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CAUSES OF INFILTRATION INTO YELLOW-BROWN PUMICE SOILS

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ABSTRACT

Infiltration measurements on 108 plots in the Otutira experimental basin have been carried out. Statistical analysis reveals that infiltration is correlated with a large number of soil properties and that the best prediction equation gives an explanation of only 57 percent. It is concluded that infiltration is least into soils beneath pasture which have been compacted by land use practices, especially when these soils have low pre-existing soil moistures.

INTRODUCTION

An earlier paper (Selby, 1970) has described the construction of an infiltrometer and the preliminary results from a series of 108 trials of infiltration into the yellow-brown pumice soils of the Otutira IHD experimental basin. The trials were carried out in areas of scrub, pasture and ungrazed grass (Fig. 1).

In an attempt to develop an understanding of the properties of the soil which influence infiltration, soil samples were taken for laboratory analysis. Thirty core samples were taken from each of the six sample sites, each core being 10 cm deep and 6 cm in diameter. Because the infiltration samples themselves could not be sampled without destroying their usefulness for infiltration studies the 30 samples were taken from 10 positions, chosen by a random method with a deck of cards and a quadrat frame, around the site from which the infiltration samples were taken.

STATISTICAL ANALYSIS

Statistical analyses were carried out in an attempt to provide answers to the following questions:

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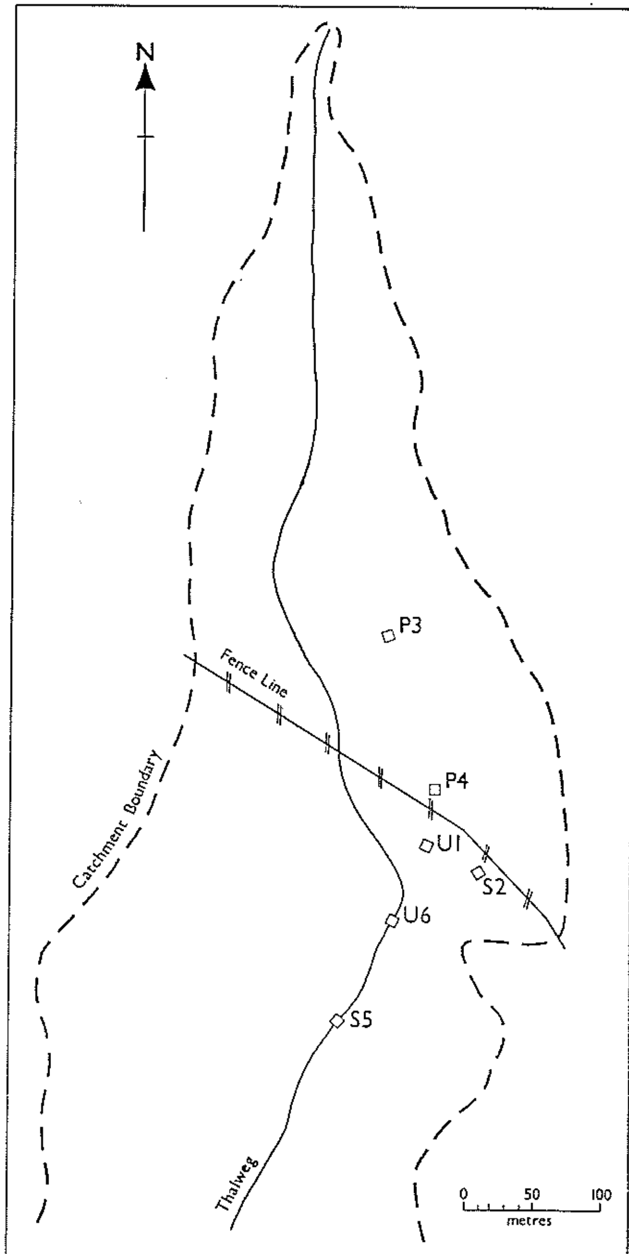

FIG. 1 — The six sample sites for infiltration studies. P – pasture; U – ungrazed grass; S – scrub.

(1) Are the differences in mean infiltration under the three vegetation types statistically significant?
(2) Do the soil properties differ significantly from one vegetation type to another?
(3) To what soil properties is infiltration related?
(4) Is it possible to provide a satisfactory prediction of infiltration rates by measuring easily determined soil properties?

