University of Helsinki
Faculty of Science
Department of Geology

# TREE-RING DATING IN ESTONIA

**ALAR LÄÄNELAID**

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To be presented, with the permission of the Faculty of Science of the University of Helsinki, for public criticism in Auditorium E204, Physicum, Kumpula, Gustaf Hällströmin katu 2, University of Helsinki, on November 29th, at 2 o'clock in the afternoon.

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| Custos: | Prof. Matti Eronen, Department of Geology, Faculty of Science of University of Helsinki, Finland |
| Opponent: | Prof. Dieter Eckstein, Institute for Wood Biology of University of Hamburg, Germany |
| Reviewers: | Dr. Tomasz Wazny, Dendrochronological Laboratory, Faculty of Conservation and Restoration of Academy of Fine Arts, Warsaw, Poland |
| | Prof. Olavi Heikkinen, Department of Geography of University of Oulu, Finland |



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Tartu Ülikooli Kirjastuse trükikoda
Tiigi 78, Tartu 50410
Tellimus nr. 488

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# LIST OF ORIGINAL PUBLICATIONS

This thesis is based on the following original papers, which are enclosed as copies in this volume and referred to by Roman numerals:

I Tree-ring dating in Estonia: The roof of the Nõo church. — Dendrochronologia, 1996, 14, p. 217–221. With summaries in English and Italian. Reviewed in Geographical Abstracts: Physical Geography.

II Dendrochronological dating of the Uppsala House in Tartu, Estonia. — Dendrochronologia, 1997, 15, p. 191–198. With summaries in English, German and Italian. Reviewed in Geographical Abstracts: Physical Geography.

III A network of tree-ring series in Estonia. — In: Stravinskiene, V., Juknys, R. (editors), Proceedings of the International Conference Dendrochronology and Environmental Trends, 17–21 June, 1998, Kaunas, Lithuania. Kaunas, 1998, p. 264–270. Abstracted in a CAB journal.

IV Dendrokronoloogia uurimisseis Eestis. — Ajalooline ajakiri, 1999, 3/4 (106/107), p. 141–152. In Estonian; Summary: The Situation of Dating by Means of Dendrochronology in Estonia. Abstracted and indexed in Historical Abstracts.

V Five pine samples represent climate impact as well as eleven pines. — In: Kolström, T., Lindholm, M., Viinanen, R. (editors), Conifer growth variability during the Holocene in Northern Europe. Proceedings of the meeting in Lund, Sweden 16–19 March 2000. University of Joensuu, Faculty of Forestry, Research Notes 108, p. 119–128.

VI Läänelaid, A., Rohtla, M. & Sander, H. Age of Big Oaks in Tallinn, Estonia. Baltic Forestry, 2001, Vol. 7, No. 1, p. 35–45. With Russian summary. CAB Forestry Abstracts and CAB TREECD cover the Journal.

# PREFACE

Tree-ring dating has been long a non-cultivated field in the landscape of science in Estonia. The onset of the discipline is sometimes being placed even in the nineteenth century. While in West European countries tree-ring dating has been practised for decades and has established traditions, the Baltic countries (with exception of the Dendroclimatochronological laboratory in Kaunas, Lithuania, and some research conducted in Latvia) did not have recourse to this approach for a long period of time. There were several reasons behind that situation. Firstly, the incorporation of the Baltic countries into the Soviet Union has to be taken into account, and its scientific community which was rather isolated from the western one in some fields; secondly, the absence or lack of computation equipment, and the development of specific software were a serious hindrance to research during the said decades in the Baltics.

Now the situation has changed considerably: during the last ten years Estonian scientists have had the opportunity to communicate with their colleagues in the West as well as in the East. Fortunately, this great change has been accompanied by a fast computerisation of science. Mostly due to these factors, the Estonian dendrochronology has been integrating into the European dendrochronology, and reaching the European level in scientific knowledge, equipment, techniques and, to some extent, also in results.

At the present moment a modest laboratory of tree-ring dating is operating under the Institute of Geography of University of Tartu in Estonia. Among the other sub-fields of dendrochronology, tree-ring dating has proved to be well applicable in Estonia, and it has yielded the first results. These results were preceded by the present author's years long search for appropriate research material (growing trees, archaeological and construction wood), and suitable standardisation methods for tree-ring series. Many of these problems were overcome by an active communication with colleagues from other countries. In the course of the work the author learned much about the anatomical characteristics of wood, logging and building practice in Estonia, and distribution of construction timber in space and time. The techniques used in Estonia are by all means the same as in the up-to-date tree-ring laboratories in Western Europe.

A network of dated tree-ring series has been developed in Estonia by now, and it enables to reliably date architectural objects back to the fifteenth century incl., and in certain cases even to the thirteenth century. The Estonian tree-ring network has been closely connected to the tree-ring chronologies of neighbouring countries around the Baltic Sea. The present state of the knowledge in tree-ring research in Estonia allows the author to draw some conclusions in the form of this thesis, and establish research targets for further work.

# 1. INTRODUCTION

## 1.1. What is tree-ring dating?

Tree-ring dating or dendrochronology in the wider sense of the word is the science about annual growth rings of trees, and various applications of the knowledge in forestry, ecology, history, etc. There is a wide choice of references available on the basic principles of the subject both in literature and in the Internet (e.g., http://web.utk.edu/˘grissino/, in Estonian: http://www.botany.ut.ee/lectures/dendro.html), so it is probably not necessary to refer them here. In a more strict sense, tree-ring dating deals with determining the age of wood and constructions made of that wood. Moreover, it is possible to determine the age of wooden items, for instance, musical instruments or paintings on wood.

## 1.2. Briefly about the background in Europe

Tree-ring dating has proved to be productive in Europe over several decades already. Based on developments of the art in forest botany by B. Huber in 1940-1960, and in view of the scientific achievements of the USA, the European dendrochronologists have elaborated a set of methods for reliable tree-ring dating of buildings and artefacts. There are many tree-ring laboratories in Europe that have specialised mainly in dating problems. Hundreds of old buildings and archaeological wood samples were dated in old towns of Germany. The mediaeval castles of Switzerland have been dendrochronologically well studied. Tree rings determined the age of archaeological wood findings from excavations in Norway and Sweden. Wooden churches in Finland have fixed building dates due to tree rings. Tree-ring dating of wooden rafts of Novgorod in Russia is also a well-known example. There are much more dating examples in addition to the ones mentioned here. To conclude, it could be said that once the methods have been elaborated, and reference network has been established, tree-ring dating has become a common practice in most of the European countries.

European community of tree-ring researchers (over one hundred members) has organised good scientific contacts, and shares their methods and advances. Since 1983, a special scientific journal *Dendrochronologia* has been published in Verona, Italy. There are more or less regular conferences for European dendrochronologists (Euro-Dendro) held biennially in different countries.

