ALEXE ALEXE

WORLDWIDE FOREST MENSURATION HISTORY

III

FOREST MENSURATION HISTORY OF SOUTHERN, SOUTH-EASTERN EUROPE, RUSSIA AND OTHER COUNTRIES OF THE FORMER USSR

BUCHAREST
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CONTENT

FOREWORD

History is important – not only to understanding the past, but to guiding the future. Dr. Alexe Alexe completed a monumental task by compiling a seven-volume set on **Worldwide Forest Mensuration History**. The material is presented by country in order to highlight the contribution of each country to the development of forest mensuration.

The chapters begin with a description of the land area, round wood production, main species, forestry education and research organizations, and primary forestry and related journals in the subject country. Where sufficient information exists, this introductory material is followed by a review of important contributions made to the topic areas of (1) tree volume, taper, and form, (2) tree growth, (3) site evaluation, (4) stand structure, (5) growth and yield prediction, (6) weight and biomass, (7) tree-ring studies, and (8) forest inventory. A chronology of selected noteworthy events is given, as well as a list of selected contributors (by time period and topic), and each chapter is concluded with additional comments by the author. The complete work contains information from 93 countries and is based on over 10,000 bibliographical references. The focus is on literature of the 19th and 20th centuries (the most recent citations included--except for a few cases - are for 1999), but in instances where significant work on forest mensuration was published prior to the 19th century (e.g., in Germany and France), reference is made to that literature. It varies from volume to volume, but typically around 40 percent of the citations are for literature published in 1980 or later. Criteria used for selecting what literature to cite included: originality (at the time when the work was completed), methodological features, frequency of citation in the primary literature, and publication in main-line journals. Special attention was also given to listing books on forest mensuration and on review articles and bibliographies.

In preparing a history of forest mensuration, the author had three primary purposes. First, was to organize the material at the country level in order to provide a better understanding of the development of this discipline in given geographical areas and within an overall historical framework. Second, was to supply a reasonably comprehensive base of information about important aspects of forest mensuration. And third, was to enable those desiring information on the roots of forest mensuration to locate key literature in the shortest possible time. This bibliographical material fulfills many informational needs, including identifying key contributions and important milestones in forest mensuration.

Although the past is unchanging, it can be interpreted in different ways. Subjectivity is inherent in any account of history. Dr. Alexe did an admirable job of seeking out the most important contributions to forest mensuration in each country and organizing the material chronologically and by topic area. **Worldwide Forest Mensuration History** is a treasure trove that can aid students, instructors, researchers, and practitioners in gaining a perspective on the development of forest mensuration around the world and in finding key information quickly and efficiently. Forestry professionals worldwide, especially those specializing in and devoted to the measurement of trees and forests, are indebted to Dr. Alexe for his Herculean effort to compile a comprehensive global history of forest mensuration.

Harold E. Burkhart
Department of Forest Resources and Environmental Conservation
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061, U.S.A.

PREFACE

This is the third volume of "Worldwide Mensuration History" and refers to "Forest Mensuration Hystory of Southern, South-Eastern Europe, Russia and other countries of the former USSR" containing the following countries: Portugal, Spain, Bulgaria, Greece, Hungary, Israel, Italy, Romania, Turkey, former Yugoslavia, Russian Federation and other countries of former USSR. The inclusion of above mentioned countries in this volume is in accordance with FAO classification (FAO 1995-124).

We adopted the concept of forest mensuration "*in sensu lato*" by including in this discipline all its main four branches: (1) timber mensuration (including biomass studies), (2) evaluation of forest site productivity (which has strong connections with ecology and soil science), (3) tree-ring studies (or dendrochronology "*in sensu lato*" containing dendrochronology "*in sensu stricto*", dendroclimatology and dendroecology), and forest inventory including sampling, remote sensing and GIS techniques.

The text is organized on country level and depending on the availability of information, mentioned papers or events are grouped as follows: (1) tree, (2) site evaluation, (3) stand structure, (4) stand growth and yield, (5) weight and biomass studies, (6) tree ring studies, (7) forest inventory. In the countries with a reasonable reviewed works the text is supplied with: a) a chronology of selected works or events, b) a list of selected contributors, and c) comments. In all cases the presentation of works or events is given in chronological order. The text of every country contains "General information" which refer on the total land area, forest area, vegetation (species and forest types), volume and biomass per hectare, round wood production, teaching and research institutions involved in forest mensuration, leading journals and periodicals, and general literature with forestry or historical information - if available.

In all countries the methodological aspects were underlined, especially such as modelling of growth and yield, bio-mathematical oriented models, sampling methods, remote sensing and GIS techniques.

In our opinion a history of forest mensuration at country level, offers a better understanding of the development of this discipline in a given geographical and historical frame. On the other hand the knowledge of the forest mensuration history in a large number of countries represent a valuable premise for elaboration of different syntheses on regional or global level by topics. This was the first purpose of our book. The second purpose was to supply the reader with a reasonable data base of information. In the first volume have been included 1046 references out of which 38 % refer to papers published after 1980 and 16 % to that published between 1991 and 1999.

Many works published before 1980 contain information that are still valid today and have been "rediscovered" later and presented as new ideas, because the original text was ignored or forgotten. The early literature has its high historical importance and help the understanding of the evolution of a specific subject.

For selection of cited papers we used as criteria: originality (at the time when the considered work was completed), methodological features, originality or/and uniqueness of the case studies, and frequency of citations in the core monographs, forest mensuration books, and articles published in the primary journals and serials in forestry and adjacent disciplines.

The most difficult problem was the selection of cited papers in our book. Any selection is strongly correlated with the problem of the sample representativity.

We discussed this problem with many specialists in forestry, statistics and history. The general opinion was that in history book there is a doubt and a risk of subjectivity cannot be avoided in totality. This is why we hesitated a long time to prepare our texts for publication. We are not sure that we succeeded to perform the huge task to present the facts in the proper manner, at least acceptable as a first valid version.

We are conscious that our available bibliographical material could be presented in other different versions. They say the past is unchanging and the future is open to many directions (at least sometimes) but the past could be interpreted in different ways and this is why we consider that the history is more than knowledge of the past, it is a background for forecasting different possible alternatives and scenarios.

We would like that this book on history of forest mensuration to be considered above all as an act of culture because it is dedicated to all humans interested in the preservation of forests and whose profession is connected in a way with forestry.

Alexe Alexe

Bucharest, January, 2004

TECHNICAL NOTE

The history is presented separately for each country. In this respect the principle of "land priority" was applied, in sense that all references on a given country are included in the text of this country regardless of the nationality of the author(s). The papers which refer to more than one country are mentioned in the involved countries. If the nationality of the author(s) is unknown, the paper was included in the country in which it has been published.

The definition of terms as forest land, other wooded land and biomass are adopted according to that specified in FAO forestry paper 124/1995: "Forest resources assessment 1990" pp. 41 and 42 as follows:

Forest land: "with tree crown cover (stand density) of more than about 20 % of the area. Continuous forests with trees usually growing more than about 7 m in height and able to produce wood. This included both closed forest formations where trees of various storeys and undergrowth cover a high proportion of the ground and open forest formations with a continuous grass layer in which tree synusia cover at least 10% of the ground." (p.41).

Other wooded lands: "Land which has some forestry characteristics but is not forest as defined above. It includes: open woodland and scrub, shrub and brushland (see below), wheter or not used for pasture or range. It excludes land occupied by "Trees outside the forest" (see below), (p. 41).

Scrub, shrub and brushland: "Land with scrub, shrub or stunted trees where the main woody elements are shrubs (usually) more than 50 cm and less than 7 m in height), covering more than about 20 % of area, not primarily used for agricultural or other non-forestry purposes, such as grazing of domestic animals. "Trees outside the forest are excluded" (p. 42). Scrub is a land covered with trees and brushes of poor quality.

Biomass is the oven-dry weight of all species of trees to a minimum dbh of 10 cm, above ground only, and includes main stems, branches, twigs, leaves and fruits.

Biomass was determined according to a model detailed in the above-mentioned FAO work.

For site and forest site productivity the following definitions have been adopted (unless otherwise specified) after European Forest Institute, Research Report No. 5, 1966, p. 2:

"The term **site** is used to describe the sum of environmental conditions (biotic, edaphic, topographic and climatic conditions, including atmospheric composition) in existence at a particular location".

"**Forest site productivity** is defined as the woody biomass production potential of a site. In this project the term site productivity is limited to the wood production potential of a site for a particular tree species, provenance or forest type. For example, growth of volume, basal area or height may serve as an indicator of site productivity" (From the Introduction of EFI Research Report No. 5/1996 written by Heinrich Spiecker).

1. PORTUGAL

General information

Land area: 86,550 sq.km (33,418 sq.mi), forest and other wooded land: 31,020 sq.km (11,977 sq.mi.), total forest: 2,755,000 ha (10,637 sq.mi.) or 32 % of land area; volume 68 m^3/ha, biomass: 45 tons/ha (FAO 1995-124: Forest resources assessment).

Round wood production: industrial round wood 10.8 mil. m^3, fuel and charcoal 0.6 mil. m^3 total round wood 11.4 mil. m^3, (World Resources 1996-97, table 9.3, p.220).

Forest vegetation: temperate mixed forests in north, dry and Mediterranean forests in south and coastal area.

- Conifers (44 %)
- Broad-leaved (56 %)
- Main species: *Pinus pinaster* (1.2 mil. ha), oak spp. 1.1 mil. ha (0.7 mil. ha *Quercus suber; Q. ilex, Q. pyrenaica, Q. lusitanica*), chestnut spp. (*Castanea* spp.); plantations: *Eucalyptus globulus, E. camaldulensis* (17 % of the forested area of the country), Euramerican poplars, Scots pine (*Pinus sylvestris*), *Pseudotsuga* spp.

Forestry education and research organizations involved in the areas of forest mensuration and forest management (date of establishment in brackets):

- Instituto Superior de Agronomia, Departamento de Ingeneria Forestal, Lisboa, (1917).
- National Forest Research Station, Lisboa, (1977).
- National Forest Research Station, Forest Production and Management Department, Lisboa, (1977).
- National Forest Research Station, Natural Resources Management Department, Lisboa, 1977.
- University of Tras-os-Montes e Alto Duro, Forestry Department, (1975).

Publications:

- Silva Lusitanica

Eucalyptus short history. *Eucalyptus* spp. are trees originally from Australia and were introduced first in Portugal as ornamental near farm houses, in road side or as windbreaks. The first eucalypts planted in Europe are probably those planted in 1829 at Vila Nova de Gaia near Porto but reliable records are available after 1852 (Pimental 1876). Large plantations have been established in different regions of Portugal and their area expanded after the Second World War as a result of pulp industry expansion in Portugal. About 95 % of eucalypt plantations are made of *Eucalyptus globulus* (M. Tomé 1988).

Early history. The first attempt to establish a management of State's property dates from 1868 but a regular organization did not take place until 1872 when, under General Director - of Commerce and Industries, a forest administrator with a technical staff, chiefs division were installed. "The only really well managed forest, the pride of the Portuguese foresters, is (1907) the forest of Leiria in Estremandura, a planted pinery of about 25,000 acres, on which over 50 men of various grades are (1907) employed with naval store distilleries, impregnating works, and saw mills. Its management (in natural seed tree system) dates from 1892."..."As a result of a very full report, in 1882, a reboisement law was enacted under which some of the sand dunes were fixed"… "There are provisions for forestry education in the School of Agriculture at Lisbon, or the education for higher positions in forest service may be secured at German or French forest schools, and some have secured it at Vallambrosa" (Fernow 1911, pp. 360-364).

1.1. Volume tables and equations

Among earlier volume tables should be mentioned the tables constructed in 1958 for pine (Pinheiro manso) by Games and Andrate. A review of volume and growth functions of *Eucalyptus globulus* were developed by Leal (1982).

Multiple attribute decision and aid techniques have been used by Jos and Margarida Tomé (1992) for the selection of methods for volume and taper prediction of *Eucalyptus globulus*. They used the most common models of volume tables, compatible and non - compatible taper curves, and volume ratio equations and fitted them to data of *E. globulus* plantations. By the methods of multiple attribute decision the models were ranked according to different statistics. Using the Pressler-Bitterlich method Pinto M. G. de S. (1996) constructed local single entry volume tables for *Betula* sp., *Castanea crenata, Quercus robur* and *Quercus rubra*.

Cited authors:

Games and Andrate 1982, Leal 1982, Pinto, M. G. de S. 1996, Tomé J. and Tomé M. 1992.

1.2. Stand structure

Available information refer to 1988-1994 period. Carvaldo Oliveira (1988) used height (*h*)/diameter (*d, dbh*) ratio in growth models on thinning practices in the case of maritime pine (*Pinus pinaster*) stands. The ratio *h/d* has been used on a large scale in Europe for the estimation of the risk of storm damage (wind and snow). The problem of *h/d* ratio and crown area in the mountainous forests stands at central Portugal was also investigated by Pinto da Costa and Maria Emflia (1993). They discussed the importance of *h/d* ratio as an indicator of trees and stands stability used for thinning strategies and for growing models.

Since 1990 (Carvalho Oliveira and Pinto da Costa 1990, and C. A. Oliveira 1992) a research project on mixed stands in Portugal has been under way. Methods of stand structure analysed in mixed stands were detailed in Pinto da Costa's dissertation at Universidade Técnica de Lisboa. (1992 a) and first results of this research project in mountainous forest stand in Central Portugal were presented by the same author at a IUFRO meeting held in Eberswalde (1992 b). The best source of references from mixed stands (research plots, measurements and results) is that of Pinto da Costa and Preuhsler's work presented at the IUFRO Symposium at Lausã-Portugal (1994).

Cited authors:

Carvalho Oliveira 1988, 1992: Carvalho Oliveira and Pinto da Costa 1990, Pinto da Costa 1992 a, 1992 b; Pinto da Costa and Maria Emfilia 1993, Pinto da Costa and Preuhsler 1994.

1.3. Growth and yield. Modelling

A review of growth and yield studies in Portugal with a presentation of future expectations of Portuguese Forestry was published by Tomé in 1983.

Among yield tables will be mentioned Carvalho Oliveira's (1985) table for "pinheiro bravo" in mountainous and hilly areas, and Duarte's et al. (1991) tables of *Pinus pinaster* in Tamêga Valley for 15-55 years age and presented for three quality classes in function of dominant height 12,16 and 20 m at the age of 35 year.

In 1988-89 twenty-two permanent plots for growth and yield studies were laid in the most important forests and the first results of the researches of this project in mountainous forest stands at central Portugal were published in 1992 at the IUFRO Centennial.

In 1988 Margarida Tomé developed a distance-independent growth and yield model for eucalyptus (*E. globulus*) plantations in central and northern Portugal. The model is based on data from 120 permanent plots. It should be mentioned that at the age of 10 year the dominant height ranges between 12 and 28 m and basal area between 8 and 32 m^2. The author emphasized the influence of site factors in both growth functions and relationships between variables (taper curves, height-diameter curves). The same author selected growth functions for eucalypt plantations (1992) and estimated their growth trends in Greece and Portugal (1995).

Barreto (1996) introduced mathematical models for the growth modelling of self-thinned pure uneven-aged stands of Corsican pine [*Pinus nigra* subsp. *laricio* (*Pinus nigra* var. *maritima*)] and beech (*Fagus sylvatica*) of different ages.

The effects of environmental factors such as temperature, photoperiod and humidity on diameter growth are described by Figueiredo and Almeida (1996) in case of *Pinus pinaster* on coastal sand dunes in Aveiro region of Portugal.

Soares et al. (1994) discussed the evaluation of a growth model for forest management using continuous forest inventory data and underlined that "Model evaluation is not one simple procedure, but consists of a number of interrelated steps that should not be separated from each other or from model construction. It is pointed out that models can only be evaluated in relative terms, and their predictive value is always open to question" (Forest Ecology and Management 71, 1995, p. 251). As an example they analyzed a case study with PBRAVO growth model for maritime pine and concluded that this model is not proper for forest management purposes because its forecasts lacked sufficient accuracy.

An exploratory analysis of growth trends in Portuguese Forests was completed by Tomé et al., in 1996.

In 1994 there are two models (GLOBUS and EUSOP) developed by Tomé (1988), Carvalho (1992), and Carvalho et al. (1994) for eucalyptus growth and development but these models are not generally applicable in all site conditions. GLOBUS and EUSOP models contain submodels for dominant height and basal area. In 1998 Amaro et al. examined and developed the dominant heigtt growth model of a stand in eucalyptus plantations. They adopted for dominant height the definition given by Avery and Burkhart (1983) as the total height average of dominant trees considered as the tallest single tree for each 100 m^2 (Tomé 1988) as measured with a hypsometer. Amaro et al. (1998) considered difference forms of Chapman-Richard and Lundqvist-Korf biological growth model derived for use in modelling dominant height growth using data from remeasured permanent plots. The final Amaro's et al. (1998) model is a difference form of Chapman-Richards equation with the *m* shape parameter constrained by initial stand conditions. (after authors' abstract).

Cited authors:

Amaro et al 1998, Avery and Burkhart 1983, Baretto 1996, Carvalho Oliveira 1985, Carvalho

1992, Carvalho et. al. 1994, Duarte et al. 1991, Fernow 1911, Figueiredo and Almeida 1996, Pinto da Costa Emilia 1992, Soares et al. 1994, Tomé M. I. 1983, 1988, 1992, 1995; Tomé et al. 1996.

1. 4. Remote sensing

Santos et al. (1981) described the methodology of visual or automatic interpretation of the Landsat data most commonly used in forestry.

1.5. Chronology of selected works

1876: First reliable records on *Eucalyptus globulus* plantations in Portugal (S. Pimentel).

1981: Methodology for interpretation of the Landsat data (J. R. Dos Santos et al.).

1982: Revised functions for volume and growth of *Eucalyptus globulus* (L. C. Leal).

1983: A review of growth and yield studies in Portugal (M. M. Tomé).

1988: A distance-independent growth and yield model for eucalyptus plantations (M. Tomé).

1990-1994: Lousã project on the structure and growth of mixed stands in Portugal (Carvalho Oliveira 1990, Pinto da Costa 1992, 1994; Pinto da Costa and Preuhsler 1994.

1988 and 1993: Studies on *h/d* ratio as a reliable indicator of trees and stands stability (Carvalho Oliveira 1988, Pinto da Costa and Maria Emflia 1993).

1991: Yield tables for *Pinus pinaster* for three quality classes, age and height as entries (C. Duarte, E. Ribeiro and J. Cosme).

1992: Selection of growth functions for eucalyptus plantations (Margarida Tomé).

1992: Selection of methods for volume and taper prediction of *Eucalyptus globulus* using multiple decision aid techniques (J. Tomé and Margarida Tomé).

1994: Evaluation of a growth model for forest management using continuous forest inventory data (P. Soares, M. Tom,, J. P. Skovsgaard and J. K. Vanclay).

1995: Growth trends of forest in Greece and Portugal (M. Tomé).

1996: Mathematical models for the growth modelling of self-thinned pure stands of *Pinus nigra* var. *maritima* and *Fagus sylvatica*, L. S. Barreto).

1996: Single entry volume tables for *Betula* sp., *Castanea crenata, Quercus robur* and *Quercus rubra* (M. G. de S. Pinto).

1.6. Selected contributors

Author	Printing years	Field
A. M. Carvalho Oliveira	1980s, 1990s	4
J. R. Dos Santos	1980s	7
E. Pinto da Costa	1990s	3
M. Tomé	1980s, 1990s	4

1 = tree and primary products, 3 = stand structure, 4 = growth and yield modeling, 7 = forest inventory and remote sensing

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FIGUEIREDO, J. P.; DE ALMEIDA, V. V. 1996. Ritmo anual de crecimento em circumfêrencia da *Pinus pinaster* Ait. nas dunas do litoral - regiao de Aveiro. (Annual pattern of circumference growth of *Pinus pinaster* Ait. on coastal sand dunes - in the Aveiro region of Portugal). Silva Lusitana 4 (2): 243-249, Lisboa.

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GUERREIRO, G. 1958. Brefs commentaires sur la sylviculture portugaise. (Short comments on Portuguese silviculture). Bull. Soc. For. Royal Belgique, no. 1.

LEAL, L. C. 1982. Revisão das Funções de Volume e Crescimento do *Eucalyptus globulus* Labill em Matas da Celbi. (Review of volume and growth functions of *Eucalyptus globulus*). Relatório de Actividades do curso de Engenheiro Silvicultor, Lisboa.

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PINTO, M. G. DE S. 1996. Tabelas de Volume de Simples estrada para *Betula* sp. *Castanea crenata, Quercus robur* e *Quercus rubra* no entre douro e minho. (Single entry volume tables for *Betula* sp., *Castanea crenata, Quercus robur* and *Quercus rubra*). Silva Lusitana 4 (2): 171-183.

SANTOS, J. R. DOS; HERNANDEZ FILHO, P.; SHIMABUKURO, Y. E. 1981. [Method of interpretation of remote sensing data and applications to vegetation]. San José dos Campos, Portugal Instituto de Pesquisas Espaciais, S4 pp. From Geo Abstracts, G. (Remote Sensing, Photogrammetry and Cartography) No. 1984-2, 84 G/0694.

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2. SPAIN

General information

Land area 499,370 sq. km (192,814 sq. mi.), forest and other wooded land: 256,220 sq. km (98,930 sq. mi.), total forest: 8,388,000 ha (32,387 sq. mi.) or 17 % of land area; volume 56 m^3/ha, biomass 66 tons/ha (FAO 1995-124: Forest resources assessment).

Round wood production: industrial round wood 13.2 mil. m^3, fuel and charcoal 2 mil. m^3, total round wood 15.2 mil. m^3 (World Resources table 9.3, p. 220).

Forest vegetation: temperate mixed and Mediterranean forests.

- Conifers 44 %
- Broad-leaved 56 %
- Main species: *Quercus ilex*, other oaks (*Q. suber, Q. robur, Q. petraea*), pine (*Pinus pinaster, P. halepensis, P. sylvestris*), European beech (*Fagus sylvatica*), *Eucalyptus* spp., *Euramerican poplars, Pinus maritima*.
- Forest regions: 1) Northern part of the country and Pirinei Mountains region (temperate mixed forests) are covered with forest species represented especially by fir (*Abies alba*), European larch (*Larix europaea*). *Pinus* spp., European beech (*Fagus sylvatica*) and spruce (*Picea abies*), *Pinus radiata* and *P. pinaster*. 2) Mediterranean region with the predominance of *Pinus maritima, P. canarensis, P. halepensis, P. pinea, P. laricio, P. pinaster, Quercus ilex, Q. suber* and *Euramerican poplars*. 3) In the central region (Maseta plateau) predominant species are represented by: *Pinus sylvestris*, oak spp. (*Quercus ilex, Q. lusitanica, Q. suber, Q. toza, Q. robur, Q. sessiliflora, Q. coccifera*; at higher elevation (1000 m) in Sierra de Ronda and Sierra de Pinar there are highly productive stands of *Abies pinsapo*.

Forestry education and research organizations involved in areas of forest mensuration and forest management (date of establishment in brackets):

- Universidad Politecnica de Madrid, Escuela Tecnica Superior Ingenieros de Montes, Madrid (1845).
- Escuela Universitaria de Ingenieria Tecnica Forestal, Madrid (1961).
- Centro Capacitacion y Experimentacion Forestal, Cazorla-Jaen, (1969).
- Instituto Nacional de Investigacion y Tecnologia Agraria y Alimentaria (INIA), Madrid, (1971).
- Universidad Autonoma de Barcelona, Centro de Investigacion y Aplicacione Forestales (CREAF), Barcelona, (1987).

Publications:
- Revista de Montes (established in 1877).
- Comunicaciones INIA, Recursos Naturales, Madrid.
- Investigación Agraria, Sistemas y Recursos Forestales.
- Ediciones del Instituto forestal de Investigaciones y Experiencias, Madrid.

Information on the 1960s level:
- Ministerio de Agricultura, España, 1965, Inventario Forestal Nacional Avila (National forest inventory. Avila).
- Ministerio de Agricultura, España 1963-1965. Memoria sobre los actividades el periodo 1963-1966 (Activity during 1963-1966 period).
- University of Santiago de Compostela, Spanish Journal of Rural Development

Forest mensuration textbooks:

MACKAY, E. 1964. Dasometria. Escuela Superior de Ingenieras de Montes - Madrid.

PARDÉ, J.; J. BOUCHON. 1994. Dasometria. (Translated from French "Dendrometria"). Editorial Paraninfo, Madrid.

Details on legislation, forest administration and early history of Spain were presented by Fernow in his brief history of forestry (1911, pp. 349-360).

According to Fernow (1911): in 1351 Pedro I imposed heavy fines upon forest destroyers and in 1518 a system of forest guards was established. In 1748 Ferdinand VI placed all forests under government supervision, but in 1812 Cortes of Cadiz, under the influence of the spirit of French Revolution, rescinded these orders and abolished all restrictions. In 1840 "We find that several young men were sent to the forest school at Tharandt (Germany)… under the influence of these men a commission to formulate a forest law was instituted in 1846, and in the same year, carrying out ordinances of 1835 and 1843, a forest school was established at Villaviciosa de Odon, later (1869) transferred to Escorial near Madrid… organized after German models by Bernardo della Torre Royas as first Director. The creation of a forest department, however, Cuerpo de Montes, had to wait until 1853" (pp. 355-356). After 1877 a considerable book literature is also developed (p. 310).

2.1. Tree and tree volume tables

Earlier volume tables were constructed by Morenza (1951) for *Pinus insignis* in northern Spain. Later (1984) Pardo developed tables for volumes of felling Populus 'I-214' in Valle Medio del Ebro.

In 1989 Cuevas Gozalo developed volume equations for beech in the Ovocantabric Navarra. Treble entry volume tables (dbh, total height and diameter 4 m above stumps) for use in forest management and based on sets of volume equations for merchantable stem volumes over bark have been presented by Martinez Millove et al. in 1992 for the main forest tree species in Spain: *Pinus sylvestris, P. uncinata, P. pinea, P. halepensis, P. laricio. (P. nigra var. maritima), P. pinaster, Abies alba, Quercus robur/Q. petraea* and *Fagus sylvatica*.

Morales et al. (1996) investigated in laurel forests, in Tenerife (Canary Islands), leaf distribution patterns in individual trees (branching pattern, leaf distribution area, dry weight, number and allometric relations). Three species were studied (*Persea indica, Laurus azorica* and *Erica arborea*). They concluded that in all species the crown architecture corresponded to Rauh's model and leaf area was highly correlated with stem diameter.

Cited authors:

Cuevas Gazolo 1989, Martinez et al. 1992, Morales et al. 1996, Morenza 1991, Pardo 1984.

2.2. Stand structure

Caritat et al. (1991) studied the structure, biomass and growth in six plots of *Quercus suber* stands, in Girona. They established that the best stand had a commercial cork production of 9.6 t/ha but the growth mainly depends on tree age and water supply. The structure and dynamics of an *Abies pinsapo* forest was investigated in southern Spain by Arista (1995).

In connection with the laurel forests in Tenerife, Morales et al. (1996) investigated also the site, stand structure and stand leaf area distribution. This forest in the Agua Garcia mountains of Tenerife is located at 820 m altitude and is a national hardwood forest composed of six major species: *Laurus azorica, Persea indica, Myrica faya, Erica arborea* and two *Ilex* spp. The studied stand had 1693 trees/ha, 33.7 m^2/ha basal area, above ground volume 231 m^3/ha (mass 204 t/ha), diameters 6-46 cm. This case was mentioned here as a curiosity because this type of evergreen broad-leaved forest represents a relict which was spread on very large areas in Mediterranean region about 20 million years ago.

At Madrid University, in 1997, Alvarez Gonzales analyzed and characterized, in his dissertation, the distribution of *Pinus pinaster* stands.

Cited authors:

Arista 1995, Caritat et al. 1991, Gonzales 1997, Morales et al. 1996.

2.3. Stand growth and yield

Early information on yield of *Eucalyptus globulus* were supplied by Escheverria (1952) and by Ballarin (1952) who constructed yield tables for this species.

Information on yield of *Pinus insignis* firstly available from Escheverria (1956).

In 1974 Pita and Madrigal presented probably, the earliest Spanish mathematical model for the construction of *Pinus sylvestris* yield tables. They tested three fundamental relations: (1) "The first relation classifies the site quality for the evolution of the dominant height (H_o) in function of age (T). The site index, at the typical age of 50 years, goes from 7 m (site V) to 19 m (site I). (2) The second relation expresses the mean square spacing (100/N) in function of dominant height (H_o) and the site index (T). (3) The third relation will join the mean square diameter (Dg) of the stand (before thinning) with the same spacing ($100/\sqrt{N}$) and the dominant height (H_o). These three relations are the base for the study of the evolution of the other variables, which characterize the yield tables" (p. 302).

In 1981 there have been published Garcia Abejon's variable density yield tables of *Pinus sylvestris* in Sistema Ibérico and later (1984) for the same species in Sistema Central, which contains the provinces of Avila, Madrid and Segovia, and in 1986 for Sistema Pirenaico.

Dendrometrical studies were developed by Tomas (1982) on yield of European Beech (*Fagus sylvatica*) in Santa Fe del Montseny Valley.

Magrigal et al. (1992) constructed yield tables for *Fagus sylvatica* in Navarra. The growth and yield of *Pinus pinaster* in Galicia were determined by Rodriguez Soalleiro in 1995.

Montero et al. (1996) presented the case studies of growing stock and height growth evolution in Spanish forests.

Cited authors:

Ballarin 1952, Escheverria 1952, 1956: Garcia Abejón 1981, Garcia Abejón and Gomez Loranca 1984, Garcia Abejón and Tella Ferreiro 1986, Magrigal et al. 1992, Montero et al. 1996, Pita and Madrigal 1974, Rodriguez Soalleiro 1995, Tomas 1982.

2.4. Weight and biomass studies

Weight tables for biomass estimation of *Quercus pyrenaica* in Leon Province were constructed by Gonzales Donces in 1989 for stems over 2.5 cm dbh, and the total height was used as an independent variable for the estimation of fresh weight and fresh and dry bole weight and dbh and height/dbh as independent variables for fresh and dry branch weight estimation.

In a xeric stand of *Quercus ilex* in a montane Mediterranean forest root biomass of 91 t/ha (excluding roots under 1 cm diameter) and above ground biomass of 79 t/ha were determined by Canadell and Rodá in 1991 who measured in a mesic site, for this species, 160 t/ha above ground biomass and 63 t/ha a below-ground biomass.

San Miguel Ayanz et al. (1991) developed weight tables for individual stems of *Quercus pyrenaica* in coppices in the Central Massif of Spain (Sistema Central Español).

The aboveground biomass in beech forest and the scots pine plantation in the Sierra de la Demada area of northern Spain were studied by Santa Regina et al. (1977): at the mean age of 50 years they founded a total biomass of 152.1 t/ha in the pine forest and 134.2 t/ha in the beech forest, and the litter fall was 5791 kg/ha in the pine forest and 4682 kg/ha in the beech forest, but the higher biomass by diameter classes in the beech forest indicates that will be not suitable to use pine instead of beech.

Cited authors:

Gonzales Donces 1989, Canadell and Roda 1991, San Miguel Ayanz et al. 1992, Santa Regina et al. 1997.

2.5. Tree-ring studies

Before 1980 few dendrochronological studies were carried out in Spain or Portugal.

We have no information about tree-ring studies in Spain before 1976 when Creus and Puigdefabregas published in Logroňo an article containing information on history of climatology in connection with *Pinus uncinata* dendrochronology while Garcia and Génova completed in 1982 a dendrochronological analysis and productivity study of this species. In 1980 Martinez et al. analyzed periodical fluctuations within a dendrochronology established in the Pyrenees.

Génova and Garcia (1984) completed dendroclimatological analyses in Macio del Montseny using as species *Castanea sativa* Mill.

Dendroclimatology of mountain pine (*Pinus uncinata* Ram) in the central plain was a subject of Génova's studies (1986). Because of its broad altitudinal range and long age, the mountain pine is suitable for dendrochronological investigations. Génova used samples from trees growing in Sierra de Cebollera and the dated series were used to develop a ring-width index chronology which was compared with local climate data. Variability of ring width proved to be related first of all to precipitations but temperature may be also important indicating a complex climate response. Studies using this species will be important for all Mediterranean area, not only for dendroclimatology, but also for ecophysiology of subalpine plots in the Mediterranean area (according to Génova).

Gutiérrez Emilia investigated in her Ph.D. Dissertation (Univ. de Barcelona), (1987) dendrochronology of *Fagus sylvatica, Pinus uncinata, Pinus sylvestris* in Catalunya. Gutiérrez developed in 1989 (published in 1991) a dendroclimatological study of *Pinus sylvestris* (two modern tree-ring width chronologies) in the Mountains of Prades (1989). These two chronologies (161 and 124 year long) have been studied in relation to the local sub-mediterranean climate and the results of response function analysis indicate the sensitivity of this species to summer water stress, and they are affected by precipitation in September of the previous year and in March and June of current year of growth. December mean monthly temperature affected growth (there is a significant positive correlation with growth). She concluded that at least in southern Catalonia the "major factors controlling the southern distribution of *P. sylvestri*s may be related not only to water stress in summer but also to the amount of precipitation at the beginning of the growing season and in autumn, even in mild winters" (Tree-Ring Bull. 49/1989, p. 1).

Creus et al. (1992) presented a review of the new dendrochronologies for Spanish Mediterranean zone.

A remarkable review of dendrochronological research in Spain (49 references and a list of over 100 Spanish chronologies published up to 1994, publications and doctoral theses on dendrochronology) was completed by Pérez Antelo in 1994. Most of the chronologies are related to *Pinus uncinata* and *Pinus sylvestris* from mountainous areas.

Caritat's et al. (1995) a 14 years (1978-1992) sequence of cork-ring width chronology correlated with rainfall and temperature data represents probably the first dendrochronological study of this type on *Quercus suber* L. *Quercus* trees were growing in dehesa (grassland with scattered trees) in Cáceres, Extremadura southwestern Spain with the average width of cork growth rings between 2.05 and 4.37 mm. According to authors the rain periods with the most important influence on cork growth are located between November to June and November to September. Temperature shows a negative correlation with cork growth except the coldest period, April and September when temperature has an important influence on phellogen activation.

Evolution of phytoclimatical studies in Spain based on dendrochronology was reviewed by Manrique M. (1999). Manrique E. and Fernandez-Cancio, A. (2000) presented extreme climatic events in dendroclimatic reconstructions from Spain.

Cited authors:

Caritat et al. 1996, Creus and Puigdefabregas 1976, Creus et al. 1992, Garcia and Génova 1982, Génova 1986, Genova and Garcia 1984, Gutiérrez 1987, 1989/1991, Manrique E. and Fernandez-Cancio A. 2000, Manrique M. 1999, Martinez et al. 1980, Pérez 1994.

2. 6. Forest inventory and remote sensing

2. 6. 1. Forest inventory

An early proposal to use mathematical statistics in forest inventory (sampling plots) was made in 1953 by Sanchez Chrespo and Cobian.

The first national inventory in Spain was carried out in 1965-1974 and the second one between 1986-1995, and it will be repeated every 10 years (Millán Martinez 1978, 1987; Millán Martinez and Aranguren 1993).

The results of the first national forest inventory of Spain (INF-I) furnished a better knowledge of the forest area as a necessary basis for forest policy on different levels.

The IFN-II was completed by the "Instituto para la Conservación de la Naturaleza" (ICONA).

According to Millán Martinez and Aranguren, A. V. (1993) the IFN-II had the following objectives: 1) "to collect up to date information about Spanish forests for the elaboration of the national and CEE forest statistics and 2) to provide useful data for planning and improvement of forest resources. The inventory design had the following characteristics: it was a systematic sampling with stratification; the province was the basic unit for sampling design, the inventory will be continous with a ten years cycle, the basic units for results presentation are the provinces and the Autonomous lands (fifty provinces are integrated into seventeen Autonomous lands, every year approximately a tenth of the total surface is inventoried, including, if possible, complete autonomous lands, classification and estimation of surfaces were made from digitized maps, field sampling was systematically distributed over the forest area, on the corners of the UTM 1 km grid… Trees with dbh greater than 7.5 cm, 12.5 cm, 22.5 cm and 42.5 cm were selected for mensuration into four concentric circles with radius of 5, 10, 15 and 25 m respectively. The handbook "Segundo Inventario Forestal Nacional, Explicaciones y Métodos" edited by ICONA, presented a detailed description of the methodology." (pp. 77-79).

Multiresource Forest Inventory was accepted in Spain on province level having as object timber and non timber forest products (Garcia-Guemes 1997, Millan-Martinez 1997). The organization in charge of MRIS is CIFOR-INA, ETSI de Montes.

2. 6. 2. Remote sensing

In 1950s photogrammetry was commonly used in Spanish forestry (Carderera 1956). Carre's manual on the use of aerial photographs was translated by Navarro in 1975.

Landsat 5 Thematic Mapper (TM) data were used to map forest fires and monitor vegetation recovery over burnt areas in Valencia (López and Caselles 1991). López Soria et al. used in 1991 digital images from circumpolar weather satellites in detecting the risk of forest fires. According to their results NDVI (Normalized Difference Vegetation Index) reflects the phenological development of the vegetation.

Linear Spectral Mixture Modelling (LSMM) has developed in 1990s as a remote sensing technique for the analysis of the biophysical and compositional character of ground surfaces. García-Haro et al. (1996) reported the potentional of LSMM. "High spectral resolution reflectance measurements of soil-plant mixtures with different soil colors and plant densities were carried out in a laboratory experiment (25 cm tall plants of *Quercus rotundifolia)*. It is concluded that the use of LSMM technique can be operational in the monitoring of vegetation from satellite data (For. Abs. 2808/1997).

Lobo et al. (1997) used a hierarchical approach to classify temporal sequences of images of the Normalized Difference Vegetation Index (NDVI) from the Advanced Very High Resolution Radiometer (AVHRR) on the Iberian peninsula of Spain. It is concluded that the analysis of temporal series NDVI yield relevant ecological information at finer scales and with more detailed legends that had not been attempted until now, and therefore, are suitable for regional scale applications. The results also indicate the interest of a bioclimatic analysis and modelling of the NDVI signatures for their correct ecological understanding. Maps at a global scale can be produced based on such an understanding" (For. Abs. 2722/1997).

Cited authors (2.6):

Carderera 1956, Garcia-Guemes 1997, Garcia-Hara et al. 1996, Lobo et al. 1997, López Garcia and Caselles 1991, López Soria et al. 1991, Millán 1978, 1987; Millán and Aranguren 1993, Millán and Condes 1997, Sanchez Chrespo and Cobian 1953.

2.7. Chronology of selected works

1952: Yield study and yield tables for *Eucalyptus globulus*. (I. E. Ballarin, J. B. Echeverria).

1950s: The use of aerial photography in forestry (L. Carderera).

1964: Textbook on forest mensuration (E. Makay).

1965-1974: The first national forest inventory.

1974: Probably the earliest Spanish mathematical model for the construction of yield tables based on three fundamental relations (A. P. Pita and A. Madrigal).

1976: Early dendroclimatological study based on annual rings of *Pinus uncinata* (J. Creus and J. Puigdefábregas).

1981-1986: Variable density yield tables for *Pinus sylvestris* in the: Sistema Iberico (J. L. Garcia Abejon 1981), Sistema Central: provinces of Avila, Madrid and Segovia (J. L. Garcia Abejon and J. A. Gomez Loranca 1984), Sistema Pirenaico (J. L. Garcia Abejon and G. Tella Ferreiro 1986).

1982: Dendrochronology and productivity of *Pinus uncinata* (C. A. Garcia).

1986-1995: The second national forest inventory (F. J. Martinez-Millán).

1986: Dendroclimatology of mountain pine [*Pinus uncinata* Ram. in the central plain of Spain (Ricardo Génova)].

1987: Dendrochronology of *Fagus sylvatica, Pinus uncinata, Pinus sylvestris* in Catalonia (Emilia Gutiérrez).

1991: Biomass of *Quercus ilex* in a montane Mediterranean forest (J. Canadell and F. Rod).

1991: Structure and growth of *Quercus suber* stands in Girona (A. Caritat, M. L. Molinas and M. Oliva).

1991: The use of thematic mapper data (López Garcia and M. J. Caselles).

1991: Use of digital images from circumpolar weather satellites in detecting the risk of forest fires (Lopez Soria et al.).

1992: Sets of tree volume equations and volume tables for the main forest tree species in Spain: *Pinus sylvestris, P. uncinata, P. pinea, P. halepensis, P. nigra* var. *maritima, P. pinaster, Abies alba, Quercus robur/Q. petraea* and *Fagus sylvatica* (F. J. Martinez Millan, P. Ara Lazaro and Gonzales Doncel).

1992: Weight tables for individual stems of *Quercus pyrenaica* (A. San Miguel Ayanz, A. Ferrández Cancio and J. San Miguel Ayanz J.).

1994: Review of dendrochronological research in Spain (A. Pérez Antelo).

1994: Translation into Spanish from French of the "Dendrometria" written by Pardé and Bouchon in France.

1996: Annual cork-ring width variability of *Quercus suber* L. (A. Caritat, M. Molinas and E. Gutierrez).

1997: The start of multi resources forest inventories.

1997: Regional scale hierarchical classification of temporal series of AVHRR vegetation index (A. Lobo et al.).

1998: A complex mensurational study of the relict laurel forests in Tenerife, Canary Islands (D. Morales, M. Jiménez Soledad: A. M. Gonzáles-Rodriguez and J. Čermák).

2000: Extreme climate events in dendroclimatic reconstructions from Spain (E. Manrique and A. Fernandez-Cancio).

2.8. Selected contributors

Author	Printing years	Fields
A. Caritat	1990s	3, 4, 5, 6
J. B. Echeverria	1950s	4
J. L. Garcia Abejón	1980s	4
Emilia Gutiérrez	1980s ,1990s	6
F. J. Martínez Millan	1970s-1990s	1, 7
A. Pérez Antelo	1990s	6

1 = tree, 2 = site evaluation, 3 = stand structure, 4 = growth and yield, modelling, 5 = weight and biomass, 6 = tree ring studies, 7 = forest inventory and remote sensing

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3. BULGARIA

General information

Land area 110,190 sq. km (42,546 sq. mi.), forest and other wooded land: 36,860 sq. km (14,221 sq. mi.), total forest: 3,386,000 ha (13,074 sq. mi.) or 31 % of land area, volume 118 m^3/ha, biomass: 61 tons/ha (FAO 1995-124: Forest resources assessment).

Round wood production: industrial round wood 1.9 mil. m^3, fuel and charcoal 1.7 mil. m^3, total round wood 3.6 mil. m^3 (World Resources 1996-97, p. 220).

Forest vegetation: temperate mixed forests

- Conifers 17 %
- Broad-leaved 83 %
- Main species: oaks (*Quercus cerris, Q. frainetto, Q. robur*), European beech (*Fagus sylvatica*), hornbeam (*Carpinus betulus*), Scots pine (*Pinus sylvestris*), Norway spruce (*Picea abies*), Pinus nigra ssp. nigra, fir (*Abies alba*).

Forestry education and research organizations involved in the areas of forest mensuration and forest management (date of establishment in brackets):

- Higher Institute of Forestry and Wood Technology, Sofia (1925).
- Forest Research Institute, Sofia (1928).

Publications (Primary Journals and Serials):

- Gorsko Stopanstvo, Sofija.
- Nauchni Trudove, Nauchno-Isledovatelski Institut za Gorata I Gorskoto Stopanstvo, Sofija.
- Gorskostopanska Nauka.

3.1. Tree mensuration

Early available information refer to Michailoff's researches on spruce bark (1936) and stem form of the trees of this species in Bulgaria (1938).

In 1953 Duchovnikov constructed taper tables for Scots pine, and in 1958 Sirakoff applied the empirical method of normal curves of decreasing coefficients of stem diameter (tapering) and considered this method as a basic one for forest mensuration both in theory and in practice.

Dimitrov (1976) applied the method of regression for determination of spruce form factors and used mathematical statistics to establish the relationships between tree height and diameter at breast height (dbh).

3.2. Stand structure, growth and yield

In 1962, Šikov published the results of his investigations on growth and yield of even-aged spruce stands (*Picea abies*) in Bulgaria. Šikov's yield tables refer to five site classes (h_g and age as entry variables) for 20-150 years old stands.

At the age of 80 the stand height (the height of a mean tree having the average basal area: G/N) is located between 14.1 and 27.7 m, and the mean increment between 4.5-13.8 m^3/ha/yr. According to these data the Bulgarian spruce has a lower productivity than that growing in the neighbouring Romania where the comparable values are 15.3-34.7 m and 5.7-16.4 m^3/h/yr, (Romanian data after Armăşescu, 1965).

Kr'stanov et al. (1984) constructed volume tables for poplar taking into account the structure of plantations. Using 3770 sample trees he developed volume tables for each of the three clones, age-groups and stand densities, showing volume in m^3 for 5, 6, 7, … 35 m and dbh 6, 10, 14, … 54 cm (Based on information from Forestry Abstracts 3228/1985).

In the next year (1963) Šikov presented growth structure and productivity of some mixed stands of Scots pine and Norway spruce. Nedjalkov (1967) provided data on selection mixed forest of spruce, fir and beech proposing the measures for their management.

3.3. Biomass studies

A few studies completed between 1984 and 1987 will be mentioned.

After a review of world literature on the use of regression analysis to develop multi-functional models for the biomass of stem that can be applied in thinnings in Scots pine plantations, Georgiev (1984) used several regression equations for the determination of crown biomass and stem biomass. New data on aboveground biomass and its components in Scots pine plantations were supplied by Belyakov et al. in 1985.

Grozeva et al. (1986) established the structure and chemical composition of biomass in a Norway spruce stand in the Rila Mountains – a place with a high resonance in the history of Christian orthodox religion.

In 1987, Dimitrov and other six authors published biomass growth tables for Scots pine plantations.

3.4. Tree-ring studies

Grozev and Delkov (1995) performed dendrochronological assessment of the conditions of the Scots pine ecosystems in the Dupkata biosphere reserve in western Rhodope Mountains. The established mean chronology covers the period 1802-1992. The ring smooth sequence of descending and ascending increment periods proved the stability of these pine ecosystems which are well-adapted to local climate and April to August rainfall seems to have the greatest influence on annual increment.

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4. GREECE

General information

Land area: 129,620 sq. km (50,048 sq. mi.), forest and other wooded land: 60,320 sq. km (23,290 sq. mi), total forest: 2,512,00 ha (9,699 sq. mi.) or 19 % of land area; volume: 63 m^3/ha, biomass: 34 tons/ha (FAO 1995-124: Forest resources assessment).

Round wood production: industrial round wood 1.2 mil. m^3, fuel and charcoal 1.5 mil. m^3, total round wood 2.7 mil. m^3 (World Resources 1996-1997, Table 9.3, p. 220).

Forest vegetation: temperate mixed forests in the mountainous regions of Macedonia, Tracia and Thesalia, and Mediterranean type dry forests.

- Conifers 29 %
- Broad-leaved 71 %
- Main species: European beech (*Fagus sylvatica*) 10 %, fir (*Abies alba*) 9 %, *Pinus laricio, P. halepensis, P. brutia, P. pinea, Cupressus sempervirens*, oak spp. (*Quercus coccifera, Q. aegelops*), chestnut spp. (*Castanea* spp.).

Forestry education and research organization involved in the areas of forests mensuration and forests management:

- Faculty of Forestry, Athens, established in 1917 and transferred in 1928 to the University of Thessaloniki.
- First forestry Institute established in 1929: now Forest Research Institute of Thessaloniki established in 1961.

Literature:

Information on 1907 and 1911 level: B. FERNOW: A brief history of forestry in Europe, the United States and other countries (pp. 327-334).

Information on 1958 level: METAXAS, N.; K. MAKRIS. 1958. Les Forêts et la sylviculture hellénique. (Forest and Greek silviculture). Societ. Roy. For. Belgique (S.R.F.B.), no. 8-9.

4.1. Tree mensuration

The methods of construction of the volume tables (double-entry) and tariffs (one-entry) were analysed by Georgopoulos (1957, a). Later, in 1988 Matis constructed volume tables for *Abies borisii-regis* using the equation

$$\ln(v) = -0.912 + 0.961 \ln (d^2H)$$

specific to a double entry volume table (d = dbh and H = tree total height).

4.2. Stand volume, growth, modelling and biomass

Georgopoulos (1957 b) indicated how to determine stand volume using samples. Gatzojannis and Warela (1992) developed a height growth model as a site classification system for Norway spruce using 98 stem analyses in northern Greece and established a local system of site index curves based on age at breast height and total height of dominant trees.

Tsoumis (1983) presented a short paper on forest biomass utilization in Greece.

A height growth model as a site classification system for Norway spruce was constructed by Gatzojannis and Warela in 1992.

Galanos et al. completed in 1999 a model to determine growing stock and volume increment of beech stands in Greece (In 1992 forest inventory in Greece indicates that beech (*Fagus sylvatica*) forests cover about 357 000 ha).

4.3. Forest inventory and remote sensing

Lagrange multiplier method and plot-double sampling were applied to estimate the first volume at minimum cost. Compared to the sampling plot, the error was increased by 10.45 % and the cost decreased by 7.35 % (Stamatellos and Blioumis 1997).

Satellite imagery (Landsat TM and SPOT) was used in 1990 by Toulios, Yassong and Moutsoulas for land-use mapping in West Messinia. The following land use patterns were identified: olive groves, vineyards, fig trees, orchards, non-irigated winter crops, annual irrigated crops, green houses, meadows, abandoned land bare land, shrubland, woodland, riparian vegetation, mudflats, beaches, urban land, quarries and excavations.

4.4. Fernow's (1911) comments on Greek forestry

Fernow's (1911) comments on Greek forestry are reproduced in this book taking into account theirs historical value:

"The history of the country has been so unfortunate and the political conditions so unsetted that only lately efforts at improvement in economic conditions could hope to receive attention. For centuries, after Greece had became a Roman province (146 B. C.), it changed rulers, Romans, Byzantines, Franks, Venetians following each other, until, between 1460 and 1473, it came under the Turkish yoke. As a result of an insurrection started in 1821, freedom, but no settled order as yet, was attained in 1829… By the time this new era had arrived these was probably little valuable forest worthy of the name left, except in the inaccessible mountain districts." (p. 327-328).

"Although certain districts, like Attica, were already practically denuded in Plato's time, there is little doubt that originally the whole of Greece with small exceptions was a continuous forest. The destruction of the forest, protected by thousands of gods and nymphs in holy groves, proceeded slowly under the regime of the ancient Greeks, until the fanaticism of the Christian religion led to a war against these pagan strongholds, and the holy groves were reduced by axe and fire. Turkish misrule for centuries, overtaxation, reckless cutting, extensive herding of goats and sheeps, and fires have reduced the forest area until now when it occupies only 12 or 14 per cent of the land area (25,000 square miles). In 1854, a survey developed about 2 million acres of woodlands (probably an excessive figure for the now 2.5 million people, while 67 percent, of the surface is a useless waste, and only 20 per cent, under cultivation, so that the general aspect of the century is desolate" (p. 328).

"It is belived that Greece in ancient times was more fertile than it is now, and that the deterioration is due to deforestation. Undoubtedly, soil conditions favored such deterioration, for, with the exception of the Pindus range, which is composed of metamorphic rock, a poor, dry limestone is characteristic of the country, except where fertile, alluvial and diluvial deposits cover it in valleys along the coast. The climate is, however, so favorable that even the poor soil would readily reclothe itself if left alone." (pp. 329-330).

"Dr. Chloros, who obtained his education in Germany, became finally Forest Director and was responsible for securing further legislation in 1888, the object of which was, as a first step towards improvement, to survey and delimit and round off the state property… In 1899, a change in the permit system was made, but hardly for the better, justices of the peace being empowered, under certain conditions, to issue such permits. Nor do we find in 1901 anything more than expressions of good wishes, and desire for further legislation, beside some attempts at popular education, through the formation of tree-planting associations under the patronage of the Crown Princess. In 1905 no change in conditions are reported. Forest fires still continue as a common occurrence" (p. 334).

After almost a century, according to FAO-1995 data it seems that forest situation has been improved but the ancient Greek forest are lost forever.

Greek forest mensuration was influenced since the beginning by German literature.

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GALANOS, F.; ALBANIS, K.; APATSIDES, L. 1999. Ein Modell zur Ermittlung von Vorrat und Zuwachs griechisher Buchenbestande. (A model to determine growing stock and volume increment of beech stands in Greece). Centralblatt für das Gesamte Forstwessen (1999) 116(3): 159-172.

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TSOUMIS, G. 1983. Forest biomass utilization in Greece. In: Côte, pp. 109-115.

5. HUNGARY

General information

Land area: 92,130 sq. km (35,573 sq. mi.), forest and other wooded land: 16,650 sq. km (6,467 sq. mi.), total forest: 1,675,000 ha (6,467 sq. mi.) or 18 % of land area; volume: 172 m^3/ha, biomass: 111 tons/ha (FAO 1995-124: Forest resources assessment).

Round wood production: industrial round wood 2.8 mil. m^3, fuel and charcoal 2.3 mil. m^3, total round wood 5.1 mil. m^3 (World Resources 1996-97, Table 9.3, p. 220).

Forest vegetation: temperate mixed forests

- Conifers 15.7 %
- Broad-leaved 84.3 % (after Kotar et al. 1995)
- Main species: oaks (*Quercus cerris, Q. robur*), black locust (*Robinia pseudacacia*), European beech (*Fagus sylvatica*), hornbeam (*Carpinus betulus*), aspen (*Populus* spp.), Norway spruce (*Picea abies*), pines (*Pinus* spp.)

Forestry education and research organizations involved in the areas of forest mensuration and forest management (date of establishment in brackets):

- University of Forestry and Wood Sciences, Sopron (1808?).
- Forest Research Institute, Budapest, 1949.

Publications (Primary Journals and Serials):

- Az Erdö, Budapest
- Erdészeti Lapok, Budapest
- Erdészeti Kutatások, Budapest
- Erdészeti Kisérletek, Budapest (1898)

According to Fernow (1911) at the beginning of 19th century, forestry was a ”subject in the agricultural school at Keszthely, and in 1808, in the school of mines in Schemnitz (Selmeczbanya), a German forester, Wilkins, filling the chair, while a special forest school was established at Hermannstandt in 1817. The forestry courses at Schemnitz were enlarged and the school reorganized in 1846 and again in 1872; one of the changes being the use of the Hungarian language in its instruction, which had originally been German. In 1904, the course, which was 3 years and only optionally 4 (one year for engineering education), was made 4 years for all, and is obligatory for all higher grade State officials… A forest experiment station was established in 1898; it issued a quaterly magazine, Irdeszeti Kiserletek, in which its results are recorded. A Hungarian forestry association was formed in 1866.” (p. 184).

Literature:

KERESZTESI, BÉLA. 1991. Forestry in Hungary 1920-1985. Budapest, Akadémiai Kiadó. (This is a revised and updated version of the original “Magyar erdészet” 1954-1979), English, 477 pp.

5.1. Tree and primary products

Kovacs (1935) published a paper on the law of stem repartition by diameter categories (dbh) in even-aged stands.

Pallay (1955) developed investigations for determining conversion factors for stacked fuelwood, and Lamfalussy (1956) discussed the determinations of assortments in stems.

Mendlik (1983) presented new results of research on the stemwood, merchantable timber and total wood volume of beech. According to this author, wood volume tables constructed before for beech in Hungary assumed that the form factor is a constant for stems of a given height class. The new volume tables have errors of up to +90 % in volume of tall and narrow trees.

Estimation of wood volume on the basis of stump was completed by Kollewentz in 1987.

Examining the possibilities of developing local volume tables Horváth (1984) concluded after the measurements of sample trees, that Näslund’s volume equation was more reliable than several other equations (Näslund’s equation is $v = b_0 + b_1d^2 + b_2d^2h + b_3h^2 + b_4dh^2$, where v = stem volume, d = dbh and h = height of the tree).

5.2. Stand structure, growth and yield tables

Fekete (1939) presented in a short paper the existing yield tables in Hungary and the percentage of trees by diameter categories depending on the mean stand diameter, a work based on an idea of Schiffel (1903).

After 1940, a new generation of yield tables, generally based on equations and computerized data, was completed by the works of Magyar, Koltay, Kovacs et al. and a sample of these tables is shown in Table 5.2.-1.

Hungarian yield tables constructed by Magyar (1940) and Koltay (1956) for black locust and poplar respectively, should be especially mentioned not only for the fact that they utilized dominant height as one of the entries instead of average height, but for the original way of site classes (productivity classes) formation which was proposed by Magyar. For example, in the case of poplar, 10 productivity classes were defined (Fig. 5.2.-1.), but the ten bands have not equal width as in the tables constructed after old Baur's method (see Germany chapter). The width increases progressively from class X to class I, the band of class X is the narrowest and that of class I the widest. Site classes were constructed in such a way that their border values (curves 1-11) represents at any age a geometrical progression with ratio q. If H1, H2, H3... is the limit of dominant height of class I, II, etc., the following ratios are valid at any age:

$\frac{H_{11}}{H_{10}} = \frac{H_{10}}{H_9} = \frac{H_9}{H_8} \ldots = \frac{H_2}{H_1} = q$ and $H_1 \cdot q = H_2$; $H_2 \cdot q = H_3$ ... $H_{10} \cdot q = H_{11}$; the general

relation is $H_n = H_1\ q^{n-1}$, $q = \sqrt[n-1]{\frac{H_n}{H_1}}$ and for ten classes $q = \sqrt[10]{\frac{H_{11}}{H_1}}$

TABLE 5.2.-1. A sample of Hungarian yield tables

Year	Author(s)	Species	Remarks
1940	J. Magyar	*Robinia pseudacacia* (black locust)	Utilized dominant height
1956	G. Koltay	Poplar sp.	Site classes with equal or different amplitude. Dominant height is used.
1972	R. Solymos	Scots pine Austrian pine Norway spruce	
1983	A. Béky	Sessile oak of seedling origin	Based on equations for processing of data by computer.
1983 1983	F. Kovács G. Mendlik	Ash Beech	Mean height of 100 years old, class I, is centred on 36 m
1985	A. Béky	Hornbeam	
1986	F. Kovács	Turkey oak (*Quercus cerris*)	Site class I has a medium 100 yr site index of 34 m. The mathematical model is included.
1986	F. Kovács	Austrian pine	
1986	K. Rédei J. Gál	*Robinia pseudacacia* (black locust)	Tables derived from equations.
1987	F. Kovács	Ash, stands of seed origin (*Fraxinus excelsior*)	Yield tables were generated from data collected in Hungary on plots established in 1969.
1987	R. Kiss Z. Somogyi G. Juhász	Pedunculata oak (*Quercus robur)*	It is a new table based on measurements of 142 permanent plots, 6-138 yr. old.
1987	B. Lessény K. Rédei	Improved cultivars of *Robinia pseudacacia*	Yield tables for sawlog production are given for five cultivars grown at Gödöllö (seen).

