Hydrol. Earth Syst. Sci. Discuss., referee comment RC2
https://doi.org/10.5194/hess-2021-298-RC2, 2021

Comment on hess-2021-298

Anonymous Referee #2

Referee comment on "Compaction effects on evaporation and salt precipitation in drying porous media" by Nurit Goldberg-Yehuda et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-298-RC2, 2021

The paper discusses the impact of soil compaction leading to a vertical gradient in hydraulic properties and grain size distribution on evaporation from soils, on the formation of salt crusts, and on the feedbacks between salt crust formation and evaporation dynamics. An interesting aspect is that the formation of a salt crust can have an additional impact on the dynamics of evaporation from saline soils, in addition to the impact of the osmotic potential on the vapor pressure. Depending on the hydraulic properties of the porous medium and of the salt crust, either the evaporation is reduced instantaneously when the salt crust is formed or the evaporation may be sustained at a potential rate for a certain time after the crust was formed (an aspect that clearly comes out of the numerical simulations which could be highlighted more). The timing of the reduction depends on the hydraulic properties of the salt crust and the underlying porous medium. The paper discusses in detail how the vertical variations (or gradients) in hydraulic properties of the underlying porous medium play a role in the evaporation dynamics and salt crust formation.

One part of the paper presents the impact of compaction on vertical gradients in grain and pore size of a coarse sand. Two types of methods are used: micro CT and macroscopic images of colored sand particles from which particle displacements and changes in bulk densities are derived. The CT images clearly show the effect of compaction on pore and grain sizes and that the compaction effects are larger near the surface but vanish deeper in the soil sample. Effects of compaction are also visible in the macroscopic images but unlike what the authors write, I do not see convincing vertical gradients in compaction in these images.

A coarse sand is investigated and compaction of this coarse sand clearly led to a change in particle size due to a breaking up of sand particles. However, I am wondering whether compaction would have a similar effect on particle size in other texture classes (fine sand, silt, clay). Another aspect is that coarse sands are not known as soils where compaction has large effects on porosity. I would expect larger effects of compaction in silty and clayey soils. This could be addressed maybe in the discussion section.

In a second part of the paper, simulation and lab experiments are carried out to demonstrate the effect vertical gradients in soil properties on evaporation dynamics from saline soils (including salt crust formation). The impact of compaction on evaporation is demonstrated in these sections using a layered porous medium with layers with different grain size distributions with larger grain sizes deeper and smaller grain sizes closer to the soil surface (information about the bulk density is not given). The layered profile is then compared with a uniform profile that consists of a mix of grain sizes. This mix of grain sizes should represent the non-compacted soil. But, I wonder whether this is a consistent representation of the non-compacted soil. To be consistent, the authors should have used a uniform system that consists of the grains from the lowest layer in their layered setup. By using a mixture of grains, they generate a porous medium with a wider pore size distribution (as is reflected in the lower n value) and also a lower porosity (as is reflected in the lower saturated water content) which therefore has also a higher bulk density. The comparison between the mixed-uniform and layered systems is therefore not a suitable analogue for a comparison between compacted and non-compacted soil. The mixed uniform soil represents a medium with a wider grain size distribution and pore size distribution. According to the first part of the paper, this should be a characteristic of the top compacted layer but not of the non-compacted soil. Therefore, I think that authors should best include a new experiment with a uniform sample that represents the non-compacted lower soil layer.

In general, the paper was well written. But, some parts should be described more clearly since readers might easily draw incorrect conclusions from certain sentences. For instance, the focus on the higher capillary suction that can be exerted by a fine top soil layer gives the impression that more water can be pulled up from coarser deeper soil layers than in case the fine textured layer is not present and that therefore more water can be evaporated when a fine textured layer is present at the soil surface. First, the authors should always make clear when they make comparisons with what they are comparing, i.e. what is the base case: the uniform fine texture layer or the uniform coarse texture layer. Often comparisons are made but it is not explicitly clear with what the comparison is made. In the list of detailed comments, examples of these comparisons are given. Second, the conclusion that more water can be pulled from underlying coarser layers when a fine layer is on top is incorrect (the authors do not write this but from what they write, one could easily draw this incorrect conclusion). The reason for larger evaporation losses when a fine layer is on top is that almost the same amount of water can be extracted from the underlying coarser layers and to this amount of water, the water that can evaporate from the fine layer can be added. The conceptual figure 1 does not really illustrate this but could be easily adapted to make this clear.

