Remarks Anonymous Referee #1

General comments

R1.1.: The authors obtained important conclusions: Examining soil quality indicators of terrace soils reveals no significant signs of severe degradation, even with long-term use. The final abandonment of the cultivation system is not attributed to soil exhaustion or terrace structural instability.

The reviewer believes that in conclusion, the Authors could make a breakthrough if they separated relict, agrogenically determined responses, and recent postagrogenic properties.

In contrast to the numerous processes that are united by the phrase “agricultural soil degradation”, and for which there is a Mont Blanc of scientific facts, progressive Agropedogenesis, called progradation, is sometimes noted.

A comparison of Agrosoils that differ in the duration of agricultural load with the supposed alternation of land use practices (including those that, to one degree or another, contained agrotechnical components of a soil-saving orientation, and not always consciously applied), makes it possible to establish inherited signs of progradation. Moreover, their contradictory nature may have features of pseudo-progress [Lisetskii F.N. Agrogenic transformation of soils in the dry steppe zone under the impact of antique and recent land management practices // Eurasian Soil Science. 2008. Vol. 41. No. 8. P. 805–817.]

A1.1: Thank you for your comment. Our study will certainly benefit from the integration of the conclusions obtained and will be further enriched by the proposed approach. Throughout the manuscript, we will emphasise that the current post-agrogenic soils in the Laramate terraces are the result of sequential genetic processes and are not comparable to soils subjected to natural pedogenesis. Their evolution reflects the following major phases: 1) natural pedogenesis on undisturbed soils, 2) soils modified by intensive agricultural practices, and 3) post-agrogenetic soils.

Specific Comments

R1.2: Keywords. phytolith analysis. The reviewer draws the attention of the Authors to the fact that in the corporate community of scientists of this profile, the term phytolith is considered obsolete (due to the fact that it is narrowed), and the normative term is biomorphs.

A1.2: Thank you for your suggestion regarding the terms "phytoliths" and "biomorphs" for laboratory analysis. We are considering including "biomorphs" in the Keywords section, given its broader nature and relevance. However, we propose retaining the terms "phytoliths" and "phytolith analysis" in the abstract and subsequent sections.

R1.3: Abstract. The reviewer does not believe that the logic of this important component of the Article is ideal. For example, should I write in detail about three WRB Reference Soil Groups?

Abstract must be formatted according to international standards and include the following points.

Introductory speech about the research topic.

Purpose of scientific research.

Description of the scientific and practical significance of the work.

Description of the research methodology.

Main results, conclusions of the research work.

The value of the research conducted (what contribution this work made to the relevant field of knowledge).

The final part of the Introduction section also does not formulate the purpose of the study, but rather a list of what will be done. **[But in the Conclusion section the reader finally learns about the purpose of the study].**

A1.3: Thank you for your comment. You are right. The abstract will be structured according to international standards and suggested guidelines. Adjustments will include a concise restatement of the study objectives to achieve a comprehensive understanding of the pedological history of the Laramate area through the assessment of abandoned terrace soils and their undisturbed soil context, along with the main results and conclusions.

R1.4: 1 Introduction.

Given the fact that terrace agriculture was widely practiced in ancient times in the foothills and mountains of various regions of the world, it would be good to provide a global context in the introductory paragraph without limiting it to the Andes. As a hint, you can indicate specialized studies of ancient terraces lands (The Negev Highlands, Israel) or (Eastern Caucasus), etc.

Stavi, I., Eldad, S., Xu, C., Xu, Z., Gusarov, Y., Haiman, M., & Argaman, E. (2024). Ancient agricultural terrace walls control floods and regulate the distribution of Asphodelus ramosus geophytes in the Israeli arid Negev. Catena, 234, 107588.

Sapir, T., Mor-Mussery, A., Abu-Glion, H., Sariy, G., & Zaady, E. (2023). Reclamation of ancient agricultural terraces in the Negev Highlands; soil, archeological, hydrological, and topographical perspectives. Land Degradation & Development, 34(5), 1337-1351.

