MATHEMATICAL METHODS IN ECONOMICS

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TO THE ISSUE OF ESTIMATION THE COSTS REFORESTATION

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Abstract

We discuss the relationship between the frequency of forest fires in the Russia and the bursts of solar activity. We demonstrate the cointegration between the two variables and estimate the parameters of the model involving a Fourier series. The model is then verified against the data and used to forecast the burned area. Such forecasts can be used to estimate the volume of investments needed for reforestation and to model a variety of trends that reflect the functioning of the timber industry.

Keywords: area of forest fires, model of time series

In the countries having considerable forest resources, the timber industry is important part of national economy. The wood is a renewable resource, but reforestation demands considerable costs.

Costs (Z) for the restoration of forest resources can be calculated by the formula:

$$Z = Z_1 + Z_2 = R * S + Z_2, \qquad (1)$$

where Z_1 – the cost to restore forests after fires, Z_2 – costs of reforestation after felling, S - the area damaged by forest fires, R – the ratio of the costs of reforestation of the burnt areas. Costing Norms set by the authorities of forest management.

The method of calculating the cost of operations is well known and is not discussed in this article. Forest fires cause the greatest economic losses and environmental damage. We propose to predict the burned area S, using a time series model – harmonic Fourier series. We justify the choice of this method.

Many natural and climatic phenomena depend on periodic variations of the Sun activity, the Sun cycles. The length of one of the Sun cycles, Schwab's cycles, is 11 years on the average. The peculiarities of the forest fires in the Far East of Russia are variations of their quantity and of the out burned areas sizes with the regularity of 10-12 years. Perhaps, there is a non random cause and effect relationship between those two phenomena? To test this hypothesis let us consider two time series (fig.1).

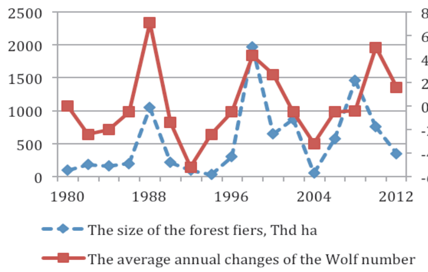

Fig. 1 The dynamic of the average annual changes of the Wolf number and of the forest fire areas in the Far East of Russia

$\Delta W_t = W_t - W_{t-1}$, (2)

$W_t = R\ (10\ g + f)$ (3),

Where g – is the number of spots groups on the Sun disc on the day of the observation, f – is the number of individual sun spots, R – is normalization coefficient characterizing observation device (the order of 1), W_t – is the Wolf average number for the current year, W_{t-1} – is the Wolf average number for the previous year of observation.

One of them (S) shows the size of the forest fires areas in the Far East of Russia [1, 2] during the period from 1980 up to 2012. The other one (ΔW) shows the dynamic of the sun activity [3]. Wolf number W [4], which is dimensionless quantity, is the widely spread index of the sun activity**.** From 10 to 12 years period variations are distinctly visible in the figure. Tentative visual analysis suggests the availability of those time series cointegration, i.e. availability of a non-random cause and effect dependence, which is expressed in the tendencies and variations coincidence.

To test the hypothesis about the availability of the cointegration let us use the empirical rule, suggested by Banerjee [5]. Let's calculate the Durbin-Watson cointegration statistic (CIDW) where means the excess of the linear regression equation

$$CIDW = \frac{\sum_{t=2}^{n}(\varepsilon_t - \varepsilon_{t-1})^2}{\sum_{t=1}^{n}(\varepsilon_t - \bar{\varepsilon})^2} = 2{,}25, \quad (4)$$

where $\varepsilon_t = S_t - \hat{S}_t$ means the excess of the linear regression equation $\hat{S}_t = f(\Delta W_t) + \varepsilon_t$, which coefficients are defined by the least square method. If *CIDW*, calculated for the equation excess, is less than the determination coefficient for this equation, the hypothesis about the availability of the cointegration is wrong. In our case *CIDW* is 2,25, so the cointegration is available. This means that the forest fire areas changing is a periodical phenomenon. The length of the period is 11 years on the average. As in the Fourier series as basic functions, accepted harmonic trigonometric functions, then use them to model processes the periodic changes of the areas of forest fires [6, 7]. Fourier series harmonics are used [8] as an analytical equation, describing the dynamic of the process studied. And the fire area *S* could be predicted with the aid of the time series.

$$S = a_0 + \sum_{k=1}^{N} Y^i{}_k \ , \quad (5)$$

$$Y^i{}_k = a_k * \cos(kt_i) + b_k * \sin(kt_i) \quad (6)$$

$$t_i = \frac{2\pi}{n} * i \quad (7)$$

Where k – is the index of the Fourier series harmonics, N – is the number of harmonics, n – is the number of the observation periods, i – is the observation period number.

$$a_0 = \frac{1}{n}\sum_{i=1}^{n} y_i \ ; \quad (8)$$

$$a_k = \frac{2}{n}\sum_{i=1}^{n} y_i * \cos(kt_i) \ ; \quad (9)$$

$$b_k = \frac{2}{n}\sum_{i=1}^{n} y_i * \sin(kt_i) \qquad (10)$$

where y_i – observational data, means the burned area in the *i*- observation period.

It is necessary to determine N is the number of harmonics. The evaluation process takes place in a few iterations, compute a new Y_k terminated when $|A_k - A_{k-1}| < \delta$, where δ is given accuracy. And $N=k$.

The original data for the model development are the sizes of the forest areas covered by fires in the Far Eastern Region during the period from 1968 up to 2012 The monitoring of the forest fire situation and its prediction will make it possible to notify about fire development and to eliminate the effects of forest fires. Some of the Fourier harmonics are demonstrated in Fig. 2.

The estimated accuracy of the prediction is shown in table 1.

Table 1

Estimated accuracy of Fourier model

Indicator description	Indicator values, Thd ha
Estimated value*, 2012	393
Actual value, 2012	352
Absolute error	41
Relative error, %	11,5
Prediction, 2014	308

*The resource: [2]

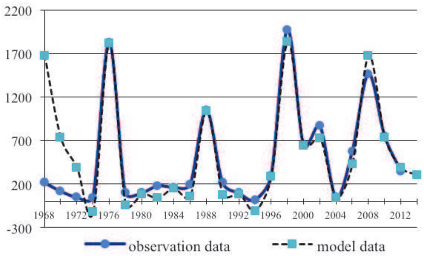

Fig. 2 Dynamic models of the prediction of the forest areas, covered by fires, in the Far East of Russia.

The resulting model allows us to predict the amount of forest burned area and to estimate the costs of reforestation, and get timely measures for the prevention of forest fires and to prepare for the fire season

model data

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