This review addresses the importance of the root zone in hydrology and discusses the root zone concept in relation to related hydrological concepts, such as soil, rhizosphere, rooting depth, critical zone, etc. The authors argue for adopting a holistic perspective of the root zone, but this argument appears to be based on a flawed application of the concepts of reductionism and holism. Much of this review reads like an extended chapter in a hydrology textbook and lacks the new perspective that one would expect from a review article. The only exception to that is section 5 with the discussion of inverse modeling towards the end of the review, which does provide a distinct perspective for avenues of future research. This manuscript could be greatly improved by focusing on that perspective and reducing the first four sections to a fraction of their current length, based on the justified assumption that readers will already be familiar with much of what is being presented in those sections.

We thank H. Jochen Schenk's community comments, and constructive suggestions. We will sharpen the first four sections especially Section 3.3, and extend section 5 about root zone estimation approaches. For the "flawed application of the concepts of reductionism and holism", please find our replies to your last question. With regard to readers being familiar with the definition of root zone storage, we disagree. In our experience there is a lot of both, conceptual and semantic, misunderstanding about root zone storage and a wide spectrum of definitions that are functionally not equivalent nor comparable are used in different disciplines. With this paper we hope to clarify at least some of these misunderstandings. Furthermore, our review has a didactic intent, aiming to contribute to the understanding of these fundamental concepts and their specific differences. While we acknowledge that these concepts may be suitable for inclusion in hydrology textbooks, to our knowledge, they have not been systematically and exhaustively covered in existing literature.

The authors contrast their view of the root zone with a variety of related concepts and largely focus on what the root zone is not (with extended use of the unequal sign ≠ in headings), which is not that helpful to the reader and sometimes confusing. For example, what is the difference between the root zone and the soil? Illustrations like Fig. 1 are often used to define the concept of soil, which is what the central circle normally represents. The authors label that circle as the root zone, but nothing in that image implies that there must be plants or roots present in that circle. It could be just microbes.

We partly agree and partly disagree with this comment. We will, in the revised version, provide upfront a much clearer explicit definition what the root zone from a water-centric is and which functions it has to and does fulfil in the terrestrial water cycle. For many applications at regional or larger scales (e.g. river basin or continental) the functionality of the root zone for water and energy fluxes may be characterized by subtly different processes than at smaller scales or from the perspective of different disciplines. At these larger scales the critical aspect of the root zone is that it provides vegetation as a whole over the entire spatial domain of interest with access to sufficient subsurface pore *volume* between field capacity and permanent wilting point to provide vegetation access to sufficient *volumes* of water. This *volume* is not necessarily related to root-depths, root-distributions, root traits or functional differences in different parts of a plant's root system. Nor does it make any assumptions on inter- or intra plant exchange fluxes, such as hydraulic redistribution by roots, mycorrhizae or other organisms. Our approach of contrasting the root zone with various related concepts serves to highlight its distinctiveness among similar terms used across different disciplines. We want to maintain the use of "≠" or "is not the same as" in the text, which is a clear demonstration of our opinion, and emphasizes the root zone as a unique entity, a viewpoint

acknowledged as “commendable” by Anonymous Referee #1. We will reshape that part of the manuscript to avoid it being “confusing” but rather clarifying.

Regarding the reference to Figure 1, we assume the reviewer meant Figure 2, since Figure 1 has no circle. But then it is still hard to understand what is meant when he states that “nothing implies that there are plants or roots in that circle”. The presence of plants or roots is implied through the intersection with the biosphere, which encompasses roots, plants, animals, microbes, fungi and other organisms.
While Fig. 2 is typically used to define the concept of soil, we argue that it is more appropriate to use the term “root zone” in this context. For example, activities such as deforestation (logging without destroying the soil, pertaining to the Anthroposphere), can significantly alter the root zone, including the biosphere and hydrosphere, even if the soil itself is not changed. Similarly, phenomena such as climate change (atmosphere) can impact the root zone (Liang et al., 2024), even though the soil itself is not changed. More details about the difference between the root zone and soil can be found in Section 3.2. In our framework, microbes and fungi in the root zone are part and parcel of the biosphere. Hence, we contend that “root zone” is the more suitable term for Fig.2.
Reference:
Liang, J., Gao, H., Fenicia, F., Xi, Q., Wang, Y., and Savenije, H. H. G.: Widespread increase of root zone storage capacity in the United States, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2024-550, 2024.

The choice of calling the root zone a “zone” also invites confusion. A zone is an area or volume existing at a particular time. A point in space and time is either within the zone or it is not, because a zone is a discrete concept. The root zone in this manuscript is mostly discussed as having a size, but at one point (line 574), the authors assert the zone consists of a gradient, which implies a continuous distribution that does not have a definable size. They criticize researchers for attempting to determine rooting depth (lines 590-591), but in the next sentence argue for determining the root zone’s size (line 591). Surely, depth is one dimension of size. Some of this discussion about what the root zone is and how it compares to related concepts simply boils down to semantics and is not that helpful to the reader.
While we understand the semantic nuances involved in defining terms like “zone”, we believe it is crucial to clarify and delineate the characteristics of the root zone for a comprehensive understanding. The debate over whether a "zone" refers to a spatial area or depth is not merely a matter of semantics but rather pertains to the conceptualization of a dynamic and complex entity. As such, we completely agree with the reviewer that a “zone” is a “[…] volume existing at a particular time” as it thus implicitly highlights the dynamic nature of the root-zone, in which vegetation, i.e. the ensemble of all individual plants within the spatial domain of interest, continuously adapts to ever changing climatic conditions so as to provide access to sufficiently large subsurface *volumes* of water. This can involve many different adaptations, including but not limited to: (1) adjustment of root depth/density/lateral extent of individual plants, (2) replacement of individual plants by other, better adapted plants with different root systems and water use/management strategies, and (3) natural or human induced changes in density of vegetation cover. For us it is important to clarify that the root-zone cannot be understood as a stationary, static concept but that it is constantly evolving.

