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Farm Carbon Storage Network

Agenda

- 5:45 **Teas & Coffee**
- 6:00 **Introduction to the Farm Carbon Storage Network**
- 6:20 **Soil Carbon**

- 7:00 **BREAK**

- 7:15 **Carbon in Hedges & Trees**
- 7:45 **Q&A & Finish**

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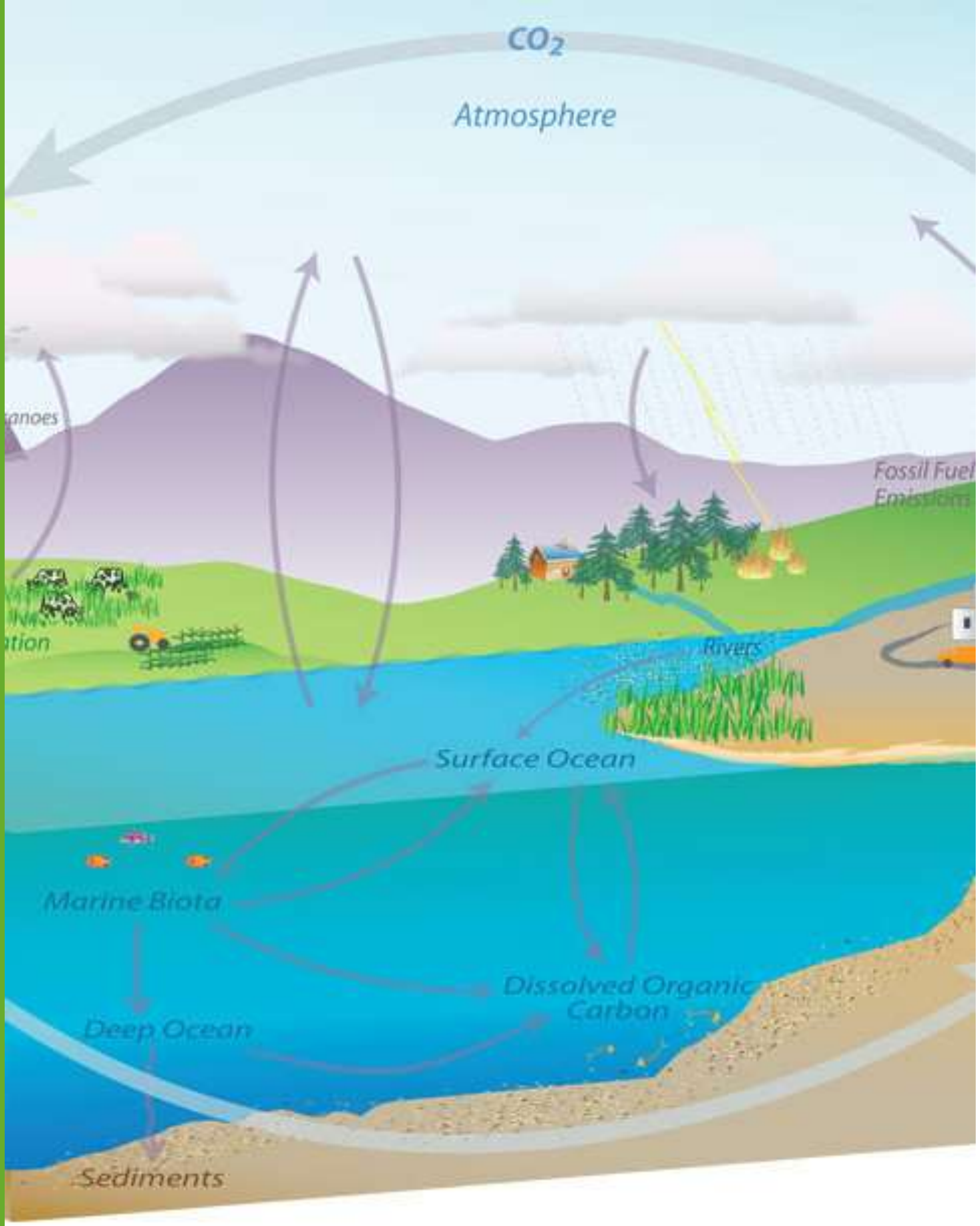

The Carbon Cycle

- The movement of carbon through sources and sinks
- Ideally atmospheric carbon content would find balance

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Storage vs Sequestration

- Storage is the sum of the 'carbon' that is in the soil or biomass at a given time.

- Sequestration is additional carbon that is transferred from the atmosphere to the other carbon sinks, trees, hedges and soils.

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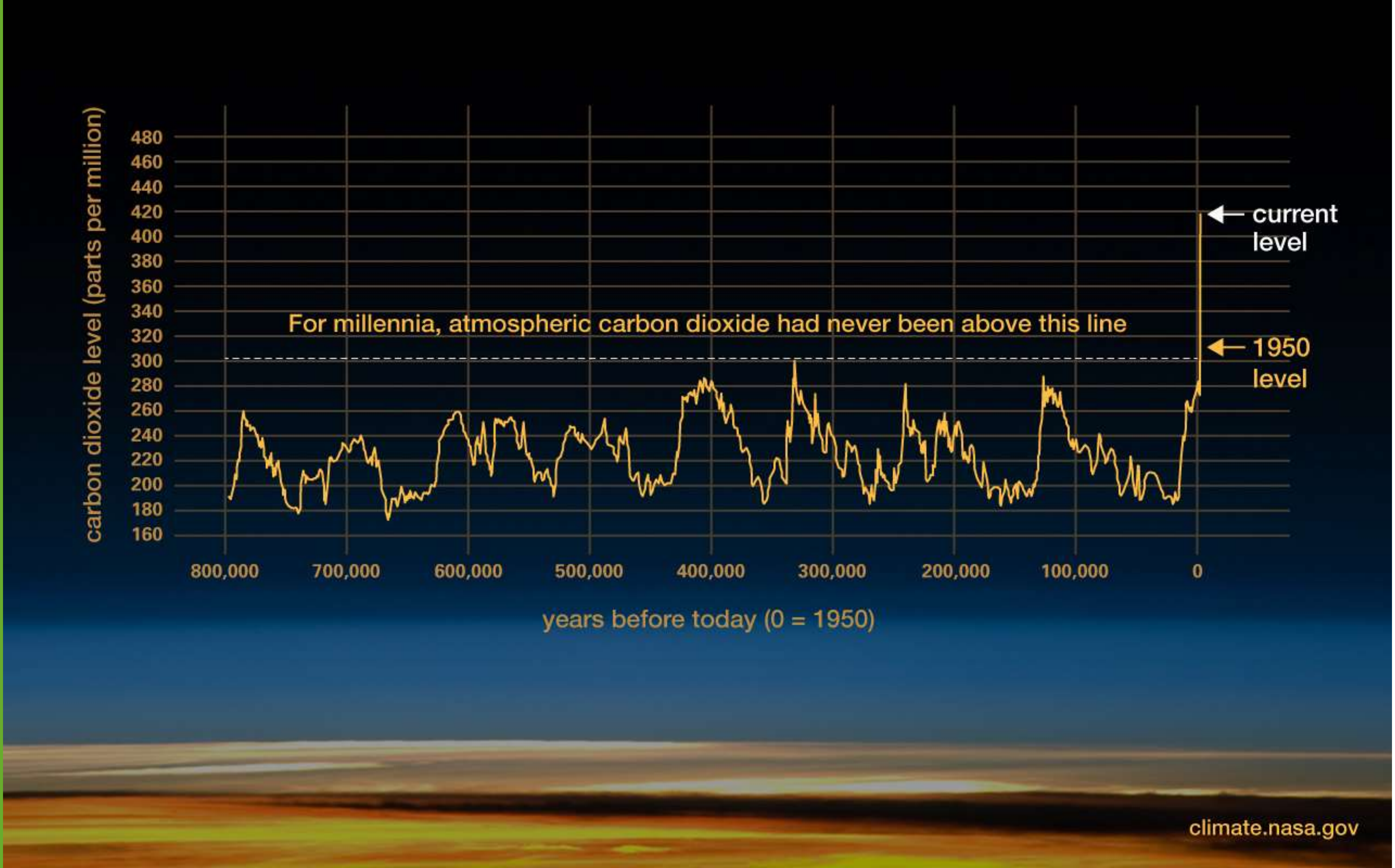

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The carbon audit and stored carbon

There is no direct link!

- Carbon audit is a GHG emissions calculator
- Carbon stored on farms is what is already there.
- Sequestration can be included but need to be directly linked to farming practices if going to reduce enterprise emissions.

Why this project is important..

- Can’t measure it, can’t manage it
- Accurate Baseline is crucial!
- Global and national goals to increase carbon sequestration
- Little data available on Scottish farms carbon storage

What we did

Across 5 farms in Scotland we carried out:

- Soil sampling for organic and inorganic carbon
- UAV surveys to determine the carbon stored in above ground biomass using LiDAR sensors.

Fundamentals of Soil Carbon

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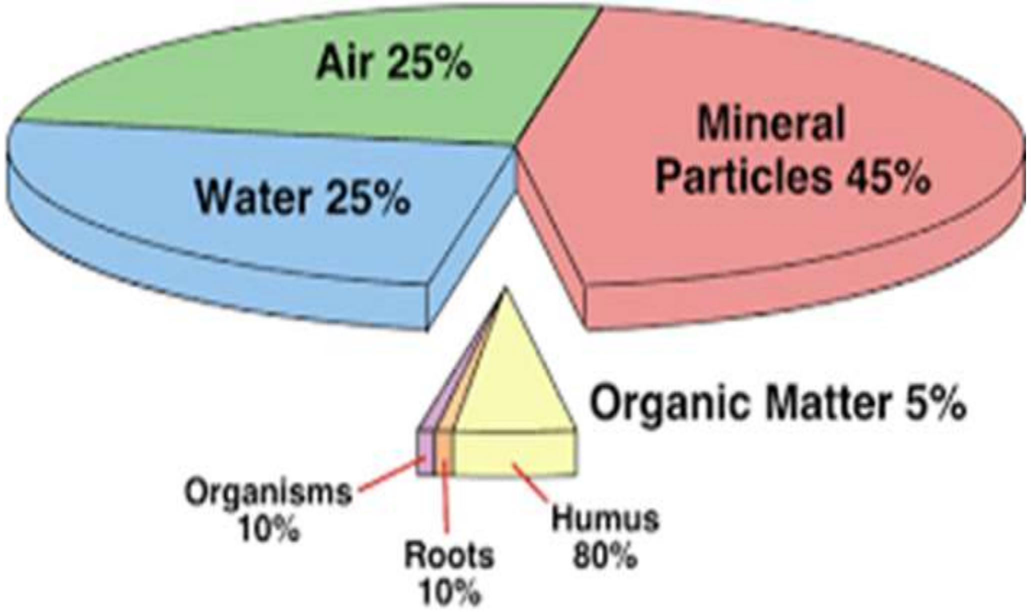
Dr Sarah Buckingham
Senior Consultant

Soil composition



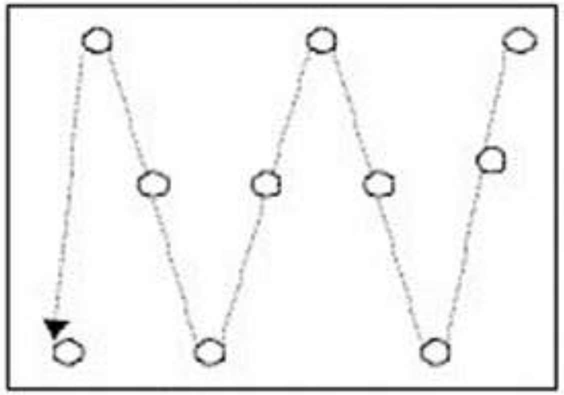
Soil organic matter (SOM)

- Derived from the breakdown of leaf litter, dead roots, plant material and animal waste
- C, N, P, K, Ca and other nutrients

SOM = Approx. 58% carbon (SOC)

After the world's oceans, soil is the largest C store;
3x amount held in the atmosphere

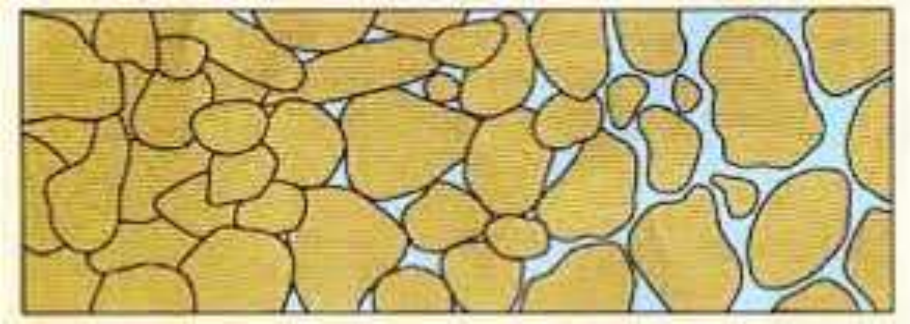
Measuring soil carbon stocks



SOC concentration:
Loss on ignition (no standard universal method)
Elemental analyser.

