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Some biological and ecological problems of dendroclimatology

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The Organizers of this Symposium asked me to give my view on the principal trends of progress in dendroclimatology and considerations about outlooks of future investigations in this sphere of knowledge. It is a difficult task as dendroclimatic problems are very complicated ones. To carry out such investigations it is necessary to make use of methodical approaches and data developed and obtained in different branches of science (plant physiology, forest science, ecology, meteorology, heliogeophysics, etc.). However this task is being facilitated by the fact as the problems of dendroclimatology had been discussed specially at the Second International Workshop on Global Dendroclimatology which had taken place in Norwich in 1980 (Hughes, Kelly, Pilcher, LaMarche 1980). Many conclusions and recommendations elaborated at this Workshop are actual nowadays and will be the guiding principles in the future. That is why I want to concentrate upon only that problems to which less attention has been paid at the Workshop, especially upon some biological and ecological problems of dendroclimatology.

Dendroclimatology always had been the most important branch of dendrochronology. Unremitting interest in these researches is caused by the fact that tree-ring analysis is the most accurate and reliable source of information on remote past, it may be obtained for the larger part of land territory and even for a certain part of aquatoria (Wu, Lough 1987). The importance of conducting of dendroclimatic researches has been increased, especially lately, in connection with peculiar significance of the problem of possible climatic changes under the influence of human activity.

The main task of dendroclimatic researches is obtaining possibly more qualitative and long-term reconstructions of possibly more quantity of climatic variables both for individual points and for vast territories. However one should not be limited oneself in solving this task only. Having data on climatic conditions of the past one may and must use it for studying on climatic changes, for ascertaining factors which determine this variability, for revealing relationships between climatic changes and dynamics of ecosystems of different levels of organization, for study on relationships between climatic changes and human economic activity.

There has been a great progress in dendroclimatic investigation during the last decades. Many point and spatial reconstructions have been conducted till now (Hughes, Kelly, Pilcher, LaMarche 1982, Brubaker, Cook 1984, Hughes, Schweingruber, Cartwright, Kelly 1984, Stahle, Cleveland, Hehr 1988, Graibill, Shiyatov 1989). Especially one must be mentioned about spatial reconstructions of many climatic variables which were carried out by Fritts (1976, in press) for the North America and by the Group of European scientists (Schweingruber, Hughes, Briffa, Jones, Wigley) for the West and Central Europe. Essential progress in development of many tree-ring chronologies has been obtained, particularly in regions which have not been studied with dendroclimatic point of view, for example in the eastern part of North America (Stahle, Cleveland, Hehr 1988, Cook, Cole 1989), Mediterranean (Serre 1978, Genova 1986, Serre-Bachet 1987), Central Asia (Wu, Lin 1987, Hughes, Davies 1987, Borshova 1981), the European part of the USSR and the Ural Mountains (Bitvinskas, Kairaitis 1979, Shiyatov 1986). There have been used some reliable multiple statistical methods for describing, extracting and enhancing of climatic signal (Cook, Kairiukstis 1990).

The problem of obtaining more reliable and long-term reconstructions on the base of using tree-ring chronologies is complex and versatile. Special attention has to be paid for choice of objects under study, using a sufficient number of replicates, accurate measuring of chosen growth characteristics, annual rings dating, choosing the suitable methods of standardization. A quality of climatic reconstructions depends primarily on it. Actually, if these requirements are not be fulfilled any mathematical and statistical methods and resorts will not lead to desirable results.

It has been noticed repeatedly about necessity for the elaboration of the methods of standardization of tree-ring chronologies which might extract climatic oscillations of low frequencies (Hughes, Kelly, Pilcher, LaMarche 1980). Up-to-date methods of standardization allow to discover the oscillations which duration is nearly twice less than duration of individual chronologies, that is it does not exceed usually 150-200 years. Using "corridor" method I succeeded in obtaining more long-term climatically

caused oscillations in the Polar Urals (Shiyatov 1986). But this problem has not been solved so far. Perhaps constructing of more perfect models of tree growth will promote in its solution.

