# LIMMMA Documentation

2025-02-17

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# Preface

# Introduction

(Notes)

Biological, social and physical sciences – community engaged. Landscape change – ecosystem services, well-being, livelihoods. Critical transition zones – impact of 'sustainability' interventions. Understanding use of different system framings and forms of knowledge/evidence across scales. Decision making for resilient future landscapes which support ecosystem services and wellbeing.

Understanding the changing function and value of multifunctional landscapes and how they are shaped. Build up detailed multifunctional landscape mosaic of social, cultural, biophysical and economic issues associated with the suitability and impact of NbS/nature recovery. (Connectivities, co-benefits, trade-offs) Strong contextual foundation for utilizing emerging science from Nature Returns and others. Increased involvement of local communities including citizen science. Sharing lessons from NbS interventions over the long-term. Support and contextualise NbS policy and plans and their evaluation. Gain real-time feedback from policy interventions. Scale up lessons from pilot site living labs.

# 1 Getting Started

## 1.1 Setting up a new project

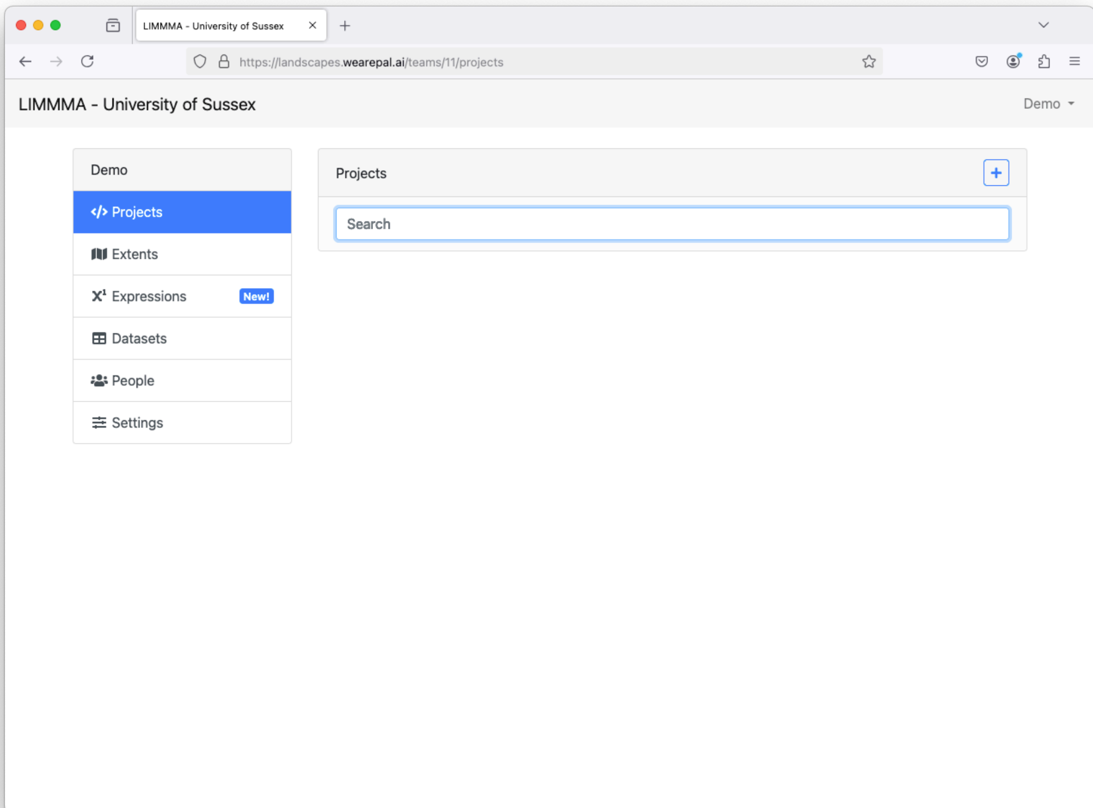


