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Supplementary Material

Tab. S1 - TTCyber Sensor Overview.

Component	Description	Measurement Principle	Technical Details
Spectrometer	Multispectral sensor capturing 28 spectral bands (410 to 940 nm). Measures sub-canopy light.	Light intensity recorded across spectral bands; converted using calibration.	AS7265x + AS7341; 28 bands; ±10nm wavelength accuracy; autogain.
Sap Flow Probe	Monitors sap velocity using thermal pulse methods.	Heat Pulse Velocity (HPV), Heat Ratio Method (HRM), or Transient Thermal Dissipation (TTD).	3-needle probe (heater, upstream, downstream); 7.5 mm spacing; ~0.5 cm/hr error.
Growth Sensor	Tracks radial stem growth with high precision.	Magnetic linear encoder detects stem expansion via displacement.	Resolution: 0.488 µm; operating range: -40°C to 80°C; 0-4096 DN per 2 mm polepair.
Temperature & Humidity	Monitors ambient microclimate.	Capacitive RH + bandgap temperature sensor.	SHT41 sensor (digital output); RH and °C converted from DN.
Accelerometer	Detects trunk inclination and oscillations.	3-axis accelerometry.	LIS3DH chip; XYZ axis monitoring; used to assess tree stability.

Vizzarri M, Belelli Marchesini L, Piermattei A, Santopuoli G, Ottaviano M, Parisi F, Yates J, Asgharinia S, Alberti G, Antonucci S, Ascoli D, Battipaglia G, Bizzarri A, Castagneri D, Castaldi S, Cocozza C, Dionigi M, Djacenko S, Donati C, Freppaz M, Garfì V, Gentile C, Gianelle D, Giusti R, Iannuccilli M, Kabala JP, La Mantia T, Larsen S, Lasserre B, Lombardi F, Magnani F, Massari C, Matteucci G, Mazzenga F, Meloni F, Messeri A, Montella M, Niccoli F, Pellizzari S, Pindo M, Renzi F, Sala G, Salbitano F, Sammarone L, Sirca CB, Spano D, Stefani E, Tomao A, Motta R, Tognetti R, Tomelleri E, Vacchiano G, Valentini R, Marchetti M (2025).
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Tab. S2 - TTCyber Communication Overview.

Feature	LoRaWAN	NB-IoT
Data Range	Up to 15 km in rural areas (1 to 5 km in urban)	Up to 10 km (urban)
Power Consumption	Very low, ideal for battery-operated remote sensors	Low, but slightly higher than LoRa
Data Bandwidth	Low, suitable for small, infrequent payloads	Higher than LoRa, suitable for more frequent or larger payloads
Latency	High latency (1 to 2s or more)	Lower latency
Gateway Requirement	Requires local LoRaWAN gateway within range	No gateway needed, uses existing mobile infrastructure
Connectivity Infrastructure	Requires setup of gateway or use of public LoRaWAN networks	Utilizes mobile network infrastructure
Best Use Case	Remote forest with dense sensor network (30+ units)	Widely dispersed units or no local LoRa coverage
Data Access URLs	http://nature4cloud.org:5001/downloads/TTCyber/[Serial]/data.txt	http://naturetalkers.altervista.org/TTCyber/[Serial]/ttcloud.txt

Vizzarri M, Belelli Marchesini L, Piermattei A, Santopuoli G, Ottaviano M, Parisi F, Yates J, Asgharinia S, Alberti G, Antonucci S, Ascoli D, Battipaglia G, Bizzarri A, Castagneri D, Castaldi S, Cocozza C, Dionigi M, Djacenko S, Donati C, Freppaz M, Garfì V, Gentile C, Gianelle D, Giusti R, Iannuccilli M, Kabala JP, La Mantia T, Larsen S, Lasserre B, Lombardi F, Magnani F, Massari C, Matteucci G, Mazzenga F, Meloni F, Messeri A, Montella M, Niccoli F, Pellizzari S, Pindo M, Renzi F, Sala G, Salbitano F, Sammarone L, Sirca CB, Spano D, Stefani E, Tomao A, Motta R, Tognetti R, Tomelleri E, Vacchiano G, Valentini R, Marchetti M (2025).
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Fig. S1 - Main output from preliminary results of monitoring activities. Air Temperature (°C).

