Ecomatik

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Plant Growth
Sap Flow
Soil Moisture

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Dendrometer*

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Why we need dendrometer?

Dendrometers are instruments for continuous measurement of plant growth (changes of the plant diameter). Data of dendrometer document the reactions of plants to environment in high temporal resolution.

In ecophysiological research environmental parameters are measured hourly or shorter. The plant parameters such as yield, biomass and tree rings are only available annually. It is quite difficult to compare hourly data with annual data. Significance of such cause-effect studies on different time scales is limited.

Dendrometer allows us to record the plant parameters at the same time interval, such as environmental parameters. The data therefore permit the direct assignment of plant responses to environmental influences. Dendrometer are therefore a cost-effective and useful tool for ecophysiological studies

Applications

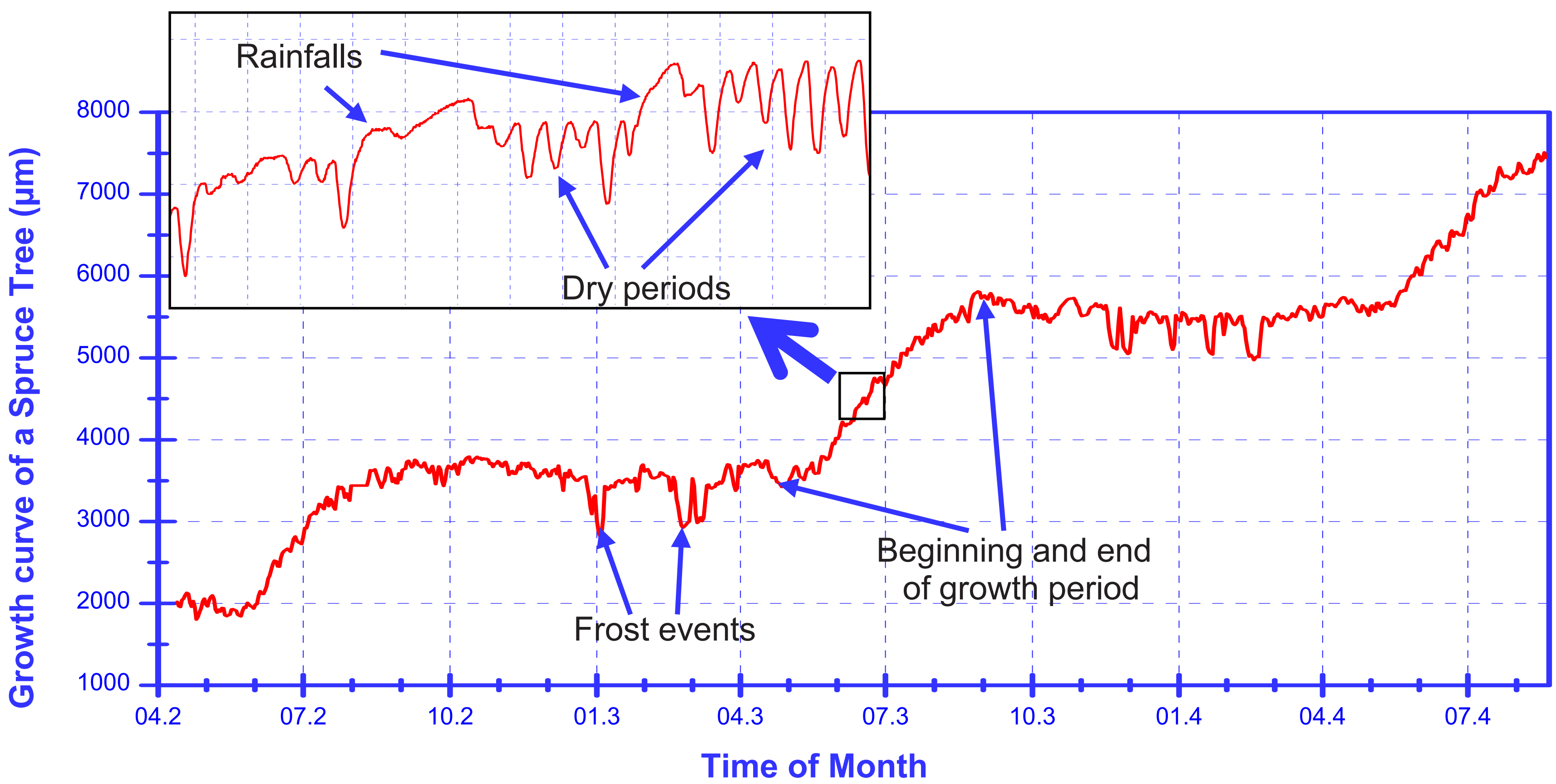
- Monitoring of the growth processes of plants
- Monitoring the water status of plants
- Examination of the influence of environmental factors on plant growth
- Precise dating of the beginning and end of growing season
- Precise determination of the point of frost events
- Estimation of the water content in plants (in combination with sap flow measurement the transpiration can be calculated continuously)
- Irrigation control
- Monitoring and investigation of the stability of road and park trees or branches

Benefits of Ecomatik Dendrometers

- Protected by several patented techniques
- Low power consumption, as more than one year records only with an internal battery
- More than 15 years of worldwide use (more than 40 countries, polar regions, tropical, high mountain)
- Resolution up to 0.2 microns (depending on data logger)
- Temperature effect compensated
- Large selection for different measurement requirements: radius, diameter, circumference, fruit, vegetables, vertical changes
- Compatible with all popular data loggers (e.g. Campbell, Delta-T, Datataker). ECOMATIK provides a Dendrometer logger (DL15), which runs on an internal battery more than two years.

Available Dendrometer Types

Name	Abbreviation	Suitable for diameter of
Radius dendrometer	DR	>8 cm
Diameter dendrometer small	DD-S	0-5 cm
Diameter dendrometer large	DD-L	3-30 cm
Circumference dendrometer 1	DC1	5-30 cm
Circumference dendrometer 2	DC2	>5 cm
Circumference dendrometer 3	DC3	>5 cm
Fruit and vegetable dendrometer	DF	0-11 cm
Vertical dendrometer	DV	>8 cm



A typical dendrometer curve

* Patents pending

DR Radius Dendrometer

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The sensor is anchored by two special screws in the heartwood. The changes outside of the heartwood correspond to the radial growth. The arrangement ensures high stability for long-term measurements.

