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Interactive comment on "Non-stationarity of electrical resistivity and soil moisture relationship in heterogeneous soil system: a case study" *by* D. Michot et al.

D. Michot et al.

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Answer to reviewer #2 comments. We kindly thank the reviewer for his useful comments and suggestions. Comments led to an improvement of our manuscript. Answer to all comments can be found below. Added text is indicated in yellow (see revised version attached). Please find attached the figures and Supplementary materials.

Referee #2

Fig S1: representing depth on the x-axis of a graph is kind of hard to read and also different from all other figures in the paper, consider changing this.

Information about particle-size distribution was published in Ghazavi et al. (2008). Since Figure S1 is difficult to read, we removed it from this manuscript.

3. Results: I find this section very hard to read as many things are mentioned in the text, but it is unclear why which information is relevant and how it links to any of the questions.

We completely rearranged the text to focus on our message.

Sect 3.1: I am unsure of the interest of this section as it is not much in any of the further results and conclusions. The take home message that the year was wet could be outright stated (maybe with the numbers for precipitation or net rainfall against the normal)

Thank you for your suggestion. We moved this paragraph to the study site section, since the climatic context data is not useful in the results section. Since we used cumulative net rainfall between periods, we consider that this information helps readers understand the climatic context. In our discussion and conclusions, we highlight that the studied year was particularly wet.

Fig2a: it would be more logical to plot PET as negative and Precipitation positive so their axes and plotting position/direction conforms with the net rainfall figure Fig2b: because the periods between ERT observations are irregular it is illogical to summarize the net rainfall to those period (especially for the other years). I would advise to summarize rainfall to regular (monthly or biweekly?) periods: Both rainfall and PET are positive values. In hydrology, rainfall is always presented by inverting the y axis. We changed the figure to show both PET and rainfall in the same direction. For the periods, it is consistent to consider cumulative rainfall between two time steps, since soil moisture at time t depends on the previous amount of rainfall. We are interested in cumulative rainfall between two ERT measurements.

Fig 3: There are too many lines in this graph to tell them apart, even when enlarged on the digital version.

The objective of this figure is to show that the statistical distribution does not change, except for the driest period (T10). This result highlights that neither electrical resistivity nor ïĄź changes from T01 to T09. This is why the Pdf curves are closed. The main difference in Pdfs was observed between T06 and T10, which are easily distinguished in our graph.

Fig4: The differences between the 10 sub-figures are minimal and near impossible to see or interpret in a meaningful way for the reader.

We agree with you, since the change in ERT maps was very weak. The change in ER maps for the topsoil is easy to identify and shows effects of both soil dryness (from T01 to T10) and rainfall (e.g. at T05). Such maps, as raw data, would help to understand ER dynamics during the studied period.

Fig 5: the small graphs showing the changes are good, but the placement around the coloured section out of order makes this figure hard to follow. Separating the graphs from the cross section and presenting them in order would help.

Thank you for your suggestion. We separated Fig. 5 into two parts to show changes in ER and matric potential separately.

Fig S4: The interpolation of metric potential in these figures is really off. It would be expected to be more layered with less fitting to the mean (am I right that there are only values measured at the crosses?). Also I would not expect to see large negative potentials under the groundwater level

Thank you for your comment; indeed, something is wrong from kriging the data. Since we separated matric potential profiles from variation in ER, we feel that this figure is not necessary. Coherent matric potential distributions obtained from simulations of water flow are presented in Thomas et al. (2012).

Fig 6 (and text): How is the top soil layer defined? Throughout the manuscript there

are a number of mentions of top soil (or topsoil) layers it is unclear which is used here

The topsoil corresponds to the layer from the soil surface to a depth of 50 cm, as indicated in the text (section 2.2). There was a mistake in the text, since we used both “topsoil” and “top soil”.

Fig 8: the Waxman and smit model represents a curve function and should thus be represented as such as is essentially independent from available observations. Why is it shown as points in this figure?

