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# ANALYSING THE SOUND SPEED THROUGH THE WOOD OF HORSE CHESTNUT TREES (*AESCULUS HIPPOCASTANUM* LIN.)

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**Abstract:** *The aim of this study was to analyze the way in which the sound propagates through the horse chestnut wood of standing trees. In this regard, 15 trees of horse chestnut (Aesculus hippocastanum Lin.) were chosen from a park from Braşov, Romania. Sensors of an acoustic scanner were placed on the trunk of trees, at levels of 50, 100 and 150 cm above the ground to see the differences in terms of sound speed within healthy tress and trees showing obvious defects. It was found that the minimum values of sound speed were between 147-893 m/s while the maximum ones ranged between 1275-2550 m/s. However, it was typical for the speeds to range between 1001-1500 m/s, showing a potential good health state and stability of the trees. Nevertheless, it is very important that, in the assessment of the wood quality of standing trees and when assessing their stability, to take into account no only the analyses undertaken by acoustic scanners, which offer clues only on the quality of wood at the analyzed level, but also other tests, including the visual inspection.*

**Key words:** *quality of wood, speed of sound, acoustic tomography.*

## 1. Introduction

Wood quality of standing trees has always been a topic of special interest for forestry research. Assessing and maintaining the stability of trees is particularly important, not only for the trees located in forests, but also for those trees located in urban green spaces and near the communication and transportation infrastructure corridors, because they represent a valuable public asset, having multiple functions. To exercise their functions for a long period of time, such trees are conditioned by their health state which can be maintained by a proper care work.

Wood quality can be assessed using either destructive or non-destructive methods [3]. One of the non-destructive methods is the acoustic tomography. However, there is not a general agreement whether the acoustic tomography is a purely non-destructive method since some authors see this method as being non-destructive [15], while others see it as

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being almost non-destructive [6], because the nails that support the sound sensors must penetrate the wood.

According to the existing studies [4], [5], [9] and [10], ultrasound tomography allows researchers to reconstruct the distribution of sound wave speed as propagated through an sampled section, based on the idea that when a sensor is hit by a hammer, the timers from the other sensors are automatically switched on [2], [7] and [11] while in the moment when the sound reaches the receiving sensor, the vibration of the stress wave stops the sensor timer, recording the propagation time of the sound wave. Therefore, the sensors used to detect internal wood defects successively fulfil the role of transmitters and receivers and should be placed along the stem's perimeter, at the level of the analyzed section [16] in a number large enough to capture, as accurately as possible, the complexity of the analyzed section [11].

However, the existing studies [4] and [11] also state that the sound tomography provides only data related to the analyzed section and not for the entire tree. In addition, it is recommended to couple the sound tomography with other evaluation methods [5], [13] and [14], of which visual evaluations play a particularly important role. Some researches emphasized that the rot located inside the trunk can be underestimated by acoustic tomography, while the radial cracks could be overestimated [15].

The goal of this study was to evaluate the sound propagation speed through horse chestnut wood to compare the speeds, and to relate them with internal defects.

## 2. Research Methodology

A field study was carried out in the Gheorghe Dima Park, Braşov (Fig. 1), Romania, an area located in the historical part of the city that is characterized by an urban climate.

The equipment used in the field measurements consisted of: a TruPulse TM 200 equipment that was used to measure the tree heights, a compass that was used to point the cardinal directions, an acoustic scanner - Arbotom Rinntech - that was used to determine the propagation speeds of sound through wood, and a tape that was used for setting up the position of the sensors on the analyzed circumferences.

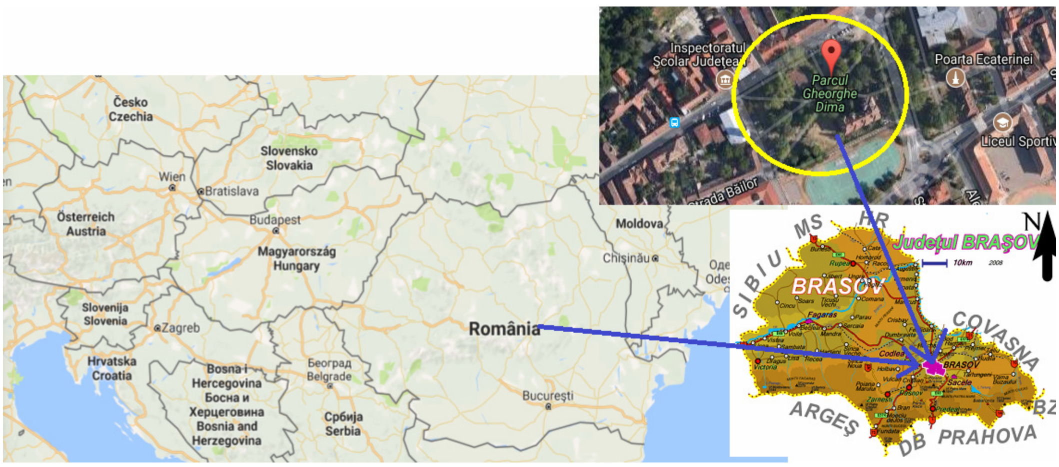


Fig. 1. *Location of field measurements. Sources:* [17], [18] and [19]