## 1.3. The background in Estonia

Estonia became engaged in the dendrochronological research in the early 1970s, when architect Kalvi Aluve was inspired by the dating success of historians from the Institute of History in Moscow. He started to sample historical buildings in Estonia, and, together with an assistant, measured tree-ring widths in saw-cut samples, and dated a number of buildings in West Estonia (Aluve, 1978). His tree-ring sequences went back to the tenth century. Unfortunately, he and his assistant had no background in biology. The dating of buildings was carried out visually on graphs of single sample series only. That work took place in the pre-computer Estonia. Kalvi Aluve did not continue his work on tree-ring dating later.

Approximately at the same time, Alar Läänelaid started tree-ring studies of pines growing on raised bogs under the scientific guidance of late Prof. Viktor Masing. These studies were completed in his graduation thesis at the Tartu State University. During the next years I measured and studied a number of archaeological wood specimens, excavated in the city of Tartu, Estonia. With aid of a large computer, and later with a primitive PC, my assistant and myself tried to date the archaeological wood specimens, and to elaborate a computer program to that end. Generally, we were then not yet able to date the samples reliably.

In 1989 I had the first opportunity to work for a month at the laboratory of the Institute of Wood Biology of the University of Hamburg. Good relationship with the head of the laboratory, Prof. Dieter Eckstein, paved the way for my next work visits to Hamburg during 1990s. We studied dendroclimatologically the increment series of growing larches (*Larix decidua* Mill.) from Tartu, and then concentrated our efforts on the dating of construction wood from Estonia. During my work in Hamburg I learned contemporary dating techniques, and obtained skills for tree-ring dating by graphs and computer programs.

The next multi-year task was to sample extensively in Estonia both from living trees and buildings in order to form a basis for a dendrochronological network of dated tree-ring series. By that time I had an electric corer for dry wood. This tool enabled me to sample independently from the repair works of buildings, where some beam-ends would be removed and used by me as tree-ring samples. In four years I sampled mainly in country churches in Estonia, and measured these samples at the University of Hamburg. The first dated object was a roof construction of Nõo church in South Estonia (Läänelaid, Tiirmaa, 1995). Its tree-ring series appeared to be reliably related to the pine chronology of Gotland established by Th. Bartholin. In order to research the next objects from Estonia, tree-ring chronologies from neighbouring countries as well as the Estonian newly dated series were used as references.

The current geographical networks of averaged tree-ring series of Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* Karst.) in Estonia have been developed by the author. Temporal extension of the networks goes from the living tree series back to the fifteenth century. One dated average series from Estonia goes back to the thirteenth century (dated foremost with the aid of foreign chronologies). In addition to this, several stands of living pines and spruces were sampled to get a local reference of growing trees. These samples provide a good material for further dendroclimatological studies. Planted larches (*Larix decidua* Mill. and *L. sibirica* Ledeb.) served as source for studying the regularities of sapwood formation in conifers. Sampling of big oak trees (*Quercus robur* L.) in Estonia sparked an idea of a new, graphical method of age assessment of thick trees.

## 1.4. Basic principles and aims of the research

The investigation of tree rings in Estonia was carried out in accordance with the basic principles of dendrochronology. These principles include the assumption that a uniform climate reigns over a large region, and that trees growing in that area react similarly to the year-to-year fluctuations of the climatic factors. These assumptions enable cross-dating — matching of ring width series of several trees with each other, allowing the identification of the exact year of formation of each tree ring. Actual cross-dating includes a set of procedures for valid results.

The problems for tree-ring study in Estonia were the following:

1) How large is the climatically uniform region in Estonia for trees, especially for Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* Karst.)?
2) Do trees (pine and spruce) in our climate react adequately (in certain sites) to year-to-year fluctuations of the climate?
3) Is the extension of climatically uniform region(s) in Estonia related (and to what extent) to tree species and other features?
4) Is it possible to cross-date tree-ring series from Estonia with those from its neighbouring regions?
5) How far it is feasible to develop the temporal extension of tree-ring series (of pine and spruce) in Estonia?
6) What is the approximate rate of individual growth fluctuations of trees in Estonia that is necessary for the assessment a proper sample size in cross-dating?

These initial problems were set out prior this investigation. In the course of the work some of these problems were solved, some new ones arose, and some expected as well as some unexpected results were achieved.

# 2. MATERIAL AND METHODS

## 2.1. STUDY MATERIAL

The material for this investigation originates both from living conifers and construction timber. The former comes from growing primeval forest sites of Scots pine and Norway spruce in different parts of Estonia. The provenance of the latter is mainly roof constructions of country churches and other buildings all over Estonia.

Sampling was carried out all over Estonia in the forest sites and other recent wood sources outlined below. In some cases (Imavere and Verevi) the origin of the timber was not known.

Pines (*Pinus sylvestris* L.):

1. Häädemeeste dune forest, 12 pines
2. Imavere saw mill, 10 pines
3. Järvselja *Vacc. vitis-idaea* type, forest block 274, 12 pines
4. Järvselja, forest block 261, 12 pines
5. Karepa dune forest, 12 pines
6. Kiidjärve *Vacc. vitis-idaea* type, 9 pines
7. Raadna dune forest, 12 pines
8. Raeküla forest on sandy soil, 10 pines
9. Türi park, 10 pines
10. Verevi bridge, Elva, 11 pines
11. Vormsi dune forest, 12 pines

Spruces (*Picea abies* Karst.):

1. Imavere saw mill, 10 spruces
2. Järvselja, forest block 261, 18 spruces
3. Ääro farm forest, Põlva county, 4 spruces

The following construction objects were sampled for obtaining historical wood. The tree species was determined microscopically for each sample core, so the objects are listed separately for pine and spruce samples. In each construction or constructional stage a minimum 10 cores were obtained, to select the best synchronizing ones among them. The number of samples (cores) obtained (cores) is indicated for every construction.

Pines:

1. Albu mansion — 16
2. Elisabeth Church, Pärnu — 13
3. Gustav Adolf Gymnasium, Tallinn — 21
4. Haljala Church — 25
5. Harju-Risti Church — 25

6. Jakobi St. 37, Tartu — 16
7. Jaani Church, Tartu — 23
8. Karja Church — 15
9. Karlova Mansion, Tartu — 17
10. Keila Church — 29
11. Kihelkonna Church — 20
12. Korsi farmhouse, Ruhnu — 16
13. Kursi Church — 28
14. Kuusalu Church — 12
15. Martna Church — 6
16. Nõo Church — 17
17. Pühavaimu St. 8, Pärnu — 12
18. Ruhnu Church — 19
19. Saue St. 11, Haapsalu — 11
20. Tampere House, Tartu — 12
21. Treffner Gymnasium, Tartu — 22
22. Vormsi Church — 24