Figure 1.1: Projects

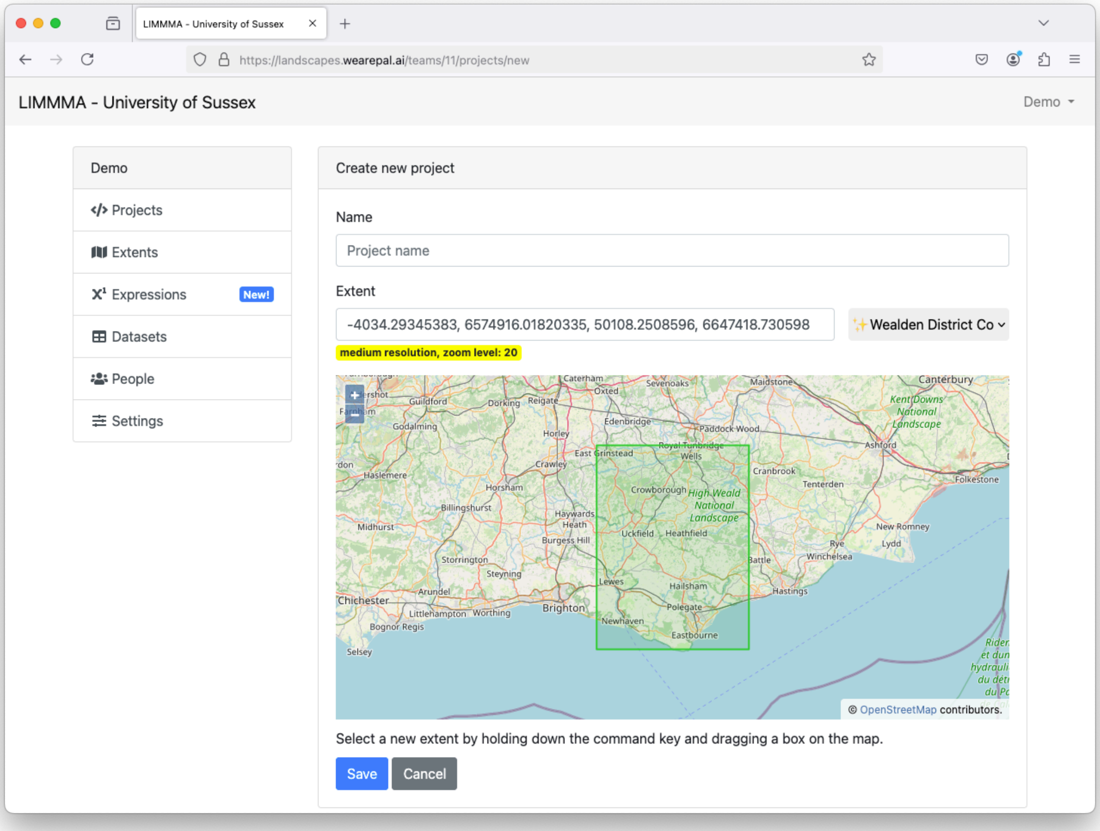


Figure 1.2: Extent

### 1.1.1 Create an account

### 1.1.2 Create a new project and set extent

## 1.2 Map View

### 1.2.1 Adding layers

### 1.2.2 Snapshot tool

## 1.3 Model View

# 2 Key Features

# 3 Use Case 1: Above Ground Carbon

As part of the Nature Returns research project with Natural England, the LIMMMA team worked with Kew Wakehurst on landscape-based carbon storage modelling. This involved using habitat maps, remote sensing data and equations for estimating the amount of carbon stored above ground (in vegetation such as trees and hedgerows) and below ground (in soils) across a diverse landscape of woodland, grassland and built up areas at different scales including 1) Wakehurst site, 2) Wealden District Council, 3) Southeast England with potential to be scaled nationally.

In the following walkthrough we demonstrate how the above ground carbon models were created and tested using LIMMMA.

## 3.1 Basic Concepts

If you are new to the idea of thinking about the landscape as a store of carbon then there are a few basic concepts you need to understand before we go any further. If you already know all about vegetative carbon and soil carbon you can skip to the next section.