Benefits

- Stability against wind, snow, falling branches and fruits
- Low pressure at the measuring point
- Suitable for large trees (diameter> 8 cm)
- Ideal for long-term measurement with less manpower

Limits

- Trunk is injured by drilling (the damage can be minimized by tree resin)
- Suitable only for larger trees (diameter > 8 cm)

Delivery

- Complete with 2 m cable

Options / Ordering Information

- Cable extension (please specify in meters)
- Installation tools (tree resin, hand drill)
- Data Logger

Technical specifications

Name	**Radius Dendrometer (DR)**
Suitable for plant size	Diameter > 8 cm
Range of the sensor	11 mm
Accuracy	±0.12 - ±1% (dependent on data logger used)
Resolution	±0.1 - ±2.6 µm (dependent on data logger used)
Linearity	1%
Thermal expansion coefficient of sensor	<0.1 µm/K
Operating conditions	Air temperature: -30 - 80° C, air humidity: 0-100

DD-S Diameter Dendrometer Small

The DD-S is designed specifically for agricultural plants, small trees and branches (diameter < 5 cm). Due to a patented mounting method, the dendrometer also provides for very small plants stable readings.

Benefits

- Suitable for small trees and agricultural plants
- The plants do not have to bear the weight of the dendrometer
- Measures diameter changes
- No Injury to plants
- Minimal load on the target
- Stability against wind, snow, falling small branches and small fruits
- Ordering by size of plants possible

Limits

- Not suitable for diameter greater than 5 cm (see Type DD-L)

Delivery

- Complete with 2 m cable
- Fixing materials and installation tools (wrench)

Options / Ordering Information

- Cable extension (please specify in meters)
- If necessary, different frame size
- Data Logger

Technical specifications

Name	**Diameter Dendrometer Small (DD-S)**
Suitable for plant size	Diameter 0 -5 cm (on request extendable)
Range of the sensor	11 mm
Accuracy	±0.12 - ±1% (dependent on data logger used)
Resolution	±0.1 - ±2.6 µm (dependent on data logger used)
Linearity	1%
Thermal expansion coefficient of sensor	<0.1 µm/K
Operating conditions	Air temperature: -30 - 80° C, air humidity: 0-100

DD-L Diameter Dendrometer Large

The sensor is mounted on a patented fastening technology at the plant. The sensor remains stable fixed at the measuring point without exerting too much pressure on the measuring point. The model is suitable for diameter of 3-30 cm.

Benefits
- Suitable for diameter 3-30 cm
- Measures diameter changes
- No Injury to plants
- Minimal load on the target
- Stability against wind, snow, falling small branches and small fruits
- Ordering by size of plants possible

Limits
- Not suitable for diameter greater than 30 cm

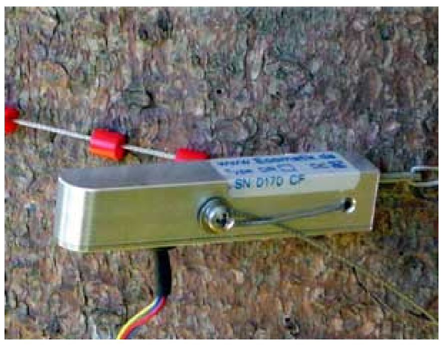
Delivery
- Complete with 2 m cable
- Fixing materials and installation tools (wrench)

Options / Ordering Information
- Cable extension (please specify in meters)
- If necessary, different frame size
- Data Logger

Technical specifications

Name	**Diameter Dendrometer Large (DD-L)**
Suitable for plant size	Diameter 3-20 cm (on request reducible)
Range of the sensor	11 mm
Accuracy	±0.12 - ±1% (dependent on data logger used)
Resolution	±0.1 - ±2.6 µm (dependent on data logger used)
Linearity	1%
Thermal expansion coefficient of sensor	<0.1 µm/K
Operating conditions	Air temperature: -30 - 80° C, air humidity: 0-100

DC1 Circumference Dendrometer



The Circumference Dendrometer 1 is the simple version for the measurement of circumference changes of plants. The sensor is mounted on the plant with a wire cable with a very low coefficient of thermal expansion. The slide rings reduce the friction between the wire cable and the tree bark. They also decrease the pressure of wire cable on the tree.

Benefits
- Suitable for diameter 5-30 cm
- No injury to plants
- Easy installation
- Stability against wind, snow, falling small branches and small fruits
- Readings directly correspond to the circumference changes

Limits
- Because of the tension of the wire cable is applied in the tangential direction the pressure of the wire cable to the tree depends on tree size. The smaller the tree, the greater the pressure. Thus the measured data between trees of different diameters are usually not comparable. In such cases, we recommend the use of Circumference Dendrometer 2 (DC2).

Delivery
- Complete with 2 m cables and 1 m wire cable

Options / Ordering Information
- Cable extension (please specify in meters)
- Extension of the wire cable (please specify in meters)
- Data Logger

Technical specifications

Name	**Circumference Dendrometer 1 (DC1)**
Suitable for plant size	Diameter 5-30 cm
Range of the sensor	11 mm
Accuracy	±0.12 - ±1% (dependent on data logger used)
Resolution	±0.1 - ±2.6 µm (dependent on data logger used)
Linearity	1%
Thermal expansion coefficient of sensor	<0.1 µm/K
Thermal expansion coefficient of the wire cable	$<1.4 \times 10^{-6}$/K
Operating conditions	Air temperature: -30 - 80° C, air humidity: 0-100

DC2 Circumference Dendrometer 2

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The DC2 is the improved version of the DC1. The tension is not applied in a tangential, but in the radial direction. The pressure of the wire cable to the tree is independent of tree size. The data of different tree sizes are comparable.
The sensor is mounted on a wire cable with very low thermal expansion coefficient at tree. The slide rings reduce the friction between the wire cable and the tree bark. They also decrease the pressure on the tree.

