying volatility is to check the adequacy of the studied empirical mathematical production function, and the tasks of statistical study of arable land area volatility are the following:

- measuring the strength of oscillations;
- studying the type of oscillations, decomposing complex oscillations into heterogeneous components;
- studying changes in oscillation over time;
- studying variations in oscillation in a spatial or other set of objects;
- studying oscillation factors and its statistical and mathematical modeling.

Let us briefly dwell on the procedure for determining the oscillation indicators. The main absolute indicators characterizing the strength of oscillations are:

1) the amplitude, or range of oscillations - this is the difference between the algebraic largest deviation from the trend over the period and the smallest algebraic deviation.

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$$A_R = e_{\max} - e_{\min}$$

2) the average linear deviation (by modulus) is calculated using the formula:

$$|\bar{e}| = \frac{\sum_{t=1}^{n} |e_i|}{n} \quad , \qquad (3)$$

where e_i – deviations of actual levels from the trend;

n – number of levels;

3) the main absolute indicator of variability is considered to be the mean square deviation of the residuals. If the period under consideration is a sample, according to which an assessment of the general value of variability in a given process is made for forecasting (extrapolation) purposes, then the assessment of the general mean square deviation of the residuals is calculated using the formula:

$$S_{y(t)} = \sqrt{\frac{\sum_{t=1}^{n} (y_i - y_{pi})^2}{n - P}} \qquad (4)$$

where P – number of trend parameters, including the free term;

y_i – i-th level of the studied indicator;

y_{pi} – calculated value of the i-th level, calculated according to the trend.

In addition to absolute indicators, the number of oscillation indicators should also include relative indicators, the role of which is that only in them is a measure of the intensity of the oscillatory process expressed that is comparable for different series. Relative indicators are constructed as the ratio of absolute indicators to the average level of the dynamic series for the same period. Thus, based on the standard

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deviation, it is possible to calculate the relative indicator $V_{y(t)}$ – the coefficient of oscillation, which is expressed by the formula:

$$V_{y(t)} = \frac{S_{y(t)}}{\bar{y}}$$

The system of oscillation indicators should be supplemented by stability indicators as a property opposite to oscillation. The stability coefficient is a value equal to:

$$\delta = 1 - V_{y(t)} \quad (6)$$

or the complement of the coefficient of oscillation to unity.

An essential characteristic of oscillation is the type of oscillation. A number of methods have been proposed to study the type of oscillation. Thus, M.J. Condel [17] proposed a criterion of peaks of «turning points», or local extremes in a series of deviations from the trend. He proved that with a random distribution of oscillations in time, the number of local extremes is on average equal to:

$$K_m = \frac{2}{3}(n-2), \quad (7)$$

with standard deviation

$$\sigma = \sqrt{\frac{16n-29}{90}} \quad (8)$$

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The criterion of randomness with a 5% level of significance, i.e. with a confidence probability of 95%, is the fulfillment of the inequality:

$$k > \left[k_m - 1.96\sqrt{\sigma_k^2}\right] , \tag{9}$$

Where square brackets mean the integer part of the number, k is the total number of turning points. If this inequality is not satisfied, the trend model is considered inadequate.

In our case, according to the above-described principle, the total number of turning points is determined to be k = 12, which is greater than the calculated value calculated using formulas (7) and (8). The condition of inequality (9) is satisfied, which means that the horoscopic trend model is *adequate*.

Another method for determining the type of oscillation, which takes into account not only the order of alternation of the values of deviations from the trend, but also these values themselves, is autocorrelation analysis. It consists of calculating the autocorrelation coefficients in a series of deviations from the trend with a shift of 1, 2, 3, etc.

The resulting series of autocorrelation coefficients forms the so-called «autocorrelation function». Already by the first-order autocorrelation coefficient, that is, with a shift of one year, one can fairly reliably judge the prevailing type of oscillations. The first-order autocorrelation coefficient is calculated by the formula:

$$A_e = \frac{\sum_{i=1}^{n-1} e_i e_{i+1}}{\frac{e_1^2}{2} + \sum_{i=2}^{n-1} e_i + \frac{e_n^2}{2}} , \tag{10}$$

In our case, the value of the first-order autocorrelation coefficient calculated using formula (10) is A_e=6.07, which shows *the long-term nature and significance* of oscillation.

The absence of significant autocorrelation in the residual sequence e_i can be verified using a number of criteria, the most common of which is the Durbin–Watson *d*-criterion [17]. The calculated value of this criterion is determined using the formula:

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$$d = \frac{\sum_{i=2}^{n}(e_i - e_{i-1})^2}{\sum_{i=1}^{n} e_i^2} \qquad (11)$$

Note that the calculated value of the Durbin-Watson criterion in the range from 2 to 4 indicates a negative relationship; in this case, it should be transformed using the formula $d' = 4 - d$ and further use the value d'.

In our case, the value of the Durbin-Watson criterion calculated using formula (11) is d=130.05, which is greater than its upper critical value (1.54), which means that there *is no autocorrelation* in the statistical material being studied.

If the residual sequence e_i is distributed according to the normal law, then its mathematical expectation must be equal to zero. This condition is checked on the basis of Student's t-criterion according to the formula:

$$t = \frac{\bar{e} - 0}{S_e}\sqrt{n}, \qquad (12)$$

where $\bar{e}$ - arithmetic mean of residual sequence levels e_i; S_e - standard (root mean square) deviation for this sequence.

If the calculated value t less than table value t_α student's t-statistics with a given significance level α and number of degrees of freedom n-1, then the hypothesis that the mathematical expectation of the random sequence is equal to zero is accepted; otherwise, this hypothesis is rejected and the model is considered inadequate.