### 3.1.1 Carbon Cycle

As an essential element of life, carbon is taken in, stored and released by all living organisms. Through photosynthesis plants remove carbon dioxide from the air, use the carbon to grow and release oxygen back into the air. Although they also release carbon dioxide, over the course of their life cycle, plants are net consumers of carbon. When they die their carbon enters the soil. Some of this carbon becomes food for organisms in the soil and makes its way back into the air, but, under the right circumstances, a portion of it can remain there indefinitely. Although the amount of carbon flowing through the vegetation and soil in any landscape is constantly changing, given the right information we can estimate a snapshot the total amount of carbon stored in the landscape at a specific point in time and potentially predict the net impact of that landscape on carbon emissions over a given period of time.

### 3.1.2 Estimating Stored Carbon

The first step towards making these kind of predictions is to estimate the stock of carbon stored in the landscape and map its distribution across space. Below is a visual illustration of the basic methods used to make such estimates.

Imagine a landscape with a mixture of woodland, farmland, residential areas and urban/sub-urban trees and other greenery.

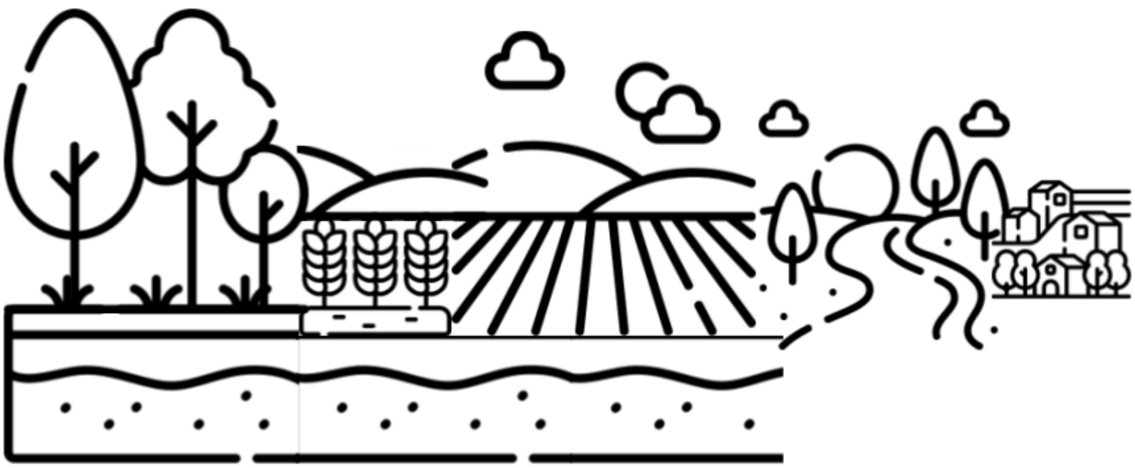

Figure 3.1: How much carbon is stored in this landscape?

Above the ground, carbon is stored for long periods of time in large areas of woodland, hedges and lone trees in agricultural fields as well as individual trees in amongst buildings and roads. Arable crops and wild grasslands store much smaller amounts of carbon for very short periods of time until their carbon is either consumed by humans or animals (to be released again to the air) or is gradually incorporated into the soil as they decompose.

