Dear Editor,

The English has been improved using AJE services as you requested. The cover letter from AJE is produced in this document and the modifications we did are highlighted in yellow in the following pages after the AJE letter.

These edits are described below. We performed all the requested modifications proposed by reviewers #2 and #1. We are indicating the way it has been answered (in blue below). We changed the title as requested, but it has been modified by the AJE review.

We tried also to rework a bit the abstract as requested by reviewer #2. We made several modifications as requested by the reviewers.

I hope this paper is now acceptable for your journal.

Sincerely yours

Michel

1 Answer to Anonymous Referee #1

Submitted on 31 Oct 2014

Suggestions for revision or reasons for rejection (will be published if the paper is accepted for final publication)
Although the authors rewrote more than 50% of the paper, it still seems to be a somewhat sloppy work. It is a pity for an exciting experiment, but the results are too preliminary. The authors merely touch the basic elements of erosion processes (for instance soil physical properties) and do not discuss this in an appropriate way.
Although "this paper has been corrected by experienced article writers", this writers did not a good job. The manuscript still contains a huge number of errors and untidiness. (for example: three different citations: Oostwood and Ergenzinger; Oostwoud and Ergezinger; Oostwould and Ergenzinger ???).

Corrected

There are two identical Tables 1 ....The use of English language is still somewhat inappropriate.

We have submitted to AJE

Therefore all in all the manuscript should be rejected.

2 Answer to Anonymous Referee #2

Submitted on 21 Dec 2014

The research described in this article is very interesting because it addresses the question
Suggestions for revision or reasons for rejection (will be published if the paper is accepted for final publication)
One of the major issue in all three reviews of the initial manuscript was the weak analysis and discussion of the results with regard to the (not really explicitly) formulated problem. By

including several scientific references in the discussion as well as pointing out some specific processes such as the role of crack closing this aspect has improved. However, the paper still lacks the specific problem that should be resolved and the hypotheses to be checked. This is a continuing weakness of the manuscript, that probably is difficult to rectify in this state of the research. The chapter « data processing » has undergone a substantial improvement. This applies also for the data documentation in the results part. The figures are now much more informative and better explained. Concerning the language the specific terminology is generally correctly used although there are several minor spelling errors..

Here some special issues :

The abstract should be written more explicitely. It should be more than a description of what has been done.

We tried to slightly restructure the abstract and underlined the implication for erosion and also infiltration

The soil profile must be described properly, at least texture must be given (see review #1)

We have now described the soil profile with soil terminology even if there is no vegetation and soil development, we indicate the fact that no vegetation cover exists for the considered sample.

TLS data aquisition is time consuming : What was the actual time resolution? In table 1 and 2 has to be given the total scan time on the sample box and not only the starting (or ending point). In the present form the column caption « aquisition time » is not correct. When data acquisition is more than 10 minutes, this would include an important unsharpness in the data. In this case it is crucial, to know whether the scan was horizontally (then we have a bias in the data) or vertically (then the long sampling time only adds noise to the data)

We change the table headers and indicate the scan duration in minutes. In addition, the time of acquisition per cm. from left to right is now given.

The paragraph beginning at line 86 cannot be understood. What is « about 1.3 litres fell on the box » ? This paragraph contains several spelling errors.

We modified the paragraph by adding the total amount of rain 5.5 mm.

Final suggestion:
Under the precondition that the mentioned points are resolved, I can recommend the publication of the manuscript in HESS, mainly because the presented methodology in erosion research is still upcoming and because the transfer of a bulk micro hillslope to the lab is somewhat original.

February 10, 2015

Dear Michel Jaboyedoff,

Thank you for choosing American Journal Experts. This manuscript, “Erosion processes in black marl soils at the millimetre scale: preliminary insights from an analogous model,” demonstrates the ever-increasing utility of laser scanning technology in our understanding of natural processes by examining the minute processes occurring on a sloped soil surface. The first editor and I have revised the paper for grammar, phrasing, punctuation, and diction. A number of our changes are addressed directly in the text, and I have outlined several of the major changes below.

The choice of the correct preposition is a difficult aspect of the English language. In your manuscript, prepositions were edited to reflect standard English usage. For example, “changes of the soil surface” was changed to “changes in the soil surface”, and “present at the surface of the sample” was edited to “present on the surface of the sample”.

In certain cases, sentences were restructured to eliminate weak or imprecise phrasing. For example, the sentence “It is clear from Figures 6 and 7 that the material has expanded...” was changed to “Figures 6 and 7 clearly show that the material has expanded...” Where possible, sentences should be constructed such that they contain nouns or pronouns other than “it” as their subject unless “it” refers to a specific noun.

Formal language is preferred in scientific writing. For this reason, the following edits were made in your manuscript: “about 10 cm” was changed to “approximately 10 cm” and “several artefacts” was changed to “certain artefacts”.

Comments were left in several places where further clarification would be helpful or where confirmation of the meaning of the text is necessary. Please review these comments and all our changes carefully to ensure that the final version of the manuscript is fully accurate.

Thank you again for using our editing services; we wish you the best of luck with your submission.

