SENSORS AND INSTRUMENTATION IN AGROFORESTRY RESEARCH

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Farm Woodland Forum
Annual Meeting 16th June 2022

MONITORING OF RAINFALL IN REAL-TIME

Matt Cooper - PhD project on Forest Hydrology

"Investigating the role of different forest types for natural flood risk management"

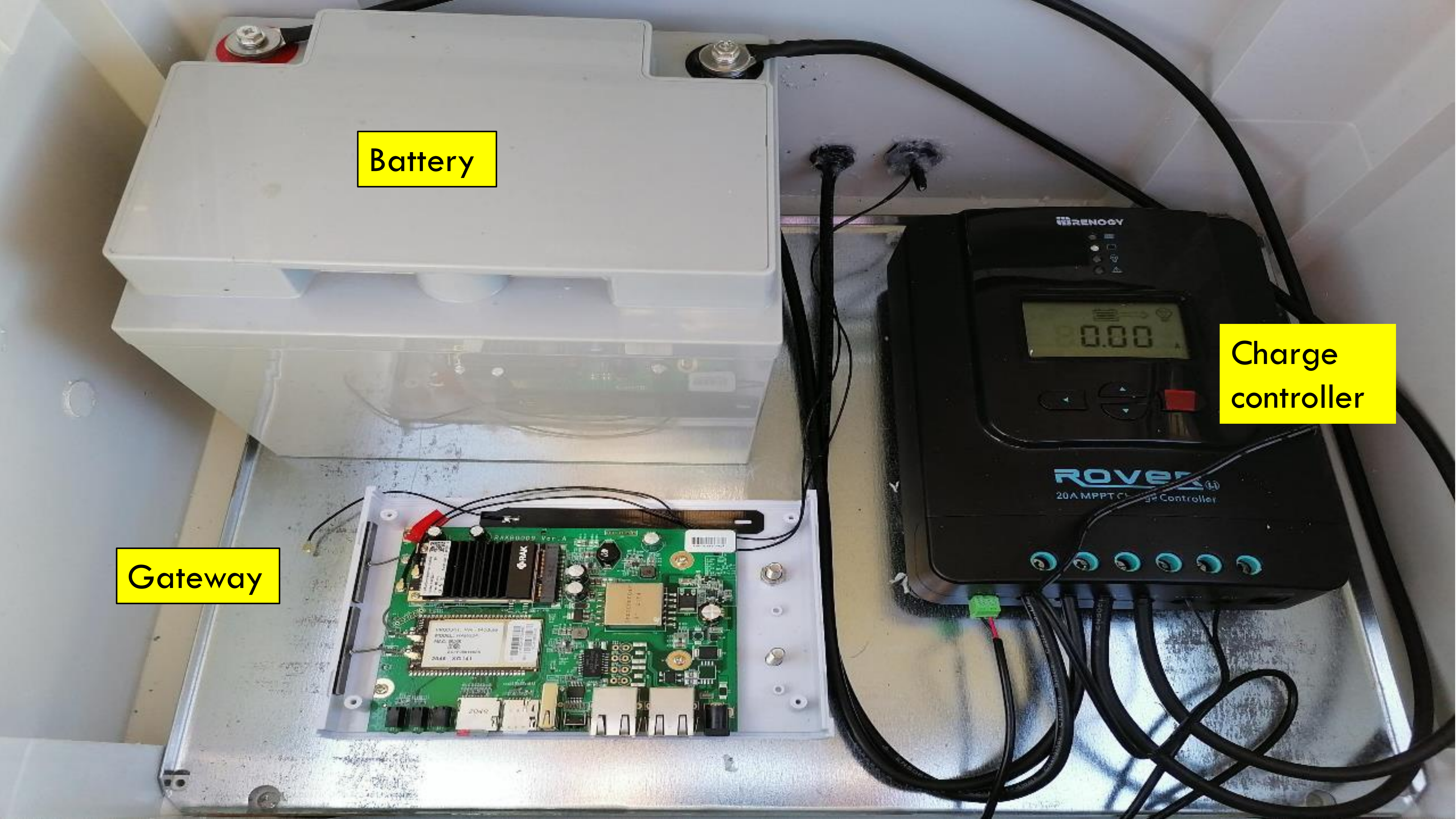
Four different forest cover 'types':

- Mature coniferous
- Young coniferous
- Mature deciduous
- Young deciduous

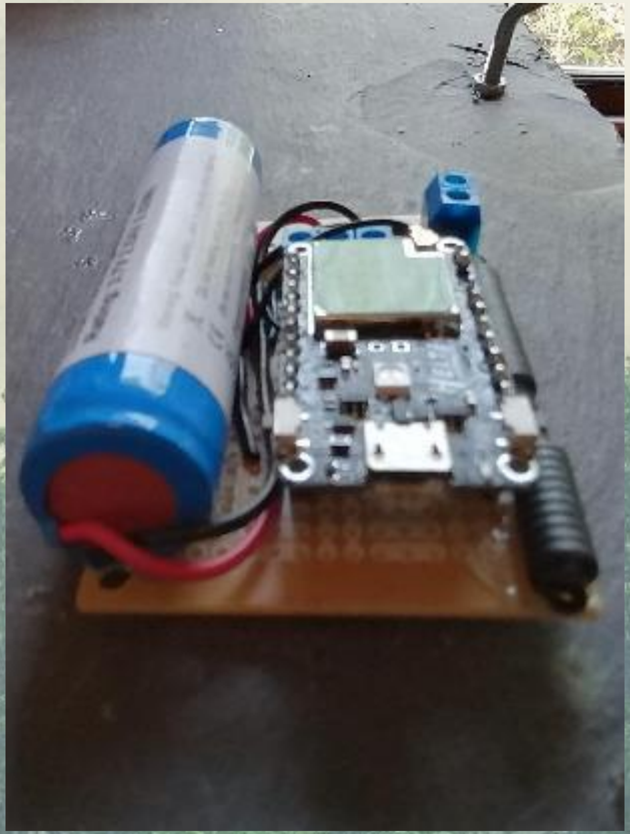
Tipping buckets located in the remote Pennal Catchment near Machynlleth