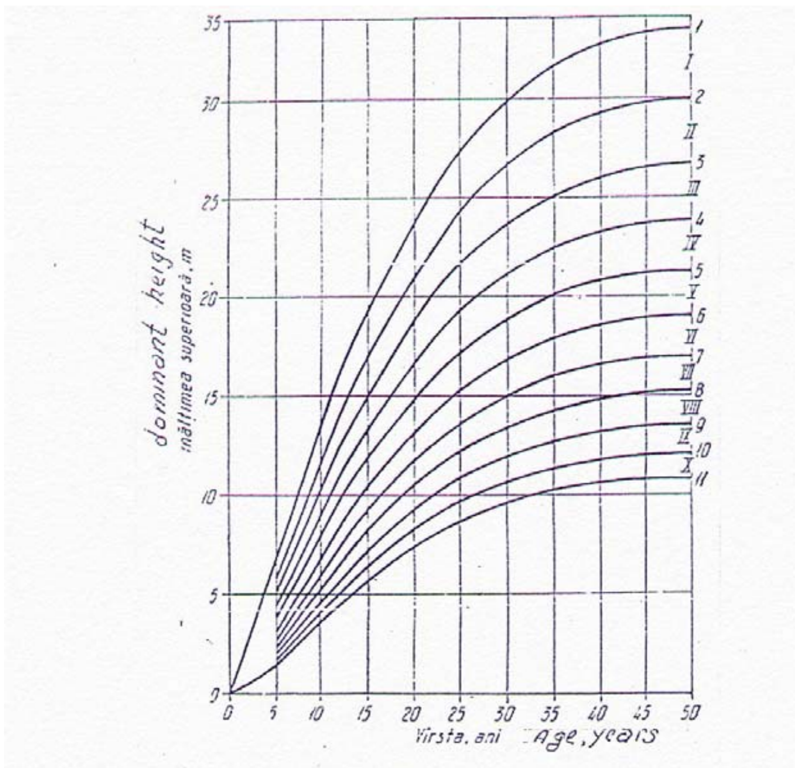

Fig. 5.2.-1. Formation of site classes with progressively increasing amplitude.
SOURCE: Original Koltay 1956. Reproduced after Singhe and Toma, Dendrometrie, 1958, p. 322, fig. 136, Bucureşti, Edit. Agro-Silvică

Figure 5.2.-2. shows poplar volume per hectare depending on the dominant stand height after Koltay's volume tables. Figure 5.2.-2. suggested that the Eichhorn rule should be improved taking into account the age of the stand.

In 1972, Solymos investigated the structure and productivity (yield) of the spruce stands and constructed yield tables having 10 classes. According to these tables a stand of 80 years old in class II has a dominant height of 27.6 m up untill 29 m and a mean annual volume increment of 8.2 m^3/ha and year.

Csontos et al. (1982) established different relations between stand structural factors in mature stands of Scots pine, black locust, *Quercus cerris, Q. petraea* and beech. Stand volume was correlated with stand basal area, mean height and stem number. The single correlation factor declined in the order: stand basal area > mean height > mean diameter > stem number.

Kowács investigated the increment of Turkey oak (*Quercus cerris*) natural stands in 1988, providing new data for this wide-spread species in Hungary.

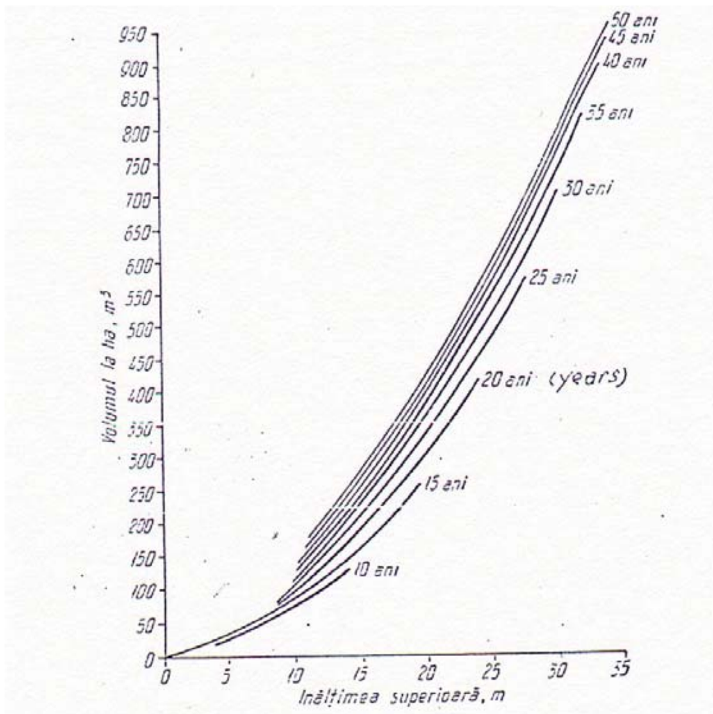

Fig. 5.2.-2. Poplar's volume per hectare by age categories depending on dominant height.
SOURCE: Original Koltay 1956. Transl. into Romanian "Plopul", Edit. Agro-Silvică Bucureşti, Reproduced after Stinghe and Toma, Dendrometrie 1958, p. 328, fig. 140, Bucureşti, Ed. Agro-Silvică de Stat

Kotar et al. (1995) examined growth trends of forests in Hungary and Slovenia and concluded that "In Hungary the growth trend of forests has been variable, but generally, increasing over the last century ... in 1920 the forest cover amounted to 11.7 % which had increased by 1992 to 18.5 % ...". The growing stock (m^3/ha) increased during the period 1980-1990: for oak from 202 to 219, for beech from 350 to 358, for Turkey oak from 204 to 217, for poplars from 106 to 122, for black locust from 125 to 119, for conifers from 172 to 186.

5.3. Other works

Zoltán Fekete published in 1951 a remarkable textbook on forest mensuration ("Erdoblecsléstan"). Early Romanian yield tables used Fekete's technique for determination of stand current increment in volume.

Quantification and utilization of forest biomass in Hungary was investigated by Solymos (1974, 1983) especially in the case of Scots pine and Austrian pine stands.

A short review on the use of plants as indicators of heavy metals (dendrochronochemistry) was completed by Kovacs and Podani in 1986.

Hildebrandt (1993) (who included Hungary in Central Europe but excluded France from this region) mentioned that aerial photography was used before 1939 in Hungary by Szabo and Sebor, and airborn remote sensing was experimentally applied before 1969 (Sopron).

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6. ISRAEL

General information

Land area: 20,210 sq. km (7,842 sq. mi.), forest and other wooded land: 124,000 ha (479 sq. mi.), total forest: 102,000 ha (394 sq. mi.) or 5 % of land area; volume: 36 m^3/ha, biomass: 54 tons/ha (FAO 1995-124: Forest resources assessment).

Round wood production: industrial round wood 100,000 m^3 fuel and charcoal 13,000 m^3, total wood 113,000 m^3 (World Resources 1996-97, Table 9.3, p. 201).

Forest vegetation: Mediterranean type.

Conifers	15 %
Broad leaved	85 %

Main species: plantations of *Pinus halepensis, P. brutia, Eucalyptus gomphocephalus, E. occidentalis, E. calmaldulensis, Cupressus sempervirens* (Italian cypress) and *Acacia salicina*.

Forestry education and research organizations involved in forest mensuration and forest management:

• Agricultural Research Organization, Department of Agronomy and Natural Resources, Volcani Center, Bet Dagan, established in 1928.

Available data on forest mensuration works

1944: Gindel, J. from Forest Research Laboratory, Agricultural Research Station Rehovot, Palestine, published in Tree-Ring Bulletin an article under the title "Aleppo pine as a medium for tree-ring analysis". *Pinus halepensis* is indigenous to Palestine and shows early and great sensivity to climatic factors, especially rain and temperature but discrepancies appear between the relative ring width and the amount of winter rainfall as a result of unfavorable distribution of rain, at high or low temperature, and the intensity of khamsin winds during the seasonal growth. The dynamics of these factors are favourable for the formation of false rings (more frequently outer rings). Ghindel explained that "the formation of the outer usually well-defined false rings on Mount Carmel, Palestine not far from Haifa, takes place under climatic conditions similar to those in which false rings are formed at Carmel in California. The similarity of tree growth at two Carmel sites which are distant 6350 miles from each other is very suggestive".

In 1963, Fahn, A., Wachs, N., and G. Ginzburg published the results of "Dendrochronological studies in the Negev".

Zohar, V. and Karschon, R. (1984) constructed "General volume tables for Italian cypress in Israel", a leaflet published by the Department of Forestry, Agricultural Research Organization.

In the field of biomass studies two articles were available:

"Above-ground biomass tables for Italian cypress (*Cupressus sempervirens*) from Israel" by Y. Zahar (1995) and H. M. Lövenstein and P. R. Berliner's (1993) “Biometric relationships for non-destructive above ground biomass estimation in young plantations of *Acacia salicina* Lindl. and *Eucalyptus occidentalis* Endl.”

The plantation was located at an experimental runoff farm in the Negev desert. The cited authors noted that for both species the biomass was linearly and logarithmically correlated with the square of the basal area diameter at 0.2 (DB) and with DB multiplied by the height of the tree.

Israel is a country involved in multi - resource forest inventories (MRIs) based on questionnaire survey and literature review. Land Development Authority is in charge of MRIs whose scope is local and the objectives are: recreation, timber, landscape, value.

The MRI questionnaire for Israel was completed on October 9, 1997 by Sachs, Menachem.

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7. ITALY

General information

Land area: 301,280 sq. km (116,329 sq. mi.), forest and other wooded land: 85,500 sq. km (33,013 sq. mi.), total forest: 6,750,000 ha (26,063 sq. mi.) or 22 % of land area; volume: 110 m^3/ha, biomass: 81 tons/ha (FAO 1995-124: Forest resources assessment).

Round wood production: industrial round wood 4.5 mil. m^3, fuel and charcoal 4.8 mil. m^3, total round wood 9.3 mil. m^3 (World Resources 1996-97, Table 9.3, p. 220).

Forest vegetation: temperate mixed forests (in the north) and Mediterranean forest type in the south, Sardinia and Sicily.

Forest vegetation: temperate mixed forests (in the north) and Mediterranean forest type in the south, Sardinia and Sicily.

- Conifers 20 %
- Broad-leaved 80 %
- Main species: oaks (*Quercus lanuginosa, Q. robur, Q. cerris, Q. frainetto*), European beech (*Fagus sylvatica*), American poplars, Norway spruce (*Picea abies*), fir (Abies alba); in the Mediterranean forests: *Quercus suber, Q. ilex*, sweet chestnut (*Castanea sativa*), *Pinus pinaster, Pinus pinea, Pinus halepensis, Cupressus sempervirens, Clea cleaster, Laurus nobilis, Juniperus macrocarpa.*

Forestry education and research organizations involved in the areas of forest mensuration and forest management (date of establishment in brackets):

- Universita degli Studi di Bari, Facolta di Agraria, Bari (1972).
- Universita degli Studi di Firenze, Facolta di Agraria e science Forestali, Firenze (1936).
- Universita degli Studi di Padova, Facolta di Agraria, Corso di Laurea in Scienze Forestali, Padova (1946).
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- Instituto Italiano di Dendrocronologia, c/o Museo Civico di Storia Naturale, Verona.

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- Monti e Boschi
- Annali della Facolta di Agraria, Universita Cattolica
- Annali dell Instituto Sperimentale per l'Assestamento Forestale e per l'Alpicoltura
- Annali dell' Instituto Sperimentale per la Silvicoltura, Firenze.
- Dendronatura, Semestrale dell Associatione Forestale del Tretino.
- Cellulosa e Carta
- Atti dell' Instituto di Ecologia e Silvicoltura, Universita degli Studii, Padova.
- Annali, Accademia Italiana di Scienze Forestali, Univ. Padova.
- University of Torino, Department Agroselviter/Silviculture, Torino (1991).
- University of Tuscia, Department of Forest Environment and Forest Resources, Viterbo (1990).
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CAMAITI, A. 1958. Les Forêts d'Italie (Forests in Italy). Bull. S.R.F.B., no. 2.

TOSI, V.; M. MARCHETTI. 1997. Country report for Italy. In: Study on European Forestry Information and Communication System. Reports on forest inventory and survey systems. Vol. 1 CH-11-99-001-EN-C Luxembourg: European Commission, pp. 423-646.

Fernow presented in 1907 and 1911 a short history of Italian forestry (pp. 335-348, ed. 1911) during the 19th century presenting forest conditions, development of forest policy, education and literature. He mentioned that "the first forest school was organized by Balestrieri, who had studied in Germany, at the Agricultural School around the year 1848, transferred to the Technical Institute in Turin in 1851. This school continued until 1869, and from 1863, had been recognized by the state, assaying its graduate employment in state service. In 1869, the State established a forest school of its own (Institute Forestale) at Vallambrosa near Florence, with a three years course (since 1886, four years, and in 1900, with eleven professors and 40 students." (pp. 447-448).

7.1. Textbooks on forest mensuration

Among a few available textbooks on forest mensuration should be mentioned first of all Generoso Patrone's classical "Lezioni di Dendrometria" (Lectures on forest mensuration published in four editions in Firenze: 1938 (430 pp.), 1941, 1963 and 1976.

The Forest Direction in Italy published a detailed work (vol. 1 in 1952, 207 pp. and vol. 2 in 1960, 181 pp.) on the determination of wood volume (stereometrical tables et al. under the coordination of Dr. Cesare Volpini: “Determinazione della masse lignose dei Boschi”.

Patrone (1976) completed “Elementi di auxonomia diferenziale” (Elements of differential growth) and sustained that the multiannual growth process (seasonal growth process during more years) is a continuous process which permits the use of differential and integral calculus. He mentioned this for the first time in 1941, when he discussed in these lectures the culmination of current and mean increment.

A new textbook on forest mensuration was published in 1983 by Bernetti and La Marca containing about 360 pp. and edited by Cooperativa SCAF di Peppi (Ar.).

Cited authors:

Bernetti and La Marca 1983, Forest Direction in Italy (Dr. Volpini) 1952, 1960; Patrone 1938, 1941, 1963, 1976.

7.2. Tree mensuration

Generoso Patrone (1938) constructed a lot of volume tables based on a graphical method called in France by Pardé (1961) the Italian method (“méthode italienne”). A detailed description of this method is given in Patrone’s forest mensuration books and a summary is included in Pardé’s “Dendrometrie” (1961, p. 163 and 164). Patrone’s and his pupil’s volume tables are usually double-entries associated as a rule with a tariff of less accuracy and a table of bark percentage, stem volume being given according to dbh and tree total height. These tables are usually local or regional. A good example of Patrone’s technique is given in the case of fir volume tables in the Panareggio area (1955). A lot of volume tables constructed before 1960 are included in two volumes (1952 and 1960) published by the Direction of Forests and mentioned in 7.1.

In 1982, Bartorelli and Paganucci published a work on stereodendrometry in a silver fir forest and described the use of the Dendrophoto apparatus. They calculated the volume of the stem part hidden by the crown, using the the main stem volume and tree height (For. Abs. 4532/1988).

In 1984, the Italian “Instituto Sperimentale per l’Assestamento Forestale per l’Apicoltura” published in “Dendronatura” (no. 7: 63-64) a review of double-entry volume tables used during the National Inventory (Inventario Forestale Nazionale Italiano – IFNI).

Hellrigl (1960) advocated the use of Bitterlich's relascope and called this technique of measurements as "una nuova teoria dendrometrica" (a new forest mensuration theory). Hellrigl also constructed a registering calliper that provides directly the tree basal area. In 1961 Hellrigl determined form factors using the relascope and in 1962 computed volume using this device.

Giordano (1966) completed a remarkable book (3rd ed., 375 pp.) containing the aspects of wood volume determination – felled and standing trees. Later, in 1977 Bernetti presented double-entry volume tables for *Abies alba, Picea abies, Pinus nigra* and *Fagus sylvatica*.

Schirone et al. (1987) constructed a highly sensitive automatic band dendrometer to measure tree increment.

Interesting data on the growth of the Douglas-fir (*Pseudotsuga menziesii,* species introduced in Italy during the first decade of the 20th century) having exceptional dimensions at the age of 75 years should be mentioned (Camoldi forest, Arezzo, altitude 900 m, 1770 mm rainfall, mean annual temperature 8.7°C):

dbh (cm):	88	70	85
height (m):	36.4	36.1	39.3

and at the age of 75 years, the mean volume increment was still increasing (Lopresti 1988).

Researches on the tree growth of Norway spruce (abete rosso) and silver fir (abete bianco) in Trentino were developed in 1989 by Bronzini et al.

Attention was paid to the stem analysis. Frattegiani and Wolynski (1990) completed a brief literature review (58 references) on stem analysis including the following aspects: collection of data in the field, determination of measurements for stem sections, age/height relations, and volume determination.

Fabbio et al. (1990) compared five methods for estimating height-age relations in the stem analysis work of *Pinus nigra*. One of the methods is a new algorithm (ISSA), for which program details are given in an appendix.

Frattegiani et al. (1990) developed ANAFUS 2 – a program for stem analysis. This program determined stem increment data by the SMILCOMP program which is used in connection with the measuring SMIL 3 program. Fabbio et al. (1994) used second differences for height estimation in stem analysis named ISSA – a new method for estimating heights at different ages from crosscut ring count.

A simple method for transforming stem volume tables to merchantable volume tables was developed by Corona and Ferrara (1992): STIMASS, a program that can calculate from existing stem volume tables, an exponent that can be used in conjunction with taper equations to determine merchantable volume.

The evaluation of standing tree quality in the case of oak and ash was proposed in 1996 by Favero et al.

Table 7.2.-1. presents a sample of Italian volume tables.

TABLE 7.2.-1. A Sample of Italian volume tables

Year	Author(s)	Species	Remarks
1954	G. Patrone	Beech (*Fagus sylvatica*)	
1955	G. Patrone	Spruce (*Picea abies*)	
1980-82	C. Castellani G. Ghidini V. Tosi	Aleppo pine (*Pinus halepensis*)	
1982	A. Famiglietti R. Manetti	*Quercus cerris* *Quercus petraea* *Quercus pubescens* and hybrids	Local double-entry volume tables for Matera forest
1983	A. Eccher A. Ferrara	Pino insigne (*Pinus radiata)*	Local volume tables for: Tuscania, Rome, Termoli and Massa, Maritima are presented together with one general table derived from the local ones.
1983	L. Hermain	Black pine (*Pinus nigra)*	A double-entry VT including bark and excluding bark and a tariff table for rapid stem volume estimation. A model for local volume table construction.
1987	P. Corona A. Ferrara	Scots pine (*Pinus sylvestris*)	Over and under bark stem taper equations and volume equations to calculate the tree volume and volume to any height or upper stem diameter of individual stems. Basic data for mature stands.
1987	A. Quaglino A. Nosenzo C. Marchisio S. Durantes		Double-entry volume tables in even-aged mainly pure stands in the High Susa Valley, Torino. Comparison of results obtained using various volume equations.
1991	O. Ciancio P. de Angelis R. Valentini	Maritime pine	Volume tables (single and double-entry) for the stands at Mt. Rufeno, Latium
1991	M. Penzo G. Bernetti	Black pine	Volume and assortment tables for pine in the Tuscany area.

Cited authors:

Bartorelli and Paganucci 1982, Bronzini et al. 1989, Bernetti 1977, Ciancio et al. 1991, Corona and Ferrara 1987, 1992; Eccher and Ferrara 1983, Fabio et al. 1990, 1994; Famiglietti and Manetti 1982, Faero et al. 1996, Frattegiani and Wolynski 1990, Frattegiani et al. 1990, Giordano 1966, Hellrigl 1960 a, 1960 b, 1961, 1963; Hermanin 1983, ITALY - Inventario Forestale Nazionale Italiano (IFNI), Lopresti 1988, Patrone 1955, 1976; Pardé 1961 (France), Quaglino et al. 1987, Schirone et al. 1987.

7.3. Stand structure

Susmel (1959) examined the relationship between average height of the highest trees and different biometrical characteristics in a selection forest with normal density (volume of standing trees, increment percentage etc.).

In 1980, Favero studied the equations used for fitting height curve. Marin and Scotti (1987) analyzed the development in time of diameter distribution as a function of initial stand conditions and presented a mathematical model for Douglas-fir in the Apennines. They studied the diameter distribution in unthinned Douglas fir stands in order to derive a model to produce stand tables in the Apennines for given dominant height and stand density to show the changes in diameter distribution in unthinned stands.

Cited authors:

Favero 1980, Marin and Scotti 1987, Susmel 1956.

7.4. Stand growth and yield

Among Italian yield tables (tavola alsometrica) will be mentioned, as examples, those constructed by Patrone (1954) (beech), Castellani et al. (1980-1982) (Aleppo pine, Penzo and Bernetti (1991) (black pine), Hermanin and Belosi (1993) (*Ostrya carpinifolia* - coppice in northern Appenines), and Ferrara et al. (1996) (*Quercus cerris*).

The use of magnetic-type recorders in forest surveys and on the plots in Italy was mentioned by Hellrigl in 1964. In 1965, Prevosto presented the results of his studies on the growth of Euro-American poplar "I 214" under different conditions of the Lombardo-Piemontese plain in relation with planting distances. Among others, Bernetti (1980) was interested in the law of forest growth.

A new, entirely optical method of determining growing stock based on a combination of sampling with a relascope and a range finder which gives the average stand diameter, was developed by Bonamini in 1988, but the final volume of the stand is obtained using single-entry volume tables.

Corona and Ferrara (1991) developed measuring techniques for assessing basal area increment of forest stands.

In the 1990s the modelling in forestry became common in Italy. Some examples are presented in this text: Corona (1995) and Scotti et al. (1995) performed growth modelling in Douglas fir plantations. Ferrara et al. (1996) developed dendrometric and alsometric research on *Quercus cerris* coppices of the Vitalba Valley in Basilicata. They used a new method for height growth modelling and constructed yield tables by this method which is a part of a wider tree growth modelling project in Italy. A new procedure for the estimation of relations between top height and tree age was proposed.

A matrix approach for modelling forest growth with management data was experimented by Virgilietti and Buongiorno (1997) in the Italian Alps - the possibility and difficulties in constructing growth models from past Forest Administration records were underlined.

In 1998 Battaglia and Sands discussed the problem of process-based forests productivity models and their application to forest management.

Cited authors:

Battaglia and Sands 1998, Bernetti 1980, Bonamini 1988, Castellani et al. 1980-1982, Corona and Ferrara 1991, Famiglietti, 1982, Famiglietti and Curbo 1979, Ferrara et al. 1996, Hellrigl 1964, Hermanin and Belosi 1993, Patrone 1954, Penzo and Bernetti 1991, Prevosto 1965, Scotti et al. 1995, Virgilietti and Buongiorno 1997.

7.5. Weight and biomass

Hellrigl (1974) developed probably the earliest biomass tables for fir and relations for its determinations (methodological aspects). In the same year, Cantiani (1974) presented the new data on biomass of fir trees.

In 1979, Famiglietti and Curto prepared allometric tables for stands of radiata pine and maritima pine and based on these tables determined the biomass. For instance, at the age of 20 years the annual increment of total biomass is 48.4 kg for radiata pine and 41.5 kg for maritime pine.

Double-entry tables for the fresh weight of coppice schoots of holm oak (*Quercus ilex*), pubescent oak (*Quercus pubescens*), chestnut (*Castanea sativa*), Turkey oak (*Q. cerris*) and Italian alder (*Alnus cordata*) in the Bussente watershed, Salerno, were constructed by Famiglietti in 1982.

Leonardi and Rapp (1990) determined biomass production and nutrient use during regrowth of holm oak coppice. They observed that the early years were characterized by a higher need for nitrogen, phosphorus and potassium, compared with the mature stands. After the third year, calcium became important for the development of stems.

Cited authors:

Famiglietti 1982, Famiglietti and Curto 1979, Hellrigl 1974, Leonardi and Rapp 1990.

7.6. Tree-ring studies

According to Studhalter et al. (1963) it was only around A.D. 1500 when the annual formation of the tree rings was first suggested by Leonardo da Vinci. Malpighi made in 1675 the first anatomical investigations of annual rings and described the characteristics that distinguish springwood from summerwood.

7.6.1. Dendrochronology

The problem of synchronization of chronological series was discussed in Italy by Corona in 1963, and oscillations and discordances, later in 1966. In 1985 Serre-Bachet developed a multicenturies chronology in southern Italy (Fig. 7.6.-1.). The Box-Jenkins models of forest interior tree-ring chronologies were used in Italy by Biondi and Swetnam in 1987.

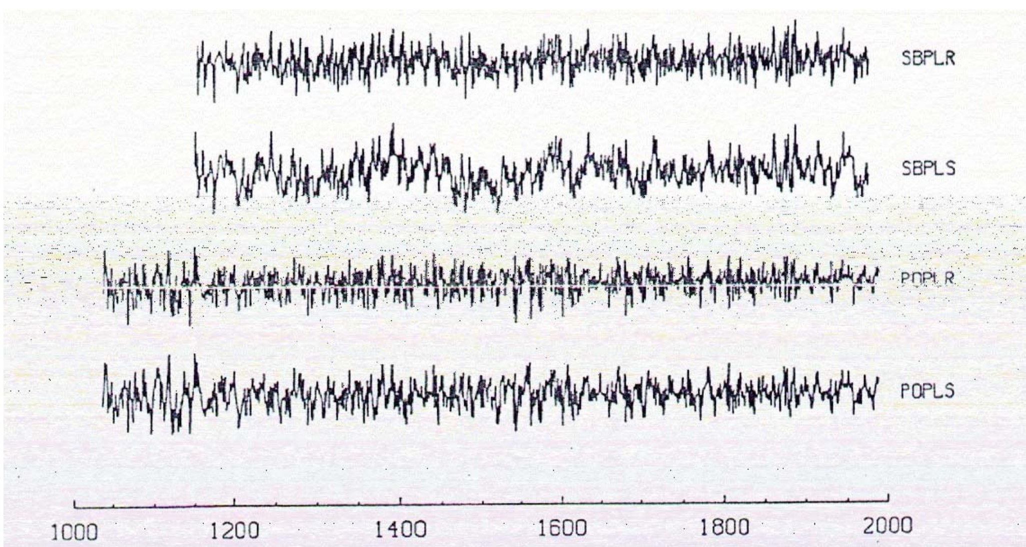

Fig. 7.6.-1. Time-series graphs of standard and residual *Pinus leucodermis* chronologies. SBPLS is Serre-Bachet's (1985) chronology; SBPLR is the residual chronology derived by fitting an AR (3) model to SBPLS. The other two chronologies are the standard and residual chronologies developed in this study (Table 2)

SOURCE: Biondi, Franco 1992 b, "Development of the tree-ring network for the Italian Peninsula", Tree-Ring Bulletin (U.S.A.), vol. 52, p. 26, fig. 4.

7.6.2. Dendroclimatology

Dendroclimatological analyses became more frequent and used more complicated methods, and modelling especially in the 1990s.

The early results of the dendroclimatological analyses in eastern Trentino, using spruce (*Picea abies* (L.) Karst.) were presented in 1991 by Brugnoli and Gandolfo. Biodi (1993) mentioned climatic signals in tree-rings of *Fagus sylvatica* from the central Apennines.

Brandini et al. (1995) established relations between climate and radial growth in Norway spruce and modelled the relationship for spruce stands in Valle di Fiemine, northern Italy, altitude 1400-1900 m. Growth ring widths were compared with temperature and rainfall. Ring growth is positively correlated with April rainfall, minimum May and June temperatures, and maximum July temperatures of the year of growth. Brandini et al.(1995) used nine climatic variables (parameters) for the construction of a prediction model that explained 79.5 % of the variation in growth.

Corona et al. (1995) concluded that stem annual increments (AVI) can be used as ecobiological indicator in Turkey oak (*Quercus cerris* L.). AVI was compared with annual ring increment (ARI) measured at dbh and the results indicated that AVI is no better than ARI as a means to express the relationships with macroclimatic factors. In the examined stands (the Gargano region of southern Italy) the most important factor which influenced the AVI growth rates were autumn and spring rainfall amounts while ARI is strongly influenced by the June averages of daily minima and maxima.

Dendrochronological studies with silver fir (*Abies alba*) and Norway spruce (*Picea abies*), carried out in Italy, were summarized by Brunetti et al. (1996), and in this summary dendroclimatological aspects have been concluded.

Corona (1996) presented a short overview of the use of dendrochronology in connection with climatic variations.

Nola (1996) completed a brief review of dendroclimatological studies in the reconstruction of past climate, especially in western Europe. Romagnoli analyzed the wood anatomical parameters (early wood and late wood) in relation to the amount of seasonal variation of precipitation. Romagnoli and Codipietro (1996) carried out a dendrochronological and dendroclimatological analysis of *Quercus cerris* samples from different sites. The Latium region was suitable for these type of researches due to its environmental variability (orography, climate, soil). Their analyses showed that the majority of pointer years were related to spring precipitation and June temperature. The cited authors used an automatic image analysis system and new methods for histological quantitative representation.

Urbinati et al. (1996) investigated the relations between growth and climate of larch (*Larix* spp.), arrola pine (*Pinus cembra*) and spruce (*Picea albies*) growing at timberline) in Boite Valley Cortina d'Ampezzo, at 2100-2300 m altidude, and found that “A high diameter growth rate occurred during a 50-days period in late July/August, which resulted in the almost complete formation of the growth ring for the year”.

7.6.3. Other dendrochrological works

Bracco and Nola (1990) analyzed annual growth ring (usual analysis) and developed a computer program (in BASIC) that incorporates identification and quantification of abrupt growth changes. In the same year (1990), Fabbio and al. developed a program for collecting and checking data from SMIL 3, a measuring system for increment. The software named SMILCOMP is described and developed for managing increment data. The measuring device has a goniometer for angle correction in order to determine ring width.

In 1992, Biondi presented the development of the tree-ring network for the Italian peninsula and noted that “The new Italian network presented here is another mosaic stone needed to complete existing tree-ring databases, such as those developed by Schweingruber (1985) and Serre Bachet (1992)” (Tree-Ring Bull., vol. 52, p. 27). Ferretti et al. (1992) adopted a new approach to experimental data evaluation from *Pinus pinea* Sardinia tree-ring analyses using ion chromatographic determination of P, CL and S: “... the method permits analysis of individual growth rings using a minimum amount of material for complete combustion”. Various applications of dendrochronology in Italy are presented in 1996 by Pignatelli.

Cited authors:

Backmeroff 1996, Bebber 1990, Biondi 1992 a, 1992 b, 1993, 1994; Biondi and Swetnam 1987, Biondi and Visani 1996, Bracco and Nola 1990, Brandini et al. 1995. Brugnoli and Gandolfo 1991, Brunetti et al. 1996, Corona E. 1963, 1966, 1996; Corona P. 1995, Fabbio et al. 1990, Ferretti et al. 1992, Nola 1996, Pignatelli 1996, Serre-Bachet 1985, Studhalter et al. 1963, Urbinati 1996.

7. 7. Forest inventory and remote sensing

7. 7. 1. Forest inventory

The first Italian National Forest Inventory (IFNI) was completed in 1985 (Italy, Instituto Sperimentale per l’Assestamento Forestale e per l’Alpicoltura: Operational planning (1983), Maps (1988a), Description of methodology and results (1988b)). A detailed presentation of this inventory was given also by Castellani et al. in 1986.

A procedure to choose plot size and number to obtain an optimum combination based on statistical measures of variability and a computer program developed to select best sample size was presented in 1989 by Corona and Ferrara.

Preto (1993) analyzed past and present inventorying and monitoring systems and underlined the "urgent need of improving the integration and coordination of these works on national and global level by linking monitoring and assessment of natural resources to sustainable development and integrating ecological problems to social and economic aspects.

Preto mentioned that "The philosophy of the inventory methods the applied in the USA is totally different from European ones; in the latter case efforts are directed towards obtaining precise information at low cost for the relatively small management units, while in the former the tendency is to supplement the data obtained from a low intensity sampling of the whole area with additional information on small units of assessment" (p. 3). Preto's analysis is based in fact on two major technical innovations introduced in forest inventory in fact on global level: statistical methods (since early 1920) and the use of photographs (in some places before 1920). Preto appreciated what is accepted now almost on global level: "The forest inventory of the 21st century isn't a simple system of evaluating the amount of timber produced anymore. It will be an integrated system of obtaining and using information concerning the functionality and dynamics of forest ecosystems together with their relationships with the larger environment and surrounding society" (p. 5).

The new concepts introduced in Italian forest inventory are exposed in 1995 by Tosy (methods, results and perspectives). The idea of multi-resource forest inventories was accepted and developed in Italy during the 1990s: recreation areas (Scrinzi et al. 1995), MRI questionnaire for Italy recreation survey (Tosi 1997).

In Italy MRIs (Tosi and Marchetti 1997) are based upon MRI questionnaire survey and literature review. The organization in charge of MRIs is Instituto Sperimentale per l'Assesstamento Forestale e per l'Alpicoltura, the scope is national and the objectives comprise: 1) timber and NWGS (Non Wood Goods and Services; 2) the recreation.

7. 7. 2. Remote sensing

Aerial photography is used in Italian forestry at least since 1948 when Duilio Cosma mentioned the potentialities and limitation of direct estimation of stand volume from aerial photographs, the aspect examined by many writers since the time of Zieger (1928, Germany). In 1954 Cosma published a brief treatise in Italian: "Aerophotogrammetria forestale".

Later, in 1980s and 1990s the remote sensing was used on a larger scale in Italy.

In 1988, Forenza and Iannelli tried interdisciplinary environmental planning that became possible using thematic mapper (TM) and remote sensing systems for mountainous or forested areas.

Scrinzi and Tosi (1989) estimated forest dieback using large-scale aerial photography taken at low altitude from a helicopter with a pair of 35 mm cameras, one located with normal color film and one with infrared (IR) false colour film. “Agreement between the ground and aerial surveys for the state of trees health varied between 65 and 95 %”.

Catena et al. (1990) proposed a census method for ungulates in the Appennines and Mediterranean scrub habitats; an infrared scanner mounted on a helicopter was used at night in March and October 1989.

Palla et al. (1990) used a thermal scanner for quicker, damage-free monitoring of the health of single trees and numbers of game animals in densely wooded areas (For. Abs. 1094/1993).

Preliminary results of research to assess the potential of the air-borne scanner DAEDALUS 1268 ATM for use in forest management were published by Chiggio et al. in 1991.

A short presentation of the FIRS (Forest Information from Remote Sensing) project and its links to the PHARE environmental programme was completed by Folving et al. in 1995 with the main purpose to assist in providing information from remotely sensed data for a forest information system in Europe.

Application of GPS (Global Positioning System) in Italian forestry was presented by Biasini et al. (1996) (for monitoring forest areas affected by fire), Floris et al. (1996) (factors which can influence the accuracy of GPS: stem density and stem size influence accuracy more than canopy cover or density, error in coppice forests was about 1.7 m but in high forest 3.3 m).

Preto (1997) supplied the reader with a brief description of the use of GPS and DGPS (Differential Global Positioning System) in forestry, from an Italian perspective. Preto noted that “some manufacturers have made rather exaggerated claims for the accuracy of the GPS instruments. However, for updating the large scale surveys, where modern or reliable maps are not available, the accuracy is adequate to positions within 100 m. The DGPS eliminates many source errors and is more accurate (to about 10 m), but DGPS requires expensive hardware and software systems” (For. Abstracts 2727/1998).

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Biasini 1996, Castellani et al. 1986, Catena et al. 1990, Ghiggio et al. 1991, Corona and Ferrara 1989, Cosma 1948, 1954; Floris et al. 1996, Folving et al. 1995, Florenza and Iannelli 1988, Italy- Instituto Sperimentale per l’Assestamento Forestale e per l’Alpicoltura 1983, 1988a, 1988b; Palla et al. 1990, Preto 1993, 1997; Scrinzi and Tosi 1989, Scrinzi et al. 1995, Tosi 1995, 1997; Tosi and Marchetti 1997.

7.8. Chronology of the selected works

1500 (about): Annual formation of tree rings was first suggested by Leonardo da Vinci (Studhalter et al. 1963).

1675: First anatomical investigations of annual rings and description of the characteristics which distinguish spring wood from summer wood (Marcello Malpighi, after Studhalter et al. 1963).

1938 (1941, 1944, 1963): Textbook: “Lezioni di Dendrometria” (Lectures on forest mensuration) by Generoso Patrone.

1938: Generoso Patrone’s graphical method for construction of volume tables (Italian method).

1952, 1960: Determination of wood volume in forest. Vol. 1 in 1952 and vol. 2 in 1960 (Direction of Italian Forests).

1954: A textbook: Photogrammetry in forestry (Duilio Cosma).

1976: Textbook: Elements of differential growth (Elementi di auxonomia diferentiale) by Generoso Patrone.

1979: Allometric tables for stands of radiata pine and maritima pine, and determination of biomass based on these tables (A. Famiglietti and A. Curto).

1983: Textbook: “Elementi di Dendrometria” (Elements of forest mensuration) by G. Bernetti and O. La Marca.

1985: Multicenturies dendrochronology in southern Italy (F. Serre-Bachet).

1987: One of the early in Italy: Stem taper and volume equations (P. Corona, A. Ferrara).

1987: Development over time of diameter distribution as a function of initial stand conditions and a mathematical model to produce stand tables. The case of Douglas fir in the Apennines (R. Marin and R. Scotti).

1988: National forest inventory 1985. Description of methodology and results (Italy, Instituto Sperimentale per l’Assestamento Forestale e per l’Apicoltura).

1989: Optimum combination of sample plot number and size in forest inventories (P. Corona and A. Ferrara).

1990: New developments in the field of stem dendrometrical analysis (M. Frattegiani and A. Wolynski 1990, G. Fabio, M. Frattegiani and M. C. Menetti 1990, M. Frattegiani, S. Gheti and M. C. Manetti 1990).

1990s: The expansion of dendroclimatological analyses and use of models (F. Biondi 1993: P. Corona, M. Romagnoli and L. Torrini 1995; M. Brunetti, C. Gandolfo and G. P. Gandolfo 1996; E. Corona 1996; P. Nola 1996; M. Romagnoli 1996; M. Romagnoli and G. Codipietro 1996; C. Urbinati, M. Carrer, T. Anfodillo and S. Rento 1996).

1990s: Modelling in forestry became common in Italy.

1990: Proposed census method for ungulates (G. Catena, P. Magagnoli, L. Palla).

1992: A simple method for transforming stem volume tables to merchantable volume tables: STIMASS program (P. Corona and A. Ferrara).

1992, 1994: A summary of the development of tree-ring network for Italian peninsula (Franco Biondi).

1993: Past and present of inventorying and monitoring systems (G. Preto).

1996: Dendrometric and allometric research on *Quercus cerris* coppices using a new method for height growth modelling and construction of yield tables by this method that is a part of a wider tree growth modelling project in Italy. A new procedure for estimation of the relations between top height and tree age was proposed (A. Ferrara, G. Mancino and F. Verrastro).

1996: A new approach to experimental data evaluation from tree ring analysis using ion chromatographic determination of P, Cl and S (O. Pignatelli).

1997: A matrix approach for modelling forest growth with management data (P. Virgilietti and J. Buongiorno).

1997: Country report on Italian forest inventory (Vittorio Tosi and Marco Marchetti).

7.9. Selected contributors

Author	Printing years	Field(s)
G. Patrone	1930s-1970s	01, 1, 3, 4, 5
D. Cosma	1940s-1950s	7
E. Corona	1960s-1990s	6
B. Hellrigl	1960s, 1970s	1, 4
A. Famiglietti	1970s, 1980s	1, 4, 5
G. Bernetti	1980s	01
R. del Favero	1980s, 1990s	6
F. Biondi	1990s	6
G. Fabbio	1990s	1, 4, 5
A. Ferrara	1990s	4
G. Preto	1990s	7
S.G. Scrinzi	1980s-1990s	7
V. Tosi	1990s	7

01 = textbooks, 1 = tree and primary products, 3 = stand structure, 4 = stand growth and yield, 5 = weight and biomass, 6 = tree ring studies, 7 = forest inventory and remote sensing.

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8. ROMANIA

General information

Land area: 229,540 sq. km (88,629 sq. mi), forest and other wooded land: 62,650 sq. km (24,190 sq. mi), total forest: 6,190,000 ha (23,901 sq. mi.) or 27 % of land area; volume: 212 m^3/ha, biomass: 110 tons/ha (FAO 1995-124: Forest resources assessment).

Round wood production: industrial round wood 9.7 mil. m^3, fuel and charcoal 2.4 mil. m^3, total round wood 12.1 mil. m^3.(World Resources 1996-97, Table 9.3, p. 220).

Forest vegetation: temperate mixed forests

• Conifers 26 %
• Broad-leaved 74 %
• Main species: European beech (*Fagus sylvatica*) 35%, oaks (*Quercus petraea, Q. cerris, Q. frainetto, Q. robur*), Norway spruce (*Picea abies*), fir (*Abies alba*).

Forestry education and research organizations involved in the areas of forest mensuration and forest management (date of establishment in brackets):

• University "Transilvania", Faculty of Silviculture, and Faculty of Forestry Engineering, Braşov (1948).
• University "Ştefan cel Mare", Faculty of Silviculture (1990).

Before 1948 forestry high education was included in Polytehnical Institute Bucharest (1933).

• Forest Research and Management Institute, Bucharest (1933).

Publications (Primary Journals and Serials):

• Revista Pădurilor, Bucureşti.
• Studii şi Cercetări (Analele Institutului de Cercetări Silvice).
• Publicaţiile Institutului de Cercetări Forestiere, Bucureşti (Series I, II, III, IV.), (Seria I Studii şi Cercetării), ICES, ICAS, INCEF.
• Analele Academiei Române.
• Buletinul Universităţii Braşov (Transilvania).

Historical notice. Fernow, the outstanding American forester of German origin, made in his forest history (1907 and 1911) the following comments related to Romania:

"… by the Congress of Berlin (1878), ending the Russo-Turkish war, these States were recognized as independent kingdoms, namely Bulgaria, Serbia, Montenegro, Roumelia and Roumania, while Bosnia-Hercegovin was placed under Austrian administration. With the exception of Roumania, these people are still in the lower stage of civilization, the countries undeveloped, the forest still serves largely for the mast and pasturage, probably less than 24 percent of the country being forest covered, mostly with decidous trees, oak, beech and walnut, etc. Romania alone has systematically taken the advantage of her freedom from Turkish rule in developing a modern civilization, and can also boast the beginning of a forestry system" (1911, p. 321).

"The first comprehensive law organizing the state property and inaugurating a protective policy was enacted in 1881. This law recognized State, Royal and Communal property as of public concern, and also placed such private property under supervision as was situated on step slopes, near watercourses, and near the boundaries (of strategic importance). These areas, coming under the protective policy, comprise 84 per cent of the whole forest area. They were not to be cleared except by special permit, and not to be exploited except under specially approved working plans. In 1885, three French foresters were called in to organize a State forest department and to inaugurate the making of working plans" (1911, p. 325).

"In 1889, a Forestry Association (Progresul Silvic) was formed which pushes the propaganda with its organ, Revista pădurilor " (1911, p. 326).

Fernow's sources were Mihail Vasilescu 1891, "Die forstwirtschaflichen Verhaltnisse Roumaniens" and "Notice sur les forêts Roumaine", in Statistica pădurilor Statului, 1903.

The first forest school was established in March 1860, in Pantelimon near Bucharest. A lot of French and German books were used by Romanian foresters during the second part of the 19th century. The first books on forestry in Romanian language were published since 1865-1867 as translations from German and French.

Among the first Romanian authors in the field of forest mensuration should be mentioned Ioachim Popovici (1915), I. Popescu-Zeletin (1937), V. N. Stinghe and D. A. Sburlan (1927).

8.1. Selected books, textbooks and booklets on forest mensuration or containing information on this subject

Forest mensuration, named in Romania, as in many other European countries, "dendrometrie", term derived from the Greek δέγδρογ = tree, and μετρέω = measurement, was considered by Stinghe and Toma (1949-1958) to have as purpose the measurement of trees and stands, that is determination of dimensions, form and volume as that of age and growth of tree, and determination of stand volume, age and growth. It is also the task of forest mensuration to establish the volume of pieces obtained after the tree is cut. The operation of volume determination of tree or stands is named “cubare” [cubing] (p. 5, Stinghe et Toma 1958).

Giurgiu (1968, 1979) like other autors enlarged the previous definition and considered that “dendrometria [forest mensuration] represents in fact a forest biometrics, more precisely, a biometrics of trees and stands” and “…forest mensuration (dendrometria) should be understood as an application of mathematical statistics methods in a given case of biology namely the measurement of trees, stands and even of a forest on large areas” (Giurgiu 1979, p. 13). It should be underlined that we and other authors, included the tree-ring studies in forest mensuration.

Among the first texts on forestry published in Romanian language between 1865-1867 should be mentioned a booklet on forest trees by Iuliu Barasch, and notes on practical silviculture by Petre S. Aurelian. Textbooks on forest mensuration appeared later. In 1893 Isopescu translated from German a forest mensuration written by A. Guttemberg. A Romanian pioneer work refers to the forest inventory and was written by Ioachim Popovici (1915), the subject being continued later (1937, 1947) by I. Popescu-Zeletin. Information on forest mensuration were included in booklets of Neagoe (1902) and Teodorescu (1919). Among early works should be mentioned the researches on black locust growth carried out by the outstanding Romanian forester Marin Drăcea (1926).

In 1927 it was printed the first edition of the “Agenda Forestieră” (Forestry handbook) and reprinted in 1930, 1941 and 1968. The third part of this handbook (1941) refers to forest mensuration and is divided in four chapters. (I) Volume determination of felled trees , (II) Volume of standing trees, (III) Forest inventory, and (IV) Determination of age and growth of trees and stands, and is almost totality based on a compilation of foreign literature (French: Caziot 1924, Chaude 1936, Huffel 1924, Italian: Fogli, Patrone; German: Grundner-Schwappach 1913, Schwappach 1912, Eberhardt 1916, Wiedemann 1938, van Laer 1936, Müller R. 1941, Neumeister; Austrian: Schindler 1876, Mocker, Hempel, Weiss and Feistmantel 1909; U.S.A.: Chapman 1924, Bruce-Schumacher 1935). ”Agenda Forestieră” was the best handbook printed in Romania after the first World War and was awarded by the Romanian Academy. More content details of this handbook will be useful for the knowledge of technical methods used in practice at least between 1927 and 1948 in Romania. The handbook contains: stem, form factors from Bavarian table, Bavarian two entry volume tables for spruce, fir, larch, Scots pine, beech, birch, oak; stem taper tables from Fromme (Germany), factors for stacked wood (Germany), tree assortments tables from Switzerland (Flury) for fir, spruce, beech, oak, scots pine, birch. Draudt, Urich, Hartig old German methods for determination of stand volume and assortments, Schwappach (1902, 1905, 1911, 1912 yield tables for spruce, alder, beech, birch, oak); Eichhorn 1902 (for fir), Feistmantel (for coppice: oak, beech, alder) – Austria. The strong influence of German literature is clear. Another handbook was published by Guran in 1933. In 1952 were published Romanian tables for beech by Botezat, Toma and Sabău.

Since 1951 the influence of Russian literature has became evident by translation in 1951 of Anuchin's forest mensuration which was published in 1954. A forester's handbook was printed in 1955 (V. Stinghe et al.) with a 133 pages chapter on forest mensuration.

The selected books textbooks and booklets on forest mensuration or containing information on this subject are presented in Table 8.1.-1.

TABLE 8.1.-1. Selected books, textbooks and booklets on forest mensuration or containing notable information on this subject

Year	Author(s)	Title	Remarks
1896	A. Guttemberg	Dendrometrie [Forest mensuration]	Translation from the German original, by Isopescu
1902	D. B. Neagoe	Călăuza silvicultorului [Forester's guide]	
1919	Gh. Teodorescu	Călăuza silvicultorului [A guide for forest estimator].	
1926	M. Drăcea	Beiträge zur Kenntnis der Robinie in Rumänien [About the knowledge of black locust in Romania]	Inaugural dissertation
1927, 1930 edn. 2, 1941 edn. 3	V. N. Stinghe D. A. Sburlan	Agenda forestieră [Forestry handbook]	In edn. 1941 chapter 3, pp. 103-230
1933	I. Guran	Metode de cubajul pădurilor [Methods for determination of forest volume in Piatra Neamt area]	Piatra Neamț
1949	Ministerul Silviculturii [Ministry of Silviculture]	Tabele forestiere [Forestry tables]	Contains Feistmantel-Weiss' yield tables 1936 edition.
1949	V. N. Stinghe	Curs de dendrometrie [Lectures on forest mensuration]	Lithographed

TABLE 8.1.-1. (cont)

1952	T. Botezat G. T. Toma V. Sabău	Tabele de sortare pentru fag [Assortment tables for beech]	
1954	N. P. Anuchin	Taxația forestieră [Forest mensuration]	Translated from Russian. Wrong translation of this title - it should have been ”Dendrometrie”.
1955, 1958	V. Stinghe D. Sburlan Th. Bălănică G. T. Toma et al.	Manualul inginerului forestier [Forester's handbook]	A 133 pp. Chapter referring to forest mensuration
1955	T. Dorin	Elemente de calcul statistic pentru silvicultori [Elements of statistical calculus for foresters]	
1955	V. Giurgiu	Metode grafice de cubaj [Graphical methods for volume determination]	
1955	R. Ichim	Curs de dendrometrie [Lectures on forest mensuration]	Lithographed
1957	I. Popescu-Zeletin and eight other authors	Tabele dendrometrice [Forest mensuration tables]	A textbook of 1320 pp.
1958	V. Stinghe G. T. Toma	Dendrometrie [Forest mensuration]	
1960	I. Milescu et al.	Tabele de cubaj şi sortare pentru arbori şi arboreta [Volume and assortment tables for trees and stands]	
1961	V. Giurgiu	Clasa de productivitate [Productivity class]	
1961	I. Popescu-Zeletin	Metoda auxometrului comparator [The method of the ”comparative auxometer”]	The paper refers to diameter growth
1964	Alexe Alexe	Pinul silvestru [The Scots pine]	A monograph. A chapter refers to forest mensuration pp. 159-209
1965	Th. Bălănică et al.	Dictionar forestier polyglot [Forestry polyglot dictionary]	
1965	S. Armăşescu et al.	Cercetări asupra productiei, creşterii şi calității arboretelor de molid [Researches on yield, growth and quality of spruce stands]	

TABLE 8.1.-1. (cont)

Year	Author(s)	Title	Remarks
1965	S. Armăşescu et al.	Cercetări asupra productiei, creşterii şi calității arboretelor de brad din R. S. România [Researches on yield, growth and quality of fir stands]	
1965	V. Giurgiu	Algoritmi pentru calcule dendrometrice [Algorithms for forest mensuration calculations]	
1965	Giurgiu V. Decei, I. Armăşescu S.	Tabele dendrometrice pentru amenajarea şi punerea în valoare a pădurilor	Ed. CDF, Bucureşti. In these books are included assortment tables for 17 species.
1966	I. Decei	Cercetări privind producția, creşterea şi calitatea arboretelor de salcie din sămânţă [Researches on yield, growth and quality of willow stands of seed origin]	
1966	Gh. Marcu et al.	Studiul cauzelor şi al metodelor de prevenire şi combatere a uscării stejarului [Researches on oak dieback causes, and on the method to prevent it]	Forest mensurational aspects: pp. 209-272.
1967	S. Armăşescu et al.	Cercetări biometrice privind creşterea, producția şi calitatea arboretelor de fag din România [Biometrical researches on growth, yield and quality of beech stands]	
1967	I. Milescu A. Alexe H. Nicovescu P. Suciu	Fagul [The beech]	A comprehensive monograph. Chapter 8 refers to forest mensurational aspects pp. 278-335
1968	V. Giurgiu	Cercetări privind inventarierea statistică a arboretelor [Researches on statistical inventory of stands]	
1968	V. Giurgiu	Dendrometrie [Forest mensuration]	
1971	I. Popescu-Zeletin V. G. Mocanu	Cercetări asupra biomasei şi creşterii sinuziilor de arbori. În: Cercetări ecologice din Podişul Babadag. (Investigations on the biomass and the tree sinusia growth)	In: "Ecological researches in Babadag Plateau" I. Popescu-Zeletin – coordinator

TABLE 8.1.-1. (cont)

Year	Author(s)	Title	Remarks
1972	V. Giurgiu	Metode ale statisticii matematice aplicate in silvicultură [Methods of mathematical statistics applied in forestry]	
1972	V. Giurgiu	Curba de contur a fusului la principalele specii forestiere din R. S. România [Stem curve of the main species in Romania]	
1972	V. Giurgiu I. Decei S. Armăşescu	Biometria arborilor şi arboretelor [Biometrics of trees and stands]	
1974	V. Giurgiu	Metode ale cercetărilor operaționale şi calculatoarelor electronice aplicate în silvicultură [Methods of operational research and electronical computer application in forestry]	
1975	I. Decei	Proporția şi sortimentarea dimensionala a crăcilor la speciile de gorun, stejar, cer, salcâm şi fag [Proportion and dimensional assortments of the branches of *Quercus petraea, Q. robur, Q. cerris*, black locust, and beech branches]	
1978	T. Popovici et al.	Terminologie forestieră [Forest terminology]	
1979	V. Giurgiu	Dendrometrie si auxologie forestieră [Forest mensuration]	"Auxologie" refers to the laws of growth
1979	D. Cr. Stoiculescu	Cercetări biometrice asupra chiparosului de baltă *Taxodium distichum* (L). Rich [Biometrical investigations on *Taxodium distichum*]	Doctoral thesis Bucharest.
1983	A. Alexe I. Milescu	Inventarierea padurilor (Forest inventory)	A reference book
1988	A. Rusu	Fotografia aeriană şi teledetecția în economia forestieră [Aerial photography and teledetection in forestry]	
1989	V. Giurgiu S. Armasescu et al.	Fundamente auxologice pentru îngrijirea şi conducerea arboretelor [Auxological fundamentals for stand tending and thinnings]	
1994	Iosif Leahu	Dendrometrie [Forest mensuration]	

The following are the forest mensuration textbooks written and published in Romania: Stinghe 1949 (lithographed), Ichim 1957 (lithographed), Stinghe and Toma 1958, Giurgiu 1968, Giurgiu 1979, Leahu 1994, and Alexe and Milescu 1983, the last one refers only to forest inventory (a detailed reference book).

The first printed forest mensuration textbook (Stinghe and Toma 1958) has the following content: (1) Introduction; (2) Theoretical bases for stem volume determination; (3) Techiques and instruments for measurement of lengths, thicknesses, and heights; (4) Volume determination of forest trees; (5) Volume determination of standing trees; (6) Theoretical bases of stand volume determination; (7) Practical methods for stand volume determination; (8) Assortments of standing wood; (9) Age of trees and stands; (10) Auxometria (Growth determination); (11) Auxonomia (Laws of growth). This is a standard forest mensuration in which the terms “Auxometria” and “Auxonomia” were introduced for the first time in Romanian forest literature.

Giurgiu’s (1968) forest mensuration, based on many statistical procedures, was a prelude of his forest mensuration textbook published in 1979. The book is based on mathematical statistics methods and biological aspects of tree and stands and devided in two parts with the following chapters: Part. I “Dendrometrie”(forest mensuration): (1) Introduction; (2) Stem form; (3) Measurement of tree and its component parts; (4) Stands structure; (5) Stand volume determination; (6) Quality and assortments of trees and stands;(7) “Auxometrie” or tree and stand growth measurement; (8) Forest inventory. Part II “Auxologie forestieră” (forest auxology or biological interpretation of growth); (9) Introductive elements; (10) Tree auxology; (11) Stand growth depending on their age; (12) Stand organization (management), productivity and their stability; (13) The rise of forest yield by soil and genetic amelioration; (14) Disturbance of normal growth; (15) Elements of dendrochronology.

Leahu’s (1994) forest mensuration used as a model the previous textbook (Giurgiu 1979) and presented new aspects published in literature, especially after 1979. The book is first of all a manual for students of forestry faculties.

Different tables used in forest mensuration, especially volume tables, yield and assortment tables, were put together in two monumental textbooks: “Tabele dendrometrice” (Forest mensuration tables) a collective work coordinated by I. Popescu-Zeletin (1957) and 15 years later a new generation of tables (entirely based on mathematical statistics methods): “Biometria arborilor şi arboretelor” (Biometrics of trees and stands) by V. Giurgiu, I. Decei and S. Armăşescu.

I. Popescu-Zeletin’s (1957) textbook was highly appreciated in France by Pardé (1961): “…qui ont réuni en un énorme volume (1320 pp.) toute la documentation chiffrée dont peut rêver un forestier sur les arbres de son pays. Les tables de cubage concernent l'une aprés l'autre dix-huit essences donnant le bois fort par arbre ou le menu bois, le volume de l'écorce ou les assortiments de qualité possible… Elles sont complétées par les tables de coefficients de forme, de coefficients de décroisance, et bien d'autres qui font de cette oeuvre magistrale une comme jamais encore réunie en dendrométrie" (p. 175) ["…which contains within an enormous volume all tabelar documentation which a forester can dream about the trees of his country. Volume tables refer to the stem of 18 species, bark and the assortments of a given quality… They are complected by form coefficients and form quotients, decrease coefficients (taper) and also others, fact that made this magistral work something what was not yet completed in forest mensuration].

The second synthesis (V. Giurgiu et al. 1972) deserves at least the same appreciation. It contains volume tables for 28 species, assortment tables (by dimensions) for 25 species, yield tables for 15 species and other tables. This monograph was unique of this kind in Europe in 1979 (Giurgiu 1979 p. 21).

Among different monographs containing information on forest mensuration aspects should be mentioned the works carried out by: Stinghe et al. 1955, 1958 (Forester's handbook), Milescu et al. 1960 (Volume and assortments tables), Alexe 1964 [Scots pine: biometrical tables-(p. 186-209): form factors, form quotients, volume tables, taper, yield and assortment tables etc.], Marcu 1965 (Studies on *Quercus frainetto*), Marcu 1966 (Researches on oak dieback), Milescu, Alexe, Nicovescu, Suciu 1967 (Beech-monograph), I. Popescu-Zeletin and Mocanu 1971 (Investigations on tree growth), Giurgiu 1972 (Methods of mathematical statistics applied in forestry).

Cited authors:

Alexe 1964; Alexe and Milescu 1983, Anuchin 1954 (translation), Armăşescu et al. 1965 a, 1965 b, 1967, Bălănică et al. 1965, Botezat et al. 1952; Decei 1966, 1975; Dorin 1955, Drăcea 1926, Giurgiu 1955, 1961, 1965, 1967, 1968, 1969, 1972 a, 1972 b, 1974, 1979; Giurgiu, Decei and Armăşescu 1972, Giurgiu et al. 1965, Giurgiu et al. 1989, Guran 1933, Guttemberg 1898, Ichim 1957, Leahu 1994, Marcu et al. 1966, Milescu et al. 1960, Milescu et al. 1967, Ministerul Silviculturii 1949, Neagoe 1902, Popescu-Zeletin 1937, 1947, Popescu-Zeletin 1961, Popescu-Zeletin et al. 1957, Popescu-Zeletin and Mocanu 1971, Popovici I. 1915, Popovici et al. 1978, Rusu 1988, Stinghe 1949, Stinghe and Sburlan 1927, 1930, 1941, 1968; Stinghe and Toma 1958, Stinghe et al. 1955, 1958, Stoiculescu 1979, Teodorescu 1919.

8.2. Instruments and measurement of trees and primary products

The calipers were used for diameter measurements before 1900. In 1905 P. Teodorescu constructed a caliper named "a new caliper". Later calipers were constructed by Harnagea, I. Popescu-Zeletin, I. Dăscălescu and D. Ciurileanu.

Among different hypsometers Christen’s was used on a large scale. Other hypsometers were used on a restrained scale: curve Faustman, Weise, Abney, Haga, Wimmenauer and later Blume-Leiss. Barr-Strand was used by Decei (1977) for measurement of diameters on the upper parts of the stem. Caliper was also used for height estimation with the help of a lead and cord attached to caliper’s arms. Dăscălescu and Popescu-Zeletin investigated the errors due to the caliper measurements (1933). The first forestry slide rule was constructed in 1935 by Popescu-Zeletin and another one by Giurgiu in 1957. A more detailed description of measurement instruments used in Romania was provided by Stinghe and Toma (1958) and Giurgiu (1979). The Bitterlich technique was firstly presented in Romania by Ichim in 1956 and now is used on a large scale for tree diameters measurement, heights and stand basal area. In 1956, Timciuc proposed (for the first time) the use of a portable recorder to register data obtained during trees measurements and other data necessary for working plans of forest inventories. His idea was applied in practice, in Italy by Hellrige in 1964. The length of logs or fallen trees was measured with tapes (usually metalic).