Borisov, A. V., Kashirskaya, N. N., El'tsov, M. V., Pinskoy, V. N., Plekhanova, L. N., & Idrisov, I. A. (2021). Soils of ancient agricultural terraces of the Eastern Caucasus. Eurasian Soil Science, 54(5), 665-679.

A1.4: Thank you for your comment. Including a brief description of terrace cultivation in other regions of the world provides essential context for understanding this phenomenon on a global scale. Particular attention should be given to regions with similar climatic conditions and ancient farming systems, such as central and southern Mexico, the Caucasus, the Mediterranean, and Israel.

R1.5: b) The authors of the text Article actively (14 times) use the works of Sandor, J. A. and Eash, N. S. This is scientifically correct, because the pioneering contribution of one of these scientists to the development of this topic is significant. **Jonathan A. Sandor (Department of Agronomy, Iowa State University, Ames, Iowa, USA)**

However, the Reviewer would like to point out that both works in References are from 1995, and the key author has more recent Articles.

Eash, N. S. and Sandor, J. A.: Soil chronosequence and geomorphology in a semi-arid valley in the Andes of southern Peru, Geoderma, 65, 59–79, https://doi.org/10.1016/0016-7061(94)00025-6, 1995.

Sandor, J. A. and Eash, N. S.: Ancient Agricultural Soils in the Andes of Southern Peru, Soil Science Society of America Journal, 59, 170–179, https://doi.org/10.2136/sssaj1995.03615995005900010026x, 1995.

In this regard, the Reviewer believes that in addition to priority works, one cannot ignore the most generalizing previous research of the Author (J. A. Sandor) and the large Chapter 2006, as well as the most recent Article on ancient terraces lands in the Chile region.

Sandor, J. A. (2006). Ancient agricultural terraces and soils. In (Ed.) Warkentin, B. P., Footprints in the soil: People and ideas in soil history (pp. 505–534). Elsevier

Sandor, J. A., Huckleberry, G., Hayashida, F. M., Parcero-Oubiña, C., Salazar, D., Troncoso, A., & Ferro-Vázquez, C. (2022). Soils in ancient irrigated agricultural terraces in the Atacama Desert, Chile. Geoarchaeology, 37(1), 96-119.

A1.5: Thank you for your comment. Our study will indeed benefit from the inclusion of newly published literature. Accordingly, the manuscript will be complemented by incorporating recent studies on terraces in neighbouring regions, such as the Chilean Atacama region.

R1.6: L 105-106: «The altitude of the mountainous region ranges from 2000 m to 4200 m asl.». This amplitude is of a "background" informational nature, while the reader, if he looks at the three lower insets of Figure 1, then they all reflect valley-river landscapes, which obviously have a significantly lower altitude, which, if indicated, are more useful for understanding geomorphology of study sites.

It is strange that the Authors, speaking about landscapes where there were terraces, limited themselves to section 2.2 Geology. The reviewer believes that this block needs a Relief (Topography) section, where a full-fledged geomorphological analysis is very important: with a range of heights, where there are terraces, slopes, exposure, shape of slopes, etc.

A1.6: Thank you for your valuable suggestion. The authors agree that the inclusion of a comprehensive geomorphological analysis of the study area will provide a more detailed understanding of the morphodynamics and their effects on the structural stability of the terrace system. The following elements will be included:

1. Description of the main structural features and units of the middle and upper Rio Grande.
2. Relief and morphological analysis of the fluvial subsystems of the Ingenio, Viscas and Palpa rivers using available topographic information (NASA, 2019; ONERN, 1971).
3. Analysis of the morphological situation of each terrace system within the landscape.

R1.7: The historical-agrarian section is missing; what agricultural technologies were used in the past? (depth of processing, crops, etc.).

A1.7: Ethnohistorical studies on agrarian technologies (e.g., crops, tillage tools, irrigation techniques, camelid dung application, crop rotation, surface burning) are unfortunately scarce and almost non-existent in the Laramate area.

