〈論 文〉

A SIMPLED MODEL FOR HIGHER ORDER SCANNING CURVES IN THE SOIL WATER CHARACTERISTIC FUNCTION

——土壤水分 特性函數의 高次 SCANNING 커브에 對한 簡略한 모델——

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Abstract

A simplified model for higher order scanning curves in the soil water characteristic function is suggested. The conceptual hysteresis models developed by Mualem[8,9] are simplied for higher order scanning curves. Higher order drying curves are regarded as primary drying curves and the last wetting reversal point is assumed to be on the main wetting curve by moving that point vertically downward. For the higher order wetting curves, it is assumed that these curves can be regarded as primary curves and the last wetting reversal point sits on the imaginary main drying curve which passes through the last wetting reversal point. The water content computed from the simplified model are compared with those obtained from Mualem's original model for second order scanning curves. It is found that absolute differences beween the two methods aree relatively small and the simplified mdel always underestimates for higher order drying curves while it overestimates for higher order wetting curves. Hence, those two tend to compensate each other for repeated drying-wetting processes. The simplified model approximates higher order scanning curves well and reduces computation considerably.

要 旨

土壤水分 特性函數의 高次 scanning 커브에 對한 簡略한 모델을 開發하였다. Mualem 의 개념적 履歷모델을 高次 scanning 커브에 대하여 간략하게 變形시켰다. 즉, 高次 乾燥曲線에 對하여는 마지막 轉向點을 鉛直下向으로 移動시켜 主濕潤曲線과 만나는 點을 轉向點으로 하는 一次乾燥曲線으로 간주하였다. 또, 高次 濕潤曲線에 대하여는 마지막 轉向點을 지나는 가상의 主乾燥曲線에서 出發하는 一次습윤곡선으로 간주하였다.

이 簡略한 모델을 사용하여 二次 scanning 커브에 대하여 計算한 土壤 함수량과 Mualem 의 모델을 이용해서 구한 토양 함수량을 比較하였다. 그 結果 두 모델 사이의 絕對誤差는 比較的 작았으며, 簡略한 모델이 Mualem 모델 보다 高次 乾燥時에는 항상 낮게, 高次 濕潤時에는 항상 높게 含水量을 推定하였다. 따라서 건조와 습윤을 반복하는 경우 誤差는 서

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로 상쇄된다. 本 硏究에서 開發된 簡略한 모델이 高次 scanning 커브에서의 土壤 含水量을 잘 推定하였으며 計算과정을 많이 감소시켰다.

1. INTRODUCTION

The relationship between pressure head and water content is required in most soil water flow studies. This relationship is not a single valued function for a soil but a complicated multi-valued function because of hysteresis. Many empirical based analytical equations to predict pressure head-water content relationships for isothermal conditions have been proposed.[1,4,13]

Dane and Wierenga[3] studied the effect of hysteresis on soil water movement, and concluded that this can be better predicted when the hysteresis is taken into account. Mualem[7,8,9] applied the similarity hypothesis in modeling capillary hysteresis of soil water characteristics. For the capillary hysteresis study, Mualem and Dagan[12] developed a dependent domain theory, and later Mualem[10] modified this theory to account for the effect of the pore water blockage against air entry.

Mualem[11] predicteda main wetting curve from a measured primary curve based on a nondimensional hysteresis model. Milly and Eagleson[6] modified Mualem's model for higher order scanning curves. However, their model requires several steps of calulations. Jaynes[5] compared 4 models of soil water hysteresis, namely, the point method, the slope method, the linear method, and the conceptual model. He found that the first two methods showed considerable pumping when numerous drying-wetting cycle was employed.

In the present study, a simple hysteresis model is developed by modifying Mualem's model[8,9] for higher order scanning curves. Comparisons between the simplified model and the Mualem's model are made.

2. SOIL WATER CHARACTERISTIC MODEL

Mualem[8] assumed that the pore group distribution function may be represented as a product of two independent functions as:

$$f(\bar{\rho},\bar{r}) = l(\bar{\rho})m(\bar{r}) \cdots\cdots (1)$$

where $\bar{r}$=normalized radius of pore opening, and

$\bar{\rho}$=normalized radius of pores.