Log volume was determined, since the 19^{th} century, usually by Huber formula, but Smalian formula was also used. A detailed determination of round wood volume in practice was given by M. Prodan (1939, 1940) who is originally from Romania and he worked as forester in Romanian province, Bucovina. Toma (1945) investigated the difference between exact and expeditive (quik) log volume determination and after the measurement of 1.000 felled spruce trees with dbh. of 8-48 cm and length of 10-46 m concluded that the total volume of stems determined with Huber’s formula (δl) is less than 3.65 % that was calculated by sumuum of 2 m length sections. On the other hand, for a long time (as in other European countries) was used the so-called formula of compensated diameters

$$V = \frac{\Pi}{4} l \left(\frac{d_o + d_n}{2} \right)^2$$

that permited only one calculus for obtaining g = the area of the middle section of a log. This formula is not correct in comparison with

$$V = l \left(\frac{g_o + g_n}{2} \right)$$

(formula of the two terminal section of a log or Smalian formula) and gives smaller results for a paraboloid and cone but is better for neiloid; in some cases the difference may overtake 5 % in the case of a paraboloid form of log (Stinghe and Toma 1958).

Researches on volume determination of stacked wood, respectively of converting factors of stacked wood in solid content ("*factor de cubaj*" in Romanian) or converting factor of solid content in stacked wood ("*factor de aşezare*" in Romanian) were carried out by Toma (1948), Decei (1959, 1962, 1968), Decei and Anca (1968) and Lupuşanscki (1976). For conversion of stacked wood in solid content the most used procedure was that of diagonals.

Cited authors:

Dascălescu and Popescu-Zeletin 1933, Decei 1959, 1962, 1968; Decei and Anca 1968, Giurgiu 1957, 1979, Hellrige 1964 (Italy), Ichim 1956, Lupuşanscki 1976, Popescu-Zeletin 1935, Prodan M. 1939, 1940; Stinghe and Toma 1958, Timciuc 1956, Teodorescu Paul 1905, Toma 1945,1948.

8.3. Tree form

Up to 1950 in Romania were accepted form factors ($f_{1.3}$) from Bavarian volume tables of stem or whole tree, some of them being published in "Agenda forestieră" (Stinghe and Sburlan 1927, 1930, 1941) and refer to spruce, fir, larch-for stem, and pine, birch, beech, oak and poplar (p. 128-133, ed. 1941). The first Romanian $f_{1.3}$ form factors were determined by Stinghe in 1937 for black locust in Oltenia province, and in 1940 by Toma for spruce in Călimani Mountains. The first form factors having a general valability were calculated by Toma and Armăşescu in 1950 and the first quotients by T. Dorin and R. Dissescu in 1952 - for beech, spruce, Turkey oak, fir, lime, and oak.

The following intervals of form factor values were obtained by Toma and Armăşescu in 1950:

beech	0.591-0.489
spruce	0.578-0.344
Quercus cerris	0.660-0.460
fir	0.545-0.333
lime	0.603-0.444
oak	0.586-0.461

Since 1950 the Forestry Research Institute has determined $f_{1.3}$ values for all important species, and published them in table form in "Tabele dendrometrice" 1957 under the leadership of I. Popescu-Zeletin. An example of $f_{1.3}$ tables for fir is given in Table 8.3.-1., and tables for diameter taper (Table 8.3.-2.) and form quotients for 14 have been included in the same textbook. Form quotient values depend on dbh. and tree height:

Artificial form quotient for trees having… diameter cm

Height (m)	10	20	30	40	50	60
14	0.72	0.65				
18		0.70				
22		0.71	0.67	0.59		
26		0.71	0.68	0.63	0.60	
30			0.69	0.65	0.63	0.56
34				0.66	0.64	0.58

From: I. Popescu-Zeletin et al. 1957.

TABLE 8.3.-1. Form factors A = fir (stem) depending on diameter and B = depending on height and species

A. fir (stem) depending on diameter

D = .. cm	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36
Form Factors ($f_{1.3}$)	0.545	0.540	0.535	0.530	0.525	0.520	0.515	0.511	0.506	0.501	0.496	0.491	0.486	0.481	0.476

B. depending on height and species

h	Coeficienţii de formă ai arborelui întreg pentru speciile*							H m
	St.	Ce.	Fa.	Ca.	Te.	Fr.	Pa.şi Ju	
	oak	Turkey oak	beech	Horn beam	lime	ash	maple	
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.
11	575	530	555	568	570	552	603	11
12	573	518	545	552	561	515	597	12
13	570	507	536	545	554	503	587	13
14	568	498	529	542	548	500	576	14
15	566	489	523	541	543	500	567	15
16	562	478	517	541	539	500	560	16
17	559	470	513	541	536	500	556	17
18	556	465	509	541	533	499	554	18
19	553	461	506	541	530	498	551	19
20	550	460	503	540	526	498	549	20
.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.

*Form factors refer to all tree species

SOURCE: I. Popescu-Zeletin et al. 1957. Reproduced after Stinghe and Toma, 1958, Dendrometrie, p. 95, table 10 for A. and 11 for B., Ministry of Agric. and Silvic. Ed. Agro-Silvică de Stat.

TABELE 8.3.-2. Spruce: decreasing of the stem diameter (taper)

Molid spruce db=14 cm Tabelă de descreştere a diametrului fusului

h	Vol. fus cu * coajă	Speci-ficari	Înălțimea secțiuni…în m (section height)									
m	Fara coajă m³		1	3	5	7	9	11	13	15	17	19
10	0.081	d_1	14.000	12.400	9.800	7.300	4.00					
		m_1	0.031	0.024	0.015	0.008	0.003					
		%	38.000	68.000	87.000	96.00	100					
	0.071	d_2	13.200	11.700	9.100	6.700	3.500					
		m_2	0.027	0.022	0.013	0.007	0.002					
12	0.097	d_1	14.000	12.800	11.000	9.000	6.200	3.100				
		m_1	0.031	0.026	0.019	0.013	0.006	0.002				
		%	32.000	59.000	78.000	92.000	98.000	100				
	0.085	d_2	13.200	12.300	10.300	8.300	5.600	2.700				
		m_2	0.027	0.024	0.020	0.014	0.009	0.004				
14	0.113	d_1	14.000	13.000	12.000	10.000	8.000	5.500	2.700			
		m_1	0.031	0.027	0.023	0.016	0.010	0.005	0.001			
		%	27.000	51.000	72.000	86.000	95.000	99.000	100			
	0.990	d_2	13.200	12.300	11.300	9.300	7.400	5.000	2.300			
		m_2	0.027	0.024	0.020	0.014	0.009	0.004	0.001			
16	0.130	d_1	14.000	13.200	12.500	11.000	9.400	7.400	4.900	2.200		
		m_1	0.031	0.027	0.025	0.019	0.014	0.009	0.004	0.001		
			23.000	45.000	64.000	78.000	89.000	96.000	99.000	100		
	0.114	d_2	13.200	12.500	11.700	10.300	8.700	6.800	4.400	1.800		
		m_2	0.027	0.025	0.022	0.017	0.012	0.007	0.003	0.001		
18	0.147	d_1	14.000	13.300	12.600	11.900	10.300	8.900	7.100	4.600	2.000	
		m_1	0.031	0.028	0.025	0.022	0.017	0.012	0.008	0.003	0.001	
		%	21.000	40.000	57.000	72.000	84.000	92.000	97.000	99.000	100	
	0.128	d_2	13.200	12.500	11.800	11.100	9.600	8.300	6.500	4.100	1.600	
		m_2	0.027	0.025	0.022	0.019	0.014	0.011	0.007	0.003	–	
20	0.166	d_1	14.000	13.400	12.900	12.300	11.200	9.900	8.300	6.800	4.300	1.800
		m_1	0.031	0.028	0.026	0.024	0.020	0.015	0.011	0.007	0.001	0.001
		%	19.000	36.000	51.000	66.000	78.000	87.000	93.000	98.000	99.000	100
	0.144	d_2	13.200	12.600	12.100	11.500	10.600	9.200	7.700	6.200	3.800	1.500
		m_2	0.027	0.025	0.023	0.021	0.018	0.013	0.009	0.006	0.002	–

*Stem volume with bark/stem volume without bark, m³ h = height in m, db = dbh.
SOURCE: Original I. Popescu-Zeletin et al. 1957, Tabele dendrometice, Bucharest Reproduced after Stinghe and Toma 1958, Dendrometria, p. 104, table 16, Min. of Agric. and Sylvic. Ed. Agro-Silvică de Stat

One of the first tables of diameter decreasing (taper) was constructed by R. Dissescu et al. in 1953 for spruce, fir, beech and poplar.

Giurgiu (1955) investigated spruce form quotients using mathematical statistics procedures (1955 a) and corellation between form quotients q_2 and q_5 for volume determination of standing trees (1955 b).

Milescu et al. (1960) studied the form of *Quercus pedunculiflora* trees.

For the first time Iacovlev (1961 a) determined form factors and form quotients for Scots pine in eastern Carpathiens.

Alexe (1964) determined the average values of form quotients (q_2) by groups of *Pinus sylvestris* forest types (p. 161):

Group of Scots pine forest types	Average value of q_2	Difference in % mean value for all types = 100
Pineta excelsiora and *Pineta majora* (very high productivity)	0.653	-2.5
Pineta media (medium productivity)	0.661	-1.5
Pineta minora (low productivity)	0.703	+10.0
Mean value for all forest types of Scots pine	0.662	0

The differences between q_2 values considered as errors is transferred to tree volume about 1.3 times. It seems that every forest type group is characterized by a specific form of trees, different in the case of the same values of diameter and height categories.

The form factors of Scots pine stems are located between 0.601 and 0.381 not overtaking the spruce values (0.578-0.344) in the same area of d and h values.

Giurgiu (1965) published a booklet on algorithms used in forest mensuration calculus among which is mentioned a regression equation of the longitudinal curve of stem expressed by a polynom of the 10^{th} degree, and the relationship between form quotient $k_{0.5}$ and the series of k_i form quotients. Based on this relation Giurgiu (1972) determined the equations of the longitudinal curve of stem for main species growing in Romania, and which represent the theoretical basis for the development of volume and assortment tables. The general form of this equation is $d_i = k_i\, d_{0.1}$ where k_i represents the decrease factor (natural form quotient) and d_i is diameter at different heights along the stem and $d_{0.1}$ = diameter at 0.1 of stem height.

The mean values of q form quotient

$$K = q_2 = \text{classic} = \frac{d_{0,5h}}{dbh}$$

($d_{0,5h}$ = diameter at 0,5 height of tree) determined for Romanian trees are the following (original Giurgiu, Decei and Armăşescu 1972, reproduced after Giurgiu 1979, p. 33):

Rank:

1. Grey alder (*Alunus incana* (L.) Moench), anin alb 0.70
2. Silver fir (*Abies alba* Mill.), brad 0.69

3. Austrian pine (*Pinus nigra* Arn.), pin negru	0.69
4. European aspen (*Populus tremula* L.), plop tremurător	0.69
5. European beech (*Fagus sylvatica* L.), fag	0.68
6. European oak (*Quercus robur* L.), stejar pedunculat	0.68
7. European oak [*Quercus petraea* (Matt.) Liebl.], gorun	0.67
8. Norway spruce [*Picea abies* (L.) Karst.], molid	0.67
9. Elm (*Ulmus minor* Mill.), ulm	0.67
10. Common alder [*Alunus glutinosa* (L.) Gaertn], anin negru	0.66
11. European ash (*Fraxinus excelsior* L.), frasin	0.65
12. Douglas fir [*Pseudotsuga menziesii* (Mirb.) Franco], Duglas	0.65
13. European larch (*Larix decidua* Mill.), larice	0.64
14. Hornbeam (*Carpinus betulus* L.), carpen	0.64
15. Turkey oak (*Quercus cerris* L.), cer	0.63
16. Norway maple (*Acer platanoides* L.), paltin	0.63
17. Field maple (*Acer compestre* L.), jugastru	0.63
18. White and black poplar (*Populus alba* L. and *Populus nigra* L.), plop alb and plop negru	0.62
19. European birch (*Betula pendula*), mesteacăn	0.60
20. Black locust, robinia (*Robinia pseudacacia* L.), salcâm	0.60
21. White willow (*Salix alba* L.), salcie albă	0.58
22. Euramerican poplars (*Populus* X), plopi euramericani	0.55

Form and content of wood of Euramerican poplars belonging to clone R-16 were determined by Decei in 1977.

In connection with the tree form, the following dimensions of the biggest Romanian trees should be mentioned: spruce, district Buzău, Nehoiaşi range, dbh 2.4 m, h = 62 m, age 400 - 450 years and, fir Romuli forest, Năsăud range, dbh 1.5 m, h = 56-58 m, age 400 - 500 years (after I. Popescu-Zeletin 1964).

Cited authors:

Alexe 1964, Decei 1977, Dissescu et al.1953, Giurgiu 1955 a, 1955 b, 1965, 1972, 1979; Giurgiu et al. 1972, Iacovlev 1961, Milescu et al.1960, Milescu, Alexe et al. 1967, Popescu-Zeletin et al. 1957, Stinghe 1937, Stinghe and Sburlan 1927, 1930, 1941; Toma 1940, 1941.

8.4. Volume tables and equations

The bavarian volume tables were used for a long time in Romanian forest mensuration, at last up until 1940-1950 when the first Romanian tables began to be constructed. The German volume tables can be found in early forest publications (Guttemberg 1898, Teodorescu 1919, Stinghe and Sburlan 1927, 1930, 1941, Chiriacescu and Lungu 1941).

Stinghe (1937) determined for black locust planted in Oltenia province: form factors ($f_{1.3}$), form height (hf) and volume table that as far as we know should be considered as the first Romanian volume table. Toma (1941) constructed the first double-entry volume table for Norway spruce located in Călimani Mountains (Table 8.4.-1.) and, later he developed volume tables (tariffs) for oak trees.

TABLE 8.4.-1. The first Romanian double-entry volume table for Norway spruce in Călimani Mountains (by G. Toma 1941)
Tabela 9-Table (tarife) de cubaj (după G.Toma)

(SPRUCE >50 years) MOLID peste 50 ani (Călimani)												
Înălți-mea în m (height, m)	(dbh) Când la 1,30 m diametrul este de …cm											
	15	16	17	18	19	20	21	22	23	24	25	26
	Volumul fusului în dm^3 (Stem volume dm^3)											
12	99	—	—	—	—	—	—	—	—	—	—	—
13	108	123	138	—	—	—	—	—	—	—	—	—
14	118	134	151	167	183	200	216	232	—	—	—	—
15	128	146	164	181	199	218	236	254	271	290	—	—
16	137	157	177	196	216	236	256	276	296	316	337	355
17	147	168	190	210	232	253	276	299	320	343	365	387
18	157	180	203	225	248	271	296	321	344	369	394	418
19	166	191	216	240	264	289	316	343	369	396	423	449
20	176	202	228	254	281	307	336	365	393	422	451	481
21	186	214	240	269	297	325	356	387	418	449	480	512
22	195	225	254	283	313	343	375	409	442	475	509	543
23	205	237	267	298	329	360	396	432	466	502	537	575
24	215	248	280	312	345	378	416	454	491	528	566	660
25	224	259	293	327	362	396	436	476	515	555	595	637
26	234	271	306	342	378	414	456	498	539	581	623	668
27	—	282	310	356	394	423	476	520	564	608	652	700
28	—	—	332	371	410	450	496	542	588	634	681	731
29	—	—	—	385	427	467	516	565	613	661	709	762
30	—	—	—	400	443	485	536	587	637	687	738	794
31	—	—	—	—	459	593	556	609	661	714	767	825
32	—	—	—	—	—	524	576	631	686	740	795	836
33	—	—	—	—	—	—	—	—	710	767	824	888
34	—	—	—	—	—	—	—	—	—	—	—	919

SOURCE: Reproduced after Stinghe and Sburlan, "Agenda forestieră" ed. 1941, p. 141, table 9.

In 1950, the Romanian Forestry Research Institute (ICES) published general volume tables for fir, spruce, oak, Turkey oak, hornbeam, black locust, ash, Norway maple (*Acer platanoides*) and field maple (*Acer campestre*). In Romania of the 1950s was used also an analytical method based on Kopezky-Gerhardt line of volumes expressed by a general equation. Using this method in Hungary, Ronai constructed the volume tables that are similar with tariffs and his tables refer to timber over 7-10 cm diameter at upper part of the stem, and a detailed description of this method was presented in 1953 by the Romanian

Institute for Forest Management (I.S.P) under the coordination of V. Sabău.

Decei (1954) published his birch volume tables.

Giurgiu (1955) presented a review of graphical methods to be used for volume determination in forestry.

The monumental work "Tabele dendrometrice"(1957) (Tables for forest mensuration) was published under the coordination of I. Popescu-Zeletin, in which all volume tables constructed up till 1955-1956 were included. An example of this first generation of volume tables based on graphical methods is shown in Table 8.4.-2., which is an extract of a spruce volume table.

TABLE 8.4.-2. Volume table for spruce (extract) based on graphical methods
Tablă de cubaj pentru molid - Tabela 17

d_b (dbh,cm)	Volumul fusului in m^3 la diametrul de bază ... (Stem volume in m^3 for dbh…)												
h (height,m)	…	12	14	16	18	20	22	24	26	28	30	32	34	…
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
21		0.133	0.176	0.221	0.272	0.328	0.396	0.451	0.516	0.587	0.659	0.734	0.810	….
22			0.186	0.232	0.286	0.345	0.406	0.474	0.543	0.616	0.693	0.772	0.854	….
23			0.196	0.244	0.300	0.362	0.427	0.498	0.570	0.648	0.729	0.813	0.899	….
24			0.206	0.256	0.314	0.379	0.448	0.522	0.598	0.681	0.766	0.854	0.945	….
25			0.217	0.268	0.328	0.396	0.468	0.546	0.626	0.713	0.802	0.895	0.990	….
26				0.281	0.343	0.413	0.489	0.570	0.655	0.746	0.839	0.936	1.036	….
27				0.294	0.358	0.430	0.510	0.596	0.684	0.779	0.877	0.978	1.083	….
28					0.373	0.448	0.532	0.622	0.714	0.813	0.915	1.021	1.131	….
29					0.389	0.466	0.544	0.649	0.745	0.848	0.954	1.065	1.179	….
30					0.405	0.485	0.577	0.676	0.776	0.883	0.994	1.109	1.227	….
31						0.504	0.600	0.704	0.808	0.919	1.035	1.154	1.276	….
32							0.624	0.732	0.841	0.956	1.076	1.199	1.326	….
33							0.648	0.761	0.874	0.994	1.118	1.245	1.377	….
34								0.790	0.908	1.033	1.160	1.292	1.428	….
35									0.942	1.073	1.204	1.339	1.479	….
36										1.113	1.248	1.387	1.531	….
37											1.294	1.439	1.583	….
38											1.340	1.486	1.636	….
39													1.689	….
40														….
														….
														….
														….
														….

SOURCE: The original table was published in the collection of Forest Research Institute: I. Popescu-Zeletin et al. 1957, "Table dendrometrice". This extract is reproduced after Stinghe and Toma, 1958, "Dendrometrie", p. 108, Table 17, Ed. Agro-Silvică de Stat, Bucharest.

R. Dissescu and M. Stănescu (1956) proposed a method for the construction of volume tables (tariffs) and considered it as a new one. They proposed the replacement of compensate curve by a straight line with the equation

$$V = ad + bd^2 \quad \text{and}$$

$$V = k d_b^m$$

which, using logarithms, become log V = log k + m log d_b (d_b = dbh, V = tree volume). This method (equation) was firstly used in the U.S.A by H. Arthur Meyer and discussed in detail in Revue Forestiere Française no. 7/1949, by L. S. Mayer's formula was $V = kd^b$ but in France d = dbh was replaced by girth and the formula became $V = kc^b$ and was used for the construction of the same French volume tables using logarithmical paper. L. S. also commented an article signed by Souloumiac in Revue des Eaux et Forêts in November 1947 in which the volume is expressed depending on a parabola of third degree but with the girth introduced in the formula, instead of diameter.

Toma constructed tariffs for selection forest (Norway spruce and beech) in Valea Lupului forest and published them in 1958 in his forest mensuration textbook. These tariffs, first of this kind in Romania, are presented in Table 8.4.-3.

Another set of volume tables and the assortment tables for trees and stands was completed by the Institute of Forest Research, the works being coordinated by Milescu Ion (1960).

TABLE 8.4.-3. Tariff for selection forest Valea Lupului-Curtea de Argeş, Romania. Tarif de cubaj pentru codru grădinărit în U.P.IX Valea Lupului din M.U.F.B. Argeşul Superior (Toma)

Diametrul[5] cm	Brad[1]		Fag[2]	
	h[3] m	v[4] m^3	h m	v m^3
16	11.0	0.12	9.0	0.10
20	15.0	0.24	11.0	0.19
24	19.0	0.43	15.0	0.35
28	23.0	0.70	19.0	0.59
32	27.0	1.05	23.0	0.92
36	29.0	1.40	26.0	1.32
40	31.0	1.81	27.5	1.72
44	32.0	2.22	28.5	2.16
48	32.5	2.62	29.5	2.66
52	33.0	3.06	30.0	3.17
56	33.0	3.47	30.5	3.74
Diametrul cm	Brad		Fag	
	h m	v m^3	h m	v m^3
60	33	3.89	31.0	4.36
64	33	4.33	31.5	5.05
68	33	4.81	31.5	5.70
72	33	5.33	31.5	6.39
76	33	5.87	32.0	7.23
80	33	6.44	32.0	8.01
84	33	7.02	32.0	8.83
88	33	7.61	32.5	9.84
92	33	8.23	32.5	10.76
96	33	8.84	33.0	11.90
100	33	9.49	33.0	12.91

1) fir, 2) beech, 3) tree height, 4) tree volume, 5) dbh

SOURCE: Stinghe and Toma, 1958, Dendrometrie, p.215, table 59, Ed. Agro-Silvică de Stat, Bucureşti.

The first volume table (double entry) for Scots pine grown in natural stands in eastern Carpathians was constructed in 1961 by A. Iacovlev and reprinted in 1964 (A. Alexe).

The form and volume of *Quercus pedunculiflora* K. Koch were studied by I. Popescu-Zeletin and Mocanu (1966) who used the equation:

$$\log v = \log a_0 + a_1 \log(d \cdot h)$$

where d = dbh and h = height

They also used for *Q. pedunculiflora* and *Q. pubescens* the equation

$$v = a + b\,(dbh)^2$$

which is in fact the Hummel-Abadie method (recognized by the mentioned authors), and is shown in Fig. 8.4.-1.

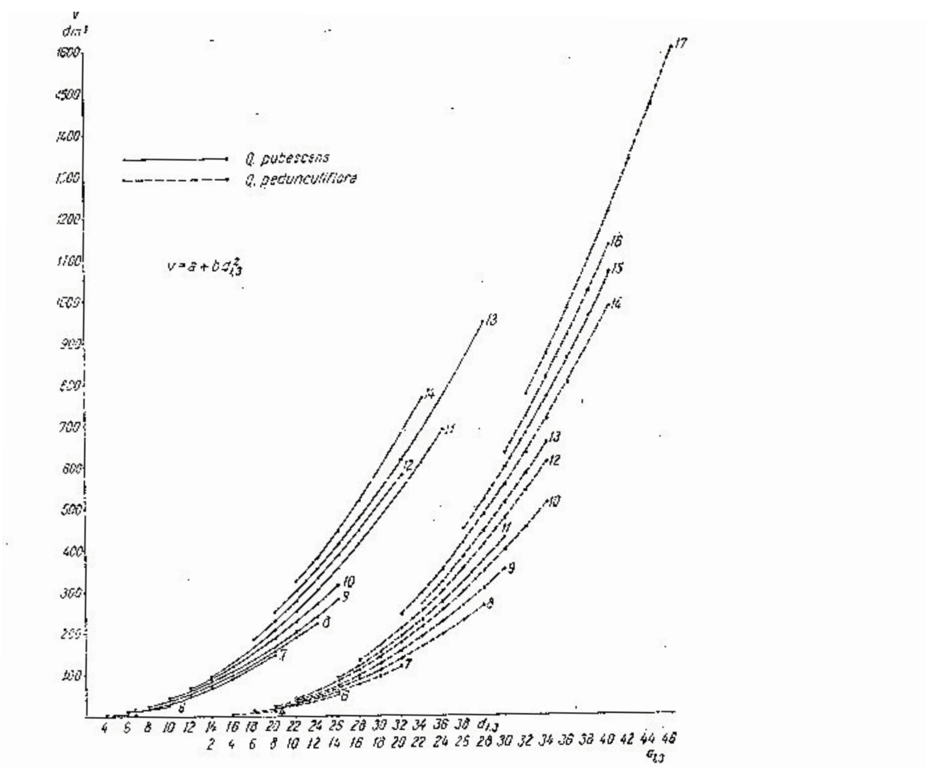


Fig. 8.4.-1. Variability of volume by height categories in connection with $d_{1,3}$ = dbh in the case of *Quercus pubescens* and *Q. pedunculiflora,* based on Hummel-Abadie method applied in Romania by I. Popescu-Zeletin and Mocanu.

SOURCE: I. Popescu-Zeletin and V. G. Mocanu 1971, "Cercetări asupra biomasei şi creşterii sinuziilor de arbori.Cercetări ecologice din podişul Babadag" Ed. Academia R.S.R, Bucureşti, p. 153, Fig. 10.

Giurgiu (1965, 1969) proposed for tree volume the following equations:

$$v = 0.785 f_{0,1}\, d^2\, h\, Q^2$$

where $f_{0,1}$ = natural form factor, diameter at 0,1 height.
d = dbh
Q = f(d,h).
v = tree volume

and $$v = b_0 + b_1 d + b_2 d_2 + \text{------} + b_n d_n$$

In 1972, it was published the second monumental Romanian textbook: “Biometria arborilor şi arboretelor din Romania” (“Biometrics of trees and stands” - by Giurgiu, Decei and Armăşescu) in which the new volume tables based on equations were included.

In 1974 (a), Giurgiu recommended for tree volume the use of the following Prodan’s (1965) equation whose standard error is 7-10 %:

$$\log v = b_0 + b_1 \log d + b_2 \log^2 d + b_3 \log h + b_4 \log^2 h$$

where v = tree volume
d = dbh
h = tree height

and based on Romanian volume tables (1972), Giurgiu (1975) determined the b_0, b_1, b_2, b_3 and b_4 regression coefficients (Table 8.4.-4.) which is a synthesis of Romanian volume tables.

The mathematical expression of volume tables is applied on general level being included in the informational system of estimation of wood quantity for felling (SIAPV), for the forest and inventories monitoring during elaboration of working plans as in information (SUPERPAD), (Leahu 1994, p. 225-226).

Cited authors:

Alexe 1964, Chiriacescu and Lungu 1940, Decei 1954, Dissescu and Stănescu 1956, Giurgiu 1955, 1965, 1969, 1972, 1974, 1975, 1979; Guttemberg 1989, Iacovlev 1961 (b), ICES 1959, Leahu 1994, Milescu et al. 1960, I. Popescu-Zeletin et al. 1957, Popescu-Zeletin and Mocanu, Prodan 1965, Sabău 1953, Stinghe 1937, Stinghe and Toma 1958, Teodorescu 1919, Toma 1941, 1946, 1947.

TABLE 8.4.-4. The analytical synthesis of Romanian volume tables-30 species.
(Regression coefficients of tree volume equation:
$\log v = b_0 + b_1 \log d + b_2 \log^2 d + b_3 \log h + b_4 \log^2 h$).

No. art.	SPECIA (Species)	COEFICIENȚII (Coefficiets)				
		b_0	b_1	b_2	b_3	b_4
1	Molid (spruce)	-4.0239	1.9341	-0.0722	0.6365	0.1720
2	Brad (fir)	-4.3449	2.1354	-0.1067	0.9380	0.0228
3	Larice (larch)	-4.5494	2.2060	-0.1136	1.0115	0.0129
4	Pin silvestru (Scots pine)	-3.8295	1.8341	-0.0448	0.3115	0.3525
5	Pin negru (Austrian pine)	-3.9669	1.9701	0.0102	0.4858	0.1330
6	Duglas (Douglas fir)	-4.3490	1.8688	0.0424	1.1411	-0.1047
7	Fag (beech)	-4.1209	1.3791	0.2127	1.1992	-0.0584
8	Mesteacăn (birch)	-4.0893	2.2480	-0.2062	0.1946	0.4147
9	Anin alb (grey alder)	-3.1870	1.6750	0.1001	-0.4990	0.5902
10	Salcie căprească (willow)	-3.9395	1.6688	0.1090	0.7781	0.0269
11	Plop tremurător (trembling poplar)	-4.1190	1.7812	0.0528	0.8533	0,0654
12	Gorun (oak)	-4.1529	2.3082	-0.1008	0.5059	0.1205
13	Carpen (hornbeam)	-4.1329	2.1302	-0.0013	0.4514	0.1732
14	Frasin (ash)	-3.5136	1.2676	0.3102	0.4929	0.0962
15	Stejar (oak)	-4.0536	1.8905	0.0469	0.8059	-0.0045
16	Paltin (maple)	-3.4513	1.0200	0.3997	0.6660	0.0210
17	Tei (lime)	-4.3847	1.9302	0.0209	1.2900	-0.1903
18	Jugastru (field maple)	-3.8876	1.8559	0.0394	0.5945	0.0742
19	Cer (Turkey oak)	-3.7007	2.0140	-0.0602	-0.1108	0.4811
20	Anin negru (black alder)	-4.0622	1.7148	0.1014	0.8010	0.0530
21	Ulm (elm)	-4.3988	2.1569	-0.0933	1.0728	-0.0708
22	Salcâm (robinia)	-3.3288	1.8070	0.0292	-0.4155	0.5455
23	Stejar pufos (oak)	-3.4539	1.1119	0.3108	0.5356	0.2139
24	Stejar brumuriu (oak)	-4.1434	1.4486	0.0204	1.4084	0.0409
25	Plop alb şi negru (poplars)	-3.7433	1.9342	0.0013	-0.0161	0.4099
26	Plop euramerican (Euram. poplar)					
27	Salcie sămânță (willow)	-3.3821	1.4466	0.1089	-0.1963	0,5681
28	Salcie sulinari (willow sprouts)	-4.3684	2.0766	-0.1296	0.6843	0.2745
29	Gârniță (*Quercus frainetto*)	-4.1352	1.5598	0.0302	0.8572	0.1791
30	Plop euramerican (Euram. poplars)	-4.0208	1.7079	0.0081	0.9158	0.0096
	-clona R 16	-3.9829	1.4108	0.1852	0.8254	0.1139
	-clona I 214	-3.5829	1.7319	0.1264	0.1536	0.2098

SOURCE: Original Giurgiu 1975. Reproduced after V. Giurgiu 1979, "Dendrometrie şi auxologie forestieră", p. 118, tabel 3.7., Ed. Ceres, Bucharest

8.5. Biometrical studies on leaves, branches, bark, stump and roots

8.5.1. Leaves and branches

The first study on leaves and shoots (weight) in the case of *Quercus pubescens* and *Q. pedunculiflora* were carried out by V. Mocanu in 1968 who introduced the "crown index" expressed by $d_c h_c$ product, in which d_c = crown diameter and h_c = crown length, and proved that leaves weight depend on this index. For both species the weight of fresh leaves is the same up to 30 value of crown index. In the most developed crown have been found 35 kg fresh leaves on *Q. pubescens* and 47 kg on *Q. pedunculiflora*. The first species has in medium 2747 (2200-3923) leaves per kilogram and the second 1961 (1397-1974). The weight of dry *Quercus pubescens* leaves represents about 50 % (47.6-51.2) from green weight and 45,8 (45.3-46.4) in the case of *Quercus pedunculiflora*.

In 1971 I. Popescu-Zeletin and Mocanu developed detailed studies on leaves of *Quercus pubescens* and *Q. pedunculiflora* (size, area, number of shoots on tree, weight and growth) growing on Babadag Plateau province of Dobrogea. They establish that when the length of a leaf (L) is between 5 and 13 cm the width (l) is given by regression equation $l = 0.88 + 0.64\ L$ for *Q. pubescens* and $l = 0.55 + 0.69\ L$ in the case of *Q. pedunculiflora*, and outside this interval the regression is curvilinear. The leaves area is varying between 5 and 50 cm^2 in the case of *Q. pubescens,* and 5-110 cm^2 for *Q. pedunculiflora*. One kilogram of fresh leaves has an average area of 4.6 m^2 (3.747-5.426) for *Q. pubescens* and 5.86 m^2 (4.794-6.875) for *Q. pedunculiflora*. The number of green shoots (n) has a high variability and depend on d = dbh according to exponential regression equation:

$$n=31.18e^{0.05208d}\ 1.3\ (Q.\ pubescens) \qquad \text{and}$$

$$n = 34.18e^{0.04807d}\ 1.3\ (Q.\ pedunculiflora)$$

Dissescu and Dissescu (1974) determined a correlation between apparent dimension of crown and area of leaves in the case of black locust. The same authors established the necessary dimensional relations for an expeditive assessment of the leaves area.

The crown index (as defined by Mocanu in 1968) was also used by I. Popescu-Zeletin et al. (1975) investigating the trees grown in uneven-aged stands of beech and fir in Sinaia area. They found in the case of big beech trees about 875.000 leaves and 1.5-2 billion leaves on fir, while on oak were found 80.000-100.000 leaves per tree; per kilogram were determined for beech 5.700 fresh leaves on 12.900 dry leaves and 84.500 respectively 169.000 in the case of fir.

Gabriela Dissescu and Coca (1973) studied the variability of the number of leaves on oak species. In the same year, G. Dissescu (1973) determined the foliar area of a tree (S) depending on dbh = l or the horizontal projection of crown (g_c) using the following regression equations:

$$\log S = a_0 + a_1 \log b \text{ and } S = a_0 + a_1 g_c$$

Renata Giurgiu (1972) and Konnert (1978) established the following equations for determination of oak leaves area (*Quercus robur*):

$$S = b_0 + b_1\, l_1^2$$
$$S = b_0 + b_1\, l_2^2$$
$$S = b_0 + b_1 l_1 l_2$$

where: l_1 is width and l_2 is the length of a leaf.

G. Dissescu (1976) investigated the variability of the tree-leaves number according to dbh = d of different oak species. She used the regression equation $\log n = b_0 + b_1 \log d$, where b_0 coefficient was 1.864 (*Q. robur*) and 2.436 (*Q. petraea*) and b_1 was located between 1509 (*Q. petraea*) and 2.018 (*Q. robur*).

The number of leaves is determined by many factors and in 1982 Decei using data from 20-60 years old beech stands developed the following regression equation taking into account the tree dbh (x_1), the tree position in stand (x_2), site productivity (x_3) expressed by productivity class the stand (site index), stand age (x_4) and stand density (x_5) – n being the number of leaves in thousand:

$$n=5.401+2.240x_1-3.505x_2+4.006x_3+0.080x_4-2.957x_5$$

Decei and Andron (1984) determined, in a complex study on biomass, the number of leaves (n, in thousand) depending on dbh(x) for beech, sessile oak, spruce and fir with data from equations:

Beech	$n = 12.00375-1.4795x+0.12246x^2$
Sessile oak	$n = 0.99430-0.22759x+0.04530x^2$
Spruce	$n = 4911.60491+567.96038x-1.35455x^2$
Fir	$n = -866.48715+132.01059x+1.25934x^2$

The early data on branches volume and proportion are included in I. Popescu-Zeletin's et al. (1957) collection of tables for forest mensuration and later in Giurgiu-Decei-Armăşescu (1972) collection of tables. More detailed researches were carried out by I. Popescu-Zeletin and Mocanu (1971) on *Quercus pubescens* and *Quercus pedunculiflora* and Decei (1975 b) who determined proportion of dimensional assortments of oak (*Quercus robur, Q. cerris*), black locust and beech trees; his tables are also reproduced in Giurgiu's (1979) forest mensuration. Decei presented branches volume depending on species, tree origin (seed or sprouts), crown length and branches diameter, and a special table containing the branches percentage (by dimension categories) for different tree diameters (dbh). Later, in 1984 Decei and Andron determined the following average percentage of branches out of the total tree aboveground volume: 13 % (12-15 %) for beech, 10 % for sessile oak, 9 % for spruce and fir.

8.5.2. Bark

The first data on bark proportion were published by Stinghe and Sburlan (1927, 1930, 1941) who reproduced in "Agenda Forestieră" (edn. 1927) the values established at the end of the 19th century by Burckhard and Schindler (p. 188, table 34, in Ed. 1941).

During the 1950s the first Romanian tables were prepared for bark on the main species and published in 1957 (I. Popescu-Zeletin et al.). These tables refer to 12 species.

Based on Giurgiu's (1972) work on stem curves of the main Romanian species Giurgiu, Decei and Armăşescu (1972) prepared new tables containing data on bark of 24 species.

In 1982, Decei calculated the following average values of bark percentage out of the tree aboveground volume: beech 5 %, sessile oak 15 %, Norway spruce 9 % and fir 7 %.

8.5.3. Stump and roots

Stinghe and Sburlan (1927, 1930, 1941) reproduced (p. 188 and 229 edn. 1941, "Agenda Forestieră") Burckhard and Schindler's old data (1876) on proportion of stump and root wood of trees and stands for the main European species.

The first estimation of stump and root wood belongs to Stinghe and Toma (1958, p. 118). They considered that the underground part of tree represents for mature trees 15-25 % of the total aboveground volume.

There are known the difficulties of studies on stump and root system and this is why the data frequency on this subject is low.

The first Romanian researches were carried out by Valeriu Enescu (1961) who investigated the root system of the main species cultivated on sandy soils. In 1965 Enescu published in Marcu's monograph on oak decline in Romania the results of his studies on the rooting types of different oak species (*Quercus robur, Q. petraea, Q. cerris, Q. frainetto*) and lime in different forests where oak decline phenomena was presented and concluded that the root systems of oak and lime trees of seed origin, in the same environmental conditions belong to the same type with medium profundity 1.40-1.60 (2.40 m) depth and the medium root-horizontal spreading radius is greater than the penetrating depth, which use intensively the horizon A and very poorly the horizon B because of its compactness and impermeability, as a limitative factor in the stands presenting the decline phenomena, resulted the same rooting type without taking into account neither the species nor the site, but the rest of the characteristics remained peculiar or specific to a certain species or site (the numerous thin roots of lime tree, *Q. cerris* and especially *Q. frainetto* are penetrating to a greater depth). The rooting system of the sapling individuals is both quantitatively and qualitatively different from those of seed origin having an unsatisfactory structure shape and development to perform the vital functions of the potential activity level of the aboveground parts.

A detailed study on *Quercus frainetto* root system was completed by G. Marcu in 1960s and published in 1965. Marcu compared *Q. frainetto* root system with that of *Q. petraea* and concluded: 1) *Q. frainetto* root system (QFRS) is very well developed in soil depth (up to 3-3.5 m) and on horizontal level, the major part of the roots is located in the first 60 cm of soil profile; 2) the horizontal projection of root system is larger than that of the crown, at all ages (since 20 up to 150 years) ; 3) *Q. frainetto* roots are able to penetrate the compact and clayey B horizon; 4) root concrescence is frequent; there are not essential differences between *Q. frainetto, Q. petraea* and *Q. robur* root systems concerning the general form but there are differences which refer to rooting depth and horizontal development which in *Q. frainetto* case is more spread on horizontal level and as a rule is deeper.

Decei and Georgescu (1975) investigated the volume of stump and roots of Norway spruce and concluded that the spruce stump volume is highly correlated (R = 0,93) with the aboveground volume according to the regression equation:

$$y = 1.527+0.102x$$

where y = stump tree volume in dm^3 and x = aboveground volume in dm^3. The measurements on root system of different species in different site conditions were also completed, on a smaller scale by C. D. Chiriță et al. (1977).

A remarkable work was developed and completed by Decei (1984, 1987) on the underground part of trees (volume and biomass). Decei collected data from 440 uprooted beech (*Fagus sylvatica*), sessile oak (*Quercus petraea*), Norway spruce *(Picea abies*) and fir (*Abies alba*), and determined root distribution below ground – the volume and biomass were calculated for trees of different ages, from 20 to 120 years. The underground volume of stump and roots (with diameter more than one mm) was about 20 % of above ground volume:

Percentage from above ground volume

	Stump	Roots	Total underground volume
Beech	10	9	19
Sessile oak	12	10	22
Spruce	9	11	19
Fir	9	8	17

The above data are only in part in concordance with Singhe's and Toma's (1958, p. 118) estimation for mature trees (15-25 %).

Decei (1984) constructed also a table in which the percentage of under ground volume (root and stump) out of the above ground volume is given by species and trees dbh. In this work Decei presented the total length of roots (diameter >1 mm) depending on dbh for beech, and percentage repartition of the roots volume by soil depth.

It must be underlined that 89-95 % of the root volume (diam. > 1mm) is located in 0-60 cm soil stratum.

Cited authors (8.4.5.):

Chiriță et al. 1977, Dissescu, G. 1974, 1976; Dissescu G. and Coca 1973, Dissescu and Dissescu 1972, 1974; Decei 1975, 1984, 1987; Decei and Andron 1984, Decei and Georgescu P. 1975, Decei et al. 1982, Enescu Valeriu 1961, 1966; Giurgiu, R. 1972, Giurgiu 1972, Giurgiu – Decei – Armăşescu 1972, Konnert 1978, G. Marcu 1965, 1966; Mocanu 1968, I. Popescu-Zeletin and Mocanu 1971, Popescu-Zeletin et al. 1957, Popescu-Zeletin et al. 1975, Stinghe and Toma 1958.

8.6. Tree growth

Stem analysis as a destructive method for determination of tree growth was practiced in Romania at least since the 1940s in forest research.

The first Romanian studies on the tree growth using undestructive methods were carried out by Popescu-Zeletin in cooperation with other researchers since 1960.

In 1960 Popescu-Zeletin in cooperation with V. Mocanu, S. Puiu and V. Enescu developed a method for determination of tree diameter growth during growing period, and in the same year Popescu-Zeletin, Puiu and Mocanu published some data on black locust diameter growth during growing period. In the next year (1961) Popescu-Zeletin described his original method based on "comparatory auxometer" and published in another paper the measurement results of the trees radial growth during growing season of *Populus x euramericana*

(Dode) Goinier, cultivar *marilandica*. This type of researches on Euramerican poplars continued in 1962 in cooperation with S. Papadopol, E. Pârvu and V. Papadopol.

In 1964, Popescu-Zeletin presented a device that was able to register the daily radial growth of trees. This device called "Dendroauxograph" is a combination between comparatory auxometer and a clock functional during a week and has a cylinder that supports a paper for diagrams on which the smallest variation of growth is recorded.

The auxometrical recordings performed beyond the growth periods (in summer or winter), evidenced the "stem plasticity phenomenon" (determined by other factors than growth, especially high and low temperatures) and investigated in 1968 by Popescu-Zeletin and Florescu (fir stem in uneven-aged stands during the vegetative repose), V. Stănescu et al. in 1973, and four consecutive years by Popescu-Zeletin and Mocanu (1971) whose results of researches are summarized in Table 8.6.-1. and Figure 8.6.-1.

TABLE 8.6.-1. Maximum contractions of diameter in % from annual growth in the case of different species

YEAR	TREES	Contrageri vara 1)								Contrageri iarna 2)							
		A_1	A_2	A_3				A_4		A_1	A_2	A_3				A_4	
		Q. pub.	*Q. pedf.*	*Tilia*	*Carp.*	*Frax.*	*Q. dal.*	*Frax.*	*Q. dal.*	*Q. pub.*	*Q. pedf.*	*Tilia*	*Carp.*	*Frax.*	*Q. dal.*	*Frax.*	*Q. dal.*
	mici*	48	31	-	7	-	-	-	8	33	28	-	36	-	-	-	22
1961	mijlocii	32	12	9	5	32	-	80	9	19	17	36	20	63	-	75	18
	mari	33	6	6	3	27	18	66	9	27	10	37	16	37	28	56	23
	mici	27	40	-	2	-	-	-	12	90	59	-	11	-	-	-	22
1962	mijlocii	21	12	6	5	49	-13	82	11	64	34	71	19	84	-	97	25
	mari	15	6	7	2	40		78	9	54	14	65	13	82	29	73	25
	mici	58	18	-	3	-	-	-	8	67	16	-	20	-	-	-	12
1963	mijlocii	9	3	11	2	65	-	95	3	23	8	50	10	95	-	65	11
	mari	12	2	4	3	27	4	56	1	5	6	42	16	31	13	51	10
	mici	80	-	-	9	-	-	-	-								
1964	mijlocii	61	-	40	3	67	-	-	-								
	mari	51	-	10	7	48	12	-	-								

	A = Type of association:		dbh (cm)	height (m)
A_1 =	*Quercus pubescens (Q. pub.)*	37	10.3	6.8
A_2 =	*Quercus pedunculiflora (Q. pedf.)*	37	11.1	8.6
A_3 =	*Q. dalechampii (Q. dal.)*			
	Tilia	67-72	16-30	12.6-18.2
	Carpinus betulus (Carp.)			
	Fraxinus (Frax.)			
A_4 =	*Q. dalechampii (Q. dal.)*			
	Fraxinus sp.	72	17.6-27.9	12.3-14.0
	Tilia			

1) = summer contractions; 2) = winter contractions; *mici = small; mijlocii = medium; mari = big

SOURCE: I. Popescu-Zeletin and Mocanu, 1971, "Cercetări asupra biomasei şi creşterii sinuziilor de arbori. Cercetări ecologice în podişul Babadag. (Investigations on the biomass and the trees sinusia growth. Ecological researches on Babadag plateau). Ed Academiei R. R. România (now Ed. Academiei Române), Bucureşti 1971, I. Popescu-Zeletin ed. p. 190.

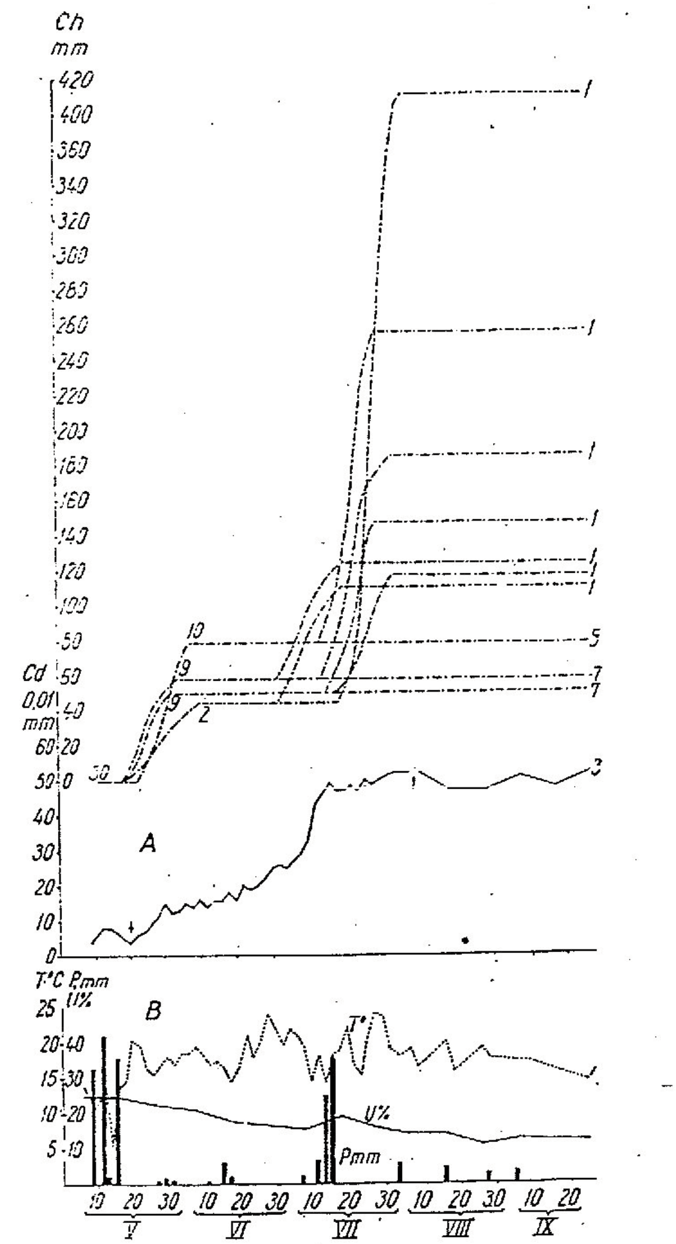


Fig. 8.6.-1. A. Growth dynamics (in length) of terminal shoots and of radial growth of dbh in the case of *Quercus pedunculiflora.* **B**. Seasonal variability of air temperature (T,°C), rain fall (P, mm) and soil humidity (U %). 1, 2, 7, 9… number of trees; multiple presence of the same number indicates that from the same tree were examined more shoots whose growth is different.

SOURCE: Ibid. Table 8.6.-1. (I. Popescu-Zeletin and Mocanu, 1971), p. 172, fig.

Popescu-Zeletin and V. Mocanu (1971) published the synthesis of their four years works on height and radial growth in different tree association (sinusia) on Babadag plateau, in Dogrogea province. They noted the nonexistence of a concordance between height and radial growth, fact exemplified in Figure 8.6.-2. for *Quercus pedunculiflora.* The dynamics of radial growth during the vegetative period were recorded between 1961-1964 years.

Popescu-Zeletin and Mocanu investigated also the growth of *Quercus pubescens* and *Q. pedunculiflora* leaves.

Giurgiu (1967) underlined in a work on stand growth that in the case of individual trees age and position of tree in the vertical profile is determinant and this is why the repartition of growth of annual ring along the tree stem depend on structure (evenaged or unevenaged). Giurgiu seems to be the first who mentioned in Romanian forest literature the existence of cycles in tree radial growth (1974).

In Giurgiu's (1979) forest mensuration there is a special chapter (chapter 10, pp. 489-510) dedicated to peculiarities of tree growth (height during the growing season and the whole life, for the diameter in growing season, the transversal section, the longitudinal section, the dependence of diameter growth on age, and the tree volume growth).

The defoliation, especially two times defoliations proved to be very dangerous factors that strongly affect the trees growth.

The declining trees growth was studied in detail by S.Armăşescu in Marcu's (1966) monograph on oak decline.

Influence of defoliation on the tree growth was also studied later by Popescu-Zeletin and Fraţian (1973).

An early work of the draught influence on tree growth of different species and on wood structure was completed in 1956 by A. Iacovlev.

Lupe (1969) underlined the negative effect of flooded stand on oak and spruce trees; the same thing was remarked by Giurgiu (1970) in flooded plantations of Euroamerican poplars.

Negative effects of industrial pollution on tree growth was analized by Ianculescu (1977) in Baia-Mare area. From methodological point of view Ianculescu's work is based according to Giurgiu (1979, p. 65) on the method developed by Vinš and Pollanschutz 1977 (see Allgemeine Forstzeitung, 1977, no. 6). In fact the use of growth relative index is a very old method used since the 1920s in dendrochronology (U.S.A.).

A synthesis of the effects of pollution (tree growth included) was completed by Giurgiu (1978) in his textbook "Conservarea pădurilor" (Forest conservation).

Cited authors:

Alexe 1964, Armăşescu et al. 1966, Enescu 1965, Fratian 1973, Giurgiu 1967, 1970, 1974, 1978, 1979; Iacovlev 1956, Ianculescu 1977, Lupe 1969, Marcu 1965, Marcu et al. 1966, Popescu-Zeletin 1961a, 1961b, 1964; Popescu-Zeletin and Florescu 1968, Popescu-Zeletin and Mocanu 1971, Popescu-Zeletin et al. 1960, Popescu-Zeletin et al. 1960, 1961, 1962; Stănescu V. 1973.

8.7. Tree and stand timber assortments

During the 20th century the following methods were used for determination of tree and stand assortments: (1) sample plots on which all trees were cu;, (2) estimation of assortments for each standing tree; (3) sample trees (Draudt, Urich I, Urich II and Hartig procedures); (4) assortment tables for trees and stands; (5) computerized determination of assortments based on taper models.

Up until the 1950s the most frequent procedures for estimation of stand assortments were Urich I and Urich II .

In the Stinghe and Sburlan's forest handbook (1927, 1930, 1941) are mentioned two large categories of assortments: wood with diameter above 14 cm at small end, and wood expressed in stocked steres. In this handbook are presented tree assortment tables developed by Flury (Tables of the Forest Research Stations of Switzerland) for spruce, fir and beech trees, a table for oak, beech, birch, Scots pine published by Fromme in Forstl. Kalendertasche, and for stand some old tables constructed by Hempel and Schindler (1876) published in Wien and some data on oak extracted from Schwappach's (1912) book.

One of the early Romanian works on wood assortment problem was published by Michail Prodan in "Revista Pădurilor" 1938/1939.

The first Romanian assortment tables were constructed in 1951 (for beech trees grown in northern Oltenia and for spruce) by Forest Research Institute (ICES) in cooperation with the Institute for Forest Management and included in a booklet signed by Botezat, Toma and Sabău (1952, for beech) and later (1957) in the first collection of tables for forest mensuration (I. Popescu-Zeletin et al. 1957). These early tables were constructed using Tretiakov's method adapted for Romania by G. T. Toma.

Romanian 1950s assortment tables were constructed for three quality categories depending on the percentage of timber for work:

	Percentage of timber for work	
Quality category	Beech	Spruce
I	> 50 %	> 80 %
II	30-50 %	60-80 %
III	under 30 %	under 60 %

The first collection of dendrometrical tables (Popescu-Zeletin et al. 1957) contains stand assortment tables with three entries: stand quality, average stand values for height and dbh.

In 1957, Decei proposed a procedure for assortment determination of trees included in the allowable cut. This procedure is based on sample trees and stand measurements. In the above mentioned collection are included the tables completed by Decei and which are named "unique volume and assortment tables for trees",

Theoretical bases for qualitative assortments determination of trees were summarized by Decei and Dissescu in 1960 and expressed in Table 8.7.-1.; this problem was discussed again by Decei in 1965.

TABLE 8.7.-1. Qualitative classification of trees

Species group	Quality class	Steady wooden part of tree expressed in 0.1h units (h= tree height)	Average percentage possible to be utilized from stem volume in case of conifers or from total volume of broad-leaved		Coefficient of equivalence
			Wood for work	fuel wood	
Conifers	I	>60	98	2	0.1
	II	0.4-0.60	92	8	0.94
	III	0.10-0.40	79	21	0.81
	IV	<0.10	15	85	0.15
Broad-leaved	I	>50	86	14	1.00
	II	0.25-0.50	70	30	0.81
	III	0.10-0.25	49	51	0.57
	IV	<0.10	15	85	0.17

SOURCE: Decei and Dissescu 1960, Revista Pădurilor, Bucureşti. Reprinted by Leahu 1994, Dendrometrie, p. 267, Ed. Didactică şi Pedagogică, R.A., Bucureşti

The classification presented in Table 8.7.-1. is based on repartition of volume along the stem. Using the coefficients of equivalence is possible to determine the number of "trees with wood for work" and the number of "fuel trees" by transformation of the trees from classes II,III and IV in the number of trees belonging to class I by multiplication of the number of trees of these classes with the value of the coefficient of equivalence.

For simplification of calculus have been constructed special tables which permit determination of the number of "trees with wood for work" and "fuel trees" depending on the number of trees of each quality class (Decei 1972, in Giurgiu, Decei and Armăşescu 1972: "Biometrics of trees and stands in Romania").

Milescu et al. (1960) published a synthesis volume and assortment tables in which are included Giurgiu's assortment tables for spruce, fir, beech, oak, lime, Euramerican poplars and willow stands, with two entries: quality class and average diameter of stands. Five years later Giurgiu, Decei and Armăşescu (1965) constructed assortment tables for even-aged stands for 17 species, tables that were included in an improved form in their 1972 collection of tables. On the other hand, in this book the yield tables were completed with assortment tables. This combination of yield tables and assortment tables was practiced in Germany (since the 1930s), where Mitscherlich constructed this types of tables for beech, oak, spruce and Scots pine. In the 1972 collection assortment tables were improved and exemplified in this text by Tables 8.7.-2. and 8.7.-3. which refer to primary dimensional assortment and industrial assortment tables for trees.

Alexe (1964) constructed assortment tables for Scots pine stands using as entry characteristics age category (medium, mature or old) and the average height and diameter of the stand.

TABLE 8.7.-2. Extract from the fir tree primary and dimensional assortment table in Romania

Sortarea dimensională a lemnului de lucru (1)							Sortarea primară (2)			Lemn de foc din arbori de foc(3) ff
Lemn gros (4)			Lemn mijlociu (5)		Lemn subțire(6) <10 cm s	Lemn lucru(7) L	Coaja lemn lucru(8) co	Lemn de foc(9)		
>34 cm G	24-34 cm g	20-24 cm gs	14-20 cm m	10-14 cm m				> 5 cm fl	<5 cm cr	
Procente din volumul total al fusului (Stem total volume in percent)										
-	-	18	53	14	2	87	10	1	2	98
-	-	39	40	7	2	88	10	1	1	99
-	14	38	29	6	1	88	10	1	1	99
-	31	31	21	4	1	88	10	1	1	99
-	44	25	16	3	-	88	10	1	1	99

1) dimensional assortments of wood for work, 2) primary assortments, 3) fuel wood from the "fuel trees", 4) thick wood, 5) medium wood, 6) small wood, 7) wood for work, 8) the bark of the wood for work, 9) wood for fuel.

SOURCE: Giurgiu, Decei, Armăşescu, 1972, "Biometria arborilor şi arboretelor din România" (Biometrics of trees and stands in Romania), Ed. Ceres, Bucureşti, Reprinted by Giurgiu 1979, "Dendrometrie şi auxologie forestieră", p. 337, Table 6.3. Ed. Ceres, Bucureşti.

TABLE 8.7.-3. Extract from the industrial assortments table for beech trees in Romania

d cm (dbh)	Clasa de calitate a arborelui (Tree quality class)											
	I			II			III			IV		
	Indicele de sortare industrială a lemnului de lucru în lemn apt pentru[1]											
	Derulaj [2]	Cherestea [3]	Construcții Rurale [4]	Derulaj	Cheresta	Construcții Ruraule	Derulaj	Cheresta	Construcțiii Rurale [5]	Derulaj	Cheresta	Construcții Rurale [5]
	Procente din volumul arborelui întreg (Percentage from tree total volume)											
22	-	41	39	-	28	29	-	15	18	-	1	3
24	1	51	28	-	36	21	-	19	14	-	1	3
26	3	56	21	1	43	13	1	22	9	-	1	3
28	8	56	17	3	46	8	1	24	7	-	2	3
30	13	55	13	5	46	6	2	24	6	-	2	3
32	17	53	11	6	46	5	2	25	5	-	2	3
34	20	52	9	7	46	4	2	26	4	-	3	2
36	22	52	6	9	45	3	2	26	4	-	3	2
38	23	52	5	10	45	2	2	27	3	-	3	2
40	25	51	4	11	44	2	2	28	2	-	4	2

1) Indices for industrial assortments of wood for work good for: 2) veneer, 3) saw wood, 4) building, 5) rural building
SOURCE: Ibid. Table 8.7.-2. In Giurgiu reprint (1979), p. 337, Table 6.4.

For old natural Scots pine stands Alexe (1964) determined the following average values of "timber for work " and "saw timber" by forest type:

Forest type	Percentage of timber for work (stem volume with bark)	
	Total (%)	Saw timber minimum 14 cm at the small end (%)
PE Pinetum maximum asperuletoso-oxalidosum	77	71
PS Pinetum major Luzuletoso-asperuletosum	77	67
PL Pinetum luzuletoso-rubosum	75	62
PV Pinetum myrtiloso-callunosum	75	55
PSm Pinetum saxatile-alticolum	67	45
Pscalc. Pinetum saxatile calcicolum	67	35
PSc Pinetum saxatile	62	35
PT Pinetum sphagnosum	62	10

In order to estimate the stand quality in case of Scots pine, it was adopted the following criterium (Alexe 1964) :

Percentage of timber for work out of stem volume of standing tree	Quality class
> 70	I
51-70	II
< 50	III

Since 1964 the determination of stand assortments has been completed by computers which determine the optimum assortment solution, indices of dimensional and industrial assortments being introduced in computer's memory (Giurgiu 1974 d). On the other hand, it should be mentioned that primary dimensional assortments were established by computer using the taper equation of stem (Giurgiu 1965,1972a).