Best Regards,

Matthew D.
Senior Editor
American Journal Experts

Erosion processes in black ~~-~~marl soils~~s~~ at the millimetre~~er~~ scale: ~~,~~ ~~the~~ preliminary insights from an ~~analogical~~ analogous model

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Correspondence to: M. Jaboyedoff (michel.jaboyedoff@unil.ch)

Abstract

~~In order t~~To investigate ~~some of~~ the ~~millimetre~~ millimetre-scale surface processes caused by natural rainfall, an undisturbed sample of badlands soil (1 m long, 0.5 m wide and 0.15 m thick) ~~has been~~was carefully extracted ~~in situ~~. The sample is composed of black ~~-~~marl~~s~~ soil~~,~~ ~~coming~~ from a badlands area of the Draix Observatory (SE ~~of~~ France). After ~~it thoughtful~~ extraction, the undisturbed sample ~~has been~~was placed ~~with~~ at the same slope angle (45°) as its ~~was originally~~original orientation ~~placed set in situ~~ and~~. This portion of soil~~ was then monitored for several processes ~~by~~ via a terrestrial laser scanner (TLS) with ~~a millimetre~~ millimetre-scale accuracy and resolution. This experiment ~~allowed the identificationying of~~identified several surface processes interpreted as micro-landslides, swelling of the black ~~-~~marl~~s~~ material and lateral expansion ~~closing~~ that closed desiccation cracks. These micro-processes illustrate the complexity of the surface micro-topography changes ~~processes~~ that ~~that are~~ control~~ling~~ erosion and infiltration rates over time~~s by surface micro-topography changes~~.

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1 Introduction

Small black ~~-~~marl~~s~~ watersheds have strong responses to climate forcing (Malet et al., 2007). This study aims to better understand the erosional behaviour and the micro-morphological evolution ~~on~~ of these materials caused by micro-scale mass ~~-~~movements ~~as~~ in response to precipitation. The goal of this experiment was to extract an undisturbed sample of black marl~~s~~ and expose this material to a natural rainfall event~~,~~ in order to monitor the sample's surface evolution using a 3D laser scanner. This monitoring has permitted us to study ~~in high detail~~ the micro-topographic surface deformation and erosion processes ~~with high detail which~~that may ~~also~~ have ~~also~~ an impact on infiltration rates during rainfall events (Mitchell and van Genuchten, 1993; Römkens and Prasad, 2006). In addition, ~~such~~ these surface changes may also ~~have an impact on~~play a role in the triggering ~~factor~~ of landslides (Galeandro et al., 2014). ~~Unlike as first intended~~Contrary to the original intention, t~~T~~he duration of the experiment and the rainfall intensity ~~does~~ did not permit ~~to~~ investigation~~e~~ of ~~the~~ splash erosion~~ as first intended~~, which can be important when rainfall is intense (Selby, 1993), because its effect ~~is~~ was below the resolution of our acquisition and because ~~of the rather low~~the intensity of the rainfall~~,~~ was rather low~~which can be important when rainfall is intense (Selby, 1993)~~.

In the past, several studies of artificial ~~-~~rain simulations have been performed ~~on the site of~~ at the Draix Observatory (ORE Draix), which is ~~an observatory~~ dedicated to the ~~the~~ research ~~of on~~of mountain hydrology and erosional processes. Previous ~~works~~ studies focused on the measurement of sediment transport (Oostwoud Wijdenes and Ergenzinger, 1998) and runoff ~~in~~ as a function of precipitation~~s~~ (Mathys et al., 2005). The badlands ground surface ~~ground~~ evolution has already been monitored during rainfall simulations by using a pin-type micro-relief ~~-~~meter and photography~~ies~~ (Torri et al., 1999; Mathys et al., 2005), but these tools were not able to reach the same precision as a laser scanner. Recent studies ~~showed~~ have shown the potential~~ity~~ ~~of~~ for observing and characterizing erosional processes at the level of micro-topography using a laser scanner (Schmid et al., 2004; Barneveld et al., 2013).

The soil sample was extracted from the Draix experimental site ~~of Draix~~ (ORE Draix, IRSTEA), a badlands area near the city of Digne-les-Bains in the southern ~~of~~ French Alps~~, a badlands area near the city of Digne-les-Bains~~. The experiment ~~has been~~was performed in Lausanne (Switzerland), where the precipitation~~s~~ ~~can be considered~~is similar to the Alpine region. For the monitoring of the sample surface, a terrestrial laser scanner (TLS) ~~TLS has been~~was used to (1) identify ~~part some of~~ the ~~millimetre~~ millimetre-scale processes that ~~are~~ control~~ling~~ erosion and infiltration by (2) quantifying the swelling of the material in the marls during rainfall events and (3) mapping all ~~the~~ possible modifications of the terrain surface.

