3 Tree Characteristics and Acoustic Sensors

The foundation of forestry is closely related to forest mensuration, which is a keystone for obtaining quantifiable information when decision making for stands and individual trees. This chapter is devoted to tree characterization, using acoustic sensors for the following three topics: the morphological characteristics of trees, their mechanical and genetic characteristics related to timber quality, and tree characterization for sylvicultural practice. The studies of these aspects are required for the management inventory of forests, for timber volume estimation, for forestry planning and protection and for optimal timber management practices, such as pruning, thinning and logging operations.

3.1 Morphological Characteristics

Two main morphological characteristics are required for timber volume estimation and growth inventory in forest: the diameter and the height of a tree. It is generally accepted that the estimation and modeling of the height/diameter ratio for forest inventory require an important data base, which is time-consuming and is often performed using a small proportion of the sampled trees.

The diameter of the tree is currently measured with mechanical and electronic calipers, diameter sticks and tapes (McCornnell et al. 1984; Reynolds and Wilson 1989). This operation needs direct contact with the stem and is tedious over long periods. The development of ultrasonic and laser sensors has provided a noncontact method which allows the measurement of trunk diameters, the estimation of cross-sectional area and the collection and recording of data without manual entry.

The device developed by Upchurch et al. (1992, 1993), an ultrasonic caliper, uses high frequency waves of 25 kHz and two transducers to detect the presence of an object and to measure the time of flight (t) from the transmitter to the object and back to the receiver. The distance (d) is estimated with the formula $2t = d/v$, where v is the speed of sound in air, which is about 330 m/s and which needs to be adjusted for the temperature at which the measurement is taken. The distance between the tree and the sensor decreases as the diameter of the tree increases, when the transducers are aligned with the center of the trunk, using a stick. For diameters between 5.2 cm and 13.8 cm, the system has an accuracy of 0.05 cm in a temperature range between 0 °C and 34 °C. The major and minor axis of the trunk cross-section can be identified.

The development of mobile robotics and sonar modules combine ultrasonic (49 kHz) and laser techniques for measurements in dense forests and for all types of terrain and surroundings (Haglof 2003). The parameters measured are the distance and the angle to an optional part of the tree or to a reference point on the tree, or to the top and bottom of the tree, which allow calculation of the height and diameter of the tree at a reference point, as can be seen from Fig 3.1.

Taking into account the mechanical stability of trees against wind and storm, two other morphological parameters must be considered: root systems and crown characteristics.

Detailed information about root zone architecture and functionality can be obtained with a ground-penetrating radar technique which provides 3D images (Martinis 2002; Stokes et al. 2002; Nadezhdina and Cermak 2003) or by "air-spade" excavation, using a supersonic air stream which removes the soil around the dense network of roots (Rizzo and Gross 2000; Nadezhdina and Cermak 2003). The image obtained with a geo-radar operating at 450 MHz for about 30 m^2 ground surface is given in Fig. 3.2, in which only roots with a diameter greater than 20 mm are observed. The supersonic air stream is produced by a device related to a compressor delivering 0.8 m^3/s of air at a pressure of 0.6 MPa, "giving a stream with a speed of Mach 2".

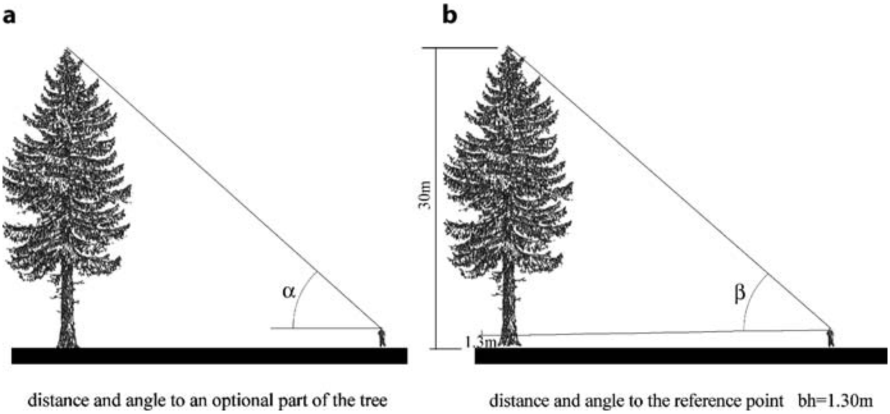

Fig. 3.1. Ultrasonic measurements of the height and diameter of trees. **a** Ultrasonic measurement of tree diameter when the transmitter and receiver are aligned with the center of the cross-section, using a hook device and engaging the device against the far side of the tree (Upchurch et al. 1992). Reprinted by permission of the American Society of Agricultural Engineers, copyright 2005. **b** Ultrasonic and laser measurements of the distance and angle to an optional point or to a reference point

