Response to comments of REF#1

We would like to thank the referee for the thorough reviewing of our manuscript. The Comments and criticisms have been taken into account and the questions answered here below :

Q: The Authors state that "location was not a significant discriminating factor when all methods were considered together". I have not clear what is the reason to check a location effect in this particular case. Moreover, this result could be more or less expected in the sense that the variability between methods masks the variability between locations.

R: Rather than the location, the associated land-use (rubber tree plantation, natural forest and pasture) is often assumed to modify deeply the unsaturated soil hydraulic properties. This will be mentioned more precisely in the text of the Abstract.

Q: Introduction ". . . to a complete characterization of hydraulic characteristic curves. Finally we compared. . .". The passage from an introductive reasoning to the description of the aims of the investigation is too abrupt.

R: The sentence has been reworded to smoothen the transition between the introductive part and the description of the aims.

Q: Materials and methods The cylinder used for the beerkan experiment was small (10.2 cm in diameter), implying that there was the risk not to sample a representative surface area. Why did the Authors make this choice?

R: The choice of the diameter of the cylinder for Beerkan method was motivated by the experience from literature (Braud et al. 2005) and the availability of the material. As the soil in this area is sandy and has little or no structure, it was assumed that the diameter of the infiltration cylinder would not impact the representativity of measurement. This point will be developed further

Q: It was not clear how many replicate beerkan infiltration runs were carried out at each site. Six runs were reported in the text (page 6107) but three to 11 runs were reported in Table 3. Moreover, for the beerkan method, this table lists a sample size for each site differing with the considered parameter.

R: The number of replicates for Beerkan method infiltration tests was modified in the text from "six" to "three to eleven". The size of the samples differed from one location to another because only exploitable data have been shown.

Q: A description of the disc infiltrometer experiment and the applied procedure to analyze the data was not provided.

R: The experimental procedure for tension disc infiltrometer will be added to the text. The principle of the tension disc infiltrometer is based on maintaining the water in the apparatus under a controlled tension, so that only pores with higher matric potential can be filled. With this technique the biomacopores, cracks and other structures promoting preferential flow can be ignored, to measure hydraulic conductivity strictly in the soil matric.

Tension disc infiltrometer consist of a water reservoir, a Mariotte bubling tower, and a contact disc of diameter 20 cm covered with a microporous nylon membrane (with a pore diameter of 20 micrometers). The outlet of water reservoir was connected to the center of the disc with a flexible plastic tube. Quality of the measurement depends largely on the preparation of the device. Therefore, in order to ensure good saturation of the apparatus, avoiding the presence of any air bubble, water was introduced by suction into the device. The disc was immersed into a water filled bucket, and a slight vacuum controlled with a hand pump was used to suck the water into the disc and the reservoir. This procedure also contributed to proper saturation of the nylon membrane. The depth of the immersed inlet tube in the Mariotte tube controls the tension potential h0 applied to water at the disc membrane by adjusting the water height in the air inlet tube. Soil surface has to be cleared of vegetation and leveled to ensure perfect contact with the infiltration disc. Usually the soil surface was slightly covered with clean fine sand to get a smooth horizontal surface and to provide a good contact between the base of the disc and the soil below. As the soil surface is never perfectly horizontal, the relative position of the infiltration disk with the water reservoir is not necessarily constant. Therefore it important to measure it in order to calculate the actual water potential head h0 (cm) controlled with the immersed tube of the Mariotte device.

In order to calculate saturated hydraulic conductivity with the multipotential method (Perroux and White, 1988; Smettem and Clothier, 1989), the infiltration measurements have been realised for two different suctions values and interpreted with Wooding's method (Wooding, 1968; Akeny et al., 1991; Angulo-Jaramillo et al., 2000).

The tension values used for the experiments were not always exactly the same as they partly controlled by the soil microtopography. But were generally between -15 and -10 hPa for the higher tension and between -7 and -3 hPa for the lower tension.

Q: An appreciably larger disc (20 cm) was used for the disc infiltrometer experiment than the beerkan run. I think that an effect of the source size on the measured soil parameters should be expected. Why did the Authors use sources with a so different size?

R: The diameter of the disc infiltrometer was indeed almost twice of the diameter of the infiltration cylinder. This difference was mainly explained by the availability of the different equipments, especially for the infiltration cylinder. However according to Anderson and Bouma (1973) and Bouma (1980) the representative elementary volume of sandy soil for measuring hydraulic conductivity is usually considered to be 100 cm3.