Spruces:
1. Albu Mansion — 6
2. Ambla Church — 9
3. Anna Church — 10
4. Elisabeth Church, Pärnu — 8
5. Esna Manor — 10
6. Gustav Adolf Gymnasium, Tallinn — 4
7. Haki farmhouse, Põlva county — 15
8. Jakobi St. 45, Tartu — 12
9. Järva-Madise Church — 16
10. Kalame fisherman's house, Lääne-Viru county — 11
11. Katarina mole, Pärnu — 7
12. Koeru Church — 18
13. Karlova Mansion, Tartu — 18
14. Kullamaa Church — 15
15. Kursi Church — 33
16. Martna Church — 16
17. Mihkli Church — 11
18. Noarootsi Church — 13
19. Pärna forester's house, Lääne county — 6
20. Rootsi-Mihkli Church, Tallinn — 15
21. Saadjärve Mansion — 16
22. Tampere House, Tartu — 16
23. Tallinn Gate, Pärnu — 7
24. Uppsala House, Tartu — 30
25. Väike-Maarja Chapel — 12

## 2.2. METHODS

### 2.2.1. Sampling

Sampling of living trees was carried out mostly by a 40-cm long increment corer by Suunto. Sampling of construction wood was carried out by a corer produced by Th. Bartholin. Sites for sampling living trees were chosen to find old-aged conifers in relatively homogeneous site conditions all over Estonia. The chosen sites represent forests used as a source of construction timber in earlier centuries. Larches in parks were sampled mainly for studying regularities of formation of sapwood and heartwood in tree stems. The sample trees were cored at the height of 1.3 m above ground level as a rule; in some cases at lower heights — 1.0, 1.1 or 1.2 m above ground level. The height of sampling and the point of compass were recorded for each core. As a rule, healthy and uninjured dominant and co-dominant trees of a stand were chosen for sampling.

In the case of construction wood, the sampling sites were consulted with the architect of the reconstruction project. Sampling of wood with a preserved waney edge was one of the most important criteria. Usually a minimum of ten cores was obtained from different beams from each presumed construction stage of a building. All the cores were numbered, and their construction provenance was recorded.

### 2.2.2. Measuring

First, the measuring of the samples was carried out by using a binocular microscope with a measuring scale in the ocular with 0.05-mm unit, while the measurements were written down by hand. Most of the cores were still measured by using measuring devices (e.g. Lintab) in the University of Hamburg, in the University of Lund and later in the University of Tartu. The computer programs for measuring were either CATRAS or TSAP. The measurement unit of the measuring devices in all of the aforementioned laboratories is 0.01 mm, and the measurements were saved automatically. Prior to measurement, wet samples were surfaced by a sharp cutter and treated with chalk powder.

### 2.2.3. Synchronizing

The curves of annual increment of the trees were printed out, and carefully compared visually on the light table. All tree-ring series were synchronized by using similarity coefficients — the Student's t-criterion and the sign test W in the program CATRAS (Aniol, 1983). Zero rings were added into the series when necessary.

### 2.2.4. Averaging

The tree-ring sequences, which showed high similarity both visually on graphs, and by similarity coefficients, were averaged into a mean curve of a forest stand or a construction stage. The program CATRAS was used for this purpose.

### 2.2.5. Dating

The averaged tree-ring series as well as the original measurement series were cross-dated visually and by the t-criterion, using all other dated mean series and chronologies in my possession. The reference chronologies included these from Sweden (Bartholin, personal), Finland (Zetterberg, personal), northwestern Russia (Lovelius, 2000), Latvia (Zunde, personal), Lithuania (Stravinskiene, 1987; Špalte, 1979), and Poland (Zielski, 1995).

### 2.2.6. Graphical method of age assessment of trees

A new method for determining the age of trees was developed in the course of the dendrochronological studies of old growing trees. The method is graphical, and it is based on the cumulative growth curve of annual increment of a tree. If the corer does not reach the geometrical centre of the tree trunk, simply counting the tree rings cannot assess the age of the tree. In such cases the applied method includes the following operations:

1) The width of all tree-rings will be measured,
2) The radius of the tree is calculated from the perimeter of the tree trunk; the thickness of the bark is subtracted from the radius;
3) The length of the core (or the sum of tree-ring widths in it) is subtracted from the radius of the stemwood; the distance is part of the radius that is not covered by the core;
4) The measured ring widths will be added one by one to distance obtained, and the sequence will be depicted as a graph (abscissa — years, ordinate — radius of the tree stem);
5) The graph will be smoothly prolonged until crossing the X-axis; the crossing point indicates the approximate number of years of growing from zero to the present radius of the tree.

Preciseness of the method depends on the thickness of the tree, the portion of the measured tree-rings in radius, and the fluctuativity of the ring widths. The method still yields a much more realistic assessment of the age of a tree than a pure observation.

# 3. RESULTS AND DISCUSSION

The main results of the doctoral thesis were published in the six scientific articles copied here. Herewith I present shortly the outlines of the results of these papers. In addition, it should be mentioned that I initiated the research of tree-rings in Estonia much earlier, and the results of the work were also reflected in some earlier publications.

**Paper I** presents the first published results of my tree-ring dating in Estonia: dating of the Nõo church, carried out by following the methods of European dendrochronologists. The lack of skills in sampling can be seen from the fact that the waney edge of the timbers was not always found. Therefore the individual tree-ring series end at different years (I, Fig. 2). In this paper a proposition for the usage of raw timber was made. The dendrochronological dating was checked by comparison of the mean curve of Nõo church with extraordinary weather records from the beginning of the 18$^{th}$ century.

**Paper II** deals similarly with the dating of a historical building, the Uppsala House in Tartu. Unlike the previous paper, this study has used tree-ring samples falling into three construction stages (II, Fig. 3). Most of the samples have waney edges. Due to the construction stages and location of the sampled timbers in the building, it was possible to draw conclusions about the building history of the house. The dating results enabled to correct the suggested building time of the house. This study shows that tree-ring dating can solve problems exceeding the frames of dendrochronology.

**Paper III** is the first generalization of my years long work in developing a geographical network of mean tree-ring series in Estonia. The network covers most of the territory of Estonia (III, Fig. 1). Temporally it covers the period from the middle of 16$^{th}$ century to the second half of the 19$^{th}$ century (III, Fig. 2 and 3). Samples from recent trees were not included in this paper. In fact, there are two geographical tree-ring networks in Estonia — one for pine and the other for spruce. Both these tree species are important construction woods in Estonia. The figures 2 and 3 display a hindrance to finding historical wood in Estonia: the North War (1700–1721) was very destructive in this region, and therefore it was difficult to find older wood from the buildings. However, there is still wood preserved from the pre-war period. One of the challenges mentioned was the St.John's Church in Tartu, the wooden raft of which was dated to the first half of the 14$^{th}$ century. The Scandinavian, Finnish and North German chronologies initially served as temporal “anchors” for the mean tree-ring series of Estonian buildings. Later Estonian mean series were cross-dated also independently.

