HTTPS://WWW.NATURE4.ORG/

TREETALKER VERSION: TT+

Suggested firmware: TT3_2_plus.5_0h

# TT+ User Manual




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## 1. Introduction

Nature4.0 is developing a set of IoT devices dedicated to environmental monitoring including terrestrial ecosystems and ocean applications. One of our application (see www.nature4.org) is the TreeTalker which we provide in several versions: TT+ (using thermal dissipation for sap flow), TT++ (using heat pulse velocity), TT-CARBON (for specific carbon sequestration studies) and TT-FIRE (for fire prevention and detection).
The present manual refers to TT+ that use the thermal dissipation probe for sap flow measurements (Granier method).

*A brief on sap flow measurements by the thermal dissipation method (Granier method)*
The transpiration rate of whole plants is closely approximated by the sap flow rate in the main stem or trunk. For these reasons there is a need for a relatively simple and affordable device to continuously monitor the sap flow rate in trees of all sizes. A method for that purpose was proposed by Granier (Granier, 1987), who inserted a needle, containing an electric heater, in the sapwood of a trunk and measured the difference between the temperature of the heated needle and that of the sapwood some distance below the needle. The method is relatively simple and it is called the Thermal Dissipation Probe (TDP) method. TDP heated needle is an improved heat dissipation sensor, as proposed by Granier, which measures the temperature of a line heat source implanted in the sapwood of a tree, referenced to the sapwood temperature at a location well below the heated needle. The probe measures the sapwood heat dissipation, which increases with sap flow and cool the heat source. When the sap flow velocity is zero or minimal, the temperature difference (ΔT) between the two sensors is maximal. When the flow increases, this temperature difference decreases. Moreover, many factors are involved to decide about the number of inserted probes in the trunk to measure sap flow, such as tree's diameter and stem uniformity. A single probe may be used on trees 3-5" (to 125 mm) in diameter, but two or more probes are recommended for trees in the 5-8" (to 200 mm) diameter range. Very large trees, over 8" (200 mm) may require four or more. In closed canopies, where trees are more uniform in size and spacing, good results are reported with just one probe per tree, regardless of size. It should be understood that the sap flow velocity varies within the sapwood, so unknown parameters like sapwood thickness introduces some uncertainty in the calculation of the sap flow.

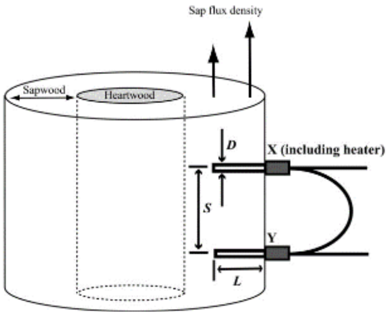


Figure 1.Sup flux density in greenwood stem based on Granier method

In the following, Nature 4.0 describes a new product, TT+, which meets the above needs to measure sap flow and some other variables related to tree physiology and meteorological parameters.

## 2. TT+ Layout

Taking advantage of IoT, a new device the Tree-Talker version “TT+”, is developed to measure simultaneously important individual tree scale ecophysiological parameters as well as some additional ecosystem-related variables. Key parameters are:

1) Tree radial growth, as an indicator of photosynthetic carbon allocation in biomass

2) Sap flow, as an indicator of tree transpiration and functionality of xylem transport

3) Xylem moisture content as indicator of hydraulic functionality

4) Light penetration in the canopy in terms of fractional absorbed radiation

5) Light spectral components related to foliage dieback and physiology

6) Tree stability parameters to allow real time forecast of potential tree fallings.

Additional parameters such as air relative humidity and air temperature will be also monitored at high frequency to have comparable time scale between abiotic parameters and short-term plant responses.

