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GRAZING MANAGEMENT PARAMETERS IN SEMI-ARID TUSSOCK HIGH COUNTRY

A thesis
submitted in partial fulfilment
of the requirements for the Degree
of
Master of Agricultural Science
in the
University of Canterbury
by
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Lincoln College
1979

GRAZING MANAGEMENT PARAMETERS IN SEMI-ARID TUSSOCK HIGH COUNTRY

by A.B. Edge

At Tara Hills High Country Research Station in North Otago the herbage available on 500.1 ha of steep semi-arid high country was measured for one growing season using a capacitance probe instrument. The technique was evaluated for suitability in steep tussock grassland, and the pattern of grazing pressure on three parallel blocks which comprised the study area was determined. The botanical composition of fresh herbage was estimated visually and related to information about the diet of the sheep obtained from a limited series of faecal cuticle analyses.

Fifteen land units were mapped according to the following criteria: Contour concavity, aspect, vegetation and landform elements. The effective pastoral area of each land unit was derived by discounting the rock outcrops and correcting for slope. Two permanent 25m transects were located on each land unit.

The thirty transects were measured by capacitance probe on twelve occasions from 31st August 1977 to 9th May 1978. Three to six hours were required for two people to sample and traverse a single block. At each transect inter-tussock herbage was cut in random handfuls at ground-level and placed in a cardboard box beneath the probes until the mean value of 25 readings from the line was obtained. The freshweight and dryweight of the samples were recorded. Available dry matter on each
block was estimated from the mean land unit values weighted for effective area. The results ranged from 200 kg ha\(^{-1}\) to 1300 kg ha\(^{-1}\). The water content of the herbage on the sunny faces and watercourses averaged 59\% over the growing season; the shady land units, 53\% and the cold/crest land units 43\%. On the basis of Penman evapotranspiration data, free soil moisture was present on 63 days in the same nine month period.

Grazing pressure on two of the blocks during seasonal set stocking with merinos was commonly 5-7 stock units/tonne ADM. The third was grazed for more of the summer at 4 s.u./t.ADM or less. The highest grazing pressure recorded was 14 s.u./t.ADM but overall, evidence of undergrazing rather than overgrazing was found. Annual stocking rates were less than in previous years, although management followed normal practices. The botanical composition of the fresh intertussock herbage along each transect was visually estimated, and quantities derived via the appropriate capacitance readings. The overall vegetation and cover on each land unit was also sampled and comparisons drawn.

Four random samples of dung were collected within blocks in autumn and cuticle analyses obtained. Changes in the rank of forage species from field abundance to diet are presented. The specific selection pressures for fifteen species are estimated.

The ability of the capacitance technique impartially to measure herbage water in the tussock grasslands is confirmed \((r_{\text{water.meter reading}} = 0.78\) for 688 samples November to May). The use of seasonal regression equations is examined. The parameters "inferred digestible dry matter (based on water content) and "digestible dry matter" \((\text{in vitro})\) are again proposed as suitable alternatives to available dry matter so that the relationship between herbage water measured by capacitance and the quality of high country forage is
efficiently exploited.

The utility of the stratification process by which the land units were derived is discussed and the number and location of the sampling sites are reassessed.
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CHAPTER I

INTRODUCTION

1.1 BACKGROUND

The Tussock Grasslands and Mountain Lands Institute has noted the lack of close relationship between land development expenditure in the high country and subsequent increases in farm produce. Substantial overall growth in livestock numbers and output occurred in the period 1966-1973 for which the Institute has published results of a complete enumeration survey. Other sectors of the pastoral industry were somewhat stagnant during the same interval. However, initial results from a pastoral lands utilization survey first applied to forty runs as an adjunct to the 1977/79 complete enumeration (in press), contain abundant examples of terrain on one run or on one part of a run supporting ten to twenty times the stocking load that is carried on similarly treated terrain of the same soil nearby (O'Connor, 1977b). Differences in grazing management of oversown and topdressed areas can soon give rise to such spectacular differences in pasture production and composition.

Early attempts in New Zealand to measure herbage production in the tussock grasslands using an electronic capacitance meter were frustrated by very wide variation between meter readings and the dry matter of the samples calibrated therefrom (K.F. O'Connor, pers. comm.). Much of the variation was found to be caused by differences in the herbage water: dry matter ratio among the samples.

Harris (1978) used an electronic capacitance meter as a sampling aid in humid, unimproved high country. Both he and Stevens (1977)
presented grazing pressure data expressed in digestible dry matter as well as available dry matter terms. Clarke (1977) reported a pilot trial conducted with E.J. Costello, which correlated capacitance readings most closely with the digestible dry matter of herbage from sources which included unimproved high country.

1.2 PURPOSE

This study was planned to measure attributes of grazing management practice on steep high country, improved but low yielding because of low rainfall. For one growing season the production of available dry matter and its utilization by seasonally set-stocked merinos under normal management were examined. At the same time the capacitance probe technique for measuring standing pasture was examined for convenience and efficiency in a steep and low yielding range environment. The sampling method adopted was that developed by B.E. Allan of the Ministry of Agriculture and Fisheries at Tara Hills in winter 1977.

As a choice of site, Tara Hills afforded steep improved tussock grassland of diverse aspect and altitude, along with very good access and technical assistance. The following sections outline the original proposal for a thesis study in pastoral range management. Amendments to the original proposal are noted in parentheses.

1.3 PROCEDURE

1.31 To select pastoral blocks at Tara Hills High Country Research Station according to access, compactness and seasons of use for grazing.

1.32 To stratify these blocks by aspect, slope, altitude and vegetation criteria and quantify the strata as to their effective grazing-
To monitor changes in available dry matter during periods of grazing (spelling periods were subsequently included) on each block. To measure species composition of the strata. (Digestibility determinations were proposed but unavailable.) To estimate available soil moisture during the sampling period.

To collate stock movements and the productivity of the sheep grazed on the study blocks from the records of Tara Hills farm staff. To observe sheep during the summer from vantage points on each block and estimate their grazing distribution between the strata. (The vantage points were inadequate for one observer; this proposal was supplanted by a limited series of faecal cuticle analyses of late summer and autumn diet from which some inferences as to grazing distribution could be made.)

OBJECTIVE

To derive the seasonal pattern of grazing pressure on semi-arid tussock high country in the 1977/8 growing season. The measuring technique invited examination of the hypothesis that capacitance probes accurately assess the water content of intertussock herbage and that with careful sampling so as to collect herbage representative for both herbage water and dry matter constituents, the latter parameter could be conveniently derived. The capacitance technique was also under consideration as a feasible means of gathering several years' available herbage from steep high country as one prerequisite for modelling such a grazing system.
PART I: GRAZING RESEARCH AND THE MANAGEMENT OF IMPROVED RANGE

The best understanding of run sheep requirements is substantially intuitive, derived from years of experience often spanning several human generations. However, measured information besides wool weights, lambing percentage and body weights of sale stock is needed for the adequate transfer of successful management techniques to other runs of similar environment and for efficient transfer through time. Thus the principles of responsible management are elucidated and pastoralism can be upheld as a proven contender among the flush of alternative uses which are making claims on the high country. "It is a special irony that so much attention has been given of recent years to the question of land retirement and so little to the matters of utilization of herbage on land that is grazed by domestic stock" - O'Connor (1977b).

On developed range, nutrient cycles, especially that of nitrogen, are accelerated and defoliation must keep pace. Otherwise the new nutrients are held in a storehouse of introduced plants and invigorated residents which becomes "standing dead", a sink for both sunlight and nutrients.

This chapter first considers the activities of sheep and the influences these have on pasture, then the responses of the pasture in space and through time, and finally the difficulties and the rewards of measuring pasture production and utilization.
2.1 THE BEHAVIOUR AND INFLUENCE OF GRAZING SHEEP

The main activities of grazing sheep and cattle are eating, walking, resting and excretion. The corresponding effects on pasture are defoliation, treading, loading and nutrient return.

2.11 Eating - defoliation

Sheep spend between 33% and 50% of each 24 hour day grazing, according to the literature reviewed by Harris (1978). Cheviots in Scotland observed by Tribe (1949) for a whole year averaged 9.5 hours/daytime. Proportionally more grazing during darkness was done during the short nights of summer than was the case in other seasons. Border Leicester merino wethers and ewes monitored by Arnold (1962) for a 20 month period at Canberra grazed for 8.2±1 hours daily. Except in spring, two-thirds of the grazing time was spent between 6 a.m. and 6 p.m. Night grazing activity usually peaked about midnight. Although each animal behaved as an independent individual with respect to grazing time they often associated with the same peers to form a loose sub-flock of up to six sheep. There were distinct seasonal changes in grazing pattern.

The half-bred wethers and hoggets observed by Harris (1978) on unimproved summer range at Glenthorne, central Canterbury, spent 73% of the time between 7.40 a.m. and 7.00 p.m. grazing, not in proportion to grazing pressure but more as a reflection of the overall low quality diet. Night grazing was not measured.

Grazing activity decreased markedly between 10 a.m. and 2 p.m. at Glenthorne, effectively dividing the daylight period into early morning and evening grazings. This pattern is found in free ranging sheep in both hemispheres. Stevens (1977) commented that the early morning grazing is more intense and reputedly less selective than the evening
grazing (e.g. Kothmann, 1966).

On improved montane range at Brooksdale, which has a somewhat similar climate to Glenthorne, Stevens (loc. cit.) found the grazing behaviour and distribution of half-bred ewes could best be explained in terms of the incidence and storage of solar radiation. The evening campsites were in the warmest areas of the block. Early morning grazing tended to be initiated by, and follow, the movement of the sun. Thus the more intense morning grazing occurred on sunny faces close to the evening campsites. The stock arrived in shady areas when almost replete and so grazed only intermittently until mid-afternoon. Before dusk they had returned to the sunny faces and were preparing to camp. When the quantity of forage declined the sheep would graze longer on the shady areas without reducing the time spent on sunny areas.

Sheep observed by Hercus (1961a) on a 32 ha oversown block above Hawea Flat appeared to remain in altitude-specific groups which made three or more traverses of the block in the course of each day's grazing. Soon after the onset of winter frosts, grazing was concentrated on the sunny faces until October.

Arnold (1963) calculated that the daily food requirement by sheep of 1.2kg DM can be obtained through jaws 3 cm wide from pasture yielding 15.5g DM.m$^{-1}$ (150kg ha$^{-1}$) or more. Sheep in poor condition increase their rate of intake before increasing the time spent grazing. The rate of intake is more closely associated with plant or tiller height rather than yield. Allden and Whittaker (1970) found that grazing time and rate of intake of fresh herbage by lambs and hoggets were both constant on sown plots yielding in excess of 3000kg DM ha$^{-1}$. When only 500kg DM ha$^{-1}$ were available the rate of consumption was only one quarter although the time spent grazing was doubled. The rate of dry matter (rather than fresh herbage) intake was constant above 1800kg ADM ha$^{-1}$. 
This is comparable to the minimum optimum of 1540kg ADM ha\(^{-1}\) suggested by Willoughby (1958) for young merinos in a harsh environment where set stocking was desirable.

The number of bites required to harvest one day's forage was found by Allden and Whittaker (1970) to range between 8000 and 42,000. If each bite defoliates 9.7 cm\(^2\) of the earth's surface, and if ground cover is complete but the herbage short, one sheep would graze one hectare in 248 days. \textit{Lolium rigidum} tillers 3.7 cm long were eaten at the rate of 1.0g DM minute\(^{-1}\), tillers 7.7 cm long at 7.1g DM minute\(^{-1}\), an exponential increase in consumption.

Cordova, Wallace and Pieper (1978) warn that "most intake estimates for grazing livestock appear to vary more with techniques used and researchers involved than with forages and environmental conditions tested". Furthermore the trend worldwide is now to express intake in terms of metabolic body weight which is \((\text{live weight})^{0.73}\).

Caution is also needed when defoliation regimes are described. Spedding (1965) stated there is little evidence that continuous and rotational grazing under conditions of "correct" stocking result in different frequencies of defoliation of the individual plant units involved. Therefore "set stocking" is a better term for continuous animal presence. The distinction can be made, however, that rotational grazing is known to be intermittent for all plant units. In the high country the palatability of many species is low and accessibility indifferent so that much herbage is never grazed under contemporary management.

2.12 Walking-treading

The Scottish cheviots observed by Tribe (1949) walked 4.2 km/24 hours. Between 7 p.m. and 7 a.m. only 0.8 km was travelled. Seasonally, the most ranging occurred in spring and autumn.
American rangeland literature reviewed by Harris (1978) agrees that, during daylight, walking occupies 12 to 14% of the sheep's time. The Glenthorne sheep spent only 4% of the day walking between November and March, mostly around 7 a.m., 9 a.m. and 3 p.m. (Harris, 1978). The time spent standing was 9%.

On a flat 1400 ha saltbush range in the semi-arid zone of New South Wales, merinos travelled 8 km daily (Squires, 1974). The movement towards water initially included grazing but became brisker and finally the sheep would break into a run. They drank for 3-5 minutes and walked directly back to the current grazing area. It is important that sheep walk long distances so that the grazing pressure on vegetation close to water is not intolerably high. Pasture at distances greater than 2.4 km from water is still likely to be under-utilised (Squires and Hindley, 1970) although sheep grazing beyond 3 km usually only make one trip to water each day.

