Dispersion inside woodland using CO_2 data measured at Mill Haft

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Background & Motivation

Vegetation is often regarded as an effective approach to mitigate air pollution in an urban area because of its absorption and deposition function [1]. However, the mitigating capacity of vegetation is only part of story and vegetation may cause an increase in concentration of pollutants due to other physical processes, for example:

- trees set barriers on wind flow, thereby decreasing the ventilation and dispersion of pollutants [2];
- large surface areas of leaves increase the aerodynamic roughness [3];
- tree canopies impede the exchanges between the pollutants released at ground level and the fresh air coming from the layer above the roofs [4].

Investigating how trees influence the dispersion process of air pollutants is of great importance for the purpose of minimising the negative effects on their concentrations and make vegetation work better to improve urban air quality. The BIFoR site provides an ideal field laboratory to study the dispersion process of CO_2 inside woodlands.

Objectives

- To study the effects of wind speed on CO_2 dispersion process inside a woodland
- To examine the effects of tree density on CO_2 dispersion process inside a woodland

Methodology

- Data used for analysis consist of first-hand data measured by an hand-held CO_2 sensor at the height of about 2 m for four days and second-hand data from April to June 2017 provided by the BIFoR site at the levels of 2 m, 10 m and 25 m. The measuring points for the first-hand data are along a transect and in the downwind direction on the specific days.
- First, the box plots are drawn out separately based on these data. Second, the values of 25th, 50th and 75th percentile are extracted from the box plots under different wind speed and tree density which can be connected into curves. Third, the trend lines are added to the curves and each trend line owns a fitting formula whose format is "y=kx+b". The slope of the lines (values of "k") is the decreasing rate of CO_2 concentrations with the increasing distance from the emitting source and then the influence of the two parameters in the objectives can be revealed.
- The measuring lines in the downwind direction and the distribution of the sensors within each ring is showed in Fig. 1 and Fig. 2.

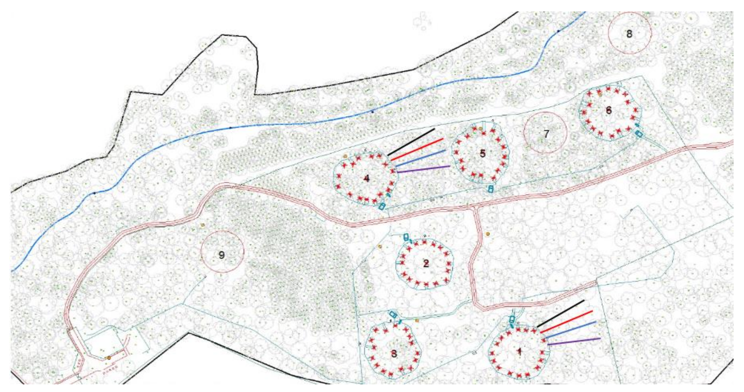

Fig. 1. Map of the sites with the marked measuring lines

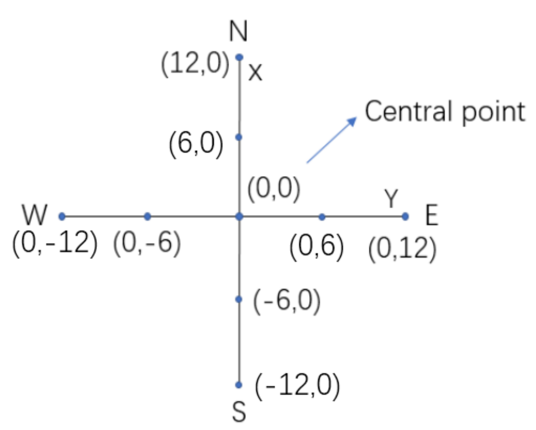

Fig. 2. Distribution of the sensors within each ring

Discussion

- According to the results of the first-hand data, under a higher wind speed and a lower tree density, CO_2 is dispersed faster. Atmospheric turbulence causes transport of the scalar from the source to the observation point [5]. The higher wind speed will induce more turbulence which can contribute to the dispersion processes. In other words, wind plays an important role in diluting the CO_2 concentrations and the higher the wind speed is, the more the dilution will be. Once CO_2 is emitted from the source, wind passing through the space between leaves and trunks is the dominant dispersion process. The lower tree density means there are less obstacles for the dispersion which will benefit the CO_2 dispersion.
- The results of the second-hand data at the layer 2 m show that trunks of trees mainly influence the dispersion process; the CO_2 concentrations remain around 570 ppm inside the ring; with the increasing distance from the emitting source, the CO_2 concentration decreases slightly from the initial concentration. However, for the layer of 25 m where the tree canopies are located, CO_2 concentrations remain around 550 ppm, but fluctuate fairly significantly near the downwind side of the ring, which may be linked to the local leaf density; this needs a further study for a comprehensive explanation.

