# Tree Diagnostics

## Instrument supported tree stability evaluation


Ferenc Divos

Fakopp Enterprise Bt. (since 1994)

University of Sopron, Hungary (since 1989)

# Fakopp Enterprise, Hungary

Serving arborist since 1994

Fa – kopp are two Hungarinan words: Wood - knock

# 25 YEARS
## SERVING ARBORISTS


First European Wood NDT Symposium, Sopron, Hungary September 1994.

Microsecond Timer is on display at the first time.

Tree Diagnostics

Fakopp Enterprise

SUMO - Rugged Tablets
Arb-Ex - Air Excavator

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# Surveying equipment for Arborists

Diagnostic tools sales and training.
Advanced Training for level 3
assessments and Consultancy services.

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Tree Diagnostics Ltd.

# FAKOPP Enterprise

## Forestry and Forest Products Research

**Main activities**

- ✓ Nondestructive testing
- ✓ Acoustic and electronic methods
- ✓ Acoustic sensor development
- ✓ Equipment development
- ✓ Algorithm development
- ✓ Trainings

# FAKOPP Enterprise

## Forestry and Forest Products Research

**Field of applications**

- ✓ **<u>Urban tree diagnostics</u>**
- ✓ Lumber strength grading
- ✓ Evaluation of wooden structures
- ✓ Wood selection for musical instruments

Our mission is to support arborists
Withinstruments for tree diagnostics.

Our goal is to keep urban trees as long as possible, while maintaining safety.

Microsecond Timer

ArborSonic 3D

ArborElectro

Pulling Test „elasto”

DynaTrunk

DynaRoot

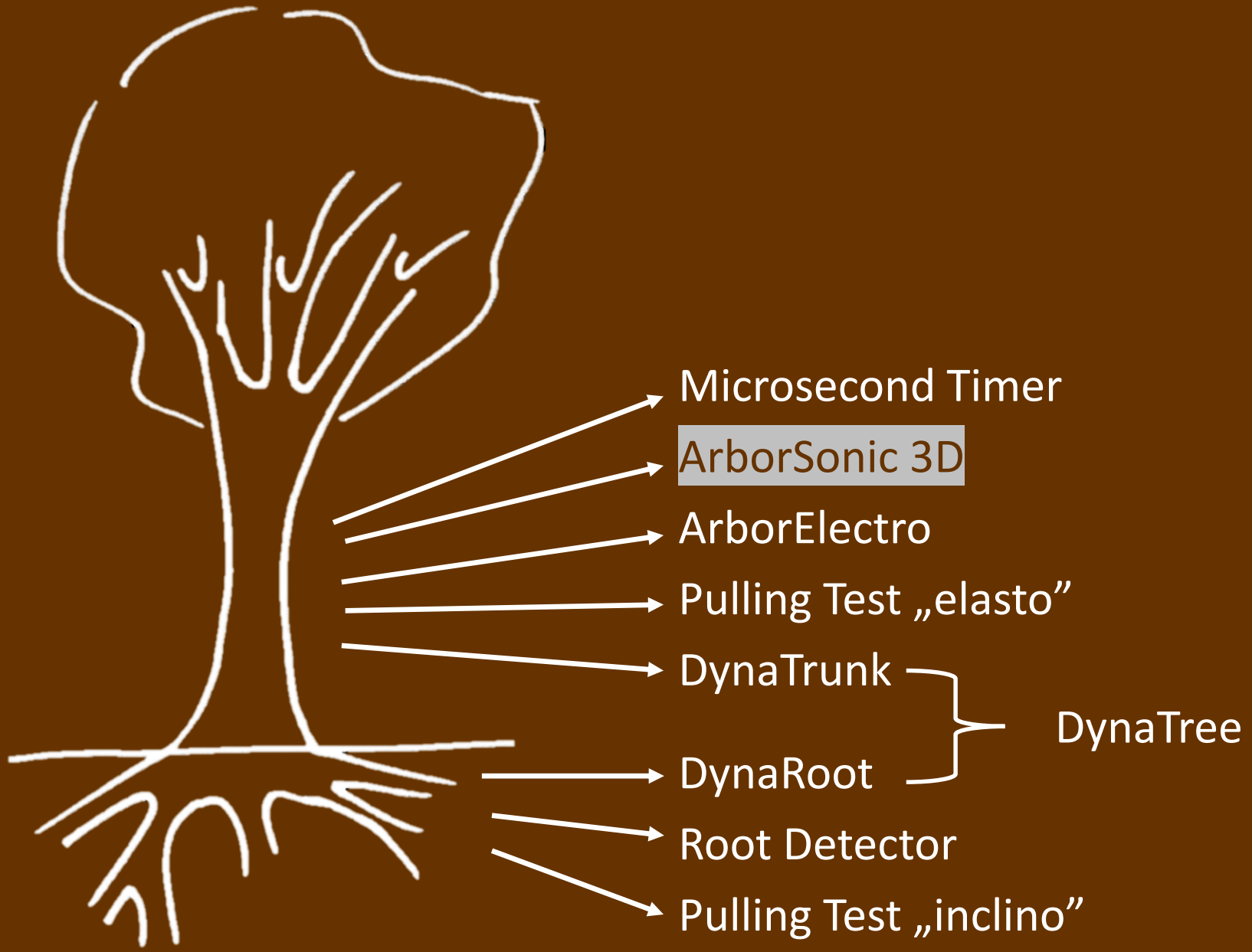
DynaTree

Root Detector

Pulling Test „inclino”


# Microsecond Timer


FAKOPP


Microsecond Timer
ArborSonic 3D
ArborElectro
Pulling Test „elasto”
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Root Detector
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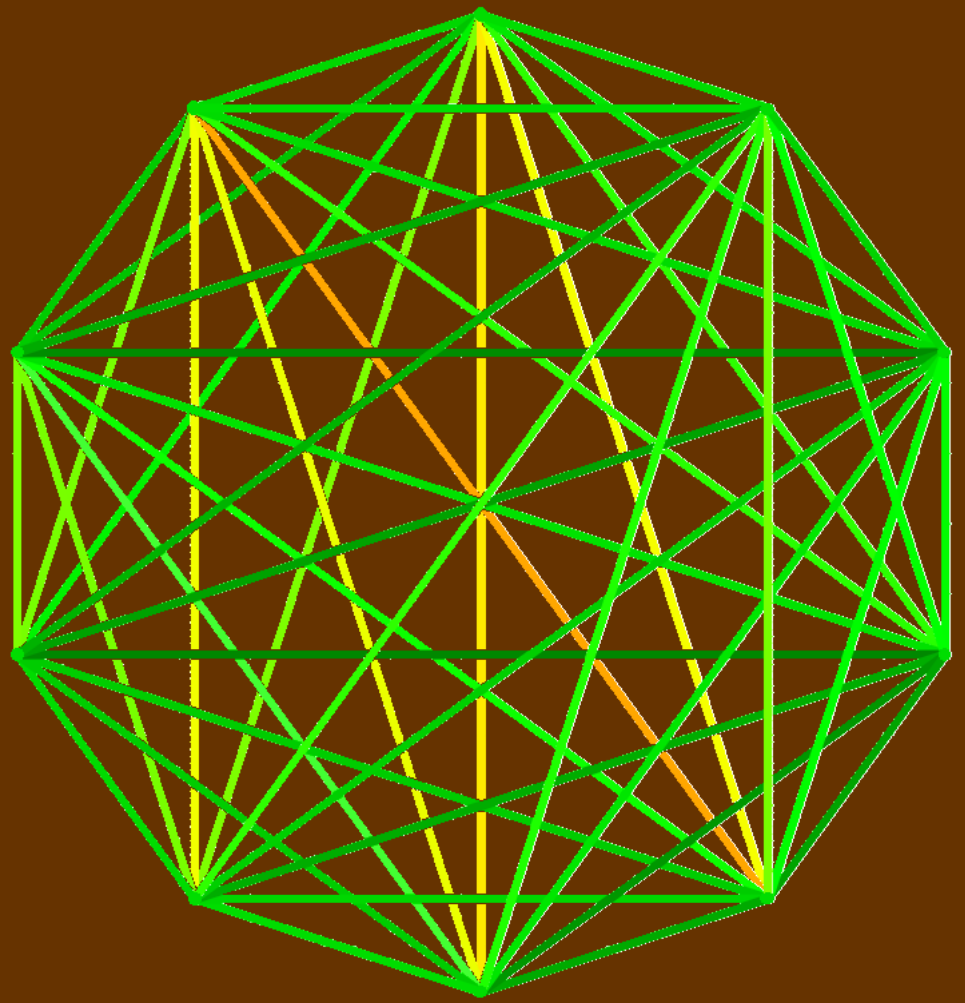
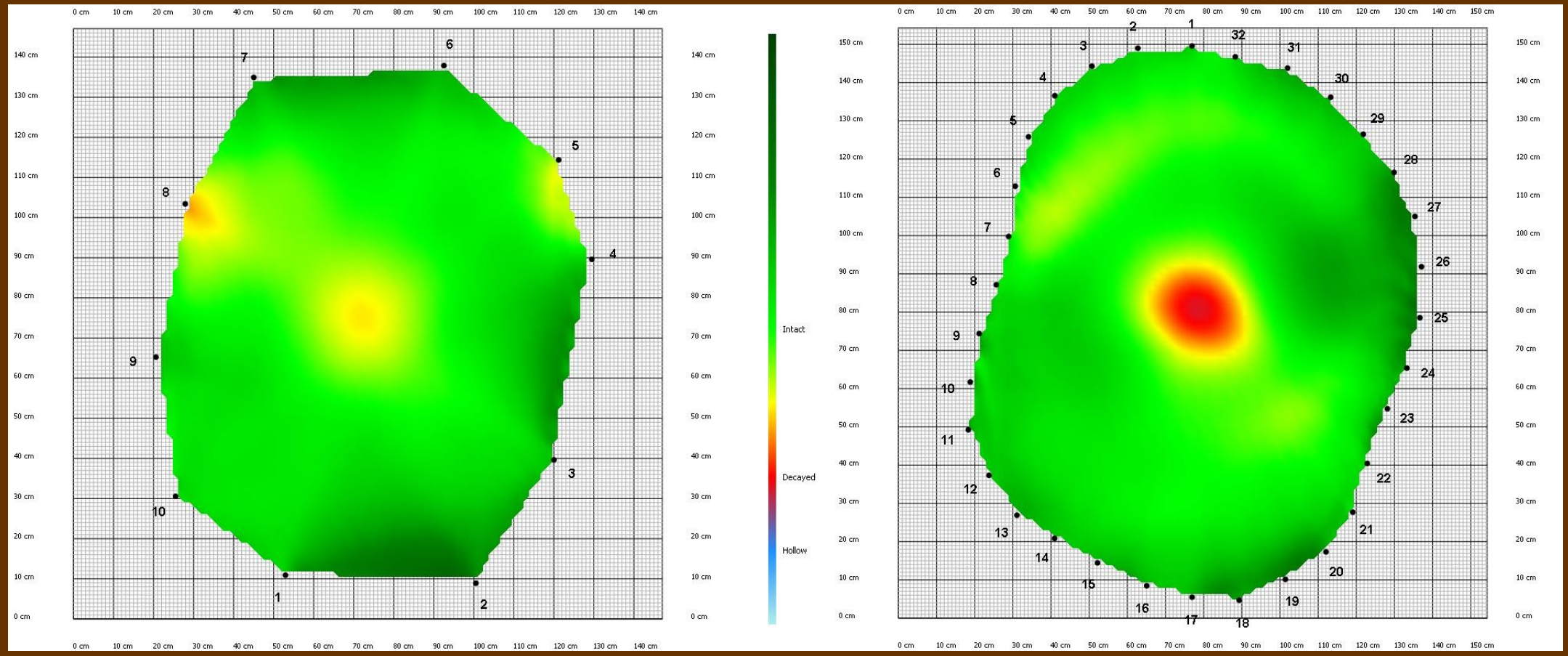
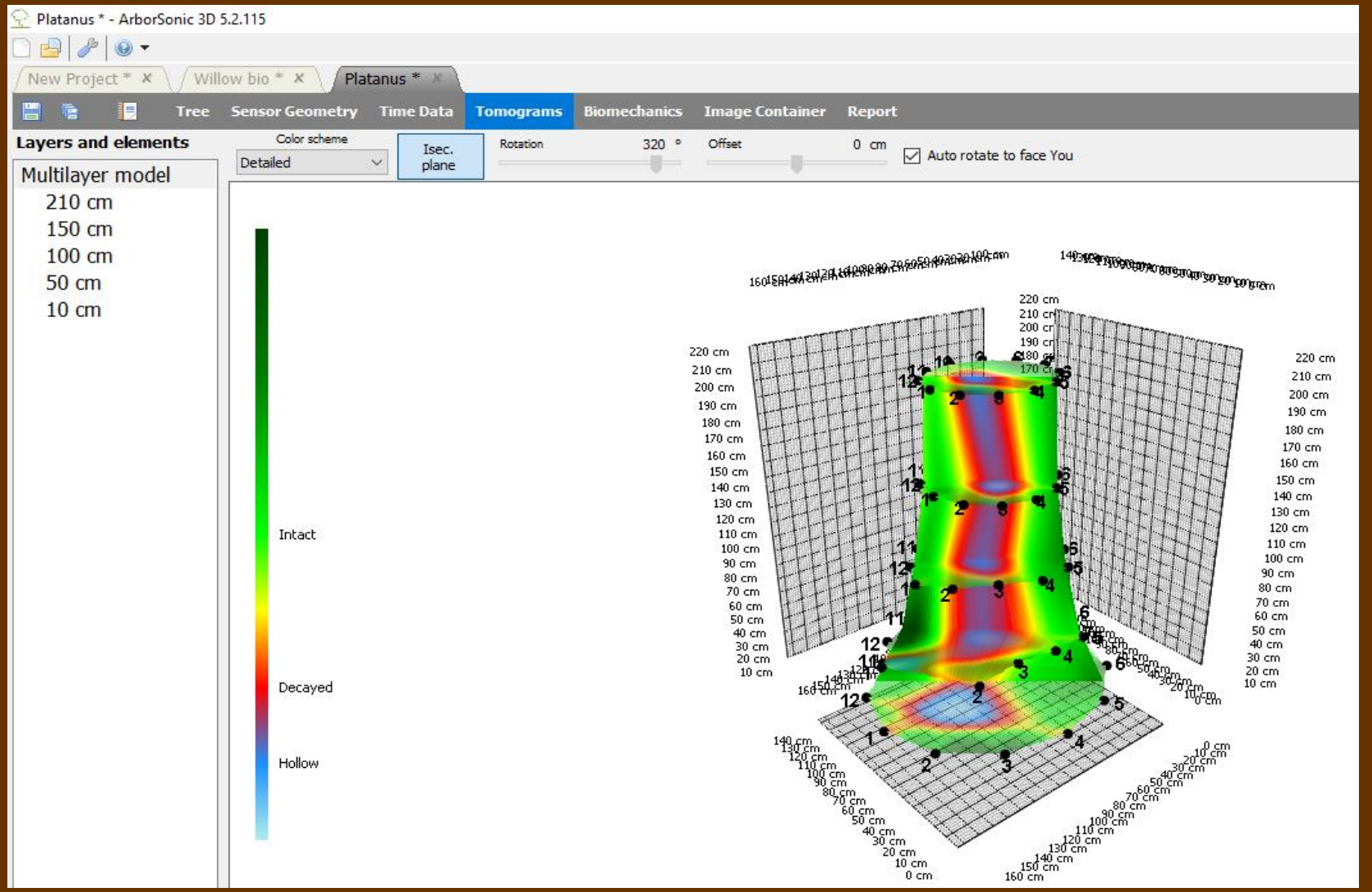
# Tomography