Lynch (1967) observed home ranging behaviour in merino wethers on a 320 ha hill block in the northern tableland of New South Wales. The 400 sheep formed seven mutually exclusive groups containing from 2 members to 300 on areas of 10-200 ha. When disturbed the sheep confined their evasive action within the perimeters of their home range unless specifically chased outside. Lynch warned that home ranging behaviour in merinos is by no means universal. Although it is quite common in mountainous country, it is apparently non-existent on treeless plains.

Merino ewes and lambs on a 2400 ha semi-arid range were observed by Lynch (1967) to cover the entire area during a two week period when feed was relatively abundant. However, many places were traversed but not grazed as the stock walked up to 13 km daily en route to various preferred areas. Another dispersal mechanism is social dominance.
(Hunter and Milner, 1963) by which weaker sheep may be precluded from pockets of highly preferred pasture.

2.13 Resting-loading

Time spent resting by sheep is often also used for rumination and sheltering, so that this conveniently recorded non-activity often masks at least two simultaneous activities.

Rumination apparently requires sufficient physical exertion to keep sheep from true sleep (in Hafez et al., 1969). Arnold (1962) observed nine rumination periods totalling 1.3-5.4 hours. They were more often at night but interspersed between grazing periods also. Another (consensus) estimate puts rumination time at 8-10 hours during which time about 500 boli are regurgitated and each chewed 78 times (Hafez et al., 1969).

Observers have most often recorded "resting" times rather than "standing" time; "ruminating", which occurs in both attitudes; or "idling". Cheviots spent almost 13 hours resting (Tribe, 1949). Merinos rested for 8.4 hours during daytime in November and 5.6 hours in March (Squires, 1974). Half-breds rested for 1.6 hours during summer days (Harris, 1978). At midday, an average of 40% of the sheep under observation were resting.

Sheltering from heat was observed at the extreme by Lynch (1967). When daily temperature exceeded 43°C the merinos were camped by 7.30 a.m. and did not stir until about 6 p.m. Merino hoggets on a hill block at Tara Hills were observed by the author to commence sheltering about 8.50 a.m. on a hot day at the end of November, and remain standing in tight clusters behind scrub and rock outcrops until after 4 p.m. Harris (1978) observed a significant increase in the midday sheltering of standing sheep in March (despite increasing grazing pressure) which he attributed to prevalence of flies and/or a photoperiodic response to the
autumnal equinox by which grazing is somewhat inhibited.

The effects of the resting activities of sheep on pasture are best described in terms of dung and urine return. The differential loading the soil sustains is less important than the differential nutrient return which stems from unequal use, particularly by range sheep, of the land surface available to them.

Stock camps in North Island hill country occupy 15% of sheep paddocks and up to 30% of moderate hills (Mauger, 1977). Sheep camps on ridge crests and the peripheral transit areas occupied 35% of a moderately steep hill pasture stratified by Gillingham and During (1973) but produced 40% of the total production in summer and 50% in winter. Dense ryegrass promoted in the best hill camp conditions must be contrasted with dense nettle, horehound, barley grass or yarrow sometimes found with bare ground beneath shelter bushes or, in semi-arid conditions, between the shallow benches formed by sheep at favoured ridge sites.

2.14 Excretion-nutrient return

Domestic sheep defaecate 6-15 times daily (Hughes, 1975), and urinate 9-13 times (Hafez et al., 1969). Three variables are the roughage and water content of the diet, and human disturbance. As with cattle, there is no fixed pattern of defaecation but the accumulation of dung at preferred resting sites is marked. About one third of the total dung from merinos stocked at three different rates on 1.2 ha flat paddocks was found on less than 5% of the area (Hilder, 1966). Similar concentration of urine was inferred from soil tests for exchangeable potassium.

Although the long-term evenness of dung and urine return on flat plots has been demonstrated (Sears, 1953) the behaviour of stock on hill paddocks precludes the effective fusing of dung and urine patches across the landscape. Mauger (1977) listed four transfers of nutrients via the
rumen from the sites where assimilated by plants: inter-track to track; sidings to camps; lower two-thirds of the block to the upper third; and from cold, exposed faces to warm, sunny faces. The upslope movement is to some extent counteracted by the drift regime and the downslope movement of nutrients in surface runoff (studied by McColl and Gibson, 1979) and in ground water.

2.2 PASTURE RESPONSES TO GRAZING

2.21 The fate of undefoliated herbage

The physiology of growth in festucoid perennial grasses was described by Evans, Wardlaw and Williams (1964). In winter some tillering and strong root growth are likely to occur. The tempo of these processes increases until early spring, when accelerated leaf growth and stem elongation take place following floral initiation. In summer, after flowering, leaf growth declines, but there is some resumption of tillering and root growth. Rhizomes develop rapidly at this time. In autumn a marked increase in tillering and the initiation and growth of roots take place. The number of tillers present in winter is often double that of summer.

Leaf and stem growth on established tillers are favoured by long days and moderately high temperatures. Root growth and abundant tillering are promoted by short days and low temperatures, but in the absence of shading.

Annuals and biennials are also significant components of rangeland, either as resident species or successful adventives and because the improved perennials, having been bred for milder conditions, do not establish complete dominance. Evans (1973) described one advantage of the annual life form in a semi-arid environment of initially moist soil with no recharge over a period. The perennial already has a root system
extended to potential depth and so grows under increasing moisture stress but the annual is continually extending its root system into fresh soil, tapping additional water and growing more uniformly.

The fate of undefoliated annuals becomes highly visible while the growing season is still in progress, but this bank of dead stalks will not be added to for a further year. Moreover, the stalks do suggest successful seed-set and the opportunity for utilizing those species the following spring. Leaf death within a perennial sward is comparatively obscured and regrettable (Campbell, 1964; Hunt, 1971).

Dead herbage in dairy pasture under four different grazing regimes was most abundant in February (Campbell, 1964). Under controlled hard (2.99 cows/ha) grazing, dead herbage then comprised 36% of the available dry matter and uncontrolled, "lax" (2.35 cows/ha) grazing, 49%. Utilization under the four treatments over three years was in the range 17% - 38% (annual averages). The rate of disappearance of dead material was not measured so variation in this parameter due to climate cannot be inferred.

The maximum leaf death rate in ryegrass-white clover pasture was 62 kg/ha/day in spring, and decomposition accounted for up to 34 kg/ha/day (Hunt, 1971). In autumn both rates were approximately halved. Dead leaves made up almost all of the litter in the pasture. Even in the first 30 to 40 days of regrowth after defoliation, 10% of the new herbage died.

Korte and Sheath (1978) studied the relative importance of growth and decay in a Nui ryegrass-white clover sward grazed by ewes when the canopy intercepted 95% of noon sunlight, so that the leaf area index (LAI) was reduced to either 0-0.2 or 0.6-1.0. Total net herbage growth rates for late spring/summer were the same for both lax and hard grazed ryegrass-white clover but the average rate of "live" herbage accumulation
was 62 kg DM/ha/day after lax grazing and 76 kg DM/ha/day after hard grazing, a significant difference. Stubble residual after grazing is generally regarded as capable of continued growth - but death may intervene. Of the dead material which accumulated in this laxly grazed sward, 70% was residual leaf lamina and grass sheaths. The contribution of ungrazed mature leaves to the litter was minimised by grazing at 95% light interception rather than any later.

The significance of the autumn flush phenomenon was related by Campbell (1964) to accelerated decomposition of dead dry matter of low water content and the simultaneous resumption of growth by the living plants. Both processes are stimulated by rain, and nutrients from the first foster the second. The quantity of ADM may in fact decline but it is the fresh herbage which the managers observe and indeed the digestibility does improve (cf. Radcliffe, Young and Clarke, 1976).

Some high country runs with semi-improved grassland which is unsuitable for hay or root crops conserve pasture produced in the latter part of the growing season as foggage for consumption in the following September. Forage is most needed then by ewes in late pregnancy, but is least available under the traditional system of managing winter country (Allan, Clarke, Costello and O'Connor, 1976). The effects of frost on leaf survival of cocksfoot were examined by Douglas and Drew (1969) on that part of Tara Hills where the present study took place. At sunny sites on 1st August the herbage was 79% frosted at 46% digestible organic matter (DOM); 21% unfrosted at 75% DOM. From the shady site the 75% frosted component yielded 49% DOM and 25% unfrosted 67% DOM, presumably due to somewhat reduced extremes of temperature. Cocksfoot from the fan site was 95% frosted, so the conclusion was "an undesirable situation where the grass which is the major species recommended for tussock grassland oversowing is unsatisfactory for the critical winter feed
period." However, the shelter afforded by dead, outer cocksfoot leaves to the inner leaves where the growth habit is tussocky should not be overlooked (cf. Eadie and Black, 1968).

The maximum benefits of natural shelter to the winter microclimate of improved grasses in the high country is suggested from limited measurements by O'Connor (1971) in tall tussock associations in Castle Hill Basin and at Glentanner in the Mackenzie Country. Apparent losses of green sward herbage expressed in drymatter terms were most often 40% under Chionochloa rubra and C. rigidà but ranged from 41% to 94% in the absence of tussocks.

Fescue tussock on semi-improved plots in the upper Rangitata was insufficient to foster the carry-over into late winter of highly digestible forage, regardless of closure date (Allan et al., 1976). The dead leached herbage which accumulated was inadequate for ewe nutrition although only a little lower in digestibility than fescue tussock itself. Cocksfoot in plots closed in November made better spring growth the following year but the summer and autumn grazing foregone would argue against such a closure on most runs. Allan et al. concur with Vartha and Clifford (1971) who advised the use of conserved standing herbage by early winter in the high country, whilst its quality is still high.

The guiding principle in utilization of herbage is to avoid grazing the same block at the same time in the growing season every year (Hercus, 1961b). In the Scottish experience, year long set stocking which allows highly selective grazing encourages a vicious cycle in which the quality of available herbage is diluted by the build-up and carry-over of mature herbage (Eadie and Black, 1968). The overall nutrition of sheep on Agrostis-Festuca pasture was improved by reducing the quantity of standing dead matter from 2200 kg ha\(^{-1}\) to 600 kg ha\(^{-1}\)
and through careful grazing management for the utilization of early summer production.

On the drier American range, overgrazing is a greater problem. Deferment to allow replenishment, particularly through the seeding of tall grasses, is unsuccessful if the carrying capacity of the remaining area is exceeded. Harlan (1956) considered a continuous grazing system is probably just as satisfactory and somewhat more economical unless the deferred-rotation system is effective in bringing about the ecesis of better range plants (cf. Dyksterhuis, 1949). Hercus (1961b) urged a "rest" for New Zealand winter country below 800 m, until shady hill faces have been fenced from sunny, so that nucleus populations of desirable perennial species can improve in yield and cover. If the sheep are moved to summer country or to a "sacrifice" block by mid-November rather than December the improved grasses are spared close grazing during this critical growth period (cf. Moore and Biddiscombe, 1964).

2.22 Defoliation and Regrowth

In 1970 Brougham referred to the hiatus, especially evident in New Zealand over the preceding twenty years, of lavish pasture production unmatched by animal output. His recommendation for dairy pasture management was for hard grazing in winter at about six-weekly intervals, decreasing into spring. From late October to late December more cover should be left because a large proportion of the ryegrass tillers then have meristems more than 2.5 cm above ground. Severe grazing at this time reduces the growth of roots and the concentration of carbohydrates in the perennating organs (Moore and Biddiscombe, 1964). During summer Brougham (1970) recorded a 25% increase in the soil moisture (0 - 7.5 cm) at Palmerston North when herbage cover was maintained.

Smetham (1975) inferred from the literature that 2 cm is the general optimum grazing height for perennial ryegrass, and 10 cm for
less prostrate grasses to avoid any penalty in yield. Dairy production per hectare is in theory not depressed until utilization exceeds at least 65% of total ADM at a single grazing. Greenhalgh (1970) achieved such utilization under "put and take" stocking but Campbell (1966a) with 2.99 cows/ha - more than normal in the industry - measured only 33% utilization. Differences in animal production in Campbell's experiment resulted more from differences in utilization of the pasture grown than from any large variations in the quantity of pasture produced under the four stocking rates. Thus the management is as important as stocking rate in increasing pasture utilization (Campbell 1966b).

In the hill and high country the range in pasture production is often immense in both space and time, especially after moderate top-dressing (McLeod, 1974; O'Connor, 1976b), and furthermore the stock actively discriminate against large portions of the terrain and of plant communities. The respective merits of partial or full utilization are indicated, however, by discovering the true limiting factors to herbage production in each particular environment (O'Connor, 1965).

The contrast between annual stocking rates of 0.6 s.u. ha\(^{-1}\) and 11.5 s.u. ha\(^{-1}\) on paired undeveloped and developed hill faces on Ribbonwood Station, Omarama, highlights the merits of white clover and cocksfoot which were the main contributors to increased production on the developed block (Scott and Maunsell, 1974). The half-bred hoggets were supplemented as required during spring and summer, whereas management of flock ewes during lactation is commonly restricted to set stocking for the animals' sake on developing pastures. The grazing pressure there is often lower than that sustained by the unimproved grassland where the ewes summer after weaning (Hughes and O'Connor, 1976). The hill country farmer can partially resolve this paradox by the practice of rotational grazing between weaning and lambing (e.g.
Smith, 1978) but the runholder may have only a small proportion of his run in the necessary improved pastures. Widespread oversowing with modest topdressing in the high country has often led to serious pasture composition problems (Hughes and O'Connor, 1976), when neither subdivision nor grazing management have been intensified. However, there are cases where sale stock and dry sheep are being manipulated as part of a whole-run management system for the more correct utilization of improved blocks.

