Dear Dr David Dunkerley (Topical Editor),

We thank the Topical Editor and reviewers for their comments and suggestions that helped to improve the quality of the manuscript.

Please find below the point-by-point response to the reviewers' comments. Reviewer' comments are in italic, the authors' replies are in bold.

Following the suggestion of Referee #2; the manuscript title has been changed to: '**Sensitivity analysis of point and parametric pedotransfer functions for estimating water retention of soils in Algeria'.**

Some of the comments were general across more than one referee (R) and these are treated together (I, II, and III below) in a joint reply to the tow referees:

I. Database: all two reviewers have an opinion about this part. ***R1****: In lines 106 to 113 it is said that the RETC code was used to fit the van Genuchten SWRC to the experimental data, but at line 102 it is reported that the experimental data were determined at two tensiometer–pressure potentials, that are -33 and -1500 kPa. Therefore it seems that the four parameters of the SWRCs (θs, θr, α, n, while m is constrained to m = 1- 1/n) are fitted by means of two experimetal points only for, each curve.*
If this is the case, and no other constraints were introduced, the set of parameters is not univocally identified for each soil, and the further analyses on the parametric approach lose their significance.
I therefore recommend that either (1) the Authors better detail the followed procedure for this approach, so that it is clear how main experimental points the procedure is based on or whether there were other constraints to univocally identify the fitted parameter set; or (2) they remove the part about the parametric approach and better develop that about the point approach. ***R1****: l.103"moisture" ->"water content". Field capacity or soil saturation? Samples in Richards's apparatus are usually saturated. Moreover field capacity (regarded to as the soil water content which remains in the soil after abundand imbibition and when percolation is materially decreased) can be quite small water content, even smaller than the water content at 33 kPa.* ***R1****: ll.199—203 I agree with this sentence, but in this case it can also be due to the undetermination of the interpolated parameters (see the General Comments).* ***R2****: Page 3, line 88: I am missing a short description of the study area and information on soil types.* ***R2****: Page 3, lines 102-103: I would rephrase it as follows: 'The water retention values at -33 kPa and -1500 kPa were obtained by the Richards's apparatus. Undisturbed soil samples were collected near field capacity with 100 cm3-cylinders'.* ***R2****: Page 3, lines 100-105: The authors should provide references for all the lab methods.*

Our reply: **This part will be addressed in the revised paper as follows (see page 1 to 3, lines 85 to 116):**

The soil dataset used for this study was collected from various regions in Algeria, mainly in the north, which has a Mediterranean climate. It contained 242 samples, with basic soil properties: texture fractions (based on the USDA system; clay and silty-clayey for most of the soils, Fig. 3a), BD, OM content and water content at -33 kPa and -1500kPa. Descriptive statistics of the development and validation datasets are presented in Table 1. The available database was split into two datasets. Subset 1, which was used to develop the PTFs, contained 78.1% of the samples. Used as the calibration set, they were collected from the coastal plain of Annaba in north-eastern Algeria (13 samples), the Beni Slimane plain of Media (42 samples), the Kherba El Abadia plain of Ain Defla (54 samples) and the Lower Cheliff plain in north-western Algeria (80 samples). Subset 2 contained the remaining 21.9% of the samples. Used to verify the PTFs, they were collected from Benziane valley in the lower south-western Cheliff plain. The depth of the two upper horizons varied from site to site, with a maximum of 30 cm for surface horizons and more than 30 cm for subsurface horizons.

PSD analysis was conducted using the international Robinson's pipette method (Robinson, 1922). Undisturbed soil samples obtained with 500-1,000 cm3 cylinders were used to determine BD. The SWR values at -33 kPa and -1500 kPa were obtained using Richards's apparatus (Richards et al., 1943). Undisturbed soil samples were collected near field capacity with 100 cm3 cylinders. Water content was measured using the gravimetric method at 105°C (24 h). Organic carbon content was determined using the wet oxidation method (Walkley and

Black, 1934). Variation in soil texture in the dataset is displayed using the textural triangle proposed by FAO (1990) in Figure 3b.
The SWR model devised by Van Genuchten (1980) is defined as:

$$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{(1+|\alpha h|^n)^m} \quad (1)$$

Where θr and θs are residual and saturated soil-water content (cm3 cm–3), respectively, and α (cm–1) and n are the shape factors of the SWR function. The VG parameters were indirectly estimated for each soil sample from four levels of measured data inputs: sand, silt and clay percentages, and BD using the Rosetta model H3 (Schaap et al., 2001). The 'm' parameter was calculated as follows: m = 1 -1 / n.

The references were also added in the reference list.

II. Development of PTFs: ***R1****: I encourage the Authors to explicitly present the PTFs they obtained for the investigated sample of soils.****R1****: l.177 Table 2 is not cited before Table 3. This is a good point to explicitly provide the formulae of the obtained PTFs.* ***R2****: lines 147-149: The elements of equations 6 and 7 are not explained Page 4.* ***R2****: What do the authors mean by cubic model in Table 2?.*

Our reply: This part will be addressed in the revised paper as follows (see page 4 lines 117 to 145):
Two approaches were used in this study to develop the PTFs: point PTFs for estimating SWR for particular points of pressure (h); and parametric PTFs for predicting the VG parameters. Each water content level at selected water potentials of -33 kPa and -1500 kPa and estimated VG parameters were related to basic soil properties (i.e., sand, silt, clay content, OM content and BD) using multiple regression techniques (Table 2). The most significant input variables were determined using the Pearson correlation (α =5%). T For the multiple-linear regression (MLR) models, the general form of the resulting equations was expressed thus:
$Y= a_0+ b_1 X_1 + b_2 X_2 + b_3X_3 +b_4 X_4$ **(2)**
For the multiple-non-linear regression (MNLR) models, it was expressed thus:
$Y= a_0 + b_1X_1 + b_2X_2 + b_3X_1\hat{}2 + b_4X_2\hat{}\ 2 + b_5X\ _1\hat{}3 + b_6X_2\hat{}3 + b_7\ X_1{*}\ X_2 + b_8X_1\hat{}2{*}\ X_2 + b_9\ X_1{*}X_2\hat{}2$
(3)
Where Y represents the dependent variable, a_0 is the intercept; b_1…, bn are the regression coefficients, and X1 to X4 refer to the independent variables representing the basic soil properties.

The prediction quality of the point and parametric PTFs developed from Algerian soils were then compared with three Rosetta PTFs (H1, H2 and H3). We chose the Rosetta model because it gives the user flexibility in inputting the data required (Stumpp et al., 2009), with the option of five levels based on input data (Schaap et al. 2002):

- **H1: Textural classes (USDA system);**
- **H2 : Clay+Silt+Sand;**
- **H3: Clay+Silt+Sand+ BD;**
- **H4: Clay+Silt+Sand+ BD +Volumic water at -33 kPa;**
- **H5: Clay+Silt+Sand+ BD +Volumic water at -33 kPa + Volumic water at -1500 kPa.**

The Rosetta model was also chosen because it has given reasonable predictions in several evaluation studies (Frederick et al., 2004, Nemes et al., 2003). In our study, the three Rosetta model levels (H1, H2, and H3) were selected to compare their performance in the Algerian soils because they require only texture data and BD as inputs, as well as the locally developed PTFs.

III. Global sensitivity analysis (GSA) approach: ***R1****: l.161 Explicit what does the constraint Xi? stand for.* ***R1****: l.145 Title not necessary.* ***R2****: Page 1, line 27: What did the authors mean by: 'favourable impact'?.* ***R2****: Page 4, lines 141-142: ': may manage the functions and non-linear and nonmonotonic models': this sentence is not clear to me. Please rephrase.*

Our reply: **This part will be addressed in the revised paper as follows (see page 1 to 3, lines 165 to 204):**

GSA involves determining which part of the variance in model response is due to variance in which input variable or group of inputs. The impact of the parameters is quantified by calculating the global sensitivity indices.

The Sobol method (Sobol, 1990) is an independent GSA method based on decomposition of the variance. When the model is non-linear and non-monotonic, the decomposition of the output variance is still defined and can be used. The Sobol model is represented by the following function:

$$Y= f\,(X_1, X_2, X_3,\ldots\ldots,X_p) \qquad (7)$$

Where Y is the model output (or objective function) and $X=(X_1,\ldots, X_p)$ is the input variable set.

$$V(Y) = V\,(E\,(Y|X)) + E\,(Var\,(Y|X)) \qquad (8)$$

Where V(Y) is the total variance in the model, V (E(Y|X)) and E (Var(Y|X)) signify variance in the conditional expected value and expected value of the conditional variance, respectively. When the input variables X_i are independent, the variance decomposition of the model is:

$$V(Y) = \sum_{i=1}^{p} V_i + \sum_i \sum_j V_{ij} + + \sum_i \sum_j \sum_p V_{ijp} + \ldots\ldots\ldots + V_{1,2,3,\ldots,p}$$

(9)

$$V_i = V\,[\,E(Y|X_i)]$$

$$V_{ij} = V\,[\,E(Y|X_i, X_j)] - V_i - V_j$$

$$V_{ijp} = V\,[\,E(Y|X_i, X_j, X_p)] - V_{ij} - V_{ip} - V_{jp} - V_i - V_j - V_p$$

Where V_i is the proportion of variance due to variable X_i. Dividing V_i by V(Y) produces the expression of the first-order sensitivity index (S_i), such that:

$$S_i = \frac{V_i}{V(Y)} = \frac{V[E(Y/X_i)]}{V(Y)} \qquad (10)$$

The term S_i is the measure that guarantees an informed choice in cases where the factors are correlated and interact (Saltelli and Tarantola, 2002). This index is always between 0 and 1, and represents a proper measurement of the sensitivity used to classify the input variables in order of importance (Saltelli and Tarantola, 2001).

In order to quantify variation in the sensitivity index (V_{Si}) of an input factor X_i, we fixed it at $Xi = Xi*$ ($Xi*$: the average when the variable follows the normal distribution, the median when the variable follows the lognormal distribution). In order to calculate how much this assumption changed the variance of Y, we used this formula:

$$V_{Si} = \left(\frac{V[E(Y/X)]}{V(Y)} - \frac{V[E(Y/Xi{=}Xi*)]}{V(Y)}\right) * 100 \qquad (11)$$

$V_{Si} > 0$ and S_i close to 1 indicate increasing accuracy of PTFs;
$V_{Si} < 0$ and S_i close to 1 indicate increasing accuracy of PTFs;
$V_{Si} > 0$ and S_i close to 0 indicate decreasing accuracy of PTFs;
$V_{Si} < 0$ and S_i close to 0 indicate decreasing accuracy of PTFs.

In addition, combining the RMSE and S_i enabled us to detect the contribution of each variable to improvement in the quality of prediction of the PTFs.

