RESPONSE TO REVIEW COMMENTS

We thank the reviewer for the valuable input, which has helped improve the quality of our manuscript. Our responses are provided below. **Please note that the original comments are in black letters and our responses are in blue letters**. In addition to these responses, we will provide a revised manuscript that reflect the proposed changes, as well as a copy with the tracked changes where revisions were implemented.

In summary:

1. We have significantly enhanced the flow, clarity, and precision of the text. The abstract is also very clear in terms of objectives, methodology, and findings.
2. We have put all our results into context, by providing all the relevant literature that has quantified soil surface roughness at the examined bare smooth soil surface conditions, explicitly acknowledging the studies with results that show the increase in roughness and added missing references (e.g., Kamphorst et al., 2000; Vázquez et al., 2008). We have also updated Fig. 5 to depict the changes seen in RR with respect to initial RR from our study and other studies.
3. We discussed the advantages by focusing on a single rainfall event rather than successive events in the context of this study.
4. We have added information regarding the soil characteristics considered in the study.
5. We have provided two additional commonly used indices for soil surface roughness. Their values and trends with rainfall are in good agreement with RR and crossover length, and in support of our conclusions.

General Comments:

This study analyses soil surface roughness evolution after a single event of simulated rainfall with three different intensities, namely 30, 60 and 75 mm/h. Two indices used to describe the magnitude of soil surface roughness indicate increasing values of this variable after rainfall addition.

In my opinion this manuscript does not contain significant results. This is because the experimental work has been limited to one rainfall event, and this is obviously a main weakness in any study about soil surface roughness evolution (either increase or decay). In addition, authors claim that the results are new, as they state that i) "Findings show a consistent increase in roughness under the action of rainfall for initial microroughness length scales of 2 mm" and ii) "This contradicts existing literature where a monotonic decay of roughness of soil surfaces with rainfall is recorded for disturbed surfaces". However, please note that i) again, the increase in roughness (instead of a expected decrease) has been found only for the first event. What about successive events); results are not reported. ii) Increases in soil surface roughness after simulated surface rainfall and for

disturbed soil surfaces have been previously reported (Please, see Vidal Vázquez et al., 2008. Assessing soil surface roughness decay during simulated rainfall by multifractal analysis. Nonlin. Processes Geophys., 15, 457–468). In this paper the evolution of the surface of three different soils was studied during successive events; two of the studied soils showed soil surface roughness increased after the first event (similar to your results)e second, but it decreased after the second and successive events; the third soil studied showed scarce trend to either increasing or decreasing surface roughness values following successive rainfall events.

Response:
There are a number of different reasons why our study focuses on the evolution of soil surface roughness under single storm events. First, the goal of our experiments is to offer generic, controlled conditions to isolate the effects of raindrop impact on roughness from other processes (i.e., runoff). We meet this goal by checking how raindrop impacts roughness under representative for the region rainfall intensities. We are focusing on single events as these experiments allow us to control the antecedent soil moisture conditions and initial bed surface structure. All single storm event experiments start from the same antecedent soil moisture conditions and initial bed surface structure to facilitate comparisons under different intensities and enable comparisons with the reported literature. We acknowledge that a single storm event represents a rather idealistic case scenario and that a series of storm events can be important and should be examined in future studies.

Specific Comments:

Comment 1: The obtained results should be put into context, with relevant references. This opinion is based in the fact that relevant studies about soil surface roughness, (including the previously cited Vidal Vázquez et al., 2008. Nonlin. Processes Geophys., 15, 457–468, and Kamphorst et al. 2000. Soil Science Society of America Journal 64(5): 1479.1458. By the way, these two manuscript present examples of soil surface roughness assessed by laser scanner as in your work. In the first work quoted (Vidal Vazquez et al., 2008) the magnitude of the roughness is not very different from that in your work and in the second (Kamphorst et al., 2000) several plots also are representative for conditions of rather low values of roughness.

Response:
Per the reviewer's suggestion, the results of our study have been put into context, adding the relevant references related to rainfall simulation experiments and the associated evolution of soil surface roughness for smooth surfaces.

First of all, we expanded our results and discussion to elaborate on the comparison with other studies. The study of Vazquez et al. (2008) has been added along with the already cited work of Huang and Bradford (1992), Rosa et al. (2012), and Zheng et al. (2014), all of them providing indications that under certain conditions, roughness may increase with rainfall (See Page 8, lines 3-19 and Table 1).

