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Discussions

Interactive comment on "The impact of road and railway embankments on runoff and soil erosion in eastern Spain" *by* P. Pereira et al.

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General comments:

This article deals with a topic of widespread relevance to readers interested in soil erosion, water quality degradation, runoff development, and the effects of land development (roads in particular) on hydro-geomorphic processes. I commend the authors for their detailed-accounting of their work and findings described in this paper. There is no doubt in my mind that this article may be accepted for publication after some changes, but I would like to invite its authors to consider my recommendations for improving its readability and some of its analyses. I will provide detailed comments and recommendations below but most of these can be summarized in these few points.

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Answer: Dr. Carlos, thank you very much for the time that you dedicate to this revision. We appreciate your comments and revisions to your paper. We all agree that your suggestions helped to increase the paper quality.

First, it would be useful for the paper to provide a better understanding of what are the particular issues related to runoff development and erosion in this region of Spain. What was the driver for this, and all other runoff-erosion studies, that have been conducted in this area. There is a hint of an issue related to flooding and accumulation of sediment, but these are mentioned in the conclusions. I strongly recommend adding some text commenting on the justification for the study from a water resources, ecologic, and/or infrastructure perspective, and/or whatever another theme that might be relevant or important.

Answer: Thank you very much for raise this question. To be honest, we think that we have made a good literature revision about the impacts of railway and road embankments, because it is this the objective of the paper, and we mentioned why it was relevant in this region of Spain. Here very few studies were carried out on the impact of road and railway impacts in this area of Spain. This is already a good justification to carry out this work. Yes, we mentioned about potential problems related to flooding and sediment accumulation. If you see the introduction with attention in the page 12951 line 2 we mentioned that "This infrastructure created embankments and cut slopes, and little is known about the erosional response of these areas to rainfall and the disturbance they induce in their ecosystems, both on and off site." From the infrastructure perspective we mentioned in the page 12951-12952 that "In the Mediterranean, insufficient studies have been carried out on soil and water losses along roads, despite the fact that it is widely accepted that they contribute high yields of sediments and water". This justifies our work.

Secondly, there are too many details and the main findings are hard to extract. These become a bit clearer in the discussion section but still I believe that they are not properly highlighted. Part of the problem might be the large number of dependent variables that

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the study is trying to explain. I believe that some of the crucial ones that merit special attention are total runoff & runoff coefficients, steady state infiltration capacities, and soil erosion rates. The other dependent variables discussed I believe are secondary to these and do not add too much to the physical understanding of runoff and sediment generation.

Answer: We remove the regression analysis from this version of the paper because as you mentioned the study design would not allow studying embankments covered and uncovered by vegetation. We agree with this. The work now is better. In addition, the number of experiments carried out in scrubland and citrus plots, would not produce a realistic model. Together, the models were very good, but if analyzed individually, the performance was not the best and these results

Third, the presentation of data is concentrated in tables which is ok, but the paper might benefit from displaying some of these as graphs. For example, basic comparisons of runoff coefficients displayed in a column-style (bar) graph by surface type will help drive the point that more runoff is generated from embankments than orchards and shrubland, in addition to providing an easily interpretable idea of the magnitude of the differences. Also, since the data is already presented in a table format, addition of these values within the text is unnecessary and makes it more difficult to read.

Answer: We believe that the data shown in the tables can resume very well the information and reduce the length of the paper. We deleted the F and K-W from the paper and the average and standard deviation.

Fourth, a potentially clear format to present the statistical analyses (the regression analyses in particular) and key findings might be to have these laid out explicitly as equations. Runoff = f (X, Y, Z). These might be embedded between paragraphs or in a table format but this could serve as a way to make the findings more clear.

Answer: We removed the regression analysis from the paper.

Fifth, the authors make the point that vegetation cover is the key factor controlling runoff and erosion, but the study design does not allow for isolating this factor from the potential effects of slope, coarse fragment abundance, bulk density, etc.

Answer: Soil organic matter and vegetation are the aspects that more contributed to reducing the runoff. The objective of the study was to compare the impact of road and railway impacts in the variables studied in relation to the most common land uses in the studied area. It is true that we did not study embankments with high vegetation cover, however, if you look at the descriptive analysis and PCA you can see that the behavior of the variables is different in each of the studied areas. Areas with high vegetation cover and organic matter are associated with high times to runoff, time to ponding and steady state-state infiltration. In opposition, they show a negative correlation (opposite side of the figure 3a in the first draft) with the sediment content, bare soil, sediment yield, etc. . ...

