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RAINFALL INTERCEPTION BY AN EVERGREEN BEECH FOREST, NELSON, NEW ZEALAND

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ABSTRACT

Rowe, L.K., 1983. Rainfall interception by an evergreen beech forest, Nelson, New Zealand. J. Hydrol., 66: 143—158.

Throughfall under a beech (*Nothofagus*) forest canopy at Donald Creek, Nelson, averaged 69% of the rain falling on the canopy, i.e. 1060 mm of 1530 mm in a year of normal rainfall. Using an estimate for stemflow at 2% of gross rainfall, interception loss averaged 29% of the annual rainfall, or 440 mm $yr.^{-1}$. Seasonal differences in interception loss were significant, ranging from 22% in winter to 35% in summer, and resulted from seasonal variation in evaporation rates from a wet canopy. Seasonal variation in rainfall rate was slight.

Four models, storm linear regression, monthly linear regression, sine curve and Gash's analytical model, were tested by comparison of predicted and observed interception. All gave very satisfactory estimates ($<$ 10% error) and tended to slightly underestimate the measured interception loss.

INTRODUCTION

Hydrological investigations at Big Bush State Forest, near Korere, Nelson, New Zealand, were designed by the Forest Research Institute in 1975 to assess the impact of various forest manipulation regimes on the hydrologic behaviour of four small catchments (O'Loughlin et al., 1978). Two studies of rainfall interception were undertaken to provide a better understanding of the water balances of the catchments.

Previous studies of rainfall interception in *Nothofagus* forests in New Zealand have been reported by Miller (1963), and Aldridge and Jackson (1973) for hard beech (*N. truncata*) at Taita (near Wellington); by Rowe (1975) for mountain beech (*N. solandri* var. *cliffortioides*) on the Craigieburn Range, Canterbury; and by Rowe (1979) for a mixed beech—podocarp—hardwood forest near Reefton. The implications of changing the dominantly *Nothofagus* forest cover, and its associated interception characteristics, for catchment water yield have been discussed by Jackson (1972, 1973), Pearce and Rowe (1979) and Pearce et al. (1980a, b). If rainfall is greater than

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~ 1500 mm yr.$^{-1}$, water yield changes after vegetation manipulation are likely to be dominated by changes in interception loss (Pearce and Rowe, 1979).

This paper presents data collected over the five years between April 1977 and March 1982 on a site with a mixed beech (*Nothofagus* spp.) canopy. The main analysis has been carried out on the first four years of data. The final year of data has been used to test the rainfall—interception loss relationships derived from the earlier data.

PLOT DESCRIPTION AND EXPERIMENTAL METHODS

The study site was adjacent to the experimental catchments located in Donald Creek (41°36'S, 171°44'E), a tributary of the Tadmor River (Fig. 1).

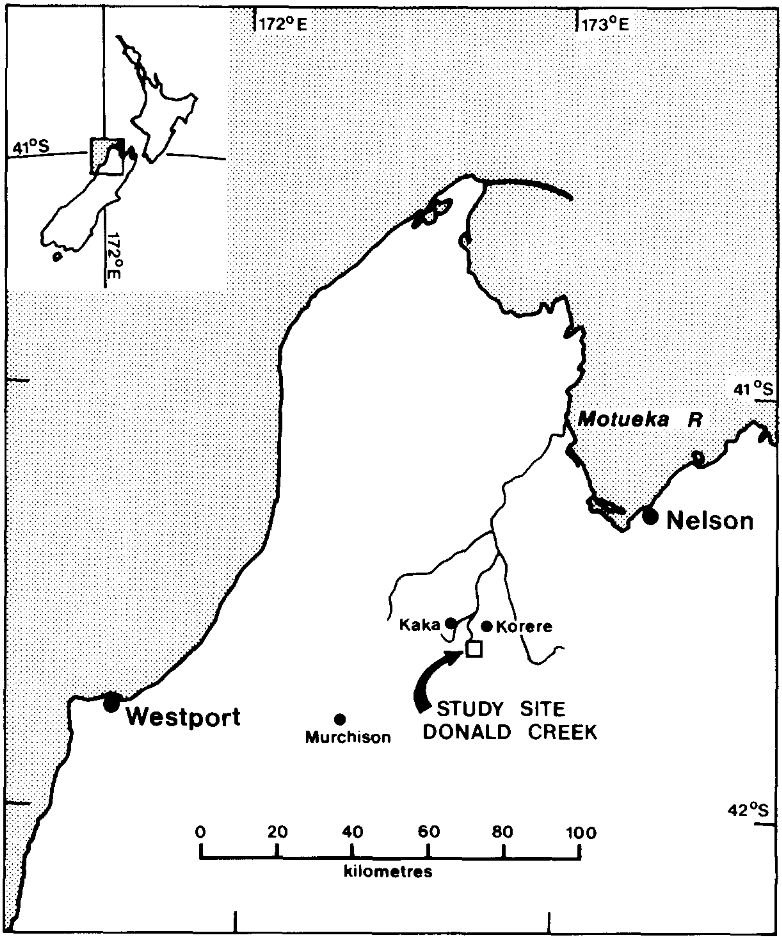


Fig. 1. Location map of study area, Donald Creek, Nelson, New Zealand.

