Root Dynamics Under Elevated CO_2 in a Free Air Carbon Enrichment (FACE) Experiment

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Research Questions

1. How does eCO_2 impact **fine root biomass** in a mature, deciduous forest?
2. How does eCO_2 impact **fine root morphology (length, diameter and SRL)** in a mature, deciduous forest?
3. How does eCO_2 impact **fine root carbon content** in a mature, deciduous forest?
4. How does eCO_2 impact **fine root depth distribution** in a mature, deciduous forest?

Background

Increasing levels of atmospheric CO_2 results in **photosynthetic enhancement** and **increased carbon (C) sequestration** in many tree species. However, it remains largely unclear if, where, and for how long, this C is stored as biomass within living vegetation in forests.

Fine roots make up only **<5% of combined forest biomass** yet are said to represent **~1/3 of global NPP**. Understanding the impact of elevated carbon dioxide (eCO_2) on fine roots is vital for improving the **accuracy of couple biosphere-atmosphere** models and the comprehensive understanding of **future global C budgets.**

To sustain photosynthetic enhancement, trees are likely to require higher intake of nutrients from the soil. Therefore, eCO_2 is hypothesized to **stimulate increased fine root biomass**, a **deeper fine root depth distribution** (to avoid high levels of competition in the surface layers) and an **increased specific root length** (SRL) (the length-to- mass ratio of a root).

Free Air Carbon Enrichment (FACE) experiments are valuable in understanding full ecosystem responses to eCO_2 but have consistently been applied to young aggrading forests and plantations. This study is carried out at **BIFoR FACE**, the only FACE experiment globally in a native, mature, deciduous forest. Here, patches of the forest are fertilised with levels of CO_2 predicted to be the 2050 atmospheric norm (+550ppm).

Fig 1: The Birmingham Institute of Forest Research FACE (BIFoR FACE) experiment from above (Image source: RIBA Journal)