Results

Effects of wind speed inside and outside of Ring 1 (first-hand data)

Table. 1. The values of "k" within Ring 1 (first-hand data)

	Date	25th percentile(Q1)	50th percentile(Q2)	75th percentile(Q3)
morning data	04/12	-1.3292	-1.5750	-3.9111
	04/19	-1.3194	-1.5472	-1.3333
	06/08	-1.3349	-2.2306	-2.5722
	06/22	-1.3058	-2.1167	-2.0708
afternoon data	04/12	-2.0361	-1.9111	-1.4333
	04/19	-1.5944	-1.6722	-1.4222
	06/08	-1.9944	-2.6889	-2.7056
	06/22	-1.8736	-2.5278	-2.6958

Table. 2. The values of "k" out of Ring 1(first-hand data)

	Date	25th percentile(Q1)	50th percentile(Q2)	75th percentile(Q3)
morning data	04.12	-2.2471	-2.3211	-2.6503
	04.19	-1.7791	-1.9394	-2.5839
	06.08	-2.3287	-2.6090	-2.7637
	06.22	-2.2284	-2.5484	-2.6344
afternoon data	04.12	-2.2214	-2.2879	-2.3523
	04.19	-1.9802	-2.1678	-2.3033
	06.08	-2.1209	-2.2284	-2.3505
	06.22	-2.0731	-2.1226	-2.2912

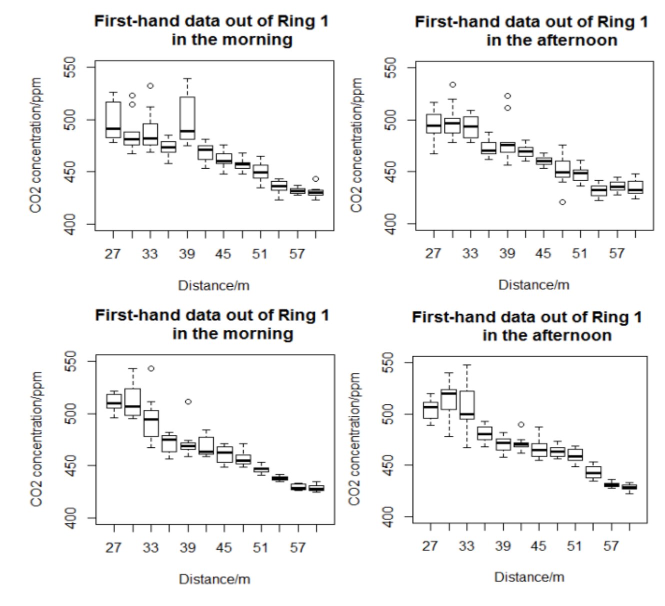

Fig. 3. CO_2 concentrations out of Ring 1 on days of low winds

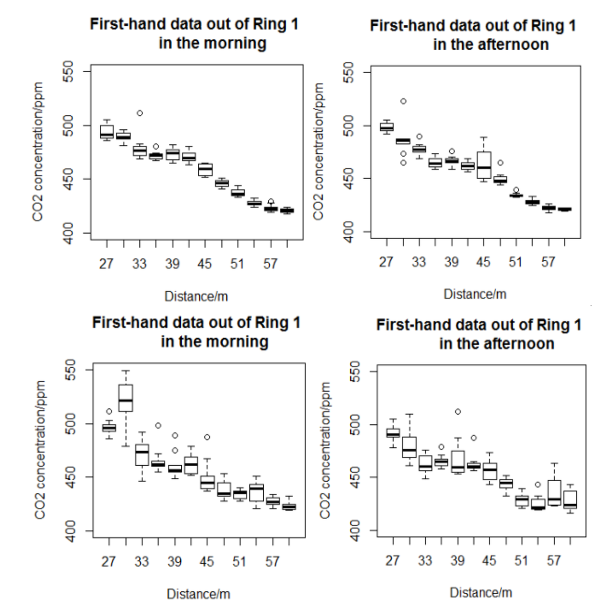

Fig. 4. CO_2 concentrations out of Ring 1 on days of high winds

Effects of tree density inside and outside of Ring 1 and 4 (first-hand data)