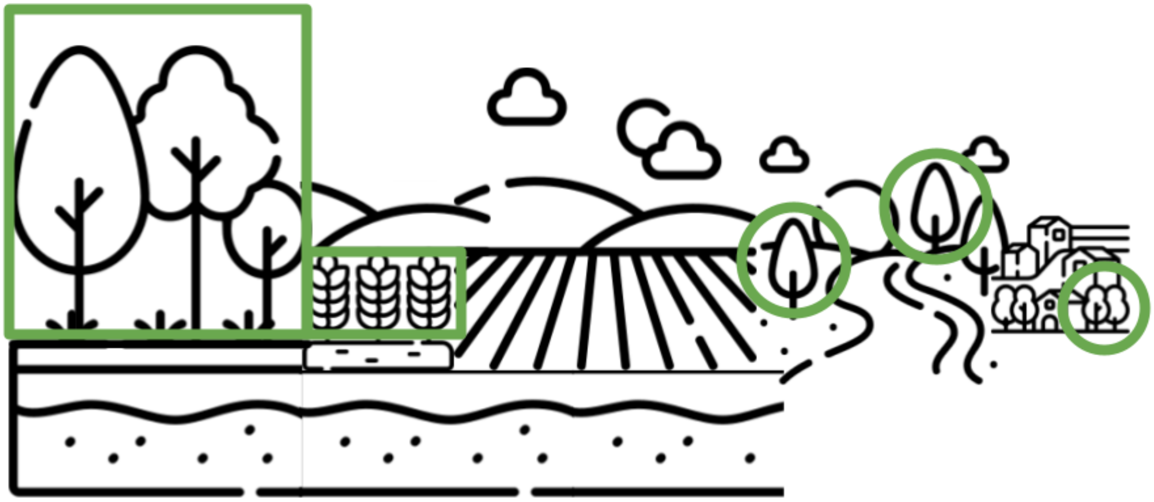

Figure 3.2: Carbon stored above ground in vegetation

Carbon in rotting plant matter from trees and other vegetation, once incorporated into the soil becomes part of the soil-carbon-cycle and a portion of it is stored for various periods of time. Under the right conditions, the soil can accumulate a vast store of carbon which may remain locked away for long periods of time. Taking account of above and below ground carbon, over the course of 100 years a native broadleaf woodland can store between 300 - 350 tonnes of carbon per hectare.[1] If we convert that to an annual figure (3 - 3.5 tons) we can see that this is roughly equal to 80% of the average carbon footprint per person in the UK (4.4 tons[2]).

[1] https://www.woodlandtrust.org.uk/plant-trees/woodland-carbon-farmers-and-landowners/.

[2] https://ourworldindata.org/co2-and-greenhouse-gas-emissions.

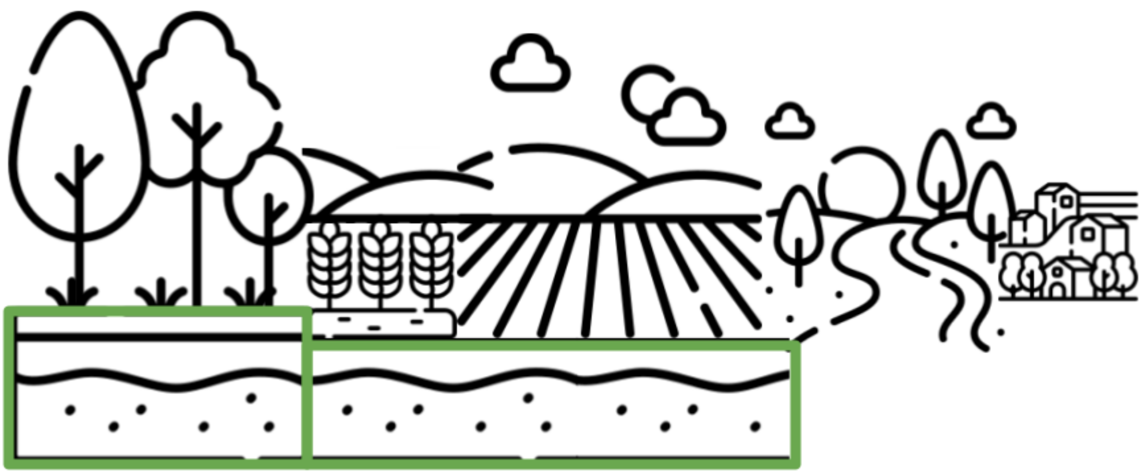

Figure 3.3: Carbon stored below ground in soils

The starting point for estimating the distribution of stored carbon in a landscape is to classify it into different habitats (broadleaf woodland, coniferous woodland, grassland, arable, etc.). Then we assign a fixed estimate (based on field research) of the amount of carbon stored per unit of each habitat.

