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Assessing Functions of Pedotransference to Determine Microporosity for a Soil (Typic Hapludox) under Two Conditions of Use in the Orinoco Region Colombia

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Microporosity is a property that influences not only on fluid dynamics but also on the flow of chemical substances and plant growth. Likewise, it is known that microporosity is difficult to be determined due to the broad variety of methods that implies using of equipment and assemblage, that in certain cases might be onerous. On the other hand, functions of pedotransference is a fundamental tool to estimate indirectly and affordable the soil properties which have been complex and expensive to be measured, in function to others which are less complex and have a lower cost. Therefore, the purpose of this study was obtaining functions of pedotransference (FP) of continuous type, using Multiple Linear Regression (MLR) to assess microporosity of a typic hapludox soil. This research was carried out in Villavicencio, Meta, Colombia using a data set of 12 physical and chemical properties of two locations submitted to different uses (a plot with agroforestry system and a plot with previous biennial crops under conventional management). Both

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plots in the study area were sampled in a matrix of 17 X 17 m resulting in 24 samples per area. ANOVA and the SNK tests indicated that the use and the soil management modify significantly properties such as moist retention capacity, clay content, phosphorous content and pH. Through the MLR method was obtained FP to stimulate microporosity with R^2 of 0,49 and 0,41 using field capacity and the electrical connectivity saturated as regressors variables. In addition, other functions that determine field capacity and microporosity in function of clay showed significance and the high power of prediction R^2 de 0,65. In conclusion, hydraulic parameters from assessed soils can be determined by functions of pedotransference with the MLR method, which proves the great potential of this tool as support for decision making in the field of soil sciences.

Keywords: Physical soil properties; linear regressions; soil management; microporosity; soil quality; soil water; agroforestry system; conventional management.

1. INTRODUCTION

For the assessment of soil quality is necessary to measure different properties that are useful to discover the process which occurs on it, whether physical, chemical, biological or mix, which has a direct relationship with its capacity to fulfil its function in the ecosystem or agroecosystem [1]. The microporosity also denominated as textural porosity is composed by the volume of the finest pores of the soil, in charge of water storage, and which are located into the peds (intra-pedal). This is a property with agroecological importance due to the control of the main relations between the solid, liquid or gaseous phases, relating to the process of compaction, oxygen availability, biological activity, organic matter decomposition, root growth [2]. Moreover, other studies point out that microporosity play an important role in water availability in the plant [3], the biodegradation of herbicides [4] and the productive response of different crops [5], however, it has a particularity that exists different methodologies with complex procedures which difficult its determination. On the other hand, the latest generation methods are expensive and complex, in addition, it requires minimum three days to articulate the sample and generate reliable values. Mathematics methods, denominated functions of pedotransference (FP) allows to translate available data to necessary or useful data, which is finally, an indirect and low-cost technique [6]. [7] Explain the use of this method by a generated equation (or function) where one property can be related in function of other(s) which is easier to determine [8]. Therefore, a few researchers have proposed and demonstrated that efficiency in the evaluation of variables or soil properties such as hydraulic conductivity [9,10], soil moisture retention curves [11],[8] infiltration [12], purification, decomposition and fertilization [13].

In Colombia it has been developed functions of pedotransference with positives results for the calculation of hydraulic conductivity in the Cauca Valley soils [14,15] they also have been used to estimate the water retention curve and the hydraulic conductivity through the software AquaCrop, for crops such as rice and potato [16]. Moreover, it has also been proposed theoretically as an objective and accurate method for determining friability [17], despite these efforts it is necessary to increment the knowledge and the development of different methods for other soil properties. This study aims to obtain functions of pedotransference (FP) of continuous type, using multiple linear regressions (MLR) to calculate the microporosity of a Typic Hapludox soil under two conditions of use.

2. MATERIALS AND METHODS

The study area is located in the University of the Llanos in the village Barcelona (4.072142N, -72.48725W), municipality of Villavicencio, Meta department, in the Orinoco Region, Colombia. This research was carried out in soils under the Typic Hapludox classification [18]. From this study area two plots were selected. The first plot belongs to the clonal cocoa garden (*Theobroma cacao)* as agroforestry system (AFS) in combination with yopo (*Anadenanthera peregrina*) and acacia (*Acacia mangium*). The second plot corresponds to a soil where semi-annual crops are sown under conventional management (CM).

