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COMPARISON OF TREES AND NDT METHODS

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ABSTRACT

Tree stability is an important subject because of public safety. There are several methods to study the stability of a tree. All discussed in this article are non-destructive (NDT) ones which are helping to keep alive our trees in recreational parks and forests, as well as in other urban areas, etc.

The aim of this article was to prove that even if there is a fungi attack on a tree, it can still be safe. Sometimes botanists and gardeners decide to cut down trees just because they are not healthy any more. Even if some of these trees are still strong enough to survive even the strongest winds in their area.

This paper describes several NDT methods, like visual evaluation, acoustic and impedance tomography, root measurement and pulling test.

Two trees were selected for demonstration. These pines (both of them are *Picea abies*) stand just about 2 meter far from each other, so the conditions for them were the same for all the time, except one thing. An injury happened to one of them years ago. Today this tree is infected with fungi and also grew its trunk wider at ground height as a visual indication of the internal decay.

All the measurements were done and the results were presented. The visual differences of the infected tree are the wider trunk and the fungi that can be seen some parts of the year. Acoustic tomography was done with 10 channels in 3 layers while the impedance tomography was done with 24 channels in 3 layers. The layers were the same at 0.3, at 1 and at 1.7 m height from the ground. The decay could be seen in both measurements. The safety of the trunk was estimated in both layers.

The roots were detected, and results were mapped. The pulling test was also done. These techniques were also compared. The uprooting plate and the stability of the roots were estimated. The stability was estimated from the pulling test as well. Results show that the healthy tree has higher safety factor for both in trunk and in root. While the attacked tree is also quite safe, in conclusion it should be kept.

KEYWORDS: NDT, safety factor, pulling test, acoustic tomography, impedance tomography, root mapping.

INTRODUCTION

It is easy to ask why save a tree if it can be dangerous. Studies show us that even only one plant around us can change our lives, decreasing stress factors, making us more creative or happier. (Shibata and Suzuki 2004, Taylor et al. 1998).

So the answer is because it's worth it. An old tree which had been alive for decades or may be even for centuries is simply not replaceable. Additionally in many cases it comes to light that these great old trees are in better condition than we would think.

The aim of this paper is to present testing methods to estimate a tree's safety to help botanists' and arborists' work to keep older trees alive while maintaining safety.

An additional aim was to show how these methods can complete each other to get information about several parts of the tree. Finally we also tried to compare these methods to get better information about the conditions of the trees.

MATERIAL AND METHODS

The selected trees

Two spruces (*Picea abies*) were selected. These trees are inside the botanical garden of the University of West Hungary. The trees are located next to each other in an alley. They are 1.7 m far from each other. Both of them are 92 years old.

As being so close to each other the effects happened to these trees were the same during the years. There is only one exception. One of the trees was attacked by violent, root rot fungus, the honey fungus (*Armillaria mellea*). It can be seen on Fig. 1. The exact time of this attack is unknown. (Day 1927, Glaeser 2007).

Fig. 1: The honey fungus on the attacked tree.

These two trees were found to be a perfect example for a comparison of healthy and attacked trees. They are seen on Fig. 2.

The healthy tree is 20.5 m high, the crown area is 23.7 m^2, the crown centre high is at 13.3 m high, and it has no incline.

The attacked tree is 20 m high, the crown area is 30.4 m^2, the crown centre high is at 12.7 m high, and it has a 1° incline.

Fig. 2: The selected trees with their crown areas.

Acoustic tomography

Acoustic tomography is a well-known measuring technique. With it help decays, internal cracks, hollows or holes inside a tree can be found. In practice the trunk and the major branches can be tested by this technique. (Divos et al. 2007).

Acoustic tomography is based on the velocity change of the sound in different materials. The speed of the sound signal is measured. It changes depending the amount of decay in the tree material. (Of course the speed also depends on the species, the anatomical orientation, the temperature, etc.) Fig. 3 is showing the difference between healthy and decayed material. (Divos and Szalai 2002).

The sound is much slower in air than in wood. This is why the sound reaches the detector through the wood material first even it needs to travel a longer path.