Considering the texture (mainly sandy) and especially the lack of structure of the soil in the different locations (except in the forest) the volume of the soil samples exceed the Representative Elementary Volume. Therefore despite not having been measured on strictly the same volumes or areas but still in the order of magnitude (Beerkan 800 cm3, Disc infiltrometer 2000 cm3, Evaporation 1500 cm3) the results for the different methods can legitimately be considered as adequate.

Q: The number of soil samples used to characterize each site with the evaporation and the inverse methods was two (text, page 6108) or two or three (Table 3). On what basis did the Authors believe that this was an appropriate sample size for soil characterization at a site?

More in general, the Authors should explain the reasons why, for a given method, the applied experimental procedure, including sampled soil volume and number of replicated measurements, was initially thought to be adequate for soil hydraulic characterization.

R: The number or replicates for each method depended on the time necessary to perform the measurement, and secondly on the quality of the measurement. Therefore there are much less evaporation measurements, as each experiment lasts two weeks, than Beerkan measurements (around 30 to 60 min for one infiltration experiment) or disc infiltrometer measurements (2 to 6 hours). Finally, as stated previously, it also depended on the number of exploitable measurements, for the results of the infiltration experiment reveal only after processing the data, and some have to be discarded.

Q: Including a short description of the approach used to adjust the curves obtained with BEST to van Genuchten with Mualem conditions (page 6107) would allow an easier reading of the paper.

R: The original Beerkan method provides van Genuchten's retention parameters for Burdine condition (m=1-2/n). The retention curve was plotted according to these parameters and the equation with Mualem condition (m=1-1/n) was adjusted with a Marquardt procedure to fit the new parameters. In fact by changing from Burdine to Mualem condition all the parameters were affected.

Q: The Authors should also explain how they established the constant evaporation rate of 8×10-9 m s-1 (page 6108).

R: The constant evaporation rate was obtained by placing the soil samples in an oven constantly heated at 40°C with air renewal.

Q: As reported on page 6105, soil water content and pressure head was monitored continuously at each site for three years (2007-2009) at 7 and 5 depths, respectively. It is not clear the reason why only a part of these data were used (2.3 Evaluation of the methods). In my opinion, it would be more logical to use all the experimental information to make the modeling check.

R: Thought the tension was recorded over a wider period than presented here, the measurements were not continuous simultaneously for the three tensiometers. The tension data suffer from several long gaps due to various technical problems (air entry for the upper tensiometer, pressure sensor failures, etc ..) . The modeling was therefore not possible continuously for the entire period.

Q: I am puzzled about the possibility to obtain a statistically (and also physically) plausible information with only three data points (page 6111). Again, the Authors should convince a reader that their experimental methods and procedures were sound and that applying statistical testing was meaningful, despite the very small sample sizes.

R: As explained previously the number of data depended on the time required to perform the measurements and on the number of measurements that finally were exploitable. The statistics used in the paper namely non parametric tests are aimed to give information on for very small samples ($N<6$) and therefore seem to be adapted for this study.

Q: Results and discussion I found this section too much poor in terms of interpretation of the results since I did not find any attempt to suggest possible reasons of the detected differences. I only show a few examples to be clearer, but the problem is general. In comparison with the beerkan method, the disc infiltrometer yielded higher Ks values at some sites and lower Ks values at other sites. Why? In my opinion, a possibility could be that sample sizes were too small to yield reliable results. But this should not be the interpretation by the Authors because it would imply that the experiment was not properly realized. Another example is the lack of any attempt to explain the results of the statistical analysis (pages 6114-6115). Still another example is the fact that hysteresis was expected, due to the soil textural characteristics, but it was not detected in the investigation (page 6117).

R: The discussion about the interpretation of the different results has been increased in the text :

Tension disc infiltrometer measurements are very dependent on the quality of the contact between the disc and the soil surface. Despite all the efforts this requirement can be quite difficult to fulfill.

Moreover, in sandy soils local hydrophobicity can occur (especially in rubber tree plantations, where natural rubber is known to have water repellent properties) and therefore affect infiltration dynamics. This phenomenon was affecting particularly the measurements with disc infiltrometer, as soil suction was the driving force. Whereas for Beerkan method the contact is not a problem and due to the slight positive charge hydrophobicity is less problematic.

Though Beerkan and disc infiltrometer method are realized with an imbibition experiment, they don't exactly provide the parameters representing imbibition. In fact disc infiltration method described the saturated hydraulic conductivity and therefore does not provide any information about the wetting part of the retention or hydraulic conductivity curve. For the Beerkan method, parameter α is derived from the infiltration experiment but the procedure to determine it is derived from parameters available in databases but that are usually derived from drainage experiments. Beerkan method can't be considered as a method describing strictly an infiltration process as infiltration and drainage data are used together. However, in order to simplify the manuscript we chose not to mention this discussion about hysteresis, as more specific measurements would have been necessary.