2.1 Conceptual Framework

With a view to understanding stepwise the methodological approach to be followed, Fig. 1 clarifies the conceptual framework of this study.

2.2 Sampling Design

Two selected plots (AFS & CM) were measured with a sub-meter GPS. Data obtained from the GPS was exported to the free license software QGIS version 2.18.17 [19]. Using this research tool, the sampling model was designed, which consisted of a grid or matrix of 17 x 17 m, counting 24 points per plot. The georeferencing of each of the 24 sampling points was recorded to the GPS in order to locate them in the field. Finally, the disturbed samples and non-disturbed were analyzed in the lab.

2.3 Variables Evaluated in the Soil

Bulk density (BD) (Cylinder), Particle density (PD) (Pycnometer), Total Porosity (TP) (Equation 1), Texture (T) (Bouyoucos), soil penetration resistance (PR) (Penetrometer), field capacity (FC), permanent wilting point (PWP) (Richards stress equipment), Microporosity (Mi) (Centrifuge), Macroporosity (Ma) (equation 3), soil organic matter (S.O.M) (Walkley and Black), pH in H2O and KCl 1M (Potentiometric), Δ-pH (equation 2), Phosphorus (P) (Bray II), were the physical and chemical properties used in this study. These variables were determined according to the methodologies endorsed by the Geographical Institute Agustín Codazzi [20]. Microporosity was estimated following the methodology described by Jaramillo [21].

$$TP = 1 - (BD/PD)*100 \quad (1)$$

$$\Delta pH = pH\ KCl - pH\ H2O \quad (2)$$

$$Ma = TP - Mi \quad (3)$$

The value of the particle density (PD) was determined by the Pycnometer method [22]. In order to calculate the hydraulic conductivity to saturation (Ksat), through the software *hydraulic properties calculator*, which is developed by Laboratories Dr. Calderón [23], that is often used for mineral or low soil organic matter (S.O.M) soil, based on the percentage of sand (S) and clay (C) for the estimation of 6 properties (including Ksat). With the obtained results in the laboratory, a database (data set) was created to determine the pedotransference equation.

2.4 Statistical Analysis

With a view to explaining differences between the properties of both plots and determining management effects, descriptive and variance statistics analysis were performed with the SNK

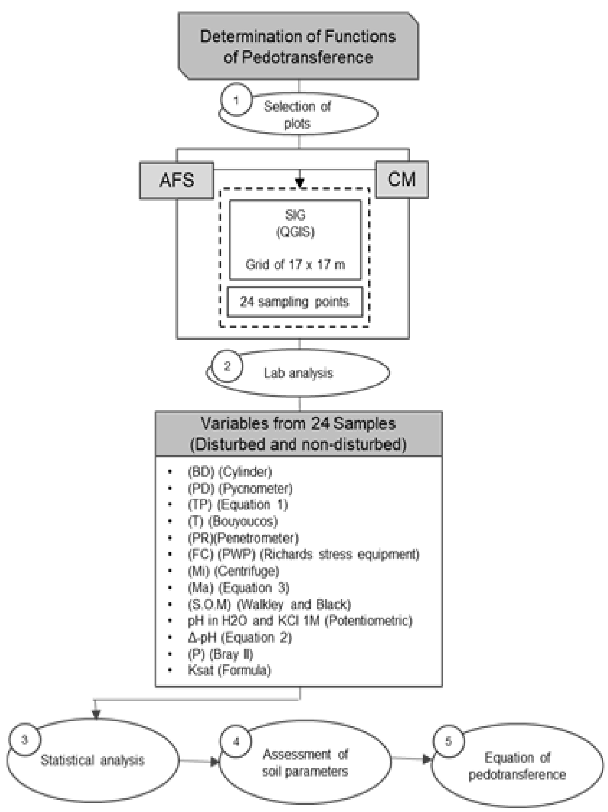

Fig. 1. Conceptual framework of this research

statistic at 95% probability ($p < 0.05$). Pearson correlation analysis was carried out among the different properties, omitting the relationships of variables that served as a parameter for the calculation of another one such as the % of Organic Carbon (OC) and soil organic matter (S.O.M), and the bulk density (BD) and total porosity (TP).

