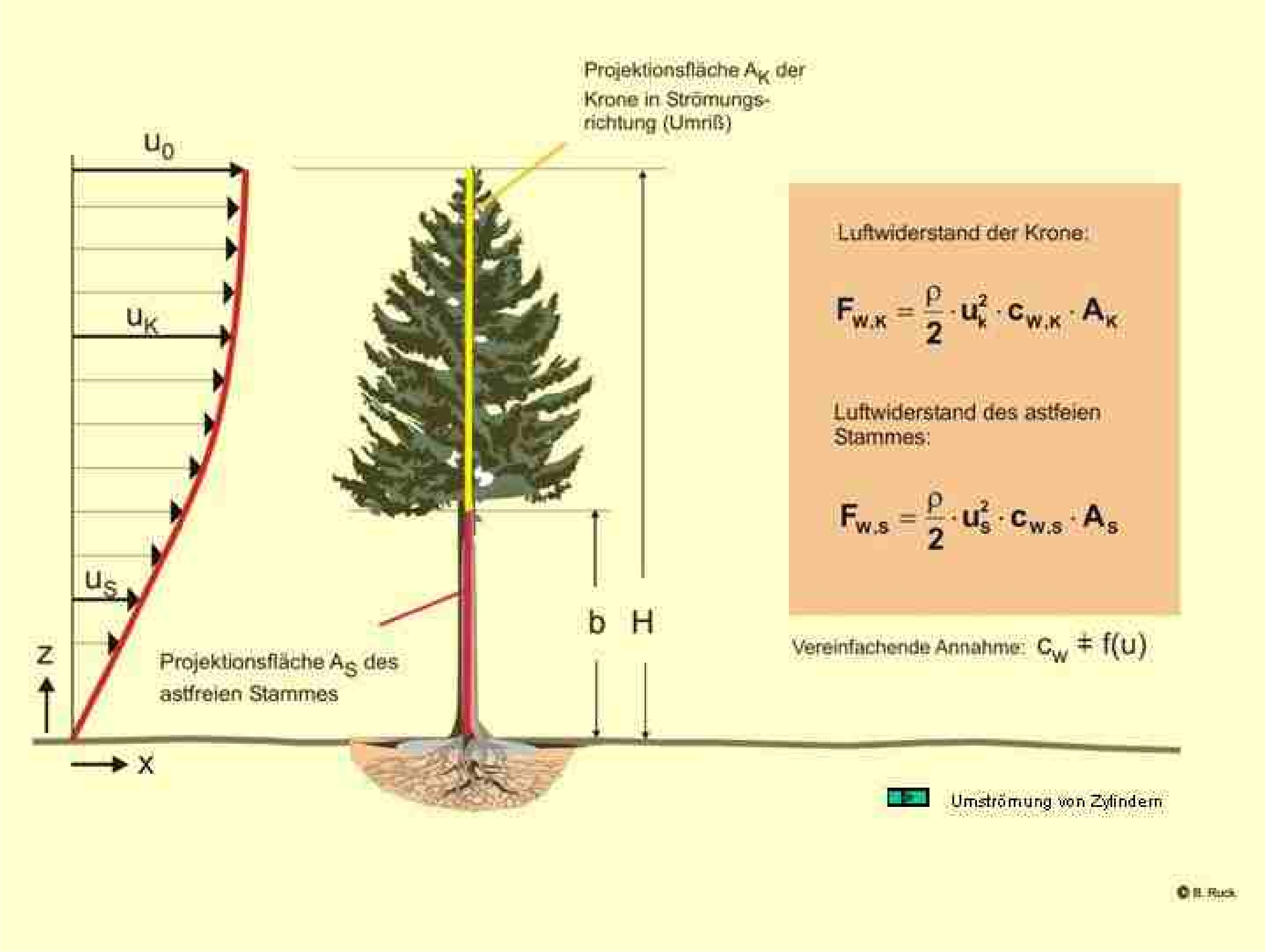
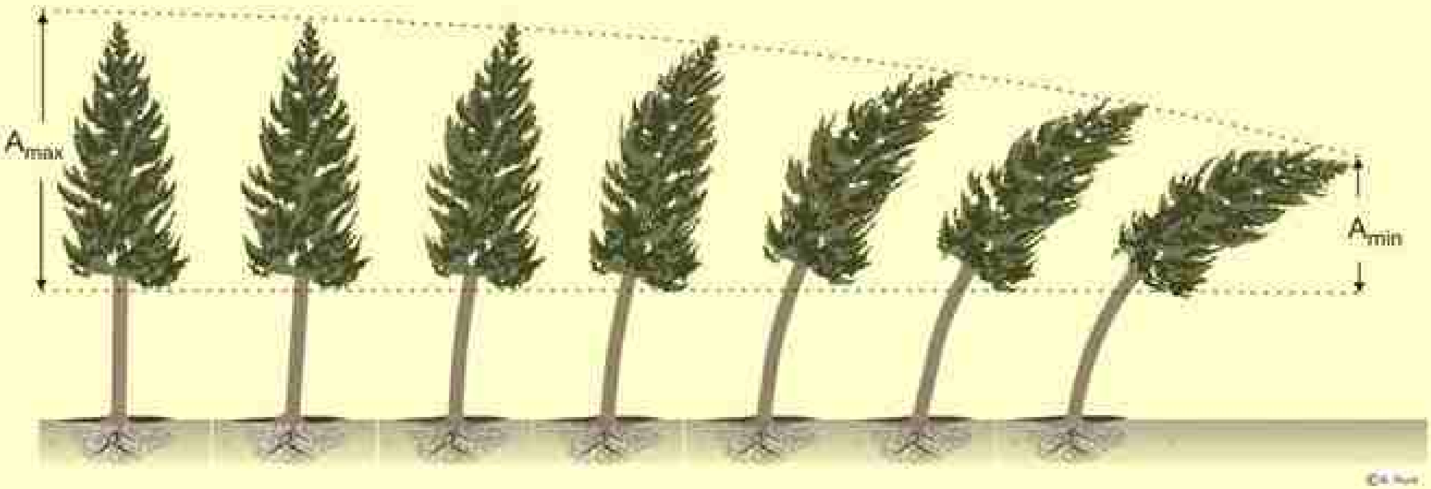
Wind load, crwon cabling,