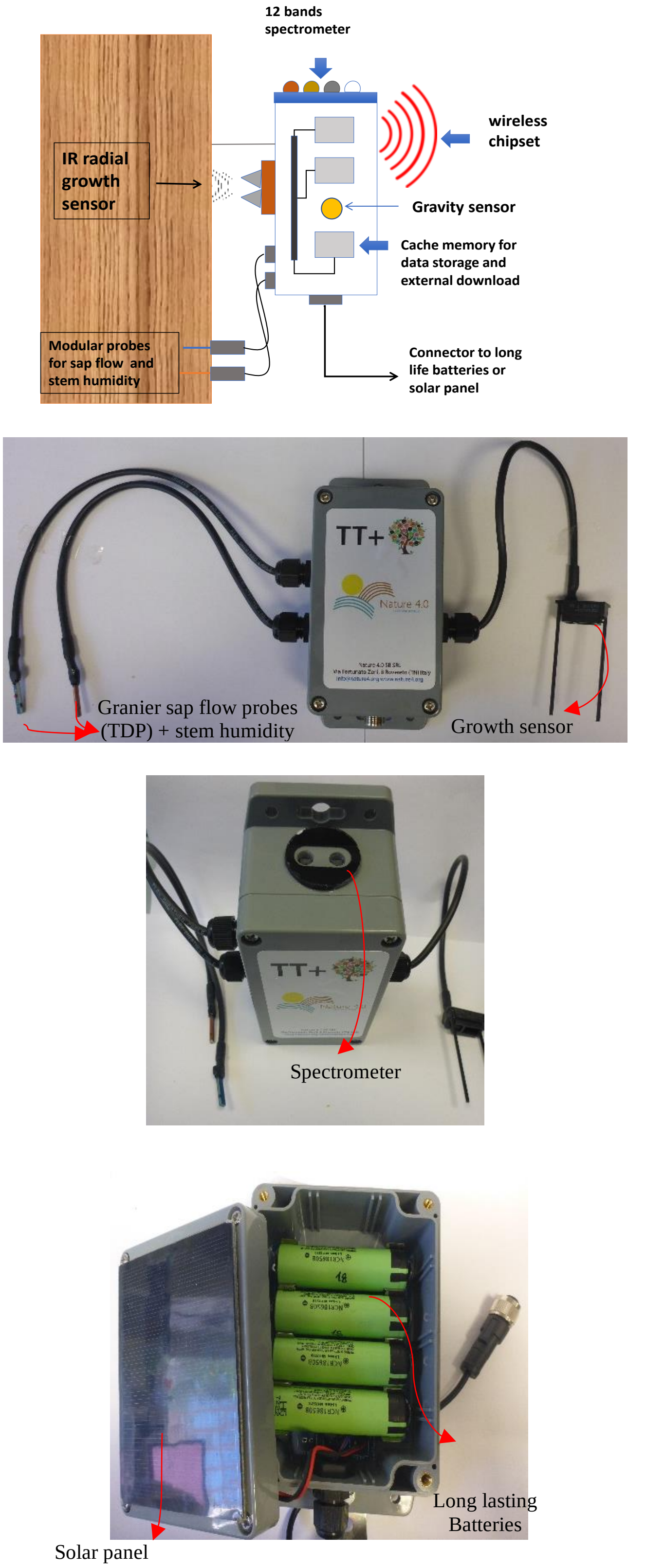


Figure 2. TT+ layout

| TT+ Structure | |
|---|---|
| 1 | Microprocessor reset button |
| 2 | Microprocessor External crystal 8 MHz |
| 3 | Microprocessor |
| 4 | Square frequency generator |
| 5 | Voltage regulator 3,3V |
| 6 | Accelerometer |
| 7 | Microprocessor serial programming header |
| 8 | Radio Antenna 868MHz |
| 9 | Diode, save device from reverse battery polarity insertion |
| 10 | Radio Module 868MHz |
| 11 | Heat probe connector |
| 12 | Reference probe connector |
| 13 | Growth sensor connector |
| 14 | Battery connection |
| 15 | Spectrometer |

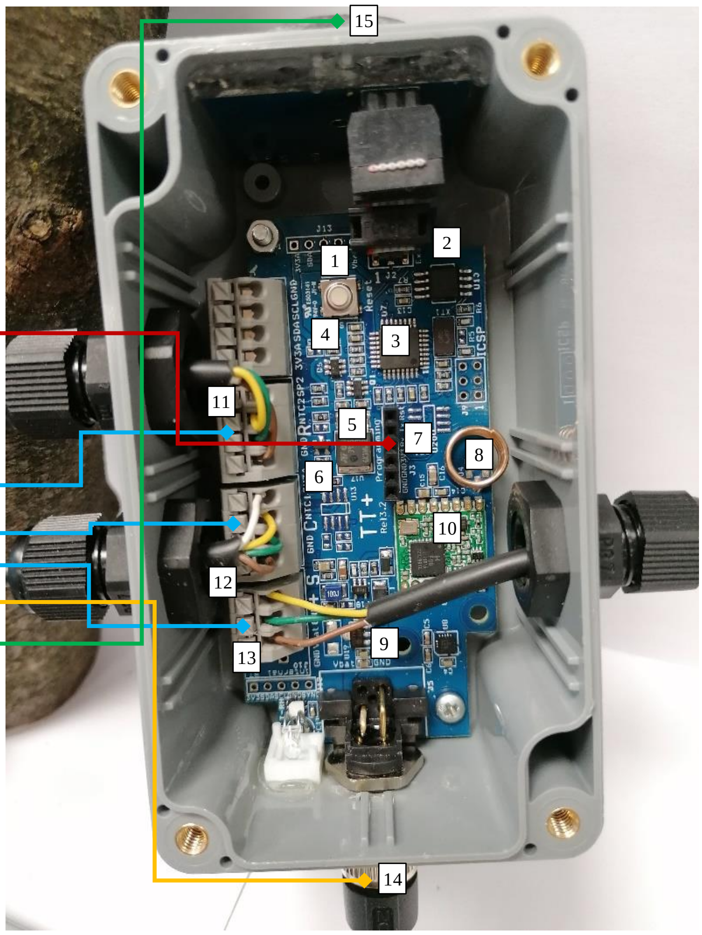


Figure 3. TT+ structure

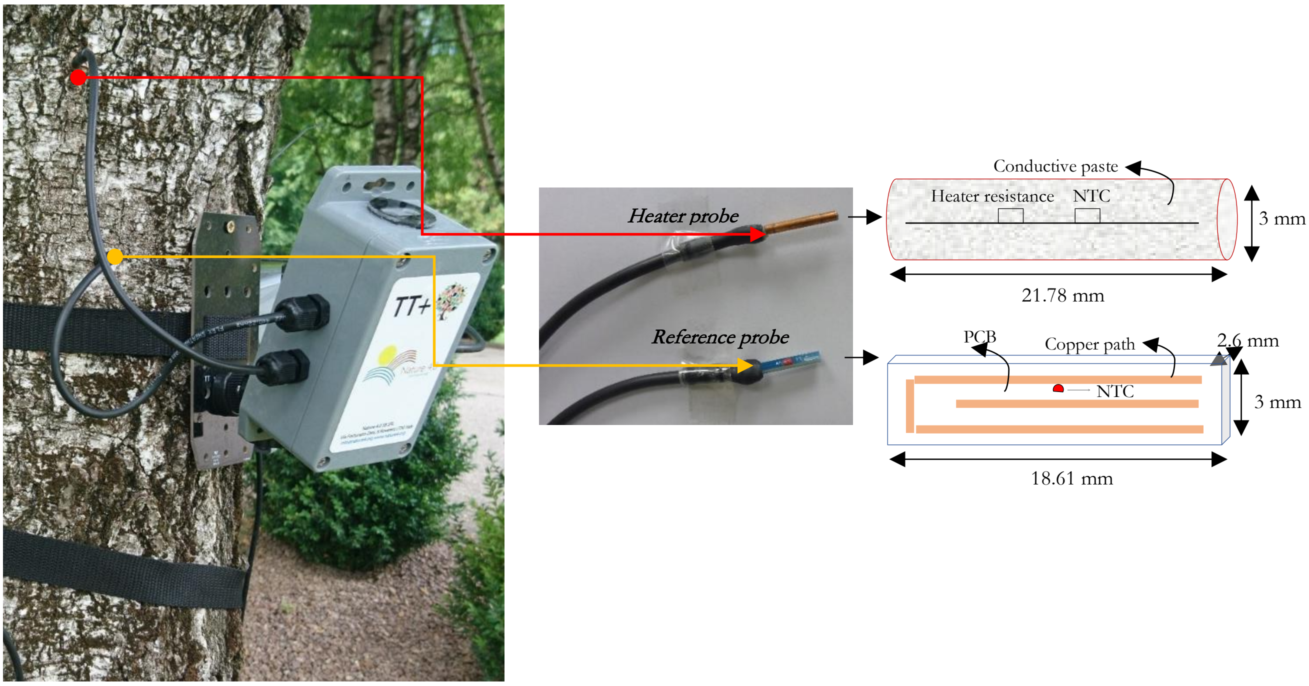


Figure 4. Heater and reference probes in Granier_Type method

## 3. TT+ Data String

Each TreeTalkers is hosted by a TTcloud and then all data transmits to the data server at the following address www.altervista.org.
For each forest site, one TTcloud with a cluster of TreeTalkers is connected. A cluster maximum can include 48 TTs but, to avoid radio collisions, the ideal situation is to keep 20 to 30.
You can access your data in the following commands:
http://naturetalkers.altervista.org/"*insert your TTcloud ID*"/ttcloud.txt
Click the link below to see an example of TT+ data string:
http://naturetalkers.altervista.org/C1960060/ttcloud.txt