Goodman-Elgar (2008) and Nanavati et al. (2016) highlight the advantages of non-mechanized tillage tools in their studies on pre-Hispanic terraces at Viejo Sangayaico in the nearby upper Ica and Paca valleys, respectively. Tools like the *chaquitaclla*, which have been used in the Peruvian Andes since ancient times and remain part of the current rural landscape, typically till the soil to a depth of 30 cm with their curved metal or wooden tips. In conjunction with another traditional hand-tillage tool, the *ranccana*, these tools facilitate soil cultivation with less destructiveness compared to industrial ploughing. It is reasonable to infer their use on the Laramate terraces. Future work should test this hypothesis and explore their actual effects on the Laramate terrace soils.

The potential role of organic fertilizers of animal origin (e.g., camelid dung) needs to be systematically addressed in future studies. Handley et al. (2023) found that the Chicha Soras terrace system was likely maintained by the regular addition of camelid dung. Although the addition of organic nitrogen sources (e.g., urea or compost) was difficult to detect in the Laramate terraces, their use cannot be completely excluded. Studies of domestic animal densities in an archaeological context, using oribatid mite concentrations as an indirect indicator of manuring, such as those carried out in the Patacancha Valley in Cuzco by Chepstow-Lusty et al. (2007), could be considered in future work to better understand this hypothesis.

Reliable information on crops in the Laramate area comes from a recent publication by Mader et al. (2024). The study indicates that maize was most likely an important crop on the agricultural terraces around the Cutamalla archaeological site.

With the information currently available, the picture of the agricultural history of the Laramate region is only partial, but there is significant potential for future studies.

R1.8: For example, Table 2: 50-70 cm = 1 grain Zea Mays. Why at such a depth? Is this the result of formation turnover? [L 856: «terric horizons with a total thickness of 50 cm»].

A1.8: Thank you for your observation. Regarding the presence of a maize grain on Pe10-31/4 of Sihuilca (Bwt 50-70 cm), we interpret its origin to be from the former soil surface (Ah 20-50 cm) during an early phase of cultivation, prior to the terrace construction. This is more likely than a later incorporation from the uppermost Ap horizons.

The mixing of the soil substrate in the 30 cm thick horizon at Ah, and its subsequent translocation into the underlying Bwt horizon, is plausible considering the combined action of the available tillage tools of the time and the influence of local burrowing fauna. It is interpreted that the Sihuilca site experienced early agricultural use, specifically the cultivation of maize, during the initial stages of the Late Formative/Early Horizon or possibly even earlier.

R1.9: With the indicated phase of aridization and the emergence of river valleys, did the contribution of irrigation manifest itself in the transformation of the agricultural system?

A1.9: Thank you for your question. Despite technological advances in terracing and irrigation techniques during the Middle Horizon, these innovations did not lead to a massive transformation of agricultural systems in the Laramate region. Although there were a small number of newly established irrigated terrace systems in the area, they represented a relatively small proportion of the cultivated area. In addition, most of these terraces were located in areas with poorer soil quality that had not previously been used for agriculture. Thus, although the agricultural utilisation of previously unused land through technological improvements represents a systemic development, it did not lead to a profound transformation of the agricultural system in the study area.

R1.10: Figure 5. Between 0 and 85 cm I would like to see the depth values at the boundaries of the horizons.

A1.10: We appreciate your feedback. Due to space and design constraints, the boundaries of each horizon in this figure are indicated indirectly by the lateral graphic scale. The boundaries are shown in centimetres as follows: Ap1: 0-10, Ap2: 10-20, Ah: 20-50, Bwt: 50-70, C1: 70-85. This information is also provided in Chapter 4.2.1 of the manuscript, as well as in the supplementary section.

R1.11: L 195. Anthrosols. This most important component of the study is described very sparingly. The reviewer believes that it is important to show that there is a dual nature of Soils of ancient agricultural terraces, on the one hand, as cultural soils that are formed as a result of Agropedogenesis [Kuzyakov, Y., & Zamanian, K. (2019), and on the other hand, these are postagrogenic soils with inherited characteristics from their prehistory.

Kuzyakov, Y., & Zamanian, K. (2019). Reviews and syntheses: Agropedogenesis—Humankind as the sixth soil-forming factor and attractors of agricultural soil degradation. Biogeosciences, 16(24), 4783–4803. https://doi.org/10.5194/bg-16-4783-2019.