and pruning effects

Frank Rinn, Heidelberg


Projektionsfläche A_K der
Krone in Strömungs-
richtung (Umriß)
u_0
u_K
u_S
z
x
b
H
Projektionsfläche A_S des
astfreien Stammes
Luftwiderstand der Krone:
$F_{W,K} = \frac{\rho}{2} \cdot u_K^2 \cdot c_{W,K} \cdot A_K$
Luftwiderstand des astfeien
Stammes:
$F_{W,S} = \frac{\rho}{2} \cdot u_S^2 \cdot c_{W,S} \cdot A_S$
Vereinfachende Annahme: $c_W \neq f(u)$
Umströmung von Zylindern
© B. Ruck

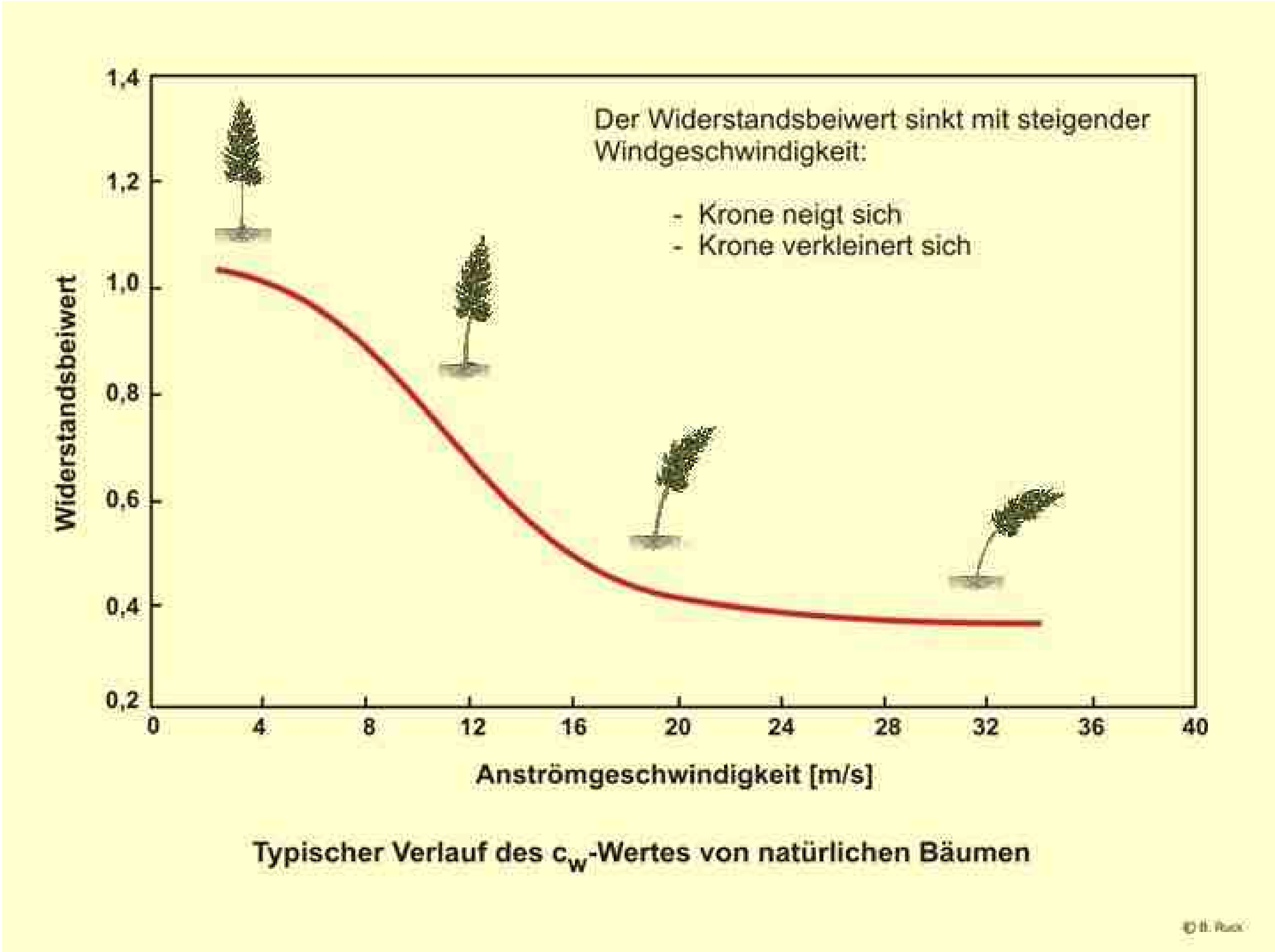
Windbedingte Neigung des Baumes und Verformung der Krone