The Waxman and Smits model can predict a more or less continuous curve. We predicted soil water content from ER data of the points, corresponding to measured matric potential. The objective was to predict soil moisture from ER using two methods (e.g. Waxman and Smits vs. Van Genuchten Model). Discussion: 4.1 l10-15: I think this interpretation of the information in the ER inversion is very farfetched. It can very well be an effect of the roots themselves on ER, an inversion artefact or something else. There is not enough data to support any interpretation in this case. True, there is no way to demonstrate that this artifact comes from the roots themselves or from weathering due to preferential flow. We simply hypothesized that this structure may result from a higher degree of bedrock weathering caused by preferential flow at the main taproot proximity. We have added your suggestion, that the root system itself may disturb the ER signal, as a possibility.

L25 – 30: It seems likely that this low resistivity zone is related to saturated soil, but I do not get how high hydraulic conductivity and infiltration rate play a role in this, there does not seem to be data to support this interpretation.

You are right, the high Ks in this zone are not the main factor controlling water reaching the soil surface and may contribute to increases in infiltration. Downslope from the hedgerow, the proximity of the wetland is probably the main factor controlling of this low resistivity. We removed this part of the text.

4.2: p973L15 –p974L10: the precision in the root system description does not reflect the inherent uncertainties in an ERT system; I do think that these interpretations are insufficiently supported.

True, the references cited do not help to interpret our results better. We removed this section (line 973-L15 to 973-L): 4.3 L25: The ER for up4 seems to be almost constant over the whole period.it is hard to see this as a shift from one group to another

We observed a small change in ER, whereas matric potential showed a large change (from 1 to -620 hPa). At UP4, we observed chloride accumulation (see Grimaldi et al., 2009) and a significant increase between high and low groundwater level periods. Despite soil dryness, ER remained constant, probably due to an increase in ion concentration (see Fig. 4 in Grimaldi et al., 2009). Such data are not available for our study period; to avoid extrapolation, this point was not discussed in the present manuscript.

4.3 and 4.4: The main problem here seems to be that three different models are used which contradict each other. 1: It is clear that the relation between ER and matric potential is not constant (different in T06 and T10, fig 7) 2: The relation between VWC and matric potential is assumed constant (van Genuchten model). Therefore 3: No single set of Waxman Smit parameters can be valid as it links 1 an2 together. > The most likely reason is that especially in the presence of clay, ER and soil water are not uniquely relatable. Possibly this is in some way addressed in fig 10? But this figure is not discussed or referenced at all in the text.

In the manuscript, we used a set of parameters for the Waxman and Smits model. The retention curve from the VGM model was fitted using laboratory measurements. We hypothesize that many relationships should be used for the heterogeneous soils of the toposequence studied. Figure 10 summarizes the methodology used.

"Predicting VWC from ERT has become a classical approach widely used by geophysicists. The method we developed has several steps, from data acquisition to processing (Fig. 10). Changes in ER over time were predicted without removing the effect of soil

temperature variations over the study period, since these data were missing. Pdfs of ER and matric potential were helpful for analyzing the statistical range of data and selecting the relevant monitoring time. The most contrasting times, corresponding to the wettest (T06) and driest (T10) states, were analyzed. ER and matric potential data from the unsaturated zone were extracted to analyze the relationship between ER and matric potential (Fig. 10). The simplified petro-physical model of Waxman and Smits was then used to convert ER data to VWC. VWC was also predicted using retention curves (Fig. 10)."

Conclusions: L6-8. ERT rather reveals the combined effect very easily, but individual contributions are more difficult to consider:

This sentence was confusing; we replaced it with," The geophysical signal reveals combined contributions from the main parameters (i.e. structure, water content, fluid composition), but their individual effects are more difficult to assess."

P977 L 19: the conclusion section is no place for assumptions

We rearranged the conclusion.

Please also note the supplement to this comment:
http://www.soil-discuss.net/2/C606/2015/soild-2-C606-2015-supplement.zip

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Interactive comment on SOIL Discuss., 2, 955, 2015.