In our case, the value of the t-criterion calculated using formula (12) (test of the equality of the mathematical expectation of the values of the levels of the residual sequence $e_{i\ zero}$) equals t = - 0,010, which is much less than the critical value (2.073) determined from the Student's table at the significance level α=0,05 and the number of degrees of freedom n-1 or 21-1 = 20). Hence, the null hypothesis is accepted, and the constructed *model is adequate.*

Verification of the compliance of the distribution of the random component with the normal distribution law can be performed by various methods (studies of asymmetry and excess indicators, Westergard method, RS criterion, etc.) [17]. We consider the simplest method based on the RS criterion. This criterion is determined by the formula:

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$$RS = \frac{R_{размах}}{s_{\dot{y}}} = \frac{e_{\max} - e_{\min}}{\sqrt{\sum_{i=1}^{n} e_i / (n-1)}} \quad (13)$$

In our case, the value of the RS criterion calculated using formula (13) is $RS = 3.28$, which falls within the interval between the critical limits (1.95 – 6.55), determined from the table «Critical limits of the RS ratio» [17]. Consequently, the null hypothesis is accepted, and the constructed *model is adequate*.

To conduct further analysis for the purpose of making a forecast of the area of arable land in the Republic of Kazakhstan, it is necessary to establish the presence of a dynamic trend in the dynamic series of the area of arable land.

We will determine the average annual growth rate for aligned levels using the formula:

$$\overline{T} = \sqrt[n-1]{\frac{\tilde{y}_{tn}}{\tilde{y}_{t0}}},$$

Where $\tilde{y}_{tn}$ or $\tilde{y}_{t0}$ – final and initial theoretical levels calculated according to the trend; *n* is the number of levels.

For the Republic of Kazakhstan, the average annual growth rate is:

$$\overline{T} = \sqrt[(21-1)]{\frac{24045.05}{21127.73}} \approx 1.006 \, or \, 100.65\%.$$

For the period 2001-2022, the area of arable land in the Republic of Kazakhstan has increased annually by an average of 0.65% or 137.3 thousand hectares. Let us determine the indicators of variability of the area of arable land in the Republic of Kazakhstan:

1. The range of fluctuations along the trend. Calculated using the formula (2)

$$A_k = 478{,}64 - (-297{,}9) = 776{,}54 \text{ thousand hectares}$$

Let's calculate the range of fluctuations of the actual series using the formula:

$R = y_{\max} - y_{\min}$ or R=25016,0 -21147,7 = 3868,3 thousand hectares,

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Where y_{max} *and* y_{min} – maximum and minimum levels of the dynamic series.

In the Republic of Kazakhstan, the difference between the levels of arable land area in favorable and unfavorable years was 776.54 thousand hectares; the difference between the deviations of actual levels from the trend - maximum and minimum - was 3868.3 thousand hectares.

2) Average linear deviation. We calculate it using formula (3), the numerator value is 3428.99, which is calculated using our program in the MS Excel environment:

$$|\overline{E}| = \frac{\sum_{t=1}^{n}|E_t|}{n} = \frac{3428,99}{21} = 163,285 \quad \text{thousand hectares.}$$

During the period 2001-2022, the area of arable land in Kazakhstan deviated from the trend level by 163.285 thousand hectares.

3) Standard deviation of residuals. Calculate using the formula (5):

$$\overline{S}_{(t)} = \sqrt{\frac{95510{,}248}{21-4}} \approx 237{,}03 \text{ thousand hectares}$$

For the period 2001-2022, the area of arable land deviated from the trend level by an average of 237.03 thousand hectares. Note that this standard deviation of the residuals differs from the standard deviation, which is calculated automatically in our program using the built-in STDEV.B() function. This standard deviation takes into account the trend parameters. Therefore, after selecting the most suitable trend function, it is necessary to enter the number of trend parameters, including the free term.

4) Coefficient of oscillation. Calculate using the formula (5):

$$V_{y(t)} = \frac{237{,}03}{23029{,}64} \approx 0{,}01 \approx 1{,}0\%$$

Thus, the variability of the area of arable land can be characterized: $0{,}01 < 0{,}1$ – as weak and is 1.0% of the average long-term level. This means that the area of arable land in Kazakhstan annually deviated from the long-term level by an average of 1.0%

Let's calculate the stability coefficient using the formula (6):

$$\delta_{уст.} = 1 - 0{,}01 = 0{,}99 \quad \text{or } 99{,}0\% .$$

On average, due to annual volatility, 99.0% of the level calculated by the trend is ensured.

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Let us determine the type of oscillations by the number of «turning points». The average expected number of turning points in a series of randomly distributed deviations of actual levels from the trend is determined by the formula (7):

$$K_m = \frac{2}{3}(21-2) = 12{,}7$$

We calculate the standard deviation using the formula (8):

$$\sigma = \sqrt{\frac{16\cdot 21-29}{90}} \approx 1{,}94$$

.

Based on a number of deviations of actual levels from theoretical ones, we determine the actual number of turning points; the actual number of deviations is equal to or more than 1.4 is equal to

$$K_{\phi} = 6$$

.

Since the number of these deviations is within the limits

$$K_m \pm 2\cdot\sigma = 12{,}7 \pm 2\cdot 1{,}94 = 12{,}7 \pm 3{,}88,$$

Then the hypothesis about the random distribution of fluctuations in the area of arable land over time is confirmed.

Thus, as a result of the above analysis, *an astrological model* of the main trend of dynamics by years of the horoscope was constructed, and the indicators, degree and type of variability of the area of arable land in the Republic of Kazakhstan were determined.

Since the stability indicator calculated above does not reflect the evolution of levels and characterizes the stability of the levels of the series with minimal fluctuations, then to assess the stability of the dynamics of the area of arable land, we will calculate the Spearman rank correlation coefficient, which is determined by the formula:

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$$K_p = 1 - \frac{6\sum d^2}{n^3 - n}, \quad (14)$$

Where d – the difference between the ranks of the levels of the studied series and the ranks of the years in the series (the value is calculated $\sum d^2 = 266$); *n* – number of pairs of observations.