Benefits

- Suitable for all tree sizes (> 5 cm)
- Pressure of the wire cable to the tree independent of tree size
- Automatic adjustment of the tension, sensitive measurements even with very large trees
- No injury to plants
- Stability against wind, snow, falling small branches and small fruits
- Easy installation
- Easy adjustment by the integrated turnbuckle

Limits

- The data must be converted (free Excel program available)
- The tree must be roughly circular

Delivery

- Complete with 2 m cable and 1 m wire cable

Options / Ordering Information

- Cable extension (please specify in meters)
- Extension of the wire cable (please specify in meters)
- Free Excel program for data conversion
- Data Logger

Technical specifications

Name	**Circumference Dendrometer 2 (DC2)**
Suitable for plant size	Diameter > 5 cm
Range of the sensor	15 mm
Range in diameter	Because of the unique design the real measuring range in diameter is dependent from the tree size. Tree Diameter (cm) – Measuring Range (mm) 10 – 10 40 – 7 100 – 5
Accuracy	±0.12 - ±1% (dependent on data logger used)
Resolution	±2 - ±3.6 µm (dependent on data logger used)
Linearity	2%
Thermal expansion coefficient of sensor	<0.1 µm/K
Thermal expansion coefficient of the wire cable	<1.4 $\times 10^{-6}$/K
Operating conditions	Air temperature: -30 - 40° C, air humidity: 0-100

DC3 Circumference Dendrometer 3

The DC3 has the same structure as DC2. Only the sensor measuring range is greater than DC2. This meets the measurement requirements of fast-growing trees.
The **benefits, limits, delivery**, and **ordering information** of DC3 is the same as that of DC2.

Technical specifications

Name	**Circumference Dendrometer 3 (DC3)**
Suitable for plant size	Diameter > 5 cm
Range of the sensor	25 mm
Range in diameter	Tree Diameter (cm) – Measuring Range (mm) 10 – 23 40 – 17 100 – 12
Resolution	±3.3 - ±6.0 µm (dependent on data logger used)
Linearity	0.7%
Accuracy, Thermal expansion coefficient of sensor and wire cable, and Operating conditions is the same as that of DC2	

DF Fruit and Vegetable Dendrometer

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Fruit and Vegetable Dendrometer is the special version for circular targets. The fruit in the measuring frame is firmly fixed without affecting its growth. The frame bears the weight of the target.

Benefits
- Suitable for diameter between 0 and 11 cm (other size on request)
- Fruits do not have to bear the weight of the dendrometers
- Measures diameter changes
- No Injury to fruits
- Stability against wind, snow, falling small branches and small fruits

Limits
- Not suitable for very soft fruit and vegetables (such as ripe tomatoes)

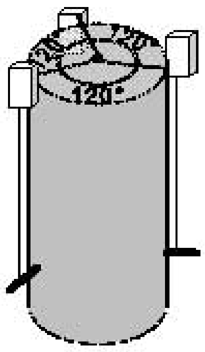
Delivery
- Complete with 2 m cable
- Fixing materials and installation tools (wrench)

Options / Ordering Information
- Cable extension (please specify in meters)
- If necessary, different frame size
- Data Logger

Technical specifications

Name	Fruit and Vegetable Dendrometer (DF)
Suitable for plant size	Diameter 0 -11 cm (on request reducible)
Range of the sensor	15 mm
Accuracy	±0.12 - ±1% (dependent on data logger used)
Resolution	±2 - ±3.6 µm (dependent on data logger used)
Linearity	2%
Thermal expansion coefficient of sensor	<0.1 µm/K
Operating conditions	Air temperature: -30 - 80° C, air humidity: 0-100

DV Vertical Dendrometer

The Vertical dendrometer is developed to determine the vertical changes (not growth) of trees continuously. Because the trees vary in length according to water status, wind direction and curvature, the vertical change is an interesting measure to assess the water status, mechanical stress, stability and direction of growth of the trees.
In order to cover the different causes (water status, curvature) separately, a parallel measurement is of three directions with three vertical dendrometers necessary.

Benefits
- Suitable for large trees (diameter>8 cm)
- Stability against wind, snow, falling branches and fruits

Limits
- Trunk is injured by drilling (the damage can be minimized by tree resin)

Delivery
- Complete with 2 m cable

Options / Ordering Information
- Cable extension (please specify in meters)
- Installation tools (tree resin, hand drill)
- Data Logger

Technical specifications

Name	DV Vertical Dendrometer
Suitable for plant size	Diameter > 8 cm
Range of the sensor	11 mm
Accuracy	±0.12 - ±1% (dependent on data logger used)
Resolution	±0.1 - ±2.6 µm (dependent on data logger used)
Linearity	1%
Thermal expansion coefficient of sensor	<0.1 µm/K
Thermal expansion coefficient of the wire cable	$<1.4 \times 10^{-6}$/K
Operating conditions	Air temperature: -30 - 80° C, air humidity: 0-100

Data Logging and Communication

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ECOMATIK dendrometers are compatible with all popular data loggers (e.g. Campbell, Delta-T, DT80). We give you support for connecting our dendrometers with the data loggers.

ECOMATIK provides a wireless data logger and den dendrometer data logger DL15.

The Wireless Data Logger: Logs and wirelessly transmits real-time data to your computer, suitable for intensively monitoring tree growth in small area (green house, nursery).

Dendrometer Data Logger (DL15)

The DL15 is a battery powered, weather proof, 4-channel data logger. It runs on an internal battery more than one year. It is suitable for long-term monitoring tree growth.

Technical specifications

Name	**Dendrometer Data Logger (DL15)**
Memory	64 Kb (43 000 readings) If you connect 4 dendrometers, and collect data every 30 min., the memory will store data of 43000/48/5= 179 days
Resolution	2.6 µm for Dendrometer types: DD-L, DD-S, DC1, DR, DV 3.6 µm for Dendrometer types: DC2, DF 6 µm for Dendrometer type: DC3
Accuracy	±1% Temperature effects compensated
Interface	USB interface to PC
Channel	4, for connecting up to 4 dendrometers
Logging Interval	1 sec. to 18 hours
Power supply	One 3-Volt CR-2032 Lithium battery. A new battery will typically last one year if logging interval is greater than one minute
Environment	Suitable for outdoor conditions Temperature: Logging: -20° to 70° C, Launch/Readout: 0° to 50° C, Humidity: 0-95%, non-condensing