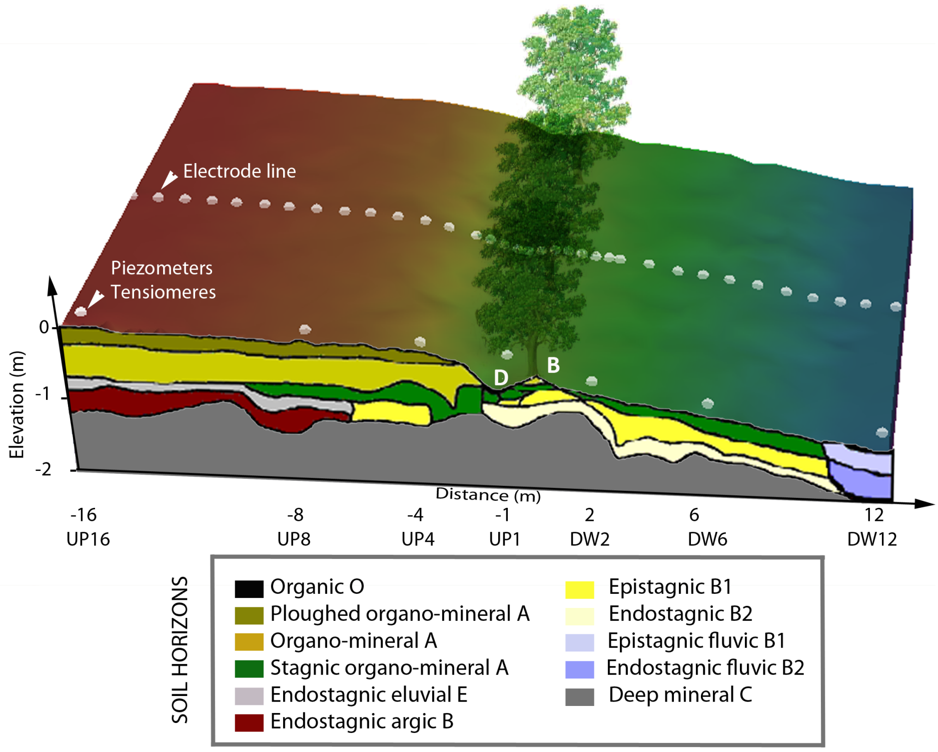

Electrode line
Piezometers
Tensiomeres
Elevation (m)
0
-1
-2
D
B
Distance (m)
-16
UP16
-8
UP8
-4
UP4
-1
UP1
2
DW2
6
DW6
12
DW12
SOIL HORIZONS
Organic O
Ploughed organo-mineral A
Organo-mineral A
Stagnic organo-mineral A
Endostagnic eluvial E
Endostagnic argic B
Epistagnic B1
Endostagnic B2
Epistagnic fluvic B1
Endostagnic fluvic B2
Deep mineral C

Fig. 1.

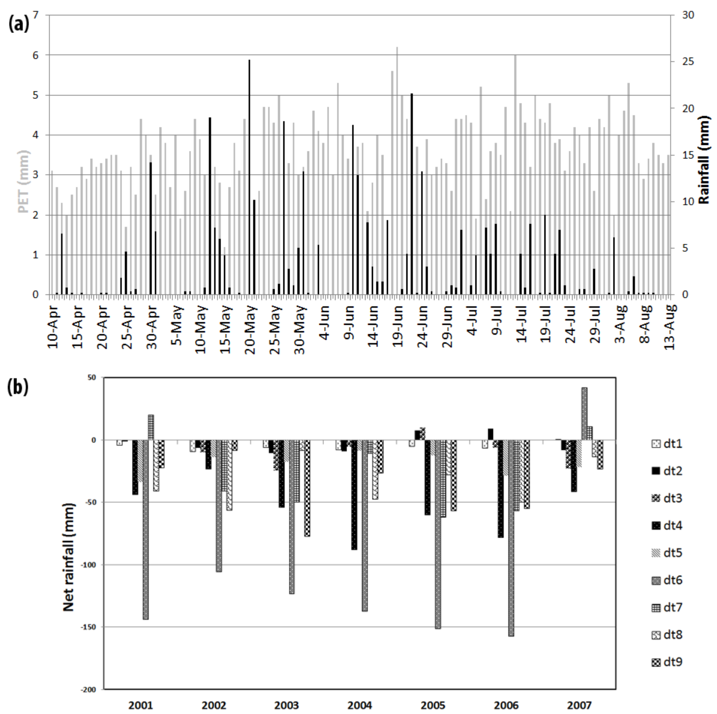

(a)
PET (mm)
Rainfall (mm)
10-Apr
15-Apr
20-Apr
25-Apr
30-Apr
5-May
10-May
15-May
20-May
25-May
30-May
4-Jun
9-Jun
14-Jun
19-Jun
24-Jun
29-Jun
4-Jul
9-Jul
14-Jul
19-Jul
24-Jul
29-Jul
3-Aug
8-Aug
13-Aug
(b)
Net rainfall (mm)
2001
2002
2003
2004
2005
2006
2007
dt1
dt2
dt3
dt4
dt5
dt6
dt7
dt8
dt9

Fig. 2.