The coefficient of ranks of years and levels of the dynamic series can take values in the range from -1 to 1. If the level of each year is higher than the previous one, then the ranks of the levels of the series and years coincide, i.e. continuity of growth. At Kp= 0, growth is unstable. The closer Kp is to 1, the more stable is the decrease or increase in the studied indicator.

$$K_p = 1 - \frac{6 \cdot 266}{21^3 - 21} = 1 - 0{,}173 = 0{,}827.$$

The calculated coefficient of stability of the dynamics of the arable land area in the Republic of Kazakhstan indicates the presence of a stable increase in the studied indicator. Therefore, the forecast model should provide the established growth rate of the forecast indicator.

A conclusion about the adequacy of the trend model is made if all the above checks of the properties of the residual sequence give a positive result. This means that *the situational (astrological) trend model we have constructed is adequate*.

In the process of analysis, it is important to establish the role of systematic and random variability of the arable land area. For this, the following indicators are calculated:

1. *Total variance*

$$G^2_{общ} = \frac{\Sigma(y_i - \bar{y})^2}{n-1} \quad (15)$$

where y_i – actual levels of the series; $\bar{y}$ – average level of the series for the period; *n* – number of levels. For the Republic of Kazakhstan, the total dispersion is equal to:

This indicator characterizes the overall variability of the arable land area, caused by both natural meteorological factors and controlled factors.

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2. *Residual (random) variance.* Calculated using the formula:

$$G^2_{ocm} = \frac{\sum (y_i - \tilde{y}_{(t)})^2}{n-1} \quad \text{or} \quad G^2_{ocm} = \frac{955098}{21-1} = 47754{,}9\,.$$

This indicator summarizes the deviations of actual yields from the theoretical ones, caused mainly by reasons beyond human control, primarily meteorological conditions.

3. *Coefficient of random variability.* Characterizes the role of random factors in the overall variability of the arable land area, the lower this indicator, the less the arable land area depends on meteorological factors. It is calculated using the formula:

$$\delta = \frac{G^2_{ocm}}{G^2_{o\delta щ}}, \text{ hereof } \delta = \frac{47754{,}9}{1316397{,}47} = 0{,}04 \quad or \quad 4\%.$$

For the period 1997-2022, the role of random factors beyond human control in the annual fluctuations in the area of arable land in the Republic of Kazakhstan was measured at 4%.

4. *Factorial (explained) variance:*

$$G^2_{фак} = G^2_{o\delta щ} - G^2_{ocm}, \text{ hereof } G^2_{фак} = 1316397{,}47 - 47754{,}9 = 1268642{,}57.$$

This indicator characterizes the systematic variability of the area of arable land, caused by controlled factors.

5. *Coefficient of determination.* Characterizes the influence of the value of factor dispersion on the total dispersion, the higher this indicator, the more the area depends on the level of agricultural activities and other controlled factors, and vice versa. For a theoretical series interpolated according to an astrological model, it is calculated using the formula:

$$R^2 = 1 - \frac{G^2_{ocm}}{G^2_{o\delta щ}}, \text{ hereof } R^2 = 1 - 0{,}04 = 0{,}96 \quad or \quad 96\%.$$

Thus, for the period 1997-2022, 96% of the annual variability of the arable land area in the Republic of Kazakhstan depends on controlled factors.

Note that the model we modified describes well the dynamics of the variability of the arable land area, as evidenced by the value of the determination coefficient, which increased from 0.92 (obtained in the initial trend) to 0.96.

6. *Correlation index.* Calculated using the well-known formula:

$$\eta = \sqrt{1 - \frac{G^2_{ocm}}{G^2_{o\delta щ}}} \quad \text{or} \quad \eta = \sqrt{0{,}96} \approx 0{,}982.$$

His indicator characterizes the dependence of the arable land area on the level of agricultural technology, organization and management of production. The dependence between the arable land area and controlled factors in the Republic of Kazakhstan is strong. The correlation coefficient is significant, since according

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to the Fisher criterion, with a confidence probability of 0.95 and n = 21, correlation coefficients over 0.5 are significant.

Next, we will make a point and interval forecast of the area of arable land in the Republic of Kazakhstan for 10 years.

As shown above, it is completely justified to use in forecasting the productivity of agricultural lands the SCNCF in agricultural production, expressed in years of the horoscope, described by the dynamics of variability, which should be understood as statistically measurable long-term variability of the studied indicator of plant growing, in particular, the area of arable land. Therefore, along the length of the forecast period, we copy, i.e. we model the established dynamics of variability by years of the horoscope of the area of arable land.

The count of the order of the year continues along the length of the lead, and we begin the forecast from 2022, the year of the «*Bars*», where astrological modeling is realized, i.e. the energy potential of the events of the current 2021. This year is in the cage ([1]72) – planet Venus, events occur based on the synchronization of Venus. The area is expected to grow by the average value of its long-term variability. For this purpose, the average values for the horoscope cycles are subtracted from the current value of the order of the forecast year: the deviation (fluctuation) of the previous (neighboring) year, the «*Cow*» years (which we will designate as $\bar{k}$), and deviation (fluctuation) of the years of the «*leopard*». Then the calculation moves on to the next year of the horoscope and continues along the entire length of the lead [18]. In this case, for the forecast period $\bar{k} = const$.

After such clarification, the astrological model for predicting the area of arable land by horoscope years in the Republic of Kazakhstan is transformed into this form:

$$y_{(n+i)} = 20717 + 442 \cdot (n + i - \bar{k} - \bar{d}_i) - 32{,}273 \cdot (n + i - \bar{k} - \bar{d}_i)^2 + 0{,}9994 \cdot (n + i - \bar{k} - \bar{d}_i)^3,$$
$$i = 1, 2, \ldots L,$$

where $\bar{k}$ – average value of oscillation of the previous *(adjacent to the beginning of the predicted)* years according to horoscope cycles ($\bar{k} = const$);

$\bar{d}_i$ – average value of variability of the *i*-th forecast year;

L– forecast length (lead period).