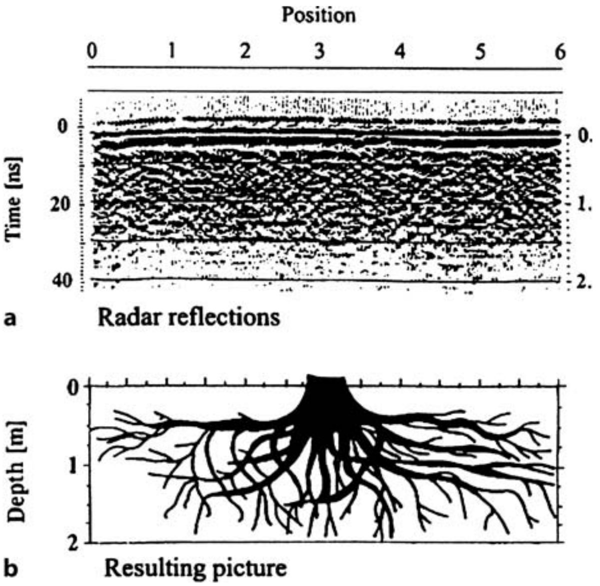

Fig. 3.2. Geo-radar image of the root system of a large oak tree (Nadezhdina and Cermak 2003). Reprinted by permission of Oxford University Press, copyright 2005. **a** Radar wave-path across the root system, **b** image of root system deduced from the radar data

Remote sensing for management inventory of forest condition and for forest protection needs information about canopy characteristics which can by studied using microwaves and radar techniques (McKerrow and Harper 1999; Bucur 2003).

3.2 Mechanical Characteristics

The stability against wind, storm, and snow or ice breakage of standing trees is directly related to the physical and mechanical properties of the fresh wood of the stem. For this purpose, static and dynamic acoustic methods were developed, concentrated mainly on determining the modulus of elasticity in the fiber direction. For static measurements, different devices were developed (Koizumi 1987, 1990; Launay et al. 2000; Takata and Teraoka 2002), based on the tree-bending test. The deflection caused by bending moment induced by the application of an external charge has been used for the calculation of stem Young's modulus E in the fiber direction (Lanbourg 1989). Brüchert et al. (2000) studied flexural stem variation by introducing defined mechanical parameters, such as: *structural Young's modulus*, which is the Young's modulus of the stem, *flexural stiffness*, which is the product between the Young's modulus and the axial second inertia momentum of the elliptical area of the stem ($I_a = 0.25\pi ba^3$, where a and b are the half diameters of the elliptical cross-area of the trunk) and the *global buckling* coefficient under the stem's own weight, which allows calculation of the tree safety factor under buckling.

Theoretical development of dynamic testing methods was proposed by Axmon and Hansson (1999, 2000) using modal analysis and by Ouïs (2001) with the analysis of the damping response of a tree to shock.

The description of the vibrational behavior of trees can be made in a time domain and in a frequency domain. Signal analysis in a time domain allows the determination of the velocity of propagation of the vibration and, in contrast, frequency analysis of the vibration allows the determination of damping characteristics of the signal related to the attenuation phenomena of wave propagation.

The mechanical characteristics of standing trees related to the elastic moduli can be achieved by measuring the velocity of propagation of the mechanical vibration. The most popular methods for velocity measurements are stress wave and ultrasonic velocity methods. Both methods are based on the time propagation measurement of an impulse traveling through a standing tree. Knowing the wave propagation time into the tree, it is very easy to calculate the propagation velocity and the corresponding modulus of elasticity. In the case of the stress wave method, the impulse is produced by a mechanical shock; and in the case of the ultrasonic method, the impulse is electronically produced by a piezoelectric transducer.

The measurement of the damping characteristics of the signal traveling through standing trees is much more complex and is used mainly for the detection of internal defects related to the presence of decay (Ouïs 2001) or the proportion of juvenile wood when the analysis of the dispersion of multiple elastic waveguide modes is performed (Laverty 2001). The method developed by Ouïs (2001) is based on the assumption that each tree has proper vibration characteristics, related to the reverberation time that can be defined together with a characteristic response spectrum (transfer function). This method was inspired by the oldest test performed by foresters when they "listen to the sounding trees".

3.2.1 Devices and Instrumentation

Figure 3.3 shows the measurement device for the stress wave method. The stress wave is generated by a shock induced by a hammer. The receivers are two accelerometers, the first one located at point 1 for velocity measurements in a longitudinal direction and the second one located at point 2 for measurements of radial velocity. The stress wave frequency is in the range 12 kHz.

The distribution of the sensors for modal analysis is given in Fig. 3.4. The stress wave propagates from the emission point to points 1, 2, etc., through the cross-section, in a straight line. The surface wave propagates at the periphery of the trunk and is received at the same points 1, 2, 3, etc. The shock is produced with a standard hammer and is received by accelerometers. For stress waves, the time of flight increases continuously from the emission point to a maximum corresponding to point 6 and decreases symmetrically from position 6 to position 12. The propagation time of surface waves increases linearly from position 1 to position 12, covering the entire circumference. The velocity of the surface wave is constant at the periphery of the stem.

