AUTHORS' RESPONSE TO THE REVIEW COMMENT
ANONYMOUS REFEREE #2

Manuscript **hess-2016-93** entitled

"Repeated electromagnetic induction measurements for mapping soil moisture at the field scale: validation with data from a wireless soil moisture monitoring network"

by Edoardo Martini, Ulrike Werban, Steffen Zacharias, Marco Pohle, Peter Dietrich, and Ute Wollschläger

We would like to thank the anonymous referee #2 for the constructive comments, which will certainly improve the quality of the paper.
We will improve the revised manuscript according to his/her recommendations. In the following, we addressed all the comments.

Reviewer's comment

"For the most part this is a well-written manuscript that clearly describes what was done in the study. The methods and analysis are sound, and the results make a meaningful contribution to our understanding of EMI techniques and their relationship (or lack thereof, in some cases) to soil water content. I have just a few minor comments and suggestions for the authors.
Page 2, Line 20 – "To a higher clay. . ." should be "A higher clay. . ."

Authors' response

We thank the referee for this recommendation. We will change the sentence to:
"*A higher clay content and/or higher organic matter content usually correspond to a higher content of adsorbed water* […]"

Reviewer's comment

"Page 2, Line 25 – In addition to Corwin et al., 2008, I suggest citing Brevik and Fenton, 2004, which may be the first published field study working with EMI that addressed this."

Authors' response

We agree and will add the suggested citations.

Reviewer's comment

"Page 2, Lines 24-26 – In addition to Doolittle et al., 2001 in line 24 I suggest citing Heilig et al., 2011. In addition to Abdu et al., 2008 in line 25 I suggest citing Heil and Schmidhalter, 2012. And in addition to Al-Gaadi, 2012 in line 26 I suggest citing Brevik and Fenton, 2004 and Islam et al., 2014. This enhances the citations a bit and makes the three citations suddenly used for soil organic carbon in line 27 not look so

out of place (only 1 citation is used for every idea in this section except for SOC). Another citation or two for some of the other ideas where I haven't made specific suggestions wouldn't be a bad thing either."

Authors' response

We believe that the reviewer refers here to Page 3 instead Page 2. We agree on the suggested citations and we thank the reviewer for the useful hint. We propose to improve the section (Page 3, Lines 23-31) by adding some citations (underlined in the text below). In order to provide two examples for every item, we would not add the citation of Brevik and Fenton (2004) as suggested by the reviewer, simply because it will be cited elsewhere (in Page 2, Line 25: see comment above). Similarly, we would like to delete the citation of Werban et al. (2009) which is already cited elsewhere in the manuscript (in Page 3, Line 21).

The improved paragraph would be as follows:

"The fact that ECa measured with EMI responds to variations of several soil properties encouraged its use for a broad range of scopes. Examples of the application of EMI-based ECa measurements include soil salinity (e.g., Doolittle et al., 2001; Heilig et al., 2011), spatial pattern of soil texture (e.g., Abdu et al., 2008; Heil and Schmidhalter, 2012), lateral boundaries between soil types (e.g., Anderson-Cook et al., 2002; James et al., 2003), depth to clay-rich layers (e.g., Saey et al., 2009; Doolittle at al., 1994), clay content (e.g., King et al., 2005; Weller et al., 2007), soil compaction (e.g., Al-Gaadi, 2012; Islam et al., 2014), soil CEC (e.g., Headley et al., 2004; Triantafilis et al., 2009), soil organic carbon (e.g., Martinez et al., 2009; ~~Werban et al., 2009;~~ Altdorff et al., 2016), assessment of soil quality (e.g., Johnson et al., 2001; Corwin and Lesch, 2005), detection of buried services (e.g., Won and Huang, 2004; El -Quady et al., 2014), and mapping of active layer thickness in permafrost areas (e.g., Hauck and Kneisel, 2008 ; Dafflon et al., 2013). ECa is widely used in the context of precision agriculture for, e.g., refining existing soil maps (e.g., Doolittle et al., 2008; Martini et al., 2013), precision farming (e.g., Lück et al., 2009; Scudiero et al., 2015) and harvest zoning (e.g., Frogbrook and Oliver, 2007; Priori et al., 2013)."

Added references are:

Anderson-Cook, C.M., Alley, M.M., Roygard, J.K.F., Khosla, R., Noble, R.B., Doolittle, J.A.: Differentiating soil types using electromagnetic conductivity and crop yield maps. Soil Sci. Soc. Am. J. 66 (5), 1562–1570, 2002.

Doolittle, J.A., Sudduth, K.A., Kitchen, N.R., Indorante, S.J.: Estimating depth to claypans using electromagnetic inductive methods. J. Soil Water Conserv. 49 (6), 552–555, 1994.

Doolittle, J.A., Windhorn, R.D., Withers, D.L., Zwicker, S.E., Heisner, F.E., McLeese, B.L.: Soil scientists revisit a high-intensity soil survey in Northwest Illinois with electromagnetic induction and tradition methods. Soil Surv. Horiz. 49 (4), 102–108, 2008.