Worldwide users of our dendrometers in more than 40 countries

Universitat Politècnica de Catalunya, Barcelona
Chinese Academy of Forestry, Beijing
Swiss Federal Institute for Forest, Snow and Landscape, Birmensdorf
Universität Bonn, Dendroökologisches Labor, Bonn
Deutsche Forschungsgemeinschaft, Bonn
DBIO-APNA, Brussels
Vrije Universiteit Brussel, Brussels
INRA-EPHYSE, CESTAS Cedex
Brandenburgische Technische Universität, Cottbus
Debrecen University, Debrecen
Johann Heinrich von Thünen-Institut, Eberswalde
University of Erlangen-Nuremberg, Erlangen
University Duisburg-Essen,Essen
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Bayerische Landesanstalt für Landwirtschaft, Freising
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Johannes Gutenberg University Mainz, Mainz
Ludwig-Maximilians-University Munich, München
Helmholtz Zentrum München, Neuherberg
Tulane University, New Orleans
Lamont-Doherty Earth Observatory of Columbia, New York
USDA Forest Service, Olympia
Norwegian Univ of Life Sciences, Oslo
University of Oxford, Oxford
Helmholtz-Zentrum Potsdam, Potsdam
Beuth Hochschule für Technik Berlin, Potsdam-Bornim
CSIR Natural Resources and the Environment, Pretoria
Direction de la recherche forestière, Québec
McGill University, Québec
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National Taiwan University, Taipei
Bayerisches Amt für forstliche Saat- und Pflanzenzucht, Teisendorf
Technische Universität Dresden, Tharandt
University of Aarhus, Tjele
University of Arizona,Tucson

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SF-L Sap Flow Sensor*

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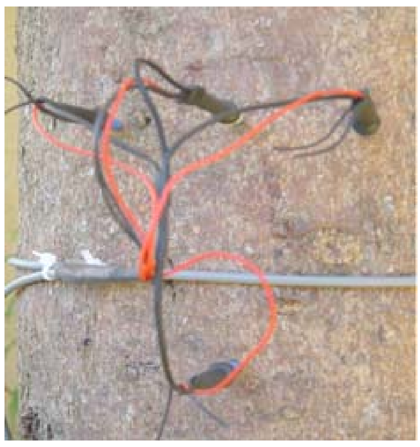

- Continuous monitoring of sap flow in trees
- Improved “well known” Granier Sap Flow Sensor
- Accurate measurement of night-time sap flow
- Enhanced accuracy and reliability
- Simplified data processing
- Complete installation tools

Introduction

The well known Granier sap flow sensor, i.e. thermal dissipation probe (Granier, 1985) uses heat as a tracer of sap flow. Due to its simplicity, reliability and affordability, several scientists have used the Granier technique all over the world. However, the technique has always had some shortcomings, which include:

1). Granier technique determines arbitrarily the sap flow to a zero value every night. This contravenes the possibility of night-time transpiration (Granier, 1987) and the fact of refilling process of tree body during the night. (Do and Rocheteau, 2002).

2). The technique ignores the effect of natural temperature gradients of the sap-wood being measured, which range between +/- 1.5 ° C (fig. 1) and can cause considerable error in the results (DO and Rocheteau, 2002).

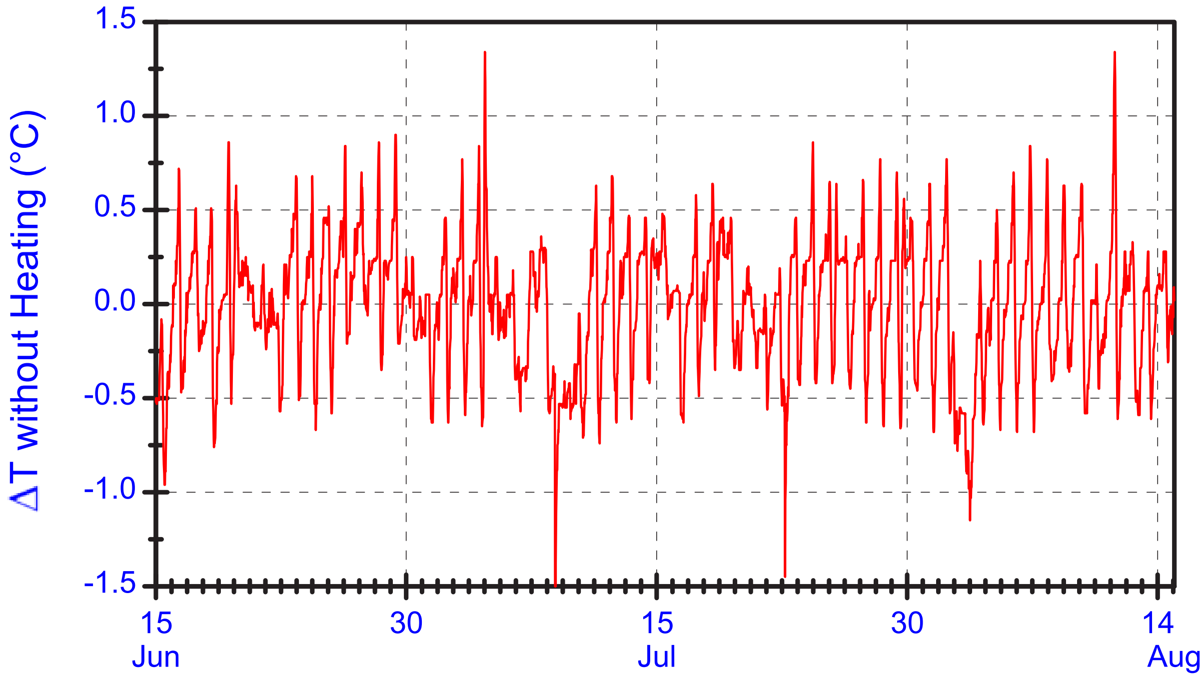

Fig.1 Vertical temperature gradients of a 40- year old spruce tree, measured with a Granier sensor without heating.

The SF-L Sensor

The SF-L sensor takes into consideration the variations of the natural temperature gradients of sapwood. The sensor uses two reference thermocouples to continuously record background temperature gradients (*ΔTR1, ΔTR2*) of the sapwood. During data processing, values of the temperature diffe-rences between the heated needle and the sapwood ambient temperature (*ΔT*) are corrected by the *ΔTR1, ΔTR2*.