Other researches on stand quality were carried out by Armăşescu et al. 1965 a (spruce), 1965 b (fir), 1967 (beech), 1969 (black locust) and Decei 1966 (willow).

In 1965 Giurgiu, Decei and Armăşescu published a booklet containing tables for forest management and the so-called "*act de punere în valoare-APV*" (an inventory of trees planned for felling); in this booklet there are included tables for primary (wood for work, fuel wood) and dimensional assortments for even-aged stands of 17 species.

The mathematical expression of Romanian forest mensuration was one of the remarkable works completed by Giurgiu in 1975.

Decei (1975 a) investigated the determination of defects of beech standing trees and established the following analytical expression for stem rot, the most important defect of the trees of this species:

$$Y = 2.138447 – 0.80582x_1 + 0.04759x_2 + 0.01378x_3 + 0.00791x_4 + 0.00425x_5 + 0.00355x_6$$

where y = the height up to which rot is present

X_1= stand site class

X_2= tree height (m)

X_3= year from appearance of rot or wound

X_4= tree age

X_5= tree dbh (cm)

X_6= wound opening (cm)

Decei also determined in the above mentioned paper: (1) the depth of rot in stem (y) which is correlated with the time since the tree was wounded (x):

$$y= x^2/ (0.0714 + 0.625x + 0.0216x^2)$$

and (2) a set of regression equations for the knot distance of penetration (y in mm) in stem wood depending on knot type, stem diameter at knot level (x in cm) and the angle of exterior trace of knot "moustakes" (x1, in sexagesimal degree):

Type of knot by form:

(1) oval and prominent	y = 0.955 + 0.379x
(2) cylindrical and prominent	y = 1.046 + 0.413x
(3) oval and flat	y = 1.140 + 0.336x
(4) cylindrical, prolonged and flat	y = 0.571 + 0.412x
(5) geneal equation	y= 0.318 + 0.0076x1 + 0.0086x

Radu Ichim (1975) investigated wood quality of spruce trees in northern Romania based on external characteristics and developed similar equations for stem rot.

Decei (1977 a) proposed criteria for qualitative evaluation of oak trees taking into account the stand site class. In 1975, Decei published a work on branches proportion and dimensional assortments of oak species (*Quercus robur, Q. petraea, Q. cerris*) black locust and beech.

After 1975 some state standards of assortment were modified: these primary assortments contain four categories: wood for work ("*lemn de lucru*"), bark of wood for work ("*coaja lemnului de lucru*"), fire wood with diameter above 5 cm ("*lemnul de foc cu diametrul mai mare de 5 cm*"), and tree top and branches under 5 cm diameter ("*vârfuri şi crăci cu diametrul sub 5 cm*"). According to Decei (1980 – cited by Leahu 1994) the dimensional assortments can be conventionally devided depending on the end diameter:

Assortment	Symbol	Conifers	Broad-leaved
thick wood	G	> 34	> 40
thick wood II	g	24-34	-
thick wood III	gs	20-24	24-40
medium wood I	M	14-20	20-24
medium wood II	m	10-14	16-20
medium wood III	ms	-	12-16
small wood	m	< 10	< 10

Round wood for industrial or building purposes is divided in primary and industrial assortments. The industrial assortments are established by special modifying standards and refer to logs for: sounding board (resonant wood), veneer, sawing (lumber), sleeper. Apart from logs there are other assortments such as: pitrops timber, cordwood, pole wood, pulp wood and others.

Cited authors:

Alexe 1964, Armăşescu et al. 1967, 1969, 1965 a, 1965 b; Botezat et al. 1952, Decei 1957, 1965, 1966, 1975a, 1975, 1977a; Decei and Dissescu 1960, Giurgiu 1965, 1972a, 1974d, 1975; Giurgiu–Decei–Armăşescu 1965, 1972; Ichim 1975, Milescu et al. 1960, Mitscherlich 1939 (Germany), Popescu-Zeletin et al. 1957, Prodan M. 1938, 1939, Stinghe and Sburlan 1927, 1930, 1941, Stinghe and Toma 1958.

8.8. Evaluation of forest site quality

The capacity of a site to be more or less favourable to the development of trees represents its quality and depends on forest species because for one species the site quality can be high and for other medium or even low.

Productivity refers to a stand and depend on site quality. Stand productivity can be measured by average height – dominant height or total medium yield at a given age.

The evaluation in Romania of the site quality is based on a large scale on the average height or dominant height of trees of a given species and at a given age. Other possibilities used for the site quality evaluation are ground vegetation and direct evaluation of site quality by determination of its characteristics, especially soil.

The stand biometric characteristics, especially the average height as indicator of site quality for a given species have been used in Romania since the beginning of forest mensuration works. According to the data on the average height of the first Romanian yield tables (1957) for evenaged stands it is clear that site quality depend on species:

Species	Limits (m)	Total amplitude (m)	One site class amplitude in the system of five site classes
Spruce	14.4-39.4	25.0	5.0
Fir	16.0-34.2	18.2	3.6
Beech	16.5-36.0	19.5	3.9
Quercus petraea	14.8-31.3	16.5	3.3
Q. robur	19.3-34.3	15.0	3.0
Q. frainetto	14.2-26.0	11.8	2.8
Q. cerris	16.8-29.5	12.7	2.5
Hornbeam	18.3-30.1	11.8	2.4
Lime	16.9-28.8	11.9	2.4

Stinghe and Toma (1958) proved that for an average height of 28 m at 100 years correspond different stand productivity levels, classes, site classes, respectively:

Species	Site class
Spruce II.8	*Q. robur* II.6
Fir II.2	*Q.cerris* I.1
Beech II.5	Hornbeam I.4
Lime 0.8	*Q. petraea* I.5

and productivity classes for a species, as a rule, are not equal with that of other species (Fig. 8.8.-1.).

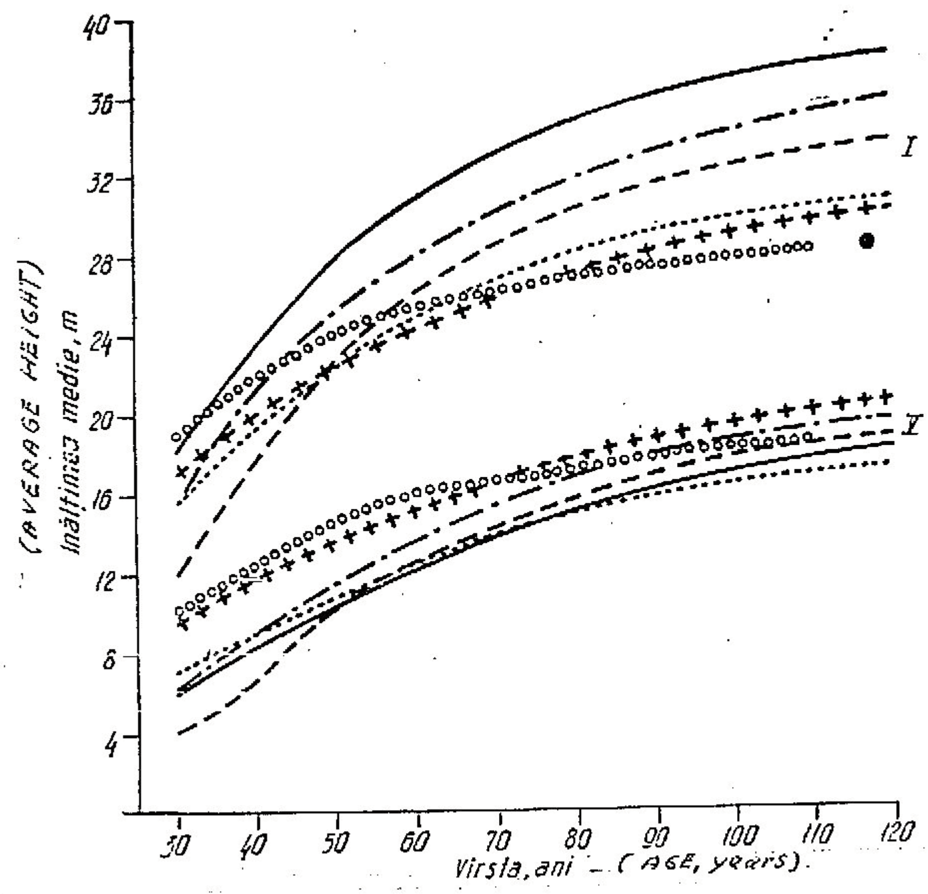


Fig. 8.8.-1. Variability with age of average height in spruce, fir, beech, sessile oak, hornbeam and lime stands in site class I and V.
—spruce ----- fir –•–•– beech …….sessile oak +++++ hornbeam ° ° ° ° lime
SOURCE: Stinghe and Toma 1958, Dendrometrie, p. 336, fig. 141. Ed. Agro-Silvică de Stat, Bucureşti.

This type of site class is relative (relative productivity classes).

In order to compare stands of different species which belong to the same productivity class it is necessary to adopt a unique (absolute) system of classification. For example, the absolute productivity class 28 that means the class in which a stand of any species has an average height of 28 m at 100 years. Figure 8.8-2 presents the situation of cases shown in Figure 8.8.-1.

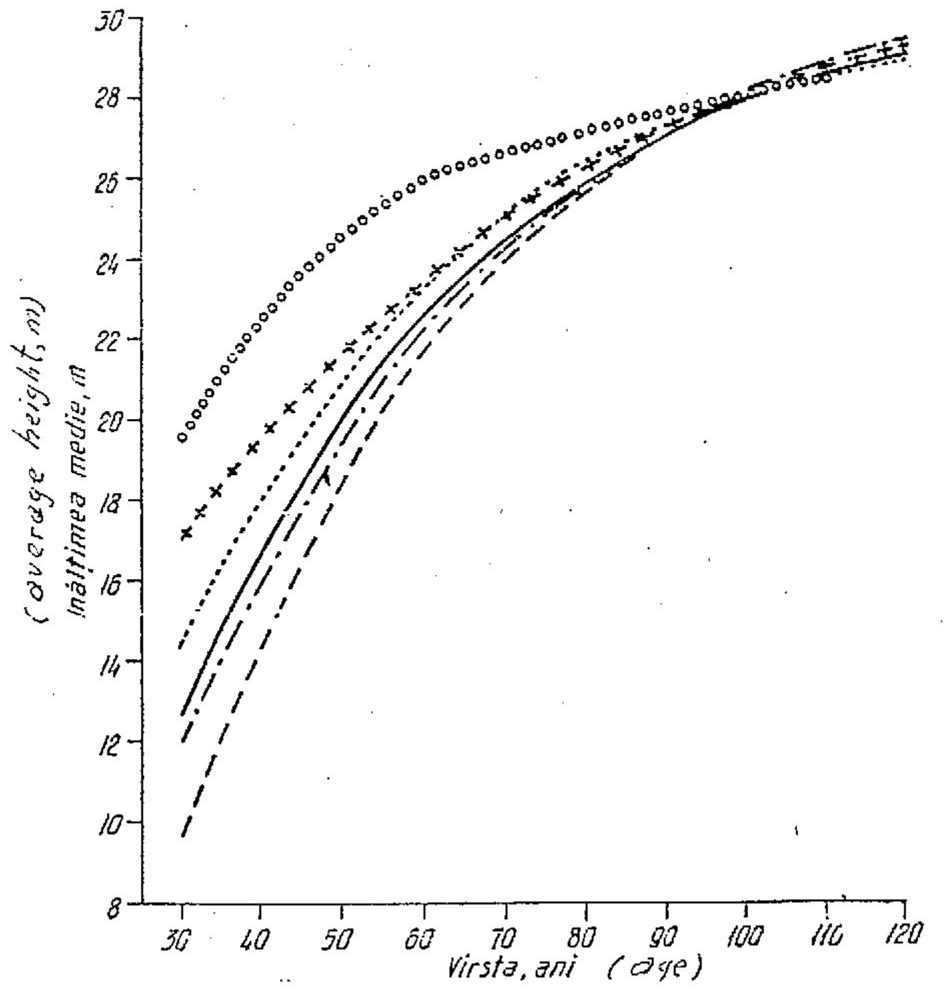


Fig. 8.8.-2. Variability with age of average height in spruce, fir, beech, sessile oak, hornbeam and lime stands in absolute productivity class 28 (H = 28 m at 100 years).

——— spruce – – – – fir –•–•–•– beech ……..sessile oak +++++ hornbeam ° ° ° ° lime

SOURCE: Stinghe and Toma 1958, Dendrometrie, p. 337, fig. 142. Ed. Agro-Silvică de Stat, Bucureşti.

Fig. 8.8.-2. shows how fast or slow the considered species are growing.

An absolute system of stand productivity is presented in section 8.12.

In 1953, Rucăreanu proposed the evaluation of stand productivity and site quality using the average height of the tallest trees:

Productivity class Tallest tree height (m)	I	II	III	IV	V
Fir, spruce	> 42	36-42	30-36	24-30	< 24
Beech	> 38	32-38	26-32	20-26	< 20

This idea belongs to Prodan (1949), from Germany.

In 1961 Giurgiu in "Clasa de productivitate" (Productivity class) noted that it is useful to obtain an indicator able to reflect for all species their potential productivity and considered as fitted for this purpose the total yield at the age of absolute maturity (exploitation). Next year (1962) he observed that there is a corellation between site quality and the percentage of high quality trees and viceversa.

Decei and Armăşescu (1977) recommended dominant height as an indicator of site quality and proposed for its determination the height measurement of the bigest trees ($\bar{d} + \bar{s}$, $\bar{d}$ = bigest tree mean diameter and $\bar{s}$ = standard deviation).

G r o u n d v e g e t a t i o n as an indicator of site quality was not used on a large scale in Romania. The Romanian botanists and foresters who used ground vegetation as indicator were influenced by the principles of Braun–Blanquet (1928, 1951) phytosociological school. In phytosociology the main units are associations and subassociations that could be compared with forest types. The association is determined depending on the presence and frequence of rare characteristical plants and can be used to the assessment of site conditions.

Among the Romanian authors with genuine phytosociological works should be mentioned: Guşuleac 1930, Borza 1938, Georgescu 1934, Paucă A. 1941, Morariu 1943 and 1944, Borza 1946, Beldie 1951, Borza and Boscaiu 1965.

Doina Ivan (1979) published in 1979 "Fitocenologia şi vegetația României" (Phytocenology and vegetation in Romania). The term "Phytocenology" is not identical with any western phytosociological school. The term was coined in the Soviet Union and should be considered as a symbol of separate school of geobotanic in which the vegetal association is not determined on the basis of characteristical rare plants but depending on edifing and dominant plants. Other works under phytosociological influence have been completed by Beldie 1941 (Wood vegetation in Bucegi Mountains), Beldie 1956 (The problem of relations between vegetation and site), Dihoru and Doniță 1970 (Flora and vegetation of

Babadag Plateau), Bândiu 1971 (Ecological factors and vegetation). A special work is indicator flora in Romanian forest, written by Beldie and Chiriță (1967).

Forest types for whose basic elements of delimitation are the tree species composition and their productivity, include site and offer a good indication of its quality. Presentation of a history of the Romanian forest typology is beyond the purpose of this book, and only the most important works will be mentioned. In Romania since the 1950s two schools tried to obtain supremacy: the school of forest typology (tree composition as determinant element) under the leadership of Sergiu Paşcovschi in cooperation with V. Leandru (1958) and site typology leaded by Constantin Chiriță et al. (1954, 1964, 1977). In 1957 during a conference on typology, the foresters tried to unify these schools without any success.

Paşcovschi's school represents an adaptation of Sukacev typological principles to Romanian conditions (Sukacev 1931, 1932, 1947) and on his turn Sukacev's typology has its roots in F. G. Morozov's advanced conception on forest (ed. IV 1928, ed. VII 1949) and stand types expressed in 1903-1904 and published later (1931), after his death due to of his pupil V. V Guman. Among the early works that are close to Morozov's and Sukacev's concept of stand type (later it was adopted the term: forest type) it should be mentioned those written by: Przemetchi 1921 (stand types as basis for silviculture), Przemetchi 1937 (Planting techique), Eliescu G. (About the theory of stand types), Georgescu 1941 (*Quercus cerris* stands as forest type), Georgescu and Constantinescu 1945 (Natural forest types in low and high plains of Oltenia province), Leandru and Mehedinți 1953 (Typological studies in experimental forest ranges Braşov, Câmpulung – Moldovenesc, Sinaia, Coşula, Feteşti).

Among Paşcovschi's studies it will be mentioned: 1945 (stand types in the forest "Casa Verde" (Green House)), 1951 (typology perspectives in Romania), 1954 (50 years of forest typology in Romania and U.S.S.R.), 1959 (in problem of relations between vegetation and site), and his outstanding synthesis (in cooperation with V. Leandru) on forest types in Romania (1958).

Chiriță considered the site and especially the soil as the most important element in his typology and classification of sites. Among the works of this school are mentioned Chiriță 1943 (limiting sites for sessile oak determined by soil factor), 1953 (a textbook on forest soil), Chiriță et al. 1954 (the natural forest type in Carpathians between Olt and Prahova rivers), Chiriță et al. 1964 (naturalistic and methodological fundaments of typology and site classification), Chiriță et al. 1977 (Forest sites). Because of the importance accorded to soil and ground vegetation Chiriță's sites typology was considered to be influenced by Pogrebniak' (1955 leader of Ukrainean typology) and in a way by phytosociological works (Beldie). It should be underlined that according to Pogrebniak and

Chiriță in a site type can be included two or a few forest types.

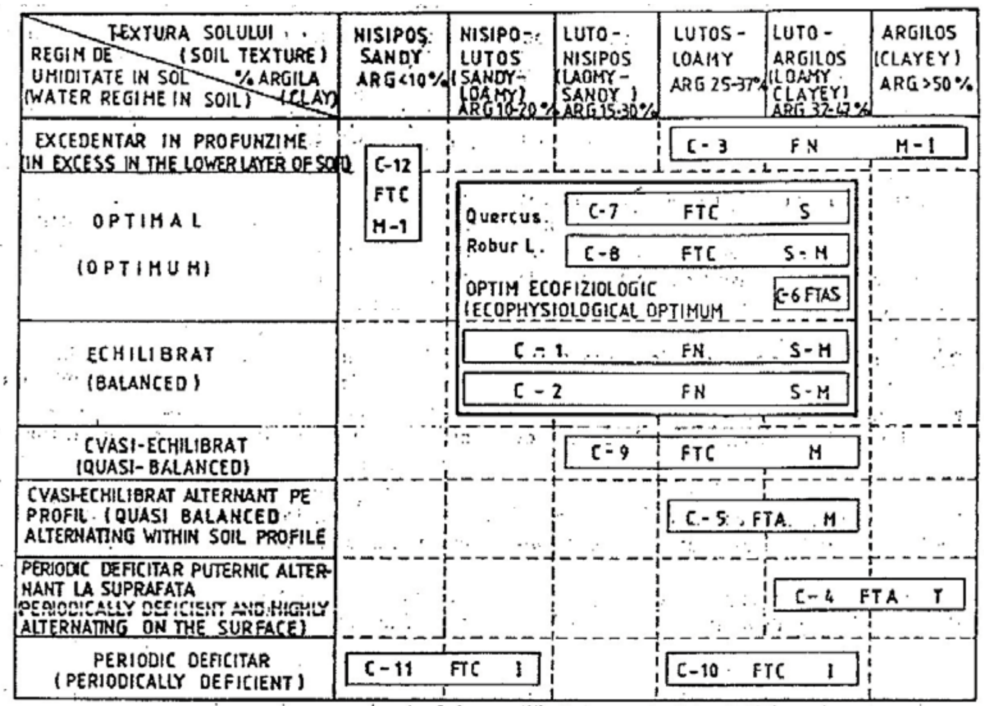
Forest ecosystem. New concepts such as forest ecosystem and forest biogeocenology (Sukaciov 1960, Sukaciov and Dîlis 1964, Whittaker 1972) influenced Romanian ecology and in 1990 Doniță, Chiriță, Stănescu (coordonators) and other authors published "Tipuri de ecosisteme forestiere din Romania" (Forest ecosystem types in Romania).

Doniță (1979) defined the forest ecosystem: "... as a model of a lot of real ecosystems, similar enough from the point of view of biocoenoses quality and biotops, having structural and functional characteristics qualitative distinct from that of other sets of ecosystems" (p. 26). The principles of forest ecosystem classification are based on the works of Chiriță et al. (1964), Stănescu (1981) and Doniță (1981 – not mentioned in his "selected bibliography"). In a ecosystem type are "included" forest vegetation (forest type) and site type (with the main characteristics of soil as humus type, water regime and others) – the productivity of forest trees is taken into account (four classes of productivity: high productivity (class I+II), medium productivity (class III), low productivity (class IV and V) and very low productivity (under class V). The name-diagnosis of an ecosystem include: predominant forest trees species composition, stand productivity class, humus type, soil(s) main type(s), soil hydric regim and ground vegetation type (dominant species).

A new ecophysiological concept "correspondence type" was introduced in Romanian literature by Alexe in 1995, in the case of *Quercus robur*. The correspondence type (C) between mineral nutrition (physiotype), environment and trees development represents a sort of "symbiosis" between physiotype and forest ecosystem (EF) that is defined by its diagnosis. In the frame of C diagnosis it is compulsory to display species name (S), the physiotype, the main characteristics of the environment and the nature of tree development (mainly growth or in the case of stands class productivity). The central aim of C concept is the development of similar silvicultural techniques for each C type or groups of C types.

The term physiotype was coined by Kinzel (Austria) in 1972, and defined as "the totality of physiological peculiarities common and characteristic of the individuals of given species, group of species, genus, family etc. in conditions of a given environment". The first physiotypes were described in Romania by Alexe in 1987 for *Quercus petraea* Liebl., and later for other oak species: Alexe-Aurelia Surdu-Monica Ionescu 1995 (*Q. robur*), Alexe and Aurelia Surdu 1996 (*Quercus pubescens* Willd. and C types), Alexe and Monica Ionescu 1997 (*Quercus pedunculiflora* and C types).

As an example it will be described the physiotypes and C types for *Quercus robur* L. and a scheme in which it is shown how the system is working (Fig. 8.8.-3.).



Poziția tipurilor de corespondențe C (fiziotip-mediu-dezvoltare) în raport cu regimul de umiditate şi Textura solului în stejarul pedunculat din România. (Position of correspondence types C (physiotype-environment-developement) in connection with water regime in soil and soil texture in the case of *Quercus robur* L. in Romania). Fiziotipuri (physiotypes): FN = normal, FTA = tolerant acid, FTC = tolerant la calciu (calcium tolerant). Dezvoltarea arborilor şi arboretelor (developement of tres and stands): I = inferioară (low), M = medie (medium), S = superioară (high).

Fig. 8.8.-3. Correspondence types C (physiotype – environment – development) in connection with water regime in soil and soil texture in the case of *Quercus robur* in Romania.
SOURCE: Alexe 1995, Revista Pădurilor 3, p. 16, fig. 1.

Quercus robur L. normal physiotype (FN): trees on well or medium supplied soils with mineral nutrients, pH (H_2O) 5.1-6.8 (7.2), calcium ions 1.000-2.000 (2.500) ppm DW, nitrogen nutrition based on both forms (species) ($N\text{-}NO_3$ and $N\text{-}NH_4$), nutrient utilization efficiency: high for Mg, low for N (16000-33000 ppm DW (dry weight) in the leaves), high content of Si in the leaves (>3.500 ppm DW); optimal to medium development of trees, sometimes low in the presence of limiting ecological factors such as drought, defoliators and MLO. Average leaves ratios: Ca/K = 0.9 N/S = 13, P/S = 0.8, Mn/Fe = 2. During the drought periods the trees are exposed to the defoliators because of the leaves higher nitrogen concentrations. Sites at 50-500 m altitude, 7-11.5 ^{0}C average annual temperature, 500-750 (800) mm annual precipitation.

Quercus robur L. acid tolerant physiotype (FTA): trees in the stands located within the whole forest zone of the country and confined to acidic soils (pH < 5.0 (5.3)); tolerant to Al^{3+} and Mn^{2+} in excess and reduced supply with N, Mg, Ca, B and Zn, during the period with water excess in soil; nitrogen nutrition based almost exclusively on N-NH4, high content of Mn in the leaves (750-1.530 ppm DW), average ratios in the leaves: 0.6 = Ca/K, 6 = N/S, P/S = 1, Mn/Fe = 5, high efficiency in nitrogen utilization, very sensitive to all kinds of stress (climatic, biologic, human); trees with low development except within the sites with short period of water excess in soil.

Quercus robur L. calcium tolerant physiotype (FTC): trees in the stands located especially in the river meadows within forest zone and afforested steppe 5 (100-300 (500) m altitude, 735-11°C average annual temperature, 380-700 mm annual precipitation; high excess of calcium in soil (>2.000 ppm DW), pH (6.5) 7-9, nitrogen nutrition almost exclusively based on N-NO_3, very efficient in the use of Mn, Fe and S; because of low level of Si in tissue the trees are more exposed to the defoliators; trees with optimal development on the river meadow sites but low in the Danube Delta and forest steppe plains; in the leaves: Mn = 15-120 ppm DW, average ratios: Ca/K = 0.6, N/S = 9, P/S = 1, Mn/Fe = 0.3.

The oak decline that is a very complex phenomenon could be also connected with wrong utilization of physiotypes. One of the major necessary factors for a normal mineral nutrition is the development of large crowns and a good root mycorrhized system (Alexe 1991).

Quercus robur L. correspondences (C).

C–1: *Quercus robur* L. (QR) mesophilic, ± thermophilic, normal physiotype FN with ± optimum-medium development of trees in the stands (DTS) located on the plain and plateau areas or low slopes within the forest zone of the southern part of Romania.

C–2: QR mesophilic, less thermophilic, FN with ± optimum-medium DST, located on the low slopes and plateau areas within the Moldavian and Transylvanian forest zone.

C–3: QR mesophilic, FN with medium-low DTS located on the old terraces without external drainage, with water excess in the lower part of the soil profile within the forest zone.

C–4: QR mesophilic, FTA, low DTS on soils with high acidity on the plateau areas and old terraces without drainage and on alluvial plains.

C–5: QR mesophilic, FTA, medium DTS on the soils with high acidity on the plateau areas and old terraces ± drained and alluvial plains with temporary water excess in soil.

C–6: QR hydrophilic, FTA, ± optimum DTS, on acid soils in not flooded meadows on the hilly forest zone.

C–7: QR hydrophilic, FTC, optimum DTS located in not or seldom flooded river meadows within the forest zone.

C–8: QR hydrophilic, FTC, medium-optimum DTS located on the periodically short time flooded river meadows within the forest and forested steppe zones.

C–9: QR mesophilic, FTC, medium DTS on not flooded or very rarely flooded river meadows in afferested steppe.

C–10: QR semixerophilic, FTC, low DTS, located on the plains and plateaus areas of afforested steppe.

C–11: QR mesophilic-semixerophilic, FTC, low DTS, located between sandy dunes.

C–12: QR hydrophilic, FTC, low DTS, located on sandy soils of Danube Delta.

In connection with the stands predisposition to the oak-decline phenomena, the following rankings, in the decreasing order, have been established for C types: C-4, C-5, C-3, C-12, C-10, C-11, C-1 and C-2 (stands with reduced canopy), C-1 and C-2 (stands with normal canopy). More than 6.000 analyses of soils and leaves were carried out for description of physiotypes and C types in case of the above mentioned oak species.

Cited authors:

Alexe 1987,1995; Alexe and Aurelia Surdu 1996 a, 1996 b; Alexe and Monica Ionescu 1997, Alexe et al. 1995, Bândiu 1971, Beldie 1941, 1951, 1952, 1956; Beldie and Chiriță 1967, Borza 1934, 1946; Borza and Boscaiu 1965, Braun-Blanquet 1928, 1951 (Germany), Chiriță 1943, 1953, 1982; Chiriță et al. 1954, 1964, 1977; Decei and Armăşescu 1977, Dihoru and Doniță 1970, Doniță et al. 1990, Eliescu 1939, Georgescu C. 1934, 1941, Georgescu and Constantinescu 1945, Giurgiu 1961, 1962; Guşuleac 1930, Ivan Doina 1979, Kinzel 1972 (Austria), Leandru and Mehedinți 1953, Morozov 1931, 1928, 1949, Morariu 1943, 1944; Paşcovschi 1945, 1951, 1954, 1956; Paşcovschi in colab. Leandru 1958, Paucă A. 1941, Pogrebneak 1955, Prodan 1949 (Germany), Przemetchi 1921, Przemetchi and Vasilescu 1937, Rucăreanu 1953, Stănescu V. 1981, Sukacev 1931, 1932, 1947, 1960; Sukacev and Dîlis 1964, Whittaker 1972 (U.K.), Lucrările Conferinței de Tipologie 1957.

8.9. Stand structure

During 50 years a lot of works were published on Romanian stand structure. These studies refer to vertical structure of a stand graphically exemplified by Fig. 8.9.-1. for mixed forest and 8.9.-2. for a virgin forest.

The early researches on the characteristics of irregular stands were performed by Gh. Predescu.

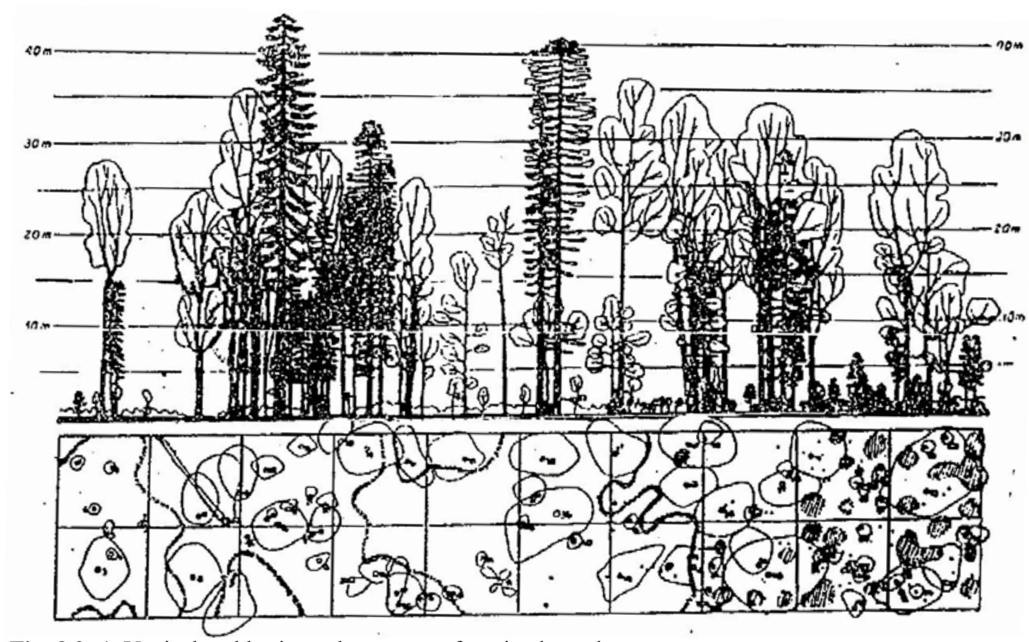


Fig. 8.9.-1. Vertical and horizontal structure of a mixed stand.
SOURCE: Leahu 1994, Dendrometrie, p. 116, fig. 5.2., Ed. Didactică şi Pedagogică, R.A., Bucureşti.

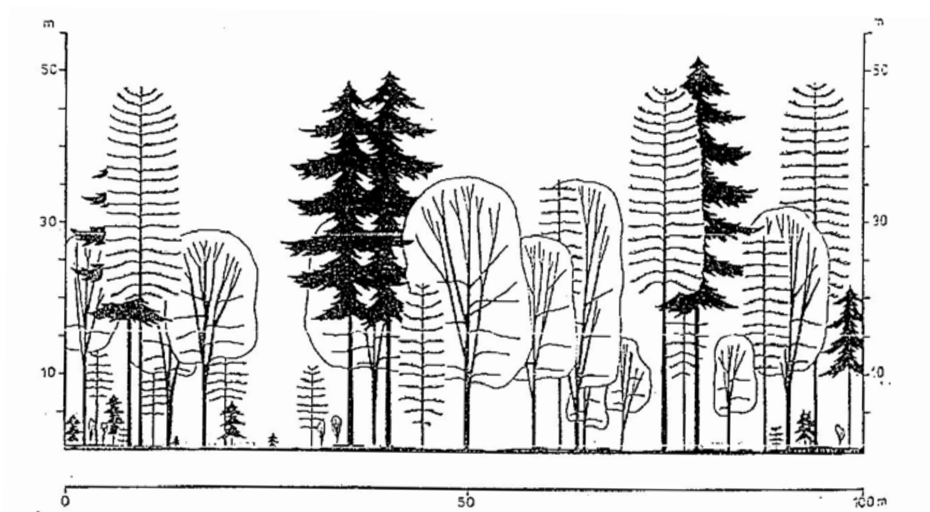


Fig. 8.9.-2. Profile drawing from the strict forest reserve Slatioara, Romania. The tree species composition consists of spruce, fir and beech (in: Schmidt-Vogt, 1991, Die Fichte, II/3, Parey Verlag, Hamburg-Berlin).

In 1958 Stinghe and Toma considered the existence in Romania of three types of stand structure: even-aged, uneven-aged and transition between the previous two structures.

According to the distribution of trees by diameter and height categories the three major types of stand structure are distinguished by Giurgiu (1979): even-aged stands, uneven-aged selection forest and uneven-aged and partly selection forest (Fig. 8.9.-3.).

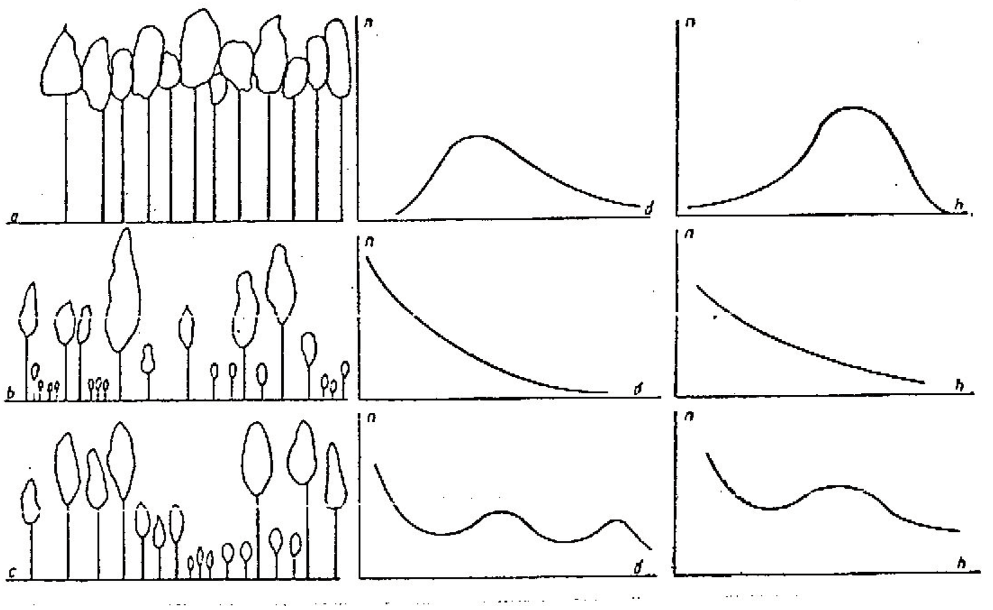


Fig. 8.9.-3. Schematic representation of stand structure: (a) even-aged, (b) uneven-aged selection forest, (c) uneven-aged and partly selection forest.
SOURCE: Giurgiu 1979, Dendrometrie şi auxologie forestieră, p. 172, fig. 4.11., Editura Ceres, Bucureşti.

Because the age is one of the most important characteristics of trees and stands it is useful to know the longevity of species. The following data on the tree longevity were given by Giurgiu (1979, p. 145) for some species growing in Romania (years) :

Norway spruce	400	Sycamore	600
Fir	400	Common oak	1500
Larch	500	Lime	800-1000
Scots pine	450	Elm	500
Yew	3000	Hornbeam	150
Beech	600-900	Black poplar	150

The stand structure is characterized by the following repartition of trees according to: age, diameter, height form, tree form (form factor), volume, tree growth, tree quality, crown dimensions, position of trees in the stand, distance between trees, and in the case of even-aged stands the mean values of: age, diameter, height tree volume (Giurgiu 1969, 1979, Leahu 1994). Other important structural characteristics are storey number, density expressed by indicators such as: crown density of the stand (consistență) defined as degree of canopy closeness, density index (“*indicele de densitate*”) which reflecs the capacity of a stand to contain a certain number of trees per unit area (usually hectars), coverage indexes (“*indicele de acoperire*”) which is a ratio between trees crown projection area of a stand and the area of this stand, density index (“*indicele de densitate*”) which is a ratio between the real volume of stand per unit area and volume considered as being normal for the given stand conditions whose value is given by yield tables, and, similarly, the index of basal area as ratio between stand basal area (per unit area of land) and the value of this indicator given by yield tables.

T. Dorin (1945) noted that the accuracy of forest inventories depends on the type of its structure.

Dissescu et al. (1957) established the relationship between diameters and height of trees in fir stands.

Giurgiu (1958) advocated for an analytical “taxație” (Russian term for forest mensuration) of Romanian forest. By “analytical forest mensuration” is understood a forest mensuration based on Tretyakov’s (1927) theory of “stands elements”. The stand element is defined by Tretyakov as one homogenous species and even-aged stand or a part of a mixed, multistorey or one uneven-aged stand formed by trees of the same species, located in the same storey and belonging to the same generation and grown in the same homogenous environmental (site) conditions. Stinghe and Toma (1958, p. 136) explained that in the case of one species even-aged, homogenous and with the uniform site characteristics, the term “element of stand” has the same meaning as the term “stand”. In a mixed stand with spruce and fir forming only one storey there are two stand elements: spruce, fir. In this case the term of stand element coincides with each of the two species. In a multistorey and one species stand, each storey represents a stand element. In uneven-aged stands with a few generations of trees. every generation of the trees represents a stand element. Giurgiu (1958) recommended that yield tables should be considered as yield tables of normal element stands. A separation of an uneven-aged spruce stand (three generations) in stand elements is shown in Figure 8.9.-4. and Table 8.9.-1.

Giurgiu discovered that in the regions of the curves interference (Fig. 8.9.-4.) stand elements can be identified after bark color, rhytidom structure, presence or absence of lichens on the stems, the angle between stem and basis of branches, form and density of crown.

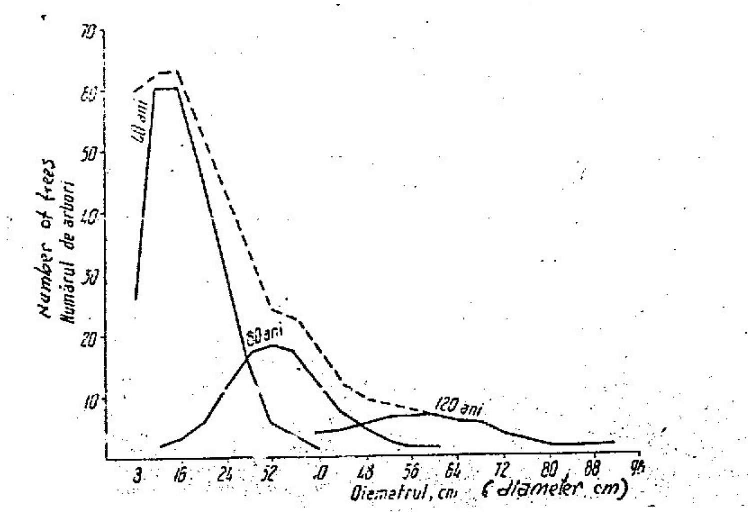


Fig. 8.9.-4. Separation of a multiaged spruce stand in three elements of stand, (even-aged) having 40, 80 and 120 years.
SOURCE: Original data from Giurgiu, cited by Stinghe and Toma 1958, Dendrometrie, p. 137, fig. 8.4., Editura Agro-Silvică de Stat, Bucureşti.

TABLE 8.9.-1. Separation of spruce multiaged stand in three even-aged stand elements

Stand element	Diameters category, cm																					
	8	12	16	20	24	28	32	36	40	44	48	52	56	60	64	68	72	76	80	84	88	92
Spruce	26	60	60	46	30	15	**5**	**3**	**1**													
40 yr.		2	3	6	12	17	**18**	**17**	**12**	7	4	2	1	1								
80 yr.							**1**	**2**	**4**	4	5	6	6	6	5	5	3	2	1	1	1	1
120 yr.																						
Total (trees)	26	62	63	52	42	32	24	22	17	11	9	8	7	7	5	5	3	2	1	1	1	1

The frame includes three generations of trees having 32-40 cm dbh.
SOURCE: Stinghe and Toma 1958, Dendrometria, p. 137, table 26, Editura Agro-Silvică de Stat Bucureşti.

The use of stand elements has been generalized in Romanian forest management since the 1960s. In practice a stand element is separated in a stand only if its volume is greater than 30 m^3/ha, otherwise it is included in the next closer element.

Stinghe and Toma (1958) accepted the hypothesis on Gaussian (normal) distribution of tree by diameter categories, but Giurgiu (1979, p. 158) demonstrated that the law of normal distribution is not suitable for characterization of stand structure in comparison with tree diameter distribution and has systematical deviation characterized by asymmetry and excess, and proposed and used Charlier tip A distribution in which the asymmetry and excess coefficients are taken into account.

In 1959, Costea C. published early data on fir and beech unevenaged stands (partly selection forest).

The first relationship between the horizontal projection of tree crown and diameter in a stand was established by Dissescu in 1960.

In the work of Milescu et al. (1960) there are presented unique height series (5-7 series for each species) which are independent of age. These series type (firstly proposed by Kräuter (1958 in Germany)) make possible, depending on average stand height and diameter, the determination of height of all diameter categories. Later it was adopted in practice a new type of height series which is analytically constructed based on the regression equations of height curves determined according the average stand height and diameter.

Armăşescu and Decei (1961) established the average stand diameter by counting trees from small to big, and this average diameter is located after counting 55 % of trees in case of oak, 58 % for spruce and 60 % for beech.

Popescu-Zeletin et al. (1961 a) investigated height variability in time and that of age in the case of big trees growing in natural uneven-aged stand and discovered a close correlation (r = 0.817) between the tree age and diameter.

During the 1960s a series of works on structure of uneven-aged stand has been completed. Costea C. (1962) published a monograph on selection forest, Popescu-Zeletin and R. Dissescu (1962) classified the uneven-aged stands after a system similar with that completed in 1949 by Prodan in Germany, and noted that in these type of stands there is a relative stability of the relation between diameters and heights. This stability represents the theoretical basis for construction of unique series of heights (Prodan 1949). Later (1965), Giurgiu developed unique series of heights using relative values.

In 1964, Popescu-Zeletin and R. Dissescu investigated the structure of virgin forest on the Penteleu Mountain (relation age-dbh) and constructed unique series of height and volumes for uneven-aged stands of spruce, fir and beech according to Prodan's (1949) model. In 1966 the same researchers established a classification of uneven-aged stands which are included in five types of trees distribution by diameter categories based on Mayer's (1933) equation $y=ke^{-\alpha x}$ where y = N = number of trees by diameter category and x = diameter category (Table 8.9.-2. and Figure 8.9.-5.).

In connection with this subject they also presented a paper at the XIV IUFRO Congress held in München in 1967 (vol. VI, section 25).

Ichim's (1968) researches on variability of tree form and repartition in a spruce stand by form factors and form quotient classes proved that the form factors variability is higher than that of the form quotients.

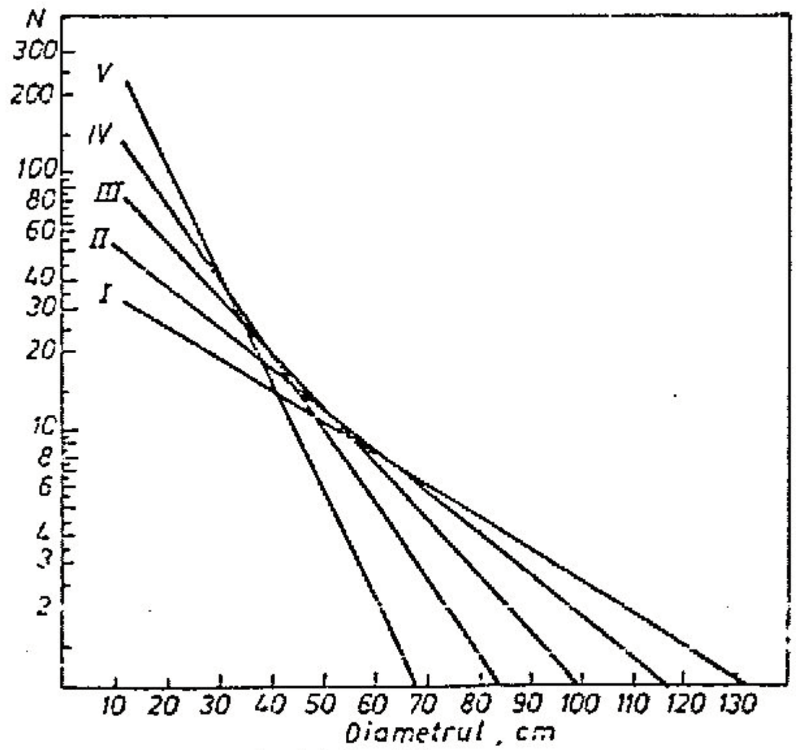


Fig. 8.9.-5. Frequencies curves of the number of trees (N) by diameter categories (d) for five types of structure, characterizing the natural uneven-aged stands in the Carpathian Mountains.
SOURCE: Ibid. Table 8.4.9.-2.: Popescu-Zeletin and Dissescu 1966. In Giurgiu's 1979 "Dendrometria şi Auxologia Forestieră", p. 169, fig. 4.10.

TABLE 8.9.-2. Coefficients of regression for equations of curves of frequencies for type $N=ke^{-\alpha x}$.

Tipul de structură (structure type)	k	α
I	43.4	0.0286
II	76.9	0.0373
III	144.2	0.0497
IV	294.8	0.0677
V	723.4	0.0968

SOURCE: I. Popescu-Zeletin and R. Dissescu 1966, "Caracterizarea şi clasificarea după structură a arboretelor pluriene din Carpaţii R.S.R.", Biletin Ştiinţific Academia R.S.R., no. 1. Reproduced after Giurgiu 1979, "Dendrometrie şi Auxologie Forestieră", p. 170, table 4.7., Editura Ceres.

In his "optimum ages for logging" Giurgiu (1962) noted the existence of a correlation between the site productivity and percentage of high quality trees and viceversa.

In Giurgiu's (1965) work "Algorithm for dendrometrical calculus" it will be noted the following contributions: (1) a proposal for a function which expresses the height curve (h) in dependence of average stand height (h_g) and average stand diameter (d_g):

$$h=[\ (b_0+b_1 d_g(\frac{d_g}{d}-1)+1]h_g$$

where d_g is the stand average diameter, h_g is the stand average height, d = diameter category and h = estimation of average height for a certain diameter category; (2) an unique series of the heights in relative values; (3) an equation of volume curve depending on dbh = d for respective category:

$$V = b_0 + b_1 d^2 + b_2 l^{-b_3\ d^2}$$

(4) a determined volume curves depending on dbh, stand average diameter and stand average volume and relative values of volumes by diameter categories in uneven-aged stands; (5) a frequency function of volumes which has the form of Charlier type A.

In a booklet of 1967 on the stands growth studies, Giurgiu concluded that in even-aged stands the position of the height curve (h/d) changes with the stand height and age (Fig. 8.9.-6.), but this phenomenon has been known in Germany since the 19th century, and later in the U.S.S.R.

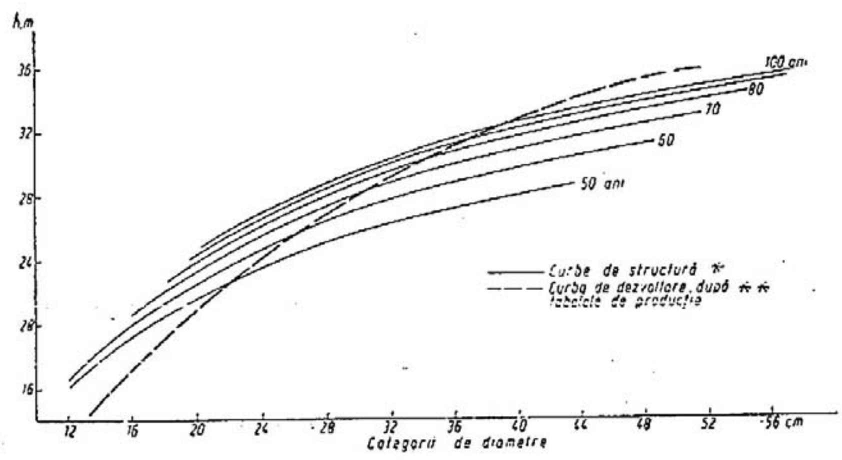


Fig. 8.9.-6. The shift with age of the height curves of spruce even aged stands of second site class.
* ——— structural curves   ** -------- the development curve from yield tables
SOURCE: Giurgiu 1979, "Dendrometrie şi auxologie forestieră" p. 187, fig. 4.17., Editura Ceres, Bucureşti.

On the other hand, in the same work Giurgiu established the following equation of crown diameter (d_{cr}) depending on tree height dbh

$$d_{cr} = \frac{1}{h}(b_0+b_1d)$$

and established also the connexion between crown length and tree height.

In order to transform the uneven-aged natural stands in selected forest, R. Dissescu (1968) constructed tables (important for practice) containing the number of trees and volume per unit area (hectare) for each of the five types of previously established structures.

Giurgiu (1968, 1969) proposed the use of Pearson type beta (ß(αγ) distribution for the determination of trees repartition by diameter categories and investigated in detail (Fig. 8.9.-7.) the variability of the index density (volume) from one to another plot within the same stand and noted that the normal distribution is specific in a homogenous stands only when the sample units (plots) are large enough (at least 0.03 ha); for 0.01 ha plots the distribution is of Pearson I type, while for 0.02 ha is of Charlier type.

In the case of even-aged and relatively even-aged stands Giurgiu (1969 c) recommended the use of Charlier distribution for characterization of tree distribution by diameter categories. For the normal even-aged highly productive spruce stands Giurgiu established the equations:

$$S = 1.1+0.20d_g,$$

$$\alpha_3 = 0.24+0.011d_g \quad \text{and}$$

$$\alpha_4 = 0.44-0.022d_g$$

where S = standard deviation, α_3 = simmetry index, α_4 = excess index and d_g = average diameter of the stand. It is possible to establish regression equations by species, between the average diameter of stand (d_g) and each parameter of Charlier frequency function. For trees distribution by height (h) Giurgiu adopted Charlier type A and proposed for spruce even-aged stand of high productivity the following mathematical model of structure:

$$\hat{n}_{\%} = \frac{200}{1.0+0.12\bar{h}}\left[f(u)+0.108f^{III}(u)+0.21f^{IV}(u)\right]$$

where $\hat{n}_{\%}$ = relative frequency in percentage by height categories from 2 in 2 meters, $\bar{h}$ = average height of stand f(u), f^{III}(u), f^{IV}(u) frequency function are of normal distribution and its derivative of III and IV degree. In this model it was taken into account: statistical relationship $S_h=1.0+1.13\bar{h}$ between standard deviation of heights in the stand (S_h), stand average height, values –0.65 for coefficient of asymmetry and 0.20 for the coefficient of excess.

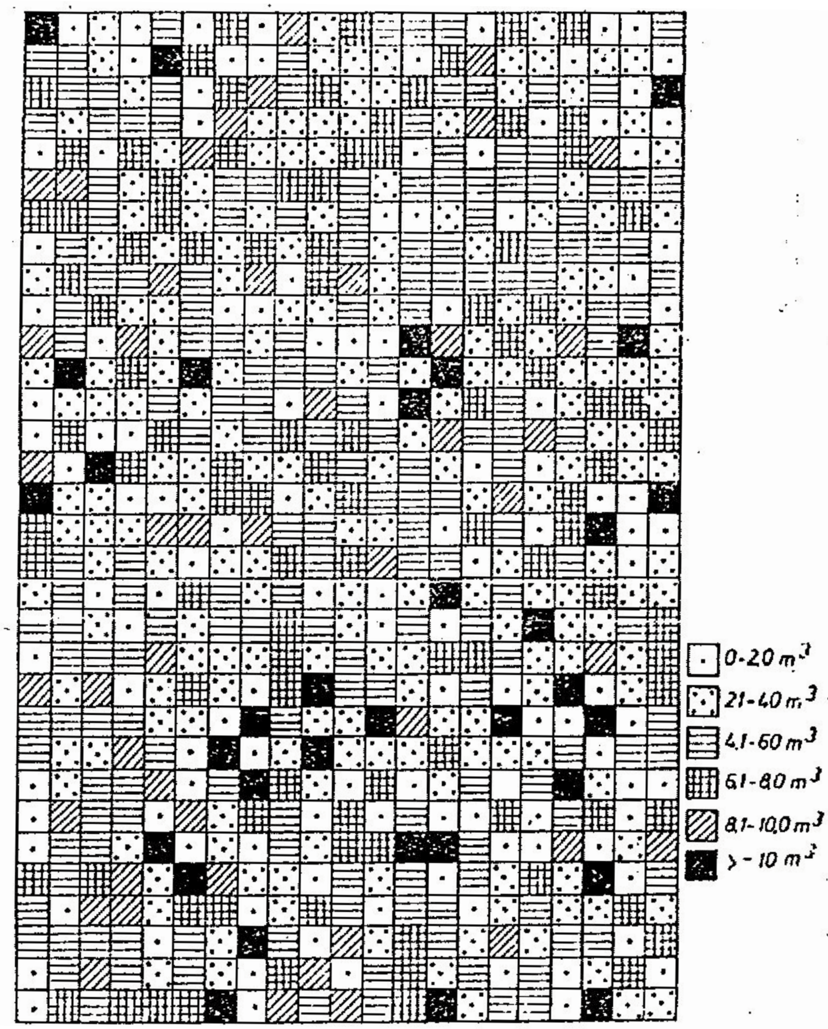


Fig. 8.9.-7. Chart of the lot (parcel) 61 Production Unit (UP) II, forest range Snagov (volume in m³ on the plots of 100 m²).
SOURCE: Giurgiu 1979, "Dendrometrie şi Auxologie Forestieră", p. 252, fig. 4.7.8, Ed. Ceres, Bucureşti.

Armăşescu (1971) in his doctoral thesis investigated the structural characteristics of the even-aged stands of the main forest species growing in Romania. The structure of unevenen-aged beech stands in the basin of the river Argeş was studied by Leahu (1971).

Information on structural characteristics of the stand are included in Giurgiu (1972 b) and Giurgiu-Armăşescu-Decei (1972) textbooks.

Leahu (1973) examined the structure of the uneven-aged stands in connexion with the system theory. The peculiarities of growth in uneven-aged stand were compared by Giurgiu (1974 b) with those of the even-aged stands. In this work Giurgiu proposed for height curve h(dbh) the equation

$$\log h = b_0 + b_1 \log d + b_2 \log^2 d,$$

d = dbh and included it in the elaborated programs for computers.

Considering the stand upper height ($h_{dom.}$) as an indicator of site productivity Decei and Armăşescu (1977) decided to determine this height ($h_{sup.}$), taking into account the bigest trees d +s respectively the mean of 8-12 height measured in the large diameter categories.

Leahu (1978) proposed new modalities for characterization of the uneven-aged stand structures and used (1978 b) simulation to establish the management influence on forest structure.

In connexion with windthrows Barbu (1979) noted the influence of spruce stand density on trees stability.

A large chapter on the stand structure, covering more than 100 pages (144-259), is included in Giurgiu's 1979 forest mensuration.

In 1981, Leahu presented a mathematical model of the stand structure. Armăşescu et al. (1982) analized the dynamics of even-aged spruce stand structure on permanent plots. Dissescu and Leahu (1982) developed new investigation on structure of beech stands growing in the Carpathian Mountains.

A method of establishing optimum structures based on the calculus of informational enegy was proposed in 1985 by Leahu who developed in the same year a deductive mathematical model for the optimization of stand structure.

Information on structure and stability of the spruce natural old high forest in the Giumalău Mountain were supplied in 1986 by Cenuşă.

In 1987 it was published Dissescu and Leahu's booklet on methods of modelling an optimum distribution of trees by diameter categories in connexion with forest protection functions, and Leahu's mathematical structure models of even-aged stands according to the trees height.

Between 1988 and 1992 Leahu published a set of works on the problems of stand structure such as: a mathematical mode of expression of connections between relative heights ($h_r = h/h_g$) and diameters ($d_r = d/h_g$) in the even-aged stands (1988), the practical value of mean tree in the stand structure knowledge (1989), modelling the dynamics of structure of the even-aged and relatively even-aged stands (1996a). Simulation of macrostructure of the spruce stands with resonant wood (wood for sounding-board) (1990b), the structure of the even-aged stands as effect of silvicultural and management activities (1990-1991), a simplified way to express the “laws” of the mixed stands (1992). In Leahu’s (1994) forest mensuration is included a special and interesting chapter on stand structure (pp. 111-214).

Iacob presented: (1) a procedure for the determination of unimodal distributions to be applied in forestry (1995 a); (2) the trees distribution in biogroups of natural mixed stands (1995 b), and (3) optimization of stand and forest structure by mathematical modern methods for the determination of the target composition of stands and the allowable cut of a given part of a forest (doctoral thesis).

Cited authors:

Alexe 1984-1986; Armăşescu 1971; Armăşescu and Decei 1961, Armăşescu et al. 1982, Barbu 1979, Cenuşă 1986, Costea C. 1959, 1962, Decei and Armăşescu 1977, R. Dissescu 1960, 1968; R. Dissescu and Leahu 1982, 1987; R. Dissescu et al. 1957, Dorin 1954, Giurgiu 1958, 1962, 1965, 1967, 1968, 1969 (c), 1972 (b), 1974 (b), 1979; Giurgiu-Decei-Armăşescu 1972, Iacob 1995 a, 1995 b, 1996; Ichim 1968, Krauter G. (Germany) 1958, Leahu 1971, 1973, 1978a, 1981, 1985a, 1985b, 1987, 1988, 1989, 1990a, 1990b, 1990-1991, 1992, 1994; Mayer 1933 (Switzerland), Milescu et al. 1960, Popescu-Zeletin and Dissescu 1962, 1964, 1966, 1967; Popescu-Zeletin et al. 1957, Popescu-Zeletin et al. 1961 a; Prodan 1949 (Germany), Seceleanu 1978 b, Stinghe and Toma 1958.

8.10. Stand volume determination and special height and volume tables

In 1915, according to Ioachim Popovici, in Romania a forest strip method was in use, the strips being in fact long plots. In 1927, 1930, 1941 Stinghe and Suburlan noted the following procedures used in Romania for the stand volume determination: plots of 2.000 m^2 (40x50 m), 2.500 m^2 (50x50 m), 5.000 m^2 (50x100 m) and in the case of selling, a detailed determination of volume was covering 10 % of the stand area while in working plans 1/20 or 1/30 of the area was inventoried using two entry volume tables (usually Bavarian) in that case was necessary the construction of height curve by diameter classes. Other methods were: the use of the stand average tree, the methods based on sample trees:Urich I and II, Draudt, and Hartig out of which Urich II was used on a large scale up to 1950s; quick techniques: Metzger, Weise, Gerding-Borggreve, the ocular estimations used by experienced wood dealers and the method of yield tables (usually German or Austrian). Some parts of this methods were mentioned in 1933 by I. Guran and in 1935 by G. T. Toma.