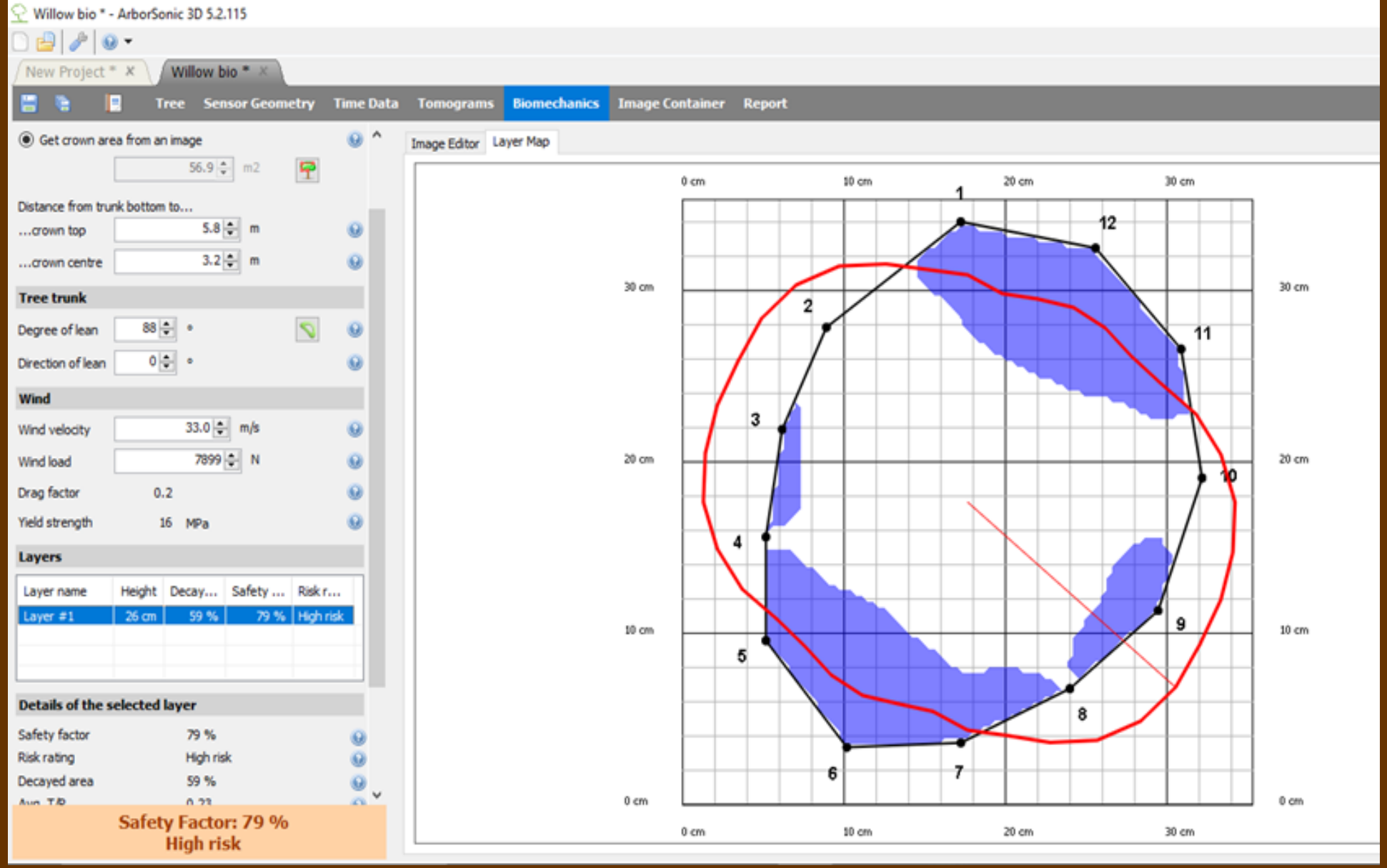
Quick result within 15 -20 minutes

# Tomography

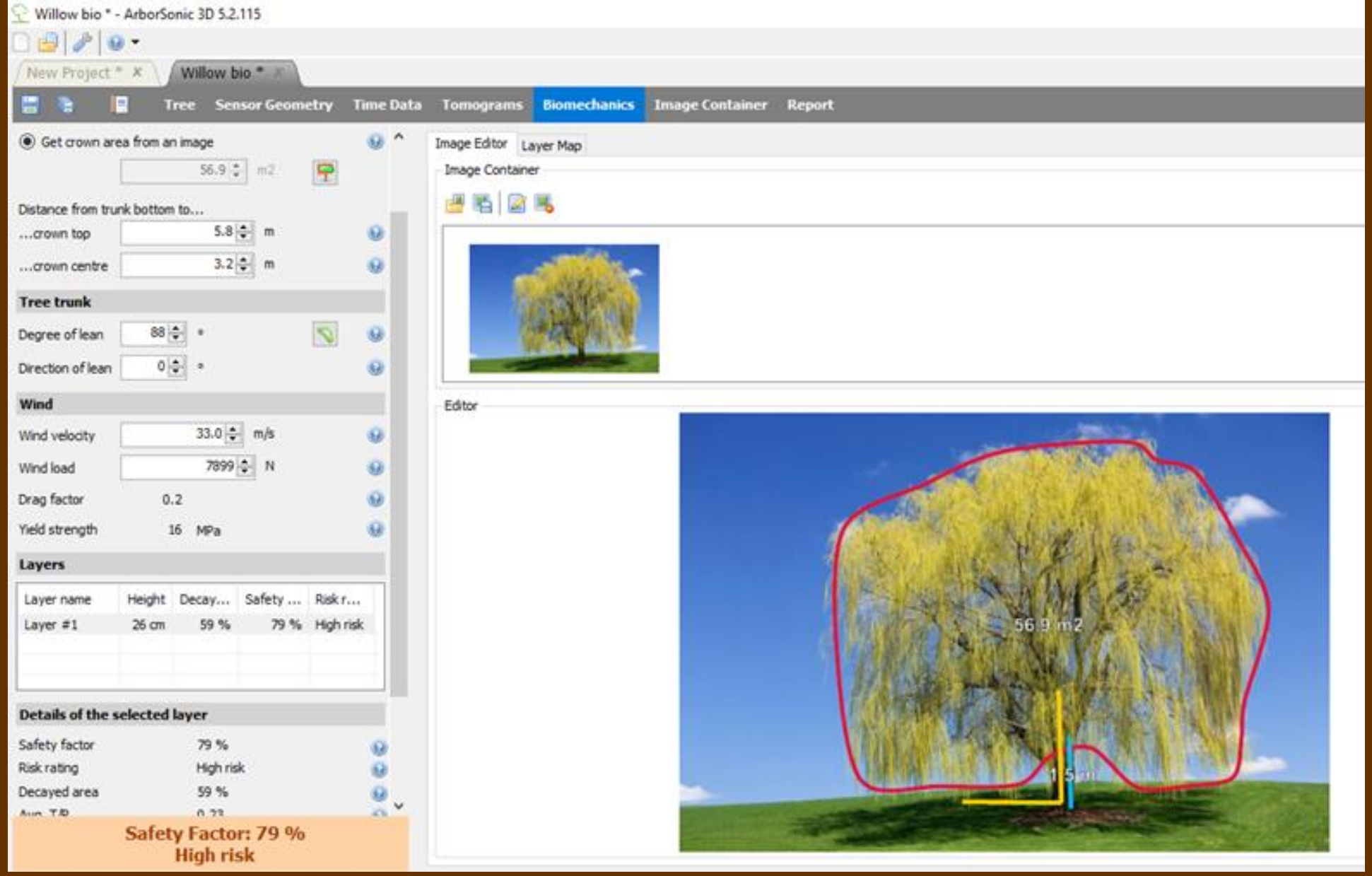




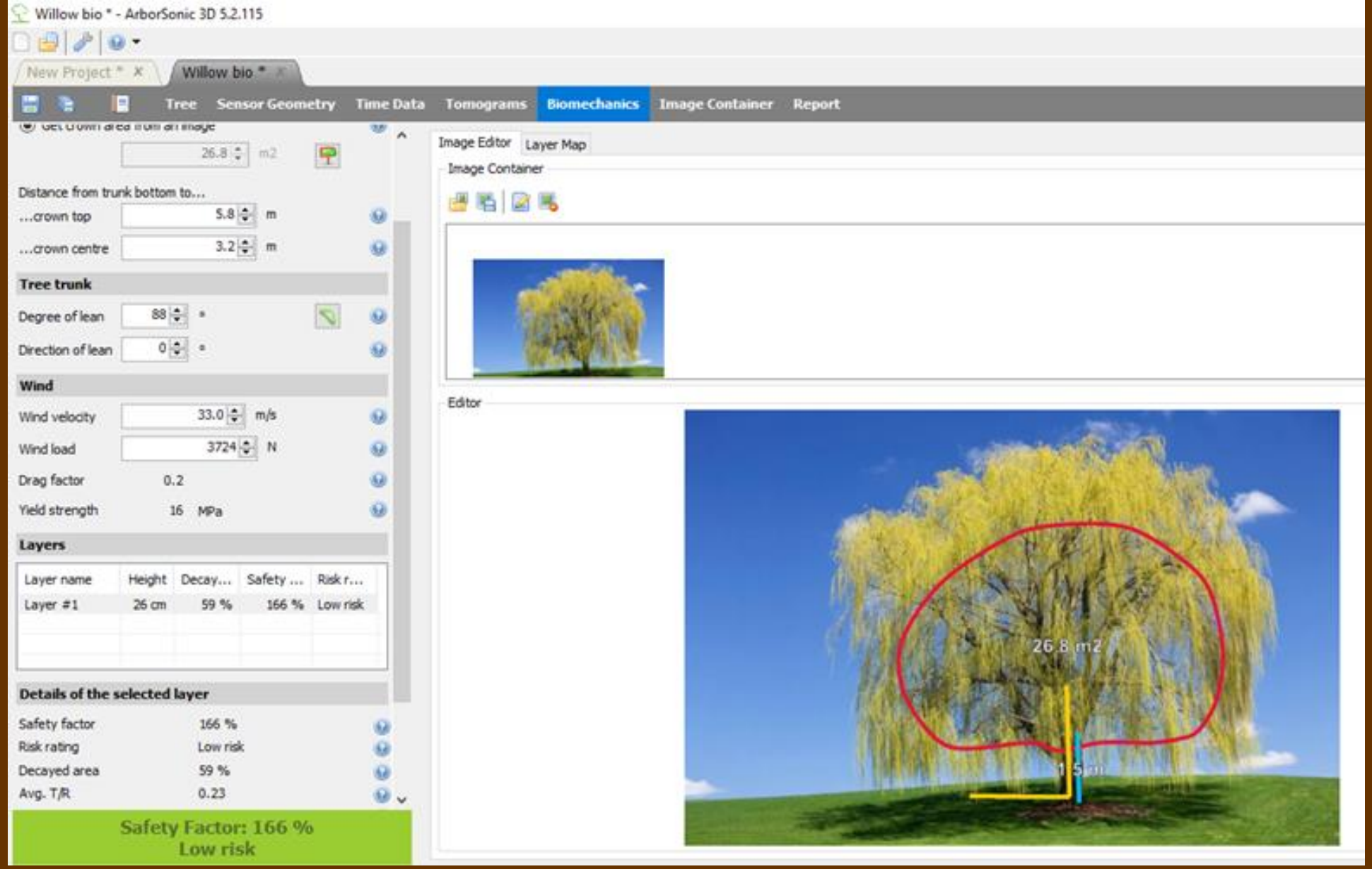

A 3D representation of a stem section can be created by stitching together multiple 2D scan's. This enables the location of decay and higher quality wood to be represented.




The software provides stability information, helping understand the **Biomechanics** and a likely response to loading provides a **Safety Factor**.




Dimensional details can be drawn directly onto a scaled photograph to provide an estimation of canopy volume, informing wind load & **SF**.




Where High Risk trees are found, canopy dimensions can be virtually pruned to show a canopy volume which generates an acceptable Low Risk Safety Factor.

# Simplified Safety Factor calculation

$$SF = \frac{\sigma_{compression\ strength\ otree}}{\sigma_{wind+weight}} = \frac{\sigma_{compression\ strength\ otree}}{\frac{m\,g}{A_{trunk}} + \frac{16c\rho V^2 A h_{cc} D}{\pi(D^4 - d^4)}}$$

$\sigma_{tree}$ : compression strength of the given species wood material (Pa)

$\sigma_{wind+weight}$ : mechanical stress made by the wind and self weight Pa)

m : mass of the tree (kg)

g : gravitation acceleration9,81 $m/s^2$

ρ : air density ($kg/m^3$)

D : Tree trunk diameter d: diameter of central positioned hole (m)

V : max. wind speed at 10m height

$h_{cc}$ : crown central height

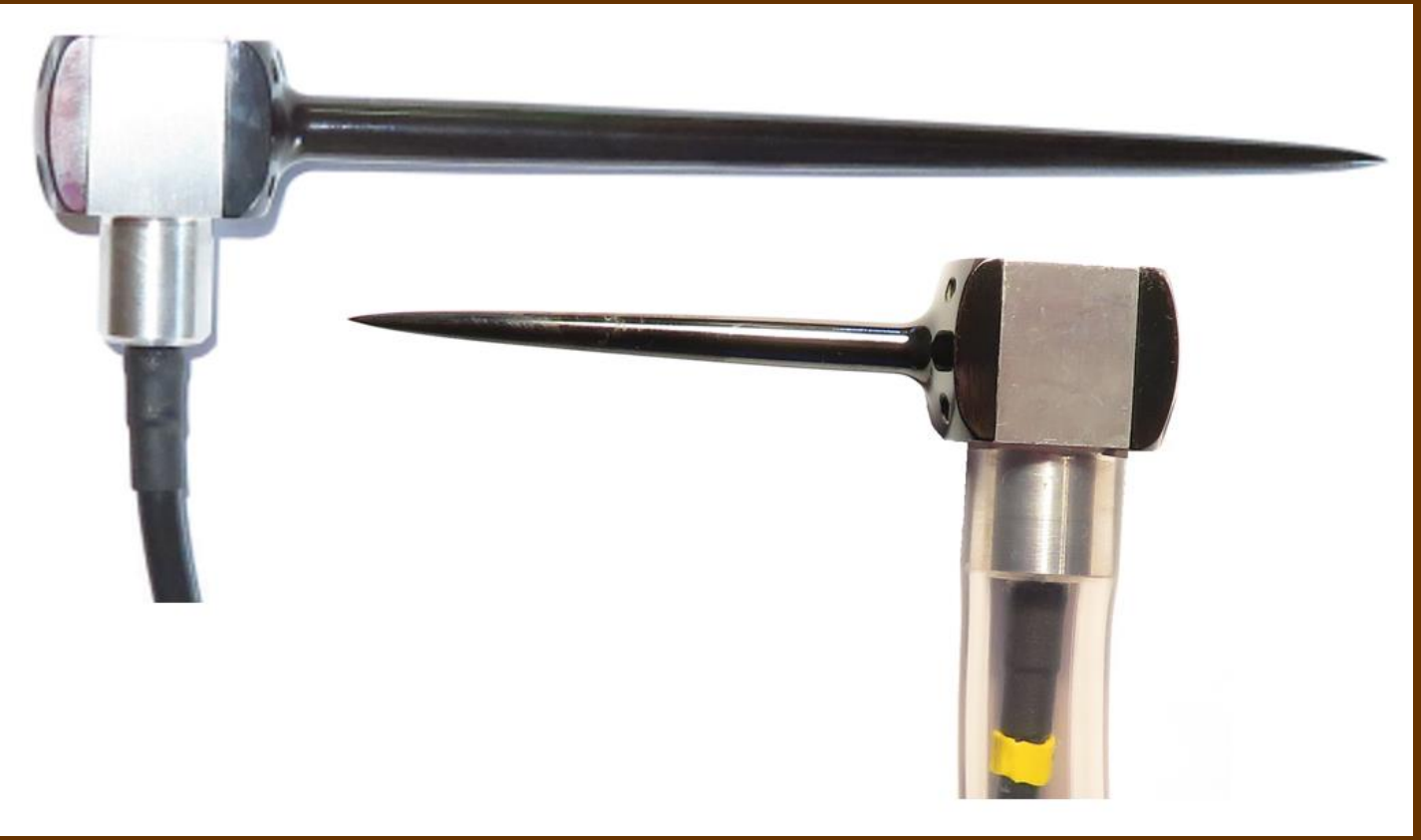
A : Crown area

$A_{trunk}$ : Cross-section area of the tree trunk ($m^2$)

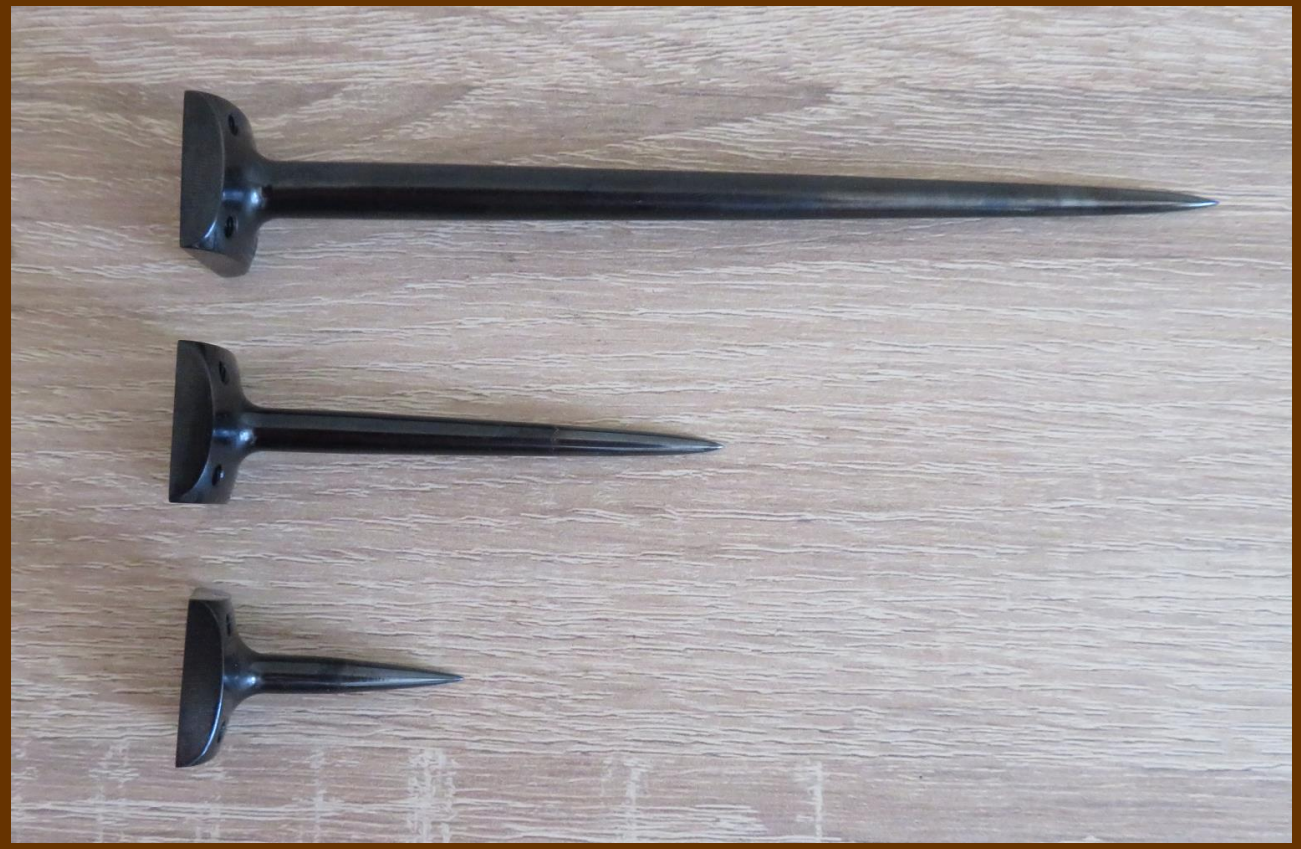
c: aerodynamic drug factor (-)

Tree is standing alone and not leaning, calculation at ground level.