10.02.20 13:14:46,52010001;263;4D;1581336000;35316;35135;62750;42514;17;26;210;-3894;0;-76;0;-1319;0;35234;29259;8905;79185
10.02.20
13:15:02,52010001;264;49;1581336000;3315;2985;10053;12202;12064;12370;7513;9705;11017;9242;6211;4368;50;3

In order to organize the data, each string of TT+ can be arranged with specific headers as a below table format.

Table 1. TT+ data sample

| **TT+ 3.2. (Granier_Type+12 Spectral Bands)** | | | |
|---|---|---|---|
| ***string' type 4D*** | ***example*** | ***string' type 49*** | ***example*** |
| Server Date | 10.02.20 | Server Date | 10.02.20 |
| Server Time | 13:14:46 | Server Time | 13:15:02 |
| TT ID | 52010001 | TT ID | 52010001 |
| record_number | 263 | record_number | 264 |
| device type | 4D | device type | 49 |
| Timestamp | 1581336000 | Timestamp | 1581336000 |
| Tref_0 [d.n.] | 35316 | AS7263_610 [d.n.] | 334 |
| Theat_0 [d.n.] | 35135 | AS7263_680 [d.n.] | 70 |
| growth sensor [d.n] | 56434 | AS7263_730 [d.n.] | 53 |
| adc_bandgap [d.n.] | 42514 | AS7263_760 [d.n.] | 48 |
| number of bits | 17 | AS7263_810 [d.n.] | 56 |
| Air relative humidity [%] | 26 | AS7263_860 [d.n.] | 51 |
| Air temperature [10*° C] | 210 | AS7262_450 [d.n.] | 50 |
| g_z(mean) [d.n.] | 376 | AS7262_500 [d.n.] | 67 |
| g_z(std.dev) [d.n.] | 0 | AS7262_550 [d.n.] | 297 |
| g_y (mean) [d.n.] | 1980 | AS7262_570 [d.n.] | 243 |
| g_y (std.dev) [d.n.] | 0 | AS7262_600 [d.n.] | 362 |
| g_x (mean) [d.n.] | 3604 | AS7262_650 [d.n.] | 145 |
| g_x (std.dev) [d.n.] | 0 | integration time | 50 |
| Tref_1 [d.n.] | 35234 | gain | 3 |
| Theat_1 [d.n.] | 29259 | | |
| *StWC [freq* (Hz)] | 49951 | | |
| adc_Vbat [d.n.] | 79185 | | |

***Note:***

The second way to reach the data is connecting directly to a device. Each TT+ has 16 Mb internal memory in order to save data (> than 10 years). Data can be uploaded directly from TT+ by 6 pins cable which can connect to microprocessor serial programming header (see figure 3 block no. 7).

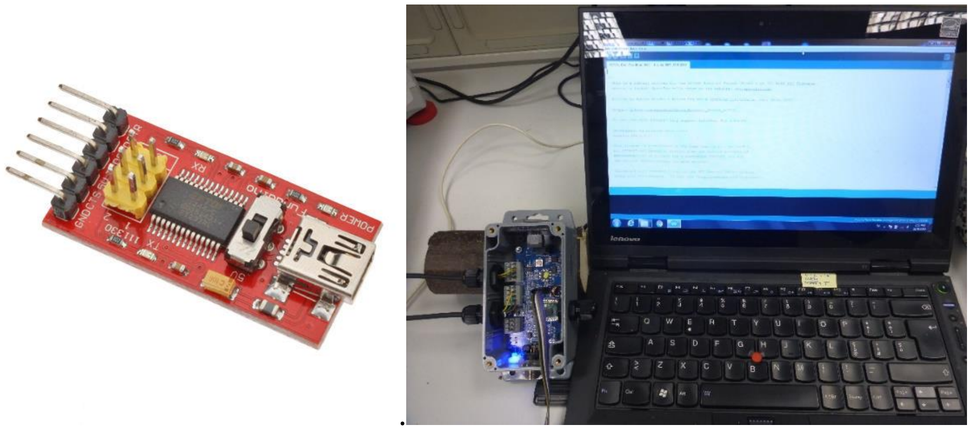

Figure 5. Uploading TT+ data directly by 6 pins cable

## 4. Explanation of Data String

### *4.1. Date & Time*

- "10.02.20 13:14:46"; is the timestamp of the server when the router transmits the data. This timestamp may or not coincide with the real timestamp of the measurement (see later) since it depends on the availability of the GPRS signal. Thus, it cannot be used as real timestamp.

### *4.2. Serial Number*

- "52010001"; Serial number of TT+ which distinguish each device from others

### *4.3. Record Number*

- "263"; progressive number of the record in memory (hexadecimal) (in order to convert to the number, use the following formula in EXCEL:

Equation 1. f = HEX2DEC*(record_number)

### *4.4. Device Type*

- "4D" & "49"; identification code for the device type. 4D and 49 codes are scheduled for the different measurement logs in TT+.

### *4.5. Timestamp*

- "1581336000"; timestamp of the router when the individual device send the data string. The timestamp is the number of seconds since 1st January 1970. This way of representing time is called UNIX timestamp or EPOCH time and it is the basis of any computer in the world (https://www.epochconverter.com/).

