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INFILTRATION AND SOIL PHYSICAL PROPERTIES

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ABSTRACT

An investigation was carried out into the relationship between soil physical properties and various infiltration parameters. The results of both simple and multiple regression analyses showed that there was little association. It is concluded that the technique of measuring infiltration by the double ring method is responsible for this lack of association.

INTRODUCTION

The rate of water intake into the soil is commonly measured by ring infiltrometers as described by Bertrand (1965). Various authors have investigated the relationship between infiltration as determined by this method and the physical properties of the soils; Free *et al.* (1940) used results obtained on 68 soils in the United States, and found significant correlations (1% level) between the rate of infiltration as measured for the third hour of the wet run and the soil properties in Table 1.

Canarache *et al.* (1969) investigated the relationships between infiltration rates measured by double-ring infiltrometers and soil physical properties (top 100 cm) of 150 measurements on Rumanian soils. Using the logarithm of the infiltration rate for the sixth hour calculated from Kostiakov's (1932) equation, they found simple and multiple correlations significant at 1% as shown in Table 2.

In a parallel investigation of 137 measurements Canarache *et al.* (1969), using a single-ring infiltrometer, made measurements in steps corresponding to main soil horizons of pits. Measurements were made for 2 hours, and the logarithm of the average rate during the last hour was correlated with the physical properties of the relevant horizons. Correlations significant at 1% are shown in Table 3.

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TABLE 1 — Soil properties.

	Correlation coefficients	
	Topsoil	Subsoil
Macroporosity (%)	+0.36	+0.54
Organic matter (%)	+0.50	+0.40
Clay (%)	—	−0.42
Bulk density	—	−0.33
Total porosity (%)	—	+0.36

TABLE 2 — Correlation coefficients with log IR_0.

Field capacity minus moisture content (%) [*MD*]	−0.24
Hydraulic conductivity (cm/s) [*K*]	+0.52
K and *MD*	0.61
Macroporosity (%) [*MP*]	0.36
MP and *MD*	0.45
Clay content (%) [*C*]	−0.36
Total porosity (%) [*TP*] and clay content	0.36
TP, *C* and *MD*	0.50

TABLE 3 — Correlation coefficients with log IR_2.

Field capacity minus moisture content (%)	−0.22
Hydraulic conductivity (cm/s) [*K*]	0.51
K and *MD*	0.55
Macroporosity (%) [*MP*]	0.54
MP and *MD*	0.64
Total porosity (%) [*TP*]	0.28
Clay content (%) [*C*] and *TP*	0.32
TP, *C* and *MD*	0.46

The infiltration indices used by Free *et al.* (1940) and Canarache *et al.* (1969) are not related in any high degree to the measured soil physical properties; the highest simple correlation accounts for only 29% of the variation and the highest multiple for 41%.

The results of infiltration measurements generally fit equations of the form

$$I = kt^{n}$$

or

$$I = St^{-\frac{1}{2}} + A$$

In these equations I is the intake rate (L/T), and k, n, S and A are parameters that vary from soil to soil. The first of these equations is due to Kostiakov (1932) and the second to Philip (1957). It was decided to determine whether these parameters and the accumulated 1-hour and 3-hour intakes were related to the physical properties of 21 soils of Otago.

TABLE 4 — Infiltration parameters.

