RC2: 'Comment on egusphere-2024-2047', Anonymous Referee #2, 04 Oct 2024 reply

This manuscript investigates the effect of terracing on soil organic carbon (SOC) dynamics in the Loess Plateau region, with a focus on the impacts of different vegetation types (wheat, apple, grassland, trees, etc.). Given the global significance of agricultural terraces and the urgent need to develop management practices that can sequester atmospheric carbon as SOC, this topic is valuable and interesting. However, I have identified several issues that prevent me from giving a positive evaluation of this manuscript.

Response：We appreciate the valuable comments provided by the reviewers. We have taken your key points into serious consideration and made targeted revisions and improvements. We have included data on soil bulk density and soil pH, among other physicochemical properties, to further discuss the mechanisms by which terracing and vegetation types affect SOC dynamics. We added high-resolution data on soil organic carbon distribution and slope to further explore the impact of topography on soil organic carbon distribution. We have revised the abstract format according to the requirements of the journal Biogeosciences (BG). Additionally, we have thoroughly checked and corrected grammatical errors and issues related to language logic throughout the paper.

Major concerns:

The manuscript discussed the mechanisms through which terracing and vegetation types impact SOC dynamics, identified various potential factors such as water content, soil fertility, erosion reduction, roots, biomass, and crops (see sections 4.2 and 4.3). However, none of these factors were measured in this study—only SOC content was assessed for all samples (as seen in all figures and tables, which only present SOC content data). This approach significantly reduces the value of the paper and introduces considerable uncertainty in the discussions and conclusions. Could the authors include additional data in their current analysis, such as nutrients, root biomass, slope gradients, and bulk density, to better support their interpretations?

Without such data, the value of current manuscript is difficult to discern.

Response： We have carefully considered your suggestions and made additions and improvements to the relevant sections of the paper. Below are our specific responses:

You mentioned that we discussed various potential factors affecting the dynamics of soil organic carbon (SOC) but did not actually measure these factors. This is indeed a shortcoming on our part that may introduce some uncertainty. To address this, we have added data on soil bulk density and pH value, integrating this information into sections 4.2 and 4.3 to better support our arguments.

We also recognize that relying solely on SOC content data may not fully explain the mechanisms behind SOC dynamics. In sections 4.2 and 4.3, we will provide additional analysis on how soil bulk density and pH value impact SOC, strengthening our discussion.

Furthermore, we will candidly address the limitations in our data collection and measurement metrics within the research limitations section, and we commit to improving our data collection methods in future studies to enhance the reliability of our analysis.

The specific modification details are as follows:

4.2 Effect of terraces abandonment on SOC

As in other parts of the world, industrialization and urbanization have led to a large population flock from rural to urban areas as in China, resulting in the abandonment of a large number of productive potential farmlands (Wiesmeier et al., 2012; Cai et al., 2016). Furthermore, climate change induced extreme weather events such as drought and heavy rainfall can also accelerate soil erosion and loss of soil organic carbon in the abandoned terraces (Lal, 2004). We measured the physicochemical properties of the soil in terraced fields with different usage statuses (Table 2). The results show that the soil bulk density in abandoned terraces is significantly higher compared to the actively used ones. This increased bulk density may lead to reduced soil aeration, thereby inhibiting the decomposition of organic matter. Furthermore, the soil pH in abandoned terraces has also decreased, which may affect the stability of organic matter. However, climate change can also impact the vegetation succession on abandoned terraces, which in turn affects the soil organic carbon dynamics (Davidson & Janssens, 2006). When the terraced fields were abandoned in this research, the SOC content of the abandoned terraces was lower than that of the terraces in use. This is caused by the limited abandoned time. Abandoned terraces may have accumulated a significant amount of organic matter during their previous use. However, due to a lack of fertilization now, this organic matter is gradually being mineralized and decomposed, which reduces the soil organic carbon (SOC) content (Lal, 2004; Wiesmeier et al., 2019). In contrast, terraces that are still in use maintain higher SOC levels thanks to continual fertilization (Nardi et al., 2004). Additionally, the abandoned terraces are more susceptible to climate change induced soil disturbance and erosion, leading to the loss of nutrient-rich topsoil, which further decreases SOC levels (Zhao et al., 2013). Our data also shows that the surface soil organic carbon (SOC) content in abandoned terraced fields (0-15 cm) is significantly lower than that in actively used terraced fields, which may be related to higher soil bulk density, lower pH, and surface soil erosion (Table 2). To produce significant environmental benefits, the land must remain abandoned for an extended period to accumulate substantial amounts of both plant biomass and the species that constitute intact ecological communities. This process can take decades to reach levels of carbon sequestration or biodiversity comparable to those of undisturbed ecosystems (Crawford et al., 2022; Poorter et al., 2016). Due to the limited water resources available in semi-arid areas, a longer natural or assisted recovery time is required. Therefore, the duration of land abandonment is a crucial factor influencing the dynamic changes SOC (Djuma et al., 2020; Badalamenti et al., 2019). In related studies in other regions, soil carbon stocks increased by 13% and 16% in cropland abandoned for 15 and 35 years, respectively (Novara et al., 2014). With the abandonment of disposal time extended, vegetation types gradually transition to grassland, scrub, and forest and the death of plants and animals return to the soil as organic matter, increasing the number of soil aggregates and further increasing the carbon content of the soil (Liu et al., 2020). Therefore, ecological restoration of newly abandoned terraces should be carried out as soon as possible. After short-term abandonment, the terraced fields showed a special change pattern at different depths in this study. SOC content first decreased and then increased with increasing soil depth. The decrease in surface SOC was controlled by the decrease in agricultural fertilizer inputs, while the increase in deep SOC was caused by the inability to utilize deep soil nutrients due to the death of crop roots.

