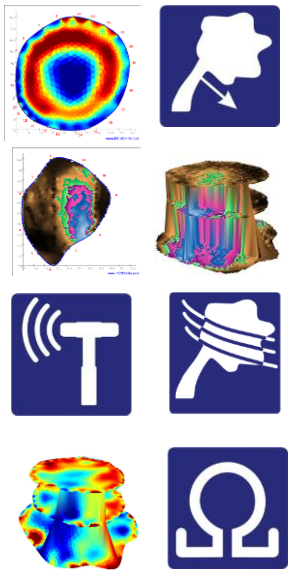
PiCUS

Tree Inspection Equipment



Tree Pulling Test
Sonic Tomography
Dynamic Sway Motion
Electric Resistance Tomography

www.argus-electronic.de

Description of Tree Inspection Equipment of

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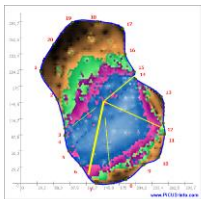
Rostock, October 2013

Contents

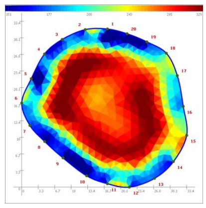
1. Products of argus electronic for Tree Decay Detection

The development of tree inspection instruments in our company started in 1997 by designing the PiCUS Sonic Tomograph in a cooperation of ***argus electronic gmbh*** and the ***Institut für Gehölze & Landschaft Dr. Gustke GmbH***. The worldwide launch of the PiCUS Sonic Tomograph was in 1999. It is now working in 30 countries on six continents.

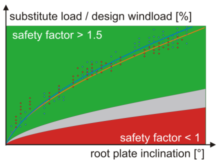
Ever since this time we are improving our technologies and develop new instruments to cover a wider range of tree inspection tasks.
Today our company offers a whole product family for the detection of decay and defects in trees:



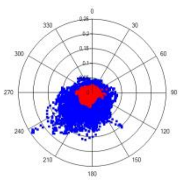
PiCUS® Sonic Tomograph. The PiCUS Sonic Tomograph investigates the tree by using sonic waves. The instrument measures the time of flight of the sonic signals that have been generated by a hammer. By using accurate tree geometry information the software calculates the apparent sonic velocities and draws a “velocity” or “E-module” map of the tree. The velocity of sound in wood depends on the modulus of elasticity (MOE) and the density of the wood itself and therefore with the health of the wood. Full resolution tomograms can be recorded with as few as 6 sonic sensors by using the electronic hammer.
The PiCUS Sonic Tomograph has won the **Technology Award 2000** of the German Federal State of Mecklenburg-Vorpommern.



PiCUS : Treetronic® – Electrical Resistance Tomograph (ERT). The Treetronic uses electric current/voltage to investigate the tree. The result of the measurement is a 2 dimensional map of the apparent electrical resistance of the tree. Chemical properties of the wood affect the resistivity; most of all: water content, the structure of the cells, ion concentration and others. The chemical properties are changed if decay etc. is in the tree. The Treetronic can detect very early stages of decay above and to some extend below ground.



TreeQinetic - There are two major types of tree failure: uprooting and breaking. A **static pulling test** can be used to estimate the uprooting and breaking safety of a tree. The TreeQinetic system is designed to collect data during static tree pulling tests. It can also be used to record the sway motion of trees in winds.



Tree Motion Sensors (TMS) – the TMS sensors are used to record the sway motion of trees in natural winds over longer periods of time. The tilt data recorded helps to identify trees with root-anchorage problems at very little effort.

PiCUS Calliper. The PiCUS Calliper is an instrument to record the geometry of the tomography level quickly and accurately. This geometry data is needed for sonic and electric resistance tomography inspections. It is particularly useful for testing large or irregularly shaped trees.

2. Frequently asked questions (FAQ)

1. **What is the difference between Sonic Tomography and Electric Resistance Tomography?**
   Sonic Tomography uses sonic waves to obtain "mechanical" information about the wood of the tree. *Electric resistance tomography* uses electric current to gain "chemical" information about the wood. In short, two *different* types of information are obtained by using these two different methods.

2. **What is the difference between PiCUS 2 and PiCUS 3**
   The PiCUS 3 was released in October 2012. It is the compact and lightweight version of the previous model. Basically, both systems are using the same technology and can do the same work. The PiCUS 3 is easier to operate, can work with or without a PC, has less cables etc. A full list of features can be found in the PiCUS 3 information pdf.

3. **How many sonic sensors do I need?**
   PiCUS technology distinguishes between sensors (the sonic sensor that receives and registers the sonic signals) and a measuring point (MP). The MP is a simple nail. By tapping on knocking on this nail, you create sonic waves. You attach the sensors to the nails and these receive the sonic signals and register them. The PiCUS system can also use MORE measuring points (nails) than sensors, which is important when you wish to inspect larger trees using only a limited number of sensors.
   The distance between measuring points should be between15 and 40 cm. Very smooth and round trees will require fewer measuring points, whereas trees with buttress roots and very uneven circumferences will require more.
   The PiCUS 3 can be equipped with 6 or 12 sensors. Both versions can test any size of tree.

   The largest tree we have ever tested was this sequoia sempervirens (a redwood in California), which was over 5 meters in diameter. To take the measurements, we placed 66 MP but only needed to use 16 sensors (Version PiCUS 2).

4. **What are the limits of Sonic Tomography?**
   Cracks in wood are real barriers for the sonic waves. They appear in the tomogram much larger than they really are and may thus lead to incorrect conclusions about the tree. To identify "star shaped" cracks, the PiCUS software contains a CrackDect Function. We also recommended using other inspection methods, such as the Treetronic electric impedance tomography.

5. **How important is the exact geometry?**
   Velocity calculations are based on the formula:
   Velocity = distance / time
   The more accurate the geometry of the measuring level is, the more accurate the tomograms will be. The PiCUS software offers you a number of functions to measure the geometry efficiently. The triangulation method is most accurate.

6. **Do I need the electronic calliper?**
   The electronic calliper is a very efficient tool to measure the positions of the measuring points. In can help you record even complex geometries in a matter of minutes. Mechanical standard callipers can also be used.