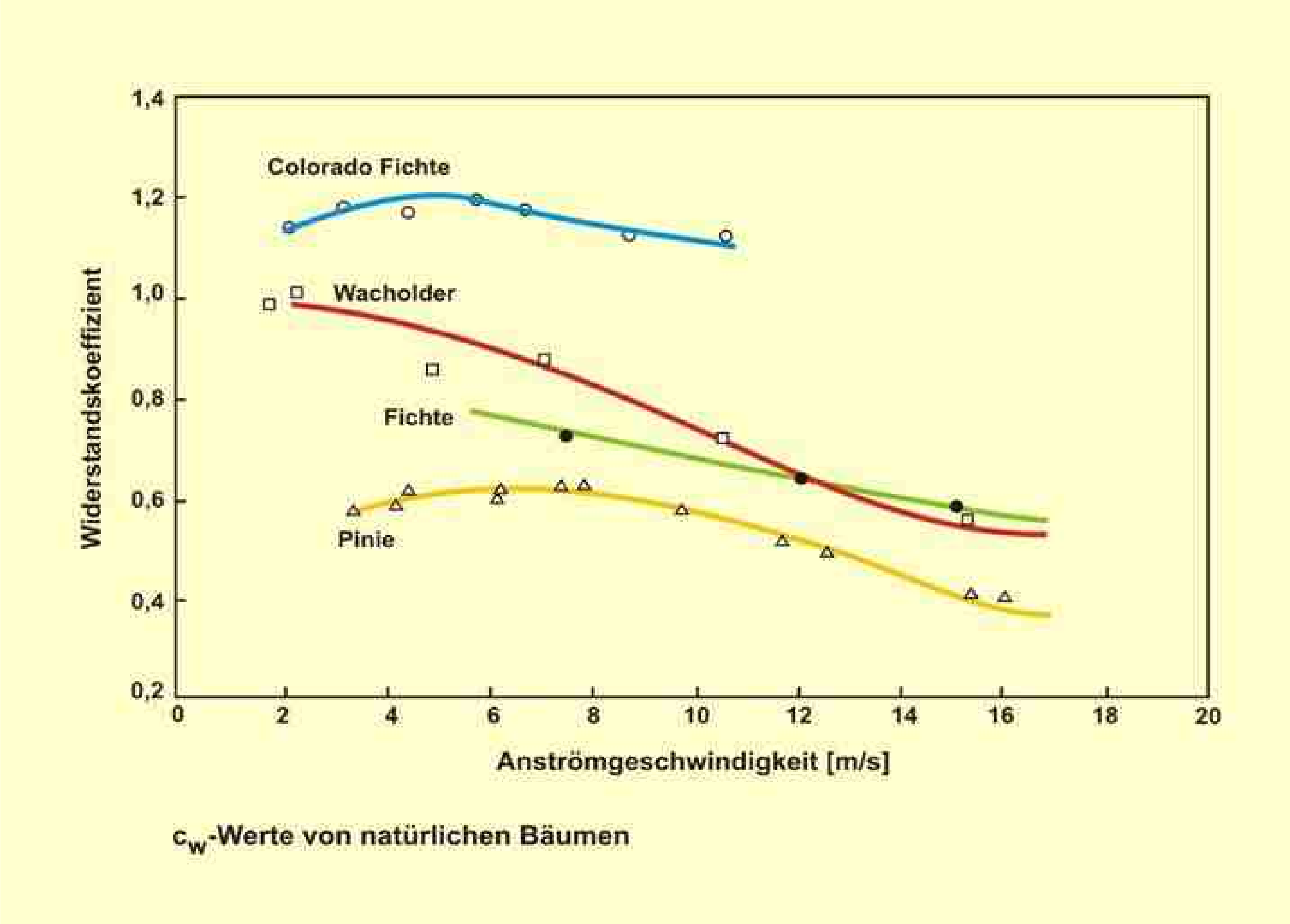


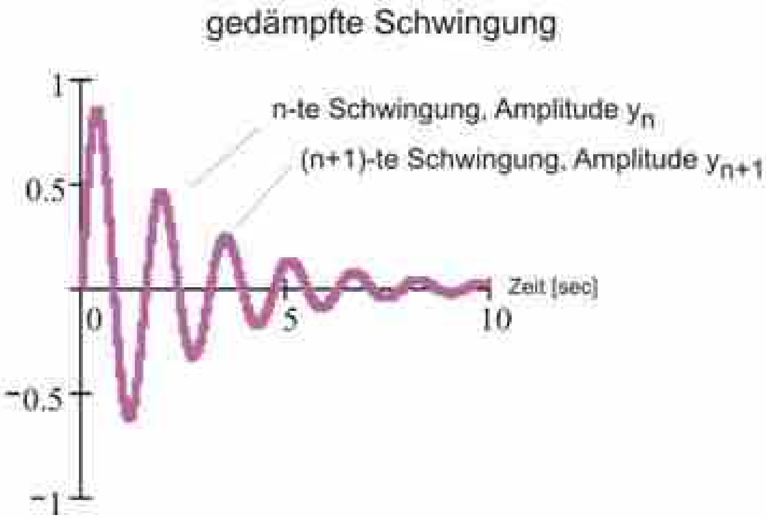
Ablauf:

1. Neigung des Baumes
   - Beginn der Biegung des Stamms und der Krone

2. Verformung der Krone
   - Verkleinerung der Stirnfläche zum Wind
   - Verkleinerung des Kronenvolumens
   - Abnahme der Porosität (Verdichtung)
   - Absinken des Kronenschwerpunkts


1,4
1,2
1,0
0,8
0,6
0,4
0,2
Widerstandsbeiwert
Der Widerstandsbeiwert sinkt mit steigender Windgeschwindigkeit:
- Krone neigt sich
- Krone verkleinert sich
0
4
8
12
16
20
24
28
32
36
40
Anströmgeschwindigkeit [m/s]
Typischer Verlauf des c_w-Wertes von natürlichen Bäumen
© B. Ruck


Colorado Fichte
Wacholder
Fichte
Pinie
Widerstandskoeffizient
1,4
1,2
1,0
0,8
0,6
0,4
0,2
0
2
4
6
8
10
12
14
16
18
20
Anströmgeschwindigkeit [m/s]
c_w-Werte von natürlichen Bäumen



Dämpfungsverhältnis

$$D = \frac{y_n}{y_{n+1}}$$

logarithmisches Dekrement

$$\delta = \ln D \quad \text{oder} \quad \delta = \frac{1}{k} \cdot \ln \frac{y_n}{y_{n+k}} \quad \text{mit k: Anzahl der Perioden}$$

Wird ein Baum durch eine Windböe angestoßen, so kann er Schwingungen ausführen, deren Amplitude von Periode zu Periode wieder abnimmt. Man spricht hierbei von Dämpfung. Das Verhältnis zweier gleichsinnig aufeinander folgender Maximalausschläge y_n und y_{n+1} wird als Dämpfungsverhältnis D bezeichnet. Der natürliche Logarithmus des Dämpfungsverhältnisses D wird als logarithmisches Dekrement $\delta = \ln D$ bezeichnet und dient zur Klassifizierung des Dämpfungsverhaltens.