Table. 3. The values of "k" within Ring 1 and 4 (first-hand data)

	Date	Ring numbers	25th percentile(Q1)	50th percentile(Q2)	75th percentile(Q3)
morning data	04.19	Ring 1	-1.7194	-1.9472	-1.5417
	04.19	Ring 4	-1.6944	-1.9056	-1.4222
	06.08	Ring 1	-1.3139	-2.2306	-2.5722
	06.08	Ring 4	-1.3083	-2.1889	-2.1514
afternoon data	04.19	Ring 1	-1.8944	-2.6278	-2.1361
	04.19	Ring 4	-0.7708	-2.1361	-1.8278
	06.08	Ring 1	-1.7944	-2.6889	-3.3528
	06.08	Ring 4	-1.3417	-2.5167	-3.2417

Table. 4. The values of "k" out of Ring 1 and 4 (first-hand data)

	Date	Ring number	25th percentile(Q1)	50th percentile(Q2)	75th percentile(Q3)
morning data	04/19	Ring 1	-1.9791	-1.9394	-2.9839
	04/19	Ring 4	-1.8785	-2.0909	-2.8057
	06/08	Ring 1	-2.3287	-2.4487	-2.6454
	06/08	Ring 4	-1.1439	-1.2576	-1.4216
afternoon data	04/19	Ring 1	-1.9802	-2.1678	-2.8033
	04/19	Ring 4	-1.7229	-2.1841	-2.6177
	06/08	Ring 1	-1.8805	-1.9190	-1.8348
	06/08	Ring 4	-1.3945	-1.5455	-1.5921

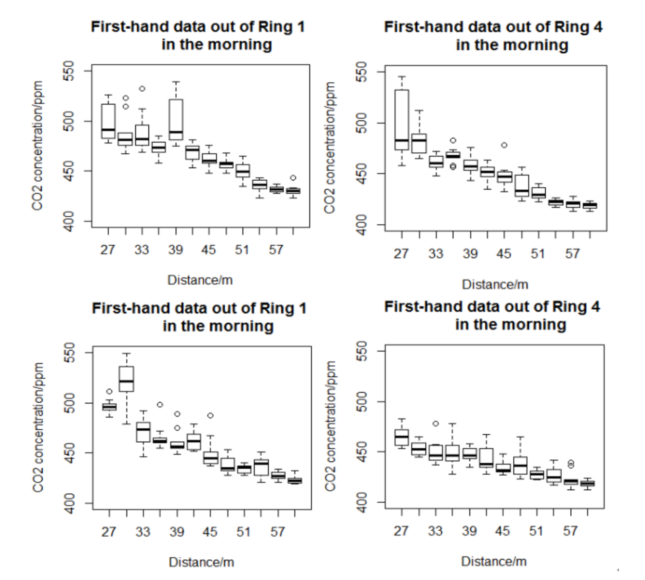

Fig. 5. CO_2 concentrations out of Ring 1 and 4 on morning of 08th June and 19th April

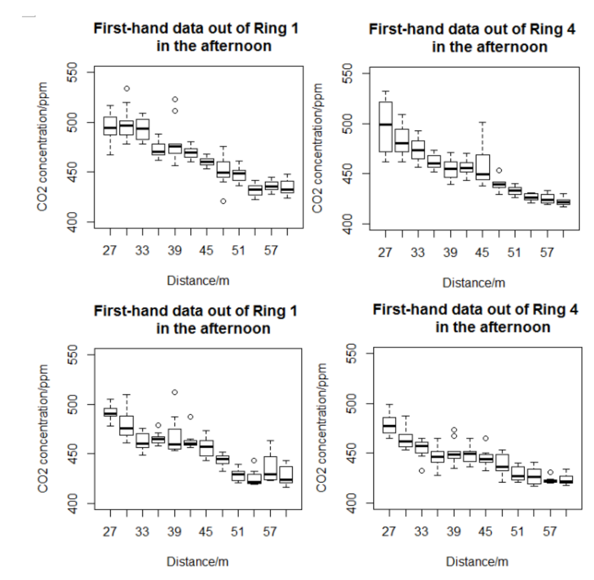

Fig. 6. CO_2 concentrations out of Ring 1 and 4 on afternoon of 08th June and 19th April