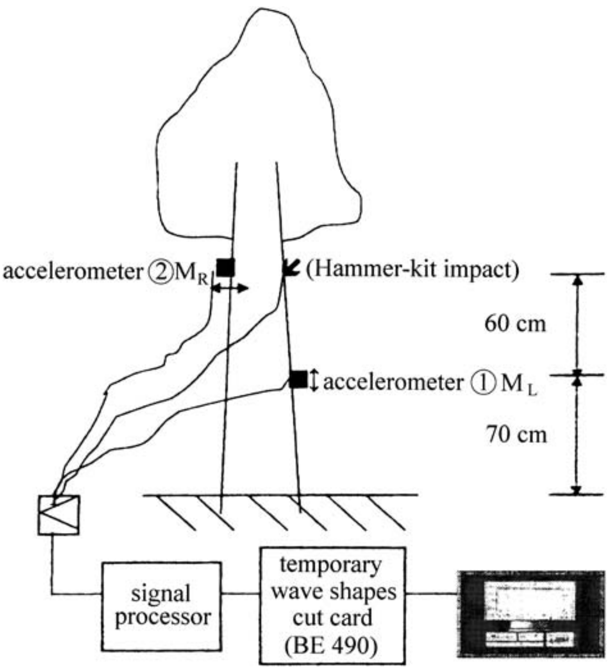

Fig. 3.3. Device for stress wave method on a standing tree (Chuang and Wang 2001). Reprinted by permission of the Japan Wood Research Society, copyright 2005

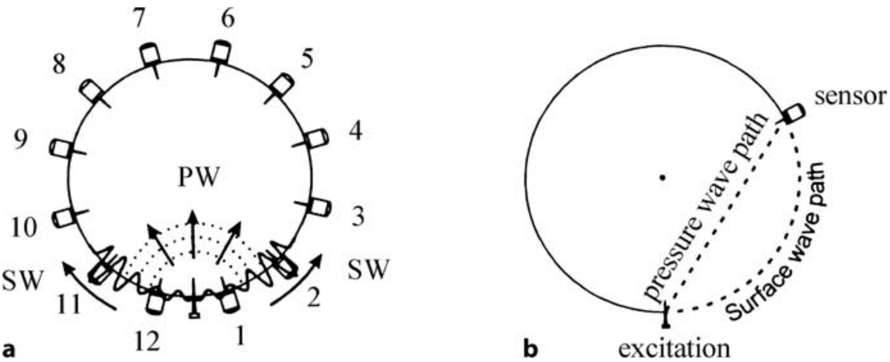

Fig. 3.4. Location of accelerometers for modal analysis (Axmon et al. 2004). Reprinted by permission of Oxford University Press, copyright 2005. **a** For stress wave (SW) velocity measurements, the shock is induced at point P. **b** Propagation path of surface waves

From modal analysis, temporal and spatial frequencies are estimated for each spatial mode shape of vibration, which is associated with the temporal frequency of the stress wave. The pattern generated by the surface waves is separable from the pattern generated by the stress wave. The discrepancy between the calculated and measured frequency then indicates whether the tested tree has internal defects or not.

The ultrasonic device utilizes two piezoelectric transducers (one for the emission and other for the reception of the signal), which are located in similar way as for the stress wave method. The frequency range is much higher than that used for stress wave measurements and can range between 20 kHz and 1 MHz.

3.2.2 Mechanical Characteristics of Standing Trees

For the mechanical characterization of standing trees, the literature available today mentions two parameters: the moduli of elasticity in axial (longitudinal, L) and in radial (R) directions. Very often the abbreviation MOE is advanced, which in mechanical terms corresponds to the Young's modulus in a longitudinal direction. Values of the elastic moduli in L and R directions derived from ultrasonic measurements are given in Table 3.1.

The variation in the structural Young's modulus as a function of height for dominant and suppressed spruce trees, submitted to different thinning regimes, is given in Fig. 3.5. Sylvicultural practice plays an important role in the differences observed in the mechanical properties of trees. Young's modulus decreases with stem diameter, the suppressed trees having higher values.

Table 3.1. Elastic moduli and ultrasonic velocities in L and R directions in Douglas fir trees (Bucur 1995)

Parameter	Unit	Pruned tree	Control tree
Velocity in R direction	(m/s)	1,589	1,272
Velocity in L direction	(m/s)	6,006	5,528
Density	(kg/m^3)	547	550
Modulus of elasticity in R direction	10^8 N/m^2	138.11	88.98
Modulus of elasticity in L direction	10^8 N/m^2	197.31	168.07

3.2.3 Detection of Internal Defects in Standing Trees

For the detection of internal defects in standing trees, two main groups of methods were developed: the ultrasonic velocity method (Bucur 1985; Leininger