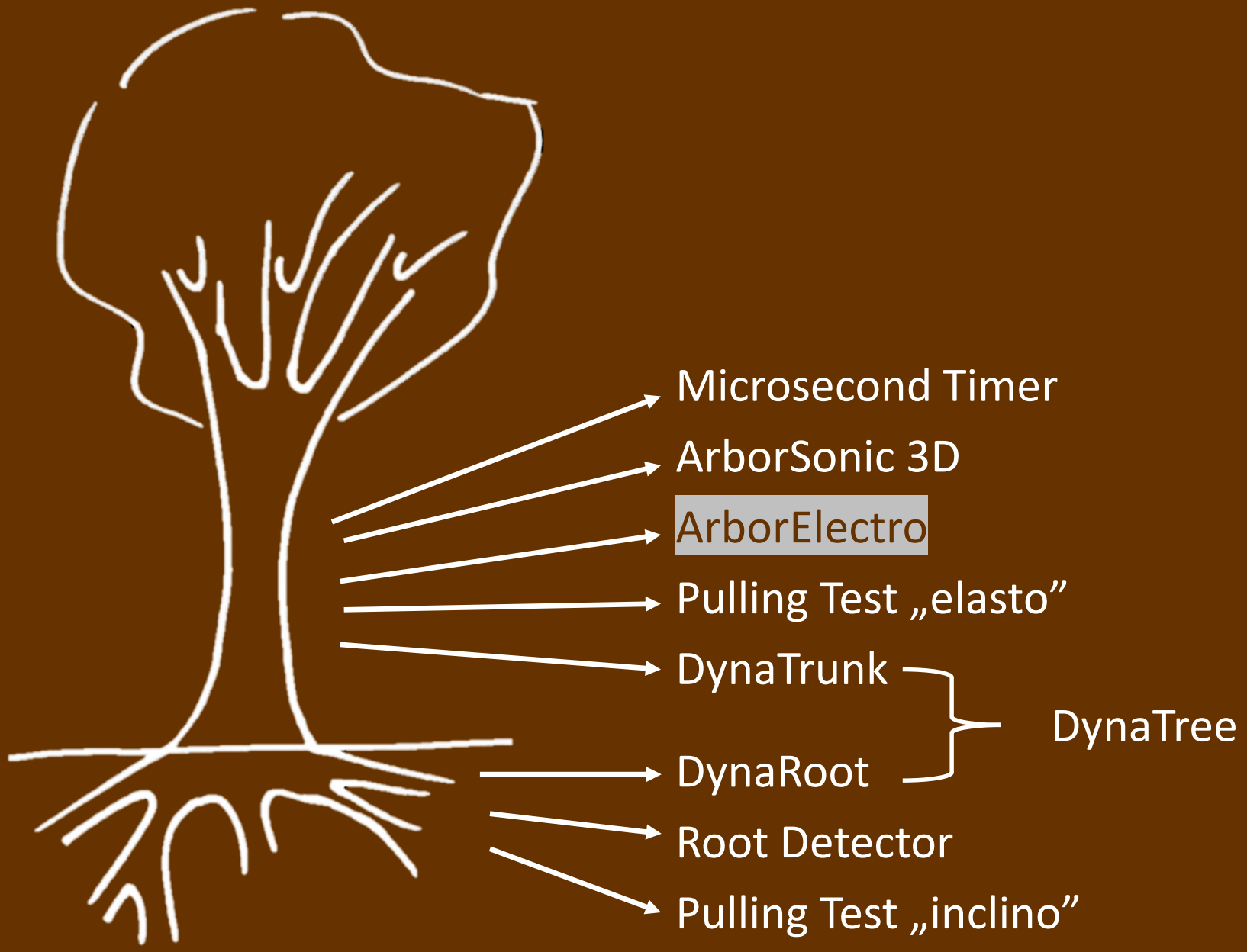
# Extra possibilities



# Extra possibilities



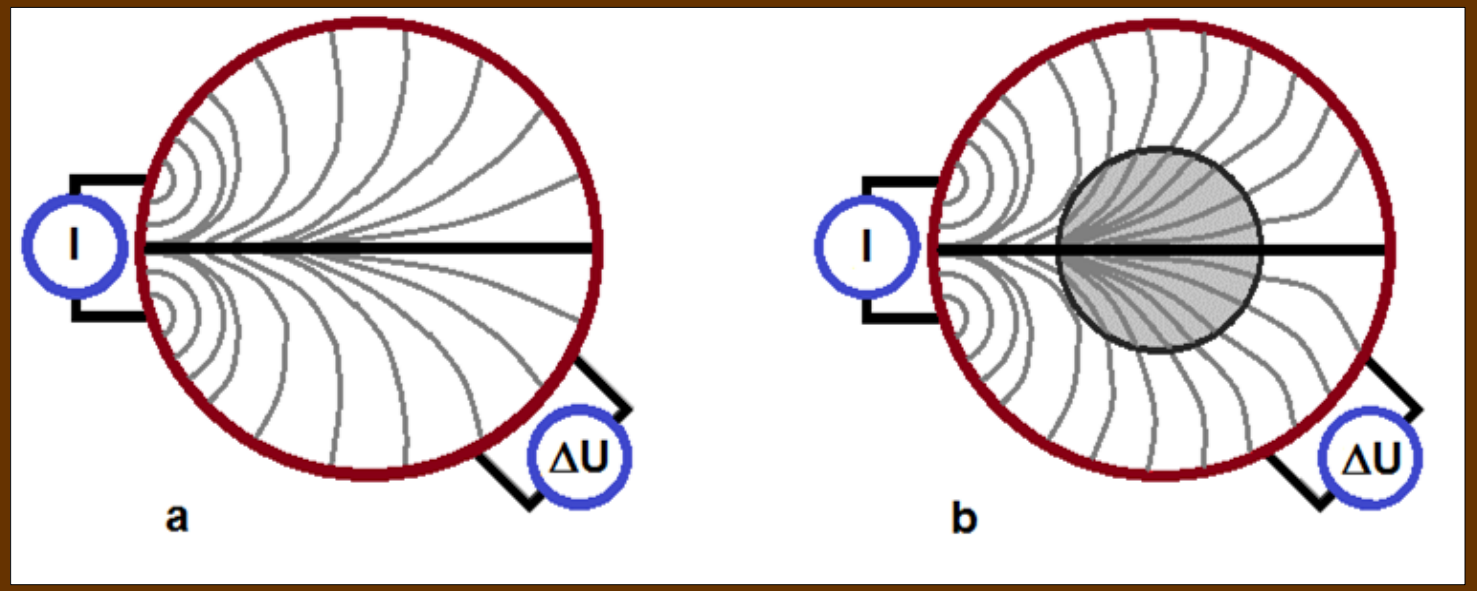
# Carbon fiber calipers for quick recognition of irregular geometry


Microsecond Timer
ArborSonic 3D
ArborElectro
Pulling Test „elasto”
DynaTrunk
DynaRoot
DynaTree
Root Detector
Pulling Test „inclino”


# Electronic Impedance tomography

# Electronic Impedance Tomography

- From geophysics
- Currents and Voltages
- Sensitive for ion concentrates
- Sensitive for fungal activity
- 32 channels

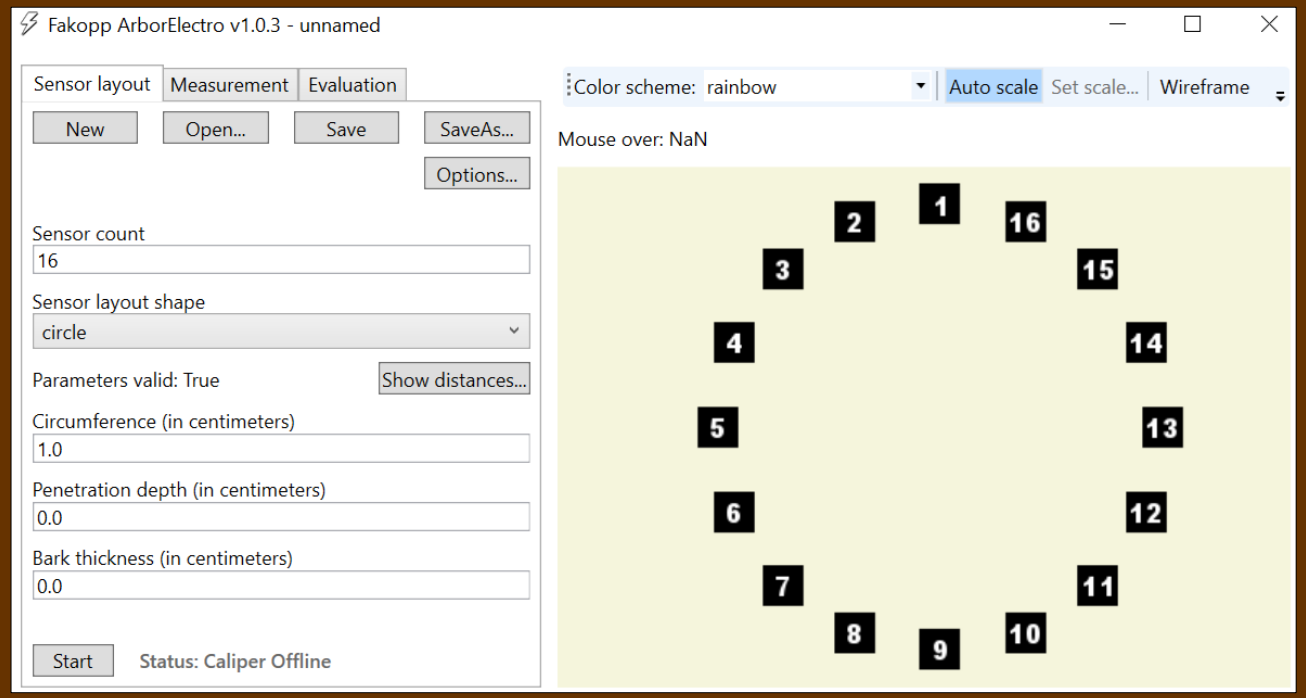


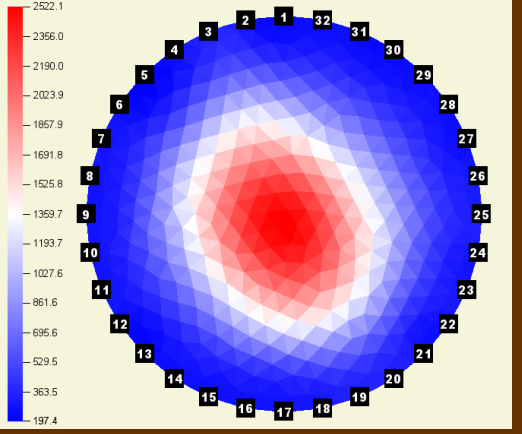
# Electronic Impedance Tomography


Stainless steel electrodes, diameter is 1.5 mm.

# EIT Software

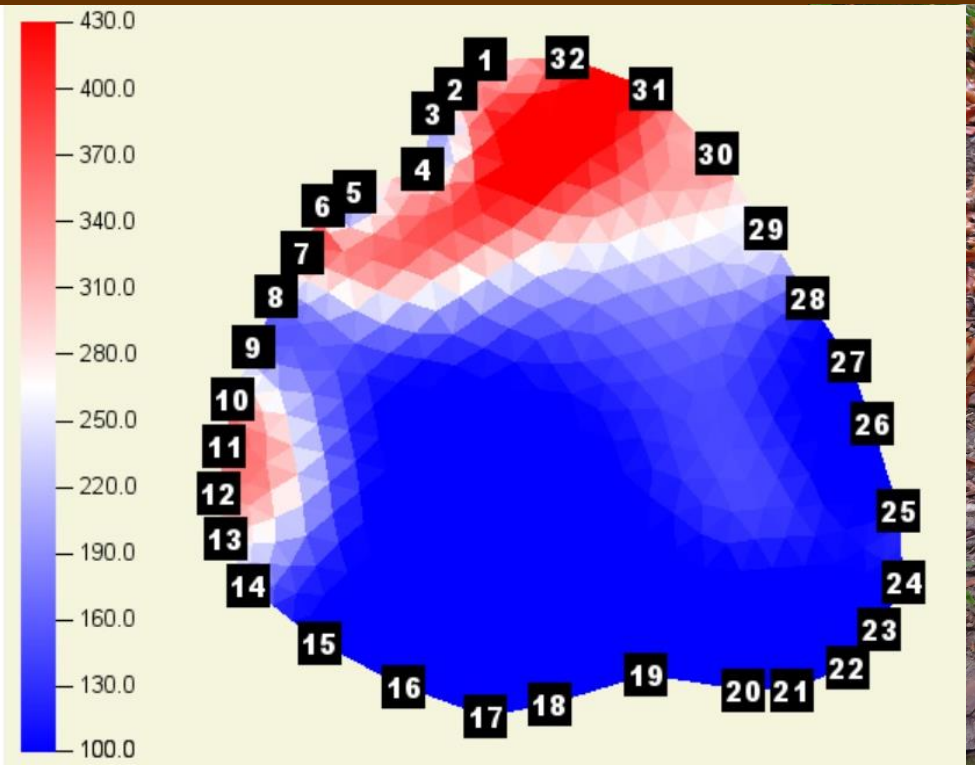
- Bluetooth connection
- Measurement control and evaluation
- Circular, elliptic and irregular geometries
- Caliper is integrated

