HERIOT WATT UNIVERSITY

Data-driven agroforestry

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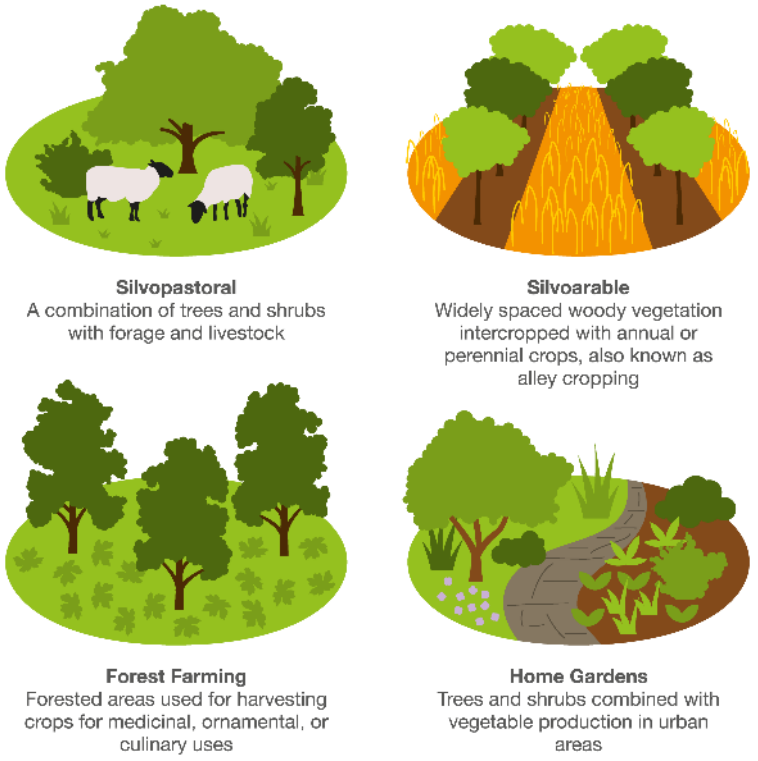
Outline

1. Agroforestry
2. Precision agriculture
3. Precision livestock farming
4. Motivation
5. Definition of Data Driven Agroforestry
6. Proposed sensors
7. Conclusion

Agroforestry

- Multifunctional land use system
- Take advantage of interaction between components
- Most measurements are destructive and expensive
- Lack of research combining sensors and agroforestry



Precision Agriculture

- Management strategy which accounts for temporal and spatial variability
- High use of wireless sensor networks and *in situ* sensing
- Mostly for monocropping systems

	Measurands
Soil measurements	Moisture Temperature Nutrients pH Texture Salinity
Environmental measurements	Atmospheric pressure Temperature Humidity Light intensity Wind speed Wind direction CO2
Plant measurements	Growth

Precision Livestock Farming

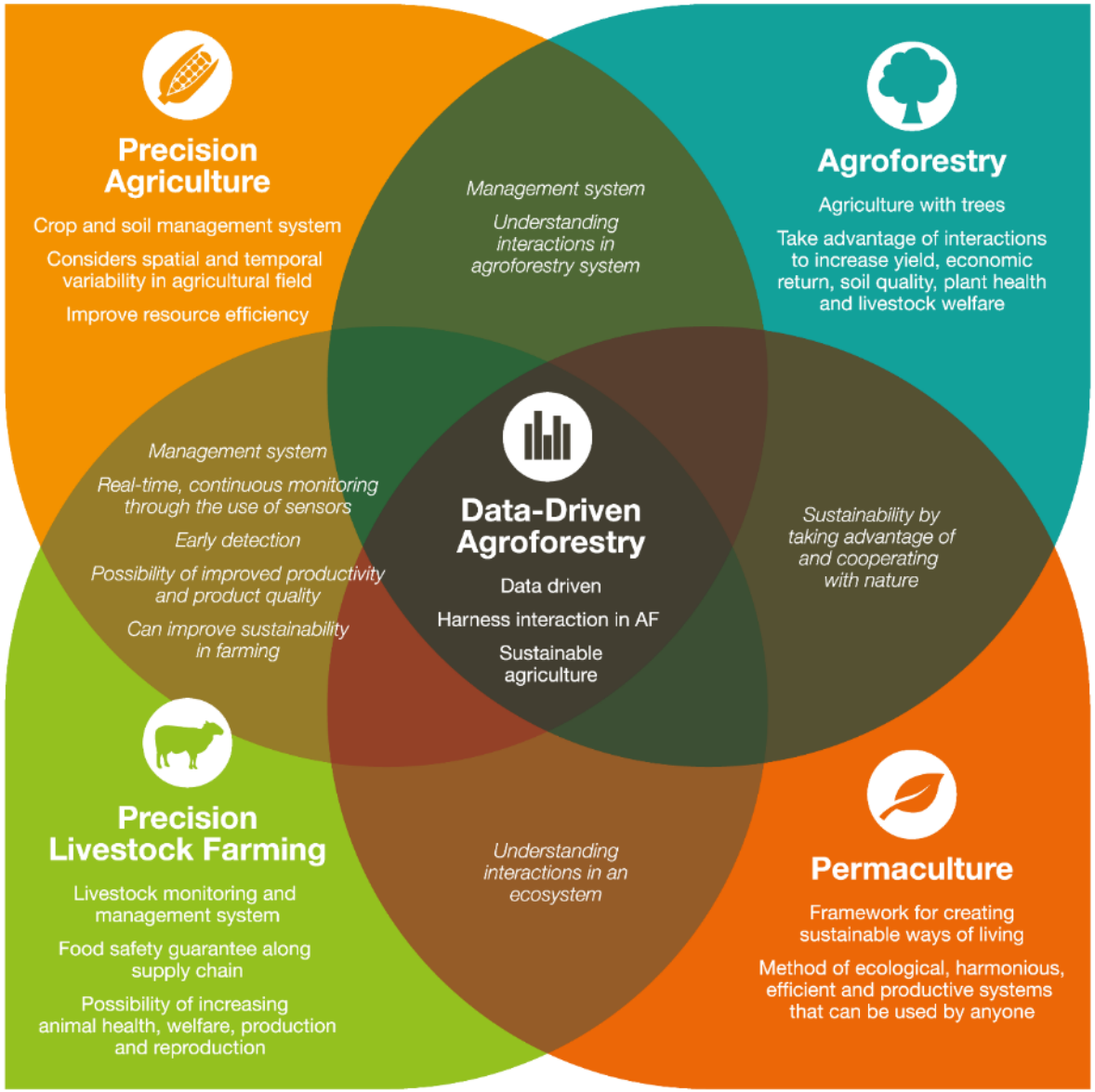
- Livestock management through use of real-time, continuous monitoring of animal health, welfare, production, and reproduction
- Early detection

	Measurands
Animal identification	RFID
Body weight measurements	Walk-over-weigh platforms Image processing
Location	GPS Bluetooth
Behaviour	GPS Accelerometers Acoustic sensors Pressure sensors Inertial measurement units (IMU)
Virtual fencing	GPS