A1.11: Thank you for your feedback. The authors agree that the concept of anthrosols needs to be further developed in the text. The following aspects should be addressed:

1. The formation of anthropogenic soils in relation to the processes of agropedogenesis and their behaviour after the final abandonment of agricultural use.
2. Diagnostic characteristics of anthrosols in relation to local climatology and conditions of formation.

3. A brief overview of anthrosols on agricultural terraces, which are a typical feature of the Peruvian Andes landscape. Although the recovery process of the Laramate soils has clearly begun, it remains unclear to what extent the current soil properties reflect the post-agrogenetic process and the degradation level previously reached. A valuable approach to understanding the dimensions of agrogenetic and post-agrogenetic processes described by Kuzyakov and Zamanian, (2019) is offered by a group of terraces not included in this study but investigated in the field: the Patachana system (14°15'24 "S, 74°49'37 "W, 3425 m a.s.l.). This system shares typological similarities with Sihuilca, Ayllapampa, and Santa María but features unique prehispanic irrigation characteristics. Unlike other systems in the Laramate region, largely abandoned after 1532 CE, the Patachana system has been intensively used since the colonial period. Therefore, the Patachana system is a valuable site for evaluating ancient agrogenetic soils without post-agrogenetic traits and should be considered in future research to validate Kuzyakov and Zamanian's (2019) model of agrogenetic soils.
R1.12: L 265. Above The authors have used WRB many times and a reference to it earlier would have been more appropriate. And so this is a repetition of what has already been used.
A1.12: Thank you for your note. However, we believe that this specific reference to the description of the field data and soil classification system should remain in the methods section. Previous mentions of the WRB refer to the soil groups found in the region; subsequent mentions will be removed.
R1.13: L 284: Mg2+), Kalium (K+), Calcium (Ca2+). All valences must be given in uppercase Mg2+…
A1.13: Your observation is correct, thank you. Valences should be written in uppercase letters according to the standards. This will be corrected in the revised version of the manuscript.
R1.14: 5.2.2 Soil acidity, nutrient availability and soil quality. The application in the section on soil quality characteristics was not implemented (an integral assessment was not obtained based on the available indicators of potential fertility).
A1.14: Thank you for your feedback. The authors agree that the section needs to provide a comprehensive assessment of the agro-ecological potential for specific crops within the terrace systems, and to emphasize the relevance of a central theme of this research: the

management of soil resources through agricultural practices. Indicators such as soil acidity and CEC/BS are well-known for assessing soil quality and are effective for evaluating soil responses to intensive agricultural practices. These indicators reflect efforts to mitigate the negative effects of intensive cultivation (e.g., nutrient depletion or soil acidification) and to optimize crop production, particularly through the incorporation of organic matter into the topsoil and soil mixing during terrace construction.
R1.15: References. When comparing 1260 and 1265 onwards: why is the Title Article given either in capital or in lowercase letters?
A1.15: Thank you for your comment. The inconsistencies in our reference section are due to the direct import of bibliography files in different formats. Your observation is correct, and we will ensure that the references are formatted consistently in a future version of the manuscript.
R1.16: Supplementary. SuppFig1 (b). The reviewer stubbornly does not see the boundary of the transition to the AC horizon. Look, you have an OM of 2.2% and below 2.2%, Munsell color = the same, so the photo objectively shows that there was a clear error in determining the boundary. Perhaps this is a buried humus layer. (Very bad photo? Crooked ruler, half of the profile in the shadow).
A1.16: Thank you for this important note. We agree with your remark. The high content of mixed anthropogenic material (animal bones, pottery fragments, and terrace building material fragments) at Pe10-30/4 led to an incorrect determination and interpretation of the horizon at this level. The terrace serves both agricultural and domestic functions, which is evident in the high level of reworked material. Based on field observations, macromorphological data, and available analyses, we propose to reassign the profile sequence as follows: Ap1, Ap2, Ah1, Ah2, C. It will be explicitly stated in the manuscript that all horizons in this profile are particularly diffuse. This distinction is supported by the attached data analysis, where the variations are very subtle. The Ap1-Ap2 and Ah1-Ah2 blocks can be grouped by their clay content and soil skeleton content as distinguishing features.
R1.17: Supplementary Table S1: Pedochemical analysis. Why are commas used and not periods as separators for numbers?