The study step was that of undertaking measurements using the Arbotom acoustic scanner, for which were established three sampling levels (50, 100 and 150 cm above the ground), a method that is accepted and adopted also by other researchers [15].

Field evaluation of the wood quality was carried out on a number of 15 horse chestnut trees - *Aesculus hippocastanum* (Lin.) selected from a number of 22 trees sampled in the study location. For each tree were measured the biometric characteristics (height and breast-height diameter) and were identified the external defects on each cardinal direction. Such evaluations allowed the correlation of tomograms with the location of the identified external defects.

During the field study, each transmitter was stimulated by 10 impulses given by a hammer, aiming to reduce the transmission errors (delta smaller than 10% - [12] and [14]), obeying this way the manufacturer's recommendations which specify that in the environments characterized by increased noise levels the number of impulses should be higher.

After determining the levels at which the tomograms were planned to be taken, the north direction was set because the sensor no. 1 should be placed on this direction (Fig. 2), and thus the interpretation of the results would be easier. This step was followed by the fastening of the sensors' support nails, in a way that allowed to follow the circumference of the analyzed section. They were placed as far as possible on each groove of the circumference of the trunk. On the first nail was placed a tape which was deployed on the top of the other nails, and locked-back on the sensor 1, enabling this way the determination of exact position for each sensor on the circumference. On each of the nails were mounted, clockwise, the sensors that were connected each other using connection cables. Then, the sensor no. 1 was connected to the scanner and the latter to the laptop. All of these initial steps have been completed by checks.

Each of the sensors, starting with the sensor no. 1 (Fig. 2 – a.), was used as transmitter (Fig. 2 – b.), i.e. the impulses induced by a hammer on sensor 1 were transmitted to all other sensors acting as receptors. The same procedure was used for each sensor in the sequence.

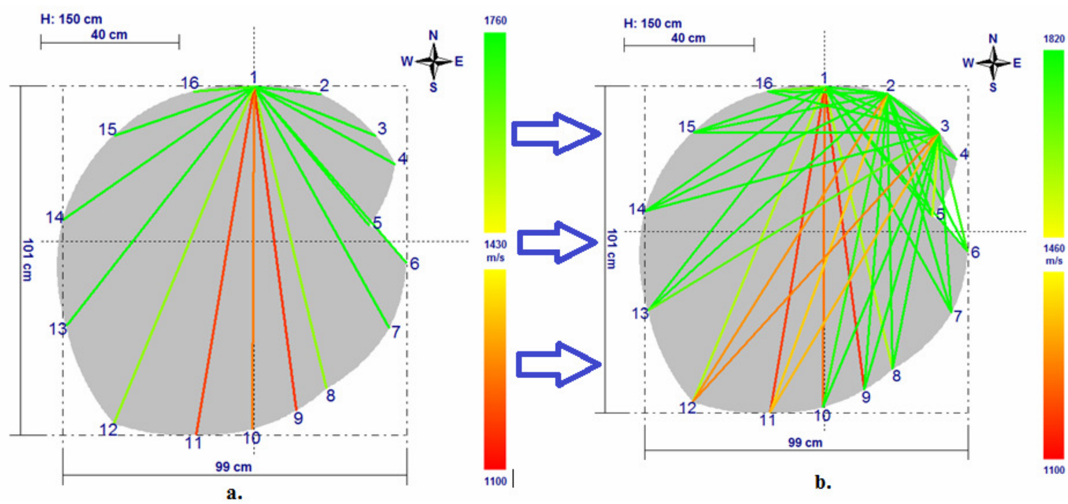


Fig. 2. *Sound transmission: a. from the transmitter (sensor 1) to the receivers (sensors 2-16); b. from the transmitter (sensor 3) to the receivers (sensors 1-2, 4-16)*