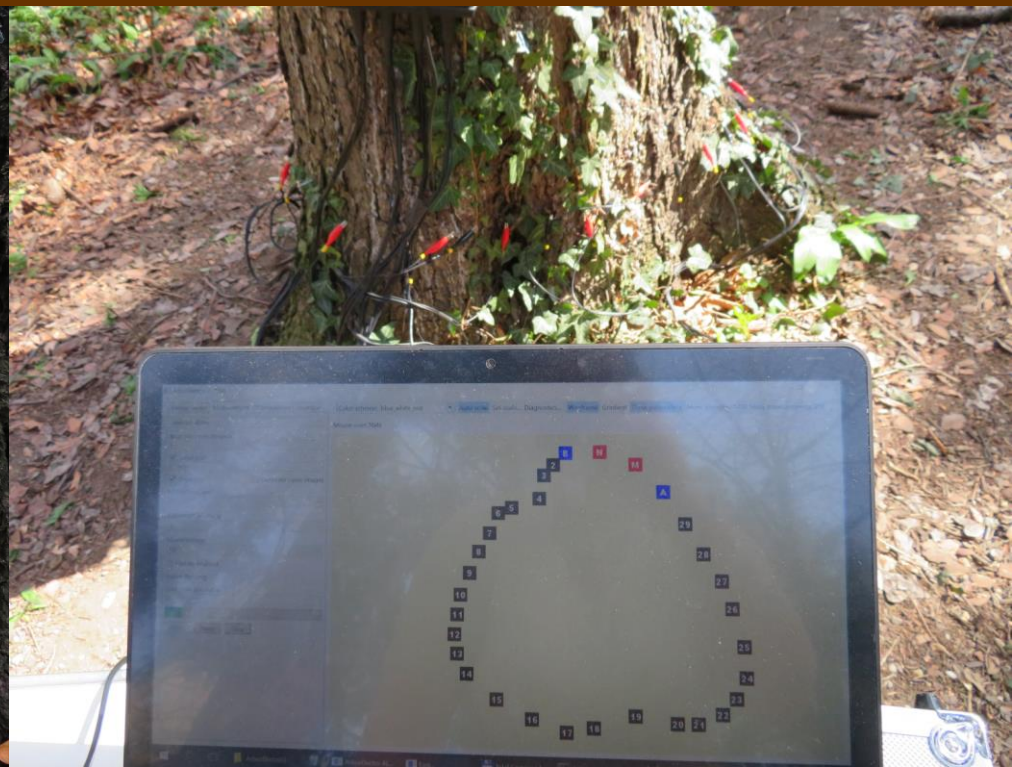




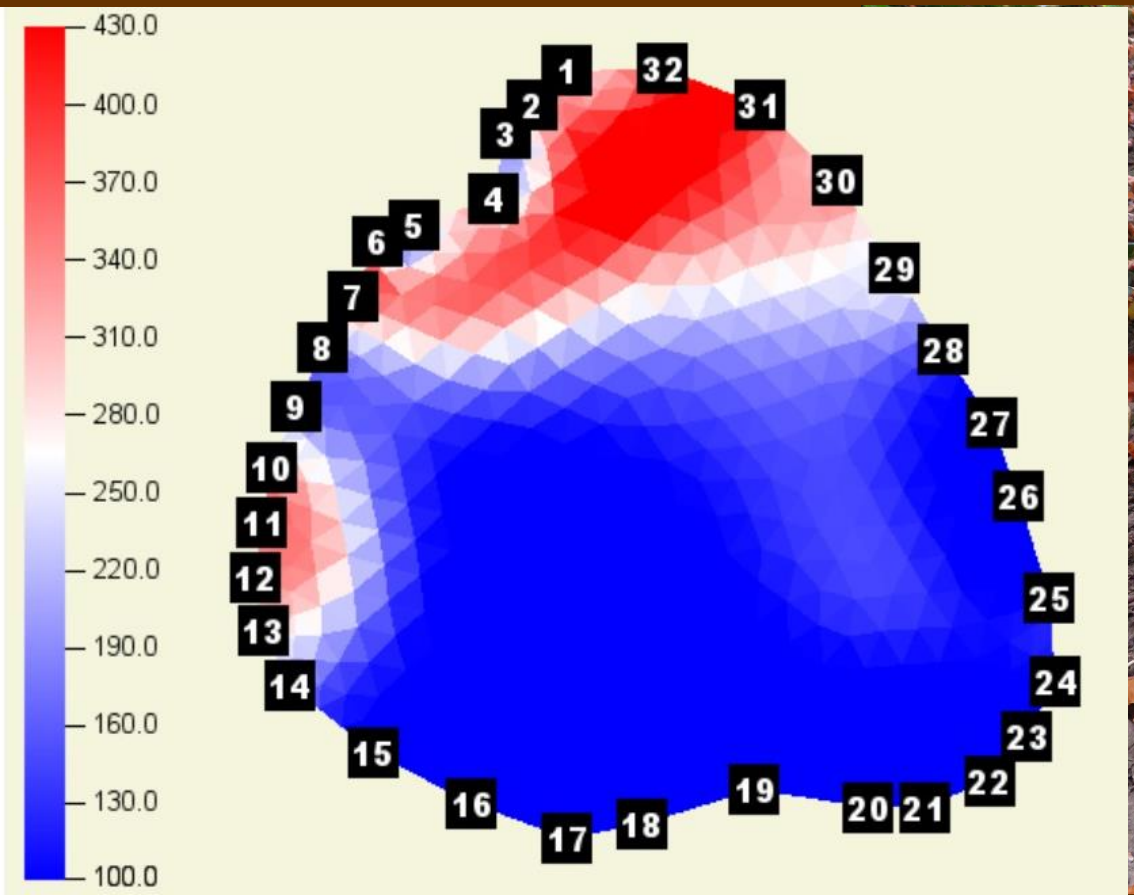

# Intact spruce

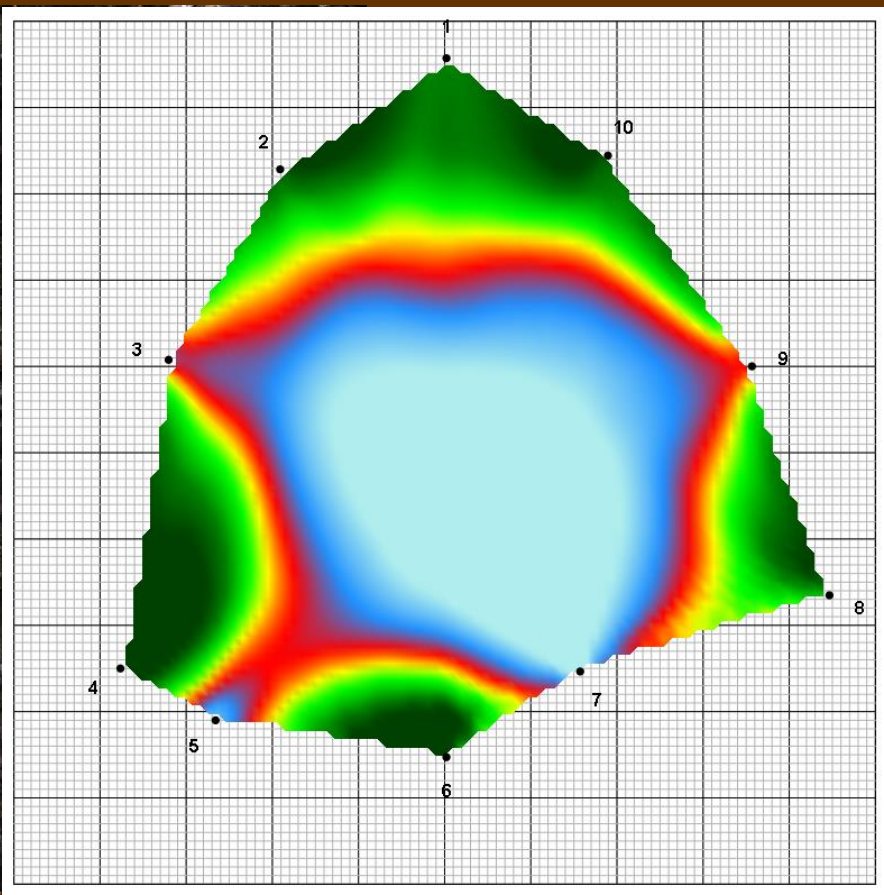
# Attacked spruce



# Attacked spruce



Microsecond Timer

ArborSonic 3D

ArborElectro

Pulling Test „elasto”

DynaTrunk

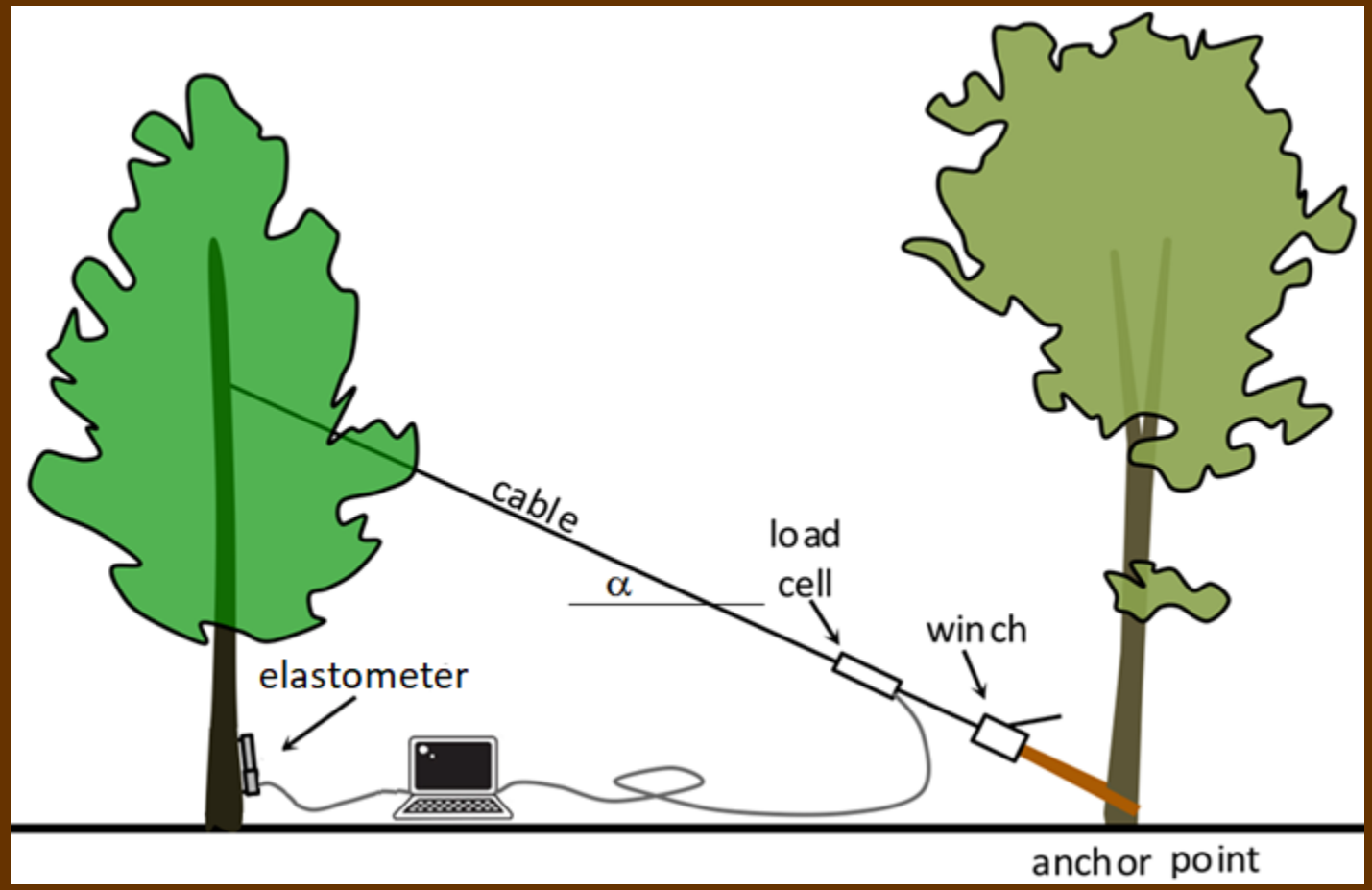
DynaRoot

DynaTree

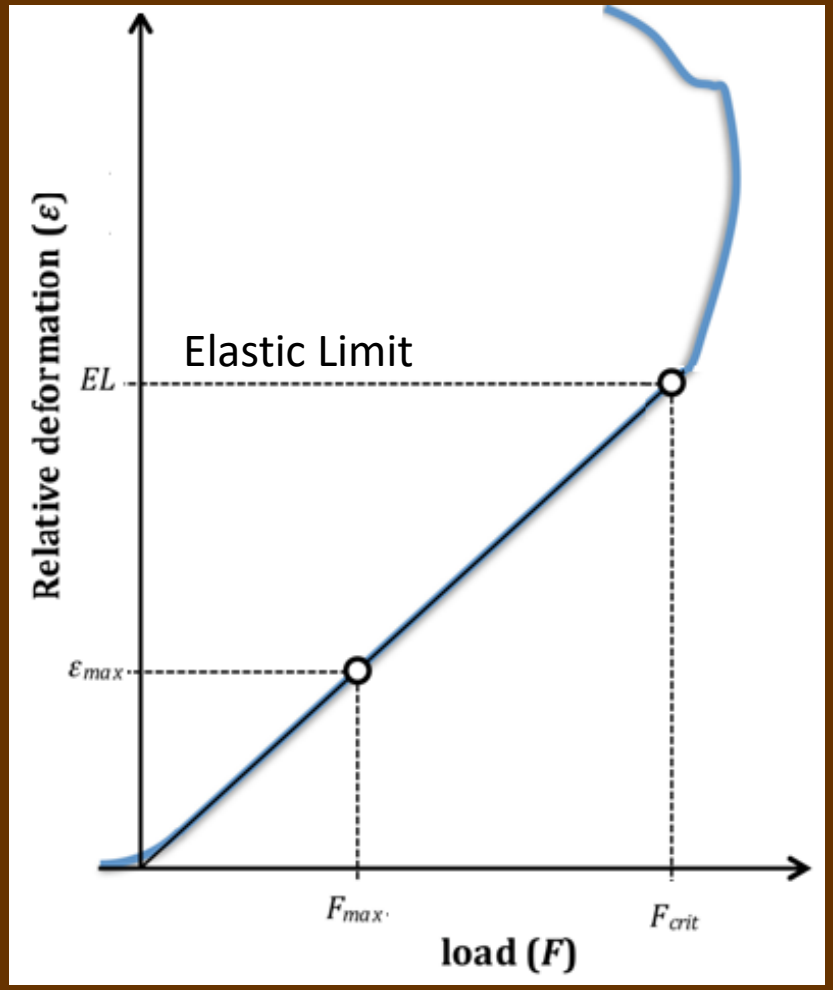
Root Detector

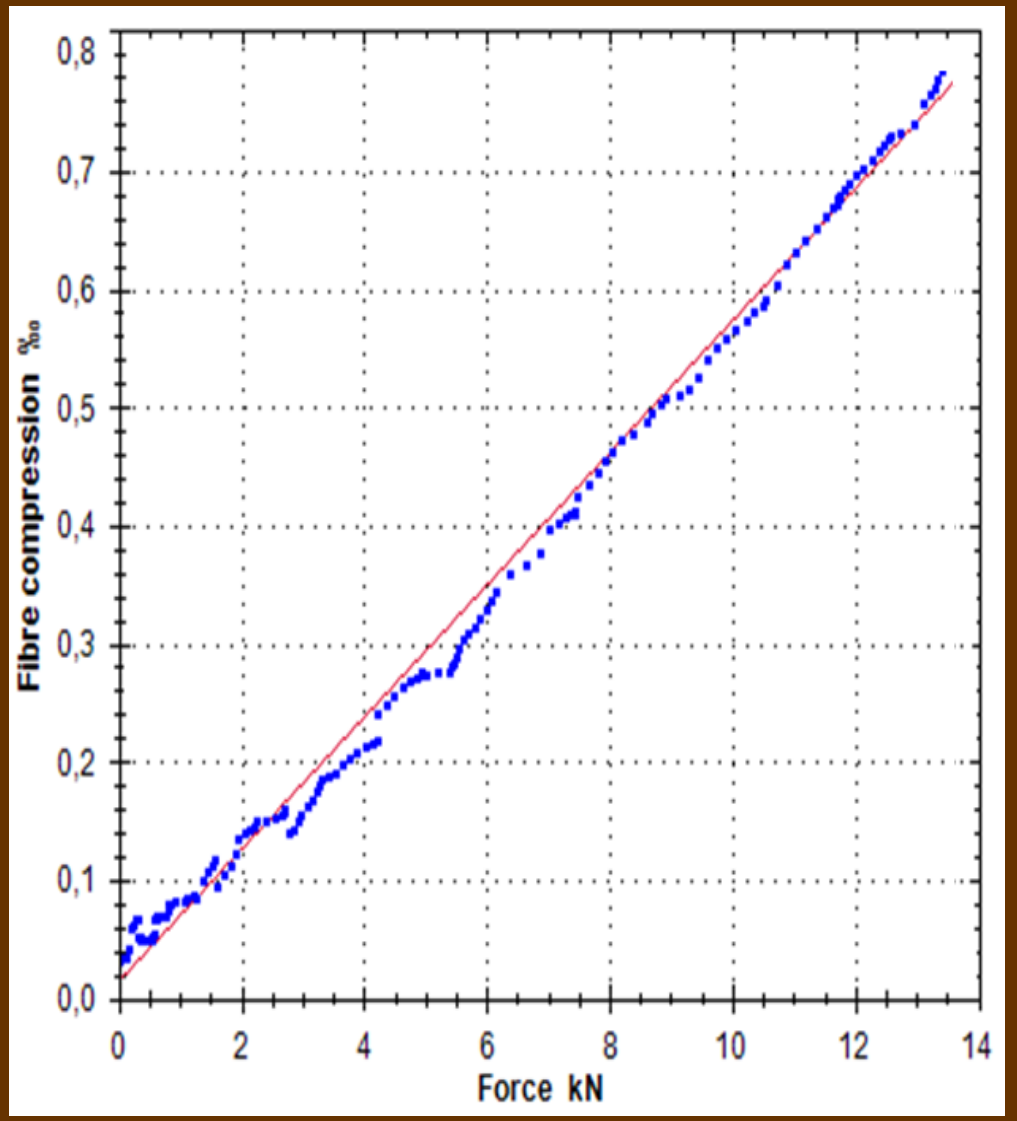
Pulling Test „inclino”

# Pulling test setup „elasto”




elastometer


Relative deformation (ε)
Elastic Limit
EL
$\varepsilon_{max}$
$F_{max}$
$F_{crit}$
load (F)


Fibre compression ‰
0,8
0,7
0,6
0,5
0,4
0,3
0,2
0,1
0,0
0
2
4
6
8
10
12
14
Force kN

Microsecond Timer

ArborSonic 3D

ArborElectro

Pulling Test „elasto”