2.5 Determination of Function of Pedotransference

The multiple linear regressions method (MLR) [24,25,26] was assessed by the minimum square method, using microporosity as the dependent variable of the soil, and as return variables, the physical and chemical properties evaluated in the laboratory. Through the analysis of variance (ANOVA-statistic of *F*), the significance of each of the terms of the function was determined. The R^2 was used as an index of prediction for pedotransference functions [27] and the results were discarded functions with the lowest R^2.

When any of the values were non-significant, it was used the graphical method in which the performance of the partial residues from the dependent variables and the response variable (microporosity), with the aim of observing some trend in the regression variable evaluated. The adjustments in the mathematical model and the analysis of the dispersion diagram were part of the final verification, that consisted in determining the absence of trend of the return variables as a function of the evaluated residues of the dependent variable (microporosity) [28]. Statistical analysis was performed by the statistical programing language "RStudio" version 3.3.2. [29].

3. RESULTS AND DISCUSSION

3.1 Effect of Management on Soil Properties

The texture for both plots (AFS and CM) was the same according to the textures triangle (FArA), however, ANOVA (Table 1) showed significant differences in the content of clays (C) and silt (St), field capacity (FC), permanent wilting point (PWP) and the saturated hydraulic conductivity (Ksat); properties related to water dynamics.

In the AFS plot, higher values of C and FC and lower values of PWP were obtained. This indicates a greater capacity of this plot to store water of usable type for the plants [30]. Such capacity in this plot might have a strong influence by a greater amount of clays since they generate a greater colloidal surface and therefore greater retention of water. In other words, clay soils can retain a greater amount of useful water than sandy soils [31]. On the other hand, the tillage applied to the CM plot may be creating negative effects in water conservation, in addition, inadequate soil preparation practices generate loss in moisture retention capacity [32] as well as in the distribution and stability of the porous system [33]. The continuous breakdown of soil aggregates by the excessive tillage [31] in the CM plot and the high rainfall in the area [34] promotes argiluviation processes (leaching from clays) due to the clays can descend by gravity effect to the walls of drier pores with the possibility of filling them [35], and form hardened layers by sedimentation such as a claypan [21], or accumulate in certain points due to the influence of the microrelief. In addition, in the same plot, colloids have a greater susceptibility and tendency to dispersion (or de-coagulation) due to the effect of pH (higher value but no significant difference) and temperature (it is assumed greater due to lack of coverage). In this sense, such a phenomenon might be explained by the fact of higher pH, greater susceptibility to dispersion and higher temperature, showing a greater tendency to de-coagulate. Moreover, the ΔpH had a higher value with significant difference and free negative charges showed an influence in the dispersion [35].

Although the saturated hydraulic conductivity (Ksat) was moderate-high for both plots (AFS and CM) [21]), the CM plot showed significant differences and higher value in comparison to the AFS plot, indicating that in CM the water moves more easily when the soil is saturated. This result might be explained by the fact that over tillage can generate preferential routes for water flow and / or air flow, in addition, to the structural changes, an increase of vertical Ksat occurs while decreasing the horizontal in a light soil with subsequent tillage; phenomenon that may be occurring in CM [36]. Microporosity (Mi) was high for both plots and the optimal values were considered between 10 and 15% [33], being significantly higher for the CM plot (Table 1). A soil with high microporosity can have a high capacity for water retention and storage [15]. In this study the CM plot (which had higher microporosity) has less capacity to retain moisture and less macroporosity than the AFS plot, that means that the porosity of the second one can be comprised mostly by pores that retain useful moisture for plants [31].