7. **What is the difference between Shigometer and Treetronic?**
   Both Shigometer and Treetronic try to get the same information about the consistency of the wood (“what is the electric resistance?”), but the working principle is different. The Shigometer required you to drill a hole into the tree and it collected the information about the wood along the drill-line. This is a direct conductivity measurement, meaning two electrodes touch the wood in order to measure voltage and current.
   The Treetronic uses a more accurate 4-electrode setup. Two electrodes are used to get the current into the tree; two other electrodes measure the drop of voltage at a different position. In doing so, the Treetronic can collect data of the entire cross section. In the strictest sense, this is data of a column of the tree.
   The calculation of the Treetronic are also very different from those of the Shigometer. The results of the Treetronic measurements are recorded in an Electric Resistance Tomogramm (ERT). Interpreting an ERT requires experience and knowledge of the particular species of tree. An ERT can provide valuable additional information about the type of damage in a tree.
   Example: When measuring a beech tree with Meripilus giganteus, the sonic tomograph will not be able to detect this fungus well because the wood in the stem is not affected by the fungus growth. The Treetronic would show very high conductivity which, in beech trees, is a clear indication for a fungus infection that increases moisture content. In this case, the Treetronic can also provide you with a look underneath the ground because of the 3-dimensional nature of the measurements. The sonic tomograph does not give you any information from below the ground level.

8. **How many probes do I need to use the Treetronic?**
   The number of Treetronic channels or probes is 24. Electric resistance tomography requires more measuring points than sonic tomography in order to get good resolution. In many situations it is best simply to double the number of sonic measuring points in order to get a good electric resistance reading. For instance, if the sound tomogram was recorded with 10 measuring points, the electric resistance tomogram should have 20 probes. You can measure larger trees by combining up to 3 Treetronic instruments.

9. **Do the instruments require annual servicing?**
   No. The sensors do not need to be calibrated regularly, but argus does offer check-up and maintenance services according to the regulations ISO9000 and others.

10. **Do I need training to operate the PiCUS unit?**
    Yes. Training on the instruments is highly recommended and will take 1 or 2 days.

11. What are the recommended configurations for my PiCUS system?

The number of measuring points (MP) is no longer that important because of the electronic hammer that is part of every PiCUS system. The PiCUS 3 can be equipped with 6 or 12 sensors.

Minimal setup:
PiCUS Sonic Tomograph – 6 or 12 sensors
PiCUS Standard software
Mechanical calliper (such as Haglöf, etc.)

Standard setup:
PiCUS Sonic Tomograph – 6 or 12 sensors
PiCUS Electronic Calliper
PiCUS 3-D Expert software

Scientific / Expert Setup:
PiCUS Sonic Tomograph – 6 or 12 sensors
PiCUS Electronic Calliper
PiCUS Expert software
Treetronic - Electric Resistance Tomograph

Combining sonic tomograms and electric resistance tomograms will give you much more information. The SoT – ERT combination is the best available technology in imaging technologies for trees. Thus, using a 6-Sensor PiCUS AND the Treetronic gives more and better information than “just” a 12 Sensor PiCUS system.

12. Do the tomograms show sapwood – heartwood of the trees?

Yes. Particularly the Treetronic shows you the sapwood / heartwood accurately in many situations. In trees with defects (decay or cavities), the sapwood – heartwood is more difficult to find.

13. Can I see growth rings in the tomograms?

No. Growth rings are much too small to detect with this technology.

14. Do the tomograms give me any information about the roots?

The sonic tomograms (SoT) do not give you any information about the roots. They only give information about the level of tomography.
The electric resistance tomogram (ERT) produces an integral of the resistance of a certain section of the tree. The length of this section is approximately equal to the diameter of the tree itself. Thus the ERT can give you information about the roots when you measure near ground level, particularly about the decay in roots.

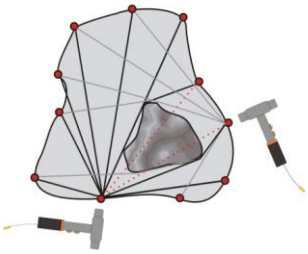
15. Can I use the PiCUS for root mapping / detection?

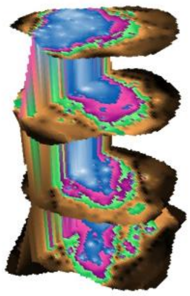
Using the Sonic Tomograph instruments for root detection is limited. Under perfect conditions it could be possible to detect large roots near the tree under the surface.

3. PiCUS Sonic Tomograph

3.1. Working principle

The PiCUS® Sonic Tomograph is an instrument to detect decay and cavities in standing trees non-invasively. The velocity of sound waves in wood depends on the modulus of elasticity and the density of the wood itself. The PiCUS unit tracks the speed of these waves. Most damage and disease causes fractures, cavities, or rot and reduces the wood's elasticity and density. This sketch on the left displays the basic working principle, in that sound waves cannot take a direct path through the wood (red dotted line) if there is a cavity between the transmitter and receiver.





The results of the sonic investigation are recorded in a Sonic Tomogram (SoT). The tomogram on the right shows a 3D graphic of 4 separate scans. The tomogram uses different colours to display the various properties of the wood:

- Areas of high E-module/density, where the fastest velocities can be found, are represented in (dark) browns – indicating healthy wood.
- The meaning of green varies according to the defect. It often describes the distance between healthy and damaged wood, but can also indicate early fungus infection.
- Violets and blues represent areas of slower sound velocities (meaning low E-modulus).

The colour scale (black-brown, green, violet-blue-white) is ranges from the fastest to the slowest velocity.

The PiCUS 3 is the latest version of the sonic tomography. Compared to other models it is very compact, lightweight and more easy to operate. The sonic sensors are attached to the main unit by two sensor-cable looms. These cable looms have replaced the modular concept of the PiCUS 2. The PiCUS 3 can be used autarkic, with no PC. In this case the tomogram is shown on the integrated screen.

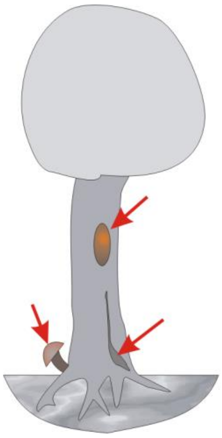
PiCUS 3 at the tree

Measuring case

PiCUS 3 sensor

Taking sonic measurements with the PiCUS unit involves four basic steps:

1. **Determine the level, number, and positions of measuring points and mount the equipment on the tree**
2. **Measure the geometry of the tree at the level you are working at**
3. **Take the sonic measurements**
4. **Calculate the tomogram**



3.2. Determining the measuring level

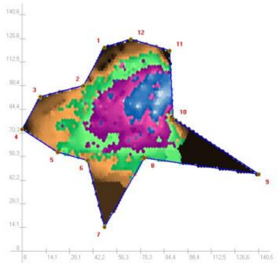
To determine the measuring level, first conduct a thorough visual inspection of the tree and also a sound evaluation with the mallet. Look for external signs of internal defects, such as fungus growth, cracks, cavities, damaged bark, etc. Use all of your knowledge about trees and diseases and choose the measuring level according to your visual assessment of the tree.