**Paper IV** gives a more detailed overview of the buildings dendrochronologically dated in Estonia by the moment of writing the article in 1998. The Estonian paper is supplied with an English summary. Results of the analysis of over 800 wood samples, and dating of nineteen historical buildings are described in this paper. In some buildings there were several construction stages, which rendered different datings. It should be mentioned that in the case of parish churches dendrochronological dating of their roof construction was carried out, not of the building itself. Usually, the churches themselves were centuries older, but no wood had preserved from the building time of stonewalls. One exception to this was Kursi Church: the documented building year of the church was AD 1648, and the dendrochronological dating of three preserved beams on the walls appeared to be AD 1647. These beams represent a rare timber originating from the pre-North War epoch. In addition to the remarkable age, these samples supported the theory that carpenters used to build houses of raw timber in the past centuries. This information enabled to establish the building time with high probability, and attribute it to the year after the dendrochronological dating time. Building history of some historic houses in Tartu, the Tampere House and the Uppsala House, was analysed and matched with the written sources. The dendrochronological datings introduced corrections into the building history of these houses. In the case of all the dated objects, the reference chronologies and the corresponding Student's t-values were indicated.

**Paper V** provides an experimental argument to the reasonable number of sample trees. The problem of sample size is widely discussed by dendrochronologists of different countries. The answer to this question has been various: e.g. T. Bitvinskas (1974) considered 25–50 sample trees to be sufficient for calculating the average ring widths of a stand. H. C. Fritts (1976) reported that at least two radii from 20 or 30 trees of the same general age in a given site were sampled. He also mentioned that 10 trees were sufficient for a sample on arid sites, but there was no strict rule for an adequate sample size for climatic analysis. F. H. Schweingruber, L. Kairiukstis, and S. Shiyatov (1990) concluded that 20–30 trees were usually used for obtaining a mean tree-ring chronology, but in certain regions and sites where there were just one or two limiting factors to tree growth, only 5–7 sample trees were taken to be sufficient. We presume that the reasonable sample size can be rather different according to the climate, site conditions and objectives of the research.

In this paper eleven tree-ring sequences from eleven pines were intercorrelated and arranged in the decreasing order of the average Student's t-value. The mean ring width series were calculated by adding the tree-ring sequences one by one to the sequence with the highest average t-value. Next, the eleven mean series (including the series represented by one tree-ring sequence) were correlated with thirteen reference chronologies, mostly from the neighbouring regions of Estonia (V, Table 2). It appeared that high t-values with the references were achieved already in the first five averaged sequences. Increasing the number of the averaged tree-ring sequences had practically no effect on their correlation with the references (V, Fig. 3). We presume that the common variance of tree rings is mainly due to common climate in the region. So, at least on the basis of these pines that grew on the northern coast of Estonia, we can conclude that five pines can represent the climatic impact as well as eleven pines. It should be emphasised that these five pines were selected from the eleven pine samples according to their average t-value with other sample pines. Thus, the results of the experiment proved that eleven sample trees can be enough to select the best representatives from them for averaging. This also supports my practice in sampling construction wood in Estonia: usually I have sampled 10 beams as a minimum (and up to 30 as a maximum), and averaged 5–10 best synchronizing sequences of them.

**Paper VI**, written by two co-authors, and me is a switch from construction wood to extant trees. As growing trees are available for researchers with all their parts, they represent a good model for studying the wood in constructions. Several methodological questions of tree-ring dating can be explained on the example of growing trees. For instance, information on the relative portion of sapwood in a tree trunk helps to date timber without waney edge. The decreasing rate of timber during seasoning can be studied on wood samples extracted from raw stems. It is possible to check the accuracy of the counted number of tree rings against the tree-ring samples of planted trees. Growing trees provide evidence on site conditions, and the characteristics of tree rings in the site. Growth dynamics of trees reflect changes in site conditions (cutting, planting, etc.) during the lifetime of the trees. In this paper I present a new method for assessing the age of big and hollow trees. The method is based on cumulative graphs of annual increment of wood. It was described above in the chapter on methods. Results of the graphical age estimation of the trees were checked with another new method (the bark method) developed by the co-author M. Rohtla in combination with some written sources found by the other co-author H. Sander. It appeared that these methods might be complementary to each other, depending on the trees under study. Information on the age of big trees planted near houses can provide supplementary information on the history of the property found from the houses, and thus either support (or disclaim) the dendrochronological dating of the buildings.

The big oaks studied in Tallinn also provide good data for further studies of sapwood/heartwood rate of oaks in Estonia. It is known that this rate differs in oaks growing in different parts of Europe (Eckstein *et al.*, 1986; Wazny, 1990). The problem of sapwood/heartwood rate of oaks in Estonia has arisen in dendrochronological dating of the few oak timbers in our historical buildings, but especially in the dating of oak panels of paintings. The timber of these boards is allegedly of Baltic origin (Zunde, 1998–1999). First successful attempts of dendrochronological dating of old paintings have been already made by the author: by now oak panels of four Flemish paintings of 16$^{th}$–17$^{th}$ centuries have been dated.

* * *

These six papers here represent more generalised results of my research in tree-rings. There are several other papers where certain questions of tree-ring dating or building objects have been discussed (No. 15, 23, 30). Several earlier papers (e.g. No. 14, 24, 28) served as methodological preparation for tree-ring dating. The main work included extensive sampling and dating of buildings during half a decade all over Estonia (No. 31, 32, 177). The results of this work include more than twenty dated historical buildings or their roof constructions. Paper III and also a paper published in *The Palaeobotanist*, India, show that the Estonian mean series of tree rings are well datable with tree-ring chronologies of the neighbouring regions such as Sweden, Finland, northwestern Russia, Latvia, Lithuania, and even Poland and North Germany. Alongside with construction wood, sampling and investigation of growing trees is continued. A manuscript with co-author D. Eckstein will explain the effect of climate variables on the annual growth of pines in Estonia. The results of that investigation support the idea of a uniform dendroclimatic region that covers areas at the both sides of the Baltic Sea. Due to the location in the same dendroclimatic region as parts of Fennoscandia, northwestern Russia and the Baltics, it is possible to date Estonian tree-ring series reliably with references from these areas.

As a result of the investigations, the wooden constructions of the following objects were dated by widths of tree-rings. For each object, the number of dated samples (cores) and the temporal extent of the averaged tree-ring series are indicated:

Pines:

| | | | |
|---|---|---|---|
| 1. | Albu mansion | 4 | 1604–1733 |
| 2. | Elisabeth Church, Pärnu | 8 | 1584–1745 |
| 3. | Gustav Adolf Gymnasium, Tallinn | 8 | 1297–1448 |
| 4. | Haljala Church | 11 | 1713–1831 |
| 5. | Harju-Risti Church | 10 | 1772–1876 |
| 6. | Jakobi St. 37, Tartu | 6 | 1567–1814 |
| 7. | Jaani Church, Tartu | 15 | 1125–1320 |
| 8. | Karja Church | 7 | 1733–1865 |
| 9. | Karlova Mansion, Tartu | 6 | 1704–1793 |
| 10. | Keila Church | 6 | 1742–1859 |
| 11. | Kihelkonna Church | 5 | 1604–1681 |
| | | 12 | 1801–1874 |
| 12. | Korsi farmhouse, Ruhnu | 5 | 1528–1685 |
| 13. | Kursi Church | 8 | 1704–1765 |
| 14. | Kuusalu Church | 9 | 1700–1783 |
| 15. | Martna Church | 8 | 1783–1862 |
| 16. | Nõo Church | 11 | 1601–1738 |
| 17. | Pühavaimu St. 8, Pärnu | 9 | 1580–1765 |
| | | 3 | 1779–1877 |
| 18. | Ruhnu Church | 6 | 1545–1641 |
| | | 6 | 1679–1850 |
| 19. | Saue St. 11, Haapsalu | 4 | 1725–1782 |
| 20. | Tampere House, Tartu | 6 | 1688–1771 |

| | | | |
|---|---|---|---|
| 21. | Treffner Gymnasium, Tartu | 7 | 1617–1771 |
| | | 6 | 1603–1784 |
| 22. | Vormsi Church | 9 | 1756–1883 |

