Chapter 11. Estimation of Saturated Hydraulic Conductivity and Final Infiltration Rate

11.1 Indirect Methods

While field measurements permit an exact determination of soil hydraulic properties, they are time consuming. Moreover, many studies are concerned with large areas of land that may exhibit substantial spatial variability in soil hydraulic properties. The cost-effectiveness of obtaining soil hydraulic properties can be improved by using indirect methods, which allow the prediction of hydraulic properties from more easily measured procedures. Pedotransfer functions (PTFs) allow easily measurable soil property data such as particle-size distributions, bulk density and organic matter content to be used to predict soil hydraulic properties. PTFs are becoming increasingly popular for estimating soil hydraulic properties.

In recent years, several scientists (Sobieraj et al, 2001; Jarvis et al, 2002; Paydar, 2003) evaluated performance of PTFs for estimating saturated hydraulic conductivity using texture, the mean geometrical particle size, organic carbon, bulk density and effective porosity as predictor variables. They all found poor predictions of saturated hydraulic conductivity for most of soils. Therefore, indirect prediction of saturated hydraulic conductivity remains difficult and uncertain.

In this study, we tried to assess the potential of developing PTFs from measured soil hydraulic property data for soils of this region.

11.2 Correlation Analysis

11.2.1 Saturated Hydraulic Conductivity

Correlation analysis of all the measured hydraulic parameters of Horizon B1 were carried out to determine which parameters were closely related to saturated hydraulic conductivity. If the soil parameters showed strong correlation with saturated hydraulic conductivity, they could be used to develop pedotransfer functions for the prediction of saturated hydraulic conductivity. Sandmount sand and Sandmount sand phase soils were excluded from the correlation analysis as they were significantly different from other soil types. The results of the analysis are summarised in Table 11.1.

The results show that Ksat of Horizon B1 is not strongly correlated to soil physical properties such as clay %, silt %, sand % and bulk density (BD). The ratio of exchangeable Ca and Mg as well as ratio of EM_v and EM_h showed higher correlation with Ksat than other soil properties. However, the correlation is not strong enough to develop an indirect method for estimating hydraulic conductivity from these soil properties.

Table 11.1 Correlation Analysis of Horizon B1

	Correlation Coefficient	
	KsatB1	Log(KsatB1)
Clay	-0.15	-0.13
Silt	0.11	0.07
Sand	0.10	0.09
BD	0.13	0.02
Depth A	-0.03	-0.10
dg	0.15	0.14
pH	-0.13	0.02
EC	0.01	0.13
OM	0.00	0.10
Ca	-0.14	-0.09
Mg	-0.21	-0.14
Na	-0.11	0.01
K	-0.06	0.00
TC*	-0.19	-0.11
ESP	-0.09	0.06
Ca/Mg	0.40	0.17
EM_h	-0.13	0.03
EM_v	-0.17	-0.01
EM_v/EM_h	-0.28	-0.26

Note * TC = total cations, which is sum of Ca, Mg, Na and K

Figure 11.1 shows the relationships between soil physical properties and Ksat of Horizon B1 plotted on log scales. Ksat showed a decreasing trend with clay content but the scatter of data is very large. Figure 11.2 shows relationships between soil chemical properties and Ksat of Horizon B1 plotted on log scales. The scatters of data are very large and its difficult to find any relationship between Ksat and soil chemical properties.