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2 Geological setting~~s~~

The badlands near the village of Draix are composed of weathered black ~~-~~marls of Middle Jurassic age (Callovo-Oxfordian). The~~is~~ black marl formation is more than 2,000 m thick in ~~some~~ certain places (Antoine *et al*., 1995). The ~~studied~~ study site has no vegetal cover~~. The~~, and the regolith is usually ~~about~~ approximately 40 cm to 1 m thick (Maquaire et al., 2002; Antoine et al., 1995). ~~About~~The upper approximately 10 cm of the ~~top of the~~ regolith is ~~constituted of by~~ loose detrital material ~~made~~ composed of local clasts and platelets ~~produced locally~~ (Maquaire et al., 2002).~~,~~ ~~which~~ This regolith corresponds to a sandy loam when it has been exposed ~~during a time~~for long enough to be disaggregated by weathering (Antoine et al., 1995). When ~~this~~ the upper regolith layer is fresh, it can be considered ~~as~~ loamy sand or sand. Below the regolith is ~~constituted of~~ a layer of ~~plate~~ plate-like unstructured rock. Finally, ~~a~~ compacted regolith ~~of~~ 10 to -20 cm thick lies in contact with the bedrock (Maquaire et al., 2002). The clay size fraction ~~content~~ of the black ~~-~~marls located in this part of France has been ~~measured at~~found to be 35±5% (Caris et Van Asch, 1991), but the clay mineral content is ~~of~~ approximately 10% and is~~,~~ ~~mainly~~ primarily illite ~~and~~ with traces of smectite and interstratified clay minerals (Antoine et al., 1995). During rainfall events, water infiltrates the ground, and the material ~~can~~ swells because of the ~~fine~~ behaviour of the fine-grained material ~~behaviour~~ and chemical reactions (Antoine et al., 1995). The loose ~~upper~~ upper-layer detrital material is very sensitive to erosion and is a good candidate for experiments ~~of~~ ~~on~~involving surface processes imaging.

3 Methods

3.1 Samples

The sample of soil used for this experiment was extracted from a marl outcrop with a 45° slope. ~~and~~ T~~t~~he bedding crossing the surface of the outcrop is close to ~~a~~ perpendicular (Fig~~.~~ure 1a). Nevertheless, the loose detrital material at the surface does not display any identifiable bedding structure. The sample is 1 m long, 0.5 m wide and 0.15 m thick. To extract this sample of soil, a metal case ~~has been~~was designed to keep ~~undisturbed~~ the soil structure undisturbed (Figure 1). The extraction~~is~~ was performed by pressing the bottomless box into the ground and inserting the bottom plate via~~,~~ tapping with a hammer ~~to slide the bottom plate of the box in order~~ to isolate a sample of the ~~bedrock~~soil. This sample ~~has been~~was stored in the laboratory in dry conditions, which ~~can be~~were similar to natural

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Comment [SE1]: Please clarify what the bedding is perpendicular to. Perhaps "normal to the face of the outcrop" would provide more information.

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Comment [SE2]: Please ensure that the intended meaning has been maintained in this edit.

conditions, ~~during~~ for 3 months before the experiment started~~, which can be similar to natural conditions~~.

3.2 Experiment ~~settings~~~~setup~~design

On ~~the~~ 31^{st} May, 2011, the soil sample was exposed to ~~a~~ natural rainfall from 11h01 to 17h47. During the experiment, the soil sample was ~~located~~ kept in its ~~extractionng~~ metal extraction casing~~, which~~ and ~~has been~~was tilted ~~by~~ at 45° in order to ~~get~~ obtain the same inclination as its in situ conditions.

The soil sample was scanned every 30 minutes using a ground-based TLS Leica ScanStation II, ~~that~~ which produces point-clouds (x, y, and z data) in a three-~~3-dimensionna~~dimensional~~l~~ space (Figure 1c). The direction of the laser pulses' line-of-sight and the recorded time-of-flight determine the position of the measured points. The rainfall ~~has been~~was measured by the weather station ~~of~~ at the University of Lausanne (PluvioMADD2 from MADD Technology), located ~~at~~ 500 m from the experiment ~~place~~location.

~~Since t~~The sample was dry at the beginning of the experiment. The total precipitation during the experiment was ~~of~~ 5.5 mm, which corresponds to ~~about~~approximately 1.3 litres ~~that~~ enter~~ed~~ing the metal case. Most of the rain–fall was absorbed by the sediment, ~~which limited~~limiting the transport of sediment by runoff. ~~As a c~~Consequen~~ce~~tly, the sample did not reach full saturation. We suspect that a small quantity of evaporation may have occurred during the experiment, but we did not weigh~~t~~ the box before and after the experiment, and this minor influence has been neglected in our study.

3.3 Data acquisition

The surface evolution ~~has been~~was monitored for 6 hours and 46 minutes by 12 successive laser scan acquisitions. The first scan and the last scan (acquired at 11h01 ~~11:01~~ and 17h47, respectively) ~~have~~ had ~~approximatively~~ a point spacing of approximately 0.001 m with a duration time of 8 min. All the other scans ~~have~~ had a 0.002 m point spacing for a duration of 2 min. From 0 to 50 m, 50% of the laser beam is ~~in~~ at a diameter of 4 mm ~~diameter~~ at full width half height (FWHH) (Leica Geosystems AG, 2007). The scans ~~are~~ were acquired vertically from ~~the~~ left to ~~the~~ right~~ of the box~~, which means that one centimetre in width is scanned in less than 2.4 ~~sec.~~ for the 2 min. scans and less than 9.6 s~~ec.~~ for the 8 min. scans. The scan distance was 2 m. The instrument was not moved throughout the experiment,

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Comment [QCE3]: Please include both the name of the supplier/manufacturer and their location (including city, state, and country) for all specialized equipment, software, and reagents.

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meaning that the position and the orientation of the scans ~~is~~ are identical for all ~~of the~~ acquisitions. ~~As a consequence~~Therefore, no scan alignment was necessary to compare the obtained point clouds.

3.4 Data processing

The point clouds were “manually” cleaned ~~from~~ of the points that ~~are~~ were not imaging the surface of the sample, i.e., the metal casing sides, the background of the scenery and ~~some~~ several artefacts, including points ~~away from~~not located on the terrain’s surface, such as rain drops. Only the surface of the sample was kept. Every cleaned scan has a very high point density: more than 400,~~'~~000 points for the first and last acquisitions and a minimum of 110,~~'~~000 points for the ~~rest of these~~other scans (Table 1).