3.3. Measuring the geometry of the tree at the measuring level

When calculating the tomogram, sound velocities are measured using set distances and time recorded between these points. This means that it is important to note the geometry of the measuring level (positions of nails) as accurately as possible. There are several ways to enter the geometry of the tomography test level.

1. Simple circular or elliptical geometry
2. Free shape geometry - Triangulation

The PiCUS Calliper can efficiently carry out the triangulation measurements needed to calculate the exact positions of each measuring point. Using the electronic PiCUS calliper allows you to plot any tree shape quickly and accurately.



Tomogram / cross section photo of tree[1] with butress roots
On the right: Electronic calliper in work and in transport positions.

[1] Recorded by Craig Hallam, ENSPEC, Australia

3.4. Taking sonic measurements

Sonic signals are created on all nails (MP) by tapping with the electronic hammer.
The tapping pin of the hammer is attached to the nail and a short sharp tap generates the acoustic wave. Display and buttons on the hammer are used to specify the tapping point. This way one can perform measurements on trees with more nails than sensors.

Display shows current tapping position

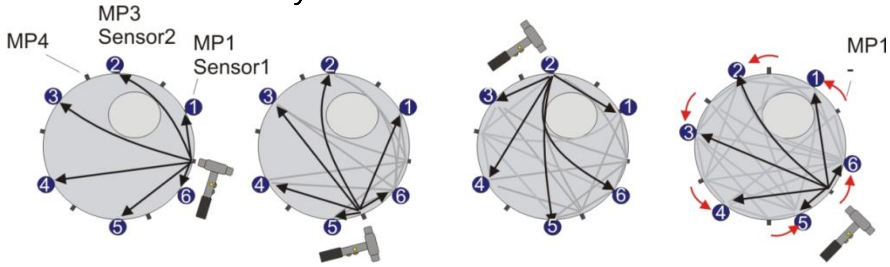
Buttons to set the tapping positions

3.5. Few sensors – much tomogram

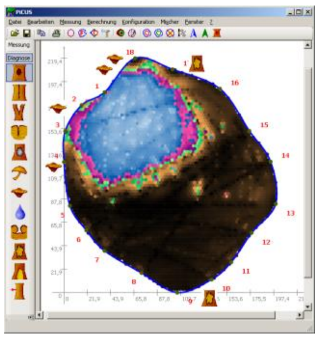
The standard way to measure sonic data is to place a sonic sensor on each measuring point (nail). This means that if there are 10 measuring points (nails) along the circumference, you would need to use 10 sonic sensors. The impulse is generated on each measuring point (nail) and recorded on the sensors at the other 9 points.

The electronic hammer allows you to use fewer sonic sensors than measuring points. This enables you to use smaller PiCUS systems in a fully functional manner. This hammer is also helpful when working on large trees, where the number of measuring points required exceeds the number of sonic sensors you have. The measurements obtained will be very similar to standard values, but it may take you longer to conduct the measurements. The sketch shows a different variation of the measuring procedure using fewer sensors than measuring points. As you can see, it is possible to conduct a “12 sensor” PiCUS test using only 6 sensors. This technology works for both PiCUS 2 and PiCUS 3 systems.

Black squares = Measuring points (nails), Blue points = placement of the sonic sensors



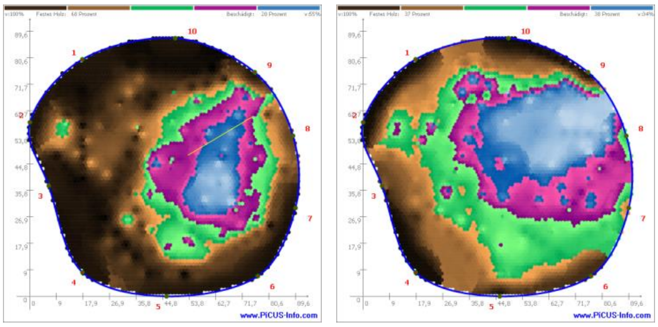
3.6. Calculating a Tomogram



The PiCUS Sonic Tomograph is the first to use “relative velocity” reconstruction algorithms. Earlier devices relied on absolute sound velocities, which were measured in meters per second. However, absolute sonic velocities vary among species, among the trees of the same species and even within the same tree. Thus the calculation transforms all velocities you measure into “relative” velocities.
The tomogram shows the ability of the wood to transmit acoustic waves.

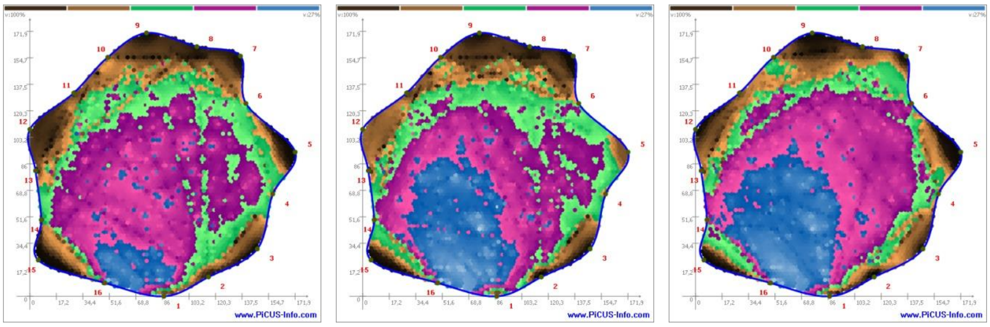
3.7. Time lines

Trees can be tomographed every couple of years to find out about the progress of a decay. When doing so it is important to use the same MP-positions all the time.
The example[2] shows the progress of a fungus infection in a beech tree. The tree was tested in 2007 and in 2011.



SoT 2007 20110

These scans of an oak tree show that the tree can stop the growth of the fungus to certain extend. The decayed area gets worse and worse but the size of the defect stays constant.

