Three notes on an unthinned stand of Sitka spruce (Picea Sitchensis (Bong.) Carr.) in the forest of Marbæk plantage

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by
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Preface

This paper contains three notes on an extensive dataset gathered in an unthinned stand of Sitka spruce (*Picea sitchensis* (Bong.) Carr.) in the forest of Marbæk plantage.

The first note describes the data collection and stand history. The second note describes the semi-automated growth ring recognition routine that was developed and applied. The third note describes the structure and contents of the database.

Acknowledgements

Lars Wichmann, May 2001.

Chapter 1

Data collection

1.1 Data collection

The data and data collection procedures are presented in the following section.

1.1.1 Stand description

The subject of this investigation is a 0.42 ha stand in the forest of Marbæk Plantage, which is situated at the west coast of Denmark (8°18' E, 55°25' N) approximately 15 km north of Esbjerg. The soil consists of deep sandy glacial deposits from the Saale ice age, offering good drainage and poor nutrient supply. Further, due to deforestation and prevalent sand drift a spodic horizon (podzol) developed during the late middle ages. The average annual precipitation for the past 57 years is 768 mm (medium to high) with a standard deviation of 141 mm. The growths conditions are further influenced by the prevailing strong westerly winds. Finally, the close proximity to the North Sea result in large deposits of mineral salts, e.g. sodium chloride, which also has a negative impact on tree growth.

1.1.2 Procedures

All standing trees, dead as well as alive, were numbered and positioned manually prior to felling (Fig. 1.1). The positioning was carried out using a grid of steel measuring bands stretched between the stand edges and corners, which were fixed and positioned initially. Four trees had two live stems, which were conceived as two individual trees. Dead double stems were excluded regardless of their size.

The temporal height development was registered for all live trees by measuring the distance (in centimeters) between breast height (1.3 m) and each branch whorl using a steel measuring band. The location of branch whorls was determined by visual inspection of the stem and by occasional counts of shoot numbers on adjacent branches. For dead trees the total height was measured only.

The 5th and 10th branch whorl were extracted and the longitudinal development (shoot length in cm) and cardinal direction of the branches were measured using a protractor (Fig. 1.2). The shoot lengths were measured as the lengths from the center of the stem to the shoots (Fig. 1.2) starting with last years shoot and ending with the 4th respectively 5th shoot. Further, the
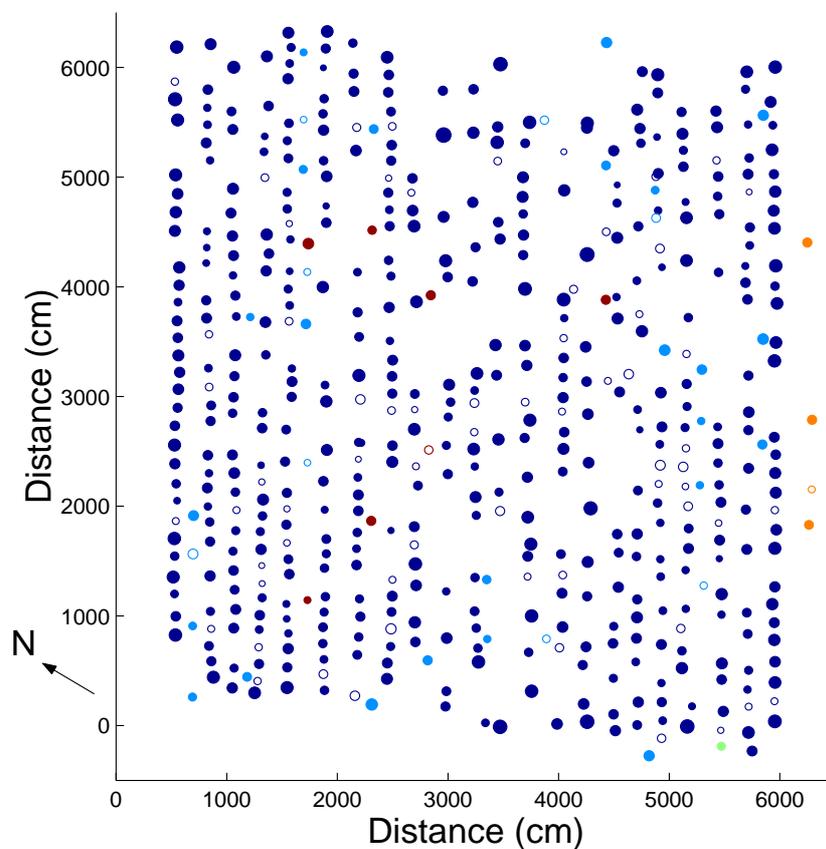
Figure 1.1: Stand Map.

crown depth in 1999 was registered as the height of the lowest living branch, i.e. at least one branch with green leaves.