Lavers 1983

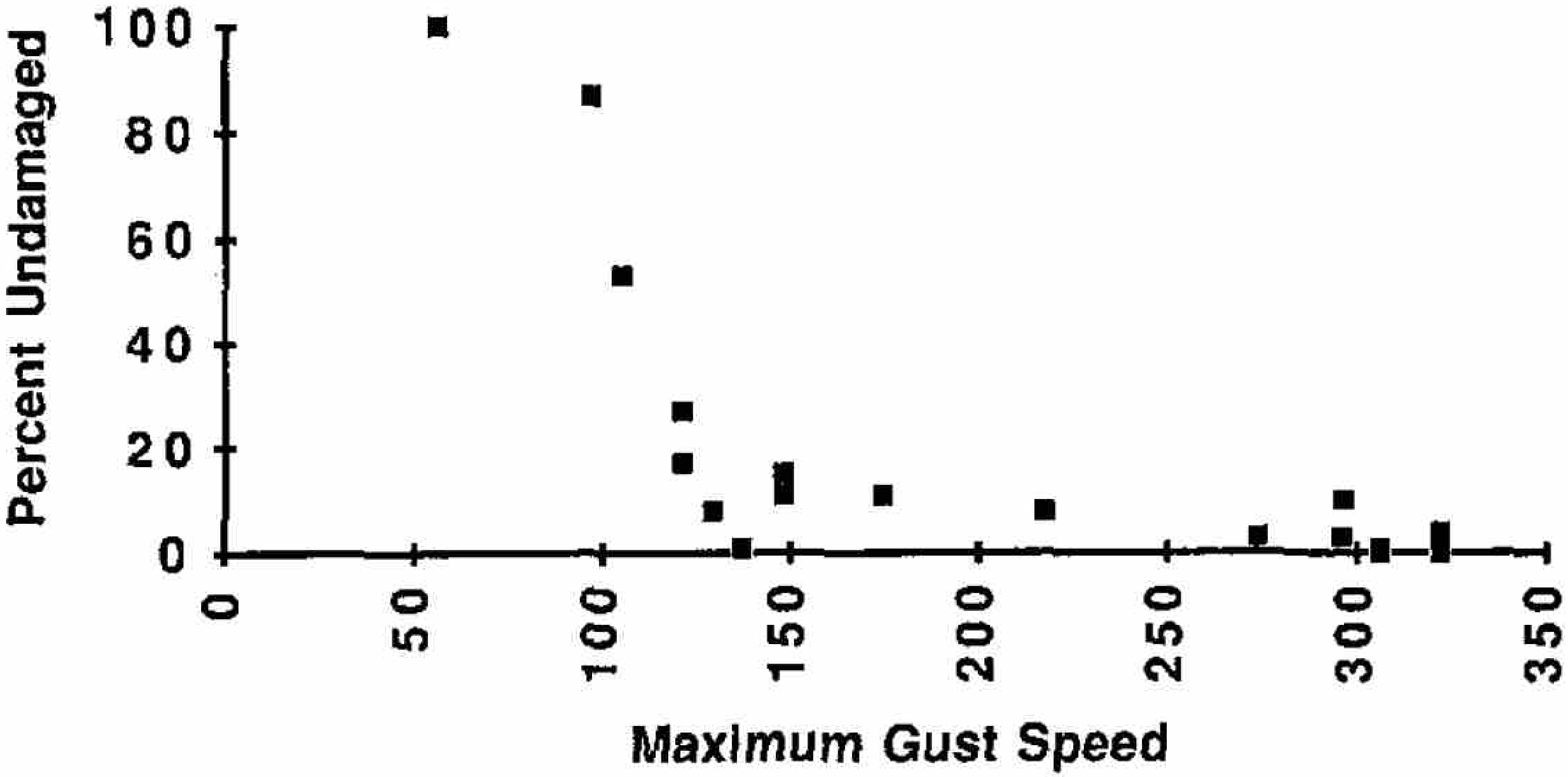