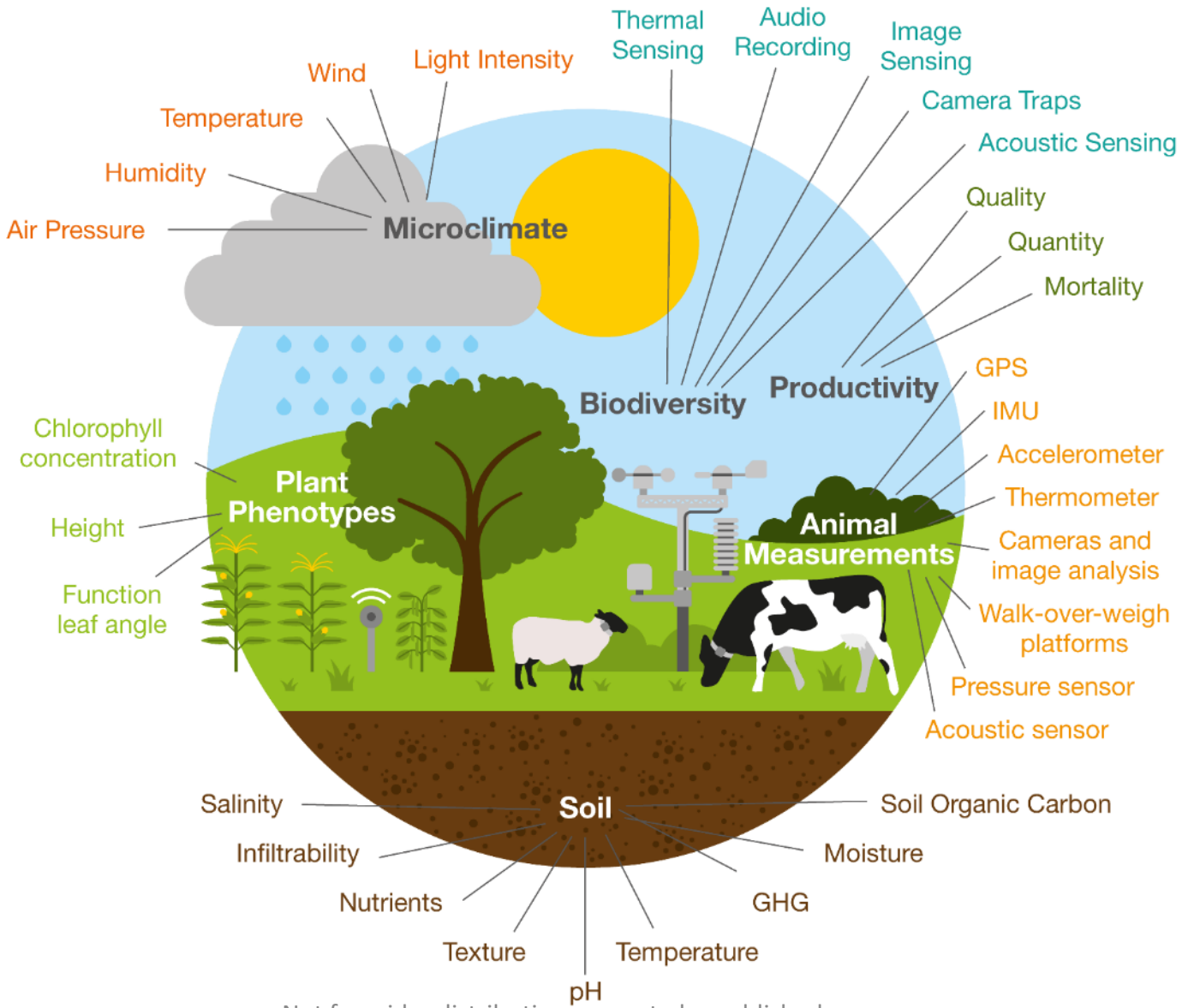
Motivation

- Lack of real-time, spatial and temporal data in agroforestry
- Potential of precision agriculture and precision livestock farming for providing data for better field management
- Combination of these results in Data-Driven Agroforestry

DEFINITION OF DATA DRIVEN AGROFORESTRY



TYPES OF MEASUREMENT



Precision Agriculture (PA)

Category	Measurand	Sensing Modality	Sensor
Soil	Moisture	Capacitance	EC-5
		Capacitance	10HS
		Capacitance	SEN0193
		Resistance	FC-28
		Resistance	Watermark
		Resistance	SEN13322
	pH	Current	Atlas pH probe
	Temperature	Digital thermometer	DS18B20
Microclimate	Temperature	Capacitance	Si7021
		Resistance	DHT11
		Resistance	DHT22
	Humidity	Capacitance	Si7021
		Resistance	DHT11
		Resistance	DHT22
		Resistance	C10-M53R
	Atmospheric pressure	Piezoresistive	MPX4115S
		Piezoresistive	BMP180
	Light intensity	Photodetector	BH175FVI
	Rain	Tipping bucket	DL-TBRG
		Resistance	RD01
	Wind	Cup anemometer	PCE-A420
		Hot-wire anemometer	Testo 405
		Ultrasonic anemometers	Windsonic M

Agroforestry (AF)

Category	Measurand	Sensing modality	Sensor
Biodiversity	Animal and pest detection	Acoustic	NCA
		Thermal	NCA
		Imaging	NCA
	Pollinators	Development needed	
Plant	Growth	Imaging	NCA
		Piezoresistive	NCA
		Piezoelectric	NCA
		Capacitance	NCA
	Health	Imaging	BF3703
Soil	GHG	Micrometeorological	NCA
		Chamber	NCA
		Remote sensing	NCA
	Nutrient concentration	Development needed	

Precision Livestock Farming (PLF)

Category	Measurand	Sensing modality	Sensor	Product Name
Cattle	Weight	Walk-over-weigh	G06000 Gallagher Loadbar	Datamuster
	Temperature	thermometer		smaXtec
	Heat	accelerometer		Ceres Tag
		accelerometer		smaXtec
		accelerometer		SensHub
		accelerometer		Moomonitor+
		accelerometer		IceTag & IceQube
		accelerometer		Moocall
		accelerometer		eShephard
	Activity	accelerometer		Ceres Tag
		accelerometer		smaXtec
		accelerometer		SensHub
		accelerometer		Moomonitor+
		accelerometer		IceTag & IceQube
		accelerometer		Halter
		accelerometer		Vence
	Calving	Walk-over-weigh	G06000 Gallagher Loadbar	Datamuster
		accelerometer		smaXtec
		accelerometer		Allflex SensHub
		accelerometer		Moocall
		accelerometer		CalveSense
		accelerometer		eShephard
	Fencing	GPS		Ceres Tag
		GPS		Halter
		GPS		Vence
Pig	Weight	Image analysis	Phone camera	Pigwei
Cattle, sheep, goat	Activity	accelerometer		NoFence
	Fencing	GPS		NoFence
Cattle, sheep, goat, horse	Activity	accelerometer		digitanimal
	Fencing	GPS		digitanimal

NCA: Not commercially available

Conclusion

- Defined Data-Driven Agroforestry (DDA)
  - Sustainable agricultural method
  - Management decisions based on spatial and temporal, real-time data
  - Harness interactions of different AF components to our benefit
  - Shine light on interactions between the components
- Proposed measurements and sensors for DDA
- Identified gaps in sensor development
  - Soil nutrient and soil GHG,
  - Pest and biodiversity detection,
  - Plant growth and health.

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Thank you!