The new sensor therefore considerably enhances accuracy and reliability in sap flow measurements through continuous correction of natural temperature gradients of the sapwood. In contrast to Granier tech-nique, SF-L sensor provides a very stable and more accurate ΔTmax value (temperature difference between the heated needle and the sapwood ambient tempera-ture when sap flow=0). ΔTmax value is attained under conditions of zero transpiration and zero tree body refilling. This means 100% air humidity and zero tree diameter expanse. The diameter changes are detectable with high accuracy Ecomatik dendrometer (fig. 3).

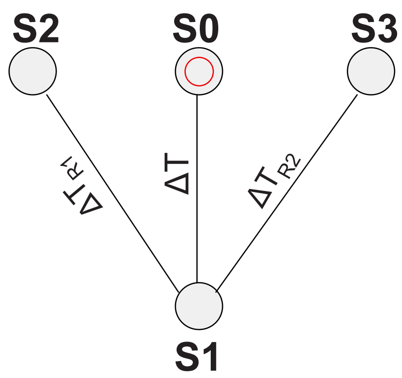

Fig. 2 Schematic diagram of the SF-L sensor

Usually there is only one universal ΔTmax in a growth period of a tree. The ΔT values in the night are dependent on the refilling state of the tree and the transpiration demand and ra-rely attainΔTmax. Correct determination ΔTmax value enables accurate measurements of the night sap flow. With the SF-L sensor, data pro-cessing is also highly simplified because it is no longer necessary to search for maximum temperature differences every night.

The SF-L sensor is easy to use. All necessary tools and spare parts are available at ECOMATIK.

* Patents pending

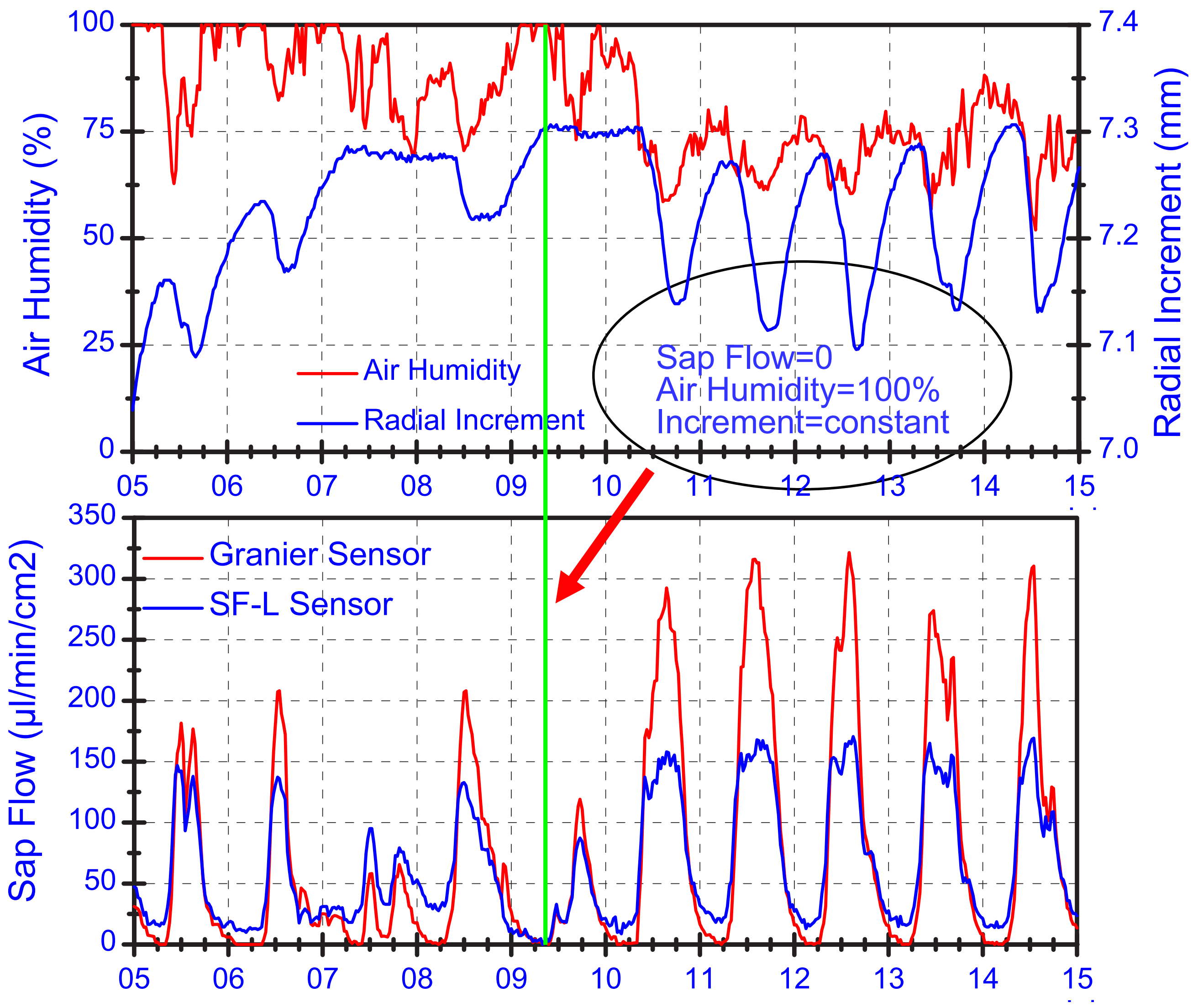

Fig. 3 Above: Air humidity and radial changes of a 40-year old spruce tree measured with an Ecomatik dendrometer type DD. Increase in diameter at night indicates that the tree continues to take up water even during nighttime hence sap flow is not zero.
Below: Comparison between sap flow measured with Granier sensor (red line) and with SF-L sensor (blue line). The Granier sensor shows zero sap flow every night while the SF-L detects zero value only on the night of 9. July, when air humidity reached 100% and the tree body fully saturated with water.