The water content for any retention process can be determined by integrating Eq. (1) over the filled pore domain. As a matter of convenience, ϕ is defined as:

$$\phi(h)=\theta(h)-\theta_r \cdots\cdots (2)$$

where $\phi(h)$=effective water content at pressure head h,

$\theta(h)$=actual water content at pressure head h, and

θ_r=residual water content, which is the minimum water content value at which $d\theta/dh$ approaches zero on a retention curve.

Mualem[8] developed hysteretic water retention models for the primary and higher order scanning curves by integrating Eq. (1), and expressing the results in terms of two main curves. For the primary drying curve:

$$\phi\left({}_{h_{\min}}{}^{h_1}{}_{h}\right)=\phi_w(h)+\frac{\phi_w(h_1)-\phi_w(h)}{\phi_s-\phi_w(h)}[\phi_d(h)-\phi_w(h)] \cdots\cdots (3)$$

For the primary wetting curve:

$$\phi\left({}^{h_{\max}}{}_{h_1}{}^{h}\right)=\phi_w(h)+\frac{\phi_s-\phi_w(h)}{\phi_s-\phi_w(h_1)}[\phi_d(h_1)-\phi_w(h_1)] \cdots\cdots (4)$$

where $\phi\left({}_{h_{\min}}{}^{h_1}{}_{h}\right)$=effective water content at pressure head h after pressure head increased from $h_{\min}$ to h_1(wetting) and then decreased to h (drying),

$\phi\left({}^{h_{max}}{}_{h_1}{}^{h}\right)$=effective water content at pressure head h after pressure head decreased from h_{max} to h_1(drying) and then increased to h (wetting),

$\phi_w(h)$=effective water content at pressure head h on the main wetting curve,

$\phi_d(h)$=effective water content at pressure head h on the main drying curve,

$\phi_w(h_1)$=effective water content at reversal pressure head h_1 on the main wetting curve,

$\phi_d(h_1)$=effective water content at wetting reversal pressure head h_1 on the main drying curve, and

ϕ_s=effective water content at saturation.

The relationships of Eqs. (3) and (4) are graphically illustrated on Figures 1a and 1b, where point 1 represents the reversal point.

For the higher order scanning curves, which occur after a series of alternating processes of wetting and drying, the water content can be determined in the same manner, by integrating over the filled pore domain as given in Mualem.[8] However, the higher order scanning curves create many operational problems because of the larger number of variables introduced. It is not simple to use those higher order scanning models in practical problems.

Milly and Eagleson[(6)] modified Mualem's model for higher order scanning curves. Figure 2 shows the concept of their simplification. They assumed that the higher order wetting (drying) curve BC (FG) is coincident with the primary wetting (drying) curve DC(HG). They computed watər content at D(H) on the main drying (wetting) curve from the values at B (F). Then, they applied primary curve equations (3) and (4) with the values at D(H) to determine water content at the current pressure head at C(G). This approach is much simpler than the original Mualem's model; however, it still requires the determination of the water content at the wetting reversal point of the assumed primary curves on the main curves, D(H), and requires several steps of computations.

For higher order drying curves, $\phi_w(h_1)$ in Eq. (3) can be replaced by $\phi(h_1)$ by assuming that the higher order drying curve can be

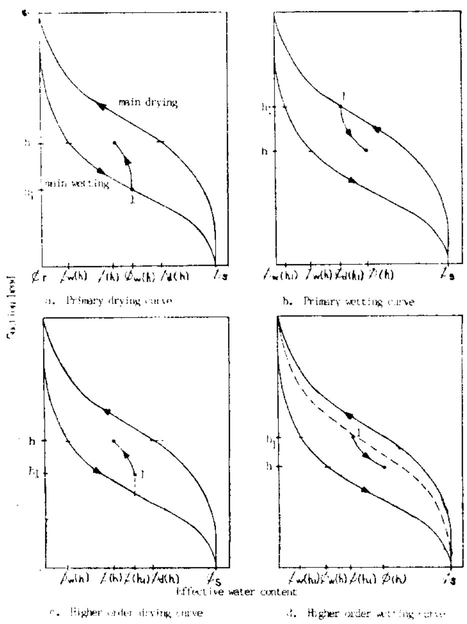
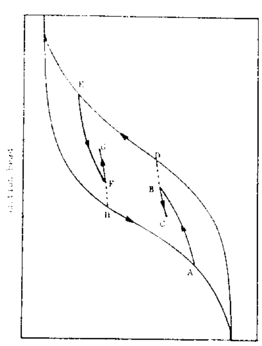


Fig. 1. Primary and higher order scanning curves.