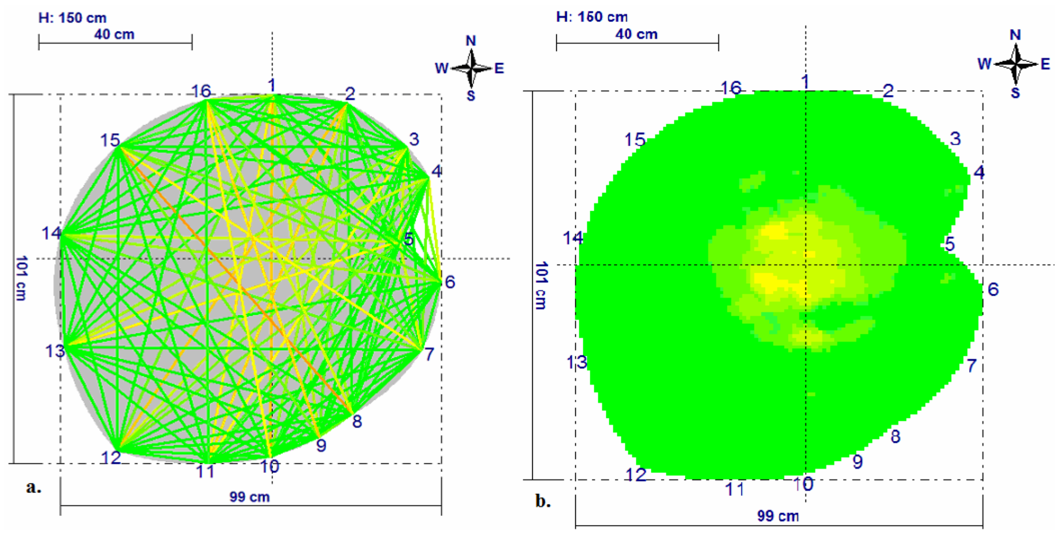


Fig. 3. *Construction of the tomogram (b.) based on the sound propagation speeds between the sensors (a.)*

After using the last sensor as a transmitter, the recording stopped, the tomogram was checked, and the measurement was saved.

The software of the used equipment automatically calculates the straight-line distance between the sensors acting as transmitter and receivers and, based on the sound propagation time from the transmitter to the receiver, it calculates the speed and draws a straight line whose color corresponds to a speed category (Fig. 2). Based on the recorded speeds and the traced straight lines [2], the software constructs a map of speeds which represents the tomographic image of the analyzed section (Fig. 3).

## 3. Results and Discussions

For the analyzed horse chestnut trees, the diameters at the breast height ranged from 54 to 111 cm, so the number of used sensors was related to the tree diameter. Thus, by taking into account the literature recommendations [11] and [16], according to which the number of sensors must be large enough to capture the complexity of the analyzed section, in this study were used between 9 (tree no. 11, sections located at 100 and 150 cm above the ground) and 21 sensors (trees no. 14 and 16, section located at 50 cm above the ground).

Based on the tomograms, there were obtained the speeds of sound through the wood, which are shown in Table 1, and graphically rendered in Figures 4 and 5, for the minimum and maximum speeds.

However, there were situations in which the sound has not been transmitted between all the pairs of transmitter-receiver sensors. Therefore, at some levels were recorded fewer connections than the maximum number of possibilities (Table 1). This was the case of the following trees: 1, 3, 6, 8, 9, 12, 14, 16 and 22 (Table 2).