- Timestamp have to convert in real time by the following formula:

Equation 2. f = (((Timestamp/60)/60)/24) + DATE (1970, 1, 1)

For example, 1581336000 timestamp is equal to 02/06/2020 11.00 AM

### *4.6. Ref & Heat Probes Temperature*

Reference probe (Tref [d.n.]) and heating probe (Theat [d.n.]) transmit stem temperature data in forms of digital number before and after heating. In order to convert the digital numbers to temperature data, please apply the below polynomial regression equation:

Equation 3. Temperature (°C) = 127.6-0.006045*D.N. + 1.26E-07*D.N.^2 - 1.15E-12*D.N.^3

S = 0.999273 R-Sq = 99.9% R-Sq(adj) = 99.9%

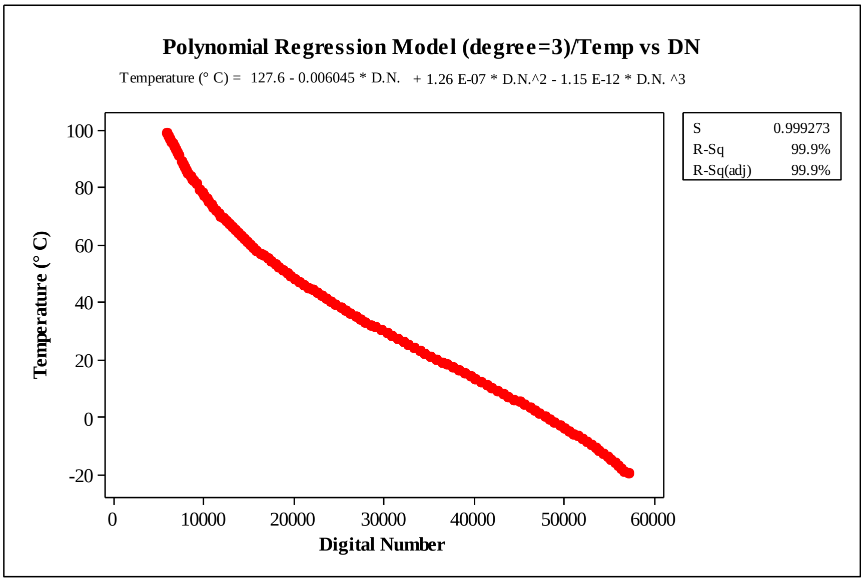


Figure 6. Relation between digital number & temperature with polynomial fitting curve

Table 2 shows an example of converting the digital numbers to temperature data.

Table 2. Example of converted digital numbers to temperature (° C)

| *Condition* | *probe* | *D.N.* | *Temperature (° C)* |
|---|---|---|---|
| *Befor heating* | Tref_0 [d.n.] | 35316 | 20.62 |
| | Theat_0 [d.n.] | 35135 | 20.88 |
| *After heating* | Tref_1 [d.n.] | 35234 | 20.74 |
| | Theat_1 [d.n.] | 29259 | 29.79 |

### 4.6.1. Sap flow

After recording temperature data before and after heating inside stem, we are able to estimate sap flow which in this case the method follows Granier_Type approach. The TT+ version is designed to measure sap flow according to the thermal dissipation method (TDP) with cyclic heating system (10 minutes of heating/ 50 minutes of cooling). A probe pairs is inserted in the main trunk with a vertical separation of 10 cm, facing north to avoid direct solar heating. One of the probe is heated while the other is used to measure the reference temperature and includes a capacitive sensor of wood humidity. Granier equation is used to determine sap flux density in TDP devices.

Equation 4. $$F_d = 118.99[\frac{\Delta T_{max} - \Delta T}{\Delta T}]^{1.231}$$

Where $F_d$ is the sap flux density ($gm^{-2}s^{-1}$), $\Delta T$ is the actual temperature gradient between the two probes after heating and $\Delta T_{max}$ the maximum temperature gradient measured between the probes after heating in a given time period.

Please check the below link for the reference paper:
http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.600.943&rep=rep1&type=pdf

In addition, you can apply Do & Rocheteau method to estimate sup flux density to consider both temperature measurements at the end of cooling (Tref_0 & Theat_0) and heating (Tref_1 & Theat_1) periods.

Equation 5. $$F_d = 118.99[\frac{\Delta T_{max}}{\Delta T_{on} - \Delta T_{off}} - 1]^{1.231}$$

$\Delta T_{on}$ = Theat_1 - Tref_1 and $\Delta T_{off}$ = Theat_0 - Tref_0

Please check the below link for the reference paper:
https://academic.oup.com/treephys/article/22/9/649/1655537

## 4.7. Growth Rate

- 62750; stem radial growth is measured by an infra-red pulsed distance sensor positioned at few centimeters away from the tree trunk’s surface and kept in place by a carbon fiber stick anchored in the xylem. The mentioned digital number shows an example of sharp sensor record – when it is 0 in this case the sensor is not installed.

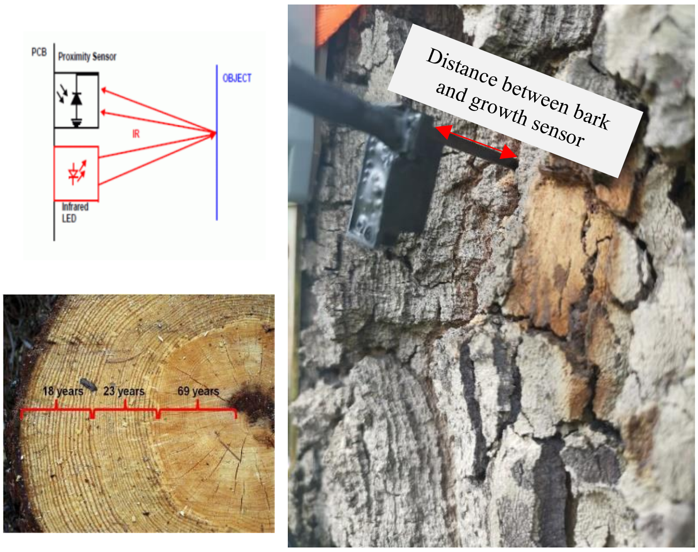


Figure 7. Installed growth sensor which can measure distance between bark to sensor

Considering the total length of sharp sensor (50 mm) and the insertion depth of the sensor in a tree (typically between 10 to 18 mm), below are some recalculations of source data to find a calibration regression model to convert recorded digital number by growth sensor to valuable length unit.