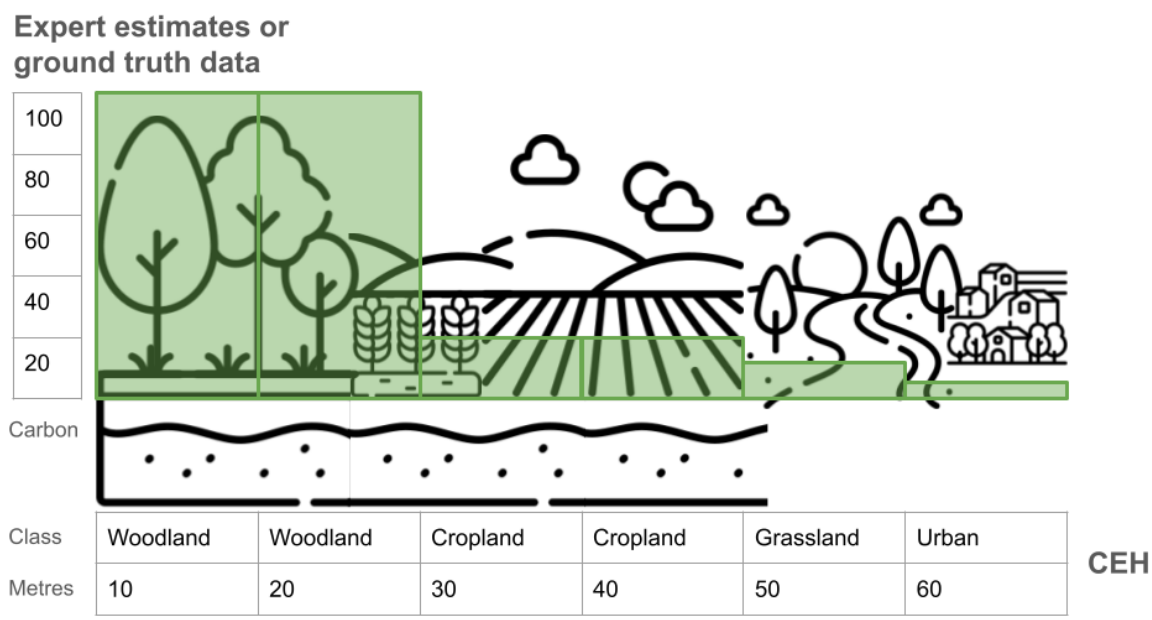


Figure 3.4: Estimating above ground carbon based on habitat classifications

Of course, within each habitat there are huge variations in the density and height of vegetation as well as the quantity of carbon accumulated in soils. These variations are not captured by a simple average per unit of habitat. Additional data is needed to reflect within-habitat variations, such as topography. Lidar measurements can give us an estimate of the height of trees and other vegetation and some indication of the density of vegetation. This data can then be used in equations to estimate the total vegetative carbon distribution across a single habitat such as broadleaved woodland. To supplement the habitat-based estimates we can also use AI-assisted feature detection on satellite imagery or areal imagery to identify lone trees or street trees which would otherwise not be included in the habitat classifications.

Using LIMMMA we can make use of these different sources of data and try out multiple combinations of data and methods for transforming them into carbon density maps. The next section explains the different approaches demonstrated in ....

## 3.2 Methodologies and Datasets

Our aim in this project was to create a workflow for generating and improving geospatial estimates of the amount of carbon stored above ground in the natural landscape which met the following requirements:

1. Use open access national datasets.
2. Scaleable from local to national.
3. Easily compare across different models at different scales.
4. Rapidly improve with new data, equations (e.g. allometric) and methodologies as they emerge from ongoing research.

The data and methods adopted are summarised in the following diagram.