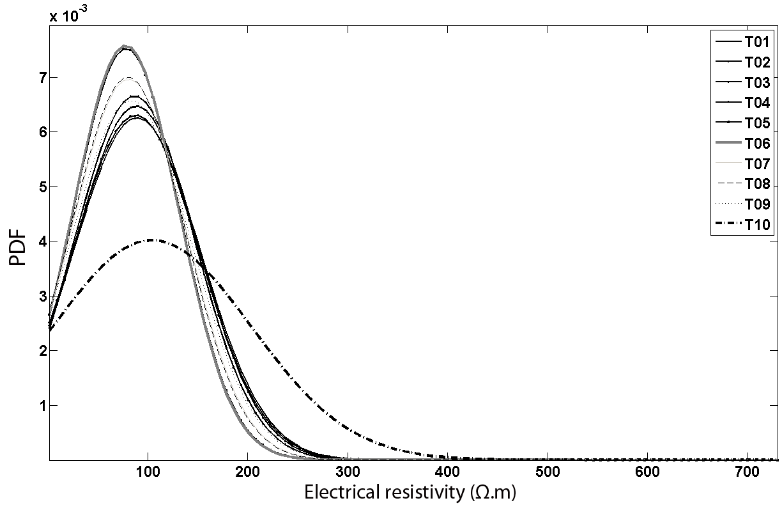

x 10^-3
PDF
Electrical resistivity (Ω.m)
T01
T02
T03
T04
T05
T06
T07
T08
T09
T10

Fig. 3.

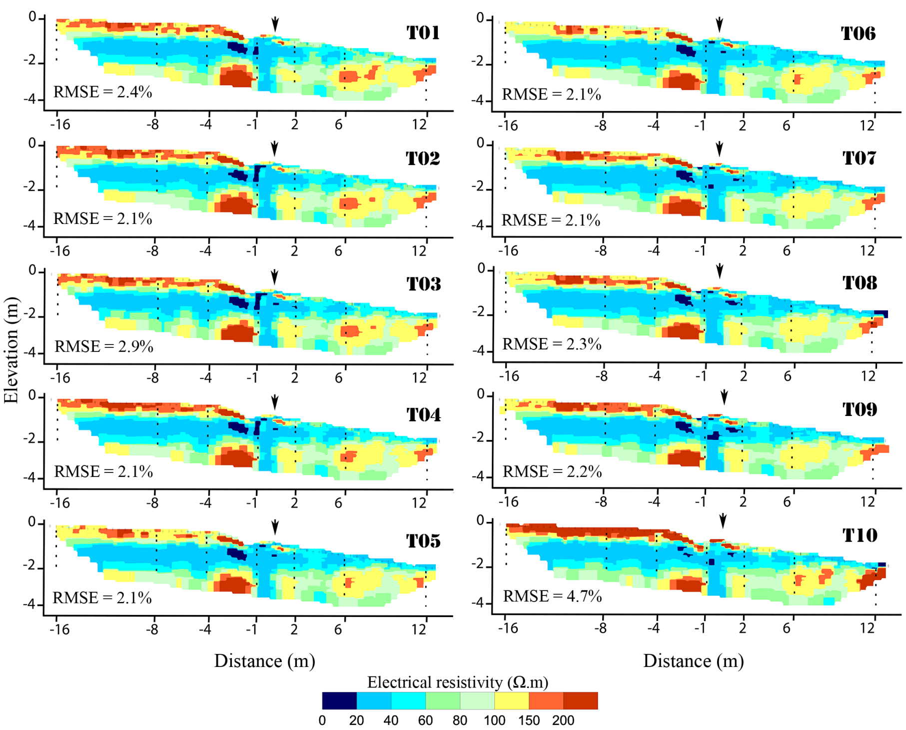

T01
RMSE = 2.4%
T02
RMSE = 2.1%
T03
RMSE = 2.9%
T04
RMSE = 2.1%
T05
RMSE = 2.1%
T06
RMSE = 2.1%
T07
RMSE = 2.1%
T08
RMSE = 2.3%
T09
RMSE = 2.2%
T10
RMSE = 4.7%
Elevation (m)
Distance (m)
Electrical resistivity (Ω.m)

Fig. 4.