2.23 Response to Treading

The effects of treading on improved pasture are largely beneficial (Sears, 1953). The sole of the sward is kept open, encouraging ryegrass at the expense of mat-forming weed grasses. The detrimental effects of concentrated treading by stock have been studied in New Zealand by Edmond (reviewed by Brown and Evans, 1973). On wet hill country, hoof damage in early winter was deleterious to grass cover when the soil was saturated (Suckling, 1959).

In dry soil conditions, crushing and bruising of plant leaves are likely to occur rather than soil deformation. The perennating organs of erect grasses such as *Dactylis glomerata* and *Holcus lanatus* are more susceptible to damage than those of the prostrate hemi-cryptophytes. *Lolium perenne* was found by Edmond (in Brown and Evans, 1973) to successfully withstand treading at twice the stocking rate typical of high producing pastures. The cushioning benefits of tall herbage to subsequent pasture production, and in terms of soil compaction, were reported by Brown (1973) and O'Connor (1956) who compared treading by sheep and cattle respectively on ungrazed and close grazed or mown swards.

On rangeland the distances walked by stock to water, to shelter and between mouthfuls are greatly increased, but treading effects are
less than on tame pastures. Two qualities of the vegetation further reduce treading: the tufted and tussock growth habit is more prevalent and in dry regions plant cover is discontinuous, so there is more incentive and opportunity for sheep to walk around and between larger plants.

Two situations are especially influenced by treading: the heavily tracked surrounds of water troughs in semi-arid flat range which Squires (1974) has mapped, and steep hillsides of preferred aspect. Radcliffe (1968) reported 11% of loessic hillslopes of 24° were occupied by sheep tracks and up to 40% of mudstone slopes of 37°. Dislodgement of soil from around plants by hooves and gravity would be commonplace if the tracks were not so comprehensive, but it must be remembered that the tracks would never have formed if the vegetation previously occupying the tracked area had not been killed.

2.24 Response to Nutrients

Decomposition pathways which include grazing animals increase the concentration of nitrogen and phosphorous in subsequent herbage produced (Floate, 1970). Of these nutrients, plus sulphur, which is also generally deficient in the high country, nitrogen is most easily lost and widely needed in the agrobiocystem. Unlike the minerals it can be volatilized or denitrified to and fixed from the atmosphere. Because of its fundamental incorporation in protein, nitrogen is needed by microorganisms during the decomposition of organic matter which mineralises the other nutrients. When available in excess it may be leached as nitrate and becomes a pollutant.

Most plants obtain nitrogen as soil mineral-N, the "pool" of which is mainly controlled in turn by the size of the soil organic-N pool and the soil carbon content (Hoglund, Crush, Brock, Ball and Carran, 1979). Legumes fix nitrogen in the measure that mineral-N uptake falls short of
their requirements (Hoglund and Brock, 1978). Trials in improved pastures throughout New Zealand discussed by Hoglund et al. (1979) did not support the common view that clover yield decreases as soil nitrogen availability increases due to increased competition from grasses in the sward. Rather, clover yield was found to be particularly responsive to summer rainfall (as is true in the high country when the adventive grasses are in post-flowing depression) whereas grass yields were relatively insensitive to climate except for winter temperature. These nitrogen parameters all gave significant correlations with measured grass yields: anaerobic mineral-N, organic carbon:nitrogen ratio and total soil-N.

In semi-arid grassland in North Dakota, nitrogen was eliminated as a growth-limiting factor by application of 300 kg ha\(^{-1}\) of nitrogen fertilizer (Power, 1970). The N-immobilising capacity of that soil was satisfied and two years later almost half the fertilizer nitrogen remained beneath the dryland pasture as mineral-N, a further 36% had meanwhile been incorporated in plant growth. From irrigated grassland 70% of the nitrogen had been utilized. In that environment leaching of nitrates was not encountered. There is a warning for similar natural environments, however, from Harlan (1956). Where moisture is the limiting factor to herbage production, artificial nitrogen is not likely to be helpful. Many range grasses (North American species) have a very narrow range of efficient nitrogen utilization and therefore there would be scope for invader species to establish while mopping up the surplus.

New Zealand agriculture is based on artificial phosphate (rather than nitrogen) which invigorates the nitrogen-fixing legume component of sown pastures so that the volume of cyclic nitrogen is enhanced. Grazing animals prevent excessive competition for light and nutrients from grasses and, most importantly, enhance the flow rate of cyclic-N by
partitioning most herbage nitrogen into the urine, and organic carbon into the dung. The high solubility and rapid plant uptake of urine-N allow multiple recycling of some nitrogen within a season (Henzell, 1968).

Mobstocking of topdressed plots at five high country sites in the Mackenzie (O'Connor and Clifford, 1966) demonstrated the striking effect on production of cycling all herbage-N through the grazing sheep for four years. The urine nitrogen compensated for the eventual decline in vigour of the clover (and decline in nitrogen increments through fixation) which was due to competition for nutrients from resident browntop, sweet vernal, Yorkshire fog, chewings fescue or Kentucky bluegrass (O'Connor, 1966). However at Tara Hills (the driest site) heavy grazing in the years following clover establishment was of little benefit because of increasing moisture competition from the resident cocksfoot.

Of the main pasture nutrients ingested by sheep, about 11% of the phosphorous is eventually removed in animal products, 5% of nitrogen and 1% of potassium (Gillingham and During, 1973). The transfer of nutrients in this experiment indicated the central ridge crest was to be avoided in future topdressing operations. The recommendation of Mauger (1977) for North Island hill country is to omit the lower third of the paddocks when applying superphosphate, but to apply more than the base rate to shady faces where these can be effectively grazed. Suckling (1959) recorded differences in annual herbage production of about 10,000 kg ha⁻¹ or 110% between stock camps on both sunny and shady aspects and the nutrient-donating hillsides.

Close grazed swards induced locally in the high country by the camping activity of ruminants have been related to biologically active mull-type soil conditions by O'Connor (1977a), using the evidence of Stevens (1977) and Harris (1978) from humid New Zealand range which paralleled the Scottish highland experience of Nicholson (1974). Such
short grass swards reminiscent of intensively managed pasture are stable under grazing compared to humid mor-type range and semi-arid grasslands. Succession has been deflected in favour of zones of "disturbance climax" (Dasmann, 1972) which may be degraded by stock tracks and durable dicotyledonous weeds only under extreme use. The Scottish two-pasture system developed to improve the nutrition cycle of ewes (Eadie, 1971) has arisen from observed pasture response to nutrient and grazing distribution. Pastoral developers in New Zealand also have the opportunity to emulate or apply the stock camp example of intense sward nutrition coupled with intense utilization to oversowing, topdressing or fencing strategy and all-importantly, the subsequent management.

2.3 MEASURING HILL PASTURE PARAMETERS

2.31 The Supply of Available Dry Matter

Radcliffe, Dale and Viggers (1968) wrote "very few assessments of pasture production on hill country have been made" and "the authors do not know of any estimates from steep hillsides with broken topography". Radcliffe et al. recorded pasture production at three and six weekly intervals on such a site at Whatawhata using both the trim and difference techniques. Yields did not vary significantly due to slope or sheep tracks. The trim technique, which more closely simulates hard grazing by sheep, measured 60% more available dry matter than the difference technique after 48 weeks. Similarly, three-weekly cutting yielded about 15% more herbage than six-weekly, using either technique. The 2.2 ha paddock measured was so diverse as to accommodate six groups of terrain which produced between 3,300 and 7,800 kg ha⁻¹ ADM during the trial.

Further investigation of the trim and difference techniques was carried out on improved hill paddocks at Cooper's Creek and Geraldine (Radcliffe, 1971). The recognised peaks and depressions in seasonal
production were emphasized by the trim technique. However, the per cent standard errors of the samples in each growth period were highly correlated \((r = 0.8)\) with mean yield during the same period. No such relationship was found for the difference technique. In May and July decomposition of herbage gave rise to some negative results from the difference technique underlining the need to distinguish between maximum gross aerial growth (Morris, 1970) and harvested yield, which is net aerial growth above cutting level at that point in time. Trimming plots to ground level, rather than reel mower height as is possible on flat and rolling pasture, permitted only clover and flatweeds to make regrowth during dry periods at Cooper's Creek and yet any mowing is artificial. Close grazing seldom reduces the assimilating leaf bulk so immediately and drastically as mowing (Klapp, 1938).

To increase sensitivity and allow measurement over short regrowth intervals the response surface method, which allows daily estimates of pasture growth, has now been adopted in New Zealand (Hoglund and Brock, 1978; Hoglund et al., 1979). Ten self-contained paddocks are grazed in rotation. At 2-3 weekly intervals all except the paddock currently containing sheep are measured with an electronic capacitance probe and a single \(0.26 \text{ m}^2\) cut is made of herbage yielding close to the mean of 20 readings/paddock. The prediction equation is a comprehensive polynomial which includes time of year and days since grazing.

Visual estimates of pasture yield make efficient use of the accumulated experience of agronomists. Height is likely to influence the operators at the expense of density (Campbell and Arnold, 1973). The dry-weight-rank method of 't Mannetje and Haydock (1963) estimates the three most numerous species from a number of quadrats in terms of dry weight, and applies constant multipliers so that a maximum of 70.2% composition can be resolved for a dominant species. The comparative
yield method of Haydock and Shaw (1975) is also based on dry matter so both are applicable to rangeland containing dead forage. The latter method rates the yields of random quadrats with respect to a set of 5 or 9 quadrats preselected in the field to provide a reference scale during sampling. Estimates of mean yield were generally within 4% of the actual mean. Haydock and Shaw found the variability of the population was the main problem rather than precision with individual estimates. This would be especially so in hill pastures.

2.32 Utilization of Available Dry Matter

Animal output is the final output in deciding the efficiency of grazing management systems, but it cannot be the sole criterion because it seldom provides reasons for the differences between systems (Campbell, 1961). Only concurrent pasture measurement can uncover differences in pasture utilization and so this must be the final arbiter in deciding the efficiency with which forage is recognized and consumed by the stock.

Intensive utilization of dairy pasture by strip grazing can reach 92% of herbage above grazing height (Greenhalgh, 1970). Intake at this level was 11.4 kg DM/cow/day, whereas at 58% utilization each cow could consume 20.4 kg DM/day. Single grazing utilization of improved pasture by 15 cows/ha was 53% during lactation and 61% when on maintenance rations (Thomson, 1977). Traditional management of Scottish hill ewes results in 15-20% utilization of available herbage (Newbould, 1974). Scott and Maunsell (1974) were unable to obtain reasonable estimates of utilization on the hill blocks at Ribbonwood except on the best sections of the developed blocks. Tussocks and matagouri hindered the placement of cages and variability, slow growth and coarse texture were all problems in comparing ADM inside and outside.
Korte and Sheath (1978) proposed net live herbage as a more relevant parameter than net ADM when considering "harvested" or "harvestable" production by an agrobiosystem. Available dry matter can prove a misleading parameter in research where treatments possess different rates of dead matter accumulation or loss due to different utilization levels or canopy structures, particularly if the grazing animals will not eat dead herbage. Certainly in the high country most of the tussock species which so often visually dominate the biomass can only be regarded as incidentals in the diet of sheep because the dying leaves successfully protect the emergent leaves and because of the low mineral content, associated with too much cell wall.

Systems thinking must recognise possible benefits from herbage that dies before it is eaten. Morris (1970) suggested the sacrificial transfer of nitrogen and phosphorous from senescent leaves to the youngest leaves. Standing dead matter can be a feed-buffer in times of drought or snow and while in reserve it will help insulate younger growth from frost damage (Eadie and Black, 1968; cf. Williams, 1977).

2.33 Grazing Pressure

Grazing pressure is an integrative or omnibus parameter. Its great value is to indicate the stress under which both pastures and animals are operating (Smetham, 1975). Contradictory results of grazing management experiments are often explained by variations in grazing pressure. Only where grazing pressure is high enough to limit growth substantially for an important proportion of the year is controlled grazing likely to be beneficial (Morley, 1966).

The objectives of grazing management are to foster a stable biological system from which maximum profits can be obtained while minimising animal stress (Morley, 1966). Herbage production is not to
be constrained merely to match the nutritional requirements of livestock. Mott (1960) even urged that grazing pressure be equalised by artificial "put and take" on all treatments in grazing experiments: "no one would think of charging the unconsumed feed to the animals in the dry lot and yet this is precisely what is done in the grazing trial when the pastures are not grazed to their carrying capacity and the animal product is expressed on a unit-area basis." The disadvantage of this proposal is that such research would be ill-suited to adoption by farmers (cf. Morley and Spedding, 1968).

Other warnings about experimental design have been made by Brougham (1970). A strict rotation should not be followed regardless of pasture conditions. Management of different stocking rate treatments should be flexible. Continuous and rotational grazing trials have often erred in failing to compare differences in utilization of the feed produced, particularly where various conservation policies have been included in the design.

Grazing pressure as expressed by Campbell (1966a) included grazing days and spelling days so that seasonal and annual calculations of grazing pressure could be made for controlled and uncontrolled grazing systems stocked at different rates. The concept is used in rangeland in its simplest form - "the actual animal to forage ratio at a specific time" (Kothmann, 1974; Mott, 1960). This expression is conveniently applied to seasonal set stocking but its validity must be related to managerial wisdom concerning the grazing distribution of the stock and intelligent appraisal of forage which in hill country is so often diluted by tussocks, scrub and rock.