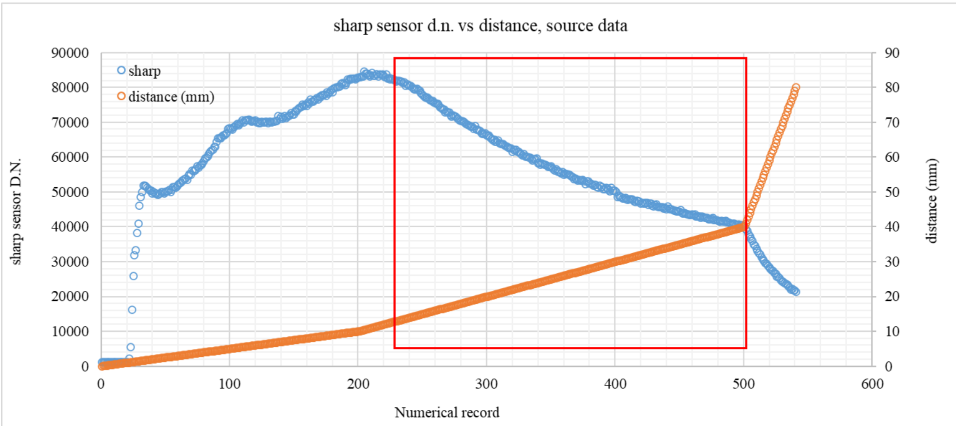


Figure 8. Data source of recorded digital numbers by sharp sensor equivalent to the different-distance set

A 2nd-degree polynomial regression model applied to analyze the relationship between distance and reported digital numbers by a sharp sensor.

Equation 6. $\text{Distance (mm)} = 0.000000008*(\text{sharp sensor D.N.})^2 - 0.0016*(\text{sharp sensor D.N.}) + 89.032$

$R^2 = 0.9947$

Table 3. Example of data sample

| ***sharp (D.N.)*** | ***distance (mm)*** |
|---|---|
| 40000 | 37.832 |
| 45000 | 33.232 |
| 60000 | 21.832 |
| 70000 | 16.232 |
| 85000 | 10.832 |

The equation is applicable for the range of 40000 to 85000 sharp sensor D.N. which is equal to 38 to 10 mm, correspondingly. Please see the below graphs.

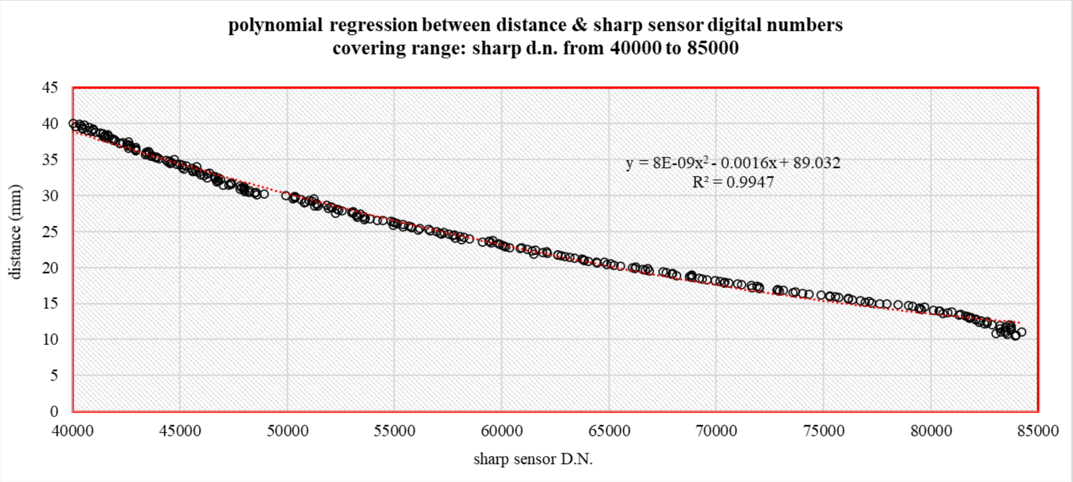


Figure 9. Data selection to define relationship between sharp sensor reported-values and corresponding distances

### *4.8. Battery Voltage*

To have the battery voltage in mV (millivolt), apply the formula 9:

Equation 7. $$\text{Battery\_Voltage (mV)} = 2 * \text{mV\_bandgap} * \frac{adc\_Vbat\ [d.n.]}{adc\_bandgap\ [d.n.]}$$

Where, mV_bandgap is the band gap reference voltage of the Atmel328 (=1100 mV per datasheet), adc_Vbat [d.n.] and adc_bandgap [d.n.] are ADC converter numeric values. Table 3 shows an example of estimated supply voltage.

Table 4. Example of estimated supply voltage (mV) based on adc_Vbat [d.n.] and adc_bandgap [d.n.]

| *Variable* | *digital number* | *Battery voltage (mV)* |
|---|---|---|
| *mV_bandgap (constant)* | 1100 | |
| *adc_bandgap [d.n.]* | 42514 | ***4097.64*** |
| *adc_Vbat [d.n.]* | 79185 | |

Note:

Even if the microprocessor and other components will run under low battery (in principle at 2.2 V) we do suggest to recharge battery at the level of 3.5V, below such threshold we cannot guarantee on the proper functioning of the sensors.

### 4.9. Data Resolution

- "17"; number of measurement resolution bits

### 4.10. Meteorological Data

- "26"; air relative humidity (%)
- "210"; air temperature (×10 ,° C then 21 ° C)

Air temperature and humidity sensor is placed facing a small hole in the back of the box covered by a Goretex™ membrane to avoid water to go inside but still permeable to water vapor.

### 4.11. Tree Stability

- "-3894"; value of the acceleration on the Z axis (Note: 4096 corresponds to 1g)
- "0"; square of the Z variance on the measure (standard deviation)
- "-76"; value of the acceleration on the Y axis
- "0"; square of the Y variance on the measure
- "-1319"; value of the acceleration on the X axis.
- "0"; square of the X variance on the measure.

Treetalker is able to record oscillation of tree due to gravity with Spherical Coordinate System. With basic trigonometry, φ, the angle between the gravity vector and the z-axis can be assessed by using equation 10 (Fisher, 2010). This capability will improve the monitoring of forest ecosystem resilience against wind impact.