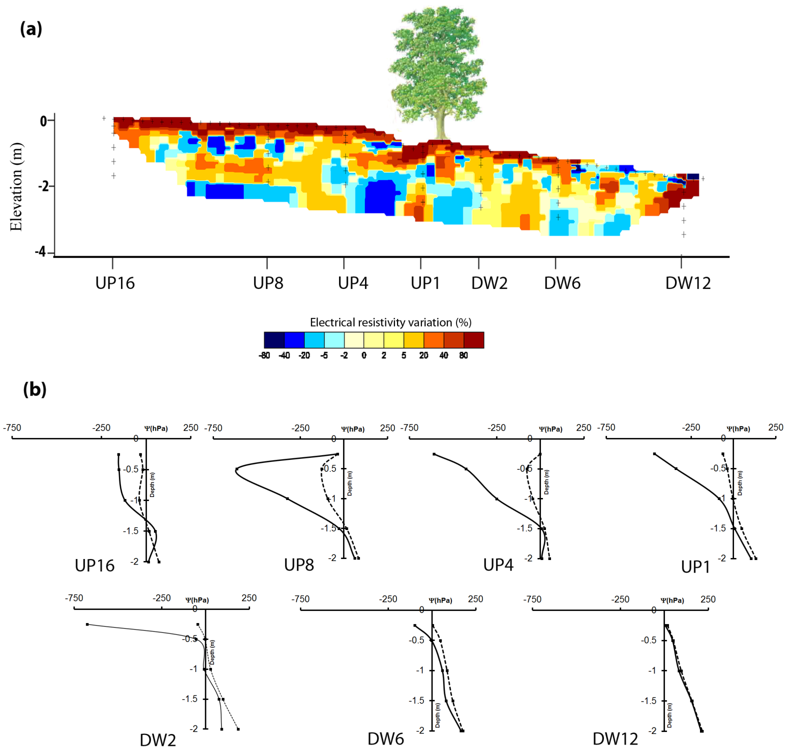

(a)
Elevation (m)
0
-2
-4
UP16
UP8
UP4
UP1
DW2
DW6
DW12
Electrical resistivity variation (%)
-80 -40 -20 -5 -2 0 2 5 20 40 80
(b)
Ψ(hPa)
-750
-250
250
Depth (m)
UP16
UP8
UP4
UP1
DW2
DW6
DW12

Fig. 5.