In an attempt to answer these questions, analyses of variance, and linear regressions were carried out on the infiltration and soil variables. Explanation of the coding used in the statistical analyses is given in Appendix 1.

Analysis of Variance

The results of the analyses of variance of sample means are given in Table 1. It can be seen that both infiltration and the various soil properties (with one exception) have significantly different sample means. Pre-existing soil moisture and angle of slope were experimentally controlled to give a range of values and their sample means are therefore of little consequence. Because vegetation length for scrub could not be obtained directly from measurement on the small sampled plots, an index value based on dry weight equivalent had to be used. This also, then, invalidates any comparison of variance about the mean.

Correlation and Stepwise Multiple Regression Analysis

The simple linear correlations between all variables are given in Table 2. It is evident that infiltration is not highly correlated with any single variable. Only pre-existing soil moisture (MOIS) and aggregation (AGG1, AGG2) stand out as being closely correlated with infiltration. This conclusion is reinforced by the stepwise multiple regression (Table 3). Pre-existing soil moisture (MOIS) explains 18.8 percent of the infiltration, and the addition of aggregation (AGG1) increases the explanation to 36.6 percent. The third variable, root density (VEGS), increases the explanation to 51.9 percent but the addition of further variables adds little to our understanding and eight variables provide only a 61 percent explanation. The best prediction equation which can be produced, with all variables contributing significantly, therefore has only a low level of explanation.

$$\text{Predicted INFL} = 557.36 + 15.44\ (\text{MOIS}) - 938.88\ (\text{AGG1}) + 172.17\ (\text{VEGS}) + 99.07\ (\text{ORG2})$$

with F: 34.83*** and r^2: 0.575.

TABLE 1 — Results of analysis of variance for infiltration and soil properties among three vegetation types.

Soil properties	*Pasture* Mean	*Pasture* Sample size	*Ungrazed grass* Mean	*Ungrazed grass* Sample size	*Scrub* Mean	*Scrub* Sample size	Overall mean	F value
Total of 108 samples								
INFL	289.72	36	1002.42	36	820.92	36	—	17.292***
MOIS	22.52	36	22.00	36	26.08	36	—	0.429
VEGN	4.28	36	12.92	36	(92.0)	—	—	—
SLOP	(15)	3	(15)	3	(15)	3	—	—
COMP	4594.25	36	4529.08	36	3024.50	36	—	12.237***
SHER	32.241	36	37.432	36	12.578	36	—	88.106***
Properties of soils of each vegetation area								
PTC1	4.2	20	4.8	20	2.8	20	3.93	4.768***
PTC2	23.2	20	25.6	20	23.7	20	24.17	0.793
PTC3	64.8	20	58.2	20	61.7	20	61.57	4.521**
PTC4	7.8	20	11.0	20	11.8	20	10.20	7.722***
AGG1	25.6	20	22.6	20	15.6	20	21.27	4.402**
AGG2	34.5	20	32.1	20	21.1	20	29.23	5.709***
ORG1	14.8	20	18.4	20	12.5	20	15.23	4.145**
ORG2	14.6	20	16.4	20	11.4	20	14.13	4.300**
VEGS	2.2	20	3.4	20	1.0	20	2.20	14.212***
BULK	0.74	20	0.66	20	0.62	20	0.67	6.175***
PART	2.18	20	2.09	20	2.01	20	2.09	4.277**
PORO	66.4	20	68.4	20	69.1	20	67.97	2.600*
MAC1	4.4	20	4.3	20	6.8	20	5.17	10.227***
MAC2	6.8	20	6.6	20	10.0	20	7.80	8.957***

Confidence levels: $\alpha=0.10$(*), $\alpha=0.05$(**), $\alpha=0.01$(***)
N.B. — Values for VEGN for scrub areas are an index. Values for MOIS and SLOP are manipulated to give a range.

TABLE 2 — Matrix of simple linear correlation coefficients between infiltration and properties of yellow-brown pumice soils.