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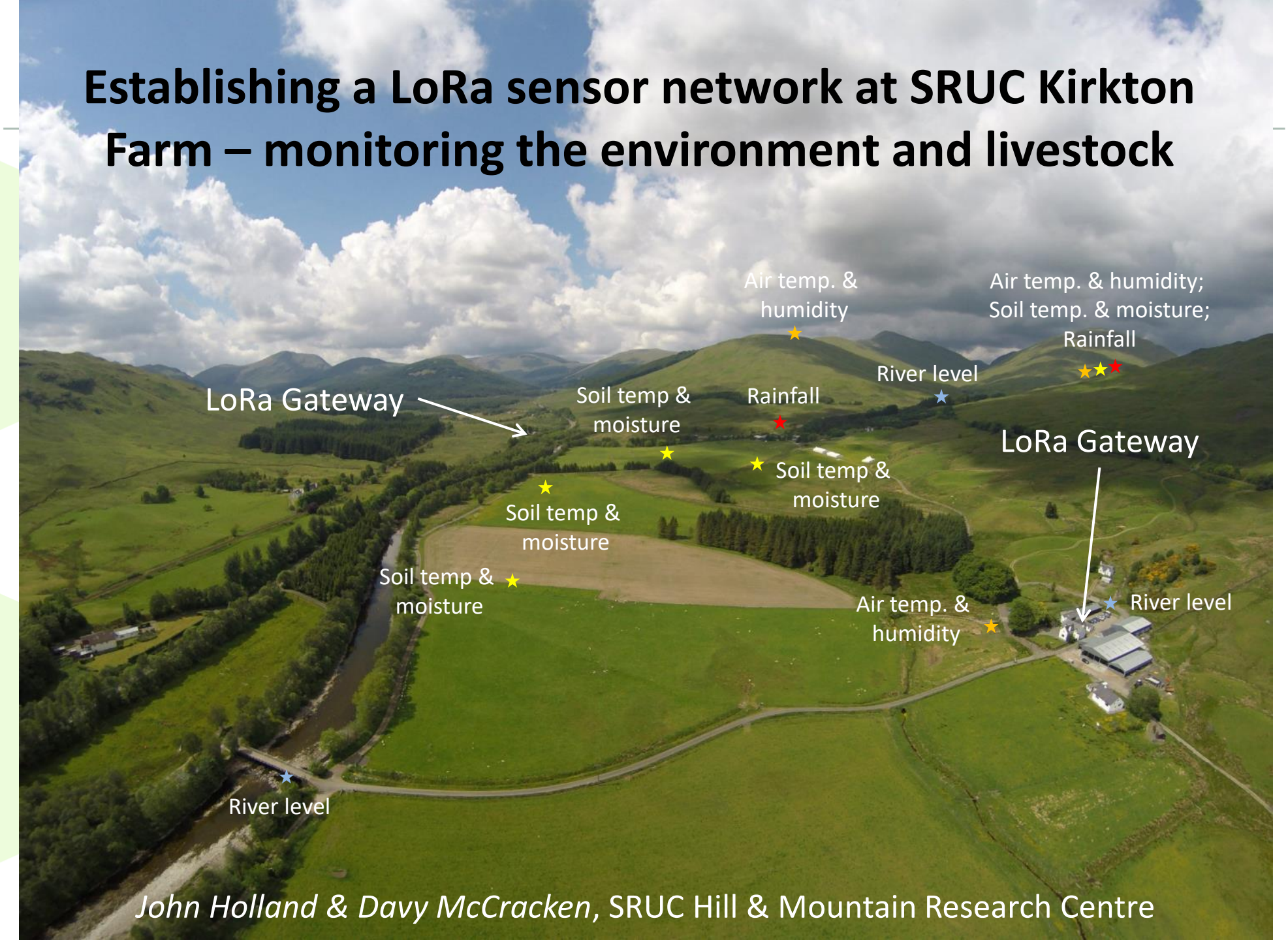
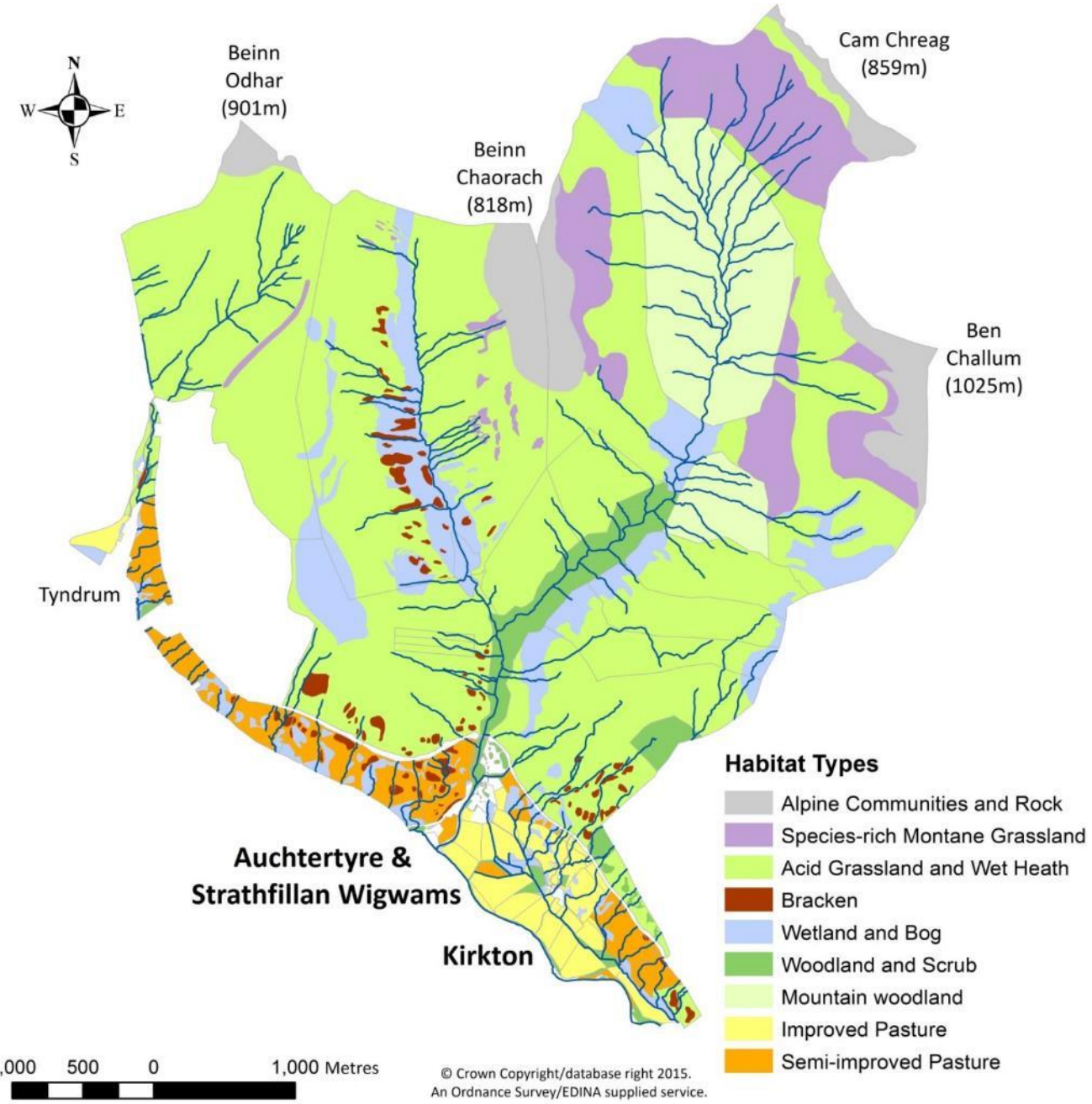
Establishing a LoRa sensor network at SRUC Kirkton Farm – monitoring the environment and livestock



John Holland & Davy McCracken, SRUC Hill & Mountain Research Centre

SRUC

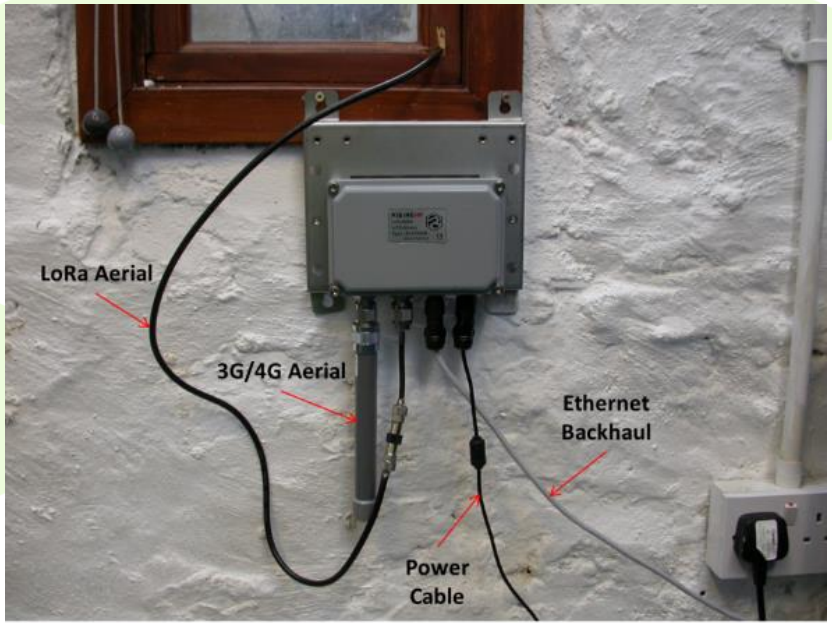
SRUC Kirkton & Auchtertyre



- Area: 2225 ha
- Altitude: 180 - 1025 m
- 3 river catchments
- Geology – metamorphic Dalradian mica-schist (650 million years old)
- Soils – pH 3.6-7.3; podzols; peaty podzols; peats; poorly developed mountain soils; alluvial soils on the floodplain.
- 1300 breeding ewes (Scottish Blackface, Lleyn, Black Welsh Mountain)
- 40 Aberdeen Angus cross Shorthorn suckler cows