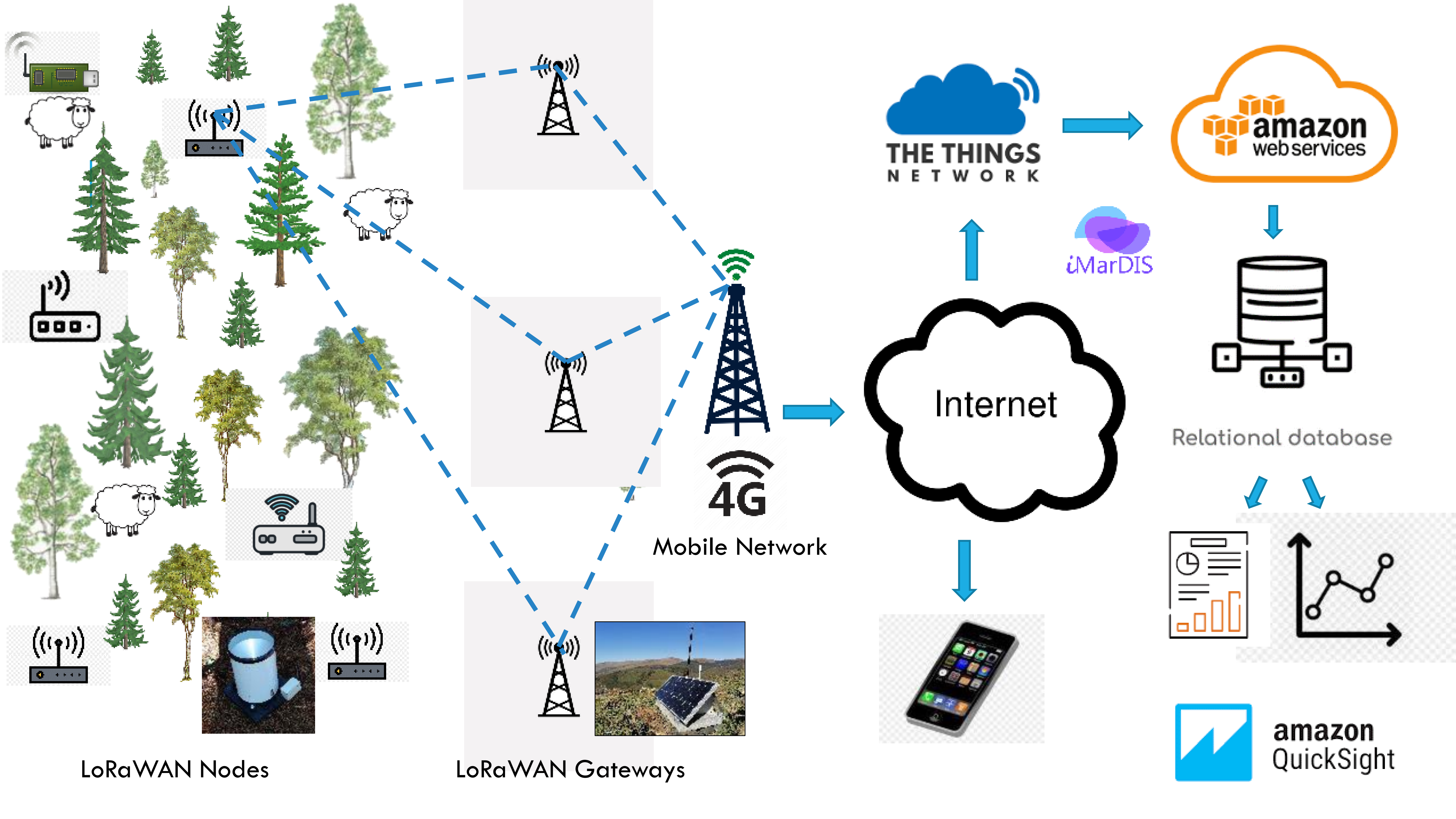
Long Range Wide Area Networks (LoRaWAN) and the Internet of Things

THE GATEWAY



Battery
Charge controller
Gateway
RENOGY
0.00
ROVER
20A MPPT Charge Controller





THE THINGS NETWORK
amazon web services
iMarDIS
Internet
4G
Mobile Network
Relational database
amazon QuickSight
LoRaWAN Nodes
LoRaWAN Gateways


v3dashboard
ic
ic rain
ic2 ic1 ic3 ic4
mc
mc rain
mc1 mc2 casella-1 mc4 mc3
imd
imd rain
imd3 imd2 imd4 imd1
oak
oak rain
oak4 oak1 oak3 oak2
Open gauges
Open gauges
school highpoint openguage
md
md rain
md3 md4 md2 md1
oak events
oak events
oak4 oak1 oak3 oak2
ic events
ic events
ic2 ic1 ic3 ic4
imd events
imd events
imd3 imd2 imd4 imd1
mc events
mc events
mc1 mc2 casella-1 mc4 mc3
md events
md events
md4 md3 md2 md1
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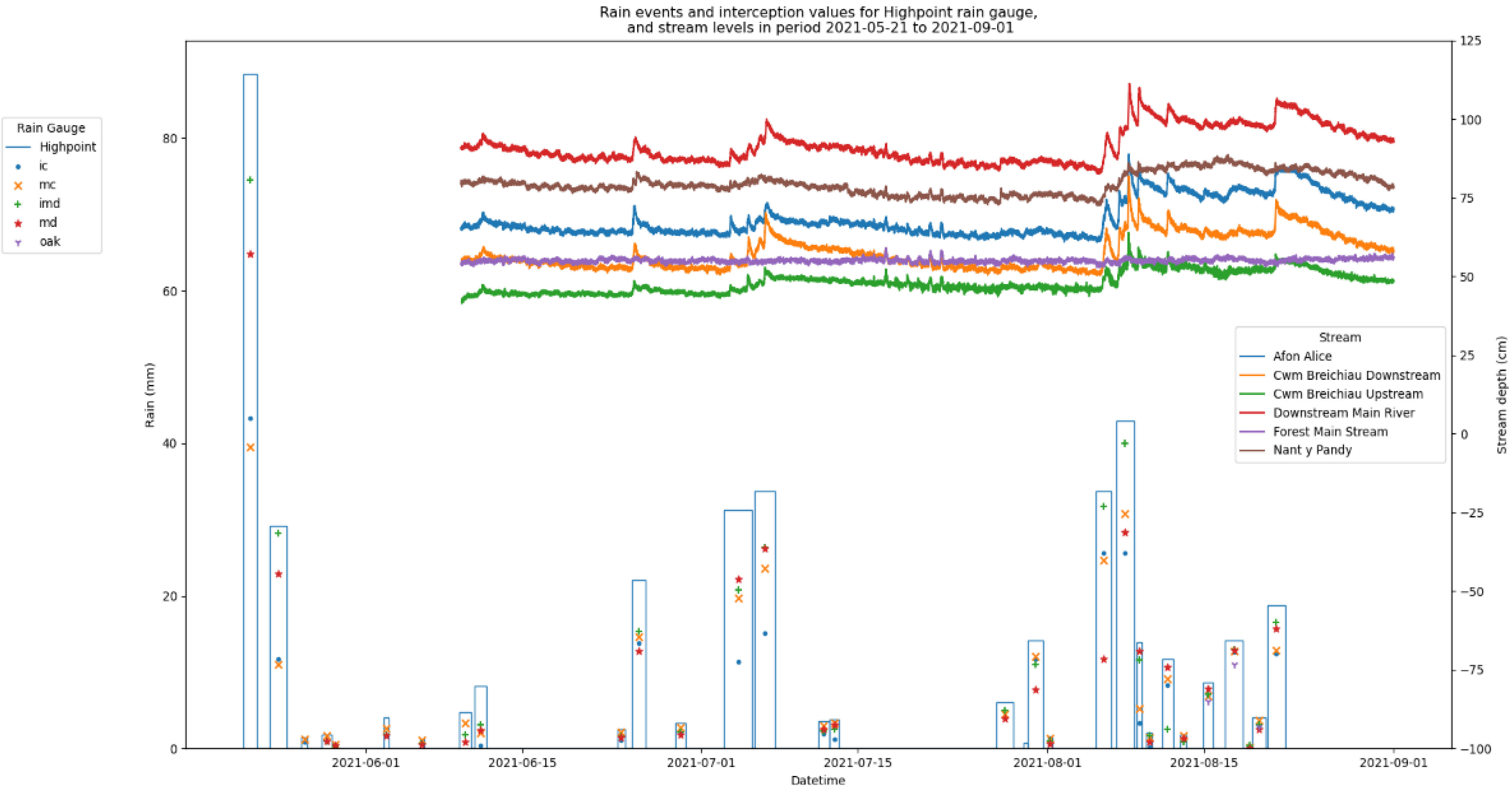
open gauge events
school highpoint openguage
Sa 10:00
Su 10:00
Mo 10:00
Tu 11:00



Rain events and interception values for Highpoint rain gauge,
and stream levels in period 2021-05-21 to 2021-09-01
Rain Gauge
Highpoint
ic
mc
imd
md
oak
Stream
Afon Alice
Cwm Breichiau Downstream
Cwm Breichiau Upstream
Downstream Main River
Forest Main Stream
Nant y Pandy
Rain (mm)
Stream depth (cm)
Datetime
0
20
40
60
80
125
100
75
50
25
0
−25
−50
−75
−100
2021-06-01
2021-06-15
2021-07-01
2021-07-15
2021-08-01
2021-08-15
2021-09-01