TABLE I

Selected characteristics of the interception plot, *Nothofagus* forest, Donald Creek, Nelson

Plot area (m^2)	320
Trough area (m^2)	9,803
Ground slope (°)	12
Stems/plot $>$ 2 cm d.b.h.	67
$>$ 10 cm d.b.h.	20
$>$ 30 cm d.b.h.	9
Basal area ($m^2\ ha^{-1}$)	55.8

Soils of the area are shallow stony podzolised yellow-brown earths (Hope Hill Soils) underlain by the lower Pleistocene Moutere Gravel Formation, with a forest cover dominated by red beech (*N. fusca*), hard beech (*N. truncata*), other hardwoods and *Podocarpus* spp. (O'Loughlin et al., 1978). Table I lists some of the characteristics of the interception study plot. The plot vegetation was effectively a single-storeyed closed canopy with *N. fusca* and *N. truncata* co-dominant. Occasional *Nothofagus* seedlings, *Cyathodes* spp. and *Coprosma* spp. made up the sparse understorey.

Gross rainfall was measured by one Lambrecht® pluviograph in a large clearing (Lower Donald, LD) 50 m from the interception plot. A manually-read 125-mm-diameter raingauge at the same site and another pluviograph, 1.5 km distant, were used to check the reliability of the rainfall record.

Throughfall under hardwood forest canopy can be extremely variable. The coefficients of variation of storm throughfall collected by a network of fifteen randomly located 127-mm-diameter raingauges under *N. solandri* var. *cliffortioides* was frequently over 50% and had a median value of 38% (Rowe, 1975). Other studies have indicated that large numbers of rain-gauges are necessary for adequate throughfall sampling. Czarnowski and Olszewski (1970) required 30 gauges to give a mean value within 5% of that measured by 100 gauges under a deciduous hardwood canopy in summer, and Peterson and Rolfe (1979) needed over 40 gauges when measuring summer rainfall under an oak—hickory stand. In this study, a trough system similar to that used by Rowe (1979) was used to minimise the expected variation.

Throughfall was collected by six troughs of 10-cm wide plastic household guttering laid out in parallel lengths of 15.2 m at 3-m intervals, 50 cm above the litter to avoid ground splash. This system gave an equivalent area to ~ 775 raingauges of 127 mm diameter. Collected throughfall was led off to a bank of six inter-connected 200-l drums, one of which was equipped with a Belfort® FW*1* water level recorder, allowing resolution of throughfall to ~ 0.15 mm. Although there is some potential for significant wetting losses with such a large trough area, previous studies indicate that such losses are very small (Rowe, 1979; Pearce et al., 1980b).

Stemflow was not measured because previous studies in *Nothofagus* forests in New Zealand (Rowe, 1975, 1979) and hardwood studies elsewhere (Ovington, 1954; Rogerson and Byrnes, 1968; Jackson, 1975) have shown that stemflow is generally a very small proportion (~ 2%) of gross rainfall.

All statistical tests refer to the 95% confidence level. Minor discrepancies sometimes occur in tables and between tables because of rounding off, allowing for occasional missing records or, when a storm overlapped 2 months, allocating all of the event to the month containing the major portion.

RESULTS AND DISCUSSION

Rainfall (R)

Annual rainfall totals at the Lower Donald pluviograph (LD) for the four years of the study are shown in Table II together with some comparable data for Kaka (N.Z. Meteorological Service Station G*12561*), 5 km northwest of the study site (N.Z.M.S., 1973; K.A. Polglaze, Kaka, pers. commun., 1977–1982). At Lower Donald Creek, 12-monthly rainfall totals ranged from 1320 to 1770 mm; equivalent totals at Kaka were respectively 85% and 122% of the annual normal rainfall. The average rainfall measured at Lower Donald Creek (1490 mm) was slightly less than the annual normal which was estimated as 1530 mm.

Monthly values at Lower Donald Creek ranged from 16 mm for January 1981 to 265 mm in September 1980, with corresponding totals at Kaka of 17% and 183% of normal (Table III). The driest extended period was December 1980 to February 1981 during which only 88 mm fell at Lower Donald Creek and 103 mm at Kaka, 29% of normal. October 1979 to January 1980 was the wettest period, with 800 mm recorded at Lower Donald Creek. The 895 mm measured at Kaka was 173% of normal.

Daily rainfalls were not exceptional. The highest recorded 24-hr. falls at Lower Donald Creek were 82 and 84 mm, corresponding to a recurrence interval of ~ 2 yr. as estimated from Tomlinson (1980). On a yearly basis there was an average of 168 rain days, each of which averaged 8.9 mm of rain. The number of isolated storms, wet periods separated by at least 12 hr.