Effects of wind speed inside Ring 1 at different heights

Table. 5. The values of "k" within Ring 1 (second-hand data)

layer levels	wind speed levels	25th percentile(Q1)	50th percentile(Q2)	75th percentile(Q3)
layer of 2m	0-2 $m \cdot s^{-1}$	-0.2458	-0.8583	-0.5667
	2-4 $m \cdot s^{-1}$	-1.6958	-1.4417	-0.9792
	4-9 $m \cdot s^{-1}$	-2.0292	-1.9667	-2.2708
layer of 10m	0-2 $m \cdot s^{-1}$	-1.6250	-2.7417	-3.8708
	2-4 $m \cdot s^{-1}$	-2.4042	-3.3167	-5.0542
	4-9 $m \cdot s^{-1}$	-2.6083	-3.6833	-6.2167
layer of 25m	0-2 $m \cdot s^{-1}$	1.3167	1.3083	2.7985
	2-4 $m \cdot s^{-1}$	1.1833	1.8	2.5125
	4-9 $m \cdot s^{-1}$	0.5083	1.5	2.35

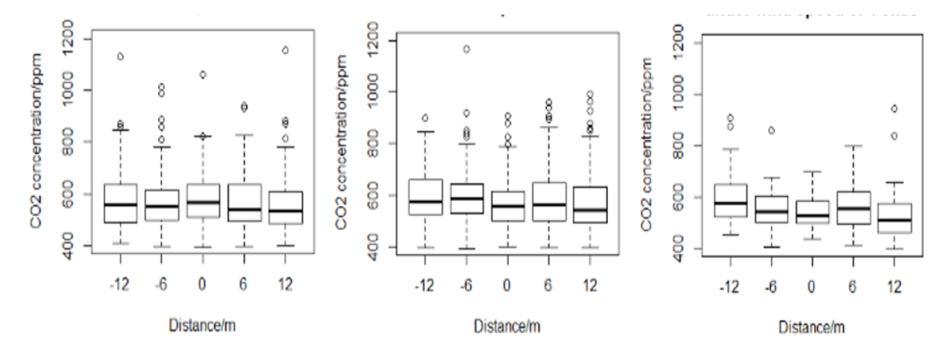

Fig. 7. CO_2 concentrations within Ring 1 at the layer of 2m under different wind levels

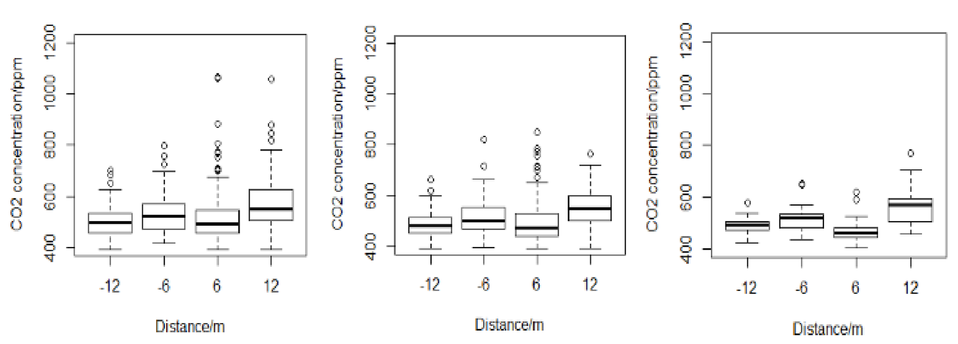

Fig. 8. CO_2 concentrations within Ring 1 at the layer of 25m under different wind levels