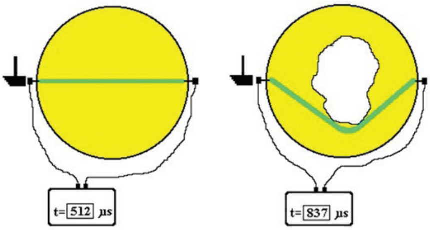

Fig. 3: The detection time depends on the conditions of the wood material.

In the applied equipment the sound transmitter and the receiver is built together. During the measurements 10 of these transmitter-detectors were used. A filtered back projection evaluation was used to create velocity distribution of the cross-section. The results could be seen after the evaluation as a 2D figure.

The measurement was done in 3 different layers in both of the trees. The layers were at 0.3, 1 and 1.7 m high measured from the ground. As the measurements were in multi layers, a 3D image could be prepared.

By analysing the data, safety factors (SF_{trunk}) of the trunk was calculated.

$$SF_{trunk} = \sigma_{cst} / (\sigma_{wind} + \sigma_{ow}) \tag{1}$$

where: σ_{cst} ($N.m^{-2}$) - the compression strength which depends on the tree species. It is 21 MPa for spruce. (Wessolly and Erb 1998, the Stuttgart table of wood strength).
σ_{wind} ($N.m^{-2}$) - the highest compression stress created by the wind in the examined cross section. (120 $km.h^{-1}$ wind speed was used during the calculations according to the old Hungarian standard.)
σ_{ow} ($N.m^{-2}$) - the compression stress coming from the weight of the tree. This stress is calculated from the tree's height, and diameter.

The values of compression stress created by wind and weight are depending on the level of the measurement.

The compression stress from the wind is calculated as detailed in the below. (Note that this calculation was not made as the EUROCODE describes how to estimate the wind load. The estimation which was used during the calculations is more conservative than the EUROCODE as long as the tree's height is under 22 m and the tree is in an urban area.)

$$\sigma_{wind} = M_{wind} * z / I \tag{2}$$

where: M_{wind} (Nm) - the moment,
z (m) - the distance from the neutral axis (this is the axis where there is no stress or strain during the bending),
I (m^4) - the second moment of inertia of the cross section.

During the calculations a computer program calculated the second moment of inertias for the axis going through the center of mass in every 5°. The smallest, worst value was used for the estimations.

$$M_{wind} = F_{wind} * h_{cc} \tag{3}$$

where: F_{wind} (N) - the force generated by the wind
h_{cc} (m) -the height of the crown's center.

$$F_{wind} = (\rho/2)*v^2*A_{crown}*C_{drag} \tag{4}$$

where: ρ ($kg.m^{-3}$) - the density of air, v ($m.s^{-1}$) is the wind speed (33.3 $m.s^{-1}$ was used for the estimation),
A_{crown} (m^2) - the surface of the crown and the trunk in the direction of the wind and
C_{drag} - the drag factor depending on the tree species. The drag factor for spruce is 0.2. (Wessolly 1989).

The tension coming from the weight of the tree is $\sigma_{ow} = (m * g) / A_{section}$ where m (kg) is the net weight of the tree (trunk and branches) above the proper level (g is the gravitational constant). The tree weight was estimated by a beam with constant diameter. (Generally this estimation gives back more weight than the tree's real weight.) $A_{section}$ (m^2) is the cross- section in the proper level.

The calculations detailed above can also apply if the trunk has an inclination. The safety factor SF_{trunk} calculated in this way gives information whether we should count the trunk breaking at a given level during wind load or not.

Impedance tomography

The impedance tomography measurement method originates from geophysics. It is applied for wood materials since 1998.

During measuring wood, and mainly on living trees, it, like acoustic tomography can find inner differences, changes in the examined tree or log. Impedance tomography uses electricity instead of sound waves (which are used by acoustic tomography). Comparing to acoustic tomography the impedance tomography works based on other phenomenon and finds other kind of changes. Because of this we can gain additional information from this. So more detailed picture is available about the inner material of the tree or wood sample. (Nicolotti et al. 2003).

The impedance tomography measurement is based on electrodes. These are on the surface, on the periphery of the examined material. The electricity is leaded into the material on two of the electrodes. The emerging electric field depends on the distribution of the resistance. It can be seen on Fig. 4. Two electrodes measure, based on the highest voltage difference. The leader electrodes are changed during the measurement to get a 2D picture of the inner part.

