Analysis of Tree-Ring Chronologies by Digital Graphical Data Processing Method

E E Lukashik, A A Ivanov and D V Semenov
Yaroslav-the-Wise Novgorod State University, 41, B. St. Petersburgskaya str., Veliky Novgorod, Russian Federation
E-mail: lukashik-proekt@yandex.ru

Abstract. The tree-ring analysis makes it possible to carry out a retrospective assessment of the influence of various environmental parameters on the growth and development of woody vegetation, as well as to determine their contribution to changes in radial growth in the context of the life cycle. Based on the study of tree rings, the absolute and relative dating of the layers of wood growth is made, and it is also possible to reconstruct the events occurring in a given ecosystem and having an impact on a specific tree or plantation. Various methods and tools based on computer data processing are currently used to measure the width of annual layers, which allow measurements to be carried out in a semi-automatic mode, while saving time and increasing the accuracy of measurements. The article discusses one of such methods for studying wood cores based on digitizing the pattern of tree rings and a program for positioning points, which makes it possible to exclude the use of expensive laboratory equipment, while maintaining the necessary measurement accuracy.

1. Introduction
Tree rings are archives of the past and biological indicators of the present, allowing one to study the influence of environmental factors on the growth and development of a woody plant over decades or centuries, as well as to simulate the further development of a tree under certain conditions. [1, 2, 3].

The growth patterns of woody plants are of fundamental interest for forestry. Prospects for the use of dendrochronological information for silvicultural purposes are reduced to four main areas: the study of the factors of the formation of the growing stock, genetic evolutionary studies in populations of forest tree species, the reconstruction of the history of forest phytocenoses and the assessment of the health status of individual trees and the forest stand as a whole. [4, 5].

For carrying out tree-ring analysis in growing plantations, the starting material is most often wood samples taken with the help of an age drill – cores. The most important indicators for forestry, determined by wood cores, are the age of the tree and radial growth, on the measurement of which the correlation dependence on environmental factors is determined, the current and future productivity of the stand is determined.

2. Objects and methods of research
We carried out experimental work on the possibilities of measuring the age of a tree, radial growth by digitizing the pattern of tree rings and subsequent graphic processing of samples in the Cybis Coordinate Recorder (CooRecorder) and Abris + computer programs. The data obtained were used to plot the
correlation dependence of the radial growth on the age of the tree under the given growing conditions. Cores were taken from model trees of European spruce using a Pressler’s age drill on a sample plot.

3. Results and discussion

The measurement of the width of tree rings can be carried out in various ways, differing in the laboriousness and accuracy of the results obtained. Well-distinguishable, coniferous tree rings can be measured by an instrumental method using a magnifying glass and a caliper, however, for measuring a large number of wood cores, this method will be very laborious, and the measurement accuracy decreases in proportion to the decrease in the tree ring width.

To perform instrumental measurements of the width of tree rings, special devices are used, for example, LINTAB, which allow measurements in a semi-automatic mode, while saving a significant amount of time. This equipment allows you to measure the width of the early and late layers of radial growth of wood with an accuracy of 0.01 mm. To process the measurement results by the LINTAB device, the TSAPWin program is used, which allows one to enter measurement data into a computer, correct and analyze the obtained data, present them in tabular and graphical form. This program for the study of tree rings presents their characteristics, allows one to measure, compare, determine and correct several series of measurements [6, 7].

The measurement accuracy is also influenced by the visibility of the tree rings on the wood sample. During dendrochronological studies, due to insufficient visual distinction between the zones of late and early wood, errors in dating often occur, associated with both incorrect counting of the number of visible rings and the impossibility of identifying fallen out and false rings. This inevitably limits the number of objects examined, reduces the reliability of conclusions and leads to distortion of the results [8]. To increase the contrast of the rings, the core surface is cleaned with a sharp cutting tool, followed by impregnation with chemical solutions or mechanical rubbing into the cell pores of finely ground powder of chalk, calcium oxide or talc [9]. This stage is an important component of the processing of any wood sample and can significantly increase the reliability of tree-ring information.

In the absence of special laboratory equipment, measurements can be made using flatbed scanners, digital photographic equipment and software for processing graphic information.

We carried out an experiment to determine the possibility of obtaining sufficiently accurate measurements of the growth ring thickness to plot the correlation dependence of the radial growth on the age of the tree using the CooRecorder and Abris + software. Wood cores of European spruce were chosen as prototypes. Digitization was performed using a flatbed scanner of the KYOCERA TASKalfa 1800 multifunctional device, Samsung SCX-3200 and a Canon EOS 600D digital SLR camera with a Canon 35mm f / 2.0 lens. To increase the contrast of the growth rings, the cores were impregnated with linseed oil-oxol in one layer, followed by drying for 24 hours.