The interval forecast is calculated taking into account the annual fluctuations in the area of arable land using the formula:

$$U_i = y_{(n+i)} \pm S_{n+i} \cdot K_i, \tag{16}$$

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Where

$$K_i = t_\alpha \cdot \sqrt{1 + \frac{1}{n} + \frac{(n+L)^2}{\sum_{i=1}^{n+L} t_i^2} + \frac{\sum_{i=1}^{n+L} t_i^4 - 2(n+L)^2 \cdot \sum_{i=1}^{n+L} t_i^2 + n(n+L)^4}{n \cdot \sum_{i=1}^{n+L} t_i^4 - (\sum_{i=1}^{n+L} t_i^2)^2}}, \quad i = L, L-1, \cdots, 1, \qquad (17)$$

there t_α - Table value of the Student's criterion at the significance level

α =0,05 (at degrees of freedom *f*=23-3=20, t_α =2,093);

t_i - ordinal number of the i-th point forecast.

S_{n+i} - the standard deviation of the i-th forecast year, which, taking into account the variability of the arable land area, is recommended to be calculated using the formula:

$$S_{n+i} = y_{n+i\cdot} \cdot V_{y(t)} \qquad (18)$$

For example, knowing the value of the coefficient of variability (0.01), which is defined above, we calculate the standard deviation for 2018 using the given formula:

$$S_{(2018)} = 25646 \cdot 0{,}01 = 256{,}46 \text{ thousand hectares.}$$

Let us make an interval forecast of the average annual level of arable land area in the Republic of Kazakhstan for 2018-2030. To do this, we will first calculate the average area for the year in the middle of the lead period, since the point forecast of the average annual level is equal to the point forecast of the level calculated according to the trend for the year in the middle of the forecast base period. The trend equation for the Republic of Kazakhstan has the form:

$$U_i = y_{(n+i)} \pm V_{y(i)} \cdot y_{n+i} \cdot K_i \qquad (19)$$

The technology for calculating the coefficient (K_i) in the MS Excel environment is given in the work [8].

Probable forecast errors with a probability of 0.95 (Student's *t*-test with the number of degrees of freedom *n*–4 = 21 – 4=17 and a significance level of 0.05 is 2.093) for the forecasted years are given in Table 1. All other calculations are summarized in the same table.

The graph of the results of point and interval forecasting of the area of arable land in the Republic of Kazakhstan is shown in Figure 1.

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As can be seen from this graph, both in point and interval forecasting, the dynamics of the annual variability of the area of arable land by the years of the horoscope is preserved with a noticeable tendency to increase the overall growth rate.

Thus, with a probability of 0.95, one should expect the average annual level of arable land area in the Republic of Kazakhstan for 2018-2030 within the limits given in Table 1 and in the graph, Fig. 1.

Table 1. Results of forecasting the area of arable land in the Republic of Kazakhstan, thousand hectares

Years	Point forecast value	$\pm V_{y(i)} \cdot y_{n+i} \cdot K_i$	Interval forecast value	
			Upper limit	Lower limit
2018	24586,22	± 0,01 · 24586,22 · 2,41	25196,68	23975,75
2019	25099,74	± 0,01 · 25099,74 · 2,43	25727,21	24472,28
2020	25692,24	± 0,01 · 25692,24 · 2,45	26339,95	25044,54
2021	26369,65	± 0,01 · 26369,65 · 2,48	27041,54	25697,76
2022	27137,91	± 0,01 · 27137,91 · 2,51	27839,00	26436,82
2023	28002,95	± 0,01 · 28002,95 · 2,56	28740,05	27265,85
2024	28970,73	± 0,01 · 28970,73 · 2,63	29753,98	28187,48
2025	30047,18	± 0,01 · 30047,18 · 2,74	30893,99	29200,37
2026	31238,24	± 0,01 · 31238,24 · 2,95	32186,09	30290,39
2027	32549,84	± 0,01 · 32549,84 · 3,50	33723,15	31376,54

After receiving the results of forecasting the development of arable land area, using the Microsoft Office suite of office programs and the normative method, using the standards we developed given in the work [19] and the correlation model: $N=f(F_n)$ *(where N is the presence of tractors of all brands in the fleet and* F_n *is the area of arable land in thousand hectares*), we are starting strategic forecasting and planning of the required quantity of agricultural tractors of the agro-industrial complex of the RK.