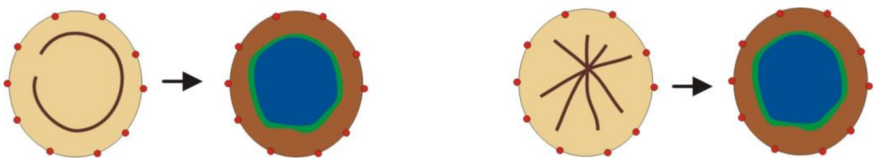


SoT 2006 2008 2010

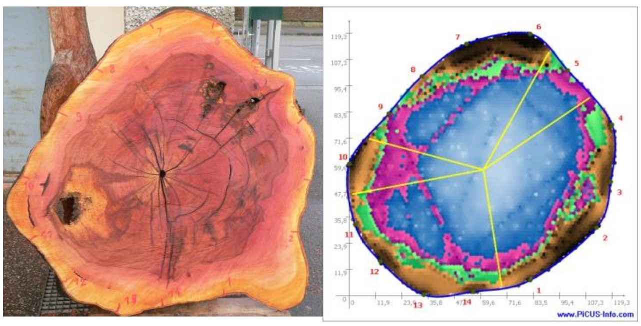
3.8. PiCUS CrackDect - Crack Detection with the PiCUS Sonic Tomograph

Cracks are severe sonic barriers for sonic waves. There are two main types of cracks:

- “Star-shaped cracks” run from the centre of the tree to the outer fibres
- “Ring cracks” run parallel to the circumference



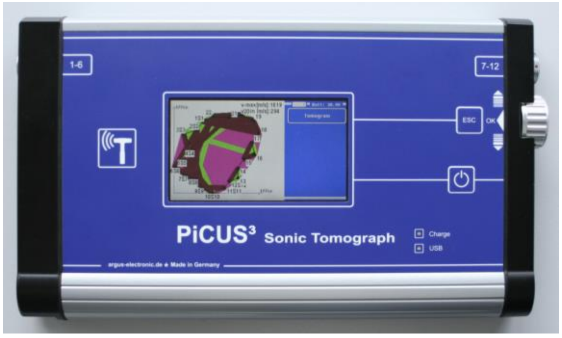
Both types of cracks can lead to errors in your tomograms. The PiCUS system is capable of identifying star-shaped cracks in many cases. The program checks for the presence of radial cracks and indicates their likely positions in the tomogram with yellow lines. The example shows a Platanus tree[3] with cracks and decay.



[2] Daten: Andreas Block-Daniel, Deutschland
[3] City of Strasbourg, France

3.9. PiCUS 3 the latest version of the PiCUS

The PiCUS 3 is the compact version of our proven sonic tomograph. The PiCUS 3 can be used autarkic or with a PC. Two sensor-cable looms with 6 sensors each can be attached to the control unit. However, like the predecessor the PiCUS 3 can work on an unlimited number of measuring points.

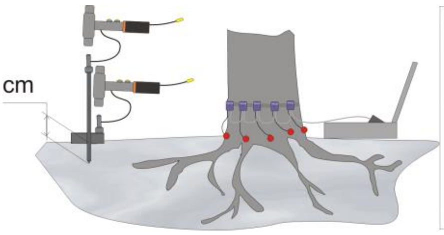



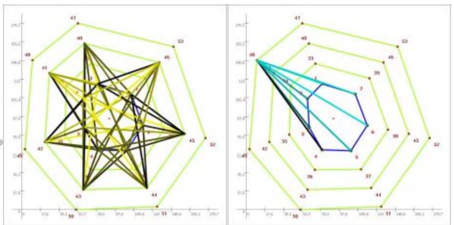
PiCUS 3 – 6 or 12 sensors "Pre-view" of tomograms Sonic sensor

The PiCUS 3 is optimized for daily work: fast and easy to operate and – due to the light weight – easy to carry. It has integrated GPS and altimeter to collect additional information about the tree. Another new function of the PiCUS 3 is the „Three-point-test" which can be used prior to a full tomogramm to decide if that tomogramm is needed.

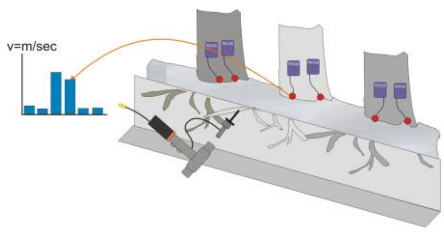
3.10. Sonic scans on roots

The PiCUS hardware can also be used for other measurements, one of which involves obtaining information about a tree's roots. To do this, the PiCUS sensors need to be placed on the trunk of the tree just above ground level. Sonic impulses are generated using a small metal plate and/or a metal pole and hammer at set positions around the tree, and the PiCUS unit measures the travel times of these impulses. By analysing these times, the system can give us limited information about the larger roots. This method only works in certain situations. Best results can be obtained with solitary trees which are not too close to buildings, cellars, pipes, or other solid constructions. The measurements can be greatly influenced by soil compression, water content, and by large objects in the ground (such as rocks).





Left: Setup of the measuring hardware for root mapping
Right: Software shows result of a root scan. Darker lines indicate higher sonic velocity.



In contrast to this, the tree-roots allocation does often work when it becomes necessary to determine which roots belong to which tree. At constructions sites with multiple trees close to a building, evaluators can use test pits to help allocate roots and decide if a tree must be removed. In such situations the PiCUS hardware can help.

3.11. Advantages of using the PiCUS

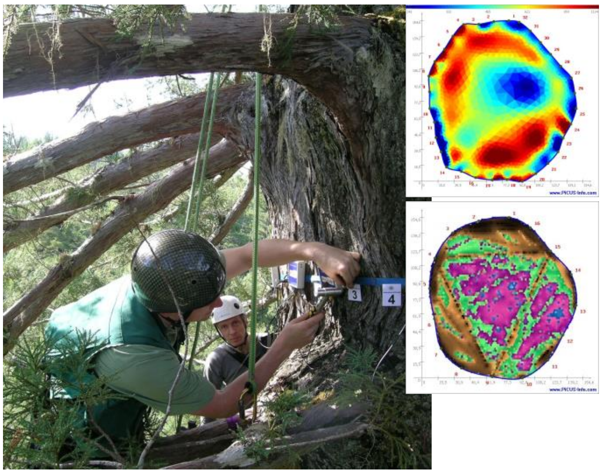
- Using tomograms of the same tree to track changes easily over a long period of time helps with **long term tree maintenance**.
- Can be used on nearly **any size of tree**. The lower limit for a tree diameter is approximately 30 cm.
- **Easy to** understand **tomograms**: The areas of different density are easy to identify with the PiCUS colour-coding. ("Your customers will love the images!.." say BTL, The Netherlands, PiCUS users since 2000.)
- **Detect Cracks easily**: The PiCUS CrackDect system is capable of detecting star-shaped cracks and prevents you from reaching wrong conclusions about a tree's status.
- The PiCUS is **easy to operate:** If you have a sound knowledge of trees and some technical capabilities, you can easily learn to use the PiCUS unit.
- The PiCUS can use **more measuring points than sonic – sensors**. Full resolution tomograms of nearly any tree can be recorded with as few as 6 to 12 sonic sensors by using the **electronic hammer**. A measuring point is a common roofing nail – **no special nails needed**!
- Works well **independent of noise levels**. PiCUS can eliminate surrounding noise with its technology and can even be operated near roads with heavy traffic and in strong winds.
- The PiCUS works best in **combination with the Treetronic** – electric resistance tomograph. Both technologies do give totally different type of information about the wood, thus the interpretation of the results is more reliable.
- **Sensitive sonic sensors** on the PiCUS unit yield excellent results, even on larger and damaged trees.
- Sonic data is compiled with **relative calculations** to compensate for different wood densities of each species, enabling you to work on species not yet tested. Also the PiCUS calculation algorithms compensate for a wide range of force used in tapping on sensors.
- **Sensors are easy to mount**: PiCUS Sonic sensors are very small and can be easily mounted on nearly every position on the trunk - even in the narrow gaps between buttress roots. This is important for investigations performed near ground level. The sensors are lightweight and the nails do not need to go far into the wood – only through the bark. This is important for trees with thin barks.
- Advanced **software**: The PiCUS Software is easy to operate and offers you many functions for analysing and presenting the data. The PiCUS control software runs on Windows PCs and Pocket PCs.
- The comprehensive **manual** guides users through all steps and problematic situations.
- **Precise geometry recording** of the tree at the measuring level: The PiCUS Software uses a triangulation method, which is the most accurate way to determine the exact positions of the sensors. However, very simple geometry functions, requiring a measuring tape only, can be used on circular trees.
- The mechanic-electronic **PiCUS Calliper** is an efficient and accurate tool for recording the positions of measuring points.
- **Root-tree-allocation:** Using the PiCUS hardware can help you answer questions like "which root belongs to which tree?" This is especially useful at building sites where roots have been uncovered and need to be identified as belonging to one of the nearby trees.