TABLE II

Twelve-monthly rainfall, April 1977–March 1981, for Lower Donald Creek (LD) and Kaka

Period	Kaka (mm)	% Normal	LD (mm)	LD/Kaka (%)
Normal (1941–1970)	1,653	—	—	—
1977–1978	1,390	84	1,350	97
1978–1979	1,690	102	1,540	91
1979–1980	2,010	122	1,770	88
1980–1981	1,420	86	1,320	93
1977–1981	1,610	97	1,490	93

TABLE III

Monthly rainfall values (mm) for Lower Donald Creek (LD) and Kaka raingauges, April 1977—March 1981

	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.
Kaka normal	147	170	140	152	150	140	142	135	130	109	114	124
Kaka mean	101	151	135	124	152	155	201	129	164	97	77	141
% Normal	69	89	96	82	101	111	142	96	126	89	68	114
LD minimum	80	90	77	70	115	91	131	96	54	16	18	59
LD maximum	112	206	174	157	190	265	236	156	226	221	131	181
LD mean	92	129	120	117	139	153	179	120	152	84	79	130
% Kaka	91	85	89	94	91	99	89	93	93	87	102	92

with no rain, was 410 with an average total rain of 13.7 mm. The 12-hr. interval was used to discriminate between storms as this was long enough to allow a canopy to dry out completely (Jackson, 1975).

At least 0.1 mm of rain fell on an average of 1325 clock hours per year although this was not necessarily continuous during the hour. Mean hourly rainfall rates were 1.12, 1.08 and 1.18 mm per clock hour for the year, winter (April—September) and summer (October—March), respectively. The most intense period of rain was recorded during a thunderstorm on February 4, 1978 when 34.5 mm fell in 40 min.

$\bar{R}$, a measure of the mean rainfall rate falling on a saturated canopy (Gash, 1979; Pearce et al., 1980b; Pearce and Rowe, 1981) was estimated at 2.03, 1.95 and 2.11 mm hr.$^{-1}$ for the year, winter and summer, respectively. Summer rainfall was slightly more intense than during winter, possibly due to summer thunderstorm activity.

Throughfall (T)

Table IV summarises annual throughfall and rainfall. For the four years of study, annual throughfall averaged 1035 mm, 69% of the 1490-mm average rainfall measured at Lower Donald Creek, and ranged between ~ 900 and 1200 mm yr.$^{-1}$ (Table IV). As rainfall was slightly below normal at Kaka during this period, throughfall in a year of average rainfall would be ~ 1060 mm. The percentage of rainfall collected as throughfall in this study (69%) was similar to the 73% measured for the mixed evergreen stand at Reefton (Rowe, 1979), and to the 67—71% reported by Ovington (1954) for *N. obliqua* in the United Kingdom. Miller (1963) and Aldridge and Jackson (1973) both reported much lower throughfall percentages for *N. truncata* stands at Taita, 50—60% and 45.4%, respectively. Summer-only throughfall of 66% is lower than the 69% reported for *N. solandri* var. *cliffortioides* in the Craigieburn Range (Rowe, 1975). Results for other hardwood forest studies indicate percentage throughfall is in the range 60—90%

TABLE IV

Annual throughfall, stemflow, interception loss and rainfall, Donald Creek, Nelson, April 1977—March 1981

Year	Throughfall (mm)	Stemflow* (mm)	Interception loss (mm)	Rainfall (mm)
1977—1978	925	25	390	1,345
1978—1979	1,080	30	435	1,540
1979—1980	1,215	35	535	1,780
1980—1981	910	25	370	1,305
Mean	1,035	30	430	1,490

*Stemflow estimated as 2% of rainfall.

(Ovington, 1954; Zinke, 1967; Aussenac, 1968; Langford and O'Shaughnessy, 1977; Prebble and Stirk, 1980).

Monthly throughfall showed a seasonal pattern, with a greater proportion of rainfall reaching the ground in winter (April—September) than in summer (October—March) (Fig. 2). The winter maximum throughfall averaged ~ 75% and the summer minimum 63%. Most of the individual monthly percentages were within ± 5% of their corresponding means. Values outside this range, all on the low side, were associated with monthly rainfalls much lower than average. For the 3 months with percentage throughfalls of 47, 46 and 35%, the respective monthly rainfalls were very low at 28 mm from eight storms, 16 mm from seven storms and 18 mm from nine storms.