<u>Some additional referee comments were raised</u>

<u>Referee # 1 (Dr. S. Barontini)</u>

1. **Detailed comments and technical notes**

ll.37—38 explain whether it refers to the hydrological state of the soil or to the characterization of the hydrological properties: **It will be removed**
l.47 _ ! _ ((in all the paper): **It will be modified.**
l.*51 Uniform all the paper to the version "van Genuchten" (or to "Van Genuchten"):* **It will be modified.**

l.59 ”different environments from which they were derived for”: **It will be modified.**
l.63 ”and hydraulic conductivity as well”: **It will be modified.**
l.106 ”defended”->”defined”: **It will be modified.**
l.119 Add something like ”the following measures of the errors”, or something else, to make the article more readable: **As suggested by the reviewer it will be addressed as: “In order to assess the validity of the PTFs developed, we used the following criteria: mean prediction error (ME) to indicate the bias of the estimate; root mean square error (RMSE) to assess the quality of the prediction (it is frequently used in studies on PTFs); and the index of agreement (d) developed by Willmott and Wicks (1980) and Willmott (1981) as a standardized measure of the degree of model prediction error.(see page 4 lines 147 to 152).**
l.131 Check equation (4), I think that there should not be 1/ n:
The index of agreement (Willmott and Wicks, 1980; Willmott, 1981):

$$\boldsymbol{d} = 1 - \frac{\frac{\boldsymbol{1}}{\boldsymbol{n}}\sum_{i=1}^{n}(\boldsymbol{\theta}_{\mathrm{p}} - \boldsymbol{\theta}_{\mathrm{m}})^2}{\sum_{i=1}^{n}\left[\left|(\boldsymbol{\theta}_{\mathrm{p}} - \overline{\boldsymbol{\theta}}_{\mathrm{m}})\right| + \left|(\boldsymbol{\theta}_{\mathrm{m}} - \overline{\boldsymbol{\theta}}_{\mathrm{m}})\right|\right]^2}$$

The index of agreement varies from 0 to 1 with higher index values indicating that the modeled values θ_p have better agreement with the observationsθ_m. (See page 4 to 3 lines 159 to 163).
l.145 Title not necessary: **Indeed. It will be removed.**
l.233 Avoid referring to the conductivity as the framework of the article seems to be based on Mualem’s predictive approach to the relative conductivity function (as it follows from the constraint on m): **It will be removed**
l.244 and followings Consider the idea of collecting all the analyses regarding the texture in one paragraph only, thus restructuring the paragraphs regarding sand, sil and clay. This can strongly help the readability of the discussion. Many analyses of previous Authors are reported: I suggest to explicitly detail whether your results are according or discording to previous ones: **the reviewer is right. This will be addressed in the revised manuscript (see page 7 to 9 lines 260 to 345).**
l.291 ”They increase in organic matter” with. . . ?. **It will be removed.**
l.306 and followings Typically clay is very important at characterising the water retention, even if it can lose sensitivity for great values of clay content: in which sense does it sound the statement of line 317?: **Indeed, this part will be removed.**
l.353 I agree with the conclusion but it seems to be quite in contrast to what observed after the reported analyses and the last conclusion: I suggest to better detail this point or remove it. **As suggested by the reviewer, this part will be removed.**
Further minor comments: (i) correct some typos, (ii) check the consistency of the references list and alphabetically order it, (iii) change the colour of histograms and bar– graphs to ensure the readibility also in B&W printing: **All these comments will be addressed in the revised manuscript.**

Anonymous Referee #2

Overall opinion

This is an interesting paper covering an important topic, namely the prediction of soil hydraulic properties, particularly the soil water retention curve for soils in Algeria. However, there are a number of issues that need to be addressed before publication could be recommended.

1. **General comments**

The real major issue that I have with this paper is its lack of novelty. A large number of papers on pedotransfer functions are being submitted to various peer-reviewed journals, which basically all follow the same pattern as this paper does:
1. Data are collected locally 2. ’Foreign’ PTFs are tested 3. ’Home’ PTFs are often developed, but not always 4. Home PTFs are deemed better - or a foreign PTF is found better than others.
I agree that using global sensitivity analysis is very useful in decomposing the variance of the response (soil water retention) into contributions from the individual input variables. However, this analysis does not add any new information on what is already known in literature about the contribution of various predictors to the predictive quality of point and parameter-based PTFs. This issue is long known and has been shown/commented on by many papers by now.

Another weakness of the paper is its lack of clarity in many parts of the text. I expanded more on this in the specific and technical comments and the authors need to work on that. Good proofreading and editing would considerably improve the quality of the manuscript.

Our reply: **We also agree with the reviewer that a large number of papers on pedotransfer functions basically discuss the same point about limits on estimates of specific model to a local region or a particular bioclimatic environment when applied in a different context. That's why we developed local pedotransfer functions in this paper; no studies have been conducted before on this subject in Algeria.**

But beside this quite usual approach; the sensitivity analysis aims at more original objective. The idea is to rank by order of importance the input variables of Algerian FPT such as bulk density, soil texture, and organic matter content at -33 and -1500 kPa in order firstly to detect the contribution of each variable in improving estimates of soil water retention and secondly to identify the source of error and weakness in FPT in each textural class.

As a new analytical tool, we proposed to quantify the variation of the first sensitivity index (Vis) after fixing each variable in a central value $\mathrm{Xi} = \mathrm{Xi}*$ ($\mathrm{Xi}*$:the average when the variable follows the normal distribution, the median when the variable follows the lognormal distribution). The variation (Vis) calculated by the corrected formula (answer: Page 1, line 27) specified in the section (II.2.3) in each textural class for both pressure point gives us an idea about the role of each input in improving the estimate (performance) or in the weakness of FPT (error).

What's more we characterized the water retention of Algerians soil by confronting the results of the global sensitivity analysis with research results that address the relationship among the soil water retention and the variables commonly used as input in PTF (Clay, Loam, Sand, bulk density and organic matter).

In the revised paper we will include an analysis a part of development of PTF in the section II.

2. Specific comments

Page 1, lines 39-40: I would suggest: 'hydrologists face the situation where soil hydraulic data such as water retention or hydraulic conductivity are often missing. Therefore, pedotransfer functions (PTFs) are used as an alternative to estimate these properties.' **It will be done as suggested by the reviewer (see page 1, lines 37-39).**

Page 1, lines 40-41: I do not agree that reports on the evaluation of PTFs outside the area of development are rare (see general comments above). This is one of the main topics in PTF studies. **Indeed. It will be modified as follows: the extrapolation of PTFs in different agropedoclimatic context limits their performance (Touil et al., 2016). (See page 1, lines 39-40).**

Page 2, line 54: Water retention points are not part of the widespread input data for PTF: **Indeed. It will be removed. And the sentence will be modified as follows: Schaap et al. (2001) developed the Rosetta package based on the artificial neural network method (ANN), which implements five hierarchical models to predict these parameters with well-defined limits (the soil texture classes only) and the input data (texture, density, and one or two values of water content at -33 and -1500 kPa).**

Page 2, lines 57-58: I am missing something here; why should we call it an advantage? **It will be modified as follow: 97 % are based on multiple linear and polynomial regression of nth order techniques (Botula et al. 2014). (See page 2, lines 55-56).**

Page 2, line 61: I would expect more recent references:

Mirus, B. B.,: Evaluating the importance of characterizing soil structure and horizons in parameterizing a hydrologic process model, Hydrological Processes, 29(21), 4611-4623, 2015.

The references were also added in the reference list. (See page 2, line 59).

Page 2, line 62: Could the authors provide some references? **We will add the following reference (See page 2, line 61):**

Bruand, A., Perez-fernandez, P., duval, O., quetin, P., nicoullaud, B., gaillard, H., raison, L., pessaud, J.F. and prud'homme, L. : Estimation des propriétés de rétention en eau des sols: utilisation de classe de pédotransfert après stratifications texturale et texturo-structurale. Etud. Gest. Sols, 9:105-125, 2002.

Pachepsky, Y. A., Rawls, W.J.: Soil structure and pedotransfer function, Eur, J. Soil Sci, (54), 443-452, 2003.

The references were also added in the reference list.

Page 2, line 63: I would expect: 'Soil-water retention and hydraulic conductivity vary widely and non-linearly with soil water potential': **It will be done as suggested by the reviewer. (See *page 2, line 62)*.**

Page 2, line 68: Could the authors also provide more recent references: **We will add the following reference (See Page 2, line 67):**

Vereecken, H., Feyen, J., Maes, J. and Darius, P.: Estimating the soil moisture retention characteristic from texture, bulk density, and carbon content, Soil Sci, 148,389-403, 1989.

Winfield, K.A., Nimmo, J.R., Izbicki, J.A., and MartinResolving, P.M.: Structural Influences on Water-Retention Properties of Alluvial Deposits, Vadose Zone Journal, (5), 706-719, 2006.

The references were also added in the reference list.

Page 3, lines 85-86: 'comparing the predictive performance with the Rosetta models': this looks like a third objective: **Indeed, this sentence will be removed.**

Page 3, line 93: n has been used to design three different variables: (1) number of soil samples in a subset (Page 3, line 93); (2) shape factor of the water retention function (Page 3, line 111); (3) number of horizons (Page 4, line 125): **we will address these remarks in the revised manuscript as follows:**

(1) Page 3, line 93: Subset 1, which was used to develop the PTFs, contained 78.1% of the samples. Used as the calibration set, they were collected from the coastal plain of Annaba in north-eastern Algeria (13 samples), the Beni Slimane plain of Media (42 samples), the Kherba El Abadia plain of Ain Defla (54 samples) and the Lower Cheliff plain in north-western Algeria (80 samples). Subset 2 contained the remaining 21.9% of the samples. Used to verify the PTFs, they were collected from Benziane valley in the lower south-western Cheliff plain (see page 3, line 95). (2) Page 3, line 111: n shape factor of the water retention function (see page 3, line 114). (3) Page 4, line 125: N: number of horizons (see page 4, line 155).

Page 3, line 96: What did the authors mean by: 'soil series was used as the calibration set'? See also Page 3, line 97, 98: **It an error, the first sentence (Page 3, line 96) will be removed. The second sentence (Page 3, line 97, 98) will be: Subset 2 contained the remaining 21.9% of the samples. Used to verify the PTFs, they were collected from Benziane valley in the lower south-western Cheliff plain (see page 3, lines 98-100).**

Page 3, line 122: What did the authors mean by: 'standardised module'?: **It will be modified as follows: the index of agreement (d) developed by Willmott and Wicks (1980), and Willmott (1981) as a standardized measure of the degree of model prediction error (see Page 3, line 151).**

Page 4, line 126: What did the authors mean by: 'The estimate is even less skewed than ME and is close to 0'?: **It will be modified as follows: with N, number of horizons, θp, θm, predicted and measured volumetric water content, respectively. The estimate is better when ME is close to 0'. Also, negative ME values indicate an average underestimation of θm, while positive values indicate overestimation (see page 4, line 156-158).**

Page 5, line 172: The first reason mentioned by the authors for selecting the Rosetta PTFs in their study seems weak to me as these PTFs have been published 15 years ago. **It will be modified as follows: The prediction quality of the point and parametric PTFs developed from Algerian soils were then compared with three Rosetta PTFs (H1, H2 and H3). We chose the Rosetta model because it gives the user flexibility in inputting the data required (Stumpp et al., 2009), with the option of five levels based on input data (Schaap et al. 2002). (See page 4 lines 133-136).**

Page 5, line 175: The authors should give more details on Rosetta models H1, H2 and H3:

The Rosetta FPTs (Schaap et al. 2002) are distinct as five levels based on the input data (see page 4 lines 136-141):

H1: The textural classes (USDA classification):

H2: Clay+Silt+Sand

H3: Clay+Silt+Sand+ Bulk density

H4: Clay+Silt+Sand+ Bulk density+Volumic water at -33 kPa

H5: Clay+Silt+Sand+ Bulk density+Volumic water at -33 kPa+ Volumic water at -1500 kPa

Page 5, lines 175-176: The second reason for selecting the Rosetta PTFs should be better explained: **It will be modified as following: The Rosetta model was also chosen because it has given reasonable predictions in several evaluation studies (Frederick et al., 2004, Nemes et al., 2003). In our study, the three Rosetta model levels (H1, H2, and H3) were selected to compare their performance in the Algerian soils because they require only texture data and BD as inputs, as well as the locally developed PTFs (see page 4 lines 143-146).**

Page 5, line 188: What did the authors mean by 'adapt better'?: **It will be changed by : "gave a better estimation than" (See page 6, line 219).**

Page 5, line 193: 'Other evaluation criteria noted that the index of agreement also shows that the point PTF is': this sentence is not clear and should be rephrased: **It will be modified as follows : The index of agreement results showed that point PTFs were more suitable for Lower Cheliff soils**

than parametric PTFs (Figure 6), with values of 0.9975 and 0.9911 cm^3 cm^{-3}). (See page 6 lines 223-224).