Water content

Fig. 2. Simplication of the higher order curves used by Milly and Eagleson(1980)

regarded as a primary curve and can be extended vertically downward from the last wetting reversal point to the main wetting curve as shown on Figure 1c. Then, for the higher order drying curves:

$$\phi\left(\cdots {}^{h_1}{}_{h}\right)=\phi_w(h)+\frac{\phi(h_1)-\phi_w(h)}{\phi_s-\phi_w(h)}[\phi_d(h)-\phi_w(h)] \cdots\cdots(5)$$

where $\phi\left(\cdots {}^{h_1}{}_{h}\right)$ = effective water content at pressure head h after a series of drying and wetting cycles, culminating in a pressure head decrease from h_1 to h, and

$\phi(h_1)$ = effective water content at the wetting reversal pressure head h_1.

For higher order wetting curves, $\phi_d(h_1)$ in Eq. (4) can be replaced by $\phi(h_1)$ by assuming that an imaginary main drying curve(dashed line) passes through the last wetting reversal point 1 on Figure 1d. Then, for the higher order wetting curve:

$$\phi\left(\cdots {}_{h_1}{}^{h}\right)=\phi_w(h)+\frac{\phi_s-\phi_w(h)}{\phi_s-\phi_w(h_1)}[\phi(h_1)-\phi_w(h_1)] \cdots\cdots(6)$$

where $\phi\left(\cdots {}_{h_1}{}^{h}\right)$ = effective water content at pressure head h after a series of drying and wetting cycles, culminating in a pressure head increase from h_1 to h.

Eqs. (3) through (6) are expressed in terms of two main curves.

In a subsequent paper, Mualem[9] proposed an extended similarity hypothesis by assuming that the pore group distribution function may be represented by a one-variable function instead of two-variable unknown function as:

$$f(\bar{\rho},\bar{r})=l(\bar{\rho})l(\bar{r}) \cdots\cdots(7)$$

Using Eq. (7), Mualem showed that a universal hysteresis function can be derived. On the basis of one main curve, the other main curve and all scanning curves can be defined. The advantage of this model is that it greatly reduces the information necessary to define fully the water retention behavior of a soil. From this extended similarity hypothesis the relationship between the two main curves can be derived as:

$$\phi_w(h)=\phi_s-[\phi_s(\phi_s-\phi_d(h))]^{1/2} \cdots\cdots(8)$$

and

$$\phi_d(h)=\left[2-\phi_w(h)\phi_s^{-1}\right]\phi_w(h) \cdots\cdots(9)$$

By introducing either Eq. (8) or (9) into Eqs. (3) through (6), the scanning curves can be expressed in terms of either one of the main curves. To express in terms of the main wetting curve, substitute Eq. (9) into Eqs. (3) and (4) for the primary curves:

$$\phi\left({}_{h_{min}}{}^{h_1}{}_{h}\right)=\phi_w(h)+\phi_w(h)\phi_s^{-1}[\phi_w(h_1)-\phi_w(h)] \cdots\cdots(10)$$

$$\phi\left({}^{h_{max}}{}_{h_1}{}^{h}\right)=\phi_w(h)+\phi_w(h_1)[1-\phi_s^{-1}\phi_w(h)] \cdots\cdots(11)$$