We have created Figure 5 to better reflect the relevance of our results. It has been updated to show the rainfall induced relative change in RR with respect to the initial RR of the soil surfaces from our study and the studies outlined above. It is suggested that roughness may increase with raindrop impact for a range of low initial RR values (< 5 mm), while it consistently decays for high initial RR values (> 5 mm). It is also clear that our study captures the behavior of RR for an initial range that was not covered before.

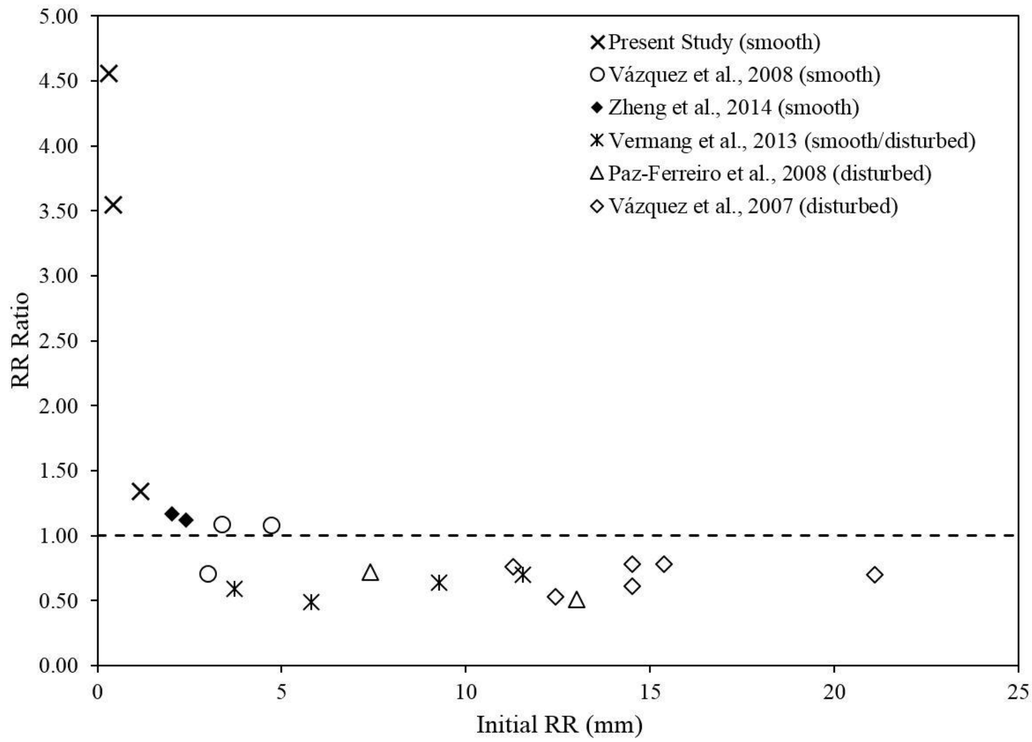

Figure 5: Random Roughness (RR) Ratio versus initial RR for this study and other selected studies.

Findings of Vázquez et al. (2008) have been added to Table 1. In addition, our results are discussed in the light of the other cited studies in the Results section (Page, lines):

Finally, the study of Kamphorst et al. (2000) has been added to the Discussion and Conclusions section of the manuscript in support of the relationship between microroughness and depression storage (Page 10, lines 14-16):
"Increase in microroughness further infers increase in depression storage at the soil surface prior to runoff generation (Kamphorst et al., 2000), which can affect ponding and flow pathway patterns especially at the onset of a storm event (Onstad, 1984)."

Comment 2: In my opinion, adding more experimental data (successive events) would allow that this manuscript reaches international standards.

Response:
We do acknowledge the importance of accounting for successive events but this is not the focus of the specific study as stated earlier. We are therefore not dismissive of the reviewer's request.

Having said that, it is also important to note that the labor and level of detail required to perform the experimental runs presented in the study is significant, as it can be seen in Fig. 1b and 2. It takes about 10 days to prepare and run each test. This is done for 9 runs, so roughly a period of 3 months.

In addition, any revision of this manuscript should address the following points:

Comment 3: Text should be ameliorated the text, which is not precise and provide a more clear presentation.

Response:
The text was substantially improved in terms of clarity, grammar, language and structure. A significant amount of effort has been put to enhance the flow and precision of the text. A number of modifications include: Correction of grammatical errors. We moved and modified the first paragraph of the Results of the previous version of the manuscript to the Materials and Methods section, since it is more relevant there (Page 7, lines 12-18). The last section was more appropriately renamed to Discussion and Conclusions. Results are presented in a clear manner, as explained in Comment 1 above.