Page 6, lines 199-200: Did the authors perform a significance test to confirm this?: **It will be modified as follows: As Table 3 shows, there was no significant difference in RMSE values between the parametric PTFs and Rosetta H2 at -1500 kPa (RMSE: 0.0605 cm^3 cm^{-3} and 0.0636 cm^3 cm^{-3}, respectively).(See page 6 lines 228-229).**

Page 6, lines 216-217: ': with Si in order to (OM: 0.821; 0.630) and (C %: 0.782; 0.585) at -33 kPa and -1500 kPa, respectively (Fig. 2)': this sentence should be rephrased: **This sentence will be modified as follows: It was clear for the PTFs developed that OM% and clay percentages (C%) were the variables with the greatest impact (Figure 2). For the point PTFs (MLR), the most sensitive estimations were at two pressure points (S_i: 0.821; 0.782 at -33 kPa and 0.630; 0.585 at -1500 kPa for OM% and C%, respectively. (See page 7 lines 237-240).**

Page 6, line 227: m is directly linked to n by a simple relation (see Page 3, line 113). Therefore, we should only consider 4 parameters: ϴs, ϴr, α and n: **Indeed. (VG parameters: θ_r, θ_s, α, n). (See page 7 lines 248).**

Page 7, line 241: What did the authors mean by 'The stability in estimation of PTF before and after classification'?: **It mean that we didn't observe the improvement in quality estimation of the parametric and point PTFs in the fine and very fine class. This sentence will be modified as follows: The results showed that after the textural grouping, there was an improvement in the quality estimation of PTFs only in the medium class (Figure 4). A better prediction at -1500 kPa was provided by point PTFs (RMSE = 0.027 cm^3 cm^{-3}) and parametric PTFs (RMSE = 0.038 cm^3 cm^{-3}) at -1500 kPa. (See page 7 lines 257-259).**

Page 7, lines 265-266: What did the authors mean by: 'when the variation sensitivity index calculated for sand is the leading'? Please rephrase: **It will be modified as follows: when the variation of the first order S_i for sand was the most important (see page 8 lines 278).**

Page 7, line 276: What did the authors mean by 'the majority presence'? Please rephrase: **It will be removed.**

Page 8, lines 290-294: These 2 sentences are not clear to me. Please rephrase: **It will be modified as follows: This might also explain the fact that many soils with high clay content in the database are Vertisols in which BD and VWC are lower (Rawls et al., 2003). The inclusion of BD as an input provides information on pore volume, which can influence the performance of PTFs when applied to soil with high clay content (see page 9 lines page 322-325).**

Page 8, lines 300-301: Which variable do the authors refer to?: **It will be modified as follows: With BD and texture as inputs in point PTF (MLR), predicted values very close to the experimental results are obtained (see page 9 lines 231-232).**

Page 8, line 306: What did the authors mean by: 'favourable sensitivity'? Please rephrase: **In the medium texture class, there was increasing accuracy in PTFs after fixing the clay content at -33 kPa (see page 8 lines 295-296).**

Page 8, line 315: What did the authors mean by: 'advanced water retention'? Please rephrase: I**t will be modified as follows: SWR was higher in the very fine and fine classes than in the medium class, because they quickly drained water initially retained (see page 8 lines 303-305).**

Page 8, line 320 to Page 9, line 321: This sentence is not clear to me. How the global sensitivity class and the silt can be estimates of water content? Please rephrase: I**t will be modified as follows : The GSA showed that the silt percentage had a stronger impact on the estimation of parametric PTFs at -1500 kPa than at -33 kPa with the MNLR model (see page 8 lines 307-309).**

Page 9, line 322: What did the authors mean by: 'the main values of V_{Si}'? Please rephrase: I**t will be modified as follows: After textural grouping, an important variation in the first order S_i was observed in the medium class (-36.7% to -1500 kPa). (See page 8 lines 309-310).**

Page 9, line 323: 'or the texture is pure clay': I do not understand this part of the sentence. Please rephrase: **It will be removed.**

Page 9, line 325: Do the authors refer to the estimate of water retention or of the van Genucthen parameters?: **Indeed: It will be modified as follows: It was clear that the silt percentage has an important role in estimating VG's parameters (α, n), and that its use as an input influences the estimate in the medium and fine classes (see page 8, 9 lines 311-312).**

Page 9, lines 325-327: These 2 sentences are not clear to me. What did the authors mean by 'favourable impact', 'a better pedological interpretation'? Please rephrase: **It will be modified as follows: There was an increasing accuracy, however, in the PTFs recorded in the fine class at -1500 kPa. With silt and clay as inputs, there was a better estimation (see page 9 lines 313-314).**

Page 9, lines 335-336: ': : :as the latter is always considered as the best predictor of soil water retention particularly in clayey soils'. Could the authors support this affirmation by references to recent literature?: **It will be removed.**

Page 9, line 336: What did the authors mean by 'positive sensitivity impact'? Please rephrase: **This sentence will be modified as follows: the increasing accuracy of parametric PTFs, however, was apparent for medium-textured soils at -33 kPa, where OM was used as an input to predict θ_s (see page 9 lines 339-341).**

Page 9, lines 345-347: This sentence is very weak and does not add on what is already well known from previous studies: **It will be modified as follows:**

The objective of this study was to analyze the sensitivity of estimating the SWR properties of Algerian soil using PTFs. We developed and validated point and parametric PTFs from basic soil properties using regression techniques and compared their predictive capabilities with the Rosetta models (H1, H2, and H3). (See page 9-10 lines 348-352).

Page 9, line 348: ': : :predicts more accuracy than: : :': Please rephrase: **it will be modified as follows: The reliability tests showed that point PTFs produce more accurate estimations than parametric PTFs (see page 10 lines 351-352).**

Page 9, lines Tables and figures - Tables and figures should be self-explanatory in their titles and contents. The authors should provide all the necessary information such as explanation for abbreviations, measurement units, etc. Please see also specific comments.

- The order of captions of tables and figures should generally correspond with the order of appearance in the text: **All these comments will be addressed in the revised manuscript**

3. Technical comments

Page 1, lines 20-21: the way values of RMSE are reported in the abstract is confusing. Page 1, line 21: RMSE values are in cm3 cm-3 as units for water retention. Page 1, line 28: medium textural class Page 2, lines 44-45: 'estimated' instead of 'constructed' Page 2, line 47: the parameters of the van Genuchten model (_s, _r, _ and n) have been introduced before the van Genuchten model itself (line 51). It would be more logical to remove them in line 47 and insert them in line 53. Page 2, line 53: I would suggest: ': to predict the van Genuchten parameters (_s, _r, _ and n) with soil texture classes only: : :' Page 2, line 54: 'bulk density' instead of 'density' Page 2, line 55: 'Pedotransfer functions' instead of 'PTFs' Page 2, line 60: 'water retention' instead of 'the water retention' Page 2, line 72: 'pedotransfer' should be deleted Page 2, line 76: 'complementary' instead of 'complimentary' Page 3, lines 82-83: I would suggest: 'Deriving and validating two approaches of PTFs using regression methods:' Page 3, line 87: 'input perturbation' is not appropriate. Please rephrase. Page 3, line 92: I would suggest: 'The PTFs are developed using a database of soil samples collected from some regions in Algeria' Page 3, line 93: 'contains' instead of 'containing' Page 3, line 99: 'more than 30 cm' instead of 'upper than 30 cm' Page 3, line 100: 'was conducted using: : :' Page 3, line 100: I would suggest: 'Undisturbed soil samples taken: : :' Page 3, line 101: '(According to the case)' should be deleted Page 3, line 104: I would sug- gest: 'Water content measurements were conducted by the gravimetric method' Page 3, line 106: The word 'defended' is inappropriate. Please rephrase Page 3, lines 111- 112: 'were calculated' instead of 'will be calculated' Page 3, line 117: 'by comparing the values that they predicted' Page 3, lines 118-119: I would suggest: 'To discuss the validity of the PTF developed, we used the following criteria:' Page 3, lines 119-120: 'the root mean square error (RMSE)' instead of 'the mean square error (RMSE)' Page 3, line 120: 'of the quality of the prediction' instead of 'of quality prediction' Page 4, line 129: 'the root mean square error (RMSE)' instead of 'the mean square error (RMSE)' Page 4, lines 143-144: Is it X1 or X1? This needs to be uniform. Page 4, line 144: I would suggest: ': : :X=(X1,: : :, Xp) is the input variable set' Page 4, lines 147-149: The elements of equations 6 and 7 are not explained Page 4, line 157: 'between 0 and 1' instead of 'between [0.1]' Page 5, line 161: What is Xi in equation 9? Page 5, line 168: I am missing sentences that introduce Table 1 and Table 2. Moreover, Table 2 is not mentioned in the whole text. Page 5, line 170: I would suggest as title: 'Development of PTFs' Page 5, lines 172-173: With respect to the title in line 170, this sentence should be placed at the end of the paragraph Page 5, line 177: 'soil water retention' instead of 'the soil water retentions' Page 5, line 184: I would suggest: 'the point MLR PTFs' instead of 'the PTF points (MLR)' Page 5, line 185: '0.041 and 0.044' instead of '0,041 and 0,044' Page 5, line 188: 'parametric PTFs' instead of 'parametric PTF' Page 5, line 189: 'neural' instead of 'neuron' Page 5, line 189: 0.0613 and 0.0605 cm3 cm-3 Page 6, line 199: 'while' should be deleted Page 6, line 207: 'PTFs' instead of 'pedotransfer functions' Page 6, line 209: 'fundamental to understand the: : :' instead of 'fundamental to understanding the: : :' Page 6, line 211: 'as bulk density' instead of 'as the bulk density' Page 6, lines 214-217: This sentence is too long and should be divided into 2 sentences.*