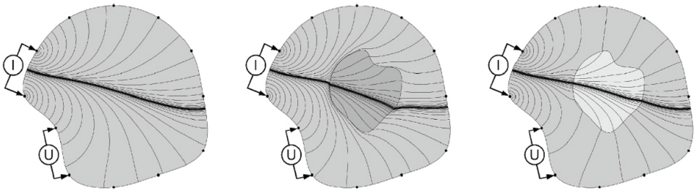

Fig. 4: Model of the electric field in homogenous material (left), material with a good conductivity part inside (middle) and material with a very good conductivity part inside. (source: Picus Treetronic).

On the example on Fig. 4 on left side there is a healthy tree with homogenous conductivity distribution. If there is a higher resistant part in the middle, equipotential lines will shift. Therefore higher voltage can be measured on the periphery.

If there is a part with high electrical conductivity inside the material it attracts the voltage lines. Therefore lower resistance can be measure on the surface.

After a measuring series a resistance map can be made. The examined cross-section is divided into small triangles. A proper color scale is used in the images to highlight the different specific resistance values. The color scale is exponential according to the very high changes that can occur in resistance.

The number of electrodes limits the resolution. As more electrodes are used the resolution become higher and more precise result is made. The used unit is Ohm * m.

In brief the impedance tomography shows the specific resistance disturbance in a cross-section of the examined tree with a non-destructive method. Using the result the health, the stability and other factors of the tree can be estimated.

Pulling test

The inclino-type pulling test is a good and the only reliable tool to get information about the roots' condition. The wind load is simulated by a cable. During the test the pulling force and the inclination of the trunk at ground level are measured. It is seen on Fig. 5.

For this measurement the cable should be as close to the crown centre as it can be. While the inclinometer should be as close to the ground as it is possible. The anchorage should bear the force. It can be another tree or something else as well. (Neild and Wood 1999, Peltola et al. 2000).

During the measurement the inclination of the measured tree was under 0.2°. The force and the inclination were measured continuously with 1 data/sec. The program uses filters to keep the proper data. A function can be fitted to the curve of the data. So the tipping force and moment can be estimated.

From these data – and from the wind speed estimation which was detailed in the Acoustic Tomography part – the roots' safety factor SF_{root} can be calculated.

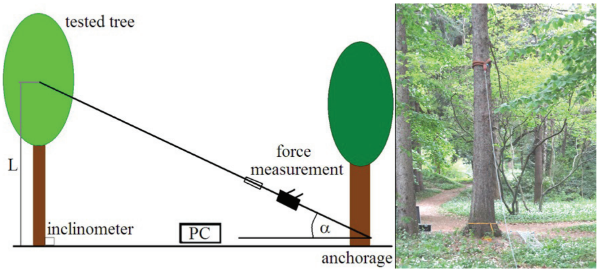

Fig. 5: Pulling test model and reality.

$$SF_{root} = M_{tipp} / M_{wind} \tag{5}$$

where: M_{wind} (Nm) - the moment of the wind,
M_{tipp} (Nm) - the estimated tipping moment.
$M_{tipp} = F_{tipp} * (L / \cos \alpha)$ where F_{tipp} is the tipping force,
L - the cable's high on the examined tree and α is the cable's degree as seen on Fig. 5.

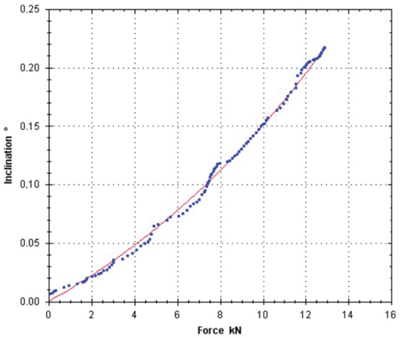

Fig. 6: Inclination and force, measured data and fitted curve.

F_{tipp} was estimated by the function which minimizes the following difference: $(\varphi - \varphi_{calc})^2$. Where φ is the measured inclination in degrees and φ_{calc} is from the fitted curve.

$$\varphi_{calc} = 0.33 \tan (1.34 (F / F_{tipp})) + 0.5 (F / F_{tipp})2 - 0.1 (F / F_{tipp}) \tag{6}$$

where: F - the measured force.