Lastly, there might be a bit of over-citation. I recommend reducing the number of citations listed whenever possible, as oftentimes the long interruptions associated to these got in the way of the flow of the article. I would not mind revising an edited version of this article if the editor deems it is necessary.

Answer: We deleted many citations

Detailed comments

Abstract:

Line 6: Including transport and deposition in this sentence hints that these will be attended to in this study, but they are not. Consider deleting these.

Answer: We deleted

Lines 13-15: Numbers within parentheses might be unnecessary here.

Answer: We deleted

Line 15: …more active…Instead consider higher, faster.

Line 16: Are these in order from highest to lowest? Somehow explicitly state so here.

Answer: Yes

Line 16: The term 'non-sustainable' might have some implications (e.g., soil productivity) that are not relevant to this study. Replace with a more relevant term or delete.

Answer: Thank you very much for your comment. However, we think that that the erosion levels identified here were not sustainable since soil erosion is considered as a loss of a soil service, independently of the place where it is located. In this case, soil erosion may be one of the causes of the difficulty for vegetation establishment. So, it is a loss of productivity, not in the agronomic term.

Line 17 & 22: Units should be Mg ha-1 hr-1, right?

Answer: Thanks we changed.

Line 18: "runoff connectivity" This term in itself is full of ambiguity although there have been many attempts to define it. None of the terms I am familiar with allude to your suggested use particularly in such a small area. I strongly encourage to not try to explain the short time frame between ponding and runoff yield by using this term.

Answer: Thank you very much for raise this question. Runoff Connectivity occurs at several scales, including plot scale. Even at small scale is a process that can be measured and observed as we have done in this work. Basically is the time that the water takes to go from a place to the other and this can be observed at plot scale, independently of the size of the study area. Low times to ponding and high runoff and especially short time of Time to runoff-time to ponding is an evidence of high connectivity.

Introduction

Line 1: instead of 'are' use: ': : :have been heavily influenced by humans for millennia.'

Answer: Changed

Line 7: There roads 'likely' resulted?

Answer: We changed to "The construction of these roads…"

Line 8: There seems to be an abrupt shift from historical road network development to modern without an appropriate transition.

Answer: We added "In the present" as transition.

Line 14: I much rather being the introduction with this paragraph and only have a brief reference to historical landscape alteration.

Answer: We do not understand what you mean by this comment. We believe that we have done a brief historical context of the topic

Lines 19-25: Reduce the number of citations.

Answer: We reduced

Line 25: Delete: ": : :as we will demonstrate here."

Answer: Deleted.

Line 27: Not clear what is meant by roads creating new 'landforms'… erosional features, a steep scarpment?. Also, reduce number of citations. Somewhere in here there should be an explanation as to why this is important in this region of Spain.

Answer: Thanks for your comment. We mean that roads create new landscape features (geoforms or landforms)…We explained in the text why it is important in Spain why road and railway embankments impacts in Spain are important.

Line 4, p. 12951: What is meant here by 'ecosystem'? The embankment?

Answer: We mean in the ecosystems where they are constructed

Line 9: This seems to be discussing work done elsewhere (not in Spain).

Answer: In Spain there is not so much work carried out on this topic. We think it is important to give some background about the previous works in other regions of the world.

Lines 9-16: First, many citations make reading this paragraph difficult. Second, not clear to me what the point is here. Have any of these studies quantified the role of embankments and compared these to other portions of the road prism or other eroding surfaces? Make a quantitative assessment of the importance of embankments as sediment sources in other studies.

Answer: We reduced the number of citations. These works have studied the impacts of road embankments in soil erosion, and this is what we want to show here. We want to point also that road embankments study have been neglected in comparison to other works.

Lines 17-25: The combination of references from Spain with those from abroad make understanding this paragraph difficult. Stating that little quantitative information exists on erosion from embankments and in the effectiveness of erosion control practices should be stated more concisely. What are 'exact quantifications' and why do you need them to implement erosion control strategies?

Answer: We rephrase this part and we separate the studies carried out from Spain and the others carried out abroad. We changed "quantifications" for "studies". We need to implement erosion control strategies to reduce the soil erosion in road embankments

Line 28: "...are or even bare..." Awkward wording.

Answer: we changed to " or bare"

Lines 28-29: Sentence seems to be repeating what has been stated previously.

Answer: We agree with you. We delete it.

Page 12952; Line 1: This contradicts what you have mentioned previously that little

work has been done.

Answer: When we mention that there are few studies, we refer to road embankments.

Lines 4-7: What is the rationale behind these comparisons? Is shrubland meant to provide a 'control'? Why the comparison with citrus plantations? Also, you may explicitly state that this is being done by way of rainfall simulations and at a small plot scale.