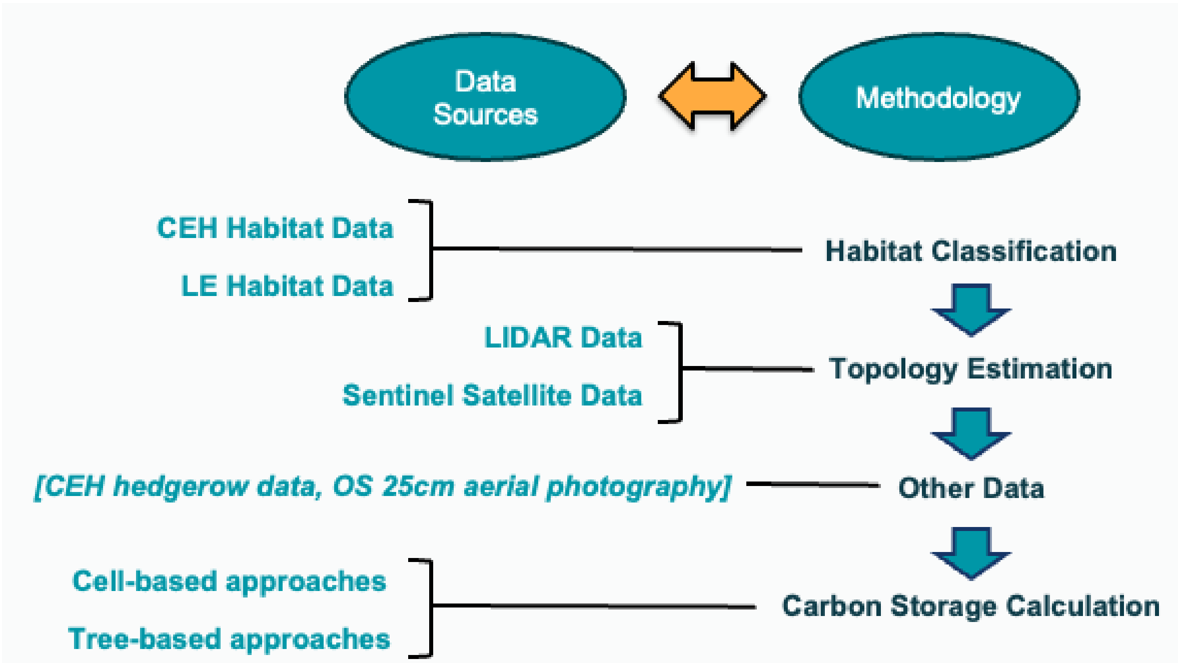


Figure 3.5: Above Ground Carbon data and methodology

Two options for generating the habitat basemap for carbon estimates were imported: one from CEH and the other from LE. LIDAR and Sentinel Satellite imagery provided the two options for topology estimation. Additional data included CEH hedgerows and OS 25cm arial photography. These data were variously used in different methods of carbon storage calculation using a cell-based approach. The four methodologies listed below build on each other iteratively to progress towards a more precise estimate of carbon storage generated by increasingly complex models with potential for continuous improvement.

| | Base model | Tree Height | Tree + Hedge Height | Feature Height |
|---|---|---|---|---|
| **Habitat** | Fine-grained habitats | Fine-grained habitats | Fine-grained habitats | Broad 'arable' habitats |
| **Topology** | N/A | Woodland habitat tree height estimates | Woodland habitat tree height estimates | Arable habitat feature height estimates |
| **Other Data** | N/A | N/A | CEH hedgerow data | N/A |
| **Carbon Storage Calculation** | Fixed carbon storage figure per habitat | Woodland carbon storage estimate from feature height in cell. Fixed carbon storage figure other habitats | Woodland and hedge carbon storage estimate from feature height in cell. Fixed carbon storage others | Arable habitat features carbon storage estimate from feature height in cell. Fixed carbon storage others |

Figure 3.6: Above Ground Carbon evolving methodologies

In the image below we can see how each model progressively improves the fidelity of carbon estimate maps by variously increasing their resolution and coverage.