Table 1

*Propagation of sound speed through the wood of horse chestnut trees*

| Tree no. | Level above ground [cm] | Diameter [cm] | No. of sensors | Number of possible connections | Characteristics of $v_{min}$ | | | Characteristics of $v_{max}$ | | | Sensors that did not propagate the sounds |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Speed [m/s] | Distance between sensors [cm] | Direction | Speed [m/s] | Distance between sensors [cm] | Direction | |
| 1 | 50 | 119 | 19 | 342 | 394 | 82 | 12 – 17 | 2045 | 32 | 10 – 12 | – |
| | 100 | 111 | 19 | 340* | 273 | 56 | 9 – 12 | 1659 | 51 | 16 – 1 | 17 – 18; 18 – 17 |
| | 150 | 110 | 18 | 302** | 147 | 63 | 2 – 11 | 1716 | 58 | 6 – 9 | 14 – 15; 15 – 14; 15 – 16; 16 – 15 |
| 2 | 50 | 67 | 12 | 132 | 589 | 16 | 7 – 8 | 1832 | 37 | 1 – 11 | – |
| | 100 | 62 | 10 | 90 | 871 | 25 | 1 – 2 | 1920 | 15 | 4 – 3 | – |
| | 150 | 60 | 10 | 90 | 824 | 15 | 5 – 4 | 2108 | 21 | 4 – 3 | – |
| 3 | 50 | 86 | 18 | 300*** | 678 | 10 | 10 – 9 | 1472 | 65 | 2 – 16 | 3 – 4; 4 – 3; 7 – 8; 8 – 7; 8 – 9; 9 – 8 |
| | 100 | 83 | 13 | 156 | 832 | 21 | 8 – 9 | 1397 | 73 | 11 – 6 | – |
| | 150 | 81 | 12 | 132 | 838 | 29 | 8 – 9 | 1316 | 73 | 4 – 8 | – |
| 6 | 50 | 52 | 11 | 102**** | 893 | 17 | 10 – 1 | 1887 | 52 | 4 – 9 | 1 – 11; 11 – 1; 5 – 6; 6 – 5; 7 – 8; 8 – 7; 10 – 11; 11- 10 |
| | 100 | 51 | 10 | 88* | 585 | 12 | 3 – 2 | 2168 | 18 | 4 – 3 | 1 – 2; 2 – 1 |
| | 145 | 57 | 10 | 88* | 863 | 28 | 6 – 4 | 1976 | 46 | 5 – 9 | 9 – 10; 10 – 9 |
| 7 | 50 | 78 | 18 | 304* | 320 | 12 | 5 – 6 | 1683 | 70 | 9 – 3 | 17 – 18; 18 – 17 |
| | 100 | 73 | 13 | 156 | 773 | 15 | 10 – 9 | 1611 | 59 | 11 – 1 | – |
| | 150 | 71 | 12 | 132 | 692 | 14 | 1 – 2 | 1539 | 37 | 11 – 9 | – |
| 8 | 50 | 83 | 15 | 210 | 610 | 49 | 2 – 6 | 2045 | 15 | 12 – 11 | – |
| | 100 | 75 | 13 | 156 | 614 | 55 | 9 – 5 | 1896 | 10 | 4 – 3 | – |
| | 150 | 73 | 11 | 108* | 606 | 49 | 10 – 7 | 1844 | 34 | 10 – 11 | 6 – 7; 7 – 6 |
| 9 | 50 | 86 | 18 | 300*** | 722 | 11 | 3 – 4 | 2387 | 30 | 1 – 18 | 5 – 6; 6 – 5; 6 – 7; 7 – 6; 7 – 8; 8 - 7 |
| | 100 | 77 | 17 | 270* | 763 | 13 | 7 – 8 | 1957 | 22 | 2 – 1 | 5 – 6; 6 – 5 |
| | 150 | 73 | 14 | 182 | 852 | 14 | 6 – 5 | 2549 | 21 | 14 – 1 | – |

Table 1 (continued)