Frogbrook, Z.L.,Oliver,M.A.: Identifying management zones in agricultural fields using spatially constrained classification of soil and ancillary data. Soil Use Manag. 23, 40–51, 2007.

Hauck, C., and C. Kneisel: Applied geophysics in periglacial environments. Cambridge Univ. Press, Cambridge, UK, 2008.

Hedley, C.B., Yule, I.J., Eastwood, C.R., Sheperd, T.G., Arnold, G.: Rapid identification of soil textural and management zones using electromagnetic induction sensing in soils. Aust. J. Soil Res. 42, 389–400, 2004.

Won, I.J. and H. Huang: Magnetometers and Electro-magnetometers. The leading Edge, 23, pp. 448–451, 2004.

Johnson, C.K., Doran, J.W., Duke, H.R., Wienhold, B.J., Eskridge, K.M., Shanahan, J.F.: Field-scale conductivity mapping for delineating soil condition. Soil Sci. Soc. Am. J. 65, 1829–1837, 2001.

King, J.A., Dampney, P.M.R., Lark, R.M., Wheeler, H.C., Bradley, R.I., Mayr, T.R.: Mapping potential crop management zones within fields: use of yield-map series and patterns of soil physical properties identified by electromagnetic induction sensing. Precis. Agric. 6, 167–181, 2005.

Reviewer's comment

"Page 5, Line 23 – What is the status of the Wollschläger et al., submitted paper? Has it been accepted yet? If not, it should be removed. There is no guarantee that a submitted paper will be accepted. If it is not accepted, this paper ends up with a reference to something that does not exist."

Authors' response

The paper is currently under review but not accepted yet. However, it currently is the only publication in English providing an overview about the actual installations in the Schäfertal catchment. We will check the status in case of acceptance of this manuscript and remove the citation if the paper is not accepted until then.

Reviewer's comment

"Page 8, Lines 7-8 – This sentence could use a reference to a situation where equipment in the field has been documented to cause issues for EMI surveys, such as Lamb et al., 2005."

Authors' response

We thank the referee for the hint. We offer to add a different citation, and refer to a recent study (Rudolph et al., 2016) where the authors removed measurement points within a radius of 2 m from underground cables connecting TDR probes. We believe that this example better illustrates the problem.

Reference:

Rudolph S., C. Wongleecharoen, R.M. Lark, B.P. Marchant, S. Garré, M. Herbst, H. Vereecken, and L. Weihermüller: Soil apparent conductivity measurements for planning and analysis of agricultural experiments: A case study from Western-Thailand. Geoderma 267:220-229, 2016.

Reviewer's comment

"Page 13, Line 26 – ". . .measured with EMI." This should be changed to ". . .measured with EMI at this location." Given the proven site-specific nature of EMI applied to soils studies and the relatively strong

correlations that have been recorded between soil water content and EMI at some other locations, it seems important to acknowledge that this statement is not necessarily valid at all locations."

Authors' response

We thank the referee for this comment. We agree with the suggested improvement. However, we would like to remark that proper interpretation of spatial EMI field measurements is fundamental, as changes of ECa can easily be attributed to changes of θ although they are often triggered by co-dependencies between the factors which affect the EMI signal (as we discuss in the manuscript from Page 14, Line 15 to Page 15, Line 12). Often these possible co-dependencies have not been addressed in the existing studies.

We would like to change the paragraph (Page 13, Lines 25-28) to:

"*In summary, our observations suggest that, for the Schäfertal hillslope site, soil properties (such as texture, porosity and organic matter content) and, of secondary importance, temporal variations of* EC_W*, control the spatial pattern of ECa measured with EMI. Soil moisture itself has only a minor effect on ECa, although it is clear that it acts as the carrying agent for transporting the ions leading to* EC_W*. Given the proven site-specific nature of EMI applied to soil studies and the relatively strong correlations that have been recorded between soil water content and ECa at some other locations, it seems important to acknowledge that this statement is not necessarily valid at all sites. Nevertheless, it must be considered that if EMI surveys would have been conducted only on measurement dates in April, July and August 2013, ECa would have been interpreted as a reasonable proxy for* θ *(Figure 4), which clearly shows the importance of time-series data for proper interpretation of EMI.*"

Reviewer's comment

*"Figure 4 – The individual graphs are so small they are difficult to read. If there is a way to increase their size (maybe portrait orientation rather than landscape?) it would be beneficial. Also, the caption says ". . .as well as p-values, when significant. . .". However, every p value on every graph that has one says "p < 0.05". If that is what is going to be entered, you may as well just have a symbol, such as *, that goes behind every R2 value for significant relationships. Given the wording in the caption, I was expecting to see information such as p = 0.02, p = 0.04, p < 0.01, etc."*

Authors' response

We agree and will modify the figure to make the single plots readable, and we will change the indication of the *p* values as suggested.