Dependent variable: / Independent variables:	INFL	MOIS	VEGN	SLOP	COMP	SHER	PTC1	PTC2	PTC3	PTC4	AGG1	AGG2	ORG1	ORG2	VEGS	BULK	PART	PORO	MAC1	MAC2
INFL	-	0.433	0.184	0.058	-0.165	-0.035	0.091	0.158	-0.328	0.243	-0.359	-0.341	0.004	-0.075	0.182	-0.124	0.089	0.223	-0.102	-0.119
MOIS	0.433	-	0.103	-0.111	-0.652	0.189	0.007	-0.346	0.137	0.213	0.137	0.068	-0.030	0.082	0.035	-0.320	-0.117	0.410	0.245	0.219
VEGN	0.184	0.103	-	-0.000	-0.439	-0.753	-0.833	-0.131	-0.004	0.587	-0.688	-0.769	-0.540	-0.737	-0.662	-0.496	-0.482	0.407	0.696	0.694
SLOP	0.058	-0.111	-0.000	-	0.119	-0.042	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000	-0.000
COMP	-0.165	-0.652	-0.439	0.119	-	0.027	0.289	0.301	-0.043	-0.472	0.036	0.106	0.086	0.098	0.294	0.536	0.428	-0.525	-0.553	-0.534
SHER	-0.035	0.189	-0.753	-0.042	0.027	-	0.797	-0.075	-0.104	-0.138	0.714	0.755	0.614	0.827	0.648	0.014	0.171	0.107	-0.350	-0.369
PTC1	0.091	0.007	-0.833	-0.000	0.289	0.797	-	0.306	-0.392	-0.259	0.503	0.620	0.781	0.846	0.638	0.231	0.414	-0.060	-0.658	-0.684
PTC2	0.158	-0.346	-0.131	-0.000	0.301	-0.075	0.306	-	-0.781	-0.148	-0.424	-0.217	0.472	0.063	-0.134	0.428	0.234	-0.499	-0.549	-0.533
PTC3	-0.328	0.137	-0.004	-0.000	-0.043	-0.104	-0.392	-0.781	-	-0.424	0.255	0.076	-0.697	-0.346	-0.049	0.170	0.195	-0.105	0.190	0.192
PTC4	0.243	0.213	0.587	-0.000	-0.472	-0.138	-0.259	-0.148	-0.424	-	-0.097	-0.124	0.168	0.073	-0.131	-0.939	-0.845	0.830	0.746	0.735
AGG1	-0.359	0.137	-0.688	-0.000	0.036	0.714	0.503	-0.424	0.255	-0.097	-	0.976	0.470	0.792	0.439	-0.150	-0.153	0.152	0.035	0.029
AGG2	-0.341	0.068	0.769	-0.000	0.106	0.755	0.620	-0.217	0.076	-0.124	0.976	-	0.628	0.876	0.447	-0.073	-0.117	0.059	-0.089	-0.091
ORG1	0.004	-0.030	0.540	-0.000	-0.086	0.614	0.781	0.472	-0.697	0.168	0.470	0.628	-	0.877	0.252	-0.135	-0.138	0.122	-0.247	-0.261
ORG2	-0.075	0.082	-0.737	-0.000	0.098	0.827	0.846	0.063	-0.346	0.073	0.792	0.876	0.877	-	0.551	-0.168	-0.086	0.212	-0.220	-0.236
VEGS	0.182	0.035	-0.662	-0.000	0.294	0.648	0.638	-0.134	-0.049	-0.131	0.439	0.447	0.252	0.551	-	0.108	0.293	0.016	-0.472	-0.472
BULK	-0.124	-0.320	-0.496	0.000	0.536	0.014	0.231	0.428	0.170	-0.939	-0.150	-0.073	-0.135	-0.168	0.108	-	0.848	-0.932	-0.841	-0.820
PART	0.089	-0.117	-0.482	0.000	0.428	0.171	0.414	0.234	0.195	-0.845	-0.153	-0.117	-0.138	-0.086	0.293	0.848	-	-0.601	-0.865	-0.879
PORO	0.223	0.410	0.407	-0.000	-0.525	0.107	-0.060	-0.499	-0.105	0.830	0.152	0.059	0.122	0.212	0.016	-0.932	-0.601	-	0.690	0.648
MAC1	-0.102	0.245	0.696	-0.000	-0.553	-0.350	-0.658	-0.549	0.190	0.746	0.035	-0.089	-0.247	-0.220	-0.472	-0.841	-0.865	0.690	-	0.997
MAC2	-0.119	0.219	0.694	0.000	-0.534	-0.369	-0.684	-0.533	0.192	0.735	0.029	-0.091	-0.261	-0.236	-0.472	-0.820	-0.879	0.648	0.997	-

Significance levels: $\alpha=0.10$, $r=0.344$; $\alpha=0.05$, $r=0.404$; $\alpha=0.01$, $r=0.515$.