The constants were estimated during experiments. Measured data and fitted curve of an measurement are seen on Fig. 6.

Root mapping

The velocity of the sound is different in soil (cc. 300 $m.s^{-1}$) and in the roots (cc. 3000 $m.s^{-1}$). This phenomenon can be used to find the bigger roots of a tree.

The measuring equipment consists of a transmitter, a receiver and a time measuring part.

The transmitter is located on the trunk, close to the ground. The receiver is moved around the tree in a constant distance. The distance from the trunk was 0.5, 1 and 1.5 m. The receiver was moved by 15 cm between every measurement. It can be seen on Fig. 7 on the left side.

The transmitter was hit by a hammer (just like during the acoustic tomography). The signal's travelling time was measured. When the receiver was closer to a root the time decreased spectacularly. We signed the way of the root. See on Fig. 7.

With the applied 0.4 m long spike this measurement can find roots no deeper than 0.5 m. The roots of spruces are usually in this area.

Fig. 7: The root's paths are signed.

From the collected data a root map was made. The uprooting plate was estimated. And a second safety factor of the roots was calculated, SF_{map}.

The calculation of SF_{map} is in experimental stage. It contains several assumptions and simplifications.

$$SF_{map} = M_{soil} / M_{wind} \tag{7}$$

where: M_{soil} - the uprooting moment calculated from the soil's shear strength,
M_{wind} - the moment from the wind load calculated as it is detailed in the Acoustic Tomography part.

$$M_{soil} = c_{soil} * A_{plate} * h_{roots} \tag{8}$$

where: c_{soil} - the shear strength of the soil (it was assumed to be 50 $kN.m^{-2}$),
A_{plate} - the area of the root plate and
hroots is the deepness of the root plate (it was assumed to be 0.5 m).

RESULTS

Visual evaluation

During the visual evaluation we declared the fungi attacked tree to have a wider trunk. The trunk shape of the attacked tree is more widening than the healthy tree's trunk at ground level. The values of wideness can be seen in Tab. 1.

Tab. 1: The diameter of the trees (in meters) in different levels and in different directions. The ratios help to see the wideness' change. (EW: east-west direction; NS: north-south direction).

	Ground EW	**Ground NS**	**0.3 m EW**	**0.3 m NS**	**1 m EW**	**1 m NS**	**Ground/1m EW**	**Ground/1m NS**
Healthy	0.67	0.70	0.53	0.52	0.44	0.48	1.52	1.46
Attacked	0.89	0.92	0.71	0.65	0.60	0.53	1.48	1.74

The sporocarp, the fruiting body of honey fungus (*Armillaria mellea*) is visible on the north side of the attacked trunk, mainly in autumn (Fig. 1.).

After the other measurements (acoustic and impedance tomography) more resin was produced by the attacked tree than the healthy one.

Acoustic tomography

The acoustic tomography gave us the pictures of the layers seen on Fig. 8.

Healthy materials and decayed ones are seen clearly. The healthy tree is in good conditions. The most of its material is not rotted or decayed. The attacked tree has a hollow inside which becomes smaller from ground to the height 1.7 m.