Page 6, lines 215-216: ‘at two pressure points’ instead of ‘in two pressure points’ Page 6, line 219: ‘in third place’ instead of ‘in third order’ Page 6, line 222: ‘MLR’ instead of ‘linear multiple regression’ Page 6, line 224: I would suggest: ‘point PTF using MLR is mainly based on: : :’ Page 6, line 225: I would suggest: ‘parametric PTF using MNLR’ Page 6, line 226: I would suggest: ‘which has other inputs than tex- ture and bulk density’ Page 6, line 229: I would suggest: ‘textural grouping’ instead of ‘textural classification’ (see Page 6, line 234) Page 6, lines 231-232: I would suggest: ‘: : :used to develop PTFs from basic soil characteristics to estimate water retention for different textural classes’ Page 6, line 235: ‘FAO’ instead of ‘FOA’ Page 6, line 238: I would suggest: ‘textural grouping’ instead of ‘textural stratification’ Page 6, line 239: I would suggest: ‘a better prediction at -1500 kPa was provided by point PTF’ Page 7, lines 242-243: I would suggest: ‘explained by difficulties in linking water retention properties of the soil samples with their particle size distribution as...’ Page 7, line 244: I would suggest: ‘After textural grouping, MLR and MNLR PTFs developed are: : :’ Page 7, line 247: I would suggest: ‘In the MNLR PTFs’ instead of ‘Into the MNLR’ Page 7, line 259: ‘fractions’ instead of ‘fraction’ Page 7, line 260: ‘observed’ instead of ‘observe’ Page 7, line 268: ‘in all texture classes’ instead of ‘on all texture classes’ Page 7, line 269: ‘in the validation dataset’ instead of ‘in the dataset of validation’ Page 7, line 275: ‘increases’ instead of ‘increase’ Page 7, line 280: ‘low sand content’ instead of ‘small sand content’ Page 8, line 283: ‘This is the second most influential variable’ Page 8, line 285: ‘bulk density’ instead of ‘the bulk density’ Page 8, line 289: ‘highly related’ instead of ‘hugely related’ Page 8, line 291: Vertisols Page 8, lines 299-300: ‘has a major influence’ instead of ‘is a major influence’ Page 8, lines 301-302: I would suggest: ‘predicted values very close to the experimental results are obtained’ Page 8, line 303: I would suggest: ‘depends on the type of regression techniques’ Page 8, line 309: ‘PTFs’ instead of ‘PTF’ Page 8, line 312: ‘with Clay (%)’ instead of ‘with the Clay (%)’ Page 8, line 315: ‘than’ instead of ‘t’ Page 8, line 319: I would suggest: ‘at high and medium soil water potentials’ Page 8, lines 321-322: I would suggest: ‘textural grouping’ Page 9, line 323: I would suggest: ‘The lowest values were recorded’ Page 9, line 324: ‘of’ should be deleted Page 9, lines 330-331: I would suggest: ‘textural grouping’ Page 9, lines 331-332: I would suggest: ‘by the poor OM content in the Algeria soil samples’ Page 9, lines 331-332, 333-334: Sometimes ‘OM’, sometimes ‘organic matter’. Please be consistent Page 9, line 333: I would suggest: ‘...water retention. Danalatos et al. (1994) attributed it to...’ Page 9, lines 337-338: I would suggest: ‘to predict _s values’ instead of ‘to predict saturated soil water contents’ Page 9, line 348: ‘Indeed’ should be deleted Page 9, line 354: I would suggest: ‘textural grouping’ Page 9, line 355: ‘classes’ instead of ‘class’ Page 10, lines 359-360: I would suggest: with clay content > 60% Page 10, line 361: I would suggest: ‘textural grouping’ Tables and figures Tables Table 1: - I would suggest as title: ‘Soil characteristics of the development and validation datasets’ - I would suggest PSD (particle size distribution) instead of Granulometry - ‘CV: coefficient of variation’ is reported three times on the same table’ Table 2: - the line separating MLR and MNLR PTFs is not at the right place - ‘Point PTFs’ instead of ‘Points PTF’ - ‘multiple R2’ instead of ‘R2 multiple’ - a, b, c,...j are not clearly explained. It would be good to write a general equation with a, b, c,...j as coefficients for more clarity - _ should be in kPa-1 - (respectively) should be deleted Table 3: - I would suggest as title: ‘Evaluation criteria of water retention pedotransfer functions at -33 kPa and -1500 kPa’ Table 4 is missing Table 5: - I would suggest as title: ‘Variation of first order sensitivity index along different textural classes’ - What does ‘Abs’ mean? Table 6: - I would suggest as title: ‘Pearson correlation matrix between basic soil characteristics in the validation dataset of 53 soil samples’ Figures Each figure caption should be located beneath the respective figure Figures 1, 2, 4, 5 and 6: ‘,’ should be replaced by ‘.’ Figure 2: - I would suggest as title: ‘Particle size distribution of xx soil samples from Algeria according to the FAO textural triangle’ Figure 3: - Figure 3 is not mentioned in the text Figure 4: - I would suggest as title: ‘Root mean square error (RMSE) values calculated for different textural classes’ Figure 5: - I would suggest as title: ‘Variation of first sensitivity index with RMSE after textural grouping’ Figure 6: - Police sizes on the 2 graphs are not the same - ‘Point PTF’ instead: **All these comments will be addressed in the revised manuscript.**

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Dear Dr David Dunkerley (Topical Editor),

Following is the revised version of manuscript. Changes have been highlighted using Tow different colors based on reviewer comments. Changes based on first reviewer comments are highlighted yellow; changes based on second reviewer comments are highlighted green.

Sincerely,

Sami Touil and co-authors

Sensitivity analysis of point and parametric pedotransfer functions for estimating water retention of soils in Algeria

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Abstract

Improving the accuracy of pedotransfer functions (PTFs) requires studying how ~~the uncertainty in~~ prediction uncertainty can be apportioned to different sources of uncertainty in inputs. In this study, the question ~~is,~~addressed was: W~~w~~hich variable input is the ~~principal~~ main ~~one~~ or ~~the~~ ~~a~~the ~~better~~ best comple~~i~~mentary predictor of water retention, and at which water potential ~~level~~? Two approaches were adopted to generate PTFs: ~~—~~multiple linear regressions (MLR) for point PTFs; and ~~the~~ multiple non-linear regressions (MNLR) for parametric PTFs. Reliability tests showed that ~~the~~ point PTFs provided~~s~~ better estimates than ~~the~~ parametric ~~model~~ PTFs (RMSE: 0.0414; 0.0444 cm^{3} cm^{-3} and 0.0613; 0.0605 cm^{3} cm^{-3} ~~-~~at -33 kPa and -1500 kPa, respectively). The local parametric PTFs provided better estimates than Rosetta PTFs at ~~—~~-33 kPa. N~~However, n~~o significant difference in accuracy, however, was found between the parametric PTFs and Rosetta ~~-~~H2 at -1500 kPa ~~with,~~ with ~~-~~RMSE values of ~~(~~0.0605 cm^{3} cm^{-3} and 0.0636 cm^{3} cm^{-3}, respectively~~)~~. The results of ~~the global overall~~global sensitivity analyses (GSAs) showed that the mathematical formalism of PTFs and ~~its~~ their input variables reacted differently in terms of point pressure and texture. The point and parametric PTFs ~~are~~ were sensitive ~~primarily~~ mainly to the sand fraction in the fine and medium textural classes. The use of clay percentage (C %) and bulk density (BD) as inputs in the medium textural class improved the estimation of PTFs at -33 kPa.

Keywords: soil~~-~~water retention, multiple regressions, pedotransfer function, sensitivity

I. Introduction

P~~The p~~redictive information on the spatial distribution of soil ~~-~~water and its availability for plants ~~will allow~~enables producers to take effective decisions ~~to maximise profitability~~ (e.g., on nutrient management and plant cover) to maximizse profitability. The soil-water balance is ~~in the centre~~central to ~~of~~ many processes that influence plant growth and the degradation of soil and water resources.

Hydrologists face the situation where soil hydraulic data such as water retention or hydraulic conductivity are often missing~~Hydrologists are often faced with the~~ a ~~situation where one or more of the pedotransfer functions (PTFs) inputs are not available~~. The extrapolation of PTFs in different agropedoclimatic context limits their performance (Touil et al., 2016). The development of local

PTFs could be useful to forin meeting the agricultural requirements for modelling with reasonable accuracy.

Soil-—water retention (SWR) curves (SWRCs) can usually be estimated by using two approaches: the point PTFs and parameter PTFs. In theWith point PTFs, the soil- water retentionSWR is estimated at defined pressure points (Pachepsky et al., 1996; Minasny et al., 1999).. One of the most commonly used water retention curvesSWR curvesCs is the Van Genuchten model (1980). The With parameterisation parameter method PTFs, the estimates the parameters of soil- water retentionSWR models,, such as θs, θr, α and n, are estimated by fitting it them to the data and then relating thenit by by empirical correlation to basic soil properties (Vereecken et al., 1992; Wösten et al., 1995; Schaap et al., 1998; Minasny and McBratney, 2002; Rawls and Brakensiek, 1985; Van Genuchten et al., 1992; Wösten et al., 2001; Vereecken et al., 2010). Schaap et al. (2001) developed the Rosetta package based on the artificial neural network (ANN) method, which uses five hierarchical models to predict the van Genuchten (VG) parameters (θs, θr, α and n) with soil texture classes only and the- input data (texture, bulk density [BD], and one or two water content values at -33 and -1500 kPa).

Pedotransfer functionsPTFs for point and parametric estimation of water retentionSWR from basic soil properties can be developed by using multiple regression methods (Lin et al., 1999; Mayr and Jarvis, 1999; Tomasella et al., 2000). Some 97% of PTFs are based on multiple linear and polynomial regressions of n^{th} order techniques (Botula et al. 2014)..

Moreover, usingUsing pedotransfer functionsPTFs in environments that differ from those from which they were derived for can lead to either an underestimation e or overestimation ofe water retentionSWR. Several studies have shown that water retentionSWR is a complex function of soil structure and composition (Rawls et al., 1991; Wösten et al., 2001; Rawls et al., 2003;, Mirus et al., 2015). Applyingications of PTFs on to different textural or structurale classes may could also be a source of uncertainty (Bruand et al., 2002; Pachepsky et al., 2003). SWR and hydraulic conductivity vary widely and non-linearly with soil-water potential.. Experience has shown that Ssoil texture predominantly is the main determinant of determines the water-holding characteristics of most agricultural soils (Saxton et al., 1986). The relationship between the soil water retention curve (SWR curveC) and particle size distribution (PSD) has been, was investigated in many studies (Jonasson et al., 1992; Minasny et al., 2006; Ghanbarian et al., 2009; Xu Yang et al., 2013; Tae-Kyu Lee et al., 2014). WThe water retentionSWR depends mainly mostly on texture, and with other factors such as bulk densityBD, structure, organic matter (OM), clay type, and hysteresis may all havehaving a secondary impact (Williams et al., 1983, Saxton et al., 1986, Vereecken et al., 1989, Winfield et al., 2006).

The variability of in PTF response depends on the variability and uncertainty of one or more of the input variables. UThe uncertainty analysis in the variety of available PTF available approaches is a necessityary to minimiseminimize the error in estimation and identify its source. Recently, sensitivity analysis techniques and uncertainty analysis have begun to received considerable attention in tPTFhe studiesy of PTF (Nemes et al., 2006b; Kay et al., 1997; Grunwald et al., 2001; Deng et al., 2009;

Moeys et al., 2012; Loosvelt et al., 2013). The question ~~is,~~is: W~~w~~hich variable input is the ~~principal~~ main ~~one~~ or ~~the better~~ best complementary predictor of ~~water retention~~SWR, and at which potential? G~~The g~~lobal sensitivity analysis (GSA) ~~allows~~ enables us to study how ~~the~~ uncertainty in the output of a model can be apportioned to different sources of uncertainty in the model inputs (Saltelli et al., 2000). Generally, ~~the~~ GSA is ~~very~~ useful for identifying ~~to know~~ which variables make the main contribution ~~mostly contribute~~ to output variables (Jaques et al., 2004).