Now, Eqs. (8) through (11) can be expressed in terms of water content instead of effective water content by substituting Eq. (2) into them:

$$\theta_w(h)=\theta_s-[(\theta_s-\theta_r)(\theta_s-\theta_d(h))]^{1/2} \cdots(12)$$

$$\theta_d(h)=\theta_r+(\theta_w(h)-\theta_r)\left[\frac{2\theta_s-\theta_r-\theta_w(h)}{\theta_s-\theta_r}\right] \cdots\cdots(13)$$

$$\theta\left({}_{h_{min}}{}^{h_1}{}_{h}\right)=\theta_w(h)+\left[\frac{\theta_w(h)-\theta_r}{\theta_s-\theta_r}\right][\theta_w(h_1)-\theta_w(h)] \cdots\cdots(14)$$

$$\theta\left({}^{h_{max}}{}_{h_1}{}^{h}\right)=\theta_w(h)+\left[\frac{\theta_s-\theta_w(h)}{\theta_s-\theta_r}\right][\theta_w(h_1)-\theta_r] \cdots\cdots(15)$$

Eqs. (12) and (13) are relationships between the two main curves. Eqs. (14) and (15) are for the primary drying and wetting curves, respectively. The higher order wetting curves are obtained by substituting Eq. (2) into (6) as follows:

$$\theta\left(\cdots {}_{h_1}{}^{h}\right)=\theta_w(h)+\left[\frac{\theta_s-\theta_w(h)}{\theta_s-\theta_w(h_1)}\right]$$

$$[\theta(h_1)-\theta_w(h_1)]\cdots\cdots\cdots\cdots\cdots\cdots(16)$$

For the higher order drying curves, Eq. (14) can be used by simply replacing $\theta_w(h_1)$ by $\theta(h_1)$ since we projected the higher order curve vertically downward as shown in Fig. 1c.

$$\theta\left(\cdots{}^{h_1}{}_{h}\right)=\theta_w(h)+\left[\frac{\theta_w(h)-\theta_r}{\theta_s-\theta_r}\right][\theta(h_1)-\theta_w(h)]\cdots\cdots\cdots\cdots\cdots\cdots(17)$$

Eqs. (16) and (17) can be used for the higher order wetting and drying scanning curves, respectively. These equations are much simpler than Mualem's model[8] for higher order scanning curves.

3. COMPARISONS WITH MUALEM'S MODEL

To see the closeness of the simplified model proposed in this paper to Mualem's model, several computations were made. Since Mualem's models for third or higher order scanning curves are complicated and difficult to compute, only second order scanning curves were compared. Mualem's[8] equations for second order scanning curves can be expressed as:

$$\theta\left({}^{h_{\max}}{}_{h_1}{}^{h_2}{}_{h}\right)=\theta_w(h)+\left[\frac{\theta_w(h_2)-\theta_w(h)}{\theta_s-\theta_w(h)}\right][\theta_d(h)-\theta_w(h)]+\left[\frac{\theta_s-\theta_w(h_2)}{\theta_s-\theta_w(h_1)}\right][\theta_d(h_1)-\theta_w(h_1)]\cdots(18)$$

for the secondary drying curve, and

$$\theta\left({}_{h_{\min}}{}^{h_1}{}_{h_2}{}^{h}\right)=\theta_w(h)+\left[\frac{\theta_w(h_1)-\theta_w(h)}{\theta_s-\theta_w(h_2)}\right][\theta_d(h_2)-\theta_w(h_2)\cdots\cdots\cdots\cdots(19)$$

for the secondary wetting curve.

For the approximation of water content for a given pressure head and wetting history, information of only one main curve is required. An empirical equation, introduced by Van Genuchten,[14] was used to describe the retention curve:

$$\theta(h)=\theta_r+(\theta_s-\theta_r)\left[\frac{1}{1+(\alpha h)^n}\right]^{1-\frac{1}{n}}\cdots\cdots(20)$$

Table 1. Soil water retention parameters for Webster silty clay loam

	θ_s	θ_r	α	n
Main wetting	0.52	0.13	0.025	1.41
Main drying	0.52	0.13	0.008	1.36

where α and n are nonlinear regression parameters and h is the absolute value of pressure head. For this study, soil water retention data obtained for a Webster silty clay loam soil were used.[2]

Retention data for the main drying curve were measured in the laboratory and subsequently used to determine α and n in Eq. (20) by nonlinear regression. Eq. (12) was used to generate data points for the main wetting curve. Nonlinear regression was used on the results from Eq. (12) to determine α and n in Eq. (20) for the main wetting curve. Table 1 shows soil parameters for the Webster silty clay loam soil.