2.34 Coping with Heterogeneity

Hill management decisions are compromises because the parameters on which they are based are not uniform even within paddocks.
"Management skills and attributes make a 70% contribution to success in hill farming as compared to the 35-40% generally accepted in other agricultural and pastoral endeavours" - Mauger (1977).

Cook (1966) studied the use of slopes by range cattle for three summers in Utah. Some of the variables affecting utilization of the slope grasses were: per cent use of (lower) slope adjacent to bottom land; maximum slope gradient from site to water; per cent use of valley bottom immediately below the site; and maximum gradient from site to salt-lick. These variables were consistent for those stocking rates which utilized 35, 70 and 90% of the preferred bottom lands.

Most sheep breeds are better adapted to hill grazing than cattle. However, the Glenthorne half-breds of various classes, observed by Harris (1978) decreased in numbers from the low altitude flat lands through the downlands and mid-altitude vegetated slopes so that fewer than 10% ever entered the areas of rocky bluffs and high altitude screes. The majority of the sheep grazed in the vicinity of the wetter areas which included heavily utilized lowland "swamp" and springs in the two high basins.

Gillingham (1973) measured some decline in total dry matter as slope increased, particularly in spring, on south faces. Slope explained about 20% of variation in yield. Despite large temperature differences, production on north slopes at Whatawhata of 7.1 t DM ha⁻¹ was almost matched by south faces at 6.4 t DM ha⁻¹. Under less even rainfall which is more typical of the South Island, shady faces are likely to produce more herbage. Radcliffe, Young and Clarke (1976) measured a 14% difference in favour of a shady face over a sunny face for three years on improved browntop dominant pastures at Cooper's Creek. Sixty-four sampling sites were used, positioned randomly within soil units. The areas studied were small enough to allow even utilization through
flexible stocking rates on each aspect, thus the digestibility of both pastures was kept similar. Available dry matter, as measured fortnightly, was usually above 500 kg ha\(^{-1}\). Annual pasture production by monthly trim technique ranged from 3.5 to 7.4 t ADM ha\(^{-1}\).
CHAPTER III

REVIEW OF LITERATURE

PART II: THE DEVELOPMENT OF CAPACITANCE METERS FOR MEASURING PASTURE

The principle of measuring changes in capacitance to obtain the moisture content of test materials was first extended to vegetation in 1949. This forerunner of the current New Zealand instrument, "Charlie", used in the present study, and of similar capacitance meters developed in Europe, USA and Australia, was first used in American rangeland, by Fletcher and Robinson (1956). The first instrument to use sets of positive and negative probes rather than a measuring head of parallel plate electrodes was developed at Ruakura (Campbell, Phillips and O'Reilly, 1962).

3.1 INSTRUMENT DESIGN

Slender metallic probes are arranged vertically in rows, or rakes, by attachment to an upper frame. Each probe, however, is fully insulated, being linked only to the other probes of the same polarity. The electronic circuitry is usually housed in a box on top of the supporting frame. The principle components are two identical transistor oscillators, one of which is connected to the probes so that the radio frequency generated is altered by the dielectric constant of the standing herbage when the instrument is placed on pasture. Photographs of five diverse capacitance meters are included in Neal and Neal's review of the development of this measuring technique (1973).
3.11 Electronic Circuitry

The instrument used in this study is a copy of the Charlie described by Nichols (1973). The meter incorporates a radio frequency bridge of 5MHz standard frequency. The power source of six size C zinc-carbon or nickel-cadmium cells is modified to 4.7 volts by means of a voltage stabilizer. Full deflection (50μamp) on the fine scale is equivalent to 15 pF capacitance and on the coarse scale the response is somewhat curvilinear so that full deflection occurs at about 45 pF.

The first generation capacitance probes in New Zealand used a heterodyne system whereby the measuring and reference circuits were separate instruments and the operator matched the two by matching the radio signal received by his headphones. This system, with improvements, was also tested in New South Wales by Johns, Nicol and Watkin (1965) and in England by Back (1968). The Fletcher and Robinson (1956) instrument also featured a separate recording instrument but capacitance was then derived by matching mutual impedance.

Overall, variations on the radio-frequency bridge design have proved the most satisfactory (Alcock, 1964; Dowling, Spenser and Bouma, 1965; Neal and Neal, 1966; Alcock and Lovett, 1967; Van Dyne, Glass and Opstrup, 1968; Jones and Haydock, 1970; Nichols, 1973; Currie, Morris and Neal, 1973; Neal, Currie and Morris, 1976). Some commercial models now available incorporate digital displays and sophisticated circuits to minimize signal drift. The reference frequencies chosen for the oscillator circuit have been in the range 2-7MHz. The choice must always be a compromise because at low frequencies signal strength is impaired but with increasing frequency, capacitance is reduced in proportion to the square of the frequency and conductance increases (Neal and Neal, 1973).

Hyde and Lawrence (1964) elaborated on the significance of
conductance which had previously been a problem when probes had only been insulated by a coat of varnish (e.g. Alcock, 1964). Changes in "capacitance" are due to: (1) the dielectric properties of the fresh herbage, and (2) the plants acting as part of a circuit when leaves come into contact with insulated probes. The second effect is usually more important than the first, except where short pasture or stubble is measured. Even where plants are spaced, leaf-root-soil-root-leaf "loops" (Back, 1968) may permit conductance.

3.12 Probes

By using probes instead of plates, several individual capacitances are measured and pooled. Thus the distorting effect of isolated clumps of grass or protruding clods is minimised (Campbell et al. 1962). Most of the instruments described in the literature had from nine to 30 probes ranging in height from 12.5 cm (Lovett and Burch, 1972) to 90.0 cm (Jones and Haydock, 1970). Large numbers of probes may add stability, but they also detract from robustness and cause too much compression of vegetation in some types of sward, e.g. clover (Alcock and Lovett, 1967).

Since probes became standard, the main advance in design was the replacement of parallel positive and negative series of rakes with concentric rakes by Van Dyne, Glass and Opstrup (1968). Previously the cutting frames used to enclose the measuring head when direct double samples were required had commonly included a perimeter-strip five to eight centimetres wide outside the probes to allow for lateral interference by adjacent herbage (e.g. Campbell et al., 1962). Concentric rakes measure to a better defined boundary, viz. the outer ring of negative probes, so that the cutting frames used with the current New Zealand capacitance meters (Nichols, 1973) enclose the same area as the measuring head.
3.13 Insulation

Probes were usually insulated with PVC or polythene. Separator bars in the frame employed "Tufnol", perspex, lucite or other plastics. Substantial errors were reported when tall vegetation protruded through the top of the measuring head (e.g. Lovett and Bofinger, 1970), so Neal and Neal (1973) and Jones and Haydock (1970) both designed closed heads. Lovett and Burch (1972) used two spaced horizontal sheets of perspex.

The main variations in insulation design have occurred at the tip of the probes and support legs which usually double as probes. Campbell et al. (1962), Dowling et al. (1965) and Neal et al. (1976) all used five centimetre insulative pegs. Alcock and Lovett (1967) used 3.8 cm pegs; Jones and Haydock (1970) used 1.5 cm, and Nicholls (1973) used 0.3 cm, plus 1.2 cm ground clearance which improves the stability of the instrument. There is no consensus in the literature regarding the ground clearance required to obviate below-ground interference, although it is often corrected for when the meter is preset to zero. Only Neal and Neal (1973) have published isograms to indicate the lateral and basal fields of influence of two particular capacitance meters.

3.2 CALIBRATION

At present the capacitance probe is probably the best agent in pastoral agronomy for rapid and non-destructive measurement of the amount of succulence in herbage. The "mean" samples located for cutting are representative for this quality. The operator must ensure that the samples are also representative with respect to phenology and taxonomy.

3.21 Background

Calibrating for background factors of soil moisture, humidity and ambient temperature is usually carried out at each sampling site. This
process is referred to as 'zeroing' the instrument.

Of twenty-one papers which examined the technique of pasture estimation using capacitance probe meters, only nine described the method used to preset the instrument. Closely clipped ground was used in four cases, bare ground in three, and sheet metal twice. Harris (1978) working in steep rangeland zeroed the capacitance probe while suspending it in mid-air.

3.22 Regression

In the nineteen sixties workers everywhere tested the various capacitance meters in many pasture types to find a general regression equation whereby meter readings could be used to predict available dry matter.

Fletcher and Robinson (1956) measured a wide variety of western American range and presented separate graphs for forbs plus lush grass, and all grasses except "soggy wet".

Campbell et al. (1962) carried out 15 calibration trials on pasture of 11-39% dry matter from which samples were meticulously cut. The capacitance meter predicted 90% of the variation in weight within trials. Alcock (1964) measured 15 sward types in North Wales and derived linear regressions for each. Johns and Watkin (1965) obtained regressions of dry matter, fresh material and total water from eight swards including lucerne and oats of 20% DM and natural pasture of 52% DM. In the latter case, only 60% of the variation in dry matter, but 83% of the water content, was accounted for by the capacitance readings.

Dowling et al. (1965) measured Australian subterranean clover pastures, both wet and dry. Alcock and Lovett (1967) included hill swards and badly lodged pasture. They improved most of their regression series by including the herbage water to dry matter ratio (w:DM). Back
(1968) subsampled ryegrass white clover pasture at Hurley for dead herbage and concluded double sampling to be an ongoing necessity.

Back, Alder and Gibbs (1969) sampled improved pasture before and after rotational grazing with lambs. Their data implied that any gain from taking more than 25 meter readings/cutting site is negligible and the benefits of speed and non-destruction conferred by the capacitance technique fall off rapidly if the number of herbage cuts/site is greater than five.

Bryant, Parker, Cook and Taylor (1971) measured intensively grazed dairy pasture at Ruakura each month for two years. Ten samples were cut from each of four levels of production estimated visually but only dry weights were recorded. On this basis only half of the within paddock regressions with meter reading were significant at the five percent level, and so the technique was first brought into disrepute.

Lovett and Burch (1972) found freshweight the best regressor with meter readings (initial minus 2 cm stubble) of four grass monocultures. Smith (1974) made 112 readings and cuts on oats in Victoria. However, he rejected the technique because of excessive heterogeneity of regression between cultivars of that one species.

Neal et al. (1976) confirmed that a ratio of one cut to five capacitance readings is a reliable starting point for measuring perennial range, and 1:10 for annual species. The cuts were made to 2 cm and the herbage was weighed in the field.

Jones, Sandland and Bunch (1977) concluded that visual estimates of tropical pasture in Queensland were as effective as those predicted from capacitance regression relationships. The correlation coefficient for dry matter was significantly improved when green herbage only was dried, but herbage water was the best correlate.

Johns (1972) included seven methods of calibration for regression
in a comprehensive evaluation of capacitance methods. Johns found that "a major source of error with the regression dependent techniques is that no matter how many samples are taken from some plots, the mean meter reading and yield values for the plots will remain remote from the line of overall best fit."

3.23 Sampling the Mean

The consensus of the literature that "double sampling is necessary" has arisen because the relationship between herbage water and dry matter cannot be adequately projected through growth stages and between species so that general predictive equations can be established. Within any one pasture at any one time, however, there is a very strong linear relationship between yield of herbage water and meter reading. This knowledge was exploited by Jones and Haydock (1970) who presented a new method of sampling the mean to overcome the bias associated with prediction equations. The mean meter reading was obtained from 75 random samplings/hectare, then the herbage was cut at three positions giving the mean reading. Although the three cuts gave no information about the variation within a paddock, the meter readings themselves gave a measure of variability.

Stephen and Revfeim (1971) compared the Jones and Haydock capacitance technique with cage and random quadrat methods on sheep and cattle pastures at Invermay. The results were inconsistent, partly due to inadequate estimation of clumps of higher yielding herbage. Powell (1972) was more successful in applying the Jones and Haydock method to English ryegrass-white clover pasture.

Johns (1972) modified the method by choosing to simply cut herbage close to, rather than exactly equal to, the mean meter readings and to scale the mean of the three cuts accordingly. On the basis of three cuts/site the root mean square of deviation of estimated from
expected yield was about 150 kg ha\(^{-1}\) for this method, but in the range 230-480 kg ha\(^{-1}\) for seven regression-dependent methods.

3.3 BIAS

Improvements in design have eliminated two sources of bias. Changes in temperature were once an often mentioned source of error, but the meter circuitry now used is self-compensating. Secondly, the dielectric of the operator's legs no longer causes interference to instruments with concentric probe configuration (Nichols, 1973).

3.31 Phenology

Capacitance is proportional to the dielectric properties of fresh herbage. The dielectric constant (\(E'\)) of water is about 80, but of dry herbage only five (Mitchell, 1972). There is often, however, positive interaction between the two materials in living pasture. Two effects operating at the radio frequencies used in the technique are outlined in Jones and Haydock (1970):

1. Water plasticizes the cellulose molecules, increasing their mobility, and dielectric constant.
2. The water and salts constituting the plant sap are a conducting solution which increases the dielectric constant through interfacial polarisation.

This means the combined \(E'\) increases as greater amounts of dry matter are incorporated with the same amount of water. Conversely the \(E'\) of herbage of less than 30% DM is relatively less through dilution (e.g. Fletcher and Robinson, 1956). Jones and Haydock (1970) advise there should be no delay in taking sets of herbage cuts so as to avoid errors associated with diurnal changes in plant water content.