In Fig. 3A, actual monthly throughfall has been plotted against the corresponding monthly rainfall. Because of the seasonal trends evident in Fig. 2, the data were divided into two 6-monthly periods, April—September and

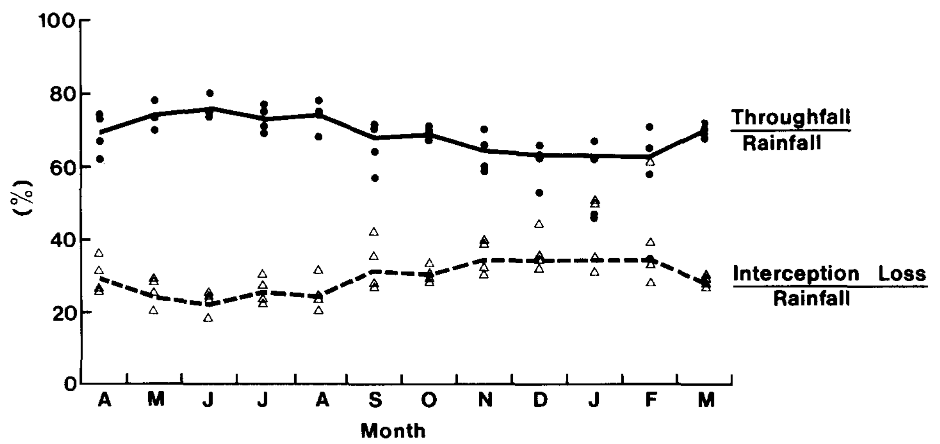
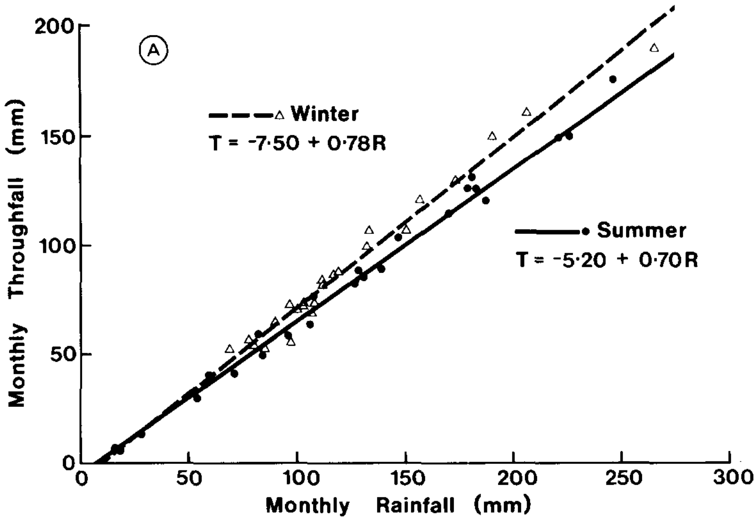


Fig. 2. Percentage monthly throughfall/rainfall and interception loss/rainfall for a beech forest stand, Donald Creek, Nelson, 1977—1981.



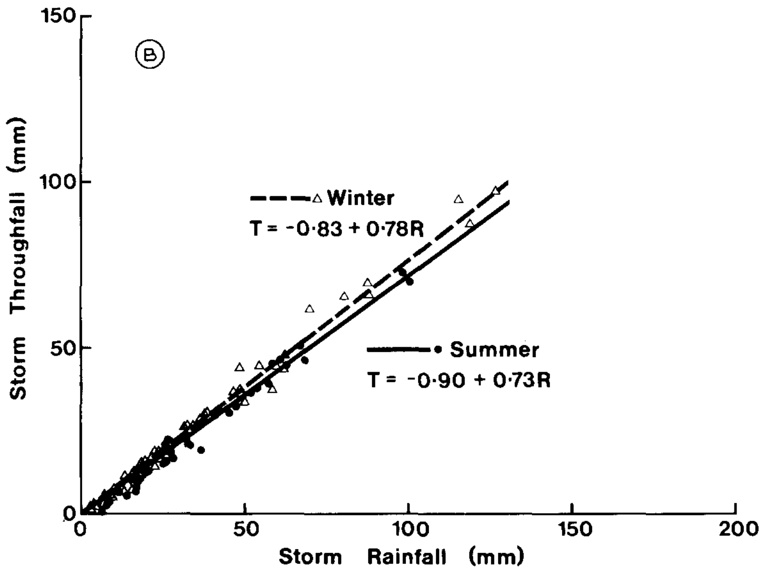


Fig. 3. Throughfall—rainfall relationships for a beech forest stand, Donald Creek, Nelson, 1977—1981: (A) monthly data; and (B) storm data. Above $R = 50$ mm all points have been plotted; below $R = 50$ mm, a representative selection of the 312 data points have been plotted to show the range of values obtained.

October—March. Linear regression analyses carried out on each data set indicated highly significant correlation between throughfall (T) and rainfall (R) with 98 and 99% of the variances being explained for winter and summer, respectively. The relationships were:

Winter monthly: $T = -7.5 + 0.78R$; $r = 0.988$, $F = 893$, $n = 24$
Summer monthly: $T = -5.2 + 0.70R$; $r = 0.996$, $F = 2316$, $n = 22$

A comparison of regression test (Freese, 1967) indicated statistically significant differences between the relationships for the two periods ($F_{slope} = 248$, $F_{level} = 8.7$, $F_{tab} = 4.1$).