SOC Stock: Quantity of C within a given volume of soil at a given time point

$$Soil\ C\ stock\ (t\ ha^{-1}) = \frac{[Depth\ (m) \times Bulk\ Density\ (kg\ m^{3}) \times C\ concentration\ (g\ kg^{-1})]}{100}$$



High BD Low BD

Spatial & temporal variation?

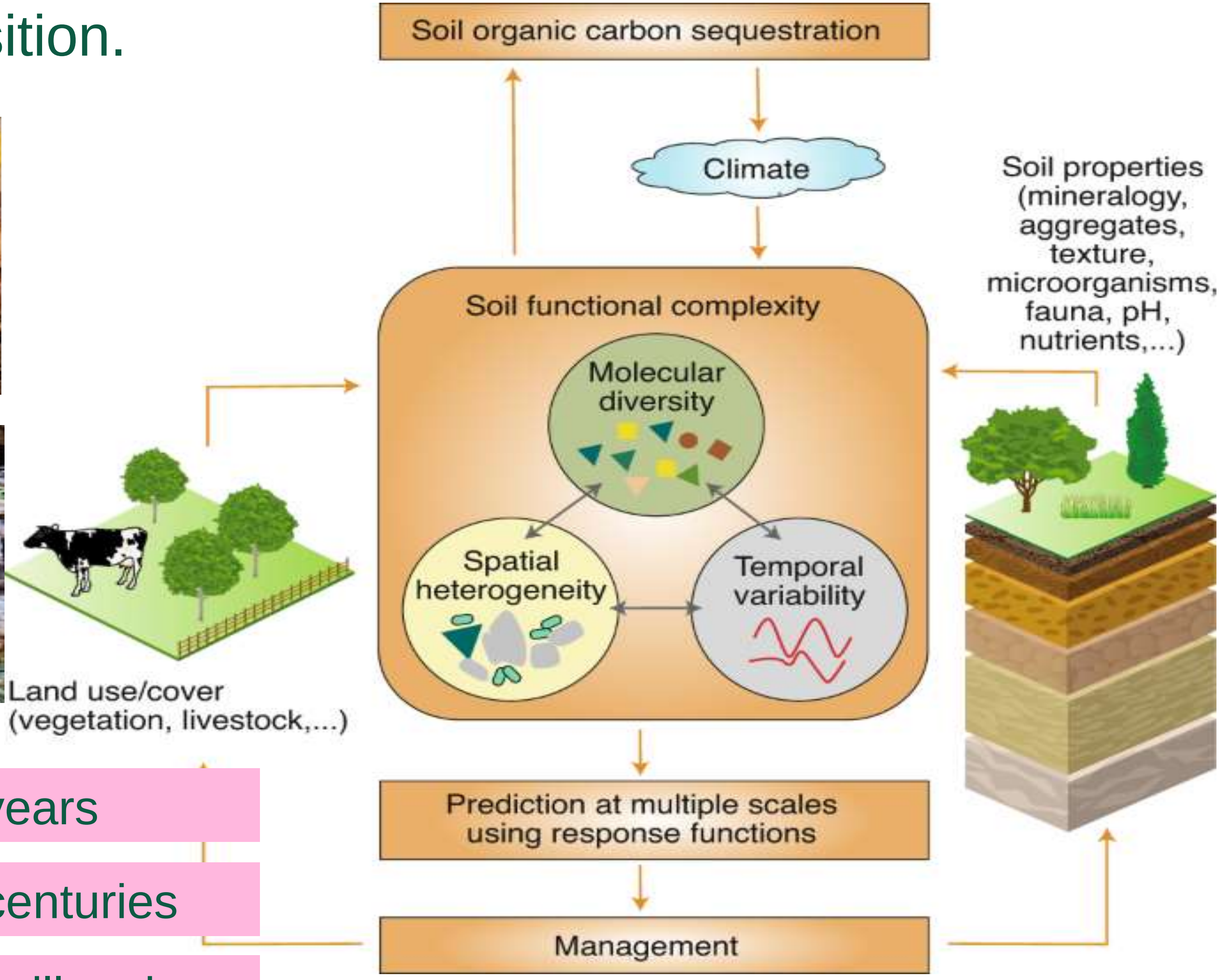
Soil composition

Mixture of material with variable composition and at different stages of decomposition.

days - years

decades - centuries

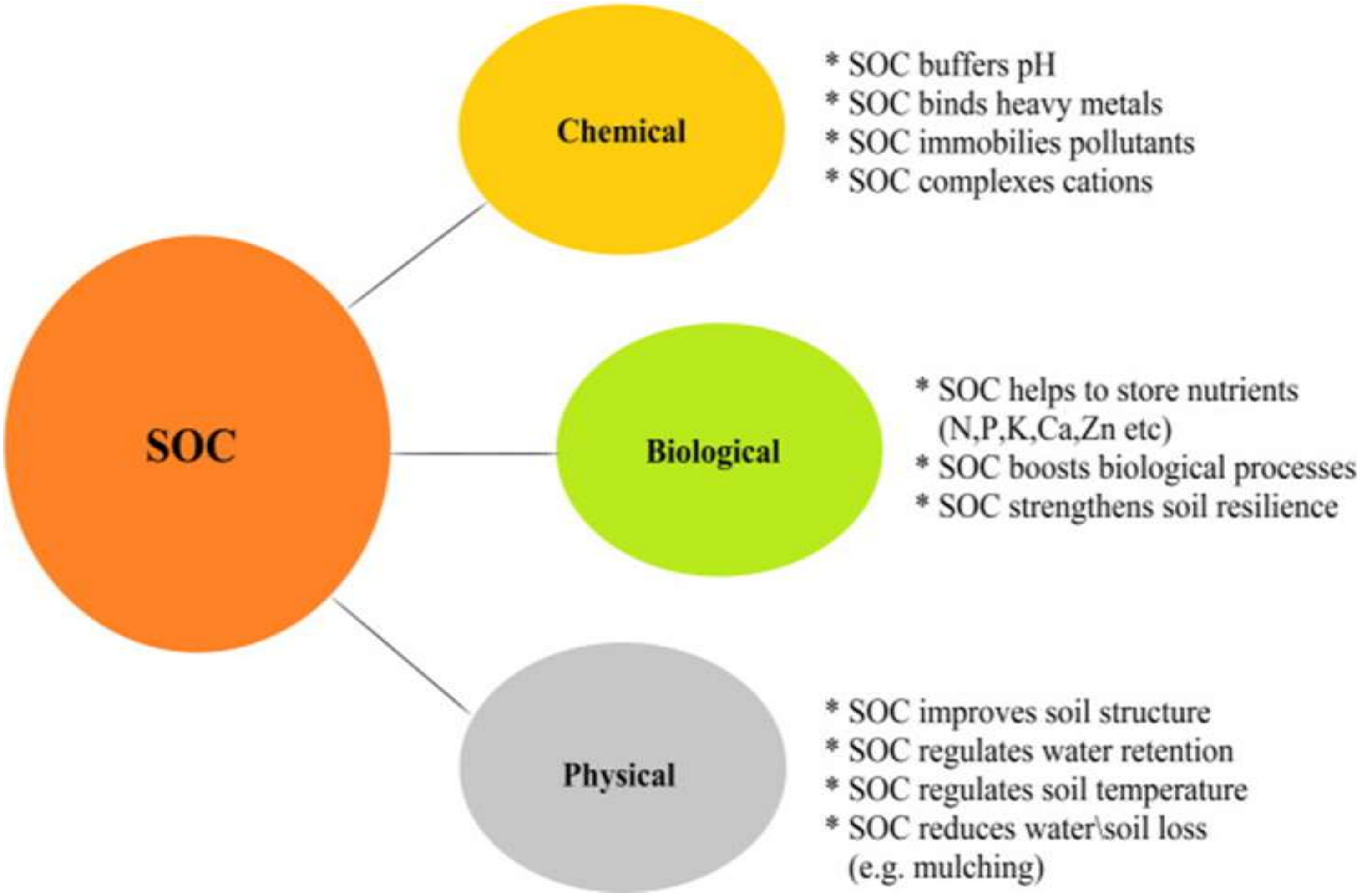
centuries - millennia



Lehmann et al (2020) Nat. Geosci. 13, 529–534

SOC functions

Complex pool of material, different size, composition and functions



- Contains nutrients
- Soil structure
- Influences water holding capacity; infiltration, storage and drainage
- Buffer capacity
- C storage

SOM and associated carbon provides soil fertility and soil health

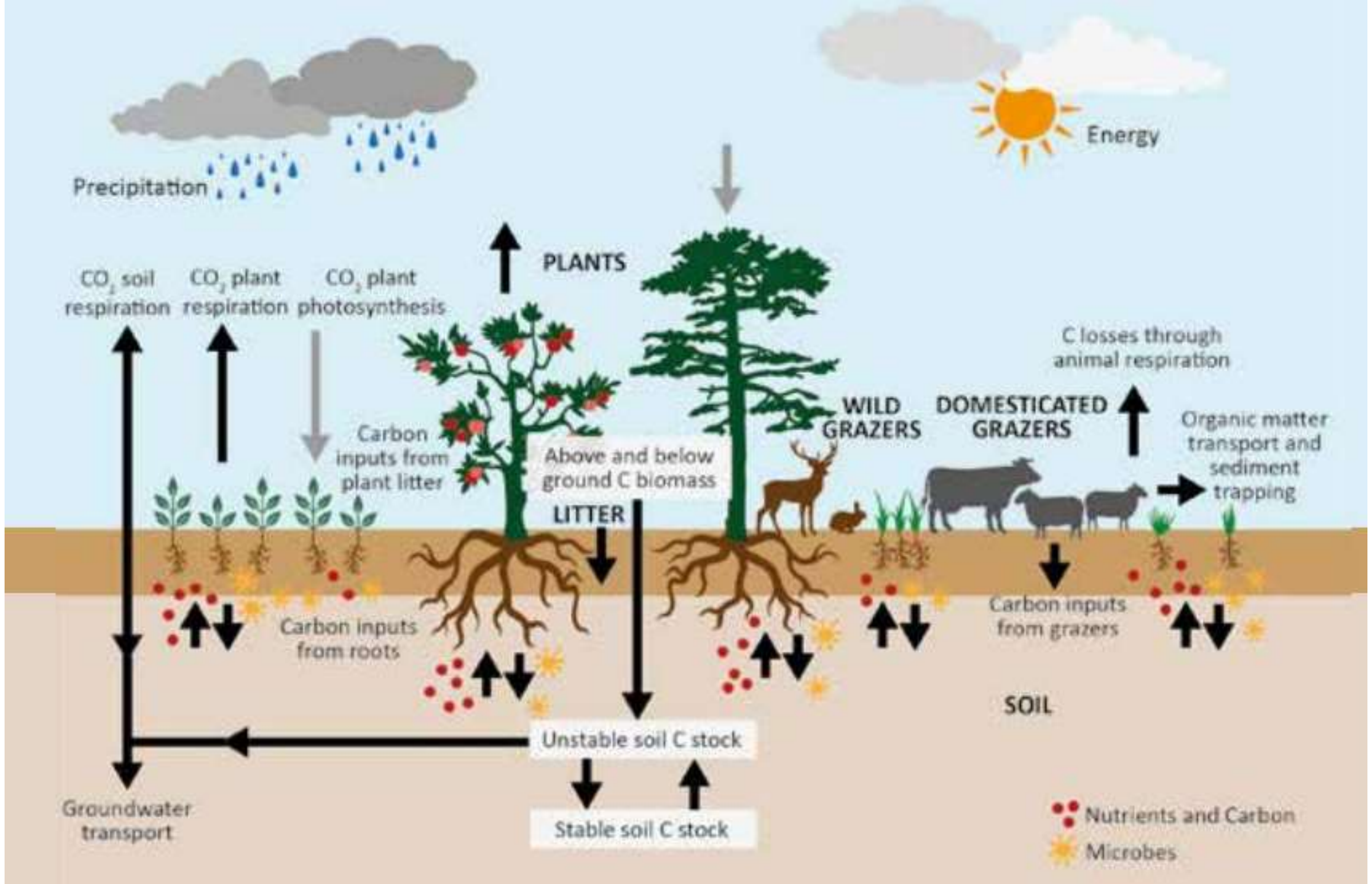
Soil carbon cycle

Key Inputs:
Photosynthesis, root material, root exudates, leaf litter, vegetation residues, manure additions