A second issue that should be explained better is the reason why the presence of the fine layer keeps the salt layer on top better connected to the deeper soil. The authors argue that it is related to the wetness of the fine layer that keeps the hydraulic connection. I think this should be rather the capillary pressure of the fine layer which is not too high (or pressure heads too low) so that the salt layer is not dried out too much and the water at the top of the salt crust stays hydraulically connected to the deeper soil. Therefore, the statement that the higher capillary pressure in the fine layer keeps the hydraulic connection between the salt crust and the deeper soil layers is to my opinion incorrect since it should rather be the opposite. In addition to showing the simulated wetness, I propose to include also simulated capillary pressure heads to make this clear.

Specific comments:

Ln 25: ‚comprised‛ The wording was not clear to me whether ‘comprised’ means an increased connectivity or decreased connectivity.

Ln 53: Isn’t the reason for compaction after tillage that soil aggregates slake after rain and the slaked particles create a crust?

Ln 54: Isn’t that the plough pan?

Ln 63: The uneven distribution of hydraulic properties does not necessarily lead to anisotropy. What determines the anisotropy is the shape, orientation of the heterogeneities.

Ln 111: manly à mainly

Ln 120: A precipitated salt layer may increase evaporation… : with respect to which conditions would the evaporation be increased? I am a bit sceptic that a salt layer can really ‘increase’ evaporation compared to the evaporation rates that would occur when there is no salt layer. Especially during phase I, when evaporation is mainly controlled by the available energy, I expect no big influence of the salt layer (even a reduction of evaporation since the albedo of the salt is higher than of the soil). I suppose the authors are referring here to the effect of the pore size distribution, which may be finer than in the underlying soil generating a higher capillary suction, on evaporation. The higher capillary suction in the top layer can lower the drying front in the underlying layer, but not more than by the thickness of the top layer. Thus, a thin top layer will lower the drying front only very little. The lowering of the drying front in the underlying layer by the thickness of the upper layer does not increase the amount of water that can be evaporated during phase I evaporation from the underlying layer. The increase in evaporation during phase I evaporation comes from the extra water that evaporates from the top layer. Thus, when this layer is very thin, there will be almost no effect on evaporation. This was also demonstrated by Li et al. (VZJ, 2020, DOI: 10.1002/vzj2.20049)

Ln 156: I agree that the higher capillary suction of the compacted top layer can pump up water from deeper in the underlying noncompated soil layer. But, this depth does not depend so much on the magnitude of the capillary suction that may be exerted (at least when it is above a certain threshold) by the compacted layer but rather on the thickness of the compacted layer. Furthermore, the depth from the top surface of the noncompated layer from which water is pumped up, does not increase. It is the depth from the soil surface that increases.

Ln 181: ‘where a continuous flow of water is sustained from the deeper layer of the soil profile to the soil surface, extending the duration of S1 and allowing more water to evaporate.’ See comments above. First, it is important to explain with respect to which condition the duration of S1 is extended. When it is with respect to a fully compacted soil layer, i.e. without an noncompated layer below it, then I think it is not correct to state in general that an noncompated layer below a compacted soil layer leads to an extension of S1. When it is with respect to evaporation from an noncompated layer, then the formulation could be read as if the extension of S1 by the presence of the compacted layer on the surface is due to the fact that more water is extracted from the underlying noncompated layer during S1. But, I think this would be a wrong interpretation since the presence of the compacted layer on top of the compacted layer cannot increase the amount of water that can be extracted from the noncompated layer. The only reason why more water can be evaporated during S1 by the presence of a compacted layer (in comparison to an noncompated soil) is because additional water is lost from the compacted layer.

Ln 183: ‘Consequently, the deeper soil layers dry out first, while the upper layers remain at relatively high levels of water content (Figure 1B(2)).’ I agree. But, if the upper layers do not lose water during S1, then S1 will not be extended and there would not be more salt precipitating. So, I think there is a conceptual problem with figure 1 because the same amount of water was lost (and therefore the same amount of salt should be precipitated) in figures 1B1 and 1B2. I propose to include also some air in the compacted layer so that water is lost from figure 1Bmore is lost.

