We would like to thank to the reviewers for the careful assessment of the manuscript and the helpful suggestions to improve the quality of our work.

We detail below each of the reviewer's comments and how we plan to address those suggestions in a revised version of the manuscript that we have not uploaded by the time of closing the period for posting comments due to the lack of time to prepare a convenient review. For the shake of clarity, the original comments by each reviewer are between quotation marks.

Reviewer 1

"**General comments**: *The manuscript is a case study in Spain to compare the variation of SOC, soil quantity indicators and isotopes induced by land-use change and erosion issues. The subjects addressed here were clear and worthy of investigation. Authors have chosen appropriate indexes (e.g. OC fractions, N, P et al.) to illustrate how olive orchard use coupled with soil erosion degrades soil quality, however, the data mining/ interpretation is insufficient and need to dig into further. In addition, the way of presenting results (Figures and Result section) are not well-structured and need to be reorganized*." After reading the reviewer's comments we agree that the dataset deserves a more thorough analysis in the manuscript, part of which was done but was discarded (erroneously) trying to have a clearer manuscript. In addition, data presentation can be organized by combining several bar charts into one using bars of different colours and textures.

"**Comment 1:** *Firstly, there are too many figures (29 figures) which are quite information poor. I highly recommend authors to reshape and combine some of them. For example, combine four individuals of Fig.3 into only one by a stacked bar chart (see attached Fig.1 as an example). Also, try to combine Fig. 2 A and B (Fig.2 as an example). Hopefully, it can reduce the number of figures from 29 to c. 11."*

We have combined Figure 2a and b into a single Figure 2 combining the 4 bars into one graph. For Figures 3a, b, c, d and Figures 4a, b, c, d, the four bar charts of each Figure have been merged into one distinguishing among treatments and depths using different colours and textures. For Figures 5a, b, c, d and Figure6a, b, c, d, the four bar charts in each one have been combined into one using a cumulative bar chart.

"Comment 2: *Secondly, a good dataset has been created in the manuscript but it is not deeply explored yet. Except for ANOVA, there are many statistics that would help out (e.g. PCA, correlation et al.). Why not try to correlate erosion/deposition rates with SOC or soil quality variables. In addition, authors have made ANOVA on reference vs orchard and orchard erosion vs orchard deposition, please give a further try to find a tendency on reference vs deposition if there are any.*"

Additionally, have expanded this analysis performing an exploratory analysis using PCA using the evaluated soil properties comparing the two areas within the olive orchard (eroded vs. deposition), complemented with a correlation analysis between the variables identified in this exploratory analysis and erosion/deposition rates in the orchard area.

“**<u>Comment 3:</u>** *Thirdly, please reorganize and give the subtitles for the Results section to make it clear and readable for audiences.*“

We have reorganized the results and discussion sections using clear subtitle names to facilitate a more clear reading and understanding.

“ **<u>Additional minor comments</u>**”

“**<u>1.</u>** *L130 L170 How did you define unprotected, physically, chemically and biochemistry protected C? POM is unprotected C, iPOM physically protected C? Please clarify in Material & Method.*”

We agree with the reviewer comment. In the revision version of the manuscript we have clarified the definition of SOC fraction. We have added the following sentences: (lines 139-141) This three-step process isolates a total of 12 fractions and it is based on the assumed link between the isolated fractions and the protection mechanisms involved in the stabilization of organic C (Six et al., 2002) (lines 155-159) The unprotected pool includes the POM and LF fractions, isolated in the first and second fractionation steps, respectively. The physically protected SOC consists of the SOC measured in the microaggregates. It includes not only the iPOM but also the hydrolysable and non-hydrolysable SOC of the intermediate fraction (53–250 µm). The chemically and biochemically protected pools correspond to that hydrolysable and non-hydrolysable SOC in the fine fraction (< 53 µm), respectively. In addition, we have added how organic carbon concentration was measured in the SOC fractions: (lines 159-161).