LoRaWAN Sensors at Kirkton & Aucterytyre

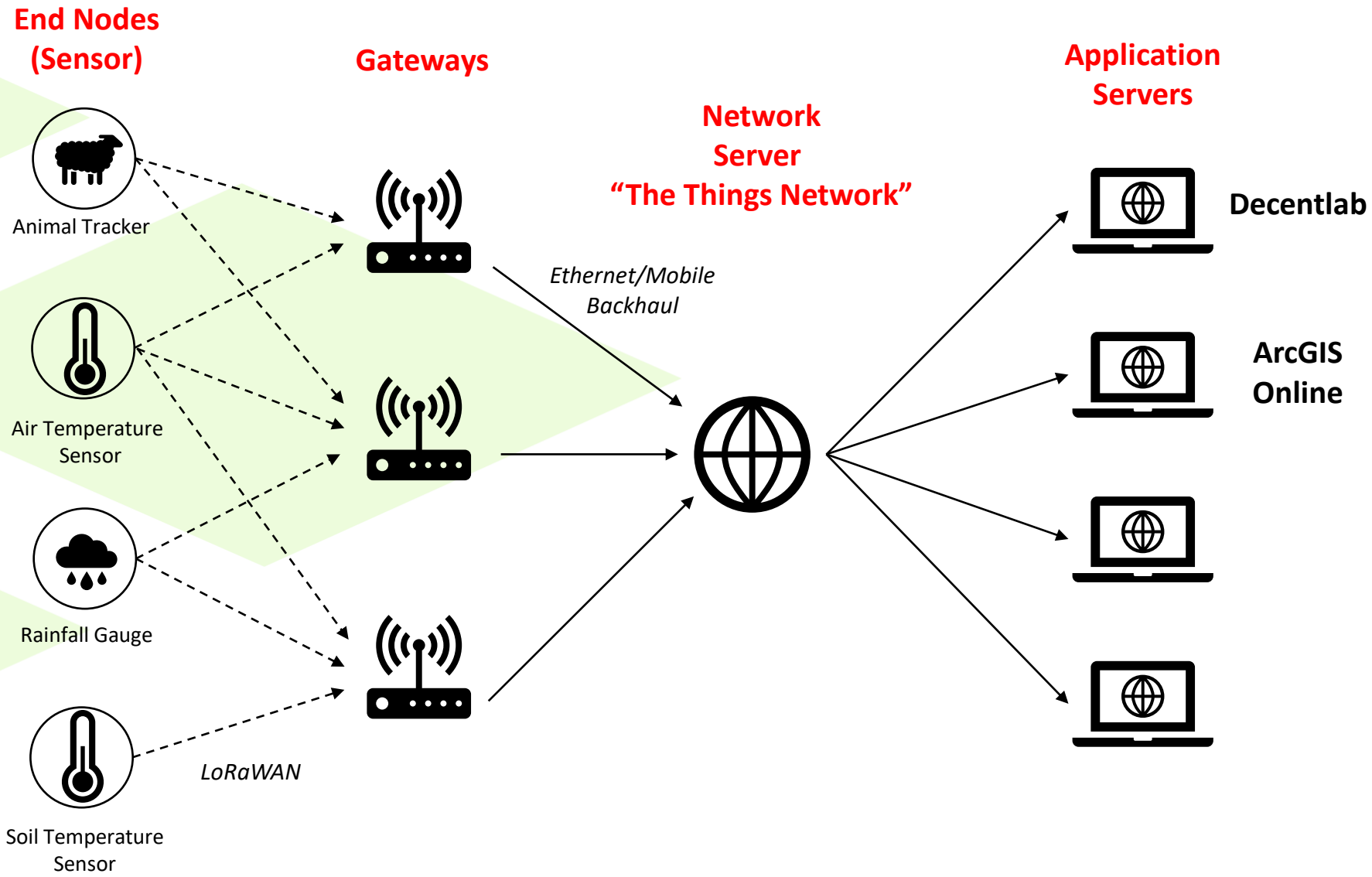
- Two indoor ethernet connected LoRaWAN gateways were established at Kirkton in 2018, enabling data from a range of sensors deployed across the farm to be accessed in near real-time via “The Things Network”.
- Two off-grid 3G connected gateways still to be deployed
- Two new Kerlink Wirnet iStations (one installed)



Indoor Ethernet connected LoRa Gateway

Off-grid 3G connected LoRa Gateway

LoRaWAN Architecture



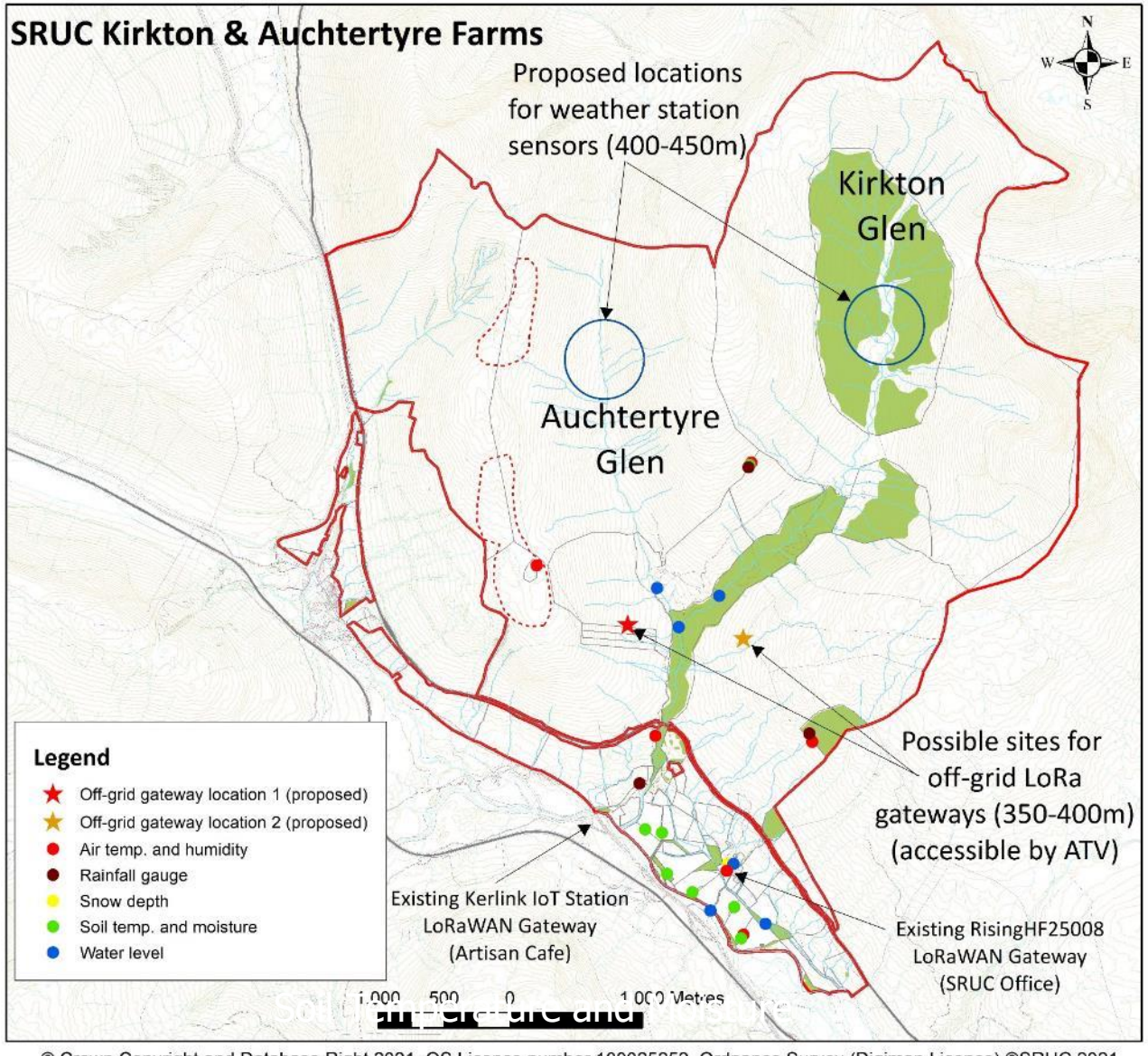
LoRa Environmental Sensors at Kirkton

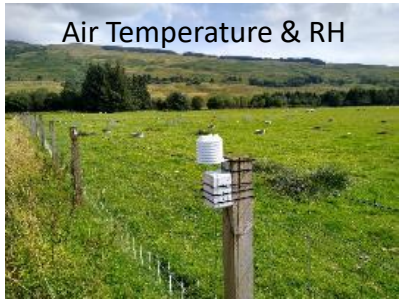
- **Sensors**
  - Air temperature and relative humidity sensors
  - Soil temperature, moisture and electrical conductivity sensors
  - Water level sensor
  - Snow depth sensor
  - Tipping bucket rain gauge
  - Soil moisture and temperature profile sensors
  - All-in-one weather station with 12 sensors
  - Water quality sensor **-** pH, temperature, dissolved oxygen, conductivity