Spruces:

| | | | |
|---|---|---|---|
| 1. | Albu Mansion | 5 | 1666–1774 |
| 2. | Ambla Church | 8 | 1666–1857 |
| 3. | Anna Church | 5 | 1743–1851 |
| 4. | Elisabeth Church, Pärnu | 5 | 1727–1891 |
| 5. | Esna Manor | 9 | 1807–1867 |
| 6. | Gustav Adolf Gymnasium, Tallinn | 3 | 1355–1448 |
| 7. | Haki farmhouse, Põlva county | 15 | 1761–1855 |
| 8. | Jakobi St. 45, Tartu | 12 | 1696–1828 |
| 9. | Järva-Madise Church | 5 | 1615–1768 |
| 10. | Kalame fisherman's house, Lääne-Viru county | 10 | 1673–1858 |
| 11. | Katarina mole, Pärnu | 4 | 1624–1803 |
| 12. | Koeru Church | 10 | 1755–1847 |
| 13. | Karlova Mansion, Tartu | 4 | 1704–1790 |
| | | 7 | 1690–1843 |
| 14. | Kullamaa Church | 15 | 1653–1865 |
| 15. | Kursi Church | 5 | 1730–1826 |
| 16. | Martna Church | 4 | 1803–1861 |
| 17. | Mihkli Church | 2 | 1644–1738 |
| 18. | Noarootsi Church | 3 | 1774–1870 |
| 19. | Pärna forester's house, Lääne county | 3 | 1777–1858 |
| 20. | Rootsi-Mihkli Church, Tallinn | 8 | 1642–1770 |
| 21. | Saadjärve Mansion | 6 | 1695–1791 |
| | | 7 | 1764–1880 |
| 22. | Tampere House, Tartu | 10 | 1576–1753 |
| 23. | Tallinn Gate, Pärnu | 4 | 1711–1806 |
| 24. | Uppsala House, Tartu | 30 | 1648–1781 |
| 25. | Väike-Maarja Chapel | 9 | 1701–1807 |

At the present moment, the continuous tree-ring sequences of pines cover AD 1528–1999, and two separate series cover AD 1125–1448. In the case of spruce, the continuous coverage is for AD 1576–1998 and AD 1355–1448. New findings of old wood would help to fill the gap between the series. Still, a number of questions remain open. The work continues to develop and extend the geographical and temporal networks of dated mean tree-ring series for different tree species, first for pine and spruce as construction wood in Estonia. Especially the synchronization of some spruce series posed problems. Long spruce series would remarkably improve the quality of the network of spruce series in Estonia. Other tree species such as larches and oak have helped to study some of the methodological problems of dating.

# 4. CONCLUSIONS

The results of the tree-ring studies represented by these six papers and other scientific publications of the author enable to draw some general conclusions. Some of the conclusions are more important for dendrochronology, and some of them for history. The main conclusions of this thesis can be outlined as follows:

1. Estonian tree-ring series of pine (*Pinus sylvestris* L.) and spruce (*Picea abies* Karst.) for both woods from historical buildings as well as growing trees are reliably datable between themselves, and with the tree-ring chronologies of the neighbouring areas around the Baltic Sea. This means that Estonia belongs to the same dendroclimatological region together with the central part of Sweden, southern Finland, northwestern Russia, and Latvia. This applies first of all to pine; as for spruce, some further research is necessary. This conclusion is supported by a recent dendroclimatological study of Estonian pines.
2. It was possible to find construction timber in Estonia for dendrochronological dating for about the period of AD 1750 to 1900 (as a rule, later constructions were not sampled), and in few cases also for earlier period (prior to the North War in 1700–1721). The expectations to find timber that is older, and to extend the tree-ring chronologies further to the past are high, since not all of the old buildings in Estonia have been investigated.
3. Out of the two tree species used in buildings in Estonia, pine slightly prevailed over spruce. The latter was datable within its constructional context with pine constructions. Tree-ring series of spruce were also datable with pine series to a certain extent. The practice of sampling minimally 10 trees from a construction and averaging at least five of them have found experimental support.
4. The methods used were elaborated, and the dating results obtained only due to good co-operation with tree-ring specialists from the other European tree-ring laboratories, who shared their skills, enabled me to use their software, and gave reference chronologies for initial dating of the Estonian tree-ring series.

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# 7. YHTEENVETO

Suomenkielinen tiivistelmä
Alar Läänelaid: Iänmääritys puulustojen avulla Virossa Tohtorinväitöskirja.
Helsingin yliopisto, Helsinki, 2002. 98 s.

Tohtorinväitöskirja perustuu kuuteen kansainvälisissä referoitavissa tieteellisissä julkaisuissa ilmestyneeseen kirjoitukseen ja muutamiin Virossa julkaistuhin kirjoituksiin. Tutkimus käsittelee puun vuosirenkaan eli luston mittaisten sarjojen maantieteellisen verkoston kehitystä Virossa. Puurungossa vuosittain muodostuvat kerrostumat — lustot — ovat vuosittain eri levyisiä riippuen sääolosuhteista. Samassa ilmastossa puilla muodostuvat samanlaiset vuosirenkaat. Tutkimuksen eräänä päämääränä olikin pyrkimys selvittää, onko ilmasto koko Virossa niin tasaista, että puiden lustonleveyksien sarjat ovat keskenään samankaltaisia. Siihen tarkoitukseen kirjoittaja suoritti Viron eri osissa kasvavien mäntyjen koekairauksia, laski niitten lustonleveyssarjojen keskiarvot ja vertaili niitä keskenään sekä naapurialueiden lustonleveyksien kronologiaan (artikkeli V). Ilmeni, että puiden vuosirengaskuviot ovat keskenään aika samankaltaisia Viroa laajemmalla alueella — Ruotsin keskiosasta Venäjälle, Etelä-Suomesta Lättiin, Liettuaan ja Puolaan. Tämä seikka laskee perustan Viron vuosirengassarjojen synkronisoinnille naapurialueiden kronologioiden kanssa. Vuosirengassarjojen samankaltaisuutta hyödynnetään rakennuksien dendrokronoligisessa määrityksessä. Nõon kirkon kattotuolien ja Tarton Uppsalan talon seinähirsien lustonleveyksien sarjojen keskiarvot mahdollistavat vertailukronologioiden avulla rakennushirsien kaatoa edeltäneen viimeisen kasvuvuoden sekä suurella todennäköisyydellä myös asianomaisten rakenteiden rakennusvuosien määrityksen (vastaavasti artikkelit I ja II). Seuraavaksi otin näytteitä useampien pitäjänkirkkojen kattotuoleista ja ajoitin niitten lustonleveyssarjoja naapurialueiden kronologioiden avulla sekä vertasin niitä keskenään. Muodostin lustosarjojen maantieteellisen verkoston Virossa (artikkeli III). Tarkemmin on kyse kahden rakennuksissa käytetyn puulajin verkostosta — erikseen mäntyjen (*Pinus sylvestris* L.) ja kuusien (*Picea abies* Karst.) vuosirengassarjojen perusteella. Ajoitettujen rakennuksien lustonleveyksien sarjat sijoittuvat edellisiin vuosisatoihin, mikä siirtää lustonleveyksien sarjat kauemmas menneisyyteen. Mainitun kirjoituksen valmistuessa vanhin ajoitettu vuosirengassarja oli Kursin kirkon kolmen muuriru'un keskiarvo, dendrokronologisen ajoituksen mukaan AD 1647. Tämä sarja ulottuu vuoteen 1532. Seikkaperäinen yleiskatsaus kirjoittajan vuoteen 1998 asti ajoitetuista rakennuksista Virossa on esillä artikkelissa IV. Myöhemmin on siihen lisääntynyt myös vanhempia ajoitettuja rakennuksia (julkaisemattomat tiedot). Tuhoisista sodista (esim. Pohjan sota 1700–1721) huolimatta on toivoa löytää Virosta vieläkin aiemmilta vuosisadoita säilynyttä rakennuspuuta.