Q: also see points not clear from a methodological point of view. For example, the Authors do not explain the reason why, with reference to the beerkan method, a comparison was established in terms of shape parameters but not with reference to scale parameters. In any case, figure 3 is not easy to read. Moreover, it is not clear why the discussion in the text starts from figure 3d and it goes back to figure

3a.

R: The comparison was made in terms of shape parameters for all the methods. The purpose of scaling the results was to show the influence of the shape parameters between the different land-uses and especially the different methods. Moreover it is mathematically more complicated to perform the same scaling procedure with the shape parameters. However the main reason is that shape parameters depend mainly on the soil texture, that varies much less at a small scale (field, toposequence), than the scale parameters. The reduced hydraulic conductivity curves are presented in attached pdf file.

Q: According to the Authors, the data were collected on a generally gentle slope (3%, page 6105) and the field slope had a very noticeable effect on modeling validation since Hydrus 1D performed well only when infiltration was strictly 1D. In my opinion, it is necessary to better develop this part of the manuscript showing more results, also from Hydrus 2D, and also establishing comparisons between the two modeling approaches (Hydrus 1D and 2D). In addition, the Authors have the task to physically convince a reader that a slope of 3% is enough to induce substantial lateral flow. Are we sure that using the Hydrus code was in general an appropriate choice? Why?

R: This point is developed in detail in another paper (Seltacho et al. 2013) where is clearly shown that lateral drainage represents 40% of the annual rainwater according to both (experimental measurements and modeling with hydrus 2D).

Moreover the slope of the plan on which the water flowed laterally, corresponding to the interface between the sandy and clayey layer, was notably higher as the depth of the sandy layer increased from upper to lower slope position. This will be explained in more detail in the text.

References :

Anderson JL, Bouma J (1973) Relationships between hydraulic conductivity and morphometric data of an argillic horizon. Soil Sci. Soc. Amer. Proc. 37, 413-421.

Bouma, J. 1980. Field measurement of soil hydraulic properties characterizing water movement through swelling clay soils. J. Hydrol. 45: 149-158.

Braud, I., D.D. Condappa, J.M. Soria, R. Haverkamp, R. Angulo-Jaramillo, S. Galle and M. Vauclin. 2004. Use of scaled forms of the infiltration equation for the estimation of unsaturated soil hydraulic properties (the Beerkan method). European Journal of Soil Science. doi: 10.1111/j.1365-2389.2004.00660.x

Seltacho, S., Sriboonlue, V., Suwanang, N., Wiriyakitnateekul, W., Hammecker C.: Quantification and modeling of water flow in sandy soils in Northeast Thailand, In Advances in Unsaturated Soils. Bernardo Caicedo, Carol Murillo, Laureano Hoyos Julio Esteban Colmenares and Ivan Rafael Berdugo Ed. CRC Press 2013: 573–577, 2013.

Responses to comments of REF#2

We would like to thank the referee for the thorough reviewing of our manuscript. The Comments and criticisms have been taken into account and the questions answered here below :

Q: The current manuscript is concise, but difficult to assess at times. To fully appreciate the comparison, the reader currently needs to be an expert on the various approaches already, or needs to be willing to look up all of the references made to various methods and techniques. The conciseness also hampers the conclusion in my opinion; the comparison is done on a strictly statistical basis, on which the authors conclude no method out competes another, and therefore the low-cost Beerkan method is probably the best. Nonetheless, every measurement techniques has its pros and cons. The manuscript would benefit from mentioning such pros and cons in the technique description, and assessing these together with the statistical analysis. The scale dependency of the (unsaturated) hydraulic conductivity may justify discussion on the area/volume being assessed by each technique.

R: The pros and cons of each technique have been presented in the paper. The discussion about the scale dependency of unsaturated hydraulic conductivity and sample size has also been introduced into the text.

For the Beerkan method the main advantage is the simplicity of the experimental set-up which doesn't need specific material nor specialized skills. Moreover the infiltration process is usually quite rapid (less than an hour) to reach the constant infiltration rate. On the other hand the exploitation of the data is more complicated the method is based on strong hypothesis about the unsaturated hydraulic properties, namely they are supposed to follow strictly van Genuchten's retention with Burdine conditions and Brooks and Corey hydraulic conductivity expressions. Though in most of the cases this assumption agrees well, some cases, like bimodal porous networks are not taken into account.