Table 2 Soil Properties Data of Different Types of Sampling Points

Land types	Planting method	Vegetation types	0-5cm		5-15cm		15-30cm		30-60cm		60-100cm	
			Bulk density	pH value	Bulk density	pH value	Bulk density	pH value	Bulk density	pH value	Bulk density	pH value
Terrace	Single vegetation	Wheat	1.26	8.07	1.27	8.06	1.31	8.13	1.34	8.20	1.36	8.19
		Apple trees	1.26	8.11	1.27	8.11	1.31	8.15	1.34	8.21	1.36	8.21
		Potatoes	1.26	8.14	1.29	8.13	1.32	8.17	1.33	8.23	1.35	8.23
		Legumes	1.26	8.10	1.28	8.09	1.31	8.15	1.33	8.22	1.36	8.21
		Maize	1.25	8.08	1.28	8.08	1.32	8.14	1.35	8.21	1.37	8.20
		Robinia pseudoacacia L.	1.26	8.09	1.27	8.08	1.31	8.13	1.33	8.23	1.37	8.19
		Pinus tabuliformis Carr.	1.26	8.11	1.28	8.11	1.33	8.15	1.36	8.20	1.37	8.20
		Medicago sativa L.	1.26	8.12	1.28	8.11	1.33	8.16	1.36	8.21	1.37	8.22
		Vegetable	1.26	8.13	1.28	8.12	1.31	8.16	1.33	8.21	1.36	8.21
	Multiple vegetation	Apple tree-legumes	1.25	8.08	1.28	8.08	1.33	8.14	1.34	8.22	1.37	8.19
		Apple tree-potatoes	1.24	8.10	1.28	8.10	1.34	8.15	1.36	8.22	1.37	8.21
Sloping land	Single vegetation	Wheat	1.26	8.08	1.28	8.08	1.32	8.14	1.35	8.21	1.36	8.20
		Grassland	1.23	8.06	1.27	8.06	1.31	8.12	1.34	8.17	1.37	8.18
Abandoned terraces	Multiple vegetation	Apple trees and weeds	1.24	8.10	1.27	8.09	1.31	8.15	1.34	8.21	1.37	8.20

4.3 Effect of vegetation type and planting patterns on SOC in terraces

Vegetation types can influence SOC by modifying the soil's physicochemical structure and altering both the input and decomposition rates of SOC (Du et al., 2022; Wiesmeier et al., 2012; Wan et al., 2019). Our data shows that there are significant differences in soil pH values under different vegetation types (Table 2). For instance, forested areas have higher pH values, while grasslands have lower pH values. This could be an important factor contributing to the differences in SOC content among various vegetation types, as pH levels influence the decomposition and stability of organic matter. Our study demonstrated that, compared to terraced fields, the SOC content of afforested land at a 0-100 cm depth was higher and that the forest litter biomass was more than that of farmland, which was the main reason for this difference. Planted forest land reduces soil temperature, soil moisture evaporation, and soil erosion while increasing the quantity and quality of organic matter input to compensate for carbon decomposition from crop cultivation (Liu et al., 2020). The soil bulk density in forested areas is significantly lower than that in agricultural land, which is beneficial for the decomposition and accumulation of organic matter (Table 2). The afforested land is terraced forests, and the effect of preventing soil erosion is more significant. Some study shows that the SOC in immature forests (10 years old) is 17.91% higher than that in terraced cropland. The SOC concentration of a 30-year-old forest is significantly higher than that in other land covers (Xin et al., 2016). These studies further proved the carbon sequestration effect of reforestation.

Due to the problem of ecological degradation and soil erosion, various ecological measures have been taken in the Loess Plateau area, such as returning farmland to forest and grass and planting trees (Hong et al., 2020). Considering the climate and soil quality factors, the main species selected in the Loess Plateau region are drought-tolerant types of trees, and the carbon accumulation effect of different species selection also differs significantly (Li et al., 2018). *P. tabuliformis* has a higher SOC content than *R. pseudoacacia*, especially in the 0-50 cm soil layer. The pine species selected in this region is larch, with the arrival of winter a large number of pine needles and fruits are into the soil, increasing the input of organic matter in the surface layer so that the SOC content of pine forests is higher in the surface layer of the soil (0-10 cm). In humid areas, some studies also show that the soil organic carbon density of fir conifer forests is the largest among the different 11 middle forest vegetation types (Chen et al., 2007). Other studies have shown that tree species such as *P. koraiensis*, *L. gmelinii,* and *P. tabuliformis* increase soil organic carbon stocks more as silvicultural species (Hong et al., 2020). The biomass of the herbaceous plants themselves is much lower than that of trees, and the limited amount of organic matter entering the soil, and the fact that *M. sativa* is mainly used as a source of fodder for the animals raised by farmers in the region, leads to a lower SOC content in terraces planted with *M. sativa* than in those undergoing afforestation.

The SOC content of grassland at a depth of 0-100cm is lower than that of farmland. Although the grassland has organic matter after the withered herbs enter the soil, the main planting type in the terrace area is apple trees, and a large amount of fruit tree leaves will also enter the soil. The lower pH value of the soil in grasslands may be a significant reason for its lower SOC content (Table 2). Grassland is a sloping land that has not been terraced, leading to slope erosion that removes a significant amount of organic matter from the soil surface. As a result, the SOC content in grassland is lower than in terraced fields (Fig.2). The ecological advantages of sequestering SOC and enhancing soil fertility could be significant, largely thanks to the widespread implementation of reforestation and various land use strategies in terraced fields across China and numerous other mountainous areas globally (Hong et al., 2020).

Crops may differ in their ability to increase SOC content due to differences in their photosynthetic capacity and root characteristics (Wegener et al., 2015). The pattern of intercropping in this area is typical of Agroforestry systems (AFS), where other crops are planted between the rows of apple trees. The SOC content of apple trees in combination with other crops was higher than in monocultures, especially in the lower and middle layers of the soil (30-100 cm). The amount of tree litter and root decomposition are important reasons for this (Pardon et al., 2017). The fallen leaves of fruit trees and some rotting apples are not removed, and these organic materials decompose to replenish SOC after entering the soil. In addition, carbon input can be achieved by decomposing (fine) tree roots and root secretions (Nair et al., 2009). For soils below 30 cm depth, tree roots produce an important role in the accumulation of soil organic carbon. When potato or legume crops are harvested, all the fruit and plant roots are removed and these lands will be tilled to grow other crops, so the input of organic matter is very limited. Agroforestry systems increase the distribution of roots in the soil and increase the recalcitrant compounds which slow the rate of mineralization through the input of organic matter (Recous et al., 2008).

