Dear Authors,

Thank you for your revisions. I believe you have addressed most of the previous comments. However, there are a couple of points that remain unresolved, particularly the comment from R2, which you noted was somewhat unclear.

As I interpret R2's intention, they are requesting that you:

1. Expand the discussion of model assumptions and how these align (or not) with the soil texture, structure, and moisture conditions at your site.

2. Explain model-specific biases, such as why certain models may under- or overestimate diffusion. This is likely linked to point 1.

3. Contextualise model performance within your specific site conditions and address whether the observed dominance of CO_2 flux is applicable to other environments.

4. Discuss the generalisability of the observed CO_2 dominance. Can this finding be expected in other soil types, climates, or land management settings?

You don't need to provide extensive additional text, these points are interrelated and can likely be addressed with some concise but focused discussion. Still, incorporating them will strengthen the discussion and better align your manuscript with R2's expectations.

Raphael VISCARRA ROSSEL

Dear Raphael,

We would like to thank you for your patience in reviewing this work.

To answer your comments, we have thoroughly read all the original articles where each of the models used in this study was first introduced. To the best of our understanding, it is not obvious to explain why one model is overestimated or underestimated the measured flux from our soil (or any specific soil). Diffusion models were developed based on different tortuosity assumptions that are hard to measure or validate. Diffusion models, in general, can belong to two categories: (1) soil-type and SWC-independent model, typically in the form $b\varepsilon^m$ for dry porous media, or (2) SWC-dependent with the addition of the water-induced linear reduction term $(\varepsilon/\varphi)^n$ for wet porous media (with b, m, n being fitting constants and depending on tortuosity). Models of both categories were developed by fitting data from soils of different textures to solve for b, m, and n; therefore, they are highly empirical. If one model of the form $b\varepsilon^m$ is overestimated, we can only say that m is too large or tortuosity is over-emphasized. Thus, we should test a few models of the same category to find the best fit.

We replaced the previous discussion on the diffusion models L335-361 with the text below:

"Seven models, including Penman (1940), Marshall (1959), Millington (1959), Millington and Quirk (1961), Currie (1970), Lai (1976), Moldrup (2000), overestimated and two models, including Campell (1985) and Sadeghi (1989) underestimated F_{CM}. In generalization, ten models can be classified into two categories based on their assumptions: (1) soil-type/SWC-independent models including Buckingham (1904), Penman (1940), Millington (1959), Campell (1985), Marshall (1959) and Lai (1989) which depends solely on air porosity, and (2) SWC-dependent models including Millington & Quirk (1961), Currie (1970), Sadeghi (1989) which also includes a water-induced linear reduction term, equal to the ratio of air-filled porosity to total porosity (ε/φ). The first category can be generalized in the form $b\varepsilon^m$ (with ε being air-filled porosity, b and m being fitting constants). Currie (1965) has shown that an equation of the form $b\varepsilon^m$ represents well diffusion in dry porous materials, with m typically falling between 1 and 2, and b from 0.5 to 1, depending on the shape of the soil particles. The second category can be generalized in the form $b\varepsilon^m (\varepsilon/\varphi)^n$ (with b, m, n being fitting constants). The addition of the term ε/φ, according to Moldrup (2000), helps to better predict diffusion in wet soils. The reasons for the difference of fitting constants (b, m, n), for example, Penman (1940) found $b = 0.66$ and $m = 1$, Marshall (1959) $b = 1$ and $m = 1.5$, are that different tortuosity models were used to develop the diffusion model, and the developed diffusion models were validated under varying soils and soil conditions where soil properties such as the pore geometry and the length of gas passage were different. The majority of models were validated against a wide spectrum of soil texture (e.g., Moldrup 2000 tested on 21 differently textured and undisturbed soils, or Sadeghi tested on 7 soils with clay content 7-51%), fitting constants (b, m, n) were therefore concluded as soil-type independent. However, biases were frequently observed, and there is no unique solution holding true for any given specific soil type (Pingintha et al., 2010; Sánchez-Cañete et al., 2017; Yan et al., 2021). For example, in our case, dry, undisturbed soil with 12.5% clay content, matching soil type examined by Sadeghi (1989), Lai (1976), and Moldrup (2000); however, Sadeghi (1989) underestimated F_{CM}, while Lai (1976) and Moldrup (2000) overestimated F_{CM}. The Buckingham model ($b = 1$, $m = 2$), one of the models of the first category for dry porous materials, showed the best prediction. However, under higher SWC, increased tortuosity and reduced flow cross-section suggest that higher m in $b\varepsilon^m$ models—or $b\varepsilon^m (\varepsilon/\varphi)^n$ models—may yield better performance. When selecting the most suitable empirical diffusion model for estimating soil gas transport, it is recommended to prioritize $b\varepsilon^m$ models for dry soils and $b\varepsilon^m (\varepsilon/\varphi)^n$ models for wet soils. Testing multiple models in the same category but differing in formulation (b, m, n values) can help assess their sensitivity and applicability to a specific site."