Soil	Philip		Kostiakov		Accumulated intake (in)	
	$S\times10^4$	$A\times10^4$	$k\times10^4$	$-n\times10^4$	1 hour	3 hours
Lowburn virgin	1627	331	985	1896	3.22	7.73
Pigburn irrigated	974	54	2418	1447	1.16	2.71
Oturehua irrigated	2188	250	1301	2853	3.20	7.20
Becks virgin	2175	249	1150	2509	3.20	7.80
Wakatipu virgin	585	384	546	558	2.75	7.79
Wakatipu irrigated	7417	273	2867	3025	7.25	13.92
Luggate irrigated	939	435	746	945	3.38	9.25
Ardgour irrigated	401	158	222	323	1.25	3.44
Lochar virgin	1025	227	533	1353	2.18	5.69
Lochar irrigated	198	186	169	—458	1.28	3.70
Maungawera irrigated	113	66	153	1986	0.47	1.37
Cluden virgin	1048	158	730	2867	1.65	4.12
Cluden irrigated	2789	32	1337	4409	2.53	4.22
Queensberry irrigated	1767	168	671	1900	2.33	5.65
Queensberry virgin	1218	247	750	1937	2.51	5.89
Blackstone virgin	—234	128	25	—3669	0.52	2.02
Blackstone irrigated	959	538	932	1034	4.00	10.76
Clyde virgin	1649	258	660	1275	2.85	7.21
Clyde irrigated	646	73	323	2426	0.79	1.62
Ngapara silt loam	3295	453	1619	2038	5.05	12.79
Molyneux virgin	809	192	495	1631	1.89	4.41

TABLE 5 — Soil physical properties.

Soil	Bulk density (g/cm^3)		Texture, 0–4 in (%)		Organic carbon (vol. %)		Macroporosity (%)	
	0–12 in	Densest layer	Silt	Clay	0–4 in	0–12 in	0–4 in	0–12 in
Lowburn virgin	1.37	1.42	15.9	15.2	2.18	1.61	25.0	23.3
Pigburn irrigated	1.27	1.58	40.6	22.1	3.85	2.76	4.9	12.1
Oturehua irrigated	1.25	1.34	17.5	20.6	2.58	1.98	16.2	20.2
Becks virgin	1.26	1.57	19.5	22.9	3.20	1.91	24.0	25.5
Wakatipu virgin	1.25	1.39	17.0	14.9	2.44	1.75	14.5	18.2
Wakatipu irrigated	0.99	1.07	26.6	18.4	3.44	2.99	11.6	18.0
Luggate irrigated	1.28	1.36	24.2	15.9	3.15	2.44	22.2	20.3
Ardgour irrigated	1.26*	1.30	20.8	15.8	3.22	2.69*	24.4	25.2*
Lochar virgin	1.30	1.41	18.1	15.6	2.04	1.37	24.6	23.7
Lochar irrigated	1.41	1.46	18.1	12.4	1.77	1.24	18.9	23.0
Maungawera irrigated	1.33	1.43	17.7	6.6	2.60	1.72	4.4	15.0
Cluden virgin	1.14	1.29	28.2	22.5	2.83	2.36	29.8	24.7
Cluden irrigated	1.25	1.49	16.0	16.7	2.66	2.03	19.0	18.1
Queensberry irrigated	1.22	1.30	33.3	1.4	3.19	2.58	20.7	21.7
Queensberry virgin	1.20	1.32	14.2	11.4	2.08	1.79	25.6	22.7
Blackstone virgin	1.27	1.37	9.4	34.4	3.27	2.05	20.7	24.1
Blackstone irrigated	1.06	1.48	17.8	20.2	2.95	2.20	23.6	24.2
Clyde virgin	1.27	1.41	22.2	15.9	2.13	1.38	21.2	24.7
Clyde irrigated	1.43	1.56	20.2	12.2	2.29	1.60	12.3	15.0
Ngapara silt loam	1.24	1.48	27.0	19.0	3.82	2.48	25.3	21.5
Molyneux virgin	1.53	1.65	10.0	8.1	1.07	0.75	27.7	25.9

* 0–8 in

METHODS

Determination of Infiltration and Soil Physical Properties

The methods used are as described in Rickard and Cossens (1966). Infiltration was measured in a 12-inch diameter ring surrounded by a 16-inch diameter buffer ring. All the infiltration measurements were made on wet runs, and soil physical properties were determined at the same time. The soils used were all those quoted in Rickard and Cossens (1966), Rickard and Cossens (1968), and Cossens and Rickard (1970), for which both physical and wet-run infiltration data were available.