Key processes:
Decomposition and mineralization

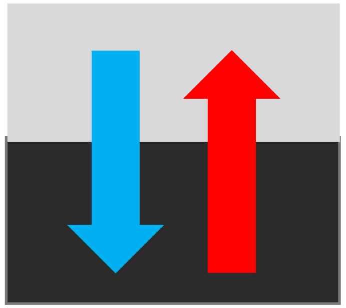
Key storage mechanisms:
Physical protection, chemical binding, within the biological pool

Key outputs:
Gas emissions (*CO_2 or CH_4*),
Leachates *(dissolved / particulate organic carbon)*
Physical loss *(erosion)*

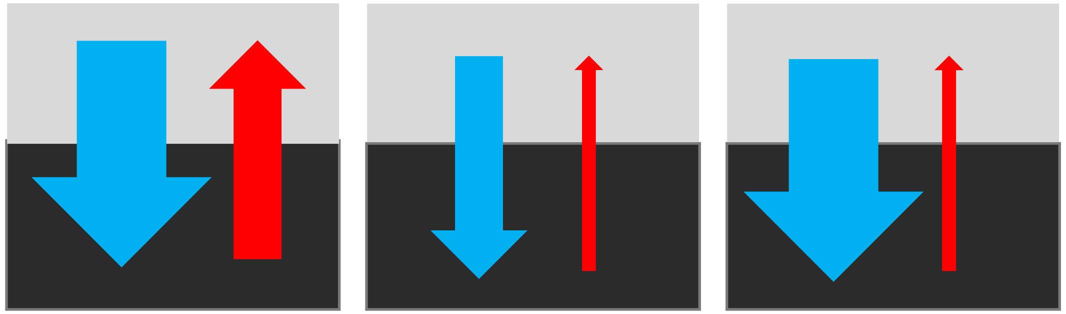


BSSS Science Note Soil Carbon (adapted from Garnett et al., 2017

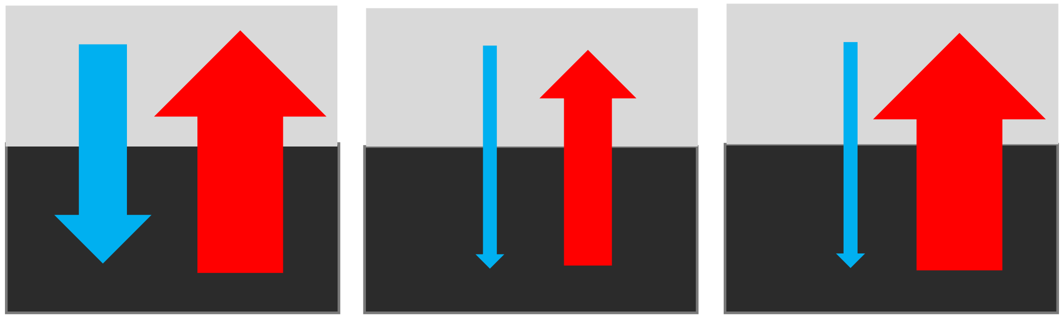
Soil carbon balance



EQUILIBRIUM
No change in soil C
C inputs = C outputs



CARBON SINK
Net gain in soil C stock
C inputs > C outputs



CARBON SOURCE
Net loss of soil C stock
C outputs > C inputs

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What controls SOC stocks?

Land use

Biomass & vegetation input

Management practices
- Tillage

Soil health

Defining and measuring soil C as a primary indicator for soil health in sustainable soil management and food production efficiency

Climate change mitigation

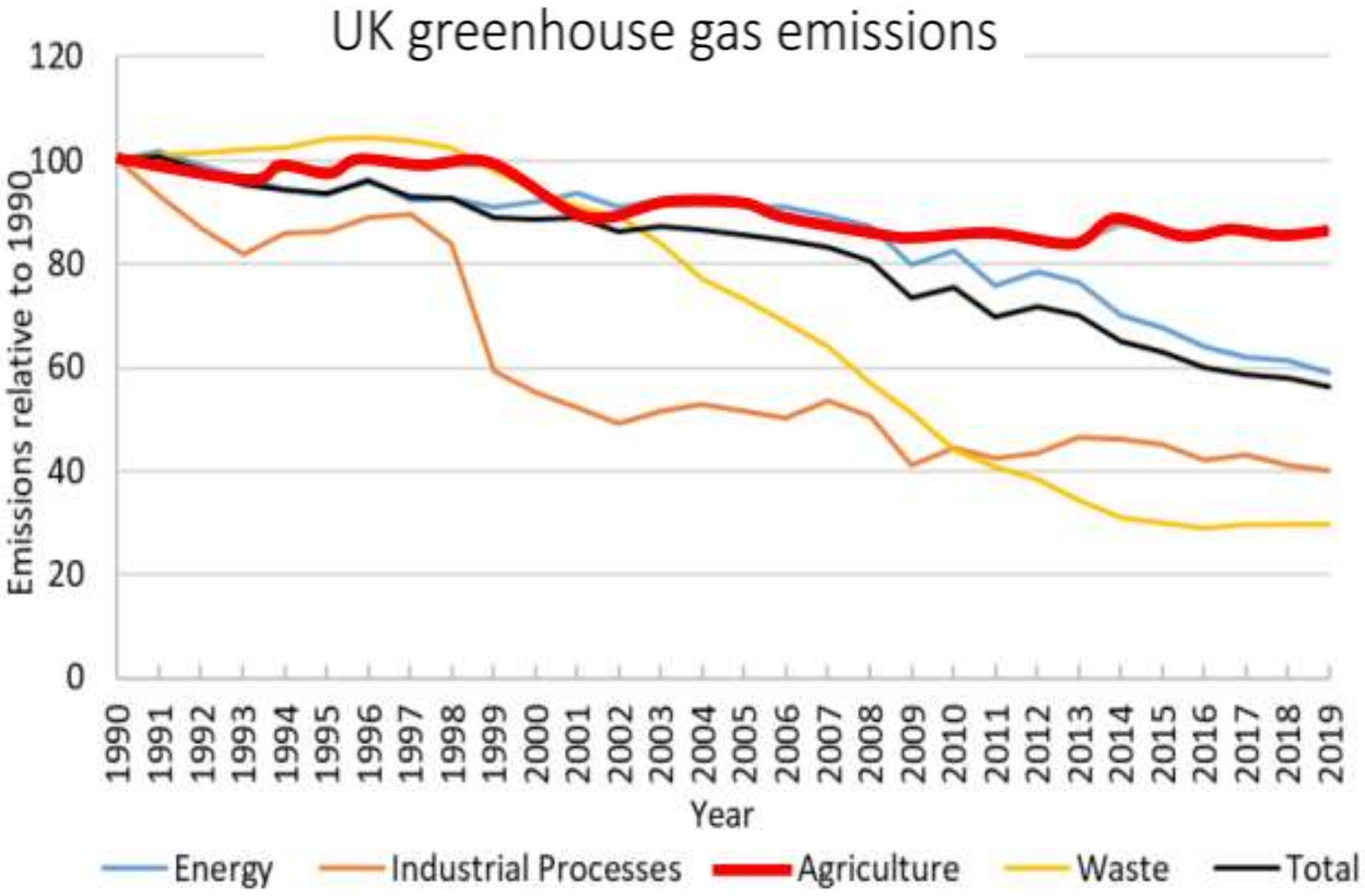
Soil management for GHG reduction, removal and sequestration

- Nutrient composition
- Redox potential
- Bacteria, fungi, earthworms nematode, mycorrhizae

Climatic factors
- Rainfall
- Temperature

(aggregation)
- Chemical stabilisation (mineral association, silt-clay
- Microbial activity and residues

Soil carbon and climate change mitigation



Trends in emissions by sector relative to 1990

Difficult to reduce GHG in agriculture

No biological process 100% efficient

Food security & production demand

Committee on Climate Change 2020

Net zero UK agriculture

UK GHG Inventory: 11% (46.4 Mt CO_2e) UK emissions from agricultural sector (2020)

Climate Change Committee suggests *"emissions from UK land use can be reduced by 64% to around 21 Mt CO_2e by 2050"*

Reduction of 25.4 Mt CO_2e / 54.7% from UK's 2020 agricultural GHG emissions

Recent research suggests using available cost-effective mitigation strategies can reduce emissions by 7.1 Mt CO_2e by 2035

= 28% of the 25.4 Mt CO_2e reduction needed to achieve the CCC's target

leaving 72% of emission reduction still to be achieved between 2035 and 2050.

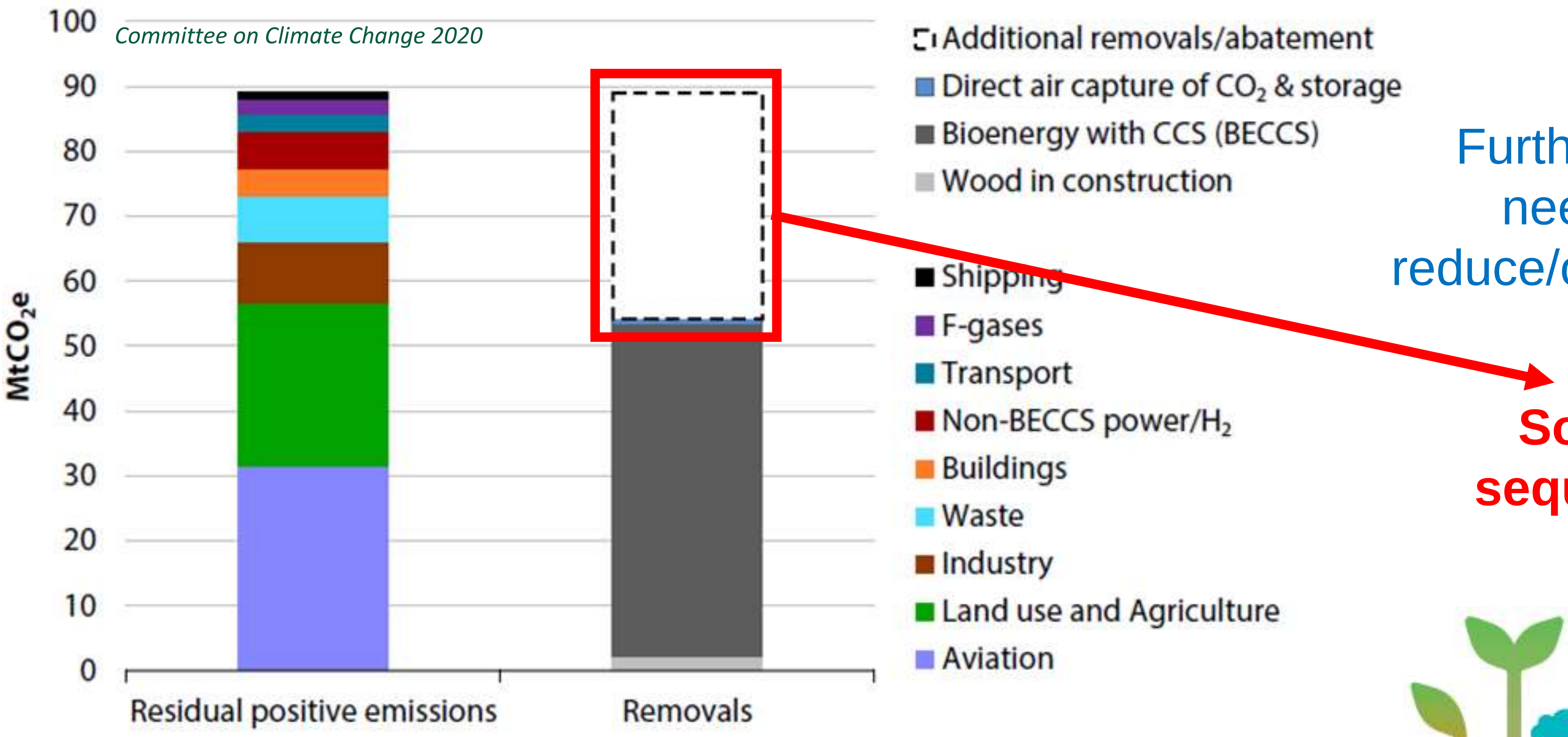
Additional consideration: Land Use, Land Use Change and Forestry sector

Net emissions of 11.49 Mt CO_2e from land associated with cropland and grasslands.