Take Home Messages

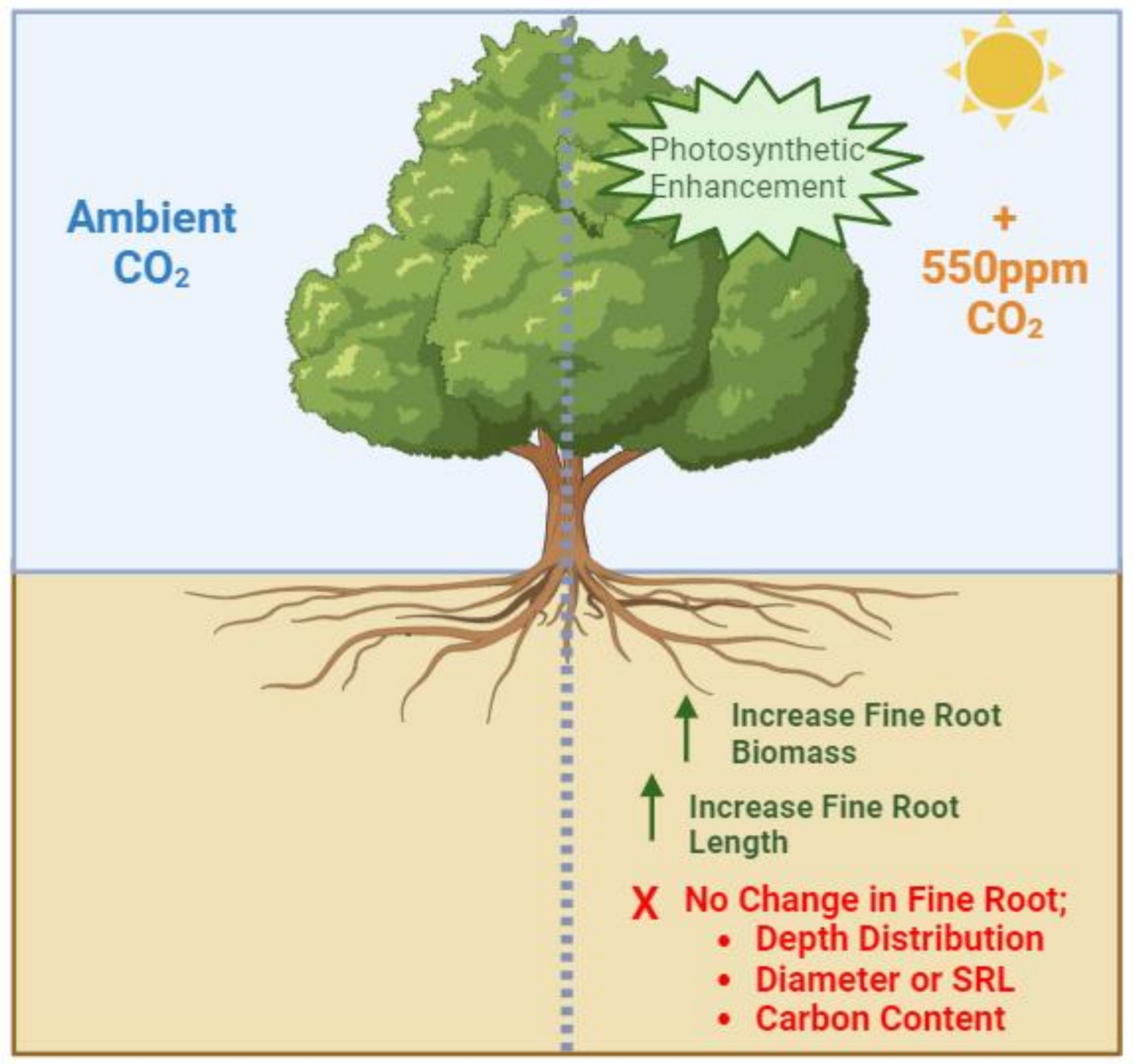