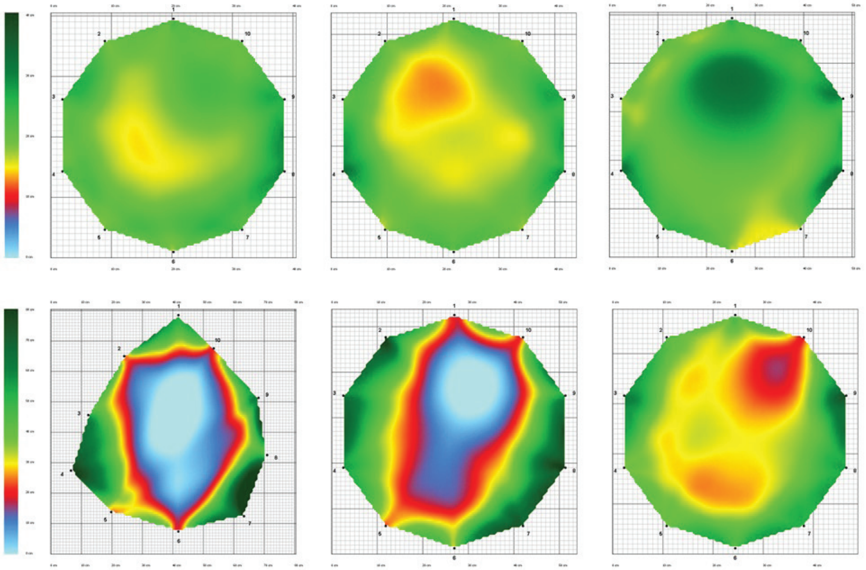

Fig. 8: Layer from the acoustic tomography. Healthy tree's layers are in the upper row, attacked tree's layers are in the lower row. Layers are from 0.3 m, 1 m and 1.7 m from left to right. Green color indicates good material while yellow and red means rotted wood. Blue refers to hollows.

The 3D pictures were also made from these layers with simple extrapolation. These are on Fig. 9.

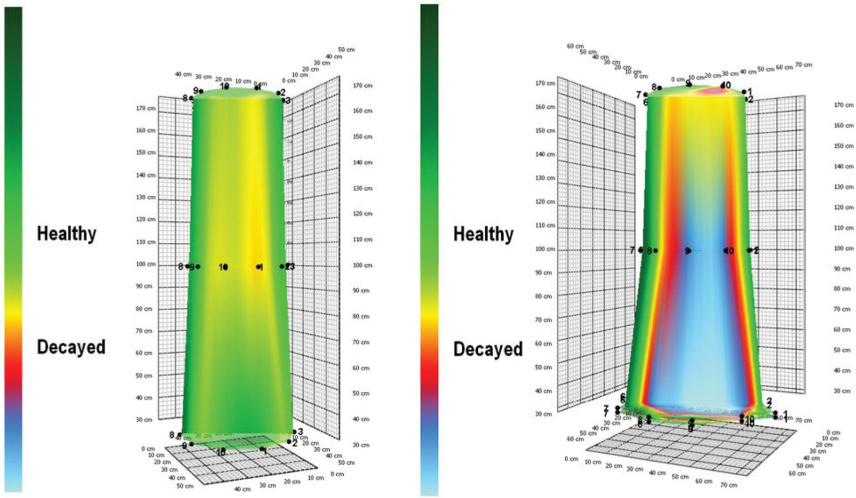

Fig. 9: 3D images from the trees.

Safety factors were calculated for each layer. These data are summarized in Tab. 2. Both of the trees are having low risk in every layer.

Tab. 2: The results of the data collected by acoustic tomography.

Healthy				
Layer name	**Height**	**Decayed area**	**Safety factor**	**Risk rating**
1. layer	1.7 m	0 %	5.08	Low risk
2. layer	1 m	5 %	5.67	Low risk
3. layer	0.3 m	0 %	8.29	Low risk
Attacked				
Layer name	**Height**	**Decayed area**	**Safety factor**	**Risk rating**
1. layer	1.7 m	23 %	4.88	Low risk
2. layer	1 m	52 %	3.92	Low risk
3. layer	0.3 m	63 %	5.86	Low risk

Impedance tomography

The specific resistances of the examined trees are between 45 and 1857 Ohm * m. The color scale was set to the same in every picture to help the "naked eye" comparison. Therefore the color means the same specific resistance on every picture.

During measuring with the impedance tomography it is advised not to use the equipment too close to the ground. Too close means less than the diameter of the tree. For example if there is a tree with a diameter 40 cm then we should start measuring above 40 cm from the ground.

If the measurement is closer to the ground it becomes too uncertain.

Note that during our work some measurements were done on a too low level. These unadvised measurements were used to try out an idea. That the uncertainty of the picture in the too low levels can come from the roots. Therefore searching for roots was tried out with these measurements. Sadly this presumption was incorrect. It was not working (at least in this level). It can be seen on Fig. 12.

There are three main cases of the impedance pictures of a living tree.