The bias most visibly associated with phenology is standing dead
matter in pasture which contributes very heavily to dry matter results, often without significantly affecting the meter reading obtained beforehand. The best capacitance probe estimates of pasture can be expected during periods of active plant growth following efficient utilisation of earlier herbage by grazing animals. However, both the meter and livestock discriminate against dry and dead matter (Johns and Watkin, 1965) so that capacitance-based estimates of grazing pressure in heterogenous pasture may in fact be less biased than estimates of available dry matter. Such estimates of grazing pressure could be defined in terms of available digestible dry matter (cf. Stevens, 1977; Harris, 1978).

The responsiveness of capacitance probes to various spatial arrangements of herbage was measured by Jones and Haydock (1970) in a setaria-paspalum-white clover sward. Undisturbed, the pasture was 33 cm high and the meter reading was 42.9 µA; when compressed to 19 cm to simulate lodging, 36.8; when cut and tied in four sheaves which were variously suspended, spaced vertically or horizontally, the readings fell to between 23.5 and 18.5. Finally the four sheaves were combined vertically in the centre of the measuring head and gave a reading of 17.0 µA.

Currie et al. (1973) studied cutting procedures and the effects of standing dead matter on capacitance probe estimates. They proved that the logical method of cutting three dimensionally all herbage subtending the measuring head, rather than material rooted in the measured area only, was indeed superior.

The upper limit to the quantity of standing herbage which could be accurately measured by capacitance instruments has seldom been studied, but Alcock (1964) did mention 3850 kg ha⁻¹ as the ceiling for accurate estimation using a measuring head with varnished probes.
The same author found that yields less than 550 kg ha$^{-1}$ were underestimated.

Lovett and Burch (1972) designed an instrument with 12.5 cm probes and sensitive circuit components specifically to measure herbage in the range 0 - 1100 kg ha$^{-1}$ which they suggested was inadequately sampled by previous designs. Quadratic regression equations of the form:

$$mr = a + b.FW + cFW^2 + d.FW/DW$$

(where the variables are meter reading, fresh weight and dry weight respectively) were found consistently to explain between 88 and 96% of the variation in yield of four individual grass species.

3.32 Dew and Soil Moisture

Campbell et al. (1962), Dowling et al. (1965), Alcock and Lovett (1967) and Lovett and Bofinger (1970) all measured wet or dew laden herbage during data collection and found the results to be acceptable. Johns and Watkin (1965) specifically investigated both dew and soil moisture effects on capacitance readings. In grass dominant pasture a heavy (0.2 mm) dew caused 6% over-estimation of dry matter. This value would be expected to alter according to the surface morphology and spatial orientation of the herbage. Jones and Haydock (1970) saturated herbage and thereby increased the meter reading from 19 to 23 µA.

Interference due to soil moisture is successfully corrected for by zeroing on bare or close-clipped ground beforehand (Johns and Watkin, 1965). However, damp clods or hillocks protruding between, or disturbing the probes during sampling, constitute a source of error. The meter tested by Jones and Haydock (1970) did not respond significantly when the soil beneath was saturated.
3.4 POTENTIAL USES

The general use to which capacitance meters can best be put in pastoral research is to quickly obtain the mean water content of herbage. Indeed seasonal predictions for this parameter seem to be feasible: Johns (1972) suggested that the use of herbage water to dry matter ratios (which can be established for pasture types from several "grab" samples) may enable data from differing pastures to be included in a single prediction equation. Progression or extrapolation to the traditional standard, available dry matter (ADM), is not the best end point of the technique. The yield of digestible dry matter is a derivation which is more compatible with the capacitance principle and the structure of forage plants.

Clarke (1977) carried out a preliminary investigation of the ability of the capacitance probe (Nichols, 1973) to predict total digestible dry matter, as an adjunct to his Ph.D. study of herbage quality in Canterbury hill and high country. He measured ten samples each of clover dominant and grass dominant lowland swards, eight samples of lucerne (all on 4/2/76) and a total of 32 pasture samples from unimproved high country (on three dates). The overall correlation coefficients of meter reading with herbage water, digestible dry matter, and available dry matter, were 0.92, 0.84 and 0.72 respectively.

One special use for capacitance meters was suggested by Campbell et al. (1962): "The measurement of pasture management and of fertilizer responses on steep hill country could be undertaken, where now the difficulty of sample cutting precludes anything but subjective estimation." The present study was one step in this direction.

Lazenby and Lovett (1975) used a capacitance meter in a large scale production trial to estimate when regrowth was slowing and therefore ready to be cut again. Grab samples for percentage dry matter
were also taken as a check. Such non-destructive monitoring of phenology during active growth is very ably performed by capacitance meters.

The only other plot and field-scale electronic technique for pasture measurement has been based on the absorption by herbage of beta radiation. Mitchell (1972) described prototype equipment which was tested in American rangeland but as yet there are no reports of adoption of the technique for evaluation.

Remote sensing by the multi-spectral scanners of Landsat satellites offers the possibility of monitoring ground cover on a regional basis (Ellis, 1977). The smallest unit of measurement will, by 1981, be 30 x 30 m. Calibration with ground conditions can be obtained by using a hand-held radiometer. However, this technique is dependent on clear skies and the time lag in obtaining the satellite output would be unacceptable to some grazing management processes.
4.1 GENERAL DESCRIPTION OF TARA HILLS

Tara Hills High Country Research Station is a substation of the Ministry of Agriculture and Fisheries (MAF) research centre at Invermay near Dunedin. Tara Hills is seven kilometres from Omarama in the Upper Waitaki and 127 kilometres from Oamaru. It was taken over by the Soil Conservation and Rivers Control Council in 1948 as an example of a very depleted, rabbit infested run. Stock numbers were at first reduced while topdressing, oversowing and irrigation were carried out on a wide scale. Carrying capacity had more than doubled when control passed to the MAF in 1966, and by 1971 stock numbers had again doubled to more than 6,000 sheep and 350 cattle (Cullen, 1971).

4.11 Topography

Tara Hills is 3340 ha in area, of which 2672 ha is hill country and steeplands ranging in altitude from 520m to 1530m, and 688 ha is alluvial fans and flats decreasing to 450m. The southwestern boundary runs directly along the divide of the Ewe range from the 1530m contour to the Omarama Stream. The bulk of the hill section comprises ridges running out to the northeast. The flats are on the fringe of the extensive Red Flat but have been modified by alluvial fans or the Omarama Stream near the northwest boundary. The property is subdivided into over 100 paddocks. Most of the hill blocks are separated by fences down each ridgeline so that they contain both shady (SE) and sunny (NW) hill faces divided by long narrow gullies.
4.12 Climate

The climate is semi-arid with cold winters and warm summers (O'Connor, 1976a). Mean annual rainfall since 1949 is 533mm (summer maximum) and open pan evaporation is 1036mm (636mm during November-February inclusive). Hours of bright sunshine are 2106 compared with 2278 at Lake Tekapo and 1931 on the east coast at Oamaru. The mean air temperature in summer is about 15° and in winter 3°. The earth temperature at 10 cm depth is above 5° for 220 days at the climatologic station (488m) and 160 days at the highest MAF meteorological site (1311m).

Detailed climatic information is collected daily from the station at headquarters and in addition weekly measurements are made at pairs of sunny and shady exclosures at 530m and 840m, access permitting.

4.13 Geology and Soils

The Ewe Range comprises non-foliated chlorite (subzone 2) semi-schist of the Haast group (Mutch, 1963). The flats were derived from glacial outwash fans from the Ahuriri River. A small area of dark arkosic sandstone occurs on the property northeast of the Otematata Fault.

The soils on Tara Hills have recently been remapped by DSIR Soil Bureau with reconsideration of pedogenesis. It was decided to apply the subhygrouss classification to all of the drier soils although some are intermediate between Yellow-grey Earths and the subxerous Brown-grey Earths of Central Otago (K.R. Dreaver, Soil Bureau, pers. comm.). Ephemeral plants associated by Taylor and Pohlen (1962) with subxerous soils include Trifolium arvense and Bromus tectorum which are favoured on some of the low hill country. However, the continued survival of Dactylis glomerata and Lolium perenne in the same environment is evidence of a somewhat kinder soil water regime. Subhygrous soils are likely to
be below field capacity for more than five months of the year and below wilting point for one to five months (Taylor and Pohlen, 1962). Within this moisture range there are difficulties in maintaining white clover (*Trifolium repens*) in the pasture.

Soils derived from colluvial and scree deposits are classified with those of the floodplains as recent soils. The fan soils and the hill soils are Upland Yellow-grey Earths. Soils on the rolling high country and highest steeplands are hydrous and dry hydrous High Country Yellow-brown Earths.

4.14 Vegetation

On the irrigated flats ryegrass and white clover have replaced fescue tussock and sheep sorrel. Dryland lucerne has been established on some of the fans.

The hill country below 900m (particularly the study area) could best be described as restored or artificial tussock grassland rather than "improved" range. By 1949 the scabweeds (*Raoulia* spp.) were the only significant contributors to ground cover. Since then scattered fescue tussocks have survived in some shady and high locations and blue tussock has spread in all such areas. Adventitious silver tussocks have established on most sunny faces and in the gullies. Matagourie is the most common shrub.

Narrow leaved snow tussock (*Chionochloa rigida*) first appears at 900m and is the dominant plant above 1100m. *C. macra* occurs at the highest elevations.

In 1971 Cullen estimated that in ten years Tara Hills could grow sufficient pasture to support about 4.2 stock units ha$^{-1}$. Since then the area of irrigation has doubled and the proportion of the property oversown and topdressed has risen from 50% to over 90%, but the overall stocking rate has only increased from 2.3 to 2.6 s.u. ha$^{-1}$ in eight years.
Grazing management has not fully kept pace with Cullen's other requirements for progress. However the practice is complicated by the need to monitor animals involved in several production experiments.

4.2 DESCRIPTION OF THE STUDY AREA

Three hill blocks which once made up most of the original Tara Hills hogget block* were chosen because of complementary aspects and periods of grazing, and good access. The lie of the land was also considered with a view to observations of sheep distribution throughout each block but this criterion was not adequately satisfied.

4.21 Topography

The terrain and aspect of the study area are illustrated in Plates 1 and 2. Schistose outcrops are numerous particularly on the sunny face of block 60 seen in the upper centre of Plate 1. Matagouri is visible in most of the gullies which curve to the left in their upper reaches beneath the divide of the lower Ewe Range. The uppermost fence-line in Plate 2 is part of the boundary with Berwen Station. Beyond this line the southwest ridges descend abruptly to the plain. The high country access track is clearly visible in Plate 2. The station headquarters are located beyond the lower right-hand margin at about 1 km distance.

4.22 Climate

Sunny and shady meteorological sites are maintained near the top of blocks 60 and 61. Weekly weather readings during the growing season of this study are presented in Appendix 1.

* The entire property was once part of the ewe block of Omarama Station, hence the naming of the Ewe Range.
Plate 1: Oblique aerial view southwest over the study area, 1949, L-r blocks 62, 61, 60 and 59.
Plate 2: Recent aerial photograph of the study area with fencelines of blocks 60-62, land unit boundaries and transect sites. (see Fig. 1)
Figure 1: Map of the study area showing blocks, land units and transect sites.
Figure 2: Soil map of the study area.
The monthly means derived from daily weather observations at the research station headquarters (488m) and monthly means from weekly records at the 850 and 830m sites were compared for the period August 1976 to May 1978. Grass minimum temperatures were about 2° higher at the sunny site than at the shady and hq. sites. Screen maximum temperatures were 1° higher than at the shady site but 2° less than hq. The 10 cm earth temperature was the same as hq. but 4° higher than the shady site. Rainfall was 22% greater than at hq. but rainfall at the shady site was only 6% greater, perhaps because of reduced exposure to wind-driven northwest rainfall. Open pan evaporation was 30% less than hq. but 10% greater than the shady site. Most of the study area, being intermediate in altitude, would fall within these climatic ranges.

4.23 Soils

The soils on the study area are mapped in Figure 2 and named according to the classification developed by DSIR Soil Bureau in 1978 (unpubl.). The Omarama Steepland Soil and Meyer Hill Soil mapped at the bottom of block 62 are on the northeast side of the Otematata Fault and so derived from sandwacke rather than schist. Both are dry subhygrous upland Yellow-grey Earths. Following are brief descriptions of the soils which developed on schist (Dreaver, pers. comm.).

**Tara Steepland Soils:** Dry subhygrous upland Yellow-grey Earth on northerly slopes exceeding 28°. A horizon 16cm brown, very friable, stony fine sandy loam. B horizon olive brown, firm, heavy silt loam which is often mixed with C horizon of extremely stony fine sandy loam.

**Berwen and Berwen Hill Soils:** (0-12° and 12-30° slopes respectively) Subhygrous upland Yellow-grey Earths. On southerly slopes above 700m. A horizon 14cm friable, very dark greyish brown, slightly stony silt loam. B horizon brown gritty silt loam with stones grading into a massive yellowish brown B horizon with weak fragipan, often
present on parent rock.

**McLay Steepland Soils:** Subhygrous upland Yellow-grey Earth on southerly slopes; related to the Berwen Soils. A horizon 14cm very friable, very dark greyish brown, stony fine sandy loam with coarse gravels and grits. Indistinct boundary with B horizon of dark yellowish brown, friable loose consistence, very gravelly silty loam. C horizon structureless light yellowish brown fine sandy loam matrix between gravel and stones.

