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Comment on bg-2022-52

Anonymous Referee #1

Referee comment on "Roots induce hydraulic redistribution to promote nutrient uptake and nutrient cycling in nutrient-rich but dry near-surface layers" by Jing Yan and Teamrat Ghezzehei, Biogeosciences Discuss., https://doi.org/10.5194/bg-2022-52-RC1, 2022

The manuscript by Yan and Ghezzehei presents a soil-plant water transport model including a two layer-based hydraulic redistribution (HR) mechanism. The model is used to study how a prescribed rhizosphere volume around the roots mediates HR effects, with a particularly strong effect on nutrient transport and uptake. The authors also show that the enhanced water content in the rhizosphere can promote decomposition of native organic matter. The topic is interesting and suitable for Biogeosciences, but the manuscript in my view is not always clear and would benefit from a thorough proof-reading. Most important, the proposed model now contains three components—rhizodeposits, organic matter, nutrients—that are connected conceptually but not mathematically. This makes hydrology and biogeochemistry in the model too un-coupled to support the conclusion that rhizodeposits are an adaptive response of plants to face dry conditions. My main comments are explained first, followed by other suggestions.

Main comments

- Nutrients are modelled independently of organic matter mineralization.

Nutrients are essentially regarded as a passive tracer, transported through the domain and taken up by plants. With higher hydraulic conductivity in the rhizosphere, nutrients are transported more rapidly according to the model, so the result that rhizosphere improves nutrient uptake is expected. Organic carbon decomposition rate is also enhanced thanks to the higher water content in the rhizosphere, which is also an expected result. In other words, both enhanced nutrient uptake and decomposition rates are a direct consequence of the model construction. This approach is simple and easy to understand, but has two drawbacks: i) nutrients are produced by decomposition of organic matter (now the two processes are independent) and ii) nutrients can be immobilized and re-mineralized by microbes in the rhizosphere (now only passively transported). Without this dynamic links between nutrient availability, organic matter and rhizosphere environmental conditions, it is difficult to say if nutrient availability actually improves thanks to the rhizosphere environment and HR.

- Rhizodeposits are not static and are costly for the plant.

One component of the model deals with organic matter decomposition, referring to "rhizospheric C mineralization" (L171)—yet, the rhizosphere is regarded as fixed in terms of both extent and hydraulic properties (driven by rhizodeposit mass of C content). However, one could argue that the rhizosphere function needs to be 'maintained' by secreting C as the rhizosphere compounds are mineralized. In the current model there is no connection between rhizosphere and organic matter decomposition, which might be a reasonable approximation given the short time scales of the investigation (individual dry-down period). However, by neglecting the dynamics of rhizosphere properties, it is not possible to estimate the costs for the plant, and thus it is difficult to conclude that rhizodeposits are adaptive and promote plant survival or growth. Is the extra nutrient uptake worth the cost of the rhizodeposits and their maintenance in the long term? Extending the model to study these long-term effects (even in a highly idealized way) is in my view necessary to "shed light on how plants can adapt to non-ideal resource distribution" (L50) and to support the conclusion that "the investment in rhizodeposits thus seems critical…" (L379). If these extensions are not feasible, the scope of the work should be adapted to avoid speculation on long-term adaptations.

- Short time frame.

Linked to the point above, the model is used to simulate a few days during a dry period, which is not enough to balance gains and costs of rhizodeposits. I wonder if at least longer simulations could be attempted to assess the behavior of the model when the soil nears the wilting point. At that point cavitation in the xylem might affect the results (see comment below). Also, longer simulations would allow studying how the deep soil water depletion affects HR occurrence.

Other comments

General: the manuscript needs proof-reading and a thorough check of sentence structure (see some examples below)

Notation: I find the notation for the soil layers and leaves counterintuitive—the deeper layer is numbered 1, then moving up we find layer 2, and finally the leaves identified by subscript 0. This numbering makes it hard to follow the text and understand the figures

L7: "happy accident" could be re-phrased in more scientific terms

L17: not clear what "roots faced with nutrient and organic matter accumulation" means

L19: missing word "could play"

L87: typo "Therefore"

L46: nitrogen is to some degree always present—do you mean that HR increased in nutrient amended plots?

L50: explain/change term "variable resourced"

Model concept: the model separates roots in two soil layers, defining them in terms of length or area per unit soil volume, but this does not imply that the model describes two long roots (Fig. 1 caption, and in L63); in fact, long roots would imply high hydraulic conductance, which has a series of consequences. I would reformulate in the caption and redraw the figure to avoid mis-interpretation; the model deals with many roots of different lengths, whose properties are defined on a per unit soil volume

L110: what are the rhizodeposits made of? Units indicate mass, but in terms of dry/wet weight, mass of C?

L118: not clear what "excluding a rhizodeposit free control" means; no rhizodeposit could mean X_0=0

L140: symbol R_b is not defined and not listed in Table A1

Eq. 15: the soil-to-leaf conductance depends on xylem water potential (cavitation curve); that is the essence of the model by Sperry et al. (1998) cited here, but this feature is not included. Given the short duration of the simulations it should not affect the results, but with longer dry-downs it could change the speed of water depletion. Small detail: I would use brackets in the order {[(…)]}

L150: why only active uptake? Passive uptake should be relatively easy to include in this framework

L151: citation should be formatted as Author (year)

L170: this section is on nutrient mineralization potential according to the title, but describes organic matter decomposition. Nutrient mineralization is related but not quite the same thing

L181: how can this model be deemed "effective in describing the role of rhizodeposition in increasing nutrient availability" since it does not describe nutrient mineralization, nor any reaction the nutrient might undergo?

L188: extra "s"?

L191: why faster water flow? If I understand correctly, water flow is driven by a water potential difference, not water content

L201: the label in Fig. 5 indicates average water potential, not water potential in zone 2

L216: is the nutrient uptake effect noticeable because of no-flow boundary conditions? Nutrients are not produced in this model, just transported and taken up by the plants

L245-246: multiple typos: space missing, “promotes”, “pronounced”

Fig. 9 caption: the model describes only active nutrient uptake, but the caption mentions passive uptake

L284: missing verb

L285: not clear link to previous sentence despite “Therefore”

L287: higher variability compared to what?

L292: longer simulations needed (see comment above)

L297: explain/change term “initialize”

L298: but if plants are so effective at promoting mineralization of native organic matter, its content will decrease through time, until it will not be able to provide nutrients; an equilibrium will be attained so the relative advantage might be temporary

L312: enhanced mineralization with respect to what control/reference state?

L326: define “good”

L332: previously it was argued that microbial activity was stimulated, not slowed down

L338: why only “often” and not always? are you referring to fertilized systems?

Table A1: check units of A, now a volume, but labelled as specific surface area