Thirteen wood discs were extracted from the stem of each living tree. Ten discs were taken at equally spaced intervals at and above 1.3 m and three discs were taken below 1.3 m, e.g. 48, 82 and 118 cm above ground level (Fig. 1.3). From dead trees, when possible, one disc was extracted at 1.3 m only. The tree number, the disc number and north direction were marked on the bottom face of each disc. The discs were debarked and stored in black plastic bags and refrigerated to prevent drying and excessive attack by blue-stain fungi before further analysis. Furthermore, the stem diameter at 16 cm was measured in N/S and E/W directions using a ruler.

Figure 1.2: Branch whorl.

The top face of the discs were sanded or planed (depending on disc size) and an image of each disc was scanned in 600×600 dpi using a standard flatbed scanner (Agfa Snapscan 600). Discs bigger than the scanner were divid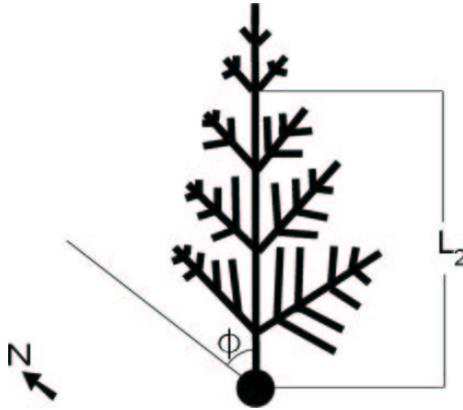ed into sections ensuring that the entire disc was scanned and that the pith was included in all images. The images were saved in TIFF-format for later analysis. Finally a 5-8 cm wide strip of wood was cut from each disc along the north/south diameter. The strips were dried and stored for later reference. Based on the digital images the radial growth (width of individual growth rings) was measured in four directions (north, south, east and west) using a combination of automated growth ring recognition by digital image analysis and a visual verification routine.[1]

For dead trees the time of death was estimated by a simple dendrochronology procedure, which consisted of a visual comparison of the measured ring width series for the dead tree with an average series from all live trees.

1.1.3 Stand history

The area was afforested with sitka spruce and mountain pine in the late 19th century and the existing stand (second generation) was planted in 1942 using a spacing of app. 1.5×1.5 m. The main species was sitka spruce (Picea sitchensis (BONG.) CARR.). Mountain pine (Pinus mugo TURRA), mixed with single Scotch pine (Pinus sylvestris L.) and Norway spruce (Picea abies (L.), KARST.) originally constituted every third row. The mountain pines

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[1]Described in another note

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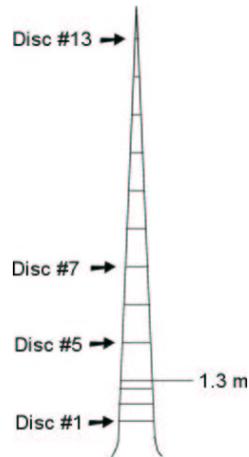
Figure 1.3: Disc extraction points

died naturally and/or were removed early in the stands life, otherwise the stand was left untouched (unthinned) until felled and analysed in the summer 1999. Finally it may be noted, that there were remnants of a slightly older hedge of white spruce (Picea glauca (MOENCH) VOSS) at the southern edge.

Species	Planted	Alive	Dead	Missing
Sitka spruce	"790"	436	88	"268"
Mountain pine,	?	0	0	all
Scotch pine,	?	25	15	?
Norway spruce,	?	6	2	?
White spruce,	?	3	0	?
and Larch	?	1	0	?
Total	1188	471	106	612

Table 1.1: The number of trees

Originally approximately 1188 trees were planted, i.e. 36 trees in each of 33 rows. From Table 1 it is evident, that there are no information regarding app. 615 of the originally planted trees. However, most of these are mountain pines.

Chapter 2

Semi-automated growth ring recognition by digital image analysis

2.1 Semi automated growth ring recognition and visual verification routines

This note contains a description of the semi automated growth ring recognition routine. First a very brief background for the routines is presented, then the background for the routines is described in detail followed by a brief outline of the routine. The note ends with some concluding remarks regarding the routines.