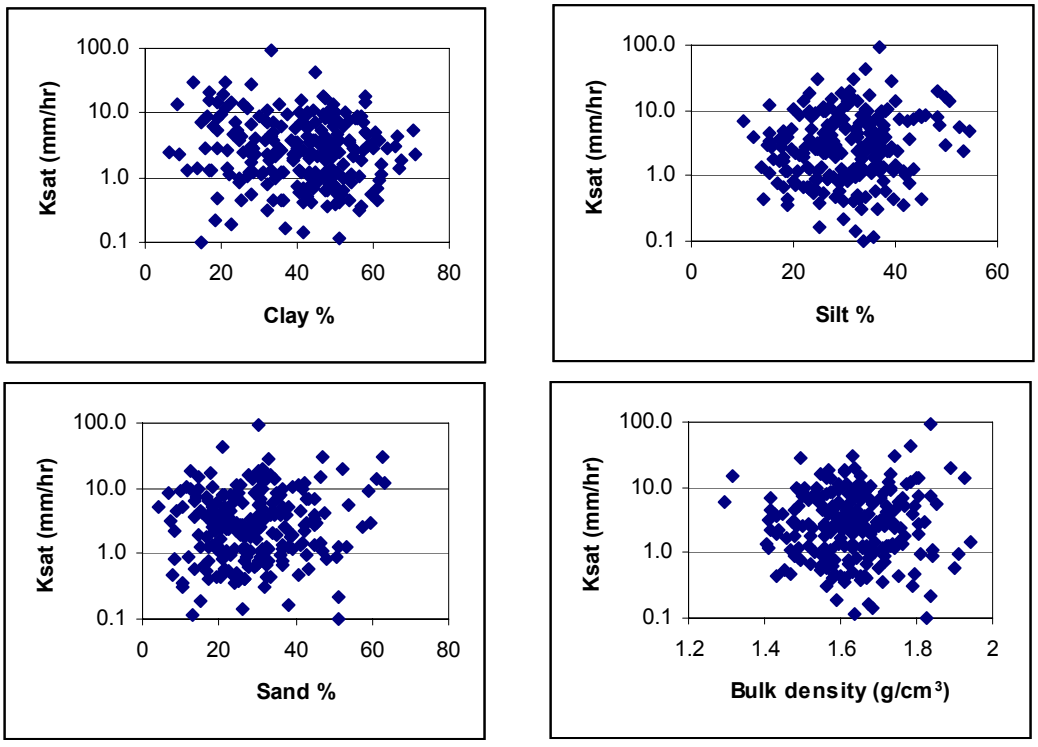

Figure 11.1 Correlation of Ksat of Horizon B1 and Soil Physical Properties

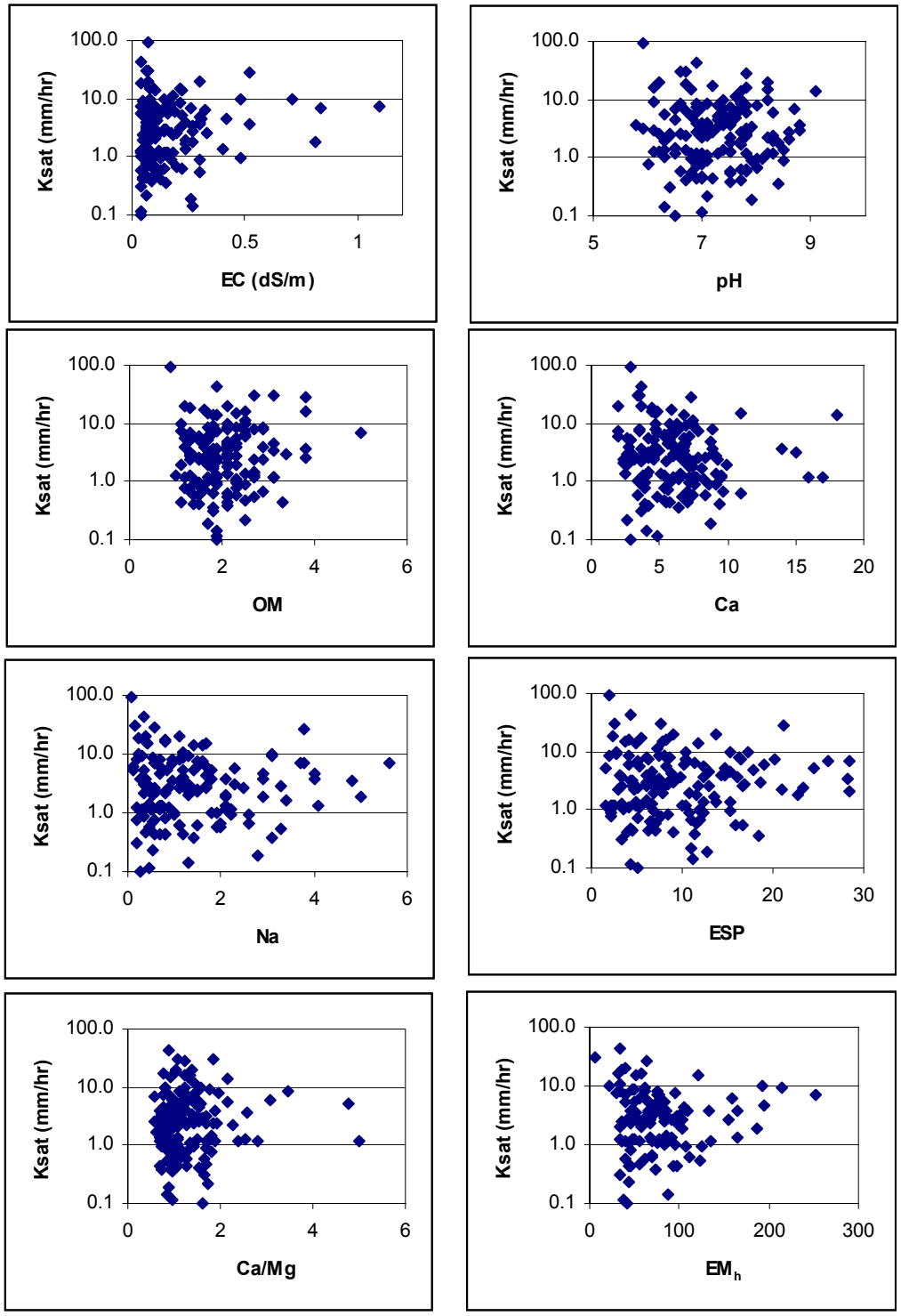

Figure 11.2 Correlation of Ksat of Horizon B1 and Soil Properties

The correlation analysis of measured soil parameters of Horizon B1 of soil groups was carried out with log transformed Ksat and results are presented in Tables 11.2. The results show that Log (Ksat) of Groups 1 and 6 is relatively strongly correlated to clay % and EM_h. However, Groups 2, 3 and 5 do not show strong correlation between Log (Ksat) and soil properties. There is no single parameter having a strong relationship with Ksat for all soil groups.

The correlation analysis of measured soil parameters of Horizon B1 of selected soil types was also carried out with log transformed Ksat and results are presented in Tables 11.3. The results show that Ksat of Horizon B1 is less strongly correlated to clay % than some of chemical properties. Different soil types show different soil parameters having strong correlation with Ksat. There is no single parameter having consistently a strong relationship with Ksat for all soil types.