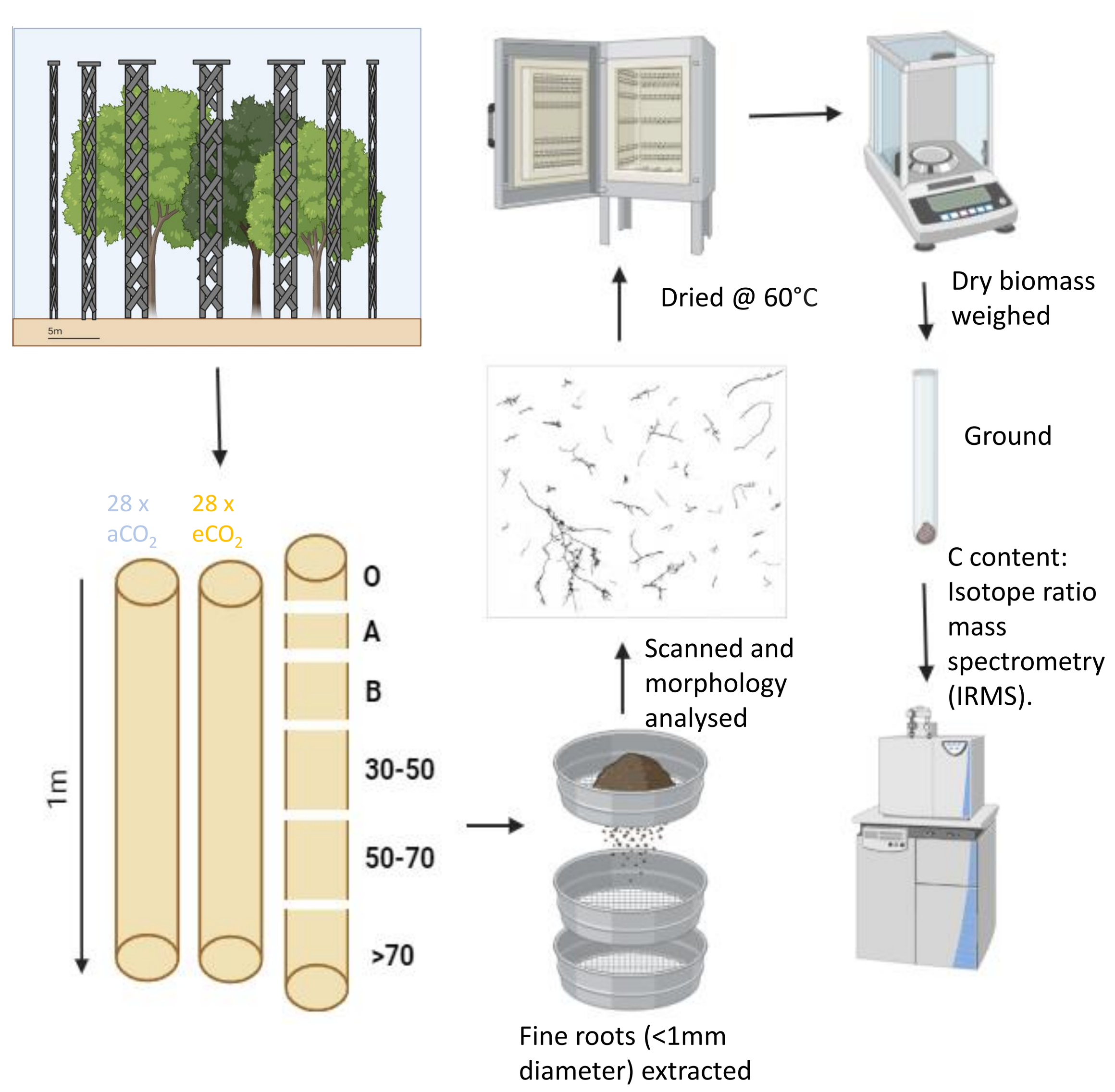