| Tree no. | Level above ground [cm] | Diameter [cm] | Number of sensors | Number of possible connections | Characteristics of $v_{min}$ | | | Characteristics of $v_{max}$ | | | Sensors that did not propagate the sounds |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Speed [m/s] | Distance between sensors [cm] | Direction | Speed [m/s] | Distance between sensors [cm] | Direction | |
| 10 | 50 | 110 | 18 | 306 | 207 | 14 | 3 – 2 | 1905 | 92 | 16 – 10 | – |
| | 100 | 106 | 14 | 182 | 526 | 21 | 13 – 14 | 1598 | 91 | 12 – 7 | – |
| | 150 | 106 | 16 | 240 | 499 | 86 | 3 – 8 | 1794 | 88 | 14 – 9 | – |
| 11 | 50 | 63 | 12 | 132 | 561 | 36 | 10 – 7 | 1561 | 19 | 12 – 1 | – |
| | 100 | 57 | 9 | 72 | 566 | 19 | 8 – 7 | 1543 | 20 | 4 – 3 | – |
| | 150 | 55 | 9 | 72 | 813 | 21 | 8 – 7 | 1582 | 16 | 4 – 3 | – |
| 12 | 50 | 74 | 11 | 110 | 525 | 73 | 11 – 6 | 1687 | 34 | 1 – 3 | – |
| | 100 | 70 | 11 | 108* | 490 | 39 | 10 – 7 | 1672 | 20 | 2 – 3 | 7 – 8; 8 – 7 |
| | 150 | 70 | 11 | 110 | 423 | 57 | 8 – 1 – 8 | 1662 | 17 | 2 – 3 | – |
| 13 | 50 | 67 | 12 | 132 | 585 | 39 | 6 – 9 | 1564 | 43 | 12 – 10 | – |
| | 100 | 64 | 11 | 110 | 354 | 15 | 2 – 3 | 1589 | 45 | 2 – 10 | – |
| | 150 | 60 | 10 | 90 | 630 | 47 | 6 – 3 | 1509 | 36 | 2 – 10 | – |
| 14 | 50 | 95 | 21 | 418* | 710 | 101 | 2 – 12 | 2206 | 56 | 12 – 16 | 4 – 5; 5 – 4 |
| | 100 | 88 | 18 | 306 | 537 | 82 | 3 – 11 | 2550 | 14 | 1 – 18 – 1 | – |
| | 150 | 84 | 18 | 306 | 680 | 56 | 3 – 14 | 2007 | 27 | 14 – 16 | – |
| 15 | 50 | 71 | 13 | 156 | 237 | 11 | 7 – 8 | 1566 | 58 | 7 – 11 | – |
| | 100 | 69 | 10 | 90 | 479 | 63 | 1 – 5 | 1275 | 20 | 9 – 10 | – |
| | 150 | 68 | 10 | 90 | 632 | 22 | 1 – 2 | 1421 | 56 | 8 – 1 | – |
| 16 | 50 | 98 | 21 | 418* | 666 | 12 | 13 – 14 | 1855 | 26 | 17 – 19 | 14 – 15; 15 – 14 |
| | 100 | 94 | 18 | 304* | 530 | 27 | 12 – 10 | 1529 | 52 | 4 – 18 | 16 – 17; 17 – 16 |
| | 150 | 92 | 18 | 304* | 514 | 13 | 7 – 6 | 1961 | 22 | 12 – 10 | 3 – 4; 4 – 3 |
| 22 | 50 | 81 | 17 | 268** | 595 | 11 | 16 – 17 | 1777 | 72 | 15 – 10 | 1 – 2; 2 – 1; 14 – 15; 15 – 14 |
| | 100 | 77 | 14 | 182 | 431 | 21 | 4 – 3 | 1621 | 66 | 3 – 8 | – |
| | 150 | 73 | 13 | 154* | 694 | 60 | 1 – 8 | 1383 | 16 | 12 – 11 | 1 – 2; 2 – 1 |

Table 2

*Number of possible directions against the real number of sound propagation directions*

| Tree no. | Location of the analyzed section [cm] | Number of sensors | Number of possible directions | The real number of directions |
|---|---|---|---|---|
| 1 | 100 | 19 | 342 | 340 |
| | 150 | 18 | 306 | 302 |
| 3 | 50 | 18 | 306 | 300 |
| 6 | 50 | 11 | 110 | 102 |
| | 100 | 10 | 90 | 88 |
| | 150 | 10 | 90 | 88 |
| 8 | 150 | 11 | 110 | 108 |
| 9 | 100 | 17 | 272 | 270 |
| | 150 | 18 | 306 | 300 |
| 12 | 100 | 11 | 110 | 108 |
| 14 | 50 | 21 | 420 | 418 |
| 16 | 50 | 21 | 420 | 418 |
| | 100 | 18 | 306 | 304 |
| | 150 | 18 | 306 | 304 |
| 22 | 150 | 13 | 156 | 154 |

In what concerns the sound propagation speeds, it was found that they had minimum values ranging from 147 m/s (tree no. 1, section located at 150 cm above ground, sensors 2-11) to 893 m/s (tree no. 6, section located at 50 cm above the ground, sensors 10 - 1) and maximum values in the range of 1275 m/s (tree no.15, section located at 100 cm above the ground, sensors 9-10) and 2549 m/s (tree no. 9, section located at 150 cm above ground, sensors 14 - 1), respectively 2550 m/s (tree no. 14, section located at 100 cm above the ground, sensors 1 - 18 - 1).

After the classification of the values on categories (Table 3), it was found that the speeds ranging between 1001-1500 m/s were predominant, with some exceptions, of either all the analyzed three sections (trees no. 1 and 15) or only one (4 trees) or two of them (one horse chestnut).

In this situation, most of the values of speed propagation ranged between 501-1000 m/s, but there was also a section, located at 100 cm above ground, where the speeds ranged between 1501 - 2000 m/s (tree no. 6). In addition, it was noted that in this case were predominant the speeds between 1001 - 1500 m/s (43-67%) and 1501 - 2000 m/s (27-50%).

It is also underlined that in the case of chestnut trees no. 1 and no. 15, the predominance of low values of the sound speed propagation through the wood was explained, to some extent, by the presence of serious external defects such as decay, open frost-cracks and hallows.