- **High quality hardware**: The PiCUS hardware consists of highest quality components to ensure a long and trouble-free service life.

3.12. PiCUS Application

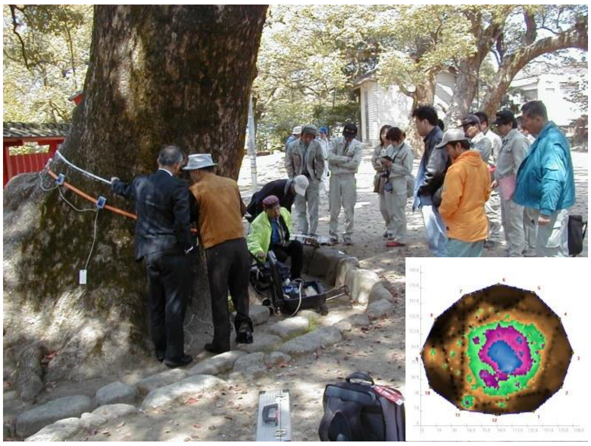
Since launching the system in 1999, the PiCUS has become a success in 30 countries around the world. These photos show its use in different places.

PiCUS on Ivenacker Oaks (Germany)



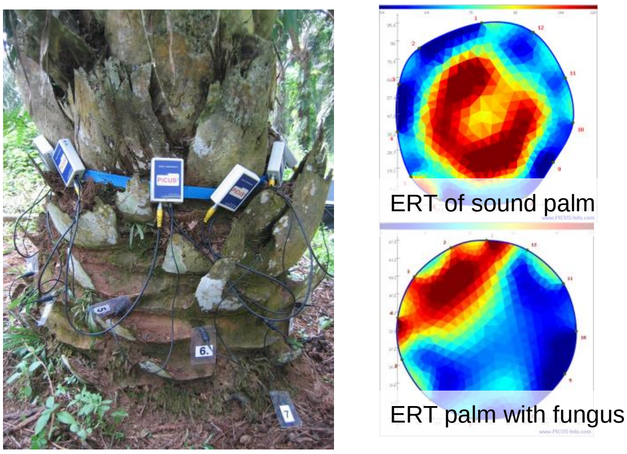
PiCUS test 93.5 meters up on a California redwood (USA)

Cedar tree in the Presidio, CA (USA)



PiCUS in Shrine in Fukuoka (Japan)

PiCUS user meeting 2008, The Netherlands



Oil-palm testing (Malaysia)

4. PiCUS : Treetronic®

4.1. Treetronic® Theory

The PiCUS Treetronic® is the **Electrical Resistance Tomograph**. The instrument uses electric current/voltage to examine the tree. The resulting measurements are displayed in a two-dimensional map showing the apparent electrical resistance of the wood, called an *Electrical Resistance Tomogram* (ERT).
To prepare the scan the measuring lines are connected to the nails, which are already known from the sonic scan. The actual measurement takes 10 to 30 seconds (with Treetronic 3).

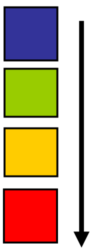
The electric resistance of the wood is influenced most of all by the

- water content
- chemical elements which change according to the status of wood and
- cell structure: reaction wood or roots do have different resistances compared to “normal wood”

When used in **combination with a Sonic Tomograph**, an ERT offers you more information about the tree. When analysing both SoT and ERT it is often possible to

- distinguish between different types of damage (for instance crack/cavity vs. decay) in many cases
- detect early stages of decay
- get information about areas above or below the measuring level. This is interesting for analysing root decay problems.

The ERT are coded with rainbow colours:



Blues indicate areas of low resistance (high water content, etc.)

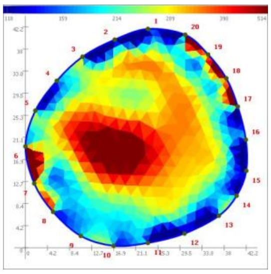
Greens and yellows show increasing resistance

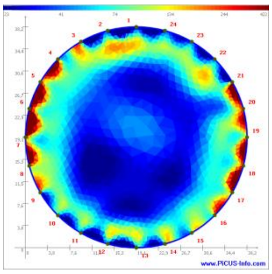
Red colours indicate areas of high resistance (lower water content, etc.)

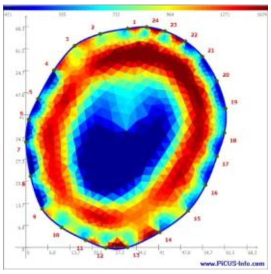
4.2. How to combine sonic and resistance tomograms

The main aspect of interpreting ERTs is the distribution of high and low conductive areas. You are looking to see where high resistance is and where low resistance is. This information needs to be compared with the normal resistance distribution in sound trees of this particular species.
The actual value of the resistance given in a tomogram is less important and less accurate, due to the ambiguity of the measuring method. The interpretation of the ERT is most accurate when done in combination with the SoT.