DynaTrunk

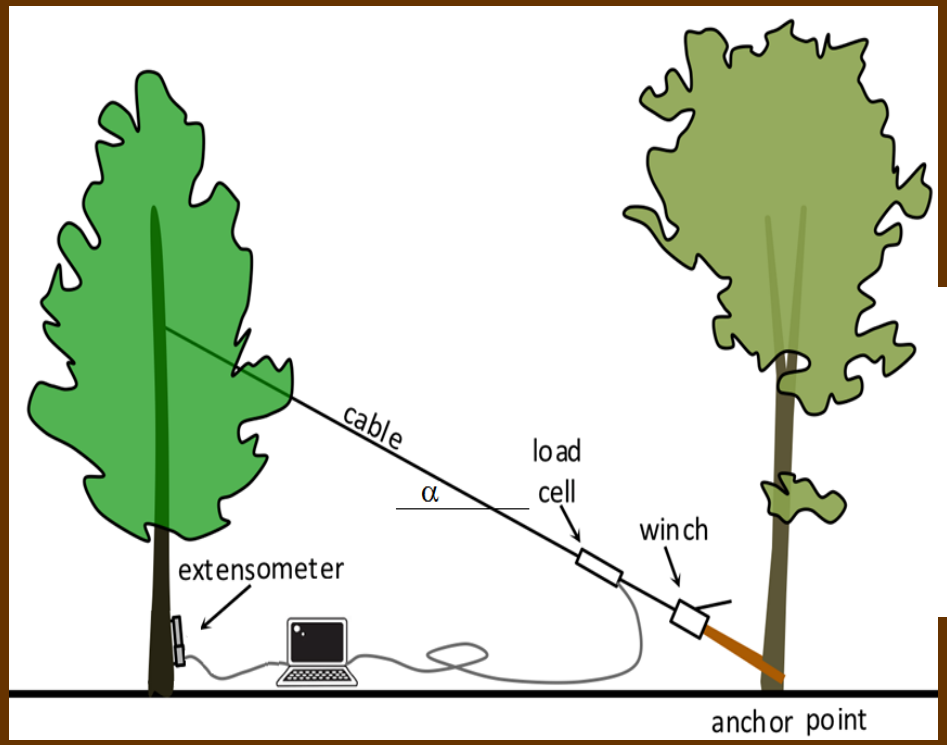
DynaRoot

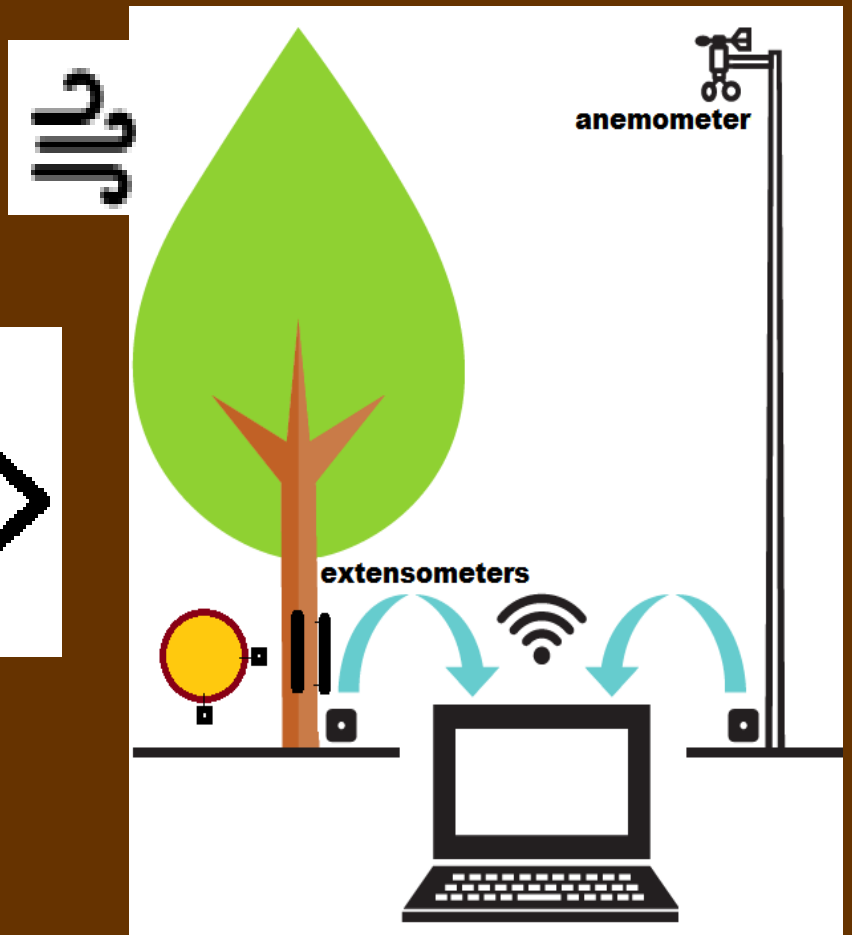
DynaTree

Root Detector

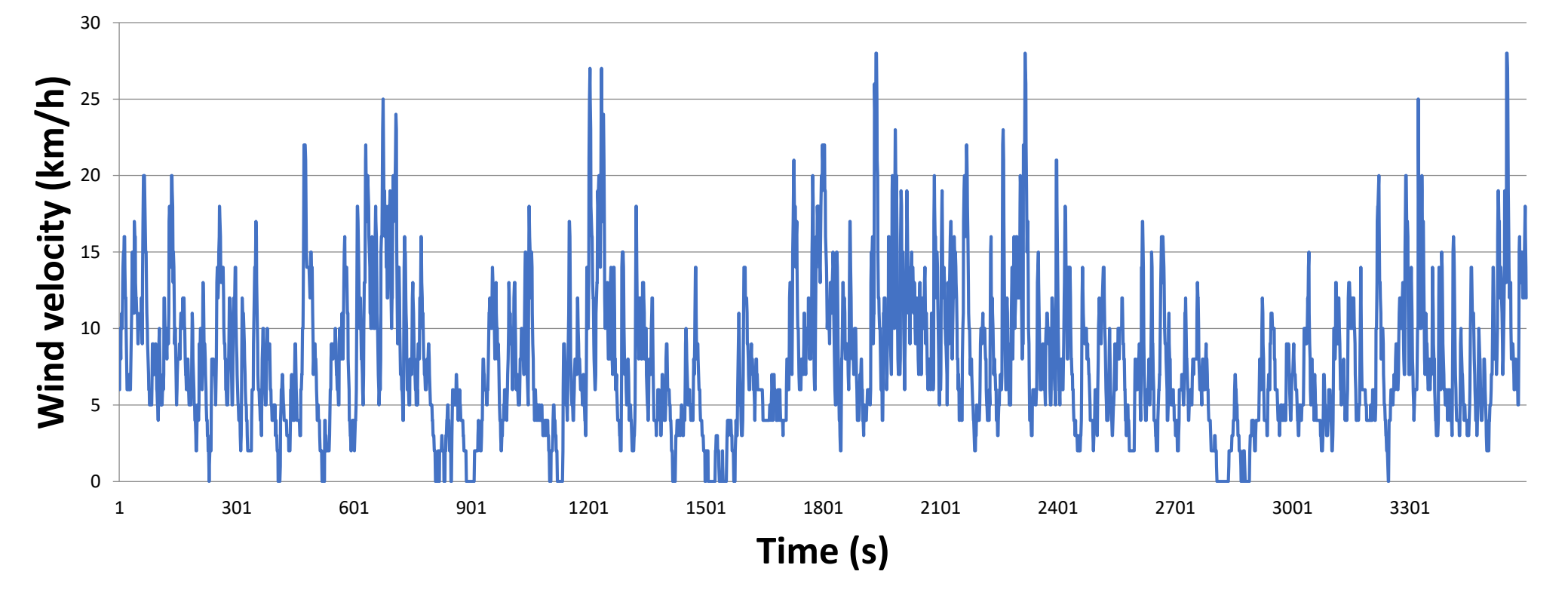
Pulling Test „inclino”

We have developed a new method (3 years old) and achieved more realistic dynamic testing based on the conventional pulling test by changing the static pulling device to the realistic wind load.



# The wind load is dynamic load



Pulling test
rope and force meter

Dynamic test
anemometer

**Idea:**

- instead of pulling by rope we are using wind
- instead of force we are using wind pressure: $p_{wind}$

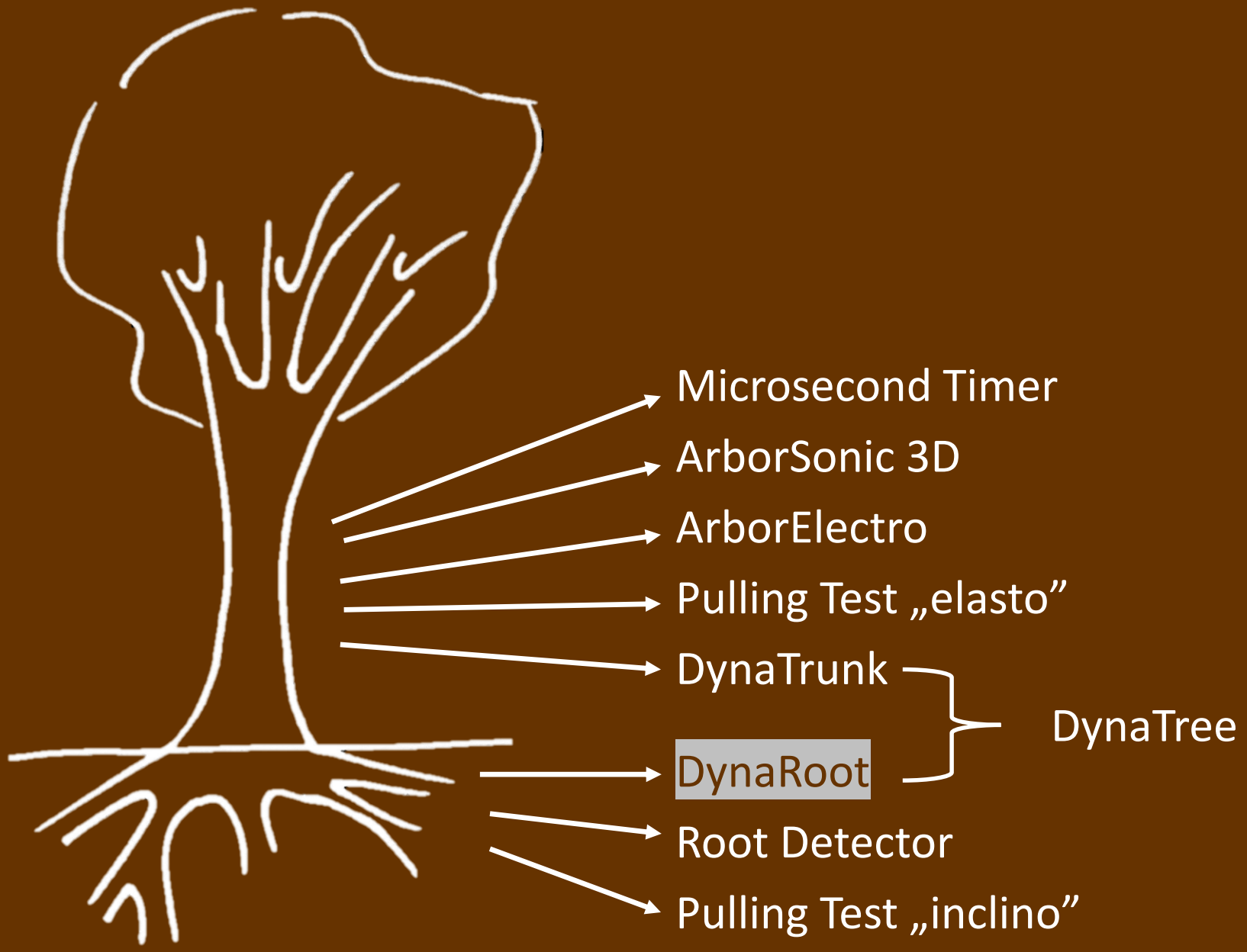
$$p_{wind} = \rho/2\ V^2$$

- where: $\rho$ is air density, V is wind gust velocity

**Consequence**

- in normal wind condition wind velocity is relatively low, therefore high sensitivity sensors are necessary: resolution is 0,001 degree. (If the 56m tall leaning tower in Pisa would suffer a change the inclination by 0,001 degree, horizontal movement of the top would be only 1 mm.)
- high sensitivity extensometer sensors are also necessary: our resolution is 0,5 micrometer!

| | | | | | | |
|---|---|---|---|---|---|---|
| wind velocity (km/h) | 10 | 20 | 40 | 60 | 90 | 120 |
| wind pressure (Pa) | 5 | 19 | 74 | 167 | 375 | 667 |


Microsecond Timer
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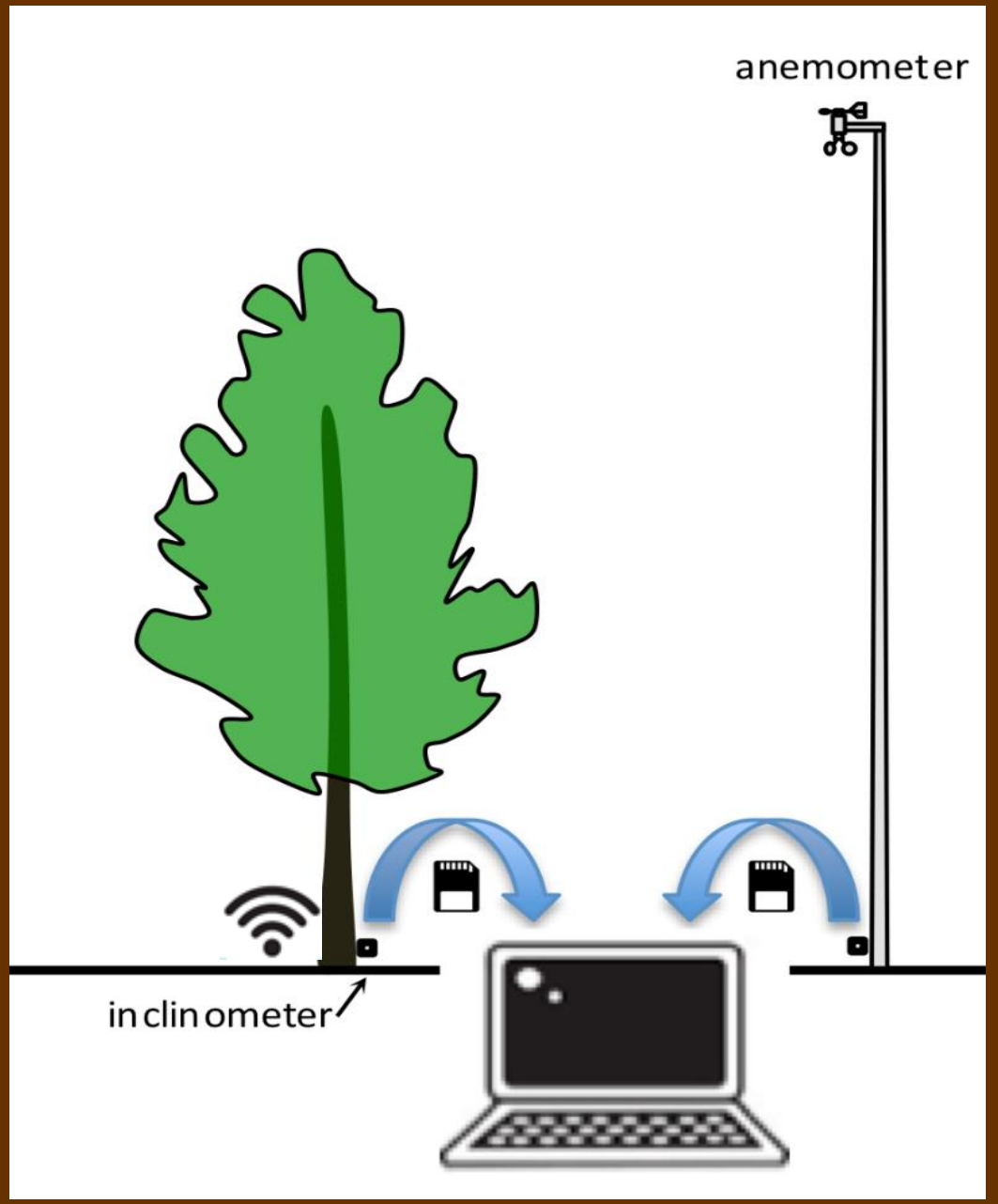
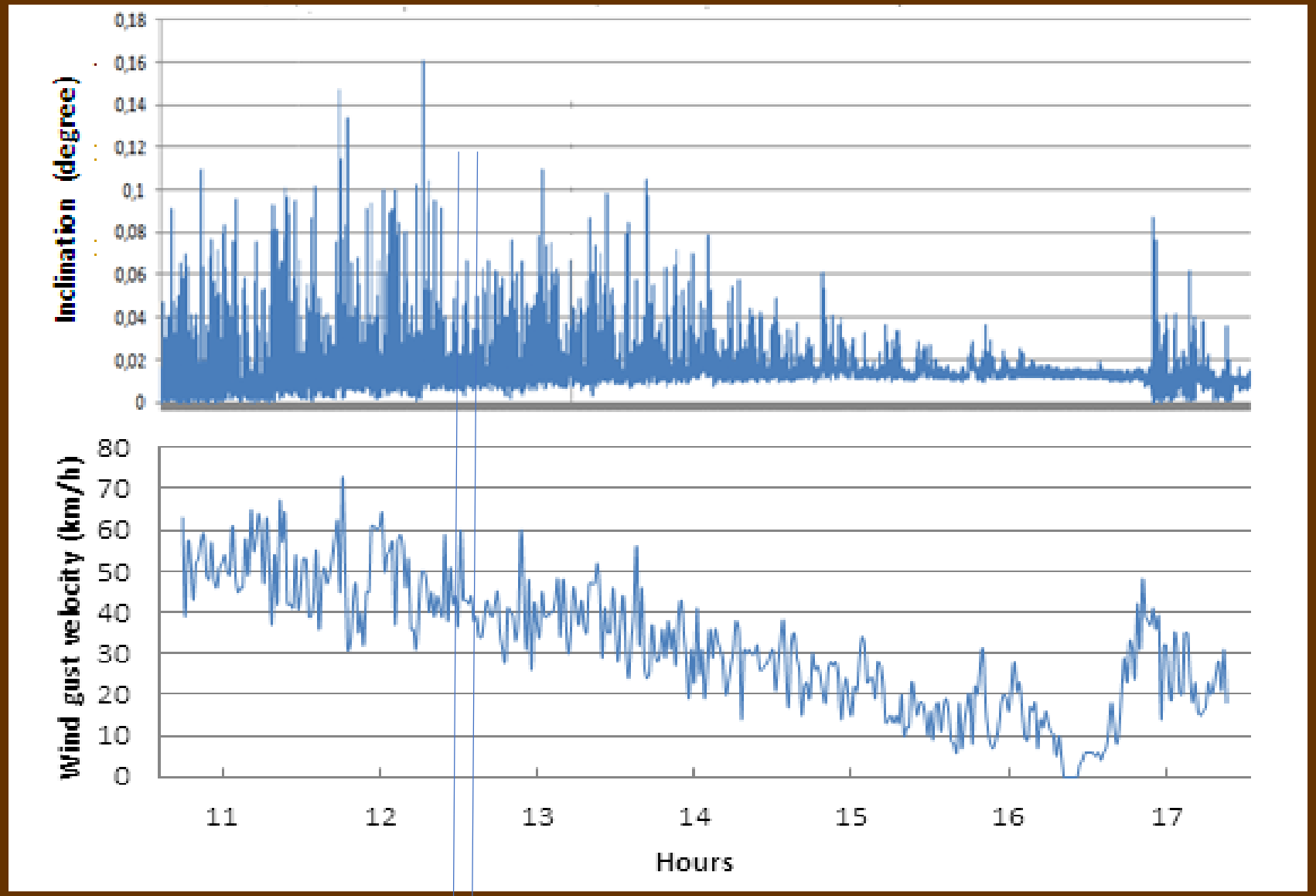
# DynaRoot - setup