Contribution of agricultural soil carbon sequestration?

Buckingham et al (2023) Frontiers of Agricultural Science and Engineering. in In Press

Net zero across sectors



Further efforts needed to reduce/offset GHGs

Soil carbon sequestration?

COP21 (2015) 4 per 1000 initiative:
"An annual growth rate of 0.4% in the soil carbon stocks (or 4‰ per year) in the first 30-40 cm of soil,."

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Soil carbon sequestration

Management practice	Increased C inputs	Reduced C losses
Improved crop rotations and increased crop residues	✓	
Cover crops	✓	
Conversion to perennial grasses and legumes	✓	✓
Manure and compost addition	✓	
No-tillage and other conservation tillage		✓
Rewetting organic (i.e., peat and muck) soils		✓
Improved grazing land management	✓	

Paustian et al 2019 Front. Clim

Soil C sequestration
AND
Soil health

Never leave soil bare and work it less, for example by using no-till methods

Introduce more intermediate crops, more row intercropping and more grass strips

Add to the hedges at field boundaries and develop agroforestry

Optimize pasture management – with longer grazing periods, for example

Restore land in poor condition e.g. the world's arid and semi-arid regions

Improve water and fertilizers management and use organic fertilizers and compost

4per1000.org

Soil carbon sequestration

Other management strategies

- Increase wooded areas. *Afforestation, reforestation, agroforestry and silvopasture, hedgerows and riparian zones*
- Restoration of peatlands

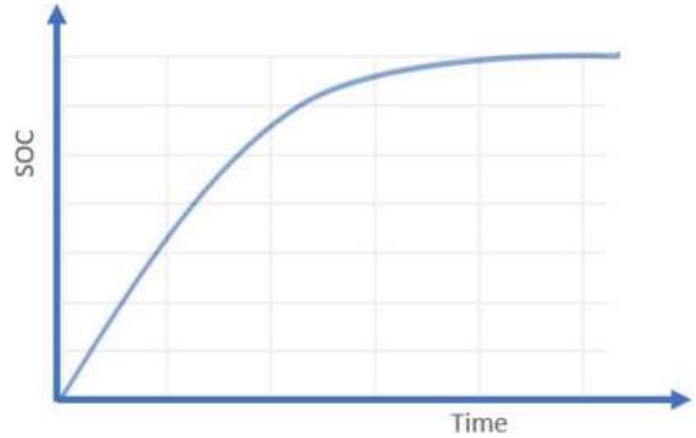
Novel applications

- Biochar
- Bioenergy crops
- Enhanced weathering
- Direct air carbon capture

Soil carbon sequestration potential

However……

- Difficult to control and quantify management effects
  Many compounding factors controlling C input, residence time & storage
- For how long do new inputs stay in the soil?
  Management effects are reversible
  Soils reach new equilibrium
- How much more can our soils store?
- Knock on effects (N dynamics)
- What is the baseline?
- How does this translate into action – future policy, regulation, and private investment schemes (C markets)?



Annual rate of carbon accumulation declines as concentrations increase

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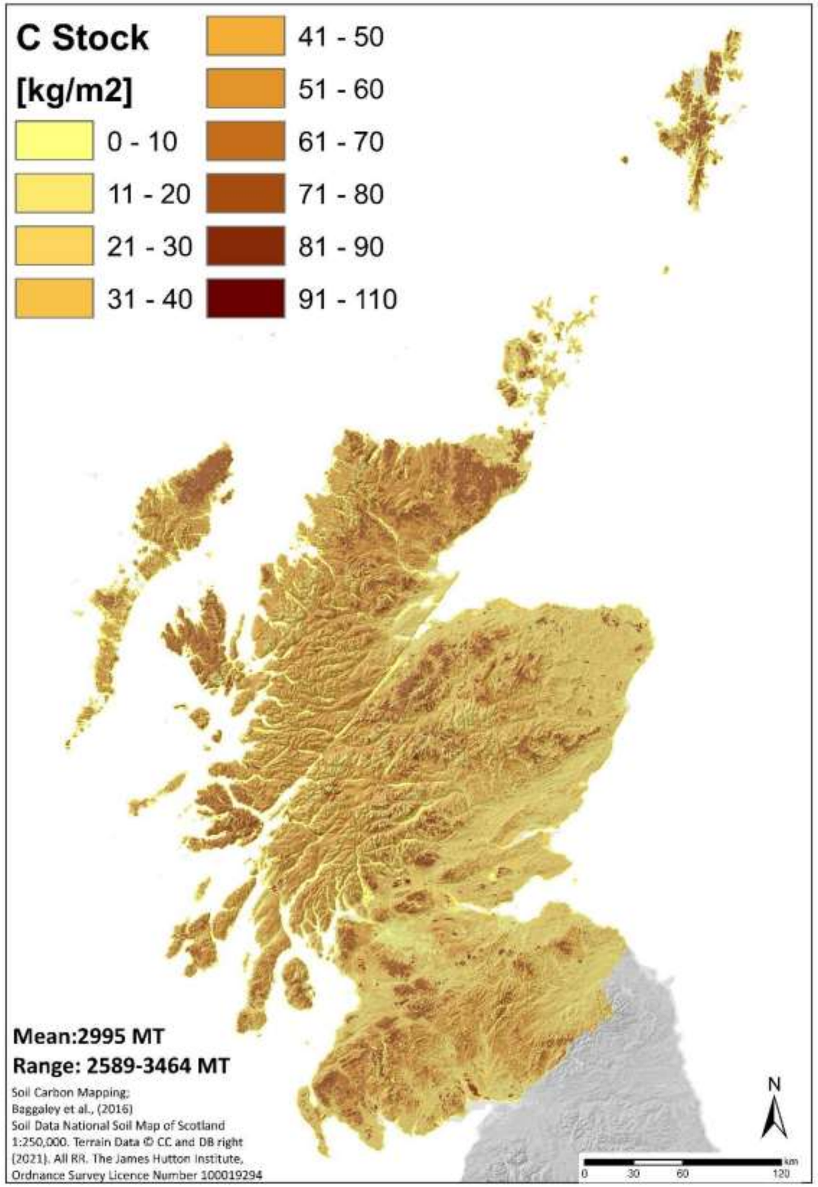
Can we store more carbon in Scottish soils?



Lilly & Baggaley 2021 Scoping study to identify current soil organic carbon stocks and the potential for increasing carbon sequestration in Scottish soils

National survey:
No statistical change in SOC stocks across arable, improved grassland, semi-natural grassland, moorland and bog.

Equilibrium / saturation?

Sequestration potential:

- 60 Mt C Scottish grassland topsoils
- 88 Mt C Scottish arable topsoils

Future loss risk:

- 112 Mt C of stored soils organic carbon

SOC conservation vs SOC increase?

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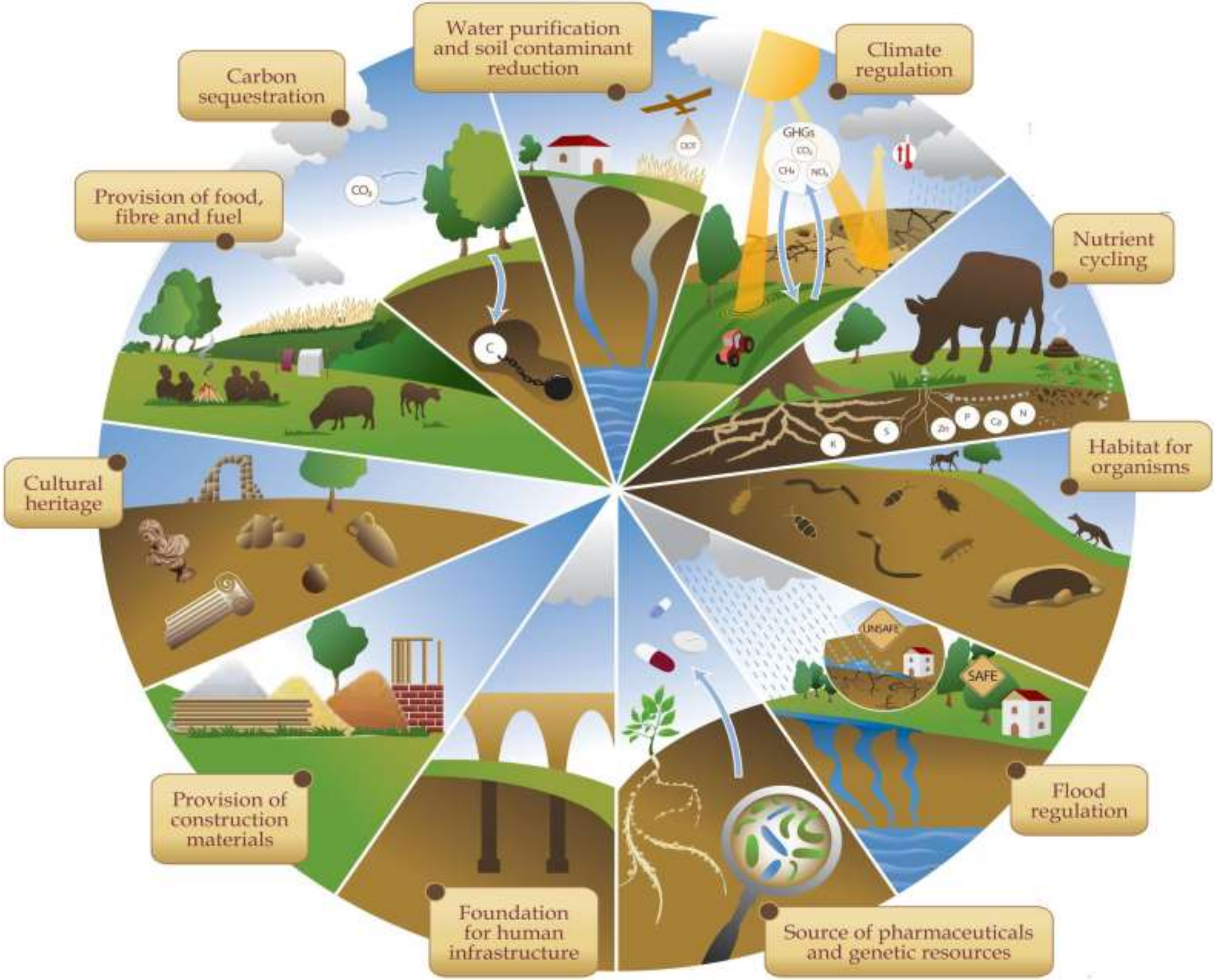
Why focus on SOM and SOC?