2.1.1 Background

There exists a number of ways to measure the width of growth rings on wood discs. Traditionally growth rings are measured mechanically using a combination of a microscope, a ruler and an operator (Cook & Kairiukstis (1990), Meilby (1999)). This method is very labour- and time consuming even when computerised. Thus, an easier way to measure the width of growth rings is by digital image analysis and a set of commercial software packages exist (Guay *et al.* (1992)). Because the underlying project is rather unique, with respect to the excessive number of discs/files and the individual quality of the wood disc images, the application of existing software might prove difficult. Thus, in order to more easily incorporate all the needs and requirements a special set of routines were programmed using the software package MatLab, v.5.3.1.29215a (R11.1), MathWorks Inc. The result is a set of MatLab routines called SAGRR (*Semi Automated Growth Ring Recognition*). The images analysed are digital 600×600 dpi grey scale images. Thus, each image constitutes a n×m matrix of grey scale values g, $g = [0 : 256], 0 = black, 256 = white$. The resolution may be choosen arbitrarily, albeit some degree of detail is required, and the above was chosen mainly for practical reasons, i.e. storage and hardware limitations.

2.1.2 Theory of the routine

Annual rings on wood (softwood) discs appears as bright sections of early wood gradually blending into a darker sections of late wood. The transition between late wood in one year and early wood the following year appears (through sanding and/or planning) quite sharp. The sharp transitions correspond to local maximums (ring candidates) in the image gradient function, and these local maximums may be further enhanced by averaging over a

neighbourhood.[1]

Due to cracks in the wood, resin pockets, knots and other irregularities a ring candidate do not necessarily correspond to an actual growth ring (or ring point). Therefore a mechanistic sorting procedure that removes typical freak ring candidates was invented. The procedure is described in the following.

2.1.3 Sorting procedure

The pith of each disc is, prior to the analysis, estimated as the center of gravity and then interactively located more accurately by a human operator. Then the routine finds all local maximums (ring candidates) in the gradient along a line from the pith to the bark and the ring candidates are then examined/evaluated in numerical order.

The first step is evaluation of the numerical size of the ring candidate and if the size of a ring candidate exceeds a certain value (Q1) the procedure continues. The second step is evaluation of the distance to the nearest already accepted ring candidate (a socalled ring point) and if the distance is larger than Q2 the procedure continues. The third step evaluates the minimum value[2] of the gradient function between the ring candidate and the nearest ring points, if this value is less than Q3 the evaluation continues. In step number four the relative size of the ring candidate is evaluated, i.e. the ratio between the size of the ring candidate and the minimum values found in step 3, and if the ratio is larger than Q4 the ring candidate is accepted. This procedure of ring candidate examination continues until the maximum number (Q5) of rings is found or until the sizes of the remaining ring candidates are less than Q1.

The procedure described above does not produce absolutely unambiguous results, thus it is necessary for the operator to verify the results. For this

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[1]Because the wood discs and images are of rather varying quality, due to differences in species, condition, hardness, moisture, treatment etc., the size of the averaging neighbourhood and other routine parameters may be selected arbitrarily for each wood disc. Through performance tests, on several images of varying quality, a set of sizes that perform fairly well for most discs was selected for the final analysis. The averaging was performed using 3 and 5 pixels respectively in the horizontal and vertical plane. With the employed image resolution (600×600dpi) the averaging leads ultimately to a measuring resolution of 0.2 mm

[2]The local minimums in the gradient function correspond to zones of transition between early wood and latewood within each growth ring. In other words some sort of local minimum must occur between two growth rings.

purpose the ring points from the automated growth ring recognition routine are drawn on top of the original image (overlaid) and the operator may interactively delete freak rings or add unfound rings using the mouse. After verification of the rings the number of rings in each direction is equalised also interactively by the operator.

2.1.4   Concluding remarks

The routine was used for measuring app. 6.500 discs from in total 577 trees. The time consumption was measured during the analysis. Including the visual verification the measurements of one disc (image) along 4 radii took on average 3 minutes and 14 seconds. In other words, assuming an average disc age of 30 years, it took app. 1,5 seconds to locate one ring in one direction.