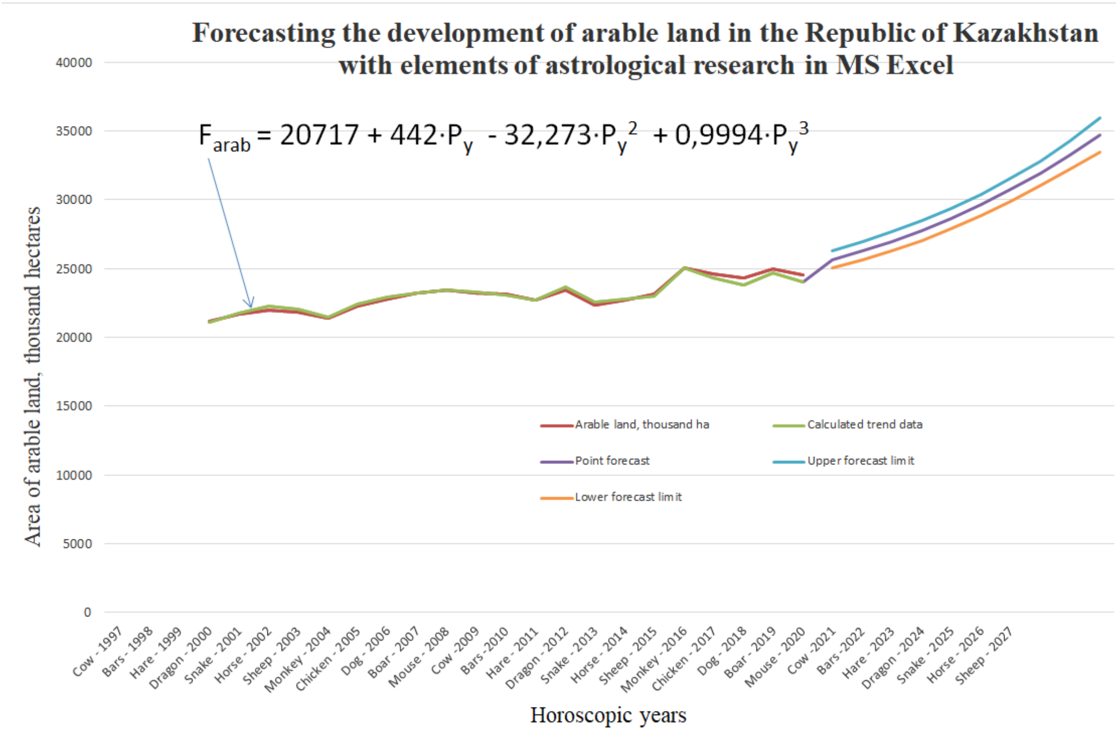

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Figure 1 – Graph of the results of forecasting the area of arable land in the Republic of Kazakhstan

In forecast calculations, the normative method is widely used, according to which the need for tractors and other machines is determined from the expression: $N_i = 0{,}01\times H_i \times F_j$, (20)

where H_i is the standard requirement for the *i*-th type of machines per 1000 ha of arable land or sowing of the *j*-th crop, pcs.; F_j is the area of arable land or sowing of the *j*-th crop, ha.

The standard method was chosen based on its simplicity, sufficient accuracy and lower labor costs when performing calculations. It is the best suited for calculating the standard need for equipment at the level of the region, region and the country as a whole. Based on the collected statistical materials (for the period from 1997 to 2022), the dependence of the required number of tractors on the volume of arable land area was established in the form of a logarithmic correlation model:

$$N = 477276{,}6\times LOG\ (F_n) - 1944724, \qquad (21)$$

with an approximation error of 4.04% and a degree of connection strength of 0.824, which is quite suitable for carrying out predictive calculations, shown in Fig. 6.

All calculations were carried out in MS Excel by constructing a table, a fragment of which is shown in Figure 2, where the first three columns (A, B and C) show the years of the forecast period, the value of the point forecast of the arable land area and the standard need for tractors (conventional reference units, taken from Table 1 [19]). In the fourth column (D), the need for tractors in conventional terms (conventional reference units) is calculated automatically):

= C4*D4; = C5*D5;…;= C13*D13.

In column (E) using the logarithmic correlation model (see Fig. 2) and in column (F) using the conversion factor (Ke=1.8), the value of which is substantiated in the work [19], calculations are carried out automatically for the years of the forecast period, where the forecast quantity is determined according to formula 21 and the standard requirement (=D4/1.8;…; =D13/1.8) for tractors of all brands in physical terms in the fleet of the Republic of Kazakhstan intended for the production of crop products.

Column (G) determines the provision of the tractor fleet of agricultural organizations in Kazakhstan as a percentage by comparing their forecast quantity with the standard requirement for the years of the forecast period:

= 100*E4/F4; = 100E5/F5; …; = 100*E13/F13.

It should be noted that, according to the calculation, a moderate increase in this indicator is observed from year to year. Further, in column (H) the renewal of the tractor fleet is provided based on the standard service life of agricultural machinery (10 years), hence the annual need for the fleet is 10% of the standard number of tractors, i.e.: = 0.10 * F4; = 0.10 * F5; …; = 0.10 * F13.

Based on the data from Figure 2, the constructed graph of the dynamics of the development of the tractor fleet in the Republic of Kazakhstan is presented in Figure 3.

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	A	B	C	D	E	F	G	H	I	J
1	**Forecasting the development of the existing fleet of tractors of all brands in the Republic of Kazakhstan and comparison with its optimal need**									
2	Years	Forecast value of arable land area, thousand hectares	Standard requirement for tractors, conventionally the standard	The need for tractors in conventional terms, conventionally	Forecast number of tractors of all brands, units.	Optimal need for tractors in physical terms, units.	Provision of tractor fleet in %	Fleet renewal, units	Remaining from last year, units.	Number of written-off tractors, units.
3	2020	24045,05			149343					
4	2021	25646,00	12,74	326730,055	162721	181517	89,6	19852	142869	6474
5	2022	26265,76	12,74	334625,841	167900	185903	90,3	20484	147417	15305
6	2023	26967,86	12,74	343570,592	173767	190873	91,0	21200	152568	15333
7	2024	27758,30	12,74	353640,688	180372	196467	91,8	22005	158367	15400
8	2025	28643,05	12,74	364912,508	187766	202729	92,6	22907	164858	15514
9	2026	29628,13	12,74	377462,429	195997	209701	93,5	23912	172086	15680
10	2027	30719,53	12,74	391366,832	205117	217426	94,3	25024	180093	15904
11	2028	31923,24	12,74	406702,095	215176	225946	95,2	26251	188924	16193
12	2029	33245,26	12,74	423544,597	226223	235303	96,1	27599	198624	16552
13	2030	34691,58	12,74	441970,716	238309	245539	97,1	29074	209235	16988
14								238309		149343
15					Forecast number of tractors of all brands, units.			Dynamics of new tractors, units	Dynamics of the balance of old tractors, units.	Dynamics of decommissioned tractors, units.
16	2020				162721			19852	142869	6474
17	2021				167900			40336	127565	21779
18	2022				173767			61535	112232	37112
19	2023				180372			83541	96832	52512
20	2024				187766			106448	81317	68026
21	2025				195997			130360	65637	83706
22	2026				205117			155384	49733	99610
23	2027				215176			181636	33540	115803
24	2028				226223			209235	16988	132355
25	2029				238309			238309	0	149343

Figure 2: Fragment of the results of forecasting the development of the fleet of tractors of all brands in the Republic of Kazakhstan and comparing it with the regulatory need in the MS Excel environment

