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 explicitly. 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 acquisition 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 « acquisition 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 at the millimetre scale: the-preliminary insights from an analogical analogous model

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Abstract

In order to investigate some of the 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 carefully extracted in situ. The sample is composed of black-marls soil, coming from a badlands area of the Draix Observatory (SE of France). After thoughtful extraction, the undisturbed sample has been placed with at the same slope angle (45°) as it's original orientation. This portion of soil, was then monitored for several processes by via a terrestrial laser scanner (TLS) with a millimetre-scale accuracy and resolution. This experiment allowed the identification of several surface processes interpreted as micro-landslides, swelling of the black-marls material and lateral expansion closing desiccation cracks. These micro-processes illustrate the complexity of the surface micro-topography changes that are controlling erosion and infiltration rates over times by surface micro-topography changes.

1 Introduction

Small black-marls watersheds have strong responses to climate forcing (Malet et al., 2007). This study aims to better understand the erosional behaviour and the micro-morphological
The goal of this experiment was to extract an undisturbed sample of black marls 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 the micro-topographic surface deformation and erosion processes in high detail, which may also have an impact on infiltration rates during rainfall events (Mitchell and van Genuchten, 1993; Römkens and Prasad, 2006). In addition, these surface changes may also have an impact on the triggering factor of landslides (Galeandro et al., 2014). Unlike as first intended, the duration of the experiment and the rainfall intensity did not permit investigations of the splash erosion as first intended, which can be important when rainfall is intense (Selby, 1993), because its effect was below the resolution of our acquisition and because of the rather low intensity of the rainfall, 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 the Draix Observatory (ORE Draix), which is an observatory dedicated to the research of mountain hydrology and erosional processes. Previous works focused on the measurement of sediment transport (Oostwoud Wijdenes and Ergenzinger, 1998) and runoff as a function of precipitation (Mathys et al., 2005). The badlands ground surface evolution has already been monitored during rainfall simulations by using a pin-type micro-relief-meter and photography (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 have shown the potentiality of 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 French Alps, a badlands area near the city of Digne-les-Bains. The experiment was performed in Lausanne (Switzerland), where the precipitations can be considered similar to the Alpine region. For the monitoring of the sample surface, a terrestrial laser scanner (TLS) has been used to (1) identify part of the millimetre-scale processes that are controlling 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.
2 Geological settings

The badlands near the village of Draix are composed of weathered black marls of Middle Jurassic age (Callovo-Oxfordian). This 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 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 by loose detrital material made composed of local clasts and platelets produced locally (Maquaire et al., 2002). This regolith corresponds to a sandy loam when it has been exposed during a time long enough to be disaggregated by weathering (Antoine et al., 1995). When 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-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 of the black marls located in this part of France has been measured to be 35±5% (Caris et Van Asch, 1991), but the clay mineral content is approximately 10% and is mainly mainly 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-layer detrital material is very sensitive to erosion and is a good candidate for experiments 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. The bedding crossing the surface of the outcrop is close to perpendicular (Figure 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 designed to keep undisturbed the soil structure undisturbed (Figure 1). The extraction 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 stored in the laboratory in dry conditions, which can be were similar to natural
conditions, during, for 3 months before the experiment started, which can be similar to natural conditions.

3.2 Experiment setup design

On the 31st May, 2011, the soil sample was exposed to a natural rainfall from 11h01 to 17h47. During the experiment, the soil sample was kept in its extraction casing, which was tilted by 45° in order to 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, which produces point clouds (x, y, and z data) in a three-dimensional 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 was measured by the weather station of the University of Lausanne (PluvioMADD2 from MADD Technology), located at 500 m from the experiment location.

Since the sample was dry at the beginning of the experiment, the total precipitation during the experiment was 5.5 mm, which corresponds to approximately 1.3 litres that entered the metal case. Most of the rainfall was absorbed by the sediment, which limited the transport of sediment by runoff. Consequently, 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 the box before and after the experiment, and this minor influence has been neglected in our study.

3.3 Data acquisition

The surface evolution was monitored for 6 hours and 46 minutes by 12 successive laser scan acquisitions. The first scan and the last scan (acquired at 11h01 and 17h47, respectively) have approximately a point spacing of 0.001 m with a duration time of 8 min. All the other scans have a 0.002 m point spacing for a duration of 2 min. From 0 to 50 m, 50% of the laser beam is at a diameter of 4 mm at full width half height (FWHH) (Leica Geosystems AG, 2007). The scans 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 sec for the 8 min. scans. The scan distance was 2 m. The instrument was not moved throughout the experiment,
meaning that the position and the orientation of the scans are identical for all of the acquisitions. As a consequence, no scan alignment was necessary to compare the obtained point clouds.