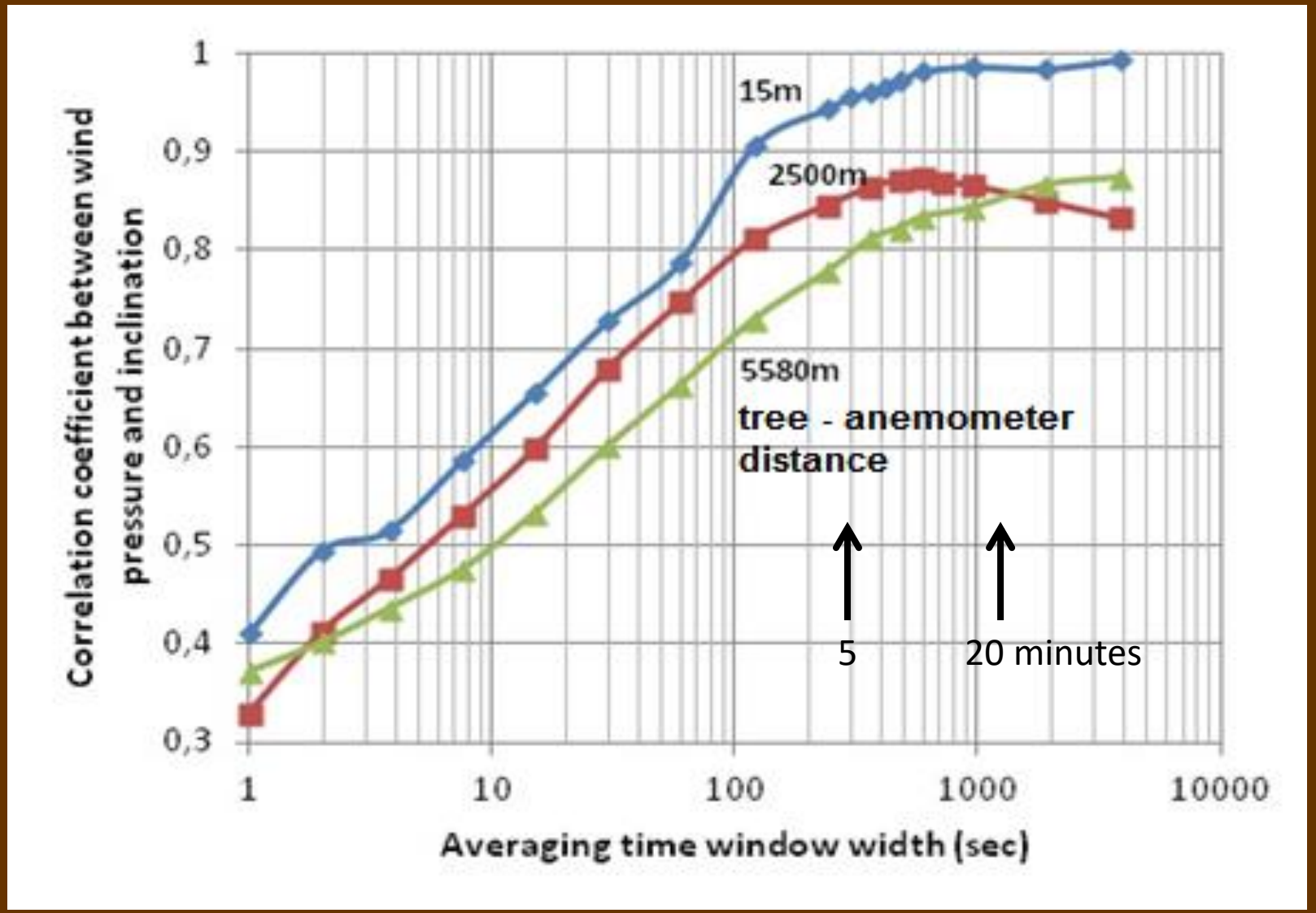
# Root Collar Inclination Sensor

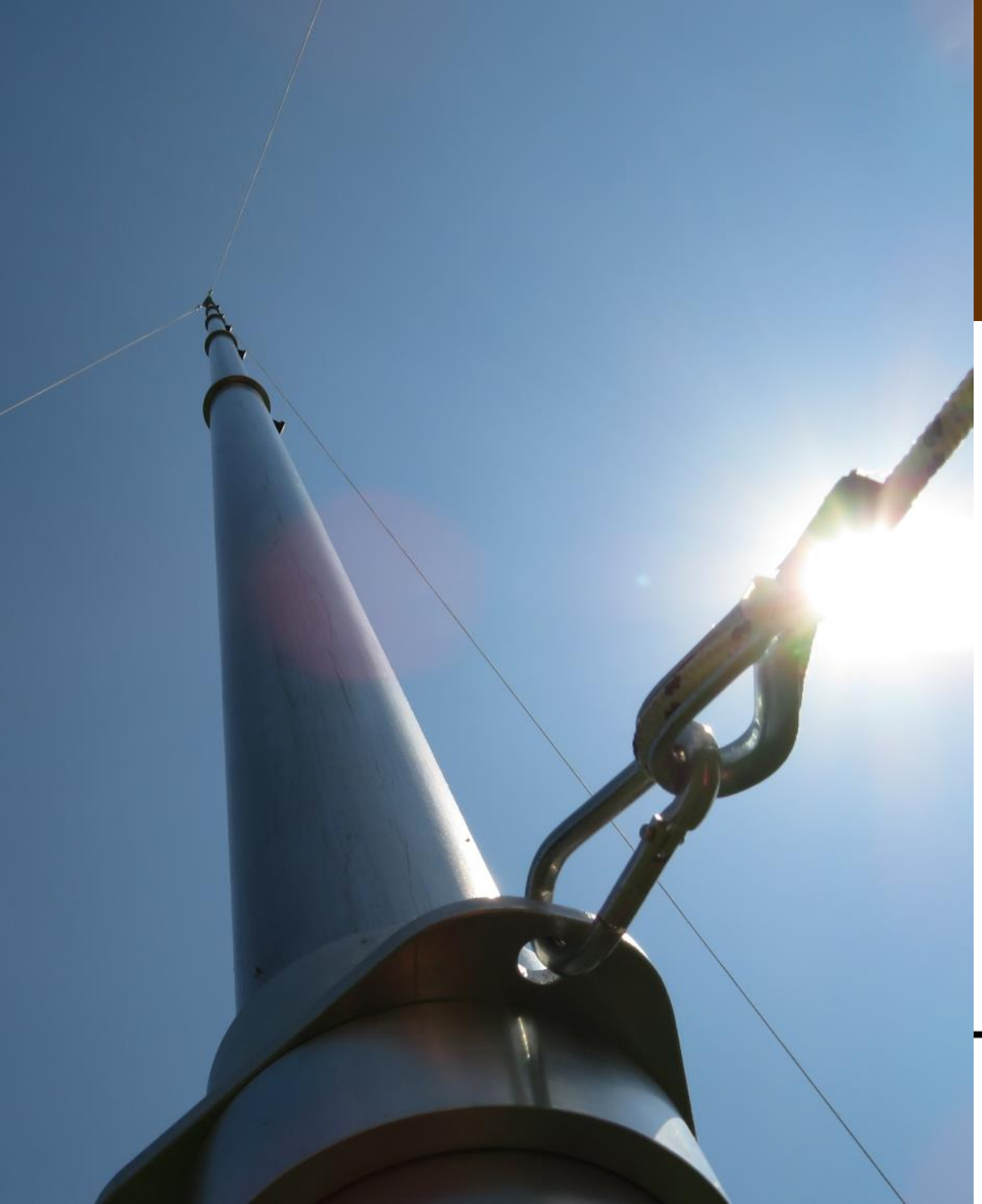

**Technical data:**

- Dual axes inclinometer
- Measuring range +/- 2 degree
- Resolution: 0,001 degree
- Temperature compensated
- Sampling rate is 10 Hz
- Integrated GPS
- Data stored on 8 GB SD card
- File name is the exact date and time, provided by GPS
- Fixed by a single screw
- Operating voltage: 12V, current: 20 mA

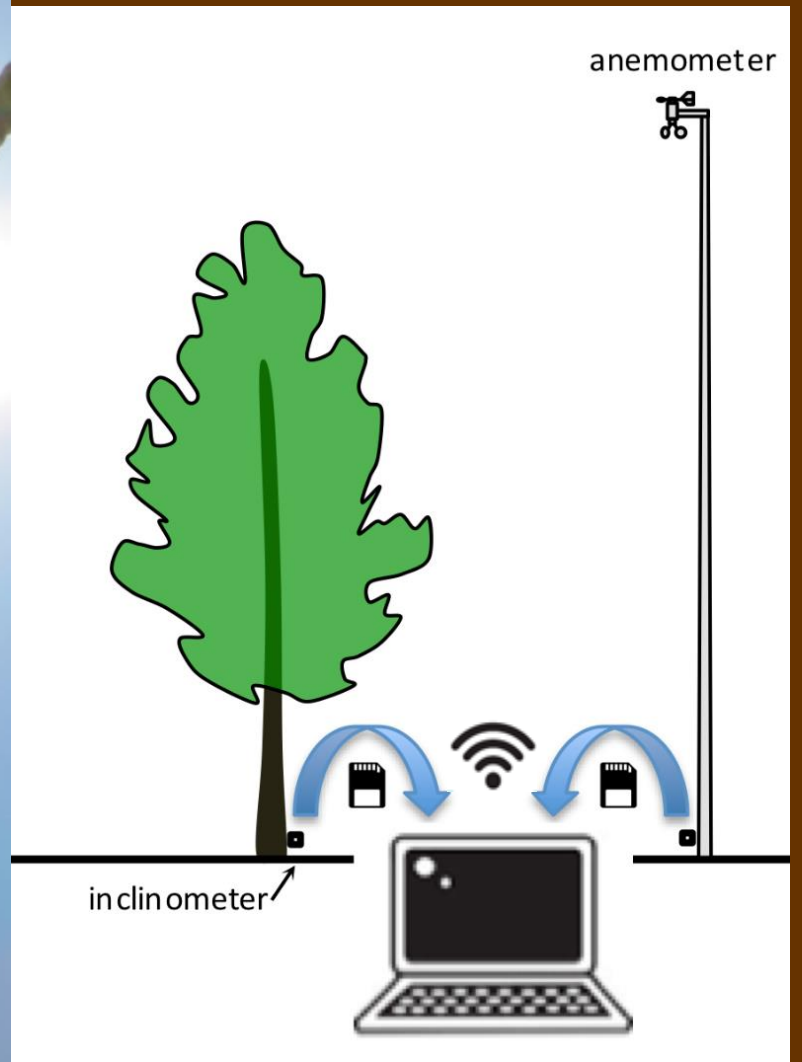



averaging time window
marked by blue lines


Correlation coefficient between wind pressure and inclination
1
0,9
0,8
0,7
0,6
0,5
0,4
0,3
15m
2500m
5580m
tree - anemometer distance
5
20 minutes
1
10
100
1000
10000
Averaging time window width (sec)

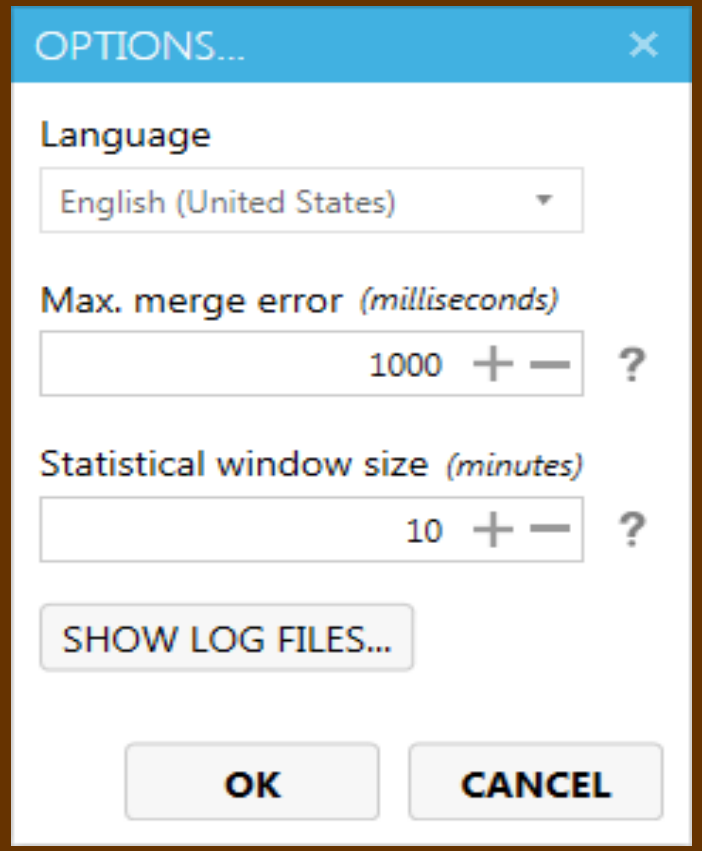


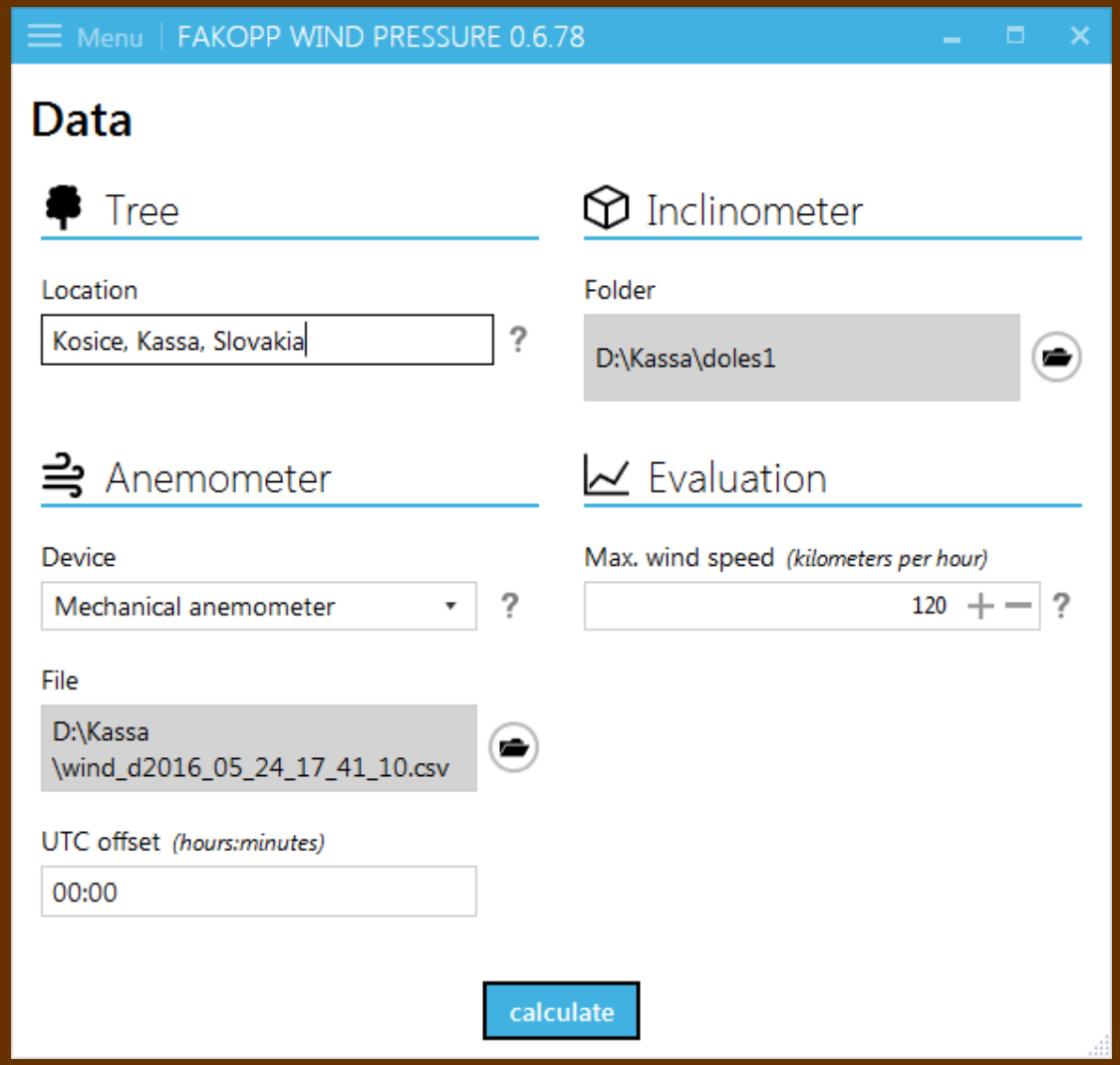
# Dynamic tests




Real wind

# The DynaRoot evaluation software

Fakopp
DynaRoot

Menu | FAKOPP DYNAROOT 0.9.25

# Evaluation

## Tree

Location

## Inclinometer

GPS

Show in browser...

## Anemometer

Average direction

210 °

## Combined data

Measurement start

2016. 11. 18. 22:28

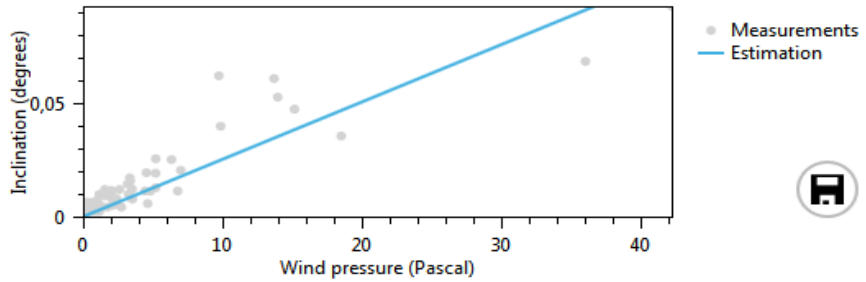
Measurement duration *(hours:minutes)*

10:52

Statistical window length *(minutes)*

5

## Chart




Critical wind pressure *(Pascal)*

644 ± 90

Ref. wind speed *(kilometers per hour)*

120

Correlation coefficient

0.9225

## Safety factor

**0.83**
high risk

Fakopp Enterprise
2016. 11. 22.

Menu | FAKOPP WIND PRESSURE 0.6.78

# Evaluation

## Tree

Location

Kosice, Kassa, Slovakia

## Inclinometer

GPS

Show in browser...

## Anemometer

Average direction

82 °

## Combined data

Measurement start

2016.05.24. 17:41

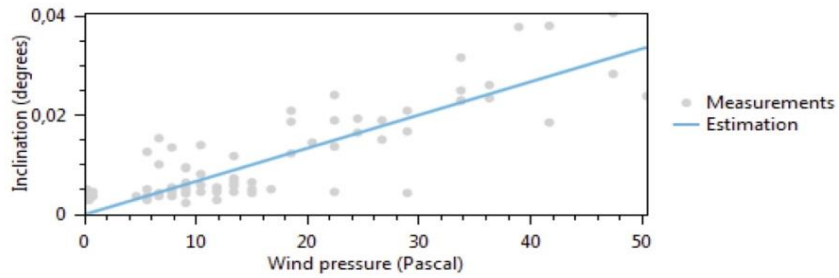
Measurement duration *(hours:minutes)*

17:05

Statistical window length *(minutes)*

10

## Chart




Critical wind pressure *(Pascal)*

2434

Crit. wind pressure error

352

Correlation coefficient

0.8562

## Safety factor

**3.65**
low risk

Fakopp Enterprise
2016.07.15.

# Dynamic safety factor determination

$$SF = \frac{M_{crit}}{M_{wind}} = \frac{p_{crit} A_{crown} h_{cr} c_w}{p_{wind} A_{crown} h_{cr} c_w} = \frac{p_{crit}}{p_{wind}}$$

The beauty of the dynamic test is, that crown area, drag factor and crown central height are not necessary in the evaluation as the measurement was done in the real given conditions.