Fig 2: Take home messages from this study. Information consolidated from Results section. Infographic designed using Biorender.

Methods



Results

1 More fine root (<1mm diameter) biomass under eCO_2 in total (A) and at all individual depth profiles up to 50cm (B).

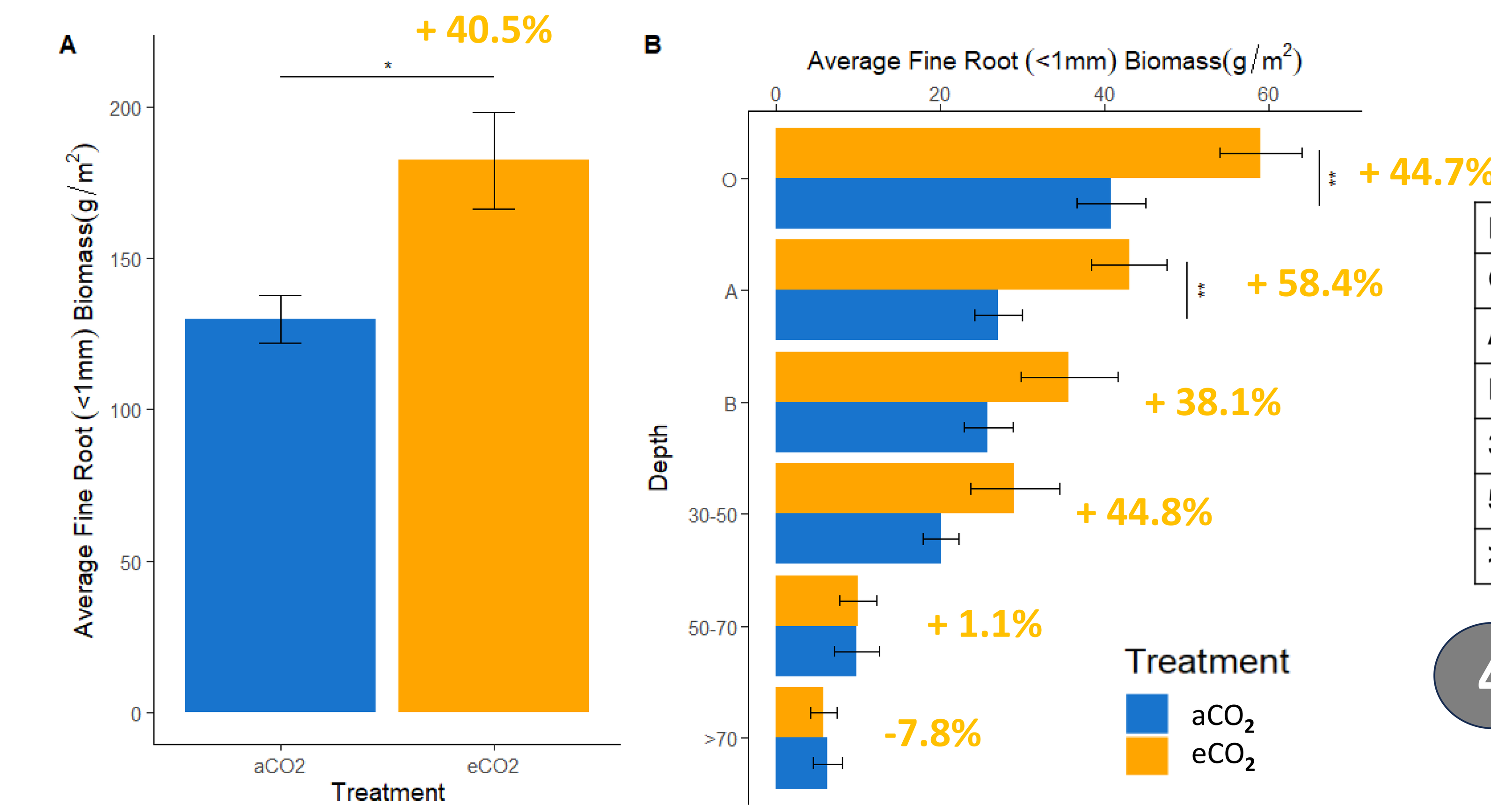


Fig 3: Average total fine root (<1mm) biomass per unit ground area (A) overall and (B) per depth profile of 1m soil cores taken in ambient (n=28) (blue) and elevated (n=28) (orange) CO_2. Error bars are ± SE.

2 The trends suggest that an increase in length drives the increase in biomass under eCO2, but length, diameter and SRL are not significantly different between treatments at any depth

	Average Length (m/m^2)			Average Diameter (mm)			Average SRL ($m\ g^{-1}$)		
Depth	aCO_2	eCO_2	**E/A Ratio**	aCO_2	eCO_2	**E/A Ratio**	aCO_2	eCO_2	**E/A Ratio**
O	58.9 ± 6.3	99.2 ± 19	**1.7** ± 0.4	0.39 ± 0.01	0.4 ± 0.01	**1** ± 0.03	42.4 ± 1.8	38.3 ± 2	**0.9** ± 0.06
A	14 ± 2.5	24.6 ± 7.2	**1.8** ± 0.6	0.41 ± 0.02	0.42 ± 0.01	**1** ± 0.06	27.1 ± 2	27.9 ± 1.9	**1** ± 0.1
B	2.1 ± 0.2	4.3 ± 1.1	**2.1** ± 0.6	0.42 ± 0.02	0.43 ± 0.01	**1** ± 0.06	22.8 ± 1.7	25.5 ± 2.5	**1.1** ± 0.1
30-50	1.5 ± 0.2	2.3 ± 0.6	**1.6** ± 0.5	0.41 ± 0.01	0.39 ± 0.03	**0.9** ± 0.07	29.6 ± 2.8	33.9 ± 2.6	**1.1** ± 0.1
50-70	0.7 ± 0.2	0.8 ± 0.3	**1.2** ± 0.6	0.33 ± 0.04	0.35 ± 0.04	**1.1** ± 0.18	28.4 ± 3.6	35.5 ± 5.2	**1.3** ± 0.2
>70	0.6 ± 0.5	1.9 ± 1	**2.2** ± 2.4	0.27 ± 0.05	0.28 ± 0.05	**0.9** ± 0.23	22.9 ± 2.8	28.2 ± 6.4	**1.2** ± 0.1

