BIFoR FACE: First Year of CO_2 Enrichment; Does it Work?

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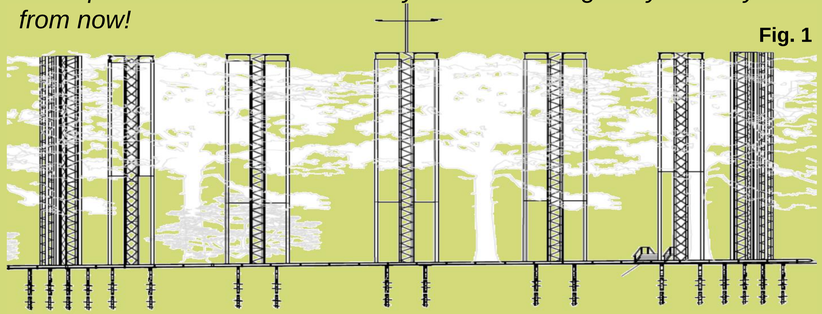
The BIFoR Free-Air Carbon Dioxide Enrichment (FACE) facility is providing a core platform to study the ten-year response of a mature temperate deciduous forest ecosystem against a large step-change in atmospheric [CO_2]. The facility located at Mill Haft Wood has been built into the extant woodland and is designed to elevate the local [CO_2] by +150 µmol mol^{-1} *within discrete, open air, woodland plots. The main experiment commenced in spring 2017. These plots are encompassed by a ring of towers (Fig. 1) that will mimic the proposed atmospheric conditions of the very near future e.g. only 30-50 years from now!*

Fig. 1



1. Experimental Set Up & Site Description

The facility (Fig. 2) enables elevated CO_2 treatments to be introduced from ground level, to just above the 24 m high canopy, in 30 m diameter rings - 3 treatment (green), 3 infrastructure control (yellow) and 3 non-infrastructure control plots. Mill Haft is a 20 ha deciduous woodland containing mature (~168 year-old) oak (*Quercus robur*) and hazel (*Corylus avellana*) coppice. The woodland consists of plant communities typical of a W10a and subcommunity W10d classification[1]. Currently, a total of 7250 trees (≥10 cm DBH) have been identified and measured, of which, 98.5% are deciduous. The upper canopy has reached its likely maximum height and averages 20 m across the site with maximum tree heights of 25 m. Welfare, office and lab. facilities are available.

There are four 25 m metrological towers on the woodland periphery and a 40 m Flux tower in the centre with atmospheric laboratory. Mill Brook stream flows across the Northern periphery of the woodland and has up- and down-stream monitoring stations.

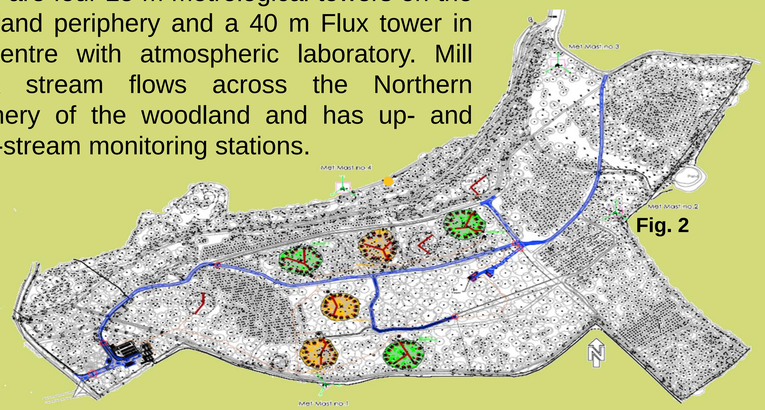


Fig. 2

2. Results

2.1: Engineering Performance

The first year of FACE fumigation system operated from the 4th April (Day 94 - Budburst) until 27th October (Day 300 - Leaf Fall) 2017, total of 207 days. The facility was expected to be operational for 2995 hours and commences from sunrise to sunset each day. The FACE fumigation system was actually functionally operational for 2928 hours (97.7% uptime). A national shortage of CO_2 caused 19 hours downtime over a 48 hour period in August.

2.2: Experimental Performance

The annual average enrichment value achieved was **148.3 ± 20.9** µmol mol^{-1} (Fig. 3).