In order to analyse an ERT, the operator will need extensive knowledge about the specific type of tree species. **Each species has a typical resistance** (water/moisture) d**istribution**. So far we have identified **three types of typical resistivity distributions** in trees.


ERT type 1


ERT Type 2

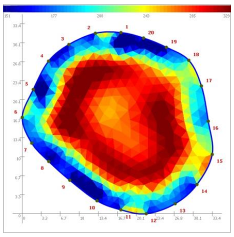

ERT Type 3

The table below shows general rules of interpretation for *ERT Type 1* trees. Most European tree species belong to type 1: *betula, tilia, fagus, pinacea, populus* and many others.

ERT Type 1 trees usually have lower resistance (blue in ERT) in the sapwood on the edge and high resistance in the heartwood (red in ERT) in the centre:

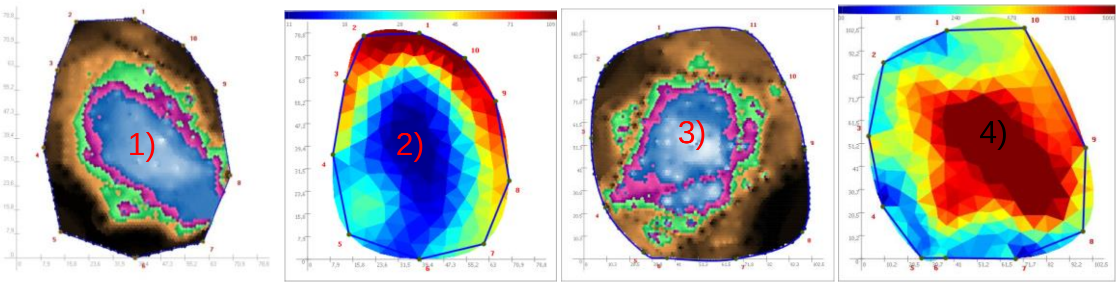
The table helps to evaluate the **centre** of the tree

SoT **Sonic velocity [m/s]**	**ERT** **Resistivity [Ω*m]**	**Conclusion**
High (brown)	High (red)	Healthy
High (brown)	Low (blue)	Still safe, but early decay
Low (blue/violet)	High (red)	Cavity / dead decay
Low (blue/violet)	Low (blue)	Active decay



4.3. Examples

4.3.1. Chestnut Trees: decay or cavity?



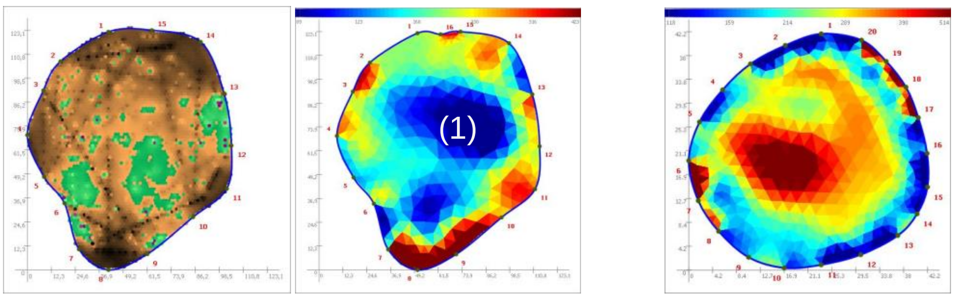
SoT of tree 1 ERT of tree 1 SoT of tree 2 ERT of tree 2

The SoT of “Tree 1” shows heavy damage (1), the type of which is initially unknown. The blue colours in the ER tomogram (2) indicate areas of low resistance; most likely due to high water content. The combination of low sonic velocities (in the SoT) and low resistance (in the ERT) is typical for active fungus infections. In the case of this chestnut tree, the diagnosis would be “pathogen wet wood”.

“Tree 2” appears to be very dry inside, as shown by the red colours in the ERT (4). This clearly indicates that this tree is not infected by wet wood disease. The ERT indicates an area of very high resistance (4); the sonic tomogram indicates low density (3). This might be a cavity.

4.3.2. Decay in roots – a beech tree with Kretschmaria deusta

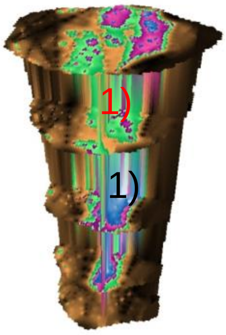
The SoT of this beech shows a typical pattern for a fungus infection: the centre of the tree does NOT have the darkest colours (i.e. highest sonic velocity), but only lighter browns. The ERT shows low resistance in the centre (1), which is a clear indication for fungus activity. The ERT on the right shows the typical resistivity distribution in a healthy beech tree.

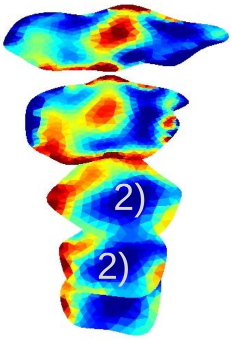


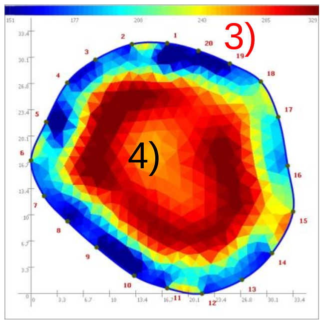
SoT ERT ERT of sound beech tree

4.3.3. Maple Tree: crack or decay?

This maple tree had an old wound which might be causing decay. To find out, two inspections were made. The SoT shows a crack-like area of low sonic velocity (1). The ERT shows very low resistivity in the centre of the trunk (2). A sound maple tree is supposed to have a high conductive blue ring (3) on the edge and a less conductive red centre (4) as shown in the ERT on the right.





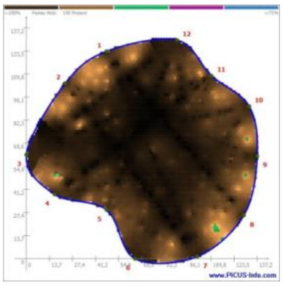
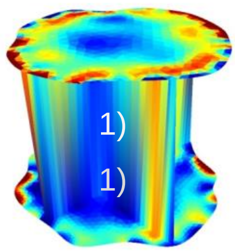
SoT ERT

Photo of the tree

ERT of sound maple. The blue ring shows bark/sapwood

4.3.4. Decay in roots – a beech tree with with Meripilus giganteus

The root system of this beech was infected with Meripilus Giganteus. A sonic scan taken at 20 cm above ground level did not show any defects. The EIT conducted at 20cm and 120cm indicates high conductivity in the centre of the trunk (1). Healthy beech trees are supposed to have less conductive centre which show as reds in EITs, as seen in the EIT in section above.