Answer: The idea behind this comparison is to identify the impacts of the soil characteristics and erosion values with the most common landscape in areas. This allows us to access the impact induced by road and railway embankments in this area. We mentioned in the materials and methods because we think is the place where the methods should be described.

General comment on intro section: It might be useful here to begin setting up your study design here by citing references that provide a backdrop to the factors you consider to be important in runoff and erosion.

Answer: We mentioned it in the materials and methods

Materials & methods Section 2.1.

Line 13: Why are citrus sites considered 'reference' sites?

Answer: citrus and shrubland are considered reference sites because is the areas which we are comparing the data obtained in the railway and road embankments. Before beginning to describe which site characteristics you measured, it is necessary to have previously justified them by indicating that these have been found to control erosion rates by other studies. This can be done in the intro section.

Answer: We would like to highlight that these areas were not considered control.

Line 25: Are these bounded plots? A picture of one of these setups would be useful. Also, pictures of all of the four surface types would also be useful.

Answer: Yes. There are bounded plots. We added a picture of the rainfall simulator used in this work.

Page 12953; Line 1: How did you control precipitation intensity to be equal for all of your runs? Did you measure precipitation onsite? This paragraph should be shortened.

Answer: We calibrated in the laboratory. Please see the Cerda et al. 2016. The paragraph is describing the methodology we think it should have a detailed explanation.

Lines 15-17: What does 'higher' imply here? This last sentence seems unnecessary.

Answer: We agree. We deleted the sentence.

Line 18: How did you measure runoff? Line 20: Calculation of sediment yields is not clear. What is meant 'weighing'? I assume you multiplied sediment concentration by runoff rate, but that does not come clear here.

Yes, weighing means that the sediment yield was assigned to a period of runoff (already explained in the text how we did the runoff and sediment sampling) and we weighed them to calculate the soil erosion

Answer:

Line 29: Term 'connectivity' here. As described above, it is problematic.

Answer: Thanks for the suggestion, but we think that the term connectivity is correctly employed here, since the difference between the time to runoff and the time to runoff at the outlet measures the connectivity, even it is at small scale.

Page 12954; Line 1: How was total rainfall determined? Line 3: Not clear what the Horton equation refers to here.

Answer: with a pluviometer in the field. The Horton equation is mentioned in Cerda (1996).

Lines 4-5: Why go back to describing how sediment yield was calculated.

C6770

Answer: We deleted. We agree.

This method section would benefit from editing to make it more orderly and shorter

Answer: We shortened were you suggested us to do it. We agree with you.

Section 2.2 Line 6: All data? All dependent and independent variables?

Answer: We mean all data analyzed.

Line 10: 'The remaining variables: : :' Not clear what is meant here. All variables must be clearly stated at some point within the text or in a table.

Answer: We added the "remaining variables"

Page 12955; Section 3.1;

Lines 11-20: I would delete all values in parentheses. The statistical significance requirements have been stated previously so there is no need to give the actual F and p values. Also, the values for the variables are already shown in Table 1.

Answer: We deleted.

Section 3.2; page 12956; Why a different section for these? Include as 3.1? Line 1: Soil moisture represents conditions existing prior to the experiment, right? Clarify.

Answer: We divided this because the variables described in 3.1 are related to soil cover and the 3.2 with soil properties and terrain characteristics. As far we remember this was discussed with the editor in the first submission and we agreed with her suggestion.

Lines 1-15: Delete all values as these are already shown in Table 2. Line 6: Delete 's' so that it reads 'content'

Answer: We deleted

Section 3.3 Line 20 (and elsewhere): There appears to be too many significant figures in some of these values.

C6771

Answer: Please accept our apologies, but we do not understand your comment.

Line 26: ': : :prevented allow runoff generation." Awkward wording. Delete 'allow'?

Answer: Thank you. We deleted "allow".

Page 12957;

Line 4: Delete 'c' so that it reads 'shrublands'

Answer: Deleted

Section 3.4

Line 8: Significant instead of Significantly? Showing some of these results in a graphical format (column chart) would be useful. Answer: Changed

Section 3.5 Lines 24-Page 12958, Line 2: The wording of these two initial sentences make understanding your key finding difficult. Basically, all dependent variables were well explained by the combination of controlling factors you considered.

Answer: We deleted the regression analysis from this paper version, for the reasons that we mentioned above

Entire section: It is very hard to pull out the essential results here. Can you concentrate the findings on some key values such as runoff coefficient, steady state infiltration rates, and erosion? Also, what are the relationships between the factors and the dependent variables... directly related or indirectly related? For example, as rock fragment increases did runoff decrease or increase?