“**<u>2.</u>** *L120 Authors collected 13 micro pits from reference sites and 8 pits from olive orchard sites. Then you created one or three composite samples for fraction/isotopic measurement or measured all micro pigs as repeats?*”

We thanks to the reviewer for this comment, which has helped us to realize that there are unclear sections in the manuscript that need to be clarified. In the olive orchard area (8 points for core samples) we treated each point and depth as a single unit for all the analysis (fraction, isotopic, …). In the reference area we sampled 13 pits and all of them were used for the isotopic analysis of ^{137}Cs, as it is shown in Table 1, while only 4 of them were used to determine the carbon fractions, and δ 15N and δ 13C isotopic analysis. This has been made clearer in the material and method section, lines 121-133.

“**3.** *L155 Please indicate the method you measuring bulk density, which was used in table 5.*”

Soil bulk density in Table 5 was measured using a hand cylindrical core sampler with a volume of 100 cm^3 (lines 175-176 of the revised version of the manuscript).

“**4.** *L205 Authors mentioned that “protected Corg in the reference and olive orchard area account for 87% and 64% of maximum soil stable Corg, respectively at the topsoil”, it means reference area has a higher percentage of protected SOC than that of an olive orchard. This tendency is contrary to what has shown in Fig.5. How do you explain it? Please detail the way* *you calculated maximum soil stable Corg in Material & Method (insert equation for example?)*".

1.- As mentioned in line 228, maximum capacity to stabilised SOC in the reference and olive orchard sites was estimated according to Hassink and Whitmore (1997). According to this model, the theoretical value of protected SOC (g C kg $soil^{-1}$) is calculated as = 21,1 + (clay content (g kg^{-1} soil) x 0,0375. Considering that there were not significant differences in the soil clay content along the catena in the olive grove soils, the average theoretical protected SOC (%) is 3,63±0,19, whereas in the reference site averaged 3,24±0,11. According to these new values, protected soil Corg in the reference site and orchard soils accounted for 49.8±11.5 % and 20.5±5.2 % of the maximum soil stable C_{org}, respectively at the topsoil. This has been noted in lines of the revised manuscript 303-305.

Figure 5 shows the contribution (in %) of the different fraction to the total soil organic carbon. Most (about 78 %) of the total SOC in the olive groves soils is protected, however because total SOC is relatively low in these soils (about 0.9 %), the concentration of protected carbon is relatively low (about 0.7 %), especially compared to the maximum theoretical value of protected SOC (3.63 %). In the reference site, the contribution of the protected SOC respect to the total SOC is much lower (about 35 %, as most of the soil organic carbon in unprotected), but because total SOC concentration is high (about 4.9 %), the concentration of protected carbon is higher (about 1.7 %) than that of the olive grove soils, and much closer to the maximum theoretical value of protected SOC (3.24 %) than the olive grove soils.

"**5.** *(L20 L300) authors suggested using δ15N as a proxy to identify degraded areas; does annual input of 5 kg N-P fertilizers play a role in the dynamic of δ15N?"*

We agree, and in the revised version of the manuscript the influence of the NP fertilizer in modifying the δ15N in relation to the reference area, probably with an slight enrichment see Alison et al. (2007), need to be considered too, lines 324-327 of the revised version of the manuscript.

Alison S. Bateman & Simon D. Kelly (2007) Fertilizer nitrogen isotope signatures, Isotopes in Environmental and Health Studies, 43:3, 237-247, DOI: 10.1080/10256010701550732

"**6.** *Please also note the supplement to this comment: https://www.soil-discuss.net/soil-2019-59/soil-2019-59-RC1-supplement.pdf*"

We have checked the comments made in the annotated version of the manuscript and these indications will be incorporated in the revised version of the manuscript.