Table 11.2 Correlation Analysis of Ksat of Horizon B1 for Soil Groups

Soil Properties	Correlation Coefficient - Log Ksat B1						
	Group 1	Group 1 ex. Ss, Ssp	Group 2	Group 3	Group 4	Group 5	Group 6
Clay	-0.54	-0.33	0.03	0.10	-0.20	0.14	-0.29
Silt	-0.24	0.23	0.01	-0.06	0.26	-0.13	0.19
Sand	0.50	0.14	-0.03	-0.07	0.08	-0.11	0.22
BD	-0.01	0.15	-0.01	-0.17	-0.56	-0.16	0.15
Depth A	0.13	0.13	-0.01	-0.23	-0.52	-0.01	-0.19
dg	0.53	0.24	0.02	-0.02	0.09	-0.11	0.35
pH	-0.51	-0.49	-0.08	0.12	0.48	0.08	-0.17
EC	-0.09	0.15	0.12	0.16	0.51	0.18	0.01
OM	-0.21	0.08	-0.12	0.03	0.73	-0.09	-0.18
Ca	-0.43	-0.14	0.01	0.14	0.16	-0.06	-0.16
Mg	-0.52	-0.31	0.01	0.07	0.14	0.07	-0.15
Na	-0.56	-0.45	0.03	0.05	0.63	0.09	-0.23
K	-0.15	0.25	0.11	0.00	0.35	-0.09	0.11
TC	-0.59	-0.37	0.03	0.11	0.34	0.02	-0.16
ESP	-0.51	-0.45	0.03	0.02	0.60	0.02	-0.19
Ca/Mg	0.55	0.41	-0.04	-0.02	0.13	-0.09	-0.17
EM_h	0.16	-0.75	-0.07	0.28	0.45	-0.03	-0.63
EM_v	0.13	-0.86	-0.06	0.27	0.36	0.11	-0.59
EM_v/EM_h	-0.22	-0.34	0.06	-0.21	-0.39	0.54	0.57

