

# **Tree Rings and Environment Dendroecology**

Fritz Hans Schweingruber

Edited by:  
Swiss Federal Institute for Forest, Snow and Landscape Research, WSL/FNP  
Birmensdorf

Paul Haupt Publishers Berne · Stuttgart · Vienna

# Contents

<b>Preface</b>	pages 5
<b>1 Introduction</b>	15
The growing field of dendroecology .....	15
The term “dendrochronology” .....	17
Large research gaps .....	17
Objective .....	19
Acknowledgements .....	19
<b>2 Growth Factors</b>	21
Genetic impact .....	22
Ageing .....	24
Tree-ring sensitivity .....	26
Sensitivity of the anatomical structure .....	26
Effect of abiotic factors .....	27
Light .....	29
Temperature .....	30
Precipitation .....	33
Wind .....	34
Nutrients .....	37
Limited root space .....	37
Mechanical damage to the crown, stem and roots .....	38
Anthropogenic air and soil pollution .....	39
<b>3 Growth Zones in Perennial Plants</b>	41
How long have tree rings existed? .....	43
Which plants have rings? .....	45
Which tissues provide a morphological picture of annual growth? .....	49
Growth zones in shoot xylem .....	49
Growth zones in the branch-stem transition area .....	49
Growth zones in root xylem .....	51
Growth zones in phloem (bast) .....	52
Growth zones in bark (periderm) .....	53
Annual growths on shoots .....	54
Short shoots in pine .....	57
Relationship between different annual growth parameters .....	59
Which climates promote tree-ring formation in woody plants? .....	59
<b>4 Basic Biological Functions Involved in Tree-Ring Formation</b>	63
Cell formation and differentiation .....	64
Cell types in the xylem .....	67
Influence of hormones and enzymes .....	69

<b>5 Tree-ring Morphology</b>	<b>71</b>
Genetic influence .....	72
Modification of the basic anatomical structure through environmental influences .....	74
Cambial activity during vegetation .....	74
Cell differentiation .....	76
Cell expansion .....	83
Cell-wall growth .....	86
Growth combinations .....	86
Reaction wood .....	86
Secondary structures .....	88
Macroscopic aspect of tree rings .....	90
<b>6 Annual Tree Growth</b>	<b>95</b>
Techniques for measuring tree-ring width growth in living trees .....	96
Procedures .....	96
Tree-ring width growth in relation to endogenous and exogenous factors .....	99
Period of wood increment .....	99
Growth patterns inside trees .....	103
Typical growth patterns of certain species .....	103
Growth patterns in relation to altitude and site .....	104
Growth patterns in relation to weather .....	104
Growth patterns in relation to water supply .....	104
Annual radial growth rates in relation to other rhythmically appearing tree characteristics .....	105
Cell expansion in relation to endogenous and exogenous factors .....	108
Cell-wall thickening in relation to endogenous and exogenous factors .....	109
<b>7 Growth in all Parts of a Tree</b>	<b>111</b>
Growth conditions in a tree .....	112
Growth in stems .....	113
Partially absent tree rings .....	115
Abrupt growth reductions .....	115
Consistency of tree-ring widths .....	116
Density fluctuations .....	117
Growth in branches .....	119
Growth in roots .....	121
Growth throughout the entire tree .....	129
<b>8 Influence of Water (Dendrohydrology)</b>	<b>131</b>
Tree and site characteristics along rivers and on land with varying water tables useful for dendrohydrological reconstructions .....	132
Impact of floods .....	142
Extreme flood influences along rivers in the temperate climate zone .....	143
Peak floods in dry regions .....	151
Ice dams in rivers in the boreal zone .....	154
Salt water ingress along coasts .....	156
Varying water level in lakes and swamps .....	157
Secular variations in the water level of a lake in northern Quebec, Canada .....	157

Relationship between water level and tree age in the Okefenokee-swamp in Florida .....	160
Salt water ingression in fresh-water flood forests ( <i>Taxodium distichum</i> , Florida) .....	160
Varying water level in bogs .....	161
Drainage of a bog in the Swiss Jura Mountains; Etang de la Gruère .....	161
Reaction of trees in the bog Etang de la Gruère to long- and short-term climatic influences .....	163
Drainage of fens in the northern Lower Alps in Switzerland .....	166
Reconstruction of bog history in northwestern Europe .....	167
Flooded forests .....	169
Inundated forests in the Amazon Basin .....	169
Construction of a dike prevents overflowing .....	171
Ponds in southern Alaska .....	171
Variations in the water table in flat lands .....	173
Sinking water level .....	173
Impact of climate on the course of a river .....	174
The Colorado River in semiarid, southwestern America .....	175
The Huruni River in New Zealand's temperate climate .....	176
Glacier rivers in the Rocky Mountains and the Alps .....	176
Driftwood in northern oceans (Dendrooceanography) .....	178
<b>9 Influence of Snow</b> .....	183
Impact of avalanches .....	184
Ecological indicators for reconstructing the intensity and frequency of avalanches .....	184
Age structure of a stand on an avalanche slope in the southern Swiss Alps .....	189
Reaction of an individual tree to recurring avalanches .....	190
Tree shapes on an avalanche slope .....	190
Impact of creeping snow .....	192
Impact of snow pressure .....	193
Tree decline on snowy sites near the alpine tree limit .....	194
<b>10 Influence of Wind</b> .....	197
Impact of wind on vegetation and trees .....	198
Adaptation of stem shapes under continual wind stress .....	202
Regeneration of forest stands after strong winds .....	203
Changing positions of trees in stands .....	208
Pattern of death and regeneration brought on by wind (wave mortality) .....	208
Trees in the active dunes of the boreal zone .....	213
<b>11 Influence of Fire</b> .....	217
Forest fires .....	218
Tree adaptation to fire .....	219
Fire characteristics and their dendrochronological analysis .....	221
Damage to the crown .....	221
Damage to the xylem .....	222
Fires in the boreal forest of Canada .....	228
Fires in semiarid forest areas and their relationship to weather and climate .....	232