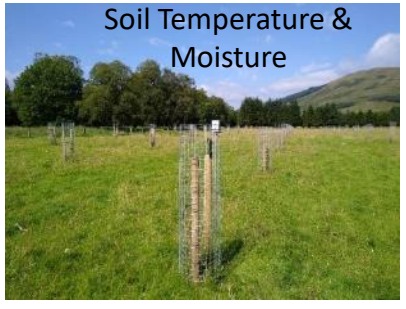





LoRaWAN-enabled Environmental Sensors

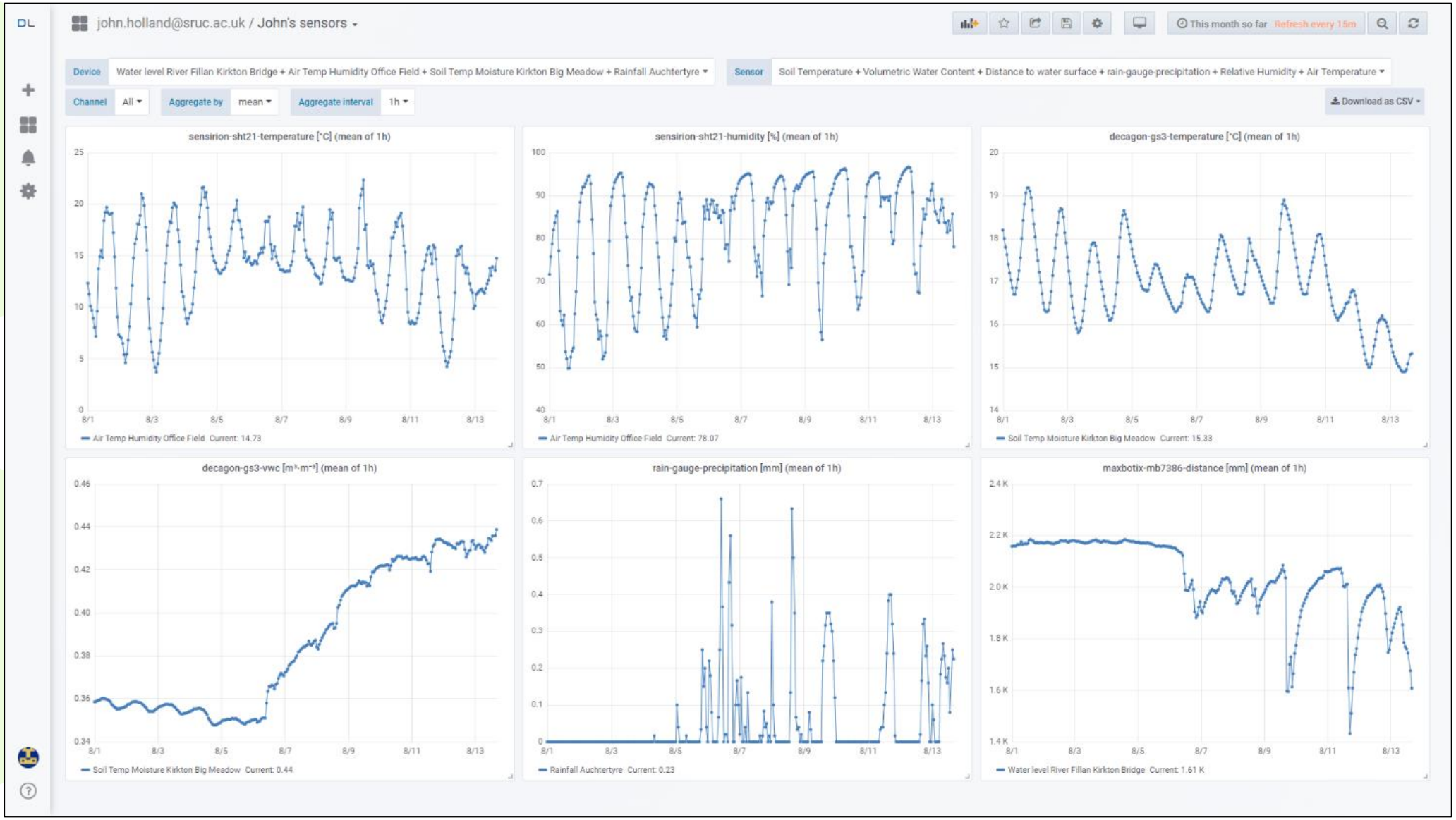






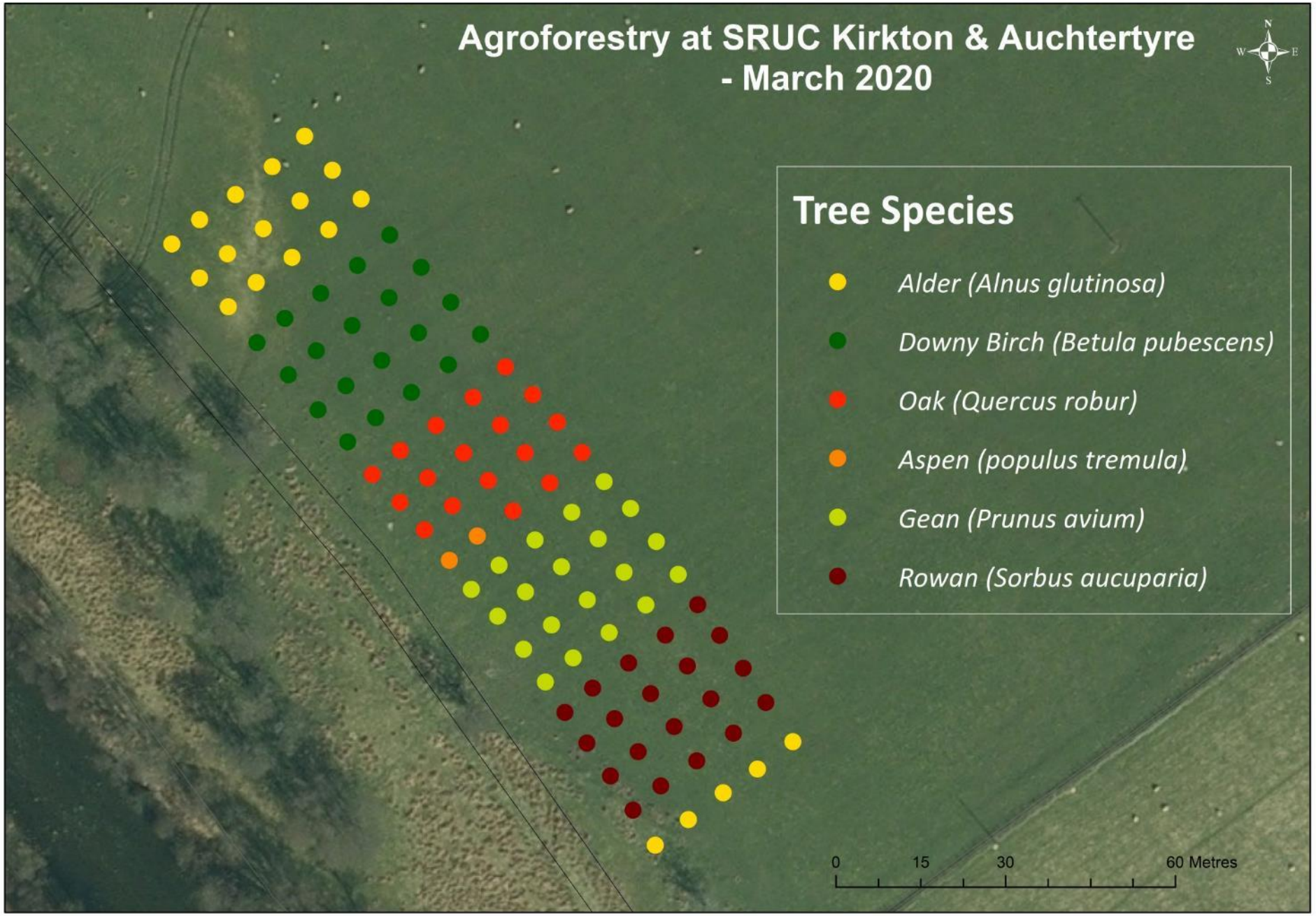
Agroforestry Plot

Decentlab Sensor Dashboard



ArcGIS Online Dashboard – Weather Sensor


Site of agroforestry plot
Planted in March 2020



SRUC

- 0.5 ha block of 100 individually protected trees in 1.5 m high weld mesh cages
- Trees at 7.14 m spacing (5 trees wide by 20 trees long)
- Sheep able to graze amongst the trees