Ultimately it is possible to measure the radial growth in any given direction through rotation of the image. On the other hand, this would demand excessive amounts of calculations and visual verification in particular. Thus, for this particular project the radial growth was examined in four directions only, e.g. north, south, east and west.

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Chapter 3

Structure and contents of the database

3.1 The database

The aim of this note is to summarise the structure and contents of the database.

The data consist of a number of information sheets (ASCII-format). The sheets are sorted in a directory structure that consists of a file (readme.txt) and 3 catalogues. Each datasheet is described in the following section.

3.1.1 Original data

The directory **data** contain all original data

The file **positions.txt** contain the positions of the trees and consists of three columns:

Column 1	Column 2	Column3
Tree number	abcisse	ordinate
-	cm	cm

The file **species.txt** contain information regarding the tree species and consist of two columns:

Column 1	Column 2
Tree number	Species number
-	1..5

Species code legend

1	sitka spruce (*Picea sitchensis*)
2	scotch pine (*Pinus sylvestris*)
3	larch (*Larix spp.*)
4	white spruce (*Picea glauca*)
5	Norway spruce (*Picea abies*)

The file **status.txt** contain information regarding the functional status of the trees and consist of two columns:

Column 1	Column 2
Tree number	Status code
-	0..2

Status code legend

0	Dead
1	Alive and healthy
2	Alive and unhealthy

The file **diameter16.txt** contain the stem diameter at height=16 cm and consist of two columns:

Column 1	Column 2
Tree number	Diameter at height 16 cm
-	cm

The files **diameters/treenumber.txt** contains width of growth rings and consist of one file for each tree. Each file contains up to 60 columns with the following format:

Column 1	Column 2	Column 3-60
Disc number	Direction	Distance from pith to rings
1-13	W=1,E=2,N=3,S=4	pixels = $\frac{1}{240}$ cm

The file **heights.txt** contain height development information and consist of 60 columns. The height is measured relative to 1.3 m above ground level:

Column 1	Column 2	Column 3-60
Disc number	Top height	height at each whorl
1-13	cm	cm

The file **lowestbranch.txt** contain information about crown depths and consist of two columns. The crown depth is measured as the distance from 1.3 m above ground level to the lowest living whorl.

Column 1	Column 2
Tree number	Height at lowest living branch
-	cm

The file **crown.txt** contain crown development information and consist of 19 columns. The shoot length is measured relative to the stem.

Columns	1	2	3	4	5	6-9
	Tree	Whorl	Branch	Direction	Diameter	Shoot lengths
	-	5 or 10	1..5	0-360°	cm	cm

Columns	11	12	13	14	15-19
	Whorl	Branch	Direction	Diameter	Shoot lengths
	5-10	1..5	0-360°	cm	cm

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The file **edge.txt** contain information regarding a partitioning of the trees in edge, center and intermediate, the file consist of 2 columns (the categories are intermediate=0, edge=1, center=2)

Column 1	Column 2
Tree number	category

The file **rows.txt** contain information regarding a partitioning of the trees in rows. The rows are numbered from left to right when viewed from the origo of the coordinate system. The file consist of 2 columns

Column 1	Column 2
Tree number	Row number

The file **sectionheights.txt** contain information regarding the start height of each section of the stem, and the file consist of 15 columns.

Column 1	Column 2-14	Column 15
Tree number	Height of each section	top height
-	cm	cm

The file **sectionlengths.txt** contain information regarding the length of each stem section, the file consist of 15 columns

Column 1	Column 2-14
Tree number	length of each section
-	cm

3.1.2 Informations sheets

The directory **info** contain information regarding the data gathering and the trees

The file **excluded.txt** contain the numbers of the dead trees that are not included in all datasets.

The file **renamed.txt** contain the conversion from double stem number to new numbers.

The file **remarks.txt** contain the practical remarks concerning the data gathering operation

the file **comments.txt** contain remarks written on the field data sheets. And consist of two columns

Column 1	Column 2
Tree number	Comment

3.1.3 Calculated data

The directory **calc** contain calculated results, such as volume and taper.

The file **volume.txt** contain the volumes calculated for each year and consist of 58 columns corresponding to year.

Column 1	Column 2	Column 3-58
Tree number -	Volume in 1999 m^3	Volume in 1998- m^3

The file **calc/taper.txt** contain the form factor calculated and consist of 58 columns corresponding to year.

Column 1	Column 2	Column 3-58
Tree number -	Formfactor in 1999 -	Formfactor in 1998- -