MONITORING FOREST HEALTH

Threats to forest health

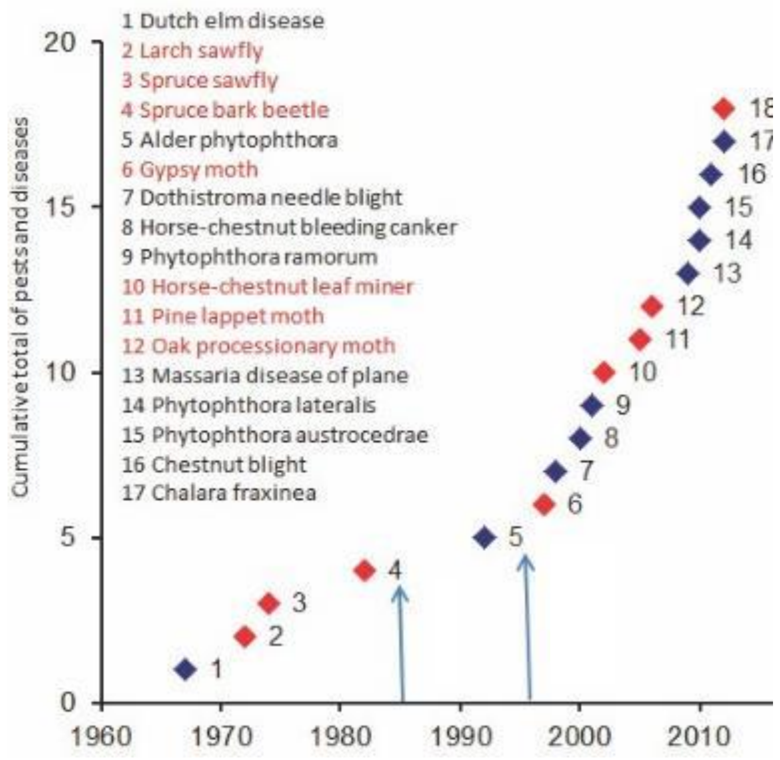
- Increase in extreme weather events.
- International trade and globalisation.
- Rapid increase in forest pest and diseases.

Forests amongst largest sources of VOCs

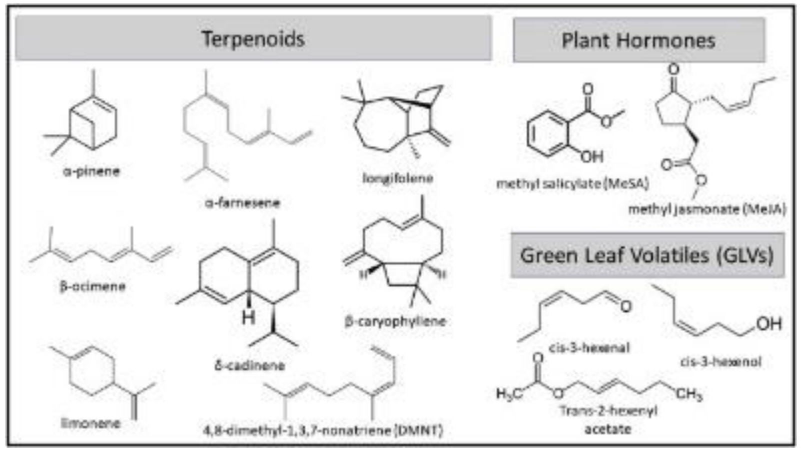
- Many species, life span from seconds to days.
- Complex interactions with environment.

Biogenic volatile organic compounds

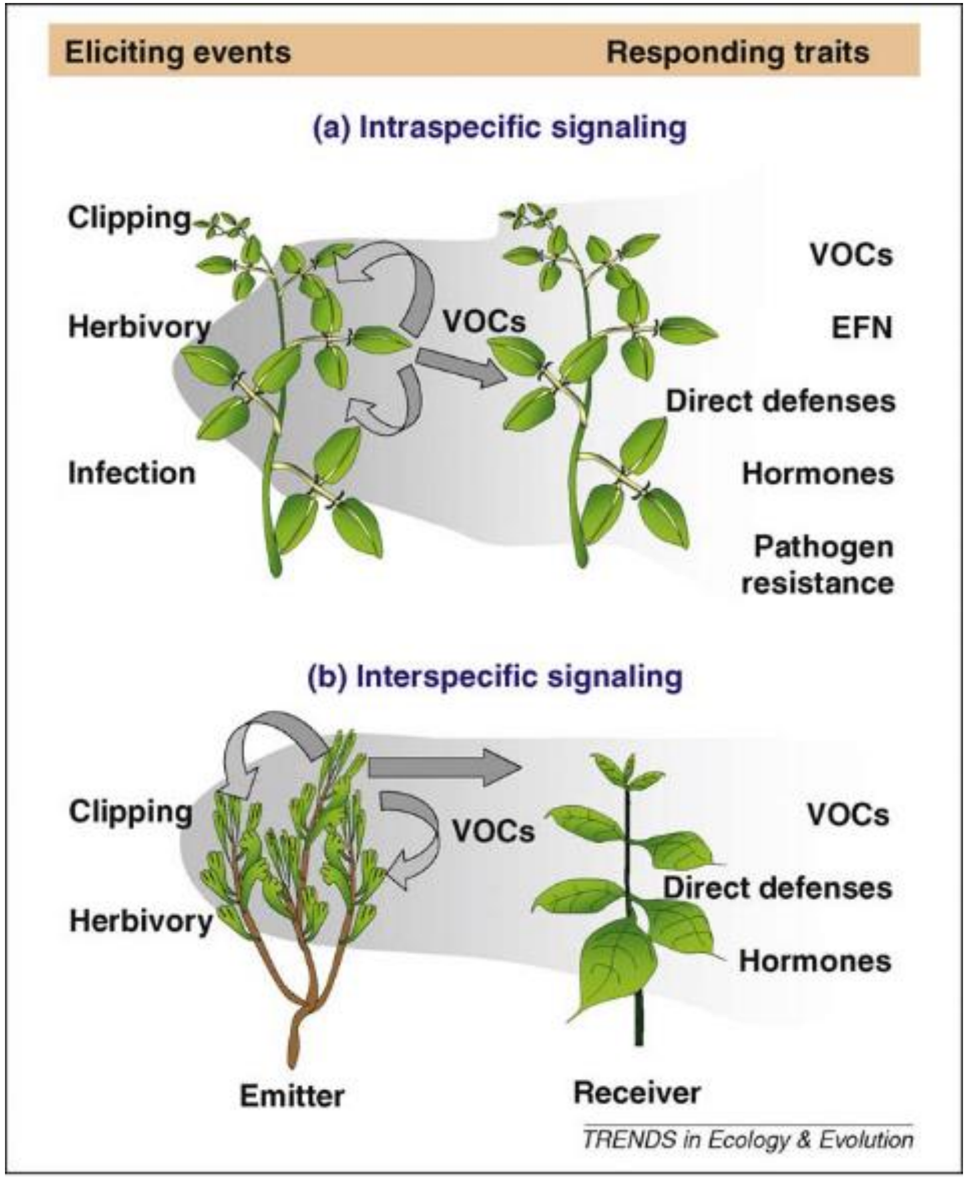
- Monoterpenes, Sesquiterpenes, Terpene derivatives
  - Released during biotic and/or biotic stress
- Plant hormones (Methyl salicylate & jasmonate)
  - Wounding, defence metabolism, defence signalling
- Green leaf volatiles (Oxygenated VOCs)
  - Produced following damage to plant tissues