Weld mesh cage
Height = 1500 cm
Diameter = 45 cm

Round posts
Length = 1650 cm
Diameter = 7.5 cm

Vole guard
(20 cm)

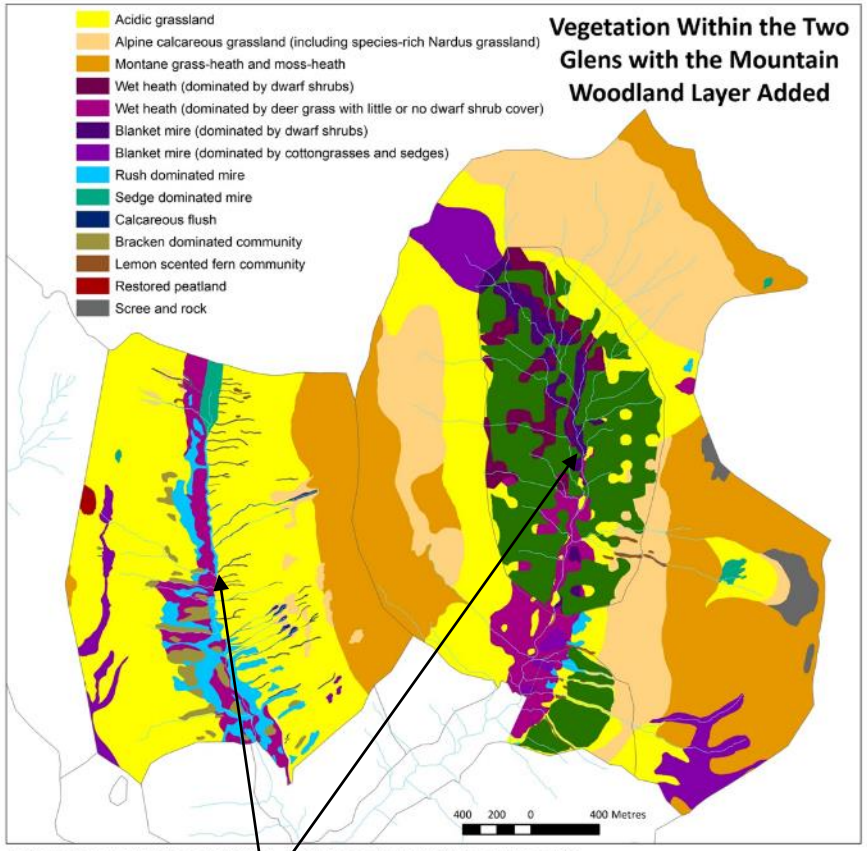
March 2020

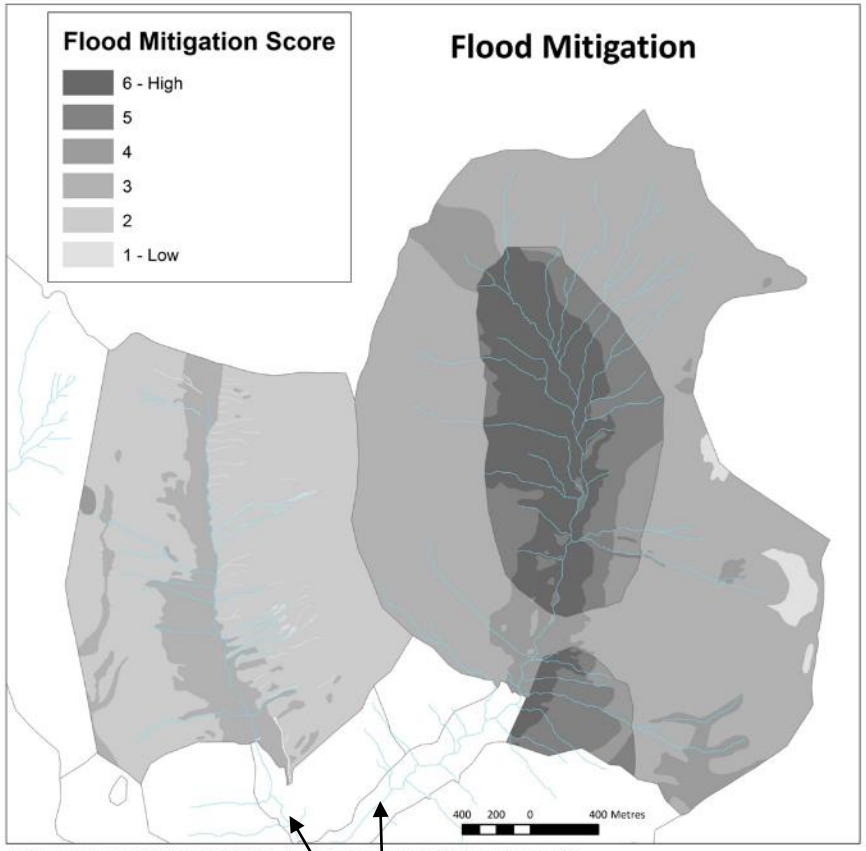
September 2021

Sensors in the Agroforestry Plot

Soil Temperature and moisture sensor

Ecosystem Services – Flood Mitigation





Weather Stations
(ATMOS 41)

River Level Sensors
(Decentlab)

