Responses to the comments from Reviewer

This manuscript investigates the effects of maize straw biochar and wheat straw biochar on soil aggregate stability by linking active organic carbon fractions, soil surface electrochemical properties, soil internal forces, and aggregate breakdown behavior. The study provides valuable insights into the mechanisms underlying biochar-induced soil structural improvement. The combination of organic carbon fraction analysis and quantitative evaluation of soil internal forces represents a meaningful contribution to the field of soil physics and soil amendment research. However, several issues regarding methodological clarification, mechanistic interpretation, and presentation should be addressed to further improve the manuscript. Therefore, I recommend **minor revision** before publication.

1. The calculation of internal soil forces is a key innovation of this study. Specific details regarding this theoretical calculation should be provided.

Response: Thank you for this valuable comment. We have added detailed calculation procedures for soil particle interaction forces.

2. The authors used Na^+-saturated soil samples to quantify aggregate stability and internal forces. Please discuss how this treatment may differ from natural soil conditions and how it affects the interpretation of the results.

Response: Thank you for this valuable comment. We agree that Na^+ saturation represents a simplified experimental condition that differs from the complex ionic environment of natural soils. In natural soils, exchangeable cations such as Ca^{2+}, Mg^{2+}, K^+, and Na^+ coexist, and their combined effects on ionic strength, electrical double-layer characteristics, and particle interactions may influence soil aggregate stability.

In this study, Na^+ saturation was employed to minimize the interference caused by heterogeneous exchangeable cations and to provide a relatively controlled system for quantitatively evaluating the intrinsic relationship between soil internal forces

(SIFs) and aggregate stability. Previous studies have shown that the polarization of Na^+ at the soil-colloid interface is very weak; therefore, it can be used to evaluate the effect of soil internal forces on aggregate stability. Therefore, the results obtained under this condition mainly reflect the mechanisms by which biochar-induced changes in soil surface properties regulate interparticle forces and aggregate stability, rather than directly representing all processes occurring under field conditions.

We have revised the Discussion and Conclusions sections to explicitly acknowledge this limitation. We further clarified that the quantitative estimation of SIFs under Na^+-saturated conditions provides mechanistic insights into biochar-induced structural changes, but the magnitude of these effects may vary under natural soil environments with diverse electrolyte compositions. Future studies involving mixed electrolyte systems, different soil types, and long-term field validation are needed to evaluate the broader applicability of this mechanism.

Please refer to lines 529–540, 551–555.

3. This paper emphasizes that biochar enhances agglomerate stability by strengthening van der Waals forces and weakening electrostatic repulsions. However, the role of hydration repulsions appears to be rarely mentioned. Please explain why hydration repulsions are neglected.

Response: Thank you for this valuable comment. In fact, hydration repulsion was incorporated into our quantitative estimation of soil internal forces. However, our discussion mainly focused on van der Waals attraction and electrostatic repulsion because these two forces exhibited the most pronounced changes in response to biochar addition. Biochar increased soil specific surface area, surface charge number, and the Hamaker constant, thereby enhancing van der Waals attractive pressure and modifying electrostatic interactions between soil particles. In contrast, hydration repulsion is primarily governed by interparticle distance and is only weakly affected by biochar-induced changes in surface properties (Figure 6). Therefore, hydration repulsion was incorporated into the calculation of soil internal forces rather than neglected.

4. Since soil electrolyte concentration varies substantially under different irrigation, salinity, and climate conditions, the authors should clarify how the laboratory electrolyte gradient relates to realistic soil environments.

Response: Thank you for this valuable comment. We appreciate the reviewer's valuable comment regarding the relationship between the laboratory electrolyte gradient and realistic soil environments. We agree that electrolyte concentrations in natural soils can vary substantially depending on irrigation practices, salinity conditions, climatic factors, and soil properties. Therefore, the electrolyte concentrations used in this study should not be interpreted as direct representations of all field soil solution conditions.

The primary objective of establishing a broad electrolyte concentration gradient was to provide a controlled experimental framework for quantifying the response of soil particle interactions under different ionic environments. By systematically modifying electrolyte concentration, we aimed to regulate the surface electrochemical conditions of soil particles and evaluate how changes in interparticle forces, including electrostatic repulsion, hydration repulsion, and van der Waals attraction, contribute to aggregate stability. In this context, the selected concentration range was designed mainly for mechanistic exploration rather than direct simulation of a specific field scenario. Some concentrations used in the laboratory experiments may exceed those commonly encountered in natural soils. Nevertheless, these controlled gradients allow the identification of critical changes in particle interaction forces and provide quantitative insights into the mechanisms controlling soil aggregate stability.

5. Natural soils typically contain a variety of exchangeable cations and a complex electrolyte composition. The limitations of the experimental design in this study should be discussed in greater detail, and future research directions involving mixed electrolyte systems or field validation should be proposed.

Response: Thank you for your suggestion. See Comment 2 for the relevant response.