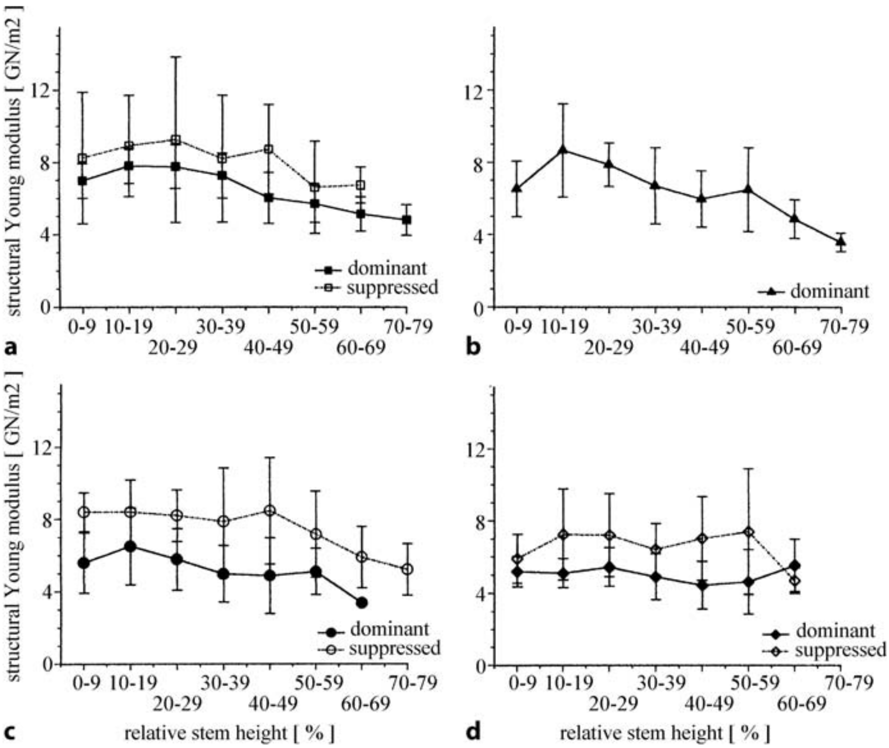

Fig. 3.5. Relationship between the structural Young's modulus and the relative stem height for dominant and suppressed spruce trees in four sites in Germany (Brüchert et al. 2000). Reprinted with permission from Elsevier, copyright 2005. *Filled symbols* represent dominant trees and *open symbols* represent suppressed trees. Sites: **a** wide spacing, **b** dense spacing, **c** initial wide spacing, **d** dense spacing, high amplitude

et al. 2001; Martinis et al. 2004) and the stress wave method (Ross 1985; Mattheck and Bethge 1993; Mattheck 1996), for which the impact response was analyzed either by modal analysis (Axmon et al. 2004), or by analysis of the damping response of the tree (Ouïs 2001) for internal decay detection in living trees or by exploration of the dispersion of multiple elastic waveguides in small diameter logs (Rizzo and Gross 2000; Laverty 2001) for the detection of the proportion of juvenile wood.

3.2.3.1 Ultrasonic Velocity Method

The development of an ultrasonic method for the detection of internal defects in trees used mainly two parameters: the time of flight of the ultrasonic signal and the ultrasonic velocity. First, only the time of flight of the ultrasonic signal was measured. Experiments reported a strong correlation between the wave propagation time and the diameter of the tree. Using this unique parameter, some small significant differences were observed between the behavior of healthy and decayed trees (Leininger et al. 2001). To improve the physical approach of signal treatment, analysis of the ultrasonic wave in a frequency domain was proposed.

The second important step for the detection of internal defects and discontinuities in living trees was achieved when ultrasonic velocity was used for nondestructive characterization and imaging of trees (Bucur 1995, 2003). In this way, tomographic imaging of the cross-section of standing trees was possible (Martinis 2002; Martinis et al. 2004), as well as visualization of the extent of any rot column (Fig. 3.6).

Ultrasonic images of the cross-section of trees can be reconstructed from all characteristic parameters of the wave such as: time of flight, velocity, amplitude, frequency spectra of the wave form, phase, energy distribution, etc. The resolution of the ultrasonic image is determined by the pixel size and the beam diameter.

The main interest for the practical application of ultrasonic methods for standing trees is the capability of this method to be very easily used in situ.

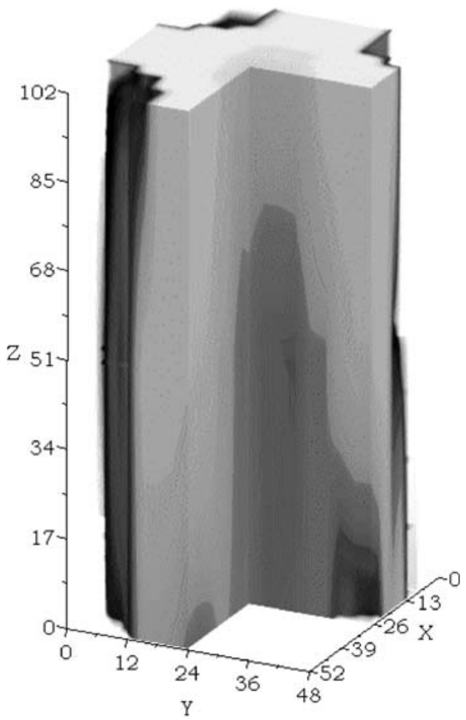

Fig. 3.6. Visualization of the extent of a rot column with ultrasonic tomography (Martinis et al. 2004). With permission from EDP Sciences, copyright 2005

The main disadvantage is the need for a good acoustic contact between the transducers and the bark or wood of the stem.

3.2.3.2
Stress Wave Method

During the past decades, the stress wave method was developed in the United States for the nondestructive estimation of the quality of wood products (Pellerin 1965; Ross 1985; Ross and Pellerin 1991, 1994; Wang et al. 2000; Pellerin and Ross 2002; Wang and Ross 2002). More recently, to evaluate the performance of the stress wave method through the detector rule for sound trees and decayed trees, Axmon et al. (2004) suggested the introduction of the parameter labeled *residual threshold,* which represents the difference between the measured frequency and the predicted, theoretical frequency of the ovaling mode for a supposed sound tree. From Fig. 3.7 (residual threshold versus surface wave velocity), it is easy to note that the sound trees are grouped in the central zone of the graph at ±46.9 Hz, while the decayed trees are located outside this zone. Successful classification within the major classes – sound and decayed trees – versus the double-sided residual threshold is given in Fig. 3.8. The success in identifying the sound trees is 74% for the residual threshold of 53 Hz.