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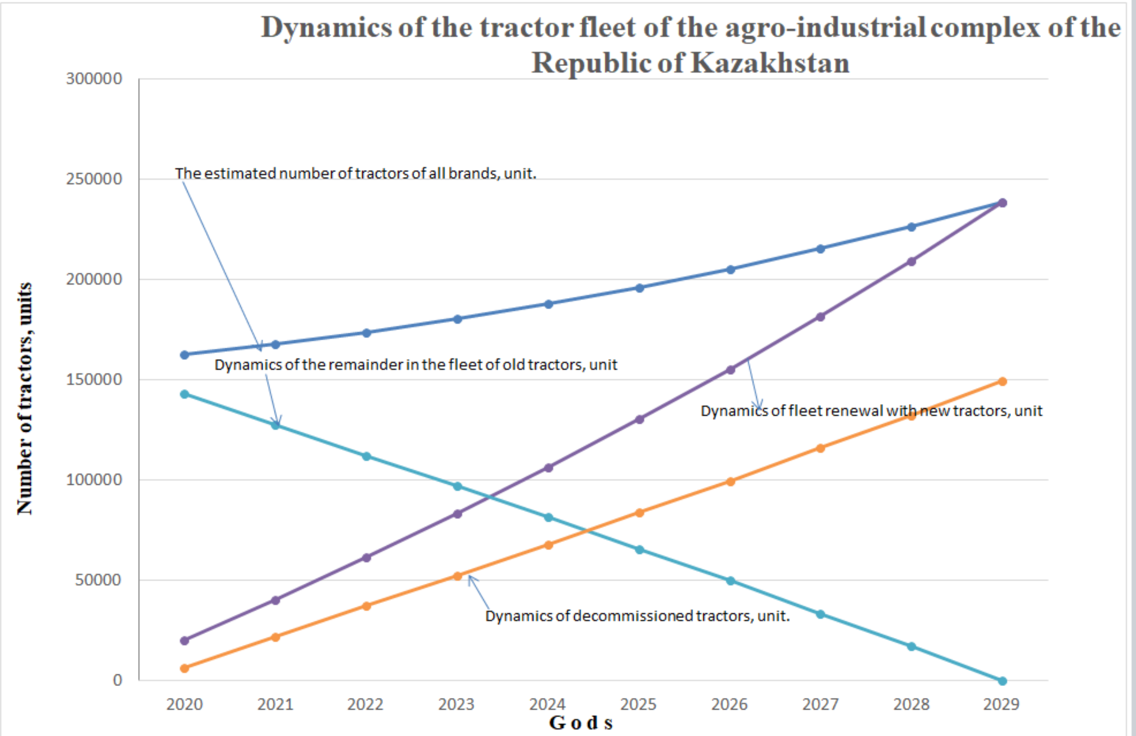

Figure 3: Dynamics of development of the tractor fleet in the Republic of Kazakhstan

The analysis of this graph and the estimated renewal of the tractor fleet for 2021-2030 shows that the replacement of obsolete and worn-out tractors with new ones (209,010 units) will be 100% of the projected need of the tractor fleet of the Republic of Kazakhstan, but in relation to the standard (230,381 units), which is 90.7%. If we take into account that the use of new powerful tractors and the improvement of production technology from year to year allow us to increase labor productivity and reduce costs, then this difference is easily leveled out. At the same time, old worn-out tractors of 10 years ago do not remain in the tractor fleet, which at the end of 2017 amounted to 146,237 units, and at the end of 2026 they are completely written off (see Fig. 2, column J14), where the number of all written-off tractors for 2016-2026 is 146,237 units (see Fig. 2 and 3).

Based on the above methodology, research and forecasting were also conducted for the required number of grain harvesting combines of the agro-industrial complex of the Republic of Kazakhstan. Here, as a criterion for testing the hypothesis about the statistical significance of the dependence of empirical data, Student's t-criterion was adopted. An analysis of gross errors was carried out from the standpoint of the economic meaning of the phenomena under study using the Smirnov-Grubbs criterion.

According to the years of the horoscope, the rank order of the studied indicator was determined, i.e., the ranked time series, and thus its annual variability was taken into account due to the astrological phenomenon, caused by the years of the horoscope and the planet Earth.

In order to analyze and forecast the ongoing phenomenon, an astrological model of the development of the area of grain crops was built:

$$F_z = 12719 + 1019{,}9 \times Ln(P_y). \qquad (22)$$

Its adequacy and accuracy were established using the approximation error criterion (Ɛ=3,6%), coefficient of determination (R^2=0,79), Spearman rank correlations (0.629>0.3597), R/S criteria (4.02<6.55), etc.

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The presence of autocorrelation, the degree of variability and stability, the correlation of M.J. Condel ranks; Durbin-Watson; randomness and turning points, etc. were also checked.

The graph of the results of point and interval forecasting of the area of grain crops in the Republic of Kazakhstan is shown in Figure 4, where the dynamics of the annual variability of the area of grain crops by the years of the horoscope is preserved with a noticeable tendency to increase the overall growth rate.

The results of the calculation for forecasting the development of the area of grain crops in the Republic of Kazakhstan, from MS Excel were summarized in Table 2.

A fragment of the calculation for forecasting the development of the fleet of grain harvesters of all brands in the Republic of Kazakhstan and a comparison with its standard requirement is shown in Figure 5. Note that an interesting trend is observed in the calculation. The annual renewal of the fleet with new combines at the level of 10% (as is customary in practice) leads to oversaturation of the fleet of combines and their premature write-off before their service life, i.e. less than 10 years of operation.

Based on the forecast calculation (Fig. 5), the constructed graph of the dynamics of the development of the grain harvester fleet in the Republic of Kazakhstan is presented in Figure 6.