Reviewer 2

"**General comments:** *This paper focuses on the impact of long-term erosion and deposition processes on different soil parameters, especially bulk soil organic carbon and its fractions, within an historical olive orchard in Andalusia, Spain. The purpose of this study is worthy giving the importance of olive orchards and intense erosion processes in Mediterranean region. The soil parameters used to illustrate the impact of land use and erosion-deposition processes on soil quality have been well chosen. However, I have many concerns about the methodology, the data analysis, and the structuration of the manuscript. Different points of the 'materials and methods' section should be completed and more detailed as the sampling method and the method used to calculate the Corg stocks. Also, how the samples of the reference site were used in the data analysis is fuzzy to me. You'll find my related questions/requests in the specific comments below. Whereas the authors chose well the parameters to study here and gather an interesting dataset, this latter seems insufficiently analyzed. I agree with referee #1, the authors should dig a bit further and try to better synthetized the results via fewer but more synthetic figures. Moreover, I have some serious concern about the way the Corg stocks and saturation capacity have been computed and treated. The authors could review the 'results' and 'discussion' sections accordingly to new data analysis and figures. Please, could you better structures these sections and add sub-titles? Please, find some specific comments and technical corrections below.*"

We have expanded the details on methodology and sampling, e.g. giving more details on the sampling equipment, calculation of the Corg stocks, etc., and improve the clarity of the data analysis following the recommendations of the three reviewers. Additionally, we have re-checked the calculations on the Corg stocks and saturation capacity and structured the results and discussion sections also including subtitles to facilitate the reading.

"**Comment §2.1 'Description of the area'**: *As the study focuses on an erosion-deposition soil catena, an elevation map of the olive orchard or a topographic profile of the sampled transect locating the soil profiles could be appreciated.*"

We have provide in the revised Figure 1 a transect showing the elevation of the sampled areas and an elevation map including the orchard and the reference area.

"**Comment §2.2 'Soil sampling'**: *The authors specified in the text that the reference site was sampled per 5 cm increments whereas the olive orchard was sampled per 10 cm increments. How did the authors compute values of soil parameters in reference site for the 10 cm increments? All the results presented in the results section concerned the 40 first cm of soil. The reference site was sampled 'until bedrock was reached (i.e., 0-5, 5-10, 10-15, 15-20cm). '(l.119-120). Does it mean that the number of sample by 10cm increment in reference site is not constant? If the bedrock can be reached at 20cm within the reference site, what are the implications for the olive orchard especially in eroded areas? What are the implications on the rock fragment content in the samples and the computation of the Corg stocks?*"

The sampling in the reference area was done manually at 5 cm depth intervals (e.g. 0-5 and 5-10 cm) and the samples were integrated to perform the analysis at 10 cm intervals (e.g. integrating 0-5 and 5-10 cm into one for 0-10 cm). We found a mistake in lines 119-120; the reference area was sampled until reaching bedrock which was located at least at 40 cm in all cases. The carbon, δ13C and δ15N analysis comes from samples from four of these pits, while the ^{137}Cs analysis comes from the 13 pits. In all these pits bedrock was below 40 cm depth. Carbon stock calculations were made for the fine soil fraction (< 2 mm) after discounting rock or stone fragments larger than 2 mm and considering soil bulk density measured using the hand cylindrical core sampler with a volume of 100 cm^3. All these have been revised in lines 121-131, and 175-176, with changes marked in red.

"**<u>Comment 3:</u>** *Could you specify somewhere what are the final numbers of values analysed by 10cm increments in the reference site and in the olive orchard please?*"

Yes. In the revised version of the text we have included the information requested by the reviewer. The number of soil samples for each 10 cm increments was 4 and 8 from the reference area and olive orchard, respectively. It is in lines 134-135 of the manuscript.