In 1953, V. Sabău used for the first time the curves of normal series of the form heights proposed in Germany by Laer (1938) and Lang (1938). The height series were established. The form height (fh) series were established according mean diameter and mean height of stands. Later in 1957 Popescu-Zeletin et al. included in their collection of tables the differences between heights by diameter categories of a given curve and those of normal height curve.

In 1955, Toma developed the first Romanian simplified yield tables based on the formula: $V = GHF$ in which V = stand volume per hectare, G = stand basal area and F = stand form factor of a normal stand with closed canopy (Table 8.10.-1.)

Toma's 1955 simplified yield table is one entry table having the average stand height as entry characteristics.

In 1969, Giurgiu (1969b) determined the height form of stands for the main species based on the relation: $V = Gh_gf_g$, h_gf_g = height form, G = stand basal area and because of a close relationship between h_g and f_g, h_g = height of average G tree and f_g is its form factor. Giurgiu used the equation $h_{fg} = b_0+b_1h_g+b_2h_g^2$ and the volume V became: $V = G(b_0+b_1h_g+b_2h\ )$. The b_0, b_1 and b_2 values were determined by Giurgiu in 1975 (Giurgiu 1979, p. 307) for the main 22 species but they are valid only for the stands with closed canopy.

In 1972, Giurgiu, Decei and Armăşescu published new simplified yield tables based on two functions of type: $V = f(h_g)$ and $G = f(h_g)$ where h_g is the height of the average tree of stand basal area G, that can be quickly determined using the Bitterlich relascope and h_g by a few measurements (Table 8.10.-2.)

In 1956, Ichim presented Bitterlich's method for measurement of stand basal area and trees characteristics.

Rucăreanu et al. (1957) investigated the accurancy of volume determination in uneven-aged stands using yield tabels. In 1958 Giurgiu introduced the "stand element" to be used in inventories of the uneven-aged stands (see 8.9.).

Stinghe and Toma (1958) mentioned in their "Dendrometria" that in the Soviet Union and Bulgaria volume tables are used in the form of volume series based not on the normal curve of heights, but on so-called "constant curve heights" and such tabels were constructed also by Giurgiu before 1958 when he was working at the Institute of Studies and Design in Silviculture (I.S.P.F.). The constant curve height is obtained by dividing the area of heights (depending on diameter of all trees of a species used for volume tables) into a certain number of strips of equal width and the curves that delimited these strips are numbered from 1 to n and are named constant heights.

TABLE 8.10.-1. The first Romanian simplified yield tables constructed in 1955 by G.T. TOMA

H	Molid (1)		Brad (2)		Fag (3)		Mesteacăn (4)		Stejar (5)		Cer (6)		Carpen (7)		Tei (8)		Salcâm (9)		H
	G	V	G	V	G	V	G	V	G	V	G	V	G	V	G	V	G	V	
6	26.2	86	19.9	76	12.1	45	7.8	27	10.3	40	11.3	47	7.1	38	13.7	62	6.2	28	6
8	28.2	130	24.8	120	15.8	76	11.3	47	13.1	65	13.8	66	11.5	62	16.3	84	8.9	42	8
10	30.8	176	28.9	170	18.9	109	14.5	73	16.1	95	16.3	88	14.5	86	19.0	114	11.0	60	10
12	33.1	224	32.8	224	22.3	147	17.7	99	18.6	128	18.8	117	16.9	116	21.6	148	13.3	80	12
14	36.4	274	36.4	284	24.7	189	20.9	131	21.2	168	21.4	149	19.0	149	24.3	187	16.0	107	14
16	39.0	330	39.8	344	27.2	231	23.8	168	23.5	211	23.9	183	20.8	183	26.9	235	18.8	142	16
18	41.6	388	42.7	404	29.6	276	26.5	207	25.8	258	26.4	222	22.3	218	29.5	286	21.5	180	18
20	43.9	446	45.3	464	32.0	321	29.0	250	28.1	309	28.9	266	23.6	252	32.1	338	23.9	218	20
22	46.1	505	47.8	524	33.6	369	31.3	292	31.0	370	31.4	318	24.4	289	34.7	393	26.0	257	22
24	48.8	567	50.2	590	34.9	416	33.2	332	34.0	435	33.9	373	25.4	325	37.3	452	28.1	295	24
26	52.0	635	52.8	660	37.0	477	-	-	37.0	502	36.5	435	26.2	360	39.8	521	30.0	336	26
28	54.7	704	55.3	734	39.6	554	-	-	40.0	568	39.0	500	26.8	394	42.4	287	31.5	378	28
30	57.0	771	57.7	814	42.0	629	-	-	42.7	636	-	-	27.4	429	-	-	32.5	421	30
32	59.2	840	59.9	893	44.0	708	-	-	45.5	708	-	-	-	-	-	-	-	-	32
34	62.0	908	62.1	973	46.5	789	-	-	49.0	790	-	-	-	-	-	-	-	-	34
36	63.7	977	-	-	48.8	872	-	-	52.6	872	-	-	-	-	-	-	-	-	36
38	66.0	1053	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38

H=height in m, (1) spruce, (2), fir, (3)=beech, (4)=birch, (5)=oak, (6)=Turkey oak, (7)=hornbeam, (8)=lime, (9) black locust.
G=basal area m^2 /ha, V=volume m^3/ha
SOURCE : Toma 1955, Revista Pădurilor 1955, p.321, "Tabelă de producție simplificată".

TABLE 8.10.-2. Giurgiu – Decei – Armăşescu's 1972 simplified yield table (extract).

Înălțimea medie, m (average height)	Molid (1)		Brad (2)		Fag (3)		Gorun (4)		Stejar (5)	
	G	V	G	V	G	V	G	V	G	V
16	38.6	316	37.5	323	26.4	220	22.9	211	23.7	214
17	40.1	346	38.9	353	27.4	241	24.3	234	24.8	237
18	41.5	377	40.3	384	28.4	263	25.6	258	26.0	261
19	42.9	408	41.7	415	29.4	286	26.9	284	27.2	286
20	44.3	439	43.1	447	30.4	309	28.2	311	28.5	313
21	45.7	470	44.5	479	31.4	333	29.5	339	29.8	341
22	47.0	501	46.0	512	32.4	358	30.8	368	31.2	371
23	48.2	533	47.5	545	33.3	384	32.1	398	32.6	402
24	49.4	565	49.0	579	34.2	411	33.4	429	34.0	434
25	50.6	597	50.5	613	35.2	439	34.7	461	35.5	467
26	51.3	630	52.0	648	36.1	468	36.0	493	37.0	501
28	54.2	694	55.0	718	38.0	529	38.6	561	40.2	573
29	55.3	726	56.5	753	39.9	561	39.9	596	41.8	612
30	56.3	753	58.0	789	40.9	594	41.2	631	43.5	652

G = basal area, m^2 /ha, V = volume m^3 /ha.
(1) = spruce, (2) = fir, (3) = beech, (4) = sessile oak, (5) = oak
SOURCE: Giurgiu, Decei, Armăşescu 1972 "Biometria arborilor şi arboretelor din România", Ed Ceres, Bucureşti. Reproduced after Giurgiu 1979, "Dendrometrie şi auxologie forestieră", p. 307, table 5.26., Ed. Ceres, Bucureşti.

Based on the series of constant height were developed tables with volume series. Every volume series represents a volume table which is given only according the diameter value being in fact a tariff. These tariffs were constructed on the basis of general double entry volume tables. Another type of tables constructed by I.S.P.F represent a single series developed for multiple volume according the number of trees (1…9). In order to use such tables for the stand volume determination it is necessary to determine its average diameter and height that are entry variables for the number of constant height trees that is the same with the number of volume series. Stinghe and Toma (1958) underlined that the volume tariffs based on constant height curves may be applied only in the mature stands. The volume series tables were constructed for the main Romanian species (Milescu et al. 1960) and used in practice between 1958 and 1965 and replaced in 1965 by the new volume series tables in which it was taken into account the influence of aver-age diameter of the stand.

Based on Prodan's (1949) work, Popescu-Zeletin and Dissescu (1962 b) used the same method and constructed the volume series for five productivity classes of uneven-aged stands of spruce, fir and beech.

In 1965, Giurgiu constructed "new modern" tables of volume series based on following equations:

(1) for diameters (d) under the stand average diameter (d_g):
For even-aged stands :

$$v = \left[-0.162 + 1.162\left(\frac{d}{d_g}\right) + 0.186e^{-4.89\left(\frac{d}{d_g}\right)^2} \right] v_g$$

(2) for diameters equal or greater than stand average diameter :

$$v = \left\{ 1.451 - 0.0167 d_g + 0.000133 d_g^2 \left[\left(\frac{d}{d_e}\right)^2 - 1 \right] + 1 \right\} v_g$$

For uneven-aged stands:

$$v = (b_0+b_1d+b_2d^2+ \text{-----} +b_7d^7)\ v_{50}$$

where d = dbh in cm

d_g = average diameter of stand basal area or central diameter of stand basal area

v_g = volume of the average of stand basal area determined depending on dg and h_g

v_{50} = average volume of the trees that belong to diameter category of 50 cm, determined depending on h_{50} (height of diameter category 50 cm).

V_g and v_{50} are obtained from equations:

$$V_g = b_0+b_1 \log d_g+b_2 \log^2 d_g+b_3 \log h_g+b_4 \log^2 h_g$$

$$V_{50} = b_0+b_1 \log {}_{50}+b_2 \log^2 50+b_3 \log h_{50}+b_4 \log^2 h_{50}$$

For the even-aged stands have been established 12 classes for V_g resulting 50 volume series for each diameter class, in total 600 volume series. In Table 8.10.-3. is given an example of new volume series for even-aged stands. The number of volume series is given in other special tables.

Today this tabelar technique represents in our opinion no more than a waste of time but it seems that the German influence of Laer (1938) and Lang (1938) accepted also in Bulgaria and Soviet Union could not be overtaken.

All the new volume series tables have been included in Giurgiu-Decei-Armăşescu's (1972) collection of tables for forest mensuration. Researches on the volume determination were carried out also by Leahu (1973) in the superior basin of the Argeş river.

TABLE 8.10.-3. Volume series for even-aged stands (extract). Average diameters: 27; 28; 29; 30 cm (diameter class VII).

d	Numărul seriei de volume (The number of volume series)									
cm	31	32	33	34	35	36	37	38	39	40
(dbh)	Volumul în metri cubi (Volume in m^3)									
8	0.040	0.041	0.042	0.043	0.044	0.044	0.045	0.046	0.047	0.049
12	0.088	0.090	0.092	0.094	0.096	0.098	0.100	0.102	0.104	0.108
16	0.176	0.180	0.184	0.189	0.193	0.197	0.201	0.205	0.209	0.216
20	0.308	0.315	0.323	0.330	0.337	0.344	0.352	0.359	0.366	0.377
24	0.481	0.493	0.504	0.515	0.527	0.538	0.549	0.561	0.572	0.589
28	0.691	0.707	0.723	0.739	0.756	0.772	0.788	0.804	0.821	0.846
32	0.920	0.942	0.964	0.986	1.007	1.092	1.051	1.072	1.094	1.128

SOURCE: Giurgiu et al. 1972, “Biometria arborilor şi arboretelor din Romania”, Ed. Ceres, Bucureşti. Reproduced after Giurgiu, 1979, “Dendrometrie şi auxologie forestieră”, Ed. Ceres, Bucureşti, p. 300, table 5.18.

Stand volume determination is discussed in Giurgiu’s work on statistical inventory of forest stand (1968), and in the following forest mensuration text-books: Stinghe and Toma 1958 (pp. 119-244), Giurgiu 1979 (pp. 260-318), Leahu 1994 (pp. 252-264) and Alexe Alexe’s 1983 monograph on “Forest inventory”.

Cited authors:

Alexe 1983, Giurgiu 1958, 1965, 1968, 1969 b, 1979; Giurgiu-Decei-Armăşescu 1972, Guran 1933, Ichim 1956, Laer 1938 (Germany), Lang 1938 (Germany), Leahu 1973, 1994; Milescu et al. 1960, Popescu-Zeletin and Dissescu 1962 b, Popescu-Zeletin, Toma et al.1957, Popovici Ioachim 1915, Prodan 1949 (Germany), Rucăreanu et al. 1957, Sabău 1953, Stinghe and Suburlan 1927, 1930, 1941, 1958; Toma 1935, 1955.

8.11 Stand growth and yield

Early references on the stand growth are mentioned in “Agenda forestieră” (Stinghe and Suburlan 1927, 1930, 1941). Information refer to different procedures on stand growth determination, the most simple being considered the use of yield tables used (then) in the country (German yield tables); another procedure was the use of two successive stand inventories (for determination of basal area and diameter growth, height and form factor supposed to remain unchanged). On more restricted areas was used the growth percentage formula (old Pressler formula) with samples obtained with a borer.

In 1951, Toma proposed the determination of volume and its growth using general volume tables. Toma et al. (1952) developed researches on the growth and productivity of black locust, hornbeam, lime, and Rucăreanu et al. (1954) investigated growth of different oak species (*Q. robur, Q. petraea, Q. frainetto* and *Q. cerris*). The above mentioned works represented the bases for the first Romanian yield tables included in Popescu-Zeletin et al. (1957) collection of dendrometrical tables. An example of comparative curves of stand current increment of volume according the first Romanian yield table is presented in Figure 8.11.-1. and Table 8.11.-1.

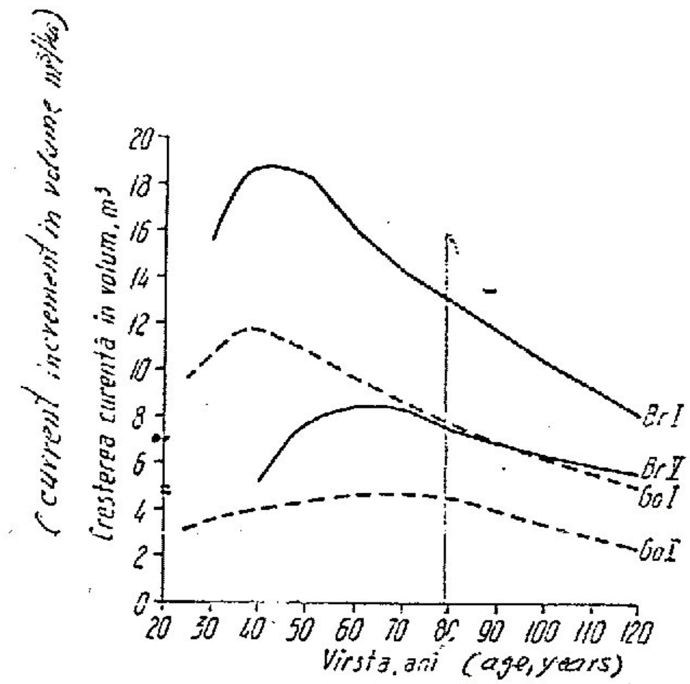


Fig. 8.11.-1. Variability with age of the current increment in volume of fir and sessile oak in the site classes I and V. Br=fir, Go=sessile oak, I,V = site classes
SOURCE: Popescu-Zeletin et al. 1957, "Tabele dendrometrice", Ed. Agrosilvică de Stat, Bucureşti. Reprinted after Stinghe and Toma 1958 " Dendrometrie", p. 347, fig. 151, Ed. Agro-Silvică de Stat.

In 1955/1956, Giurgiu proposed a procedure for the stand volume growth determination using average height form.

In the Romanian forest literature were described methods of the stand increment determination using samples taken with Pressler's borer by diameter categories: Giurgiu (1955/1956) for even-aged stands and Toma (1957) for uneven-aged stands. These methods are practically the same with the stand table projection method, an old technique practiced in Europe and even in the U.S.A (first decade of the 20th century).

TABLE 8.11.-1. Maximum value of current increment for different species and site classes, and the cor responding age (in brackets) after the first Romanian yield tables (1957 collection)

Specia (species)	Valoarea maximă a creşterii curente în volum în m³/ha şi vârsta corespunzătoare în ani la clasele de producție (Maximum value of current increment in volume in m³/ha and the corresponding age in years by site classes)				
	I	**II**	**III**	**IV**	**V**
Molid (spruce)	18.5 (35)	15.5 (40)	12.6 (45)	9.5 (50)	7.0 (60)
Brad (fir)	18.9 (45)	16.4 (45)	13.4 (50)	10.8 (55)	8.6 (65)
Fag (beech)	13.8 (45)	11.2 (45)	8.8 (50)	7.3 (55)	5.8 (60)
Gorun (sessile oak)	11.7 (40)	9.2 (50)	7.6 (60)	6.0 (65-70)	4.7 (70-75)
Stejar (oak)	13.8 (40)	11.4 (45-50)	9.3 (60)	7.4 (60)	5.7 (65-70)
Carpen (hornbeam)	11.1 (20)	9.6 (25)	8.2 (35)	6.9 (40-45)	5.7 (50)
Tei (lime)	15.1 (25)	12.5 (25)	10.1 (30)	8.4 (25-40)	7.4 (45)

SOURCE: Ibid. Fig. 8.11-1. Original Popescu-Zeletin et al. 1957. Reprinted after Stinghe and Toma 1958, p. 347, table 101.

In 1957, L. Petrescu proposed the use of dominant height in Romanian forest mensuration.

In 1962, Popescu-Zeletin and R. Dissescu developed a method for the determination of volume increment in uneven-aged stands of fir, spruce and beech.

In a monograph on Scots pine, Alexe (1964) published data on stand growth by forest types – the first work of this kind carried out in Romania.

A new set of researches on growth and yield, as bases for the new yield tables, began in 1965 and in this category should be included the investigations carried out by Armăşescu et al. 1965 a (spruce), 1965 b (fir), 1965 c, 1967 (beech), 1969 (black locust) and Decei 1966 (willow).

In the 1960s, Armăşescu developed researches on the oak stands affected by decline and included them in Marcu's monograph on oak decline (1966). Armăşescu and Marcu (1966) analyzed the diameter, height and volume increment in the following forests: Barboşi (Snagov), Lucieni (Găeşti), Reşca (Caracal), Doineagul (Drăgaşani) and found an evident decreasing of the tree ring radial growth rhythm in the last 15-16 years, previous the decline beginning (dieback). In some forests the decline phenomenon began some 25-30 years ago and afterwards evolved slowly and gradually. The study of the sections at the base of trees reveled the existence of double rings.

A investigations synthesis on the stand growth was published by Giurgiu in 1967. In the same year T. Popovici et al. (1967) exposed the premises for determination of stand volume increment by the methods based on tariff differences.

Leahu (1969) determined the volume current increment in uneven-aged stands located in the superior basin of the Argeş river by methods of growth coefficients.

A study on the growth of the Euramerican poplars cultivated in Romania was published by Giurgiu in 1970.

Armăşescu (1971) analyzed the growth characteristics of mixed stands and presented the comparison of growth, yield and structure of even and uneven-aged stands of the main forest species growing in Romania (doctoral thesis).

In his contribution to the setting up the Canadian poplar planting spacing on the inland river meadows, Marcu (1971) investigated one of the most controversial problem of poplar growing: planting density. He experienced the following planting spacing: 2x2 m, 3x2 m, 3x3 m, 4x2 m, 4x4 m, 5x5 m, 6x6 m, 7x7 m and 8x8 m. The preliminary result (after 5 and 6 years) indicated the best densities of plantations 7x7 m, 6x6 m and 8x8 m

The biometrics relationships in a stand necessary for computerized calculus (determination of average diameter, average height, productivity (site) class and stand volume) are presented by Giurgiu in 1973 (a, b).

Giurgiu (1974 b) compared the growth peculiarities of uneven-aged and even-aged stands and discovered a very close relationship (R = 0.826) between the tree age (t) and its height (h): $t = b_1h$.

In 1977, Armăşescu et al. developed researches on structural dynamics and growth of spruce and fir stands depending on site conditions and different types of thinning, and in 1982 investigated the permanent plots in order to obtain new data on structure and yield dynamics of the even-aged stands. In 1983, Marcu et al. developed new researches on yield sessile plantations outside their natural area of growing.

In 1984, Leahu and Dissescu developed a mathematical model for radial and volume growth for mixed stands.

Giurgiu et al. presented in 1989 the biometrical bases for tending and thinning of stands.

Cited authors:

Alexe 1964, Armăşescu 1971 a, 1971 b; Armăşescu et al. 1965a, 1965b, 1965c, (1967), 1969, 1977, 1988; Decei 1966, Giurgiu 1955-1956, 1967, 1970, 1973a, 1973b, 1974, 1989; Leahu 1968, 1969, 1984, Marcu 1971, Marcu et al. 1966, 1983; Petrescu L. 1957, Popescu-Zeletin et al. 1957, Popescu-Zeletin and R. Dissescu 1962 b, Popovici Traian et al. 1967, Rucăreanu et al. 1954, Toma 1951, 1957; Toma et al. 1952.

8.12. Yield tables

Before 1950 in Romanian forestry there were used German (Schwappach 1902, 1905, 1908, 1911, 1912; Eichhorn 1902) and Austrian (Feistmantel) yield tables (Stinghe and Suburlan 1927, 1930, 1941) and the local yield tables constructed by the foresters in charge with U.D.R (Uzinele Domeniului Reşiţa: Forest Property of Iron Factory Reşita).

The first set of Romanian yield tables was constructed between 1951 and 1955 and included in the collection of forest tables by Popescu-Zeletin et al., published in 1957, a monumental work that was highly appreciated both in the country and abroad. For the first set of yield tables it was applied the Baur's graphical method slightly modified. Data were collected from temporary plots, height measured with the Blume-Leiss hypsometer, the average diameter was determined using stand basal area (per hectare) and divided by the number of trees, a h-d curve was constructed and the volume determined using general volume tables (constructed previously for main species). Current increment of volume (for five years period) was determined by Fekete's (1951) procedure which consider the height diameter curve as constant after five years from the first measurement but what is valid only in mature stands and in case of young stand produced an error of 15-20 %. This aspect was largely discussed in Romanian forestry literature of 1957 year (Giurgiu 1957, Toma 1957, Rucăreanu 1957). Among the yield tables of the first generation it will be mentioned that constructed for beech – the main species in Romanian forest – by Sorin Armăşescu in 1954.

Romanian yield tables contains equal equidistant five classes and for each species two entry characteristics: age and stand average height, the tables refer to even-aged stands with closed canopy and represent the so-called "normal situation". An example of the first generation yield tables is given in Table 8.12.-1. which refer to Norway spruce and was constructed by Armăşescu.

TABLE 8.12.-1. Norway spruce: first generation yield table, Romania 1954 (1957)

Vîrsta ani	Arboret principal										arboret secundar			Arboret total					
	H m	D cm	N buc	G m^2	F 0,…	Volumul M: M_1 d>14 m^3	Volumul M: M_2 d<14 m^3	Volumul M: M m^3	Creştere anuală: curent m^3	Creştere anuală: medie m^3	N buc	M m^3	ΣM m^3	M+ΣM m^3	$\frac{\Sigma M .100}{M+\Sigma M}$ %	Creştere anuală: curentă m^3	Creştere anuală: curentă %	Creştere anuală: medie m^3	vîrstă ani
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Casa I de producţie																			
25	15.0	12.2	3097	36.2	540	12	281	293	-	11.7	-	3	3	296	1.0	17.5	8.4	11.8	25
30	18.1	15.0	2282	40.3	522	168	213	381	17.4	12.7	815	4	7	388	1.8	18.3	6.2	12.9	30
35	20.9	17.8	1760	43.8	510	327	140	467	-	13.3	522	7	14	481	2.9	18.5	4.9	13.7	35
40	23.5	20.6	1404	46.8	498	460	88	548	15.7	13.7	356	10	24	572	4.2	18.2	3.9	14.3	40
45	25.8	23.4	1153	49.6	488	562	62	624	-	13.8	251	13	37	661	5.6	17.8	3.2	14.7	45
50	27.8	26.1	972	52.0	480	638	56	694	13.3	13.9	181	17	54	718	7.2	17.3	2.8	15.0	50
55	29.6	28.6	842	54.1	473	712	45	757	-	13.8	130	21	75	832	9.0	16.7	2.1	15.1	55
60	31.0	30.6	760	55.9	466	768	40	808	8.8	13.5	82	29	104	912	11.4	15.9	2.1	15.2	60
65	32.1	32.3	698	57.2	460	808	37	845	-	13.0	62	39	143	988	14.5	15.2	1.9	15.2	65
70	33.0	33.6	656	58.2	456	842	34	876	5.9	12.5	42	42	185	1061	17.4	14.6	1.7	15.2	70
75	33.8	34.9	649	59.2	452	874	30	904	-	12.1	37	42	227	1131	20.1	11.0	1.6	15.1	75
80	34.6	36.1	586	60.0	448	902	28	930	4.8	11.6	33	42	269	1199	22.4	13.5	1.5	15.0	80
Clasa a II-a de producţie																			
25	12.3	10.8	3711	34.0	517	3	226	229	-	9.2	-	1	1	229	0.4	11.5	9.2	9.2	25
30	15.0	13.1	2790	37.6	531	31	268	299	14.0	10.0	921	1	5	304	1.6	11.9	6.5	10.1	30
35	17.4	15.5	2172	41.0	517	183	186	369	-	10.5	618	7	12	381	3.1	15.3	5.4	10.9	35
40	19.6	17.8	1776	44.2	501	307	134	438	13.4	10.9	396	9	24	459	4.6	15.5	1.2	11.5	40
45	21.6	20.0	1490	46.8	498	413	90	503	-	11.2	286	12	33	536	6.2	15.3	3.5	11.9	45
50	23.4	22.1	1280	49.1	490	489	74	563	11.3	11.3	213	15	48	611	7.9	15.0	3.0	12.2	50
55	25.0	24.1	1109	51.0	488	555	61	616	-	11.2	171	20	68	684	9.9	14.6	2.6	12.1	55
60	26.3	26.0	991	52.6	477	607	53	660	8.0	11.0	118	27	95	755	12.6	14.2	2.3	12.6	60
65	27.4	27.6	901	53.9	471	649	47	696	-	10.7	90	33	128	824	15.5	13.7	2.1	12.6	65
70	28.2	28.8	843	54.9	468	681	43	725	5.5	10.3	58	37	165	890	18.5	13.2	1.9	12.7	70
75	28.9	29.8	800	55.8	466	711	40	751	-	10.0	43	38	203	954	21.3	12.7	1.8	12.7	75
80	29.6	30.8	760	56.6	463	737	39	776	1.9	9.7	40	36	239	1015	23.5	12.2	1.6	12.7	80

1=Age, years; 2=average height; 3=average diameter; 4=number of trees/ha; 5=basal area; 6=form factor; 7-9=volume; 10=current growth; 11=maen growth; 2-11 stand which remains; 12-14 extracted trees; 12=number; 13=volume; 14=cumulated volume; 15-20=whole stand; 17-19 annual growth; 17=current ; 18=current in %, mean (19).

SOURCE: Armăşescu, S. 1954, in I. Popescu-Zeletin et al. 1957, "Tabele dendrometrice", Ed. Agro-Silvică de Stat, Bucureşti. Reproduced after Stinghe and Toma 1958, Dendrometrie, p. 235, table 69, Ed. Agro-Silvică de Stat, Bucureşti.

In Romanian yield tables there are the following functional relations:

$$\overline{G} = 0.785\,\overline{D^2}\;\overline{N}$$

$$\overline{N} = 1.274\,\frac{\overline{G}}{\overline{D^2}}$$

$$\overline{V} = \overline{G}\,\overline{HF}$$

$$I_m = \frac{\overline{V}}{T}$$

$$I_c = \frac{\overline{V}_2 - \overline{V}_1}{n}$$

$$I'_m = \frac{\overline{V} + \sum V'}{T} \qquad \text{total mean increment}$$

$$I'_c = \frac{\overline{V}_2 - \overline{V}_1}{n} + \frac{\overline{V}'}{n}$$

where: $\overline{G}$ = average value for stand basal area per unit area

$\overline{N}$ = average number of trees per unit area

$\overline{D}$ = average diameter of stand

$\overline{H}$ = average height of stand

$\overline{F}$ = average form factor of stand

$\overline{V}$ = average volume of stand

I_c= volume periodical current increment

I_m = volume periodical mean increment

T = age

$\overline{V}_1$ and $\overline{V}_2$ = volume of standing trees $T_1$and T_2 $T_2>T_1$

$\overline{V}_1'$ and $\overline{V}_2'$ = volume of removed trees at time T_1 and T_2, $T_2>T_1$

n = interval between T_1 and T_2 , usually 5 or 10 years

Between 1965 and 1970 Romanian Forestry Research Institute constructed another improved series of yield tables (Armăşescu et al. 1965 a – Norway spruce, 1965 b – fir, 1965c – beech in manuscript (printed in 1967 by Milescu et al. in 1967 and after that by Armăşescu in the same year as a separate booklet), Decei 1966 – willow, Armăşescu et al. 1969 – black locust) which were included in a collection of the new forest mensuration tables published in 1972 by Giurgiu-Decei-Armăşescu. An example of the second generation of Romanian yield tables is given in Table 8.12.-2. that refers to fir.

TABLE 8.12.-2. Second generation of Romanian yield tables: fir stands, site class 1st

T	Arboretul principal									Produse intermediare			Producția și creșterea totală				T
															Creșterea anuală		
	H	H (limite)	D	N	G	F	V	Creșterea anuală medie l.m.	H dom.	N`	V`	ΣV`	V+ΣV`	ΣV.100` / V+ΣV`	curentă l.c.t.	Medie I.m.t	
ani	m	m	cm	buc.	m²	0…	m²	m²	m	buc.	m²	m²	m²	%	m²	m²	ani
10	3.2	2.8-3.5	2.7	-	-	-	40	4.0	-	-	-	-	40	-	-	4.0	10
15	5.4	4.9-5.9	4.8	-	-	-	72	4.8	8.4	-	-	-	72	-	-	4.8	15
20	7.6	6.9-8.2	7.0	6574	25.3	0.598	15	5.7	10.8	-	-	-	115	-	-	5.7	20
25	9.8	9.0-11.6	9.4	4193	29.1	0.574	165	6.6	13.2	2381	12	12	177	6.8	12.4	7.1	25
30	12.6	11.5-13.5	12.3	2769	32.9	0.558	231	7.7	15.8	1424	19	31	262	11.8	17.2	8.7	30
35	15.4	14.1-16.5	15.4	1971	36.7	0.542	306	8.7	18.6	796	22	53	359	14.8	19.5	10.3	35
40	18.0	16.3-19.6	18.4	1515	40.3	0.530	385	9.6	21.1	456	24	77	462	16.7	20.5	11.6	40
45	20.5	18.8-22.0	21.3	1229	43.8	0.516	463	10.3	23.5	286	24	101	564	17.9	20.3	12.5	45
50	22.7	20.9-24.4	24.2	1022	47.0	0.503	537	10.7	25.7	207	26	127	664	19.1	19.9	13.3	50
55	24.5	22.5-26.4	26.9	875	49.7	0.490	597	10.9	27.4	147	31	158	755	20.9	18.0	13.7	55
60	26.0	24.1-27.9	29.3	771	52.0	0.479	648	10.8	28.9	104	33	191	839	22.8	16.8	14.0	60

* Explanation of symbols in text and table 8.12-1.

SOURCE: Armăşescu, S. et al. 1965 (b), "Cercetări asupra producției, creşterii şi calității arboretelor de brad din R. S. România", Ed. CDF (Centre for Documentation in Forestry), Bucharest.

This new generation of yield tables was adapted in such a way that it permits determination in the same time of the relative and absolute productivity class (Fig 8.12.-1.), but this cannot overtake the disadvantages of Baur's method that can be avoided only by using data from permanent plots.

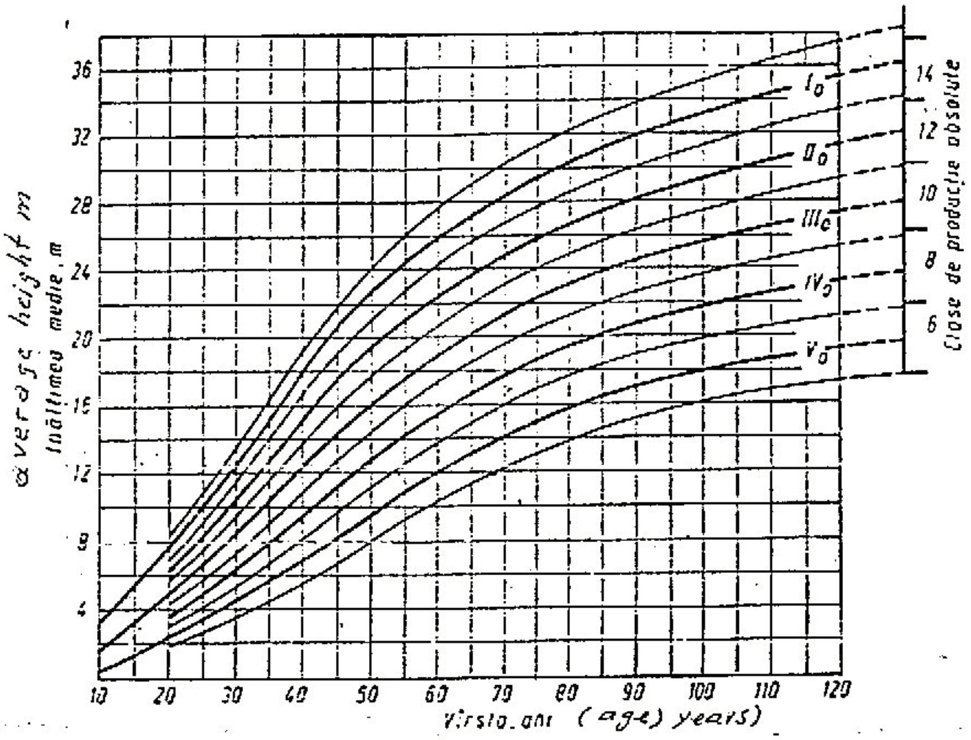


Fig. 8.12.-1. Graphic for the determination of relative site classes (I_0, II_0, III_0, IV_0, V_0) and absolute site class es (6, 8, 10, …12).
SOURCE: Ibid. Table 8.12.-2., Armăşescu et al. 1965 b. Reproduced after Giurgiu 1979, p. 547, fig. 11, 14

In 1964, Alexe published the first Romanian yield tables for Scots pine natural forest types. Alexe established the stands height curves using stem analysis for each stand and more than 150 dominant trees were analyzed. An example of this type of table is given in Table 8.12.-3. for Scots pine with *Vaccinium myrtillus* and *Calluna vulgaris*.

TABLE 8.12.-3. An example from the first tables by forest types completed in Romania

Yield table for the forest type Scots pine with **Vaccinium myrtillus** and **Calluna vulgaris**

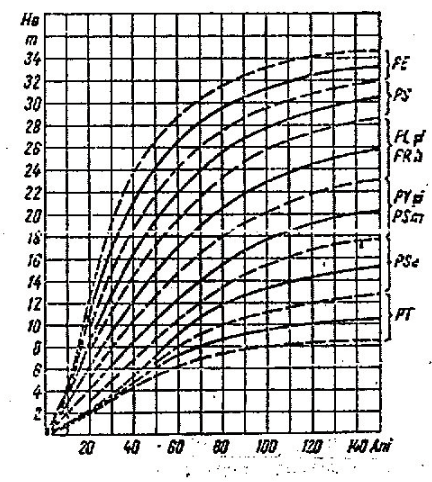
TABELA DE PRODUCȚIE PENTRU TIPUL PINET CU V**ACCINIUM MYRTILLUS** ȘI CALLUNA VULGARIS *

A	Indice de acoperire	Arboretul principal											Arboretul secundar				Producția totală			
		Înălțimea			HF	D	N	G	F	N (fus)	Crester. curentă anuală	N'	M'	ΣM'	ΣM'.100 / M+ΣM'	M+ΣM'	Creșterea anuală	
		H_G		H_s													Medie	Curentă	
		Media	Amplitudinea																
ani	-	m	M	m	m	cm	Buc.	m^2	0...	m^3	m^3	buc	m^3	m^3	%	m^3	m^3	m^3	%
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
30	1.00	6.4	4.8- 7.7	6.9	3.6	10.0	2114	16.7	555	60	-	-	-	-	-	60	2.0	-	-
40	1.00	8.4	6.8-10.3	9.2	4.3	14.0	1493	23.0	510	99	3.9	621	20	20	16.8	119	3.0	5.9	9.8
50	0.98	10.5	8.6-12.5	11.4	4.9	17.6	1086	26.4	472	129	3.0	407	35	55	29.9	184	3.7	6.5	6.6
60	0.95	12.3	10.5-14.5	13.4	5.4	20.4	881	28.8	437	156	2.7	205	31	86	35.5	242	4.0	5.8	4.5
70	0.92	14.0	12.0-16.4	15.3	6.0	23.2	719	30.4	426	182	2.6	162	28	114	38.5	296	4.2	5.4	3.5
80	0.87	15.5	13.4-17.9	16.9	6.5	26.1	591	31.5	421	205	2.3	128	27	141	40.8	346	4.3	5.0	2.7
90	0.85	16.6	14.5-19.0	18.1	6.9	28.5	511	32.6	417	225	2.0	80	24	165	42.3	390	4.3	4.4	2.1
100	0.82	17.7	15.4-20.1	19.3	7.3	30.5	455	33.3	414	243	1.8	56	20	185	43.2	428	4.3	3.8	1.7
110	0.78	18.5	16.1-20.9	20.2	7.6	32.0	422	33.9	412	258	1.5	33	16	201	43.8	459	4.2	3.1	1.3
120	0.74	19.2	16.8-21.7	20.9	7.9	33.0	400	34.2	411	270	1.2	22	13	214	44.2	484	4.0	2.5	1.0
130	0.70	19.6	17.2-22.3	21.4	8.0	34.0	379	34.4	410	275	0.5	21	12	226	45.1	501	3.9	1.7	0.6
140	0.68	20.0	17.5-22.7	21.9	8.1	34.6	367	34.5	409	279	0.4	12	10	236	45.8	515	3.7	1.4	0.5
150	0.64	20.2	17.7-22.9	22.2	8.2	35.0	358	34.5	408	283	0.4	11	8	244	46.3	527	3.5	1.2	0.4

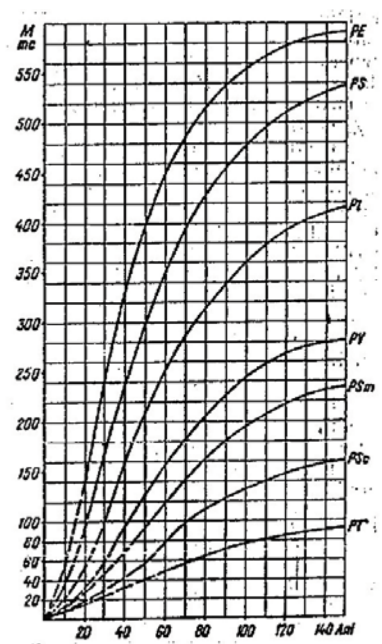
* Explanation of symbols in text and Table 8.12.-1.

SOURCE: Alexe, A., 1964, "Pinul silvestru" (The Scots pine), p.199, table XII. Ed. Agro-Silvică, București.

Alexe's yield tables reflect probably better the real dynamics of tree heights and the development of other characteristics of stand belonging to different forest types. It should be underlined that in these tables the height and volume curves of the site classes are not equidistant (Fig 8.12.-2.) and dynamics of stand average height is different when compared with other Scots pine yield tables (Plonski 1937-Poland; Tyurin 1952-URSS; Nedealkov- Sikov 1959-Bulgaria; Hummel and Christie 1969-UK, and Peterson 1952-Sweden) and show different shapes. The idea to construct yield tables by forest types was not accepted in 1964 by I. Popescu-Zeletin, V. Giurgiu and S. Armăşescu, therefore Alexe's tables were not included in their collection textbooks but later, in 1979 (p. 562), Giurgiu recognized the superiority of yield tables based on ecological peculiarities and advocated for the construction of these tables on ecological basis possibly by types of forest ecosystems which is practically the same thing with forest types depending on how it is defined (in any case the forest ecosystem is a larger concept than forest type).



A = Height - age curves



B = Volume – age curves

Fig. 8.12.-2. Variability of stand average height (HG) and volume (M, mc=m³/ha) with age in different Scots pine (*Pinus sylvestris)* forest types. Explanation of symbols for forest types: PE = Pinetum maximum asperuletoso-oxalidosum, PS = Pinetum major luzuletoso-asperuleto sum, PL = Pinetum luzuletoso-rubosum, PV = Pinetum myrtilloso-callunosum, PSm = Pinetum saxatile-alticolum, PSc = Pinetum saxatile, PT = Pinetum sphagnosum.
SOURCE: A. Alexe, 1964, "Pinul silvestru" (the Scots pine), Ed. Agro-Silvică, Bucureşti.

Armăşescu investigated the biometrical characteristics of mixed spruce–beech forests and constructed a yield table for *Picea-Abies* with *Oxalis acetosella* type located in sites with high productivity in the Carpathian Mountains (Armăşescu 1971, 1972)

In 1975, Giurgiu developed mathematical expressions of Romanian yield tables to be used in computerized programs. Giurgiu's equations were used by Dagnelie (1976) in Belgium. In the Romanian forest mensuration textbooks special chapters or sections are assigned for yield tables: Stinghe-Toma 1958 (pp. 311-348), Giurgiu 1979 (pp. 544-567), and Leahu 1944 (pp. 349-368).

Giurgiu (1979) underlined that "The modern methods of the yield tables construction evolve toward the development of complex mathematical models based on ecological concepts. In this acceptance "yield table" is only a presentation form of a completed mathematical model" (p. 557 translated by A. A.).

Cited authors:

Alexe 1964, Armăşescu 1954, 1971, 1972; Armăşescu et al. 1965 a, 1965 b, 1965 c (1967), 1969, 1972; Decei 1966, Dagnelie 1976 (Belgium), Giurgiu 1957, 1975, 1979; Giurgiu-Decei-Armăşescu 1972, Hummel and Christie 1953 (UK), Leahu 1994, Nedealkov and Sihov 1959 (Bulgaria), Petterson 1952 (Sweden), Plonski 1937 (Poland), I. Popescu-Zeletin et al. 1957, Rucăreanu 1957, Stinghe and Suburlan 1927, 1930, 1941; Stinghe and Toma 1958, Toma 1955, 1957; Tyurin 1952 (URSS), Wiedeman 1957 (Germany).

8.13. Weight and biomass studies

One of the earliest studies on quantitative variation of leaves and buds was completed by V. Mocanu in 1968, who investigated *Quercus pubescens* Wild. and *Q. pedunculiflora* C.Kokh growing on the Babadag plateau. Investigation on the biomass of the same species and area were continued in 1971 by Popescu-Zeletin and Mocanu.

G. Dissescu published in 1973 some consideration on the relation between growth and area of leaves in the case of the main species of oak growing in Romania. In 1977, G. Dissescu estimated the quantity of leaves biomass in oak stands.

Decei began his studies on weight and biomass in 1989, his first work referring to biomass of high productive trees and young beech stands (communication presented at Kyoto meeting of S.4.-1. IUFRO group).

Dissescu, Ţebrea and Decei completed in 1981 a biomass study in young stands of *Abies alba* (fir) and presented it at XVII IUFRO World Congress. In 1983 Decei determined the biomass in the stands of beech and one year before (1981) established the characteristics of crown leaves of the beech trees aged 20 and 60 years.

Stoiculescu estimated the biomass of bald cypress trees (*Taxodium distichum* (L.) Rich.) in the Romanian forest cultures (1981, 1983), and determined also the mean content of ash and mineralomass for five above ground components of the tree, depending on its dbh and height.

The most important Romanian work on biomass was carried out in 1984 by Decei and Andron who used the regression equations for different parts of tree (stem, stem bark, branches, total above ground biomass, stump, roots, total woody biomass and leaves biomass).

First of all, they determined the apparent conventional density (ACD) used for transformation of volume (given in m^3) in biomass (expressed in kg or tons). ACD was defined as a ratio between the weight (over bark) of oven dry wood and its fresh (green) volume. Obtained ACD values are given in Table 8.13.-1.

TABLE 8.13.-1. Wood apparent conventional density (ACD) by parts of tree for the main Romanian species (kg/m^3)

Species	Stem	Stem bark	Branches	Stumps	Roots
Beech	562	521	569	591	502
Sessile oak	578	446	545	583	461
Spruce	346	314	577	373	363
Fir	349	324	424	412	374

SOURCE: Decei and Andron 1984, (Researches on biomass determination of the trees and pure even-aged stands of beech, sessile oak, spruce and fir). Manuscript. Institute for Researches and Design in Forestry (ICAS), Bucharest.

Decei and Andron adopted the following basic model for biomass of beech, sessile oak, spruce and fir:

$$y = b_0 + b_1x + b_2x^2$$

where y = biomass in kg and x = dbh in cm for diameters between 8 and 48 cm. The values of b_0, b_1 and b_2 coefficients are presented in Table 8.13.-2. which represent the synthesis of their works. From the basic equations were derived a lot of tables (Tables 8.13.-2. - 8.13.-4).

For beech and sessile oak leaves biomass, Decei and Andron established the equations:

beech $y = 1.05863 - 0.15138x + 0.01329x^2$

sessile oak $y = -0.42506 + 0.13574x + 0.00342x^2$

where: y = biomass and x = dbh, y in kg and x in cm.

TABLE 8.13.-2. Coefficients of biomass equation $y = b_0 + b_1x + b_2x^2$ for Romanian main species: beech, sessile oak, spruce, fir; (y = biomass in kg, x = dbh in cm). Diameters 8-48 cm.

Biomass of…	b_0	b_1	b_2
	beech (fag)		
Stem	15.318732	-6.638185	0.788913
Bark	0.667359	-0.222557	0.038256
Branches	3.328051	-1.468714	0.145755
Stump	11.333744	-2.195539	0.131700
Roots	6.112478	-1.063212	0.077006
Total	31.514898	-10.833686	1.163722
	sessile oak (gorun)		
Stem	-30.115276	1.966838	0.392197
Bark	2.249392	-0.638419	0.086672
Branches	23.394257	-3.468593	0.152555
Stump	6.743061	-1.024974	0.086358
Roots	-2.353984	0.219882	0.032468
Total	-0.121340	-2.938531	0.750070
	spruce (molid)		
Stem	57.559520	-8.939792	0.562120
Bark	-7.533562	0.230411	0.030205
Branches	12.781745	1.677485	0.101133
Stump	-17.213639	1.012711	0.025571
Roots	-0.041320	-0.041171	0.067589
Total	232.203981	-27.474144	1.162247
	fir (brad)		
Stem	-3.218682	-3.4	0.466755
Bark	22.710280	-2.619772	0.093485
Branches	5.261076	-0.919967	0.066849
Stump	-3.628172	0.437615	0.028193
Roots	-12.625843	0.982230	0.018224
Total	8.536836	-5.599921	0.673265

SOURCE: Data extracted from Decei and Andron 1984 "Cercetări privind stabilirea biomasei arborilor şi arboretelor pure şi echiene de fag, gorun, molid şi brad", (Researches on biomass determination of trees and pure evenaged stands of beech, sessile oak, spruce and fir). Manuscript. Institute for Researches and Design in Forestry (ICAS), Bucharest.

TABLE 8.13.-3. Biomass of different parts of beech tree depending on dbh.

Diameter (dbh) cm	The content of biomass in ….										
	Stem		Bark		Branches		Stump		Roots		Total biomass
	kg	%	kg	%	kg	%	kg	%	kg	%	kg
8	12.7	62.3	1.3	6.4	0.9	4.4	3.0	14.7	2.5	12.2	20.4
12	49.3	71.3	3.5	5.1	6.7	9.7	5.2	7.5	4.4	6.4	69.1
16	111.1	71.5	6.9	4.4	17.1	11.0	11.5	7.4	8.8	5.7	155.4
20	198.1	70.8	11.3	4.1	32.3	11.5	22.1	7.9	15.7	5.7	479.7
24	310.4	70.3	17.4	3.9	52.0	11.8	36.9	6.3	25.0	5.7	441.7
28	447.9	69.9	24.4	3.8	76.5	11.9	55.9	6.7	36.7	5.7	641.4
32	610.7	69.5	32.7	3.7	105.6	12.0	79.1	9.0	50.9	5.8	879.0
36	798.8	69.2	42.2	3.6	139.4	12.1	106.9	9.3	67.6	5.8	1154.9
40	1012.0	69.0	53.0	3.6	177.7	12.1	138.2	9.4	86.8	5.9	1457.7
44	1250.6	68.8	64.9	3.6	220.9	12.2	174.1	9.5	108.4	5.9	1818.9
48	1514.3	68.6	78.1	3.5	268.6	12.2	214.2	9.7	132.5	6.0	2207.7

SOURCE: Decei and Andron 1984. (Researches on biomass determination of trees and pure evenaged stands of beech, sessile oak, spruce and fir). Manuscript. Institute for Researches and Design in Forestry (ICAS). Bucharest. p. 39. table 20.

TABLE 8.13.-4. Variability with age of green mass and biomass of a tree and a stand in Romania

Species (specia)	Age class years (clasa de vârstă.ani)	Green mass (Masa verde)		Biomass (Biomasa)	
		Tree (Arbore)	Stand (Arborete)	Tree (Arbore)	Stand (Arborete)
		kg	tons (tone)	kg	tons (tone)
Beech (Fag)	21-40	4.082	6.348	1.810	2.811
	41-60	9.092	8.468	4.329	3.975
	61-80	17.389	8.701	7.544	3.749
	81-100	23.363	10.288	10.257	4.184
	101-120	19.166	7.687	7.313	2.899
Sessile oak (Gorun)	21-40	4.280	9.051	1.590	3.491
	41-60	8.626	8.604	3.636	3.801
	61-80	14.631	7.726	5.800	3.082
	81-100	14.666	6.365	5.940	2.531
Spruce (Molid)	21-40	13.052	21.076	5.460	8.831
	41-60	25.246	21.232	11.400	9.502
	61-80	25.013	19.405	12.376	9.713
	81-100	27.543	19.730	13.620	9.622
	101-120	25.409	16.800	14.210	8.302
Fir (Brad)	21-40	19.245	33.306	8.573	14.872
	41-60	57.323	56.528	26.105	25.715
	61-80	50.773	39.644	23.414	17.320
	80-100	70.192	34.229	33.821	16.157
	101-120	100.192	29.997	65.059	17.067

SOURCE: Decei and Andron 1984. (Researches on biomass determination of trees and pure even-aged stands of beech, sessile oak, spruce and fir). Manuscript. p. 62. Institute for Researches and Design in Forestry (ICAS). Bucharest.

Cited authors:

Decei 1981, 1983; Decei and Andron 1984, Decei et al. 1982, Dissescu G. 1973, 1977: Dissescu R. et al. 1981, Mocanu 1968, Popescu-Zeletin and Mocanu 1971, Stoiculescu 1981, 1983a, 1983b.

8.14. Tree-ring studies

The first tree-ring studies in Romania were developed by A. Iacovlev in 1956a, 1956b (influence of draught on width of annual rings and wood texture), 1957 and Elian and Iacovlev 1957 (tree-rings width during the last 20-30 years and influence of weather on different forest species native and acclimatized in the experimental reservation Mihăieşti-Muscel).

Popescu-Zeletin (1964) and Popescu-Zeletin and Mocanu (1971) investigated the daily radial growth of tree-rings using an auxometer with clock.

Cyclical variations of the tree-rings was analyzed by Giurgiu in 1974 (a).

A dendrochronological series (1880-1970) in uneven-aged fir stand was compared by Giurgiu (1977a) with the dynamics of annual rain fall during the same period (Fig. 8.14.-1.). Giurgiu concluded that the correlation between indices of tree-ring growth and rainfall become higher when the precipitations of the previous 1-2 years were taken into account. This phenomenon is known for a long time in the U.S.A. and some European countries which developed earlier the dendroclimatological researches.

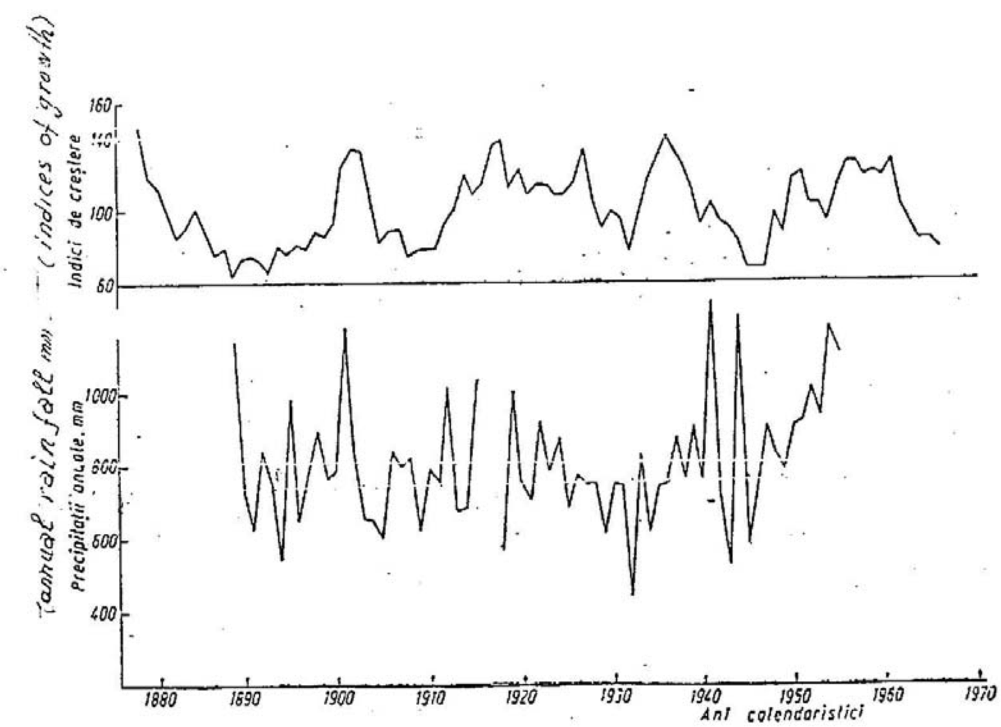


Fig. 8.14.-1. Comparison between a dendrochronological series of an unevenaged fir stand (Sinaia forest range) and dynamics of annual rain fall during the same time period.
SOURCE: Original in Giurgiu 1977 (a) “Variaţia creşterilor la arbori. starea timpului şi anii de secetă” (Variability of tree growth and weather in draught years). Academia de Ştiinţe Agricole şi Silvice. Buletin Informativ no. 5. Reproduced from Giurgiu 1979. “Dendrometrie şi auxologie forestieră”. p. 667. fig. 15.6. Editura Ceres. Bucureşti

Cited authors:

Elian and Iacovlev 1957. Giurgiu 1974 a. 1977 b. 1979; Iacovlev A. 1956 a. 1956 b. 1957; Popescu-Zeletin 1964; Popescu-Zeletin and Mocanu 1971.

8. 15. Forest inventory and remote sensing

8. 15. 1. Forest inventory and monitoring

Forest inventory in Romania was practiced on two levels: 1) stand level, presented in 8.10 and 2) forest inventory on larger areas including national inventory and monitoring.

On the stand level and not too large areas the strip method was introduced in 1915 by Ioachim Popovici and extended later, in 1937 and 1947 by Popescu-Zeletin who practically presented it as his own technique known under the name of "*firul lui Zeletin*"(Zeletin's chain or plot) was generalized in Romanian forest management planning during the 1948-1956 period and was 50 or 100 m long and 10 m wide. The second type of sampling unit was the circular plot (100-600 m^2) depending on stand structure. For delimination of circular plots was used the relascope or a Romanian constructed dendrometer.

The techniques of stand partial inventories in Romania were described by Toma in 1956.

The first resources on the inventory techniques of multiaged stands were completed by Dissescu R. (1958) who developed in 1965 the instructions for a national forest inventory based on the forest management planning data. This method was still applied in Romania in 1990s.

In 1968 Giurgiu presented the first valuable statistical study on the volume variability on the sampling plots and published the first Romanian work on the statistical inventory of stands.

Tr. Popovici et al. (1970, 1975) tried to improve (we cannot understand what for) Prodan's technique of the first stand inventory using six trees; Popovici tried sampling units containing 4,6,8 and 10 trees but the obtained results were not conclusive (Alexe and Milescu 1983, p. 148).

In 1978, Seceleanu presented a method for the establishment of a data base for forest inventory and its up dating. In the same year at a IUFRO meeting held in Bucharest, Giurgiu, Decei, Dissescu presented "same inventory methods applied in Romania's forests" while Bumbu et al. tried to explain "National forest inventory in Romania on the basis of the forest management planning data".

In 1991, Pătrăşcoiu presented the development of a national forest monitoring system.

First monitoring on national level (in Romania) is based on ground permanent plots established within a 2x2 km or 2x4 km grid. Every sample in such a grid has two permanent sample plots, located at 30 m distance of the centre of the sample having a circular form: the small circle has 28 m2 (r = 2.98 m), the medium one of 200 m^2 (r = 7.98 m), and the big circle having an area of 500 m^2

(r = 12,62 m). On the first circle the young trees under 8 cm dbh are inventoried, in the next circle there are inventoried the trees of 8.1 to 28 cm, and in the big circle the trees with diameters above 28 cm. The dendrometrical measurements are correlated with that concerning soil, water, air and tree health.

8. 15. 2. Remote sensing

An early work (probably the first) on the use of photogrammetry in the Carpathians and Danube basin forests was published in Germany in 1938 by the Romanian scientist Nicolau-Bârlad.

In 1971, Boş analized the determination of density and species structure using aerial photographs and in 1982 published a course about photogrammetry in forestry.

Two remarkable textbooks on photogrammetry and remote sensing in forestry were published in 1978 and 1988 by A. Rusu.

A special department at the Forest Research and Management Institute, Bucharest, is in charge with problems of aerophotogrammetry and remote sensing.

Cited authors:

Boş, 1971a, 1971b, 1982; Bumbu et al. 1978, Dissescu R. 1958, 1965; Giurgiu 1968a, 1968b, 1978; Nicolau-Bârlad 1938, Pătrăşcoiu 1991, Popescu Zeletin 1937, PopoviciI. 1915, Popovici Tr. et al. 1970, 1975; Rusu Aurel 1978, 1980, 1988, Seceleanu 1978, Toma 1956.

8.16. Chronology of selected works

1902: First Romanian forestry handbook (D. B. Neagoe).

1905: First Romanian caliper (Paul Teodorescu).

1915: The use of sample plots strips for volume determination (Ioachim Popovici).

1921: First description of stand types considered as a base for silviculture (Z. Przemețchi).

1927: First edition of the most popular forestry handbook “Agenda forestieră” (V. N. Stinghe and D. A. Sburlan).

1933: Methods for determination of volume in forests (I. Guran).

1934: First genuine phytosociological study performed by a forester: (C. Georgescu).

1937: First determination of form factors of black locust in Oltenia (V. N. Stinghe).

1938: An early work on the use of photogrammetry in the Carpathians and Danube basin (Nicolau-Bârlad).

1939: First comments on the theory of stand types (Gr. Eliescu).

1940: First booklet containing volume tables (N. Chiriacescu and F. Lungu).

1941: First Romanian volume tables and form factors for spruce trees grown in Călimani Mountains (G. T. Toma).

1946/1947: Tariffs for oak volume determination (G. T. Toma).

1948: First researches on converting factors of stacked wood in solid content and converting factors of solid content in stacked wood (G. T. Toma).

1949: First Romanian lithographed course on forest mensuration (V. N. Stinghe).

1950: The first Romanian general volume tables for fir, spruce, oak, *Quercus cerris*, beech, hornbeam, black locust and maple (Forest Research Institute).

1951: Determination of stand growth volume using general volume tables (G. T. Toma).

1951/1952: First assortment tables for beech in northern Oltenia (1951) and spruce (1952) (G. T. Toma).