For the second order wetting curves, water contents were computed from Eqs. (16) and (19) for the proposed simplified model and Mualem's model, respectively. Several computations were made with variable combinations of first and second wetting reversal points. Figure 3 illustrates the difference between the two models for the second order wetting curves. The simplified model shows good agreement with Mualem's model for the second order wetting curves.

For the second order drying curves, water contents were computed from Eqs. (17) and (18) for the simplified model and Mualem's model, respectively. Figure 4 shows some results of the computations for the second order drying curves. As the second wetting reversal points move further from the main wetting curve, the error in the simplified model becomes larger. Tables 2 and 3 show comparisons

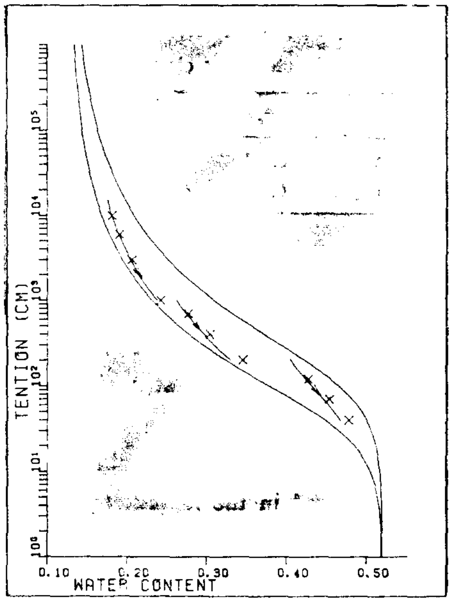


Fig. 3. Comparison of the simplified model(cross) and Mualem's model (solid line) for the second order wetting curves for Webster silty clay loam

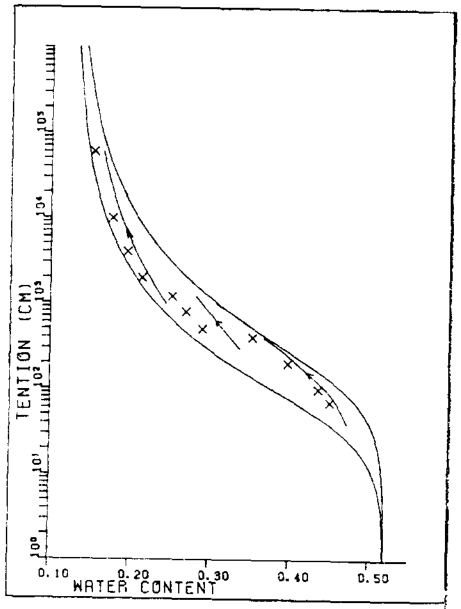


Fig. 4. Comparison of the simplified model(cross) and Mualem's model (solid line) for the second order drying curves for Webster silty clay loam.

of simplified model and Mualem's model for the second order curves at the points shown in Figures 3 and 4 and some additional points. As can be seen from Figures 3 and 4 and Tables 2 and 3, the higher order wetting curves may be reasonably approximated by the simplified model suggested in this paper. For the higher order drying curves, larger errors were introduced by the simplified model. This implies that the assumptions intronduced in the simplified model for higher order wetting curves are better than those for the higher order drying curves. Therefore, similar assumptions as in the higher order wetting curves were introduced in the higher order drying curve to see the differences in results.

Assumptions for higher order drying curves were changed to: 1) the higher order drying curve can be regarded as a primary curve and 2) the last reversal point sits on an imaginary main wetting curve that passes through this reversal point. With these assumptions Eq. (14) can be changed by substituting $\theta_w{}^*(h)$ as the value on the imaginary main wetting curve for $\theta_w(h)$.

$$\theta\left(\cdots {}^{h_1}{}_{h}\right)=\theta_w{}^*(h)+\left[\frac{\theta_w{}^*(h)-\theta_r}{\theta_s-\theta_r}\right][\theta_w{}^*(h_1)-\theta_w{}^*(h)] \quad \cdots\cdots\cdots\cdots(21)$$

When the simplified model incorporated Eq. (21), better agreement with Mualem's model was obtained as compared to the use of Eq. (17) (see Table 3). However, Eq. (21) requires additional computation to determine the water content at the current pressure head on the imaginary main wetting curve. It is suggested that the use of Eq. (21) be restricted to those cases where high accuracy in hysteresis computation is required.