Table 1. Properties of the soil for two plots with different management

Property	Plot	n	Mean	C.V	Min.	Max.	p-value
BD	AFS.	24	1,30 ± 0,12 a	8,87	1,06	1,55	0,2668
	CM.	24	1,33 ± 0,09 a	7,1	1,15	1,52	
PR	AFS.	24	1,37 ± 0,36 a	26,42	0,48	1,94	0,1781
	CM.	24	1,49 ± 0,18 a	12,18	1,08	1,78	
S	AFS.	24	50,04 ± 5,21 a	10,42	37,3	68,4	0,3207
	CM.	24	51,17 ± 1,72 a	3,35	48	54	
St	AFS.	24	25,33 ± 6,32 a	24,95	8,3	41,4	0,0435
	CM.	24	28,17 ± 2,24 b	7,96	24	34	
C	AFS.	24	24,63 ± 1,99 a	8,06	19,3	29,3	<0,0001
	CM.	24	20,67 ± 2,66 b	12,87	12	26	
Ksat	AFS.	24	0,42 ± 0,04 a	8,84	0,29	0,47	<0,0001
	CM.	24	0,70 ± 0,13 b	18,28	0,42	0,99	
%TP	AFS.	24	48,94 ± 4,42 a	9,04	30,9	58,41	0,1566
	CM.	24	50,80 ± 4,50 a	8,86	43,36	63,21	
%Mi	AFS.	24	27,93 ± 3,95 a	14,14	21,94	36,28	<0,0001
	CM.	24	35,38 ± 3,17 b	8,96	29,86	46,36	
%Ma	AFS.	24	20,53 ± 4,30 a	20,93	10,74	31,82	0,0001
	CM.	24	16,31 ± 1,85 b	11,35	11,62	19,99	
FC	AFS.	24	31,61 ± 1,49 a	4,71	26,43	34,12	<0,0001
	CM.	24	25,31 ± 1,22 b	4,8	22,88	28,44	
PWP	AFS.	24	12,91 ± 1,60 a	12,37	10,3	16,67	<0,0001
	CM.	24	16,89 ± 0,52 b	3,06	15,19	18,34	
%S.O.M	AFS.	24	3,34 ±0,34 a	0,18	2,53	4,24	0,1859
	CM.	24	3,47 ± 0,33 a	9,43	2,79	4,19	
%OC	AFS.	24	1,94 ± 0,20 a	0,18	1,47	2,46	0,1854
	CM.	24	2,01 ± 0,19 a	9,43	1,62	2,43	
P	AFS.	24	46,77 ± 17,61 a	37,66	10,6	97,2	0,0031
	CM.	24	35,35 ± 3,25 b	9,18	29	46,32	
pH H2O	AFS.	24	4,03 ± 0,31 a	7,79	3,49	5,12	0,1581
	CM.	24	4,13 ± 0,06 a	1,36	4	4,27	
pH KCl	AFS.	24	3,53 ± 0,14 a	4,09	3,24	3,92	0,1062
	CM.	24	3,59 ± 0,05 a	1,39	3,48	3,74	
Δ pH	AFS.	24	-0,37 ± 0,06 a	7,18	-0,49	-0,21	<0,0001
	CM.	24	-0,49 ± 0,08 b	7,16	-0,67	-0,31	

AFS: Agroforestry System, CM: Conventional Management, CV: coefficient of variation. Different letters show significant difference by the SNK test at (P= .05)

The higher Mi in the CM plot can be an effect of inadequate mechanization since these practices generate their increase [37], unbalancing the pore distribution and reducing the water available for the plant [38]. Ma showed a significant difference (as well as the Mi, due to its estimation method, equation 3) being larger in the AFS plot and indicating possible problems of excess drainage [33], [21]. Regarding the lower value of Ma in the CM plot can be given by the effect of intensive agricultural production, due to these soils tend to reduce their porosity [39], as well as to encourage the formation of a "plow foot" [35]. Thus, the proportion of micro and macropores by the AFS plot shows that this plot has a better condition in terms of greater balance between macro and micropores. The TP did not show significant differences, however, the Mi and the Ma did, this outcome demonstrates the importance of knowing the proportion of pores for the study and assessment of certain processes in the soil such as water flow, air and the soil-plant-atmosphere, which is similar to the approach by Hillel [40].

The phosphorus content (P) which is higher for the AFS plot (Table 1), demonstrates that one of the ecosystem services provided by a AFS increases the available P, mulch and the interchangeable cations, as well as benefiting the maintenance of total reserves of P, K, Ca and Mg in the biomass [41].