Equation 8. $$\varphi = tan^{-1}\left(\sqrt{A_{X,OUT}^2 + A_{Y,OUT}^2}/A_{Z,OUT}\right)$$

### 4.12. Stem water Content (StWC %)

"8905" frequency domain measurement (ECf (Hz)).
Stem humidity measurement is alternative capability of TT+ which is expressed as frequency signal with the range of 7000 to 14000 Hz in green wood. The range of frequencies is significantly influenced by environmental factors. High frequency occurs in very hot days and shows less stem water content. Considering the effect of wood density on frequency data, calibration models are performed on 2 different harvested stem samples (Fagus sylvatica L. & Pinus sylvestris L.) to convert the sensor-reported values to stem volumetric water content. Calibration formulas for other species are still under investigation.

In order to estimate the amount of stem water content, follow the steps below:

Step 1: Applying temperature sensitivity equation and converting ECf to $ECf_{Tref}$:

Equation 9. $$ECf_{Tref}\,(Hz) = ECf\,(Hz) - 7.3 \times (NTC1\,(°C) - NTC1_{ref}\,(°C))$$

$$NTC1_{ref} = 29\,°C$$

Step 2: Estimating stem water content (StWC %) based on linear calibration model for different species type.

Equation 10. $StWC\ (\%) = m \times Ecf_{Tref}\ (Hz) + b$

Table 5. Coefficients 'm' and 'b' are presented for a linear equation in the standard form in different species

| *Calibration equation* | m | b | $R^2$ |
|---|---|---|---|
| *Fagus sylvatica L.* | -0.0034 | 54.897 | 0.979 |
| *Pinus sylvestris L./ EcfTref<14500 Hz* | -0.0008 | 30.023 | 0.969 |
| *Pinus sylvestris L./ EcfTref>14500 Hz* | -0.01 | 173.53 | 0.978 |

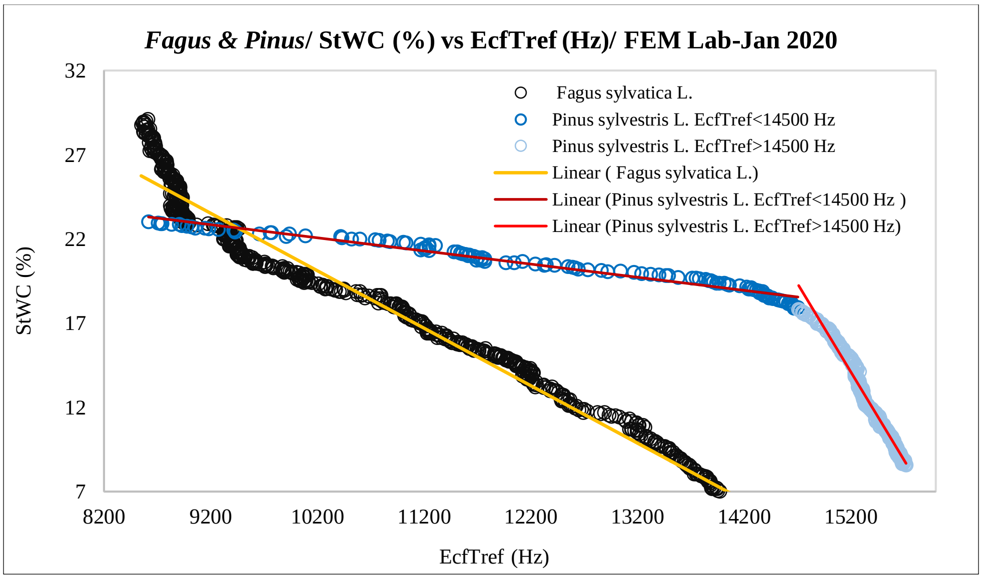


Figure 10. Linear calibration curves for wood samples of *Fagus sylvatica* L. and *Pinus* sylvestris L.

Note: To skip the wound impact on reference probe after installation of TT+, we suggest to ignore the first week of ECf (Hz) data

## *4.13. Spectral Band*

In second line of strings with 49 device type, first 4 data are same as type 4D. The rest shows canopy light transmission in 12 spectral bands 610+, , 680+, 730+, 760+, 810+, 860+ nm, 450*, 500*, 550*, 570*, 600*,  650* (* ±20 nm + ±10 nm). The internal spectrometer has been re-calibrated with a professional lab spectrometer in order to take into account the geometry of the system, including the glass shield.

The below table shows calibrated equations to convert the digital numbers (DN) in corrected spectral band:

Table 6. Calibration formulas for each wavelength in spectral bands data

| *Spectral Bands* | *Band (wavelength peak, nm)* | *Calibration Formula* |
|---|---|---|
| Near Infrared | AS7263_610 [d.n.] | # -312.45+(1.6699*DN) |
| | AS7263_680 [d.n.] | # -561.56+(1.5199*DN) |
| | AS7263_730 [d.n.] | # -1511.2+(1.6209*DN) |
| | AS7263_760 [d.n.] | # -1012.5+(1.4549*DN) |
| | AS7263_810 [d.n.] | # 91.58+(0.8414*DN) |
| | AS7263_860 [d.n.] | # 334.88+(0.531*DN) |
| Visible Light Spectrum | AS7262_450 [d.n.] | # -212.62+(0.4562*DN) |
| | AS7262_500 [d.n.] | # -232.13+(0.6257 *DN) |
| | AS7262_550 [d.n.] | # -842.1+(1.0546 *DN) |
| | AS7262_570 [d.n.] | # -666.72+(1.0462 *DN) |
| | AS7262_600 [d.n.] | # -328.08+(0.8654 *DN) |
| | AS7262_650 [d.n.] | # 202.77+(0.7829*DN) |

- 50; is the integration time of spectrometer (it is multiplied x2.8 ms from hardware) default= 50 equivalent to 140 ms

- 3; is the gain. Can be set between 0 and 3 (0=1, 1=3.7x, 2=16x, 3=64x) default is 3.

## 5. TT+ Installation

In order to install TreeTalker, Please follow below steps:
Step 1. TT+, battery pack, belt and support plates should be prepared (figure 9).