1. “Normal” distribution. Specific resistance is higher in inner part, lower in periphery.

2. “Illness” or “higher water content” distribution. Specific resistance is lower in inner part, higher in periphery.

3. “High ion concentration” distribution. Specific resistance is lower in middle part, higher in an annular part and lower again in periphery. (Brazze et al. 2011).

After comparing the trees the difference between the extremes of the impedance is clear, as it can be seen in table 3. It can be observed that the difference between the lower layers is considerably bigger than the difference between the samples in the height of 1.7 m.

Tab. 3: The extreme values of specific resistance in the trees.

Layer height (m)	Extreme	Healthy (Ohm *m)	Attacked (Ohm *m)	Healthy/Attacked
0.3	min	165	45	3.67
	max	1488	830	1.80
1	min	318	70	4.54
	max	685	1182	0.58
1.7	min	149	135	1.10
	max	1857	1229	1.51

By analyzing the picture made from the healthy tree at 0.3 m no decays, changes can be seen. The lower specific resistance part in the middle, which can be seen on the image from the lowest level turns into the higher specific resistance part till 1 m. This is like in normal cases. The blue color in the middle of the lowest level can refer to the root, and the higher water concentrations in the roots. This blue part is between 500-1000 Ohm * m. The periphery is around 400 Ohm * m.

At the 1 m level (on the healthy tree) normal distribution can be seen. In the inner part 500-700 Ohm * m is the average. While in periphery the specific resistance is around 400 Ohm * m like in the previous case.

At the layer from 1.7 m height the inner part’s specific resistance is 500-1800 Ohm * m. While the periphery is the same again, with around 400 Ohm * m. The images of the layers are seen on Fig. 10.

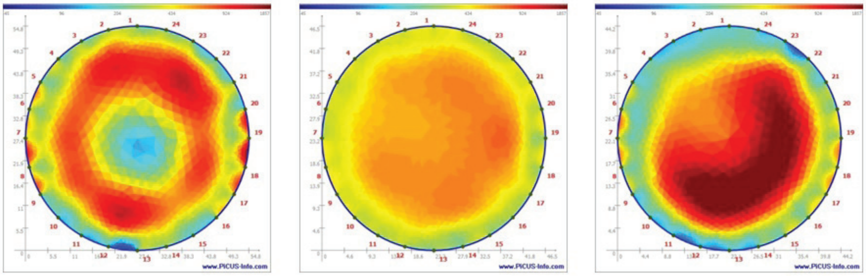

Fig. 10: The healthy tree’s layer’s images made by impedance tomography. Lowest layer is in the left side, middle is in the middle, highest is on the right side. The color scale meaning is detailed in the text.

By analyzing the images from the attacked tree other conclusions can be made. The image changes into the normal distribution only at the highest level, 1.7 m. But this change is not complete there are still some parts showing some kind of change or decay.

At 0.3 m height the blue parts can refer to the roots and higher water concentration like in the healthy tree. But it can also appear because of the fungi attack which occupies nearly the whole cross-section. The bluer parts can also refer to the widest parts of the trunk. It can be followed on the other pictures too.

The inner parts' specific resistance is around 300 Ohm * m. This is much lower than the values measured on the healthy tree. On the periphery the specific resistance is around 150 Ohm * m which is lower than the healthy one's values. (This can be followed on the other pictures too.)

In the middle level at 1m the specific resistance of the inner part is closer to the healthy one's. It is 400-1000 Ohm * m. The periphery is around 200 Ohm * m.

At 1.7 m height the specific resistance of the inner part is 500-1200 Ohm * m, which is close to the specific resistance in the healthy tree. The periphery's specific resistance is around 300 Ohm * m. Images can be seen on Fig. 11.

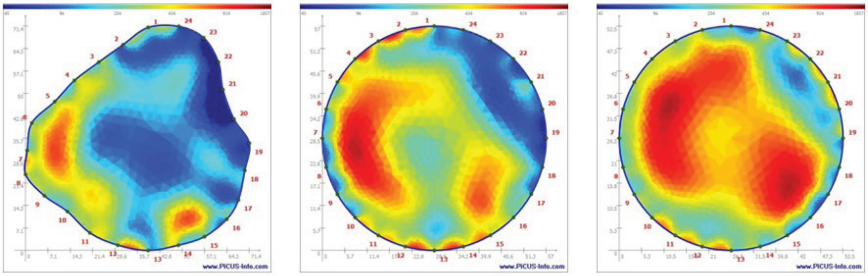

Fig. 11: The attacked tree's layer's images made by impedance tomography. Lowest layer is in the left side, middle is in the middle, highest is on the right side. The color scale meaning is detailed in the text.