1952: First assortment tables for beech (T. Botezat, G. T. Toma, V. Sabău).

1952: First researches on growth and yield of black locust, hornbeam and lime stands (G. T. Toma, S. Armăşescu, I. Popescu-Zeletin).

1953: First stem taper tables of spruce, fir, beech and poplar (R. Dissescu et al.)

1953: First use in Romania of the method of normal heights for stand volume determination based on Laer's (1938) and Lang's (1938) works (V. Sabău).

1953: Analytical method of tree volume determination (V. Sabău).

1954: The first Romanian tables for beech (S. Armăşescu).

1954: The first volume tables for birch (I. Decei).

1954: First researches on growth and yield of oak, sessile oak, *Quercus frainetto* and *Q. cerris* stands (N. Rucăreanu, G. T. Toma, S. Armăşescu).

1955: First studies on form quotients of spruce based on mathematical statistics methods (V. Giurgiu).

1955: A review of graphical methods for volume determination (V. Giurgiu).

1955/1956: Determination of stand volume growth using average form height (V. Giurgiu).

1955/1958: Handbook for forester V. II (135 pp.) – a chapter for forest mensuration (V. Stinghe, D. Sburlan, Th. Bălănică, G. T. Toma et al.).

1955: The first simplified yield table (G. T. Toma).

1956: A method for volume tables construction based on a logarithm equation (R. Dissescu and M. Stănescu).

1956: The first study on drought influence on tree-ring growth and structure (Alexe Iacovlev).

1956: First presentation of Bitterlich technique in Romania (R. Ichim).

1956: An analysis of connection between vegetation and site (S. Paşcovschi).

1957: A monumental work (1320 pp.): a collection of tables for forest mensuration (I. Popescu-Zeletin, G. T. Toma and other seven authors) highly appreciated in France by Pardé.

1958: First researches on the inventory techniques of multiaged stands (R. Dissescu).

1958: Introduction in Romanian forestry mensuration of the concept "stand elements" proposed in USSR by Tretyakov in 1927 (V. Giurgiu).

1958: An outstanding work: forest types in Romania (S. Paşovschi in cooperation with V. Leandru).

1958: First printed forest mensuration – in Romanian language (V. N. Stinghe and G. T. Toma).

1958: First use of term "auxometria" for the measurement of growth and "auxonomia" for the interpretation of the "law" of growth (G. T. Toma).

1960: Method for determination of black locust diameter growth during vegetative (growing) season (I. Popescu-Zeletin, S. Puiu and V. Mocanu).

1960: Influenced by Kräuter (1958) there were constructed unique series of heights for tree volume determination (I. Milescu et al.).

1961. 1966: Researches on root system of main species growing on sandy soils (1961) and of oak species with the same trees in decline (Valeriu Enescu).

1961: A synthesis on productivity class (V. Giurgiu).

1962: Classification of uneven-aged stands in Romania based on Prodan's (1949) system of classification (I. Popescu-Zeletin and R. Dissescu).

1962: A method for determination of volume growth in uneven–aged stands of fir, spruce and beech (I. Popescu-Zeletin and R. Dissescu).

1962: First Romanian yield tables (Scots pine) by forest types (Alexe Alexe).

1964: Biometrical tables for Scots pine – in: "Scots pine" monograph pp. 159-209 (Alexe Alexe).

1964: Biological and methodological bases of typology and classification of forest site (C. Chiriță et al.).

1964: Unique series of heights and volumes for uneven-aged stands of spruce, fir and beech constructed after Prodan's (1949) model (I. Popescu Zeletin and R. Dissescu).

1965: A synthesis concerning the algorithms for forest mensuration calculus (regression equations of stem taper, unique series of heights in relative values. Utilization of Charlier A distribution of volumes by diameter categories) (V. Giurgiu).

1965: Researches on yield growth and quality of spruce and fir stands (S. Armăşescu et al.).

1965: Yield tables for fir by forest types (S. Armăşescu).

1965: Primary and dimensional assortment of 17 species even-aged stands (V. Giurgiu, I. Decei, S. Armăşescu).

1965: Instructions for a national forest inventory based on management working plan data. (R. Dissescu).

1966: Characterization and classification according to their structure of the uneven-aged stands in Romanian Carpathian Mountains (I. Popescu-Zeletin and R. Dissescu).

1965-1967: Researches on growth and yield of beech stands. The second generation of yield tables (S. Armăşescu et al.).

1967: Ground vegetation in Romanian forest as indicator for evaluation of site quality (Al. Beldie and C. Chiriță).

1968: A method for transformation of natural uneven-aged stands in stands of selection-forest type. Repartition of trees by diameter categories depending on tree distribution type. The case of fir uneven-aged stands (R. Dissescu).

1968: First biomass studies on oak leaves (V. Mocanu).

1968: First Romanian work on statistical inventory of stands (V. Giurgiu).

1969: Researches on yield growth and quality of black locust stands in Romania (S. Armăşescu et al.).

1969: A forest mensuration textbook … (V. Giurgiu).

1969: Height form for the stands of the main forest species in Romania (V. Giurgiu).

1971: Contribution and consideration on biometrical characteristics of mixed stands (S. Armăşescu).

1971: Comparative biometrical researches on yield and structural characteristics of even-aged stands of the main forest species in Romania (S. Armăşescu).

1971: Influence on growth of the spacing in Canadian poplar plantations (Gh. Marcu).

1971: Investigation on the biomass and on the tree sinusia growth. A synthesis (I. Popescu-Zeletin and V. Mocanu).

1972: A new yield table for mixed spruce and beech stands in Romania Carpathian Mountains (S. Armăşescu).

1972: Researches on tree crown and leaves area (G. Dissescu and R. Dissescu).

1972: Taper curves for the main forest Romanian species (V. Giurgiu).

1972: A textbook on mathematical statistics methods applied to forestry (V. Giurgiu).

1973: Biometrical relationship for computerized drafting of working plans (V. Giurgiu).

1973: Researches on diameter growth dynamics and its plasticity of beech trees (V. Stănescu).

1974: Researches on growth cyclicity of trees (V. Giurgiu).

1974: A unique mathematical relation volume-diameter-height for the majority of Romanian forest species (V. Giurgiu).

1975: Proportion and dimensional assortments of oak, sessile oak, Quercus cerris, black locust and beech branches (Institute for Researches and Management in Forestry).

1975: Mathematical expression of dendrometical Romanian tables (yield tables. volume tables and other tables) (V. Giurgiu).

1977: Forest sites (C. Chiriță).

1977: Tree-rings and climate. First Romanian chronology (1880-1970) and an early dendroclimatological short study (V. Giurgiu).

1977: Influence of industrial pollution on tree growth (M. Ianculescu).

1978: Structural characteristics of uneven-aged stands (I. Leahu).

1978: The influence of simulation use in forest management (working plans) on forest structure.

1978: Forest photogrammetry - a textbook (A. Rusu).

1979: A forest mensuration textbook –629 pp. (V. Giurgiu).

1981: A mathematical model of stand structure (I. Leahu).

1981: Biomass estimation of bald cypress trees in Romanian cultures (Chr. D. Stoiculescu).

1982: Humus as an indicator of forest site quality (C. Chiriță).

1983: A book on forest inventory – 492 pp. (Alexe Alexe and I. Milescu).

1983: Determination of the bold cypress mineralomasse in the trees growing in Romania (Chr. D. Stoiculescu).

1984-1986: A systemic analysis of oaks die-back and its causes (Alexe Alexe).

1984: An exceptional work on determination of tree and stand biomass for beech, sessile oak, spruce and fir (I. Decei and Tr. Andron).

1984: A radial and volume growth model for mixed stands (I. Leahu and R. Dissescu).

1985: A mathematical model for optimization of the stand structure (I. Leahu).

1987: Modelling methods for optimum distribution of trees by diameter categories depending on forest functions (R. Dissescu and I. Leahu).

1987: Mathematical models for structure of the even-aged stands according to the height of trees (I. Leahu).

1988: Aerial photography and teledetection in forestry (A. Rusu).

1990: Forest ecosystem types in Romania (N. Doniță, C. Chiriță, V. Stănescu et al.).

1990: Modelling the structure dynamics of even-aged and relative even-aged stands (I. Leahu).

1991: The development of a national forest monitoring system (N. Pătrăşcoiu).

1994: A forest mensuration textbook –374 pp (I. Leahu).

1995: Types of correspondences between physiotypes-enviroment and tree developement (Alexe Alexe).

1996: Optimization of stand and forest structure using mathematical methods for the purpose to establish the future species proportion (Liviu Andrei Iacob).

1997: Mineral nutrition and oak decline phenomena. Physiotype-environment –tree development. A synthesis (Alexe Alexe).

8.17. Selected contributors

Author	Printing years	Field
V. N. Stinghe	1920s-1960s	01, 1, 3
I. Popescu-Zeletin	1930s-1970s	1, 01, 3, 4, 5, 6, 7
G. T. Toma	1930s-1950s	4, 1, 01
S. Armăşescu	1950s-1980s	4, 01, 3, 1
I. Decei	1950s-1980s	1, 01, 5, 4, 3, 2
R. Dissescu	1950s-1980s	3, 1, 5
V. Giurgiu	1950s-1990s	01, 3, 4, 1, 2, 6, 7
R. Ichim	1950s-1960s	01, 4, 7
A. Alexe	1950s-1990s	01, 12, 3, 4, 6, 7
I. Leahu	1960s-1990s	3, 4, 01, 1
A. Rusu	1970s-1980s	7
G. Dissescu	1970s	1, 5

01 = text book; 1 = tree and primary products; 2 = site evaluation; 3 = stand structure; 4 = stand growth and yield; 5 = weight and biomass; 6 = tree-ring studies, 7 = forest inventory and remote sensing

8.18. Comments

Early knowledge in the area of forest mensuration came in Romania (the southern part) during the second part of the 19th century via French foresters. Barbu Dimitrie Stirbey ruler prince of the country (Vallachia) asked from the French government a few specialists in forestry. They came on the first of July 1851 and established the "Forestry Commission of Vallachia" for three years. These three specialists began a reconnaissance of the forests, being accompanied by Romanian Mihail Râmniceanu, C. N. Racotă, Iosif Hartel, Teodor Gavriliu and Scarlat Trăznea. The last one was helped by Alexandru Golescu who was the commissioner for religious affairs to organize a Forest Direction within this departament and succeeded also to set up a forestry school in Pantelimon, suburb of Bucharest in March 1860. For their training the students used the following basic books: "Anweisung zur Holzzucht für Forster" (Instruction for trees cultivation for foresters) by Georg Ludwig Hartig, "Anweisung zum Waldbau" (Instruction for trees growing) by Heinrich Cotta. Management courses held by Solomon at Nancy and the work of Bernard Loretz and Adolphe Parade: "Cours élèmentaire de culture du bois" (Elementary course on the tree growth) which influenced for some decades the conception of Romanian foresters. This double French-German influence should be underlined.

The first forestry books were published, in Romanian language, in 1865-1867 and among them it should be mentioned: "*Manual de botanică forestieră*" (Manual of forest botany) by I. Barasch, "*Note de silvicultură practică*" (Notes on practical silviculture) by Petre S. Aurelian. Works on trees and stands mensuration appeared later, in 1898, a translation by Isopescu of the A. Guttemberg's forest mensuration. A pioneer work in the field of forest mensuration was that written by Ioachim Popovici (1915) resumed later (1937, 1947) by I. Popescu-Zeletin; its application being generalized during the 1948-1956 period. "*Agenda forestieră*" (Forestry handbook) written by V. N. Stinghe and D. A. Sburlan appeared in 1927 and was reprinted in 1930, 1941 and is overwhelmed by German volume and yield tables. Original Romanian works on forest mensuration appeared after 1933 when the Forest Research Institute was established. After 1950 Romanian forest mensuration was under an evident Russian influence, but fortunately this influence, in science, was not harmful. The main contributions influenced by Soviet literature consists namely in an extensive use of mathematical statistics and introduction into practice of the "stand element" which is used even today in the Romanian forest management. The major Soviet works become known in Romania by the steady efforts of Victor Giurgiu, a pupil of the outstanding Russian scientist N. P. Anuchin.

The core of Romanian forest mensuration is represented by the following works which may be considered as mile stones of its history: Stinghe and Toma (1958) (Forest mensuration), I. Popescu-Zeletin et al. (1957) (Collection of tables for forest mensuration), Giurgiu-Decei-Armăşescu's (1979) (Collection of tables for forest mensuration – a new generation), V. Giurgiu's (1983) (Forest mensuration) and maybe Alexe and Milescu's (1983) (Forest inventory treatise).

It is not easy to separate distinct periods in the evolution of Romanian forest mensuration (RFM).

At least from beginning up to the 1950s RFM was under the influence of the German literature. In the 1950s appeared the first Romanian general volume tables, the first assortment tables, the first stem taper tables and first Romanian yield tables (1955-1960 first generation of yield tables based on Baur's method and Fekete's procedure (1951) which accepted as constant after five years, the h/d curve in a stand). I. Popescu-Zeletin's et al. (1957) collection of tables and a forest mensuration textbook (Stinghe and Toma 1958) and a set of work on nomography (alignment charts) tried to improve the graphical methods (Orădeanu 1949, Petkovski 1952, Stănescu 1952, Giurgiu 1953).

The German influence was maintained after 1950. For example: (1) the use in 1953 of the method of normal heights for the stand volume determination was based on Laer (1938) and Lang (1938) works; (2) Popescu-Zeletin and Dissescu (1962) works on the structure of uneven-aged stand were based on Prodan's (1949) ideas; (3) unique series of heights and volume series constructed by Milescu et al. (1960) are inspired from Krauter (1958) work.

After 1950 two periods with major works are distinguishable: (1) the period of first volume and yield tables construction (1951-1960) and (2) the period between 1965-1970 when based on statistical method, a new generation of tables was completed and published in a collection, in 1972 (Giurgiu-Decei-Armăşescu). After 1980 the modelling especially for the stand structure was promoted, especially by Leahu on a larger scale. In fact, the early modelling works, were completed in the field of management (Dissescu - 1966, Gătej - 1968 and continuued by Seceleanu - 1975, Gătej and Tamaş - 1976, Tamaş - 1979, Ianculescu and Seceleanu - 1986).

The dominant fields show the following decreasing ranking by periods:

Before 1901	1. Tree and primary products
1901-1920	1. Tree and primary products
1921-1940	1. Tree and primary products, 2. Site evaluation
1941-1960	1. Tree and primary products, 2. Site evaluation, 3. Stand growth and yield

1961-1980 1. Tree and primary products, 2. Stand growth and yield
1981-1997 1. Stand structure, 2. Site evaluation, 2. Weight and biomass

Out of the 291 selected works cited in this chapter 14 % were published after 1980, and 3 % after 1990. It seems that the Romanian forest mensuration entered a critical period. The causes of this phenomen are strongly connected with the economical situation of the country during the transition period.

A remarkable effort was performed by Romanian foresters during 40 years (1941-1980) when were completed 81 % of the works published between 1899 and 1997, selected and cited in this book. It is notable that 42 % of the selected works were completed by V. Giurgiu, I. Popescu-Zeletin, I. Decei, S. Armăşescu, R. Dissescu, I. Leahu, G. T. Toma, A. Alexe and V. N. Stinghe.

Influenced by the literature of the most advanced countries in the field of forest mensuration, the Romanian foresters found new solutions adapted to the peculiarities of their country and succeeded in developing a forest mensuration within the frame of European standards. In spite of the remarkable successes, three fields are waiting for a more sustainable development: tree-ring studies, the construction of process-oriented models, and the use of remote sensing in the area of forest inventory and monitoring. The use of more modern devices for measurements and computing in the field of forest mensuration have to be steadily improved.

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ALEXE, A.; MILESCU, I. 1983. Inventarierea pădurilor. (Forest inventory). Editura Ceres. Bucureşti, 492 pp.

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9. TURKEY

General information

Land area: 770,790 sq. km (297,614 sq. mi.), forest and other wooded land: 201,990 sq. km (17,991 sq. mi.), total forest: 8,856,000 ha (34,194 sq. mi.) or 11 % of land area; volume: 86 m^3/ha, biomass: 63 tons/ha (FAO 1995-124 Forest resources assessment).

Round wood production: industrial round wood 5.6 mil. m^3, fuel and charcoal 9.7 mil. m^3, total round wood 15.3 mil. m^3 (World Resources 1996-97, table 9.3, p. 220).

Forest vegetation: Mediterranean and temperate mixed forests

- Conifers: 54 %
- Broad-leaved: 46 %
- Main species: conifers: *Pinus sylvestris, P. radiata* (plantations), *P. nigra, P. brutia, Abies nordmaniana, A. cilicica, Picea orientalis, Cedrus libanii, Taxus baccata, Cupressus sempervirens*; broad-leaved: *Quercus robur, Q. sessiliflora, Q. cerris, Q. pubescens, Q. ilex, Q. coccifera, Fagus orientalis, Carpinus betulus, Castanea vesca, Tilia spp., Alnus* spp.

Forestry education and research organizations involved in the areas of forest mensuration and forest management (date of establishment in brackets):

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- Istanbul University, Faculty of Forestry, Istanbul, (1857).
- East Mediterranean Forestry Research Directorate, Tarsus (1967).
- Faculty of Forestry, Artvin (Bartin Orman Facultesi), Bartin, (1993).
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- Mid - Anatolia Forest Research Institute, Ankara, (1952).
- Poplar and Fast-Growing Forest Trees Research Institute, Kocaeli, (1962).

Publications:

- Turkish Journal of Agriculture and Forestry.
- Istanbul Universitesi Orman Fakültesi Dergisi, Seri A.
- Ormancilic Araştima Enstitüsii Yanyinlari, Teknik.

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POURTET, J. 1965. Quelques aspects de la végétation forestière en Turquie occidentale. (Some aspects of forest vegetation in Western Turkey). Rev. For. Française, no. 6: 417-477.

9.1. Tree

Topçuoglu (1940) studied the repartition of growth along the stem of tree and underlined that the width of the same annual ring become larger in the upper part of the stem. He also noted that on the species with porous rings, as oaks, the cambium activity begins early, even before the formation of leaves.

Eraslan (1957) noted the importance of the mathematical statistics method in the studies on the differences of diameter growth. Kalpisiz constructed in 1958 the stem volume tables for *Fagus orientalis,* and later Birler (1987) prepared the volume tables for *Pinus radiata* for the whole country, using data collected from 300 trees in the Marmara, Trace and Black Sea regions but the oldest plantations (of this exotic species for Turkey) were only 20 years old.

Asan (1987 b) presented an interesting comparison of monumental trees in the forests of Turkey with that from other countries in the world.

The tallest tree namely *Picea orientalis* with a height of 69 m and dbh 2.25 m, located in the eastern Black Sea region, probably the tallest spruce (*Picea*) outside America is worth mentioning. Another tree among the other species was *Fagus orientalis*, 51.5 m, height.

Conversion factors for the cubic meters of firewood and industrial timber and time - related weight (since harvest) of cubic meters in the eastern Black Sea area have been established by Kuçüc in 1987. The relation between time and the weight/m^3 over about 180 days from June to November was determined for seven species.

Pinus nigra Arnold (European black pine) is one of the primarily southern European species and its area is extended from Spain to Turkey. Isik studied in 1990 the seasonal course of height and needle growth of this species, trees located in summer-dry Central Anatolia (plantation near Ankara). This detailed research provided the foresters with the following data, that should be taken into account in the silvicultural works: the terminal buds started to break in the late March end the early April, trees completed 80-85 % of their shoot elongation by the early June and ceased growth by late July. Isik noted that "Leader length in *P. nigra* in year n+1 showed a significant positive correlation with April rainfall of year n, and with the bud length formed in year n". The average terminal shoot growth (trees 8-10 years old) was 18-20 cm/year and the average needle length was 65-85 mm and it was completed during about nine weeks.

Cited authors:

Asan 1987, Birler 1987, Eraslan 1957, Isik 1990, Kalipsiz 1958, Küçük 1987, Topçuoglu 1940.

9.2. Tree-ring studies

Banister (1970) presented in a short paper the dendrochronology in the Near East (current research and future potentialities) in which mentioned that "Since 1950, the University Museum of the University of Pennsylvania has been excavating in the ancient Phrygian Empire capital city of Gordion, located in the Anatolian highlands, some 110 kilometers southwest of Ankara, Turkey. Under the direction of professor Rodney S. Young, a sizeable portion on the great City Mound has been uncovered, and in 1957 the largest earth tumulus in the region was opened... The spectacular contents of this mound known as Tumulus MM have been previously described .... and it has been postulated that the skeleton found within was that of one of the more powerful Phrygian kings, indeed, perhaps the almost legendary King Midas himself" (p. 336-337). Logs incorporated in the tomb were identified as *Juniperus drupacea* and it is supposed that the growth rings of this Sirian juniper are of annual nature. As a result of the carried out works a 806 year tree ring chronology was established (Fig. 9.2.-1.).

This is a floating chronology, that is a relative chronology "internally consistent but not anchored to a precise calendar year in time" but "is the first archaeological tree ring chronology ever developed in the Near East" (1970). Based on radiocarbon determination it was estimated that the Tumulus MM burial chamber was built around 740 to 700 B. C.

In 1987, Kantay developed dendrochronological researches on *Quercus deschorochensis* K. Koch.

Kuniholm et al. (1986) investigated excellent preserved wood on charcoal at archaeological sites in Anatolia within Aegean Dendrochronology project and finally succeeded to built an absolute chronology of the eastern Mediterranean, 2220-718 B.C. which is considered to have "important implication for Old World archaeology and prehistory".

Nuhõglu et al. (1996) using the cross sections and increment cores taken at breast height from Calabrian pine (*Pinus brutia*) determined the air pollution around thermal power plant at Yatağan, SW Turkey.

Cited authors:

Bannister 1970, Kantay 1987, Kuniholm et al. 1996, Nuhõglu et al. 1996.

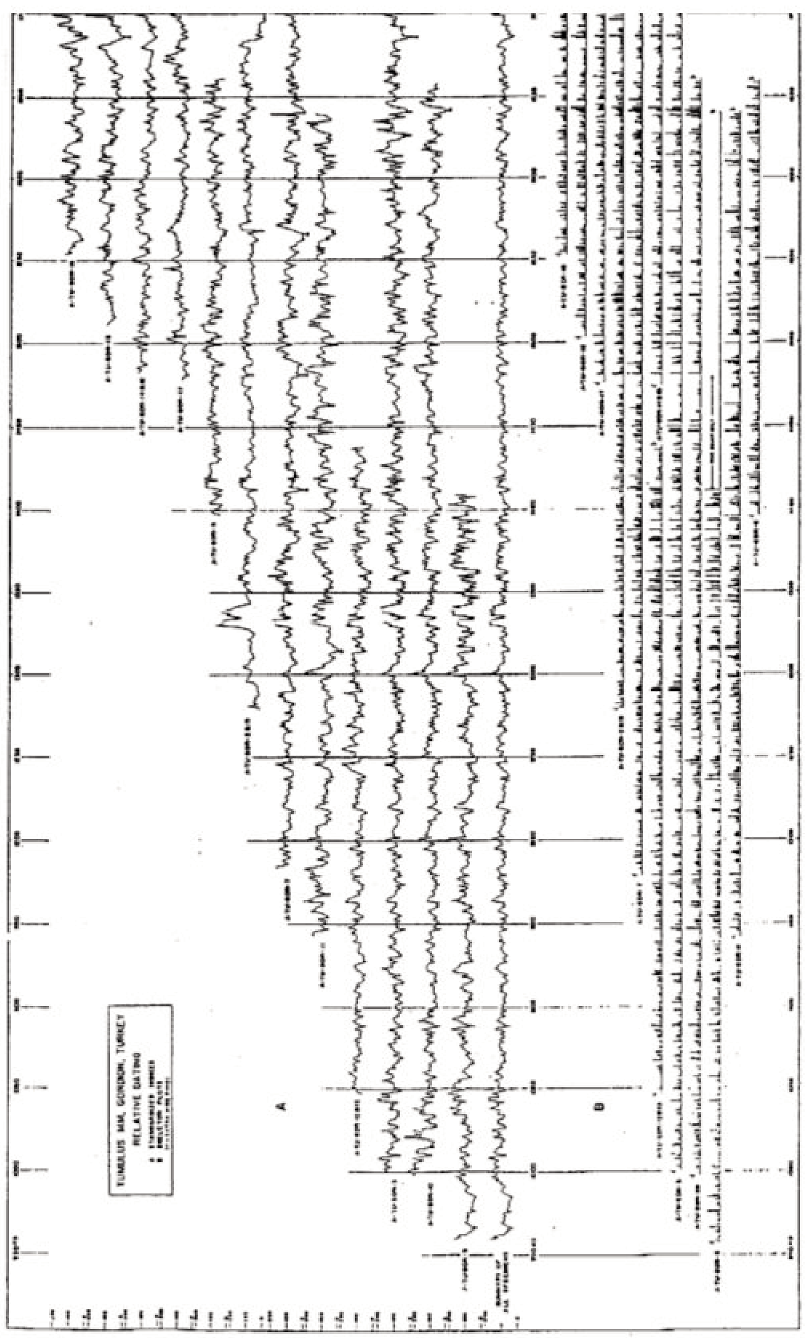

Fig. 9.2-1. A floating 806 years tree-ring chronology from Tumulus MM, Turkey.
SOURCE: Bannister, Briant, 1970 Dendrochronology in the Near East: Current researches and future potentialities. In Proceedings of the VII International Congress of Anthropology and Ethnological Sciences, Moscow, 1970, vol. 5, pp. 336-340.

9.3. Forest inventory and the use of aerial photographs

A description of the Turkish national forest inventory based on data of the working plans (management plans) was presented by Eraslan in 1978 at a IUFRO meeting held in Bucharest, Romania.

Akça (1984) analyzed the use of aerial photography in forestry, especially surveying by aid of graphic stereo-plotters or orthophoto techniques and concluded that photogrammetric are suitable for Turkey. Akça showed that the forest boundaries could be measured with a mean accuracy of ± 2.6 m from aerial photographs (scale 1:22500) using a graphic stereo-plotter and photo interpretation techniques. The same accuracy could be obtained using orthophotos scale 1:5000 or 1:10000 (For. Abs. 7439/1989).

Turkey adopted the principle of the multi-resource inventory (MRI) at a national level having as objectives: timber and non timber forest products. A MRI questionnaire for Turkey was completed by Çaliskan in 1997.

Cited authors:

Akça 1984, Çaliskan in 1997, Eraslan 1978.

9.4. Other available works

First of all should be mentioned Firat's textbook on forest mensuration (Dendrometrie), 2nd edn. (1958).

Kalipsiz investigated the productivity of *Fagus orientalis* in 1957 and constructed yield tables for *Pinus nigra* in 1959.

Asan (1987 a) developed researches on the site quality of the oriental beech (*Fagus orientalis*) using stem analyses at 28 sites (350-1710 m altitude) in Northern Turkey and obtained site index curves determined by the method of the USDA Pacific Northwest Forest and Range Experiment Station.

Asan presented the height stands curves up to 120 years old having the site indexes of 14-30 m at 80 years reference age.

Biomass tables of beech (*Fagus orientalis*) were developed by Saracoglu in 1995.

Cited authors:

Asan 1987, Firat 1958, Kalipsiz 1957, 1959, Saracoglu 1995.

9.5. Selected works in chronological order

1940: Studies on the repartition of growth along the stem of the tree (A. Topçuoglu).

1958: A textbook on forest mensuration (F. Firat).

1970: The first relative 806 years Phrygian chronology (Bryant Banister).

1978: National forest inventory description (I. Eraslan).

1995: Biomass tables of *Fagus orientalis* (N. Saracoglu).

1996: An absolute dendrochronology 2220-718 B. C. considered to have important implications for Old World archaeology and prehistory (P. I. Kuniholm).

1997: MRI questionnaire for Turkey (T. Çaliskan).

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ASAN, Ü. 1987 a Bati ve Orta Karadeniz Yöresi' Doğu Kayini ormanlarinda bonitet araştirmalari. (Site quality researches on the oriental beech (*Fagus orientalis)* forests in the western and central Black Sea region). Istanbul Universitesi Orman Fakültesi Dergisi, Seri A (1987), 37 (1) 106-130.

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KALIPSIZ, A. 1958. Schaftholz - Massentafel bei orientalischer Buche. (Stem volume tables for *Fagus orientalis*). Orman Facultesi Dergise, Istanbul, Cit. 8, Say 1.

KALIPSIZ, A. 1959. Ertragstafel für Schwarzkiefer. (Yield tables for *Pinus nigra*). Orman Facültesi Dergise, Istanbul, Cit. 9, S. 2.

KANTAY, B. 1987. Çoruh mesesi (*Quercus deschorochensis* K. Kock.) 'nde dendrokronologik araştirmalar. (Dendrochronological researches on *Quercus deschorochensis*). Istanbul Universitesi Orman Fakültetsi Dergisi. Seri A. (1987), 37 (2): 115-142.

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10. FORMER YUGOSLAVIA

General information

Land area 255,400 sq. km (98,614 sq. mi.), forest and other wooded land: 94,500 sq. km (36,503 sq. mi.), total forest: 8,371,000 ha (32,222 sq. mi.) or 33 % of land area; volume: 132 m^3/ha, biomass: 103 tons/ha (FAO 1995-124: Forest resources assessment).

Forest land area	1000 ha	sq.mi.	% of land area
• Croatia*	2458	9491	43.5
• Slovenia*	1077	4158	53.2

* SOURCE: Prins K., A. Korotkov 1994.

Round wood production:

Country	Industrial	Fuel	Total
Bosnia and Herzegovina	• •	• •	• •
Croatia Rep.	1,421,000 m^3	710,000 m^3	2,131,000 m^3
Macedonia, former Yugoslavia Rep.	• •	• •	• •
Slovenia Rep.	1,157,000 m^3	314,000 m^3	1,470,000 m^3
Yugoslavia Fed. Rep.	• •	• •	• •

SOURCE: World Resources 1996-97, Table 9.3., p. 220, data 1991-1993.

Forest vegetation: temperate mixed forests (predominant) and Mediterranean forest type only in the western part along the Adriatica Sea coast.

Conifers 17 %

Broad-leaved 83 %

Main species: European beech (*Fagus sylvatica*) – about. 50 % of total forest land area, oaks (*Quercus robur, Q. petraea, Q. cerris, Q. frainetto*), hornbeam (*Carpinus betulus*), Norway spruce (*Picea abies*), fir (*Abies alba*), *Pinus nigra* var. *austriaca*, black locust (*Robinia pseudacacia*), lime spp. (*Tilia* spp), tremble aspen (*Populus tremula*): in the Mediterranian climate: *Pinus nigra, Quercus ilicis*, chestnut sp. (*Castanea* sp.).

Forestry education and research organizations involved in the areas of forest mensuration and forest management (date of establishment in brackets):

Croatia:

- University of Zagreb, Faculty of Forestry, Zagreb, (1860).
- Forest Research Institute, Jastrebansko, (1945).

Slovenia:

- University of Ljubliana, Biotechnical Faculty, Department of Forestry, (1995).

• Slovenian Forestry Institute, Ljubliana, (1947).

In 1969, Milescu and Alexe mentioned the existence of five faculties in: Belgrade, Zagreb, Ljubliana, Sarajevo and Scoplje, and forest research institutes depending on the Academy of Science in Belgrade and Zagreb, and institutes of researches around the faculties of Silviculture.

Publications (Primary Journals and Serials):

Šumarstvo (Beograd).

Šumarski List (Croatia).

Gozdarski Vestnic (Ljubliana).

Les (Ljubliana).

Zbornik Gozdarstva in Lesarstva (Ljubliana).

Glasnic za sumake pokuse (was in print in 1935).

Vydavetelsvo Slovenke Akademie Vied (Slovenia).

Godisen Zbornik na zemjodelsko-sumarskiot Fakultat na Universitetat (Skopje).

Radovi Polioprivredno-sumarskog, Facultet Universiteta u Sarajevu.

10.1. Textbooks on forest mensuration

Early textbooks on forest mensuration were written by Leraković, (1922) ("*Dendrometrija*"), Michailoff (1952) ("*Dendrometrija*") and Klepač (1963)("*Rost i priros šumskih vrsta drvěca i sastojina*" - Growth and increment of trees and forest stands, 298 pp).

10.2. Tree mensuration, volume tables

In 1935, Levaković developed an analytical expression of growth laws and in the same year Neidhardt used the nomography for the determination of the prism shape of logs.

Mathematical law of growth of the forest trees and forest stands was again expressed by Michailoff who, advocated in 1951 the use of the statistical methods (Least squares technique) for construction of one entry volume tables (tariffs). In 1953, Klepač published the management volume tables (tariffs).

The same subject, the construction of tariffs with dbh as entry, was discussed by Emrovič (1954).

Klepač (1954) completed a comparative investigation on diameter, height, and volume increment of silver fir in the association *Abieto-Blechnetum* and published in the same year the tables and a text on the possibilities of determining the increment percentage.

Cokl (1959) constructed a new type of tariffs that are intermediary between French "tarifs lents" and "tarifs rapides". Cokl's tariffs used the general equation

$$V = \frac{M}{1600}(d-2.5)\cdot(d-7.5)$$

where M is volume in m^3 of a tree having a diameter of 45 cm, V = volume of tree and d its dbh in cm.

In 1957 Emrovič published the nomograms of Algan-Schaeffer tariffs and in 1958 a detailed information on Christen hypsometer.

Emrovič (1960) proposed a procedure of curves compensation during the construction of the double entry volume tables when graphical methods are used.

Rebula (1996) discussed the applicability of modified Algan, Schaeffer and intermediate tariffs for calculating the volume of European fir (*Abies alba*). He compared the estimates of stem volume, merchantable volume and assortments determined by Algan and Schaeffer tariffs (see France) with those determined by Slovenian intermediate tables (Cokl 1959) and concluded that the estimates from Slovenian tables are 3-7 % higher, but because Slovenian tables are easier to use he proposed a procedure for removing the error from these tables (After Forestry Abstracts 4451/1995, vol. 58, no. 6).

Cited authors:

Cokl 1959 (Slovenia), Emrovič 1954, 1960 (Croatia), Klepac (Croatia) 1953, 1954a, 1954b; Levakovič (Croatia) 1935, Michailoff (Macedonia - FYROM) 1949, 1951, Neidhardt 1935 (Croatia), Rebula (Slovenia) 1996.

10.3. Stand mensuration

An analytical expression of the stand height curve was given by Levakovič in 1935. Michailoff (1943) proposed a numerical procedure for the construction of height curve in a stand depending on diameter (h/d). In 1952, Michailoff discussed again the mathematical expression of growth and increment of the tree and of the forest stand, Cestar (1967) investigated the spruce growth in the mountainous and submountainous forest in Croatia, in a doctoral thesis, and Panič (1979) determined the volume and increment of the spruce stands in the mountain Kopacnik (Serbia). Kotar (1980) studied the growth and development of the spruce stands in the natural sites of the species in Slovenia.

In 1995, Kotar et al. presented at the 20th IUFRO World Congress, growth trends of forest in Hungary and Slovenia. According to the presented data the forest cover in Slovenia increased from 36 % in 1870 to 53 % in 1990, the growing stock increased from 129 m^3/h in 1947 to 207 m^3/h in 1990 and the current annual increment increased from 3.2 m^3/ha/year to 5.3 m^3/ha/year. Tree species composition in Slovenian forest is as follows: 34 % spruce, 13 % silver fir, 13 % larch, 1 % other conifers, 6 % beech, 28 % oaks, 5 % other broad-leaved species. Kotar et al. considered that: "The assumption that the site productivity has changed during the last three decades in Slovenie forest is more than likely and has been validated by extensive measurements of beech stands. However, this increase needs to be contrasted with a noticeable silver fir – die-back which has diminished growth. The first forest survey was carried out in 1950, and systematically repeated every 10 years" (Kotar et al., Tampere 1995, p. 271). In our opinion it should be taken into account that the productivity change (+) may be determined not only by environmental factors, but the change of the land structure should also be taken into account.

In 1996, Kotar presented an analysis of volume and height growth of fully stocked mature beech stands in Slovenia during the past three decades.

Cited authors:

Cestar (Croatia) 1967, Kotar (Slovenia) 1980, Kotar et al. (Slovenia) 1995, Levacovič (Croatia) 1035, Michailoff (1943, 1952), Panič (Serbia) 1979.

10.4. Tree-ring studies

We had only three papers available, all of them from Slovenia published in 1995: Čufar et al. (1995) considered Slovenia as a region suitable for dendrochronological investigations. They presented a short summary of the work of the Dendrochronological Laboratory of the Department of Wood Science and Technology which belongs to the Biotechnical Faculty of the University of Ljubljana. Reference chronologies have been constructed for *Abies alba, Picea abies* and *Quercus* sp.

Levanič and Čufar (1995) compared the standard chronologies of silver fir (*Abies alba*) in the Dinaric phytogeographical region of Slovenia and prepared a standard chronology of the Dinaric region for 1800-1994 period and this chronology was compared with *Abies alba* chronologies from southern Germany and Bavaria. Levanič et al. (1995) presented other four local chronologies for *Abies alba* and *Picea abies* from the same Dinaric region of Slovenia.

10 .5. Forest inventory and the use of aerial photographs

In Slovenia, the first forest survey was completed in 1950 and repeated every 10 years (see 10.3, Kotar et al. 1995).

Tomasegovic (1956) advocated the use of aerial photogrammetry for some mensurational needs in the forest management.

The colour infrared aerial photography (scale 1:8000) was used in forestry for assessment of trees damage in Medvednica Mountain region and in urban area of Zagreb (Kalafadžač 1987).

Frančula et al. (1995) presented a review of a few papers connected with geodesy and cartography in Croatian forestry including digital cartography, digital relief models, spatial modelling and use of Global Positioning System satellites.

At the end of the 1990s in Slovenia, it was promoted the principle of MRI (multi-resource inventory), at national level, having as objectives timber and environment (Kovac 1997).

Cited authors:
Frančula et al. 1995, Kalafadžač 1987, Kotar et al. 1995, Kovac 1997, Tomasegovic 1956.

10.6. Chronology of the selected works

1922: Forest mensuration textbook: "Dendrometrija" (A. Levacovič - Croatia).

1935: An analytical expression of the stand height curve and analytical expression of the growth laws. (A. Levacovič - Croatia).

1950: First forest inventory at national level in Slovenia.

1952: Forest mensuration textbook: "Dendrometrija" (J.L. Michailoff).

1954: Increment % tables and some possibilities for increment determining % (D. Klepač - Croatia).

1959: Slovenian volume tables: "Intermediary tariffs" (M. Cokl - Slovenia).

1963: A textbook on growth and increment (D. Klepač - Croatia).

1995: Standard chronology (of *Abies alba*) in the Dinaric region (T. Levanič and K. Cŭfar).

1995: A brief description and dendrochronological works in Slovenia (K. Čufar, T. Levanič and M. Zupanicic).

1996: An analysis of volume and height growth of fully stocked mature beech stands in Slovenia during the past three decades (M. Kotar - Slovenia).

1997: Multi-resource forest inventories accepted.

10.7. Selected contributors

Author	Printing years	Field
A. Levakovič	1920s-1930s	01, 1, 4
J. L. Michailoff	1940s, 1950s	1, 4, 01
B. Emrovič	1950s, 1960s	1
D. Klepač	1950s, 1960s	1, 01
M. Kotar	1980s, 1990s	4, 7
T. Levanič and K. Čufar	1990s	6

01 = textbooks, 1 = tree and primary products, 4 = stand growth and yield, 6 = tree-ring studies, 7 = forest inventory

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11. RUSSIAN FEDERATION AND OTHER COUNTRIES OF THE FORMER U.S.S.R.

General information

Land area: 21,389,990 sq. km (8,259,002 sq. mi.) forest and other wooded land 9,415,300 sq. km (3,635,391 sq. mi.), total forest: 754,958,000 ha (2,915,008 sq. mi.) or 34 % of land area; volume: 112m^3/ha, biomass: 68 tons/ha. (FAO 1995-124: Forest resources assessment).

	Forest land area		
Former U.S.S.R.*	1000 ha	sq.mi.	% of land area
Armenia	329	1,270	11.0
Azerbaijan	992	3,830	11.5
Belarus	625	24,155	30.1
Estonia Rep.	1,915	7,394	42.5
Georgia	2,758	10,649	39.6
Kazakhstan	9,643	37,233	3.5
Kyrgystan	729	2,815	3.7
Latvia Rep.	2,757	10,645	42.7
Lithuania	1,959	7,564	30.0
Moldavian Rep.	315	1,216	9.3
Russian Fed.	771,109	2,977,370	42.5
Tajikistan	410	1,583	2.9
Turkmenistan	4,127	15,935	8.5
Ukraine	9,239	35,673	15.3
Uzbekistan	1,909	7,371	4.5

* SOURCE: Prins, K. and Korotkov, A. 1994. These data are not compatible with those in Annex 1, Table 3 FAO-125, p. 12, because of differences in land classification.

94 % of the forest land of the former U.S.S.R. belongs to the Russian Federation. Out of the total forest land area of the Russian Federation, 47.68 % is located in Eastern Siberia, 21.61 % in the Far East, 12.17 % in the Ural Mountains and 9.84 % in the European North-West.

Round wood production:

Country	Round wood production (m^3)		
	Industrial round wood	Fuel and charcoal	Total round wood
Belarus	9,895,000	819,000	10,714,000
Estonia	1,365,000	928,000	2,293,000
Latvia	2,815,000	700,000	3,515,000
Russian Fed.	187,750,000	56,738,000	244,488,000

SOURCE: World Resources 1996-1997, Table 9.3, p. 220, data 1991-1993

Forest vegetation (for all countries of the former U.S.S.R.):

- Conifers 80.5%
- Broad-leaved 19.5%
- Main species: Siberian larch (*Larix sibirica*) 43.2 %, *Pinus cembra* 32.1 %, *Abies* spp. 23.1 %, Scots pine (*Pinus sylvestris*) 17.2 %, birch spp. (*Betula* spp.) 14.5 %, Siberian spruce (*Picea obovata*) 11.4 %, tremble aspen (*Populus tremula*) 2.3 %, oak spp. (*Quercus* spp.) 1.3 %, European beech (*Fagus sylvatica*) 0.4 %, other broad-leaved species 1 %.

Former U.S.S.R.: Forest vegetation types (Tepleaev 1961):

- Boreal or cool coniferous forests (90 %) in Siberia and northern European part of Russia; main species: *Larix sibirica, Picea obovata, Pinus sylvestris* and *Betula* spp.
- Temperate mixed forests cover large areas in Estonia, Latvia, Lithuania, Belarus, North-Western Ukraine, and Southern Russia; the main species are *Picea abies, Pinus sylvestris, Quercus robur, Tilia* spp. *Acer* spp. In the Far East (Russian Federation) mixed forests have more than 150 species but the most important are identical with those in the previous area plus *Taxus* spp. *Phelodendron amurense, Schizandra chinensis, Pinus koraiensis, Abies holophylla, Quercus mongolica, Tilia amurense, T. mandshurica, Juglans mandshurica.*
- Temperate broad–leaved forests are located in the European part of Russia (*Quercus robur*, *Fraxinus* spp., *Tilia* spp., *Fagus sylvatica*) in the area of Carpathians and Ural mountains.
- Dry forest (silvostepe) cover large areas in Ukraine, Republic of Moldova, Southern Russia and western Siberia.

• Warm temperate moist forests are growing along the Black Sea Coast (Southern Ukraina and Russia, Georgia).

• Dry and semidry forest types are localized in Kazakstan, Turkmenistan, Uzbekistan, Tajikistan and Kyrgystan.

Forestry education and research organizations involved in the areas of forest mensuration and forest management (data of establishment in brackets):

According to Milescu and Alexe (1969) source ("World Forests", Bucharest):

• Forest Academy in Petrograd (Sankt Petersburg, Leningrad) was founded in 1863. Similar institutes were mentioned in Moscow, Kiev, Minsk, Lvov, Voronej, Kazan, Harkov, Arhangelsk, Krasnoiarsk, Briansk.

In FAO sources (Directory of Forestry Education and Training Institutions 1994 and Directory of Forestry Research Organizations, 1995) there are mentioned only the following:

• The Russian Institute of Forest Education and training, Pushkino, Moscow District, (1962).

• Estonian Institute of Forest Researches and Nature Protection; Tartu. (1969)

• Lithuanian Forest Researches Institute, Girionys – Kaunas Region, (1950).

Publications:

• Lesnoe hozeaistvo, Moskva
• Botaniceskii Jurnal, Moskva
• Lesnoi Jurnal, Arhanghelsk
• Referativnîi Jurnal Biologhiia, Moskva
• Nauka
• Lesovedanie

Early events. "While Germany and France were forced into the adoption of forest policies through necessity, after the natural woods had been largely destroyed or devastated, Russia started upon a consecutive forest management, long before the day of absolute necessity seemed to have arrived" (Fernow 1911, p. 253).

• 1732: A number of foresters were imported from Germany and one of them, "forest expert" Fokel advocated the increase of the forest area by sowing oak in the poorly wooded districts (Fernow 1911, p. 262).

• 1800: A course in forestry at the Naval Academy (Fernow 1911, p. 270).

• 1803-1808: Several separate schools were established.

• 1813: A Forest Institute in Petersburg. This institute became the Forest Academy in 1863.

• 1840: A regular forest organization was first attempted in the forests attached to the iron furnace properties" (Fernow 1911, p. 274).

- 1843: V. S. Semenov "Taksatsiya lesa" (Forest mensuration) textbook.
- 1840s: The first forest inventories.
- 1840-1850: The first attempt to prepare Russian growth and yield tables by count Vargaci de Bedemar.
- 1858: F. von Arnold's "*Lesnaya taksatsiya*" (Forest mensuration, first edition).
- Since 1866: Annual reports are published by the Russian Forest Administration.
- Since 1870: Lesnoj Journal
- 1888: Promulgation of "A comprehensive law for the conservation of forests, private and otherwise, which in many respects resemble the French, in other respects the Swedish conservation laws" (Fernow 1911, p. 263).
- 1888: The secondary schools were established after Austrian model for rangers and under foresters.
- 1895: Arlond's history of forestry in Germany, France and Russia.

Literature for general information: Arnold 1890 (translation in German in 1893), Rudzki and Shafranov 1893, Les Forêts de la Russie (Russian Forests) 1900, Fernow 1907 and 1911 (2nd edition), Anuchin 1958, Tsepleaev 1961, Algvere 1966, Vasiliev 1961, Milescu and Alexe 1969, Barr and Braden 1988, Prins and Korotkov 1994.

11.1. Selected books, textbooks, and handbooks containing information on forest mensuration, printed between 1843 and 1999

The Russian forest mensuration literature is impressive. For a period of 156 years we selected 56 textbooks out of which 11 are "Forest mensuration" treaties, some of them published in many editions.

According to Anuchin (1952,1960) "the regular forest inventories were started in prerevolutionary Russia only in the 1840s" (p. 438, English version, 1970)

Anuchin (1970) considered that the term "forest mensuration" implies mainly the determination of the volume of whole tree and its parts, the stock of wood in stands, the age and increment of individual trees and entire stand.

As far as we know the first forest mensuration book was written on behalf of the Ministry of State Estates by V. S. Semenov, who examined different aspects of forest management and presented the determination techniques of tree and stand volumes and increments. Semenov was strongly influenced by the German literature.

The next forest mensuration textbooks were published by Arnold (1858 first and in 1868 the second edition) and Zobov (1873), the last one based entirely on

Baur's works and dealt with forest mensuration alone, independent of the forest management. The influence of the German literature was reinforced especially by the publication in 1878 of the translation in Russian of Kunze's "*Lehrbuch der Holzmesskunst*" (Forest measurement, Berlin 1873) and Baur's "*Die Holzmesscunde*" (Forest mensuration, Berlin 1860). A reaction came in a very short time by a paper published by A.F. Rudzskii (a well-known Russian scientist) in "Lesnoi zhurnal" no.1, 1880, under the title "*O soderzhanii i napravlenie lesnoi, taksaţii*" (On the scope and direction of forest mensuration), in which he rejected the German school in forest mensuration. "He considered the German texts on the subject to be divorced from practical needs" (Anuchin 1970, English translation p. 438). Rudzskii wrote his own "Forest mensuration" (1900) and was followed by the following authors of this type of textbooks: Orlov (1923, 1925, 1929 (a remarkable synthesis of scientific achievements in theoretical and practical forest mensuration in the U.S.A. and Western Europe), Turskii (1927), Tyurin (1938, 1945), Sergheev (1940, 1947), Anuchin (1952, 1960, 1970, 1977, 1982), Zacharov (1960, 1967, 1982).

Among the important textbooks it should be mentioned a brief outline of the history of the forest management (Rudzskii 1899), volume and taper tables for the major tree species published in 1913 by the Administration of the imperial Estates, early applications of mathematical statistics in forestry (Golubaev 1929, Bogoslovskii and Zinoviev 1932, Zdoric 1934, 1936). Anuchin's (1943) simplified the forest mensuration methods, which for the first time provided a nomographic method in the Russian forest mensuration literature. It will be compulsory cited: the monumental work on volume tables (1931) completed by Tovstoles et al., and other books written by Tretiakov and Gorski (1934), Tretiakov, Gorski and Samoilovitsch (1940, 1952), Moiseenko and Murasho's assortment tables (1940), Moissenko (1961).

Since 1970 many works have been oriented toward modelling and computerization; Semevsky and Semenov (1982), Kofman (1986), Karev (1993) and the excellent synthesis completed by Chertov, Komarov and Karev (1999).

Anuchin's forest mensuration is the most known among the forest mensurationists and contains the following chapters (English translation 1970):

Part. I. Chapter 1: Methods of forest mensuration; Ch. 2: Mensuration, measurements and techniques. Part. II. Measurement of first products; Ch. 3: Inventory of round timber; Ch. 4: Measurements of fuelwood and other small timber classes; Ch. 5: Measurements of sawn, cleft, hewn and other Kinds of timber. Part. III. Measurement of standing trees by means of volume tables: Ch. 6 Measurement of standing trees; Ch 7: Volume tables Part. IV. Measurement of stands; Ch. 8: Inventory characteristics of stands; Ch. 9: Enumeration; Ch. 10:

Determination of stand volumes from sample trees. Part V: Grading of timber into log classes: Ch. 11: Estimating log class yields by single–tree log. Class tables; Ch. 12: Determination of log classes by stand log class tables; Ch. 13: Determination of log classes by single trees; Ch. 14: Estimating the log class yields in a forest by the cross–cutting of sample trees. Part. VI: Measurement of increments; Ch. 15: Determination of the increment of trees; Ch. 16: Determination of the increment of stands; Ch. 17: Yield of stands. Part VII: Measurement of forest regions, allocation and inventory of felling areas; Ch. 18: Dividing the forest into management units; Ch. 19: Allocation of felling areas; Ch. 20: Economic appraisal of felling areas. Conclusions.

It should be observed that there is no chapter assigned to tree form, and its indicators such as form factor, quotient factors, etc. that are treated on a large scale especially in the German forest mensuration books.

Anuchin proposed only for $f_{1.3}$ formula $f_{1.3} = bk_s + b_o$ where k_s is the Schiffel form quotient and it is equal with $d_{0.5}/2$, while Zacharov (1961, 1967) has a chapter for the form quotients. The problem of tree form and growth was developed in a special book by Kofman and published in 1986. A list of selected textbooks, containing information on forest mensuration or having connection with this discipline is shown in Table 11.1.-1.

Cited authors:

Anuchin 1940, 1943, 1951, 1952, 1960, 1971, 1982; Anuchin et al. 1931, Arnold 1858, 1868; Baur 1860, Bogoslovskii and Zinoviev 1932, Chertov 1981, Chertov et al. 1999, Glavnoe upravlenie udelov (Main Administration of the Imperial Estates) 1913, Golubaev 1929, Gorskii 1950, Karev 1993, Kofman 1986, Kondratiev 1933, Kondratiev et al. 1923, Kosharnovskii 1950, Kozlovskii and Pavlov 1967, Kunze 1878, Ministerstvo lesnogo khozyaistva SSSR (Ministry of Forestry of the USSR), 1949, Mitropolski 1961, Moiseenko 1961, Moiseenko and Murashko 1940, Moshkalev 1984, Ovanesova and Uchenkov 1964, Orlov 1923, 1925, 1929, 1931; Polevoi 1954, Rudzskii 1872, 1899, 1900; Semenov, V. S. 1843, Semevsky and Semenov S. M. 1982, Sergheev 1940, 1947, 1953; Tkachenko 1912, Tovstoles et al. 1931, Tretiakov and Gorski 1934, Tretiakov et al. 1940, 1952, Tsentralinyi nauchnoissledovateliskii institut lesnogo, khozyaistva (Central Research Institute of Forestry) 1937, Turskii 1872, 1927; Tyurin 1938, 1945, Tyurin et al. 1945, 1956; Utkin 1975, Vaganov et al. 1985, Voropanov 1961, 1962, 1963, 1965, 1970; Zacharov 1961, 1967; Zagreev and Vaghin 1975, Zdorik 1934, 1936, 1952; Zobov 1873.

TABLE 11.1.-1. Selected books, manuals and tables containing information on forest mensuration

Year	Author(s)	Title	Remarks
1843	V. S. Semenov	Taksatsiya lesa [Forest mensuration]	Written on behalf of the Russian Ministry of State Estates
1858 (1868 2nd edn)	F. Arnold	Lesnaya taksatsiya [Forest mensuration]	The second edition dealt with forest mensuration in conjunction with forest management
1873	N. M. Zobov	Lesnaya taksatsiya [Forest mensuration]	Dealt only with forest mensuration and based on German works (Baur 1860)
1878	Franz Baur	Russian translation of "Die Holzmesscunde" [Forest mensuration]	Published in Berlin
1878	M. F. Kunze	Russian translation of the German "Forest Measurement": "Lehrbuch der Holzmesskunst".	
1872(?)	A. F. Rudszkii	Lesnaya taksatsiya [Forest mensuration]	
1872	M. K. Turskii	Tablitsy dlya taksatsii lesa [Forest mensuration tables]	
1899	A. F. Rudzskii	Kratkii ocherk istorii lesoustroistra [A brief outline of the history of forest management]	Sankt–Petersburg (Petrograd), Izd. A. F. Devriena.
1900	A. F. Rudzskii	Lesnaya taksatsiya [Forest mensuration]	Sankt–Petersburg (Petrograd), Izd. A.F. Devriena.
1912	M. Tkachenko	Das Gesetz des Inhalts der Baumstämme und seine Bedeutung für die Massen- und Sortimentstafeln [Law of stem content and its importance for volume and assortment tables]	Published in Berlin.
1913	Glavnoe upravlenie udelov [Main Administration of the Imperial Estates]	Tablitsy massy, sbega i drughie dlya glavneishikh drevesnych porod [Tables of volume, taper, etc. for major tree species]	Sankt–Petersburg (Petrograd)
1923	A. I. Kondrat'ev M. G. Groshevoi M. I. Egorov et al.	Ratsionalizatsiya sposobov Promyshlennoi taksatsii rastushego i srublennogo lesa [More efficient commercial forest mensuration methods for standing and felled trees]	Moskva - Leningrad , Goslestekhizdat.

TABLE 11.1.-1. (cont.)

Year	Author(s)	Title	Remarks
1923 1st edn., 1925 2nd edn., 1929 3rd edn.	N. M. Orlov	Lesnaya taksatsiya [Forest mensuration]	3rd edn. Leningrad, Izd. Leningradskogo lesnogo instituta
1927	G. M. Turskii	Lesnaya taksatsiya [Forest mensuration]	Maskva, Izd. "Novaya derevnya"
1929	V. V. Golubaev	Elementy matematicheskoi statistiki v prilozhenii k lesnomu delu [Elements of mathematical statistics as applied to forestry]	Moskva, Sel'khozgiz
1931	N. P. Anuchin M. I. Egorov M. G. Groshev (compilers)	Sortimentnye tablitsy dlya sosny, eli, duba, berezy i osiny [Single-tree log class tables for pine, spruce, oak, birch and aspen]	
1931	M. M. Orlov	Lesnaya uspomogatel'naya Knizhka dlya taksatsii i technicheskikh raschetov [Forestry handbook for measurement and technical computations]	8th edition Moskva-Leningrad, Sel'khozgiz 8 editions in 25 years, the first edn. probably in 1923.
1931	D. I. Tovstoles V. K. Zakharov B. A. Shustov A. V. Tyurin	Masovye tablitsy dlya sosny, eli, duba, berezy i osiny po classam bonitetov [Volume tables for pine, spruce, oak, birch and aspen by site classes]	Written on special assignment by the government
1932	S. A. Bogoslovskii V. P. Zinovév	Statisticheskii metod ucheta lesnykh resursov [Statistical method for calculating forest resources]	Moskva – Leningrad, Goslestekhizdat
1933	A. I. Kondrat'ev	K voprosu o metode issledovaniya syr'evykh baz dlya lesnoi i bumazhnoi promyshlennosti [Method for investigating the resources ofraw materials for the timber and paper industry]	Moskva – Golestekhizdat
1934	N. V. Tretiakov P. V. Gorskiy	Vyiavlenie tovarnosti drevostoev sosny i eli na korniyu [Determination of merchantable stand volume of standing Scots pine and fir]	Golesbumizdat Moskva - Leningrad

TABLE 11.1.-1. (cont.)

Year	Author(s)	Title	Remarks
1934	M. G. Zdorik	Primenenie teorii statistiki v lesnom khozyaistve [Application of the theory of statistics in forestry]	Lesopromyshlennoe delo No. 1, 1934
1936	M. G. Zdorik	Statistika dlya lesnykh spetsialistov [Statistics for forest experts]	Moskva – Leningrad, Golestekhizdat
1937	Tsentral'nyi nauchno-Issledovatel'skii institut lesnogo khozyaistva	Voprosy lesnoi taksatsii (sbornic trudov) [Central researches institute of forestry. Problems of forest mensuration (Collection of works)]	Moskva – Leningrad Goslestekhizdat
1938, 1945 2nd edn.	A. V. Týurin	Lesnaya taksatsiya [Forest mensuration]	Moskva, Goslesbumizdat
1940	N. P. Anuchin	Osnovy lesnoi taksatsii [Principles of forest mensuration]	Izd. GUUZ Narkomlesa SSSR
1940	F. P. Moiseenko A. G. Murashko	Novye sortimentnye tablitsy dlya sosny, eli, duba, ol'khi, osiny i graba [New assortment tree class tables for pine, spruce, oak, alder, aspen and hornbeam]	No. 3. – Gomel Izd. Belorusskogo NIILKh.
1940	P. N. Seergheev	Lesnaya taksatsiya [Forest mensuration]	Moskva
1940 1952 2nd edn	N. V. Tretiakov P. V.Gorskiy G. G. Samoilowitsch	Spravochnik taxatora [Forester's handbook]	Moskva – Leningrad, Goslesbumizdat
1943	N. P. Anuchin	Upproschennye metody Taksatsii lesa [Simplified forest mensuration methods]	Moskva – Leningrad, Goslestekhizdat
1945	A. V. Tyurin	Taksatsiya lesa [Forest mensuration]	Moskva – Leningrad, Goslestekhizdat
1945 1956 2nd edn.	A. V. Tyurin M. I. Naumenko P. V. Voropanov	Lesnaya vspomogatel'naya Knizhka [Forestry hand book]	Moskva – Leningrad Goslesbumizdat
1947	P. N. Sergeev	Lesnaya taksatsiya [Forest mensuration]	Moskva – Leningrad Goslesbumizdat
1949	Ministerstvo lesnogo Khozyaistva SSSR [Ministry of Forestry of the USSR]	Instruktsiya dlya takjsatsii Lesosek [Instructions for mensuration of felling areas]	Moskva- Leningrad Goslesbumizdat

TABLE 11.1.-1. (cont.)