Each TLS point cloud was first~~ly~~ rotated by 45° to obtain ~~on average a~~an approximately horizontal point cloud in order to ~~be able to~~ interpolate in 2.5~~-~~ dimensions. The interpolations were performed using an inverse distance method with a power of 1 (Shepard, 1968) ~~with~~ via Surfer 8.0 software (GoldenSoftware). The point clouds were transformed into a regular squared grid of 1 mm for the first and last scans and 2 mm for the other datasets. This provided ~~high~~ high-resolution digital elevation models (DEM) of altitude z above the mean horizontal surface. The search radius for DEM generation was defined ~~in~~ as 1.5 times higher than the pixel size, i.e., 1.5 mm for scans with a point spacing of 1 mm and 3 mm for the scans with a point spacing of 2 mm (Figure 2). Although different values of DEM cell size were tested, this value was chosen ~~such~~ as the most ~~adequate~~ satisfactory compromise between accuracy and~~/~~ resolution. The ~~so~~ generated DEMs were compared to quantify and map surface changes, i.e., mass movements and~~,~~ erosion/deposition processes. Each DEM was subtracted from the initial (or reference) DEM (DeRose et al., 1998). The resulting z difference grids have negative value pixels for ~~the~~ “erosion” and positive value pixels for ~~the~~ “deposition”. To limit the ~~'~~noise~~'~~ of the measurements, absolute value differences ~~in absolute value inferior~~ less than ~~to~~ 0.0015 m were ignored; this threshold was obtained by a trial and error procedure.

4 Results

The precipitation~~s~~ ~~started at~~lasted from 13h30 until the end of the experiment, with ~~and , then it stopped for~~a 30-minute hiatus starting ~~30 minutes around~~ at approximately 16h00~~, and then continued up to the end of the experiment~~. The maximum rainfall intensity (5.2 mm h^{-1}) ~~was~~

~~reached~~occurred at 16h30. ~~A~~ The cumulative~~ed~~ precipitation ~~amount~~quantity was ~~of~~ 5.5 mm ~~was recorded~~ at the end of the experiment. Three different surface processes of topographic changes were identified~~ and discriminated~~. ~~The f~~Figure 3 ~~displays~~ shows the difference between the initial and final scans (11h01 and 17h47, respectively). ~~The rising of~~Changes in the surface elevation (z) appear~~s~~ in blue ~~colours~~(increased elevation)~~,~~ and ~~the decrease in z appears in~~ red ~~colours~~ (decreased elevation; ~~(~~Figure 3). We considered only the changes that are fully visible in the oblique view of the experiment (i.e., the box with a slope of 45°).

The micro-topographic~~y~~ changes that occurred ~~at~~ along ~~location~~ transect 1–~~-~~2 ~~is~~ are shown in Figures 3 and 4. ~~As can be observed in~~ F~~f~~igure 4c shows~~,~~ a depression (in red) ~~is~~ formed at the top of a small ridge~~ (in red)~~, and ~~a~~ the surface elevation of a depression below this ridge ~~is filled in~~increased (in blue). This change can be interpreted as a downward mass ~~-~~movement at the millimetre scale. The small particles moved down~~, filling~~ward and filled a desiccation crack. This phenomenon occurred ~~right~~ immediately after the highest intensity rain event, between 17h00 and 17h30 (Figure 5).

When the rain intensity reached 1 mm h^{-1}, the entire surface of the soil started to rise ~~up all over the surface~~ (~~it means~~ perpendicular~~ly~~ to the surface of the 45° slope~~ at 45°~~), ~~appearing~~ which appears as a pale blue layer ~~on~~ in Figures 3 and is illustrated in F~~f~~igure 6. This process ~~affecting the entire surface has been measured from~~resulted in an overall rise of 1.5 to 3 mm ~~for~~ over the course of the ~~entire~~ experiment, i.e., ~~for~~ a cumulative~~ed~~ 5.5 mm of rain (Figure 5). ~~It starts~~The surface elevation increased slowly after the first rain. At 16h30, the surface subsided, and ~~this~~ the process was momentarily slowed down. ~~After that~~Subsequently, the processes ~~re-~~accelerated following the ~~new~~ peak in rain intensity (Figure 5). Note that no significant rise ~~of~~ in the topographic surface ~~has~~ occurred at the top of the sample, which was protected from the rain (Figure 3).

Another observed process is linked to changes ~~of~~ in the soil surface by lateral expansion (Figures 6 and 7). This process ~~has been observed~~ occurred continuously through the closing of ~~the~~ desiccation cracks,~~;~~ which were present ~~at~~ on the surface of the sample.

The ~~last~~ final observed process was the stripping of soil particles by the kinetic energy of the raindrops. Although these changes were observed by the authors during the experiment,~~.~~ ~~Unfortunately its~~ their magnitude was unfortunately too small to be significantly monitored by the ~~utilised~~ TLS used in this study.

Comment [SE4]: Please note that the highest intensity rainfall was previously said to have occurred at 16h30. Please check whether one of these statements is a typing error.