### 3.4 Data processing

The point clouds were “manually” cleaned from the points that are not imaging the surface of the sample, i.e., the metal casing sides, the background of the scenery and some artefacts, including points away from 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 the other scans (Table 1).

Each TLS point cloud was first rotated by 45° to obtain 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) 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-resolution digital elevation models (DEM) of altitude z above the mean horizontal surface. The search radius for DEM generation was defined 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 as the most adequate 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 0.0015 m were ignored; this threshold was obtained by a trial and error procedure.

### 4 Results

The precipitations started at last 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 precipitation amount was 5.5 mm was recorded at the end of the experiment. Three different surface processes of topographic changes were identified and discriminated. The Figure 3 displays shows the difference between the initial and final scans (11h01 and 17h47, respectively). The rising of Changes in the surface elevation ($z$) appears 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-topographically changes that occurred along location transect 1–2 are shown in Figures 3 and 4. As can be observed in Figure 4c shows, a depression (in red) is formed at the top of a small ridge (in red), and the surface elevation of a depression below this ridge is filled increased (in blue). This change can be interpreted as a downward mass movement at the millimetre scale. The small particles moved down, filling 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 perpendicularly to the surface of the 45° slope at 45°), appearing which appears as a pale blue layer in Figures 3 and is illustrated in Figure 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 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, the processes 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.
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. These changes were 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 approximately 50 sec). In addition, the two profiles before and after the occurrence of the changes mimic the profile changes usually observed in real landslides. Such a process can be related to the initiation of miniature debris flows (MDFs) observed by Oostoud Wijdenes and Ergenzinger (1998), but the latter needed heavy rainfall to be transformed in MDFs.

The observed rise in the surface, which reacts fully occurred with rainfall with a following 30-minute delay after the initiation of 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 cessation of rainfall and 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 this process is linked to the moderate rainfall intensities, which allows the water to infiltrate the fine-grained material, causing and swell part of the swelling fine-grained material. Furthermore, This process is not necessarily caused by clay minerals, since they are present only in small quantities (mostly primarily illite) in the study area (Antoine et al., 1995). The swelling must dissipate rapidly for moderate rainfall events because of the diffusion of water when the rainfall stops, which leads to a decrease of the effect of the water effect.

The crack-closing lateral expansion of the surface is also certainly linked to swelling, but does not retreat reverse when the rain stops. It is clear from the figures 6 and 7 clearly show that the material has expanded, bBut, and that it is not affected by the material as not transported, since no deposition was observed at the bottom. We do not find any definitive explanation for that accounts for the difference with the rising up process and the lateral expansion process. However, the difference must be related to gravity, which increases the effect of swelling downward. Then, when both the two sides of the crack touch each other make contact, the moistened zone doubles its...
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 less effective for in the downward downslope 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 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 a role for in the closure of cracks, as was shown in Figure 7. In the present case study, we demonstrated how micro-scale infiltration can influence the degradation of soil surface by inducing downward mass movements that are not reversible.

We have also shown here the great potential of 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 throughout surface mass movements at the millimetre scale. Investigations about of erosional processes using point clouds are increasing in number. They These studies use either Laser scanners for either for micro-scale surface imaging (Schmid et al., 2004; Barneveld et al., 2013) or measuring for cracks apertures (Sanchez et al., 2013). In addition, photogrammetry and especially Structure from Motion (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 This study also shows demonstrates also that material and rain intensity must be sufficient suitable to permit 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
Thanks. The authors would like to thank the Observatoire de Recherche en Environnement (ORE) of Draix, for letting us sample soil in 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.
References


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


Table 1: Summary of the TLS scans from the TLS campaign experiment for the TLS campaign on 31st of June, 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.

<table>
<thead>
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<th>Start of acquisition (duration [min])</th>
<th>Number of points before cleaning</th>
<th>Mean spacing [mm]</th>
<th>Distance from TLS [m]</th>
<th>Number of points after cleaning</th>
<th>Density [pts/cm²]</th>
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<td>2</td>
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<td>2</td>
<td>2</td>
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<td>2</td>
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</tr>
</tbody>
</table>
Figure 1: a. View of the sample collection process and the metal case (1 m x 0.5 m x 0.20 m), and the approximate orientation of the bedding, showing the bottom plate is partially 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, relatively to the metal case which is protected from rainfall by a tent.
Figure 2: A 10-cm-long downhill section of 10 cm long using the points over 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 processed with an inverse distance interpolation with a power of one.

Figure 3: A comparison of TLS scans. The colors represent topographic changes from 11h01 to 17h47. The figure also includes a surface detailed view of the surface. The locations of Figures 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. The black boxes indicate the position of the profiles in c.

Figure 5: Observed phenomenon according 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, and the lateral expansion with its intensity and mass movement processes are presented in relative scales.
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. The black boxes indicate 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).