Although the results of pH in water (H_2O) and in KCl were not significant, values of delta-pH (ΔpH) showed significant differences, being -0.37 and -

0.49 for the AFS and CM plots respectively. These outcomes demonstrate the predominance of negative charges for both plots due to H20 > KCl [42] as well as CIC > CIA for AFS plot, that can be explained by the fact that this plot has a closer proximity to the isoelectric point (equal positive charges and negative to certain pH), and as consequence has a greater proximity to the coagulation, conglomeration, and sedimentation of the colloids, in addition to having a greater retention of salts against washing [42]. Results obtained for bulk density (BD) and the penetration resistance (PR) did not highlight significant differences, however, those values were higher in CM (with lower C content). Thus, it can be said that in this plot, there is a trend to compaction, if it continues with the same soil management practices causing an increment in Da and the RP [31]. The percentage of organic carbon (OC), as well as that of organic matter (OM), did not have a significant difference, but tends to be higher in CM. This result might be explained due to the constant applications of organic fertilizers. Moreover, it should be considered that the mineralization rate in tropical soils is higher than the OM accumulation rate [38].

Microporosity (Mi) was correlated positively with FC (0.64) and PWP (-0.70) (Table 2), which indicates its relationship with the storage capacity of water usable by plants [30]. It is interesting that Ma had an inverse behavior in comparison to Mi with FC and PWP (0.53) and (-0.51) respectively, allowing inferring that low values of Mi and high of Ma can promote a wider range of usable water.

Water contained within the porous system is retained with a variable energy, and the complexity in its use depends on the energy which is adhered to the surface of the colloids of the soil, when the pore is very small the energy to extract water and take it to the inside of the plant is high [30], consequently a high Mi contributes to a high PWP, which it can be interpreted as low water supply.

According to Honorato [43] the storage pore size varies between 0.5 and 50 μm, likewise [30] explain that pores which retain water between FC (0.1 bar) and PWP (15 bars) vary between 10 μm and 300 nm, moreover, the pores that retain the useful water (PUW) have sizes between 10 to 0.2 μm [36], following the previous findings and assuming that Mi corresponds to the size range of 0.2 to 0.9 μm [37], it is likely that the Mi of the studied areas are between 0.2 and 50 μm in size, with the majority of sizes being between 0.2 to 10 μm.

Table 2. Correlation of studied variables

Variables	Pearson	p-Value
MixC	-0,53	0,0001***
MixSt	0,38	0,0078***
MixKsat	0,59	<0,0001***
MixFC	-0,7	<0,0001***
MixPWP	0,64	<0,0001***
MaxKsat	-0,45	0,0013***
MaxFC	0,53	0,0001***
MaxPWP	-0,51	0,0002***
PWPxFC	-0,76	<0,0001***
PWPxKsat	0,7	<0,0001***
KsatxFC	-0,81	<0,0001***
PWPxC	-0,48	0,0006***
FCxC	0,7	<0,0001***
FCxSt	-0,4	0,0047***
FCxP	0,37	0,0093***
PxH2O	0,45	0,0013***
BDxOC	-0,51	0,0002***
H20xKCl	0,57	<0,0001***
MaxΔpH	0,37	0,0089***
MixΔpH	-0,48	0,0006***
FCxΔpH	0,61	<0,0001**
PWPxΔpH	-0,62	<0,0001***
KsatxΔpH	-0,62	<0,0001***
CxΔpH	0,58	<0,0001***
StxΔpH	-0,35	0,0133**

*H2O: pH en H2O, KCl: pH en KCl. p = 0,01*** (Highly significant) and p = 0,05** (Significant)*

The porosity of the soil is the result of the interaction of the texture, the structure and the biological activity [31], the Mi is denominated as "textural porosity", this is evidenced by observing the relationship between the contents of C and St with this property (Table 2).