The objectives of this study ~~was~~were to:

- Develop and validate two PTF approaches using regression methods: p~~P~~oint PTFs for estimating~~on of~~ ~~soil- water retention~~SWR in~~of~~ Algerian soils at -33 kPa and ~~at~~ -1500 kPa; and p
- ~~P~~arametric PTFs for estimating the ~~Van Genuchten~~VG ~~curve~~ parameters
- Study the impact of each input on the PTF responses~~.~~

~~Studying the impact of each input on the PTFs responses.~~

II. Materials and~~&~~ methods

1. The database

The soil data~~-~~set used for this study was collected from various regions in Algeria, mainly in the north, which has a Mediterranean climate. It contained 242 samples, with basic soil properties: texture fractions (based on the USDA system; clay and silty-clayey for most of the soils, Fig. 3a), BD, OM content and water content at -33 kPa and -1500kPa. Descriptive statistics of the development and validation datasets are presented in Table 1. The available database was split into two datasets. Subset 1, which was used to develop the PTFs, contained~~s~~ 78.1~~0~~% of the samples. Used as the calibration set, they were collected from the coastal plain of Annaba ~~located~~ in ~~the~~ north-eastern ~~part of~~ Algeria (13 samples), the ~~plain of~~ Beni Slimane plain of Media (42 samples), the Kherba El Abadia plain of Ain ~~-~~D~~d~~efla (54 samples) and ~~samples randomly selected~~ the ~~from~~ Lower Cheliff plain in north-western ~~of~~ Algeria (80 samples)~~, soil series was used as the calibration set~~. Subset 2 ~~with~~ contained the remaining 21.9% of the samples. Used to verify the PTFs, they were collected from Benziane valley in the lower south-western ~~lower~~ Cheliff plain. ~~, soil series was selected to verify the PTFs.~~ The depth of the two upper horizons varied~~s~~ from site to site, with a maximum of 30 cm for surface horizons and more than 30 cm for subsurface horizons.

PSD analysis was conducted using the international Robinson's pipette method (Robinson, 1922). Undisturbed soil samples obtained with 500-1,000 cm^3 cylinders were used to determine BD. The SWR values at -33 kPa and -1500 kPa were obtained using Richards's apparatus (Richards et al., 1943). Undisturbed soil samples were collected near field capacity with 100 cm^3 cylinders. Water content was measured using the gravimetric method at 105°C (24 h). Organic carbon content was determined using the wet oxidation method (Walkley and Black, 1934). Variation in soil texture in the dataset is displayed using the textural triangle proposed by FAO (1990) in Figure 3b.

The ~~soil- water retention~~SWR model ~~of~~ devised by Van Genuchten (1980) is defined as:

$$\theta(h) = \theta_r + \frac{\theta_s - \theta_r}{(1+|\alpha h|^n)^m} \quad (1)$$

Where θ_r and θ_s are ~~the~~ residual and saturated soil-~~-~~water content~~s~~ (cm^3 cm^{-3}), respectively, and α (cm^{-1}) and n are the shape factors of the ~~water retention~~SWR function. The VG parameters were indirectly estimated for each soil sample from four levels of measured data inputs: sand, silt and clay percentages, and BD using the Rosetta model H3 (Schaap et al., 2001). The 'm' parameter was calculated as follows:

m = 1 -1 / n.

2. PTF development

Two approaches were used in this study to develop the PTFs: point PTFs for estimating SWR for particular points of pressure (h); and parametric PTFs for predicting the VG parameters. Each water content level at selected water potentials of -33 kPa and -1500 kPa and estimated VG parameters were related to basic soil properties (i.e., sand, silt, clay content, OM content and BD) using multiple regression techniques (Table 2). The most significant input variables were determined using the Pearson correlation (α =5%). T For the multiple-linear regression (MLR) models, the general form of the resulting equations was expressed thus:

$$Y= a_0+ b_1 X_1 + b_2 X_2 + b_3X_3 +b_4 X_4 \quad (2)$$

For the multiple-non-linear regression (MNLR) models, it was expressed thus:

$$Y= a_0 + b_1X_1 + b_2X_2 + b_3X_1\text{^}2 + b_4X_2\text{^} 2 + b_5X_1\text{^}3 + b_6X_2\text{^}3 + b_7 X_1 * X_2 + b_8X_1\text{^}2 * X_2 + b_9 X_1 * X_2\text{^}2 \quad (3)$$

Where Y represents the dependent variable, a_0 is the intercept; b_1..., b_n are the regression coefficients, and X_1 to X_4 refer to the independent variables representing the basic soil properties.

The prediction quality of the point and parametric PTFs developed from Algerian soils were then compared with three Rosetta PTFs (H1, H2 and H3). We chose the Rosetta model because it gives the user flexibility in inputting the data required (Stumpp et al., 2009), with the option of five levels based on input data (Schaap et al. 2002):

- H1: Textural classes (USDA system)~~;~~
- H2 : Clay+Silt+Sand
- H3: Clay+Silt+Sand+ BD
- H4: Clay+Silt+Sand+ BD +Volumic water at -33 kPa~~;~~
- H5: Clay+Silt+Sand+ BD +Volumic water at -33 kPa + Volumic water at -1500 kPa~~;~~

The Rosetta model was also chosen because it has given reasonable predictions in several evaluation studies (Frederick et al., 2004, Nemes et al., 2003). In our study, the three Rosetta model levels (H1, H2, and H3) were selected to compare their performance in the Algerian soils because they require only texture data and BD as inputs, as well as the locally developed PTFs.

3. Evaluation criteria

~~The~~ PTFs are regularly assessed by comparing the values that they predict ~~and~~ with the measured values (Pachepsky and Rawls, 1999). In order to assess the validity of the PTFs developed, we used the following criteria: mean prediction error (ME) to indicate the bias of the estimate; root mean square error (RMSE) ~~as an estimator of~~to assess the quality of the prediction ~~that was~~(iIt is frequently used in ~~the literature~~studies on ~~the pedotransfer functions~~PTFs); and the index of agreement (d) developed by Willmott and Wicks (1980) ~~,~~ and Willmott (1981) as a standardized measure of the degree of model prediction error. They ~~we~~are calculated using the following equations, respectively:

$$ \boldsymbol{ME} = \frac{1}{N}\sum_{i=1}^{n}(\theta_{\mathrm{p}} - \theta_{\mathrm{m}}) \qquad (4) $$

Where N is number of horizons, and θ_p, θ_m, predicted and measured volumetric water content, respectively. The estimate was better when ME was close to 0'. Negative ME values indicated an average underestimation of θm, whereas positive values indicated overestimation.

$$ \boldsymbol{RMSE} = \left\{\frac{1}{n}\sum_{i=1}^{n}(\theta_{\mathrm{p}} - \theta_{\mathrm{m}})^2\right\}^{\frac{1}{2}} \qquad (5) $$

Thus, the lower the RMSE, the better the estimate.

$$ \boldsymbol{d} = 1 - \frac{\frac{1}{n}\sum_{i=1}^{n}(\theta_{\mathrm{p}} - \theta_{\mathrm{m}})^2}{\sum_{i=1}^{n}\left[\left|(\theta_{\mathrm{p}} - \bar{\theta}_{\mathrm{m}})\right| + \left|(\theta_{\mathrm{m}} - \bar{\theta}_{\mathrm{m}})\right|\right]^2} \qquad (6) $$

The index of agreement varied from 0 to 1, with higher index values indicating that the modeled values θ_p were in better agreement with the observations θ_m.

4. Global sensitivity analysis (GSA)

~~The global sensitivity analysis~~GSA ~~consists of~~involves determining which part of the variance ~~of~~ in model response is due to ~~the~~ variance ~~of~~in which input variable or group of inputs. ~~These methods quantify the~~The impact of the parameters ~~are~~is quantified by ~~the calculation of~~calculating the global sensitivity indices.

The Sobol method (Sobol, 1990) is an independent GSA method based on decomposition of the variance. When the model is non-linear and non-monotonic, the decomposition of the output variance is still defined and can be used. The Sobol model is represented by the following function:

$$ Y = f(X_1, X_2, X_3, \ldots\ldots, X_p) \qquad (7) $$

Where Y is the model output (or objective function) and $X=(X_1,\ldots, X_p)$ is the input variable set.

$$ V(Y) = V(E(Y|X)) + E(Var(Y|X)) \qquad (8) $$

Where V(Y) is the total variance ~~of~~ in the model, V (E(Y|X)) and E (Var(Y|X)) signify variance ~~of~~ in the conditional expected value and ~~the~~ expected value of the conditional variance, respectively. When the input variables Xi are independent, the variance decomposition of the model is:

$$V(Y) = \sum_{i=1}^{p} V_i + \sum_i \sum_j V_{ij} + + \sum_i \sum_j \sum_p V_{ijp} + \ldots\ldots + V_{1,2,3,\ldots p} \quad (9)$$

$$V_i = V\,[\,E(Y|X_i)]$$

$$V_{ij} = V\,[\,E(Y|X_i,\, X_j)] - V_i - V_j$$

$$V_{ijp} = V\,[\,E(Y|X_i,\, X_j,\, X_p)] - V_{ij} - V_{ip} - V_{jp} - V_i - V_j - V_p$$

Where Vi is the proportion of variance due to variable Xi. Dividing V_i by V(Y) ~~we obtain~~produces the expression of the first-order sensitivity index ~~noted(~~ S_i), ~~s~~such that:

$$S_i = \frac{V_i}{V(Y)} = \frac{V[E(Y/X_i)]}{V(Y)} \quad (10)$$

The term S_i is the measure that guarantees an informed choice in ~~the~~ cases where the factors are correlated and interact (Saltelli and Tarantola, 2002). This index is always between 0 and 1, and represents a proper measurement of the sensitivity used to classify the input variables in order of importance (Saltelli and Tarantola, 2001).

In order to quantify variation in the sensitivity index (V_{Si}) of an input factor X_i, we fixed it at $Xi = Xi*$ ($Xi*$: the average when the variable follows the normal distribution, the median when the variable follows the lognormal distribution). In order to calculate how much this assumption changed the variance of Y, we used this formula:

$$V_{Si} = \left(\frac{V[E(Y/X)]}{V(Y)} - \frac{V[E(Y/\,Xi{=}Xi*)]}{V(Y)}\right) * 100 \quad (11)$$

$V_{Si} > 0$ and S_i close to 1 indicate increasing accuracy of PTFs;

$V_{Si} < 0$ and S_i close to 1 indicate increasing accuracy of PTFs;

$V_{Si} > 0$ and S_i close to 0 indicate decreasing accuracy of PTFs;

$V_{Si} < 0$ and S_i close to 0 indicate decreasing accuracy of PTFs.

~~Moreover,~~In addition, ~~coupling~~ combining the RMSE and ~~sensitivity index~~ S_i ~~allowed~~ enabled us to detect the contribution of each variable ~~for~~ into ~~the~~ improvement ~~of~~ in the quality of prediction of the PTFs.

III. Results and discussion

In Table 3, ~~the majority of~~most of the PTFs ~~evaluated~~ underestimated ~~soil water retentions~~ SWR except for ~~t~~the point ~~model~~ PTF at the two pressure points (-33 kPa and -1500 kPa). The ~~hierarchy~~ Rosetta H2 model ~~H2~~, which considers only texture as an ~~i~~input, gave a smaller ME value ~~compared with both~~than the H1 and H3 ~~hierarchies~~ models (- 0.0728; -0.0436 $cm^3\,cm^{-3}$ at -33 kPa and -1500 kPa, respectively).