There are differences between the healthy and attacked tree in the images made by impedance tomography. Locating the decay is very hard, because the same changes in resistance can refer to several different changes inside the trunk. But it still gives us very important information about the tree. The resistance referring to normal distribution, to normal or average trunk can ensure us that the attacked tree is alive. It is living, it is growing, and it is fighting against the fungus.

Pulling test

The data collected during the pulling test help us to calculate the safety factors of the roots. Three tests were done within an hour. The calculated data are summarized in Tab. 4.

The roots are in good conditions with the expected 120 km.h^{-1} wind speed.

Tab 4: The safety factors of the tree's roots from the three measurements.

	SF_{root} 1	**SF_{root} 2**	**SF_{root} 3**	**Average**	**Standard deviation**
Healthy tree	5.12	4.80	5.29	5.07	0.25
Attacked tree	3.10	2.94	3.02	3.02	0.08

Root mapping

The result of the root search is the root map which is on the Fig. 12. The trees do not grow roots towards each other. The attacked tree's main roots are in the directions where the trunk is wider.

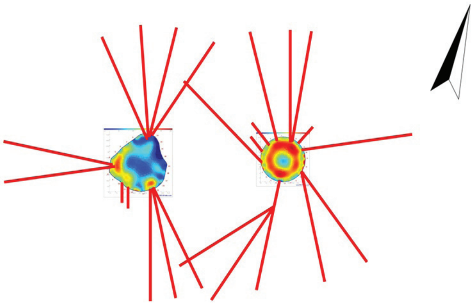

Fig. 12: Root map of the trees. The impedance tomography image from 0.3 m is fitted to the trunks. (The idea of finding the main roots with impedance tomography could not work for this layer.)

From the root map SF_{map} was calculated for both trees. SF_{map} is 1.94 for the healthy spruce and 1.27 for the attacked one. These results are much lower than the results from pulling tests. But this calculation is in experimental state, so these results are less dependable than the other data.

DISCUSSION

The aim of our work was to help gardeners, botanists and other people who are concerned about tree safety.

Several methods were tested on two trees. The tested trees were spruces (*Picea abies*) in the same botanical garden, near each other. One of the trees was healthy while the other was attacked by honey fungus (*Armillaria mellea*) which is an aggressive fungus. (Day 1927, Glaeser 2007).

The first method was visual evaluation which does not need many equipments but it can only give a superficial conclusion about the tree's conditions. During the evaluation the sporocarps, the fruiting bodies of the fungus was seen. (Wessolly et Erb 1998, Wessolly 1989). Acoustic tomography is a well-known method for finding decays and holes inside trunks or major branches. (Divos et al. 2007, Divos and Szalai 2002).

Hollow could be found on the fungi attacked tree while there was only a little decay in the healthy one. The safety factor of the trunk was estimated and the results shown that even the attacked tree could survive even 120 km.h^{-1} wind gusts, it is still in an acceptable condition.

On the other hand impedance tomography tests can give information about the inside of the measured object too. Just like acoustic tomography, it can make detailed pictures in as many layers as we wish. There are differences between healthy and decayed material on the impedance tomography pictures. But the differences seen on the images can refer to several things (decay or water, etc.). It makes locating decays hard. Acoustic tomography gives clearer image about the decay, so it seems to be better for finding holes, rots or decays. (Brazee et al. 2011 Nicolotti et al. 2003).

The condition of the roots is also an important question of the safety evaluations. These were estimated by root maps and by pulling tests.

Pulling test made by using inclinometers gives information about the roots' stability in actual soil condition. By simulating the wind load with a cable this technique can give us information about the root resistance against winds. (Neild and Wood 1999, Peltola et al. 2000). Safety factors were also calculated from these tests.