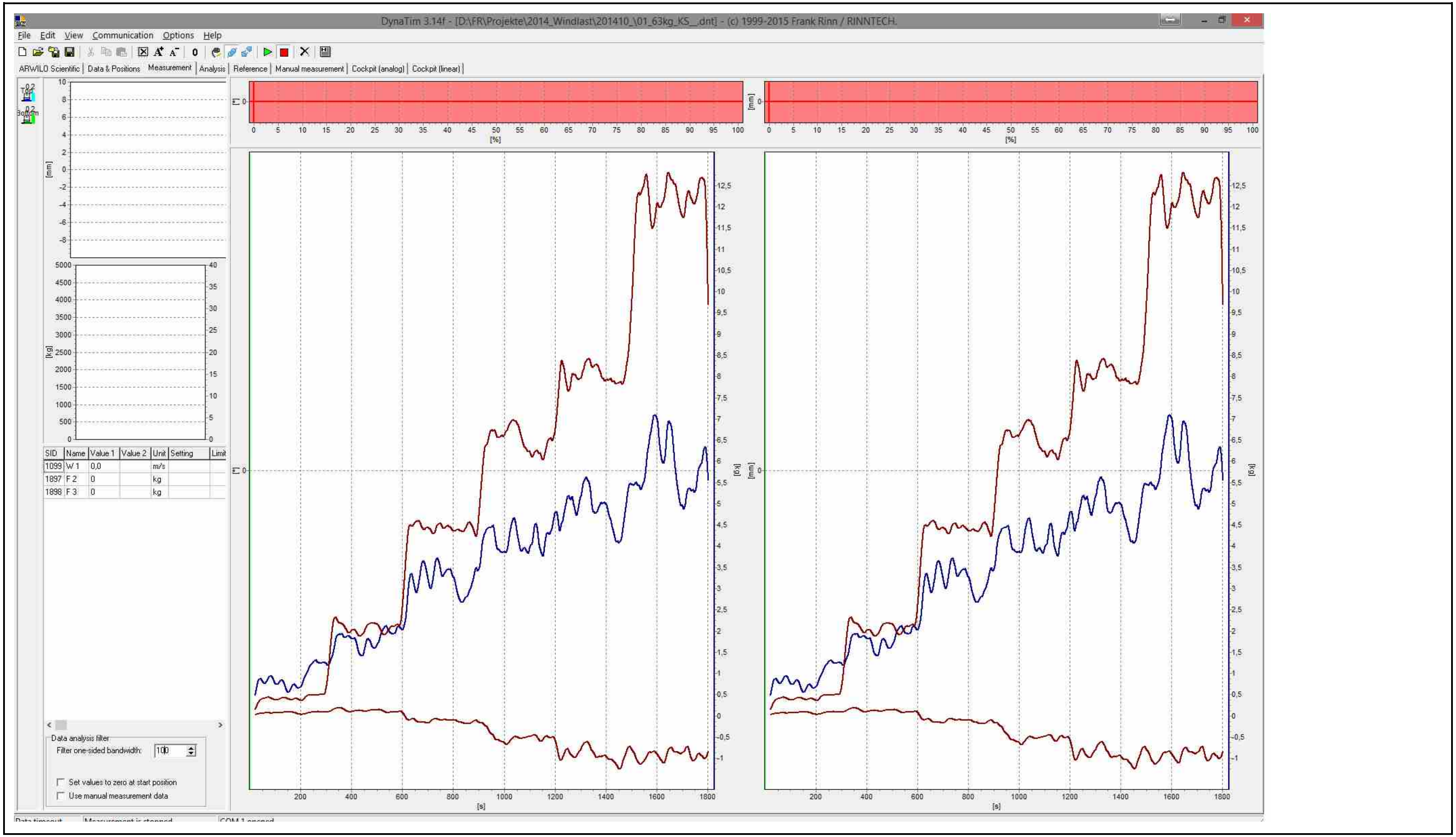
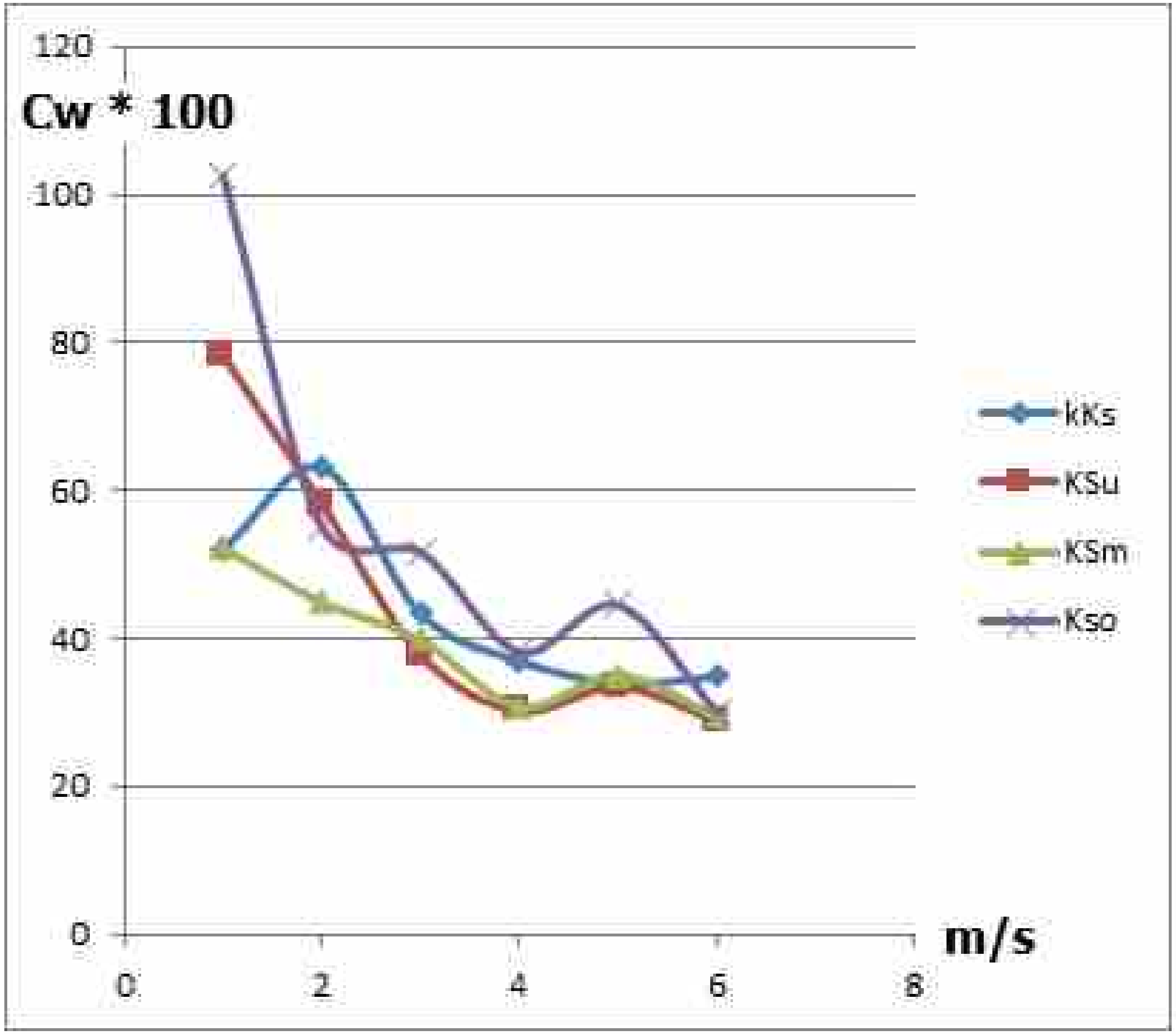