The poor ME values indicated better estimates of PTFs. T~~; t~~hey were produced after the application of point PTFs ~~points ~~followed by ~~the ~~parameterric PTF~~ sparameters~~.

Among the five tested models in the Lower Cheliff soils, the point PTFs (MLR) derived from a database taken from some Algerian soils had the lowest ~~values of ~~RMSE values (0.041 and 0.044 cm^3 cm^{-3} at -33 kPa and -1500 kPa, respectively). Performances equivalent or superior to PTFs derived by multiple regression methods have been reported in some studies (Minasny et al., 1999; Nemes et al., 2003). ~~However, the~~The non-linear models (parametric PTFs), however, gave a better estimation than the Rosetta models based on ~~the artificial neural network~~ANN (RMSE: 0.0613 and 0.0605 cm^3 cm^{-3} at -33 kPa and -1500 kPa, respectively). ~~Furthermore, the~~The RMSE and ~~the ~~ME values of the three Rosetta models also showed that H2 ~~is ~~was better than H1 ~~and ~~or H3 (Table 3).

The index of agreement results showed that point PTFs were more suitable for Lower Cheliff soils than parametric PTFs (Figure 6), with values of 0.9975 and 0.9911 cm^3 cm^{-3}). S~~A s~~imilar comparisons in different regions ~~was ~~were ~~made ~~undertaken by Minasny et al. (1999), Tomasella et al. (2003) and Ghorbani Dashtaki et al. (2010)~~.~~, who all reported ~~All have reported ~~similar differences between these two ~~types of ~~PTF approaches.

As Table 3 shows, there was no significant difference in RMSE values between the parametric PTFs and Rosetta H2 at -1500 kPa (~~-~~RMSE~~-~~: 0.0605 cm^3 cm^{-3} and 0.0636 cm^3 cm^{-3}~~-~~, respectively).

1. Sensitivity index before ~~the ~~textural grouping

In the development of PTFs, using ~~the particle-size distribution (~~PSD~~)~~ as an input is ~~generally the common~~the usual approach (texture as a~~ global~~n overall expression of ~~the particle size distribution~~PSD, clay, silt and sand content)~~,~~ and its contribution is fundamental to understanding the process of retaining water at different pressure points, although various physical and chemical characteristics are used to describe the ~~water retention curve~~SWR curve, such as ~~bulk density~~BD and ~~organic matter~~OM.

~~In this section, the~~The importance of each input variable wa~~i~~s assessed by the first order ~~sensitivity index (~~S_i~~)~~. It was clear for the PTFs developed that OM% and clay percentages (C%) were the variables with the greatest impact (Figure 2). For the point PTFs (MLR), the most sensitive estimations were at two pressure points (S_i: 0.821; 0.782 at -33 kPa and 0.630; 0.585 at -1500 kPa for OM% and C%, respectively. The percentage of silt (Si~~–~~%) ~~is ~~was ~~in a ~~second ~~range of~~in importance in parametric PTFs (0.576 at -33 kPa) after OM, followed by ~~the bulk density~~BD and ~~clay~~ C (Fig. 2). The S_i values ~~class ~~placed ~~the ~~sand content in third place in the MLR (0.262; 0.162), indiidcating that~~thus~~ its impact on the parametric model~~ is~~ was almost insignificant, with very low values ~~index ~~(S_i: 0.077; 0.017) at -33 kPa and -1500 kPa, respectively).

The prediction quality of point PTFs (MLR) can be explained, first, by taking into account the basic characteristics of soil as an input ~~through ~~from the ~~texture ~~textural and ~~structure ~~structural information given by the ~~bulk density~~BD. Second~~ly~~, point PTFs (MLR) are based mainly on these input variables, ~~compared to~~unlike ~~parametric ~~parameter PTFs (~~using ~~MNLR), which ~~has ~~have inputs other than texture and ~~the bulk density~~BD, ~~but also~~as well as other parameters (VG parameters: θr, θs, α, n).

2. Sensitivity and uncertainty analysis after the textural grouping

~~This section will analyze the~~The sensitivity of the multiple regression methods (linear and non-linear) used to develop PTFs from basic soil characteristics for estimating SWR for different textural classes was analyzed. ~~In this order we have~~We grouped the samples into three classes of particles (~~fig.~~Figure 3) ~~according to textural classes of the~~in line with ~~FOA~~ FAO guidelines (FAO, 1990): ~~,~~ ~~which give a~~ very fine ~~class~~ (12 samples);~~,~~ fine (31 samples); and medium (10 samples).

The results showed that after the textural grouping, there was an improvement in the quality estimation of PTFs only in the medium class (Figure 4). A better prediction at -1500 kPa was provided by point PTFs (RMSE = 0.027 cm^3 cm^{-3}) and parametric PTFs (RMSE = 0.038 cm^3 cm^{-3}) at -1500 kPa.

1. Texture: After textural grouping, the MLR and MNLR PTFs developed ~~are~~ were always sensitive ~~primarily~~ mainly to the sand fraction in the fine and medium classes (Table 4). The variation ~~of~~ in the first ~~sensitivity~~ S_i ~~index~~ in the point PTFs ~~is~~ was significantly greater in the medium texture class at the two pressure points (-33 kPa and -1500 kPa). In~~to~~ the MNLR, sand had~~s~~ the most influence, particularly ~~when it is applied~~with regard to the fine class (-40.9%, 18.9% at -33 kPa and 1500 kPa) and the medium class (-16.7% at -1500 kPa).
The ~~sensitivity index~~S_i of a variable quantifies the influence of its uncertainty on the output. This is the part of the variability output explained by the variability input. What ~~has been~~was confirmed after calculating the variation ~~of~~ in the first order ~~sensitivity index (V_{Si}~~S_i was~~),~~ ~~is~~ that the PTFs developed ~~are~~ were still ~~very~~ more influenced by the variability in~~of~~ sand at -33 kPa ~~more~~ than at -1500 kPa. This impact ~~can~~ could be explained by the irregularity of the dispersion of sand content in the validation database, with a coefficient of variation (CV) ~~approximately~~ of about 119% compared with~~to~~ the other input variables (33%,~~;~~ 18%,~~;~~ 9% and~~;~~ 57% for clay, silt, ~~bulk density~~BD and~~,~~ ~~organic matter~~OM, respectively). This heterogeneity ~~of~~ in the sand data series clearly influenced~~s~~ the uncertainty of ~~pedotransfer functions~~the PTF response.
~~Moreover, looking~~Looking at the matrix correlation (Table 5), the clay and silt fractions we~~a~~re significantly correlated with ~~the~~ sand content. Saltelli and Tarantola (2002) observed that when X_1 and X_2 we~~a~~re correlated with a third factor, X_3, the ~~sensitivity index~~S_i calculated depended~~s~~ on the force of this correlation as well as the distribution of X_3. In this case, the index power ~~may~~ could be influenced by this statistical association, as ~~we can~~it explains the higher value difference of index variation ~~of~~ in the sand percentage compared with the other variables (Fig. 2).
We ~~can see~~observed that point ~~MLR~~ PTF (MLR) ~~(MLR)~~ produced~~s~~ a lower error of estimation when the variation of the first order S_i for sand was the most important ~~(~~[MLR in the medium class: RMSE ~~(~~0.030; 0.027 cm^3 cm^{-3}~~)~~ with V_{Si} ~~= (~~-103% and~~,~~ 86.4%~~)~~ at -33 kPa and -1500 kPa, respectively]. A negative S_i ~~V_{Si} of~~ variation in sand content when the latter wa~~i~~s fixed ~~is noticed~~was apparent in all texture classes (Table 4). This ~~can~~ could be explained by the proportional relationship between ~~the~~ sand and clay content, particularly in the validation dataset with a dominant clay texture. Insignificant sensitivity of sand was recorded ~~in~~ for the very fine texture. Rawls et al. (2003) observed that 10% of

sand provides an increase in ~~water retention~~SWR at low clay content and a decrease in ~~water retention~~SWR at high clay content of more than 50%.

~~It is important to note the~~The relationship ~~of~~ between ~~v~~the ~~Van Genuchten's~~VG's ~~water retention~~SWR curve parameters (especially n and α) and ~~particle size distribution~~PSD ~~were conducted~~has been examined ~~recently~~ in many studies (e.g., Minasny et al., 2007; Benson et al., 2014) in order to explain why the sand impact increases in the fine texture class in parametric PTFs. It ~~can~~ could be explained by the ~~majority~~ predominant presence of sand and clay content as inputs i~~o~~n parametric PTFs. For soils with clay content between 35% and 70%, water content is ~~highly~~ greatly influenced by the percentage of sand in the soil (Loosvelt et al., 2013).

~~Furthermore~~In addition, when the sand content of ~~the~~ a sample increased~~s~~ to 60%, the drying rate wa~~i~~s ~~quicker~~ faster and water absorbing ability wa~~i~~s weaker ~~compared~~ than with the low sand content. When ~~the~~ sand content ~~decreases~~ fallsalls to 20%, the small pores occupy~~y~~ a large part of the pore structure, making the soil compact (Hao et al., 2015).

In the medium texture class, there was increasing accuracy in PTFs after fixing the clay content at -33 kPa. This ~~can~~ could be explained by the ~~reduction of~~reduced clay percentage in the medium class (mean of clay [~~(~~%]~~)~~ = 23%), which produced~~s~~ fewer errors at -33 kPa. The ~~highest~~ greatest impact of clay (%) was observed at -1500 kPa ~~on~~ in the point and parametric PTFs in different textural classes (Figure~~.~~ 4). The clay content of soils is a major predictor for modelling the permanent wilting point of soils (Minasny et al., 1999).

~~in addition, the~~The accuracy of the PTFs decreased when they were applied to some soil samples with a c~~C~~lay content (%) > 60% (Figure~~.~~ 4). In the very fine class, insignificant sensitivity ~~is~~ was recorded at all pressures defined in this study. In this class, the variation ~~of~~ in clay ~~is~~ was much lower~~,~~ ~~for the reason that~~ because ~~the latter~~it is only the dominant solid fraction, ~~and this can~~which could explain the smaller variation ~~of~~ in ~~sensitivity index~~S_i after fixing the clay percentage. SWR was higher in the very fine and fine classes than in the medium class, because they quickly drained water initially retained.

~~-In this study the~~ The silt percentage was introduced as an explanatory variable only in ~~MNLR~~ parametric PTFs (~~.~~MNLR). This fraction is known for its ability to retain water at high and medium soil water potentials. The GSA showed that the silt percentage had a stronger impact on the estimation of parametric PTFs at -1500 kPa than at -33 kPa~~-on~~ with the MNLR model. After textural grouping, an important variation in the first order S_i was observed in the medium class (-36.7% to -1500 kPa). The lowest values were recorded in the very fine class. It ~~-~~was clear that the silt percentage has an important role in estimating VG's parameters (α, n), and that ~~,~~its use as an input influences the estimate in the medium and fine classes. There was an increasing accuracy, however, in the PTFs recorded in the fine class at -1500 kPa. With silt and clay as inputs, there was a better estimation. P~~The p~~lant-available water content variation is more related to sand and silt than to clay content (Reichert et al., 2009).