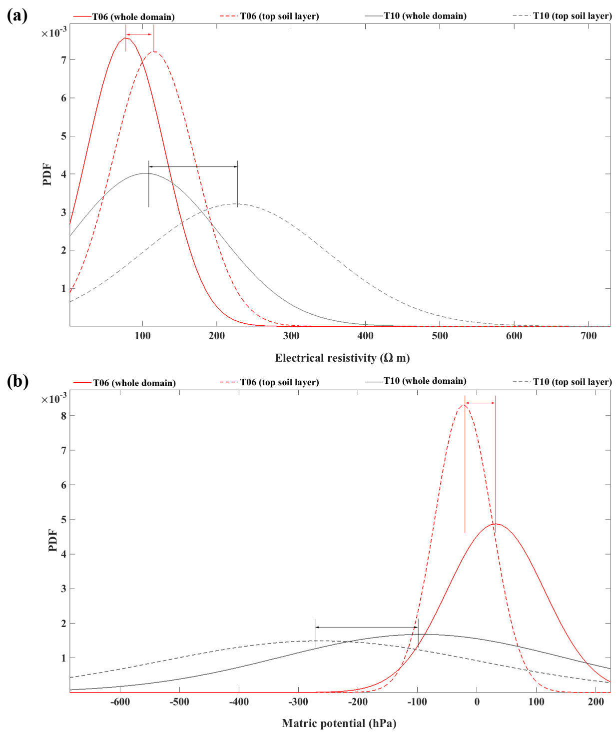
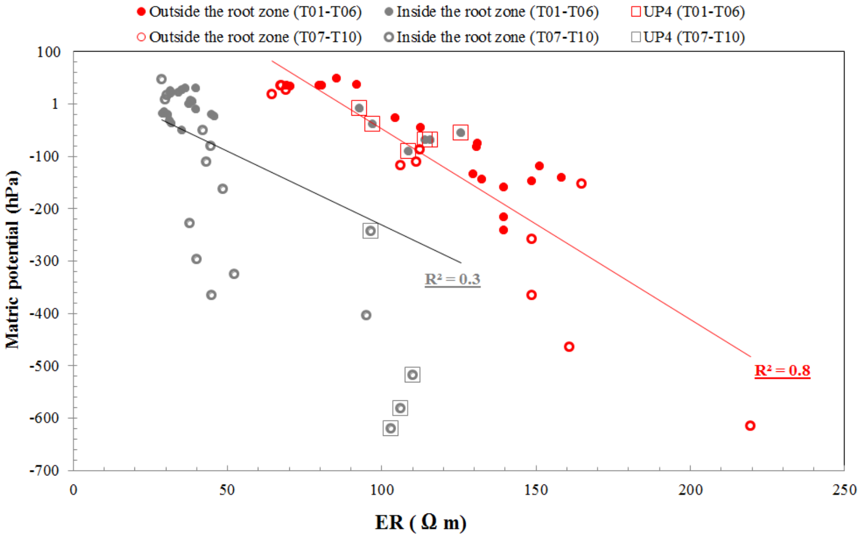
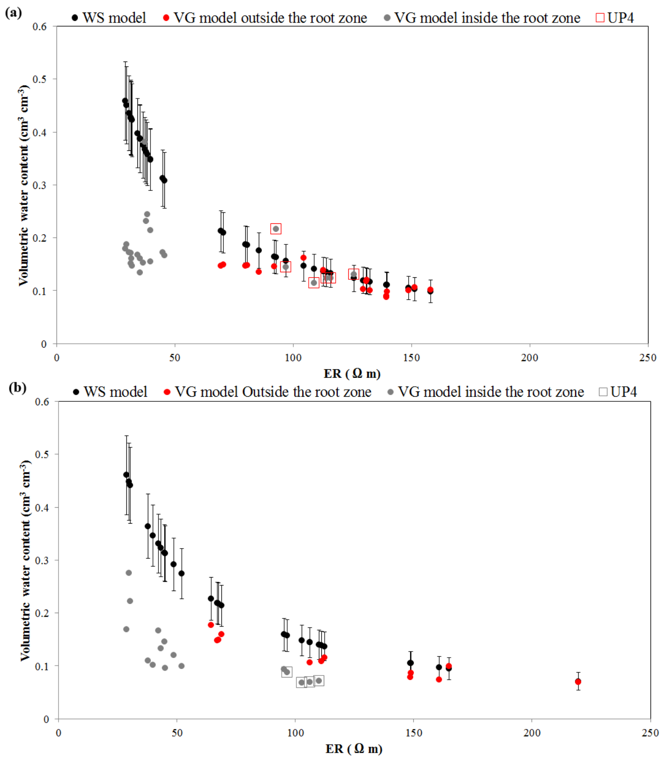

(a)
T06 (whole domain)
T06 (top soil layer)
T10 (whole domain)
T10 (top soil layer)
PDF
Electrical resistivity (Ω m)
(b)
T06 (whole domain)
T06 (top soil layer)
T10 (whole domain)
T10 (top soil layer)
PDF
Matric potential (hPa)

Fig. 6.