Fig. 3B shows the linear relationships between throughfall and rainfall on a storm basis with summer and winter sets again analysed separately. Results were:

Winter storm: $T = -0.83 + 0.78R$; $r = 0.996$, $F = 25{,}042$, $n = 199$ (1)
Summer storm: $T = -0.90 + 0.73R$; $r = 0.993$, $F = 15{,}488$, $n = 210$ (2)

These regressions explain over 98% of the statistical variance. As for the monthly relationships, the above equations were statistically significantly different ($F_{slope} = 42$, $F_{level} = 23$, $F_{tab} = 3.9$). Overseas literature summarised by Helvey and Patric (1965) has many instances of significantly different summer and winter relationships for hardwood forests; but these are invariably deciduous.

Coffay (1962) and Jackson (1975) have fitted curvilinear regression equations to their throughfall—rainfall data. No attempt was made to fit curvilinear equations to the data for this study as the graphs did not show any obvious tendency towards curvature and, in view of the high degree of statistical explanation, it was felt that any improvement would not be significant.

Interception storage capacity (S)

Interception storage capacity (S) is the amount of rainfall retained by the canopy and available for evaporation back to the atmosphere once the rain has stopped. Many overseas studies on evergreen hardwoods or on deciduous forests during the growing season indicate S ranges up to 2 mm (e.g., Zinke, 1967; Aussenac, 1968; Singh, 1977; Prebble and Stirk, 1980).

One method for estimating S is to extrapolate the relationship between throughfall and rainfall to find the amount of rain that falls before throughfall begins, i.e. R at $T = 0$ (Reynolds and Leyton, 1963; Rutter, 1963; Rowe, 1975, 1979; Singh, 1977; Prebble and Stirk, 1980). From eqs. 1 and 2, S was estimated to be 1.06 mm in winter and 1.23 mm in summer.

A similar technique extrapolates the upper envelope of throughfall—rainfall data points for storms with > 2.5 mm of rain to find S equal to R at $T = 0$ (Leyton et al., 1967). Using this method and the data in Fig. 3B, estimates for S were 0.5 and 0.7 mm for winter and summer, respectively. In another variant of this method, Gash and Morton (1978), and Pearce and Rowe (1981) extrapolated a line with slope $(1 - p_t)$ (where p_t is the proportion of rain diverted as stemflow) through the upper envelope of points with $R > 1.5$ mm to the throughfall axis. S was estimated from the negative throughfall intercept (at $R = 0$) and gave estimates for the present study area of 1.2 and 1.5 mm for winter and summer, respectively.

Comparison of storm throughfall and rainfall data to find a threshold value of rainfall below which no throughfall occurred has also been used to determine S (Rogerson and Byrnes, 1968). Variations in wind strength and rainfall intensity can, however, have a marked effect on determining S by this method as water is shaken off leaves and branches by wind gusts or raindrop impact (Singh, 1977). The variability inherent in this method is demonstrated by data in this study; 95 storms with rainfall up to 2.7 mm had no measurable throughfall whereas twelve events with between 0.2 and 1.0 mm of rainfall had measurable throughfall. Many of the zero throughfall storms were low-intensity long-duration storms in which evaporation rates would not have allowed the storage to be filled.

There were no short sharp storms during which evaporation would have been negligible, so that S could have been estimated as $S = R - T$. Difficulties in accurately reconciling the time bases from the throughfall and rainfall recorders also precluded a similar comparison for the beginnings of larger storms with high-intensity beginnings.

Of the 50 storms with gross rainfalls between 2 and 4 mm, the average difference between T and R was 1.7 mm (SE = 0.6). Because of evaporation from storage during these events, this will be an overestimate.

Using the first extrapolation technique given above, Rowe (1979) calculated S for the mixed beech stand to be ~ 2 mm. Pearce et al. (1980b), and Pearce and Rowe (1981), found values of 1.0—1.2 mm for the same data, using the method of Gash and Morton (1978). Aldridge and Jackson (1973) noted that, for *N. truncata*, no throughfall occurred in fourteen storms with gross rainfall less than 1.0 mm.

Interception loss (I)

Interception loss was treated as the complement of throughfall less an estimate for stemflow calculated at 2% of gross rainfall. The average yearly interception loss for the study period was estimated at 430 mm, 29% of the recorded rainfall (Table IV).

In a year with normal rainfall, average interception loss would be slightly higher at ~ 440 mm. During the study the measured interception loss ranged from ~ 380 mm in dry years to 535 mm in a wet year.