SoT – 20cm above ground

ERT

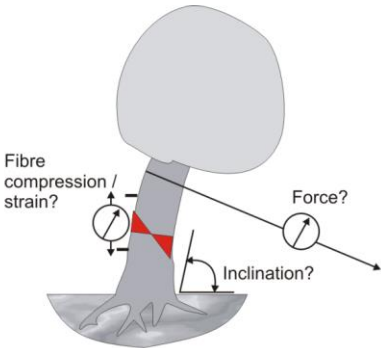
Meripilus Giganteus fruiting bodies

5. TreeQinetic® – Tree Pulling Test

5.1. Static pulling test

The tree pulling test was developed by WESSOLLY and SINN at the University of Stuttgart in the mid 1980's. It is used to assess a tree's stability with regard to stem fracture and uprooting precisely and non-invasively. The tree pulling test is performed to get information about the breaking stability of the trunk and the stability of the roots.

In a pulling test, a load (substituting for the wind) is exerted on a tree using a winch and a steel cable. The reaction of the stressed tree under this defined load is measured with high resolution devices (elastometer and inclinometer), and the data obtained are compared with those of sound trees. The major components to be considered in such calculations are the wind-load (the surface of the load-bearing structure, tree height, etc.) and the material properties of green wood.



Schematics of static tree pulling test

TreeQinetic instruments on the tree

The **TreeQinetic** System is designed to collect data during tree pulling tests. The complete system consists of:

1. One **Forcemeter** that measures the pulling force.
2. At least one **Elastometer** that measures alterations in length of the marginal fibres at a resolution of 0.001 mm.
3. At least one **Inclinometer** that measures the inclination of the tree at a resolution of 0.005°.
4. Evaluation software **ArboStat**

Another option available is to use a **wind-speed** sensor to measure the swaying motion of a tree in winds (see section 6).

The PiCUS TreeQinetic system is capable of recording data from many sensors at the same time. The whole pulling process is recorded synchronously and the data are transmitted wirelessly to a PC and registered.

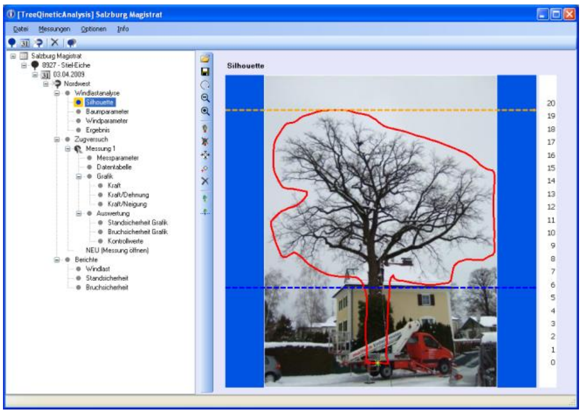
Advantages:

- **Easy, wireless measurement and continuous data transmission**
- **Modern wind load analysis**
- **User can calculate results autonomously**
- **Easy-to-understand graphical results**
- **Direct information about the breaking stability of the stem**
- **Direct information about the stability of the root system**

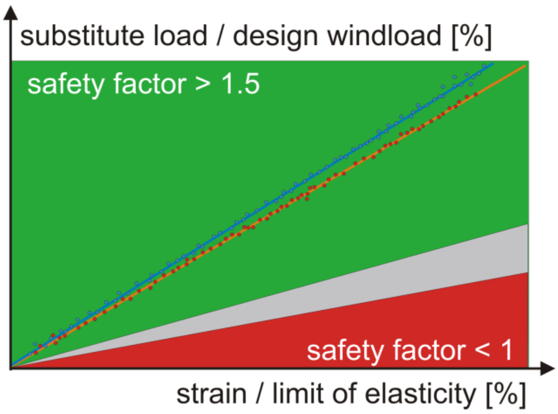
The photo on the left shows four elastometers mounted to a tree to record fibre reaction to a pulling force. The photo on the right shows a typical winch used to create the substitute wind load.

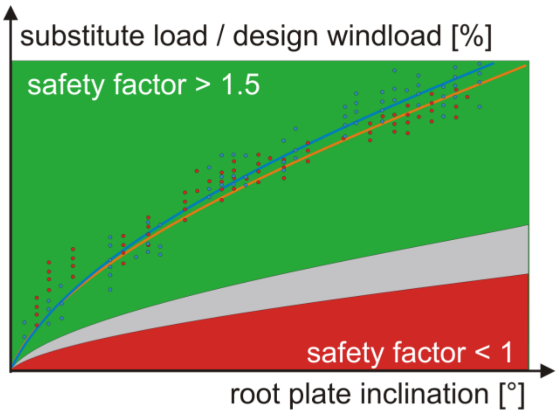
ArboStat – Evaluation software

The ArboStat evaluation software calculates the breaking stability of a trunk and the stability of its roots. To do this it uses a wind load analysis for the tree and the data of the pulling test. For the wind load analysis, the data of the tree's height, stem diameter, crown shape, wind zone, etc. are entered (see right). The resulting (wind) load to which the tree is exposed is calculated.



The **breaking stability** can be calculated by using the wind load analysis and the data of the pulling test. The results are shown in a simple green-red graphic. The relation of green to red is calculated by the wind load analysis. The data points of all elastometers are included in this graphic. If all values are located in the green area, then the breaking and fracture stability of the stem is good. The **uprooting stability** is calculated and presented in a similar way. The data of the inclinometers are drawn into another red-green graphic which is derived from the wind load analysis and the generalized tipping curve.



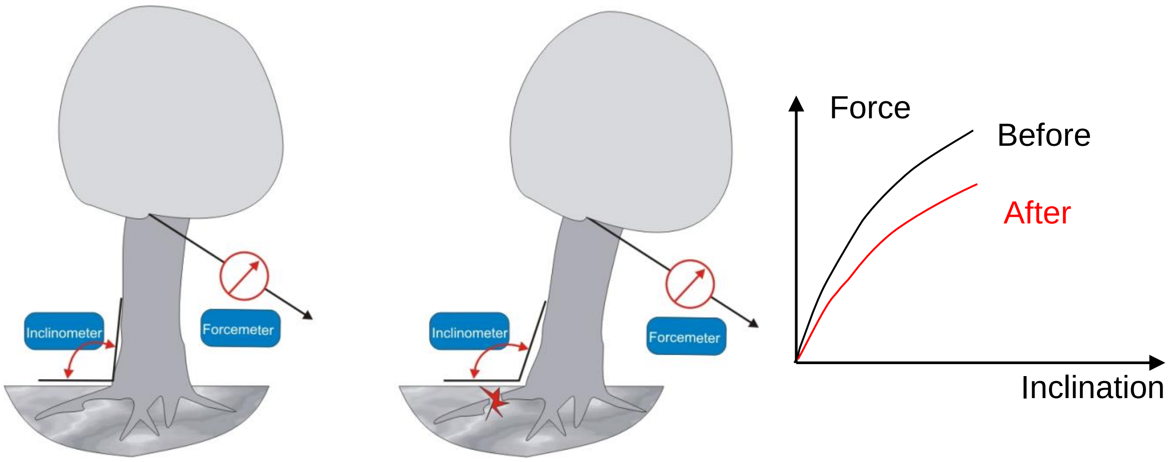


Graphic for breaking stability (left) and uprooting stability (right)

You will need a thorough introduction to the products in order to operate the measuring hardware and use the evaluation software.