Your Discussion has focused on the effects of terrace abandonment on SOC content (section 4.2), but within your analysis, only 5 out of 77 sites are abandoned terraces (only considered apple tree), this is unfortunately not ideal.

Response: We are indeed aware of the limitations posed by having only five abandoned terraced field sample sites. Due to constraints in time and funding for field research, we are unable to include more abandoned terraced field sample sites in this study.

We have supplemented our research with high-resolution remote sensing imagery data to compensate for the insufficient number of field samples. However, we honestly acknowledge that this alternative method may not fully replace the data obtained from field sampling, which could affect the representativeness and reliability of the results.

We will clearly state in the limitations section of the study that the inadequate sample size may impact the assessment of the effects of abandoned terraced fields on soil organic carbon. We will strive to increase the number of abandoned terraced field samples in future research to analyze the impact of terraced field abandonment on soil organic carbon more comprehensively.

4.4 Study limitations

The results of the study are based on field data collected over a relatively short period of time. Due to the complexity of field conditions, the number of soil profiles in some of the comparative studies in the sampling frame design was not entirely consistent. Factors such as root biomass, fertilizer management, and tillage practices also affect soil organic carbon in terraced areas. To compensate for the limited field sampling, we incorporated high-resolution remote sensing data into the analysis. However, this alternative method may not fully replace the data obtained from comprehensive field measurements, which could affect the representativeness and reliability of the results. Going forward, future research should strive to increase the number of abandoned terraced field samples and collect a wider range of soil physical, chemical and biological indicators. This would enable a more comprehensive assessment of the impacts of terraced field abandonment on soil organic carbon and its underlying driving factors. We need to do more work to understand the SOC characteristics of terraced agricultural areas and how to better utilize the terraces for carbon storage and realize the economic and ecological value of terraces.

You sampled 77 terraced sites but only 7 slopes as the non-terraced control. 7 slopes are under wheat and grassland, which is also not comparable as the terraced slopes. But I totally understand that in this region it’s very difficult/maybe impossible to find non-terraces slopes. One solution might be trying to find reference samples from the global products with high resolution if it’s possible. Or author could consider revise this paper by only focusing on the effect of difference vegetation types in terraces systems?

Response： Thank you very much for your valuable suggestions. In response to your concern regarding the insufficient number of control sites for non-terraced land, we conducted a thorough analysis and made improvements. We utilized high-resolution soil organic carbon distribution data to conduct a more comprehensive analysis of soil organic carbon (SOC) distribution within the study area. The specific revisions are as follows:

4.1 Effect of terrace construction on SOC

In the Loess Plateau area, the average SOC content of terraces 0-100cm is 1.4 times higher than that of sloping farmland (Table 1). Figure 5 clearly shows that the SOC content decreases with increasing depth. In Zhang et al. (2013), the SOC stock at 0-100 cm depth was 4.97 kg·m^{-2} in terraces and 3.09 kg·m^{-2} in sloping fields, which is

1.6 times higher than the soil organic carbon stock in sloping fields, which is consistent with the results of this study. Terracing is considered an important practice to prevent water erosion and minimize the loss of SOC (Nie et al., 2017). We can observe that areas with steeper slopes generally have lower soil organic carbon (SOC) content, while areas with gentler slopes tend to have higher SOC content (Fig. 6). This phenomenon can be explained by the fact that horizontal terraces alter the surface morphology, prolonging the surface water retention time during rainfall, which increases soil moisture in the rain-fed agricultural regions of the Loess Plateau (Xu et al., 2021). There is a positive feedback relationship between soil moisture and soil carbon (Green et al., 2019). Figure 5 shows that the soil organic carbon (SOC) content in the surface layer is significantly higher than that in the deeper layers. This may be due to the interception of precipitation by the terraced fields, which provides water for plant growth, increases plant biomass, and subsequently enhances the organic matter input into the soil. Additionally, the interception of rainfall by the terraces means that less soil fine particles are washed away, leading to an increase in the clay content of the soil. Soil clay particles have a larger specific surface area, allowing them to adsorb more soil organic carbon and enhancing the accumulation of organic carbon (Post et al., 1982). Compared to sloping land, terraces have a higher content of both clay and silt in the soil. The terraces therefore further contribute to carbon accumulation in the terraces by protecting the fine particles in the soil. In a study on the Loess Plateau, the SOC content of 0-100 cm in unterraced date palm orchards was 2.6 $g \cdot kg^{-1}$, which was lower than the soc content of terraced orchards. This evidence further demonstrates the positive effect of terracing on soil organic carbon sequestration (Gao et al., 2017).