Making a root map is a new method based on the velocity differences of sound in soil and in tree material, like root.

The root map shows the locations of the main roots. From this the “tipping plate” was estimated. But the root map is static; it can not follow changes in the soil or smaller roots’ growing. Safety factors were also estimated. These data are lower than the ones calculated from pulling test.

The root mapping is an experimental method. That is why the comparison between it and the pulling test is interesting. Root mapping can falsely show a tree as unsafe, when the already proven pulling test shows it is safe. But there is a clear correlation between the results of the different methods. The ratio of the safety factors from root mapping (1.53) and ratio of the safety factors from pulling test (1.68) are close. We believe that these close ratios may mean that the size of the root system is a strong factor in the tree stability. This topic may be worth further investigation.

CONCLUSIONS

Both trees are in good conditions. The safety factors from acoustic tomography are much higher than 1.5. The safety factors from pulling test are also much higher than 1.5. These trees – both healthy and attacked – should be kept.

The differences between healthy and attacked tree is summarized in Tab. 5. The healthy tree is in about one and half times “better condition” than the attacked one as it can be seen from Tab. 5.

Tab. 5: Safety factors and their ratios.

	SF_{trunk} 1.7 m	SF_{trunk} 1 m	SF_{trunk} 0.3 m	SF_{root}	SF_{map}
Healthy	5.08	5.67	8.29	5.07	1.94
Attacked	4.88	3.92	5.86	3.02	1.27
Healthy/Attacked	1.04	1.45	1.41	1.68	1.53

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REFERENCES

1. Brazee, N.J., Marra, R.E., Göcke, L., van Wassenaer, P., 2011: Non-destructive assessment of internal decay in three hardwood species of northeastern North America using sonic and electrical impedance tomography. Forestry 84(1): 33-39.
2. Day, W.R., 1927: The parasitism of *Armillaria mellea* in relation to conifers. Quarterly Journal of Forestry 21(1): 9-21.
3. Divos, F., Divos, P., Divos, G., 2007: Acoustic techniques: From seedling to wood structures. In: Proceedings of the 15th International Symposium on Nondestructive Testing of Wood (ed. R. J. Ross et al.). Forest Products Society, Madison, Wisconsin. Pp 3-12.

4. Divos, F., Szalai, L., 2002: Tree evaluation by acoustic tomography. In: Proceedings of the 13th International Symposium on Nondestructive Testing of Wood (ed. F. C. Beall). Forest Products Society, Madison, Wisconsin. Pp 251-256.
5. Glaeser, J.A.M., 2007: Wood decay and discoloration. In: Proceedings of the 15th International Symposium on Nondestructive Testing of Wood (ed. R. J. Ross et al.). Forest Products Society, Madison, Wisconsin. Pp 59-63.
6. Neild, S.A., Wood, C.J., 1999: Estimation stem and root-anchorage flexibility in trees. Tree Physiology 19(3): 141-151.
7. Nicolotti, G., Socco, L.V., Martinis, R., Godio, A., Sambuelli, L., 2003: Application and comparison of three tomographic techniques for detection of decay in trees. Journal of Arboriculture 29(2): 66-78.
8. Peltola, H., Kellomaki, S., Hassinen, A., Granander, M., 2000: Mechanical stability of Scots pine, Norway spruce and birch: An analysis of tree-pulling experiments in Finland. Forest Ecology and Management 135(1-3): 143-153.
9. Picus Tresstroni 2010: User Manual, ARGUS ELECTRONIC GMBH.
10. Shibata, S., Suzuki, N., 2004: Effects of an indoor plant on creative task performance and mood. Scandinavian Journal of Psychology 45(5): 373-381.
11. Taylor, A.F., Wiley, A., Kuo, F.E., Sullivan, W.C., 1998: Growing up in the inner city: Green spaces as places to grow. Environment and Behavior 30: 154-168.
12. Wessolly, L., 1989: A contribution to the proper assessment of the strength and stability of trees – Summary. Arboricultural Journal 13(1): 45-65.
13. Wessolly, L., Erb, M., 1998: Handbuch der Baumstatik und Baumkontrolle. Patzer Verlag, Berlin, Germany, Vol. 270.

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