Similar as the widely used “critical zone” concept, the definition of the critical zone is also controversial, in particular its lower boundary. As we mentioned in Section 3.2.3, “the root zone is the most active layer in the critical zone”, and “it is the crucial element of the critical zone”. The root zone has a size (which can be expressed as a “volume”, or when expresses per unit area a “depth”), and it is dynamic as well, so it has a temporal gradient. The root zone is very physical. It forms a buffer of moisture for root water uptake during droughts, and determines the partitioning of rainfall into runoff and evaporation. We are not the first to use the term “root zone”, as Anonymous Referee #2 mentioned. See a few references below.

Scholes, R. J., and B. H. Walker, An African Savanna, Cambridge Univ. Press, New York, 1993.
Laio, F. (2006), A vertically extended stochastic model of soil moisture in the root zone, Water Resour. Res., 42, W02406, doi:10.1029/2005WR004502.
Rodriguez-Iturbe, I., P. D’Odorico, F. Laio, L. Ridolfi, and S. Tamea (2007), Challenges in humid land ecohydrology: Interactions of water table and unsaturated zone with climate, soil, and vegetation, Water Resour. Res., 43, W09301, doi:10.1029/2007WR006073.

Also, none of this discussion about the nature of the root zone is new. The authors’ view of the root zone appears to be quite similar to that of a plant’s belowground zone of influence discussed by Casper et al. (2003), which the authors do not cite, or the much older concept of phytogenic fields in Russian ecology (Uranov 1965 and many others), also not mentioned in this review. If it was the aim of this review to introduce a new concept then it would be useful for the reader to learn how this differs from previous discussions, based on a thorough review of the literature.

We completely agree with that and we acknowledge the reviewer's observation that our discussion about the nature of the root zone is not novel *per se*. Our intention was not to present entirely new concepts but rather to clarify the role of the root zone in hydrological processes, which are at the core of the Earth System and which can often be misconstrued or misrepresented.
In the literature and in practice there are many different interpretations both, within the discipline of hydrology with its sub-fields and among different disciplines. For instance, the distinction between root zone moisture storage (expressed as a volume of moisture per unit area) and root depth is frequently confused. While we do not claim originality in defining the root zone, we aim to contribute to a clearer understanding of this crucial hydrological component.
Thank you for sharing these two papers. We will incorporate them into our review for a more comprehensive analysis.

The problems with semantics extend to the contrast that the authors make between a reductionist and a holistic approach to root zone modeling. A reductionist approach implies that a complex system can be explained mechanistically by the behavior of all of its parts, while a holistic approach assumes that the combination of parts of a complex system leads to emergent properties that cannot be explained as the sum of the parts’ behavior. The authors criticize what they call the reductionist approach, but not for neglecting complex interactions but for making erroneous or over-simplified assumptions (section 5.2). That is not an argument against reductionism, just an argument against bad reductionism. They argue for measuring and modeling properties of entire ecosystems through

inverse modeling, which is an empirical rather than mechanistic approach. Thus, the argument is against using a bad mechanistic approach and in favor of using a good empirical ones. This is not a contrast between reductionism and holism.

The reviewer is right in his definition of holistic versus reductionist. We shall make sure that in the revised paper this distinction is well worded. Our proposed top-down approach is indeed holistic, as it assesses system performance as a whole. This is in contrast to the reductionist approach, that breaks down system performance into individual components.

It is worth noting that empirical studies constitute the foundation of scientific inquiry across both reductionist and holistic paradigms. However, the reductionist approach often struggles with closure, particularly in defining boundaries within complex natural systems. Conversely, a holistic perspective benefits from more clearly defined boundaries, thus favoring an empirical approach. By focusing on empirical observation at the system scale, we aim to contribute to a more comprehensive understanding of the root zone and its interactions within the broader ecosystem.

It is always challenging for any review to offer a proper balance between simply reviewing and providing a new perspective. This manuscript offers very little perspective for a lot of reviewing and the perspective that is offered is largely based on a strawman argument. That said, the topic is important and worth addressing, and I hope that the reviewers' comments will help to improve this manuscript.

We thank Dr. Schenk's for his critical review and his endorsement that "the topic is important and worth addressing". In the revised version we shall certainly make use of his suggestions to further sharpen our argument and make use of the literature suggestions.

Literature Cited

Casper, B. B., H. J. Schenk, and R. B. Jackson. 2003. Defining a plant's belowground zone of influence. Ecology 84:2313-2321.

Uranov, A. A. 1965. Fitogennoe pole. (The phytogenic field. In Russian). Pages 251-254 in E. M. Lavrenko, editor. Problemy Sovremennoj Botaniki. Nauka, Moscow, Russia.