Speeds over 2000 m/s were recorded very rarely. Only 23 values corresponding to 9 sections were identified for such cases, and only 3 of them exceeded 2500 m/s (Table 3).

*Classification of sound speed propagation through wood by category* Table 3

| Tree no. | Level above ground [cm] | Diameter [cm] | Number of sensors | Intervals of speed variation [m/s] | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | < 500 | | 501 – 1000 | | 1001 – 1500 | | 1501 – 2000 | | 2001 – 2500 | | 2501 – 3000 | |
| | | | | No. | % | No. | % | No. | % | No. | % | No. | % | No. | % |
| 1 | 50 | 119 | 19 | 31 | 9 | 203 | 60 | 103 | 30 | 4 | 1 | 1 | 0 | – | – |
| | 100 | 111 | 19 | 117 | 35 | 167 | 49 | 52 | 15 | 4 | 1 | – | – | – | – |
| | 150 | 110 | 18 | 121 | 40 | 120 | 40 | 55 | 18 | 6 | 2 | – | – | – | – |
| 2 | 50 | 67 | 12 | – | – | 12 | 9 | **100** | **76** | 20 | 15 | – | – | – | – |
| | 100 | 62 | 10 | – | – | 2 | 2 | **66** | **73** | 22 | 25 | – | – | – | – |
| | 150 | 60 | 10 | – | – | 4 | 4 | 31 | 35 | **53** | **59** | 2 | 2 | – | – |
| 3 | 50 | 86 | 18 | – | – | 28 | 9 | **272** | **91** | – | – | – | – | – | – |
| | 100 | 83 | 13 | – | – | 10 | 6 | **146** | **94** | – | – | – | – | – | – |
| | 150 | 81 | 12 | – | – | 17 | 13 | **115** | **87** | – | – | – | – | – | – |
| 6 | 50 | 52 | 11 | – | – | 3 | 3 | **53** | **52** | **46** | **45** | – | – | – | – |
| | 100 | 51 | 10 | – | – | 5 | 6 | **38** | **43** | **44** | **50** | 1 | 1 | – | – |
| | 145 | 57 | 10 | – | – | 5 | 6 | **59** | **67** | **24** | **27** | – | – | – | – |
| 7 | 50 | 78 | 18 | 2 | 1 | 230 | 76 | 59 | 19 | 13 | 4 | – | – | – | – |
| | 100 | 73 | 13 | – | – | 19 | 12 | **130** | **83** | 7 | 5 | – | – | – | – |
| | 150 | 71 | 12 | – | – | 17 | 13 | **112** | **85** | 3 | 2 | – | – | – | – |
| 8 | 50 | 83 | 15 | – | – | 108 | 52 | 89 | 42 | 11 | 5 | 2 | 1 | – | – |
| | 100 | 75 | 13 | – | – | 98 | 63 | 52 | 33 | 6 | 4 | – | – | – | – |
| | 150 | 73 | 11 | – | – | 47 | 44 | 54 | 50 | 7 | 6 | – | – | – | – |
| 9 | 50 | 86 | 18 | – | – | 23 | 8 | **183** | **61** | 81 | 27 | 13 | 4 | – | – |
| | 100 | 77 | 17 | – | – | 20 | 7 | **188** | **70** | 62 | 23 | – | – | – | – |
| | 150 | 73 | 14 | – | – | 6 | 3 | **122** | **67** | 53 | 29 | – | – | 1 | 1 |
| 10 | 50 | 110 | 18 | 1 | 0 | 24 | 8 | **199** | **65** | 88 | 27 | – | – | – | – |
| | 100 | 106 | 14 | – | – | 26 | 14 | **149** | **82** | 7 | 4 | – | – | – | – |
| | 150 | 106 | 16 | 1 | 1 | 44 | 18 | **180** | **75** | 15 | 6 | – | – | – | – |
| 11 | 50 | 63 | 12 | – | – | 64 | 48 | 66 | 50 | 2 | 2 | – | – | – | – |
| | 100 | 57 | 9 | – | – | 25 | 35 | **43** | **60** | 4 | 5 | – | – | – | – |
| | 150 | 55 | 9 | – | – | 15 | 21 | **55** | **76** | 2 | 3 | – | – | – | – |
| 12 | 50 | 74 | 11 | – | – | 40 | 36 | **64** | **58** | 6 | 6 | – | – | – | – |
| | 100 | 70 | 11 | 1 | 1 | 43 | 40 | **55** | **51** | 9 | 8 | – | – | – | – |
| | 150 | 70 | 11 | 2 | 2 | 61 | 55 | 45 | 41 | 2 | 2 | – | – | – | – |
| 13 | 50 | 67 | 12 | – | – | 78 | 59 | 53 | 40 | 1 | 1 | – | – | – | – |
| | 100 | 64 | 11 | 2 | 2 | 41 | 37 | **64** | **58** | 3 | 3 | – | – | – | – |
| | 150 | 60 | 10 | – | – | 28 | 31 | **61** | **68** | 1 | 1 | – | – | – | – |
| 14 | 50 | 95 | 21 | – | – | 91 | 22 | **291** | **70** | 34 | 8 | 2 | 0 | – | – |
| | 100 | 88 | 18 | – | – | 89 | 29 | **184** | **60** | 30 | 10 | 1 | 0 | 2 | 1 |
| | 150 | 84 | 18 | – | – | 126 | 41 | **171** | **56** | 8 | 3 | 1 | 0 | – | – |
| 15 | 50 | 71 | 13 | 1 | 1 | 123 | 79 | 30 | 19 | 2 | 1 | – | – | – | – |
| | 100 | 69 | 10 | 1 | 1 | 71 | 79 | 18 | 20 | – | – | – | – | – | – |
| | 150 | 68 | 10 | – | – | 66 | 73 | 24 | 27 | – | – | – | – | – | – |
| 16 | 50 | 98 | 21 | – | – | 26 | 6 | **271** | **64** | 121 | 29 | – | – | – | – |
| | 100 | 94 | 18 | – | – | 89 | 29 | **213** | **70** | 2 | 1 | – | – | – | – |
| | 150 | 92 | 18 | – | – | 142 | 47 | **153** | **50** | 9 | 3 | – | – | – | – |
| 22 | 50 | 81 | 17 | – | – | 22 | 8 | **198** | **74** | 48 | 18 | – | – | – | – |
| | 100 | 77 | 14 | 1 | 1 | 15 | 8 | **156** | **86** | 10 | 5 | – | – | – | – |
| | 150 | 73 | 13 | – | – | 44 | 29 | **110** | **71** | – | – | – | – | – | – |