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5 Discussion and conclusions

The ~~geometric~~ topographic changes observed ~~at location~~along transect 1~~-~~-2 (Figures 3 and 4) occurred almost instantaneously, which excludes the rain splashing process.~~;~~ ~~they~~ These changes ~~were~~ are interpreted as a micro-landslide. ~~Looking at~~Based on the duration of the scans and the size of the transported mass~~ moving~~, we ~~can~~ assume that it is ~~quite~~ highly unlikely that a scan had just crossed the region of interest when the movements occurred within it (0.05 m scanned in ~~around~~ approximately 50 s~~ec.~~). In addition, the two profiles before and after the occurrence of the changes mimic the profile changes usually observed in real landslides. ~~Such a~~The observed process ~~can be~~is likely related to the initiation of miniature debris flows (MDFs) observed by Oostwoud Wijdenes and Ergenzinger (1998), but the latter needed heavy rainfall to be transformed in MDFs.

The observed rise ~~of~~ in the surface, which ~~reacts fully~~occurred ~~with rainfall with at~~following a 30~~-~~minute~~s~~ delay after the initiation of rainfall~~ with rainfall~~, is certainly linked to the swelling of the material. The soil sample experienced swelling after the first rainfall intensity peak, contraction 30 minutes after the ~~stop~~ cessation of rainfall and ~~new~~ renewed rising ~~of the topographic surface~~ once the rain started again. This measured cyclic behaviour demonstrates that the swelling and contraction of the soil surface is a reversible process. We can assume that ~~such a~~this process is linked to ~~the~~ moderate rainfall intensities~~y~~, which allow~~s~~ ~~the~~ water to infiltrate the fine-grained material, causing ~~and swell part of the~~swelling~~ fine- grained material~~. ~~Furthermore, t~~This process is not necessarily caused by clay minerals~~, since~~ because they are present only in small quantities~~y~~ (~~mostly~~ primarily illite) in the study area (Antoine et al., 1995). The swelling ~~must~~ dissipates rapidly for moderate rainfall events because of the diffusion of water when the rainfall stops, which leads~~ing~~ to a decrease ~~of~~ in the effect of the water~~ effect~~.

The crack-closing lateral expansion of the surface ~~within cracks~~ is also certainly linked to swelling~~,~~ but does not ~~retreat~~ reverse when the rain stops. ~~It is clear from the F~~Figures 6 and 7 clearly show that the material has expanded~~, b~~. ~~But~~ and that ~~it is not affected by~~the material as not transported~~, since~~ because no deposition was observed at the bottom. We ~~do not find~~have not found any definitive explanation ~~for this~~that accounts for the difference ~~with~~ between the rising ~~up~~ process and the lateral expansion process.~~,~~ ~~but~~ However, ~~it~~ the difference must be related to gravity, which increases the effect of swelling downward. ~~Then W~~When ~~both~~ the two sides of the crack ~~touch each other~~make contact, the moistened zone doubles its

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Comment [SE5]: Please clarify. The word "latter" is generally only used after 2 or more objects/options have been listed. It is unclear what 'latter' refers to here. Perhaps you mean, "but MDFs require heavy rainfall."

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thickness, decreasing the water diffusion in the material. In addition, ~~such~~ these processes must be ~~part~~ components of ~~the~~ creeping (Selby, 1993), ~~probably~~likely because ~~probably~~ the retreat by drying ~~will be~~is less effective ~~for~~ in the ~~downward~~ downslope ~~part~~portion, leading to slow progressive downward movements ~~downward~~.

The above interpretations are also important for the understanding of the infiltration process. ~~It is clear that c~~Cracks clearly play an important role in the infiltration rates (Mitchell and van Genuchten, 1993; Römkens and Prasad, 2006) and ~~subsequently~~ consequently ~~for~~ in the destabilisation of slopes (Stumpf et al., 2013; Galeandro et al., 2014). The ~~above analysed~~ processes analysed here ~~are playing~~play a role ~~for~~ in the closure of cracks, as ~~was~~ shown~~ned~~ in F~~f~~igure~~.~~ 7. In the present case study, we demonstrated how micro-scale infiltration can influence the degradation of soil surface ~~of soil~~ by inducing downward mass movements that are not reversible.

We have also shown here the great potential of ~~high~~ high-resolution three-dimensional TLS or photogrammetry point clouds ~~of TLS or photogrammetry to analyse~~for the analysis of the processes that lead to erosion through~~out~~ surface mass movements at the millimetre scale. Investigations ~~about~~ of erosional processes using point clouds are increasing in number. ~~They~~ These studies use ~~either~~ l~~L~~aser scanners for either ~~for micro~~ micro-scale surface imaging (Schmid et al., 2004; Barneveld et al., 2013) or measuring ~~for~~ crack~~s~~ apertures (Sanchez et al., 2013). In addition, photogrammetry and~~, especially,~~ s~~S~~tructure from m~~M~~otion (SfM) methods are now being developed to analyse soil surfaces (Snapir et al., 2014).

This paper shows that monitoring the changes at the millimetre scale to ~~illustrate~~ examine soil surface changes and erosion is now possible. This development will ~~help to design~~aid in designing future experiments to analyse certain ~~single~~ processes, such as swelling, crack closure, micro-landslides, and initiation of MDFs. With heavier rainfall, ~~those~~ sediments will ~~start to~~ be mobilised ~~on for~~and transported across longer distances, enabling the study of ~~like~~ MDFs and the formation of rills. ~~It~~ Thise study also ~~shows~~ demonstrates ~~also~~ that material and rain intensity must be ~~sufficient~~ suitable to permit ~~an~~ the efficient detection of rain splash processes and associated erosion; specifically, a rainfall intensity of ~~more~~ greater than 20 mm h^{-1} is necessary (Mathys et al., 2005).