New Zealand studies have reported percentage annual interception loss to be 26% for mixed beech forest (Rowe, 1979) and 30—40% for hard beech (Aldridge and Jackson, 1973). Summer-only values for mountain beech (Rowe, 1975) averaged 38.6% compared to the equivalent for this study of 32%. Studies in hardwood forests elsewhere have reported interception losses in the range 5% of gross rainfall (Nihlgard, 1969) to 38% (Dabral and Subba Rao, 1969) with most results about 20%.

As interception loss is complementary to throughfall and stemflow, the seasonal effect was again evident (Fig. 2), with average monthly losses ranging from 22% of gross rainfall in winter to 35% in summer. Actual monthly interception loss lay between 8 and 72 mm, with mean monthly amounts ranging between 25 and 55 mm.

Interception loss—rainfall models

Monthly linear regression. Fig. 4 shows the data for monthly interception loss as a function of monthly rainfall. As for throughfall, the data have been divided into summer and winter seasons. The results of the regression analyses were:

Winter:	$I = 7.9 + 0.20R$;	$r = 0.840$,	$F = 53$,	$n = 24$	(3)
Summer:	$I = 4.9 + 0.28R$;	$r = 0.973$,	$F = 361$,	$n = 22$	(4)

A comparison of regression test showed these relationships to be statistically different ($F_{\text{slope}} = 8.9$, $F_{\text{level}} = 21.8$, $F_{\text{tab}} = 4.1$).

Storm linear regression. The following equations are the results of the linear regression analyses on the storm interception loss—rainfall data:

Winter:	$I = 0.83 + 0.20R$;	$r = 0.946$,	$F = 1688$,	$n = 199$	(5)
Summer:	$I = 0.93 + 0.25R$;	$r = 0.958$,	$F = 2324$,	$n = 210$	(6)

As expected, these relationships were also statistically significantly different ($F_{\text{slope}} = 46$, $F_{\text{level}} = 28$, $F_{\text{tab}} = 3.9$).

Gash (1979) has shown that the regression slope in the above relationships (eqs. 5 and 6), is equal to $\bar{E}/\bar{R}$, where $\bar{E}$ is the mean evaporation rate from a saturated canopy and $\bar{R}$ is the measure of rainfall intensity determined earlier. From eqs. 5 and 6, $\bar{E}_w = 0.39$ and $\bar{E}_s = 0.53$ mm hr.$^{-1}$ for winter and summer,

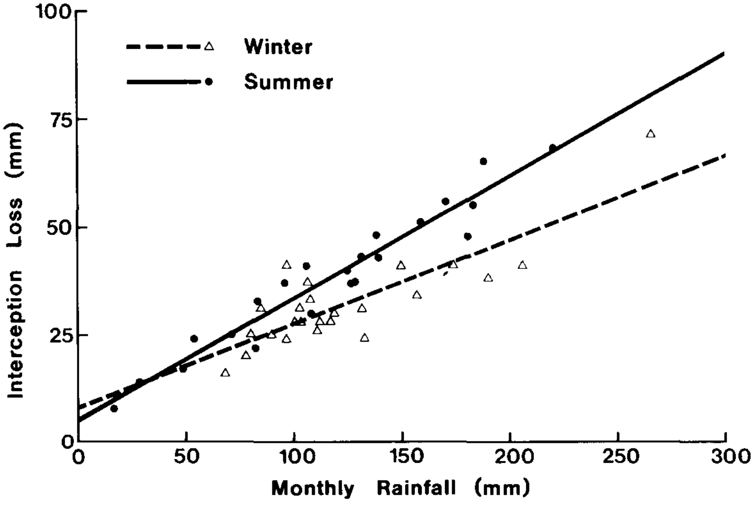


Fig. 4. Monthly interception loss—rainfall relationships for a beech forest stand, Donald Creek, Nelson, 1977—1981.

respectively (cf. $\bar{E}_w = 0.28$ and $\bar{E}_s = 0.46\,\text{mm hr.}^{-1}$ for the mixed beech forest at Reefton; Pearce and Rowe, 1981). Thus, the different seasonal interception loss regressions are a result of a higher evaporation rate in summer and not the result of differing rainfall rates.

Eqs. 5 and 6 were not able to be used to estimate interception loss because storm rainfalls of less than ~1.1 mm give interception loss estimates greater than the incident rainfall. To overcome this problem, the storm rainfall—interception loss relationships were recalculated using only storms of 5.0-mm rainfall or greater. The resulting equations were:

Winter storm: $I = 1.56 + 0.18R$; $r = 0.894$, $F = 391$, $n = 100$ (7)
Summer storm: $I = 1.68 + 0.23R$; $r = 0.935$, $F = 749$, $n =. 100$ (8)

In both cases, the intercepts were larger and the slopes were smaller than the equivalent relationships using all data. This reflects the weighting effect of a very large number of small storms at the lower end of the regression lines. Interception loss for the storms with less than 5.0 mm of rain averaged 0.85 and 1.01 mm for winter and summer, respectively.