Comment 4: Main corrections are expected in abstract, objectives and discussion and conclusion sections.

Response:

The abstract was significantly improved to clearly present our objectives, methodology, and findings (Page 1, lines 13-28). It is specified that our study focuses on a bare smooth soil surface in an agricultural field. Our study is also put into context with existing literature, and the need to consider the cases where roughness can increase is highlighted, in light of the scarcity of studies that explicitly deal with rainfall induced change in roughness for the examined microroughness scales. Results from the additional indices examined were also added (see Comment 8).

The objectives of our study are now clearly stated (Page 3, lines 20-24):
"The key specific objectives of this study are (i) to quantify the soil surface microroughness of smooth bare soil surfaces before and after the effect of rainfall, and (ii) calculate the relative change in roughness for different intensities. To meet the two specific objectives we employ four commonly used indices, the RR index, the crossover length, the variance scale from the Markov-Gaussian model, and the limiting difference. The last three indices are alternate methods and used here to supplement the RR index analysis for relative change in roughness."

Major revision has been made in the Discussion and Conclusion sections (see Responses to Reviewer 1)**.** In a nutshell, comments where it seemed that we stretched too far in the relevance of our results have been modified or removed, to be more in line with the level of the analysis. Furthermore, we provide a better insight into the significance of our study, stating that our experiments were designed to isolate the role of rainsplash on roughness from other processes such as runoff, variable water content, bare soil surface, texture, etc. Through our study we were able to determine that microroughness and its change are significant when there is no cover, which tends to happen between harvest and planting, and at the beginning of a storm event. We also provide in a clearer manner the limitations of our study, as well as the next steps for further research in terms of a better understanding and quantification of the extent to which the initial increase in roughness in the early part of the storm could have an impact on flow pathways, runoff, and processes at subsequent parts of the storm.

Comment 5: Mechanisms and reason for the increase in soil surface roughness after one event simulated rainfall.

Response:
Changes in roughness during a storm event can be attributed to compression and drag force from the raindrop impact on the soil, angular displacement due to rainsplash, aggregate fragmentation, and differential swelling (Al-Durrah and Bradford, 1982; Warrington et al., 2009; Rosa et al., 2012; Fu et al., 2016). To the best of our knowledge, no study has quantified the co-play of the outlined processes as influenced by different soil types, rainfall characteristics (e.g., median diameter of raindrop), and initial roughness conditions. Therefore, the exact mechanisms and reasons that lead to the increase in soil surface roughness are unknown.

We now acknowledge the above in the manuscript (Page 10, lines 23-26):
"The exact mechanisms leading to increase in roughness are unknown. Changes in roughness during a storm event can be attributed to compression and drag force from the raindrop impact on the soil, angular displacement due to rainsplash, aggregate fragmentation, and differential swelling (Al-Durrah and Bradford, 1982; Warrington et al., 2009; Rosa et al., 2012; Fu et al., 2016)."

Comment 6: There are also unnecessary figures, regarding the experimental setup, as the methodology employed has been largely described before.

Response:
Thank you for the comment. Other reviewers have requested that we put more information about the experimental set-up. We deem that our figures regarding the experimental setup provide the reader with the necessary information and specifics to ensure repeatability of the experiments outlined. Future research may require the repetition of the same experiments to study the coevolution and interaction between rainsplash and runoff, in order to further determine their collective influence on the hydrologic processes. We have adjusted other sections of the paper if the concern relates to space. Specifically, we have removed Figure 5 of the previous version of the manuscript and added the Figure described in Comment 1.
Finally, we have removed Figure 7 since it was considered unnecessary.

Comment 7: Soil composition and main characteristics should be also reported in the material and methods section.

Response:
We have added more information on the soil used in our study (Pages 3-4, lines 29-1):
"The soil series at the plot where the experiments were conducted is Tama (fine-silty, mixed, superactive, mesic Cumulic Endoaquoll) (http://criticalzone.org/iml/infrastructure/field-areas-iml/). It consists of 5% sand, 26% clay, 68% silt, and an organic matter content of 4.4%. The aggregate size distribution of the soil consists of 19% of the soil size fraction less than 250 μm, 48% between 250 μm and 2 mm, and 33% greater than 2 mm. These soils contain both smectite and illite, with high cation exchange capacity between 15 and 30 Meq/100 g."

Comment 8: Other significant roughness indices should be addressed, in addition to random roughness and crossover length.