Other outstanding correlations are: Ksat x FC, PWP x FC, PWP x Ksat, and FC x C with values (-0.81), (-0.76), (0.70) and (0.70) respectively, relationships between Ksat x FC and FC x C allows to infer that the C contributes significantly with moisture retention to FC, however, this reduces the Ksat, this can translate into a greater susceptibility to puddling in AFS, due to the slow water movement in clays [30]. Previous results contradict what was stated by [35] who mentions that Kandites is one of the minerals of the clay fraction of the soils in the Pie de Monte Llanero (clay 1:1), colloids make difficult the moisture retention when they increase their content in the soil.

The relationship between the BD and the OC (-0.51) verifies that the OM and the OC are parameters that can be used in the prediction of BD, similar results to the previous findings are reported in studies by Rubio [44].

The correlation between: FC x ΔpH, PWP x ΔpH, and Ksat x ΔpH (Table 2) allows to infer that electric charges can influence the retention and dynamics of water, as well as influencing physical properties such as (C, St and Mi), which may imply greater complexity in the dynamics of water movement in soil than those treated in this study. The relationships proposed by some authors between the porous system and BD [21], total porosity [2], [43] and resistance to penetration [2] were not observed in this research.

3.2 Functions of Pedotransferece for Microporosity and Other Soil Properties

The simple linear regressions (SLR) of first order were the most used because they allowed obtaining functions with levels of significance and greater prediction power than the multiple linear regressions (MLR), and the polynomial models of the 2nd or higher order, with exceptions in the function 2 (first-order MLR) and functions 4, 5 and 10 (SLR of 2nd or higher order) as shown in below table, seven properties (Mi, FC, PWP, C, Ksat, KCl and H2O) were related in 14 functions that have p-value <0.0001 in the model. The Mi was proposed as a dependent variable for 5 functions where FC, PWP, C, Ksat and $Ksat^2$ were the return variables, with values for R^2 of 0.49, 0.41, 0.36, 0.35 and 0.43 respectively, with high significance (p-Value <0.0001).

The function 1 that has as the independent variable FC has a high degree of significance, however, the predictive power is not very high, being < 50%, meaning that a little more than half of the predicted data would be far from the real one.

When PWP is the regressor variable (function 3) the R^2 (0.41) is smaller makes the predictions with this function less accurate, confirming the relationship between the porous system with the water retention capacity and the existing relationship between the Mi with the FC and the PWP [3]. Other authors have related (in functions of pedotransference) the moisture retention and the hydraulic conductivity with the texture, porosity and bulk density [26]. For the case of Ksat, the 2nd order polynomial had a greater R^2 than the 1st order, likewise for C, however, with p-value = 0.05 for $Ksat^2$ and C^2 and lower CP Mallows.

The functions with the highest R^2 values were the numbers 8, 2, 10, 6 and 6 ', where 8, 2 and 6', in addition to having the largest R^2, have the FC as a dependent variable. The function with the highest prediction power (R^2 = 0.65) was number 8, showing the potential it has to estimate FC using Ksat, function 2 (Table 3), with Mi and C as return (MLR), had a R^2 very similar (0.64) to that of function 8; Equations 6 and 6 'relate FC and PWP as dependent and return variables, with an R^2 of 0.57. The function 10 allows to obtain the pH values in KCl from the pH in water (H2O) (R^2 = 0.58), despite this being a polynomial function of 2nd order, the p-value of $H2O^2$ and the CP Mallows they were not reduced as happened in the case of Ksat and Ar. The values of R^2 resemble that reported by [44] of 0.6, who mentions that this value represents "moderate goodness of fit".

The correlation between predicted values and values of the initial "real" data set (Table 4) allowed us to identify function 5 (Mi as a function of Ksat and $Ksat^2$) as the most appropriate (0.66) to estimate the Mi based on the "centrifuge" method proposed by Jaramillo [21]. The predicted values with functions 1 and 3 (0.65 and 0.64, respectively) have a similar certainty. Functions 5 and 5 'showed that sometimes the second-order polynomial model gives greater power of prediction to the function, than that of 1st order. The variables Ksat, FC and PWP, generated the highest predictions for the Mi; but a greater correlation could be obtained if the measurement of the pores is more detailed, for example that allows to differentiate between micro, meso and macropores (even in intermediate terms) to identify which type of pore would be more influenced and correlated with the FC and / or PWP, since the size of the pores can be associated with its strength to retain water [31].