Soil carbon is just <u>ONE</u> indicator of good soil health

Holistic view:

- Conservation of SOM
- Overall soil health for resilience & sustainable food production

- Contribution to wider ecosystem functions: *(Flood management, ecosystem biodiversity)*



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Summary

- Complex process and mechanisms associated with C storages and fluxes with multiple controls to consider

- Opportunity to increase soil C in some areas – where & how?
- More measuring/monitoring soil C stocks over time alongside management practices
- Long-term investment for soil C conservation and sequestration

- Holistic view: Soils contribution to wider ecosystem functions: *(E.g. resilience to drought & flood & ecosystem biodiversity)*
- Long-term conservation of Scottish soil carbon sinks vital for soil resilience and sustainable productivity

Thank you

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Estimating above ground biomass carbon stocks using drone based LiDAR

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Goal

- Quantify carbon stored in tree and hedge above-ground biomass using remote sensing data
- In this case a drone equipped with a LiDAR sensor
- To achieve this we developed a carbon model based on current literature

Remote sensing

"Detecting and monitoring the physical characteristics of an area at a distance"

Platforms

- Satellite
- Manned aerial vehicles
- Unmanned aerial vehicles (UAVs)

Sensors

- RGB
- Multispectral & Hyperspectral
- Radar
- LiDAR

Our kit

Drone – DJI Matrice 300

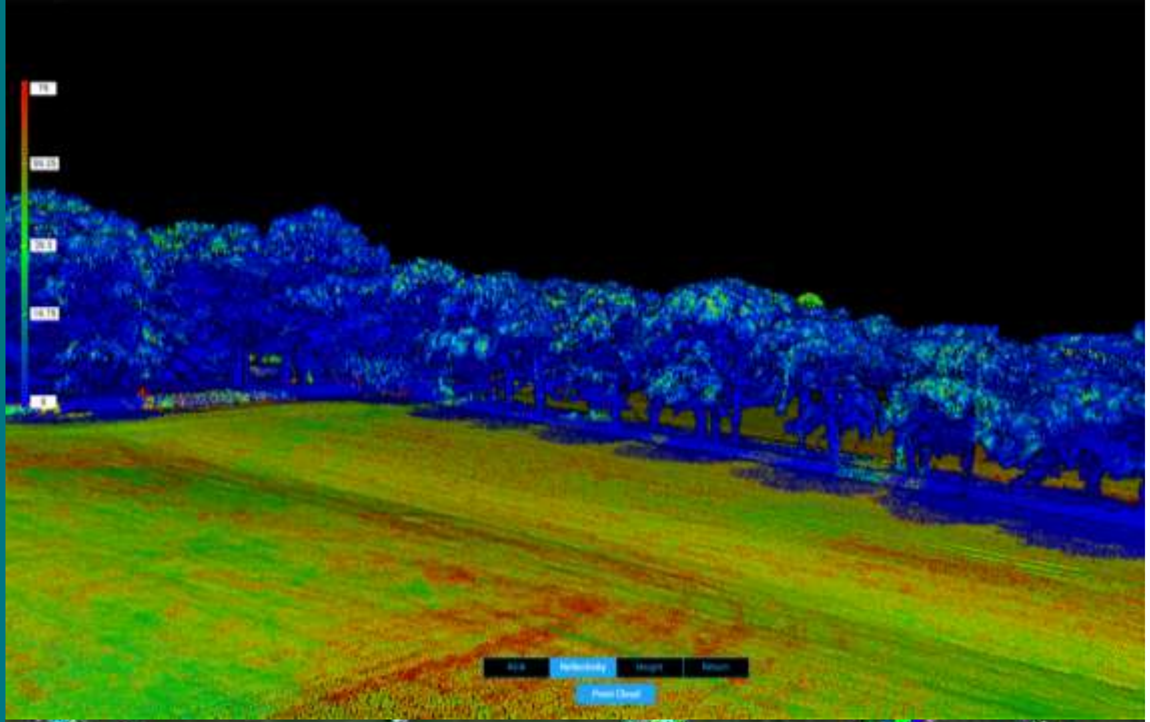
- ~40 min per battery set
- Windspeeds up to ~15 m/s
- Waterproof

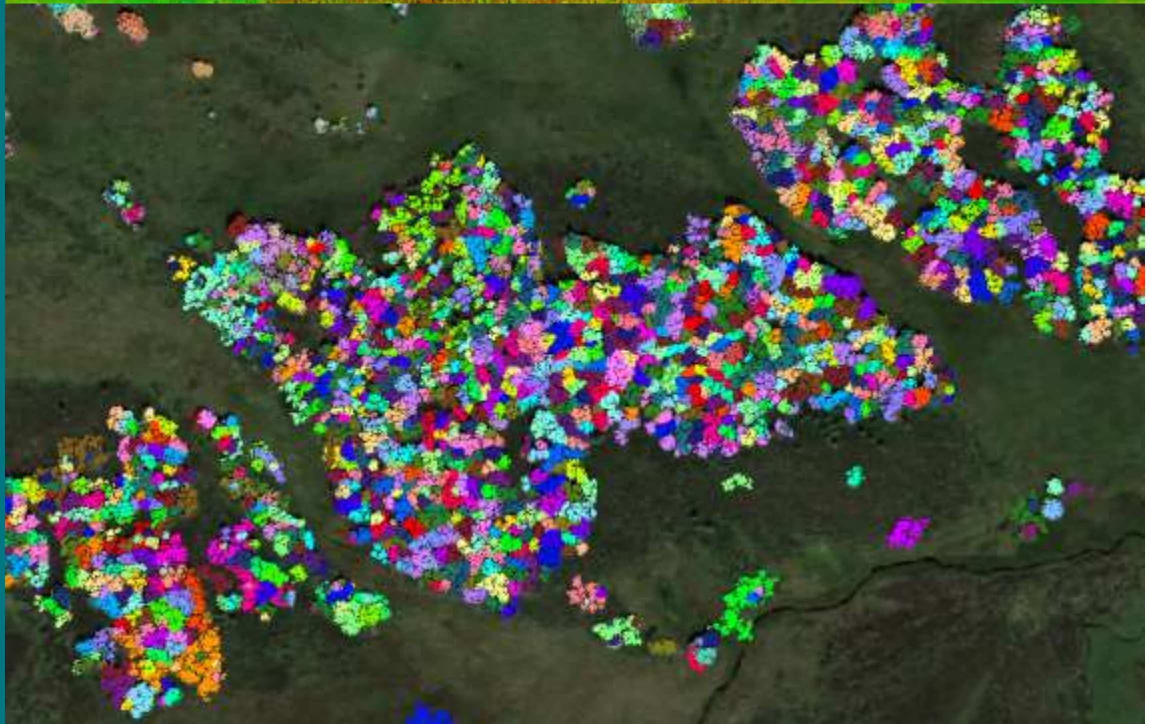
Sensor – Zenmuse L1

- LiDAR sensor
- Collects >100,000 points per second
- Can detect ground points in vegetated areas

Traditional methodologies

- Plot based assessments
  - Fell sample trees
  - DBH and height sample trees
- Full tree count and DBH assessment
  - Small plots up to 3000 trees
- Weight estimated in oven dry biomass
- ~50% of biomass = carbon
- Methods designed for plantation woodlands





Remote sensing methodologies

- Considerable research in recent years
- Platforms used include:
  - Satellites
  - Manned and unmanned aerial vehicles
  - Terrestrial laser scanning
- Data extracted can include:
  - Tree height
  - Crown diameter
  - Species type
  - DBH

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Our methodology

DATA COLLECTION:

SURVEY ALL FARM ABOVE GROUND BIOMASS

POST-PROCESSING:

PROCESS LIDAR IN PREPARATION FOR RUNNING CARBON MODEL

CARBON MODELLING:

RUN POST-PROCESSED DATA THROUGH CARBON MODEL

RESULTS:

CLEAN AND MAP MODEL OUTPUTS

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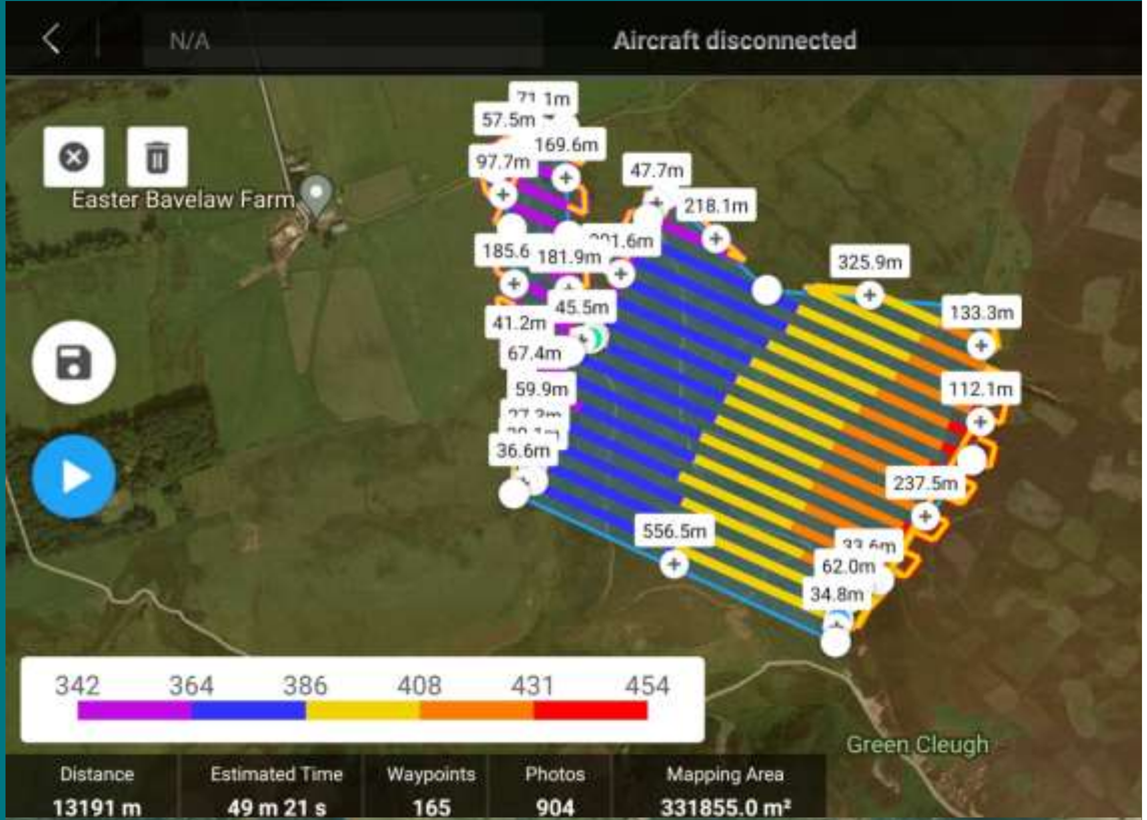

Data collection – Mission planning

- Map out flight boundaries
- Identify any potential hazards
- Set sensor settings:
  - Flight height 60m
  - 50% LiDAR overlap
  - 75% image overlap
  - 3 echoes
- *Note: data was collected during leaf-off period of the year for better lidar penetration*

Data collection – Survey

- Monitor weather conditions
- Team of two to operate drone safely
    - One to fly and second to monitor surroundings
- 6-8 flights completed per day
- Total of 11 flight days
- 3 additional days where weather prevented flights

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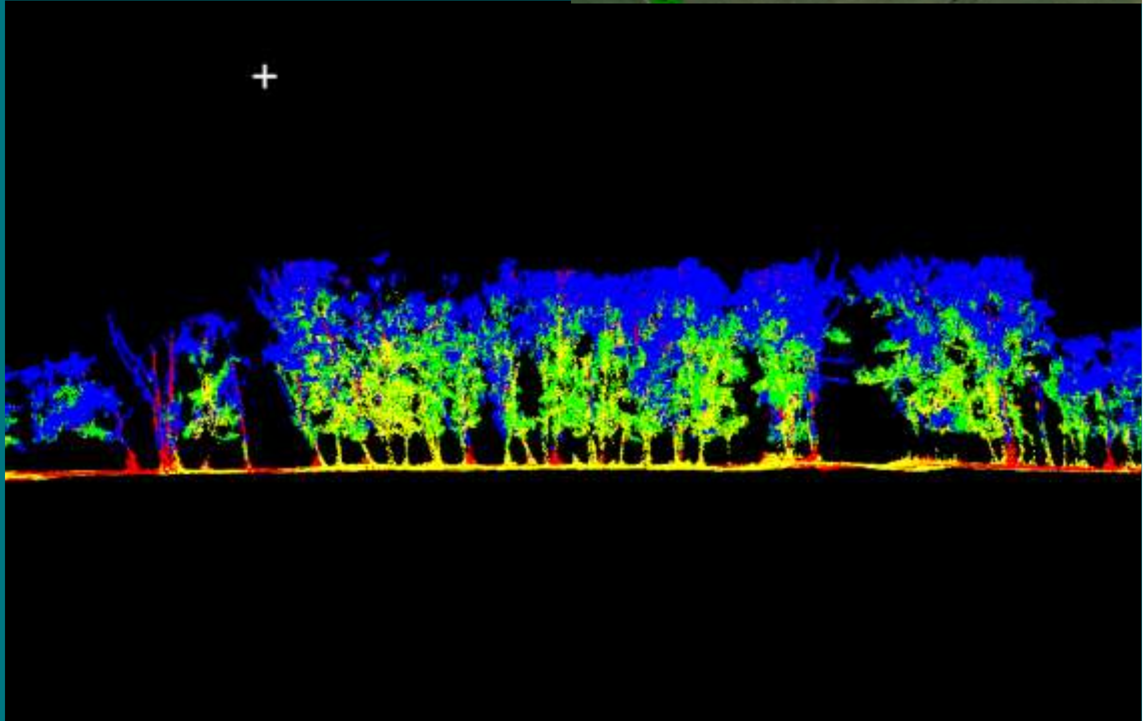