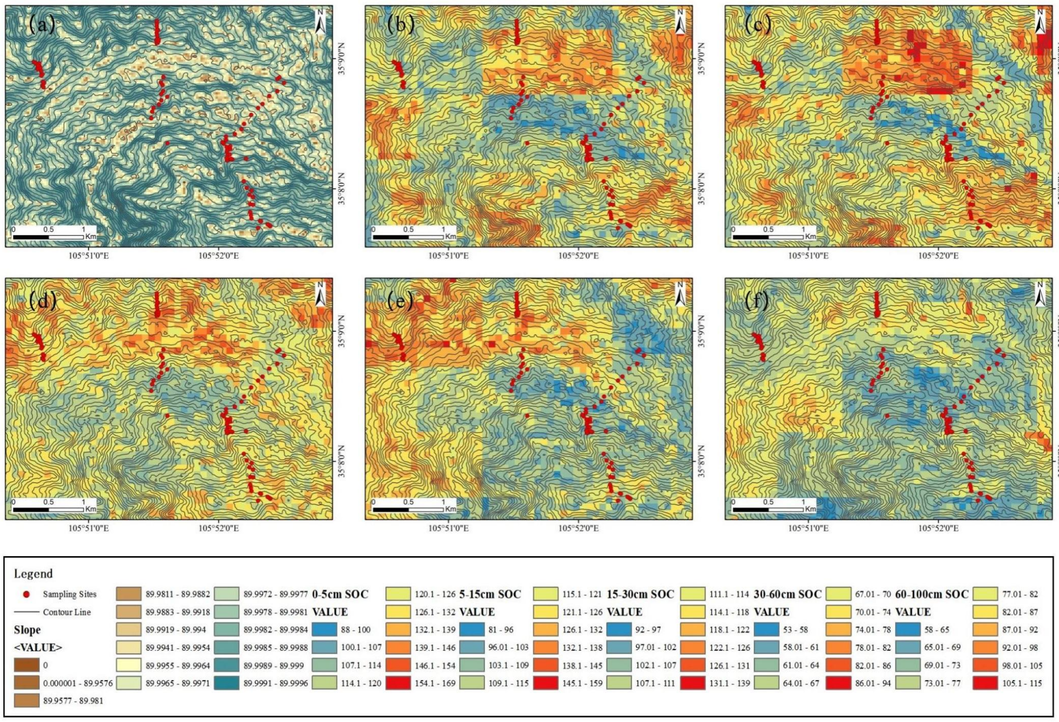

Fig.5 Distribution of slope and soil organic carbon (SOC).

(a): Slope; (b): Distribution of SOC at 0-5 cm; (c): Distribution of SOC at 5-15 cm; (d): Distribution of SOC at 15-30 cm; (e): Distribution of SOC at 30-60 cm; (f): Distribution of SOC at 60-100 cm.

More minor comments:

Abstract: I'm not sure if the format of abstract meets the requirement of BG journal. Please check

Response： Thank you for your valuable feedback. I have carefully reviewed the abstract format and made adjustments based on the requirements of the Biogeosciences (BG) journal. Here is the revised abstract:

Abstract: Terracing is widely distributed in mountainous and hilly areas worldwide to increase grain production, control soil erosion, increase soil moisture, and improve soil quality, potentially impacting soil carbon pools. This study investigates how agricultural activities and ecological restoration measures affect soil carbon pools in terraced areas of the Chinese Loess Plateau. We established an observation system in typical terraces and collected soil samples from 0-100 cm depth in terraces with different crops and ecological restoration vegetation. Our results show that terracing effectively increases soil organic carbon (SOC) content, with terraced cropland (7.7 $g·kg^{-1}$) having higher SOC than sloping cropland (4.9 $g·kg^{-1}$), In the 0-100 cm layer, SOC content in terraced wheat fields was 1.5 times higher than in sloping wheat fields, with the most significant increase in the top 0-30 cm. This increase is attributed to improved soil and water conservation capacity and agricultural activities. Short-term abandonment led to SOC loss, while replanting fruit trees and crops increased SOC. Our findings provides valuable insights for agricultural management and ecological restoration in terraced areas of the Loess Plateau and contributes to the development of effective carbon sequestration policies for terraced arable lands.

Line 27 changes in organic carbon content in terraces is mainly driven by the improved soil and water….

Response： This sentence does indeed have some grammatical issues and unclear structure. Here is the revised version:

Changes in the organic carbon content of terraced land are attributed to several factors. One major factor is the improvement in soil and water conservation capacity due to agricultural activities. Short-term abandonment of terraces can lead to a loss of soil organic carbon. Conversely, replanting fruit trees and crops can increase soil organic carbon content.

Line 45 is is?

Response： Thank you very much for your careful observation. There is indeed a repetition of "is" in the original sentence. We should correct this grammatical error. Here is the revised sentence:

Soil organic carbon is a key element of the global carbon cycle (Rossel et al., 2019) and serves as a significant indicator for assessing soil quality and land productivity (Guillaume et al., 2021; Wang et al., 2012).

Line 62 maintain soil fertility and increase…

Response：We have restructured the logic of this sentence, specifically:

Agricultural terracing is a crucial landscape engineering measure to reduce soil erosion, maintain soil fertility, and increase agricultural productivity (Doetterl et al., 2012; Zhu et al., 2021), which is one of the ways to achieve sustainable agricultural development.

Line 64. conversion of terraces into slopes?? I think it's another way around…

Response： You are completely correct; there is indeed a conceptual error here. The phrase "conversion of terraces into slopes" in the original text is incorrect. It should be the other way around, namely the conversion of slopes into terraces. We will correct this mistake in the revised manuscript and reorganize the relevant content to more accurately express the role of terrace farming. Specifically:

Agricultural terracing is a crucial landscape engineering measure to reduce soil erosion, maintain soil fertility, and increase agricultural productivity (Doetterl et al., 2012; Zhu et al., 2021), which is one of the ways to achieve sustainable agricultural development. The conversion of slopes into terraces significantly increases the cultivated area. Moreover, it helps prevent erosion problems (Arnáez et al., 2015) and effectively increases food production (Tarolli et al., 2014). Terraces are widely distributed and have created environmental benefits in countries in East Asia, the Mediterranean, and Southeast Asia (Wei et al., 2016). The terraced field construction in the Loess Plateau region of China has a long history. China has historically emphasized soil and water conservation as well as agricultural production, gradually developing and refining terracing techniques in this process. By 2005, the area had established terraced fields covering 14,790 square kilometers, accounting for 95.3% of the total arable land (Ma et al., 2015). This long history of terrace construction may influence the current processes and storage of soil organic carbon in the region. In the Chinese Loess Plateau region, a large amount of arable land has been converted to woodland and grassland through the implementation of afforestation and reforestation policies, and these measures have increased the organic carbon content of the soil (Rong et al., 2021). Many studies have shown that terracing can intercept more than 80% of rainfall runoff and sediment, and horizontal terracing can retain all rainfall to replenish soil moisture. The positive benefits of carbon capture generated by terraces come from the collection of eroded material from sloping soils. However, the conversion of natural vegetation to cropland inevitably results in a reduction of biomass and therefore a significant loss of soil organic carbon (SOC) (Aguilera et al., 2013, 2018). During the construction of terraces, it is inevitable to strip topsoil and expose deep soil, resulting in a large amount of new subsoil covering the surface of the terraces. This severe soil disturbance may alter soil organic carbon dynamics (Sidle et al., 2006), but the potential long-term benefits of terrace construction are considerable (Chen et al., 2017). Nevertheless, many terraces are experiencing ridge damage and collapse due to a lack of maintenance or land abandonment. This not only reduces soil and water conservation benefits but potentially increases erosion and carbon emissions (Arnáez et al., 2015; Wen et al., 2020).