Answer: We deleted the regression analysis from this paper version, for the reasons that you mentioned

Section 3.6 Too many details and the overall finding is lost. Check the units (g and not g m-3; Mg ha-1 hr-1 and not Mg ha-1) I am at a loss with the whole concept of the groups. What does being included in a group mean?

C6772

Answer: Thank you for raise this question. We applied a Principal component analysis (PCA) to identify the relationship between variables. This technique is important to resume the information. The PCA groups the variables with the same characteristics. When we say that a variable is part of one group mean that it is related with the variables of the same group. For example, the variables of the group 1 are correlated among them, the same for the group 2, 3 and 4. Normally, the first two factors identified by the PCA are the ones that explained the highest % of the total variation. In this case 86.87%. This was the reason why we plot these factors. We changed the units, thank you very much. We carried out this analysis in previous publications: Marcos et al. (2016) DOI:10.1016/j.scitotenv.2016.01.145, Pereira et al. (2016) DOI: 10.1002/ldr.2290, Pereira et al. (2014) DOI: 10.1002/hyp.9907, Pereira et al. (2012) DOI: 10.1002/hyp.9907

Line 26: Without displaying the hydrographs, how can you convince the reader that what you mention are steady state infiltration rates are truly steady state?

Answer: We measured in the field as in Cerda 1996.

Line 27-28: Regarding Figure 3b, why do you need this analyses. Didn't you already establish that the plots were different with regards to soil properties, etc. in Sections 3.1 and 3.2?

Answer: Thank you very much for raise this question. We think that we that the PCA analysis helped us to have a better understanding of the behavior of all variables in each treatment. As you can see in the figure 3b, it is clear that the variables studied have a different behavior in the different study areas. Road and railway embankments create a very homogeneous group, very different from citrus and scrubland plots.

In general, I am at a loss as to which factors are important in controlling hydrologic and erosion response. Are these factors the same for all surface types? Which factor(s) seem(s) to be the most important? The general comment is that the key findings are hidden behind too many details.

C6773

Answer: The PCA analysis carried out show clearly that vegetation cover and soil organic matter are related to high steady state, time to ponding, Areas with high vegetation cover and organic matter reduced sediment content, sediment yield, Soil erosion, etc. Rock fragment and slope also reduced values the variables of the group 3.

Discussion; page 12959;

Intro paragraph Reduce the number of citations A key finding that is highlighted later is the role of vegetation density, yet there is no section in the discussion devoted to it. Also, how does a plot of erosion rate versus vegetation density for the entire dataset look like?

Answer: We reduced the number of citations. We think it is clear in the PCA that the relation between erosion rate and vegetation cover is negative, there is no added value to plot this

Line 21: Replace 'land' with 'vegetation'

Answer: Changed

Line 24: 'Unsustainable' why?

Answer: We consider that this situation is unsustainable because of the high soil erosion in road embankments. The soil is considered a natural capital.

Section 4.1; Page 12960; Lines 1-7: How do you differentiate between the effect of rock fragments and slope in this case?

Answer: Thank you for raising this question. In this part of the discussions we are explaining the results of previous work about the impact of rock fragments in soil erosion. The aim here is to discuss the effects of rock fragment and not differentiate from the slope. Indeed, as you can observe in the PCA (Figure 3 old version) slope and rock fragment are part of the same group, showing that both are highly correlated.

Aren't the embankments significantly different in terms of their substrates? By that I

mean, aren't these steep cuts exposing a combination of soil and bedrock, while the citrus shrubland sites consist of soil?

Answer: Yes they are different in their substrates. The soil from road and railway embankments material is different from citrus and scrubland plots. But the idea here is highlight how these man-made infrastructures can change soil erosion in this area.

1-29: Again, I fail to capture the key finding here. There are too many details. In your study, rock fragments appears to be a factor leading to higher runoff and sediment production, but this does not agree with the literature. The literature indicates that if the rock fragments are embedded: : : Simplify your statements. Begin with your finding and then problematize it by comparing it to the literature.

Answer: We agree with your vision, but we have to explain why we entered into too many details. The results obtained were contrary to what the great part of the literature defends. This is an opportunity to go deep on the topic and try to understand why we have these results and try to find explanations for this. In our opinion is in these cases that the results need a better discussion because can open other opportunities for research and think differently of what we supposedly accepted as correct.

Line 27: I would not use the term 'ecosystem' to describe this.

Answer: we changed to "diverse soil environment".

Section 4.2 Page 12961;

Lines 7-8: "…as it shows the initiation of runoff generation is related to soil erosion and infiltration rates…" Wording is not clear. Also, why not expand on this if this seems important. Why is it important? Time to ponding says something about the initial infiltration rates.