Ln 187: ‘In noncompacted conditions, the precipitated salt crust reduces evaporation as it acts as a barrier that reduces water vapor diffusivity from the evaporation front to the soil surface and to the atmosphere (Figure 1B(1)).’ But this reduction occurs during S2 and would also occur during S2 in the compacted soil.

Ln 193: ‘…its impact on evaporation will be moderate compared to non-compacted conditions.’ I think the impact is rather related to where evaporation is taking place, i.e. small impact when the evaporation takes place at the surface of the salt crusts but larger impact when the evaporation takes place deeper in the soil profile. Also in the compacted soil, the impact of the salt crust might be large during S2 whereas its impact might be small in the noncompacted soil during S1.

Ln 226: ‘with typical grain diameter of ~500 µm (sand characteristics can be found in Nachshon, 2016)’ What does the ‘typical grain diameter’ represent: the median, mode, ….? I propose to include also a uniformity index of the grain size distribution.

Ln 245: Which Matlab libraries or toolboxes are these functions from?

Ln 260: Shouldn’t it be ‘increased’ instead ‘reduced’?

Ln 295 table 1: I would propose to include the hydraulic properties of the salt layer also in this table. The parameters are related to the particle size except for the saturated water content. Maybe a reason for this different behavior of the saturated water content with particle size could be given.

Ln 324: I think that also fluid viscosity and surface tension are influenced by the salt concentration.

Ln 360: grain sizes? Shouldn’t that be grain numbers?

Ln 400: Figure 3: grain number, grain area and mean pore distance should have units. I do not understand the relation between grain number in Fig 3A and grain number in Figure 3B.

Ln 438: ‘Nevertheless, it is evident that most of the profile underwent compaction, as most of the Δð□□· values are negative, and that maximal compaction was measured in the top parts of the sample, in agreement with the results from the micro-scale study.’ I do not really see this in figure 4B. I would rather say that the compaction is heterogeneous but does on average not differ a lot with depth.

Ln 454: ‘…including the unique pattern of drying from top to bottom,’ Shouldn’t it be reverse: unique drying from bottom to top?

Ln 474: ‘the presence of the salt crust resulted in hydraulic discontinuity between the saturated lower parts and the upper surface of the domain.’ I do not follow this statement. Looking at figure 5A2, the water content in the soil profile is quite uniform with depth so that the lower parts of the domain are not much more saturated than the upper parts of the soil column. It seems to me that the presence of the salt layer leads to a reduction of the effective hydraulic conductivity of the layered medium that consists of the salt layer and the underlying uniform soil.

Ln 480: ‘The fine media at the top of the FU profile maintained wetness conditions that enabled liquid water flow from the soil into and through the salt layer, to replenish evaporation at its upper surface.’ I think the crucial point here is the capillary suction (and not the wetness) in the upper layer since that defines the suction and conductivity of the salt layer. I suppose that in the layered profile, the capillary suction at the top of the profile was lower (water pressure head was less negative) at the time of the initiation of the salt layer than in the uniform profile. As a consequence, the conductivity of the salt layer would be larger in the layered profile than in the uniform profile so that it could sustain S1 evaporation longer.

Ln 565: please check the figure caption. The labels do not correspond with what is shown in the figure.

Ln 575, table 2. The standard deviations should have units.

Ln 639 ‘We suggest that, in the case of a homogeneous soil, the receding evaporation front breaks the hydraulic continuity to the salt crust.’ I suppose that this depends on the hydraulic properties of the homogeneous soil and not on the fact whether the profile is layered or homogeneous. What would be the difference between DI and saline solution evaporation when the homogeneous soil would consist of the fine soil layer material?

Ln 690: ‘This is attributed to the stronger capillary suction of the upper layers, at the FU structure, which pumps water from the underlying levels upwards, maintaining high saturation at the soil surface’ I rather think it is the opposite (but I am not sure and it would be helpful to show simulated capillary pressures or pressure heads). The fine layers on top keep the capillary suction for a longer time at a relatively low level so that the salt layer does not dry out and connectivity between the evaporating surface at the top of the salt layer and deeper in the soil profile is not lost. In the uniform soil layer, the capillary pressures increase more (pressure heads become more negative) so that the salt layer dries out earlier and the hydraulic connection between the top surface of the salt layer and the underlying soil is lost earlier and evaporation reduced earlier.