Kirjoitus V on luonteeltaan metodologinen. Samassa paikassa kasvavien puiden vuosirengasleveyksien sarjojen keskiarvojen astettaisen jatkolaskennan avulla saatiin keskiarvosarjat, joita verrattiin muihin vuosirengaskronologioihin. Ilmeni, että enemmän kuin viiden valikoidun (!) vuosirengassarjan keskiarvot eivät enää lisää keskiarvon samankaltaisuutta vertailusarjojen kanssa. Näin ollen jo viiden hyvän männyn lustonleveyksien sarjoissa sisältyi tieto ilmastosta, joka löytyi myös esimerkiksi yhdentoista männyn lustonleveyksien sarjoissa. Tämä kokeellinen tulos laskee perustan dendrokronologiselle käytännölle, jossa yhdestä rakennuksesta tai rakennuskaudesta otetaan vähintään kymmenen (mahdollisuuksien myötä korkeintaan 30) koenäytettä eri hirsistä ja niistä lasketaan keskiarvo vähintään viiden koenäytteen lustonleveyksien sarjoista. Tarpeellisesta ja odollisesta koenäytteiden lukumäärästä on kirjallisuudessa erilaisia näkemyksiä. Yleensä tarpeellinen koenäytteiden lukumäärä riippuu sekä puiden kasvupaikasta että tutkimuksen päämäärästä.

Kahden muun kirjoittajan (M. Rohtla ja H. Sander) kanssa yhdessä laadittu kirjoitus VI käsittelee kasvavien suurten puiden iänmäärityksen metodiikan kysymyksiä ja tuloksia, esimerkkinä Tallinnan tammet. Kasvavat puut ovat rakennuspuutavaran tutkimisen hyviä malleja, sillä niiden elämänkaari ja kasvuolosuhteet tunnetaan paremmin. Puiston puiden tapauksessa on usein tiedossa myös puiston perustamisaika, joka voi liittyä rakennuksen sijaintipaikan omistussuhteiden muuttumiseen ja rakennuksen pystytykseen. Kirjoittaja esittää kirjoituksessaan suurien ja ontojen puiden ikäämisen uuden, graafisen menetelmän. Se perustuu lustonleveyksien kumulatiivisen käyrän sujuvaan jatkamiseen, kunnes se koskee aika-akselia. Vaikkakin tietyllä epätarkkuudella, graafinen menetelmä mahdollistaa realistisemman tuloksen kuin puun visuaalinen ikääminen. Menetelmän tarkkuus riippuu rungossa säilyneiden lustojen lukumäärästä ja rungon läpimitasta. Tuloksia verrattiin toisen kirjoittajan, M. Rohtlan kehittämällä kaarnamenetelmällä saatuihin ikäämistuloksiin. H. Sander esitti tutkittavien puiden historiallisen taustan. Kasvavat puut tarjoavat tietoa myös rungon ulomman vaaleamman kerroksen suhteellisesta paksuudesta. Tiedetään, että Euroopan eri alueilla tammien ulompi vaaleampi kerros on jokseenkin eri paksuista. Tämä seikka on oleellinen juuri sellaisen puumateriaalin, jolta puuttuu kaarnanalainen kerros, esimerkiksi tammilaudoille maalattujen taulujen tarkemman ajoituksen tapauksessa. Kirjoittajan äskeiset flaamilaisten taiteilijoiden taulujen (julkaisemattomat) ajoitukset ovat todella lupaavia. On mielenkiintoista, että suuri osa hollantilaisten taiteilijoiden tauluista on maalattu Baltiasta peräisin oleville tammilaudoille.

Kyseiset kuusi kirjoitusta ovat vuosien pituisen tutkimustyön tulosten yleistys. Niitä kirjoituksia edelsi useampia metodologisia kirjoituksia, joita voi käsittää dendrokronologisen tutkimuksen esivalmisteluina. Joidenkin dendrokronologisten tutkimuskohteiden tutkimustuloksia ei ole vielä julkaistu. Vuosirengasajoituksen tuloksena on saatu aikaan koko Viroa peittävä männyn ja kuusen lustonleveyksien verkosto, joka uloittuu nykyajasta menneisyyteen 1500-luvun alkupuolelle saakka (laskuun ei ole otettu vielä julkaisemattomia tietoja). Dendrokronologisesti on ajoitettu yli 20 historiallisesti arvokasta rakennusta tai niiden rakennusvaihetta.

Väitöskirjan johtopäätöksinä voi esittää seuraavat:

1. Viron männyn (*Pinus sylvestris* L.) ja kuusen (*Picea abies* Karst.) lustonleveyssarjat ovat hyvin ajoitettavissa keskenään ja naapurialueiden lustonleveyskronologioiden avulla. Jälkimmäinen seikka osoittaa, että Viro kuuluu samaan dendroklimatologiseen alueeseen Ruotsin keskiosan, Etelä-Suomen, Venäjän luoteisosan, Lätin, Liettuan ja osittain jopa Puolan kanssa. Tämä koskee erityisesti mäntyä, sillä kuusen tapauksessa tarvitaan vielä lisätutkimuksia.
2 Virosta on mahdollista löytää dendrokronologisesti ajoitettavaa puumateriaalia aikavälistä AD 1750–1900 (myöhempää materiaalia ei ole tutkittu), vähemmässä määrin myös aikaisempaa, Pohjan sotaa (1700–1721) edeltävältä kaudelta periytyvää puumateriaalia. Tähänastisten tutkimuksien tulosten perusteella saattaa Virosta löytyä vieläkin vanhempaa puumateriaalia, sillä monet rakennukset ovat dendrokronologisesti ajoittamatta.
3. Virossa rakennusmateriaalina käytetystä kahdesta puulajista — mänty ja kuusi — on näytteissä hieman enemmän mäntyä. Kun mäntymateriaali oli ajoitettavissa naapurialueiden mäntykronologioiden avulla, kuusen lustosarjojejn ajoitus selvisi joskus männyn lustosarjoista samassa rakenteessa. Yksittäistapauksissa kuusisarjat olivat ajoitettavissa myös mäntysarjojen avulla. Koekairauksien käytäntö — vähintään 10 näytettä yhdestä rakenteesta ja keskiarvon laskeminen niistä vähintään 5:stä — sai kokeellisen oikeutuksen.