Ouïs (2001) referred also to the ovaling mode of vibration of the tree stem, for which the wavelength is $2\lambda = 2\pi R$. He defined the *reverberation time* of the decay of the mechanical shock propagating through the tree, using an original

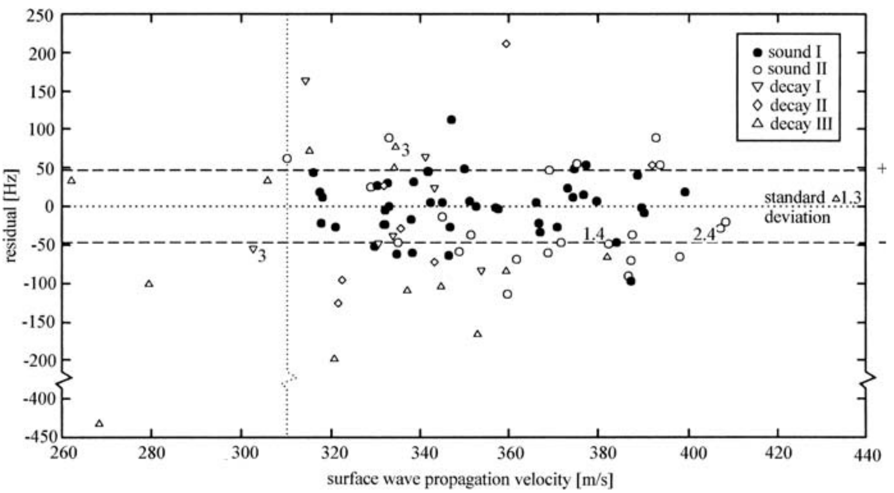

Fig. 3.7. Residual threshold (difference between measured and theoretical frequency) versus surface wave velocity (Axmon et al. 2004). Reprinted by permission of Oxford University Press, copyright 2005

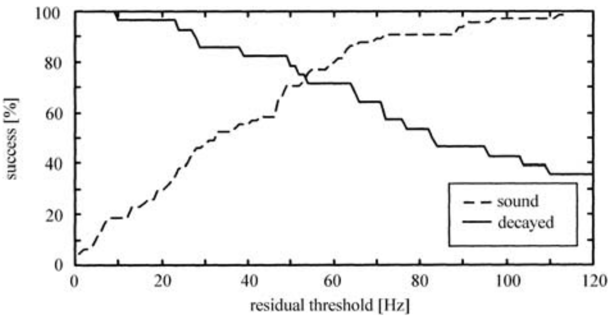

Fig. 3.8. Classification of sound and decayed trees as a function of residual threshold (Axmon et al. 2004). Reprinted by permission of Oxford University Press, copyright 2005

approach related to the analysis of the impulse response. First, the impulse response "is squared and then integrated backwards to yield the energy decay curve from which the reverberation time is calculated" as the time necessary for 10 dB decreasing of the level of the integrated impulse response. The impulse response in time and frequency domain of a sound and decayed (infested) tree is given in Fig. 3.9. An important discrepancy was observed between the velocity of impulse propagation in a sound tree (546 m/s) and a decayed tree (289 m/s). The spectrum analysis revealed harmonic components at different frequencies for sound and decayed trees, as for example for the sound tree at 1,710 Hz, 2,850 Hz, 4,170 Hz, etc. and for the decayed tree at 1,088 Hz, 1,920 Hz, 2,660 Hz, etc. This characteristic frequency distribution can be used for discriminating between sound and infested trees. The synthetic interpretation of all these experimental data is given in Fig. 3.9c. The energy decay curve versus time shows that the decayed (infested) tree lost much more energy during the decay of the impact vibration than the sound tree.

The increasing commercial interest for structural utilization of small diameter logs revealed the problems related to the estimation of the proportion and mechanical properties of juvenile wood. Laverty (2001) studied the ability to detect the proportion of juvenile wood in a log through exploration of the dispersion of multiple elastic waveguide modes propagating simultaneously. The developed model admitted that a log is composed of two concentrically cylindrical layers having a transverse isotropic symmetry and that the juvenile wood corresponds to the inner cylinder. The discrimination between the mature and juvenile wood can be made by studying the dispersion curves of vibrations propagating in the tree and by selecting the number of modes, the corresponding wavenumber of the signal and the shape of the waveguide modes. The combination of number of modes and shape of modes proved that the problem can be reduced to measuring the external diameter of the stem.

In the future, the development of a mobile device for practical application of this noninvasive technique in forests and saw-mills will be of the greatest interest for in situ appreciation of wood quality in a very big number of trees.