Disk infiltrometer is a very precise way to measure the infiltration rate and to derive hydraulic conductivity near saturation as the tension applied to the device allows for infiltration at specific matric potential values. The experiment is difficult to set up for it needs a perfect flat contact between the soil surface and the disc and is prone to many technical fails (leaks, etc ..). Moreover each experiment takes usually a very long time to reach constant infiltration rate (sometimes several hours for fine textured soils). Wooding's model used to derive saturated hydraulic conductivity from disc infiltration measurements assumes an exponential relationship between hydraulic conductivity and matric potential, that is quite different from the van Genuchten function.

Evaporation method is the only method for which the retention curve is actually measured without any a priori model. In this case the slow evaporation rate imposed at surface generated a very slight tension gradient inside the soil, with a uniform water content distribution. The draw backs of this method are the long time necessary for a soil sample to dry completely (up to two weeks) and therefore to complete the retention curve and the costly equipment (oven, computer, balance, micro-tensiometers, pressure gauge, data-logger).

The inverse modeling performed with Hydrus 1D, is an elegant method to determine the unsaturated

soil properties from evaporation data where the data used to fit the van Genuchten's parameters directly. The drawback of this method are the same as those cited previously as the evaporation experiments in controlled conditions still have to be performed.

The pedotransfer function is an extremely easy method to derive the retention curve based only on particle size distribution. Arya and Paris relationship is physically based deriving the size of the voids between the grains assuming a packing model. Nevertheless as this model, unless Beerkan method, is exclusively governed by the PSD and the bulk density of the soil, little information about the soil structure is available in the computed retention curve.

Q: The limited amount of samples in all of the measurement techniques, and the different area/volume these techniques cover are compared with location variability of which not much more is written than the textural composition of the sites, and the land use. These issues need to be discussed to make the current concluding statements more convincing.

R: Considering the texture (mainly sandy) and especially the lack of structure of the soil in the different locations (except in the forest) the volume of the soil samples exceeds the Representative Elementary Volume, that can be estimated to 100 cm3 according to ccording to Anderson and Bouma (1973) and Bouma (1980) . Therefore despite not having been measured on strictly the same volumes or areas but still in the order of magnitude (Beerkan 800 cm3, Disc infiltrometer 2000 cm3, Evaporation 1500 cm3) the results for the different methods should not be affected by the scale. The number of samples depended on two main criteria: the time and simplicity of the method, and the data finally exploitable after processing. The number of repetitions is therefore uneven and sometimes very low. In order to overcome this problem we used non parametric tests like Kruskal-Wallis aimed to deal with little and uneven sets of repetitions.

Q: Another difficulty in assessing the paper is the consistency of naming methods in the text and in the tables (including structure). Especially i) Wind's method/evaporation method/inverse method/associated inverse method and ii) pedo- transfer function(PTF)/Arya and Paris method/Arya method. With careful reading this can be overcome, but could perhaps be prevented.

R: The reviewer is completely right and the different names of the methods have been harmonized throughout the text: Beerkan, Disc infiltrometer, Evaporation, Inverse, and Arya.

Q: Some vagueness surrounds the hypothesis on page 6103 lines 19 to 23. If different land managements would change soil properties, are these changes for example a result of structural changes due to (mechanical) cultivation? Or the transgression from natural vegetation to pasture or plantation, leading to changes in root mass, and thus in soil structural changes? Can it be assumed such changes can be assessed by measuring the hydraulic properties of top soil? Or is the rationale for this study from the perspective of infiltration capacity and erosion risks? Please clarify.

R: It is assumed that the different land managements would affect structural properties of soil, due to different tillage methods, different root densities and sizes, and different biological activity of macro

fauna. Therefore the hydraulic conductivity of the top soil will be affected and the infiltration capacity (more than the erosion risks) will be modified. In the context of tropical rain patterns with heavy rainfall followed by long dry periods, with these shallow soils, the infiltration capacity is an important factor in the soil water balance. The efficiency of the rainfall is highly depended on the infiltration capacity.

Q: On page 6105 and 6106 two models for estimating soil unsaturated hydraulic properties are described. What was the motivation for using these models, instead of others?

R: The two models describing the unsaturated soil properties namely van Genuchten's functions and Brooks and Corey's function have been chosen because they correspond to the parameters possibly usable with Hydrus water flow modeling software. Moreover they also correspond to the functions used in Beerkan method.

Q: Page 6107 For the disc infiltrometer: How many repetitions at each of the sites?

R: Six to seven replications were performed as for the Beerkan method. When the variation seemed high the number of replications was increased.