Nykyaikaisen dendrokronologisen ajoituksen metodiikan käyttö ja historiallisten rakennuksien vuosirengasajoitus Virossa onnistui vain kiinteässä yhteistyössä Euroopan dendrokronologisten laboratorioiden asiantuntijoiden kanssa, jotka välittivät minulle työmenetelmiään ja kokemuksiaan, antoivat käyttööni laitteita ja softwarea sekä vertailukronologioita Viron rakennuksien ajoitusta varten.

# 8. ESTONIAN SUMMARY

Alar Läänelaid. Aastarõngasdateerimine Eestis.
Doktoritöö. Helsingi Ülikool, Helsingi, 2002. 98 lk.

Doktoritöö põhineb kuuel rahvusvaheliselt refereeritavates teadusväljaannetes avaldatud artiklil ja mitmel Eestis avaldatud artiklil. Uurimus käsitleb puude aastarõngalaiuste ridade geograafilise võrgustiku arendamist Eestis. Puutüves igal aastal moodustuvad puidukihid — aastarõngad — on aastati erineva laiusega olenevalt ilmastikust. Samas kliimas moodustuvad puudel sarnased aastarõngamustrid. Uurimuse üheks eesmärgiks oligi tõestada, kas kliima on kogu Eestis nii homogeenne, et puude aastarõngalaiuste read oleksid omavahel sarnased. Selleks võttis autor puiduproove kasvavatest mändidest Eesti eri osadest, keskmistas nende aastarõngalaiuste read ja võrdles omavahel ning naaberalade astarõngalaiuste kronoloogiatega (artikkel V). Selgus, et puude aastarõngamustrid on omavahel küllalt sarnased Eestist laiemal alal — Rootsi keskosast Venemaani, Lõuna-Soomest kuni Läti, Leedu ja Poolani. See asjaolu on aluseks Eesti aastarõngaridade sünkroniseerimisele naaberalade kronoloogiatega. Aastarõngaridade sarnasust rakendatakse dendrokronoloogias ehitiste dateerimiseks. Nõo kiriku toolvärgi ja Tartu Uppsala Maja seinapalkide aastarõngalaiuste keskmistatud read võimaldasid võrdluskronoloogiate abil määrata kindlaks palgipuude viimase kasvuaasta enne raiumist ning seega suure tõenäosusega öelda ka vastavate konstruktsioonide ehitusaastad (resp. artikkel I ja II). Järgnevalt võtsin aastate kestel puiduproove paljude kihelkonnakirikute toolvärkidest ja dateerisin nende aastarõngalaiuste ridu naaberalade kronoloogiate abil ja omavahel. Kujundasin välja aastarõngaridade geograafilise võrgustiku Eestis (artikkel III). Täpsemalt on tegemist kahe ehituseks kasutatud puuliigi võrgustikuga — eraldi mändide (*Pinus sylvestris* L.) ja kuuskede (*Picea abies* Karst.) aastarõngaridade järgi. Dateeritud ehitiste aastarõngalaiuste read paigutuvad ajaliselt eelmistesse sajanditesse, pikendades aastarõngalaiuste ridu minevikku. Nimetatud artikli kirjutamise ajaks oli vanimaks dateeritud aastarõngareaks Kursi kiriku kolme müürlati keskmine, dendrokronoloogilise dateeringuga AD 1647. See rida ulatub tagasi kuni 1532. aastani. Üksikasjalisem ülevaade autori poolt 1998. aastaks puude aastarõngaste järgi dateeritud ehitistest Eestis on esitatud artiklis IV. Hiljem on lisandunud ka vanemaid dateeritud ehitisi (avaldamata andmed). Vaatamata hävitavatele sõdadele (näit. Põhjasõda 1700–1721) on lootust leida Eestist veel varasemate sajandite säilinud puitu.

Artikkel V on metoodikalise iseloomuga. Samas kasvukohas kasvavate puude aastarõngalaiuste ridade järkjärgulise juurdekeskmistamisega saadi keskmised read, mida võrreldi teiste aastarõngakronoloogiatega. Osutus, et rohkem kui viie valitud (!) aastarõngarea keskmistamine enam ei suurendanud keskmise sarnasust võrdlusridadega. Seega juba viie hea männi aastarõngalaiuste ridades sisaldus sama informatsioon kliima kohta, mis oli ka näiteks üheteistkümne männi aastarõngalaiuste ridades. See eksperimentaalne tulemus on aluseks dendrokronoloogilisele praktikale, kus ühest ehitisest või ehitusjärgust võetakse vähemalt kümme (võimalusel kuni 30) puiduproovi eri palkidest ning neist keskmistatakse vähemalt viie proovi aastarõngalaiuste read. Vajaliku ja mõistliku proovide arvu kohta on kirjanduses mitmesuguseid seisukohti. Üldiselt oleneb vajalik proovide arv nii puude kasvukohast kui uuringu eesmärgist.

Kahe kaasautoriga (M. Rohtla ja H. Sander) kirjutatud artikkel VI käsitleb kasvavate suurte puude vanuse määramise metoodika küsimusi ja tulemusi Tallinna tammede näitel. Kasvavad puud on heaks mudeliks ehituspuidu uurimisel, kuna nende elukäik ja kasvutingimused on paremini teada. Pargipuude puhul on sageli teada ka pargi rajamise aeg, mis võib seostuda kinnistu omandi muutumise ja hoonete püstitamisega. Autor esitab artiklis uue, graafilise meetodi suurte ja õõnsate puude vanuse määramiseks. See põhineb aastarõngaste laiuste kumulatiivse kõvera sujuval pikendamisel lõikumiseni ajateljega. Ehkki teatud ebatäpsusega, annab graafiline meetod realistlikuma tulemuse kui puu vanuse visuaalne hinnang. Meetodi täpsus oleneb tüves säilinud aastarõngaste arvust ja tüve jämedusest. Tulemusi võrreldi teise kaasautori, M. Rohtla poolt väljatöötatud korbameetodil saadud vanusehinnangutega. H. Sander andis uuritud puude ajaloolise tausta. Kasvavad puud pakuvad andmeid ka maltspuidu suhtelise paksuse kohta. On teada, et Euroopa eri piirkondades on tammede maltspuit mõnevõrra erineva paksusega. See küsimus on oluline just koorealuse pinnata puidu, näiteks tammelaudadel maalide täpsemal dateerimisel. Autori viimatised tulemused Flaami maalide dateerimisel (avaldamata) on paljulubavad. On huvipakkuv, et suur osa Madalmaade kunstnike maalidest on maalitud Baltikumist pärit tammepuidule.