Vizzarri M, Belelli Marchesini L, Piermattei A, Santopuoli G, Ottaviano M, Parisi F, Yates J, Asgharinia S, Alberti G, Antonucci S, Ascoli D, Battipaglia G, Bizzarri A, Castagneri D, Castaldi S, Cocozza C, Dionigi M, Djacenko S, Donati C, Freppaz M, Garfì V, Gentile C, Gianelle D, Giusti R, Iannuccilli M, Kabala JP, La Mantia T, Larsen S, Lasserre B, Lombardi F, Magnani F, Massari C, Matteucci G, Mazzenga F, Meloni F, Messeri A, Montella M, Niccoli F, Pellizzari S, Pindo M, Renzi F, Sala G, Salbitano F, Sammarone L, Sirca CB, Spano D, Stefani E, Tomao A, Motta R, Tognetti R, Tomelleri E, Vacchiano G, Valentini R, Marchetti M (2025).
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Fig. S2 - Main output from preliminary results of monitoring activities. Radial growth (mm).

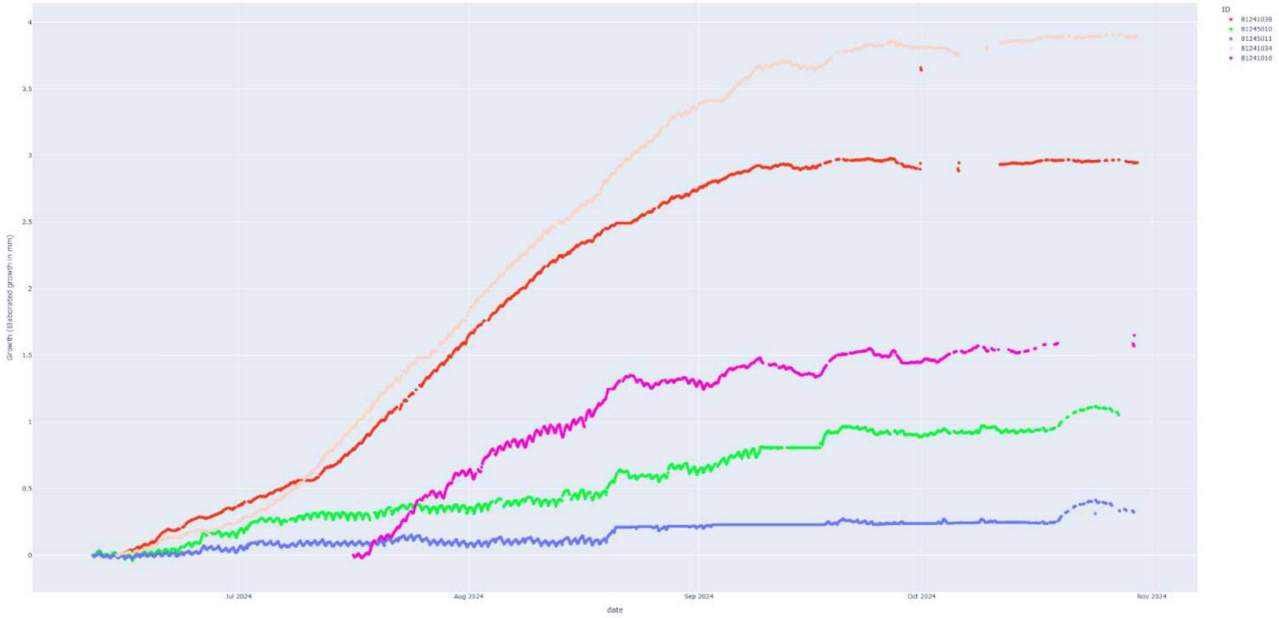
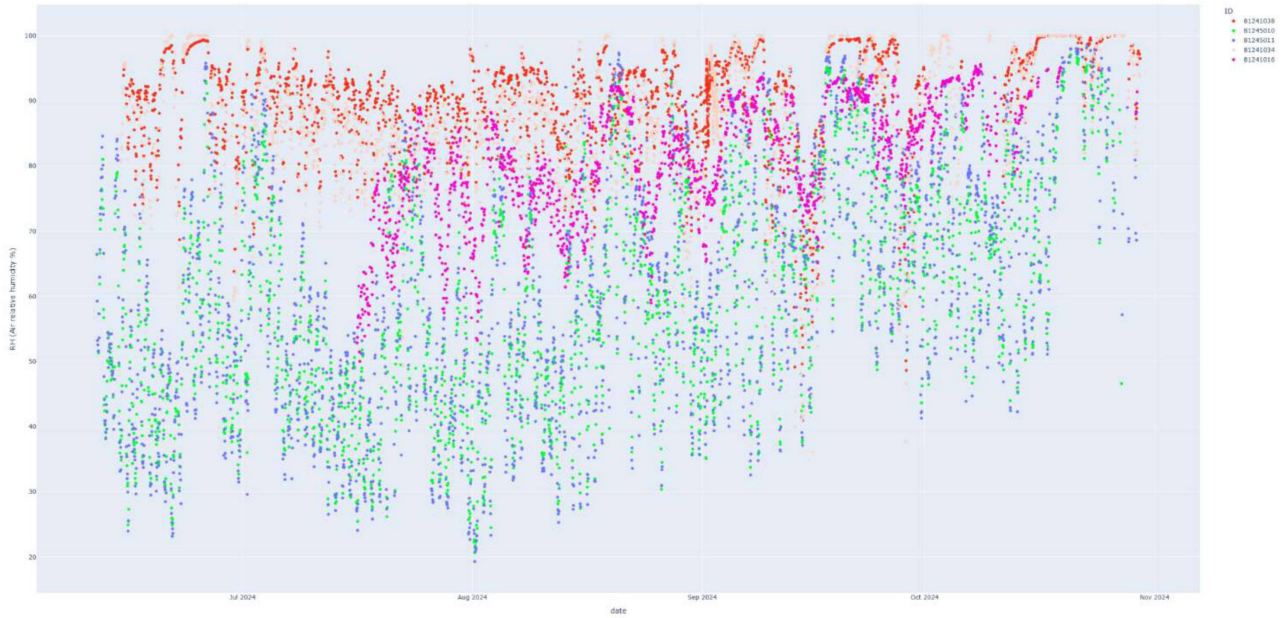