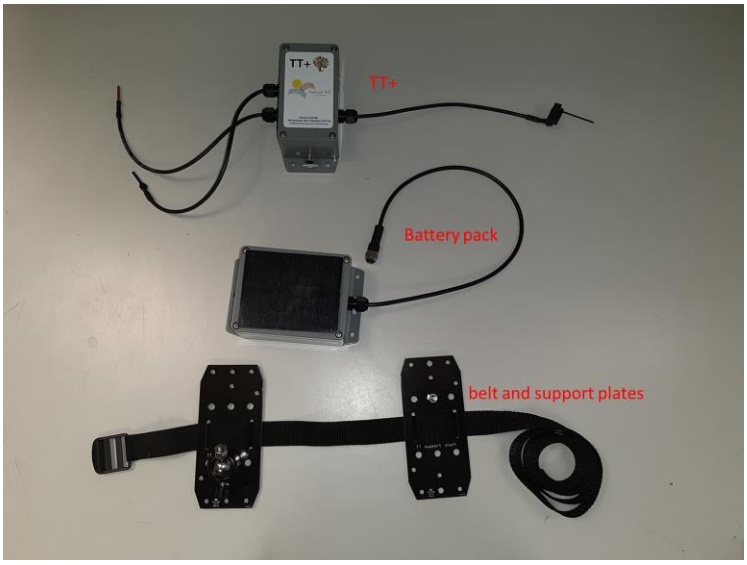

Figure 11. TT+, battery pack, belt and support plates

Step 2. Prepare some basic instruments such as drill, compass, hammer, glue, probes and angle templates to start installation (see figure 10).

Figure 12. Additional instruments to do installation

Step 3. Mostly TT+ is installed in DBH (Diameter at breast height) and toward north side, while it's better to put battery pack toward south side to save more energy by solar panel (figure 11).

Figure 13. Setting direction of TT+ and battery

Step 4. Fix TT+ and battery pack by belt and support plated with fastening and drilling them to the trunk, respectively (figure 12).

Figure 14. Fixing TT+ and battery pack to the trunk

Step 5. Mounting TT+ to the trunk should be with 20 degree angle to decrease the effect of stem shade on spectral bands data (figure 13).

Figure 15. Setting TT+ with 20 degree angle than trunk

Step 6. Use drill bit with 2 mm size to make a hole for growth sensor, put some glue on the top of fiber rod and then 10 to 18 mm of the rod should be inserted in the hole (figure 14).

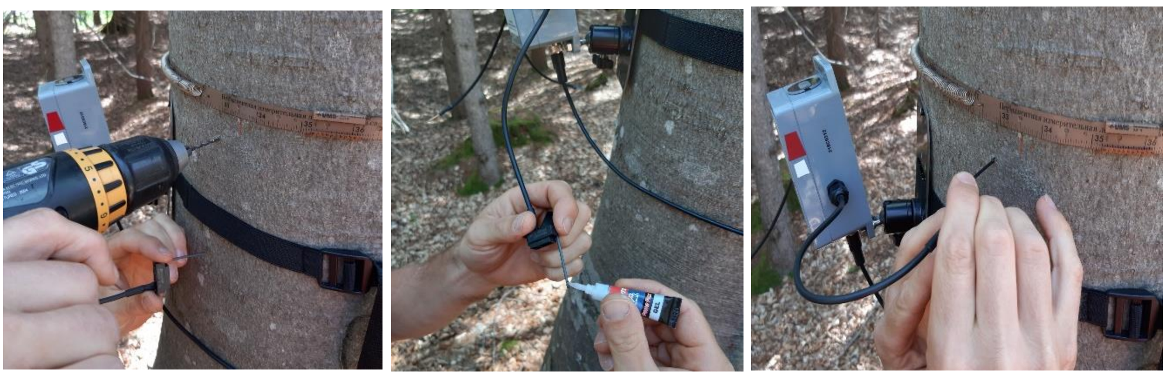

Figure 16. Drilling a hole for fiber rod and inserting growth sensor in the trunk

Step 7. Installing Granier type probes: In order to insert heater and reference probes to the trunk, first two template holes can be drilled by bit with 3 mm size with almost 10 cm distance, then heater probe can easily inserted in the upper hole due to being rounded shape, whereas, regards to reference probe form, lower round hole should change to square shape hole and finally ref probe can insert in the stem (figure 15). In order to make a square hole you need to create a tool (as in figure 15) or use a Dremel cutter model 9901 (3.2 mm).
[https://www.dremel.com/en_US/products/-/show-product/tools/9901-tungsten-carbide-cutter](https://www.dremel.com/en_US/products/-/show-product/tools/9901-tungsten-carbide-cutter).


Figure 17. Heater and reference probes template to drill holes

## 6. Acknowledgment

We acknowledge the technical support of Dromo Elettronica s.r.l (Italy) and we wish to thank Damiano Gianelle, Luca Belelli, Roberto Zampedri, Isaac Chini and Mauro Cavagna from Fondazione Edmund Mach for their help and support with Tree-Talkers installation and testing in the lab. A special thanks to Shahla Asgharinia for preparing the manual.

## 7. References

Fisher, C.J., 2010. Using an accelerometer for inclination sensing. AN-1057, Appl. note, Analog Devices.

Granier, A. (1987). Evaluation of transpiration in a Douglas fir stand by means of sap flow Measurements. Tree Physiology, 3:309-320.

Valentini, R., Marchesini, L. B., Gianelle, D., Sala, G., Yarovslavtsev, A., Vasenev, V, I., Castaldi, S., (2019). New tree monitoring systems: from Industry 4.0 to Nature 4.0. Annals of Sylvicultural Research 43(2) (in press)