The simplified model always underestimates the water content for higher order drying curves and overesimates for higher order wetting curves, as can be seen from Figures 3 and 4 and Tables 2 and 3. Consequently, for the third order or higher order scanning curves, the

Table 2. Comparison of simplified model and Mualem's model for the second order wetting scanning curvess

Pressure head (cm)*			Water content at current pressure head (cm^3/cm^3)		
1st wetting reversal	2nd wetting reversal	Current	Simplified model (A)	Mualem's model (B)	Difference+ (A−B)
−5,000	−30,000	−15,000	0.165	0.164	0.001(0.4)
		−10,000	0.170	0.170	0.001(0.6)
		− 6,000	0.180	0.178	0.002(1.0)
−2,000	−10,000	− 5,000	0.186	0.185	0.001(0.7)
		− 3,000	0.199	0.196	0.003(1.4)
		− 1,500	0.220	0.215	0.005(2.3)
− 900	− 2,600	− 2,300	0.209	0.209	0.001(0.3)
		− 1,200	0.231	0.227	0.004(1.9)
− 300	−15,000	−10,000	0.181	0.181	0.000(0.2)
		− 6,000	0.190	0.190	0.001(0.5)
		− 3,000	0.207	0.205	0.002(1.0)
− 150	− 8,000	− 5,000	0.203	0.202	0.001(0.3)
		− 1,000	0.250	0.246	0.004(1.5)
		− 600	0.272	0.267	0.005(1.9)
− 150	− 1,000	− 700	0.277	0.275	0.003(1.0)
		− 400	0.302	0.297	0.008(2.5)
		− 200	0.345	0.330	0.015(4.6)
− 90	− 600	− 400	0.318	0.314	0.004(1.2)
		− 200	0.356	0.345	0.011(3.3)
− 20	− 200	− 120	0.428	0.424	0.004(0.8)
		− 70	0.453	0.446	0.007(1.7)
		− 40	0.478	0.467	0.011(2.4)

* First wetting reversal is on the main wetting curve(A in Fig. 2), second wetting reversal is on the primary drying curve (B in Fig. 2), and current is last point (C in FIg. 2).

+Numbers in parenthesis show percent difference, 100(A−B)/B.

understimates of water content for higher order drying curves tend to be compensated by the overestimates of water content for higher order wetting curves. The reasons for the systematic over- and underestimation of the simplified model are discussed below. For the higher order drying curve, point F in Fig. 2 was assumed to be extended vertically downward to the main wetting curve which will intersect the main wetting curve at a point to the left of H. The higher order drying curve is then started from the intersection point upward toward the upper left. It is obvious that this simplified higher order drying curve will be the left of curve FG (Fig. 2), and therefore the results will be underestimates of the water content when compared to Mualem's model.

For the higher order wetting curve, compare Eqs. (16) and (19). Notice the differences in subscripts. Suscript 1 in Eq. (16) is equivalent to subscript 2 in Eq. (19) and is represented by point B in Fig. 2. Subscript 1 in Eq. (19) is represented by point A in Fig. 2. On the right hand sides of Eqs. (16) and (19), the first term and the term in the parenthesis of the second term are constant for a given wetting history. When point C is immediately next to point B(Fig. 2), the water content determined by Eqs. (16) and (19) are approximately the same because the second term of

Table 3. Comparison of simplified model and Mualem's model for the second order drying scanning curves

