METHODS OF DENDROCHRONOLOGY – I

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6. PREDICTING FUTURE GROWTH TRENDS FROM TREE-RING SERIES

6.1 A DENDROCHRONOLOGICAL APPROACH TO FORECASTING

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Description, explanation and prediction are the basic functions of each field of the science. To make solution of many problems more efficient, preventive information is necessary. Ecological forecasting by which is meant forecasting of ecological systems on varios organization levels is growing in importance for rational use and conservation of natural resorces.

If dendrochronology is a science of an ecological profile (section of bioindication), then it has every right to prediction, especially as tree-ring chronologies contain unique retrospective information. Dendrochronological forecast is a group of ecological forecast based on tree-ring data. The principal object of dendrochronological prediction is forecasting changes in tree increment estimates. Knowledge of functional relations and correlations between growth indices, environmental factors and natural processes allows also a qualitative or quantitative prediction of the latter. The commonly used reconstraction of natural conditions of the past from tree-ring data may be termed "retroprognosis".

Common methods of ecological predictions and approaches used in predictions of dynamic systems may be applied. It is necessary to take into account the peculiarities of dendrochronological series, which are discrete time series and reflect the influence of envirinmental and common factors, mainly climatic ones. Specific characteristics of these series are also the relations caused by the effect of the increment value and previous growth conditions on the growth of the current year, and possibility of statistical estimation for particular years.

Although the problem of dendrochronological forecasting was stated by F.N.Shvedov (1892) and A.E.Douglass (1928,1936) as early as the end of the past and the beginning of the current centuries, advances in this field are not considerable. Up to now the attention is mostly drawn to the reconstruction of natural processes, that is to retroprognosis.

Methodological approaches used in dendrochronological predictions may be divided into intersystemic and intrasystemic (or parametric) ones. The essence of the intersystemic approach is to use

the dynamics of one system (predictor) for forecasting another system dynamics (predictant). The parametric approach is based on the use of intraseries relations in the dendrochronological series.

The intersystemic approach shows more promise and often used in the dendrochronological forecasting. It is necessary to note, that both systems should interact, the predictor system should be ahead of the predictant one in time or parameters, and they should originate from the same source. Prediction systems are dynamical series of the sun activity, lunar and solar atmospheric tides, growth limiting factors and dendrochronological series themselves.

Possible correlations between different estimates of the sun activity and the tree growth are of the great interest up to now. It is not occasional. Their existence would support the hypothesis that the sun activity affects geophysical and biological processes. Moreover, the sun activity series are rather long and cyclic fluctuations are clearly seen in the estimates. There is much experience in long-term predicting of the sun activity.

The review of literature shows that relations between the sun activity and the tree growth are distinct in some regions, in others they are less pronounced, and in some regions they are absent at all. The pattern and narrowness of relations greatly depend on phases of the sun activity. The correlation sign may unexpectedly change. Various phase shifts have been observed. This presents dificulties in using the sun activity estimates as predictors. To obtain more reliable correlations many authors transform them. I suggest that in those regions, where correlations are sufficiently stable in time, they may be used for dendrochronological forecasting. However, it is dificult to expect much success from this method untill the sun activity mechanism influencing on natural processes on the Earth is known.

The promising method which allows to predict the most anomalous hydrometeorological and tree growth estimates is to use maximal lunar and solar atmospheric tides as a predictor (Javorski,1975,1977). The tides produce blocking anticyclones and sharp changes in atmospheric circulation. The zone of the anticyclone attack becomes droughty with increased precipitation around its periphery. The range of the maximal atmospheric tides is 300-500 km in the longitude. If atmospheric tides arise over the precipitation forming regions (over North Atlantics, for example) vast territories may become arid. Sharp changes in the redistribution of precipitation and temperature course affect the tree growth. Therefore, growth indices and atmospheric tidal intensity correlate rather well. Dendrochronological series are usually long-term and

therefore are used to reveal such correlations (Javorski,1977). Calculations of lunar and solar atmospheric tides can be made many years in advance. Thus, by applying this method it was managed to successfully predict the droughts of 1972 and 1975 in the USSR. Many cyclic fluctuations in tree growth estimates from two to some hundred years are supposed to result from the effect of the atmospheric tides.