Technical specifications

Sensor	
Sensor composition	4 needles
Needle size	33 mm length, 1.5 mm diameter
Heating zone	20 mm from top of the needle
Cable length	0.7 m, extendable to 20 m
Tree size	Diameter>20 cm
Power consumption	0.2 W +/-5%, 84 mA DC, stabilized
Output	-100 µV to 1000 µV DC
Data Recording	3 differential channels required
Power supply	
Input	12 V DC
Output	84 mA stabilized, suitable for 1 to 3 SF-L sensors

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SF-G Sap Flow Sensor

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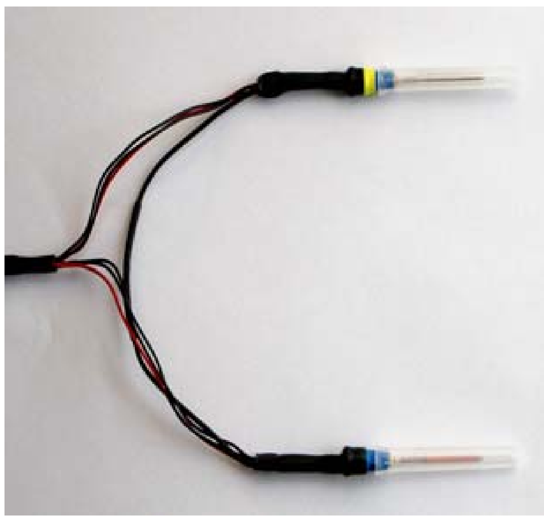

Technical Specifications

Sensor composition	2 needles
Needle size	33 mm length, 1.5 mm diameter
Heating zone	20 mm from top of the needle
Cable length	0.7 m, extendable to 20 m
Tree size	Diameter>5 cm
Power consumption	0.2 W +/-5%, 84 mA DC, stabilized
Output	100 µV to 800 µV DC
Logger requirement	1 differential channels

Introduction

The SF-G is the well-known thermal dissipa-tion probe (TDP) developed by Granier (1985) for measuring sap flow in trees. The sensor consists of two identical manufactured needles with copper-constantan thermocouples and a special heating wire. The two needles are inserted into the sapwood, one above the other 15 cm apart directly below. The top needle is heated with constant energy supply (=constant current source). The temperature difference between two needles ΔT resulted from the above heated and blow unheated needles correlates to the sap-flow-density.

Equitensiometer*

www.ecomatik.de

Type EQ15/Adapter: Equipped with screw adapter to connect with an extension tube, enabling deep soil installation

- Worldwide, the first highly accurate instrument for measuring soil matric potential
- Due to a patented technique long-term measuring stability
- Cover the whole range of soil water potential in which plant growth occurs (0 - -1500 kPa)
- Individually calibrated sensors
- Maintenance-free for outdoor conditions, not affected by over-range
- Independent operation on a wide range of soil types and conditions
- Very low power consumption
- Easy installation
- Data recording with data logger or display with simple voltmeter
- More than 5 years field testing

What is matric potential?

There are two ways to measure soil moisture status, namely: Soil water content (SWC) and soil water potential (ψs). Soil water content describes the amount of water in a given amount of soil relative to the mass of oven-dried soil. Metric potential (ψm), defined as the amount of work that must be done per unit quantity of pure water in order to transport reversibly and isothermally an infinitesimal quantity of water, identical in composition to the soil water , from a pool at an elevation and the external gas pressure of the point under consideration (Glossary of Soil Science Terms, Soil Science Society of America (SSSA), July 2000). If the specified quantity is volume, the potential is referred to as pressure (Pascal). Metric potential (= suction, moisture tension resulting from combined effects of capillarity and adsorptive forces within the soil matrix) is the main component of total soil water potential. In non-saline soils the total soil water potential (ψs) is equal to th e matric potential.

Why we need matric potential?

Plant-water relation studies require information on soil water availability (dryness of soil). Soil water availability is expressed as soil water potential (ψs), and not water content (swc). The two are however, related parameters:

Soil Water Availability = Water Potential
= f(Water Content, Soil Properties)

Soil water availability is, therefore, accu-rately described by its water potential, which is a function of water content and the soil properties. It is not possible to derive water availability only from its water content. For example, a given plant could be turgid and growing very well in a sandy soil with 10% water content, but in clay soil with the same water content, the same plant could be wilting and dying.

Even if data on both water content and soil properties are available, the derivation of water potential from them is not simple, calling for actual measurements of soil water potential.

Due to lack of practicable instruments for measuring soil water potential under field conditions scientists have often used water content measurements to study soil-water–plant relationships. The disadvantage of such water content related studies is that the results cannot be reproduced and compared under different soil conditions. Many scientists have been working on plant-water relations to assist farmers identify the threshold value for irrigation water supply and several publications exist to the effect. However, none is able to answer the question; “How much soil moisture should I keep to meet optimal demands of my plants?” On a global context, this has lead to enormous loss of water resources. This problem could be solved, if we used soil water potential instead of soil water content for our research works
and in water resource management.

* Patents pending

Principle of operation

Equitensiometer consists of two parts: water content sensor and equilibrium body. The water content sensor is permanently attached to the equilibrium body and determines the water content in the equilibrium body instantaneously. The equilibrium body has a stable soil moisture characteristic.

During measurements, the equilibrium body acquires matric potential of the surrounding soil and this is recorded by the water content sensor and converted into matricpotential

Comparison of techniques for measuring matric potential

The concept of describing soil water availability for plants using water potential (Ψ) is known since 1907 (E. Buckingham). Scientists and engineers long recognized the importance of this measure and several attempts have been made in the last century to build equipment that can directly measure soil water potential (Ψs). Currently, there are only three existing techniques available namely; tensiometer, resistance block (gypsum block, watermark) and psychrometer. All the three techniques however, have practical limitations with regard to range of operation, accuracy and costs. Accurate monitoring of soil water potential under outdoor conditions is still a pipe dream for many scientists.

Comparison of techniques for measuring matric potential

Techniques	Range (kPa)	Advantages	Disadvantages
Resistance blocks	-100- -700	1. Inexpensive	1. Must be calibrated individually by user 2. Unreliable measurement 3. Just for rough estimating the matric potential
Psychrometer	-200- -10000	1. Useful in very dry soil 2. Measures totals water potential	1. Does not function in wet soil 2. Sensitive to temperature gradients in the soil 3. Expensive 4. Not suitable for outdoor conditions
Tensiometer	0- -85	1. Relatively reliable	1. Does not function in dry soil 2. Costly maintenance and service 3. Not suitable for monitoring water availability for plants
Equi-Tensiometer	0– –1500	1. Relatively reliable 2. Covers the whole range of matric potential for plant growth 3 Maintenance-free measurement	1. No linear output

Working with Equitensiometer

- **Accuracy and Range**

Equitensiometers are individually calibrated during production and every sensor has its own calibration certificate. This guarantees high sensor accuracy.