Table 11.3 Correlation Analysis of Ksat of Horizon B1 for Soil Types

Soil Properties	Correlation Coefficient - Log Ksat B1					
	Efsl	Tl	Sfsl	Ll	Wl	Gl
Clay	-0.14	-0.22	-0.03	-0.12	0.26	-0.28
Silt	0.33	0.51	-0.14	0.08	-0.39	0.36
Sand	-0.19	-0.02	0.13	0.09	0.21	0.15
BD	-0.08	0.10	0.17	-0.02	-0.29	-0.63
Depth A	0.16	0.11	0.08	-0.32	0.01	-0.51
dg	-0.05	0.30	0.14	0.21	0.15	0.11
pH	-0.68	-0.16	-0.29	0.10	0.27	0.50
EC	-0.32	-0.09	0.17	-0.18	0.28	0.47
OM	-0.07	-0.30	-0.51	0.00	0.57	0.75
Ca	0.17	0.06	-0.04	-0.06	0.22	0.15
Mg	0.00	-0.34	-0.14	-0.09	-0.20	-0.08
Na	-0.60	-0.30	-0.02	-0.06	0.07	0.62
K	0.31	-0.19	0.08	-0.23	0.30	0.36
TC	-0.11	-0.22	-0.08	-0.11	0.11	0.29
ESP	-0.67	-0.39	-0.05	0.01	0.11	0.55
Ca/Mg	0.51	0.61	0.20	-0.02	0.35	0.32
EM_h	-0.62	-0.06	-0.25	-0.05	0.58	0.37
EM_v	-0.82	-0.08	-0.04	-0.08	0.56	0.25
EM_v/EM_h	-0.71	0.02	0.37	-0.33	-0.43	-0.58

11.2.3 Final Infiltration Rate

Correlation analysis of FIR and all other measured soil properties of Horizon B1 was carried out to determine which parameters were closely related to FIR. Sandmount sand and Sandmount sand phase soils were excluded from the correlation analysis as they were significantly different from other soil types. The results of the analysis are summarised in Table 11.4.

The results show that FIR of Horizon B1 is not strongly correlated to soil physical properties such as clay %, silt %, sand % and bulk density (BD). FIR has no strong correlation with any soil chemical property.

Table 11.4 Correlation Analysis of FIR

	Correlation Coefficient	
	FIR	Log(FIR)
Clay	-0.26	-0.19
Silt	0.15	0.18
Sand	0.20	0.08
BD	0.09	0.08
Depth A	0.09	-0.08
dg	0.24	0.15
pH	0.03	0.11
EC	-0.03	0.13
OM	0.06	-0.02
Ca	-0.03	0.05
Mg	-0.15	-0.07
Na	-0.14	-0.06
K	0.00	0.04
TC	-0.11	-0.02
ESP	-0.16	-0.12
Ca/Mg	0.29	0.21
EM_h	-0.20	-0.11
EM_v	-0.22	-0.13
EM_v/EM_h	-0.25	-0.17

Figure 11.3 shows the relationships between soil physical properties and FIR of Horizon B1 plotted on log scales. FIR showed a decreasing trend with clay content but the scatter of data is very large.

The correlation analysis of measured soil parameters of Horizon B1 for soil groups was carried out with log transformed FIR and the results are presented in Table 11.5. The results show that Log (FIR) of Groups 1 and 6 is relatively strongly correlated to clay % and EM_h. However, Groups 2 and 3 do not show strong correlation between Log (FIR) and soil properties. There is no single parameter having strong relationship with FIR for all soil groups.

The correlation analysis of measured soil parameters of Horizon B1 for selected soil types was carried out with log transformed FIR and the results are presented in Table 11.6. The results show that the FIR of Horizon B1 is less strongly correlated to clay % than to some of chemical properties. Different soil types show different soil parameters having relatively strong correlation with FIR. There is no single parameter having consistently strong relationships with FIR for all soil types. Therefore, it is difficult to develop an indirect method of estimation of FIR from other soil properties.