Fig. S3 - Main output from preliminary results of monitoring activities. Relative Humidity (%).



Vizzarri M, Belelli Marchesini L, Piermattei A, Santopuoli G, Ottaviano M, Parisi F, Yates J, Asgharinia S, Alberti G, Antonucci S, Ascoli D, Battipaglia G, Bizzarri A, Castagneri D, Castaldi S, Cocozza C, Dionigi M, Djacenko S, Donati C, Freppaz M, Garfì V, Gentile C, Gianelle D, Giusti R, Iannuccilli M, Kabala JP, La Mantia T, Larsen S, Lasserre B, Lombardi F, Magnani F, Massari C, Matteucci G, Mazzenga F, Meloni F, Messeri A, Montella M, Niccoli F, Pellizzari S, Pindo M, Renzi F, Sala G, Salbitano F, Sammarone L, Sirca CB, Spano D, Stefani E, Tomao A, Motta R, Tognetti R, Tomelleri E, Vacchiano G, Valentini R, Marchetti M (2025).
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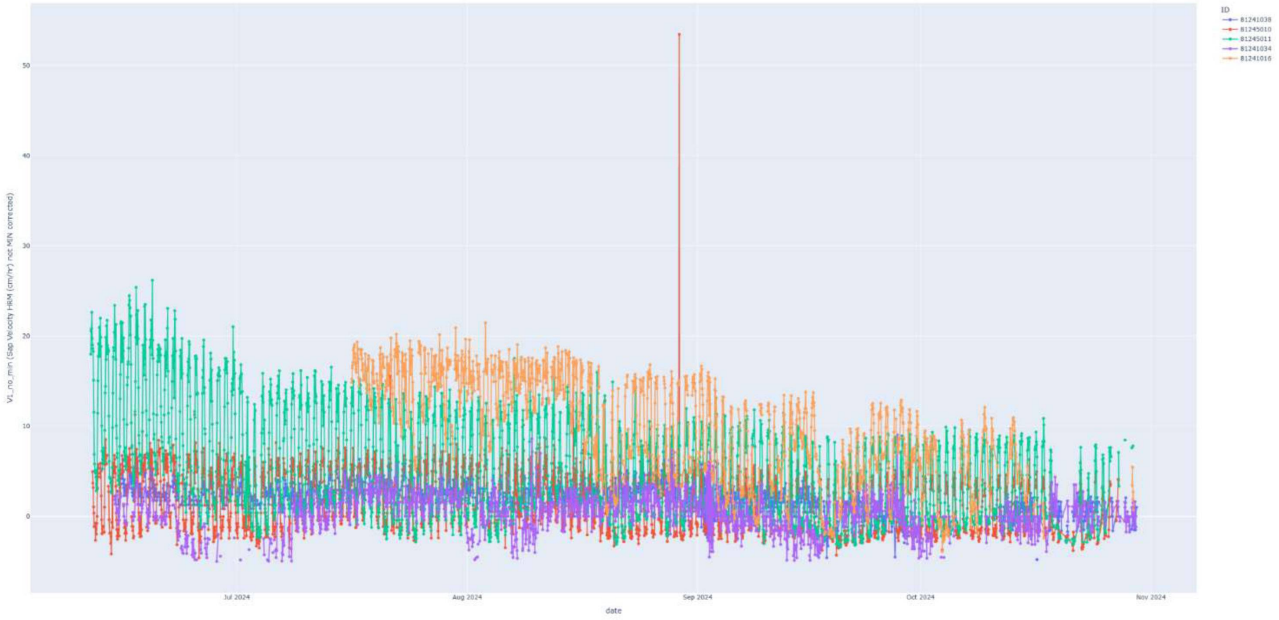
Fig. S4 - Main output from preliminary results of monitoring activities. Sap velocity (cm hr^{-1}).



Vizzarri M, Belelli Marchesini L, Piermattei A, Santopuoli G, Ottaviano M, Parisi F, Yates J, Asgharinia S, Alberti G, Antonucci S, Ascoli D, Battipaglia G, Bizzarri A, Castagneri D, Castaldi S, Cocozza C, Dionigi M, Djacenko S, Donati C, Freppaz M, Garfì V, Gentile C, Gianelle D, Giusti R, Iannuccilli M, Kabala JP, La Mantia T, Larsen S, Lasserre B, Lombardi F, Magnani F, Massari C, Matteucci G, Mazzenga F, Meloni F, Messeri A, Montella M, Niccoli F, Pellizzari S, Pindo M, Renzi F, Sala G, Salbitano F, Sammarone L, Sirca CB, Spano D, Stefani E, Tomao A, Motta R, Tognetti R, Tomelleri E, Vacchiano G, Valentini R, Marchetti M (2025).
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Tab. S3 - Main characteristics of Tree-Talker Italia Network. List of sites included in the network on May 2025.