Sine curve model. Climatic parameters which show periodic tendencies, e.g. radiation and air temperature, are generally considered to follow a sine curve (Brooks and Carruthers, 1953). The periodicity can be either a single sine curve or be made up of a number of sine and cosine terms (harmonics) which can be determined using Fourier analysis (Carson, 1963). Percentage interception loss, as shown in Fig. 2, follows a periodic form and is a function of the rate of evaporation from a free water surface which is also a function of periodic phenomena, i.e. radiation and vapour pressure deficit (related to air temperature) as in the Penman—Monteith formula (Monteith, 1965). A simple sine curve was fitted to the mean monthly percentage interception loss data, using the method of Ward (1963); the resulting curve, plotted in Fig. 5, is:

$$\%I/R = -5.9[\sin(30x + 1.0)] + 29.1 \quad (9)$$

where x = number of months since April 1 ($x = 0.5$ for April, $x = 1.5$ for May, to $x = 11.5$ for March); mean monthly $\%I/R = 29.1\%$; wave amplitude $= -5.9\%$; phase shift from April 1 $= 1.0^\circ = 1$ day; standard deviation of $I/R = 4.5\%$; standard error of the estimate (SE) = 1.6%; correlation coefficient = 0.940; and confidence limits,

$$\pm t_{0.5} \times \text{SE} = \pm 2.2 \times 1.6 = \pm 3.5\%$$

All values lie well within the 95% confidence limits.

Gash's analytical model. The three models above are very simplistic and empirical. A physically based model, that of Gash (1979), itself a simplification of the model of Rutter et al. (1975), has been tested on data from the mixed beech forest at Reefton (Pearce et al., 1980b; Pearce and Rowe, 1981). The model relates stand parameters and rainfall parameters to calculate

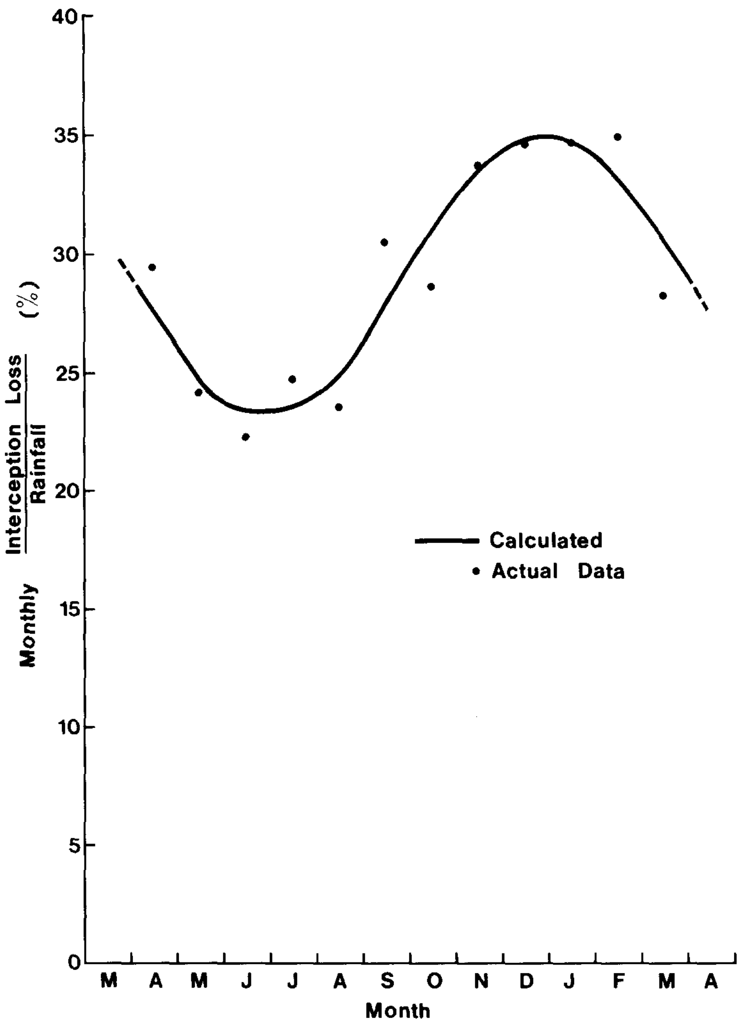


Fig. 5. Percentage monthly interception loss/rainfall, Donald Creek, Nelson, 1977—1981, with calculated sine curve.

losses from the various interception stores for different parts of a storm. Gash and Morton (1978), Gash (1979), and Pearce and Rowe (1981) describe the methods used to calculate the model parameters. As stemflow was not measured in this study, values for p_t and S_t have been assumed to be the same as those for the Reefton study (Pearce and Rowe, 1981). The model parameters determined from the first four years of data are shown in Table V.

Test of models. Data were available for interception loss and rainfall for most of the 12 months after 31 March 1981. Unfortunately, collecting-drum problems during September and November prevented the measurement of throughfall for those months so all models were tested on the 10 months available.