Answer: Thank you very much. You are correct. We added some discussion to this topic.

Line 20: The fact that higher infiltration rates were related to areas with higher vegetation cover can be used as proof that vegetation cover thus have an impact on runoff generation but says little about its ability to improve soil biota, porosity, etc. These are inferences, so the wording here should be edited accordingly. Line 26: What is your evidence suggesting that organic content is the key factor? Your study design does not isolate allow you to isolate this factor. Why not slope? Why not the abundance of coarse rock fragments? Why not bulk density? Why not vegetation cover density?

Answer: Thank you very much for raising this question. We agree that the aspects related with soil biota, porosity etc, may be considered an inference or some kind of speculation, however, we think that it is important to link all the aspects of the nature to be better understood. We believe that we are not exaggerating in these inferences. Vegetation cover and organic matter are the variables that contributed to the reduction of soil erosion (This can be observed in the PCA results). It is true that our study design did not isolate this variable, but the results of the statistical analysis are evident, in our understanding. This is the reason to carried out a PCA analysis, try to resume the results when we are working with many variables.

Page 12962; Lines 10-25: Why not leave this sort of discussion to Section 4.4?

Answer: Thank you very much. We agree with you. We resume it and move it to the section 4.4.

Section 4.3 I sincerely do not think that this topic merits a section. As I have explained above, the term is problematic and I do not think this adds much to the article's contribution to our understanding of runoff and erosion processes in this region. The study cannot contribute to the literature of 'connectivity' as it is only based on small scale observations.

Answer: Thanks for raising this question. We agree with you. We removed this section

Section 4.4 Lines 3-8: I believe this sentence is unnecessary'

Answer: The sentence was deleted

Line 8: Better proof of vegetation cover being the key factor must be given. Was there any attempt to evaluate the importance of interaction terms in the regression analyses. It might be that vegetation shows up as important for particular surfaces or for particular conditions and not others. Since the study design did not include any embankments with a dense vegetation cover, it is hard to prove that promoting vegetation cover on these surfaces will result in lower runoff/erosion rates.

Answer: Thank you very much for raise this question. We add that soil organic matter was a key factor to reduce soil erosion. It was higher in the scrubland plots than in the other study areas. Data clearly shows that the areas with high vegetation cover and organic matter in shrubland plots have the lowest rates of soil erosion. Low vegetation cover and soil organic matter in citrus and embankment plots are associated with high soil erosion and runoff plots. You are correct, this comment was very important for us and since it was difficult to find the interactions for several reasons (e.g., study design limitations or short amount of samples in citrus and scrubland plots to compare to road and railway embankments), we think that the regression analysis was not the most appropriate method, and we removed from this version of the paper and we will just leave the Principal component analysis. However, we would like to highlight that the objective of the paper is to identify the impact of railways and road embankments in soil erosion in relation to the major land uses. Once more, we really appreciate this comment.

Line 14: You have previously mentioned that vegetation does not naturally recover on these steep embankments.

Answer: We deleted

Section 5 Line 23: This is the first time that depth of soil is mentioned in the article.

Answer: We changed to organic matter

Line 24: You can definitely say that infiltration capacities for shrubland exceed 78 mm hr-1

Answer: we added

Line 25: Connectivity term used again here.

Answer: We think that connectivity here is well employed.

Page 12965

Line 2-3: I believe that the study does not highlight the need to reduce impacts. It does show that embankments erode at a high rate relative to even disturbed agricultural land, but nothing can be said about its overall impact.

Answer: Thank you for raising this question. The analysis carried out showed that the erosion rates identified in embankments are much higher that scrubland and citrus plot. In this context is important to reduce the impacts. The differences between erosion ratios are very much evident and we highlighted this. Under similar rainfall conditions, it is visible that the impacts are much higher in road and railway are much higher, thus the overall impact is high and evident.

Lines 4-5: You have implied on a solution to the problem in the discussion: improving vegetation cover. Why not insert that in here?

Answer: We added

Table 5: Delete where it reads "Check journal name." Figure 2 & 3: I do not see the value of displaying these figures.

Answer: We remove the regression analysis from the paper, thus the figure 2 was removed.

Figure 2 & 3: I do not see the value of displaying these figures.

Answer: We think that these figures are important because they show the PCA results

C6778

Figure 4: What does the gray area represent?

Answer: Photograph of road and railways in canyoles river valley. We want to highlight the lack of vegetation cover and the rill development, gray area is marly material.

Dr. Carlos, we would like to acknowledge your significant input to the increase of the quality of this paper. Thank you very much for helping us. The authors