It was considered that of the soil physical properties measured, those most likely to affect infiltration would be:

Bulk density, 0–12 inches.
Bulk density, densest 4-inch layer
(measurements made down to 2 ft).
Silt content (%), 0–4 inches.
Clay content (%), 0–4 inches.
Organic carbon (%), 0–4 inches.
Organic carbon (%), 0–12 inches.
Macroporosity (%), 0–4 inches.
Macroporosity (%), 0–12 inches.

ANALYSIS

The Kostiakov and the Philip equations were fitted to the data and the parameters of the equations determined; the correlation coefficient was 0.99 or greater in all cases. Table 4 shows these parameters and the accumulated 1-hour and 3-hour intakes, and Table 5 shows the relevant soil physical properties.

RESULTS

Table 6 shows the extremes and means for the various independent variables, and the significant linear regressions between soil properties and infiltration are given in Table 7.

Multiple regression techniques were then used to determine whether any combination of soil physical properties was related to the infiltration parameters, the results being shown in Table 8.

CONCLUSIONS

The results of this investigation show that there is very little association between infiltration as determined by the double ring method and the soil properties which would be expected to exert

TABLE 6 — Soil physical property extremes and means.

Soil property	*Maximum*	*Minimum*	*Mean*
Bulk density, 0–12 in	1.53	0.99	1.27
Bulk density, densest layer	1.65	1.07	1.41
Silt content (%)	40.6	9.4	20.7
Clay content (%)	34.4	1.4	16.3
Organic carbon (%), 0–4 in	3.85	1.07	2.70
Organic carbon (%), 0–12 in	2.99	0.75	1.99
Macroporosity (%), 0–4 in	29.8	4.4	19.9
Macroporosity (%), 0–12 in	25.9	12.1	21.3

TABLE 7 — Significant linear regressions.

Soil property (x)	*Regression equation*	r^2
Bulk density, 0–12 in	$S=1.13-0.77x$	0.32**
	$A_1=12.90-8.21x$	0.37**
	$A_3=27.60-16.90x$	0.32**
	$k=0.50-0.32x$	0.28*
Bulk density, densest layer	$S=1.05-0.63x$	0.22*
Organic carbon, 0–4 in	$k=-0.06+0.05x$	0.27*
Organic carbon, 0–12 in	$k=-0.06+0.07x$	0.32*
	$S=-0.10+0.13x$	0.20*
Percentage silt	$k=-0.02+0.005x$	0.31**

A_1, A_3=Accumulated intake, one and three hours.

TABLE 8 — Significant multiple regression equations.

Equation	r^2
$S\times10^4=-614\ BD-218\ BDL+1350$	0.33*
$=-744\ BD+1.29\ P+1065$	0.32*
$=-696\ BD+22\ OM+987$	0.32*
$A\times10^4=-193\ BD+105\ BDL+119$	0.43**
$A_1=-7.98\ BD-0.30\ BDL+13.1$	0.37*
$=-8.42\ BD-0.01\ P+13.4$	0.37*
$=-9.47\ BD-0.37\ OM+15.3$	0.37*
$A_3=-18.12\ BD+1.69\ BDL+26.7$	0.33*
$=-17.46\ BD-0.03\ P+28.8$	0.33*
$=-20.5\ BD-1.04\ OM+34.2$	0.34*
$k\times10^4=-4560\ BD+1590\ BDL+4400$	0.34*
$=\ 2310\ BD+41.4\ P+2950$	0.43**
$=-1460\ BD+500\ OM+1740$	0.35*
$=-627\ BDL+52.6\ P+686$	0.32*
$=\ 802\ BDL+820\ OM-1873$	0.34*
$=\ 31\ P+453\ OM+655$	0.38*

BD =Bulk density, 0–12 in
BDL=Bulk density, densest layer
P =Percentage silt
OM =Organic carbon, 9–12 in

an effect on the physical process of percolation; the highest variability accounted for by the regression equations is only 43%. The conclusion to be drawn is either that some other unmeasured property might be better correlated with the infiltration parameter, or that the method of measuring infiltration is unreliable. Of the two explanations the latter is the more likely, probably because the physical effect of inserting the infiltrometers disturbs the soil so that the soil within the rings is no longer representative of the soil type.

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