To produce more reliable reconstructions of climatic variables from tree-ring chronologies it is necessary to understand better the biological processes proceeding in a tree . It is of great importance to know how tree grows and develops during the growing season, what regime of principal factors is acting in one or another habitat and how they effect upon cambium activity. Having such data one might construct more perfect models of tree growth which could be used as a theoretical base for reconstruction of various factors including climatic ones. It would also give an opportunity for explaining empirical correlations between tree growth and climatic factors and for using them more correctly.

Works devoted to study on seasonal trees growth were being conducted in a number of regions, but it was necessary to notice that the quantity of fulfilled investigations of such kind was yet insufficient. During last years such researches were being carried out in Siberia (Vaganov, Shashkin, Sviderskaya, Vjisosckaja 1985). It is important to notice that the main purpose of these works was the study on the mechanism of the effect of climatic factors upon a growth and structure of annual wood layers. During last two years these works are being conducted together with American dendrochronologists. The studies of seasonal trees growth were also carried out in the dark-needle forests of the Middle Urals (Goryachev 1990). It is necessary so that such works would be conducted both for different tree species and in various phytogeographical regions.

I should like to draw your attention to a scantily explored phenomen - the reaction of tree growth, being effected by climatic factors, may change with age of tree. There exists vast literature describing that a tree passes some age stages during its life. Each of these stages is characterized by specific features of tree growth and different demands to environmental conditions. Consequently climatic information kept in individual chronologies may be not equivalent in various intervals of tree lifetime. The difference may be significant enough and it can influence upon the reliability of climatic reconstruction. Actually, the calibration and verification are usually carried out when the tree is on the age of decline, and reconstruction is done when the tree is on the ages of intensive growth and maturity. It is desirable to conduct special investigations, including those to study seasonal growth in order to evaluate this heterogeneity for various tree species and habitats. If the role of this heterogeneity appears to be significant enough, it would be necessary to develop special methods to eliminate its effects. It must be marked that the similar problem exists for the trees of different phytocenotic position, especially in the humid dense forests. Furthermore, there exists heterogeneity in tree-ring chronologies caused by the different in reaction of tree growth in the various climatic season and periods. Thus, Graybill (in press) has shown that in some chronologies developed for the Rocky Mountains (near Denver) the reaction of tree growth on climate has changed during current century. At the beginning of the century, when the climate was more cold and humid than it is now, the relationship between growth indices and precipitation was more poor. I think that the problems of evaluation of these heterogeneities and elimination of their effects should be worked upon in the coming years. This would promote to carry the more reliable paleoclimatic reconstructions. Now there is a tendency to carry dendroclimatic studies in the regions and habitats which are more favourable for growing of trees. Under such conditions climatic factors are not limiting every year, but only in some extreme years. In this case a different kind of factors can be limiting in various years. In the years with favourable climatic conditions the limiting factors are: fruiting, defoliation by insects, etc. The climatic signal is also available in chronologies developed for these habitats. To extract this signal is of interest for climatic reconstructions. The methods of evaluation, extraction and strengthen climatic signal worked out for chronologies obtained for extreme growing conditions are of little use for chronologies of comparatively favourable sites. In these case it makes no sense to use such statistical procedures as correlation and regression analyses. Really, one may hardly reveal any statistical correlations, for example, between temperature series and growth indices if it is known that the latter are changed under the influence of various factors. To extract climatic signal in chronologies developed for comparatively favourable habitats, it is necessary to develop special methods and, besides, to use another characteristics of annual tree growth, for example, wood density, number cells and sizes of cell structures, chemical composition of wood, analysis of pathological structures, image analysis, etc. Among the statistical methods which can be useful for evaluating of climatic and non-climatic factors, I can point out the method of analysis of growth indices distribution in every calendar year developed by Mazepa (1982) and then successfully used by Kucherov (1990). In order to obtain the actual picture of climatic changes of the past, it is especially significant to reconstruct the larger number of climatic variables. To solve this problem the following seems to be necessary: 1) To use much more climatic variables in the analysis. For many regions it seems desirable to use not monthly but the decade and even every-day data. 2) To use different characteristics of annual wood layers. 3) For each region at study must be obtained many chronologies for various tree species and habitats. From this point of view the mountain regions seem

to be the most suitable as they have the highest variety of habitats and, as a rule a large number of tree species can be found there.