Line 72 sloping soils? -> soils in sloping land

Response： Thank you very much for your careful review of our article and the valuable suggestions you provided. The issues you pointed out are indeed significant, and we recognize that the original wording may have led to misunderstandings or confusion. Taking your advice into consideration, we have decided to revise this sentence to convey our meaning more accurately and clearly. The revised sentence is as follows:

The positive benefits of carbon capture generated by terraces come from the collection of eroded material from soils on sloping land.

Line 81 but also

Response：Thank you very much for carefully reviewing our article and pointing out this issue. We sincerely apologize, as this was indeed an error caused by our oversight. The revised sentence is as follows:

This not only reduces soil and water conservation benefits but also potentially increases erosion and carbon emissions (Arnáez et al., 2015; Wen et al., 2020).

Thank you once again for your valuable feedback. We will be more cautious in our future work to avoid similar mistakes.

Line 98-99 I don't understand this sentence

Response： Thank you very much for carefully reviewing our article and pointing out this issue. We understand your confusion regarding this sentence and sincerely apologize for not expressing it clearly. We will revise and optimize this sentence to better fit the context and enhance clarity. The modified paragraph is as follows:

Nair et al. (2009) reviewed seven studies on soil carbon in tropical agroforestry systems, consistently demonstrating that agroforestry practices lead to higher carbon storage compared to conventional agricultural systems.

Line 102 By the end of 2012, there were 37,100 km2 of terraced fields on the Loess Plateau. please add a reference

Response： Thank you very much for your careful review and valuable suggestions. The issues you pointed out are very important, and we fully agree that references should be added for this data. The revised content is as follows:

By the end of 2012, there were 37,100 km2 of terraced fields on the Loess Plateau (Ma et al., 2015).

Ma, Y., Li, X., Guo, L., & Lin, H. (2015). Hydropedology: Interactions between pedologic and hydrologic processes across spatiotemporal scales. Earth-Science Reviews, 150, 201-220.

Line 110 to be clearer: we gathered soil samples from terraces and non-terraced slopes,

Response：We fully agree with your opinion that this revision can definitely make our description of the research methodology clearer and more accurate.

Consequently, we gathered soil samples from terraces and non-terraced slopes, including terraces with varying land use and crop types, to investigate (1) the impacts of terrace construction on SOC in the Loess Plateau region and (2) the effects of different vegetation cover and tillage activities on the carbon sink capacity of terraces.

Line 147 please check this sentence

Response：Thank you very much for your feedback. We have reorganized the logic of the sentences. Specifically:

We randomly set up 84 sampling sites in the study area, comprising 77 terraced sampling sites and 7 slope sampling sites. Recognizing that crop type, cropping pattern, and agricultural abandonment all affect the soil carbon pool of terraces, we included sampling points for different cropping patterns on the terraced sites. The distribution of sampling points across different cropping patterns was as follows: 9 sampling points each for apple trees, vegetables, wheat, legumes, potatoes, and maize; 3 sampling points each for apple tree-legume intercropping and apple tree-potato intercropping. The remaining 17 sampling points were from abandoned terraces. (Appendix, Fig. S1)

Line 188 0.7 g kg-1, report sd/se along with your mean value

Response： Thank you for your feedback. Based on your suggestions, we have made revisions and additions to the original sentence. The updated content is as follows:

The SOC content of the abandoned apple tree terraces (7.46 ± 0.76 g·kg^{-1}) was lower than that of the in-use apple tree terraces (8.16 ± 1.02 g·kg^{-1}), with a difference of 0.7 $\pm$ 1.27 g·kg^{-1}.

Line 237-240 sentence is too long

Response：Thank you very much for taking the time to review our article and for your suggestion. Based on your feedback, we have optimized and revised this sentence. The revised content is as follows:

In the 0-10 cm surface layer, the SOC content under alfalfa was significantly lower than that under the two tree species. This difference became smaller in the 10-20 cm depth. However, the difference increased again in the 20-60 cm depth. At 70-100 cm, the difference between the three vegetation types became smaller, with their SOC contents converging.

Conclusion: some statements are not supported by data -> see major comments

Response： Based on the comments you provided in the "Main Issues" section, we have made revisions. We have included data on soil bulk density and soil pH, among other physicochemical properties, to further discuss the mechanisms by which terracing and vegetation types influence soil organic carbon (SOC) dynamics. Additionally, we incorporated high-resolution data on soil organic carbon distribution and slope to further examine the impact of topography on soil organic carbon distribution. The specific modifications are as follows:

4 Discussion

4.1 Effect of terrace construction on SOC

In the Loess Plateau area, the average SOC content of terraces 0-100cm is 1.4 times higher than that of sloping farmland (Table 1). Figure 5 clearly shows that the SOC content decreases with increasing depth. In Zhang et al. (2013), the SOC stock at 0-100 cm depth was 4.97 kg·m^{-2} in terraces and 3.09 kg·m^{-2} in sloping fields, which is 1.6 times higher than the soil organic carbon stock in sloping fields, which is consistent with the results of this study. Terracing is considered an important practice to prevent water erosion and minimize the loss of SOC (Nie et al., 2017). We can observe that areas with steeper slopes generally have lower soil organic carbon (SOC) content, while areas with gentler slopes tend to have higher SOC content (Fig. 6).

This phenomenon can be explained by the fact that horizontal terraces alter the surface morphology, prolonging the surface water retention time during rainfall, which increases soil moisture in the rain-fed agricultural regions of the Loess Plateau (Xu et al., 2021). There is a positive feedback relationship between soil moisture and soil carbon (Green et al., 2019). Figure 5 shows that the soil organic carbon (SOC) content in the surface layer is significantly higher than that in the deeper layers. This may be due to the interception of precipitation by the terraced fields, which provides water for plant growth, increases plant biomass, and subsequently enhances the organic matter input into the soil. Additionally, the interception of rainfall by the terraces means that less soil fine particles are washed away, leading to an increase in the clay content of the soil. Soil clay particles have a larger specific surface area, allowing them to adsorb more soil organic carbon and enhancing the accumulation of organic carbon (Post et al., 1982). Compared to sloping land, terraces have a higher content of both clay and silt in the soil. The terraces therefore further contribute to carbon accumulation in the terraces by protecting the fine particles in the soil. In a study on the Loess Plateau, the SOC content of 0-100 cm in unterraced date palm orchards was 2.6 $g \cdot kg^{-1}$, which was lower than the soc content of terraced orchards. This evidence further demonstrates the positive effect of terracing on soil organic carbon sequestration (Gao et al., 2017).