2. Bulk density: this is the second most influential variable on the point PTF (MLR) response is by variation of sensitivity index on all textural class, mainly in the very fine textural class with elevated values at -33 kPa (V_{Si} = -50, 5%). In ~~the~~ parametric PTFs, ~~bulk density~~BD influence~~d~~s the medium class at -33 kPa. The results show~~ed~~s ~~that~~ the accuracy of quality estimation in the medium class when fixing the BD at -33 kPa ~~on~~ for the two ~~developed approach of~~ PTF approaches (Table 4). The very fine textural class ~~represents~~ represented 16 surface samples (0–30 cm) with a dominance of clay texture. In a similar study on clay soils, ~~the~~ volumetric water content (VWC) wa~~i~~s highly related to the inverse of ~~bulk density~~BD at field capacity (Bruand et al., 1996**).** This might also explain the fact that many soils with high clay content in the database are Vertisols in which BD and VWC are lower (Rawls et al., 2003). The inclusion of BD as an input provides information on pore volume, which can influence the performance of PTFs when applied to soil with high clay content. ~~—~~In addition, the soil structural information characteriz~~s~~ed by BD measurements ~~of bulk density~~ is an indirect measurement of pore space and is affected ~~primarily~~ mainly by texture and structure. For structure~~-~~less soils, primarily coarse and medium textured soils, the capillary pore-size distribution can be satisfactorily described by ~~particle size distribution~~PSD. The medium texture is relate~~d~~s in~~-a~~ general ~~way~~ to ~~the~~ pore-size distribution, as large particles give rise to large pores between them, and therefore~~,~~ ~~has~~ have a major influence on the ~~soil water retention~~SWR curve (Arya and Paris, 1981; Nimmo, 2004)**.** With BD and texture as inputs in point PTF (MLR), predicted values very close to the experimental results are obtained. ~~The results of this~~This study ~~can confirm~~showed that the effect of ~~the use of the~~using soil structural information ~~on~~ in ~~the~~ estimati~~on~~ng ~~of the soil water retention~~SWR depended on the type of regression technique (Nguyen et al., 2015).

3. Organic matter content: The most insignificant variation ~~of~~ in the S_i ~~sensitivity index (V_{Si})~~ after textural grouping ~~is attributed to the organic matter~~related to OM content. This ~~can~~ could be explained, first,~~ly~~ by the poor OM content in the Algerian soil samples. Lal (1979) ~~and~~ did not find any effect of ~~organic matter~~OM content on ~~water retention~~SWR.~~;~~ Danalatos et al. (1994) attributed this~~it~~ to the generally low ~~organic matter~~OM content in their samples. Second~~ly~~, homogeneity of the data for OM content in every textural class ~~decreases~~ reduced the variation ~~of~~ in PTF~~s~~ response. The increasing accuracy of parametric PTFs, however, was apparent for medium-textured soils at -33 kPa, where OM was used as an input to predict θ_s. ~~.~~ ~~Soil water retention~~SWR at -33 kPa is affected more strongly by ~~the~~ organic carbon than at -1500 kPa (Rawls et al., 2003). The sensitivity analysis ~~made~~ conducted by Rawls et al. (2003)~~, in order~~ to study the role of ~~organic matter~~OM content as a predictor~~,~~ show~~ed~~s that ~~water retention~~the SWR of coarse-textured soils is much more sensitive to changes in organic carbon ~~as compar~~than is the case ~~ed~~ with fine-textured soils. Bauer and Black (1981) found that the effect of organic carbon on ~~water retention~~ SWR in disturbed samples was substantial in sandy soil and marginal in medium and fine textured soils.

IV. Conclusion

The objective of this study was to analyze the sensitivity of estimating the SWR properties of Algerian soil using PTFs. We developed and validated point and parametric PTFs from basic soil properties using regression techniques and compared their predictive capabilities with the Rosetta models (H1, H2, and H3). The reliability tests showed that point PTFs produce more accurate estimations than parametric PTFs. ~~, the~~The derived parametric PTFs, however, ~~-~~provided better estimates than the Rosetta models ~~that were~~ originally developed from a large intercontinental database.

~~Furthermore, the global sensitivity analyses~~The GSA showed that the mathematical formalism of the PTF models and their input variables ~~react~~ reacted differently in terms of point pressure and textural class:

- After textural grouping, the two PTF approaches ~~of PTFs~~ developed (MLR and MNLR) ~~are~~ were always sensitive primarily to the sand fraction in the fine and medium classes at -33 kPa, rather than ~~more than~~ at -1500 kPa.
- The results ~~shows~~ illustrated ~~that~~ the accuracy of quality estimation in the medium class for the two ~~developed~~ PTF approaches ~~of PTFs~~ when fixing the clay percentage (~~C%~~C %) ~~the bulk density~~and ~~(~~BD~~)~~ at -33 kPa.
- The accuracy of PTFs decreased when they were applied to ~~some~~ soil samples with a c~~the C~~lay content > 60%.
- The most insignificant variation ~~of~~ in the S_i ~~sensitivity index V_{Si},~~ after textural grouping ~~is attributed~~was related to the ~~organic~~ OM ~~matter~~ content in Algerian soils.

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Tables:

Table 1. Soil characteristics of the developed and validated datasets.

	PSD					VWC (cm^3 cm^{-3})	
	S (%)	Si (%)	C (%)	BD (g/cm^3)	OM (%)	- 33 kPa	-1500 kPa
Samples used for ~~d~~Deriving PTF (n = 189)							
Average	17.81	39,23	42.97	1.71	0.95	0.44	0.27
Standard ~~Deviation~~deviation	10.32	10.76	13.90	0.20	0. 93	0.09	0.08
Min	1.00	9.20	4.00	0.60	0.08	0.13	0.03
Max	50.00	67.00	84.30	2.10	8.40	0.73	0.56
Coefficient of ~~Variation~~ variation (CV)	0.58	0.27	0.32	0.12	0.98	0.21	0.31
Samples used for testing ~~the~~ PTF (n = 53)							
Average	12.50	41.58	45.92	1.49	0.87	0.40	0.21
Standard ~~Deviation~~deviation	14.84	7.62	14.94	0.13	0.50	0.10	0.07
Min	-	29.00	9.00	1.15	0.20	0.14	0.07
Max	59.00	58.00	70.00	1.73	2.74	0.57	0.45
Coefficient of ~~Variation~~ variation (CV)	1.19	0.18	0.33	0.09	0.57	0.24	0.35

(*) S: sand, C: clay, Si: silt, BD: bulk density, OM: organic matter, PSD: particle size distribution, VWC: volumetric water content

Table 2. Multiple regression coefficient R^2 and regression coefficients of models developed.

		Point PTFs		***Parametric PTFs***			
		-33 kPa	**-1500 kPa**	***θs***(cm^3 cm^3)	***θr***(cm^3 cm^3)	***α***	***n***
	Regression technique	***MLR***		***MLR***	***MNLR***		
	Inputs (*)	*S%, C%, BD, OM*	*S%, C%, BD,*	*S%, C%, BD, OM*	C%,S%	Si%, S%	C%, Si%
Regression coefficients	***Multiple R²***	0.74	0.66	0.62	0.67	0.60	0.66
	a_0	0.0246	-0.0627	0.4136	9.00 × 10^{-02}	3.00 × 10^{-03}	2.90
	b_1	-0.0040	-0.0029	-0.0013	7.78 × 10^{-04}	-1.00 × 10^{-04}	-2.77 × 10^{-03}
	b_2	0.0012	0.00165	0.0002	3.20 × 10^{-04}	8.90 × 10^{-05}	-9.48 × 10^{-02}
	b_3	0.2554	0.1837	0.0177	-6.36 × 10^{-05}	5.40 × 10^{-06}	-3.66 × 10^{-04}
	b_4	0.0067		- 0.0018	1.20 × 10^{-05}	-4.50 × 10^{-06}	2.03 × 10^{-03}
	b_5	-	-	-	9.30 × 10^{-07}	-7.30 × 10^{-08}	2.49 × 10^{-06}
	b_6	-	-	-	-1.00 × 10^{-07}	4.50 × 10^{-08}	-1.50 × 10^{-05}
	b_7	-	-	-	9.00 × 10^{-02}	7.70 × 10^{-06}	2.84 × 10^{-04}
	b_8	-	-	-	7.78 × 10^{-04}	-3.10 × 10^{-08}	4.91 × 10^{-06}
	b_9	-	--	-	3.20 × 10^{-04}	-3.10 × 10^{-08}	-5.32 × 10^{-06}

(*) S: sand, C: clay, Si: silt, BD: bulk density, OM: organic matter, MLR: Multiple Linear Regression, MNLR: Multiple Non-linear Regression.

Table 3. Evaluation criteria of water retention pedotransfer functions (PTFs) at -33 kPa and -1500 kPa.

			-33 kPa	-1500 kPa
ME (cm^3 cm^{-3})	***Point PTF ~~Point~~***	MLR	0.0188	0.0261
	Parametric PTF	MNLR	-0,0016	-0.0020
	Rosetta	H1	- 0.0902	-0.0458
		H2	- 0.0728	-0.0436
		H3	-0.0991	-0.0552
RMSE (cm^3 cm^{-3})	***~~PTF Point~~Point PTF***	MLR	0.0414	0.0444
	Parametric PTF	MNLR	0.0613	0.0605
	Rosetta	H1	0.1170	0.0738
		H2	0.0970	0.0636
		H3	0.1280	0.0749
d (cm^3 cm^{-3})	***~~PTF Point~~Point PTF***	MLR	0.9975	0.9911
	Parametric PTF	MNLR	0.9938	0.9775
	Rosetta	H1	0.9623	0.9427
		H2	0.9775	0.9597
		H3	0.9519	0.9331

Table 4. Variation of first order sensitivity index (S_i) in the different textural classes.

			Si (%)		**S** (%)		**C** (%)		**BD** (g/cm^3)		**OM** (%)	
		Tex-class	**V** $_{Si}$	**A.E**	**V** $_{Si}$	**A.E**	**V** $_{Si}$	**A.E**	**V** $_{Si}$	**A.E**	**V** $_{Si}$	**A.E**
RML	**at -33 kPa**	**VF**	*Abs*		-1.2		-0.4		-50.5	-	4.6	
		F	*Abs*		-43.2	-	-10.7	-	-39.9	-	0.2	
		M	*Abs*		-103.3	-	-27.5	+	-44.4	+	-5.7	
	at -1500 kPa	**VF**	*Abs*		-0.3		0.9		-27.3	-	1.1	
		F	*Abs*		-46.2	-	-20.7	-	-41.6	-	0.1	
		M	*Abs*		-86.4	-	-52.9	-	-22.9	-	-2.3	
MNLR	**at -33 kPa**	**VF**	0.4		-0.2		0.1		-00.1		-0.05	
		F	-1.6		-40.9	-	-1.1		-2.5		-0.1	
		M	15.0		-5.2		15.1	+	21.6	+	22.3	+
	at -1500 kPa	**VF**	- 4.6		-0.3		-1.8		-1.4		-00.5	
		F	28.6	+	18.9	-	4.6		0.4		0.1	
		M	-36.7	-	-16.7	-	-22.6	-	8.9		-8.4	

Abs: absent ~~in~~ ion the model, V $_{Si}$: variation first sensitivity index; A.E.: improving estimation.

