THE MEASUREMENT OF RAINFALL AT GROUND LEVEL
(NOTE)

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For comparative studies of rainfall the use of raingauges similarly exposed at a height of 0.3 m above ground level is acceptable as a practical method (World Meteorological Organization, 1969). Errors of measurement are inherent in the exposure of raingauges in this manner, and accurate point measurement of rainfall is not achieved. A possible solution to this problem is the exposure of raingauges at ground level.

To study the differences between the catch of raingauges at 0.3 m and at ground level at Taita Experimental Station (41° 11′S, 174° 58′E), Lower Hutt, New Zealand, a raingauge exposed at ground level, in addition to the raingauge at 0.3 m, has been in use in the climatological enclosure since March 1971. In addition to this comparison, a plot was set up on a hill site to study the differences in catch amongst a ground-level raingauge, tilted raingauges and vertical raingauges on a steep slope. The ground-level raingauges were exposed in a similar manner to the ground-level raingauges used by Rodda (1967) and Green (1970).

On the hill site the ground-level raingauge was exposed normal to the slope, and in the centre of a 10 m × 10 m plot. This plot had a uniform 32° slope facing 280° true. Three vertical raingauges and three raingauges tilted normal to the slope, at a height of 0.3 m, were randomly sited within the plot. Measurements on this site were made from December 1971 to December 1972.

The ground-level raingauge and the standard raingauge at 0.3 m in the climatological enclosure were checked daily at 0900 NZST. The raingauges on the hill site were checked when possible on a daily basis, or the rainfall was accumulated for several days. The catches of the ground-level raingauge and tilted raingauges on the plot have been converted to map-area catch, which is the usual

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TABLE 1 — Monthly rainfall on hill site and climatological enclosure (mm).

	Hill site					Enclosure	
		Vertical gauges		Tilted gauges			
	Ground level	Mean	Std. dev.	Mean	Std. dev.	Ground level	Gauge at 0.3 m
Dec 1971	67.5	59.1	1.6	66.5	0.2	67.3	63.9
Jan 1972	96.9	79.3	1.3	92.9	2.7	85.1	76.8
Feb 1972	71.9	62.5	0.5	70.6	0.3	70.8	63.5
Mar 1972	130.7	116.8	1.5	128.1	0.7	134.0	122.0
Apr 1972	73.5	62.2	0.9	72.2	2.9	70.3	66.0
May 1972	166.0	133.8	1.9	159.2	0.5	152.8	141.9
Jun 1972	95.0	83.0	2.6	90.0	4.3	95.8	91.0
Jul 1972	192.4	169.5	7.1	184.5	3.3	178.2	172.9
Aug 1972	107.1	94.7	1.5	105.3	0.4	105.5	100.1
Sep 1972	74.5	60.2	0.5	73.0	0.3	73.8	68.1
Oct 1972	85.9	81.8	0.7	84.1	0.7	91.4	86.4
Nov 1972	38.8	31.5	0.2	37.6	0.5	36.0	30.7
Dec 1972	75.5	69.0	1.1	74.6	0.5	77.7	73.6
Total rainfall:	1275.7	1103.4	14.5	1238.6	7.8	1238.7	1156.9
Difference from ground level (%):		13.5		2.9			6.6

manner of expressing rainfall. Other relevant data available from observations in the climatological enclosure were rainfall intensity from a recording raingauge, daily windrun at a height of 2 m, and rainfall vectors from a vectopluviometer (Aldridge, 1975).

In the climatological enclosure over the period April 1971 to June 1974 there were 525 raindays with data available for both raingauges. For this 39-month period the total rainfall catch of the ground-level raingauge exceeded the total catch of the raingauge at a height of 0.3 m by 6.3 percent, with a monthly difference ranging from 0.6 percent to 13.5 percent. On a daily basis the percentage differences* in the catch of the raingauges generally decreases with increasing rainfall.

For the hill site from December 1971 to December 1972 the total mean catch of the vertical raingauges was 13.5 percent less than the catch of the ground-level raingauge. This was a larger difference between the raingauges at 0.3 m and ground-level than had been found in the horizontal climatological enclosure over the same period (Table 1). The larger difference was attributed to the additional catch accruing to a ground-level raingauge exposed normal to the slope (Jackson and Aldridge, 1972; Corbett, 1967). In com-

* (catch at ground level—catch at 0.3 m) × 100 ÷ catch at 0.3 m.

parison, the total mean catch of the tilted raingauges was only 2.9 percent less than the catch of the ground-level raingauge (Table 1). Green (1970) found that a raingauge at 0.3 m tilted normal to the slope gave a catch closer to that of the ground-level raingauge than did a vertical raingauge, although these results are not directly comparable with results for Taita because of raingauge differences.

To examine whether a relationship existed between differences in raingauge catch and rainfall intensity (mm/h), daily windrun at 2 m (km), or resultant inclination (deviation from vertical) of the rainfall, linear regression analyses were made for each of these factors.

There was no significant correlation between differences in raingauge catch and intensity of rainfall.

For the climatological-enclosure study, percentage differences in raingauge catch showed some correlation with daily windrun (Table 2). Large differences in raingauge catch were generally associated with high daily windrun although the variability was large, especially with daily rainfall less than 5.0 mm. The generally greater correlation coefficients for the large rainfall size classes were probably due to the longer duration of the larger daily rainfalls. Strong correlation of catch differences with daily windrun for short-term rain had not been expected as the daily windrun covers the full 24 hours of a rainday.