"**Comment 4:** *The sampling was performed by a mechanical soil core. Was it a percussion drilling machine? Was there any soil deflection/compaction of the samples due to the mechanical drilling, i.e. was there any consequence on the depths of the soil increments?*"

The mechanical soil sampling was made with a hydraulic core sample which gently rotates and push the core, and with the soil at a moisture content between 40 to 80 WHC, and therefore we did no need to hard drilling the soil, minimizing the compression of the soil samples. The sampling was made properly, insuring that the whole sample was taken for each given depth, abandoning the point and starting a new one if some problem arose (like a sample being only partially taken). A better explanation of this and the model of core equipment used have been included in the revised version of the manuscript, lines 121-130.

"**<u>Comment 5:</u>** *The Corg stocks were calculated in the study. How exactly? Did you assess the soil bulk density based on the volume and mass of the soil increments? What about the rock fragments?*"

Soil carbon stock were calculated for the fine soil fraction after discounting rock or stone fragments larger than 2 mm, and considering bulk density, and it has been clarified in lines 176-178 of the revised manuscript. .

"**<u>Comment §2.3 'Physico-chemical analysis':</u>** *Corg concentration were determined according to Walkley and Black method. Did you apply a coefficient of correction to the raw data in order to take into account for the incomplete oxidation? This correction factor may vary from 1 to 1.6 depending on land use, soil texture, organic matter quality, sampling depth or climate. You compare two sites with different land uses, texture and organic matter quality (as highlighted by the fractionation results), and different depths.*"

We thanks to the reviewers for this comment, as we have detected a mistake in the reference we used regarding the method for SOC determination. In all cases, SOC fractions and in the bulk soil, organic carbon concentrations were determined by using the wet oxidation sulfuric acid and potassium dichromate method of Anderson and Ingram (1993). We have corrected this in the revised version of the manuscript, lines 159-161.

"**Comment:** You determined the theoretical values of stable carbon saturation based on the soil particle analysis. Could you specify exactly which model you used, with the values of the parameters, please? (See my comments below concerning the results section)."

See answer to this concern in result section below

"**Comment §3 'Results':** *l. 197-199: A more correct way to compare soil Corg stocks between different land uses is on equivalent soil mass.*"

We have compared the reference area and the olive orchard in equivalent soil mass following the procedure describe in Wend and Hauser, 2013. An equivalent soil mass procedure for monitoring soil organic carbon in multiple soil layers. European Journal of Soil Science doi: 10.1111/ejss.12002 , 2013. This appears in the revised Figure 7 and in lines 221-225 of the revised manuscript.

"**Comment. 200-204:** *did you invert in the values of texture distribution between the reference and olive orchard sites? If you have estimated the theoretical values of stable carbon saturation based on the content of particles <2µm (l. 205), the olive orchard should have a higher potential than the reference site according to the clay contents proposed here, i.e. 41 and 30% in the orchard and reference site respectively. Concerning the values of theoretical stable carbon saturation, could you precise the model used to compute them please? The values you proposed (i.e., 1.94 and 1.15%C; l.205) can't be achieved based on the model a proposed by Hassink & Whitmore (1997) in the Table 4.*"

We thank the reviewer for his comments on this topic as we have detected errors on our calculations regarding the theoretical values of stable carbon saturation. As reviewer has detected, the olive orchard soils have a higher potential than reference site. We have applied the model of Hassink & Whitmore (1997). According to this model, the theoretical value of protected SOC (g C kg soil^{-1}) is calculated as = 21,1 + (clay content (g kg^{-1} soil) x 0,0375. Considering that there were not significant differences in the soil clay content along the catena in the olive grove soils, the average theoretical protected SOC (%) is 3,63$\pm$0,19, whereas in the reference site averaged 3,24$\pm$0,11. According to these new values, protected soil Corg in the reference site and orchard soils accounted for 49.8$\pm$11.5 % and 20.5$\pm$5.2 % of the maximum soil stable C_{org}, respectively at the topsoil. After this amended, conclusions have not changed respect to the first submitted version of the manuscript. In the revised version of the manuscript we have corrected the data: (lines 225-232).