Digitizing the drawing of tree rings with a DSLR camera consisted in shooting wood cores from a tripod to nadir. The cores were laid out on a sheet of white paper measuring 210x297 mm. The following shooting parameters were adjusted on the camera: aperture - f / 13, shutter speed 1/20 s., ISO speed - 200, focal length - 35 mm. Shooting was carried out in RAW format, without flash in a well-lit room. The subsequent processing of the resulting images was carried out in the graphics editor Adobe Photoshop, for some digitized samples, the color inversion function was used for a clearer separation of tree rings. Image resolution when loaded into measurement programs was 7442x10524 pixels.

To digitize the tree ring pattern in a flatbed scanner, it is recommended to cut off part of the core to obtain a flat surface that fits snugly against the scanner glass. If this stage is omitted, the image of the core becomes blurred from the central longitudinal line to the edges - such images may not be suitable for work. Scanning was carried out in full color mode with a resolution of 600 and 1200 DPI. Practically, it is indicated that 600 DPI is sufficient to measure clearly visible tree rings.

Comparing the digitization of the tree ring pattern by the method of shooting with a SLR camera and scanning the cores, the following conclusions can be drawn: when shooting with a camera, there is no need to prepare cores by cutting off the sample surface, which speeds up the digitization process; however, the quality of the resulting image is lower and varies somewhat depending on the lighting
conditions. Digitization by the method of shooting with a SLR camera is possible only for those samples on which the annual rings are clearly distinguishable and their width exceeds 0.35 mm.

Measurement of early, late wood and total tree ring width in the CooRecorder and Abris + programs is possible with an accuracy of 0.01 mm. At the same time, two boundaries are distinguished in the annual ring – from the moment of the beginning and end of the growing season. As a result of measurements, a line is obtained that describes the width of the tree growth rings. Based on the scale of the image, the distances between points are calculated and automatically entered into the log. Figure 1 shows an example of working with cores in these programs. A slight error occurs when measuring oblique growth rings, in cases where the core of the wood deviates from the center of the tree trunk.

![Figure 1](image-url) Working with wood cores in CooRecorder and Abris +.

When measuring the width of an individual annual ring and sequentially from the periphery to the center, the curvilinear axis of the core is taken into account, since after the sample has dried, the longitudinal axis is not strictly rectilinear. Thus, in an area with high curvature, the measurement line can be set perpendicular to the measured layer.

The advantage of information processing in the CooRecorder program is faster acquisition of dendrochronological information [10, 11]. In turn, Abris + does not require registration of an image in a coordinate system (unlike other geographic information systems) and is based on standard paper sheet sizes, which increases the accuracy and speed of measurements.

The obtained measurement results were used to plot the correlation dependence of the annual ring thickness (ARTh) on the age of the tree. For European spruce, the annual reductions in the thickness of the annual ring and the coefficient of determination were calculated $R^2$ (table 1).
Table 1. Dependence of radial growth on tree age.

| Species        | Diameter | Height | Age, years | $R^2$ coefficient of determination | Annual decrease in ARTh | Initial ARTh |
|----------------|----------|--------|------------|-----------------------------------|------------------------|--------------|
| European spruce| 20 cm    | 18 m   | 46         | 0.3413 Medium correlation          | -0.0405 mm            | 3.1552 mm    |
| European spruce| 26 cm    | 17 m   | 47         | 0.5999 Strong correlation          | -0.0619 мм            | 4.2906 мм    |
| European spruce| 30 cm    | 19 m   | 37         | 0.0522 Weak correlation            | -0.0226 мм            | 4.5061 мм    |
| European spruce| 34 cm    | 18 m   | 42         | 0.649 Strong correlation           | -0.1191 мм            | 6.6257 мм    |
| European spruce| 40 cm    | 17 m   | 55         | 0.1944 Medium correlation          | -0.0318 мм            | 4.5015 мм    |

In European spruce, the greatest value of the annual decrease in ARTh is presented in the III age class (-0.1191 mm), the lowest value of the annual decrease in ARTh is presented in the II age class (-0.0226 mm), the highest and lowest initial ARTh is present in III age class (6.6257 мм и 3.1552 мм соответственно). Below is a graph of the correlation between the annual ring thickness of European spruce and age, the coefficient of determination is presented in the form of a strong correlation (figure 2).

![Graph of correlation dependence of ARTh on age](image)

**Figure 2.** The graph of the correlation dependence of ARTh on the age of the tree.

4. **Conclusion**

As a result of the work carried out, it was concluded that the application of the method of digitizing the pattern of tree rings by scanning wood core samples, as well as shooting with a mirror camera, can be successfully used in most dendrochronological studies. The use of CooRecorder and Abris + software for measuring the width of early and late wood, as well as the total width of the annual ring, allows one
to reduce labor intensity and obtain results with an accuracy acceptable for silvicultural purposes (0.01 mm) without expensive laboratory equipment.

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