Table 11.5 Correlation Analysis of FIR for Soil Groups

Soil Properties	Correlation Coefficient - Log FIR						
	Group 1	Group 1 ex. Ss, Ssp	Group 2	Group 3	Group 4	Group 5	Group 6
Clay	-0.61	-0.39	-0.05	-0.06	0.27	0.22	-0.32
Silt	-0.56	-0.23	-0.08	0.25	0.01	-0.02	0.61
Sand	0.65	0.44	0.12	-0.17	-0.34	-0.39	-0.21
BD	0.09	0.07	0.09	-0.05	-0.20	-0.22	0.16
Depth A	0.35	0.35	0.02	-0.16	-0.33	-0.81	0.42
Dg	0.60	0.41	0.15	-0.04	-0.41	-0.09	0.06
PH	-0.21	-0.14	0.28	0.16	0.45	-0.48	-0.06
EC	-0.35	-0.23	0.30	0.15	0.60	0.34	0.00
OM	-0.27	0.10	-0.23	-0.14	0.22	0.33	-0.44
Ca	-0.43	-0.14	0.15	0.23	0.36	-0.18	-0.29
Mg	-0.49	-0.24	0.11	-0.04	0.37	0.27	-0.32
Na	-0.57	-0.47	0.13	0.05	0.32	0.36	-0.17
K	0.20	0.38	0.07	0.11	0.46	-0.18	-0.03
TC	-0.51	-0.23	0.16	0.12	0.43	0.12	-0.29
ESP	-0.33	-0.35	0.04	-0.01	0.16	0.47	-0.12
Ca/Mg	0.48	0.27	0.05	0.22	0.10	-0.61	0.14
EM_h	-0.05	-0.44	-0.02	0.10	0.15	0.29	-0.39
EM_v	-0.13	-0.46	0.03	0.10	0.12	0.35	-0.41
EM_v/EM_h	-0.41	-0.26	0.21	-0.03	-0.12	0.17	0.10

Table 11.6 Correlation Analysis of FIR for Soil Types

Soil Properties	Correlation - Log FIR						
	Efsl	Nfsl	Tl	Sfsl	Ll	Wl	Gl
Clay	-0.18	-0.39	0.01	-0.01	0.01	-0.43	0.01
Silt	0.14	-0.20	0.26	-0.11	0.07	0.48	0.33
Sand	0.09	0.43	-0.15	0.09	-0.07	0.00	-0.16
BD	-0.24	0.15	-0.23	-0.02	-0.01	0.04	0.05
Depth A	0.38	-0.65	-0.40	-0.19	-0.16	-0.33	-0.12
dg	0.22	0.40	-0.23	0.11	-0.01	0.48	-0.34
pH	-0.69	-0.06	-0.69	0.27	0.19	0.33	0.52
EC	-0.65	-0.08	0.10	0.45	0.06	0.23	0.44
OM	0.08	0.22	0.42	-0.15	0.01	0.08	0.26
Ca	0.25	-0.05	-0.04	-0.01	0.10	0.44	0.17
Mg	0.08	-0.19	-0.57	0.25	-0.17	-0.20	-0.24
Na	-0.85	-0.32	-0.20	0.34	0.00	0.05	0.12
K	0.34	0.35	-0.10	-0.13	0.00	-0.02	0.55
TC	-0.12	-0.11	-0.30	0.20	0.00	0.22	0.08
ESP	-0.88	-0.31	-0.15	0.21	0.05	-0.04	0.04
Ca/Mg	0.39	0.16	0.75	-0.12	0.25	0.62	0.46
EM_h	-0.67	-0.26	0.25	-0.43	-0.17	0.48	0.22
EM_v	-0.87	-0.27	0.29	-0.38	-0.21	0.47	0.19
EM_v/EM_h	-0.76	0.04	-0.25	0.15	-0.39	-0.30	-0.12