"**Comment §4 'Discussion'**: *l. 276: the value is 1.19 or 1.15%C as proposed line 205?*"

Reviewer is right on this issue, and we are deeply sorry on our errors on the calculations. The correct value is (3.64$\pm$0.23 %) and we have amended in the revised version of the manuscript: (lines 303-305) In fact, the protected Corg concentration in the topsoil of the olive orchard in the eroded area is about the 18.6±3.9 % of the upper limit of protected Corg (3.64±0.23 %) according to the model of Hassink and Whitmore (1997). This has been corrected in lines 228-232 of the manuscript.

"**Comment l. 278-280:** *here, the authors affirmed that the land degradation reduced the soil capacity for Corg stabilization. If the authors well used the model fitted by Hassink and Whitmore in 1997 ('As proposed by Hassink and Whitmore (1997), theoretical values of carbon saturation were established from the soil particle analysis' l. 158-159), they know that basically the model is in the form : X = a * clay content + b with X the soil capacity for Corg stabilization, a and b some constants. As the soils in the reference and in the olive orchard have different clay content, they have different capacity for Corg stabilization! Here, it is like the authors were affirming that the land degradation has changed soil texture… I need more explanation and proof, please.*"

We agree with the reviewer. This sentence has been deleted in the revised version of the manuscript.

"**Technical corrections Figure 1:** *Please, could you add bar scales or precise the olive orchard size in the part §2.1?"*

Yes we have included scale bars for the views in the revised Figure 1.

Reviewer 3

"General comment: *This study examines changes in selected soil properties (SOC and SOC fractions, P available P and organic N) related to soil quality and explores the application of stable isotopes as indicators of soil degradation (13C and 15N) in an Calcic Cambisol under different land uses (open Mediterranean forest and orchard) in the southwestern region of Spain. Further, authors evaluated changes in the mentioned soil properties and water stable aggregates due to soil redistribution processes comparing eroded vs depositional sites within the olive orchard (areas previously identified by 137Cs technique). Please see below some comments: "*

"**Comment 1:** *Line 23 deposition is non degraded?"*

Yes, that is our hypothesis. We will clarify this in a revised version of the manuscript, line 24

"**Comment 2:** *Clarify Lines 22-25 I miss results concerning 13C*"

We have added one line concerning δ 13C results in the revised version of the manuscript, lines 20-23.

"**Comment 3, Line 31** *Although is a text extract with meaningful information. I suggest "which seeks to increase global soil organic matter stocks by 0.4 percent per year as a compensation for the global anthropogenic C emissions" Lines 33-34 split the paragraph into two sentences.*"

Yes we have edited and divided this section into two sentences in a revised version of the manuscript, lines 30 to 32.

"**Comment 4: Line *41*** *This part seems disconnected from the previous one (soil degradation & soil quality). I suggest move this part to line 41 "Olive cultivation has been linked to severe environmental issues including the acceleration of erosion and soil degradation (e.g. Beaufoy, 2001, Scheidel and Krausmann, 2011). In fact, soil degradation is ... (Gómez, 2014).*"

We agree with the comment. We have edited this section in this way which looks more straightforward, lines 41 to 43.

"**Comment 5: Line 51** *what is the reason for?"*

It also combined cultivation in very steep slopes and areas of high rainfall erosivity. We have edited this sentence to include this evaluation in the revised version of the manuscript, line 50.

"**Comment 6: Lines 85-89?** *Please rewrite to improve the readability of the text Line 85 It would be very illustrative to include the 137Cs reference value and sd Line 109 State exactly the plant species (shrubs and annual grasses)."*

We have include the 137Cs reference which as reported by Mabit et al. (2012), based on 13 soil profiles investigated, the initial ^{137}Cs fallout in this undisturbed area was evaluated at 1925 ± 250 Bq m^{-2} (mean ± 2 standard error) with a CV of 23 %, lines 82-84 of the revised documents. We have also included a list of the most common shrubs and annual grasses in the study site in lines 109-112 of the manuscript.