Post-processing

- DJI Terra - create LiDAR point cloud
- TerraSolid – point cloud cleaning and ground classification
- QGIS – split point cloud into 3 separate categories
    - Conifer
    - Broadleaf
    - Hedgerows

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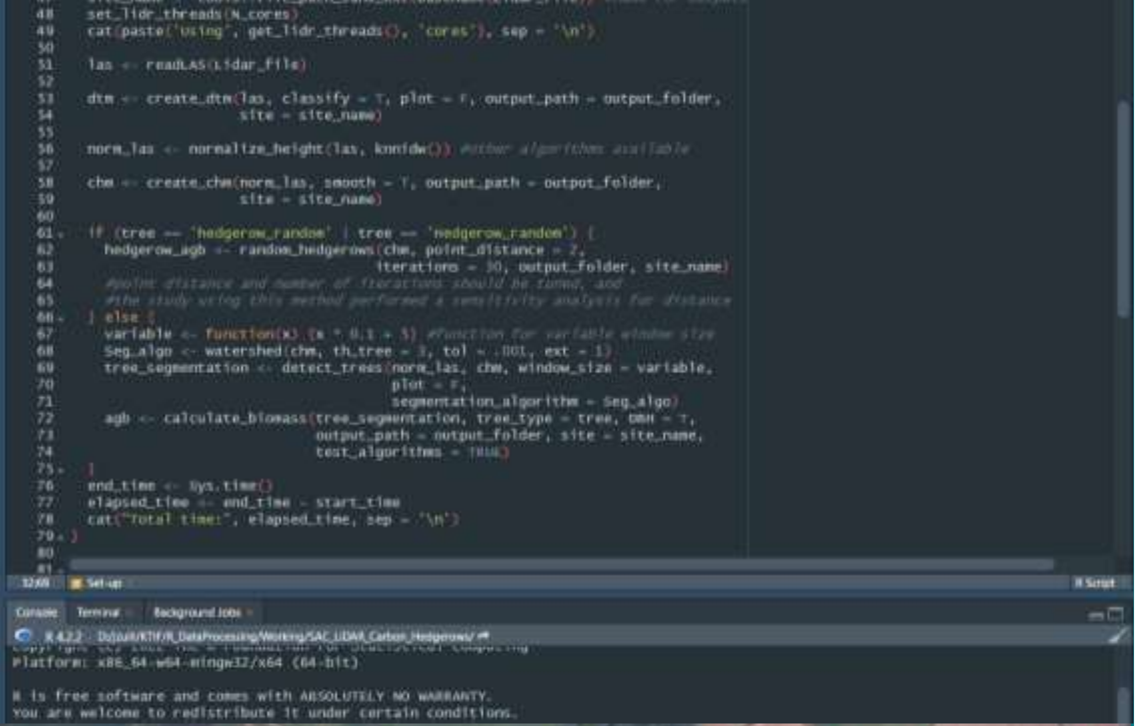
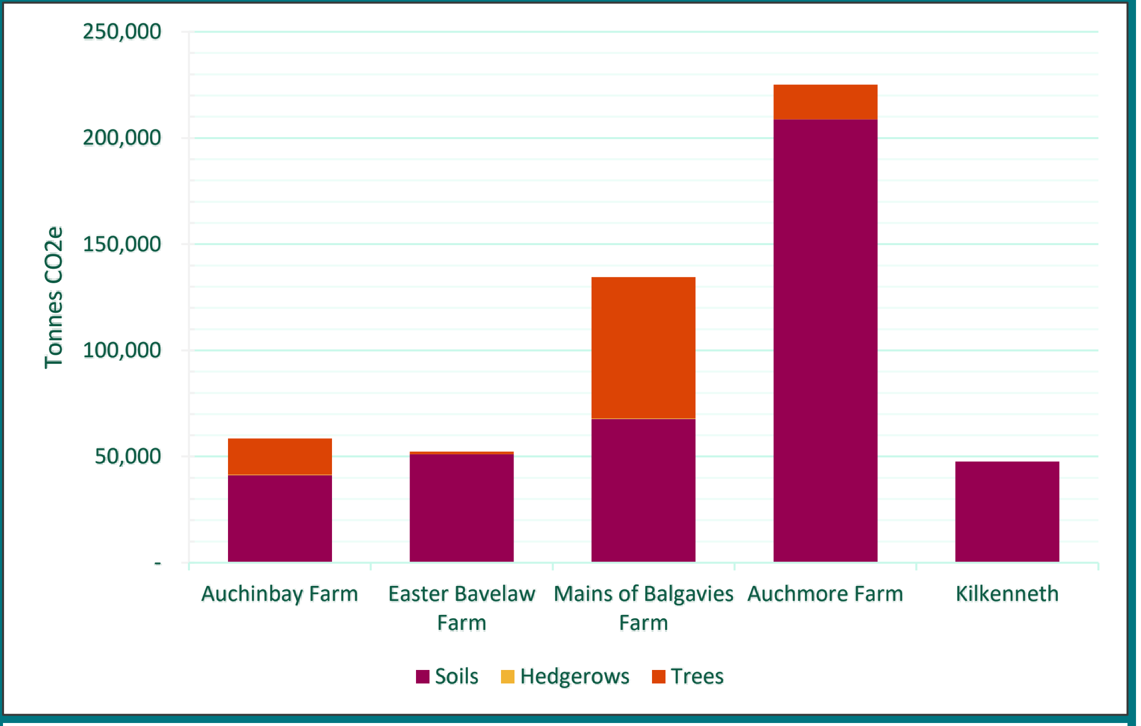


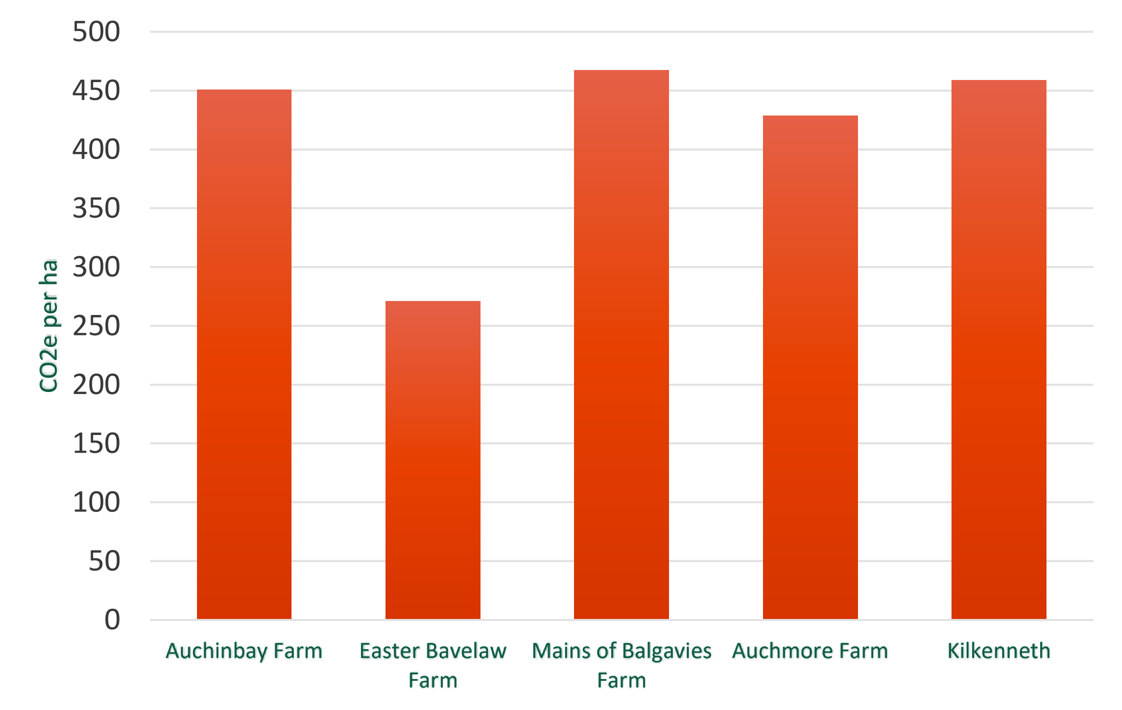
Carbon modelling – Trees

- Run separately for conifers and broadleaves
- LidR R package segments out individual trees
- Crown diameter and tree height extracted
- DBH calculated using height and diameter allometric relationship
- Biomass and carbon content of individual trees calculated using various allometric equations

Carbon modelling – Hedgerows

- Methodology from Ireland EPA (EPA, 2013)
- Random points generated along each hedgerow
- Canopy height at each point extracted
- Biomass and carbon calculated using a height based allometric equation
- Model re-run 35 times
- Mean results over the 35 iterations extracted as carbon estimate





Results

- Soil and trees hold bulk of carbon stocks
- Hedgerows contain significant amount however area covered is considerably smaller
- *Note: large portion of Easter Bavelaw unaccounted for due to young age of new planted trees*

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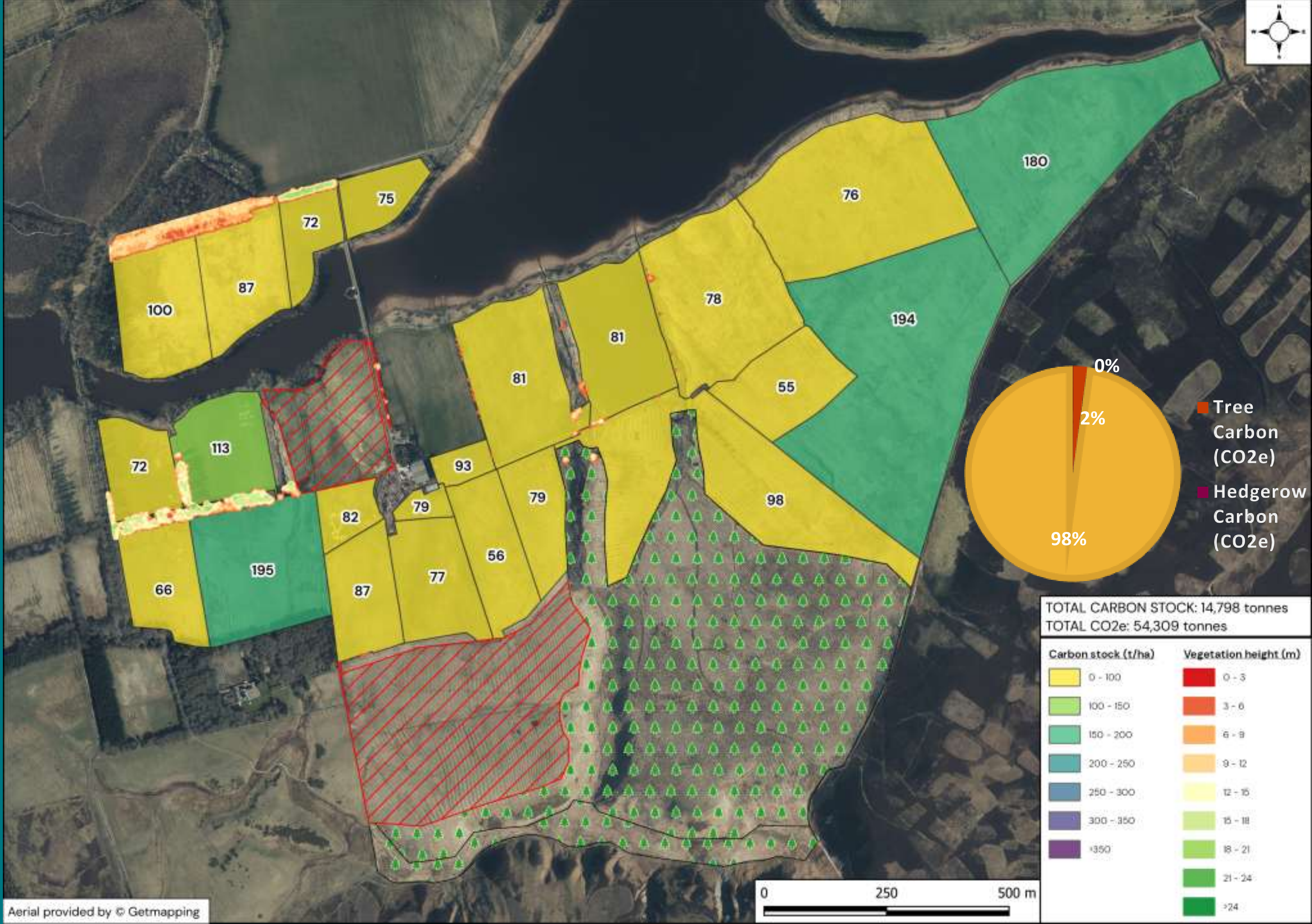
Easter Bavelaw - Sheep