Acknowledgements

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~~Thanks~~ The authors would like to thank ~~to~~ the *Observatoire de Recherche en Environnement* (ORE) of Draix~~,~~ for letting us ~~to~~ sample soil in~~to~~ a protected area. ~~Thanks are also due to~~We would also like to thank the UNIBAT service of the University of Lausanne (UNIL)~~,~~ for providing meteorological data from their weather station. We also ~~thank~~ greatly appreciate the comments and suggestions of ~~also~~ our colleagues Dr. M.-H. Derron, Benjamin Rudaz and Antonio Abellán ~~for their comments and suggestions~~. We thank American Journal Experts for the improvements of the English language of this paper.

Comment [SE6]: If each of these three colleagues has a doctorate, please use the abbreviation "Drs."

References

Antoine, P., Giraud, A., Meunier, M. and Van Asch, T.: Geological and geotechnical properties of the 'terres noires' in southeastern France: Weathering, erosion, solid transport and instability, Engineering Geology, 40, 223-234, 1995.

Barneveld, R.-J., Seeger, M. and Maalen-Johansen, I.: Assessment of terrestrial laser scanning technology for obtaining high-resolution DEMs of soils. Earth Surf. Process. Landforms, 38, 1096-9837, 2013.

Caris, J.P.T. and Van Asch, T.: Geophysical, geotechnical and hydrological investigations of a small landslide in the French Alps, Engineering Geology, 31, 249-276, 1991.

DeRose, R. C., Gomez B., Marden, M. and Trustrum, N. A.: Gully erosion in Mangatu Forest, New Zealand, estimated from digital elevation Models, Earth Surface Processes and Landforms, 23, 1045-1053, 1998.

Galeandro A., Doglioni A., Simeone V. and Šimůnek J. S.: Analysis of infiltration processes into fractured and swelling soils as triggering factors of landslides. Environ. Earth Sci. 71, 2911–2923, 2014.

Leica Geosystem AG: Leica ScanStation 2 technical note, Heerbrugg, Switzerland, Vl.07, 2007.

Malet, J.-P., Durand, Y., Remaître, A., Maquaire, O., Etchevers, P., Guyomarc'h, G., Déqué, M. and van Beek, L.P.H. Assessing the influence of climate change on the activity of landslides in the Ubaye Valley. In: McInnes, R., Jakeways, J., Fairbank, H., Mathie, E. (Eds): Proceedings of the International Conference on Landslides and Climate Change - Challenges and Solutions, Taylor & Francis, London, pp. 195-205, 2007.

Maquaire O., Ritzenthaler A., Fabre D., Ambroise B., Thiery Y., Truchet E., Truchet E., Malet J.-P. Caractérisation des profils de formations superficielles par pénétrometrie dynamique à énergie variable: application aux marnes noires de Draix (Alpes-de-Haute-Provence, France). Comptes Rendus Géosciences, 334, 835–841, 2002.

Mathys N., Klotz S., Esteves M., Descroix L. and Lapetite J.-M.: Runoff and erosion in the Black Marls of the French Alps: observations and measurements at the plot scale. Catena, 63, 261-281, 2005.

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Mitchell AR AND van Genuchten MTh. Flood irrigation of a cracked soil. Soil Science Society of America Journal. 57, 490–497, 1993.

Oostwoud Wijdenes, D.J. and Ergenzinger, P.: Erosion and sediment transport on steep marly hillslopes, Draix, Haute-Provence, France: an early experimental field study. Catena, 33, 179-200, 1998.

Römkens M.J. M. and Prasad, Rain Infiltration into swelling/shrinking/cracking soils. Agricultual Water Management 86, 96 – 205, 2006.

Sanchez M., Atique A., Kim S., Romero E. and Zielinski M. Exploring desiccation cracks in soils using a 2D profile laser device. Acta Geotechnica, 8, 583–596, 2013.

Schmid, T., Schack-Kirchner, H. and Hildebrand, E.: A Case Study of Terrestrial Laser-Scanning in Erosion Research: Calculation of Roughness Indices and Volume Balance at a Logged Forest Site. Eds: M. Thies, B. Koch, H. Spiecker and H. Weinacker: Laser-Scanners for Forest and Landscape Assessment. ISPRS Archives – V. XXXVI-8/W2 - WG VIII/2, 114-118, 2004.

Selby, M.J., Hillslope materials and processes: Oxford, UK, Oxford University Press, 252–258, 1993.

Shepard, D., A two dimensional interpolation function for irregularly-spaced data, New York, USA. Proceeding ACM '68 Proceedings of the 1968 23rd ACM national conference, 517-524 1968.

Snapir B., Hobbs S. and Waine T.W. Roughness measurements over an agricultural soil surface with Structure from Motion. ISPRS J. of Photogrammetry and Remote Sensing, 96, 210–223, 2014.

Stumpf, A., Malet, J.-P., Kerle, N., Niethammer, U., & Rothmund, S. Image-based mapping of surface fissures for the investigation of landslide dynamics. Geomorphology, 186, 12-27, 2013.

Torri, D., Regüés, D., Pellegrini, S. and Bazzoffi P.: Within-storm surface dynamics and erosive effects of rainstorms. Catena, 38, 131-150, 1999.