Better correlation than that with daily windrun was obtained when differences in raingauge catch were compared with the resultant inclination of the rainfall (Table 3), although the variability was still large for daily rainfalls less than 5.0 mm. The higher values of correlation coefficients obtained with resultant inclination of rainfall than with daily windrun may be attributed to the data used to compute resultant inclinations covering the same time period as the rainfall. Large percentage differences in raingauge catches generally corresponded to high resultant inclinations of rainfall. The most common exceptions to this relationship were for the lower daily rainfalls in the 0.1–4.9 mm daily rainfall group.

TABLE 2 — Relationship of percentage difference between gauge catches (d, %) to daily windrun (B, km) in the climatological enclosure.

No. raindays	*Rainfall (mm)*	*Linear regression*	*Correl. coeff.*	*Std deviation from regression*
314	0.1–4.9	$d=0.052B+3.593$	0.273	18.33
101	5.0–9.9	$d=0.028B+0.927$	0.547	4.71
64	10.0–19.9	$d=0.032B-0.951$	0.614	3.99
46	≥20–0	$d=0.022B-0.232$	0.492	3.94

TABLE 3 — Relationship of percentage difference between gauge catches (d, %) to resultant inclination of rainfall (i, degrees) in the climatological enclosure.

No. raindays	*Rainfall (mm)*	*Linear regression*	*Correl. coeff.*	*Std deviation from regression*
314	0.1–4.9	$d=0.600i+3.101$	0.552	14.21
101	5.0–9.9	$d=0.334i+0.679$	0.756	4.25
64	10.0–19.9	$d=0.319i+0.134$	0.842	2.73
46	⩾20.0	$d=0.285i-0.422$	0.734	3.07

There was a high proportion of raindays with low rainfall, large percentage differences in gauge catch, but with vertical rainfall, which may account for the low correlation of percentage difference in gauge catch with resultant inclinations of rainfall in the 0.1–4.9 mm group. Although the percentage differences in gauge catch may be large, the actual depth of rainfall involved in differences on raindays in the 0.1–4.9 mm group and especially on raindays with less than 2.0 mm, was very small (0.1–0.2 mm), and of the same magnitude as the precision with which rainfall was measured. In addition the vectopluviometer may be insensitive to light rainfall (Aldridge, 1975), accounting for an excessive number of raindays with computed vertical rainfall.

For the hill site, the correlation of the differences between mean vertical raingauge catch and the ground-level raingauge catch with daily windrun and resultant inclination of rainfall showed a similar pattern to the correlations for the longer period in the climatological enclosure. However, for the same period as the hill-site study, the differences in catch in the enclosure were better correlated with daily windrun and resultant inclination of rainfall than were the differences in catch on the hill site (Table 4). The differences between the mean tilted-raingauge catch and ground-level raingauge

TABLE 4 — Differences (d, %) between catches of ground-level and mean vertical or mean tilted raingauges in relation to daily windrun (B, km) and resultant inclination of rainfall (i, degrees) for rainfalls greater than 5.0 mm. December 1971 to December 1972.

Site	*Gauges compared*	*Linear regression*	*Correl. coeff.*	*Std dev. from regress.*	*No. raindays*
Hill	Ground level, vertical	$d=0.016B+9.392$	0.282	7.56	30
		$d=0.243i+9.746$	0.487	6.53	31
Hill	Ground level, tilted	$d=0.001B+1.833$	0.097	1.83	30
		$d=0.025i+1.752$	0.204	1.77	31
Enclosure	Ground level, vertical	$d=0.032B+0.095$	0.395	7.78	30
		$d=0.341i+1.117$	0.638	6.21	31

catch showed negligible correlation with daily windrun and only weak correlation with resultant inclination of rainfall (Table 4).

To test whether the resultant inclination of rainfall computed from the catches of the vectopluviometer in the climatological enclosure were applicable to the hill site, rainfall for a surface with the slope and aspect of the hill site was computed in the manner described by Jackson and Aldridge (1972). The differences between this computed rainfall and the rainfall measured in the enclosure with the raingauge at a height of 0.3 m were compared with the differences between the mean catches of the tilted raingauges and the mean catches tof the vertical raingauges on the hill site.

The enclosure data showed that the tilted-raingauge catches could be expected to exceed the vertical-raingauge catches for all rainfall except that from between northeast and southwest, when vertical-raingauge catches would exceed tilted catches. The magnitude of the differences for all rainfall depended on resultant inclination and direction of the rainfall. Observed differences were similar to those predicted except for northeasterly to southeasterly rainfall, when the predicted pattern did not occur. This indicates that resultant inclinations and directions computed from climatological-enclosure rainfall were not always indicative of the actual rainfall inclinations and directions on the hill site.

The overall percentage difference of 6.3 percent between raingauge catches in the climatological enclosure was close to percentage differences given by Stanhill (1958) (5.0 percent), Rodda (1967) (6.6 percent), and Green (1970) (5.7–10.0 percent) who all used similar raingauges, exposed in pits and at 0.3 m, as in the Taita study. Comparison with other studies was difficult, because of differences in raingauge design and exposure practices. The common point that arises in all the studies is the deficiency of raingauges exposed at heights above ground in relation to a ground-level raingauge. Most studies find some relationship between deficiency of a raingauge exposed at some height above ground and wind during the rainfall. The good correlation between raingauge-catch differences and resultant inclination of rainfall at Taita also supports this relationship, because resultant inclination of rainfall is a function of the wind force during the rainfall.

There have been very few studies reported similar to that on the hill site at Taita, in which a tilted raingauge and a ground-level raingauge on a hillside were compared. In that of Green (1970) the ground-level raingauge was a special nine-hole gauge, and therefore results are not strictly comparable with the Taita study. Without further study on other hillside sites it is not possible to state whether the small differences between tilted raingauge catch and ground-level raingauge catch in the present study are typical of all hill sites or a peculiarity of this site alone.

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