3 No significant difference in fine root carbon content between aCO_2 and eCO_2 at any depth in 2021 or 2023

	Carbon Content (g/g root)			
	2021		2023	
Depth	aCO_2	eCO_2	aCO_2	eCO_2
O	0.49 ± 0.002	0.49 ± 0.015	0.51 ± 0.005	0.52 ± 0.002
A	0.49 ± 0.011	0.49 ± 0.009	0.51 ± 0.005	0.5 ± 0.009
B	0.49 ± 0.006	0.5 ± 0.009	0.51 ± 0.007	0.52 ± 0.007
30-50	0.49 ± 0.006	0.51 ± 0.010	0.49 ± 0.003	0.5 ± 0.004
50-70	0.48 ± 0.005	0.49 ± 0.014	0.5 ± 0.007	0.51 ± 0.016
>70	0.52 ± 0.016	0.49 ± 0.012	0.5 ± 0.004	0.52 ± 0.002

4 The fine root depth distribution is not deeper under eCO_2

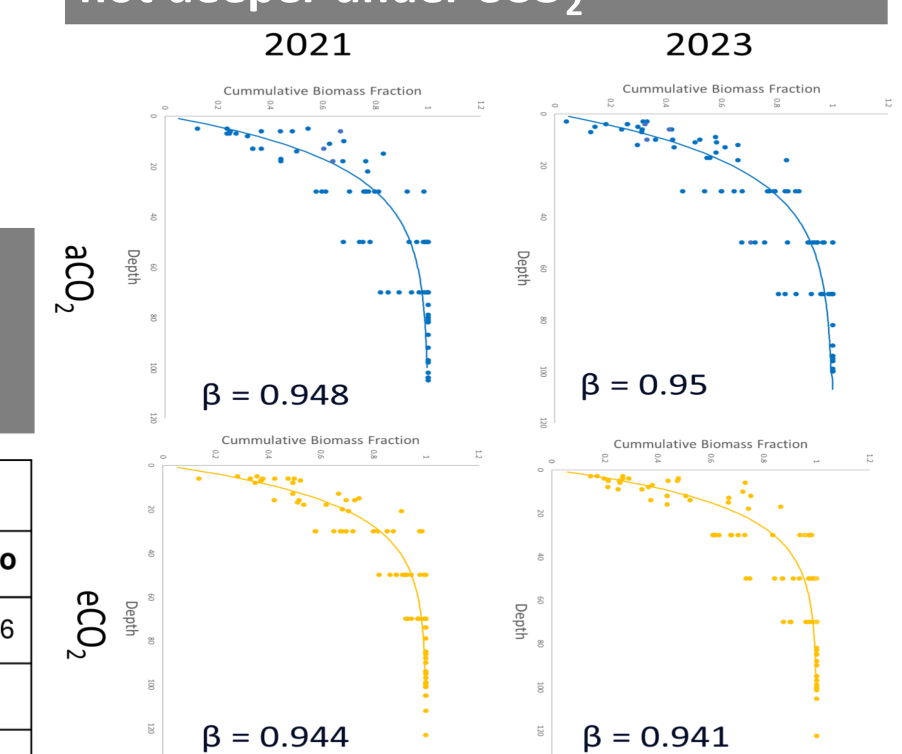


Fig 4: Cumulative root fraction as a function of soil .The data points represent the real cumulative root fraction values and the curves represent the least squares fit of β using the Gale and Grigal (1987) asymptotic equation Y = 1- β^d, where d = depth and Y = the proportion of roots from the surface to depth. Higher values of β correspond to a higher proportion of roots with depth.

Conclusions & Next Steps

- There is no impact on fine root morphology, carbon content or depth distribution, but there is more fine root biomass under eCO_2. This suggests that mature, temperate deciduous forests invest more carbon into fine root proliferation under eCO_2.
- However, these results represent a snapshot in time. In order for an increase in fine root biomass to have a lasting increase on the fine root carbon sink, there would need to be a reduction in fine root turnover rates.
- We are going to use a Minirhizotron camera (Fig.6) to understand the impact of eCO_2 on fine root growth, mortality and turnover rates.

Fig 5: Minirhizotron Images taken in the same location in August and October 2022

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