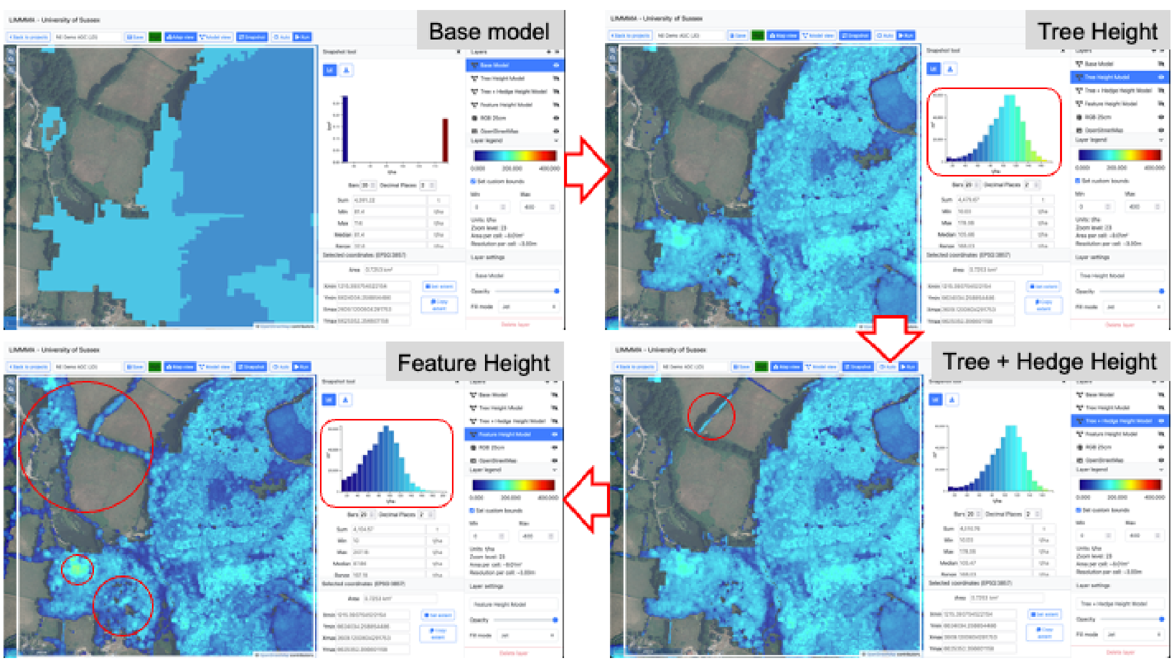


Figure 3.7: Above Ground Carbon model outputs showing increasing fidelity

And here is an example of the outputs from the model in LIMMMA map view at different scales.

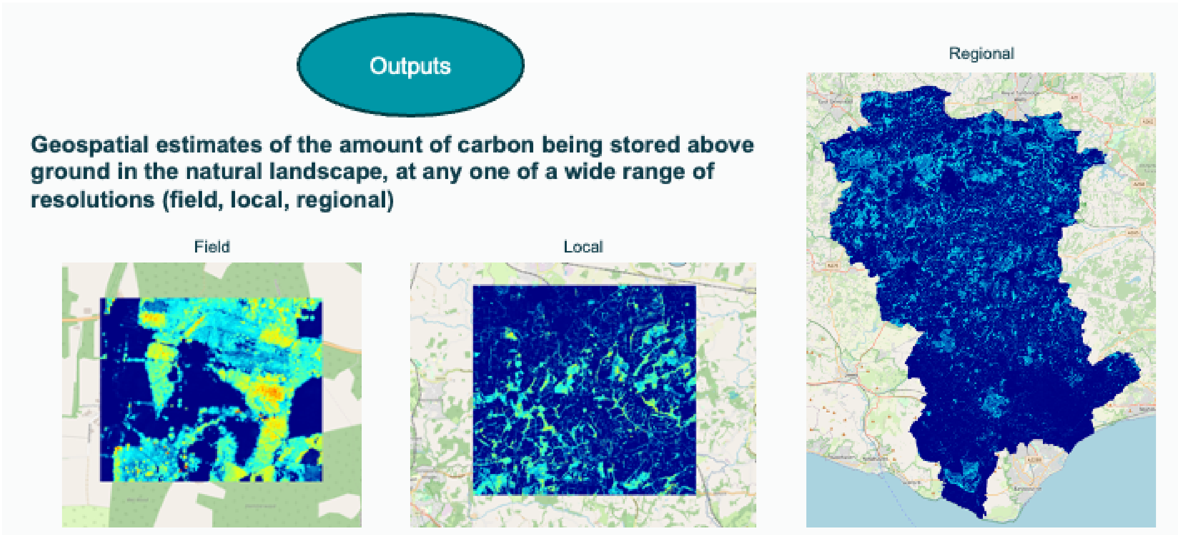


Figure 3.8: Example LIMMMA outputs

The following section describes how each of these models was built and how the outputs were created and analysed to draw conclusions about the different levels and sources of uncertainty associated with each.