ID	Site name	Site cluster	Lat. (°N)	Long. (°E)	Tree species composition
1	sito UD1 - Monte Acomizza	Sentinel	46.5503	13.5118	*Picea abies*
2	sito UD2 - Rifugio Gortani	Productive	46.5346	13.4641	*Picea abies*
3	sito UD3 - Pramollo	Transitional	46.5552	13.2847	*Picea abies*
4	sito SS1-FORESTA DORTESI - ORGOSOLO	Sentinel	40.1164	9.4360	*Quercus ilex*
5	sito SS2-SA PREDA NIEDDA - TIRSO	Productive	40.3334	9.0594	*Quercus suber*
6	sito SS3-SA PREDA NIEDDA - TIRSO	Transitional	40.3334	9.0594	*Quercus suber, Olea oleaster*
7	sito SS4-BERCHIDDA	Productive	40.7870	9.2750	*Quercus suber*
8	sito SS5-BERCHIDDA	Transitional	40.7870	9.2750	*Olea oleaster*
9	Gerola	Sentinel	46.0963	9.5343	*Larix decidua, Picea abies*
10	Intelvi	Transitional	45.9171	9.1126	*Betula pendula, Corylus avellana*
11	Masino	Productive	46.2452	9.5963	*Abies alba, Fagus sylvatica*
12	Chiusa Pesio	Productive	44.2024	7.6817	*Abies alba*
13	Chiusa Pesio	Productive	44.2118	7.6689	*Fagus sylvatica*
14	Chiusa Pesio	Transitional	44.2212	7.6658	*Fraxinus excelsior, Acer pseudoplatanus, Ulmus* spp., *Tilia cordata*
15	Gran Bosco	Sentinel	45.0434	6.9150	*Larix decidua*
16	Gran Bosco	Productive	45.0524	6.9077	*Picea abies*
17	Gran Bosco	Productive	45.0699	6.8916	*Pinus sylvestris*
18	Paneveggio	Productive	46.2904	11.7637	*Picea abies*
19	Bosco della Partecipanza	Productive	45.2278	8.2611	*Quercus robur*
20	Alpe Devero	Sentinel	46.3095	8.2375	*Larix decidua*
21	Antey (LTER)	Sentinel	45.8245	7.5622	*Larix decidua*
22	Borca di Cadore	Productive	46.4402	12.1914	*Picea abies, Abies alba*
23	Croda da Lago	Sentinel	46.4925	12.1045	*Picea abies, Larix decidua*
24	Piana degli Albanesi	Productive	37.9724	13.2995	*Pinus pinea, Pinus halepensis*
25	LIGONCHIO FAGGETA - Parco nazionale Appennino Tosco Emiliano	Productive	44.2501	10.4175	*Fagus sylvatica*
26	CASALINO_FONTANA -Parco nazionale Appennino Tosco Emiliano	Transitional	44.2494	10.4661	*Fraxinus excelsior, Acer pseudoplatanus*
27	Cansiglio	Productive	46.0667	12.4034	*Fagus sylvatica*

ID	Site name	Site cluster	Lat. (°N)	Long. (°E)	Tree species composition
28	Parco Nazionale Abruzzo	Sentinel	41.7647	13.7551	*Fagus sylvatica*
29	Parco Nazionale Abruzzo	Productive	41.7700	13.7670	*Fagus sylvatica*
30	Parco Nazionale Abruzzo	Transitional	41.7699	13.9133	*Pinus nigra* var. *italica*
31	Valbona IT02	Productive	45.8300	11.7610	*Picea abies*
32	Torgnon IT19	Sentinel	45.8300	7.5600	*Larix decidua*
33	Montagna di Torricchio IT03	Productive	42.9614	13.0192	*Fagus sylvatica*
34	Castelporziano IT18	Productive	41.7450	12.4000	*Quercus* spp.
35	Piano Limina CAL1	Other	38.4272	16.1800	*Fagus sylvatica*
36	Renon BOL1	Productive	46.5868	11.4336	*Picea abies, Pinus cembra*
37	Collelongo1 ABR1	Other	41.8494	13.5881	*Fagus sylvatica*
38	Pian del Cansiglio (TV) VEN1	Other	46.0580	12.3821	*Fagus sylvatica*
39	Bioglio (Piemonte) PIE1	Other	45.6830	8.0690	*Fagus sylvatica*
40	Sala Baganza (PR) EMI1	Other	44.7180	10.2010	*Quercus petraea*
41	Monte Rufeno Acquapendente (VT) LAZ1	Other	42.8230	11.9010	*Quercus cerris*
42	Castelporziano (RM) CPZ1	Other	41.7042	12.3572	*Quercus ilex*
43	Val d'Ultimo	Other	46.5938	11.0774	*Picea abies*
44	Mendola	Other	46.4537	11.2327	*Fagus sylvatica*
45	Carezza	Sentinel	46.4035	11.5877	*Picea abies*
46	Cembra	Productive	46.2030	11.2100	*Fagus sylvatica, Larix decidua, Abies alba, Picea abies*
47	Lavarone	Productive	45.9560	11.2810	*Fagus sylvatica, Picea abies, Abies alba*
48	Rincine	Sentinel	43.8878	11.6281	*Fagus sylvatica*
49	Vallombrosa	Productive	43.7367	11.5494	*Abies alba*
50	Sant'Antonio	Sentinel	43.6978	11.5831	*Fagus sylvatica*
51	Roccarespampani	Productive	42.3907	11.9237	*Quercus cerris*
52	Bosco Pennataro-Martelloscopio	Other	41.7340	14.1920	*Quercus cerris, Fagus sylvatica, Acer* spp., *Carpinus betulus*
53	Bosco Pennataro	Other	41.7360	14.2050	*Fagus sylvatica, Quercus cerris, Acer* spp., *Fraxinus excelsior, Carpinus betulus*
54	Roccamandolfi 1	Productive	41.4590	14.3370	*Fagus sylvatica*
55	Roccamandolfi 2	Productive	41.4530	14.3450	*Fagus sylvatica*
56	Riserva di Collemeluccio	Other	41.7170	14.3500	*Abies alba, Quercus cerris*
57	Matese Control (Falode)	Other	41.4176	14.4298	*Fagus sylvatica*