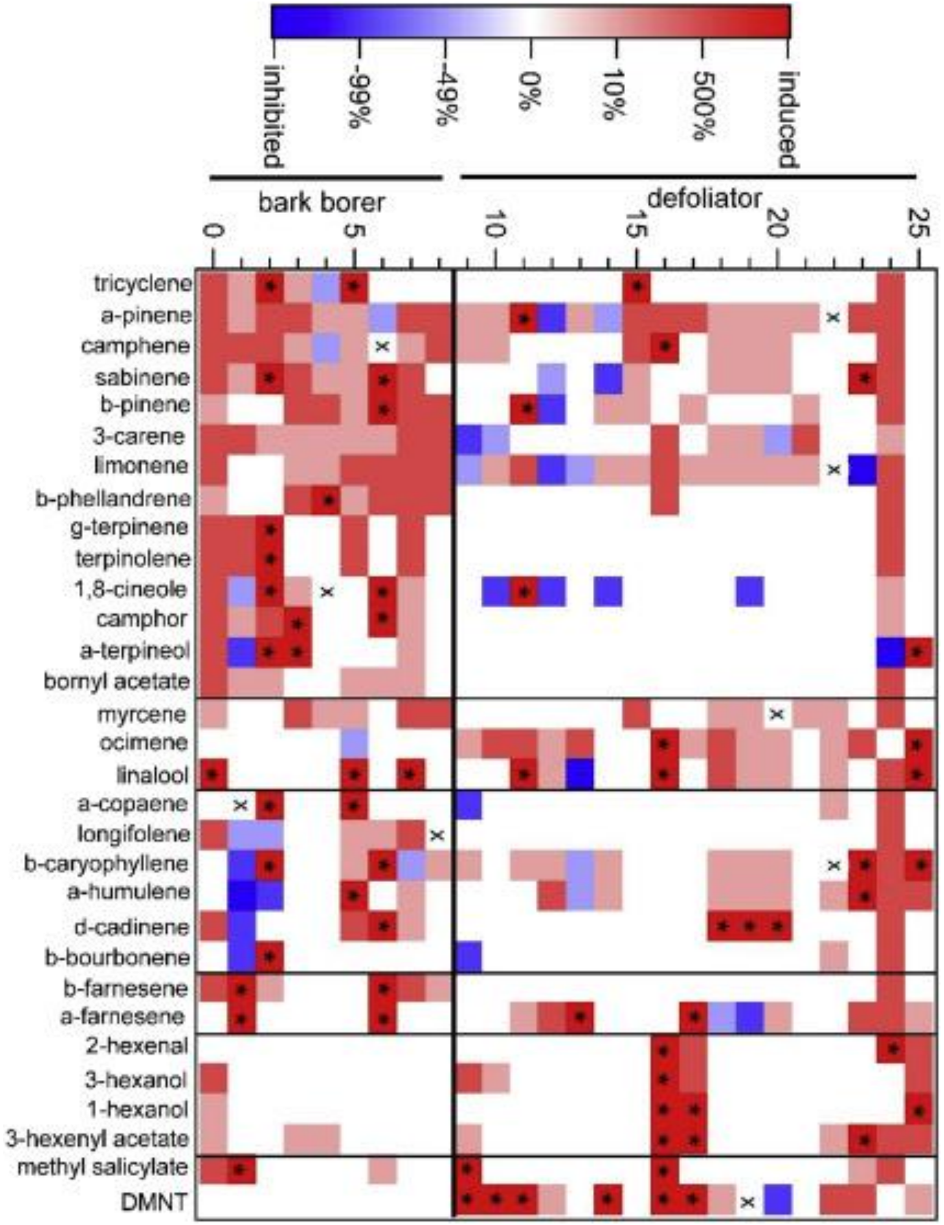
(Leather, 2014)



(Faiola & Taipale, 2020)



(Heil & Karban, 2010)



(Faiola & Taipale, 2020)

TREE STRESS AND DISEASE DETECTION

Visual and remote sensing techniques

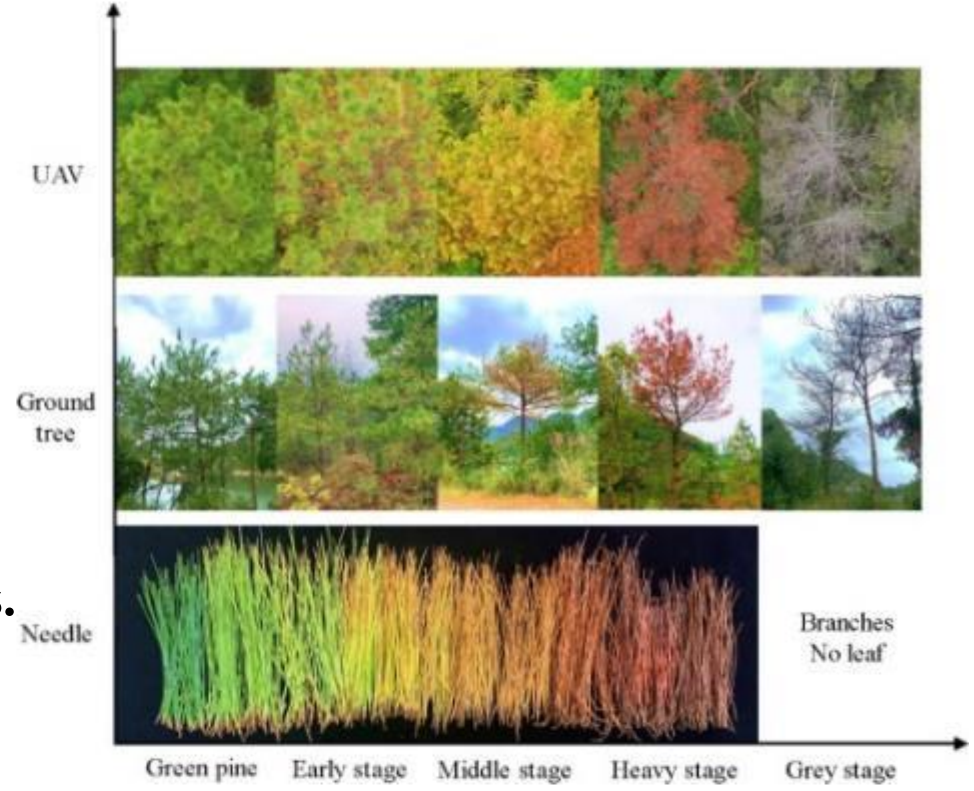
- Symptomatic only.
- Often too late for mitigation.
- Limited understanding of underlying disease.

VOC emission & detection

- Stress alters emission and spectrum of VOCs.
- Potential for advanced warning of problem events.
- Mapping of pathogen and disease spread.
- Monitoring impact of stress events.

Improvement to biosecurity and resilience

- Monoculture stands of clonal *Picea sitchensis*

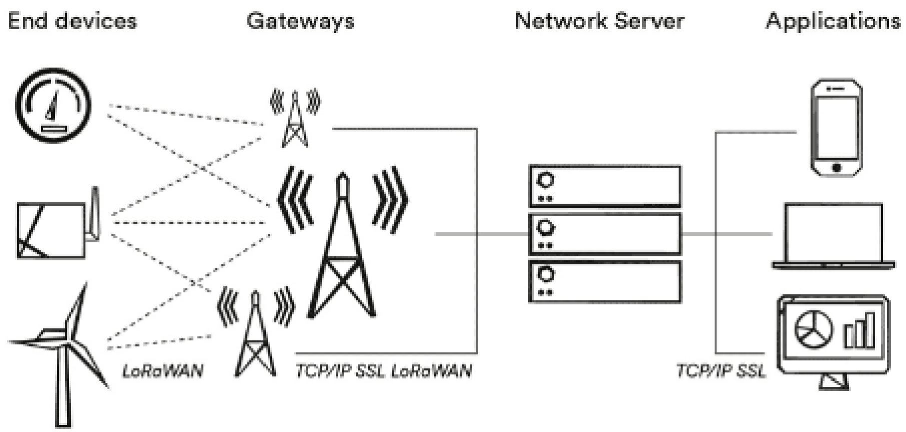


Disease detection using hyperspectral imagery (Yu et al. 2021)

SMART MONITORING OF FOREST HEALTH

Proof of concept VOC sensing technology

- Commercially available photoionisation detection (PID) sensors.
- VOC specific organic thin film transistors developed at Bangor.
- Sensor array to detect multiple species of VOC.