**Corbies Soils:** Recent soils adjacent to foothills and derived from semischist colluvium and scree deposits.

4.24 **Development of the Vegetation**

A species list for the study area is presented in Table 1. The distribution of species among the land units described in Table 2 is presented in Table 3 on the basis of abundance and sociability of each species. Quantitative estimates of the fresh weight of significant pasture species in three seasons are presented in Table 6. The influence of the vegetation on the delineation of the land units is discussed in Chapter V.

Block 60 was first oversown in 1957 with clovers, cocksfoot and ryegrass. In 1966 the sunny faces were again oversown with cocksfoot (2.2 kg ha\(^{-1}\)) and 2.2 kg each of red and white clover. Fertiliser applied was 190 kg ha\(^{-1}\) superphosphate in 1957; 190 kg 400-sulphur superphosphate in 1965 and 125 kg sulphur superphosphate in 1969, 1972, 1975 and 1978.

Block 61 was first topdressed in 1955 and then topdressed and oversown in 1958 and 1961 together with block 62 from which it was fenced off two years later. Both blocks have been topdressed since 1969 at three yearly intervals with 125 kg ha\(^{-1}\) 200-sulphur superphosphate.
TABLE 1: A plant species list for the study area, arranged by families within classes.

* denotes introduced species

Class MUSCI

POLYTRICHINEAE

POju

Polytrichum juniperinum

GRIMMIACEAE

RHcr

Rhamomitrium crispum

Class FILICOPSIDA

PTERIDACEAE

PTaq

Pteridium aquilinum var. esculentum

BLECHNACEAE

BLpe

Blechnum penna-marina

Class SPERMATOPSIDA

Subclass ANGIOSPERMAE

(1) Dicotyledones

VIOLACEAE

HYal

Hymenanthera alpina

CARYOPHYLLACEAE

ARse *

Arenaria serpyllifolia

CEho *

Cerastium holosteoides

SCun

Soleranthes uniflorus

PORTULACACEAE

NEau

Neopaxis australasica
<table>
<thead>
<tr>
<th>Family</th>
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**PLANTAGINACEAE**

**BORAGINACEAE**

**SCROPHULARIACEAE**

**LABIATAE**

(2) Monocotyledones

**JUNCACEAE**

**CYPERACEAE**

**GRAMINEAE**
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<td>FEno</td>
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<td>FEru</td>
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<td>* Holcus lanatus</td>
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<td>Poa laevis</td>
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<td>Poa pratensis</td>
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</table>

4.3 Grazing Management

Until the mid nineteenth century the study area plus the adjacent block 59 was all one block which was used for raising the biggest flocks. This is still the most important one although the larger study area block 61, can now be used as a summer biggest block after utilisation by sheep during lambing.

From mid-April to early July, 1980, heifers are usually grazed on 62 and then on 60 until late September. They are then shorn and returned to 62 for a further month. During this time, 60 and sometimes 61 before joining the main flock up one of the inner blocks. Block 60 is spilted in January and early February before recovering up to 1000 weaned lambs. These are grazed until March before moving to 67 until gale weather occurs and then finally to 63 where the cycle recommences.

This pattern imposes annual stocking rates of 1.96 x 4.5, on block 63; 2.69 on 61 and 1.47 on 62. Younglings and two year-old heifers and sometimes briefly grazed on inner block in early spring to remove rank herbage from gullies and drainage outlets.
Three years was found by O'Connor and Clifford (1966) to be a satisfactory interval between topdressings in the dry environment of Tara Hills. However, they also found trebling the rate from 125 to 375 kg ha\(^{-1}\) superphosphate caused an increase in ADM of 1 tonne ha\(^{-1}\) over the three year period on a northeasterly hillside on the study area. Plots receiving only 125 kg ha\(^{-1}\) were estimated to have produced only 310 kg ha\(^{-1}\) ADM more than the untopdressed (but formerly improved) area after three years.

The total annual yields in the third year of O'Connors' trial were 1100 kg ha\(^{-1}\) without topdressing and 5800 kg ha\(^{-1}\) after an initial application of 375 kg superphosphate followed by periodic hard grazing.

4.25 Grazing Management

Until the mid nineteen sixties the study area plus the adjacent block 59 was all one block which was used for wintering the hogget flock. This is still the most important use although the larger shady face, block 61, can now be used as a summer hogget block after utilisation by ewes during lambing.

From mid-April to early July 1100 hoggets are usually grazed on 62 and then on 60 until late September. They are then shorn and returned to 62 for a further month. Finally they graze 60 and perhaps 61 before joining the ewe flock on one of the summer blocks. Block 60 is spelled in January and early February before receiving up to 1200 weaned lambs. These are grazed until March before going to 61 until cold weather comes and then finally to 62 where the cycle recommences.

This pattern imposes annual stocking rates of 1.96 s.u. ha\(^{-1}\) on block 60; 2.00 on 61 and 1.47 on 62. Yearlings and two year-old heifers are sometimes briefly grazed on each block in early spring to remove rank herbage from gullies and seepage areas.
CHAPTER V

PROCEDURES

PART I: SELECTION OF SAMPLING SITES

5.1 MAPPING LAND UNITS

The vegetation on the study area is extremely diverse in terms of species composition, ground cover, and proportion of new growth relative to old. To measure the available dry matter of the pasture adequately it was not sufficient to obtain Charlie readings of herbage water in each situation. The extent of each association had to be estimated so the appropriate progression from herbage water to ADM could be made for that area, or land unit.

In this study the land unit is that part of a particular land system located within a particular block. The land system was defined by Christian and Stewart (1953) as an area or group of areas throughout which there is a recurring pattern of topography, soils and vegetation. Speight (1968) discussed such land systems as assemblages of land elements, rather than of land units which he recognized as a transitional category employed for descriptive convenience. In Figure 1 the digits 1 to 4 indicate those land units which are part of a land system occurring on two or all the study blocks (and presumably elsewhere in the district also). Therefore the block number is used as a prefix to establish the locality of each land unit.
**TABLE 2: Description of land units**

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<th>Land Unit</th>
<th>Hierarchical label</th>
<th>Geographical label</th>
<th>Transect Land-Form Elements (after Speight 1968)</th>
<th>Effective Area</th>
<th>Rock Outcrops</th>
<th>Mean Aspect</th>
<th>Altitude</th>
<th>Vegetation</th>
<th>Soil Survey</th>
<th>Soil % Area of Block</th>
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1 Musgrave (1977)
2 Abbreviations see Table 1

M.A.S.R. indicates mean annual stocking rate.
At Tara Hills the durability and orientation of the rock has ordered the slopes and the extent to which these can receive direct sunlight. On some of the sunny slopes moisture is limiting so that the pasture tends to grow as spaced plants with much bare ground inbetween. Where the sward is complete however, defoliation at some aspects and altitudes is sometimes insufficient to encourage new growth to replace the old following grazing. The next four sections describe the hierarchy of topographical and pastoral criteria used to map land units within each block. The land units are described in Table 2.

5.11 Contour Concavity

This criterion was used to isolate, as a first step, all gullies and watercourses on each block into one land unit. Seepage zones, riparian areas and the small fans at the foot of gullies were also included on the basis of improved soil moisture status. This was due to reduced gradient and increments by translocation from upslope.

Despite their diversity of aspect, all of the hill soils are classified as subhygrous or dry subhygrous. The most significant difference between them is the enhanced moisture status afforded by drainage convergence, i.e. marked contour concavity within an arc of 20m or so (Tonkin, pers. comm.). To these moister areas were added small fans of recent soils which are beneficiaries of the drift regime and hence of somewhat higher fertility than the contributing slopes above them.

Soil types were not otherwise taken into account during the mapping process although the trans-Otematata Fault area was checked for differences in vegetation. Comparison of Figure 2 with Figure 3 which was obtained in the year following mapping of land units demonstrates that the land units are consistent with the underlying soil types.
5.12 Aspect

The shady areas 602, 612, 615, 627 and 628 (see Figure 2) were isolated. These range in aspect from 80-200° of true north (Table 2) and because of this bias to the east, temperatures will normally be lower (Geiger, 1950), because such slopes will be incident to direct sunlight in the morning when the ground is coldest and dew is often present, as a further heat buffer, or when fog is most likely to intercept sunlight.

5.13 Vegetation

Pasture types were noted on photocopies of oblique aerial photographs of the study area during the course of several traverses made on foot to identify significant gullies and springs. This work was completed in August 1977 with the exception of land unit 609 which was identified on the basis of vegetation differences compared to 601, in November 1977 after ADM measurements had begun. Festuca novae-zelandiae was present in the new land unit and Dactylis glomerata and Lolium perenne were absent.

Land units 603 and 623 were distinguished from 601 and 621 respectively because aspect became northerly and Lolium perenne displaced Dactylis glomerata in both cases.

The important species listed for each land unit in the vegetation section of Table 2 were identified in 10 m² relevés (one per land unit) during a validation exercise (see section 5.2) in early September 1978.

5.14 Landform Elements

This criterion was seldom specifically invoked but generally supported mapping decisions made on other bases. To distinguish 626 from 624, however, "landform elements", including altitude were used. Land unit 626 comprises cocksfoot dominant "basins" in the head of the
main gully between blocks 61 and 62 and in a tributary. Land unit 624 contains cocksfoot with many other species on riparian land extending right down the catchment.

The landform element descriptions used in Table 2 approximate those of Speight (1968) whereby hill crests are notably convex in either slope gradient or contour curvature. Hillslopes exceed 3° and foot-slopes are 2°-10° and qualified as to concave or convex contour curvature.

5.15 **Effective Area**

The plane area of each land unit was measured by planimeter using cutouts from an enlargement of the 1:12,300 aerial photograph which is reproduced as Plate 2. The planimeter values were then expressed as a proportion of the total block areas as calculated by a University of Otago survey party.

The loss of grazing area due to rock outcrops was then estimated. Significant rock outcrops were identified on a larger aerial photo (scale approx. 1:7500) and drawn on a tracing. These areas were then removed and the percentage decrease in area for each block measured by planimeter. The proportional losses on each land unit were then estimated by summing the outcrops in terms of the smallest area removed. The final estimates appear in Table 2.

Increases in plane land area due to slope were obtained for each land unit using the correction table in Anderson (1972). The mean slopes in Table 2 were each calculated from several replicates measured by dividers on the 1:63,000 topographical map (NZMS 1, S116, Lindis) in which Tara Hills occurs.

After subtractions were made for rock outcrops and additions due to slope were made to the plane areas, the effective area so obtained (Table 2) was usually only a little more than the original area and sometimes slightly less.
### TABLE 3: Abundance and sociability of plant species within 10 m² relevés on each land unit.

<table>
<thead>
<tr>
<th>Relevé No.</th>
<th>601</th>
<th>621</th>
<th>603</th>
<th>613</th>
<th>623</th>
<th>604</th>
<th>614</th>
<th>624</th>
<th>626</th>
<th>602</th>
<th>612</th>
<th>628</th>
<th>615</th>
<th>627</th>
<th>609</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Land element</strong></td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>H</td>
<td>T</td>
<td>T</td>
<td>W</td>
<td>T</td>
<td>H</td>
<td>H</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td><strong>Altitude (m)</strong></td>
<td>700</td>
<td>850</td>
<td>610</td>
<td>670</td>
<td>750</td>
<td>545</td>
<td>530</td>
<td>550</td>
<td>875</td>
<td>855</td>
<td>885</td>
<td>920</td>
<td>825</td>
<td>1040</td>
<td>885</td>
</tr>
<tr>
<td><strong>Aspect (°True)</strong></td>
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<td>270</td>
<td>11</td>
<td>68</td>
<td>0</td>
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<td>23</td>
<td>311</td>
<td>79</td>
<td>101</td>
<td>202</td>
<td>135</td>
<td>158</td>
<td>293</td>
<td></td>
</tr>
<tr>
<td><strong>Angle of slope (°)</strong></td>
<td>30</td>
<td>28</td>
<td>26</td>
<td>26</td>
<td>18</td>
<td>8</td>
<td>3</td>
<td>4</td>
<td>8</td>
<td>33</td>
<td>30</td>
<td>20</td>
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<td>4</td>
<td>13</td>
</tr>
<tr>
<td><strong>Bare ground (%)</strong></td>
<td>40</td>
<td>17</td>
<td>30</td>
<td>23</td>
<td>22</td>
<td>6</td>
<td>3</td>
<td>6</td>
<td>3</td>
<td>45</td>
<td>17</td>
<td>11</td>
<td>16</td>
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<tr>
<td><strong>No. of species</strong></td>
<td>21</td>
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<td>21</td>
<td>17</td>
<td>13</td>
<td>16</td>
<td>20</td>
<td>26</td>
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<td>18</td>
<td>15</td>
<td>18</td>
<td>17</td>
<td>19</td>
</tr>
<tr>
<td><strong>Soil type</strong></td>
<td>Ts</td>
<td>Ts</td>
<td>Ts</td>
<td>Ts</td>
<td>Ts</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td><strong>Vegetation phase</strong></td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
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<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
<td>A</td>
</tr>
</tbody>
</table>

**Short Tussock Grassland spp.**

- Th Bromus segetum
- H Lolium perenne
- H Echinochloa crus-galli
- H Poa laevis
- H Verbena thapsia
- Th Erigeron anisatus
- H Festuca rubra
- Th Bromus mollis
- H Notodanthonia spp.
- Ch Ozalia corinulata
- Ch Raoulia australis
- N Rosa rubiginosa
- Th Trifolium subterraneum
- H Bromus inermis
- Ch Coprosma spp.
- H Poa pratensis
- H Carex spp.
- H Trifolium pratense

**Widespread Tussock Grassland spp.**

- H Dactylis glomerata
- H Trifolium repens
- G Rumex acetosella
- Th Trifolium dubium
- Th Arenaria serpyllifolia
- Ch Achillea millefolium
- H Oxalis colchicum
- H Geranium sessiliflorum
- N Hesperantha alpina
- N Disaerea townsonii
- Ch Carex holarctica
- H Hypochaeris radicata
- Ch Solanum waikowhero
- H Agropyron exscorum
- H Poa colensoi
- H Aegility tetula
- H Festuca novae-zelandiae
- H Anthoxanthum odoratum
- Ch Rhanzectum ciliatum
- Ch Carex hirsuta
- H Luadula rupe
- H Hieracium praealtum
- Ch Raoulia suberosa

* * signifies adventive species. 1 after Speight (1968). H hill slopes, T concave foot slopes, W water course, C crest.