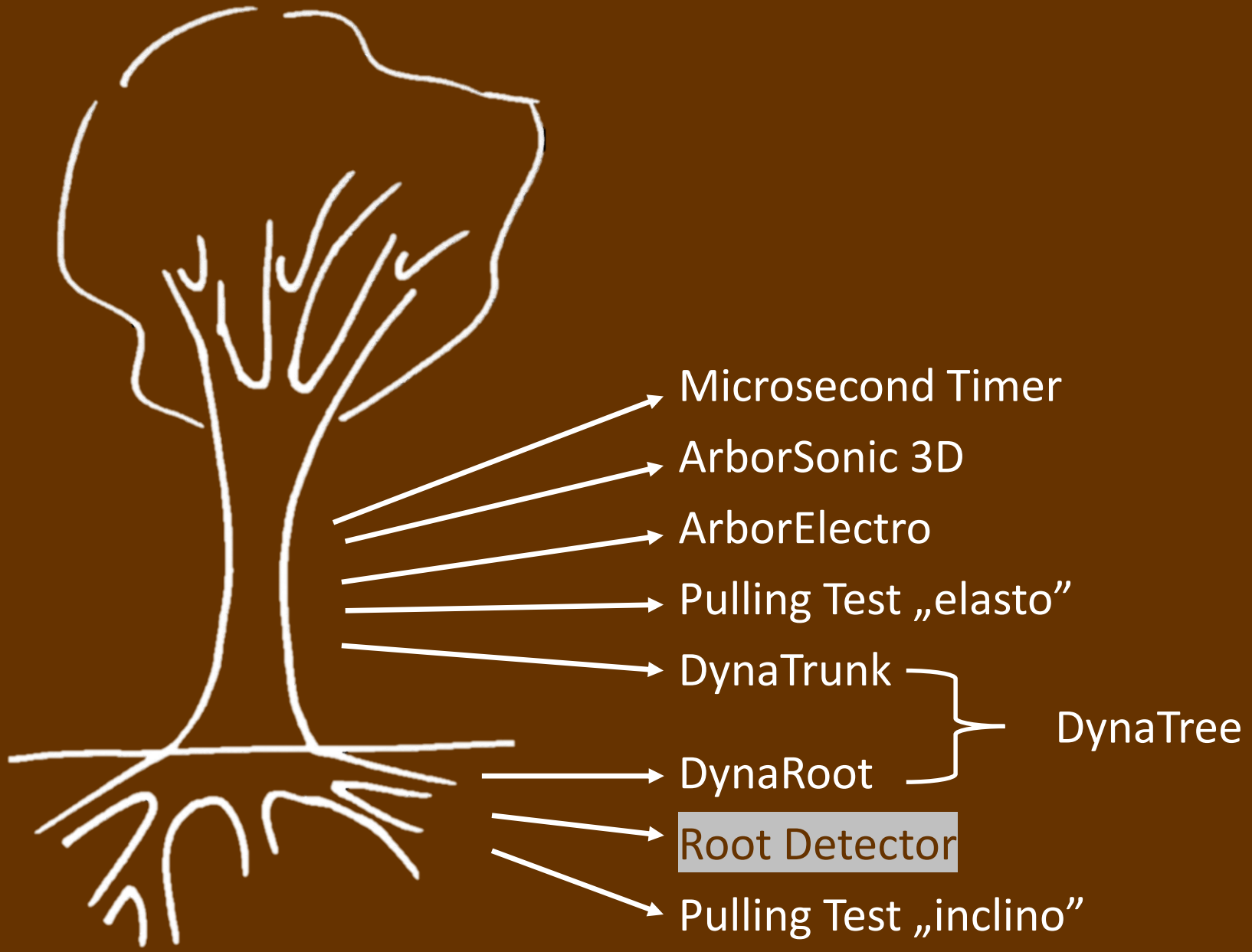
**Procedure of Dynamic Tree Evaluation technique**

0.) selecting a day when wind gust velocity is higher than 25 km/h.

1.) installation of anemometer on the top of 10m tall pole or receiving wind data of the area (maximum 1 -5 km distance between tree and anemometer. Sampling rate is 1 sample/sec or faster. Starting data capture.

2.) installation of inclination recorders and extensometers on tree trunk. Starting data capture.

3.) Collecting data for 1-3 hours, then copying data from recorders to PC for evaluation.


Microsecond Timer
ArborSonic 3D
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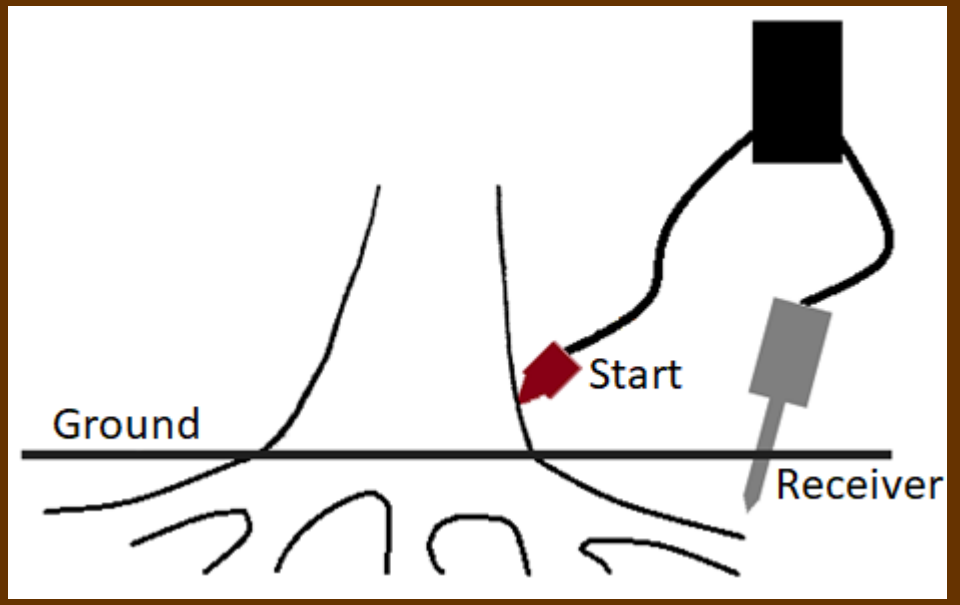
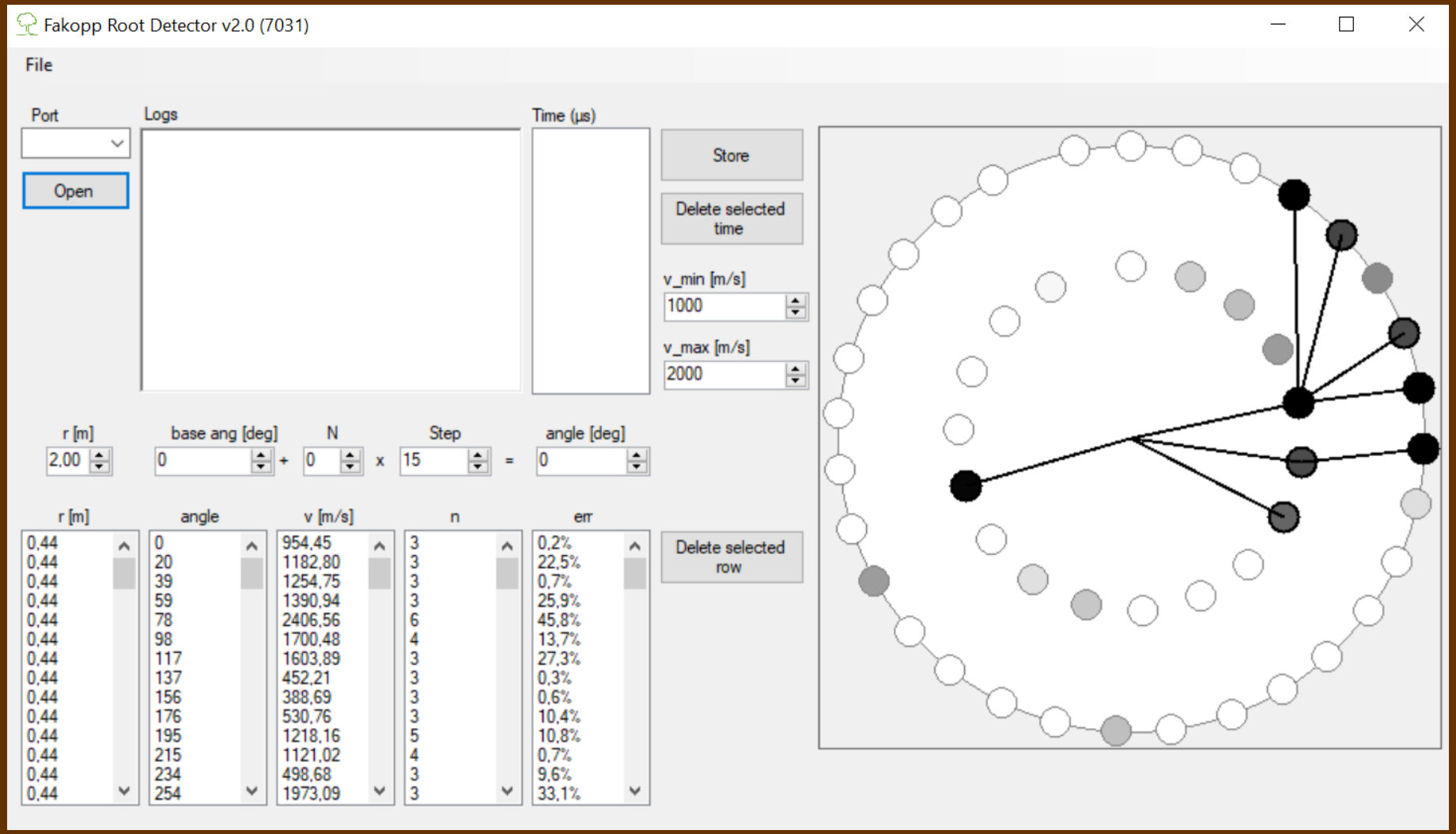
DynaRoot
Root Detector
Pulling Test „inclino”

# Root Detector



# Root Detector



Microsecond Timer

ArborSonic 3D

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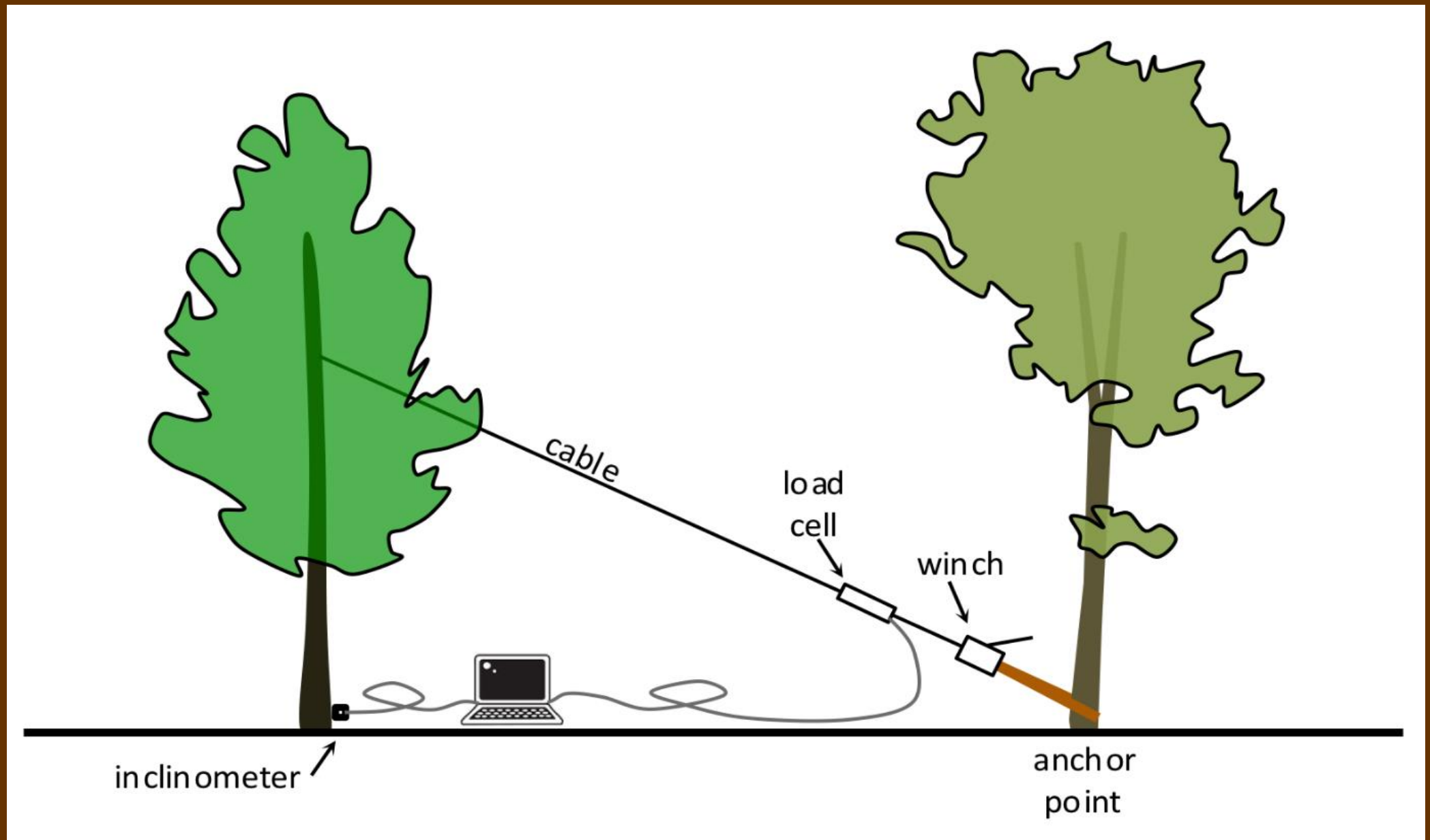
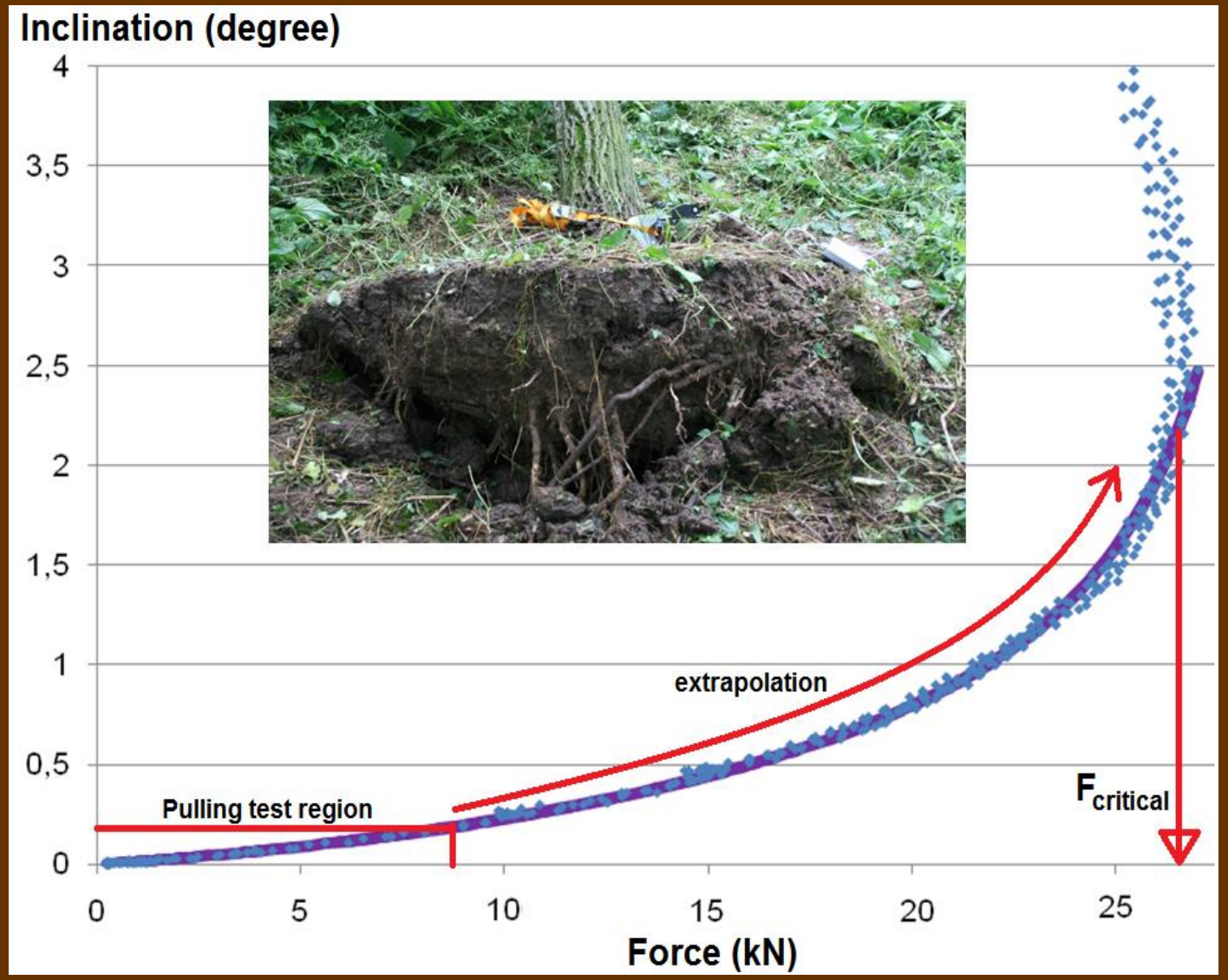
Root Detector

Pulling Test „inclino”

# Pulling test setup „inclino”

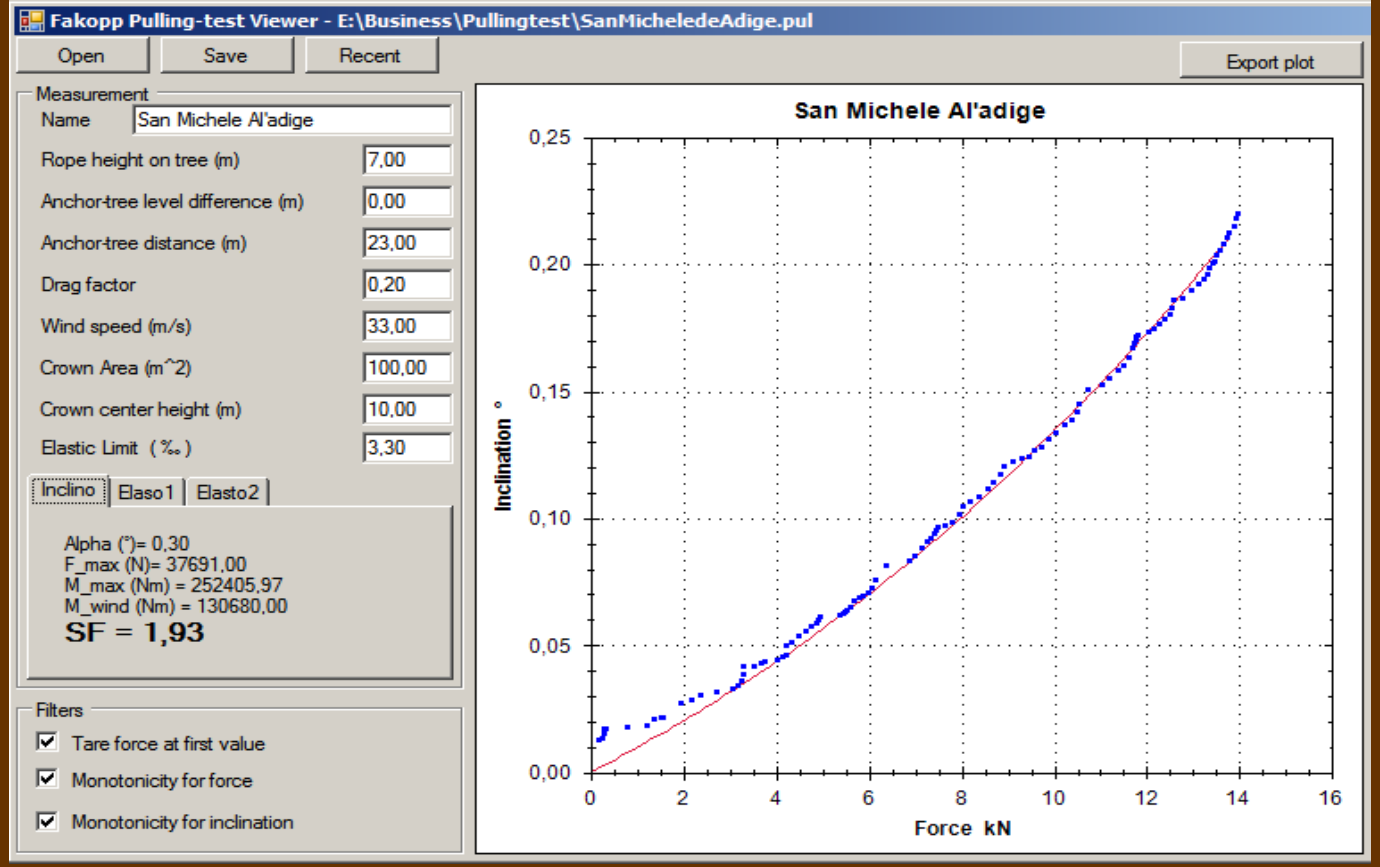


# Uprooting test




Above 2 degrees of inclination, uprooting force is not increasing.