Pressure head (cm)*			Water content at current pressure head(cm^3/cm^3)				
1st wetting reversal	2nd wetting reversal	Current	Simplified model Eq. 17(A)	Simplified model Eq. 21(B)	Mualem's model(C)	Difference+ (A−C)	Difference+ (B−C)
−20,000	−2,000	− 4,000	0.195	0.207	0.219	−0.024(10.9)	−0.012(5.3)
		− 7,000	0.183	0.193	0.207	−0.025(11.9)	−0.014(7.0)
		−10,000	0.176	0.185	0.201	−0.025(12.5)	−0.016(7.9)
		−80,000	0.150	0.155	0.177	−0.027(15.1)	−0.022(12.5)
−20,000	−1,000	− 2,000	0.217	0.227	0.238	−0.021(8.7)	−0.011(4.5)
		−10,000	0.179	0.185	0.202	−0.023(11.4)	−0.017(8.4)
		−60,000	0.154	0.158	0.179	−0.024(13.6)	−0.021(11.8)
− 7,000	−1,000	− 1,600	0.227	0.243	0.256	−0.029(11.4)	−0.013(5.0)
		− 3,000	0.208	0.221	0.239	−0.031(12.9)	−0.018(7.3)
		− 5,000	0.195	0.206	0.227	−0.032(14.1)	−0.021(9.1)
− 3,000	−300	−500	0.291	0.304	0.316	−0.026(8.1)	−0.012(3.7)
		−800	0.270	0.282	0.298	−0.028(9.4)	−0.016(5.4)
		− 1,200	0.253	0.263	0.282	−0.030(10.5)	−0.019(6.7)
− 1,000	−200	−300	0.331	0.349	0.361	−0.030(8.3)	−0.012(3.3)
		−400	0.317	0.333	0.349	−0.032(9.3)	−0.016(4.5)
		−800	0.282	0.295	0.319	−0.037(11.7)	−0.024(7.4)
−600	− 40	− 70	0.450	0.456	0.458	−0.008(1.8)	−0.002(0.4)
		−100	0.436	0.442	0.445	−0.009(2.1)	−0.003(0.7)
		−400	0.353	0.358	0.368	−0.015(4.0)	−0.010(2.7)
−500	−100	−200	0.377	0.391	0.402	−0.025(6.3)	−0.011(2.7)
		−300	0.354	0.366	0.382	−0.029(7.5)	−0.016(4.1)
		−400	0.337	0.348	0.367	−0.031(8.4)	−0.019(5.2)
− 50	− 10	− 20	0.508	0.511	0.511	−0.003(0.5)	−0.000(0.0)
		− 30	0.503	0.505	0.505	−0.003(0.5)	−0.000(0.0)
		− 40	0.497	0.499	0.500	−0.003(0.6)	−0.001(0.1)

* 1st wetting reversal point is on the main drying curve (*E* in Fig. 2), 2nd reversal is on the primary wetting curve (*F* in Fig. 2), and current is the last point (*G* in Fig. 2).

+Numbers in parentheses show percent difference(absolute) 100(A−C)/C or 100(B−C)/C.

the right hand sides in Eqs. (16) and 19) are almost the same. As point *C* moves away from point *B* (Fig. 2), the multiplying factor of the second term in Eq. (19) decreases faster than that in Eq. (16) for the same amount of decrease in the nominator. Therefore, the water content determined by Eq. (16) is greater than that by Eq. (19), and the simplified model always overestimates the water content when compared to Mualem's model for the higher order wetting curves.

Chung [2] used this simplified model for the higher order scanning curves in a soil water flow study and obtained satisfactory predictions of the soil water contents.

4. CONCLUSIONS

The hysteresis model suggested in this paper offers a simplified way to approximate water content-pressure head relationships for higher order scanning curves. The second order scanning curves predicted by this simplified model agree well with Mualem's model for most of the second order wetting curves. The discrepancy between the simplified model and Mualem's model in the second order drying curves were larger when using Eq. (17). This discrepancy was reduced to the same degree as in the case of the second order wetting model when assumptions similar to the second order wetting model were introduced. However, these assumptions in the second order drying curves require additional computation and may not be necessary unless high accuracy is required. The errors introduced by this simplified model always have opposite signs for the drying and wetting. Thus, errors do not accumulate, but rather tend to compensate one another. The simplified model presented in this paper gives a reasonable approximation to Mualem's model for highter order scanning curves and reduces computation considerably.

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