Response:

Per the reviewer's suggestion, we examined additional indices other than the RR and crossover length, which can capture soil surface roughness at the examined scales. Specifically, the variance length scale of the Markov-Gaussian model (Huang and Bradford, 1992) and the limiting difference index (Paz-Ferreiro et al., 2008) were calculated. These specific indices were selected due to their common use for the quantification of soil surface roughness, as well as due to the fact that they can capture scale dependent characteristics of the soil surface. We found good agreement in the values and rainfall induced trends between all examined indices. Below we provide the major modifications we applied to the original manuscript:

<u>Materials and Methods</u>

A brief theory and references behind the introduced indices were added along with equations and specifics for their calculations (Pages 6-7, lines 28-11):

"The Markov-Gaussian model is a random process that has been adopted for the quantification of soil surface roughness (Huang and Bradford, 1992; Vermang et al., 2013). In that case, the semivariogram is written as an exponential-type function with the following form:

$$\gamma(h) = \sigma^2\left(1 - e^{-h/L}\right), \quad (4)$$

where σ is the variance length scale, representing the mean roughness of a surface at the large scale, and L is the correlation length scale, which is a measure of the rate at which small scale roughness variations approach the constant value of σ. These indices are obtained by fitting the exponential-type function of Eq. (4) to the semivariogram obtained from Eq. (2).

Finally, the limiting difference (LD) index is another index adopted to quantify soil surface roughness. It is calculated from the first-order variogram (Linden and van Doren, 1986; Paz-Ferreiro et al., 2008), which is written in the form:

$$\Delta Z(h) = \frac{1}{n(h)}\sum_{i=1}^{n(h)}\left|Z(x_i + h) - Z(x_i)\right|, \quad (5)$$

Then, a linear relationship is fitted between 1/ΔZ(h) and 1/h:

$$1/\Delta Z(h) = a + b/h, \quad (6)$$

The limiting difference (LD) index is then calculated as $LD = 1/a$. LD has units of length, and represents the value of the first-order variance at large lag distances. It is considered as an indicator of soil surface roughness, thus adopted in the present study as an additional roughness index."

<u>Results</u>

The title of the subsection 3.2 was changed to "Changes in additional roughness indices". Moreover, a paragraph was added at the end of that section, describing the findings obtained for the introduced indices (Page 9, lines 21-33):

"Table 3 lists the Markov-Gaussian variance length scale and the limiting difference indices for the three experimental tests, and their relative change after the rainfall. These indices also show similar increase with rainfall that is of the same magnitude and trendas the RR index and crossover length, and provide a supplemental analysis about the role of rainfall intensities on the relative increase in roughness. The laser measurements from the 3 rainfall intensity

experimental runs were analyzed using all indices, namely, the random roughness, the crossover length, the Markov-Gaussian variance length scale, and the limiting difference indices. All indices show a consistent trend i.e., higher rainfall intensities result in higher relative increases in microroughness (Table 3).Overall, the results provided suggest that all the indices employed in this study may be used interchangeably in order to characterize rainfall induced changes in soil surface roughness, and can capture an increase in soil surface roughness, especially for low microroughness scales on the order of 2-5 mm. Our findings were compared against those reported in the literature. Huang and Bradford (1992) studied the evolution of soil surface roughness with the Markov-Gaussian variance length scale, and saw an increase of 6% in roughness for a surface of low initial roughness. Moreover, Paz-Ferreiro et al. (2008) used the LD index as an additional index to quantify soil surface roughness. They recorded a 10% increase in the LD index for a low roughness conventional tillage soil surface. Higher relative increase of roughness in our study (Table 3) compared to other studies, as seen in Fig. 5, are attributed to the significantly lower initial roughness conditions in addition to different soil types and management."

Tables

Table 3 below was added to the manuscript, presenting our findings regarding the last two indices that were introduced in support of the RR and crossover length:

Table 3: Summary of the rainfall induced change in the Markov-Gaussian variance length scale and limiting difference indices for the experimental tests of this study.

`	Cumulative Rainfall (mm)	Pre-rainfall σ (mm)	Post-rainfall σ (mm)	σ Ratio	Pre-rainfall *LD* (mm)	Post-rainfall *LD* (mm)	*LD* Ratio
30 mm/h	150	1.19	1.63	1.37	0.79	0.87	1.10
60 mm/h	300	0.42	1.52	3.62	0.26	0.87	3.39
75 mm/h	375	0.31	1.43	4.56	0.15	0.71	4.84

Based on the above I recommend to the editor either major revision or rejection of this manuscript.