Table 5. Pearson correlation matrix between basic soil characteristics in the validation dataset of 53 soil samples.

Variables	S_i%	S %	C (%)	BD (g/cm^3)	OM (%)
Si%	**1**				
S %	**-0.334**	**1**			
C %	-0.159	**-0.878**	**1**		
BD (g/cm3)	0.164	-0.185	0.11	**1**	
OM (g/100g)	-0.174	-0.166	0.263	-0.19	**1**

The values ~~which are~~ in bold ~~are different~~differ from 0 to a level of ~~signification~~ significance α = 0.05

Si: silt, S: sand, C: clay, BD: bulk density, OM: organic matter

Figures:

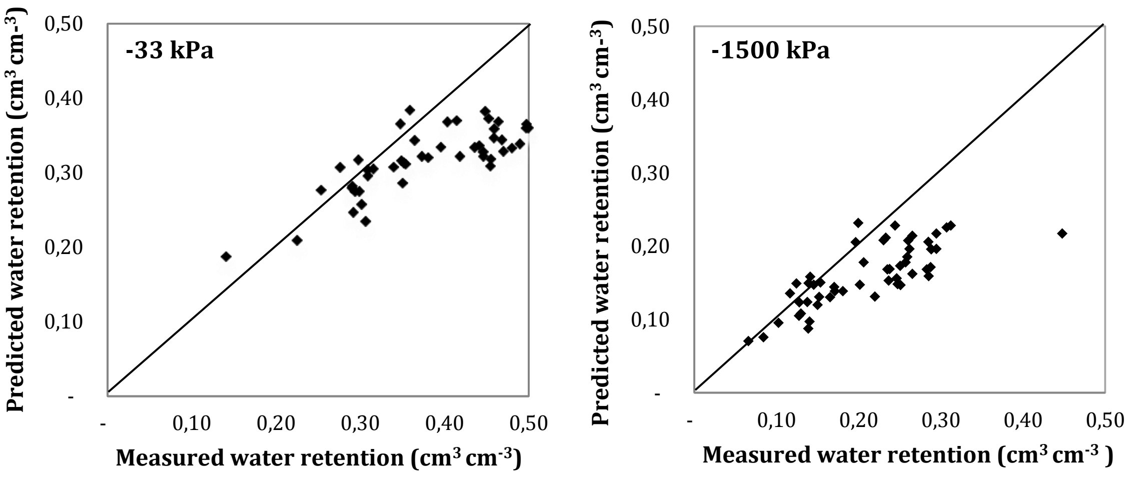


Figure 1. Scatter plots of measured versus predicted soil water retention by ~~H2~~ Rosetta H2.

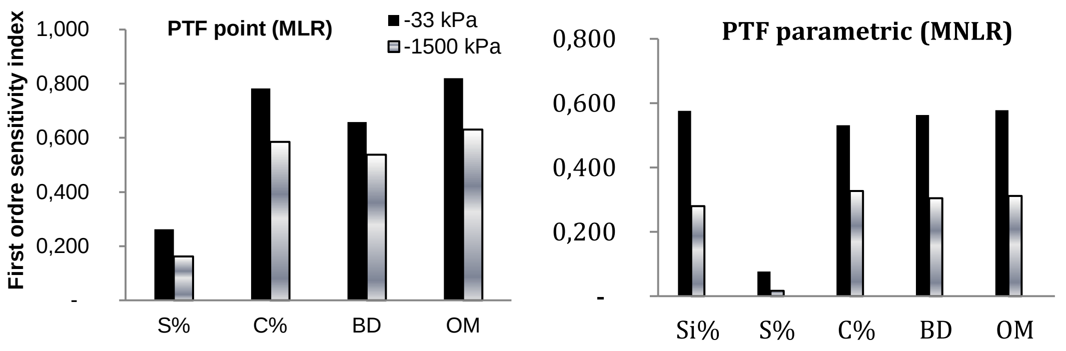


Figure 2. First order sensitivity index

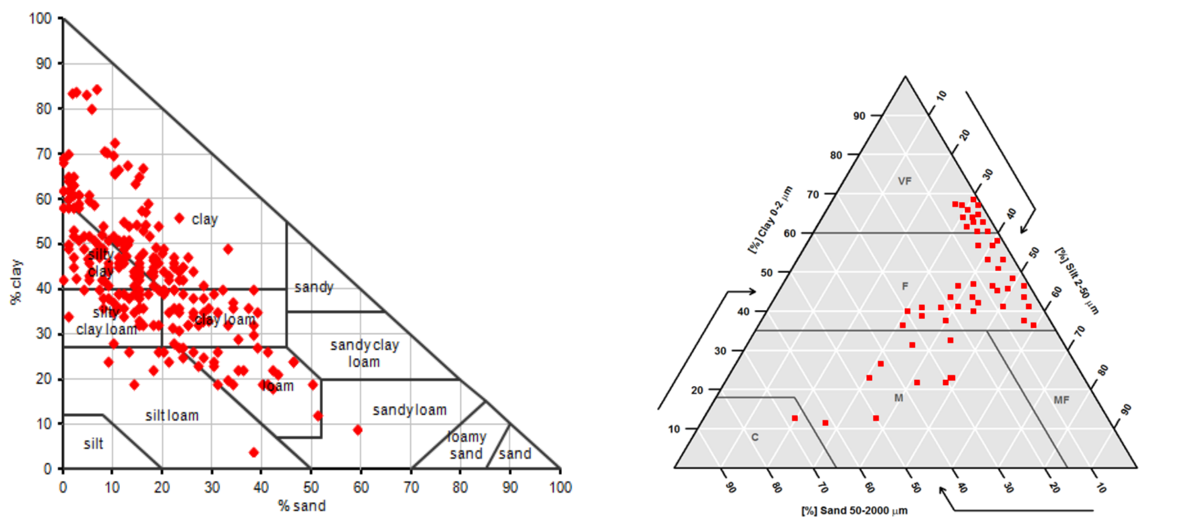
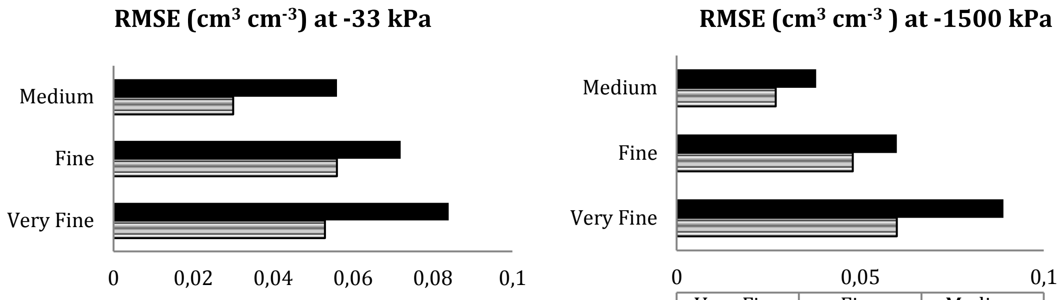


Figure 3. (a): Texture fractions of dataset (242 samples) based on USDA system. (b): Particle size distribution of 53 soil samples from Algeria according to FAO textural triangle.



	Very Fine	Fine	Medium
RMNL	0,084	0,072	0,056
RLM	0,053	0,056	0,03

	Very Fine	Fine	Medium
RMNL	0,089	0,06	0,038
RLM	0,06	0,048	0,027

Figure 4. Root mean square error (RMSE) values calculated for the different textural classes.

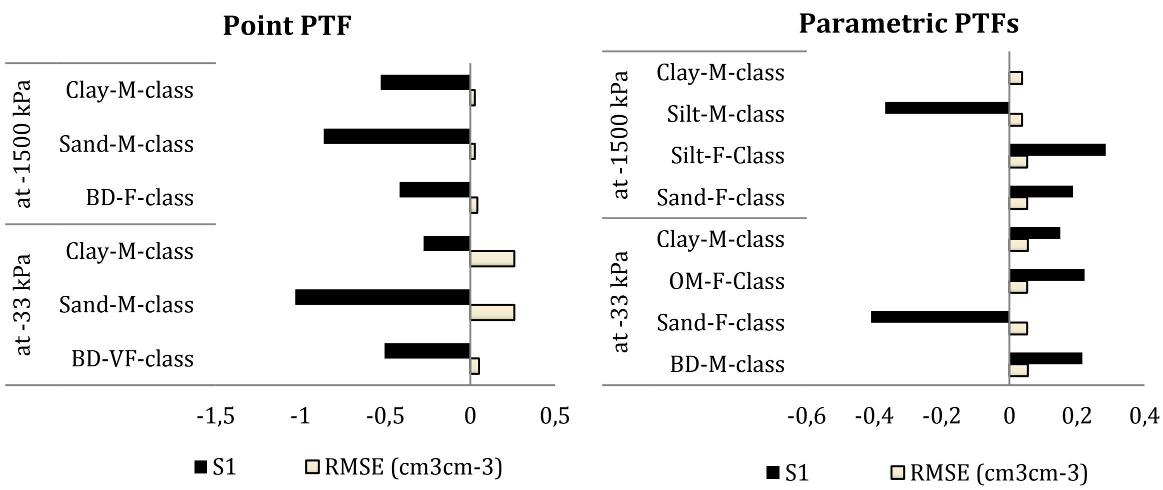


Figure 5. Variation in first sensitivity index with RMSE after textural grouping.

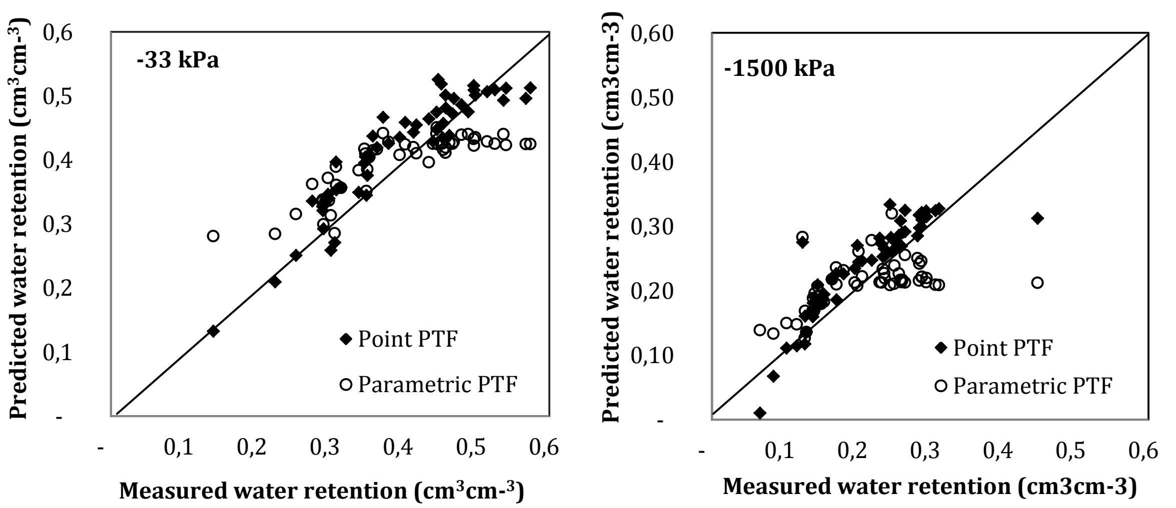


Figure 6. Scatter plots of measured soil water retention versus predicted soil water retention.