The distribution of minimum values for the sound propagation speeds, recorded on the three analyzed sections (50, 100 and 150 cm) is shown in Figure 4, where it can be seen that the values are not influenced by the above-ground level of the analyzed sections, as there were situations in which the speed recorded at 50 cm above the ground was greater than those recorded at 100 or 150 cm (case of trees no. 6, 12, 14 and 16). However, it should be noted that these values were not recorded by the same pairs of sensors. For instance, in the case of trees no. 7, 10 and 15, the values recorded for the minimum speeds of sound propagation for the section located at 50 cm above the ground were significantly lower than those recorded at the following two levels.

Figure 5 shows the distribution of the maximum speeds recorded on the investigated trees by overlaying on the same graph the values obtained for all the three analyzed levels. It can be observed that, with few exceptions, for the same tree, the maximum recorded speeds do not differ significantly between them, regardless of the level analyzed.

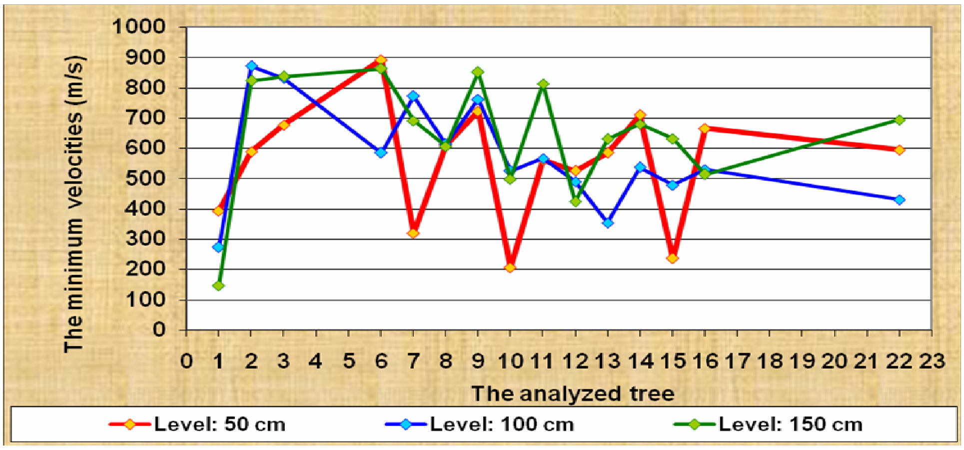


Fig. 4. *The minimum speeds of sound propagation for the three analyzed sections*