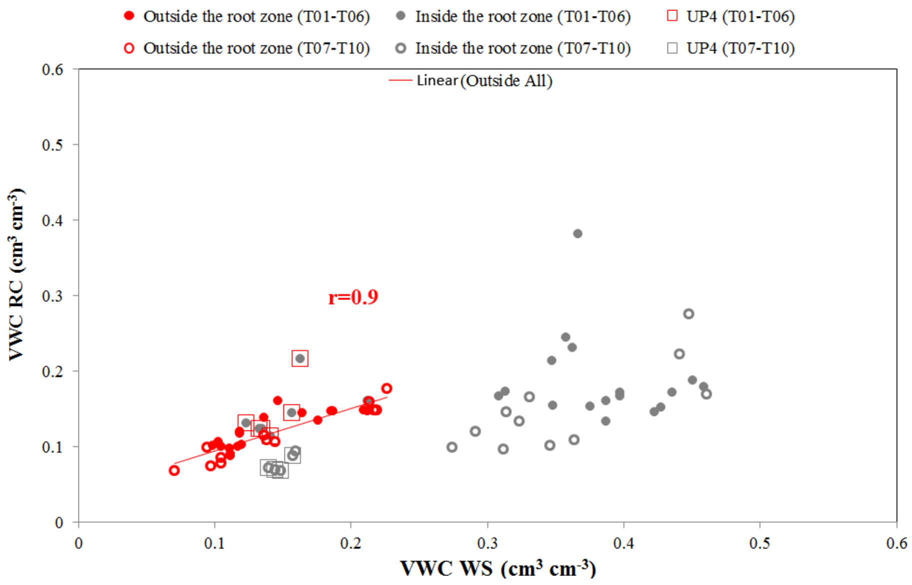
Outside the root zone (T01-T06)
Inside the root zone (T01-T06)
UP4 (T01-T06)
Outside the root zone (T07-T10)
Inside the root zone (T07-T10)
UP4 (T07-T10)
Matric potential (hPa)
ER (Ω m)
R² = 0.3
R² = 0.8

Fig. 7.



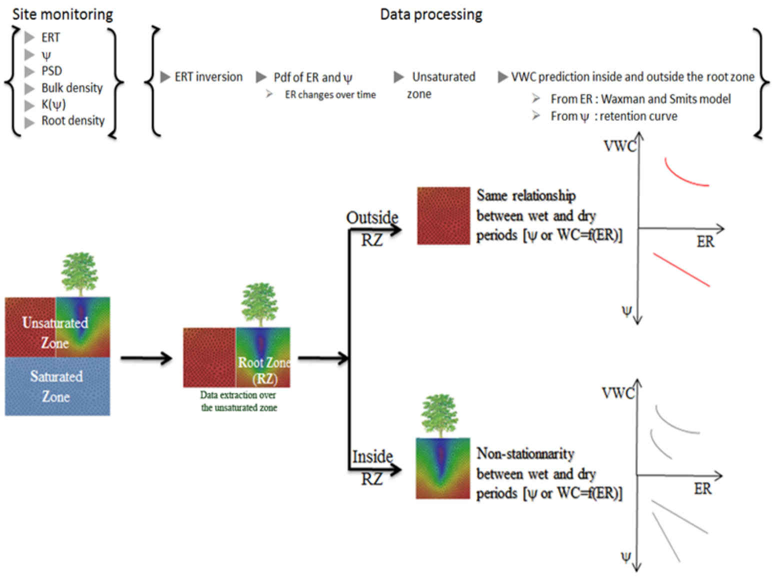
(a)
WS model
VG model outside the root zone
VG model inside the root zone
UP4
Volumetric water content (cm³ cm⁻³)
ER (Ω m)
(b)
WS model
VG model Outside the root zone
VG model inside the root zone
UP4
Volumetric water content (cm³ cm⁻³)
ER (Ω m)

Fig. 8.



Outside the root zone (T01-T06)
Inside the root zone (T01-T06)
UP4 (T01-T06)
Outside the root zone (T07-T10)
Inside the root zone (T07-T10)
UP4 (T07-T10)
Linear(Outside All)
r=0.9
VWC RC (cm³ cm⁻³)
VWC WS (cm³ cm⁻³)

Fig. 9.



Site monitoring
ERT
ψ
PSD
Bulk density
K(ψ)
Root density
Data processing
ERT inversion
Pdf of ER and ψ
ER changes over time
Unsaturated zone
VWC prediction inside and outside the root zone
From ER : Waxman and Smits model
From ψ : retention curve
Unsaturated Zone
Saturated Zone
Root Zone (RZ)
Data extraction over the unsaturated zone
Outside RZ
Inside RZ
Same relationship between wet and dry periods [ψ or WC=f(ER)]
Non-stationnarity between wet and dry periods [ψ or WC=f(ER)]
VWC
ER
ψ

Fig. 10.