Response to EC1

1. This paper presents a meta-analysis of some papers that deal with the effects of a change from conventional agricultural tillage to some form of conservation tillage (reduced tillage or no tillage). From a literature search, 59 studies were selected following a screening process to include only those studies that provided key data on Ksat, the soil saturated hydraulic conductivity. This is taken by Liao et al. to be the same as steady-state infiltrability measured across the soil surface, though technically this is not the same thing at all. One refers to flow through a saturated porous medium, the other the imbibition of water from free water above the soil to pore water beneath the soil surface. In this case there are interface issues such as surface tension, surface crust and seal effects, the influence of litter, mulch, and other factors. I think that all of this could usefully be clarified in the present ms.

Answer: Thank you for your suggestion. In the revised manuscript, we have indicated that of the 65 studies, 7 did not provide K_{sat} values, but steady-state infiltration rate values. The K_{sat} refers to flow through a saturated porous medium, and the infiltration rate represents the imbibition of water from free water above the soil to pore water beneath the soil surface. In this case there are interface issues such as surface tension, surface crust and seal effects, the influence of litter, mulch, and other factors. Nevertheless, the steady-state infiltration rate was assumed to be the K_{sat} by convention in this study (Yolcubal et al., 2004; Kirkham, 2014).

2. The paper seems to me to neglect some important issues that bear on the interpretation of the published studies. A serious issue for me is that there is no assessment of the quality of the data in the 59 studies. The authors tacitly accept all of the soil Ksat measurements as being valid and reliable measures of Ksat and suitable for their assessment of Ksat differences between forms of tillage. I do not think that this is a defensible position. It is widely-known, for instance, that the dimensions of the area of volume of soil tested influence the results of many Ksat (or steady infiltration rate) measurements. Thus, if ring or cylinder infiltrometers are used to

estimate Ksat from ponded conditions (whether single or double cylinder), the area of soil enclosed within the cylinders (expressed usually by the ring diameter) influences the result obtained. This makes intuitive sense, since a small cylinder might be underlain by a buried stone, so reducing the apparent Ksat, or by a large root macropore, so increasing the apparent Ksat. As the cylinder diameter is increased, the relative effect of such occurrences is reduced. Of course, the choice of an appropriate size of cylinder depends on the properties of the soil being tested. However, the point is that in this paper, Liao et al. simply accept all the results (not mentioning the cylinder diameter used) as valid and meaningful measurements. Unlike, for example, chemical properties, which with care can be measured precisely and unambiguously, the hydraulic properties of soils exhibit a complex dependency on the method and scale of measurement. Some authors have suggested that the measurements need to address something akin to the 'representative elementary volume' concept, adjusted to relate to the scale over which field conditions modulate Ksat.

I mention a few studies here that the authors might find helpful:

Fatehnia, M., Tawfiq, K., & Ye, M. (2016). Estimation of saturated hydraulic conductivity from double-ring infiltrometer measurements. European Journal of Soil Science, 67(2), 135-147. doi:https://doi.org/10.1111/ejss.12322

Please see Figure 6 in Fatehnia et al. (2016) for plots of infiltration rate vs ring or cylinder diameter.

Lai, J., & Ren, L. (2007). Assessing the Size Dependency of Measured Hydraulic Conductivity Using Double-Ring Infiltrometers and Numerical Simulation. Soil Science Society of America Journal, 71(6), 1667-1675. doi:https://doi.org/10.2136/sssaj2006.0227

This study concludes that inner ring diameters of > 80 cm are needed for reliable measurements.

Li, M., Liu, T., Duan, L., Luo, Y., Ma, L., Zhang, J., . . . Chen, Z. (2019). The Scale Effect of Double-Ring Infiltration and Soil Infiltration Zoning in a Semi-Arid Steppe. Water, 11(7), 1457. https://www.mdpi.com/2073-4441/11/7/1457

This is one of many additional studies of the infiltrometer scale effect.

Answer: Thank you for your suggestion. In the revised manuscript, for ring infiltrometer, the diameter of a single ring, or the diameter of the inner ring of a double ring, should be greater than 15 cm. This is because that Youngs (Journal of Soil Science, 38, 623–632, 1987) concluded that results were consistent from site to site when the ring size was at least 15 cm. Gregory et al. (Applied Turfgrass Science, 2, 1–7, 2005) also concluded that for a constant head test in sandy soil generally found in north and central Florida, a double-ring infiltrometer with 15-cm inner and 30-cm outer diameters would be suitable. In this case, the original selected literatures, such as Ouellet et al. (2008) and Abid and Lal (2009), have been deleted in the revised paper.

References:

1. Youngs, E.G. 1987. Estimating hydraulic conductivity values from ring infiltrometer measurements. Journal of Soil Science, 38, 623–632.