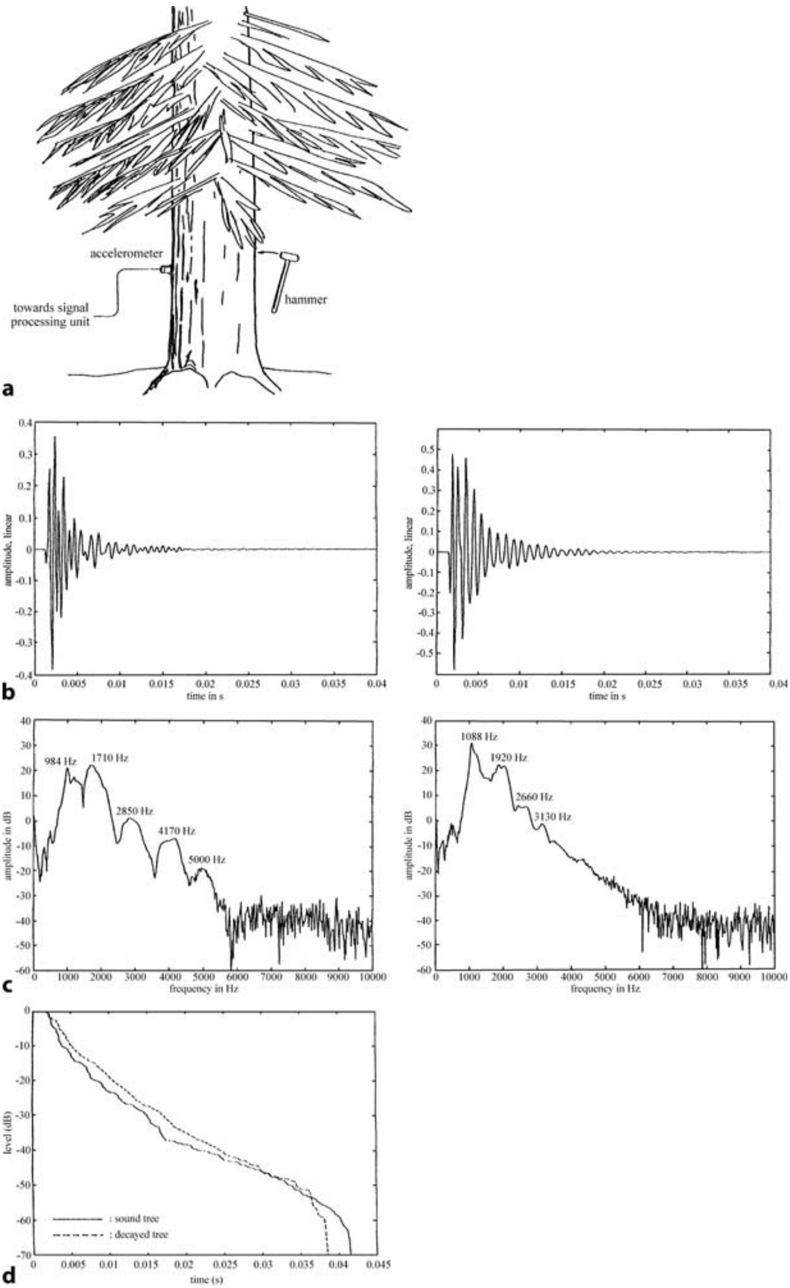

Fig. 3.9. The impulse response in time and frequency domain of sound and decayed trees (Ouïs 2001), with permission. **a** Time domain response, **b** frequency domain, **c** energy decay curve versus time, **d** energy decay curve of sound and decayed tree in time domain

3.3 Genotypic Characteristics

The genotypic effect of the variation of wood quality related to the mechanical characteristics of standing trees was studied with acoustic methods using resonance frequency FFT analysis, stress-wave or ultrasonic velocity measurements as well as with static bending methods (Koizumi 1987; Mamdy et al. 1999; Launay et al. 2000). Lindström et al. (2002) demonstrated that stiffness determination on small clear specimens from fast-growth trees can help to capture genetic breeding opportunities for improving wood quality for structural lumber, by selecting *Pinus radiata* clones with high values of Young's modulus. Nakamura (1996) noted that differences between hybrid larch families can be observed by measuring the ultrasonic velocity on standing trees. The distribution of modulus of elasticity values for trees in different strands can be used for producing maps for the management and characterization of individual forest sites.

Takata and Teraoka (2002), using static bending method on trees for different genotype groups, from plantations of cultivars of Japanese cedar (*Cryptomeria japonica*) at 19 years old, observed a wide variation in the modulus of elasticity of each genotype, ranging from 7.5% to 26.8%, as can be seen from Table 3.2.

Jacques et al. (2004), measuring Young's modulus in the L direction, compared acoustic methods (ultrasonic and resonance frequency) and a static bending method for increasing the efficiency of 16 clonal selections for modulus of elasticity for hybrid larch. The advantage of using ultrasonic velocity measurements on standing trees for genetic selection is related to the capability of this technique to integrate an important zone of the trunk and to test about 100 trees/day by two operators. The genotypic and phenotypic cor-

Table 3.2. Modulus of elasticity of different genotype groups of Japanese larch (Takata and Taraoka 2002); with permission from the Japan Wood Research Society, copyright 2005. Numbers in parentheses are the samples for the measurement of the modulus of elasticity of the trunk. CV Coefficient of variation

Genotype	Tested trees	Tree diameter (cm)		Tree height (m)		Trunk modulus of elasticity (GPa)	
	Number	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
A	31 (16)	17.4	23.1	10.8	15.8	5.53	12.2
B	26 (20)	18.5	14.4	11.4	13.4	5.38	11.2
C	15 (11)	17.5	20.7	11.3	14.3	5.68	11.0
D	9 (7)	20.2	16.3	11.5	17.5	4.81	7.5
E	8 (6)	17.6	27.4	10.8	22.8	5.69	26.8
F	6 (4)	17.8	13.8	10.7	7.3	5.39	18.8
Overall	108 (71)	17.9	20.1	11.0	15.3	5.42	14.5

relation coefficients between the modulus of elasticity determined with the ultrasonic velocity method, resonance frequency method and static bending range between 0.985 and 0.998.