Year	Author(s)	Title	Remarks
1950	P. V. Gorskii	Rukovodstvo dlya prokhozhdeniya letnei i zimnei praktiki po lesnoi taksatsii [Hand book for guidance through summer and winter forest mensuration]	Printed in Petrozavodsk
1950	N. A. Kosharnovskii	Spravochnik po taksatsii Lesomaterialov [Handbook of timber measurements]	Moskva- Leningrad, Goslesbumizdat
1951	N. P. Anucin	Promischlenaia taksatsiya Lesa [Industrial forest mensuration]	Moskva- Leningrad Goslesbumizdat
1952 1960 2nd edn. 1971 3rd edn. 1982 5th edn.	N. P. Anuchin	Lesnaya taksatsiya [Forest mensuration] Translated into Romanian in 1954, and into English in 1970	Edn. 1 and 2 Moskva – Leningrad, 3rd edn. Lesnaya promyszlenost, Moskva.
1952	M. G. Zdorik	Statistika dlya lesnych Spetsialistov [Statistics for forest experts]	Goslesbumizdat
1953	P. N. Sergeev	Lesnaya taksatsiya [Forest mensuration]	6th edn. Moskva – Leningrad 1953
1954	Polevoi	Spravochnik tacsatora [Forestry handbook]	Moskva – Leningrad Golesbumizdat
1960 (1961?) 1967 2nd edn. 1982 5th edn.	V. K. Zacharov	Lesnaya taksatsiya [Forest mensuration]	Gosudarstvenoe Izdat. “Visshaja szkola” Moskva 1961; 2nd edn. Izd. Lesnaya promyschlennost, Moskva 1967.
1961	A. Mitropol’ski	Technica staticheskih Vychislenii [Statistics techniques]	Fizmatghiz
1961	F.P. Moisenko	Tablicy dlya sortimentnogo Uczota lesa na kornyu i metodika ich sostavleniya (sosna, eli, dub, jasień, kliyon, grab, bierioza, lipa) [Assortment tables for standing trees and their method of construction (pine, spruce, oak, ash, maple, hornbeam, birch, lime)]	Edn. 3, Gosudarstvenoe Izd. BSSR, Mińk, 1961.

TABLE 11.1.-1. (cont.)

Year	Author(s)	Title	Remarks
1961-1970	P. V. Voropanov	Lektzii po lesnoy tacsatsii. Brianskii Technolgiczeskiy Institut. [Lessons on forest measurement at Briansk Technology Institut]	Cz I – 1961, Cz.II – 1962, Cz III, ksiazka 1 - 1963, ksiaz. 2 – 1965, ksiaz. 3 – 1970
1964 (1971 English translation)	V. A. Ovanesova V. S. Uchenkov (eds)	Novoe v lesnoi taksatsii [Advances in forest mensuration] No. 48	Lesnaya Promyshlenost Moskva 1964 Translated into English by N. Kaner and edited by C. Porter, Israel Program for Scientific Translations, Jerusalem 1971
1967	V. B. Kozlovskii V. M. Pavlov	[Yield tables for the main forest forming species in Russia]	(In Russian) Izdatel'stvo Lesnaja Promyslennosti, Moskva
1975	A. J. Utkin	Biologhiceskaya produktivnosti lesov. Lesovdenie i lesovdstvo Tom I [Biological productivity of forests]	Moskva
1975	V. V. Zagreev A. V. Vaghin	Osnovy lesnoy tacsatsiy. [Fundaments of forest mensuration]	Izd. Vischaya Schola, Moskva
1981	O. G. Certov	[Ecology of forest lands]	In Russian Nauka, Leningrad
1982	F. M. Semevsky S. M. Semenov	[Mathematical Modelling of Ecological Process]	In Russian Hydrometeoizdat, Leningrad
1984	A. G. Moshkalev et al.	[Reference Book on Forest Mensuration in Russian North-West]	In Russian Forest Technical Academy Leningrad
1985	E. A. Vaganov A. V. Shashkin I. V. Sviderskaya L. G. Vysotskaya	[Histometric Analysis of Woody Plant Growth]	In Russian Nauka, Novosibirsk, USSR
1986	G. V. Kofman	[Growth and Form of Trees]	In Russian Nauka, Novosibirsk
1993	G. P. Karev	[Structural models and dynamics of tree populations]	Doctoral dissertation, Center of Forest Ecology and Productivity, Moscow (In Russian)
1999	Oleg G. Chertov; Alexander S. Komarov; Georgy P. Karev	Modern approaches in forest ecosystem modelling	EFI Research Report 8 – Boston , Leiden, Köln

11.2. Tree and log measurement

Different aspects and techniques for determination of tree volume are included in Semenov's forest mensuration (1843), a lot of them from German literature. Volume determination of felled trees was presented in 1905 in the bulletin of the Sankt Petersburg Forestry Institute. In the same year Osetrov presented the methods for determination of sectional areas of stems and logs.

The method of diagonals for solid volume determination of stacked wood (for paper or fire) in steres was used in 1935 by Tyanin and Ivanov (Tyurin 1945).

Among different formulas for tree volume used in the 1930s and 1940s Tretiakov and Leporski, based on Schiffel's idea, proposed a simple formula

$$V = 0.6623\, d_{½}\, d_{¼}\, l \approx \frac{2}{3} d_{½}\, d_{1/4}\, l$$

where: v = tree or log volume, $d_{½}$ and $d_{¼}$ at 0.5 and 0.25 of l, l = length or height. This formula provided acceptable results for parabolic forms. In the same period, Kositsyn used Gauss–Simony idea and established a formula recommended later by Orlov (1931):

$$V = \frac{\pi}{4} I \left(\frac{d_{0.21} + d_{0.79}}{2} \right)$$

where: $d_{0.21}$ and $d_{0.79}$ are diameters at 0.21 and 0.79 of height (from the base to the top) and l = stem length. This formula gives fair results for all forms of stem. Mathiesen, an Estonian scientist, proposed in 1931 the method of weight center

$$v = \frac{3}{4} l \cdot d_m \sum d$$

where: d_m is the diameter which divided the longitudinal section in two equal parts (lower and upper) and d is a media between large and small dimension of a trapezoidal section (the stem is supposed to be divided into a variable number of sections). Demonstration of this formula may be found in older forest mensuration textbooks.

In 1944, it was published the unional standard GOST 2706 – 44 which refers to volume determination of stacked logs. A sample of these norms is given in Table 11.2.-1.

A pendulum hypsometer and an automatic forest caliper as new devices were described by Makarov (1950) and by Poptsov (1951) respectively.

A method of the study of the tree crown projection was developed by Raspopov in 1955.

TABLE 11.2.-1. Log volume depending on length and diameter at small end.
(Table for stacked logs)

Log length m	When the small end has......cm diameter the log volume is..........m ^{3}									
	21	22	23	24	25	26	27	28	29	30
3.0	0.120	0.130	0.140	0.150	0.170	0.180	0.200	0.220	0.230	0.250
3.5	0.140	0.150	0.170	0.180	0.200	0.210	0.230	0.250	0.270	0.290
4.0	0.160	0.180	0.190	0.210	0.230	0.250	0.270	0.290	0.310	0.330
4.5	0.190	0.200	0.220	0.240	0.260	0.280	0.300	0.330	0.350	0.380
5.0	0.210	0.230	0.250	0.270	0.290	0.320	0.340	0.370	0.390	0.420
5.5	0.230	0.250	0.280	0.300	0.320	0.350	0.380	0.410	0.440	0.470
6.0	0.260	0.280	0.310	0.330	0.360	0.390	0.420	0.450	0.480	0.520
6.5	0.280	0.310	0.340	0.360	0.390	0.430	0.460	0.490	0.530	0.560

SOURCE: USSR state standard GOST 2706 – 44.

Matveev and Matin (1956) established the coefficients for the transformation of stacked wood in solid wood, and Zakharov (1956) proposed more efficient methods for mensuration of standing timber. Dvoretskii (1957) analyzed variability and interrelationships of the mensurational characteristics.

In his first volume on biological productivity of forests, Utkin (1975) proposed different formulas for crown and root system characteristics.

A characterization of the crown form of the main forest species from photogrammetrical point of view was published by Suhih et al. in 1977.

Cited authors:

Dobrovlyanskii 1905, Dvoretskii 1957, Makarov 1950, Mathiesen 1931, Matveev and Motin 1956, Osetrov 1905, Poptsov 1951, Raspopov 1955, Semenov 1843, Sushih et al. 1977, Tyurin 1945, Utkin 1975, Zacharov 1956.

11.3. Tree form

In 1899, Mendeleev proposed for the stem form, a curve having as general equation $y = a + bx + cx^2 + dx^3$, where y is diameter in absolute value at different heights x on the stem and a, b,... are the regression coefficient (quoted after Leahu 1994, p. 16).

Other early Russian works on tree form belong to Orlov, Shusstov and Tkachenko. Orlov and Shustov published in 1912 a paper on volume and taper of pine stems. In the same year Tkachenko published in Berlin a work on stem form laws and their importance for construction of volume and assortment tables.

In 1913 the Main Administration of the Imperial Estates printed tables of volume, taper and other mensurational characteristics for the major Russian tree species. An article was published in 1917 in Lesnoi Zhurnal by Belanovskii about the investigations of the woody stem form.

Zakharov (1929) presented his contribution to studies on the variation in the shape of tree stems in oak stands in relation to mensuration of standing timber mentioning the relationship of form factors ($f_{1.3}$) with other biometrical trees characteristics.

Anuchin (1950) graphically determined the taper of tree stems (Graphical methods for the stems determination were used in the U.S.A. in the 1920s, on a large scale).

Investigations on the stem forms of Norway spruce in Lithuania and construction of taper and volume tables were performed by Butenas (1956).

New contributions on the investigation of the tree stems shape were published in the same period in Russia (1958) by Zacharov, who, later in his forest mensuration textbook (1961, 1967), included a chapter on form factors and form quotients. Computerized (EVM) tables of the stem decreasing diameters (taper) and volume tables were completed in 1968 by Pietrowski. Equation of the stem contour curve using a computerized model was also developed in 1971 by Voinov.

Korotyaev (1984) developed a mathematical model of the crown of northern spruce, presented graphs and equations describing the interrelationships of crown parameters (as lenght, width, cross-sectional area, weight et al. and expressed them in terms of conventional tree parameters as height and stem diameter. The model can be applied in the design improving of logging and transport machines (after Forestry Abstract 1271/1985).

In Belorussia, Mikhnyuk (1984) constructed models of the form factors for stem in natural Scots pine stands showing that the different regression equations and models were needed for stands of different site quality.

A simple adaptive plant model (model description and model analysis) was developed in Estonia by Oja (1985 a, b).

Shavnin (1986) proposed a determination of the stem form by the height of the point of tangency (contact) M. This point M is "where a straight line from the top of the stem to the ground, touches the silhouette of the stem tangentially." The geometry is illustrated and the formulae are derived for determining the stem form from the height of M above ground. The ratio of M to the stem height governs stem form which is the best when M is ≤0.1 of stem height, moderate when M is 0.11–0.15 and poor when M is >0,15 of the stem height (compiled after Forestry Abstracts 753/1987).

In the Irkutsk region a study on felled *Pinus sibirica* trees was developed by Kofman et al. (1989), testing different formulas to establish the interrelations of form factors, form and dimensions of tree stems (accuracy in calculating the form factor from the stem height and the form quotient). Results indicated that these universal relations (Schiffel, Karpov) and three theoretically derived formulae are not inferior in accuracy to the regression equations (local tables) (After Forestry Abstracts 8761/1992).

A study of the form of the aspen stems, modelling their form factors, was completed in 1989 by Kuleshis et Gudas in Lithuania.

Another single tree model of a pine stand in a raw humus soil ecosystem was constructed in 1990 by Chertov.

In 1994 Popov et al. tested Behre's formula (U.S.A.) and Höjer's formula for the stem volumes determination of *Pinus sylvestris* and *Pinus sibirica* trees. These formulas are taper functions, Behre's hyperbold proved to be the most suitable formula for calculating stem volume and taper, giving a greater accuracy than Huber's formula for volume and acceptable accuracy for taper.

For the first time in Russia, Berezovskaya et al. (1993) tried a fractal approach (use of fractal geometry) to the computer–analytical modelling of the tree crown, and Gurtsev et al. (1997) established a fractal structure of a branch.

Cited authors:

Anuchin 1950, Belanovskii 1917, Berezovskaya et al. 1993, Butenas 1956, Glavnoe upravlenie udelov (Main Administration of the Imperial Estates) 1913, Gurtsev 1997, Kofman et al. 1989, Korotyaev 1984, Kuleshis and Gudas 1989, Leahu 1994, Mikhnyuk 1984, Orlov and Shustov 1912, Pietrowski 1968, Popov et al. 1994, Shavnin 1986, Tkachenko 1912, Voinov 1971, Zakharov 1929, 1958, 1961, 1967.

11.4. Tree volume tables

Early Russian volume tables were compiled under the guidance of Kryudener (1904–1913). These tables with seven independent variables (species, region, forest type, positional class of tree in the canopy, age, height, diameter) were rejected by practice because of the difficulties of their application. In 1909, Kositsin investigated the theoretical ground of specific volume tables for birch and considered it as disputable.

The construction of general (unional) volume tables has began since 1928 (on special assignment by the government), under Orlov's leadership and completed by Tovstoles (Scots pine), Zaharov (Norway spruce), Shustov (oak), Tyurin (birch and trembling poplar) and published in 1931 (Tovstoles et al. 1931). These tables were constructed according to the site classes and in spite of the fact that the basic data were new, their authors maintained the principle of old Russian volume tables (1870) in which the trees were divided according to diameter and height by classes called "tables by site classes" or tables by height categories, and an example of this type of tables is presented in Table 11.4.-1.

TABLE 11.4.-1. Russian volume tables for spruce known as "tables by site classes"

Dbh	Height categories (classes), h= height m, v= volume in m³											
ob	I[a]		I		II		III		IV		V	
cm	h	v	h	v	h	v	h	v	h	v	h	v
4	5	0.004	4	0.004	4	0.003	3	0.003	2	0.003	-	-
8	12	0.031	11	0.029	9	0.026	8	0.024	7	0.021	6	0.019
12	17	0.095	15	0.086	14	0.080	13	0.074	11	0.068	10	0.062
16	21	0.208	19	0.190	18	0.178	16	0.162	14	0.147	13	0.133
20	25	0.365	23	0.343	21	0.320	19	0.294	17	0.268	15	0.238
24	27	0.581	25	0.544	23	0.503	21	0.464	19	0.422	17	0.385
28	30	0.854	28	0.792	25	0.741	23	0.684	21	0.624	19	0.564
32	31	1.170	29	1.094	27	1.023	25	0.944	22	0.864	20	0.782
36	33	1.533	31	1.452	28	1.353	26	1.253	24	1.143	21	1.033
40	34	1.954	32	1.843	29	1.723	27	1.601	25	1.460	22	1.322
44	35	2.424	33	2.284	30	2.140	28	1.993	25	1.820	-	-
48	35	2.941	33	2.774	31	2.603	29	2.422	26	2.215	-	-
52	36	3.494	34	3.294	32	3.093	29	2.904	27	2.653	-	-
56	36	4.082	34	3.864	32	3.638	30	3.413	-	-	-	-
60	37	4.723	35	4.480	32	4.221	30	3.974	-	-	-	-
64	37	5.412	35	5.144	33	4.832	-	-	-	-	-	-
68	37	6.138	35	5.854	33	5.509	-	-	-	-	-	-
72	37	6.920	35	6.604	33	6.211	-	-	-	-	-	-
76	37	7.752	35	7.375	-	-	-	-	-	-	-	-
80	37	8.593	36	8.173	-	-	-	-	-	-	-	-

SOURCE: Zakharov, V. K. in Tovstoles et al. 1931: "Massovye tablitsy dlya sosny, eli, duba, bevezy i osiny po klassam boniteta" (Volume tables according to site classes for pine, spruce, oak, birch and aspen), Moskva–Leningrad, Sel'kolkhozgiz, 1931

In 1932, Tkachenko established a rule of the trees stem volumes and its significance in volume and single-tree timber class tables. The problems of determination of the volume of logs and standing trees were discussed later by Dementiev (1950). Anuchin (1953) developed volume tables for tree–length logs and, in 1958, constructed the volume tables for top timber classes (vershinnykh lesomaterialov).

A lot of local and general volume tables were included in different handbooks as those compiled by Orlov (1931, 8th edn. in 25 years), Tretiakov (1940,1952) and Tyurin–Naumenko –Voropanov (1945, 1956), and a special chapter is assigned to volume tables in Anuchin's forest mensuration (1952, 1960, 1970, 1982).

The construction of volume tables and assortment tables based on mathematical computerized models was developed since the 1970s (Voinov 1971, Belarus).

Cited authors:

Anuchin 1952, 1953, 1958, 1960, 1970, 1982; Dement'ev 1950, Kozitsin 1909, Kryudener 1908–1913, Orlov 1931, Tovstoles et al. 1931, Tretiakov 1940, 1952; Tkachenko 1932, Tyurin-Naumenko–Voropanov 1945, 1956; Voinov 1971.

11.5. Tree growth

Elements of current increment and their correlation were examined in 1936 by Naumenko. Dvoretskii (1953) studied and demonstrated the linear changes of the tree stem increment along its length, Kostin (1961) investigated the influence of the solar activity on the tree growth and Smirnov (1964) used a micrometric technique on the periodical wood samples extracted with a time blade to establish the seasonal growth of the main forest trees. In 1968, Proskuriacov used a Pressler borer attached to a mechanical saw.

In 1975, Zeide examined the problem of modelling tree growth and three years later Rachko (1978) constructed a simulation model of the growth, Lovelius (1979) investigated tree growth variability: dendroindication of natural processes and anthropogenetic impacts (230 pp.).

Bujak and Karpov (1983) developed a comparative analysis of the radial increment dynamics.

Remarkable contributions were completed by Kiviste (Estonia) in the field of tree growth functions: 1982 - suitability of different growth functions for approximating the index rows calculated by V. V. Zagreev (development of a tree height growth model for *Pinus* plantations); 1984 - growth functions from theory to practice, growth–models; 1988 - mathematical functions of forest growth (a collection of 75 growth functions, Zeide's, Garcia's, Chapman–Richards' and Schumacher's being considered as the most "popular"). Chertov (1983) presented a qualitative approach to the species' ecological parameters evaluation with special reference to Scots pine.

In 1984, Kull and Kull presented an ecophysiological model of spruce growth and in the same year Kull' K. and Oja (1984) described the structure of physiological models of tree growth.

Bocharov and Pankov (1986) established the dependence of the current diameter increment on crown length. They examined the correlation between the current annual increment (c.a.i.) and crown length, and concluded (at least in the case of the Norway spruce trees) "that crown diameter percentage cannot be used for selecting trees with diameter increment close to average because crown percentage was not highly variable and diameter increment varied greatly. Crown percentage in trees of identical diameter did not depend on the site conditions. The crown percentage increased with increasing tree diameter. The degree of variation in crown percentage was inversely proportional to tree diameter" (After Forestry Abstracts 3602/1987).

A valuable textbook on growth and form of trees was published in Novosibirsk by Kofman in 1986 (211 pp.). Another remarkable book referring on dynamic modelling of the tree growth was written by Kull K. and Kull O. and published in Tallinn (Estonia, 1989).

Ivask et al. 1991 (Estonia) examined the problem of a fine root turnover. It is known that the estimation of the fine root productivity is not possible without the estimation of their turnover, which accounts for the major part of net primary production. Kull initiated an experiment to determine the decomposition rate of fine roots.

Sukhovolski (1996) modeled the tree growth and inter-connection between forest insects and tree plants: an optimization approach (a Dr. Sci. Thesis at Krasnoyarsk, Siberia).

Cited authors:

Bocharov and Pankov 1986, Bujak and Karpov 1983, Chertov 1983, Dvoretskii 1953, Ivask et al. 1991, Kiviste 1982, 1988; Kiviste and Nilson 1984, Kofman 1986, Kostin 1961, Kull and Kull 1984, 1989, Kull and Oja 1984, Naumenko 1936, Proskuriacov 1968, Rachko 1978, Smirnov 1964, Sukhovolski 1996, Zeide 1975.

11.6. Timber assortments

One of the earliest works on wood assortments was published in 1911 by Tkachenko in Petrograd and refers to the connection between the size of stems and the problem of assortment tables.

In the former USSR grading of timber into log classes was completed by: (1) single tree log class tables; (2) stand log class tables; (3) single trees (sample of trees) and (4) the cross–cutting of sample trees; assortment tables were based on state standards established for different timber assortments. In the former USSR, as well as in Germany, there were constructed two types of assortment tables: (1) based on diameter categories and (2) for the whole stand. The tables of the first type gave the average percentage of different assortments from the tree volume of standing tree considered 100 % in function of diameter and height. The second type of tables provided the percentage of different assortments in the stand depending on average diameter (only) or the average diameter and height. Methods of assortment tables belong to two schools having as leaders Tretiakov and Anuchin both of them based on statistics. Tretiakov advocated regional tables while Anuchin chose general tables. Anuchin argued that for the same species and dimensions there are obtained the same percentage of assortments in the majority of cases. Another simplification introduced by Anuchin is the use of decreasing of the stem (tapering) – technique used in Germany – for the establishment of working timber wood that reduced the measurement works (the statistical material). On the other hand Anuchin established that the average stand height does not influence notably the repartition of stand volume by assortment against a detailed presentation of the assortments which is an argument against a detailed presentation of the assortment tables content.

In 1923, Kondratev et al. proposed more efficient merchantable forest mensuration methods for standing and felled trees. In 1931, there were compiled by Anuchin et al. single tree log class tables for fir pine, spruce, oak, birch and aspen. Tretiakov and Gorski (1934) determined the volume of merchantable wood in standing and felled stands of Scots pine and Norway spruce.

Assortment tables for different species were included in the first (1940) and second (1952) editions of Tretiakov's et al. handbook (*Spravochnic taxatora*).

In 1940, Moiseenko and Murashko published new tree class assortment tables for pine, spruce, oak, alder, aspen and hornbeam (published in Gomel and Minsk in Belarus).

Anuchin published in 1949 assortment and merchantable wood tables for Scots pine, Norway spruce, birch and aspen and in 1951 a textbook on industrial forest mensuration of stand. Another set of assortment tables completed by Anuchin was published in 1954 and refers to Scots pine, Norway spruce, larch, Pinus cembra, fir, birch, aspen, oak and Carpathian beech.

In 1961, were published (3rd edn., Minsk, Belarus) Moiseenko's assortment tables for stands (including the method used for their construction) of: Scots pine, Norway spruce, oak, ash, maple, hornbeam, birch, common alder, tremble aspen and lime. In the same period, Anuchin and Sanin (1950s?) developed merchantable tables for stands of Siberian resinous species.

A textbook on timber hidden defects was written in 1963 by Matveev and Matin.

Until 1933 the forest quality status was expressed by the stand quality taking into account five classes. Class I included the stands with stocking 1.0 and 0.9 and the remaining classes included the stands stocked 0.8-0.7, 0.6–0.5, 0.4–0.3 and 0.2-0.1

Anuchin (English version 1970) noted that it was recently (1960s) proposed that the stands should be classified into merchantable classes based on timber yield:

Merchantable class	Timber yield, % of standing volume	
	coniferous	deciduous
I	>70	>50
II	51 to 70	31 to 50
III	up to 50	up to 50

Anuchin consequently suggested that the stand should be classified into merchantable classes according to the ratios of timber: pine stands containing at least 91 % timber trees were designated to mean merchantable class I, 71 to 90 % to mean class II and 70 % and less to mean class III. In birch stands, merchantable classes I, II and III, respectively contain at least 61 %, 41-60 % and 40 % and less timber trees (Anuchin 1970, p. 221).

Since the 1980s the computers have been used on a large scale for determination of timber assortment in stands – for example Petrosvskii and Dang Zui Sho (1984) derived a series of equations as the basis for compiling programs for computing the volume of any type of assortment in the stands.

Cited authors:

Anuchin 1949, 1951, 1954, 1960, 1970, 1982; Anuchin and Sanin 1950s (?), Anuchin et al. 1931, Kondratev et al. 1923, Matveev and Motin 1963, Moiseenko F.P.1961, Moiseenko and Murashko 1940, Petrovskii and Dang Zui Sho 1984, Tretiakov and Gorski 1934, Tretiakov et al. 1940, 1952.

11.7. Evaluation of forest site quality

"For the cruising of the vast northern forest territories in the second half of the 19th century, the division of the forest into economically homogeneous areas was based on differences in the natural soil conditions. After considerable observations, humidity and relief came to the fore as the chief factors affecting the growth and quality of the forest. According to these factors, forest areas dominated by different tree species were divided into categories subsequently called stand types… A more profound scientific elaboration of the theory of stand types is credited to the outstanding Russian silviculturist, G. F. Morozov (1867–1920)" (Anuchin, English version 1970, p. 211).

The basic principles of forest typology were expressed in a set of articles published by Morozov during 1903-1904 and summarized later in a textbook, in 1930, after his death, by the care of his pupil V. V. Guman. Morozov always recognized that his ideas were not entirely original and similar opinions were expressed by other foresters. It will be mentioned here E. F. Zeablovski, who in one of the first Russian textbook on silviculture "The elementary basis of silviculture", noted that the same species in different site conditions forms different types of stands. In 1843, another silviculturist, A. Dlatovski, proposed classes of productivity as elementary units of forest and for Scots pine he distinguished five productivity classes, and will be mentioned as examples: classes V (the worst): sandy, poor soil with likens as *Tragopogon*, pine stands have a low productivity, class I (the best): clayey–sandy moist chernozem, pine development is high. In 1880–1890, A. F. Rudzki proposed within each species units depending on soil characteristics named sections or site identities and each section to be divided according to the tree mensurational characteristics. Rudzki's pupil, D. M. Cravcinski named Rudzki's site identities as "qualities" (or fertility classes) and in the case of Norway spruce he established three qualities depending on the ground vegetation: (1) with *Oxalis acetosella, Majanthemum bifolium* and moss (Hylocomiaceae); (2) with *Vaccinium vitis–idaea* and *V. myrtillus* and (3) with *Equisetum* spp. (Tkacenco 1952). V. I. Dobrovleanski, another pupil of Rudzki, should be considered as a precursor of the typology forest sites and introduced, the term "type of ground" or "type of land" for silvicultural purposes.

Morozov, foundationer of the Russian forest typology considered "the stand type" as an elementary unit, the major criteria for the differentiation of stand types are the ecological conditions and especially soil characteristics and stand species composition (but not as a major characteristic). Later, "stand type" was replaced by "forest type" term. For the uncovered ground with forest vegetation, Morozov introduced the term "site type".

The history of forest typology is complicated and cannot be detailed here, this field being beyond the scope of this book. It is important to mention that in the former U.S.S.R. based on Morozov's primary studies two different schools evolved: the Sukachev school and the Pogrebniyak school in Ukraine. In Sukachev conception the forest type is established depending on the predominant tree species and other characteristics such as stand productivity, regeneration and succession, and ecological conditions, respectively a site is considered included in "forest type". Based on ecological criteria, the forest types can be included in a greater unit: series that contains forest types with different tree species composition but, having the similar ecological conditions. (Sukachev 1931). In this way Sukachev's series correspond with the Cajander's (Finland) forest type and the type of forest land of the Ukrainean typology of Pogrebnyak.

In the Ukrainean school conception the most important unit of classification is "type of forest land" or "type of forest territory" or "type of site conditions" that is established in accordance with two basic soil criteria: nutritional quality (A = soil very poor [bor]), B = poor, (subor), C = rich (sugrudoc), D = very rich (grud) and six grades of humidity (o = very dry soils, 1 = dry, 2 = damp, 3 =

moist, 4 = humid, and 5 = wet). Within every type of forest land may be included a different number of forest types – in Sukachev sensu (Pogrebnyak 1944).

In 1945, Sukachev published a textbook on forest types and forest growing conditions and later developed the biogenocenology – a study of a whole cenose (vegetals, animals, ecological factors) (Sukachev and Dylis 1964) – which is an ecosystemical conception of study. Researches on forest ecosystems have been completed by Utkin (1975) and many other researchers. In 1974, the forest influence of climatic factors on the forest productivity was an indirect way to evaluate the site quality (Lositskii 1974).

On the other hand, the forest site quality for a given species can be evaluated using the height of yield classes tables or the height values of Orlov's scale ('20s) constructed for all species (see 11.9.1.).

The relationships between ground vegetation and current increment of stands and site class have been investigated by Dimitrievna (1987) in the Buzuluk forest where Morozov began many years ago his studies on forest typology. Dimitrievna identified five groups of pine forest types:

	Site class
1. Pinetum cladinosum	IV
2. Calamagrostis types	III
3. Mossy types	II
4. Mossy – herbaceous types	I
5. Pinetum compositum	Ia

In Lithuania, Kuleshis (1987) developed a universal model for a dynamic determination of site class for the growth of Scots pine. This model refers to height growth of the even-aged stands and nominally even-aged stands from the age of maximum increment until they become overmature (20-130 yr). The standard height curve provided by the model was tested against 58 general or local height curves from 20 different Soviet yield tables and one table from Finland and the results demonstrated the validity of the model. In this way the evolution of site may be completed via height (height cumulative growth).

Tsvetkov and Zyabchenko (1984) "argued that silviculture and forest management must be organized on a differentiated zonal basis according to the forest types present" (For. Abs. 3283/1985).

Cited authors:

Dimitrievna 1987, Kuleshis 1987, Lositskii 1974, Morozov 1930, Orlov 1923, 1925, 1929; Pogrebnyak 1944, Sukachev 1931, 1945; Sukachev and Dylis 1964, Tkachenko 1952, Utkin 1975.

11.8. Stand structure and modelling of stands, forest biocoenoses and forest ecosystems

Among early description of stand structure iy will be mentioned Shustov's (1916) study on coppice and oak stand in Southern Russia, and Müller's (1919) presentation of Scots pine and Norway spruce mixed stands. Later, the stand structure of different stands was investigated by Levin (1949) -pine stands in the Arkhangelsk region, Dudarev (1950) - structure and growth of pine stands in the Bryansk forest region from long-term observations of permanent sample plots, Davidov (1951) - beech stands, Vaschnil and Anuchin (1959) - merchantable structure, Gusev (1962) - structure and growth of Norway spruce stands in Archangelsk region. A complex study on species composition, stand structure and size distribution of trees was performed by Pakhutchij (1995) in the virgin forest of the Komi Republic (Ural) which offers a good opportunity to study the natural processes of this type of boreal forests in taiga. The dominating species in growing stock of these forests are *Picea obovata, Pinus sibirica* and *Abies sibirica,* and about 50 % of investigated stands, having two or three stories, contains 600-2200 trees/ha and wind falls and wind breaks with local gaps (0.006-0.3 ha) are common.

An early study on variance of distances between trees was carried out in 1927 by Leskov.

In a remarkable work named "The law of unity in the structure of forest stands" Tretyakov (1927) presented his theory of "stand elements". Tretyakov considered that the "stand element" is the last unit up to which the forest can be divided. The stand element is defined by Tretyakov as a pure, homogenous stand having the same age or a part of a mixed stand, multi-storied or multi-aged formed by trees that belong to the same age and located in the same story and from the age point of view they belong to the same generation and whose development and site conditions are homogenous. The problem of stand elements was discussed later from mensurational point of view (1955). In 1957, Gorskii analyzed the forest elements and structural normality of stands which are forming the forest elements.

Levin (1955) established the normal relationship and variation of some inventory characteristics in the even-aged pine stands occurring with green mosses, and in 1957 determined the interrelationships and variation of the major mensuration characteristics of pine and spruce in the forests of the Arkhangelsk region.

In 1956, Gorshechnikov presented the Bitterlich's method and device as an original technique and instrument for stand stocking determination. Shiyatov investigated in 1965 the age structure and formation of low-density larch stands at the upper timberline in the Sob river basin (Polar Urals). Shavin (1988) proposed to express the stand density by the relationship of the mean height or mean diameter to the mean distance between the trees and named this indicators as “density by diameter” and “density by height”. He presented relevant formulae and the use of the Bitterlich relascop in this connection (density by diameter depends on the stocking). Shavnin presented two examples “the compilation of density tables and standing volume tables in which the stand density is replaced by “density by diameter“, and the construction of a tabular model of a wind resistant Norway spruce stand, showing for diameter classes 16,20…48 cm, the stems number per hectare, absolute density, density by diameter” and the wind speed at which windthrow begins (compiled after Forestry Abstract 821/1991).

Models concerning stand structure depending on height were developed by Mitropolsky (1961). Later (1986), Gusev studied changes in the height variation of trees in the taiga spruce forest and noted that in the even-aged stands the height variations depends on stand age but in general, the tree height variation depends on the type of the age structure, variation increasing with the increasing complexity of the age structure. Periodical behavior of the age-distributed tree populations was investigated also by Korzukhin et al. 1989).

Ganina (1984) discussed the features and advantages of the Weibull function as a model of the distribution for trees by diameter in an uneven-aged stand.

An exponential equation was proposed by Ciuenkov (1975) for the decrease of number of trees in connection with age, in even-aged stands.

Collective self-oppression in a uniform plant community and oscillating changes of the biomass of its members – a useful work for forestry – were investigated in 1979 by Galitsky.

The problem of trees mortality was studied by Shvidenko et al. (1995) - a system for evaluation of growth and mortality in Russian forest, and Vagin (1995) - natural mortality of spruce stands in the Moskow region. Vagin determined the regularities of tree mortality distribution by diameter classes and the fact that the number of dead trees and their volume distribution were well-characterized by Pearson distribution type III, he constructed a table of natural mortality of spruce stands for this region. In the same year, Komarov and Grabarnic (1980) developed a statistical analysis of spatial patterns based on methods using distances between nearest neighbours, while Gates (1980) analyzed the bimodality between two types of plants located at random on a lattice useful for forestry. In the same year Grabarnik and Komarova developed a statistical analysis of spatial structures and methods using distances between points.

Since the '80s modelling in the field of stand structure has been used on a large scale. Cherkashin (1981) proposed a model of spatial and age structure of forest, Grabarnik (1981) modelled spatial structure of Scots pine stands, Abzarko (1983) investigated spatial distribution and root biomass dynamics, Galitsky et al. (1982) tried modelling of the spatial pattern of genetic structure of the population, Gavrikov (1985) studied age dynamics in tree populations. Among other papers on modeling stands we noted: Karev's (1985) modelling of multi-species tree stands, Oja's (1989) modelling of succession of tree stand, Berezovskaya a and Karev's (1990) mosaic conception of spatial-temporal structure and tree stand dynamic modelling, Grabarnik's et. al. (1992) analysis of the stand spatial structure using correlation measures, Karmanova's et. al. (1992) mathematical models of spatial structure of forest community, Gavriko's et. al. (1993) trunk-top relations in a Siberian pine forest, Karev's (1993) structural models and dynamics of tree populations, Chumachenko's et. al. (1996) simulation modelling of heterogeneous uneven-aged stands spatial dynamics taking into account silvicultural treatment, and Karev's and Skomorovski's (1998) modelling of dynamics of single species tree stands.

A lot of papers were published on modelling of coenoses (biogeocoenoses, ecosystems) and some of them will be mentioned here: Poletaev's (1966) comments on mathematical models of elementary processes in biogeocoenosis, structure of forest biocoenoses (Dylis 1969), Chetverikov's (1985) modelling of forest biogeocoenoses, Busykin et. al. (1985) - analysis of forest cenoses structure, Busykin et. al. (1987) - the structure of forest coenoses, Galitski and Komarov (1987) - discrete models of plant populations, Gressakov and Fradkin (1990): computer simulation of the spatial structure of the forest biocenoses, Berezovskaya et al. (1991) - eco-physiological approach on modelling stands dynamics, Papadyuk and Chumachenko (1991) - biological simulation model of many-species uneven-aged tree stand development, Chumachenko (1992) - bioecological model of uneven-aged forests cenosis, Gussakov and Fradkin (1992) - methods of the modelling space structure of forest phytocenoses, Alekseev (1993) - size structure of tree plant populations: its principal types mechanisms of formation and use in theoretical analysis, Chertov and Komarov (1995) - dynamic modelling of Scots pine, Norway spruce and silver birch ecosystems in European boreal forests, Berezovskaya and Karev (1997) - new approaches to qualitative behaviour modelling of complex systems, and the remarkable synthesis written by Chertov, Komarov and Karev (1999) - modern approaches in forest ecosystem modelling, Karev (1995 a) - models of one generation tree population and coenoses formation, Karev (1995 b) - dynamics of forest ecosystem as a cenon metapopulation.

Examples of recently developed simulation models: Chertov and Komarov (1997) - simulation model of Scots pine, Norway spruce and silver birch ecosystem; Certov et al. (1988) - a combined simulation model of Scots pine, Norway spruce, silver birch ecosystems in the European boreal zone

Jögiste (1996) from Estonia provided interesting data on the effect of structure on growth, namely the effect of birch proportion on the growth of spruce and birch in mixed stands. Measuring diameter growth patterns of spruce (*Picea abies*) and birch (*Betula pendula* and *B. pubescens*) in even-aged mixed stand a higher proportion of birch in the stand reduced growth of both spruce and birch but the faster growth of birch compensates for the growth reduction of spruce in total stand growth.

Cited authors:

Abrazko 1983, Alekseev 1993, Anuchin 1955, Berezovskaya and Karev 1990, 1997 Berezovskaya et. al. 1991, Busykin et al. 1985, 1987; Cherkashin 1981, Chertov and Komarov 1995, 1997, Chertov et. al. 1998, Chertov, Komarov, Karev 1999, Chetverikov 1985, Chumachenko 1992, Chumacenko et al. 1996, Ciuencov 1975, Davidov 1951, Dudarev 1950, Dylis 1969, Galitsky 1979, Galitsky and Komarov 1987, Galitsky et al. 1982, Ganina 1984, Gates 1980, Gavrikov 1985, Gavrikov et al. 1993, Gorshechnikov 1956, Gorskii 1957, Grabarnic and Komarova 1980, Grabarnik and Komarov 1981, Grabarnik et al. 1992, Gusev 1962, 1986; Gussakov and Fradkin 1990, 1992, Jögiste 1996, Karev 1985, 1993, 1995 a, 1995 b; Karev and Skomorovski 1998, Karmanova et al. 1992, Komarov and Grabarnik 1980, Korzukhin et al. 1989, Leskov 1927, Levin 1949, 1955, 1957; Mitropolski 1961, Müller 1919, Oja 1989, Pakhutchij, Papadyuk and Chumachenko 1991, Poletaev 1966, Shavnin 1988, Shiyatov 1965, Shustov 1916, Shvidenko et al. 1995, Tretyakov 1927, Vagin 1995, VASCHNIL and Anuchin 1959.

11.9. Stand growth and yield. Growth modelling

11.9.1. Stand growth and yield

Techniques and data for stand growth and increment determination can be found in the early Russian treatise on forest mensuration ("*Taksatsya lesa*") written by Semenov (1843).

Since 1850 local and regional studies on stand growth and yield (some of them contains yield tables) have been carried out in different parts of Russia and later USSR. A small sample of this studies is shown in Table 11.9.1.-1.

During the 1920-1931 period Soviet forest mensuration "produced original investigations of the normalities governing the structure of stands. Workers in this field included prof. A. V. Tyurin, prof. N. V. Tretyakov and others. Tyurin's "*Vseobshchie tablitsy khoda rosta nasajderii*" (Universal yield tables) were published during the same period."(Anuchin 1970, English edn. p. 439).

TABLE 11.9.1.-1. A sample of regional or local growth and yield studies

Year	Author(s)	Species	Region, country
1850	Vargas de Bademar	Different	Sankt Peterburg province
1913	A. V. Tyurin	Scots pine	Arkhangelsk province
1926	R. V. Lyubimov V. P. Korsh	Normal cedar stands of site class III	Omsk area
1929	B. N. Tikhomirov I. A. Tishchenko	Siberian larch	Khakasskii district of Siberia
1950	A. D. Dudarev	Scots pine	Bryansk forest region
1951	N. V. Ogorodov	Closed spruce and fir stands	Forest types in the northeastern European USSR.
1958	V. V. Antanaitis	Spruce	Lithuania
1962	I. I. Gusev	Spruce	Arkhangelsk province
1966	A. Gradeckas	Spruce and Scots pine	South-western Baltic region
1967	V. M. Grachev	Spruce+ Lime	Northern Gorky region
1970	F. V. Agliullin L. P Kalachev	Spruce and Scots pine closed stands	Tatarskaya ASSR
1980	A. I. Utkin et al.	Scots pine Siberian larch	Kuibyshev region
1986	V. F. Baghinskii R. L. Terekhova	Scots pine + Spruce	Belarus
1987	E. V. Dimitrieva	Different Scots pine forest types	Buzuluk forest

During the above-mentioned period Orlov constructed (as mentioned in 11.7.) a site class scale for yield tables of all species with trees grown from seeds and for coppice. Orlov's scale is presented in Table 11.9.1.-2.

In fact Orlov's classes are absolute and in this system if a stand has an average height of 26 m at 100 years it belongs to the same site class (productivity class) indifferent of species. Orlov established seven site classes.

Another problem of yield tables was to establish the normal level of productivity what Tyurin did, before 1931 (2^{nd} edn) for pine, birch, aspen and spruce stands.

Productivity of common alder at the unional level (USSR) was determined by Davidov (1936).

TABLE 11.9.1.-2. Orlov's criterion of site classes

Age		Site class					
years	Ia	I	II	III	IV	V	Va
			Height of stands from seeds, m.				
10	6–5	5–4	4-3	3-2	2-1	-	-
20	12–10	9-8	7-6	6-5	4-3	2	1
30	16–14	13-12	11 -10	9-8	7-6	5-4	3-2
40	20–18	17-15	14-13	12 -10	9-8	7-5	4-3
50	24–21	20 -18	17-15	14 -12	11-9	8-6	5-4
60	28–24	23-20	19-17	16-14	13-11	10-8	7-5
70	30–26	25-22	21-19	18-16	15-12	11-9	8-6
80	32–28	27-24	23-21	20 -17	16-14	13-11	10-7
90	34–30	29-26	25 -23	22-19	18-15	14-12	11-8
100	35–31	30-27	26-24	23-20	19-16	15-13	12-9
110	36–32	31-29	28-25	24-21	20-17	16-13	12-10
120	38–34	33-30	29-26	25-22	21-18	17-14	13-10
140	39-35	34-31	30-27	26-23	22-19	17-14	13-10
160	40-36	35-31	30-27	26-23	22-19	18-14	13-10
			Height of coppice stands, m.				
5	5	4	3	2	1,5	1	-
10	7	6	5	4	3	2	1
15	11	10-9	8-7	6	5	4-3	2 – 1.5
20	14	13-12	11 – 10	9-8	7-6	5 – 4	3 – 2
25	16	15 – 13	12 – 11	10– 9	8 – 7	6 – 5	4 – 3
30	18	17 – 16	15 – 13	12 – 11	10 – 8	7 – 6	5 – 4
35	20	19 – 17	16 – 14	13 – 12	11 – 10	9 – 7	6 – 5
40	21	20 – 19	18 – 16	15 – 13	12 – 11	10 – 8	7 – 5
45	23	22 – 20	19 – 17	16 – 14	13 – 11.5	10 – 8.5	8 – 5.5
50	25	24 – 21	20 – 18	17-15	14 –12	11 – 8.5	8 – 6
55	26	25 – 23	22 – 19	18 – 16	15 –13	12 – 9	8 – 6
60	27	26 – 24	23 – 20	19 –16.5	16 –13.5	13 – 9.5	9 – 6.5
65	28	27- 24.5	24 – 21	20 –17	16 –13.5	13 – 10	9 – 7
70	28.5	28 – 25	24 – 21.5	21 –18	17 –14	13 – 10.5	10 – 7.5
75	29	28 – 25.5	25 – 22	21 – 18.5	18 – 14.5	14 – 11	10 – 8
80	30	29 – 26	25 – 23	22 – 19	18 –15	14 – 12	11 – 8.5
85	31	30 – 27	26 – 23.5	23 –20	19 – 15.5	15 – 13	12 – 8.5
90	31	30 – 27	26 – 23.5	23 – 20	19 – 15.5	15 – 13	12 – 8.5
100	31	30 – 28	27 – 24	23 – 21	20 –16	15 – 13	12 – 8.5
110	32	31 – 28.5	28 – 25	24 – 21	20 –17	16 –13.5	13 – 9
120	33	32-29	28-26	25-22	21 -18	17 – 13.5	13 – 9

SOURCE: Original: Orlov 1920s. (1925–1929). Reproduced after Stinghe and Toma 1958, Dendrometrie p. 331. Table 91 – reprinted from Anuchin 1954 Forest mensuration; Romanian translation (Taxația forestieră).

Tyurin (1936) proposed the determination of the trees increment from the lateral surface of the stand, a subject which was developed later by Anuchin (1960) using a sophisticated table: "Determination of the current accreation of stands by lateral surface of trees". He noted that "The intensity of forestry is characterized by the amount of the so-called current accreation. The current accreation is a quantity by which the given valuation index (diameter, height, volume, etc.) changes during a definite time in the life of the tree or the plantation, for example during the past years”. In fact the idea of determination the stems lateral area in a stand is very old (1850-1860) and belongs to Vargas de Bademar who constructed tables for lateral surface of trunks (stems). Anuchin constructed a nomogram to determine the current growth acreation of pine plantations which is based on width of the last 10 years strata (annual rings), accreation, 3 thickness and classes of bonitation (site).

Russians paid a high attention to the determination of stand growth that was studied by many researchers. Drakin and Vuevskii (1940) established different patterns in the height growth of stands.

Current increment of stands was investigated by Moiseenko and Murashko (1940), Naumenko (1940, 1946), Vaschnil and Anuchin (1952, 1959, 1982), Dzhurdzhu (1957), Voropanov (1961), Volkov (1968), Rusetskas (1986).

Moiseenko (1947) analyzed the effect of stocking on increment in multi-storied oak stands in Belarus.

The standard tables of total basal areas and stand volumes per hectare for stocking 1.0 (close stands) were constructed by Karpov (1951) and Kozlenko (1953). In the same period Davidov (1952) constructed yield tables for beech growing in closed canopy.

In a paper presented at the 5th World Forestry Congress (1960), Naumenko presented data on the oak stand productivity in Ukraine and Belarus. It is intresting the comparison between different yield tables for the II site class in the case of height and diameters (Tables 11.9.1.-3. and 11.9.1.-4.).

In 1967, Kozlowski and Pavlov published yield tables for forest formed by many forest species growing in the U.S.S.R.

Utkin (1975) developed modern researches on biological productivity of the forest ecosystems, and Kuzmichev (1977) underlined the peculiarities of the stand growth.

Zagreev and Vaghin (1975) underlined the necessity to separate by species the schemes of site classes (site classes should be established by species). Davidov (1978) noted the feature of the growth and site class of stands of fast growing species.

TABLE 11.9.1.-3. Course of growth in height of seed oak groves of the II bonitation according to experi mental tables

Authors of tables	Age of oak groves, in years										
	20	30	40	50	60	70	80	90	100	110	120
	Height (in metres)										
Naumenko	7.1	10.4	13.5	16.2	18.6	20.6	22.3	23.8	25.2	26.3	27.3
Davidov	7.5	11.1	14.0	16.6	18.9	20.9	22.6	24.1	25.5	26.6	27.5
Moiseenko	-	10.0	13.1	15.8	18.2	20.3	22.1	23.6	25.3	26.2	27.1
Wimmenauer (II-III bonitation)	6.5	9.8	13.1	15.9	18.3	20.3	22.0	23.5	24.9	26.1	27.2
Average	7.0	10.3	13.4	16.1	18.5	20.5	22.3	23.8	25.2	26.3	27.2
Deviation from average heights according to Naumenko (metres)	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.0	0.0	0.0	0.0

SOURCE: Naumenko, I. M. 1960: "General regularities in the growth of oak plantations". In: Proceedings of the Fifth World Forestry Congress, vol. I, p. 465, Univ. of Washington, Seattle, Washington, USA, Aug. 29-September 10, 1960.

TABLE 11.9.1.-4. Course of growth in height of seed oak groves of the II bonitation according to experi mental tables

Authors of tables	Age of oak groves, in years										
	20	30	40	50	60	70	80	90	100	110	120
	Height (in metres)										
Naumenko	4.3	8.0	11.7	15.5	19.2	22.8	26.2	29.6	32.8	36.0	39.0
Moiseenko	-	8.9	11.9	15.6	19.3	23.0	26.3	29.2	32.0	35.1	38.0
Wimmenauer	4.5	8.0	11.7	15.7	19.2	22.6	26.0	29.2	32.4	35.5	38.1
Average	4.4	8.3	11.8	15.6	19.2	22.8	26.2	29.3	32.4	35.5	38.5
Davidov	6.1	9.7	13.5	17.3	21.1	24.9	28.6	32.3	35.9	39.4	42.9

SOURCE: Ibidem Table 11.9.1.-3.

Livanov (1984) used an analytical method of predicting the mensurational indices of stands, method based on chlorophyll surface area of the foliage mean length of the growing season, proportion of the stem in the annual biological increment, stem form, relative age numbers, mean height, and diameter class distribution. This method can be used to predict the main mensurational indices of any stand, up to age of 100 years, as an aid to improve the forecasting and planning (After Forestry Abstracts 5123/1985).

Lositskii (1985) discussed the climatic constant of forest annual increment.

In 1987, Dimitrieva investigated the dynamics of the current increment of stands of the main groups of Scots pine forest types in the Buzuluk forest and the possibility of forecasting it. The following five groups of pine forest types have been distinguished: (1) *Pinetum cladinosum* (site class IV), (2) *Calamagrostis* types (site class III), (3) mossy types (site class IV), (4) mossy-herbaceous types (site class I) and (5) *Pinetum compositum* (site class Ia). Dimitrieva determined the radial increment patterns and cycles having the mean periods of 29 and 11 years and derived equations showing the relation of increment to solar activity by forest type groups in both cycles. On this basis she considered that it is possible to forecast the increment patterns up to 2020. The greatest increment would occur in 2002 as a result of the superimposition of the maximum of 29 and 11 years cycles (compiled after Forestry Abstracts 5782/1988). In the same year, Dimitrieva (1987) underlined the meteorological basis of the 29 year increment cycle of stands in the south-eastern forest steppe of the U.S.S.R. Her graph showed the pattern of the 29 year cycles since 1800 in relation to temperature in July, October, January and May-August and rainfall in July, April-September, October-March and October-September. On this basis the pattern of the meteorological factors and increment is predicted up to 2020±2 (compiled from Forestry Abstracts 3075/1989).

A short communication on net ecosystem productivity (NEP) in forests was presented by Kobak in 1995 at Tampere - Congress. NEP = NPP - Rh where NPP is the net primary productivity area and Rh is the total heterotrophic ecosystem respiration. He investigated the ecosystems of various types of pine, spruce and birch stands of 30 to 130 years of Petrograd region and the results have shown that mature forest of all types have a very low NEP values (maximum 4 % of NPP).

Short and long-term natural trends of Scots pine radial growth in North and mid-taiga forests in Karelia were established in 1996 by Sinkevich and Lindholm.

Cited authors:

Agliullin and Kalachev 1970, Antanaitis 1958, Anuchin 1952, 1960 a, 1960 b, 1970, Baghinskii and Terekhova 1986, Davidov 1936, 1952, 1978; Dimitrieva 1987 a, 1987 b, Drakin and Vuevskii 1940, Dudarev 1950, Dzhurdzhu 1957, Gracev 1967, Gradeckas 1966, Gusev 1962, Karpov 1951, Kobak 1995, Kozlenko 1953, Kozlovski and Pavlov 1967, Kuzmichev 1977, Livanov 1984, Lositskii 1985, Lyubimov and Korsh 1926, Moiseenko 1947, Moiseenko and Murashko 1940, Naumenko 1940, 1946, 1960; Ogorodov 1951, Polykarpov 1981 (ed.), Rusetskas 1986, Semenov 1843, Sinkevich and Lindholm 1996, Tikhomirov and Tishchenko 1929, Tyurin 1913, 1931, 1936; Utkin 1975, Utkin et al. 1980, Vargas de Bademar 1850, VASCHNIL and Anuchin 1959, Volkov 1968, Voropanov 1961, Zagreev and Vaghin 1975.

11.9.2. Stand growth modelling and analytical approach to ecophysiological forest modelling

Since the 1970s, the modelling in forest mensuration has been used in the U.S.S.R. first of all in the field of growth, especially stand growth. A sample of the published works in this field is given in Table 11.9.2.-1.

TABLE 11.9.2.-1. A sample of works on stand growth modelling in the countries of former U.S.S.R.

Year	Author(s)	Specification	Place
1972	B. Zeide	A growth model with log between involved processes	Moskva
1984	G. P. Karev	Mathematical growth model of multilayer tree stands	Siberian branch of U.S.S.R. Academy of Science.
1984	A. Kiviste	Modelling pine forest growth by types of forests	Tartu, Estonia
1984	A. Nilson A. Kiviste	Modelling the growth of pine forests according to site conditions without their typization	Tartu, Estonia
1985	G. P. Karev	On one approach to modelling tree stand growth	Krasnoyarsk
1985	T. Oja	Models of stand development	Tartu, Estonia
1985	M. Yu. Popkov	A model for predicting growth of Scots pine stand under different silvicultural regimes in the Ukraine forest steppe	Kharkov, Ukraina
1988	A. K. Kiviste	Functions of forest growth	Tartu, Estonia
1988	G. S. Razin	Growth models of Norway spruce plantations of different density	Western Ukraine
1988	V. V. Sukhanov B. S. Petropavlovskii	The use of Gompertz model to approximate the growth of spruce stands of the forest of the Maritime Territory. The model was tested on *Picea jezoensis* and compared with yield tables giving acceptable results	Vladivostok
1995	A. Shvidenko S. Venevski G. Raille S. Nelsson	A system for evaluation of growth and mortality in Russian forest	
1996	G. S. Dzebisashvili	Yield models of nominally even-aged pine stands in the Caucasus, the model was used to compile yield tables for Caucasian pine (*Pinus sylvestris* in Georgia). The tables are arranged by gradient claves, for slopes, 20^o, $21–35^o$ and $\geq 36^o$.	Georgia
1996	V. V. Kuzmicev T. N. Mindeeva G. B. Kofman	Multiple regression models for predicting stand growth, site class, height, diameter and standing volume for the main forest tree species in the Krasnoyarsk region	Krasnoyarsk, Siberia

The mathematical model of higher plant was presented in 1973 by Kudrina, but only in the 1980s the ecophysiological approach to forest modelling became more frequent as in other European countries. It should be noted the useful text-books written by Semevsky and Semenov in 1982 (Mathematical modeling of ecological process) and Berezovskaya et al. in 1991 (Modelling stands dynamics ecophysiological approach). Among other papers it should be mentioned: an ecophysiological model of spruce growth in Estonia (Kull and Kull 1984) which is a dynamic model PNU for the growth of an evergreen tree, presented in the form of a system of differential equations each one describing different stator variables (4 structural and 4 metabolic biomass components and stem height) - the model describes long term growth and not seasonal variations. In this paper the possible mechanism of growth inhibition during the second half of the life of trees is discussed; Karev's (1985) mathematical model of light competition in light-limiting self-thinning tree stands; a model of production of the tree layer in South taiga Norway spruce (Chestnykh 1986); a single tree model of pine stand/raw humus soil ecosystem – SPECOM was constructed by Chertov (1990); analytical approach to the ecophysiological forest modelling (Berezovskaya and Karev 1991, 1994); bioecological simulation model of many – species uneven–aged tree stand development (Papadyuk and Chumachenko 1991) and the new approaches to qualitative behavior modelling of complex systems proposed by Berezovskaya and Karev in 1997.

Cited authors:

Berezovskaya and Karev 1991, 1994, 1997; Berezovskaya et al. 1991, Chertov 1990, Chestnykh 1986, Dzebisashvili 1996, Karev 1984, 1985; Kiviste 1984, 1988, Kudrina 1973, Kull and Kull 1984, Kuzmichev et al. 1996, Nilson and Kiviste 1984, Oja 1985, Papadyuk and Chumachenko 1991, Popkov 1985, Razin 1988, Semesky and Semenov 1982, Svidenko et al. 1995, Sukhanov and Petropavlovskii 1988, Zeide 1972.

11.10. Weight and biomass studies

Early biomass studies were completed in Russia and former USSR countries in the '60s. A sample of these studies by species is presented in Table 11.10.-1.

Some problems on primary production of the mixed forests are mentioned by Dylis in 1969. Gorbatenko and Protopopov (1971) investigated the accuracy determination of the crown and needles of Scots pine stands. Levins et al. (1971) presented the utilization of needles and leaves in the USSR while Galvãns (1976) investigated the biomass of aspen, birch and alder, and established the functional connections between the biomass and the three dbh. Galvãns cited in his work the following authors of papers on biomass whose works were not available to us: Ilgushenko (1970), Ivanchikov (1971), Molchanov (1971), Gusev and Sokolov (1973). An interesting study on non-free growth of organism biomass was completed in 1974 by Galitsky and Komarov.

Kazimirov and Mitrukov (1978) investigated biomass variability and constructed a mathematical model of the Scots pine tree and stand phytomass. (They used data from the Karelian Republik and the Murmansk district).

TABLE 11.10.-1. A sample of weight and biomass studies containing data for different species

Year	Author(s)	Species	Area
1964	V. I. Kravcenko	Norway spruce (weight and dimensions of under and above ground parts of trees growing in stands with different stocking)	Arhangelsk
1969	U. L. Shtibe	Norway spruce trees grown in *Picetum oxalidosum* stands, (biomass of tree foliage)	Latvia
1974	A. A. Molcianov	Scots pine	European Russia
1974	A. D. Vakurov	Scots pine (whole biomass of stands)	European Russia
1976	U. I. Galvãns	Aspen Birch Alder harvested in thinnings	Latvia
1985	V. A. Bugaev M. T. Serikov A. N. Smolyanov	Phytomass of *Quercetum aegopodium* in the Shipov forest	Voronezh
1993	V. A. Usol'tsev J. K. Vanklay	Scots pine plantations and natural forests on dry steppe	Kazakhstan
1995	I. M. Danilin	*Larix gemelinii* Rupr.	Central Siberia
1996	R. A. Monserud A. A. Onuchin N. M. Tchebakova	*Pinus sylvestris* (Needle, crown, stem and root phytomass) This is the first comprehensive study on *P. sylvestris* biomass based on over 18 regional and local phytomass studies	Stands from European Russia (33°E) to Yakutia (130°E) in eastern Siberia

Abrazko (1983) studied the spatial distribution and root biomass dynamics in spruce forest ecosystems.

Based on the published data of 60 different stands, Onuchin and Borisov (1987) derived the stand regression equation for weight of foliage, crown and roots in function of stand age, standing volume and site class. Tables are given showing oven-dry weights of biomass (t/ha) in plantations and natural stands in European Russia and Siberia. The tables are treble-entry: age (15, 30, 50…150 yr.), site class (I-V) and standing volume (15, 30, 50,….475 m^3/ha) (after Forestry Abstract 3241/1985).

Usol'tsev (1988) described a procedure for compiling biomass production tables combined with yield tables; the tables show oven dry biomass in t/ha, by components (stem, branches, needles, total above ground biomass, roots and total biomass in Scots pine) natural stands (20–140 yr.) and plantations (10–60 yr.) – in both cases tables refer to site classes II and III.

The first comprehensive study on *Pinus sylvestris* biomass was completed by Monserud et al. in 1996 (see also table 11.10.-1.).

Allometric equations for phytomass, based on data for Scots pine, spruce, birch and aspen trees in European Russia were developed in 1996 by Utkin et al. The equations were derived from calculating biomass (by fractions) from dbh and height and were applied to evaluate carbon accumulation by afforestation in Vologda and Saratov regions.