Table 2. Fragment of the forecast of the area of grain crops in the Republic of Kazakhstan, thousand hectares

Years	Point forecast value	$\pm V_{y(i)} \cdot y_{n+i} \cdot K_i$	Interval forecast value	
			Upper limit	Bottom line
2021	15824,11	$\pm$ 0,05 · 15824,11 · 2,41	17597,05	14051,17
2022	15871,55	$\pm$ 0,05 · 15871,55 · 2,43	17660,49	14082,62
2023	15916,89	$\pm$ 0,05 · 15916,89 · 2,45	17724,22	14109,56
2024	15960,30	$\pm$ 0,05 · 15960,30 · 2,48	17789,27	14131,32
2025	16001,93	$\pm$ 0,05 · 16001,93 · 2,51	17857,12	14146,74
2026	16041,93	$\pm$ 0,05 · 16041,93 · 2,56	17930,10	14153,76
2027	16080,42	$\pm$ 0,05 · 16080,42 · 2,63	18012,18	14148,66
2028	16117,52	$\pm$ 0,05 · 16117,52 · 2,74	18110,93	14124,10
2029	16153,31	$\pm$ 0,05 · 16153,31 · 2,95	18243,02	14063,59
2030	16187,88	$\pm$ 0,05 · 16187,88 · 3,50	18454,69	13921,07

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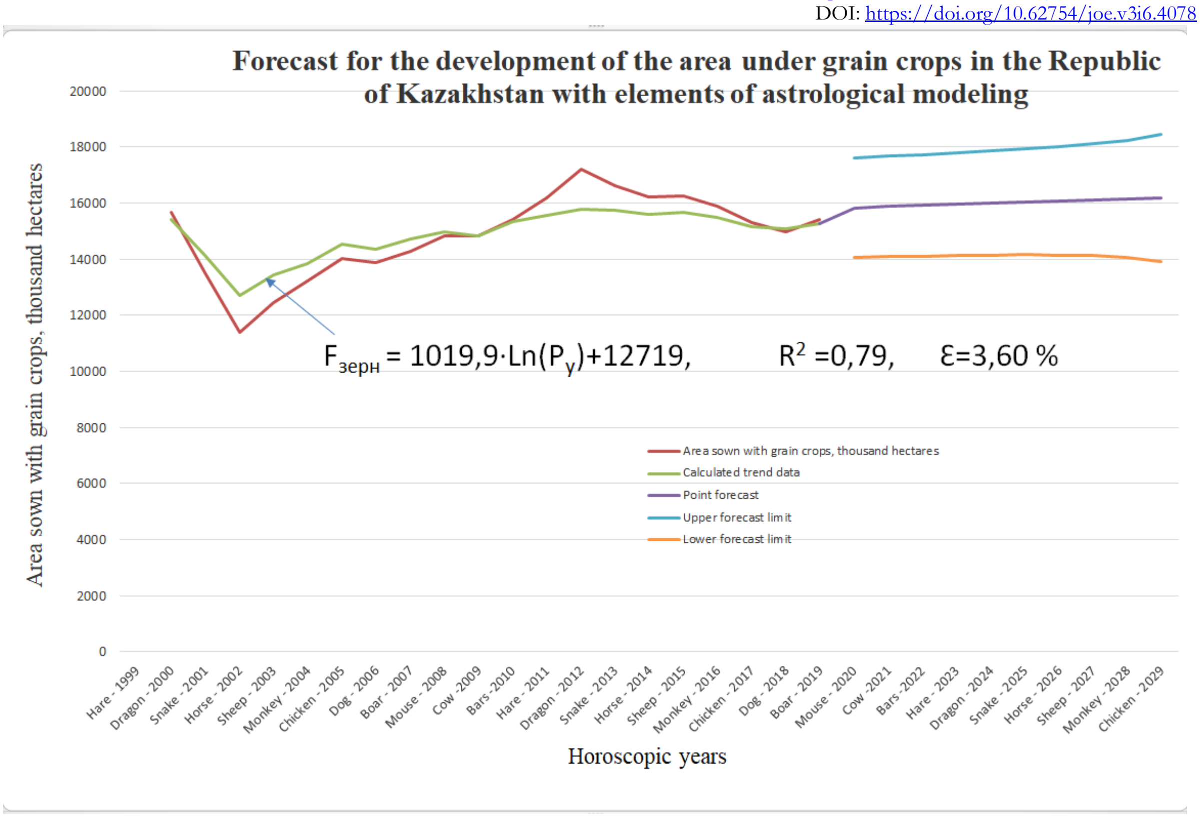

Figure 4: Forecast schedule for the development of the area of grain crops in the Republic of Kazakhstan

Analysis of the graph (Fig. 6) and the calculation results taking into account the specified optimal rate of renewal of the grain harvester fleet for 2019-2030 (Fig. 5) shows that the provision of the fleet increases annually by 5% and from 2025 this figure reaches 100%. At the end of 2030, all old combines from 10 years ago (44,331 units) are completely written off. In the fleet, the replacement of obsolete and worn-out combines with new combines in 2031 will amount to 65,649 units (see Fig. 5).

Forecasting the development of the existing fleet of combine harvesters of all brands in the Republic of Kazakhstan and comparison with its optimal need

Years	Forecast value of the area sown with grain crops, thousand hectares	Standard requirement for combines, conditional combine per 1000 hectares	Demand for combines in conventional terms, us.et.comb.	Forecast number of combines of all brands, units.	Optimal need for combines in physical terms, units.	Availability of combine harvesters fleet in %	Fleet renewal, units	Remaining from last year, units.	Number of decommissioned combines, units.
2019	15253,36	6,88	104943,12	44331	61731	71,8			
2020	15824,11	6,88	108869,87	48031	64041	75,0	4737	43293	1037
2021	15871,55	6,88	109196,29	51386	64233	80,0	5068	46318	1713
2022	15916,89	6,88	109508,21	54754	64417	85,0	5401	49354	2033
2023	15960,30	6,88	109806,84	58133	64592	90,0	5734	52399	2355
2024	16001,93	6,88	110093,29	61523	64761	95,0	6068	55455	2678
2025	16041,93	6,88	110368,50	64923	64923	100,0	6404	58519	3004
2026	16080,42	6,88	110633,32	65078	65078	100,0	6419	58660	6263
2027	16117,52	6,88	110888,51	65229	65229	100,0	6434	58795	6284
2028	16153,31	6,88	111134,74	65373	65373	100,0	6448	58925	6303
2029	16187,88	6,88	111372,62	65513	65513	100,0	6462	59052	6322
2030	16221,32	6,88	111602,71	65649	65649	100,0	6475	59174	6340
							65649		**44331**