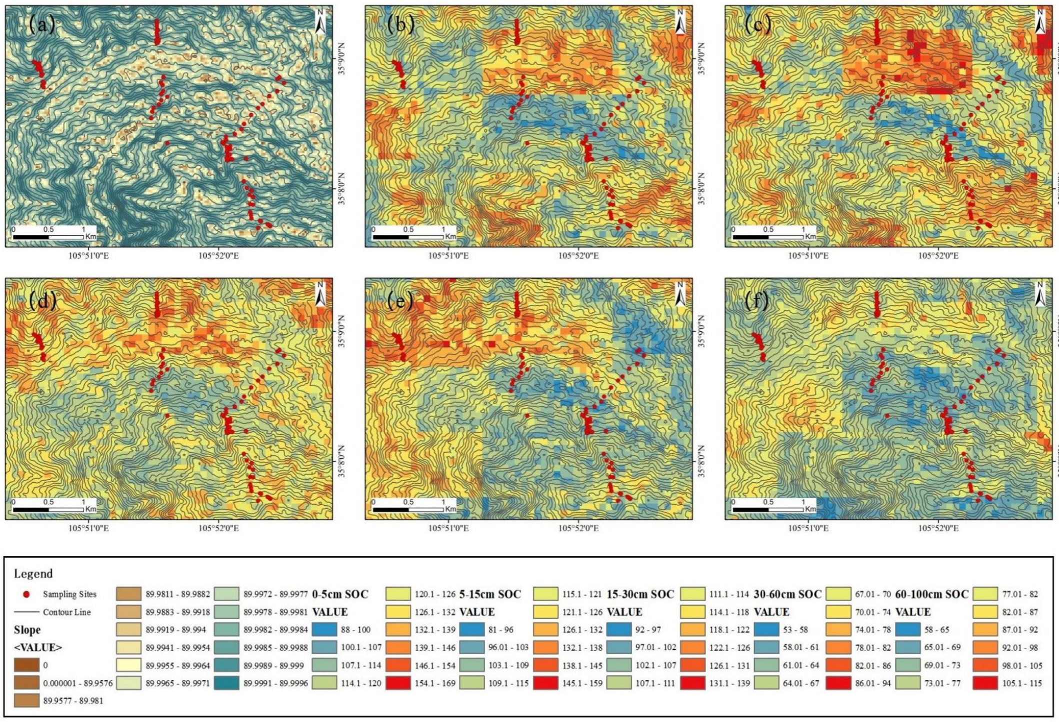

Fig.5 Distribution of slope and soil organic carbon (SOC).

(a): Slope; (b): Distribution of SOC at 0-5 cm; (c): Distribution of SOC at 5-15 cm; (d): Distribution of SOC at 15-30 cm; (e): Distribution of SOC at 30-60 cm; (f): Distribution of SOC at 60-100 cm.

The SOC varies significantly in terms of the amount of plant and animal residues entering the soil and the depth of the soil under agricultural cultivation (Koga et al., 2020). The impact of agricultural activities on the surface soil levels was stronger compared to the deeper soil levels (Li et al., 2020). In this study, we observed a significant increase in SOC in terraces than in sloping lands, particularly in the 0-30 cm soil layer (Fig.6). Post-terracing, SOC sequestration in deeper soils lagged behind that in surface soils. Furthermore, the rate of SOC change was more pronounced in the surface layer (0-20 cm) compared to the deeper layer (20-100 cm). Precipitation in the region is limited and cannot replenish deep soil water, and the erosion of precipitation on the slope surface also mainly takes away the top soil layer. Therefore, the soil and water conservation effect brought by terrace construction is limited, so for the soil depth increases, this effect will become smaller. The impact of terracing on SOC sequestration diminishes as soil depth increases (Deng, Liu, and Shangguan., 2014). As soil depth increases, the water stored in the terraces cannot penetrate deeper soils and deeper soils will maintain their properties. Therefore, the management and conservation of terrace topsoil are important to ensure local food production and enhance the carbon sink function (Li et al., 2014).