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Table 1: Summary of the TLS scans ~~table of from~~in the TLS campaign experiment ~~for the TLS campaign of the~~on 31~~st of~~ June, ~~of~~ 2010. This table compiles the information concerning the scan time, the number of points before and after cleaning, the mean spacing between the points and the density of points.

Start of acquisition (duration [min])	Number of points before cleaning	Mean spacing [mm]	Distance from TLS [m]	Number of points after cleaning	Density [pts/cm^2]
11h01 (8)	601349	1	2	496391	84.84
12h00 (2)	149951	2	2	123233	21.06
14h00 (2)	149951	2	2	123477	21.10
14h30 (2)	149951	2	2	123269	21.07
15h00 (2)	149951	2	2	123496	21.11
15h30 (2)	149951	2	2	122857	21.00
16h00 (2)	149951	2	2	120162	20.54
16h30 (2)	149951	2	2	118301	20.22
17h00 (2)	149951	2	2	117290	20.05
17h30 (2)	149951	2	2	116322	19.88
17h32 (8)	601349	1	2	467484	79.90
17h47 (8)	601349	1	2	469906	80.31

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Figure 1: a. V~~v~~iew of the sample collection process,~~ing and~~ the metal case (1 m x 0.5 m x 0.20 m), and the approximate orientation of the bedding. ~~showing t~~The bottom plate is partially ~~entered~~ inserted~~and the approximate orientation of the bedding~~. b: View of the soil sample ~~of soil inclined at~~with an inclination of 45° during the rainfall event. c. Position of the TLS, which is protected from rainfall by a tent, relative~~ly~~ to the metal case~~ which is protected from rainfall by a tent~~.

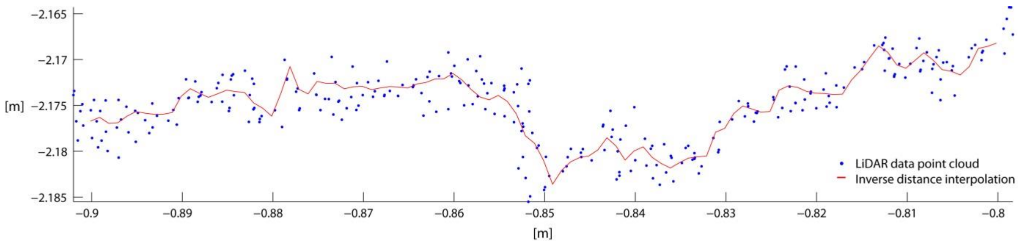

Figure 2: A 10-cm-long ~~D~~downhill section ~~of 10 cm long~~ using the points ~~over~~ from a 1-cm~~- width~~ wide swath of the original TLS data point cloud compared with the 1 mm DEM profile (17h47 scan data). The profile has been ~~performed~~ processed with an inverse distance interpolation with a power of one.

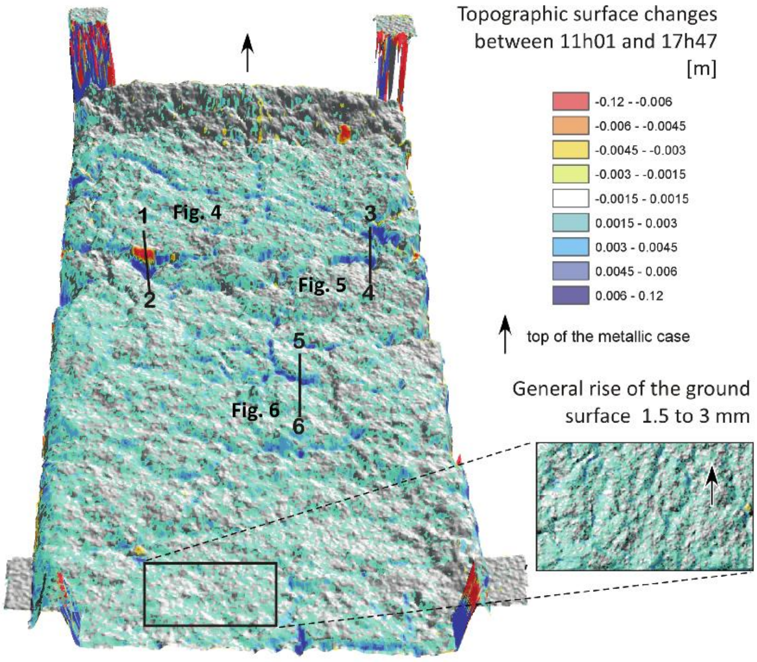

Figure 3: A comparison of TLS scans~~ comparison~~. The~~;~~ colours represent topographic changes ~~from~~ between 11h01 ~~to~~ and 17h47. ~~and~~ The figure also includes a ~~surface~~ detailed view of the surface~~view~~. The locations of F~~f~~igures 4 to 6 are indicated.