Lebkov and Kaplina (1997) investigated structure and dynamics of the Scots pine stands according to the relationship of needle mass and the biometric indices of the trees. For the stands of 25-78 years aged (Central Russia) they concluded that the change in the stand structure" as regards foliage biomass with dbh and age is quite stable and the functional role of the foliage changes with age: in the young stands the large amount of foliage ensures rapid increase in stand biomass, whereas in stands approaching maturity a much smaller amount of foliage is sufficient for rapid increase in wood volume".

To estimate the forest biomass Usoltsev and Hoffmann (1997) combined harvest sample data with inventory data. This paper is an example of how recursive multiple regression analysis can combine forest inventory data with harvest biomass data. The cited authors investigated *Pinus sylvestris* branch biomass for Severka Forest Farm (Urals).

Utkin et al. (1997) compared the allometric regression equation and mensurational data for individual trees (*Pinus sylvestris, Picea abies* and *Betula alba* in Vologda and Volgograd regions of Russia) to determine the amounts of carbon. The results obtained were compared with data supplied by using conversion coefficients (ratios of phytomass to stemwood). The authors concluded that "the conversion – volumetric method was reliable for making of the amounts of phytomass (and carbon), both for aggregations of areas (subcompartments) and for individual sample plots".

Cited authors:

Abrazko 1983, Bugaev et al. 1985, Danilin 1995, Dylis 1969, Galitsky and Komarov 1974, Galvãns 1976, Gorbatenko and Protopopov 1971, Kazimirov and Mitrukov 1978, Kravcenko 1964, Lebkov and Kaplina 1997, Levins et al. 1971, Molchianov 1974, Monserud et al. 1996, Onuchin and Borisov 1984, Shtibe 1969, Usol'tsev 1988, Usol'tsev and Hoffmann 1997, Usol'tsev and Vanklay 1993, Utkin et al. 1996, Utkin et al. 1997, Vakurov 1974.

11.11. Tree-ring studies

11.11.1. Early works, institutional frame and publications

Shvedov (1892) was the first Russian dendrochronologist. He studied tree-rings of the black locust (*Robinia pseudacacia* L.) growing in the streets of Odessa and discovered a close relation between ring widths and precipitation from September to August and the periodicity of narrow rings regularly repeated at three and nine years. Based on these observations, Shedov predicted the drought of 1891 year. After that these investigations were not continued for a long period of time. After 1930 some articles began to be published covering the methodological basis of dendrochronology and this is the case of Zaozersky (1934) who discussed the methods of retrospective revealing of climatic conditions by the tree growth study, and Tolsky (1936) who wrote on the exposure of climatic changes, the basis of the growth analysis. Kostin (1940) investigated the repetitiveness of droughts in Voronez region (based on data of the annual growth of European ash). Abstracts of the American dendrologists (Douglass, W. Glock) were published by Jashnov in 1925 (climatic cycles and tree growth), Krishtofovitsh (1934) - tree ring as the basis of historical and prehistorical chronologies, Chrgian (1938) - Waldo Glock: principles and methods of tree-ring analysis), and were highly appreciated.

Sustained researches in the field of dendrochronology have begun since the 1950s and especially since 1959 when the first Dendrochronological Laboratory was organized at the Institute of Archaeology of the USSR Academy of Sciences (Moscow) under the leadership of Professor Kolchin (Kolchin 1963).

In 1968, the First All-Union Conference on Dendrochronology and Dendroclimatology was held in Vilnius (Lithuania) and the Dendroclimatochronological Group of the Institute of Botany of the Lithuanian Academy of Sciences (in Kaunas) was organized, and reorganized in 1976 into the Dendroclimatochronological Laboratory remains during the Soviet period as the largest scientific unit in this field (Britvinskas 1978, Shivatov 1988).

Dendrochronological investigations in the USSR were coordinated by the Comission for Dendroclimatology of the USSR Academy of Sciences. This commission sponsored All Union Meetings (Conferences) on dendrochronology and dendroclimatology problems: 1968 Vilnius, 1972 Kaunas, 1978 Archangelsk, 1983 Irkutsk, 1987 Irkutsk. In 1980, Dendrochronological Bank of the Soviet Union (DBSU) was founded at the Dendroclimatochronological Laboratory of the Lithuanian Forest Research Institute of Forestry. The proceedings "Dendroclimatological Scales of the Soviet Union" (1978, 1981, 1984, 1987), and the bibliographic references "Dendroclimatochronology, 1900–1970" were published in Vilnius in 1978 (Shiyatov 1988, Kairiakstis and Shiyatov 1990).

A remarkable review of the dendrochronological works completed in the USSR by Stepan Shiyatov was published in 1988 in "Tree Ring Bulletin" (Vol. 48). Another shorter review was published two years later, in 1990, by L. Kairiukstis and Stepan Shiyatov. In this second review the authors considered that four basic points are essential for evaluating the dendroclimatology in the USSR and we will try to summarize them using the extracts from their own text: (1) "Soviet scientists have arrived at the general conclusion that dendroclimatical investigations are best based on a precisely understood ecological background and carried out on a large spatial scale by means of the dendrochronological profile method: north–south and east–west", (2) "Studies are based on carbon isotope measurements of exactly dated tree rings", (3) Cyclicity in dendrochronological studies provided a basis for the subdivision of regions on a dendroclimatic basis. In this field there remains a need for a high degree of vigorous testing and verification", (4)"…dendroclimatology in the Soviet Union, particularly owing to prognostic activities, has become an important tool in forestry and regional planning" (Kairiukstis and Shiyatov 1990, p. 16 and 17).

11.11.2. Tree-ring chronologies

Up to 1988 about 370 tree-ring chronologies in the form of indices (relative values of tree-rings with) have been published in the USSR, out of which 115 are from eastern and southern regions of the country, including the Urals. The majority of chronologies was obtained from coniferous species such as *Larix, Pinus, Picea* and *Abies genera*; among broad-leaved *Quercus* species are predominant (Shiyatov 1988). Table 11.11.2.-1. shows the longest published chronologies between 1975 and 1995.

11.11.3. Dendroclimatology

Dendrochronological investigation methods and the effects of annual tree-ring width were presented during 10 years by Rudakov (1951, 1958, 1961). Gursky et al. (1953) completed a qualitative reconstruction of humidity in the middle Asia highlands during a thousand years using ring widths of Turkestan juniper (*Juniperus turkestanika* Kom.) Ring width was used on a large scale for the reconstruction of climatic conditions by: Galazy (1954), who analyzed altitudinal limit of arboreal vegetation in the Eastern Siberia mountains, Dimitrieva (1959) studied the climatic influences on tree growth in the Karelian Neck, Zwiedris and Sacinieks (1960)* and Zwiedris and Matuzanis (1962)* in developed researches - Latvia (*cited after Kairiukstis and Shiyatov 1990).

TABLE 11.11.2.-1. The longest tree-ring chronologies published between 1975 and 1995

Publishing year	Author(s)	Species	Chronology length (years)	Area
1975	S. Shiyatov	*Larix sibirica* Ldb.	865	North–western Siberia
1977	B. A. Kolchin N. V. Chernich	*Pinus sylvestris* L.	1200	Novgorod
1977	B. A. Kolchin N. V. Chernich	*Juniperus turkestanika* Kom.	1224	Middle Asia
1978	M. F. Adamenko	*Larix sibirica* Ldb.	677	Altai Mountains
1986	S. Shiyatov	*Larix sibirica* Ldb.	1010	Polar Urals
1995	G. A. Ivanova	*Pinus sylvestris* L.	360	Central Yakutia

Using the tree-ring width Kostin (1960) established climatic changes in the Central forest – steppe region of the Russian Plain and the repetitiveness of dry and moist periods in this region (1963).

Liseev (1962) underlined the quantitative characteristics of the influence of climatic factors on tree growth and Bitvinskas (1965) pointed out the effect of climatic factors on the tree ring growth while Kairiukstis and Yudovalkis (1970) disclosed the peculiarities of the seasonal tree growth in the light of dendrochronological and dendroclimatological investigations.

Glebov and Pogodina (1972) investigated the stand growth of some bog forests at the Tomsk (Siberia) station in connection with hydrothermal conditions.

In 1974, Bitvinskas published the first book in Russian language on "Dendroclimatological investigations".

A study on radial growth dynamics of the oak stands in Lithuania, and its relations with the environment, climate and solar activity was completed by Bitvinskas and Kairaitis in 1975. In the same year, Javorsky (1975) discussed the problem of astro-dynamic-statistic forecasting of the climate conditions in which it is possible the formation of droughts and over wettings. Growth dynamics of larch was proposed by Adamenko (1978) as indicator of the thermal regime of summer seasons in the Gorny Altar, and Bitvinskas (1978) correlated again the growth of trees with the environmental conditions.

A summary of dendroclimatochronology of the north-western part of the European sector of the USSR based on the works of the Dendroclimatochronological Laboratory of the Institute of Botany in Lithuania was presented in 1981 by Bitvinskas on the Symposium on "The Influence of Changes in Solar Activity on Climate". Later (1984) the mentioned scientist formulated the fundamentals of dendroclimatological research in Lithuania.

Borshova (1981) established the effects of climatic factors on the radial tree growth of *Pinus schrenkiana* in the Zailiysky Alatau (The Tien Shan Forests.).

Mazepa (1982) presented a method of computing annual growth indexes for a generalized dendroclimatological series, Shiyatov and Mazepa (1986) examined natural fluctations of climate (in the eastern regions of the USSR) based on tree ring consideration of more reliable dendroclimatological series and the analysis of cycle components (the Corridor method of standartization).

Kairiukstis and Dubinskaia (1986) used the rhythmic radial tree-ring oscillations for prediction of climatic variability.

Adamenko (1986), based on dendrochronological methods, reconstructed the thermal regime dynamics of the summer seasons during the 14th -20th centuries in the Gorny Altai.

The first dendrochronological reconstruction of the seasonal temperature (of mean June-July) over the past millennium for the sub-Arctic (Polar Urals) was performed by Graybill and Shiyatov (1989) using *Larix sibirica* tree-rings.

Johansen (1995) obtained a tree-ring chronology covering the period between 1631-1991 using Dahurian larch (*Larix gmelinii*) growing near Kolymskaya (the lower Kolyma River region, Siberia) and proved that June temperatures have a significant positive influence on the width of ring growth. This species, growing near tree limit, proved to be an indicator of changes in summer temperatures.

Grigaliunas (1996) studied radial increment of *Quercus robur* in eight regions of Lithuania and noted that the variations in climate and background pollution have no significant effect on the radial growth of the dominant trees that declined insignificantly over 150 years which indicate that the Lithuanian climate is still acceptable for oaks growth.

11.11.4. Dendrochronoecology

In 1955 and 1967 Galazy used tree-ring chronologies, tree growth dynamics of the trees growing on the Baikal lake region.

For indication of slope processes, Turmanina (1971) used some morpho-anatomical peculiarities of trees and in 1972 established the peculiarities of the growth near the Elbrus Mountain.

Dendrochronological analysis of coniferous trees growth damaged by forest insects was performed in 1972 by Vaganov et al. in 1972 and later by Kucherov (1987) in the case of *Lymantria dispar* and its effects on radial growth in the Southern Urals.

The effect of seed crop on the annual layers of spruce (*Picea excelsa* Link.) and Siberian fir in the South Pre-Baikalie determined the reduction of the ring width (Danilov 1953, Voronin 1986).

In 1979, dendrochronological and dendroecological investigations were developed in the Ukrainian Carpathians highlands by Kolishchuk while Evdokimov considered tree ring growth as a function of drainage intensity of the horsetail - bogmoss spruce stands in the Komi Autonomous Republic, and Turmanina established a connection between tree-rigs and avalanches in the upper reaches of the Baksan Valley.

Adamenko et al. (1986) considered the elemental composition of the season increment as a characteristic of natural and anthropogeneous factors. This relation between the chemical composition of annual wood layers and environment was also underlined by Chetverikov (1986) and in case of pollutants on forest phytocenoses, by Saborov (1987).

Evdokimenko and Koptsev (1987) described the peculiarity of the annual increment of the forest under extreme conditions - an example of the lightpine forest in the Baikal region. Goryachev (1987) confirmed that the ecological factors affected on seasonal radial growth the dynamics in dark coniferous forests in the Middle Urals.

In 1987 Shiyatov and Ulianov tried the dating of windthrows by dendrochronological methods.

11.11.5. Dendrochronology and study of forest ecosystem dynamics

In the ‘70s and ‘80s the tree-ring analysis have been frequently used for the study of forest ecosystem dynamics. Shiyatov (1988) explained this approach by "the fact that majority of Soviet dendrochronologists are foresters and they work in Forestry and Ecological Institutes”.

Shiyatov explained that the work of Soviet dendrochronologists is based on a form of forest ecosystem dynamics named the cyclic form. Within the cold and temperate zones, the annual fluctuations and long-term changes in climatic conditions significantly affect the composition and structure of forest ecosystems. Changes of forest environments caused by climatic variations (moisture and heat supply, droughts, fires, floods, snow avalanches, and other catastrophic phenomena) are the main resources of the cyclic forest dynamics. The duration and amplitude of the processes that are not strictly periodic, but change to some extent, allowing the estimate of the oscillation parameters by statistical methods are named cyclic: not only short-term fluctuations (daily, seasonal, annual, intrasecular), but also long-term and essential ones (secular and oversecular) should be attributed to cyclic forest dynamics, including forest vegetation succession into woodless vegetation and back. The cyclic processes can be observed in the changes of the almost all components of forest ecosystems. Most of all they are expresses in the tree growth. There are various length cycles in the dynamics of separate components of forest ecosystems (polycyclicity). But there are usually only a few dominant cycles, which bring about the highest contribution in the variability of the process... The cyclic processes are expressed primarily in regions and sites (Tree Ring Bulletin vol. 48, 1988 p. 32). Some notable contribution to study of forest dynamics was realized by the works mentioned below.

Komin studied in 1963 the influence of cyclic fluctuations of the climate on growth and age structure of the original bog forests, and in 1970 and 1972 the cyclicity of trees and stands growth dynamics of pine in the taiga zone of western Siberia. Growth stand dynamics and possibilities of their prognosis using dendrochronological methods were examined by Bitvinkas (1964). Kolishchuk (1966) studied the growth dynamics of mountain pine (*Pinus mughus* Scop.) in connection with the solar activity via tree-rings; Gortinsky (1968) investigated the annual productivity dynamics of spruce stands in southern taiga biocenoses; Shiyatov (1972) completed a dendrochronological study of *Picea obovata* in the lower Taz river.

In 1974, Bitvinskas published a textbook on dendroclimatological investigations in which the problem of cycles was mentioned. Malokvasov (1974) investigated the cyclicity in radial tree growth in Korean pine. The oversecular cycle of indices (relative value of tree-ring width) of *Larix sibirica* at the northern treeline was analyzed by Shiyatov in 1975. Olenin (1976) established the connection between radial growth in pine, bog pine stands and the secular solar cycles, and described, in 1977, the radial growth dynamics of pine stands in the middle taiga subzone of the western foot of the Ural Mountains.

Polyushkin (1979) advocated that the variability of radial stand growth is a source of information for the ecosystem dynamics prediction.

Dergachev and Derghacev (1981) investigated the regular manifestation of some natural processes in the past by radiocarbon concentration study in the tree wood layers. Mazepa (1980) used spectral presentation and linear filtering of the stationary sequences in the analysis of dendrochronological series cyclicity. Radiocarbon was used earlier by Muchamedshin (1974) in the study of juniper growth dynamics in Tian - Shan highlands. A detailed work on dendrochronology of the upper treeline in the Urals was published by Shiyatov in 1986.

Dyrenkov et al. (1987) used the dendrochronological analysis of secondary succesions in the forest.

Yadaev et al. (1991) studied the growth variability of Scots pine in Kaunas region of Lithuania using rings of the 1795-1989 period having high year to year fluctuations and developed a model for the prediction of long term growth taking into account the presence of cyclical components in the dendrochronological series.

In her seven dendrochronologies developed for Scots pine in central Yakutia, Ivanova (1995) found recurrent fluctuations in the annual tree-rings and detected some long-term cycles.

Sinevich (1995) studied tree-ring width in *Pinetum vacciniosum* forests in the Karelia Republic and discovered cycles with 20-40 and 9-13 years which were also detected in the dynamics of temperature, rain and sunny-activity, and concluded that the productivity of native pine stands will decrease up to year 2000 and after that a slow increasing could be expected.

11.11.6. Cambial activity and seasonal growth

The effect of light schedule change on the formation and structure of annual wood rings in even-aged stands was investigated in 1975 by Lobzharidze who used the microscopic method as did before Kairiukstis and Yuodvalkis in 1970, and later by Kishenko (1978) and Goryachev (1987) in the Middle Urals. The microscopic method was also used by Kishchenko (1978) in the studies of the Karelian region.

In 1981, Vaganov et al. developed a seasonal tree-growth modelling using the number and size of cells in tree rings.

A textbook on histometric analysis of woody plant growth was published by Vaganov et al. in 1985. Vaganov used a special device "Ring structure measurer” that semiautomatically registers the number and dimensions of cells in the annual rings.

In 1994, Vagonov et al. investigated seasonal growth and structure of the annual rings of larch at the northern limit of forest in Central Siberia obtaining chronologies using INDEX and SUMAX programs and concluded that June/July temperature determined 65-70 % of the annual variation in ring width. Cell dimensions were measured in order to complement the conventional ring chronologies with cell chronologies that indicate the pattern of seasonal growth. A new simulation model provided the results similar with that offered by a multiple, statistical model. Vaganov et al. discussed also the use of cell chronologies' for dendroclimatic reconstruction of temperature.

11.11.7. Dendroarchaeology

As mentioned before the first Dendrochronogical laboratory was organized at the Institute of Archaeology of the USSR Academy of Sciences (Moscow). In

1959, this laboratory was engaged in absolute dating of medieval buildings, churches, and paved wood roadways in the north-western part of the Soviet Union, in Novgorod in particular (Shiyatov 1988, p. 32). During the first year of this laboratory (1959, 1963) carried out relative dating of the Pazirik Borrows and Altai – Sajan Borrows – remote constructions in the Gorny Altai. Under the title "Dendrochronology of Novgorod" (in Russian) booklet, Kolchin (1963) presented the results of researches on medieval building in Novgorod region. Komin (1980) investigated Kazim town from dendrochronological point of view. Shiyatov (1980) dated wooden building of Mangazeia and Kolischuk et al. (1984) used archaeological and buried wood for long term scale construction.

11.11.8. Other tree-ring and dendrochonological works

Dendrochronological methods were used in criminology in the works of Rosanov (1965, 1968).

Butenas (1981) established the annual ring width of the main forest tree species of Lithuania.

Nesvetailo (1986) completed the dendrochronological dating of "telegraphic forest" in the area of Tungus meteorite fall.

A portable electronic dendrometer was constructed in the USSR for selecting resonance wood in standing trees or in logs of spruce (*Picea abies*). This device incorporates a stereoscopic microscope, a mechanism for moving the core sample horizontally, a memory unit and a data display unit. With this instrument it is possible to measure the number of annual rings, their total and mean width (separately for early and late wood and the late wood percentage). Spruce resonance wood should have rings of 1-4 mm wide and the late wood should not exceed 30 % or 20% for the sounding boards of concert pianos (Fedyukov 1990).

11.11.9. A list of cited authors of dendrochronological works by regions or countries included in the former U.S.S.R.

European part of Russia:

Schvedov 1892, Zaozersky 1934, Tolsky 1936, Kostin 1940, 1960, 1963; Rudakov 1951, 1958, 1961; Dimitrievna 1959, Liseev 1962, Kolchin 1963, Shiyatov 1965, Gortinsky 1968, *Molchanov 1970, Turmanina 1972, 1979; *Spirov and Terskov 1973, *Feklistov 1978, Evdokimov 1979, 1987; Lovelius 1979, *Barsut 1984, *Kovalev et al. 1984, Vaganov et al. 1985, Sinkevich 1995.

Urals and eastern part of Russian plain:

Adamenko 1963 a, 1963 b; Komin 1963, 1969, 1970 a, 1970 b; Shiyatov 1965, 1972, 1975, 1979, 1986; Olenin 1974, 1976, 1977; Mazepa 1982, 1986; Goryachev 1987, Graylill and Shiyatov 1989.

Northern Kazakstan and Central Asia:

Gursky 1953, *Zamotorin 1959,1963, Muchamedshin 1974, *Zacharieva 1974, *Pugachev 1975, Adamenko 1978, 1986, Borshova 1981, 1986.

Far East of Russsian Federation:

*Tarankov 1973, Malokvasov 1974, 1986; *Sabirov 1986.

Ukraine:

Kolishchuk et al. 1966, 1979, 1984.

Latvia:

Zviedris and Sacinieks 1958, 1960; Zviedris and Matuzanis 1962, Shpalte 1971, Läänelaid 1981.

Siberia:

Galaszy 1954, 1955, 1967; Komin 1963, 1970, 1980; Glebov and Pogodina 1972, Shiyatov 1972, 1975, 1980, *Glebov and Litvinenko 1976, *Buzikin 1978, Vaganov et al. 1981, 1985, 1994, Adamenko et al. 1986, *Nesvetailo 1986, Voronin 1986, Evdokimenko and Koptsev 1987, Ivanova 1995, Johansen 1995.

Lithuania:

Bitvinskas 1964, 1965, 1974, 1978a, 1978b, 1984, 1987; Kairiuktis 1968, Kairiuktis and Juodovalkis 1972, Pakalnis 1972, Vaganov et al. 1972, Bitvinskas and Kairaitis 1975, *Stupneva and Bitvinskas 1978, Butenas 1981, Derghachev+Kocharov 1981, *Karpavichus 1986, Kairiuktis and Dubinskaite 1986, Kairiuktis et al. 1987a, Yadaev et al. 1991, Grigaljunas 1996.

*) Cited by L. Kairiukstis and S. Shiyatov (1990).

Cited authors:

Adamenko 1978, 1986; Adamenko et al. 1986, Bitvinskas 1964, 1965, 1974, 1978 a, 1978b, 1981, 1984; Bitvinskas and Kairaitis 1975, Borshova 1981, Butenas 1981, Chetvertikov 1986, Chrgian 1938, Dergachev and Kocharov 1981, Dimitrievna 1959, Dyrenkov et al. 1987, Evdokimenko and Koptsev 1987, Evdokimov 1979, Fedyukov 1990, Galazy 1954, 1955, 1967; Glebov and Pogodina 1972; Gortinsky 1968, Goryachev 1987, Graybill and Shiyatov 1989, Grigaliunas 1996, Gursky et al. 1953, Jashnov 1925, Javorsky 1975, Johanson 1995, Kairiukstis and Yudovalkis 1970, Kairiukstis and Dubinskaite 1986, Kairiukstis and Shiyatov 1990, Kishchenko 1978, Kolchin 1963, Kolishchuk 1966, 1979; Kolishchuk 1984, Komin 1963, 1970, 1972, 1980; Kostin 1940, 1960, 1963; Krishtofovitsh 1934, Kucherov 1987, Liseev 1962, Lobzhanidze 1975, Malokvasov 1974, Mazepa 1982, 1986; Muchamedshin 1974, Nesvetailo 1986, Olenin 1976, 1977; Polyushkin 1979, Rosanov 1965, 1968; Rudakov 1951, 1958, 1961; Sabarov 1987, Shiyatov 1972, 1975, 1980, 1986, 1988; Shiyatov and Mazepa 1986, 1987; Shiyatov and Ulianov 1987, Shvedov 1892, Sinkevich 1995, Turmanina 1971, 1972, 1979; Tolsky 1936, Vaganov et al. 1972, Vaganov et al. 1994, Vaganov et al. 1985, Yadav et al. 1991, Zaozersky 1934, Zamotorin 1959, 1963; Zwiedris and Sacinieks 1960, Zwiedris and Matuzanis, 1962.

11. 12. Forest inventory and remote sensing

11. 12. 1. Forest inventory

As shown before in the list of early events the first forest inventories in Russia were carried out, according to Anuchin (1970), in 1840s.

In 1950, V. K. Zacharov presented the variation of the inventory characteristics of stands.

Honer et al. (1985) completed a report on the forest inventory in U.S.S.R. carried out in 1982. They presented the forest resources of U.S.S.R. and concluded that: "Inventory procedures are divided into four classes according to the intensity of survey required. Remote sensing using aerial photography and space imagery was found to be highly developed, but data processing facilities appeared to lag behind. Maps are prepared by hands. Research and development for the establishment of data bases in progress. Modelling is basically a stand approach, using nonlinear equations to describe the volume-age relationship. It is intended that the intervals between inventories be increased from 10 to 20 years with the application of a computer-assisted mapping program and the use of growth models" (For. Abs. 167/1986).

Forest inventory norms for standardizing resources in Byelorussia are presented by Atroshchenko (1985) who mentioned regression equations for calculating the basal area and volume of current annual increment (%) from age, standing volume, height and diameter and tables of the regression coefficients for different species.

Sinyakevich (1987) advocated the adoption of the ecologically/economic classification of forest resources. The six categories are taken into account. Wood, non-wood and animal products, recreational, protective, conservational and other intangible benefit (For. Abs. 3085/1989).

Polygonal sampling (the sample is formed by taking a central tree and 5-8 top-storey trees nearest to it and any smaller trees coming between them) was proposed in 1988 by Khvatov (For. Abs. 236/1992).

The system used for the survey of the State forest resources in Russia on different levels (republic, administrative territory, region, district) and the historical development of forest survey in Russia was reviewed by Pisarenko and Kulakov in 1995. They also discussed the structure of an appropriate and modern system of forest monitoring able to provide the needed data for forest management.

Strakhov et al. (1995) give an account of the state-run inventory of the Russian forest resources carried in 1995 by the GULF organization (State

Accounting of the Forest Resource), the inventory work being annually completed on an average of 37 million ha. At the enterprise level the inventory cycles vary between 10-12 years. The cited authors underlined that "The Russian state inventory of forest resources by GULF has always differed from forest inventory elsewhere in the world in that every 5 years it produces a statistical handbook of the characteristics of the forest resource, but without the corresponding forest cartography. This limits the practical usefulness of the information". Strakhov et al. (1995) reveal the influences of economic reforms (reduced state control, decentralizations of forestry administration, leasing out of forest land) on forest inventory. It is becoming increasingly difficult to collate and produce the state forest inventory data on a uniform basis, and commercially valuable inventory information on forest in being sold to Russians and foreign organizations to the detriment of Russian state interests. They recommended to reform the Russian forest inventory system, with work at the federal and the regional levels being carried out by three district operational arms: (1) GILF (State Inventory of Forest Resources); (2) Forest monitoring; and (3) Forest Management. All the information collected by these three arms should be accumulated and centrally analysed in VNIITs-lesresurs (Forest Resources Department of the Russian Forestry Service).

Usoltsev and Hoffman (1997) used recursive multiple analysis to combine forest inventory data with biomass harvest data in the case of *Pinus sylvestris*. It should be remembered that the forest biomass (stem volume and branches) are needed for determination of carbon balance, forest monitoring, and forest damage inventories.

Kukuev et al. (1997) give on account of the forest inventory system in Russia and consider that it is "a wealth of data for western researchers".

Multi-resource forest inventory (MRI) will be promoted in Russia (Filiptchouk 1997): organization in charge-All Russian Research and Information Centre for Forest Research; scope: national, objectives: timber NWGS (Non Wood Goods and Services), recreation, water, wildlife, grazing; source: questionnaire Russia. The second type of MRI: Organization in charge-Multipurpose Forest Resource Inventory; scope: local, objectives: timber, NTFP (Non Timber Forest Products), recreation, wildlife; source: questionnaire Russia 2.

MRI questionnaire for Latvia was completed in 1997 by Vazdikis.

Cited authors:

Atroshchenko 1985, Filiptchouk 1997, Honer et al. 1985, Khvatov 1988, Kukuev 1997, Pisarenko 1995, Sinyakevich 1987, Strachov 1995, Usoltsev 1997, Vazdikis 1997, Zakharov 1950.

11. 12. 2. Remote sensing

Early works on the use of aerial photography and photogrammetry in forestry were completed by Samoilovitsc (1953), Belov (1959) and Schwidefsky (1959). Samoilovitsc noted that 70 to 95% of the plant associations have been correctly identified by experimented photo interpreters working with 1:15000 or larger scale aerial photographs.

Spectral reflectance of the tree species and photo interpretation as interpretation of satellite imagery was frequently analyzed in Russian literature.

An early work (probably the earliest) on spectral reflectance of tree species was carried out by Belov and Artcybashev in 1957, and they were later followed by Kharin (1974). Kharin underlined that "Spectral reflectance of tree species can be studied by using visual and instrumental methods… the methods divided into ground, air born and laboratory. By the instrumental measurements are used spectrographs, spectrovizors, spectrophotometers and other equipment. The author (Kharin) used a recording spectrometer which worked in the spectral bands of 400-900 nm and had the accuracy of ± 3 %. Spectral reflectance was studied of many trees and shrubs of the U.S.S.R. in various geographical zones and under different ecological sites. Spectrometric data used different ecological sites. Spectrometric data were used to select the proper film-filter combinations, to identify various objects in aerial photos and to study insect damages in the forests. A scheme was developed for estimating the optimal seasons of forest aerial photography in U.S.S.R. taiga regions, desert zone and mountain regions of the Middle Asia" (from Kharin 1974, abstract).

Typical spectral reflectance curves of plants are presented in Fig. 11.12.2.-1

Among other early works on photo interpretation are those published by Kharin (1965: forestry photo interpretation, Kharin (1966), seasonal and technical specification for aerial photography of Siberian forests, and Bociarov and Samoilovici (1964), mathematical ground for the interpretation of forest aero photographs.

Elman et al. (1984) presented the ASOIL system developed by Soviet V/O Lesproekt organization for automated photo-interpretation and thematic mapping of forest (satellite information). In 1987, Elman described the equipment and methods available in the U.S.S.R. for automated interpretation and the obtainable results: delimitation of contour, land types and forest types, and production of mensurational indices.

A review of standard procedures in the U.S.S.R. for forest inventory using aerial and satellite photography was summarized by Sukhikh and Danyulis in only three pages in Lesnoe Khozyaistv 6/1987.

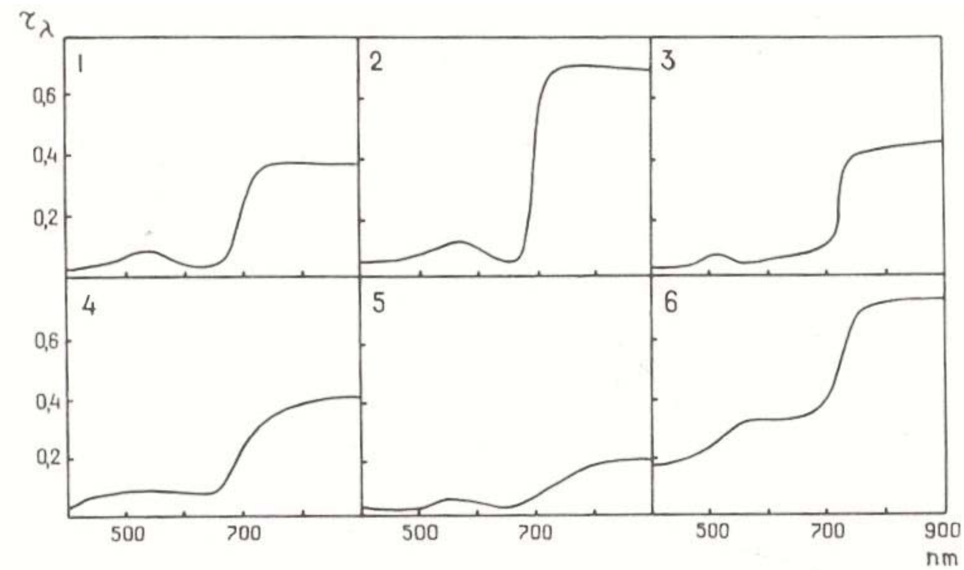

Fig. 11.12.2.-1. Typical spectral reflectance curves of plants. 1- coniferous trees (*Picea excelsa*), 2 - deciduous trees (*Populus tremula*), 3 - halophyts (*Gypsophilla sericea*), 4 - psammophyts (*Haloxylon persicum*), 5- cushion plants (*Nanophyton erinaceum*), 6 - succulenta (*Opuntia gaseliana*).

Source: Kharin, Nikolai G., "Spectral reflectance characteristics of the U.S.S.R. main tree species. In: Hildebrandt editor, IUFRO meeting proceedings 1974, p. 17.

Borisov et al. (1987) described computer techniques for automatic processing of large scale photographs for the horizontal structure determination of tree stand (scales 1:4000 - 1:8000, pine plantation 80-120 yr old). "Compared with ground surveys computer technique estimated crown radius and crown closure with mean squared errors of 8 and 12 %, respectively. The number of trees was underestimated by 18 %. Volume estimates were 201 m^3/ha from the photographs and 210 m^3/ha from the ground survey" (For. Abs. 1716/1989).

Isaev and Suknikh (1986) reviewed the use of space satellites and outlined a comprehensive monitoring system of the five autonomous interrelated blocks. These groups of tasks are related to dividing of territories into economic/landscape regions, mapping and inventorying of forest resources, protecting forests from fire, insect pest and industrial pollution. It is presented a scheme showing the integration of satellite, aircraft and ground monitoring operations (For. Abs. 4523/1987). Suknikh (1980) presented also remote sensing methods of monitoring the anthropogenic activities in the forest.

The processing of laser profilograms for forest mensuration was described by Solodukhin et al. (1985). Profilograms are made by a laser profilograf (phase-type light range-finder) installed on an aircraft. Profilograms give height of top storey, canopy density, mean crown diameter, and stand density. The cited author demonstrated the feasibility of using laser profilograms for forest inventory, especially in the case when they can be recorded on magnetic tape and analyzed automatically, by computer. New data on laser forest survey (recording of profiles on magnetic tape for subsequent computer processing) were supplied by Stolyarov and Solodukhin in 1987.

A method for matrix analysis of changes in land use from aerial photographs (scale 1:10000) taken in 1956 and 1974 over an area of 5803 ha in the Skriveri Vinogradov et al. (1987).

Remote sensing (airborne thematic mapper, spatial resolution about 10 m) was used by Vygodskaya et al. (1995) for determination of foliage weight of forest stands by comparison of the airborne scanner results with data obtained from ground measurements on the same transect (For. Abs. 9461/1996).

Aerial photography and satellite imagery was used to monitor forest cover in the western Siberia (Sedyks 1995).

Among other application of remote sensing in forestry will be mentioned: 1) the automatized identification of oak powdery mildew, *Microsphaera alphitoides*. Griff. and Moubl., on aerial photographs of oak forests, photos scale 1:15000, on a panchromatic film with a light yellow light filter, in the spectral wave-length interval 0.50-0.68 μm in August (Vinogradov and Soshnina), and 2) satellite monitoring of broad leaved forests of the Southern Urals in conditions of atmospheric pollution, using satellite images and phytocoenometric measurements (Butusov et al. 1996).

Cited authors:

Belov 1959, Belov and Artcybashev 1957, Bociarov and Samoilovici 1964, Borisov et al. 1987, Butusov et al. 1996, Elman 1987, Elman et al. 1984, Isaev and Suknikh 1986, Kharin 1965, 1966, 1974; Samoilovich 1953, Schwidefsky 1959, Sedych 1995, Solodukhin et al. 1985, Stolyarov and Solodukhin 1987, Sukhikh 1986, Sukhikh and Danyulis 1987, Vinogradov et al. 1987, Vinogradov and Soshnina 1988, Vygodskaya et al. 1995.

11.13. Chronology of selected works and events

1840s: The start of regular forest inventories in Russia (N. P. Anuchin 1970).

1843: Publication of the first textbook on forest mensuration (‘*Lesnaya tacsatsia*’) written in Russian language (V. S. Semenov).

Since 1850: Local and regional studies on stand growth and yield.

1850-1860: The idea of stem lateral area determination (SLAD) in a stand and construction of first tables for lateral surface of trees (Vargas de Bademar).

1870: Old Russian volume tables in which the trees were divided in function of diameter and height by classes named tables by height categories.

1872: Forest mensuration tables (M. K. Turskii).

1892: The first Russian dendrochronological investigation: tree-rings of the black locust (*Robinia pseudacacia* L.) growing on the Ukrainean Odessa city. Prediction of the draught of 1891 year (F. Shvedov).

1899: A brief outline of the history of forest management (A. F. Rudzskii).

1899: Mendeleev's general equation $y = a + bx + cx^2 + dx^3$ proposed for the form of stem curve.

1900: A. F. Rudzskii's forest mensuration textbook written to stop the influence of German forest mensuration literature as a results of translation of Baur's and Kunze's textbooks in this field.

1903–1904: Elaboration of the theory of stand types (F. G. Morozov).

1908–1913: Early volume tables compiled under the guidance of Kryudener. Tables have seven independent variables and were not accepted by practitioners.

1912: Law of stem content and its importance for volume and assortment tables – published in Germany (M. E. Tkachenko).

1913: Volume, taper and other tables for major tree species (Administration of the Imperial Estates).

1923: M. M. Orlov's first edition of a textbook on forest mensuration . (the 2nd edn. in 1925, 3rd edn. in 1929).

1927: N. V. Tretyakov's theory of stand elements – the last unit up to which the forest can be divided.

1927: G. M. Turskii's textbook on forest mensuration.

1929–1936: Early application of statistical methods in forest mensuration: (V. V. Golubaev (1929), S. A. Bogolovskii and V. P. Zinoviev (1932), M. G. Zdorik, (1934, 1936).

1920–1931: A. V. Tyurin's general yield tables.

1925–1929: M. M. Orlov's site class scale for yield tables of all species with trees grown from seeds and coppice.

1931: Single–tree log class tables for pine, spruce, oak, birch and aspen (N. P. Anuchin, M. I. Egorov, M. G. Groshev).

1931: The monumental work on volume tables for pine, spruce, oak, birch and aspen by site classes (D. I. Tovstoles, D. I. Tretyakov, V. V. Zakharov, B. A. Shustov, A. V. Tyurin).

1931: A. Mathiesen's method of weight center for volume determination.

1931: M. M. Orlov's forestry handbook – 8 editions in 25 years ("*Lesnaya vspomogatel'naya knizhka dlya taksatsii I teknicheskikh raschetov"*).

1931: V. N. Sukachev's typology based on ecological criteria.

1936: Elements of current increment and their correlation (I. M. Naumenko).

1936, 1960: Determination of the increment of trees from the lateral surface of the stand (A.V. Tyurin 1936, N. P. Anuchin 1960).

1938: A. V. Tyurin's textbook on forest mensuration (2^{nd} edition in 1945).

1940: New assortment tree class tables for pine spruce, oak, alder, aspen and hornbeam (F. P. Moiseenko and A. G. Murashko).

1940: P. N. Sergheev's textbook on forest mensuration.

1940: Forest handbook (Spravochnik taxatora) 2^{nd} edn. (N. V. Tretiakov, P. V. Gorskiy, G. G. Samoilovitsch).

1940s: More detailed determination of current increment of stands: F.P. Moiseenko and A. G. Murashko (1940); I. M. Naumenko (1940, 1946); F. P. Moiseenko (1947); Vaschnil and N. P. Anuchin (1959); P. V. Voropanov (1961); V. D. Volkov (1968); Yu. Yu. Rusetskas (1986).

1944: Textbook on Ukrainean typological school with type of forest land as basic unit of classification, forest types being subunits included in a basic unit (P. S. Pogrebnyak).

1944: Unional standard (norm) Gost 2706 – 44 for volume determination of stacked logs.

1949: Assortment and merchantable wood tables for Scots pine, Norway spruce, birch and aspen (N. P. Anuchin).

1949 – 1962: Structure of different stands: V. I. Levin (1949), A. D. Dudarev (1950), M. V. Davidov (1951), Vaschnil and N. P. Anuchin (1959), I.I. Gusev (1962).

1950: Variation of the inventory characteristics of stands (V. K. Zakharov).

1950: Graphical determination of the taper of the tree stems (N. P. Anuchin).

1950s: Early textbooks on the use of aerial photography in forestry: G. G. Samoilovich (1953), V. S. Belov (1959).

1950s: Standard tables of total basal area and stand volumes per hectare for stocking, 1.0 = close stands: A. N. Karpov (1951), G. M. Kozlenko (1953), M. V. Davidov (1952).

1950s: Sustained researches in the field of dendrochronology began since the 1950s. The first dendrochronological laboratory was organized in 1959 at the Institute of Archeology of the U.S.S.R. Akademy of Sciences (Moscov) under the leadership of professor B. A. Kolchin.

1957-1974: Early spectral reflectance study of tree species: S. V. Belov and E. S. Artcybashev (1957), N. G. Kharin (1965, 1974).

Since 1952: N. P. Anuchin's textbooks on forest mensuration (1952, 1960, 1970, 1977, 1982).

1955, 1967: Dendrochronological studies on the trees growing on the Baikal shores and level oscillations of the lake (G.I. Glazy).

1956: Stem form of Norway spruce in Lithuania and construction of taper and volume tables (Yu. P. Butenas).

1960: Zacharov's textbook on forest mensuration (1960, 1967, 1982).

1964, 1987: Interpretation of forest aerial photographs (M. K. Bociarov and G. I. Samoilovich 1964).

1960s: Early biomass studies: V. I. Kravcenko (1964) - Norway spruce, Arhangelsk; U. L. Shtibe (1969) - Norway Spruce, Latvia.

1961: Models concerning stand structure depending on height (A. Mitropolski).

1961: Assortment tables for standing trees and their method of construction: pine, spruce, oak, ash, maple, hornbeam, birch, lime (F. P. Moiseenko).

1963: A synthesis of dendroarcheological researches in Novgorod area – Russia (B. A. Kolchin).

1967: Yield tables for forest forming species grown in Russia – A handbook (V. B. Kozlovski and V. M. Pavlov).

1968: Computerized (EVM) tables of stem decreasing diameters (taper) and volume tables (V. S. Petrovskii).

1968: The first All-Union Conference on dendrochronology and dendroclimatology was held in Vilnius (Lithuania).

Since the 1960s: The frequent tree-ring analyses for the study of forest ecosystem dynamics: G. E. Komin (1963, 1970, 1972); V. G. Kolishchuk (1966), S. Shiyatov (1977, 1988); D. S. Malokvasov (1974), V. A. Dergachev and G. F. Kocharov (1981).

Since 1970s: The use of modelling in the field of growth, especially stand growth.

1974: The first textbook in Russian language on dendroclimatological investigations (T. T. Bitvinskas).

1975: Modern researches on biological productivity of forest ecosystems (A. I. Utkin).

1975: A text on fundaments of forest mensuration (V. V. Zagreev and A. V. Vagin).

1975, 1978: Modelling of tree growth: B. Zeide (1975), P. Rachko (1978).

1976: A dendroclimatochronological laboratory was established in Kaunas – Lithuania and remains during the Soviet period the largest scientific unit in this field (T. T. Bitvinskas 1978, S. Shiyatov 1988).

1977: The longest tree-ring chronologies: *Juniperus turkestanika* Kom. 1224 years, in Middle Asia, and *Pinus sylvestris* L. 1200 years, in Novogorod – European Russia (B. A. Kolchin, N. V. Cernik).

1978: Mathematical model of Scots pine tree and biomass (N. I. Kazimirov and A. E. Mitrukov).

Since 1980: The use on a large scale of modelling of stand structure. Examples: A. K. Cherkashin (1981) – model of spatial and age structure of forest; P. Ya. Grabarnic and A. S. Komarov (1981) – model of spatial structure of Scots pine stands; G. P. Karev's (1985) modelling of multispecies tree stands; G.P. Karev's (1993) structural models and dynamics of tree populations.

Since 1980s: Ecophisiological approach to forest modelling. Examples: F. M. Semevsky and S. M. Semenov (1982) – mathematical modelling of ecological process; F. S. Berezovskaya, G. P. Karev and A. Z. Shvidenko (1991) – modelling stands dynamics, ecophysiological approach).

Since 1980: The use of computers on a large scale for determining the volume of assortments in stand (Exp. V. S. Petrovskii and Dang Zui Sho 1984).

1980: Dendrochronological Bank of the Soviet Union was founded at the Dendroclimatological Laboratory of the Lithuanian Forest Research Institute of Forestry.

1981: A summary of dendroclimatochronology of the north – western part of the European sector of the U.S.S.R. (T. T. Bitvinskas).

1981: Seasonal tree-growth modelling using the number and size of cells in tree-rings (E. A. Vaganov, L. P. Starova, A. V. Shashkin).

1982: A method of computing annual growth indices for a generalized dendroclimatological series (V. S. Mazepa).

1984: Modelling pine forest growth by types of forests (A. Kiviste).

1984: A mathematical model of the crown of northern spruce: graphs and equations of crown parameters (L. V. Korotyaev).

1984: Ecophysiological model of spruce growth in Estonia (K. Kull and O. Kull).

1984: A textbook on dynamic modelling of tree growth (K. Kull and O. Kull – Estonia).

1984: Structure of physiological models of tree growth (K. Kull and T. Oja).

1984: Models of form factors for stem in mature Scots pine stands in Belarus showing that different regression equations and models were needed for stands of different site quality (D. V. Mikhnyuk).

1984: Reference book on forest mensuration in Russian North – West (A. G. Moshkalev et al.).

1985: The processing of laser profilograms for forest mensuration (Solodukhin V. I. et al. 1985).

Since 1985: Modelling of coenoses – biocoenoses, ecosystems (Exp.: A. N. Chetverikov's 1985; A. I. Busykin, O. P. Sekretenko and R. M. Chlebopros 1987).

Since 1985: Expansion of simulation models. (Example: Simulation model of Scots pine, Norway spruce and silver birch ecosystem by O. G. Chertov and A. S. Komarov 1997).

1985: Histometric analysis of woody plant growth (E. A. Vaganov, A. V. Shashkin, I. V. Sviderskaya).

1985: The description of forest inventory in the USSR-1982 (I. G. Honer et al.).

1986, 1987: Elemental composition of annual tree rings and pollution: M. F. Adamenko (1986), A. F. Chetverticov (1986), R. N. Saborov (1987).

1986: The dependence of current diameter increment on crown length (I. V. Bocharov and V. B. Pankov).

1986: Textbook on growth and form of trees (G. V. Kofman).

1986: Remote sensing methods of monitoring the anthropopogentic activities in the forest (V. I. Sukhikh).

1987: The relationship between ground vegetation and current increment of stands and site classes in the Buzuluk forest (E. V. Dimitrievna).

1987: A review of aerial and satellite methods of study and inventory of forests (V. I. Sukhikh).

1987: An universal model for dynamic determination of site class for the growth of Scots pine (A. A. Kuleshis).

1987: Matrix analysis of changes in land use from aerial photographs (V. V. Vinogradov).

1987: Dating of windthrows by dendrochronological methods (S. G. Shiyatov and A. V. Ulianov).

1987: Forest inventory norms, for standardizing resources in Belorussia (O. A. Atroshchenco).

1987: Automation of interpreting aerial and satellite photos for forest mensuration (R. I. Elman 1984, 1987).

1988: A collection of 75 growth functions out of which Zeide, Garcia, Chapman – Richard and Schumacher functions are considered as the most "popular" (A. K. Kiviste).

1988: A remarkable review of dendrochronological works completed in the U.S.S.R. (Stepan Shiyatov).

1988: A procedure for compiling biomass production tables combined with yield tables (V. A. Usolitsev).

1989: The first dendrochronological reconstruction of seasonal temperature (of mean June–July) over the past millennium for the sub Arctic (Polar Urals) using *Larix sibirica* tree-rings (Donald A. Graybill and Stepan G. Shiyatov).

1990: A portable electronic dendrometer was constructed for selecting resonance wood in standing trees or in logs of spruce (V. I. Fedyukov).

1990: A short summary of dendrochronological works carried out in the U.S.S.R. (L. Kairiukstis and S. Shiyatov).

1991: Analytical approach to ecophysiological forest modelling (F. S. Berezovskaya and G. P. Karev).

1991: Estimation of fine root productivity which depend on their turnover (M. Ivask, K. Lôhmus, E. Rästa).

1991: Bioecological simulation model of many – species uneven–aged tree stand development (R. V. Papadyuk and S. I. Chumachenko).

1993: First approach in Russia to the use of fractal geometry in computer – analytical modelling of tree crown (F. S. Berezovskaya).

1993: Structural models and dynamics of tree populations (G. P. Karev).

1994: The idea to complement the conventional ring chronologies with cell chronologies which indicate the pattern of seasonal growth (E. A. Vaganov, L. G. Vysotskaya, A. V. Shashkin).

1995: A complex study on the structure of a virgin forest (Vladimir Parkhutchii).

1995: A system for evaluation of growth and mortality in Russian forest (A. Shvidenko, S. Venersky, G. Raille, S. Nilsson).

1995: Natural mortality of spruce stands in Moscow Region (Vasiliy A. Vagin).

1996: The first comprehensive study on *Pinus sylvestris* biomass based on over 18 regional and local biomass studies. Stands from European Russia 33^0 E to Yakutia 130^0 E in eastern Siberia (R. A. Monserud, A. A. Onuchin, N. M. Tchebakova).

1996: Modelling tree growth and inter–connection between forest insects and tree plants. An optimization approach (V. G. Sukhovolski).

1996: Allometric equations for biomass, based on data for Scots pine, spruce, beech, birch and aspen trees in European Russia (A. I. Utkin, D. G. Zaamolodchikov, T. A. Gul'be, Ya. I. Gul'be).

1997: An account of forest inventory system in Russia (Yu. A. Kukuev).

1997: A proposal for new approaches to qualitative behaviour modelling of complex systems (F. S. Berezovskaya, G. P. Karev).

1997: Fractal structure of a branch (A. I. Gurtsev and Yu. L. Tselniker).

1997: MRI (multi-resource inventory) questionnaires for Russian Federation and Latvia.

11.14. Selected contributors

Author	Printing years	Field(s)
V. S. Semenov	1843	01
Vargas de Bademar	1850	4
F. Arnold	1858	01
A. F. Rudzskii	1870s-1900s	01
M. K. Turskii	1872	01, 1, 4
N. M. Zobov	1873	01
F. Shvedov	1892	6
G. F. Morozov	1903-1904 (1930)	01, 2
Kryudener	1908-1913	1
M. M. Orlov	1910s-1930s	01, 2
M. Tkachenko	1912-1930s	01, 1, 2
A. V. Tyurin	1910s-1940s	01, 1, 4
N. V. Tretyakov	1920s-1950s	01, 1, 3
M. V. Davidov	1930s-1970s	3, 4
A. Mathisen	1931	1
I. M. Naumenko	1930s-1960s	4, 1
V. N. Sukachev	1930s-1960s	01, 2
M. G. Zdorik	1930s-1950s	01, S
N. P. Anuchin	1940s-1980s	01, 4, 1, 3
S. I. Kostin	1940s-1960s	1, 6
V. I. Levin	1940s-1950s	3
F. P. Moiseenkoo	1940s	01, 4
P. S. Pogrebnyak	1944	01, 2
V. S. Belov	1950s	7
P. N. Sergheev	1940s-1950s	01
G. G. Samoilovich	1950s, 1960s	7
E. V. Dimitrieva	1950s-1980s	4, 6
G. I. Galazy	1950s-1980s	6
V. E. Rudakov	1950s-1960s	6
V. K. Zacharov	1950s-1960s	01, 3, 7
N.G. Kharin	1960s, 1970s	7
T. T. Bitvinskas	1960s-1980s	6
V. G. Kolishchuk	1960s-1980s	6
G. E. Komin	1960s-1980s	6
P. V. Voropanov	1960s-1970s	01, 4
M. F. Adamenko	1070s-1980s	6
L. A. Kairiukstis	1970s-1980s	6
S. G. Shiyatov	1970s-1980s	6

Author	Printing years	Field(s)
A. I. Utkin	1970s-1990s	5, 1, 3
V. I. Turmanina	1970s	6
N. T. Voinov	1970s	1
B. Zeide	1970s	1, 4
O. G. Certov	1980s-1990s	01, 4, 3
G. P. Karev	1980s-1990s	01, 3, 4
R. I. Elman	1980s	7
A. K. Kiviste	1980s	1, 4
V. I. Sukhikh	1980s	7
K. Kull’	1980s	1, 4
V. V. Vinogradov	1980s	7
V. A. Usol’tsev	1980s-1990s	5
F. S. Berezovskaya	1990s	4, 3, 1

01 = textbook on forest mensuration, 1 = tree and primary products, 2 = evaluation of forest site quality, 3 = stand structure, 4 = stand growth and yield, 5 = weight and biomass, 6 = tree-ring studies, S = statistics, 7 = forest inventory and remote sensing.

11.15. Comments

11.15.1. Some remarks of Anuchin

From historical point of view it will be useful to present some opinions expressed by Anuchin who may be considered the most representative Russian specialist in forest mensuration during the last decades of the 20th century. These opinions are summarized after the English version (1970) of his "Forest mensuration".

(1) "Entire tree stems and their parts bear a certain resemblance to regular stereometric bodies. Consequently, the course of forest mensuration includes the application of the laws and rules of stereometry to the solution of these mensuration problems related to the determination of the volumes of tree stems and their parts "(p. 4). It should be remembered that the connection between stereometry and tree stem was known in Germany since the end of the 18th century and these aspects were underlined by the Russian M. E. Tkachenko in a work published in 1912 in Germany (our remark).

(2) In his book, Anuchin "...devoted much attention to graph construction; it provides detailed treatment of the transformation of curves into straight lines. Moreover, this is a detailed description of anamorphosis which was applied, independently of the American work in forest mensuration, in the U.S.S.R. in

1940, for the elaboration of the method of constructing stand log class tables" (p. 442). It is not clear in our opinion what Anuchin wanted to tell by "independently of the American work" maybe a suggestion of equality in the field of priority, and if so, than it should be remembered that nomograms (alinement charts) and anamorphic curves were used in the U.S.A. since 1919 (Alinement Charts in Forest Mensuration, by Donald Bruce, Jour, of Forestry, vol. XVII, no. 7, Nov. 1919, p. 773; "A modification of Bruce's Method of Preparing Timber Yield Tables" by L. H. Reineke, Jour. of Agr. Research, vol. XXXV, no. 9, Nov. 1927, and Chapter X "Alignment charts and anamorphic curves "in "Forest Mensuration" by Harold C. Belyea, New York, 1931, pp. 171-190, (our remark).

(3) Anuchin underlined that "The West European dendrometric texts concentrate on enumeration methods. They do not describe the methods for the description of stands as used in the U.S.S.R. (differentiation of stands into canopy, stories, forest elements, determination of the composition and stocking according to stories, merchantable classes, etc." (p. 444).

(4) In 1970, Anuchin considered as the main problems of forest mensuration: 1) influence of tree species and the succession of species, very important for forest management; 2) new techniques for studies of multi-storied uneven-aged and mixed stands; 3) the problem of determination the trees mortality, observations should be based on permanently sample plots; 4) the existing yield tables reflect only the development of normal stands which are very rare in nature, it is necessary to construct yield tables that reflect the stand properties which are dominant in nature; 5) the use of lateral surface of stems forming a stand (which is constant quantity during a long period of time) for thedetermination of current annual increment of single trees and stands; 6) elucidation of the age-dependent variations in the yields of log classes and grades; 7) yield tables "should be constructed according to a uniform method" (p.447). Anuchin's remarks represent a point of view of a 1960s scientist. No word about modelling in spite of the fact that it appeared in other countries.

11.15.2. Our comments

The development of forest mensuration in Russia and former U.S.S.R. was determined first of all by the need of forest inventories on large areas and influenced by the diversity on the natural vegetation characterized by presence of different forest types and soils, it was influenced also by the German methods (at least in the prerevolutionary period), later by the use of the nomograms and methods of mathematical statistics and since 1970s by computerized models of different types.

In our opinion three periods may be distinguished:

(1) The period of classical forest mensuration was based on empirical and stereometrical German methods. In this period it is included the 19th century and the first three decades of the 20th century when methods of mathematical statistics began to be used. During this period appeared the first textbook on forest mensuration in Russian language, have been constructed the Russian volume and other tables (Turskii 1872) and printed forest mensuration textbooks (Semenov 1843, Arnold 1852, Zabov 1873, Rudzskii 1900, Orlov 1923, Turskii 1927). Influence of the German literature continued at least until the Revolution. In 1903-1904 was elaborated Morozov's theory of stand types, published in a textbook in 1930 (after his death), Tretiakov's theory of stand elements - the last unit up to which the forest can be divided. At the end of the period 1921-1930(31) were constructed Tyurin's general yield tables, Orlov's site class scale for yield tables of all species with trees grown from seeds and coppice, volume tables for the main species, a monumental work completed in 1931 by Tovstoles, Tretyakov, Zakharov, Schustov and Tyurin, Orlov's forestry handbook (8 editions in 25 years), and Sukachev's typology based on ecological criteria.

(2) The second period that can be named as the modern period of Russian forest mensuration is characterized by the use on a large scale of mathematical statistics methods. The beginning of this period was marked by the works of Golubaev, Bogoslowski, Zinoviev and Zdoric (1929-1936) who presented the possibilities of the use of mathematical statistics in forest mensuration. There appeared new textbooks on forest mensuration (Tyurin 1938, Sergheev 1940, Anuchin 1952, Zacharov 1960), studies on stand structure, assortment tables, a new typological school (Pogrebneak 1944), numerous studies on growth determination, early biomass studies, numerous dendrochronological studies, first models and computerized tables - especially on tree growth: Zeide (1975), Rachko 1978), natural cycles and their relation with the cycles in tree-ring series.

(3) The third period - of computerized models - began in the late 1960s and became clear after 1970, and one of the earliest works of this period was completed by Petreovskii (1968) who constructed computerized tables of decreasing stem diameters (taper) and volume tables. The use of modelling was enlarged in the 1970s especially in the area of stand growth (Zeide 1975). Since 1980 modelling has been used on a large scale in the area of stand structure (exp. Karev 1985, 1993). Modelling expansion continued with process-models of ecophysiological approach, since 1985s began the modelling of ecosystems and the expanssion of simulation models in all areas of forest mensuration. Generally, in Russia and later in U.S.S.R. a high attention was paid to biological aspects in

application and development of forest mensuration (forest types, site types, types of forest land, biological cycles, physiological processes, theory of stand elements).

In the 1990s, the first approaches to the use of fractal geometry in forest mensuration appeared: in computer - analytical modelling of tree crown (F. S. Berezovskaya 1993), and fractal structure of a branch (A. I. Gurtsev and Yu. L. Tselniker 1997).

Concerning this book the repartition of cited papers (386) by fields and time periods and by fields within each period suggested the following observations:

a) The highest frequencies of publications (papers) by fields were identified to be as follows:

Field	Period with maximum selected titles	Trends of 1981-1999 period compared with the previous 1961-1980 period
Textbooks	1921-1940	↗
Tree and primary products	1981-1999	↗
Site evaluation	1921-1960	↘
Stand structure Stand growth and yield including modelling	1981-1999	↗
Weight and biomass	1981-1999	↗
Tree-ring studies	1981-1999	↗
Forest inventory and remote sensing	1960-1998	↗

b) The dominant fields by periods show the following ranking:

The major interest in Russian forest mensuration was concentrated upon

Period	Field with the greatest number of papers
Before 1901	1. Textbooks
	2. Stand growth and yield
1901 - 1920	1. Tree and primary products
	2. Stand structure
1921 - 1940	1. Textbooks
	2. Tree and primary products
	3. Stand growth and yield
1941 - 1960	1. Tree and primary products
	2. Stand growth and yield
1961 - 1980	1. Stand growth and yield
	2. Tree and primary products
1981 - 1999	1. Stand growth and yield including modelling
	2. Forest inventory and remote sensing
	3. Stand structure

stand growth and yield including modelling (1), tree and primary products (2), and stand structure (3). Tree-ring studies were not included in this classification because all available dendronological works were included in the text of this book apart from other field where the available titles have been selected, in the text being included only those which were considered as representative, but in this selection in a way the bias was unavoidable.

For the period of 156 years (1843-1999) have been selected 386 references out of which 39% were printed after 1980 and 13% after 1990.

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