Inclination sensor





Force sensor and force display

Fakopp Zugversuch Betrachter - G:\Germany2014_Pulling\untitled15.pul

Öffnen | Speichern | Letzte | Graph speichern

**Messung**

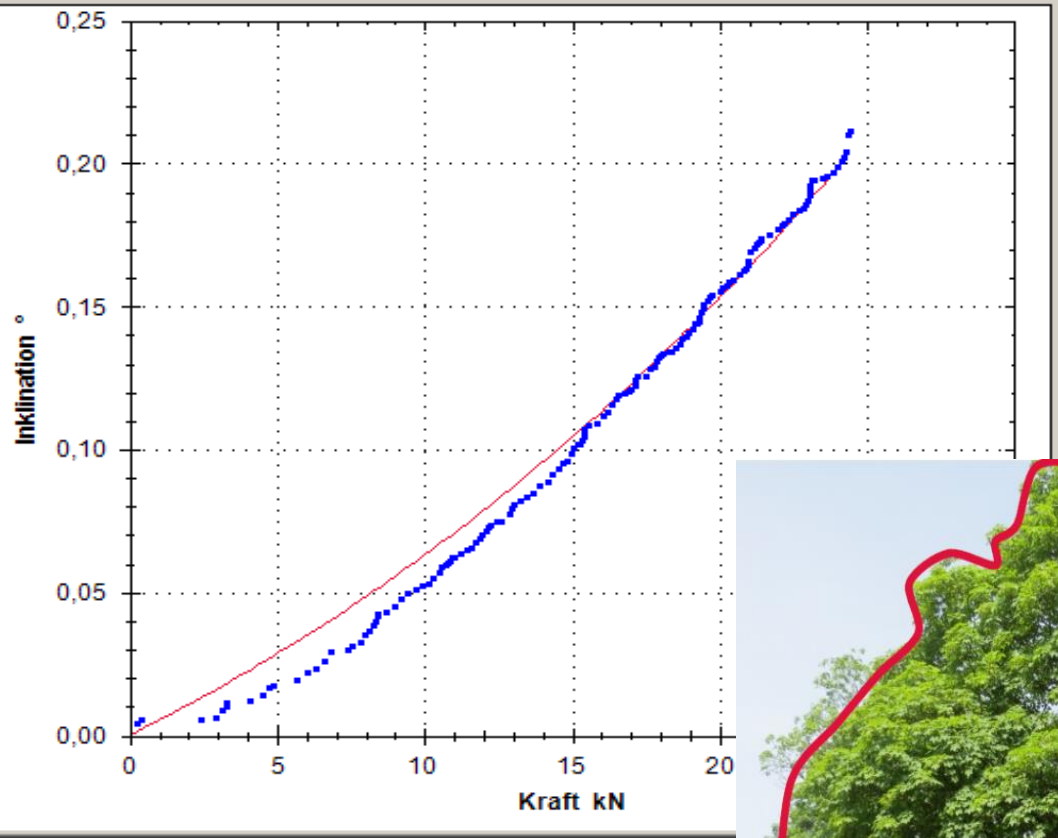
| | |
|---|---|
| Name | Baum 2 |
| Seil Höhe am Baum (m) | 5,56 |
| Anker-Baum Höhenunterschied (m) | 0,00 |
| Anker-Baum Distanz (m) | 11,1 |
| Widerstandskoeffizient | 0,25 |
| Windgeschwindigkeit (m/s) | 34,00 |
| Krone Oberfläche | 78,00 |
| Krone Zentral Höhe | 8,00 |

**Resulte**

Alpha (°)= 0,46
F_max (N)= 68505,19
M_max (Nm) = 340554,55
M_wind (Nm) = 108201,60
**SF = 3,15**

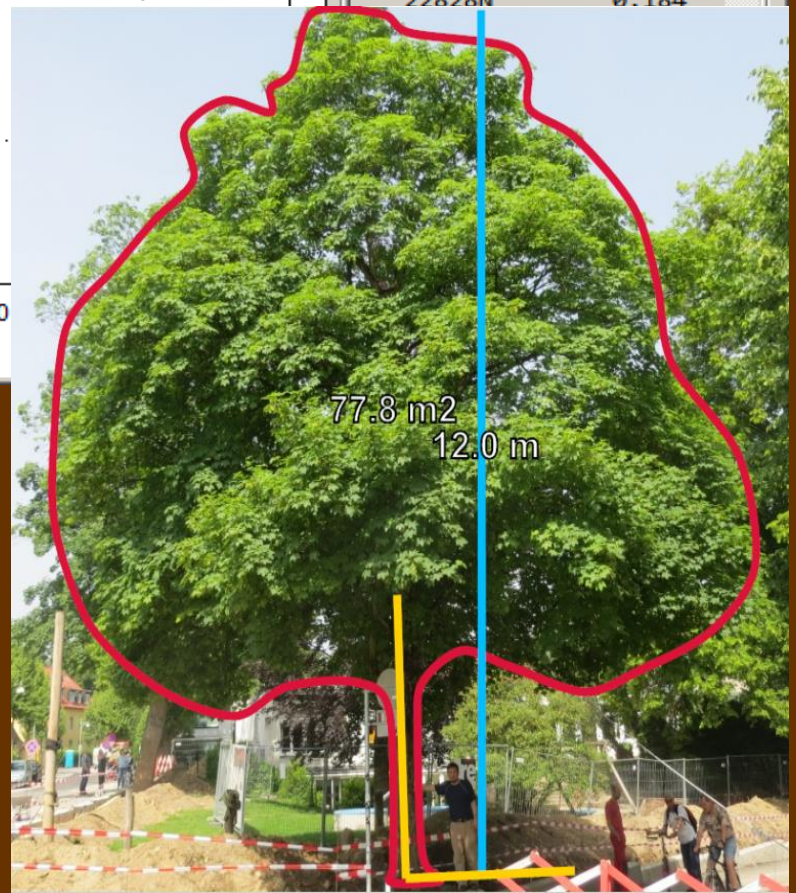
**Filter**

- [x] Tara Kraft bei erste Messpunkt
- [x] Monotonie für Kraft
- [x] Monotonie für Neigung




**Datei**

| | |
|---|---|
| 24466N | 0,211° |
| 24388N | 0,210° |
| 24299N | 0,204° |
| 24241N | 0,202° |
| 24142N | 0,201° |
| 24005N | 0,198° |
| 23838N | 0,196° |
| 23672N | 0,195° |
| 23505N | 0,195° |
| 23201N | 0,194° |
| 23132N | 0,194° |
| 23103N | 0,192° |
| 23093N | 0,191° |
| 23054N | 0,189° |
| 22985N | 0,187° |
| 22916N | 0,185° |
| 22828N | 0,184° |




An example

Microsecond Timer

ArborSonic 3D

ArborElectro

Pulling Test „elasto”

DynaTrunk

DynaTree

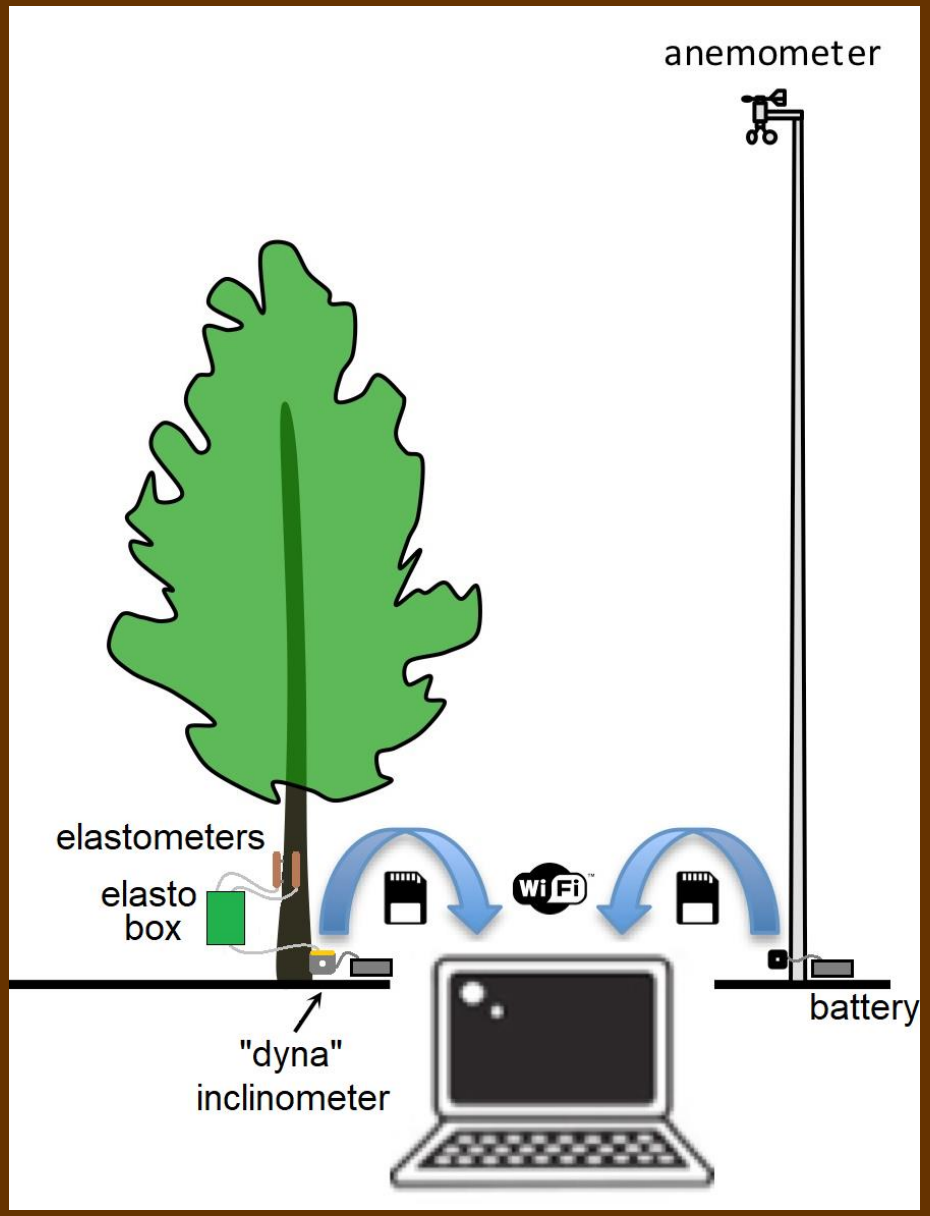
DynaRoot

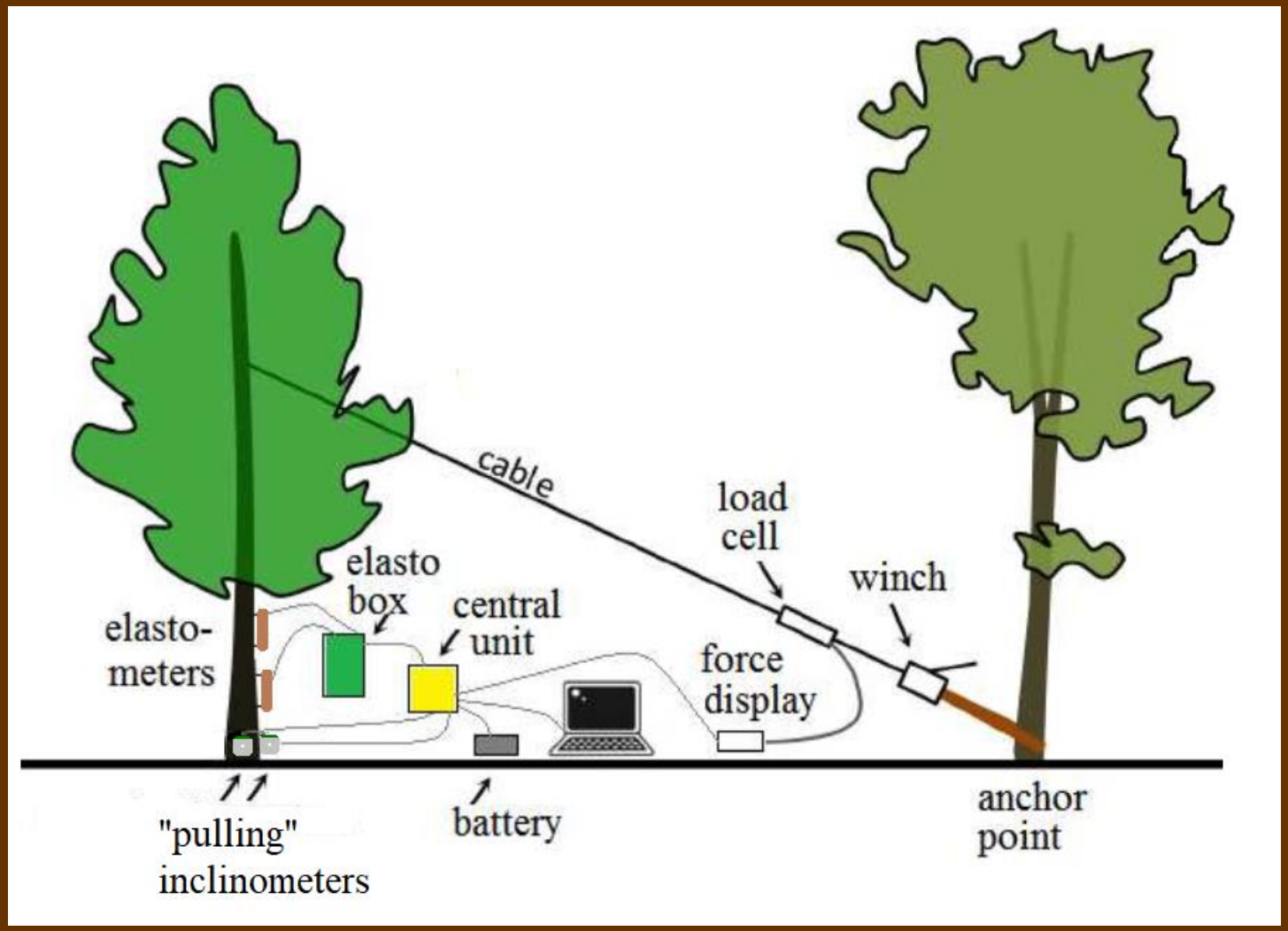
Pulling Test „inclino”

Root Detector

**Combined Pulling and dynamic test**

# Combined pulling-dynamic system




Ultrasonic Anemometer Recorder
High Precision Inclination Recorder
High Precision Inclination and Deformation Recorder
High Precision Inclination Recorder
FAKOPP PULLING TEST Dual Elastometer
1
2
FAKOPP Pulling test Central unit


DynaTree
Ultrasonic Anemometer Recorder
High Precision Inclination Recorder
High Precision Inclination and Deformation Recorder
High Precision Inclination Recorder
FAKOPP PULLING TEST Dual Elastometer
1
2
FAKOPP Pulling test Central unit
Pulling Test

# Comparison

| | Pulling test | Dynamic root evaluation |
|---|---|---|
| Anchor point | necessary | no |
| Tools | Ropes and pulling device, force meter | Anemometer |
| Load | Static | Realistic |
| Time of the test | 1 – 3 hours / tree | 3 hours / 10 trees |
| Cronw area, drag factor | nesessary | no |
| Weather condition | Wind speed < 25 km/h | Wind speed > 25 km/h |
| Result | Safety factor | Safety factor |

Microsecond Timer
ArborSonic 3D
ArborElectro
Pulling Test „elasto”
DynaTrunk

DynaRoot
Pulling Test „inclino”
Root Detector

- ✓ Fast
- ✓ Stabile
- ✓ Well packed
- ✓ Optimal in winds

- ✓ Simple
- ✓ Supports Bluetooth

# Support

Skype trainings
Remote desktop assistance
E-mail: office@fakopp.com


Thank you for the attention!