Effects of tree density inside Ring 1 & 4 at different heights

Table. 6. The values of "k" within Ring 1 and 4 (second-hand data)

layer levels	wind speed levels	Ring number	25th percentile(Q1)	50th percentile(Q2)	75th percentile(Q3)
layer of 2m	0-4 $m \cdot s^{-1}$	Ring 1	-0.8875	-1.2833	-0.7333
	0-4 $m \cdot s^{-1}$	Ring 4	2.0542	3.2833	4.3125
	4-9 $m \cdot s^{-1}$	Ring 1	-1.9625	-1.7333	-2.05
	4-9 $m \cdot s^{-1}$	Ring 4	3	3.3333	3.8333
layer of 10m	0-4 $m \cdot s^{-1}$	Ring 1	2.1583	-3.2833	-4.3875
	0-4 $m \cdot s^{-1}$	Ring 4	0.0875	0.3833	-0.525
	4-9 $m \cdot s^{-1}$	Ring 1	-2.6083	-3.3167	-6.0917
	4-9 $m \cdot s^{-1}$	Ring 4	-0.35	0.3667	0.4667
layer of 25m	0-4 $m \cdot s^{-1}$	Ring 1	1.2583	1.5	2.6417
	0-4 $m \cdot s^{-1}$	Ring 4	2.4	3.3333	3.9333
	4-9 $m \cdot s^{-1}$	Ring 1	0.4583	1.4	2.1167
	4-9 $m \cdot s^{-1}$	Ring 4	3.1917	3.05	3.4417

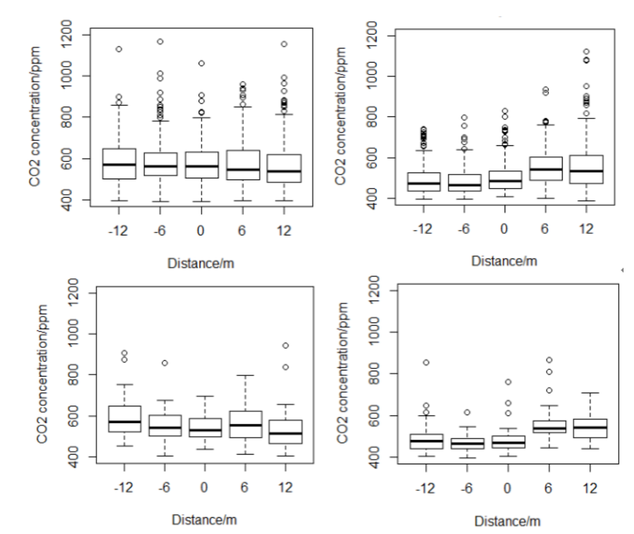

Fig. 9. CO_2 concentrations within Ring 1 and 4 at the layer of 2m under different wind levels

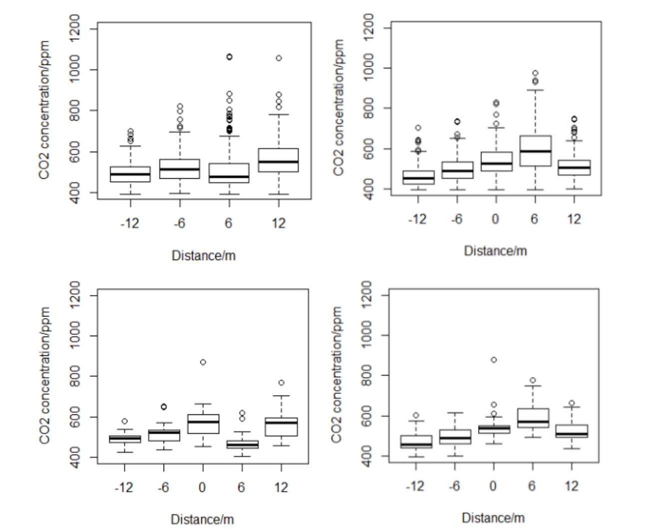

Fig. 10. CO_2 concentrations within Ring 1 and 4 at the layer of 25m under different wind levels

Conclusion

- Higher wind speed will enhance the CO_2 dispersion process
- Lower tree density will benefit the CO_2 dispersion process and such influence is not significantly affected by wind speed
- Future work is needed to compare with the dispersion in an open space

Acknowledgement

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References

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