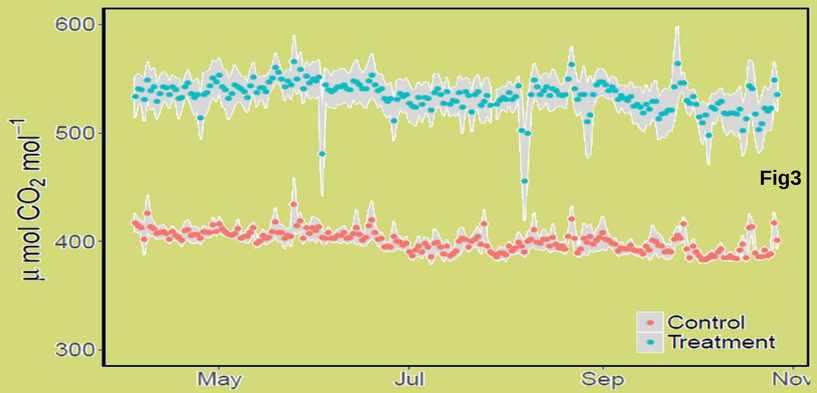


Fig3

Using the *a priori* goal set down by Hendrey[2] for acceptable performance, [CO_2] should remain within ± 20% of the set point for at least 80% of the operation time. BIFoR FACE achieved this **96.7%** of the operation time, across the three fumigated arrays (See Fig. 4a). The Control Plots (Fig. 4b) maintained ambient [CO_2] >99.9% of the operation time. The 10% operating parameter demonstrates the facilities vulnerability to short-term, wind-borne CO_2 fluctuations creating variability ±15 µmol mol^{-1} off the target.

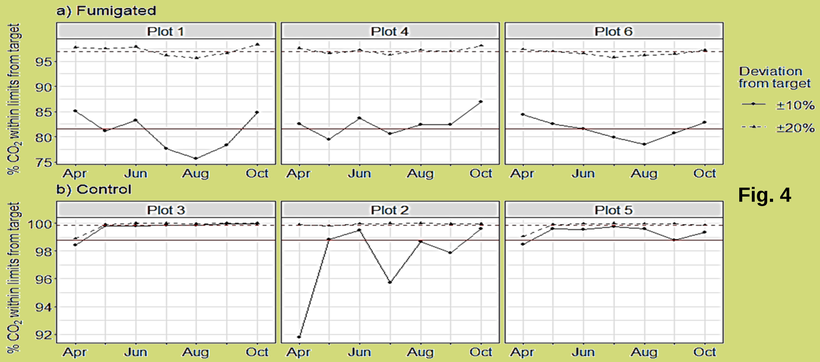


Fig. 4

4. Ambient Plots

An *a priori* target to determine if the level of [CO_2] in the control plots was deemed 'acceptable', was set to < 20 µmol mol^{-1} CO_2 than ambient for < 20% of the operation time. Infrastructure control plots at BIFoR FACE were observed with elevated levels of atmospheric CO_2 8.0 ± 5.2% of the operation time.

Analysis of the time of incidents suggests wind direction to be the prime driver of cross CO_2 contamination. Incidents were not evenly distributed amongst the control plots with Plot 5 suffering the majority of cross-wind contaminations and Plot 3 the least.

The total number of hours control plots were subjected to [CO_2] > 20 µmol mol^{-1} (of ambient) was 234.2 hours spread over the season. Monthly analysis indicates this is dependent on a plots location and heavily weighted to seasonal wind patterns. Figure 5 demonstrates that changes in wind direction, other than South and South-westerly (red arrow), have an additive impact on the ambient [CO_2] inside the control plots. Wind speed and canopy cover also have a strong effect.

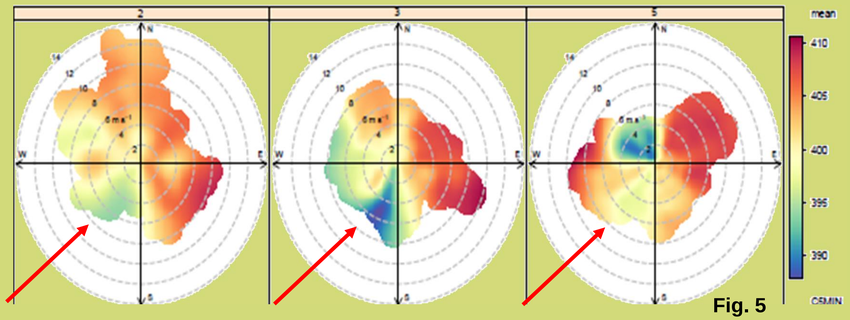


Fig. 5

5. Future Plans

- Complete install of Met Tower instrumentation before 2019 season
- Install and make operational a CO_2 monitoring system in the 3 non-infrastructure control plots (7-9) before 2020 season.

6. Conclusions

- The FACE facility exceeded its performance expectations by maintaining the set-point target of +150 µmol mol^{-1}, **96.7%** of the operation time.
- Minimal cross-contamination of introduced CO_2 was observed in the control plots. Wind-borne CO_2 from enriched plots was the point source of these elevations and dependent on wind direction.
- BIFoR FACE has been successfully operated by UoB staff and the atmospheric [CO_2] of the future achieved within Mill Haft wood.

7. Literature:

1. Rodwell, J.S. 1991. *Woodlands and scrub* (Cambridge University Press)

2. Hendrey, G. R., Ellsworth, D. S., Lewin, K. F., Nagy, J. 1999. 'A free-air enrichment system for exposing tall forest vegetation to elevated atmospheric CO2', *Global Change Biology*, 5: 293-309.

8. Acknowledgments: The BIFoR FACE facility is a research infrastructure project supported by the JABBS foundation and the University of Birmingham. Applications to work at the facility should be addressed to ARMK.