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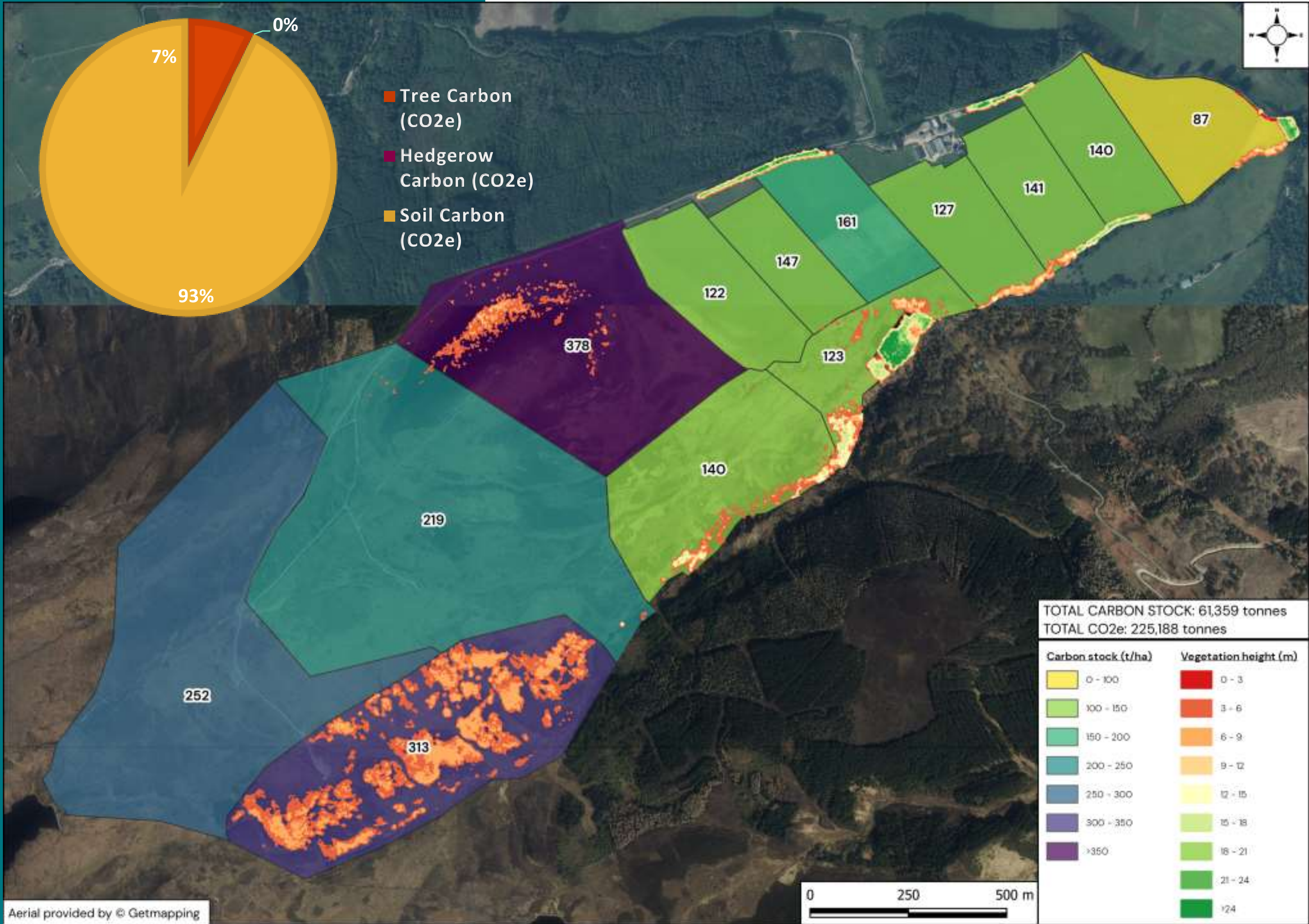
Auchmore – Beef & Sheep



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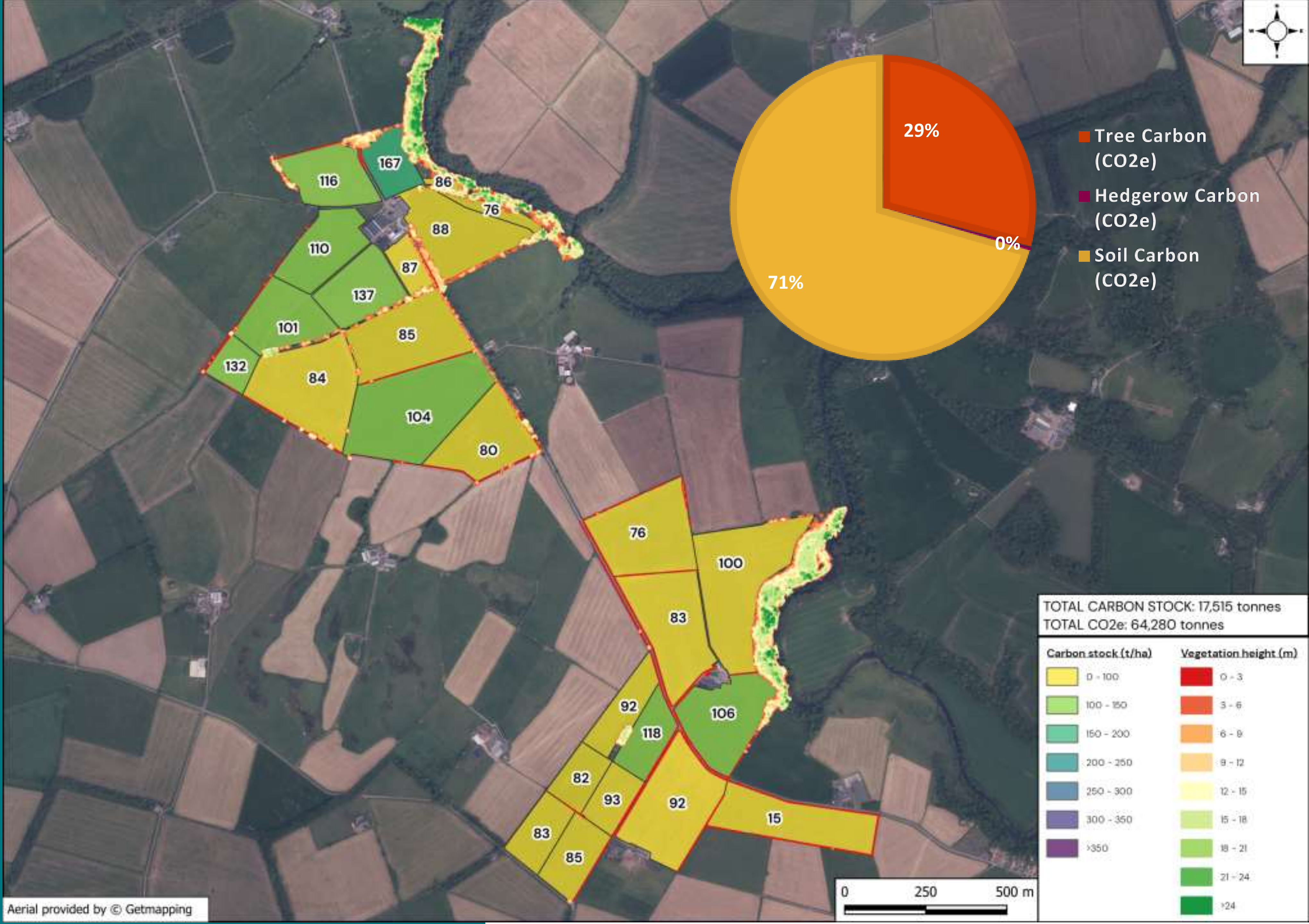
Auchinbay – Dairy