"Comment 7 Line 120 *Specify number of soil profiles deeper than 20 cm; excavation method is diddretn than mechanical method for soil sampling? Please include type of core sampler (automatic or manual soil core sampler)."*

We have revised revise the manuscript to clarify the sampling method and the number of soil profiles. In the reference area the sampling was made through manual excavation while in the olive orchard the sampling at 10 cm interval was performed using a hydraulic core sample which gently rotates and push the core. Soil moisture content was the adequate to avoid hard drilling the soil. This minimizes the compression of the samples. The sampling was made checking that the whole sample was taken for each given depth abandoning the point and starting a new one if some problem arose (like a sample being only partially taken). The bulk density values shown in Table 5 were obtained using the hand cylindrical core sampler with a volume of 100cm^3.

Regarding the number of samples and depths, there is a mistake in lines 120-122. The reference area was sampled until reaching bedrock which in same case was above 60 cm. In the case of the pits used for the carbon and isotopic analysis, 4 out of 13 were used, while all the 13 pits were used for the Cs137 analysis. In all cases these 13 pits reached 40 cm depth. Therefore, for the carbon and isotopic N and C analysis there were, for each soil depth (0-10, 10-20, 20-30, 30-40 cm) four replications in the reference area and 8 replications in the olive orchard.

All the revised text appeared in lines 120-135, and 173-175, with changes marked in red.

"**Comment 8: Line 125** *A similar table for the two reference transects could be included (^{137}Cs inventories since SRR are not applicable in ref site)."*

We have added Table in the supplementary material indicating the^{127}Cs inventories of all the points in the reference area as well as their coordinates, indicating the four one used in the analysis. Additionally we have included the average *^{137}Cs inventories* of the reference area in lines 83-85 of the revised document.

"**Comment 9:** *Line 139 with sodium polytungstate "*

This misprint will be corrected in the revised version of the manuscript, line 149.

“**Comment 10:** *Line 145 Explain in detail acid hydrolysis procedure: acid attack (acid concentration, time, temperature) and preparation for carbon analysis. Include a reference of the method.“*

As we mentioned in the material and method section (Physicochemical analysis) we have applied the method of Six et al. (2002) and modified by Stewart et al. (2009). Acid hydrolysis, described by Plante et al. (2006) consisted of incubating the samples (The silt+clay-size fraction from both the density flotation of the 53 – 250 µm fraction and the initial dispersion and physical fractionation of the < 53 µm fraction) at 95 oC for 16 h in 25 ml of 6 M HCl. After hydrolysis, the suspension was filtered and washed with deionized water over a glass-fiber filter. Residues were dried at 60 ºC and weighed. These fractions represent the non-hydrolyzable C fractions. The hydrolysable C fractions were determined by difference between the total organic C content of the fractions and the C contents of the non- hydrolyzable fractions. We have added this information in material and method section. All has been revised in lines 155-161.

“**Comment 11**; *Line 163 Clarify the number of soil samples at similar soil depth and considered for statistical analysis Line 174 fractions Line 206 topsoil is 0-10 cm?”*

It has been clarified in the text, clearly stating that for the carbon and isotopic N and C analysis there were, for each soil depth (0-10, 10-20, 20-30, 30-40 cm) four replications in the reference area and 8 replications in the olive orchard. In line 206 top-soil means 0-10 cm, this will also be clarified. Lines 134-135.

“**Comment 12***: Lines 212-216 This part should be extended and explained in depth.*”

We have revised this part expanding this explanation, text in red in paragraph between lines 359-362.

“**Comment 13***: Line 294 I consider there is no evidences from results for this statement (indicate selective deposition of soil aggregates). Please revise*”.

We have edited this section deleting this sentence.