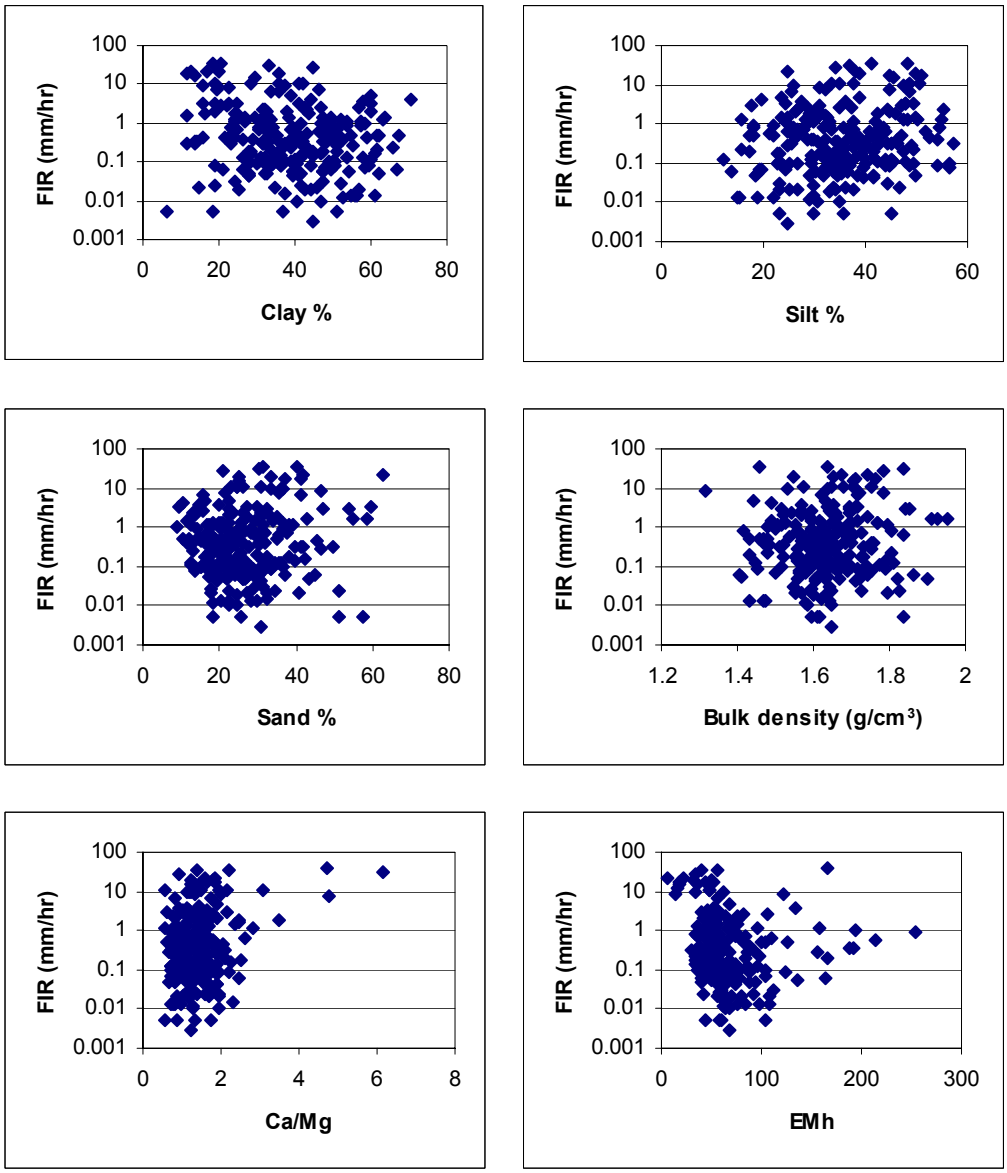

Figure 11.3 Correlation of FIR of Horizon B1 and Soil Properties

11.3 Conclusions

Consistently strong correlations between saturated hydraulic conductivity or final infiltration and easily measurable soil properties were not found. EM data measured by an EM38 instrument was also unable to describe the variability of soil saturated hydraulic conductivity within a paddock. Therefore, it is difficult to indirectly predict saturated hydraulic conductivity or final infiltration rate from easily measurable soil properties.