**Minor species:** *Chionochloa arenacea* 624(*+*); *Chlorella cardinalis* 624(*+*); *Cystophora fraseri* 628(*+*); *Dracocephalum austriacum* 626(*+*); *Agrostis sp* 624(*+*); *Arenaria serpyllifolia* 615(*+*); *Muehlenbeckia complexa* 624(*+*); *Repiera australis* 603(*+*); *Pimelea creophila* 627(*+*); *Polytrichum juniperinum* 61(*+*); *Phytophaga spherulata* 624(*+*); *Parasenecio officinalis* 624(*+*); *Verbascum virgatum* 603(*+*); *Muehlenbeckia axillaris* 626(1.3).
5.2 VALIDATION OF LAND UNITS ON THE BASIS OF VEGETATION

In early September 1978 the abundance and sociability of plant species in 10m² relevés temporarily sited on each land unit were recorded using the scale designed by Braun-Blanquet (1932). At the same time the species list (Table 1) was drawn up and the ground cover estimates appearing in Table 6 were made. The main objective however was to discern whether the botanical composition of fifteen communities in Table 6 was indeed different, or in which ways were the communities related.

The results for each land unit comprise the vertical columns of Table 3, which follows the form used by Connor (1961, 1964) in his extensive descriptions of the grassland types in the Mackenzie Country. The land units form a sequence of increasing shadiness and altitude from left to right and the plant species (with growth form and source indicated as by Connor) are ordered, within the short tussock grassland, and widespread tussock grassland categories, so that ubiquitous species occur first followed by those favouring sunny, intermediate, shady and finally elevated sites. Plants recorded in only one relevé have been relegated to the minor species list as there can be less confidence as to their actual distribution.

The main distinction made by Table 3 is between the species composition of sunny slopes and gullies - vegetation phase A and shady slopes and crests - phase B. Some differences within phase A were the unimportance of Festuca rubra in, and the virtual absence of Erodium cicutarium and Achillea millefolium from relevés 601 and 621. Notodanthonia was absent from the gully relevés 604, 614 and 624, but Poa pratensis was only found in these and in the transitional 626. An important distinction within phase B was that Agrostis tenuis was very dominant in 615 and 627 but absent from relevés 602, 609 and 628.
5.3 SITING THE TRANSECTS

When the project was planned it was intended that the grassland would be sampled by taking 25 Charlie readings at random positions within permanently marked 20m x 20m plots. After the first measurements in early spring 1977 line transects of these sites were adopted as the sampling locations. Some physical damage was thus avoided because most of the slopes are steep and repeated movement over the terrain would have affected results from subsequent random readings. The tendency to place Charlie so as to avoid tussocks where these occurred was eliminated by adopting the metre intervals on a taut 25m tape. This section now describes the site selection process whereby two transects ('a' and 'b') were located on each of the fifteen land units (Figure 1). The opportunity for replicating information through having a second transect on each land unit was prefered rather than mapping minority areas and multiplying land units in their own right, because an important objective of the project was to examine the Charlie technique itself.

5.31 Access

Vehicular access from base to the top of each of the study blocks was by a well formed four-wheel-drive track. Outward transport only was necessary so that often space was taken in either research or farm vehicles going up the hill track on other business.

Once on foot, however, the weight of stainless steel tube in the frame of Charlie, the altitude to be descended (more than 400m on each block) and the length of each block (2-3 km) all made it desirable that transects should be located to minimise back-tracking and traversing of gullies.

One block was to be measured each day so only on block 60 was it necessary to cross and recross the main gully system so as to visit both
shady and sunny aspects while still conserving altitude. On blocks 60 and 62, reaching the higher of the northerly aspect transects involved some climbing and in each case the main gullies were sampled last.

The starting point on each block was the track just below the boundary fence at the top of Figure 1. The transects were then visited in this order:

Block 60: 9a, 9b, 1a, 2a, 2b, 1b, 3a, 3b, 4a, 4b.
Block 61: 2a, 2b, 5a, 3a, 5b, 3b, 4a, 4b.
Block 62: (6a), 7a, 7b, 8a, 6b, (6a), 8b, 1a, 1b, 3a, 4a, 3b, 4b.

5.32 Variation within Land Units

Where possible the transects were located well clear of land unit boundaries so as to represent the core area rather than transitional vegetation; but the membership of any community is dynamic and some changes are inevitable within each area because biota always exist as continua. A boundary therefore is often only an imprecise dividing line near the middle of a zone of more pronounced changes.

Usually the more northerly member of each transect pair was sited somewhat lower for access reasons. Overall, transects were more often located in the lower two thirds of their land unit. Each transect was always located several hundred metres away from its pair to ensure adequate geographical representation of the land unit and the aspect of each was, on the hillslope land units, matched to the predominant aspect of the surrounding hillslope.

Often the floristic wealth of one transect could not be fully matched by its pair due to variations in altitude, aspect or soil moisture. For example the 'gully' transects in block 60 were located on sunny and shady fans; in block 61 in a steep gully and through an old channel on the main fan; in block 62 in a high gully and adjacent to the main watercourse.
5.33 **Orientation of Transects**

Both ends of the 25m transect lines were marked by a u-section galvanised fence dropper painted white ('dayglo' colours are better) and hammered into place.

Each line was gently inclined across the slope at such an angle as to avoid coincidence with any one sheep track or terracette between tracks but not so far from the horizontal that Charlie became unstable when placed perpendicular to the tape, i.e. the long axis of the machine was to approximate the hillslope. It was easier to start reading at the lower end of each transect and so climb slightly to the next metre mark than to work downhill.

5.34 **Relocated Transects**

When land unit 609 was designated the former 1a site became 9b and a 9a transect plus a new 1a were chosen. Also on block 60, 3a was moved slightly to the other side of the ridge and a more correct aspect (see Figure 1).

Other changes in November/December 1977 were made on block 62. Transect 6b was moved from near 6a to the other part of the land unit. 1a was moved from sparse vegetation opposite 8a to a more representative site north of 8a. 4b was moved slightly downstream after a heifer died in mid-transect. Cattle were also responsible for the bottom peg being displaced at 8a. A truly permanent transect would require a second peg beside the first, set very close to ground level.

5.4 **VALIDATION OF TRANSECTS**

Tests to verify that the transect pairs adequately represented the intertussock herbage on their respective land units were begun on 14 March 1978 on block 62. Available dry matter was then at the lowest
levels recorded throughout the study period. The 25 capacitance values at permanent transects were compared with those from three randomly placed transects either adjacent or on a similar hill face. Appendix 3 presents the data obtained for three transects in autumn before the exercise was deferred because of deterioration in the weather, and data from early spring for all transects on 60 and 62 plus the bottom transect on block 61. The mean of 25 meter readings (mr) and standard error are given for each transect, and the percentage difference of the permanent from the mean of the three random transect mr values, which combined are assumed to more closely reflect the herbage water everywhere on the land unit.

The three autumn results do not give confidence to the adequacy of the permanent transects in the dry conditions but in spring the mean of the 23 differences was only -6.0%. Although seven of these differences were larger than ±20%, coefficients of variation sometimes exceeded 100% in this experiment (e.g. members of the 621b comparison) and were usually greater than 50%.
6.11 **Background Capacitance**

Before each transect was read with Charlie, the instrument was calibrated to prevent contributions by topsoil moisture and ground level humidity to the recorded capacitances. Charlie was placed on a smooth patch of bare ground maintained adjacent to the 1m peg of each transect for that purpose and the meter was set to 10 and checked for stability before the pasture readings were begun.

Bare ground rather than closely clipped vegetation was chosen at all transects (except those on land unit 627) because typical pasture in that environment is dominated by discrete strongly tufted grasses and the bare soil between them. Smooth areas that could be closely clipped without killing much of the herbage and that were of only moderate slope so that Charlie could be left unattended without fear of overbalancing or sliding were unavailable. Ideally a new patch would be clipped on each sampling date, or topsoil freshly levelled, but on the hill slopes the patches were originally cut by spade and the gradient reduced so the instrument was stable. It was impractical to repeat such an operation a dozen times.

The 'zero-reading' was chosen as 10 originally to conform with a concurrent MAF project in which Charlie was used to estimate ADM on
block 66. In that situation, using the more sensitive DSIR instrument, below ground contributions to capacitance caused markedly increased readings when humpy microtopography was beneath the probes, and poorly vegetated hollows conversely gave significant negative readings which could then still be read from the scale as numbers less than 10. Later in the growing season, when dry matter was depleted in the study area, capacitance readings were often only two per cent of the range of the scale so it was of some consolation that these low values were obtained well within the working capability of the instrument rather than adjacent to the lower end of the scale.

6.12 Herbage Samples

The second calibration required was to relate herbage moisture content as indirectly measured by Charlie to the quantity of available dry matter (ADM) within which the plant-water is held as intracellular protoplasm or as sap.

The 25 transect readings were obtained at 1 m intervals except where the crowns of tussocks or rocks caused displacement, which was minimised. Overlapping of measurements did not occur because, end on to the tape, Charlie occupied only about one third of each metre. The mean and standard error were being calculated as the readings were called by the operator's assistant. The latter also greatly reduced the time taken to gather fresh herbage into bags and shared the load to be carried across the hill faces and gullies between transects.

Charlie was then set on the smooth ground with a corrugated cardboard box about 18 cm high enclosing the middle rakes of probes and spanning the width of the instrument so that a convenient subsample of six positive and six negative probes were included.

Vegetation was then clipped in random handfuls as close to ground level as practicable with a pair of blade sheep shears. Plants that had
already been closely grazed tended to be discriminated against unless this was the common situation along the transect. Small tussocks were included where these were important and flatweeds were sampled.

Several handfuls of herbage were then loosely arranged between the probes in the box so that the meter, which had been re-zeroed at ten to allow for increased insulation from the soil due to the box, read the whole number nearest the mean of the 25 transect values. (This discrepancy between readings was allowed for by the appropriate scaling factor when the ADM calculations were made.) The herbage was then shaken into a double walled paper bag, which was placed in a canvas pack after the lid was folded over. A second cut was then bagged in the same way and from the end of January onwards a third cut was taken at each transect.

Appendix 9 describes a retrospective evaluation of this 'box method' of calibrating Charlie as developed by B.E. Allan (pers. comm.) at Tara Hills and the conventional cut quadrat method which was carried out by TGMLI at Lincoln College in November 1978 using a DSIR Charlie.

6.13 Fresh Weight, Dry Weight and ADM

The fresh herbage was weighed in the bags on an electronic balance at the research station immediately the block was completed. The bags were then placed in a fan equipped drying oven and dried at 95° for 16 to 24 hours.

Immediately the bags were removed from the oven, dry weights were recorded on the same balance, which was again tared for the bag-only weight.

The mean of the two or three dry weights was adjusted arithmetically from the meter reading of the samples to the actual mean for the transect and this corrected weight, expressed in grammes, was divided by 0.01891 to obtain the ADM in kg ha⁻¹. The area of pasture subtended
by DSIR and MAF Charlies is 0.1891 m². The configuration of negative probes encircling positive probes is such that only vegetation within the measuring head significantly contributes to the capacitance reading.

6.14 **Sampling Frequency**

It was planned to measure ADM approximately every three weeks, particularly on blocks where stock were being grazed and to lengthen or reduce this cycle so as to measure a few days before stock were put on a block and a few days either side of their departure. In practice this was usually achieved, each block being measured 12 times in the 36 week growing season between 31 August 1977 and 9 May 1978, which were the first and last days on which ADM samples were taken. The dates for each block are given in the margin of Appendix 4 and the allocation of these to 12 seasons for the purpose of analysis is recorded in Table 5. On five occasions the period between measurements on any one block exceeded one month but in three of these cases the block was spelled for most of this time.

Five samplings in mid-September and October 1977 were executed by MAF staff, other course requirements keeping the author at Lincoln College, and two days were missed in January. On the remaining 31 occasions the Charlie readings and herbage collection were performed by the author, assisted by an MAF worker (see 6.12).

6.15 **Analysis of the Technique**

The objective of the analysis was to confirm the independence of the two processes used in this study to measure the ADM of improved high country pasture. These were clarified in the following statements of hypothesis or belief:

(1) The ratio of herbage water to dry matter (w:DM) is established by drying samples of fresh herbage from across the range of herbage
(2) The water content as weight per unit area of the herbage is measured by Charlie (via capacitance). Charlie is neither required for (1) nor deceived by variations in it. Charlie performs (2).

Therefore the water content of all the herbage samples taken were, in various groups, correlated with the meter readings at which they were cut so as to test the strength of that relationship and find if others were present.