Figure 5: Fragment of the results of forecasting the development of the fleet of combine harvesters of all brands in the Republic of Kazakhstan and comparing it with the regulatory need

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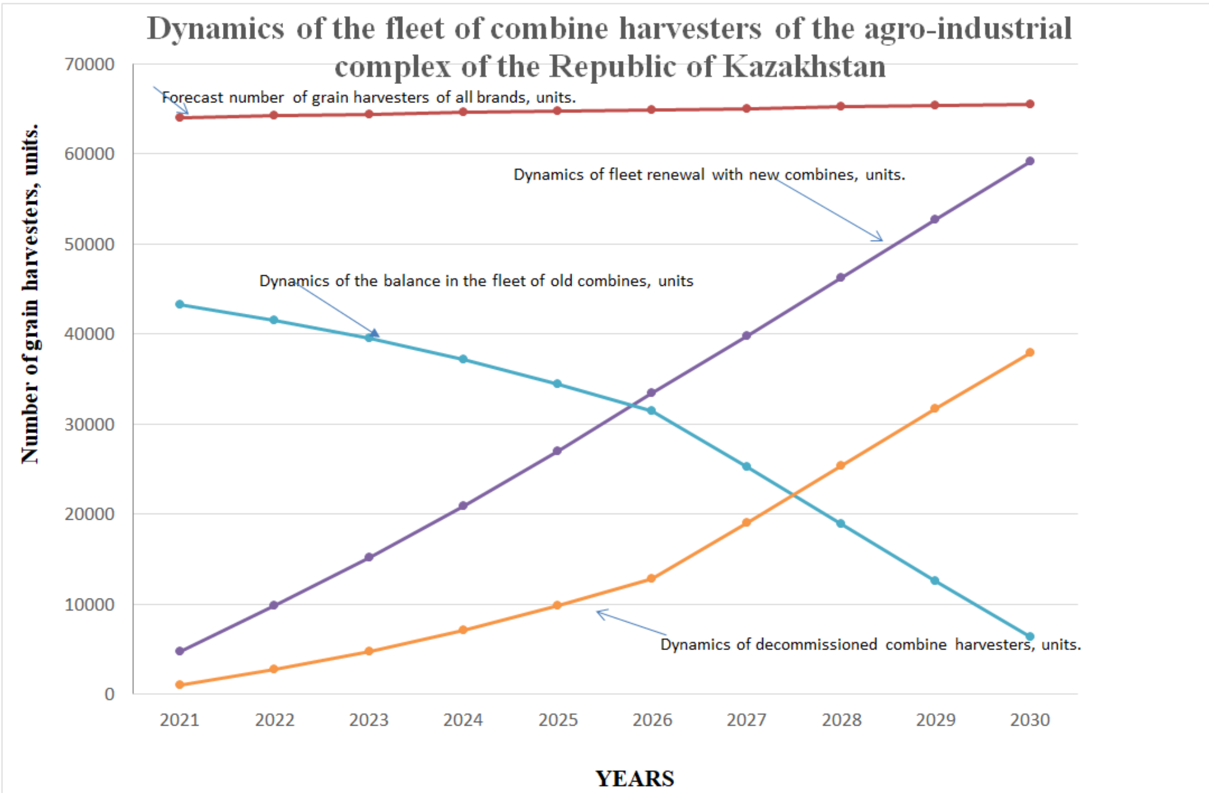

Figure 6: Dynamics of development of the fleet of combine harvesters in the Republic of Kazakhstan

In connection with the above situation, there is a need to find the optimal level of renewal of the combine fleet. For this, we use the «Parameter Selection» tool of MS Excel and determine the annual optimal level of renewal of the combine fleet, which is 9.863%. After substantiating the value of this indicator in this table, a fragment of which is shown in Figure 5, the annual optimal number of deliveries of new combines (column H) and the optimal level of write-off of obsolete and worn-out combines (column J) are automatically generated. The proposed forecasting technology was tested in the production conditions of the «Information and Computing Center of the Agency of the Republic of Kazakhstan on Statistics», Almaty and in the Republican Association of Agricultural Cooperatives «AgroSoyuz Kazakhstan». The assessment of the quality and reliability of forecasting are given in the work [19, 20].

The main results of scientific research aimed at developing astrological models and effective forecasting of agricultural production indicators, tested on the materials of the Republic of Kazakhstan, have been adopted by entrepreneurs and managers of the agro-industrial complex of the Republic of Kazakhstan.

The implementation of the results of the designated studies allows organizations of the agro-industrial complex of the Republic of Kazakhstan to achieve innovative, economic and social effects.

Conclusion

The proposed methodological approaches allow to supplement and clarify the existing ideas about the development trends, branches of agriculture in the Republic of Kazakhstan, as well as to forecast the dynamics of its development. The developed working program in the MS Excel environment and the methodology for long-term forecasting of indicators of agricultural development are quite acceptable for forecasting other indicators of agriculture; the developed models for forecasting the need for agricultural machinery allow to improve the issues necessary for the implementation of economic and organizational measures to improve the functioning of agricultural production in the Republic of Kazakhstan. The innovativeness of the proposed forecasting technology lies in the fact that for the first time it uses an astrological approach to forecasting production indicators taking into account the fluctuations not in the sample as a whole, but individually for each year of the horoscope, which increases the accuracy of the forecast.

The technologies for constructing an astrological model presented in the work can be used as a practical tool for solving a number of planning and analytical tasks, such as: planning, forecasting and analysis of enterprise activities.

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