Fires in deciduous forests .....	235
Fire in the southern Alps .....	235
Fire in the grasslands of North America .....	237
Fire in the deciduous forests of Australia .....	238
Impact of fire suppression on tree growth .....	238
Impact of lightning .....	239
<b>12 Influence of Glacial Movement (Dendroglaciology)</b> .....	<b>241</b>
Glacial-historical Methods .....	242
Trees near advancing glaciers .....	243
Reforestation of areas left behind after glacial retreat (ecesis) .....	245
Forests drowned in lakes dammed by advancing ice tongues .....	246
Reconstructing glacial movement .....	249
Glaciers in the Swiss Alps .....	249
Recent glacial movement in the Alps .....	252
Recent glacial movement in the Rocky Mountains .....	254
<b>13 Influence of Tectonic and Volcanic Activity</b> .....	<b>257</b>
Causing factors and reactions .....	258
Examples of dating volcanic eruptions .....	264
Mt. St. Helens and Sunset Crater .....	264
The Bronze Age eruption of the volcano Thera on the Santorin islands in the Aegean Sea .....	265
The Laachersee volcano in the Eifel (Germany) .....	266
Volcanic eruptions influence climate .....	266
Examples of ground uplift and subsidence .....	267
Isostatic ground uplift .....	267
Tectonic uplift .....	267
Tsunamis, ground uplift and subsidence and landslides following earthquakes ....	268
Shifting shorelines along the Atlantic coast in New Brunswick, Canada ..	270
<b>14 Influence of Mass Movement</b> .....	<b>271</b>
Impact on trees .....	272
Rockfall .....	272
Erosion .....	274
Creeping and sliding slopes .....	276
Debris flows in the mountains .....	284
Rock slides .....	287
<b>15 Influence of Animals</b> .....	<b>289</b>
Stem scars caused by mammals and birds .....	291
Scars on young trees as a result of fraying, browsing and ramming by hoofed animals .....	292
Beaver activity .....	295
Damage caused by porcupines .....	295
Trees ringed by woodpeckers .....	298
Browsing by wild and domestic animals .....	298
Defoliation caused by insects .....	302
Periodic larch bud moth ( <i>Zeiraphera diniana</i> G.N.) outbreaks .....	302
Periodic cockchafer ( <i>Melolontha hippocastani</i> and <i>Melolontha meleolontha</i> ) outbreaks .....	306

Aperiodic spruce budworm, <i>Choristoneura fumiferana</i> , <i>Ch. occidentalis</i> outbreaks .....	308
Hormonal disturbances of the cambial activity of <i>Pinus halepensis</i> by the bast scale, <i>Matsucoccus josephi</i> .....	312
Compression-wood formation caused by the woolly aphid ( <i>Adelges piceae</i> ) .....	312
Pith flecks caused by cambium-mining insects ( <i>Agromyzidae</i> , <i>Diptera</i> ) ...	315
<b>16 Influence of Fungi and Mistletoe</b> .....	317
Impact of increment boring on a tree .....	318
Oak decline in northern Germany .....	321
Fungi that influence the cambium .....	322
Cancer ( <i>Cryphonectria [Endothia] parasitica</i> ) .....	323
Rust ( <i>Puccinia arrhenatheri</i> ) on berberitzen ( <i>Berberis vulgaris</i> ) .....	323
Traumatic intercellular canals in cherry species .....	324
Gaps in a stand due to diseases .....	325
Mistletoe .....	326
<b>17 The Mutual Influence of Competition and Cooperation</b> .....	331
Competition .....	332
Population growth .....	333
Individual tree growth .....	335
Cooperation .....	337
The dynamics of shrub formations .....	339
<b>18 Influence of Man</b> .....	341
Fertilization .....	342
Impact of fertilization on volume growth .....	343
Relationship between fertilization, climate and tree growth in Central Europe ...	344
Impact of fertilization on the structure of the wood .....	345
Thinning in managed forests .....	345
Historical forest utilization .....	347
Tree Pruning .....	349
Pruning conifers .....	349
Pruning angiosperms .....	352
Pollarding .....	353
Replanting Trees .....	356
Resin tapping .....	357
Soil compression .....	359
Natural reforestation following anthropogenic utilization .....	360
Natural reforestation of agricultural land in Switzerland .....	361
Forest destruction and natural reforestation in the subalpine zone in Colorado, U.S.A. ....	363
Decline of a century-old irrigation network in Valais, Switzerland .....	365
A protection forest on a rocky cliff .....	366
Influence of "tree care" on tree growth .....	367
Crown pruning .....	368
Grafting .....	368
Hypothesis of forest decline .....	369
Introduction .....	369
Main emphases in research .....	369
Dendrochronological methods .....	373