Figure 2. Percentage of all trees surveyed receiving no damage plotted against maximum gust speed.

Crown cabling = Crown securing?

Kronen-Verun-Sicherung?

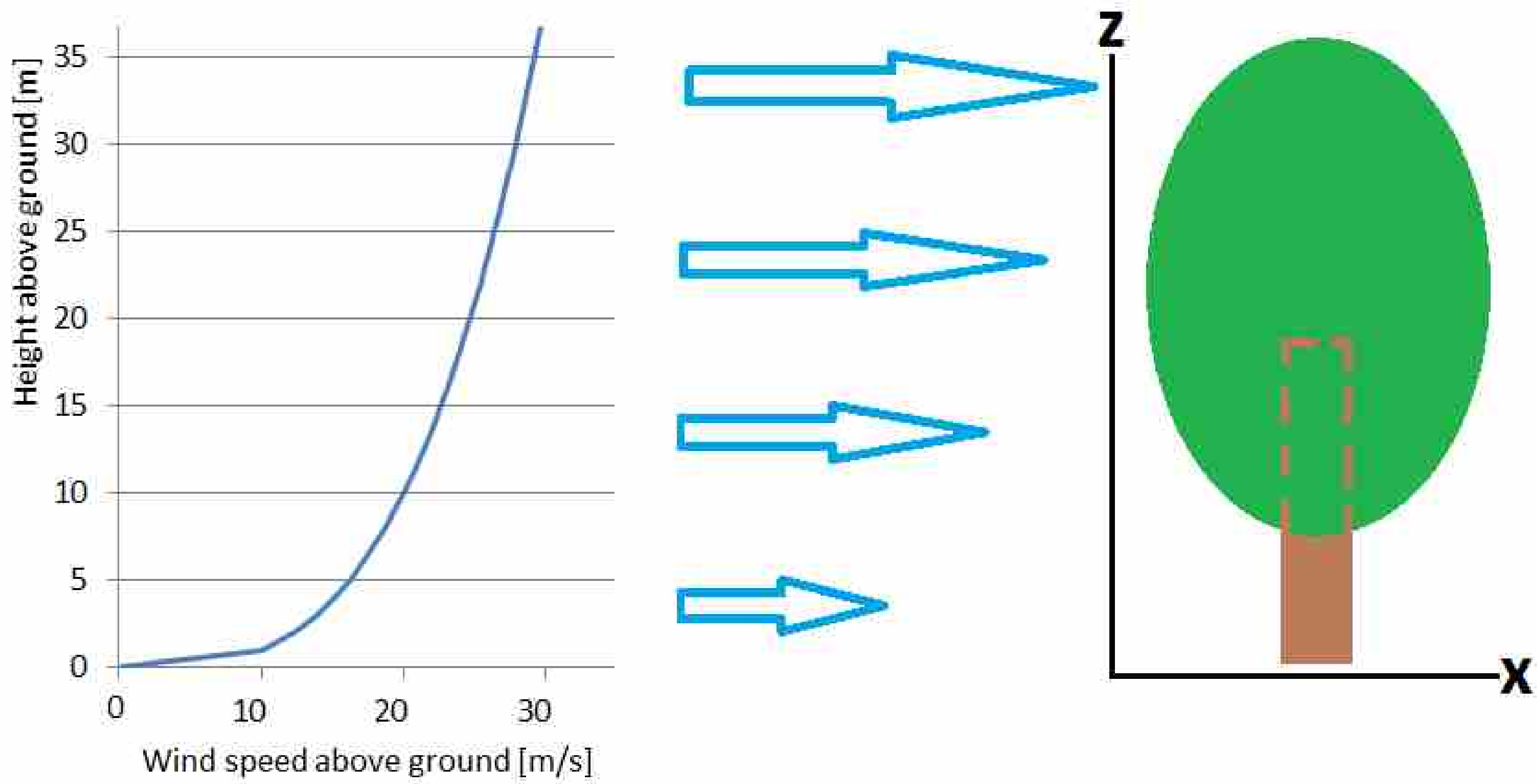

DynaTim 3.14f - [D:\FR\Projekte\2014_Windlast\201410_\01_63kg_KS_.dnt] - (c) 1999-2015 Frank Rinn / RINNTECH.
File Edit View Communication Options Help
ARWILO Scientific Data & Positions Measurement Analysis Reference Manual measurement Cockpit (analog) Cockpit (linear)
Data analysis filter
Filter one-sided bandwidth:
Set values to zero at start position
Use manual measurement data
[%]
[s]
[mm]
[kg]



really measured (Cw=) drag-coefficients (*100) with crown cables on 3 heights and without (kks) // no re-construction from strain/inclination, real force measurements!