TABLE 3 — Results of stepwise multiple regression, with infiltration as the dependent variable.

Independent variable	*Step number*	r^2	*Beta coefficient*
MOIS	1	0.188	0.6149***
AGG1	2	0.366	– 1.1605***
VEGS	3	0.519	0.1565
ORG2	4	0.575	—
SLOP	5	0.588	0.1011
SHER	6	0.596	– 0.0576
COMP	7	0.601	0.1906*
BULK	8	0.610	– 0.6422***

F value: 19.38***
r^2: 0.610
Confidence level, t_{90}: α=0.10(*), α=0.05(***), α=0.01(***)

CONCLUSIONS

The range of infiltration rates on all yellow-brown pumice soils from Otutira is large, but there is a highly significant greater mean infiltration under scrub than under pasture vegetation. Ungrazed grass samples showed an even higher mean infiltration than scrub but lower extreme values. This suggests that the change of vegetation alone is not responsible for decreasing infiltration, but that it is land use practices which are most important. The soil property which pastoral farming might be expected to modify most readily is soil compaction. Compaction is shown in Table 2 to be negatively correlated, at a high level of significance, with total porosity (–0.525) and macroporosity (–0.553 and –0.534) indicating that as compaction increases porosity decreases. It may reasonably be concluded, therefore, that the change of land use from scrub to pastoral farming has decreased infiltration rates.

The sampling and measurements required to calculate infiltration rates and curves are tedious and time consuming. Analysis of soil properties is evidently not a short cut to direct measurement because of the low degree of explanation achieved. It is evident that the yellow-brown pumice soils of the Otutira catchment are exceedingly heterogeneous in their properties, as might be expected of soils derived from coarse pumice and ash deposits which have had relatively little time in which to weather. The great range of infiltration rates in a small area, even with the same vegetation, suggests that prediction of runoff from infiltration alone is unlikely to be reliable. It would seem, therefore, that predictions should be made from catchment runoff analysis into which the infiltration variations are naturally integrated.

It appears that, because of the very variable nature of the infiltration, water running off one small area is likely to infiltrate into another area of the soil, and that much runoff is not to be expected from a drainage basin. Only 8 of the 108 test plots have been shown to be incapable of absorbing a rainfall of 47 mm/h. This figure is the maximum rainfall intensity to be expected at Taupo, the nearest meteorological station with long records, in a 50-year period (Robertson, 1963). A tentative conclusion may be that high runoff, and with it the liability to rapid erosion, is likely to be associated only with rainfalls of very high intensity, especially when they fall on pastures of low pre-existing soil moisture.

ACKNOWLEDGMENT

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APPENDIX 1 — Code names for soil properties.

In the computer analyses soil properties are distinguished by code names. These same names have been used in Tables 1 to 3. The names are listed below.

VEGN	Vegetation length.
COMP	Compaction.
SHER	Shearing resistance.
MOIS	Pre-existing soil moisture.
PTC1	Particles >6.35 mm diameter.
PTC2	Particles 6.35 to 0.635 mm diameter.
PTC3	Particles 0.635 to 0.063 mm diameter.
PTC4	Particles <0.063 mm diameter.
AGG1	Aggregation as a percentage of the total sample.
AGG2	Aggregation as a percentage of the sample exceeding 0.635 mm diameter.
ORG1	Percentage of fine organic matter in the sample.
ORG2	Total weight of organic matter as a percentage of the sample.
VEGS	Thickness of the root mat.
BULK	Bulk density.
PART	Particle density.
PORO	Total porosity.
MAC1	Macroporosity as a percentage of total sample volume.
MAC2	Macroporosity as a percentage of total pore space.