ID	Site name	Site cluster	Lat. (°N)	Long. (°E)	Tree species composition
58	Matese Stress (Campo Braca)	Other	41.4165	14.3412	*Fagus sylvatica*
59	Vesuvio Burned	Other	40.8119	14.4131	*Pinus pinaster*
60	Vesuvio Control	Other	40.8074	14.4196	*Pinus pinaster*
61	Madonie	Productive	37.8478	14.0329	*Fagus sylvatica, Abies nebrodensis*
62	Pantelleria	Sentinel	36.7773	12.0022	*Quercus ilex*
63	Val Canali-AR	Sentinel	46.2303	11.8595	*Picea abies*
64	Val Canali-FA	Sentinel	46.2290	11.8576	*Fagus sylvatica*
65	Molveno-AR	Sentinel	46.1688	10.9316	*Picea abies*
66	Molveno-FA	Sentinel	46.1639	10.9315	*Fagus sylvatica*
67	Ussita-FA	Productive	42.9440	13.1630	*Fagus sylvatica*
68	Ussita-QU	Productive	42.9490	13.1740	*Quercus robur*
69	Granaglione BO	Other	44.139	10.957	*Castanea sativa*
70	Castelporziano (RM) CPZ1	Other	41.679	12.391	*Quercus ilex*
71	Parco della Sila	Productive	39.0854	16.5781	*Pinus nigra* subsp. *laricio*
72	Parco della Sila	Transitional	39.2483	16.4629	*Pinus nigra* subsp. *laricio, Fagus sylvatica*
73	Parco della Sila	Sentinel	39.2819	16.4465	*Fagus sylvatica*
74	Passo Falzarego	Transitional	46.5220	12.0169	*Picea abies, Larix decidua, Pinus cembra*
75	Piegaro 1	Productive	42.9637	12.0586	*Pseudotsuga menziesii*
76	Piegaro 2	Productive	42.9683	12.0686	*Quercus cerris, Quercus petrea, Prunus avium*
77	Parco Nord MI	Other	45.3232	9.1245	*Quercus cerris, Fraxinus excelsior, Quercus robur*
78	Santa Sofia FC	Productive	43.5705	11.5617	*Pinus nigra, Ostrya carpinifolia*
79	Massa Marittima GR	Productive	43.0561	10.5770	*Quercus cerris, Ostrya carpinifolia, Fraxinus ornus*
80	Pollino Calabria	Sentinel	39.8241	16.0487	*Fagus sylvatica*
81	Pollino Basilicata	Sentinel	40.0346	16.0970	*Fagus sylvatica*
82	Incoronata FG	Other	41.2369	15.3887	*Quercus pubescens, Eucalyptus globulus, Cupressus sempervirens, Pinus pinaster*