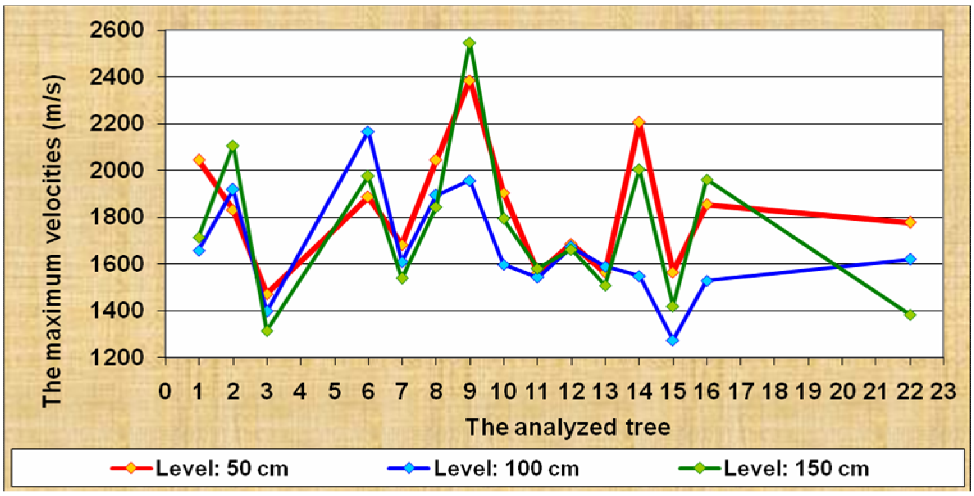


Fig. 5. *The maximum speeds of sound propagation for the three analyzed sections*

The largest differences occurred on the trees no. 9 (592 m/s) and 14 (547 m/s), and the lowest on the trees no. 12 (25 m/s) and 11 (39 m/s). It was also noted that the maximum speeds obtained at the level located at 100 cm above ground either fall between those obtained at 50 and 150 cm respectively, or were lower than the values recorded at those two levels. The exception was observed on tree no. 6, where (at level of 50 cm above ground) it was found the highest value of the speed propagation of all the investigated sections, corresponding to the tree.

Taking into account the specifications from the existing studies [2], namely that the speed of the perpendicular sound wave on the fibre should be in the range of 1000 - 2000 m/s, depending on the species, it can be mentioned that some of the analyzed trees had such values for the speed and therefore the trees shown, at the analyzed levels, healthy wood inside the trunk. This was specific for 12 trees, 8 of them being characterized by speeds in the mentioned range for all of the analyzed levels, while 4 trees had such values only for two of the studied levels.

In addition, the existing literature also mentions low sound speed when facing degraded wood [1], especially in those cases where the trees have internal decay or cracks [15].

This occurs because the wave has to cross the degraded area, resulting in a longer propagation path and in a lower speed [6]. Taking into account the above mentioned as well as Table 3, one can draw attention to the fact that some of the analyzed trees have internal defects that lead to the reduction of the sound propagation. Such a behavior characterizes the areas with low density, knowing that the dense materials allow a faster sound transfer, unlike less dense ones [5] and [12]. In addition, it should be noted that the low speeds obtained in this study provide only information on the low density of the wood at the analyzed level, and not information related to the type of defect [8], which requires other types of analyzes to exactly determine what is inside the trunk, especially since the used technique may deform the reality to some extent [15], meaning that the decayed areas can be underestimated, the radial cracks can be overestimated and the ring cracks can be assimilated with rotten areas.

## 4. Conclusions

Non-destructive techniques, such as those based on acoustic scanners, can be successfully used to determine changes inside the trunk, but the reconstructed images provide information on the speed of sound propagation through wood only for the analyzed level, and not for the entire tree. In addition, the analysis of tomograms does not reveal the type of the defect, but only indicates the lower density areas that have a negative effect on the sound propagation through the wood.

Regarding the analyzed trees, it was found that most of them have a good quality of the wood (at the analyzed levels), the sound propagation speeds being inside the interval characterizing such a state. But there were also cases in which the degradation was pronounced and the density of the wood was very low, which raise a question mark on the quality of the wood in that area. In addition, the large extension of the area characterized by low speeds of sound propagation and the fact that low values occurred at all of the 3 studied levels (50, 100 and 150 cm above the ground) draw attention to the fact that the stability of the tree can be threatened under certain conditions, such as strong winds.

However, it is not advisable to take drastic measures just based on acoustic tomography, but to supplement these results with analyses that provide more information about the type of defect and, if possible, its actual size and location, knowing that by acoustic tomography some defects can be underestimated and others overestimated.

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