How do trees and forests die? .....	373
How healthy or sick is a tree or a forest? .....	376
Do climate and weather influence a tree's health? .....	386
Does anthropogenic pollution influence tree growth? .....	391
Carbon Dioxide (CO <sub>2</sub> ) as a growth-influencing factor .....	404
Using tree rings as chemical data carriers for the construction of pollution chronologies .....	406
Prehistoric utilization of wood and forests .....	414
The utilization of wood and forests in prehistoric southern Central Europe .....	414
Raw materials for tools and appliances .....	416
Raw material for construction wood .....	418
Neolithic man influenced the landscape .....	420
Dated piles used as foundations for the reconstruction of forest utilization .....	421
Neolithic forest utilization .....	426
Sources of error .....	428
Forest utilization in recorded history .....	432
Wood transport .....	433
<b>19 Influence of Climate (Dendroclimatology)</b> .....	<b>439</b>
Introduction and questions .....	440
Methodical basics .....	441
Meteorological data .....	441
Site and stand selection .....	441
Technical methods .....	444
Analyzing continuous data series .....	445
Introduction .....	445
Material .....	446
Statistical methods .....	446
Tree-internal data series .....	449
Chronologies along changing gradients .....	450
Millennial chronologies .....	456
Chronologies from the tropics and subtropics .....	457
Chronologies from semiarid regions .....	460
Chronologies from subalpine and boreal zones in both hemispheres .....	466
Chronologies from temperate zones in the northern Hemisphere .....	470
Networks .....	471
Problems of interpretation of dendroclimatological networks .....	475
Growth rhythms over many years .....	477
Analyzing discontinuous data series .....	480
Definition of the terms: event years, pointer years, pointer values, pointer intervals, and abrupt growth changes .....	480
Event years .....	483
Master plots .....	484
Geographical distribution of event years .....	486
Pointer years in trees and on sites .....	487
Pointer values along high elevation gradients .....	490
Pointer values in beech growing at ecological limits in Switzerland .....	497
Pointer years in different geographical regions .....	500
Drought .....	501
Summer temperatures .....	503
Wind stress .....	504
Pointer years specific to individual species .....	508

Pointer years caused by fruiting (mast year) .....	511
Cracks in the stem caused by drought .....	512
Cracks in the stem caused by frost .....	514
Injuries caused by hail .....	516
Difficulties in working with pointer years .....	517
Difficulties in working with response functions .....	518
Difficulties in working with mean curves .....	522
Growth zones in fossil stems are expressions of climatic conditions in geological periods .....	524
The tree's architecture as an expression of climatic conditions .....	527
Examples from northern Quebec, Canada .....	527
Dating tree rings .....	528
Oscillations of tree limits as an expression of climatic changes .....	532
Plant reactions in relation to site factors .....	532
Recent oscillations in tree limits .....	535
History of Dendroclimatology .....	537
State of knowledge at the beginning of the 20th century .....	537
Morphological variability of tree rings in different climate zones and on different sites .....	539
The period of Andrew Ellicott Douglass (1867–1962) .....	541
Dendroclimatology in Europe between 1939 and 1961. The period of Bruno Huber .....	544
Development of dendrochronological research since the 1950s .....	548
<b>20 Isotope Ratios as Temporal and Ecological Indicators</b> .....	<b>549</b>
Basic information .....	550
The radioactive carbon ( $^{14}\text{C}$ ) (In memoriam Bernd Becker) .....	550
Impact of the earth's magnetic field causes a long-term variation .....	551
Sunspot activity has an impact on secular variations .....	552
Hydrogen bomb explosions .....	553
Impact of fossil-fuel burning on the $^{12}\text{C}/^{14}\text{C}$ ratio .....	554
Consequence for the calibration of dating organic matter .....	554
Stable isotopes .....	556
Deuterium ( $^1\text{H}/^2\text{H} = \Delta^2\text{H}$ or $\Delta\text{D}$ ) .....	556
Oxygen 18 ( $^{18}\text{O}/^{16}\text{O}$ ) .....	557
Carbon 13 ( $^{13}\text{C}/^{12}\text{C}$ ) .....	558
Influence of climate on the $\delta^{13}\text{C}/^{12}\text{C}$ .....	562
Perspectives in tree-ring research using stable isotopes .....	562
<b>21 Literature</b> .....	<b>565</b>
<b>Index of Terms</b> .....	<b>603</b>