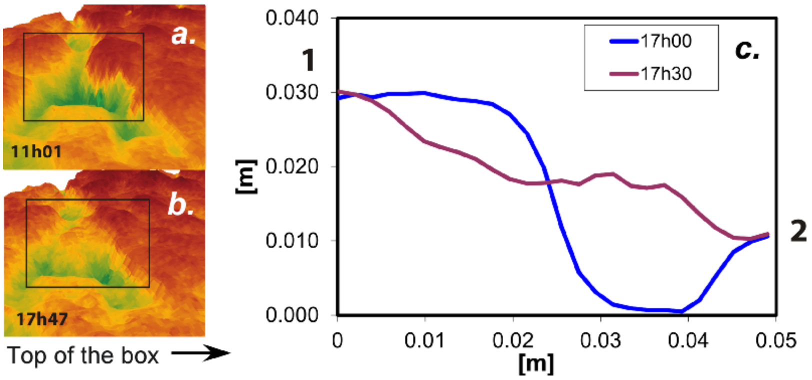

Figure 4: Profile changes showing ~~a ~~mass movement occurring between 17h00 and 17h30. ~~,~~ ~~but with the surface at 11h01 and 17h47. ~~a. A 3D view of the zone at 11h01 and b. at 17h47.~~,~~ T~~t~~he black boxes indicates~~s~~ the position of the profiles in c.

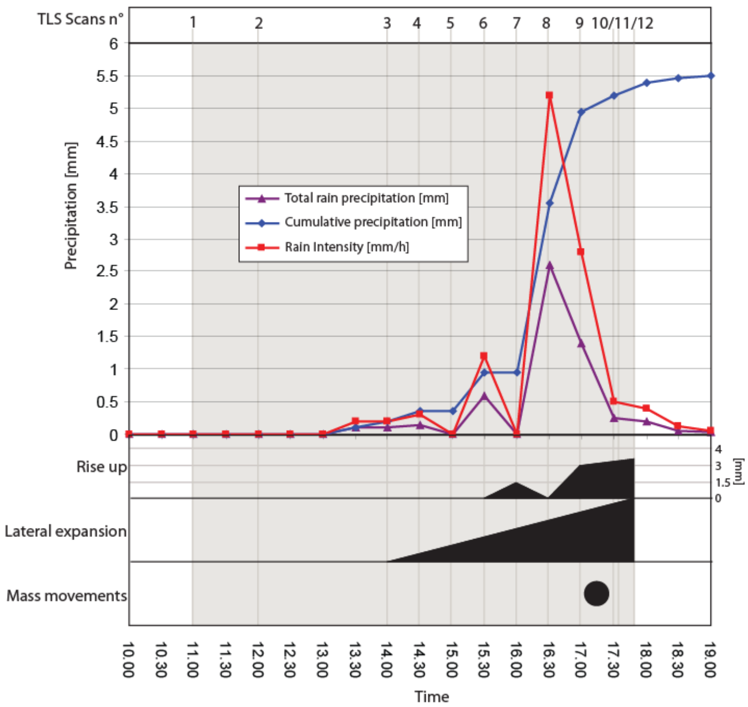

Figure 5: Observed phenomenon ~~according to the~~~~in relation~~relative to the precipitation data. The total rain amount in mm, the cumulative precipitation and the rain intensity are presented. The ~~duration of the ~~rise is shown in mm~~ing up is in mm~~, and ~~and ~~the lateral expansion ~~with its~~ intensity and mass movement processes are presented in relative scales.

Comment [SE7]: Please change "Rise up" to "Rise".

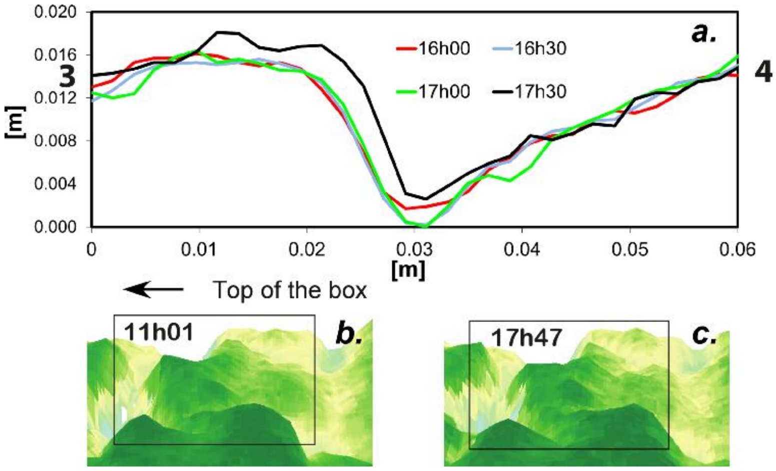

Figure 6: a. Profile changes showing the evolution of lateral expansion and surface rise ~~up from~~between 16h00 and 17h30. b. A 3D view of the zone at 11h01 and b. at 17h47.~~;~~ T~~t~~he black boxes indicate~~s~~ the position of the profiles in a.

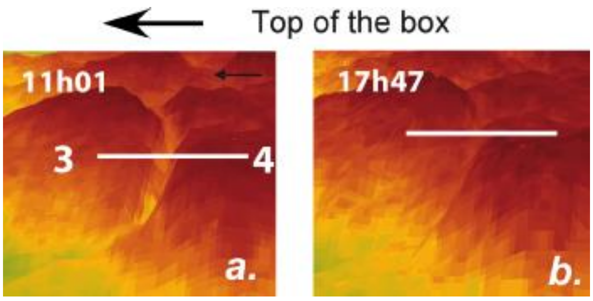

Figure 7: 3D views ~~changes showing~~ of the evolution of lateral expansion, which ~~showing~~ closes a crack ~~closure~~ between ~~from~~ 11h01 (a) ~~to~~ and 17h47 (b).