https://www.decentlab.com/

Ecosystem Services – Peatland Restoration

Air Temperature

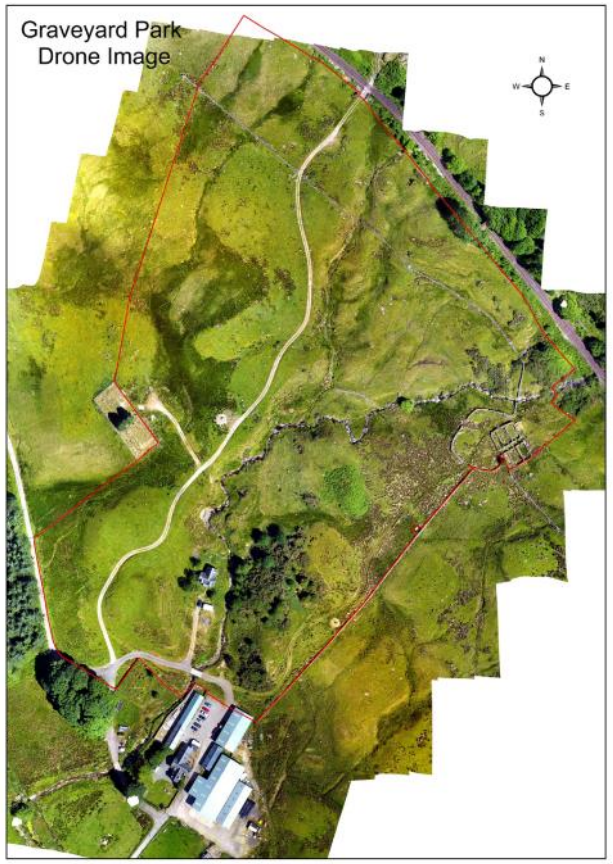
Rainfall

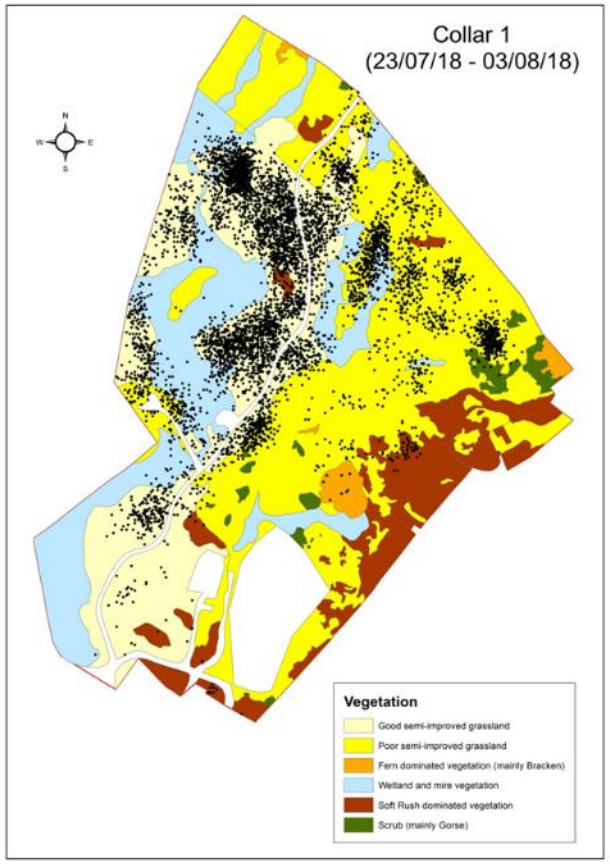
Soil Moisture & Temperature Profile

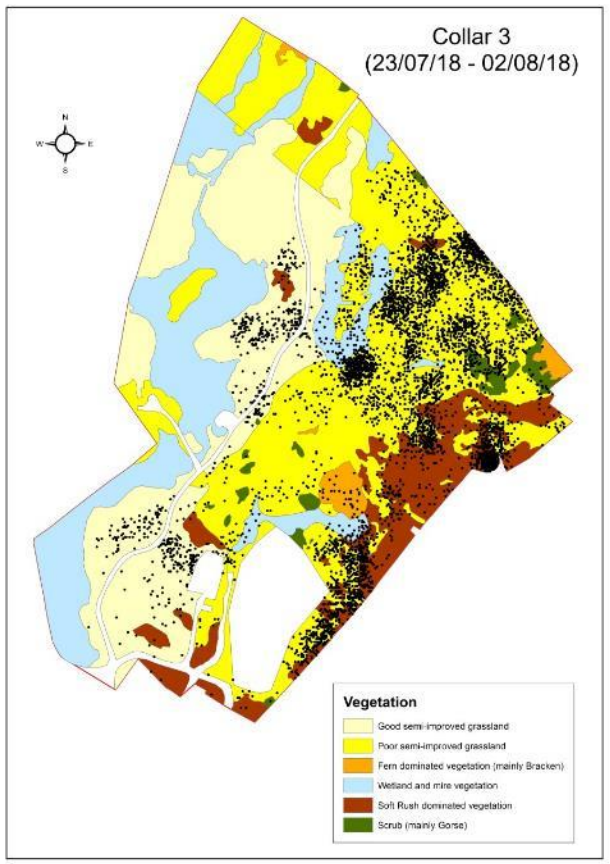
https://www.decentlab.com/

Using GPS Collars to Track Livestock

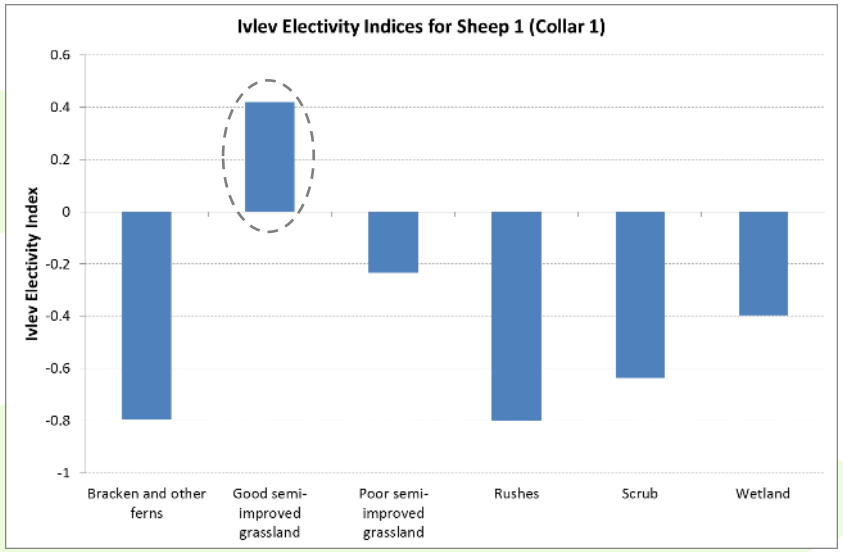


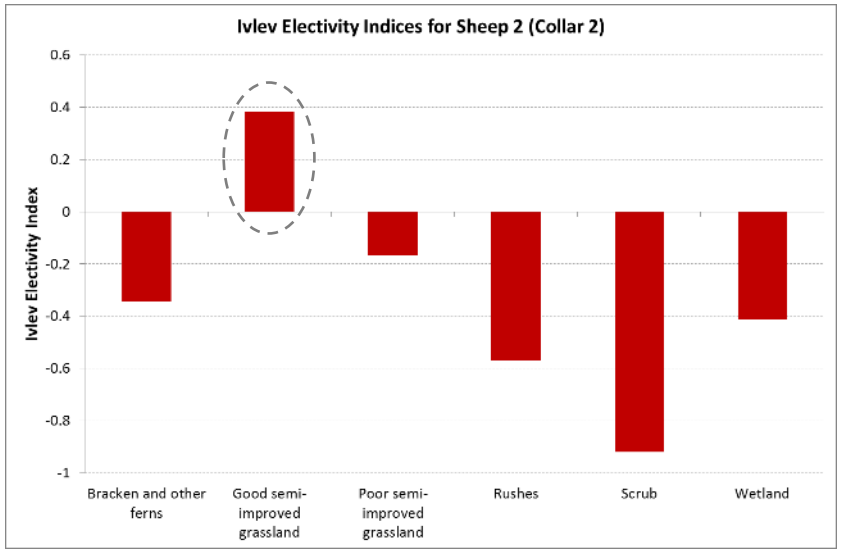



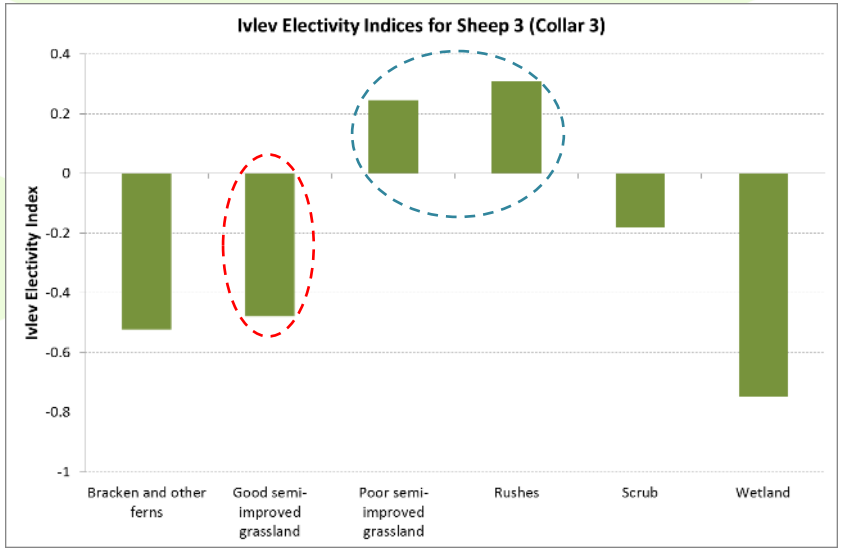


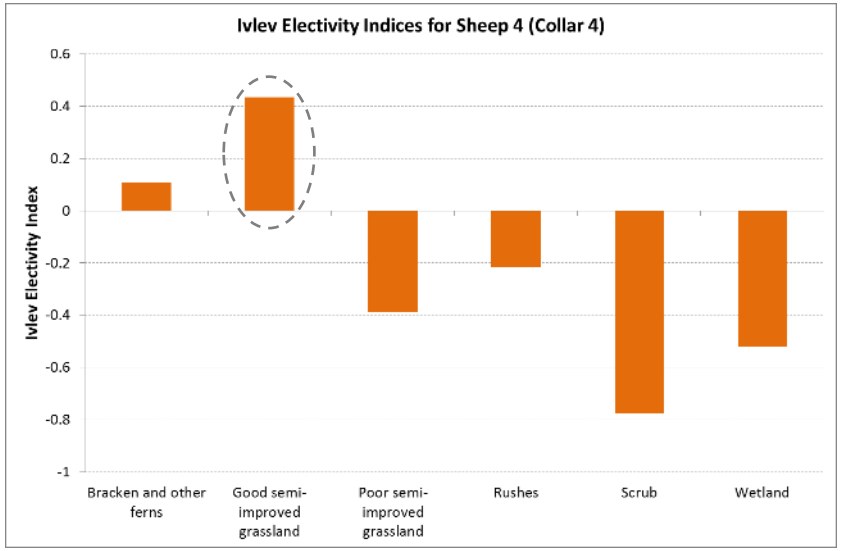


Ivlev's Electivity Index







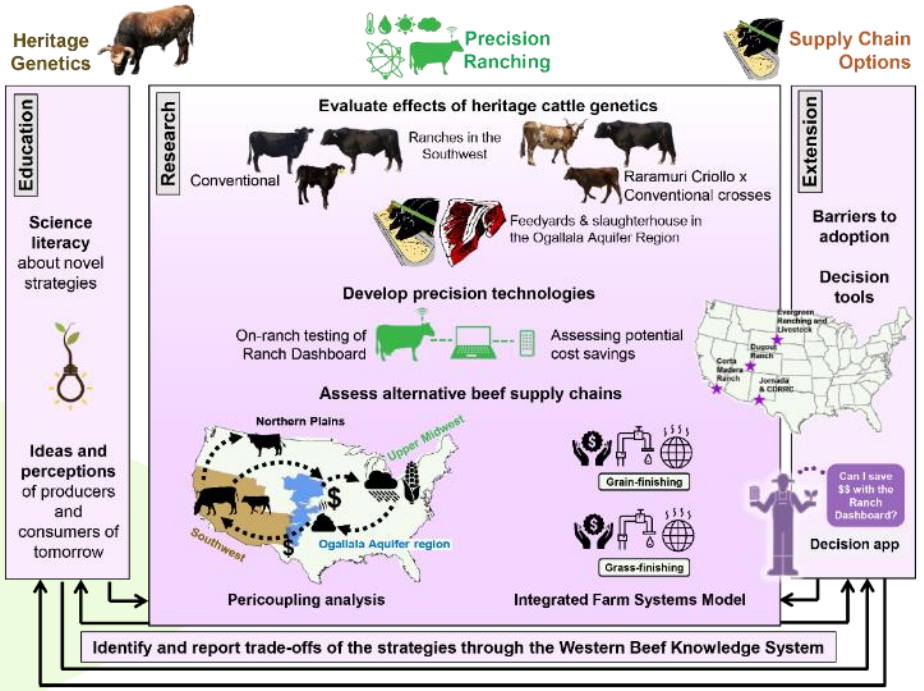


Precision Agriculture Research

SRUC

TECH CARE

https://techcare-project.eu/



Nofence Grazing technology

Sm@RT Sm@ll Ruminant Technologies

https://h2020-smart.eu/

https://southwestbeef.org/

CENSIS Sensing · Imaging · IoT



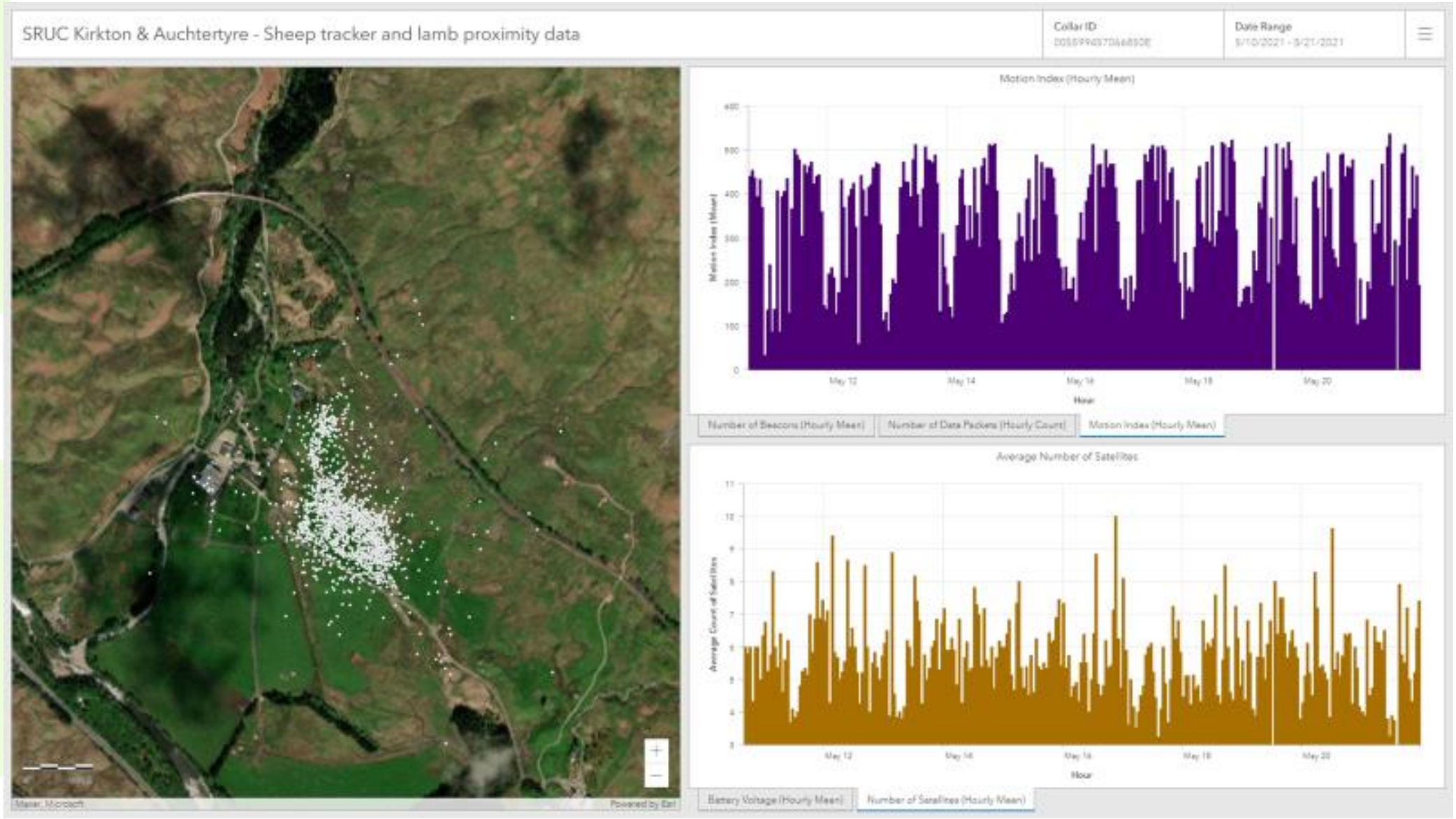



Mothering up using Bluetooth Proximity Sensors

WISP – GPS and Bluetooth Reader

Bluetooth Beacon

ArcGIS Online Dashboard – Sheep Collar



ArcGIS Online Dashboard showing the location of the Bluetooth reader (fixed location at a feed block) and graphs showing the number of Bluetooth beacons within range of the reader (hourly mean) and the number of satellites used to gain the GPS location.

Other LoRaWAN Trackers

Abeeway Compact Tracker - GPS asset tracker converted to a livestock tracker

Digitanimal – Sheep GPS tracker

Virtual Fencing

- GPS collar that produces a series of warning sounds and a weak electric pulse to guide animals to where they can eat and roam
- App allows you to create virtual paddocks, exclude areas and monitor the livestock
- Collar:
  - GPS receiver
  - Motion sensor
  - Bluetooth
  - Mobile network connectivity
  - Rechargeable battery
  - Solar panels

https://www.nofence.no/en/