TABLE V

Interception loss estimates by Gash's model for 1981—1982

	Winter	Summer
Stand parameters:		
Free throughfall coefficient, p	0.00	0.00
Proportion of rainfall going to trunks, p_t	0.02	0.02
Proportion of rainfall going to canopy, $1 - p - p_t$	0.98	0.98
Canopy storage capacity, S (mm)	1.2	1.2
Trunk storage capacity, S_t (mm)	0.03	0.03
Rainfall parameters:		
Mean rainfall rate onto saturated canopy, $\bar{R}$ (mm hr.$^{-1}$)	1.95	2.11
Mean evaporation rate from saturated canopy, $\bar{E}$ (mm hr.$^{-1}$)	0.39	0.53
$\bar{E}/\bar{R}$	0.20	0.25
Rainfall necessary to fill canopy storage, P'_g (mm)	1.37	1.44
Number of storms with rainfall $< P'_g$, m	10	13
Rainfall in m small storms, $R_s = \sum_{i=1}^{m} R_i$ (mm)	3.2	5.4
Number of storms with rainfall $\geqslant P'_g$, n	31	24
Rainfall in n large storms, $R_l = \sum_{i=1}^{n} R_i$	636.2	500.5
Number of storms with rainfall $\geqslant S_t/P_t$, q	31	24
Rainfall in $m + n - q$ storms that do not fill S_t, $R_t = \sum_{i=1}^{m+n-q} R_i$ (mm)	3.2	5.4
Components of interception loss (mm):		
For m small storms with $R < P'_g$, $(1 - p - p_t)R_s$	3.1	5.3
Wetting up canopy for n large storms, $n(1 - p - p_t)P'_g - nS$	4.4	5.1
Evaporation from saturated canopy, $\bar{E}/\bar{R} \sum_{i=1}^{n} (R_i - P'_g)$	118.7	116.5
Evaporation from storage after rainfall ceases, nS	37.2	28.8
Evaporation from trunks, $qS_t + p_tR_t$	1.0	0.8
Total losses	164.4	156.5
Measured losses (determined from Table VI)	179.2	166.2

TABLE VI

Monthly interception losses (mm), Donald Creek, Nelson — Test of linear and sine models, April 1981—March 1982

Month	Rainfall measured	Interception loss and difference from measured						
		measured	linear estimate monthly		sine estimate		linear estimate storm	
1981 Apr.	119	35.0	31.2	−3.8	32.8	−2.2	31.9	−3.1
May	117	30.0	30.7	+0.7	29.1	−0.9	27.6	−2.4
Jun.	154	40.7	38.0	−2.7	36.1	−4.6	36.0	−4.7
Jul.	219	59.7	50.6	−9.1	51.4	−8.3	51.8	−7.9
Aug.	30	13.8	13.8	0.0	7.2	−6.6	8.6	−5.2
Sep.	146	—	36.3	—	40.3	—	40.9	—
Oct.	126	41.0	40.6	−0.4	38.7	−2.3	38.1	−2.9
Nov.	179	—	56.2	—	60.2	—	51.4	—
Dec.	154	48.8	48.8	0.0	53.9	+5.1	48.7	−0.1
1982 Jan.	71	26.6	25.1	−1.5	24.7	−1.9	27.8	+1.2
Feb.	124	38.2	40.3	+2.1	41.3	+3.1	36.5	−1.7
Mar.	31	11.6	13.6	+2.0	9.4	−2.2	16.7	+5.1
Total*	1,145	345.4	332.7	−12.7	324.6	−20.8	323.7	−21.7

*Does not include September and November.

To test the monthly linear regression model, eqs. 3 and 4 were used to calculate direct estimates of interception loss from monthly rainfalls. Similarly, to test the storm model, eq. 7 or eq. 8 was applied to each storm with rainfall greater than 5.0 mm, the resulting storm interception losses were summed for the month and adjusted, using the average loss values to take account of small storms. Percentage I/R was calculated for each month using eq. 9 to test the sine curve model. This factor was then applied to the rainfall recorded during the month to obtain an estimate for interception loss. Gash's model calculations were carried out on the seasonal basis only.

The three models providing monthly estimates satisfactorily estimated the amount of interception loss over the test period, although each model gave underestimates (Table VI). The worst result, the storm linear model, was still within 7% of the measured total, whereas the linear model based on the monthly interception loss—rainfall relationship was only 3.5% short of that measured. For all models, estimates by month were generally within 10% of the measured amounts with the monthly linear estimate again being the closest. The sine model was within 6% of the measured totals but the extra computations involved may make this less useful as linear regression programmes are much more readily available.

Gash's model also gave a very close agreement between the estimated and measured interception loss totals for the two periods (Table V). Winter and summer estimates of interception loss were underestimated by 8% and 6%, respectively.

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