If we had reliable prediction of environmental factors, which determine tree growth, then tree growth forecasting would be easier and more reliable, especially for the regions with one or two limiting factors. Since long-term predictions of hydroclimatic factors are lacking or not reliable, their use as predictors is impossible so far. At present dendroclimatological series serve in the main to reconstruct the most important climatic factors (retroprognosis) and evaluate the adequation of the prediction models. Of great help in revealing correlation between growth indices and hydroclimatic factors may be the procedures employing some self-training systems (Rozenberg,Feklistov,1982).

During reconstruction of natural conditions of the past a dendrochronological series serves as a predictor. It may be a predictor to any other time series, if there is a stable and reliable relation between them, but which is shifted in time.

If we use the parametric method, one should know the extent to which the determined, regular random and purely random components are displayed in the series. There is disagreement about a determined component in dendrochronological series. Some authors claim that cyclic components may be regarded as determined only. Others do not entertain this idea and apply the methods of the theory of random stationary sequences in the analysis of cyclic components. Theoretically, the parameters of the regular random components should be predicted from the probabilistic model. But such models have not yet been developed in dendrochronology and predictions are made based on determined models, which approximate and extrapolate the observed fluctuations by sinusoids.

Intraseries development regularities are impossible to study and use for prediction purposes if sufficiently long-term series are not available. In this respect dendrochronological series have advantage over hydroclimatic ones. Accounting of prolonged cyclic fluctuatuons of growth indices is very important, so proper techniques of tree-ring standardization should be used. It should be noted, that parametric methods are less appropriate if significant qualitative changes in the predicted system are expected in future.

The cyclic procedure is most generally employed in dendrochronological forecast. It is based on revealing, approximation and extrapolation of the most important cyclic components. Each series usually contains several such cycles. Rather powerful applied mathematics and computers we have at our disposal permit apprizing the necessary parameters of the cycles. Concurrent with the maximal entropy method this procedure looks promising for evaluations of spectral densities and bandpass filters. But reality of the revealed cycles, their stability in time, mechanism of formation - all these problems, stated by A.E.Douglass, remain actual at present. Untill mechanisms of the cycles formation are known, the only procedure to evaluate their reality is to analyse their distinction in sufficient number of long chronologies. If the series contain distinct cyclic components, the latter may be used for background predictions. If small cycles are taken for extrapolation purposes, then annual forecast may be given, though it may not very reliable.

Predictions based on autoregressive function were not practicable in dendrochronology. They may be efficient in many cases, since dendrochronological series have better intrarelations than climatological ones.

Thus, I may say, there is a theoretical and methodological base for dendrochronological prediction. It is primarily the knowledge of the main regulariries of woody plants growth, systematic approach and the theory of random stationary processes. However, progress in the development of concrete ways and means in prediction is not great. It is very important to estimate prediction limits, that is to evaluate how well and how far increment changes are possible to forcast. This problem has not yet been raised or solved. We suggest that prediction would be more accurate if it is based on the series, obtained from extremal growth conditions. Better predictions are also expected for generalised series compared to mean ones.

Applied mathematics used for prediction at present is based on the assumption of stationarity of the processes. In nature there are no purely stationary processes. How this contradiction would be overcome? Possibly, the theory of non-stationary random processes will be developed to the level of practical use. In any case, the probability approuch holds greater promise for prediction than the determinate one, though predictions should be as concrete as possible. Uncertainty is not to be overcome completly in predictions. Different forecasting procedures are advisable to use. The main thing necessary for successful forecasting is the availability of reliable and long-term dendrochronological series.

Increased anthropogenic impacts on forest ecosystems and new limiting factors having appeared (air pollution, for example) make the problem of dendrochronological forecasting more complex. One can not rely on autonomy of the process and intraseries relations. Other approaches and improved models involving anthropogenic factors are necessary.

I think that dendrochronological forecasting is not only possible, but it is necessary. It also permits better understanding mechanisms of tree growth variability.

In conclusion I would like to give several quotations from N.N. Engver (1976) to summarize almost everything that was said:

1. A poor forecast is better than none.
2. Predictions based on a standard procedure are better, than those based on intuition, because the first can be always improved.
3. One may predict only what can be predicted.
4. A probability prediction is better than a determined one.
5. It is not science but a scientist, who is responsible for a poor forecast.

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