Many authors have shown that it is possible to reconstruct not only direct-acted climatic factors, but also indirect-acted ones, which are correlated with the first. This makes the possibility of reconstruction more climatic variables. In many cases we can not explain why the tree growth is closely correlated, for example, with January temperature. To reveal the mechanism of climatic factors action upon tree growth and relationships between the climatic variables are the most significant problems of dendrochronology. Specialists in different branches of science must work together to solve it. Dendroclimatic investigations are very important to solve a wide range of ecological problems, especially in the studies of forest dynamics in ecotone regions. In these regions climatic factors exert a great influence upon the composition, structure and functioning of ecosystems. Tree-ring chronologies may be used to date various phenomena in forest (determination of time of trees origin and dying off, studying of competition between species, dating of forest fires and other catastrophic phenomena). The tree-ring chronologies themselves represented by the ring widths and growth indices may be used to study the trees and forest stands productivity, while climatic information extracted from tree-ring chronologies can be used in the studies of tree generations succession, periodicity of fruiting and pest-insects outbreaks, density dynamics of tree populations, boundary changes of forest ecosystems and such important botanical and geographical boundaries as the upper, polar, lower and southern tree-lines (Gorchakovsky, Shiyatov 1985, Fritts, Swetnam 1986, Eckstein 1990).

Undoubtedly, the contribution of dendroclimatic researches in the solution of many important local and global ecological problems will be increasing. A special attention is acquired to the evaluation and prediction of possible climatic changes under the influence of human economic activity. Dendroclimatic methods which give a possibility to evaluate the past and recent climatic changes with a very high degree of resolution can be very helpful in revealing and evaluation of the trends in tree growth and climate which are due to increasing of CO_2 concentration and other gases in the atmosphere. It will be so that annual tree growth may be the first and real indicator of local and global climatic changes and other environmental conditions which are occurring in the biosphere now. Pioneer works which were carried in some regions (LaMarche, Graybill, Fritts, Rose 1984, Hari, Kuusela 1984, Hari, Arovaara 1988) are testified that unusually trends in trees growth during the last decades can be conditioned by the anthropogenic climatic changes. In connection with this a special attention must be paid to develop theoretical and methodological questions of this important ecological problem. One of the principal tasks confronting dendroclimatology nowadays is creating a rather dense network of tree-ring chronologies upon the territory of the USSR and especially for the regions of Siberia, Far East, Central Asia and the Caucasus. Till then such network will not be created it is impossible to begin solving the problems of global dendroclimatology. Manpower and financial resources available in this country now will not provide realizing it even for nearest 10-15 years. That is why mutual efforts of dendroclimatologists of different countries are necessary. It is essential to notice that for last three years two Soviet-American expeditions for collecting wood samples in the Tien Shan and Sayan Mountains have been carried out. During these expeditions rather volume collections have been made (more than 20 chronologies) and some long-term chronologies have been developed (for Juniperus turkestanica until 1300 years). If taking into account the USSR huge territory, variety of natural and climatic conditions and the fact that the most regions are hardly accessible, it is evident that even more efforts in this direction are necessary. My hope raised by the circumstance that at the International Symposium on Boreal Forests which has been hold in Archangelsk (USSR) this year, the agreement concerning the conducting of mutual international investigations in dendroclimatology at the USSR boreal zone has been achieved. A rather dense network of tree-ring chronologies for living trees must be obtained during about next three years. Special attention will be paid for the Subarctic regions where climatic conditions are the most variable and tree-ring chronologies are the most suitable for climatic reconstruction. The collection of wood samples according this project has begun since the current year, but the intensive sampling will begin from the next year. It is necessary to note that a great deal of subfossil wood is being found in the Subarctic regions and within the boreal zone of the USSR, especially in alluvial, lake and peat deposits. For instance, a lot of such wood is available in alluvial and peat deposits in the southern part of the Yamal Peninsula (Shiyatov, Surkov 1990). According to the results of radiocarbon dating the maximum age of this wood is 8500 years. Large amount of subfossil wood is available at the huge areas of peatbogs of Western Siberia Plain. Here the possibility of development of long-term chronologies are really unlimited. I suspect that a lot of subfossil wood is available in the Eastern Siberia and on the Far East as well.

In conclusion I would like to emphasize once again that very important and complicated problems are in front of dendroclimatologists now. They can be solved only with the participation of specialists of different countries and different branches of science.

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