Q: For the evaporation method an inconsistency seems to occur between the M&M and result section: Page 6108 line 4 “Two undisturbed soil samples were collected at each location” versus Table 3 evaporation/inverse n=3 (or 2 for some of the sites).

R: Three soil samples were collected for each location.

Q: Which samples were used for the PTF method described in section 2.2.5?

R: The PSD determined on the soil samples for Beerkan method were also used for the deriving retention curve with the pedo-transfer function (Arya method in the text).

Q: Section 3.6: Since infiltration was strictly 1D in one of the distinctive groups, I would ex- pect a discussion here if the results of some of the measurements techniques suffered from lateral flow. This is not mentioned in the text discussing the measurement results, it could be that by applying the algorithms to analyse the data such possible errors are assessed, but since none are described very extensively it is hard to assess.

R: None of the measurement technique was affected by lateral flow as the slope of soil surface is very slight (3%). However a point that has to be mentioned in the text is that the interface between the sandy layer and the clayey layer has a steeper slope and therefore, when the perched water-table appears

during the rainy season, water flows along this slope in the sandy layer (Seltacho et al. 2013).

Q: The conclusions focus on differences between techniques only, and do not justify the first line in the conclusions, nor the first objective of the paper.

R: The first part of the conclusions focuses mainly on the difference between the locations, and points out the different hypothesis that possibly can explain them. However this part can be extended.

Q: Table 3 and 4 only show Ks while equation 3 and 4 seem to facilitate K(theta) as well. For unsaturated flow modelling the shape of K(theta) is important. Why did the authors only plot the scaled retention curve (Fig 3), but not K(theta)?

R: Indeed in table 3 and 4 only Ks is mentioned as it is one the prime parameters used in for water flow modeling, the scaled hydraulic conductivity curves are not as informative as the retention curve for all the curves are gathered and none really stands out.

References

Anderson JL, Bouma J (1973) Relationships between hydraulic conductivity and morphometric data of an argillic horizon. Soil Sci. Soc. Amer. Proc. 37, 413-421.

Bouma, J. 1980. Field measurement of soil hydraulic properties characterizing water movement through swelling clay soils. J. Hydrol. 45: 149-158.

Seltacho, S., Sriboonlue, V., Suwanang, N., Wiriyakitnateekul, W., Hammecker C.: Quantification and modeling of water flow in sandy soils in Northeast Thailand, In Advances in Unsaturated Soils. Bernardo Caicedo, Carol Murillo, Laureano Hoyos Julio Esteban Colmenares and Ivan Rafael Berdugo Ed. CRC Press 2013: 573–577, 2013.

Reponse to F. Meskini-Vishkaee

The authors would like to thank Mrs Meskini-Vishkaee for her valuable comments and the time she dedicated to this review.

The discussion indeed did not mention interpretations about the differences obtained with the different methods as it was not the actual aim of the paper. However we agree that this part should be enhanced and some elements can be proposed especially by the fact that most of the the methods assume different kind of models. For example, the Beerkan method assumes that infiltration is governed by Haverkamp's infiltration equation and that the retention curve follows van Genuchten's functional with Burdine conditions whereas hydraulic conductivity is supposed to follow Brooks and Corey equation. For the disc infiltrometer method, infiltration is described by Wooding equation, with the assumption that hydraulic conductivity is an exponential function of soil matric potential. The pedo transfer functions of Arya et al, or Mohammadi and Vanclooster (2011) as suggested by the reviewer, despite being physically based, suppose a direct relation between the particle size and retention curve by assuming a sphere packing model, regardless the soil structure. The evaporation method and the inverse modeling start both with real experimental values obtained during a drying procedure, but finally parameters for van Genucthen functional with Mualem conditions are fitted to the experimental curves. Each method is based on strong and different hypothesis about the shape of the unsaturated hydraulic functions and or infiltration curve. It is therefore not really surprising the results obtained being different.

We think it is important to present clearly the context of this study to be able to evaluate it's practical implication. Therefore we will keep the structure of the abstract and the text.

The aim of the paper is not to test all the latest developments, in the evaluation of retention curve with PSD, but to assess the validity of some well established techniques in order to find out about the difference in soil properties depending on landuse and topographic position. Thought the model presented in Mohammadi and Vanclooster (2011) adds some improvements to the model of Arya, it is not fundamentally different.

Though it would be convenient to have some references, the results measured here for hydraulic soil properties could not been compared to previous measurements because they are the first ones performed in this area.

In order to limit the number of figures and as the scaled hydraulic conductivity curves did not show major differences we chose to concentrate on the scaled retention curves.

Indeed the results obtained with Beerkan method show different retention curve shapes mainly because parameter n is significantly lower than for other methods.