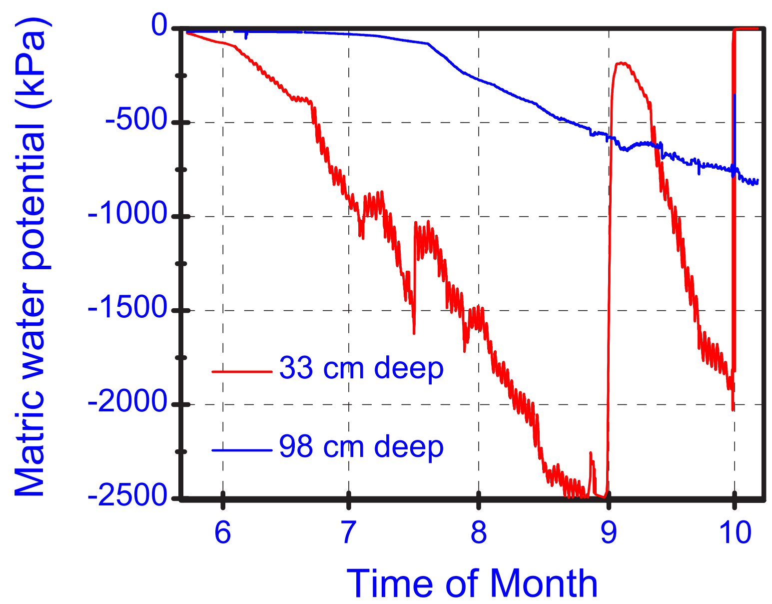

Fig.1 Course of matric potential in a Quercus suber Stand

A standard version sensor has a measuring range from 0 to -1500 kPa (0- -15 bar). For special requirements, the range can be extended up to -2500 kPa (fig. 1), but with reduced accuracy. A refill such as in transducer tensiometer is also not necessary.

- **Effect of soil properties on the measurements**

Unlike water content, water potential is an absolute measure and is independent of physical soil properties. For this reason the performance of Equitensiometer is not affected by the variation of physical soil properties (density, clay/sand/stone content and organic matter content).

The matric potential is derived from water content read within the equilibrium body. This is a decisive deviation from the gypsumblock, which converts the electrical conductivity of soil solution to matric potential and is very sensitive to conductivity of soil solution. Thus the EQ15 operates within a wide range of conditions and is independent of the soil chemical properties. However, in saline soils with conductivity>1 m S/cm, the results may be shifted to the dry range.

● Hysteresis

Equitensiometer is especially suit-able for continuously monitoring matric soil water potential. The equilibrium body consists of materials with higher water conductivity than any soil types. Under natural rains or irrigation condi-tions, the sensor can accurately follow any changes in soil matric potential without hysteresis (see fig. 2). But under artificial conditions if the matric potential is rapidly changed by more than 20 kPa/minute, the sensor may show hysteresis. This property limits instantaneous measurements with the Equitensiometer.

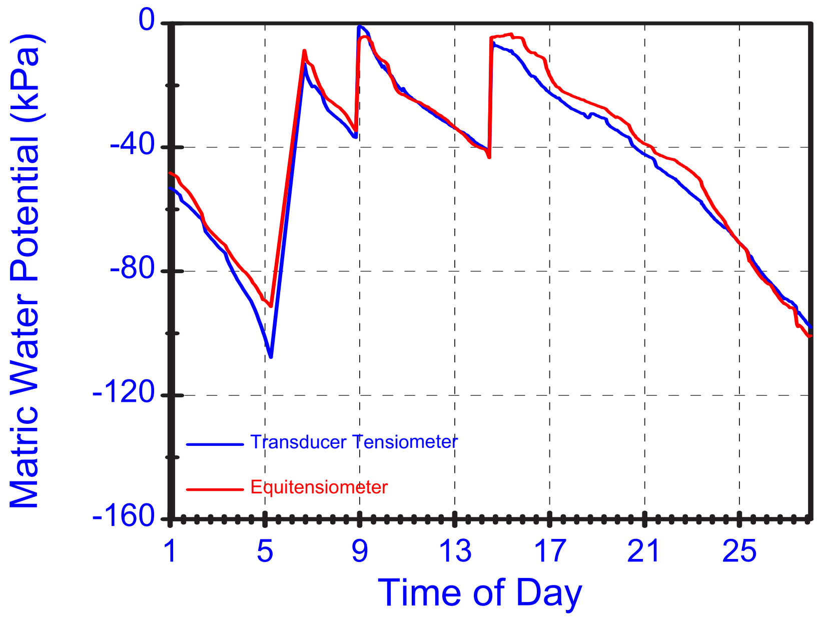

Fig. 2: Comparing the sensitivity of the EQ15 (red line) with transducer tensiometer (blue line). The soil was periodically irrigated. Either during the wetting or drying phases there were no significant differences between both sensors.

● Long term measurements

Fig. 4 shows results from Equitensiometer, when measurements were conducted in two neighbouring spruce and beech stands in Bavaria. The sensors worked for more than two years without any servicing.

● Installation

Equitensiometer is easy to install. The sen-sor is installed at the desired depth by burrowing and refilling the hole. In case of stony soil the sensor should be covered with quartz powder (or soil material with particle size between 20 to 100 µm) to improve the con-tact between the equilibrium body and soil. For installation in deep soil the use of the type EQ15/Adapter with an extension tube is re-commended. The disturbed soil structure does not affect the sensor performance.

● Data recording and Data processing

The Equitensiometer output is volt and ranges between 100 and 1000 mV. Any data logger with function of voltage measurement can be used for continuous data recording. For dis-continuous measurements, the data can be read out with a simple voltmeter. Ecomatik supplies different logger types for different requirements.

Each Equitensiometer is provided with its own calibration certificate (fig. 3), which gives the relationship between mV output, as read by the Equitensiometer, and its corresponding matric water potential in kPa. With the calibration certificate (fig. 3), the data output can easily be automatically converted into kPa by data logger or by calculating using a computer.