# 8. Appendix

## *8.1. Variation of sap flux density against air temperature and xylem moisture content in Platanus species*

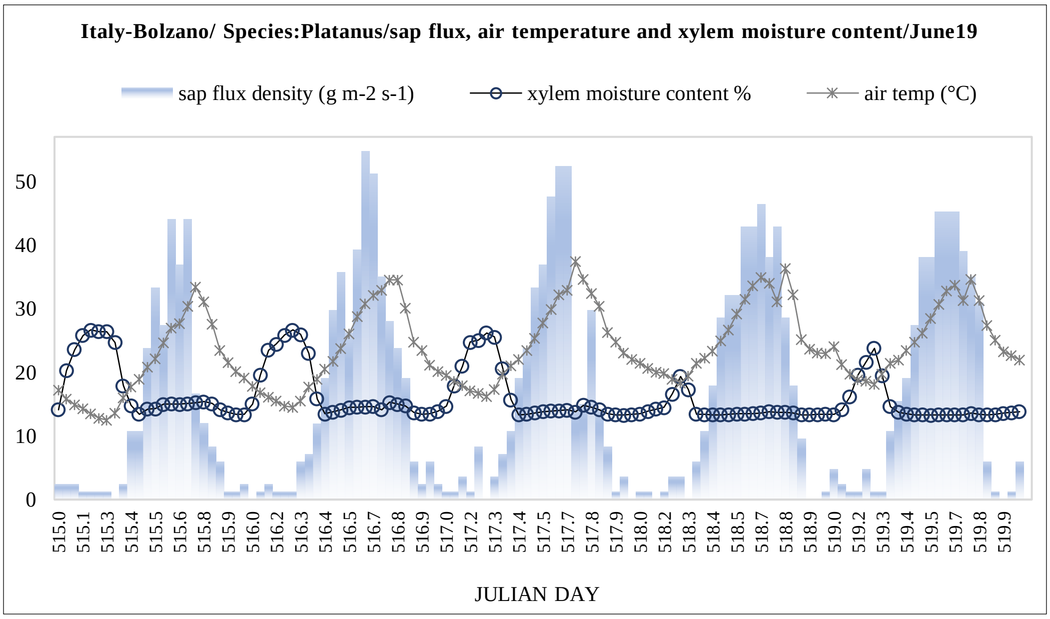


Figure 18. Dynamics of xylem moisture content of main stem with sap flux and air temperature in hourly scale

## *8.2. Transmitted radiance below the canopy in Malus Domestica species*

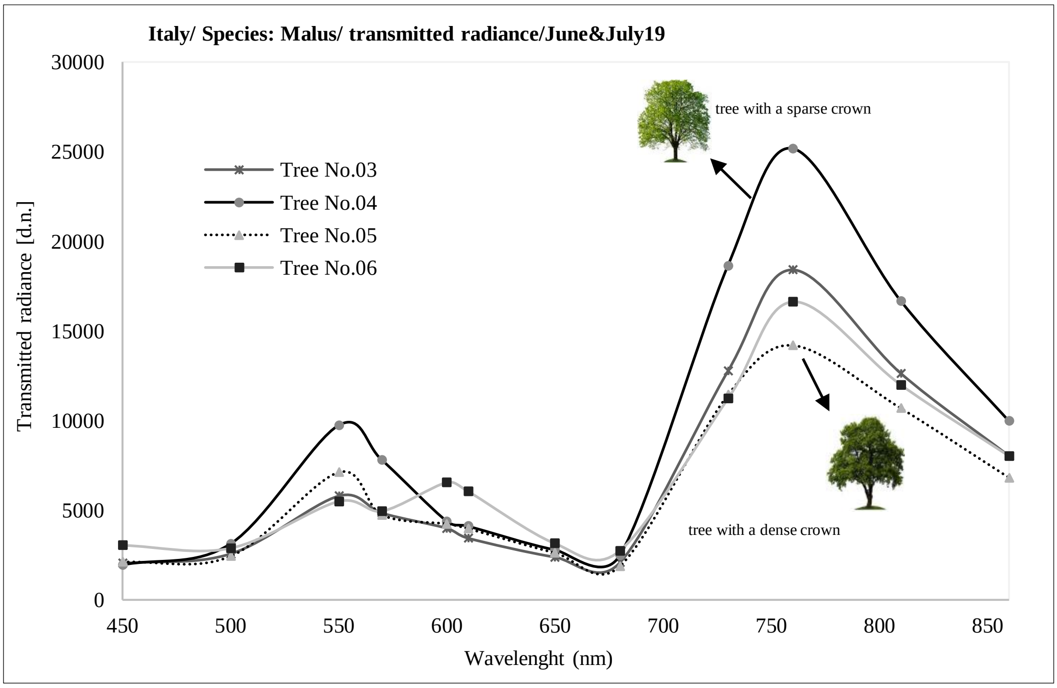


Figure 19. Average transmitted radiance below canopy at 11 am to 14 pm in 4 selected Malus trees

## *8.3. Technical characteristics of TT+*

| | Component | Description |
|---|---|---|
| **TT (TreeTalker)** | Sap flow | Reference and heated temperature probes (±0.1 °C). Thermistors manufacturer: Murata Electronics. Model: NCU18XH103F6SRB |
| | Stem humidity | Capacitive sensor<br>MicroPCB (20x3x2) mm with copper plates. |
| | Canopy light transmission | Radiometer-12 spectral bands (450, 500, 550, 570, 600, 610, 650, 680, 730, 760, 810, 860 nm)<br>(± 10 nm or ±20 nm).<br>Manufacturer: AMS. Model: AS7262 (Visible range), AS7263 (Near Infra-Red range) |
| | Tree trunk radial growth | Infra-red distance sensor (±100 µm)<br>Manufacturer:SHARP. Model: GP2Y0A51SK0F |
| | Tree trunk axis movement | Accelerometer (± 0.01°)<br>Manufacturer:NXP/Freescale. Model: Si7006 |
| | Air temperature and humidity | Thermohygrometer (±0.1 °C ; ±2 % ). Manufacturer: Silicon Labs. Model: MMA8451Q |
| | Flash memory for data storage | 16Mbyte |
| | LoRa module for data transmission | Transmission 600 m (in urban/rural environment). It can reach >3 km in case line of sight |
| | 4 Li-Ion batteries + solar panel | 3.7 V |

## *8.4. LIST OF TT+ COMMANDS (only by direct serial connection)*

With connecting directly to the TT+ by 6 pins cable, the below list could be sent to the device in order to read, delete or change the data. To connect the device you can use the provided cable with an FTDI32 converter and USB port. Once you connect with a USB port in your PC you have to use a simple serial monitor software such as serial Arduino monitor or app like PuTTY (https://putty.org/) with baud rate = 38400, parity= N, data bits=8,stop bits=1.
List of commands:

SN=2XXXXXXX.
(changing serial number)

DEFAULT
(resetting parameters)
CLEAR
(Clear all data logs)
READ_ALL
(Read all data store in TT+ flash memory as emergency backup)

TESTMODE followed by END

*(These commands put TT+ in test mode. All data are sequentially taken every 1 minute and displayed on monitor for testing/checking sensor or using in special research mode – please consider that you have about 10 seconds to send the string TESTMODE after TT+ initialization, after this time TT+ enter in sleep mode)*

<u>Note: Commands must be written in capital letters, no blanks</u>