## 3.3 Implementing models

Each model was built in LIMMMA's graphical modelling system. The following diagram shows how it is used to connect data, methods and outputs in a single visual interface.

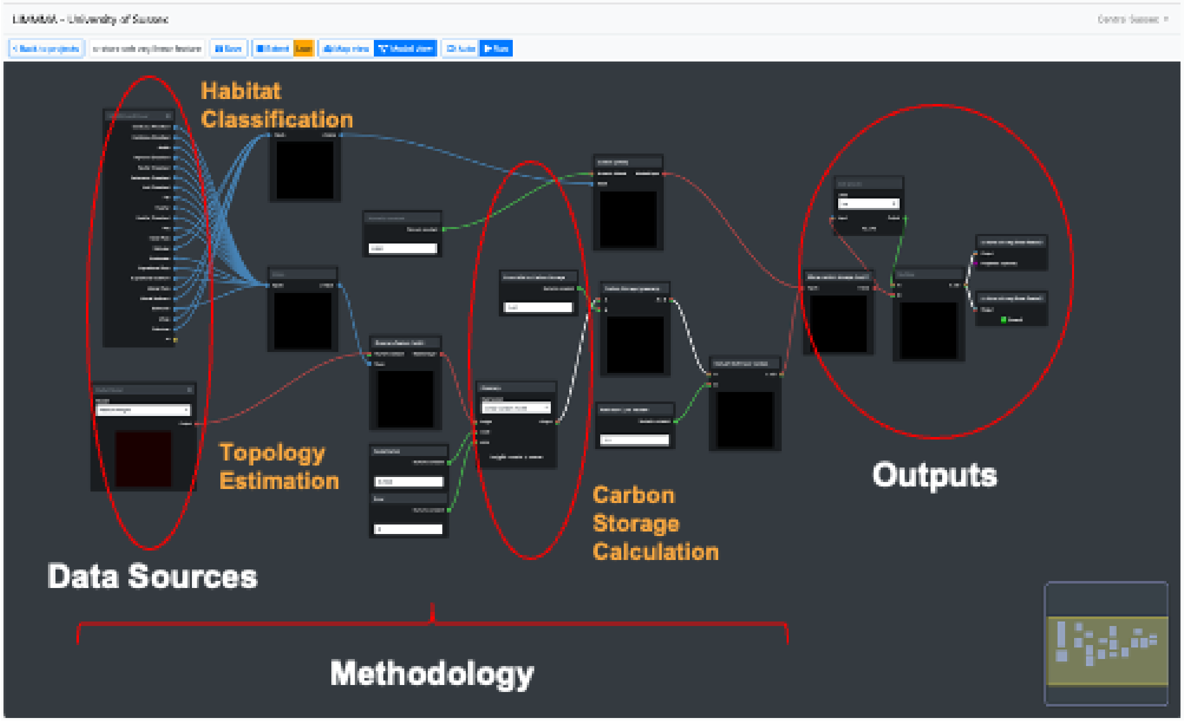


Figure 3.9: Example LIMMMA model

Having created a new project and set our desired extent, we can open the model view and start building. At first, you will be presented with a blank screen with no visible controls. Don't worry, the first thing to do is to add the data components that you want to include in your model. This is done by simply right clicking the screen and selecting from a list of whatever datasets you have already imported into you team's workspace in the LIMMMA app.

### 3.3.1 Select datasets

### 3.3.2 Transform data

### 3.3.3 Generate outputs

## 3.4 Exploring outputs

# 4 Use Case 2: Below Ground Carbon

# 5 Use Case 3: Multifunctional Landscape Analysis

# 6 Use Case 4: AI Supported Land-Use Classification