The ultrasonic velocity measurements on standing trees used for the ranking of the 16 clones gives a lower estimate of heritability and genotypic than on small clear specimens. However, this small deficiency is compensated by the enormous cost reduction related to sample preparation and by the possibility of the increasing of selection intensity by performing direct measurements on standing trees.

In the future, genetics has an important role to play in forestry for fast-grown plantations. Acoustic methods (Huang et al. 2003) can be used to grade standing trees or sawn logs according to their suitability for structural lumber or the pulp industry. The performance of these methods depends on the wide range of fundamental wood characteristics (cellulose microfibril angle in wood cells, fiber length, etc.) interlinked with acoustical properties. "In long time perspective, there are substantial benefits in using acoustics in tree breeding to screen for candidate trees with superior wood properties" (Huang et al. 2003).

3.4 Sylvicultural Practices

The influence of different spacing on standing tree quality of Japanese cedar (*Cryptomeria Japonica*) was studied by Chuang and Wang (2001) with stress wave and ultrasonic methods. The experiments evaluated the wood quality through the measurement of the modulus of elasticity of 47 old standing trees growing in five plantation sites (denoted A, B, C, D, E) with different spacing,

Table 3.3. The effect of spacing on some acoustic and mechanical characteristics of trees grown in plantations at different spacings. Data from Chuang and Wang (2001), with permission from the Japan Wood Research Society, copyright 2005

	Spacing	Diameter	Density	Velocity (m/s)				Modulus of elasticity (10^8 N/m^2)			
				Stress wave in axis		Ultrasonic wave		Stress wave		Ultrasonic wave	
	(m)	(cm)	(kg/m^3)	L	R	L	R	E_L	E_R	E_L	E_R
A	1 × 1	29.0	386	3,210	1,719	3,600	1,720	101	29.9	117	32.9
B	2 × 2	29.5	397	3,520	1,830	3,810	1,800	129	35.7	147	33.0
C	3 × 3	34.1	409	3,200	1,777	3,440	1,881	94.3	32.2	114	30.5
D	4 × 4	37.4	431	3,230	1,777	3,430	1,770	98.7	26.8	117	29.3
E	5 × 5	40.0	442	2,900	1,810	3,280	1,740	82.7	33.2	89.3	28.2

ranging from 1 × 1 m to 5 × 5 m. In each type, the trees were classified in three classes: S – superior growth trees, M – medium growth trees and P – poor growth trees. Velocities in L and R directions were measured with stress wave and ultrasonic methods. Table 3.3 summarizes the experimental data. The diameter range is between 20 cm and 40 cm.

Figure 3.10 shows a histogram of the tree diameters at breast height as a function of the site. Statistical analysis of data with multiple new-ranged Duncan's test showed that significant differences were observed between the

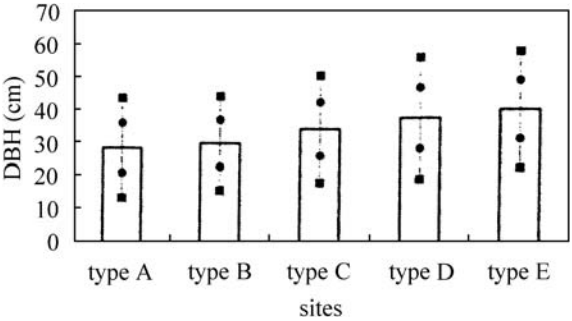

Fig. 3.10. Histogram of tree diameter at breast height for five plantation sites (Chuang and Wang 2001); with permission from the Japan wood Research Society, copyright 2005