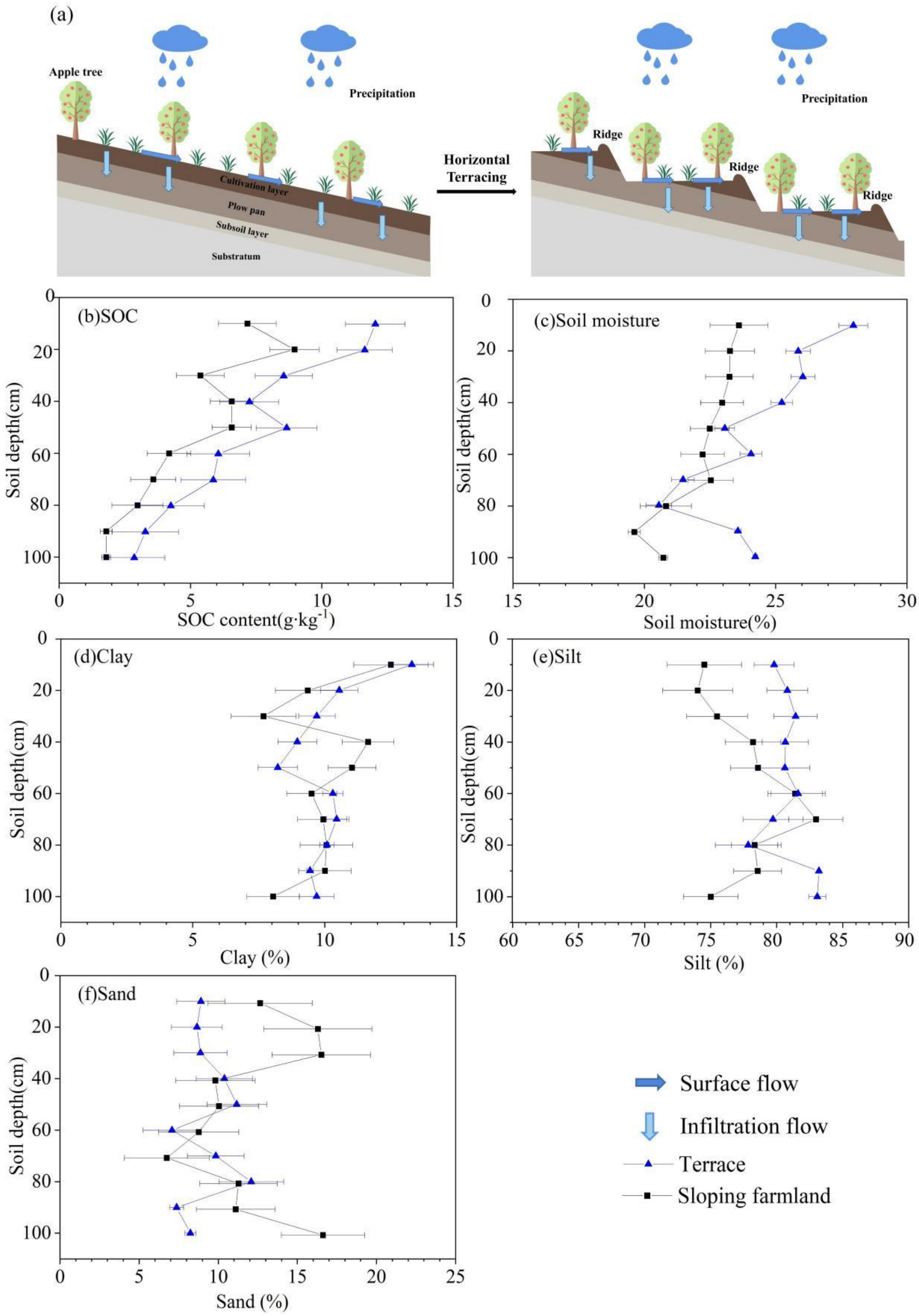

Fig.6 Effect of terrace construction on SOC, soil moisture, and soil grades.

(a): Variation in surface morphology by terrace construction; (b): variation in SOC content; (d): variation in soil moisture; (d), (e), and(f): variation in soil grades. The number of profiles is 9 for terraces and 4 for sloping fields. Bars denote the standard deviation of the mean.

4.2 Effect of terraces abandonment on SOC

As in other parts of the world, industrialization and urbanization have led to a large population flock from rural to urban areas as in China, resulting in the abandonment of a large number of productive potential farmlands (Wiesmeier et al., 2012; Cai et al., 2016). Furthermore, climate change induced extreme weather events such as drought and heavy rainfall can also accelerate soil erosion and loss of soil organic carbon in the abandoned terraces (Lal, 2004). We measured the physicochemical properties of the soil in terraced fields with different usage statuses (Table 2). The results show that the soil bulk density in abandoned terraces is significantly higher compared to the actively used ones. This increased bulk density may lead to reduced soil aeration, thereby inhibiting the decomposition of organic matter. Furthermore, the soil pH in abandoned terraces has also decreased, which may affect the stability of organic matter. However, climate change can also impact the vegetation succession on abandoned terraces, which in turn affects the soil organic carbon dynamics (Davidson & Janssens, 2006). When the terraced fields were abandoned in this research, the SOC content of the abandoned terraces was lower than that of the terraces in use. This is caused by the limited abandoned time. Abandoned terraces may have accumulated a significant amount of organic matter during their previous use. However, due to a lack of fertilization now, this organic matter is gradually being mineralized and decomposed, which reduces the soil organic carbon (SOC) content (Lal, 2004; Wiesmeier et al., 2019). In contrast, terraces that are still in use maintain higher SOC levels thanks to continual fertilization (Nardi et al., 2004). Additionally, the abandoned terraces are more susceptible to climate change induced soil disturbance and erosion, leading to the loss of nutrient-rich topsoil, which further decreases SOC levels (Zhao et al., 2013). Our data also shows that the surface soil organic carbon (SOC) content in abandoned terraced fields (0-15 cm) is significantly lower than that in actively used terraced fields, which may be related to higher soil bulk density, lower pH, and surface soil erosion (Table 2). To produce significant environmental benefits, the land must remain abandoned for an extended period to accumulate substantial amounts of both plant biomass and the species that constitute intact ecological communities. This process can take decades to reach levels of carbon sequestration or biodiversity comparable to those of undisturbed ecosystems (Crawford et al., 2022; Poorter et al., 2016). Due to the limited water resources available in semi-arid areas, a longer natural or assisted recovery time is required. Therefore, the duration of land abandonment is a crucial factor influencing the dynamic changes SOC (Djuma et al., 2020; Badalamenti et al., 2019). In related studies in other regions, soil carbon stocks increased by 13% and 16% in cropland abandoned for 15 and 35 years, respectively (Novara et al., 2014). With the abandonment of disposal time extended, vegetation types gradually transition to grassland, scrub, and forest and the death of plants and animals return to the soil as organic matter, increasing the number of soil aggregates and further increasing the carbon content of the soil (Liu et al., 2020). Therefore, ecological restoration of newly abandoned terraces should be carried out as soon as possible. After short-term abandonment, the terraced fields showed a special change pattern at different depths in this study. SOC content first decreased and then increased with increasing soil depth. The decrease in surface SOC was controlled by the decrease in agricultural fertilizer inputs, while the increase in deep SOC was caused by the inability to utilize deep soil nutrients due to the death of crop roots.