The predicted values that came closest to the maximum correlation (1.00) were those estimated with functions 8, 2 and 10, with Pearson values of 0.77, 0.76 and 0.76 respectively; functions 8 and 2 allow to estimate the FC using Mi and C, but the number 8 has greater predictive power besides incurring in a lower economic cost due to the use of a single variable, the Ksat, this agrees with the data obtained by Baker and Ellison [25]; With the Ksat

Table 3. Functions of pedotransference obtained, R^2 and significance of the model

Number	Function	R^2	p – Value	CP Mallows
1	Mi*** = 61,39*** – 1,04FC***	0,49	<0,0001	43,87
1’	FC*** = 43,23*** – 0,47Mi***	0,49	<0,0001	43,87
2	FC*** = 26,31*** - 0,30Mi*** + 0,52C***	0,64	<0,0001	20,51 21,06
3	Mi*** = 10,48*** + 1,42 PWP***	0,41	<0,0001	32,38
3’	PWP*** = 5,76*** + 0,29 Mi***	0,41	<0,0001	32,38
4	Mi*** = 10,08 + 3,04Ar*** - 0,09C² **	0,36	0,0001	5,22 7,44
5	Mi*** = 3,72 + 82,18 Ksat*** - 52,72 Ksat² **	0,43	<0,0001	12,82 8,72
5’	Mi*** = 21,60*** + 18,06 Ksat***	0,35	<0,0001	25,16
6	PWP*** = 29,46*** - 0,51 FC***	0,57	<0,0001	61,89
6’	FC*** = 45,21*** - 1,12 PWP***	0,57	<0,0001	61,89
7	FC*** = 9,54*** + 9,63 Ksat***	0,49	<0,0001	44
8	FC*** = 37,66*** - 16,53 Ksat***	0,65	<0,0001	86,29
9	FC*** = 10,57*** + 0,79 C***	0,49	<0,0001	44,64
10	KCl *** = -3,76*** + 3,23 H2O*** - 0,35 H2O² ***	0,58	<0,0001	34,21 29,16

*P = 0,05** (Significant) y P = 0,01*** (Highly significant).*

Table 4. Correlation of previous values and the initial dataset

Number	Function – Scheme/summary	Pearson	p – Value
1	Mi (FC)	0,65	<0,0001
3	Mi (PWP)	0,64	<0,0001
4	Mi (C, C²)	0,6	<0,0001
5	Mi (Ksat, Ksat²)	0,66	<0,0001
5’	Mi (Ksat)	0,59	<0,0001
2	FC (Mi, S)	0,76	<0,0001
1’	FC (Mi)	0,65	<0,0001
6’	FC (PWP)	0,67	<0,0001
8	FC (Ksat)	0,77	<0,0001
9	FC (C)	0,67	<0,0001
3’	PWP (Mi)	0,64	<0,0001
6	PWP (FC)	0,67	<0,0001
7	PWP (Ksat)	0,7	<0,0001
10	KCl (H2O, H2O²)	0,76	<0,0001

In brackets, it shows the value of the independent variable

one can also estimate the PWP (function 7) but with less precision in the prediction (0.70), the results indicate the potential of the pedotransference functions as a tool to complement databases in an indirect way and low cost with concordance with the exposed [6].

4. CONCLUSIONS

The use and management of the soil including the high influence of the farming techniques, generate changes in the properties related to water dynamics, field capacity, permanent wilting point, and saturated hydraulic conductivity. Moreover, this alteration is also given in the physical properties, which influences dynamics such as silt, clay content, microporosity, and even in chemical properties such as phosphorus. One of the more significant findings to emerge from this study is that the technique used to obtain the functions, allowed to infer an equation or relationship that estimates microporosity with moderate levels, using field capacity as a regressor variable. Likewise, it must be taken into consideration that using more properties as well as a higher number of the dataset would allow increasing the levels or the power of prediction.

Furthermore, the estimation of field capacity (FC) and permanent wilting point (PWP) through pedotransference functions is a technique that can be extrapolated to areas evaluated, either for the analysis of the property in particular (FC or PWP) or to complete databases, taking into account the use of properties closely related to the complexity of each type of soil.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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