2. Gregory, J.H., Dukes, M.D., Miller, G.L. & Jones, P.H. 2005. Analysis of double-ring infiltration techniques and development of a simple automatic water delivery system. Applied Turfgrass Science, 2, 1–7.

The cylinder or ring diameter has been mentioned in Table S2 of the supplementary file. In the “Measurement technique” column, the numbers in parentheses indicate the diameter (cm) of the device.

Table S2 Experimental conditions from a global meta-analysis of 65 studies.

Reference	N[a]	Measurement technique[b]	Measurements		OMC[e] (%)	Time interval from tillage conversion to measurement (yr)	General descriptions
			IR[c]	K_{sat}[d]			
Abu and Abubakar (2013)	6	Constant head		√		1 (2010~2011)	Cores were collect 15–30 cm).
Afyuni and Wagger (2006)	18	Constant head		√	0.91~1.40		Cores were collec and 30–45 cm).
Alletto and Coquet (2009)	9	Tension disc (8)	√	√	1.38~2.24	5 (2000~2005)	Infiltrations were and −0.1 kPa matric
Anikwe and Ubochi (2007)	3	Not provided		√	2.67	1 (2005~2006)	
Azooz and Arshad (1996)	2	Single ring (20)	√	√	1.72~4.31	15 (1978~1993)	The single ring w
Azooz et al. (1996)	8	Guelph		√	1.72~4.31	15 (1978~1993)	The K_{sat} to a dep increments was deter
Blanco-Canqui et al. (2017)	2	Constant head		√		34 (1980~2014)	Two intact soil c long) per plot were core sampler for dep 22.5–30 cm.
Blanco-Canqui et al.	4	Either constant or		√	1.45~1.63	13 (1982~1995)	Cores were collec 100 to 200 mm fr

3. Another concern that I have with this paper is the choice of test methods for the measurement of Ksat. The authors refer to the effects of drop impact on soil surfaces (e.g. lines 64-65, line 67) via the resulting sealing and crusting effects. Yet none of the measurement methods in their literature survey includes rainfall simulation on field plots, or the study of the response of 'natural plots' (those exposed to real rainfall). It is unclear why such effects should be excluded from analysis. It seems to me to be possible (perhaps probable) that by employing only static water, with no droplet impact, the methods used may well have over-estimated Ksat by excluding dynamic sealing and crusting effects. Likewise, intense rain can drive air into soil pores, thereby reducing infiltrability considerably. Field soils have some residual air content ('field saturation') which is not the same as the 'laboratory saturation' achieved by bottom-up wetting.

There are multiple published studies of conventional versus conservation tillage that do indeed employ rainfall simulation. I have listed a couple of instances below.

A paper that reports rainfall simulation results, including hydraulic conductivity, in a study comparing traditional and conservation tillage is:

Packer, I., Hamilton, G., & Koen, T. (1992). Runoff, soil loss and soil physical property changes of light textured surface soils from long term tillage treatments. Soil Research, 30(5), 789-806. doi:https://doi.org/10.1071/SR9920789

It is not clear to me why papers such as this were not discovered in the literature survey by Liao et al. If they did not locate this paper, there may be many more that were also not located. It might take a wider choice of search terms than was adopted by Liao et al. to find relevant papers.

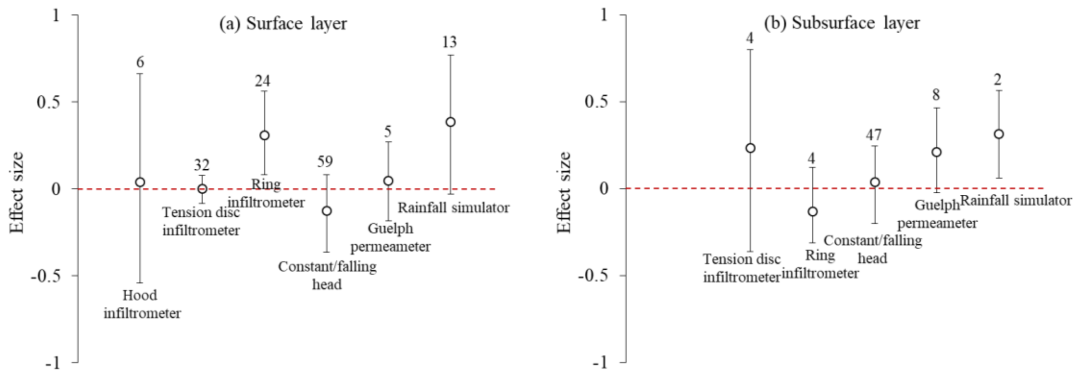
Some other examples of the application of rainfall simulation to the exploration of the effects of conservation tillage (neither is cited by Liao et al.) include:

Endale, D. M., Schomberg, H. H., Truman, C. C., Franklin, D. H., Tazisong, I. A., Jenkins, M. B., & Fisher, D. S. (2019). Runoff and nutrient losses from conventional and conservation tillage systems during fixed and variable rate rainfall simulation. Journal of Soil and Water Conservation, 74(6), 594.

doi:10.2489/jswc.74.6.594

Salem, H. M., Ali, A. M., Wu, W., & Tu, Q. (2021). Initial effect of shifting from traditional to no-tillage on runoff retention and sediment reduction under rainfall simulation. Soil Research, -. doi:https://doi.org/10.1071/SR21082

Answer: Thank you for your suggestions. In the revised paper, we selected the studies that employ rainfall simulation methods (as shown in the figure below). It is found that for surface and subsurface soil K_{sat}, the mean effect sizes under CS conversion were 0.385 (95% CI: -0.033 to 0.766) and 0.314 (95% CI: 0.062 to 0.566) for rainfall simulator, respectively. The K_{sat} measured by rainfall simulator tended to increase under CS practices. This is consistent with the findings of previous studies. For instance, Singh et al. (1994) observed that rainfall can reduce surface roughness, especially the first rains after tillage due to breakdown and sloughing of soil clods upon wetting during rainstorms. Therefore, Lampurlanés and Cantero-Martínez (2006) proposed that if a rainfall simulator had been used, greater infiltration rates would probably have been found on NT, because residues play a role similar to that of surface roughness, i.e., increasing the time for infiltration to take place. However, Gupta et al. (1997) found the lower K_{sat} values of soil in NT plots compared with those in CT plots, which was attributed to the fact that the NT practice allowed a consolidated layer to form. This was relatively impervious to the infiltrating water on the soil surface. The restricted downward movement of rain water produced lower K_{sat} under NT. Therefore, more data are needed to test the effect of conversion to CS on K_{sat} measured by rainfall simulator in the future.



Indeed, intense rain can drive air into soil pores, thereby reducing infiltrability considerably. However, K_{sat} decreases under both CT and CS. Therefore, intense rain only affects the K_{sat}, but it is difficult to judge the effect of intense rain on the influence of tillage conversion on K_{sat}.

The study of Packer et al. (1992) has been used for meta-analysis, but the studies of Endale et al. (2019) and Salem et al. (2021) has not been applied since these two studies did not include saturated hydraulic conductivity data.

4. The acceptance of published data without evaluation of effects such as the scale of measurement, even when considering just one of the methods, viz., cylinder infiltrometry, and with the lack of reference to studies that employ rainfall simulation methods. The latter have many attendant issues, but at least may capture some of the effects of surface bombardment by water drops, and the development of air entrapment, seals, crusts, etc. In turn these issues suggest that the authors may need to cast their literature searching net somewhat wider than they appear to have done, as there is a considerable relevant literature, and thorough searching is a cornerstone of thorough meta-analysis work.

Answer: Thank you for your suggestions. In the revised manuscript, for ring infiltrometer, the diameter of a single ring, or the diameter of the inner ring of a double ring, should be greater than 15 cm. This is because that Youngs (Journal of Soil Science, 38, 623–632, 1987) concluded that results were consistent from site to site when the ring size was at least 15 cm. Gregory et al. (Applied Turfgrass Science, 2, 1–7, 2005) also concluded that for a constant head test in sandy soil generally found in north and central Florida, a double-ring infiltrometer with 15-cm inner and 30-cm outer diameters would be suitable. In this case, the original selected literatures, such as Ouellet et al. (2008) and Abid and Lal (2009), have been deleted in the revised paper.

In addition, we also selected the studies that employ rainfall simulation methods (as shown in the figure below). It is found that for surface and subsurface soil K_{sat}, the mean effect sizes under CS conversion were 0.385 (95% CI: -0.033 to 0.766) and 0.314 (95% CI: 0.062 to 0.566) for rainfall simulator, respectively. The K_{sat} measured by rainfall simulator tended to increase under CS practices. This is consistent with the findings of previous studies. For instance, Singh et al. (1994) observed that rainfall can reduce surface roughness, especially the first rains after tillage due to breakdown and sloughing of soil clods upon wetting during rainstorms. Therefore, Lampurlanés and Cantero-Martínez (2006) proposed that if a rainfall simulator had been used, greater infiltration rates would probably have been found on NT, because residues play a role similar to that of surface roughness, i.e., increasing the time for infiltration to take place. However, Gupta et al. (1997) found the lower K_{sat} values of soil in NT plots compared with those in CT plots, which was attributed to the fact that the NT practice allowed a consolidated layer to form. This was relatively impervious to the infiltrating water on the soil surface. The restricted downward movement of rain water produced lower K_{sat} under NT. Therefore, more data are needed to test the effect of conversion to CS on K_{sat} measured by rainfall simulator in the future.