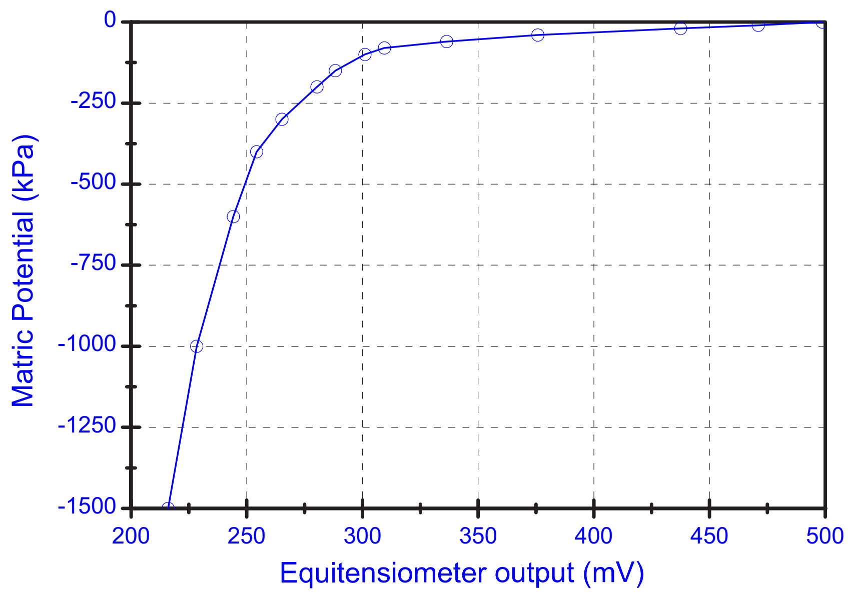

Fig. 3 Typical Calibration data of Equitensiometer

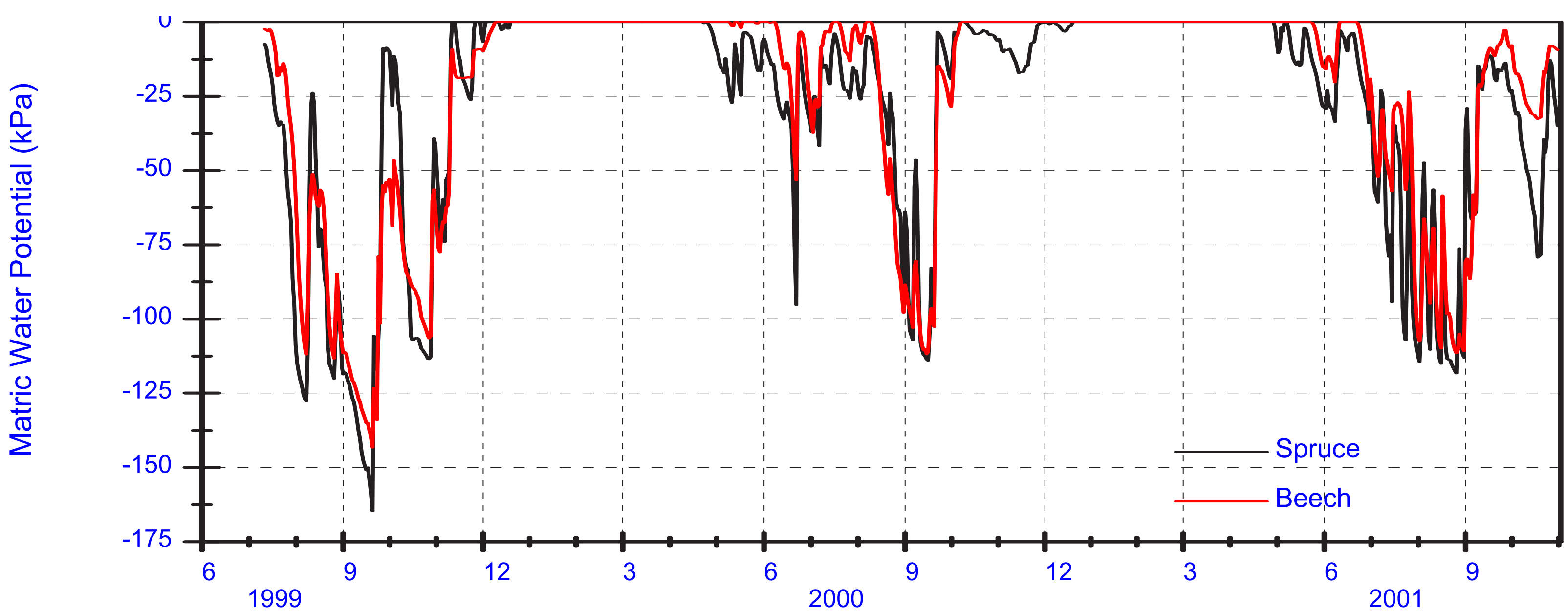

Fig. 4 Matric water potential in two neighbouring spruce and beech stands in Bavaria continu-ously measured with Equitensiometers. Corresponding to the transpiration characteristics the soil under spruce stand in Spring and in late Autumn is dryer than under beech stand (Unpublished data of Technical University of Munich).

Technical specification

Measuring parameter	Matric potential of soil.
Range	0 to –1500 kPa (0 to –15 bar).
Accuracy	Between 0 kPa and -100 kPa: ±10 kPa. Between -100 kPa and -1500 kPa: 10%.
Hysteresis	Very low, can accurately follow any changes of matric potential in soils.
Use area	Monitoring of soil hydrology, plant physiology, soil water status, Irrigation control etc.
Environment	Wide ranging soil types for long periods.
Interface	Input requirements: 5-15 V DC, Current consumption: max. 23 mA, Output signal: 100 -800 mV DC.
Case material	Stainless steel.
Dimensions and weight	Length × width × thickness = 17 cm × 4 cm × 2 cm, standard cable length: 5 m, max. Length: 100 m, weight: 350 g without cable.

Ordering Information

EQ15/Basic	Basic version for use in shallow soils
EQ15/Adapter	Equipped with a screw to connect with an extension tube, enabling installation in deep soils.
EQ15/Tube-1m **EQ15/Tube-2m**	1 m PVC extension tube. 2 m PVC extension tube.
EQ15/Cable	Additional cable fitted to EQ15. Max. recommended length 100 m.
Quartz powder	To improve the contact of EQ15 to soil, recommended for use in stony soils.
Data Logger	On request.

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