Table 2 Soil Properties Data of Different Types of Sampling Points

Land types	Planting method	Vegetation types	0-5cm		5-15cm		15-30cm		30-60cm		60-100cm	
			Bulk density	pH value	Bulk density	pH value	Bulk density	pH value	Bulk density	pH value	Bulk density	pH value
Terrace	Single vegetation	Wheat	1.26	8.07	1.27	8.06	1.31	8.13	1.34	8.20	1.36	8.19
		Apple trees	1.26	8.11	1.27	8.11	1.31	8.15	1.34	8.21	1.36	8.21
		Potatoes	1.26	8.14	1.29	8.13	1.32	8.17	1.33	8.23	1.35	8.23

		Legumes	1.26	8.10	1.28	8.09	1.31	8.15	1.33	8.22	1.36	8.21
		Maize	1.25	8.08	1.28	8.08	1.32	8.14	1.35	8.21	1.37	8.20
		Robinia pseudoacacia L.	1.26	8.09	1.27	8.08	1.31	8.13	1.33	8.23	1.37	8.19
		Pinus tabuliformis Carr.	1.26	8.11	1.28	8.11	1.33	8.15	1.36	8.20	1.37	8.20
		Medicago sativa L.	1.26	8.12	1.28	8.11	1.33	8.16	1.36	8.21	1.37	8.22
		Vegetable	1.26	8.13	1.28	8.12	1.31	8.16	1.33	8.21	1.36	8.21
	Multiple vegetation	Apple tree-legumes	1.25	8.08	1.28	8.08	1.33	8.14	1.34	8.22	1.37	8.19
		Apple tree-potatoes	1.24	8.10	1.28	8.10	1.34	8.15	1.36	8.22	1.37	8.21
Sloping land	Single vegetation	Wheat	1.26	8.08	1.28	8.08	1.32	8.14	1.35	8.21	1.36	8.20
		Grassland	1.23	8.06	1.27	8.06	1.31	8.12	1.34	8.17	1.37	8.18
Abandoned terraces	Multiple vegetation	Apple trees and weeds	1.24	8.10	1.27	8.09	1.31	8.15	1.34	8.21	1.37	8.20

4.3 Effect of vegetation type and planting patterns on SOC in terraces

Vegetation types can influence SOC by modifying the soil's physicochemical structure and altering both the input and decomposition rates of SOC (Du et al., 2022; Wiesmeier et al., 2012; Wan et al., 2019). Our data shows that there are significant differences in soil pH values under different vegetation types (Table 2). For instance, forested areas have higher pH values, while grasslands have lower pH values. This could be an important factor contributing to the differences in SOC content among various vegetation types, as pH levels influence the decomposition and stability of organic matter. Our study demonstrated that, compared to terraced fields, the SOC content of afforested land at a 0-100 cm depth was higher and that the forest litter biomass was more than that of farmland, which was the main reason for this difference. Planted forest land reduces soil temperature, soil moisture evaporation, and soil erosion while increasing the quantity and quality of organic matter input to compensate for carbon decomposition from crop cultivation (Liu et al., 2020). The soil bulk density in forested areas is significantly lower than that in agricultural land, which is beneficial for the decomposition and accumulation of organic matter (Table 2). The afforested land is terraced forests, and the effect of preventing soil erosion is more significant. Some study shows that the SOC in immature forests (10 years old) is 17.91% higher than that in terraced cropland. The SOC concentration of a 30-year-old forest is significantly higher than that in other land covers (Xin et al., 2016). These studies further proved the carbon sequestration effect of reforestation.

Due to the problem of ecological degradation and soil erosion, various ecological measures have been taken in the Loess Plateau area, such as returning farmland to forest and grass and planting trees (Hong et al., 2020). Considering the climate and soil quality factors, the main species selected in the Loess Plateau region are drought-tolerant types of trees, and the carbon accumulation effect of different species selection also differs significantly (Li et al., 2018). *P. tabuliformis* has a higher SOC content than *R. pseudoacacia*, especially in the 0-50 cm soil layer. The pine species selected in this region is larch, with the arrival of winter a large number of pine needles and fruits are into the soil, increasing the input of organic matter in the surface layer so that the SOC content of pine forests is higher in the surface layer of the soil (0-10 cm). In humid areas, some studies also show that the soil organic carbon density of fir conifer forests is the largest among the different 11 middle forest vegetation types (Chen et al., 2007). Other studies have shown that tree species such as *P. koraiensis*, *L. gmelinii,* and *P. tabuliformis* increase soil organic carbon stocks more as silvicultural species (Hong et al., 2020). The biomass of the herbaceous plants themselves is much lower than that of trees, and the limited amount of organic matter entering the soil, and the fact that *M. sativa* is mainly used as a source of fodder for the animals raised by farmers in the region, leads to a lower SOC content in terraces planted with *M. sativa* than in those undergoing afforestation.

The SOC content of grassland at a depth of 0-100cm is lower than that of farmland. Although the grassland has organic matter after the withered herbs enter the soil, the main planting type in the terrace area is apple trees, and a large amount of fruit tree leaves will also enter the soil. The lower pH value of the soil in grasslands may be a significant reason for its lower SOC content (Table 2). Grassland is a sloping land that has not been terraced, leading to slope erosion that removes a significant amount of organic matter from the soil surface. As a result, the SOC content in grassland is lower than in terraced fields (Fig.2). The ecological advantages of sequestering SOC and enhancing soil fertility could be significant, largely thanks to the widespread implementation of reforestation and various land use strategies in terraced fields across China and numerous other mountainous areas globally (Hong et al., 2020).

Crops may differ in their ability to increase SOC content due to differences in their photosynthetic capacity and root characteristics (Wegener et al., 2015). The pattern of intercropping in this area is typical of Agroforestry systems (AFS), where other crops are planted between the rows of apple trees. The SOC content of apple trees in combination with other crops was higher than in monocultures, especially in the lower and middle layers of the soil (30-100 cm). The amount of tree litter and root decomposition are important reasons for this (Pardon et al., 2017). The fallen leaves of fruit trees and some rotting apples are not removed, and these organic materials decompose to replenish SOC after entering the soil. In addition, carbon input can be achieved by decomposing (fine) tree roots and root secretions (Nair et al., 2009). For soils below 30 cm depth, tree roots produce an important role in the accumulation of soil organic carbon. When potato or legume crops are harvested, all the fruit and plant roots are removed and these lands will be tilled to grow other crops, so the input of organic matter is very limited. Agroforestry systems increase the distribution of roots in the soil and increase the recalcitrant compounds which slow the rate of mineralization through the input of organic matter (Recous et al., 2008).