A1.17: You are correct. Indeed, periods should be used consistently as the default separator for numerical decimal information throughout the manuscript, including figures, tables and appendices.

R1.18: [cmolc Ca2+/kg]. Hereinafter, valences must be in upper case (Excel will allow you to do this). Ca^{2+}

A1.18: You are right. In the revised manuscript, the valences will be written in superscript.

R1.19: The authors show Munsell color (moist). This is “field” humidity, which will change color at different sites and at different Depths. In this regard, comparability can be maintained by giving Munsell color (dry). The reviewer recommends that the authors, if such data are available, provide a replacement.

A1.19: We appreciate your feedback and the opportunity to clarify the procedures applied. The colour determination of soil sediments was conducted under laboratory conditions following specific protocols. To ensure consistency, several measures were taken, including using the same amount of homogenized soil substrate, maintaining consistent diffuse lighting conditions, utilizing the same edition of the Munsell Soil Colour Charts book (Munsell Color, 2000), and applying the same amount of water through a water sprayer to achieve a low level of moisture in the sediment.

Due to logistical and staffing constraints, conducting a new determination of this parameter in the laboratory is currently not feasible. However, we believe that the procedures outlined above adhere to the standards for laboratory measurements in soil science. We will enhance the methodology section in the revised manuscript with a more detailed description.

R1.20: The authors create confusion with the designation of carbon: C [%]; Corg, Ctot/N (Compare to L 290: «The carbon/nitrogen (C/N) ratios)»

What is the difference between C and Corg, and where does Ctot suddenly appear? (the C and Corg data differ slightly, is this due to different determination methods?). The text indicates DIN 19684-2, 1977 and CNS analyzer vario MAX (and if the values turned out to be close, what does this add scientifically?).

A1.20: We appreciate your constructive comments in this section and apologize for any confusion caused by misunderstanding of terms.

Both C [%] and Ctot [%] refer to the total carbon fraction within the soil sample, measured by elemental analysis through the CNS analyzer, encompassing both organic and inorganic fractions. To avoid confusion, future references will only use C and not Ctot. Corg specifically denotes the organic carbon fraction of the soil, determined by photometric measurement at

590 nm using a spectrophotometer via the wet combustion dichromate method. Both C and Corg are expressed as percentages.

These complementary methods (elemental analysis and wet combustion) enable a thorough interpretation of the pedogenetic process intensity. The Corg content primarily reflects pedogenetic processes, while the inorganic carbon content (Cinorg) offers insights into the nature and composition of the source rock. The inorganic carbon content is derived by subtracting the organic carbon content from the total carbon content (C - Corg = Cinorg).

Samples where the C and Corg values are almost identical, particularly in soils developed over carbonate-free parent material, underscore the intensity of the pedogenic process.

R1.21: Typically, the ratio Ctot/N is the same as Corg/N, and more elegant (by default, they write C:N, rounded to whole numbers (under a well-known rating scale).

A1.21: The Ctot/N ratio will be written as C:N. However, as the ratios within the profiles sometimes vary only slightly, we have chosen to present the ratios to one decimal place.

R1.22: If in the 1st line OM = 2.1*0.579=1.216 Corg, but not 1.0. It is necessary to clarify how the transition from OM to Corg was made (and in principle, Corg alone (without OM) would be enough).

A1.22: Thank you for your comment. To obtain the OM value indirectly, we follow the procedures for soil analysis as cited by ISRIC (van Reeuwijk, 2002, p. 23) and Barsch et al. (2000, p. 344). These procedures recommend converting organic carbon (%) to organic matter (%) by multiplying with the empirical factor 2, especially when specific information on the organic matter is unavailable (Nelson and Sommers, 1982).

References:

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