Phase 1 - Controlled environment testing

- Drought, heat, defoliation, etc.
- Continuous monitoring of VOC emissions.

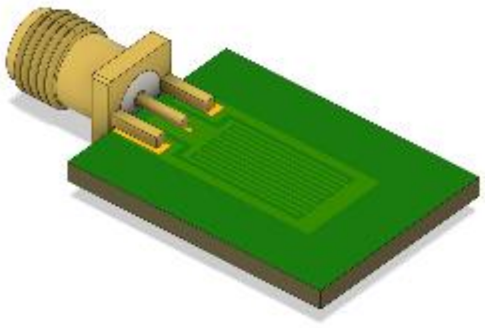
Phase 2 - Deploy as sensor nodes on LoRaWAN

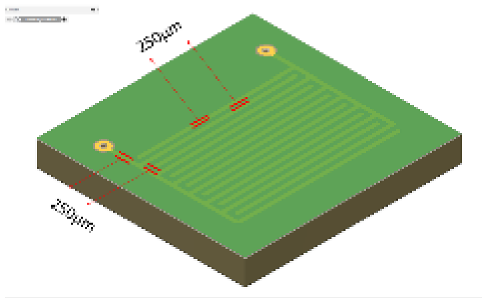
- Correlate VOC emission patterns.
- Climate and earth observation data to correlate and calibrate.
- Geospatial statistical correlation and machine learning approaches.

SENSOR DESIGN AND MANUFACTURE

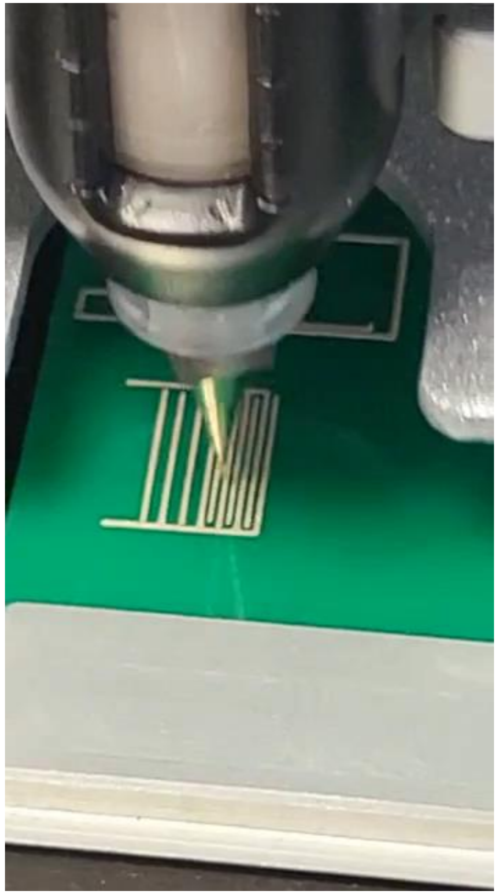
Chemiresistors based on:

- Multiwalled carbon nanotubes
- Silver nanoparticles
- Gold nanoparticles

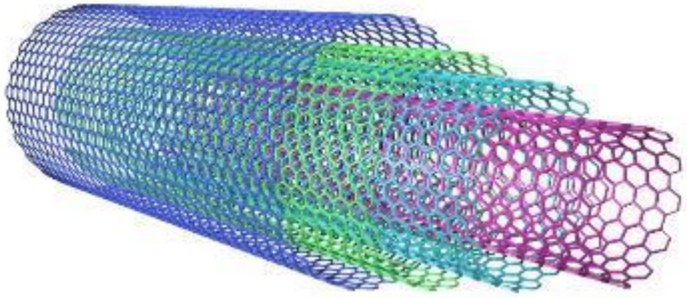




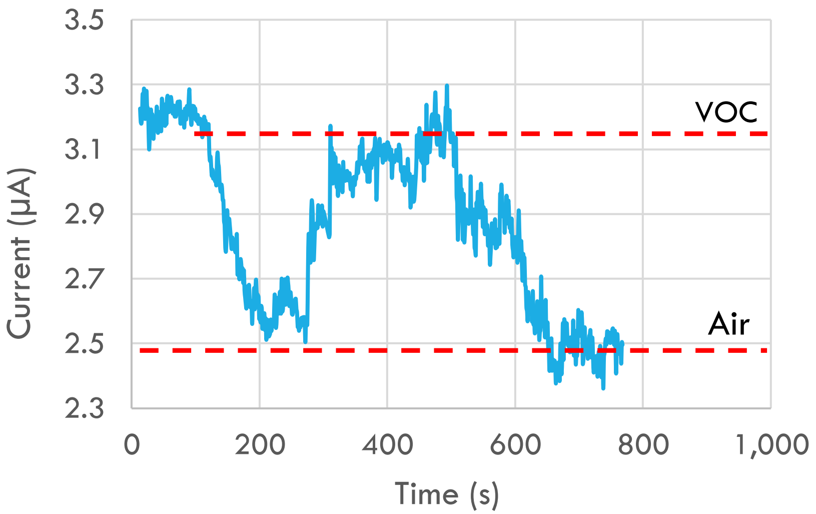
Sensor design



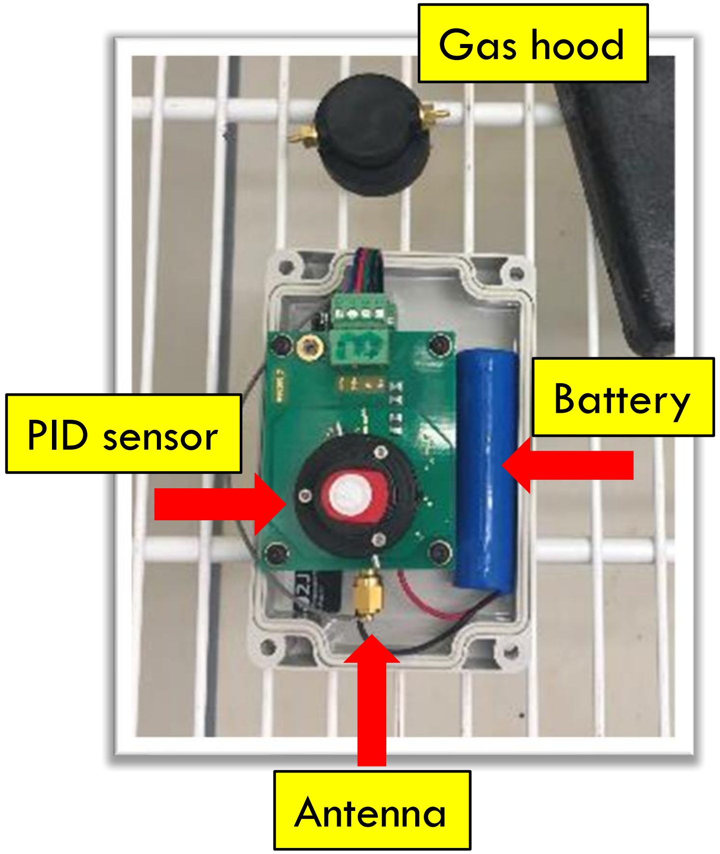
Manufacture

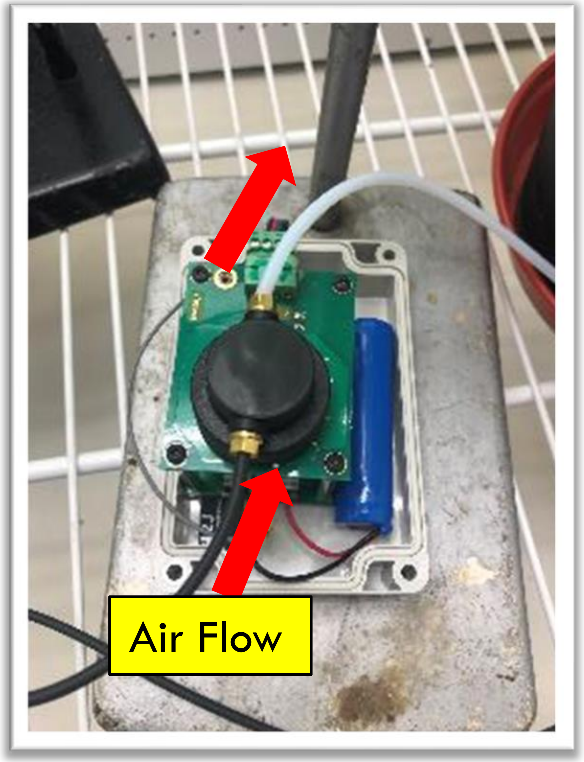


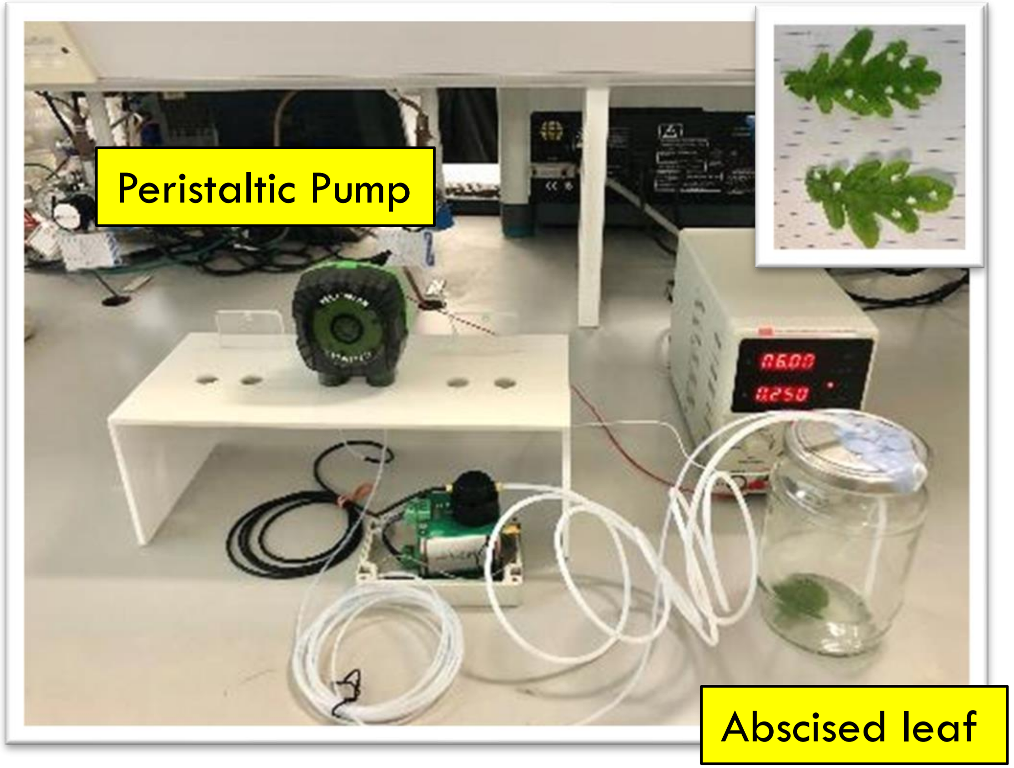
Structure of a multiwalled carbon nanotube built from graphene sheets



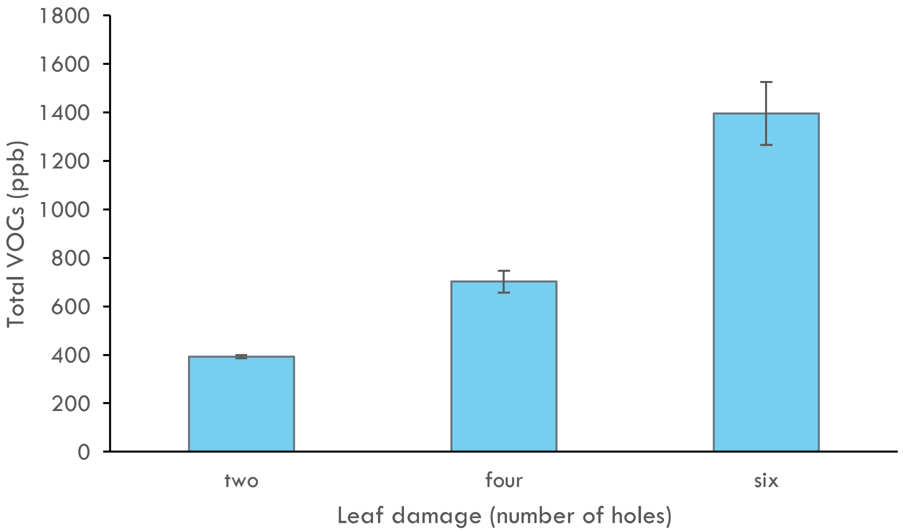
Response of carbon nanotubes to Isoprene



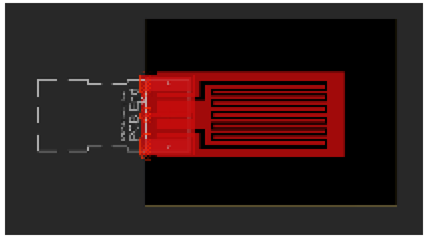


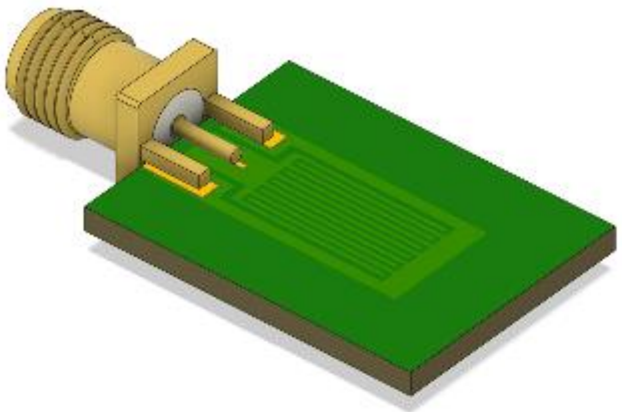


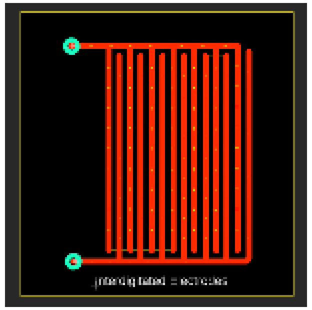
- Establishment of the mesocosm testing system.
- Assessing leaf physical damage and VOC emission response.