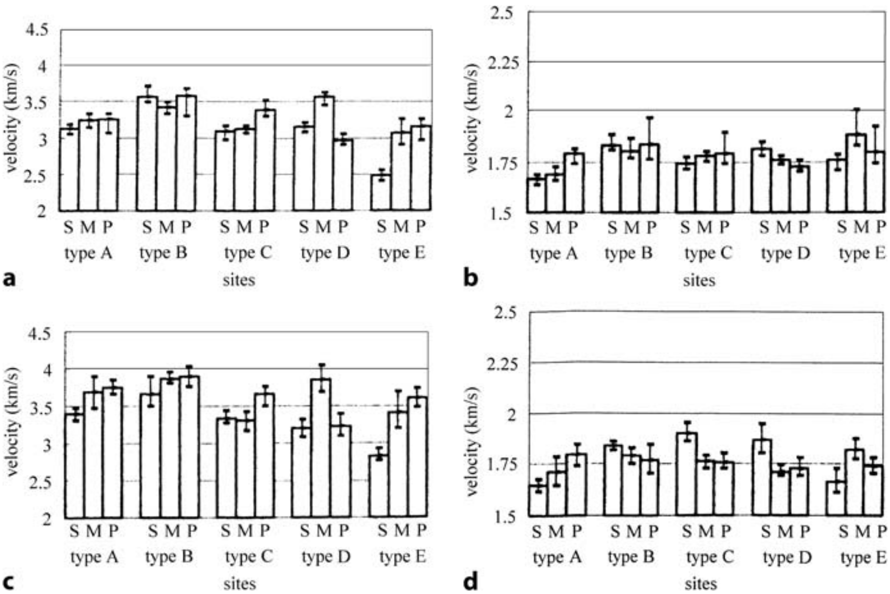

Fig. 3.11. Velocities measured with two techniques as a function of growth conditions (Chuang and Wang 2001); with permission from the Japan Wood Research Society, copyright 2005. **a** Longitudinal velocity of stress waves, **b** radial velocity of stress waves, **c** longitudinal velocity of ultrasonic waves, **d** radial velocity of ultrasonic waves

Table 3.4. Multiple new-ranged Duncan's test for the modulus of elasticity (mean and standard deviation, in 10^8 N/m^2) measured with stress wave and ultrasonic velocity methods. Data from Chuang and Wang (2001), with permission from the Japan Wood Research Society, copyright 2005

Parameter	Type				
Plantation site	Type E	Type C	Type D	Type A	Type B
E_L stress wave	82.70 ± 6.14	94.30 ± 4.18	99.70 ± 10.11	101 ± 1.13	128 ± 6.06
Significant difference at $P < 0.05$	Ns	Ns	Ns	Ns	–
Plantation site	Type D	Type A	Type C	Type E	Type B
E_R stress wave	26.80 ± 2.43	29.90 ± 2.65	32.20 ± 9.00	33.20 ± 2.18	35.70 ± 1.81
Significant dif-	Ns	Ns	Ns	Ns	–
ference at $P < 0.05$	–	–	Ns	Ns	Ns
Plantation site	Type E	Type C	Type D	Type A	Type B
E_L ultrasonic waves	99.30 ± 11.70	114.00 ± 8.98	117.99 ± 3.87	117.00 ± 6.51	147.00 ± 10.07
Significant dif-	Ns	Ns	Ns	Ns	–
ference at $P < 0.05$	–	–	–	Ns	Ns
Plantation site	Type E	Type C	Type D	Type A	Type B
E_R ultrasonic waves	28.20 ± 2.23	29.30 ± 2.43	30.50 ± 1.03	32.90 ± 1.70	33.00 ± 1.32
Significant difference at $P < 0.05$	Ns	Ns	Ns	Ns	Ns

diameter of trees belonging to sites C, D and E. But no differences were found between the diameters of trees in sites A and B.

From Table 3.3 and from Fig. 3.11, it can be noted that the values of ultrasonic velocities are slightly higher than those determined with the stress wave method. The differences are probably due to the frequency differences between the two methods. Meanwhile, a decrease can be observed in velocity value and modulus of elasticity with increased spacing between trees. This is probably due to the effects induced by increasing annual ring width, the ratio of earlywood to latewood density, etc. These parameters are directly related to the plantation spacing. As can be seen from Table 3.4, a multiple new-ranged Duncan's test for the modulus of elasticity values with ultrasonic and stress wave methods, shows that the plantations can be classified as follows: type B > type A > type D > type C > type E. The plantation type B is characterized by the highest values of the modulus of elasticity and it can be admitted that rapidly growing trees with significant spacing (5×5 m) have low strength properties.

Based on these observations, it was stated that a classification of stands can be established and optimal management practices (pruning, thinning, etc.) selected.

3.5 Summary

Tree characteristic (diameter, height, etc.) measurements using acoustic sensors are required for the management inventory of forests, for timber volume estimation and for forestry planning and protection. The main morphological characteristics for grown inventory are the diameter, the height and the height/diameter ratio. The ultrasonic caliper allows noncontact measurement of trunk diameter and estimation of the cross-sectional area and height of the tree. The development of mobile robotics and sonar modules combines ultrasonic and laser techniques for measurements in dense forests and for all types of terrain and surroundings. Beside the trunk, both the root system and crown characteristics must be taken into account for the mechanical stability of trees against wind and storm. The geo-radar technique provides 3D images, while the "air-spade" technique uses a supersonic air stream to prevent any damage during excavation of the roots. The mechanical characteristics expressed by the moduli of elasticity can be measured with the ultrasonic velocity and stress methods. For both methods, the time of propagation of a shock is measured. In the case of the ultrasonic method, an electronic pulse is used, while in the case of the stress wave method, a mechanical shock is produced by a hammer. The measurement of the damping characteristics of the signal traveling through the standing tree is much more complex and is used mainly for the detection of internal defects. Appropriate devices and instrumentation are described. Mechanical characteristics are also used for the study of genotypic characteristics of different clones. Sylvicultural practices, illustrated by the influence of spacing on the wood quality of standing trees is demonstrated through the measurement of the modulus of elasticity.