Nimetatud kuus artiklit esitavad üldistatumalt aastatepikkuste uuringute tulemusi. Neile artiklitele eelnesid mitmed metoodilised artiklid, mida võib vaadelda ettevalmistusena järgnevaile dendrokronoloogilistele uuringutele. Rea dendrokronoloogiliste uurimisobjektide uurimistulemused on veel avaldamata. Aastarõngasdateerimise tulemustena on arendatud välja Eestit kattev männi ja kuuse aastarõngalaiuste võrgustik, mis ulatub tänapäevast minevikku kuni 16. sajandi algupoolde (ei ole arvestatud veel publitseerimata andmeid). Dendrokronoloogiliselt on dateeritud üle 20 ajalooliselt väärtusliku ehitise või nende ehitusjärgu.

Käesoleva töö järeldustena võib välja tuua järgmisi:

1. Eesti männi (*Pinus sylvestris* L.) ja kuuse (*Picea abies* Karst.) aastarõngalaiuste read on hästi dateeritavad omavahel ja naaberalade aastarõngalaiuste kronoloogiate abil. Viimatimainitud tõsiasi näitab, et Eesti kuulub samasse dendroklimatoloogilisse piirkonda koos Rootsi keskosa, Lõuna-Soome, Venemaa loodeosa, Läti, Leedu ja osalt isegi Poolaga. See kehtib eriti männi kohta, kuna kuuse puhul on vaja täiendavaid uuringuid.
2. Eestis oli võimalik leida dendrokronoloogiliselt dateeritavat ehituspuitu perioodist AD 1750–1900 (hilisemat ei uuritud), vähesel hulgal ka varasemat, Põhjasõja (1700–1721) eelsest ajast pärinevat puitu. Seniste uuringute

järgi võib Eesti ehitistest veel leida vanemat puitu, kuna palju ehitisi on dendrokronoloogiliselt uurimata.

3. Eestis ehituseks kasutatud kahest puuliigist — mänd ja kuusk — esineb proovide arvus männil väike ülekaal. Kui männipuitu sai dateerida naaberalade männikronoloogiate abil, siis kuuse aastarõngaridade dateering selgus vahel männi aastarõngaridadest samas konstruktsioonis. Üksikjuhtudel olid kuuseread dateeritavad ka männiridade abil. Proovivõtmise praktika — vähemalt 10 proovi ühest konstruktsioonist ja neist vähemalt 5 keskmistada — leidis eksperimentaalse toetuse.
4. Tänapäevase dendrokronoloogilise dateerimise metoodika rakendamine ja ajalooliste ehitiste aastarõngaste järgi dateerimine Eestis sai võimalikuks ainult tänu tihedale koostööle spetsialistidega Euroopa dendrokronoloogialaboritest, kes andsid edasi töövõtteid ja kogemusi, võimaldasid kasutada seadmeid ja tarkvara ning varustasid mind võrdluskronoloogiatega esimeste Eesti ehitiste dateerimiseks.

# PUBLICATIONS

Tree-ring dating in Estonia: The roof of the Nõo church. — Dendrochronologia, 1996, 14, p. 217–221. With summaries in English and Italian. Reviewed in Geographical Abstracts: Physical Geography.

Dendrochronological dating of the Uppsala House in Tartu, Estonia. — Dendrochronologia, 1997, 15, p. 191–198. With summaries in English, German and Italian. Reviewed in Geographical Abstracts: Physical Geography.

A network of tree-ring series in Estonia. — In: Stravinskiene, V., Juknys, R. (editors), Proceedings of the International Conference Dendrochronology and Environmental Trends, 17–21 June, 1998, Kaunas, Lithuania. Kaunas, 1998, p. 264–270. Abstracted in a CAB journal.

Dendrokronoloogia uurimisseis Eestis. — Ajalooline ajakiri, 1999, 3/4 (106/107), p. 141–152. In Estonian; Summary: The Situation of Dating by Means of Dendrochronology in Estonia. Abstracted and indexed in Historical Abstracts.

Five pine samples represent climate impact as well as eleven pines. — In: Kolström, T., Lindholm, M., Viinanen, R. (editors), Conifer growth variability during the Holocene in Northern Europe. Proceedings of the meeting in Lund, Sweden 16–19 March 2000. University of Joensuu, Faculty of Forestry, Research Notes 108, p. 119–128.

Läänelaid, A., Rohtla, M. & Sander, H. Age of Big Oaks in Tallinn, Estonia. Baltic Forestry, 2001, Vol. 7, No. 1, p. 35–45. With Russian summary. CAB Forestry Abstracts and CAB TREECD cover the Journal.

# CURRICULUM VITAE

Name: Alar Läänelaid
Date and place of birth: 10 May 1951, Tartu, Estonia
Citizenship: Estonian

## Education

1967–69 Suure-Jaani Secondary School
1969–74 Tartu State University, Faculty of Biology and Geography, Department of Biology. Graduated as biologist-botanist. Diploma work defended
1975–78 Aspiranture in Tartu State University, Department of Biology. Dissertation of Candidate of Sciences defended

## Employment

1978–79 Tartu State University, senior laboratory worker at the Chair of Plant Systematic and Geobotany
1979–84 Tartu State University, assistant of the Chair of Plant Systematic and Geobotany
1984–87 Tartu State University, senior teacher at the Chair of Plant Systematic and Geobotany (since 1986: Department of Botany and Ecology)
1987–98 Tartu State University (since 1992: University of Tartu), associate professor at the Chair of Plant Systematic and Geobotany (since 1992: Chair of Botany of the Institute of Botany and Ecology)
1998 to present University of Tartu, lecturer at the Chair of Botany of Institute of Botany and Ecology

## Trained at

Institute of Botany, Kaunas, Lithuania, 1984–85; University of Hamburg, Germany, 1989, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 2000, 2001; University of Lund, Sweden, 1998

## Academic degree

Candidate of Biological Sciences in 1979 at Tartu State University, the dissertation "Bog forms of Scots pine as indicators of dynamics of raised bogs"

## Honours, awards

A certificate of merit for the 25th anniversary of botanical club of Tartu State University, from the Council of Biological-Geographical Faculty of Tartu State University, 18 November 1972, Tartu

A diploma of 1st place in the national round of Olympiad in biology "Student and the scientific-technical progress", from the Ministry of Higher Education, 1974, Tallinn

A stimulation award of innovation 1998, 12500 EEK (€ 800), for the project "Dendrochronological dating of constructional monuments", from the University of Tartu, on 3 April 1998

The White Star Medal for appreciation of the merits before the Estonian state and nation, from the President of the Republic of Estonia, on 2 February 2001.

A Tribute for long pedagogical work in the university, from the University of Tartu, on 10 May 2001.