5.2. Detection of root damages on construction sites

The TQ System can be used to detect major damages on larger roots happened during constructions.
In order to do so you need to record the force-inclination graph of the trees near the construction site. In case the “after” line is significantly worse than the „before“ line a root damage is the most likely explanation. The sketch shows the procedure.

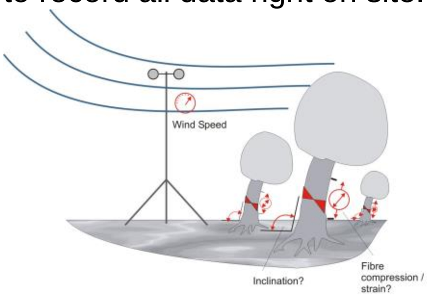


Left: measurement BEFORE the construction took place.
Centre: measurement AFTER the construction. Inclination is higher because a major root has been cut.
Right: the resulting diagrams. Less force was needed during the second test in order to reach the inclination of the test before the construction.

6. Dynamic Sway Motion of Trees

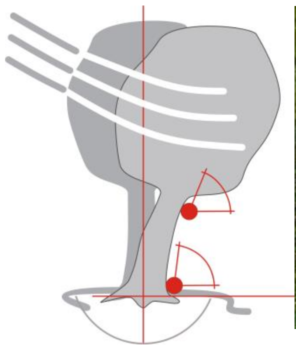
There are two types of measuring instruments in order to measure the natural sway motion of trees in winds: The TreeQinetic (TQ) System and the **Tree Motion Sensor (TMS).**

The **TQ system** can use inclinometers, elastometers and also an anemometer to measure the root plate inclination and fibre compression caused by the natural winds. The PC needs to record all data right on site.



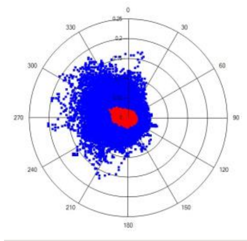
The **TMS Sensors** are tilt sensors (inclinometers) that can record the tilt of the root plate autarkic for more than 10/20 days. No PC is needed. The sampling frequency is 20Hz to record highly dynamic reactions.

One TMS, the so called Base-sensor, is mounted at the base of the tree. The tilt recorded by the base sensor is a measure for the quality of the roots-anchorage of the tree. Well anchored trees do show little movement (tilt) only.



Another TMS, the control-sensor, can be mounted 2-3 meter above ground. The control sensor helps to detect interference and to get an idea of the trunk bending.

The polar-diagram (to the right) shows the differences in inclination of base (red) - and control sensor (blue).



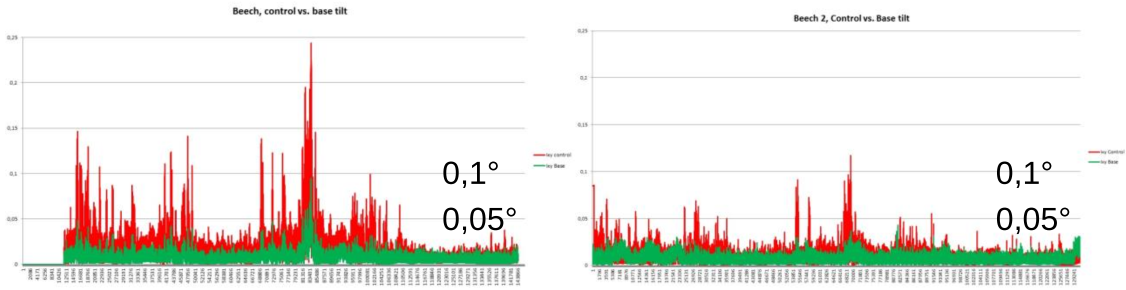
The evaluation of the data can be done via the software on this web site: www.treesensor.com.

Advantages of the TMS system:

- **Easy identification of trees with anchorage problems**
- **Real tree response to real winds is measured**
- **Easy application: set-up time approx. 5 minutes per tree**
- **Data analysis via web-site: a comprehensive report is automatically generated**
- **Easy-to-understand graphical results**

The TMS sensors can be used in many situations. However, a relatively easy way to evaluate the data is to compare the readings with other trees or to compare data recorded at different times. Here are two examples:

- Measuring many similar trees (for instance trees in rows on a parkway) to find out which tree is moving differently. This may indicate root problems. When comparing the sway motion of many similar trees, we reduce the problems involved in knowing the “normal” motion. The example shows data of two beech trees during the same wind gust. The distance between the trees is 100 meter, the maximal wind gusts had velocities of approx. 50-55 km/h.

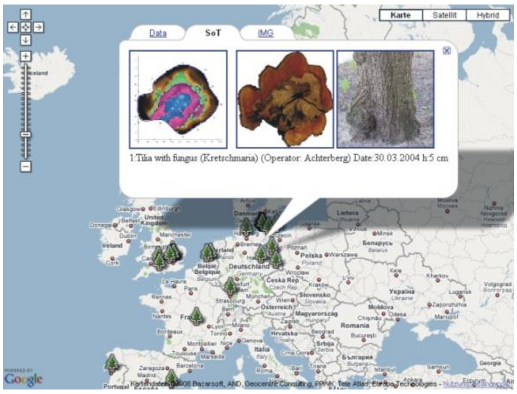


  Beech 1 (on the left) does have significantly higher root plate motion than the control beech 2 (on the right).

- Measuring a tree before and after construction work in the area. If the sway motion is significantly higher after the work, we can assume that major roots have been damaged.

7. “PiCUS World of Tomograms“ – International Tomography Data Base

We are creating an international sonic- and electric impedance tomogram data base at www.picus-info.com to enhance the exchange of information among all PiCUS users.



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