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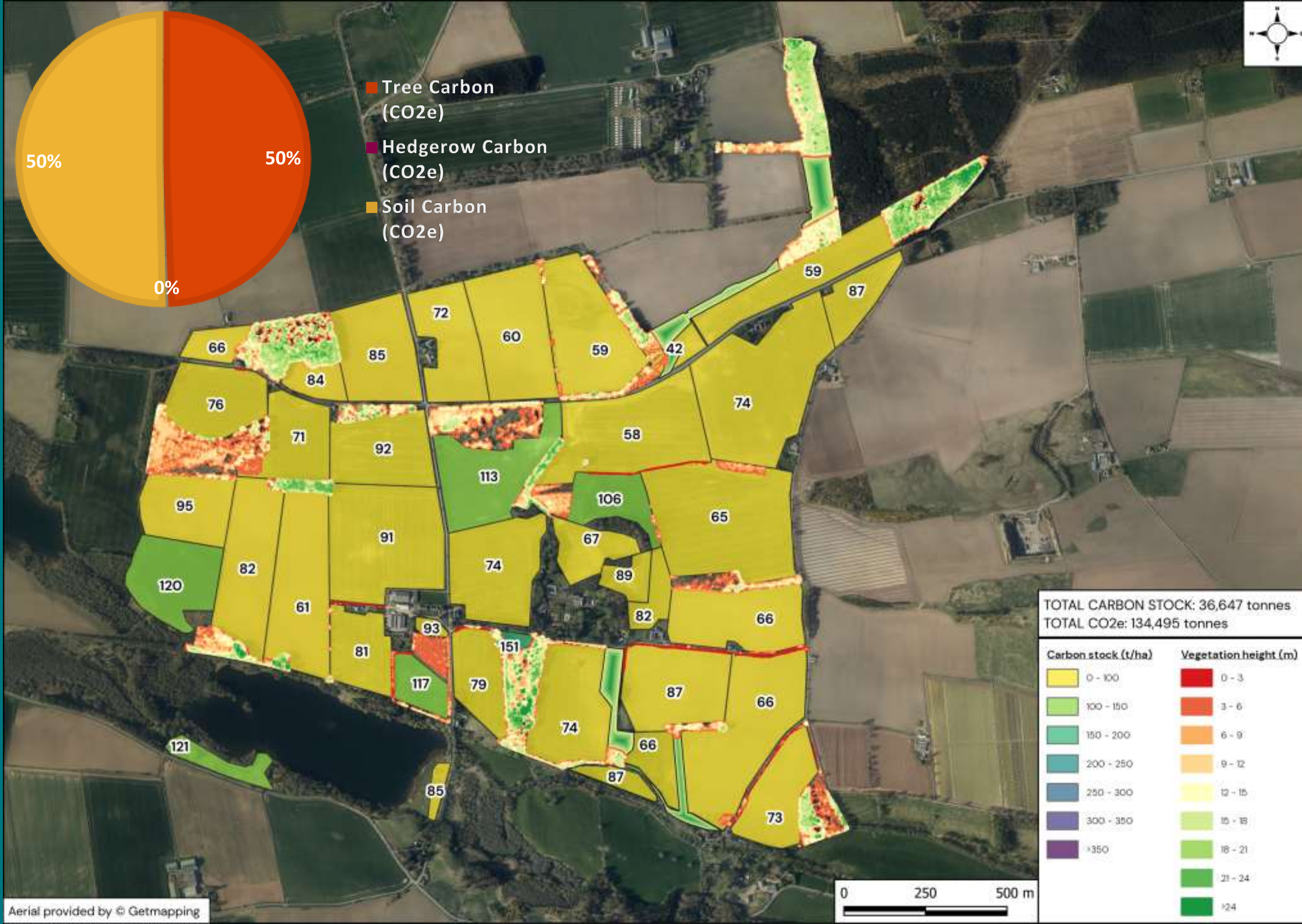
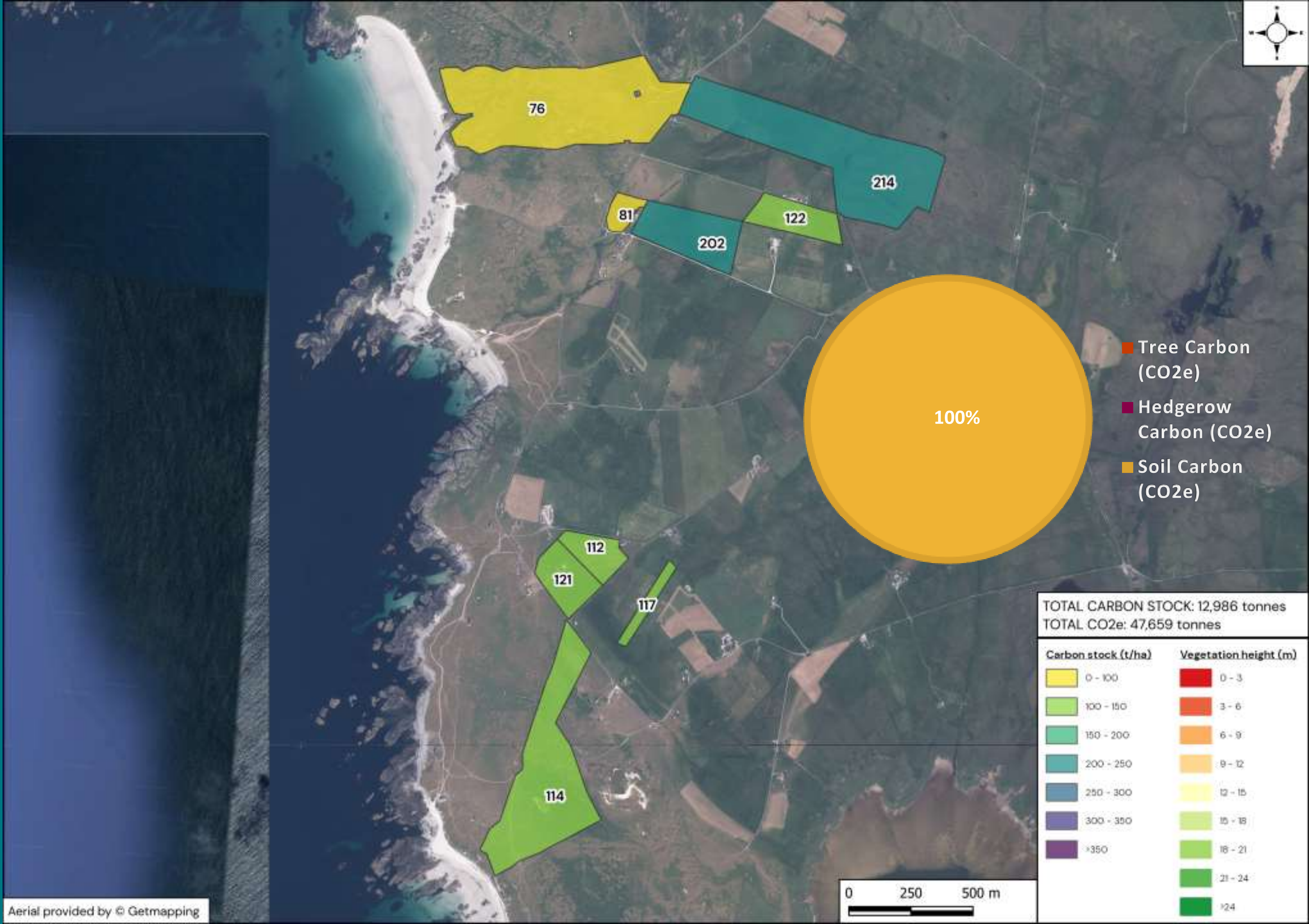
Mains of Balgavies – Arable



Kilkenneth – Croft



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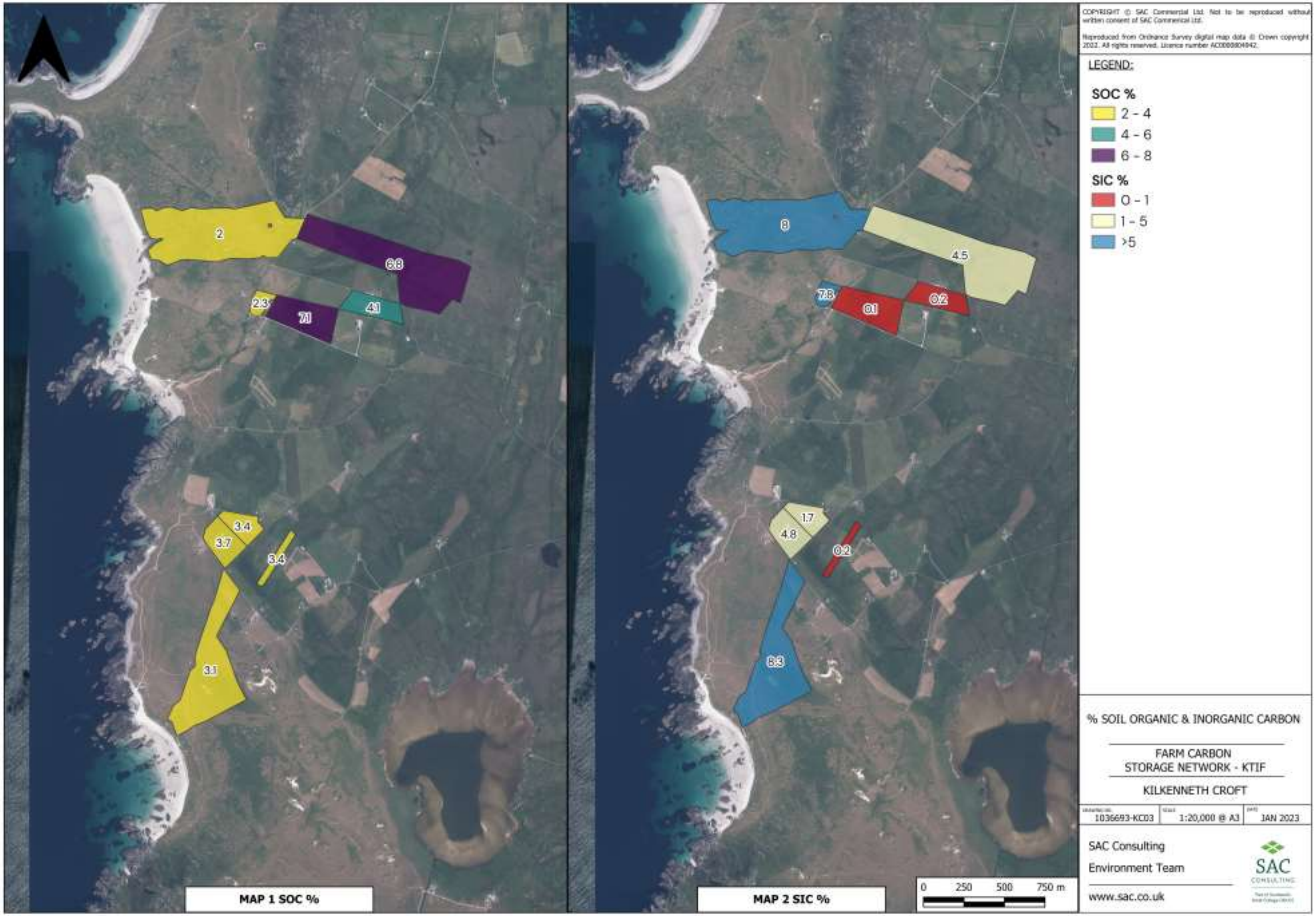
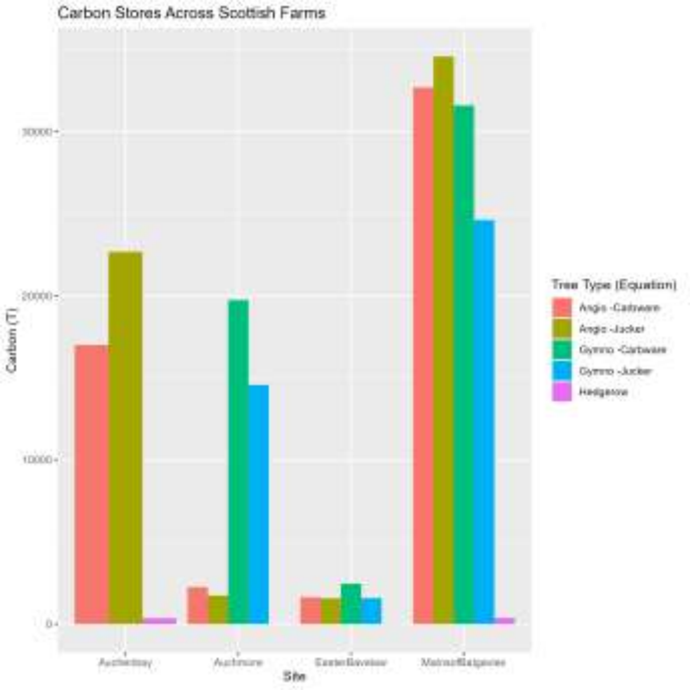
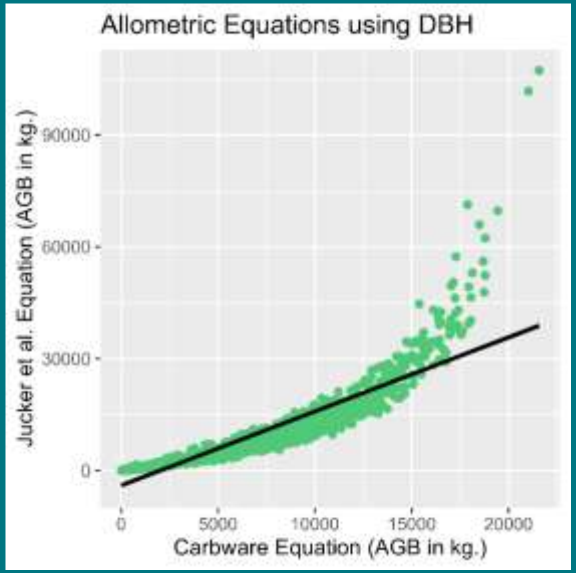
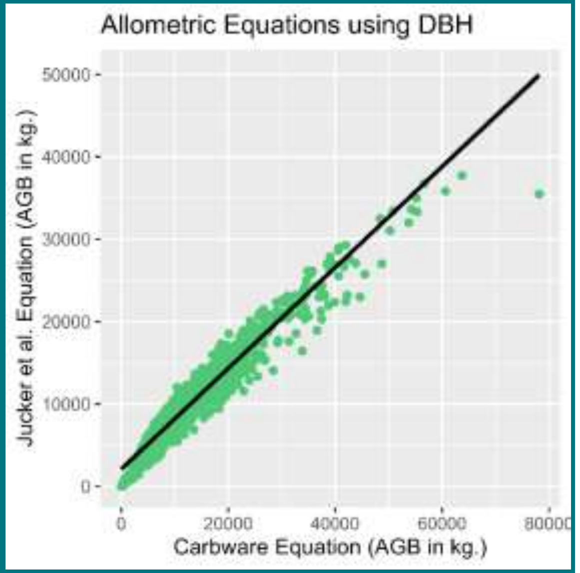




Broadleaves

Conifers





Uncertainty

- Allometric equations only as good as the data they are built from
  - Majority of equations designed for large scale regional use rather than specific sites
  - Shortage of accessible allometric tree data for Scotland
- Tree segmentation
  - Issues segmenting out canopies for smaller trees (<5m)

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Next Steps

- Incorporating lessons learned in Phase I to enhance robustness and refine accuracy of model
  - Built database of tree survey data across sites
  - Feed database into model to tailor allometric equations
  - Improve tree segmentation for >5m trees

Estimating above ground biomass carbon stocks using drone based LiDAR

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