Wind load characteristics and impact of crown reduction

Wind speed above ground level:



The rise of wind speed above ground level mainly depends on surface roughness, characterised by exponent 'a':

$$v(z) = v(z_{ref}) * \frac{z^a}{z_{ref}^a}$$

Surface type	Exponent
Town center	0.4
Suburbs	0.3
Forests	0.28
Agricultural land	0.25
Ocean	0.16

(Theoretical) Force on every (infinitesimal) point (i) of the crown sail area:

$$f_i \sim ½ * q * c * v^2$$

Sums up to the total force acting at the crown in total:

$$F = \sum f_i = ½ * q * c * v^2 * A$$

In reality, the total force mainly depends on an integral over the local wind speed to the power of two:	$F \sim \iint (v(z))^2 \, dx \, dz$

“Wind load” is usually defined as bending moment at the stem base (M), resulting from a sum (integral) over the crown area, multiplying local force with corresponding lever arm length (= height above ground ‘z’):	$M \sim \iint (v(z))^2 * z \, dx \, dz$
Replacing wind speed by its factors, such as height above ground (z) leads to bending moment depending on height of each point (I):	$M \sim \frac{v(z_{ref})^2}{z_{ref}^{2a}} \iint z^{1+2a} \, dx \, dz$
Consequently, bending moment at the stem base is proportional to crown width * tree height to the power of 2+2a:	$M \sim W * H^{2+2a}$

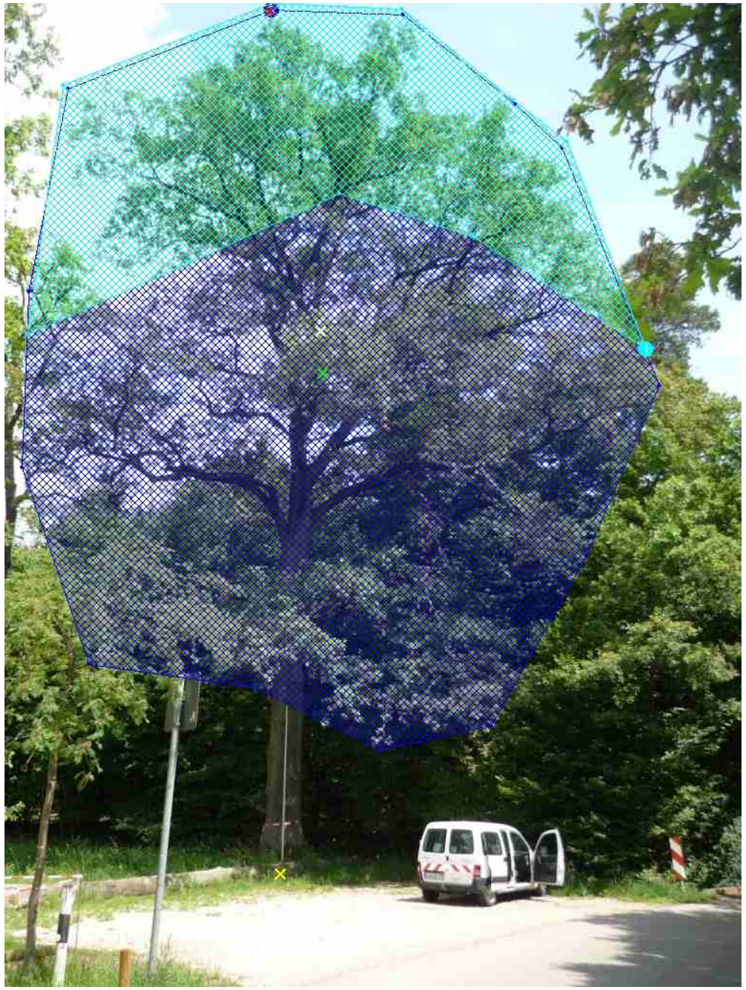
Crown width (especially of solitary trees) correlates with crown height and thus tree height:	$W \sim H$
Consequently, tree height is the most dominant factor determining stem base bending moment and thus wind load:	$M \sim H^{2 + 2a + b}$
Summarising: wind load is proportional to tree height with an exponent of 3 (or even more, depending on crown geometry and local aspects):	$M \sim H^{3}$

Any practical meaning?

Yes!

As a simple rule of thumb:

The resulting wind load reduction percentage is mostly twice (or slightly more) the amount of tree height reduction by pruning!

Reduction: height ca. 10%, sail area ca. 12%, wind load ca. 20%	Reduction: height ca. 20%, sail area ca. 30%, wind load ca. 50%
	

Summary and conclusions:

=> If real strength loss due to decay is understood and transformed correctly into required wind-load reduction, remaining pruning is usually much smaller than commonly expected. In addition, ...

=> even small reduction of crown height leads to significantly more reduction in wind load.

=> Less crown reduction leaves more biological assimilation capabilities, resulting in

- > faster/stronger reactions to damages
- > faster compensation of structural strength loss due to decay/damages/...
- > less dead wood
- > ...