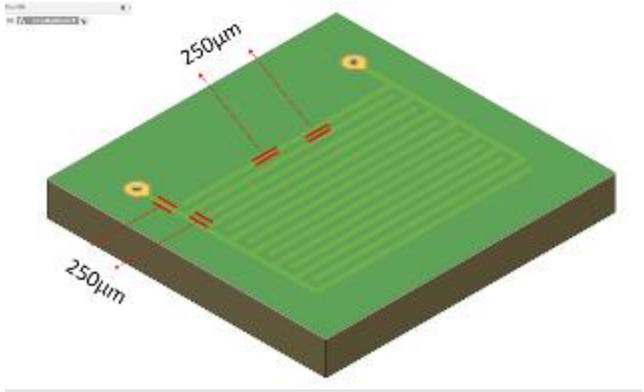


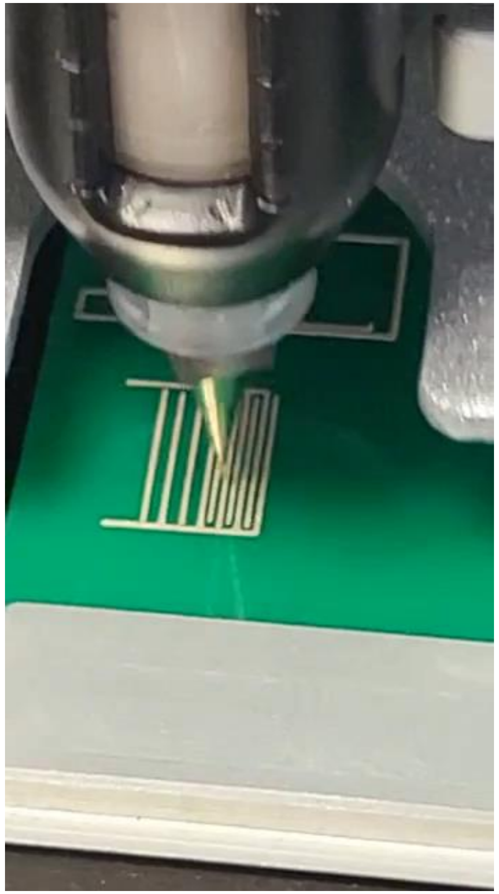
SENSOR DESIGN AND MANUFACTURE











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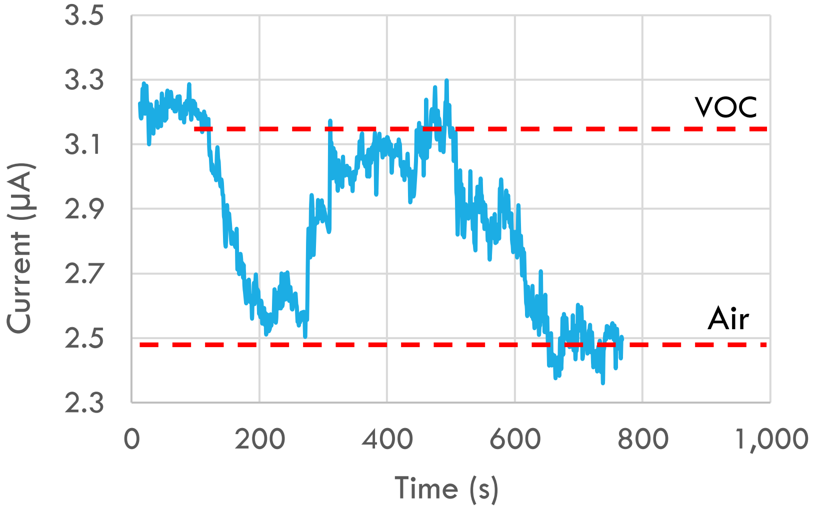


Response of carbon nanotubes to Isoprene

PRELIMINARY RESULTS

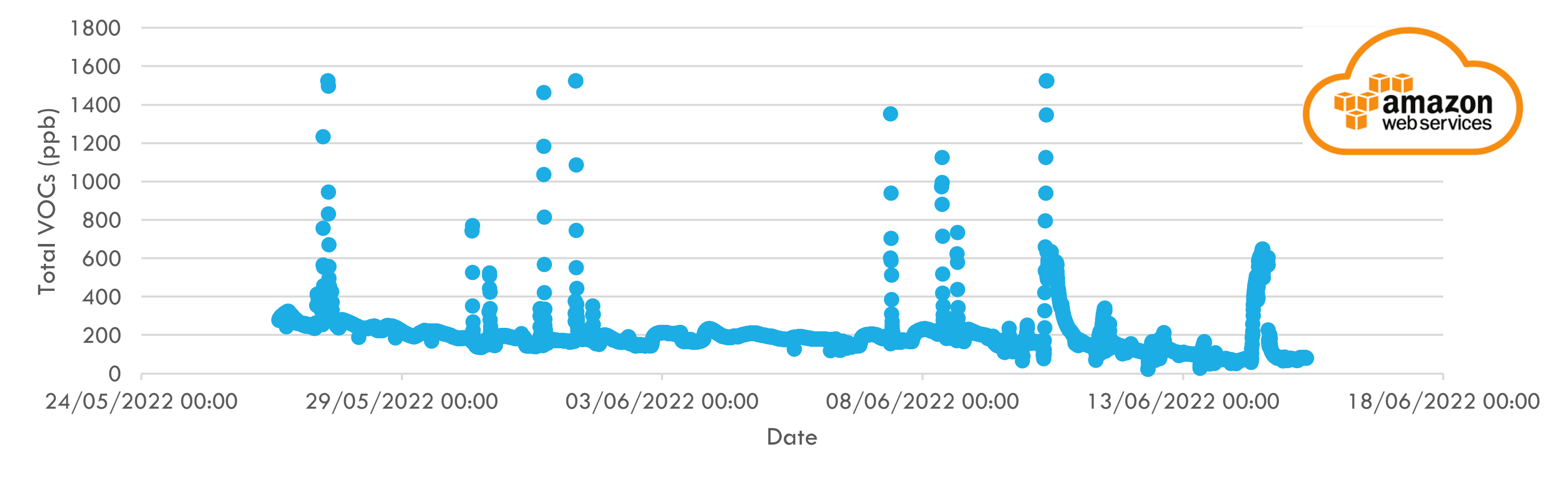
One-year-old tree saplings:

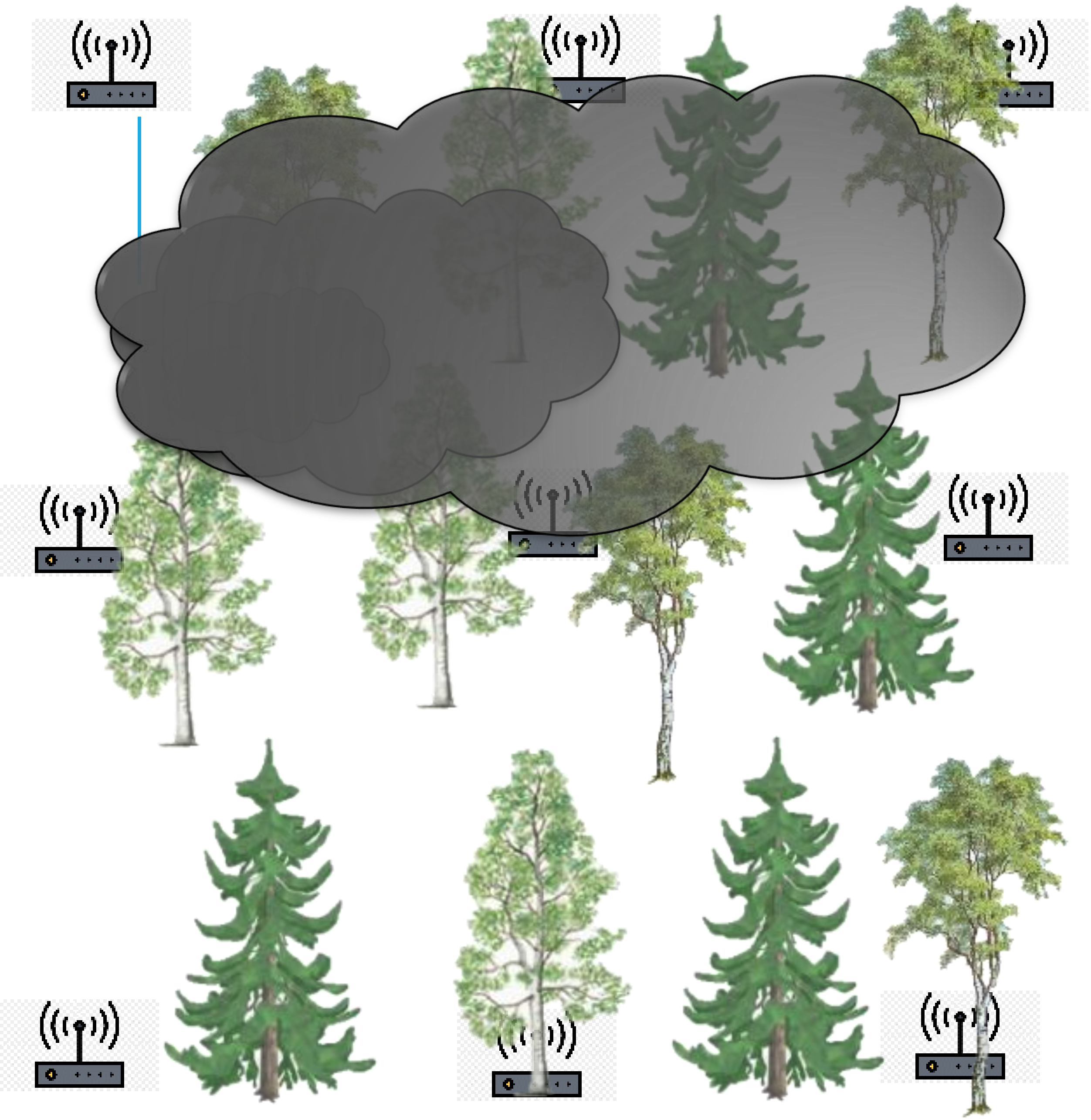
- alder (Alnus glutinosa), hazel (Corylus avellana),
- lime (Tilia cordata), aspen (Populus temulus)

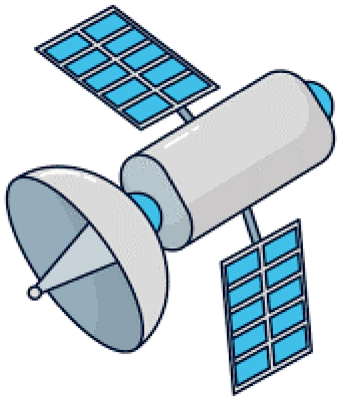
Treatments:

- Heat, drought, light stress, physical leaf damage

Continual VOC monitoring over LoRaWAN & data storage on AWS

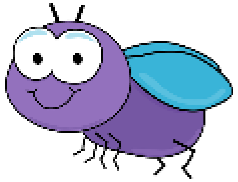




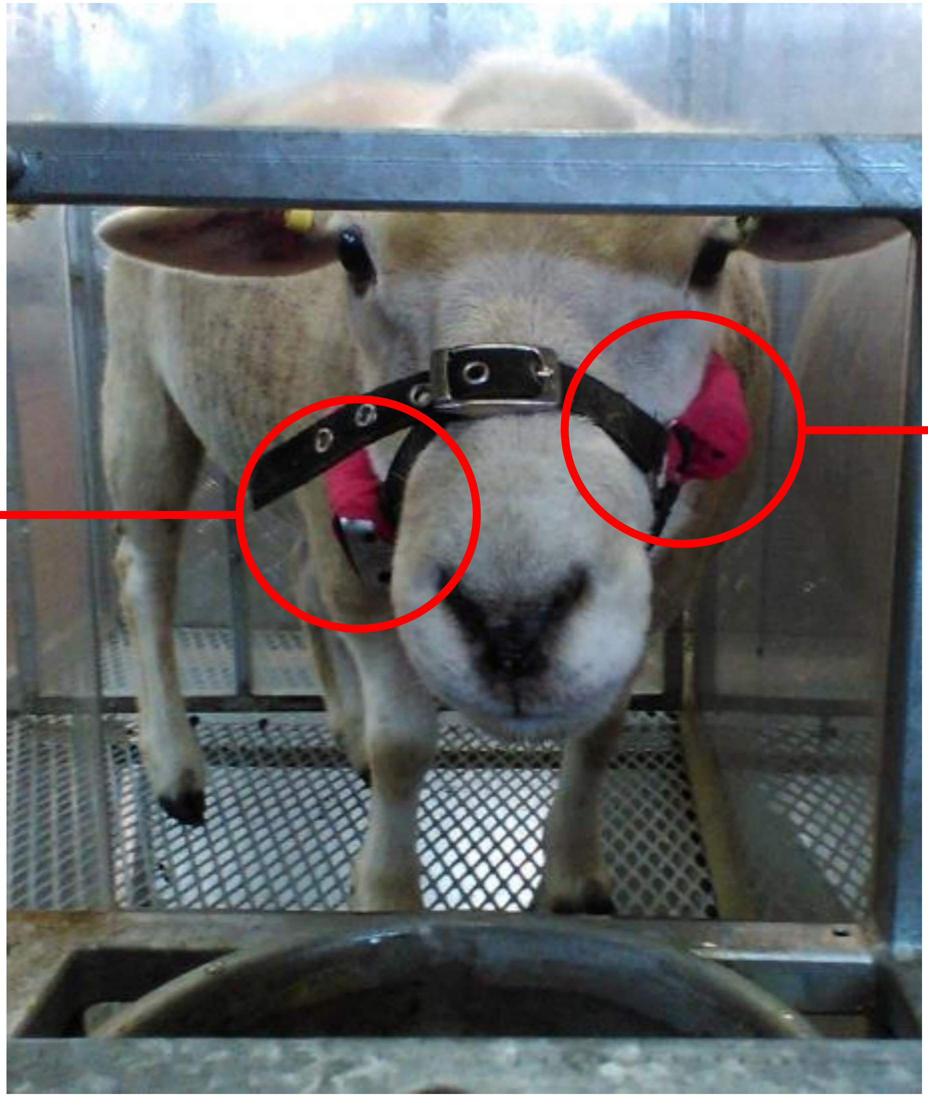


Next steps…..

- Deploy PID node mesh in natural forest and monitor to collect training data.
- Satellite spectral vegetation indices (e.g., Normalised Difference Vegetation Index, RedEdge Chlorophyll Index, Green Chlorophyll Vegetation Index, etc.) will be used to monitor plant and forest health.
- Machine learning algorithms (e.g., MLP artificial neural networks) will be used to forecast stress events from VOC emissions and microclimate data.



INSTRUMENTING LIVESTOCK



Accelerometer to detect movement
Limitation memory capacity (90 mins)
Opportunities for LoRaWAN

All animal procedures were carried out according to the Home Office scientific Procedures (Act 1986)

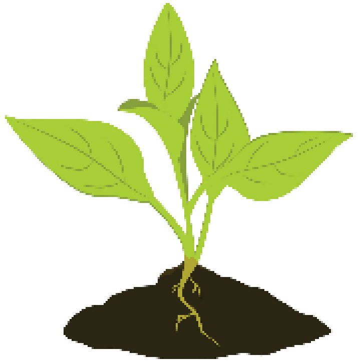
All animal procedures were conducted in accordance with the Home Office scientific Procedures (Act 1986)

REAL-TIME MONITORING POSSIBILITIES

Light/shade (PAR)

Volatiles

Temperature



Precipitation

NPK nutrient status

Soil Moisture

Animal movement/behaviour

SATELLITE IMAGERY

Normalised Difference Vegetation Index

RedEdge Chlorophyll Index

Green Chlorophyll Vegetation Index

Canopy Height