Initially, cumulative frequency histograms were drawn of herbage water (w) measured at each whole unit of capacitance. The curves fitted for these had lengthened right-hand tails, there being little room for aberrations to the left. Then 27 partial analyses of variance of capacitance, fresh weight and dry weight on various blocks, dates or types of land unit were carried out. Few significant differences were indicated so a hierarchy of land units was adopted (Table 4) and the complete data for each cut sample of herbage punched on to computer cards. (w and w:DM were computed by the programme.)

The "Statistical Package for the Social Sciences" (SPSS) was used to graph regressions of w, fresh weight, dry weight and w:DM against meter reading, and provide relevant statistics. About 64 hierarchichal and seasonal comparisons were obtained.

6.2 TECHNIQUES TO ESTIMATE FORAGE

Forage is that portion of available dry matter which stock consume under normal grazing pressure. The study of hill and high country grazing management in particular requires that forage be distinguished from herbage because 50 to 80 per cent of the pasture
grown there never enters the digestive tracts of domestic herbivores (cf. Radcliffe et al., 1976; Meurk, 1978).

The planned observations of the grazing distribution of the sheep on study blocks were abandoned but examinations of herbage composition which would help explain the distribution were carried out three times. Dung samples were collected in the latter part of the growing season so that the field abundance of plant species could be related to their importance in the sheep diet. Grazing distribution might then be more easily inferred.

6.21 The Species Composition of Fresh Herbage

A pilot "sighting-in" exercise for the visual estimation of the species contributing to available dry matter was carried out at the end of January 1978. A pegged steel quadrat made to fit Charlie was placed on representative vegetation in each of the ten land units on block 60. The species composition of the pasture enclosed was estimated by eye on a fresh weight basis to the nearest five per cent, and the cut samples were stored frozen. Fresh weight composition was chosen because this was what the eye was observing and because young succulent herbage which is usually preferred forage was thus better accounted for relative to senescent herbage.

The thawed samples were then dissected according to species and weighed, wet and dry. Of 30 comparisons, between actual and estimated per cent composition of important species, 18 were within ±5% and a further seven were ±10% apart. The correlation coefficient of actual with estimated percentage for tufted grasses was 0.84; bunched grasses (Dactylis glomerata, Poa colensoi, Festuca novae-zelandiae) 0.99; and forbs 0.91.
The method was applied to all the transects in late summer 1978 and early spring 1978 and to half in late autumn 1978. About 25 minutes was required at each transect to estimate and record all of the quadrats which were positioned along the 25m tape so as to match the areas read by Charlie. Thus the quantity of fresh herbage for each species could be obtained as a proportion of the appropriate transect ADM.

6.22 Dung Collection

Dung sampling commenced on 20th February 1978 for the purpose of identifying the plants eaten on the study area.

The first collection was made on block 62 when 349 hoggets were present. The pasture was searched for fresh dung while the block was being traversed for ADM measurements. The stock was removed just before the next visit.

On block 61 dung from 540 lambs was sampled in the same manner on 27th February and the stock was moved directly to block 60 a week later.

The first sampling on block 60 was frustrated by the very dry conditions so fresher material was gathered on a special visit on 21st March. Finally when the lambs were mustered from 60 on 1st May, they were detained for half an hour in a race and the required 0.5 kg of dung was collected.

The four samples were frozen and brought to Lincoln College where faecal cuticle analyses were carried out by TGMLI, using the method of Rogerson, Stevens and Hughes (1976).
CHAPTER VII

RESULTS

7.1 AVAILABLE DRY MATTER RESULTS

7.11 Mean Charlie Capacitance Readings

Appendix 4 presents the mean and standard error for each measurement of each transect. Each mr (meter reading) value was the mean of 25 made at one metre intervals along the transect (micro-topography and tussock crowns permitting). Except on five occasions in the spring on block 62, the fine setting of the meter was used rather than the coarse x2 scale.

Until day 154 when the MAF Charlie was commissioned, the meter readings are not directly comparable because two other instruments were used (see Table 4). The lowest readings were recorded during the mid-March sampling period. At five transects, there was then too little vegetation to allow quantitative measurement of the pasture.

7.12 Available Dry Matter on each Land Unit

Available dry matter in kg ha\(^{-1}\) for each land unit on each sampling date is presented in Appendix 5. Standard errors are also presented. These indicate the closeness or disparity of the ADM values at the two transects, which are replicate representatives of the herbage found over the whole land unit (cf. section 8.1).

Some transects were relocated after the first three samplings had been carried out on blocks 60 and 62. Production figures without a standard error attached are thus based on one satisfactory transect although information from the short-lived transects did contribute to
the analysis of sampling technique.

The transects on land units 609, 615 and 627 most often showed within pair variation, sometimes by a factor of three. These land units contained large quantities of standing herbage of low moisture content. Differences within most of the transect pairs, however, were only 250 kg ha\(^{-1}\) or less, and changes seasonally were usually similar.

Pasture availability on the shady block, 61, peaked between mid-November and the end of December on all land units. There was also a lesser flush of growth after rain in the last week of March. Most of the land units on block 60 achieved maximum production in mid-September. The stocking load on this block was increased then, but substantial regrowth had been made by mid-November after destocking in early October. Available dry matter declined in December except on the hill crests land unit and remained at about 350 kg ha\(^{-1}\) to the end of the growing season. The most ADM, 6.8 t ha\(^{-1}\), was measured in September on land unit 626 which is dominated by *Dactylis glomerata*. Production on the rest of block 62 was also at maximum then. By late November ADM had declined to summer levels which were often below 200 kg ha\(^{-1}\) on this block. Only the high altitude, little-grazed browntop land unit 627 maintained its cover although the neighbouring areas 626 and 628 were capable of resurgence when rainfall permitted. As on block 60 the autumn flush was visually impressive, and in the absence of stock, available dry matter continued to accumulate at the end of April.

7.13 Correlation of Water Content of Herbage with Charlie Reading for the Land Units Grouped as a Hierarchy

Table 4 illustrates the derivation of hierarchical names for each land unit. Each digit of such a name was shared by one or several other land units on any of the three blocks depending on shared characteristics at that level of the hierarchy. A fourth digit, i.e. 1 or 2, extended
**TABLE 4:** Hierarchical grouping of land units and correlation of weight of herbage water (w) with Charlie capacitance (mr). (Based on 23 samples/transect from seasons 4 to 12.)

<table>
<thead>
<tr>
<th>Terrain</th>
<th>Community</th>
<th>Land Unit</th>
<th>Transect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r_w.mr</td>
<td>Indicator Species</td>
<td>r_w.mr</td>
</tr>
<tr>
<td><strong>1. &quot;Sunny slopes&quot;</strong></td>
<td>0.594</td>
<td>11 POla DAg1 BRte</td>
<td>0.693</td>
</tr>
<tr>
<td></td>
<td></td>
<td>12 POla LOpe BRte</td>
<td>0.573</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2. &quot;Shady slopes&quot;</strong></td>
<td>(0.767)</td>
<td>21 POla Poco DAg1</td>
<td>0.558</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 FEno Poco DAg1</td>
<td>(0.801)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3. &quot;Gullies&quot;</strong></td>
<td>0.796</td>
<td>31 DAg1</td>
<td>0.841</td>
</tr>
<tr>
<td></td>
<td></td>
<td>32 DAg1 P0pr</td>
<td>0.796</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>4. &quot;Brown top&quot;</strong></td>
<td>(0.776)</td>
<td>41 AGte</td>
<td>(0.776)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>5. &quot;Depleted tussock&quot;</strong></td>
<td>(0.694)</td>
<td>51 P0co FEno</td>
<td>(0.694)</td>
</tr>
</tbody>
</table>

( ) - water was not the best correlation of mr.  
1 Abbreviations see Table 1.  
2 See Figure 1.  
3 See Table 3.
the names to distinguish transects 'a' from 'b' respectively, and a fifth digit, 1, 2 or 3, was used on the data cards, with the sampling day, to identify each individual herbage sample.

The list of vegetation phases at the land unit level of the hierarchy was derived independently from Braun-Blanquet estimates of plant species abundance and sociability in 10x10m releves (one on each land unit) which are presented in Table 3. Because land unit 311(626) is intermediate in character with respect to the two phases, "vegetation phase", with no further changes, will form a new first order level attachable to the existing hierarchy of Table 4. Only terrains 2 and 3 require renumbering in order to separate phase A terrains (sunny slopes and gullies) from those of phase B (shady slopes and crests).

Five grasses were particularly useful in subdividing like terrain into communities. These were Lolium perenne, Poa colensoi, Poa pratensis, Agrostis tenuis and Festuca novae-zelandiae.

The 55 combinations of sampling groups named in Table 4 were each tested for correlation of capacitance readings with fresh weight and dry weight of herbage samples as well as weight of plant water. In all but 17 groups water afforded the best correlation. Dry weight was best in only three groups. The squares of the correlation coefficients in this table indicate that changes in herbage water account for at least half the variation in meter readings in 38 of the groups tested.

7.14 Statistical Analysis of Transects Showing Poor Correlation of Herbage Water with Capacitance

Of the 29 transects for which \( r_{w, mr} \) was computed for the periods mid-November to early May, nine had values below 0.7 so that changes in water content explained less than half of the variation in capacitance.
The w:DM ratio and ADM were investigated for a possible explanation of these low correlation coefficients. This information for the nine transects chosen and the means of the balance and total are presented in Appendix 6a. It is noteworthy that all terrain groups are represented.

The difference between the mean w:hm of the subsample (1.64) and the mean of the other transects (1.63) was shown to be not significant by Student's t test. Thus the hypothesis that Charlie responds to herbage water only, without being "distracted" by dense herbage of low moisture content is sustained. The coefficients of variation within the two groups were 13% and 10% respectively. The difference between mean available dry matter is also not significant. Coefficients of variation were 27% and 13% for n = 9 and n = 20 respectively.

Appendix 6b lists w:DM and ADM from those transects where r w,vmr was greater than 0.7. As the value of r increases from 0.70 to 0.95 there is no apparent pattern in either the herbage water ratio or the available dry matter figures. The two highest r values, from both the transects on land unit 614, are based on 20 and 23 meter readings equal to 1, 2 or 4 and 1, 2 or 6 respectively. There were never large quantities of dry matter available during the November to May period on this area. The lack of capacitance diversity was most severe at transect 623b where the mean meter reading was always such that the herbage samples were obtained at mr = 1, so no correlation with herbage water could be computed.

7.15 Statistical Analysis of w:DM and mean ADM at Transects where Herbage Water was not the Best Correlate of Capacitance

Seven transects where capacitance was more closely related to fresh weight than herbage water and two where capacitance was more
closely related to dry weight were compared as a group with the other twenty transects for which $r_{w, mr}$ had been computed from samples taken in seasons 4 to 12 inclusive. Appendix 7 lists the nine transects plus herbage water ratios and mean available dry matter yields which were the two bases of comparison. The third correlation coefficient, $r_{dw, mr}$, is omitted as an invalid relationship.

The difference between the mean herbage water ratios 1.37 and 1.75 is not significant ($p=0.23$, $cv=12\%$ and $10\%$). Similarly for the overall means of available dry matter ($p=0.20$, $cv=24\%$ and $13\%$). These results possibly indicate greater difficulty in obtaining representative herbage samples from pasture of high available dry matter but low w:DM or the greater significance of any contamination by dew in such pasture. Examples of such transects are those classified under "browntop" and "depleted tussock" in Table 4. Four of these six transects appear in Appendix 7, although the correlation coefficients for 5111 and 4112 are satisfactory for both freshweight and water content. Comparison of $r^2_{fw, mr}$ and $r^2_{w, mr}$ values showed that changes in freshweight accounted for a less than five per cent improvement in the prediction of changes in capacitance reading except at transect 1222 (7\%) and 4111 (5\%).

7.16 Seasonal Relationships Between Herbage Water and Charlie

**Capacitance**

Table 5 lists the elements of linear regressions of Charlie capacitance (mr) and herbage water (w). Capacitance is here expressed as the independent variable to simplify the prediction of w from known mr (see section 7.17). The sampling days for each block, the sum of the cuts made and the instrument used are given for each season.

There does not appear to be any seasonal trend in the ability of
TABLE 5: Seasonal relationships between herbage water (w) and Charlie capacitance (mr),

\[ w = a + b \cdot mr \]

<table>
<thead>
<tr>
<th>Season</th>
<th>Sampling Days</th>
<th>No. of Cuts</th>
<th>Charlie</th>
<th>( r_{w, mr} )</th>
<th>( r^2 )</th>
<th>a</th>
<th>b</th>
<th>( s_b )</th>
<th>w/DM</th>
<th>ADM (kg ha(^{-1}))</th>
</tr>
</thead>
<tbody>
<tr>
<td>1977</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1 Early September</td>
<td>61,62,63*</td>
<td>54</td>
<td>DSIR</td>
<td>0.561</td>
<td>0.314</td>
<td>2.39</td>
<td>0.38</td>
<td>4.56</td>
<td>0.71</td>
<td>570</td>
</tr>
<tr>
<td>2 Mid September</td>
<td>80,83</td>
<td>34</td>
<td>DSIR</td>
<td>0.625</td>
<td>0.391</td>
<td>5.86</td>
<td>2.80</td>
<td>8.84</td>
<td>1.46</td>
<td>680</td>
</tr>
<tr>
<td>3 October</td>
<td>97,101,104</td>
<td>54</td>
<td>TGMLI</td>
<td>0.841</td>
<td>0.706</td>
<td>8.50</td>
<td>2.89</td>
<td>5.36</td>
<td>0.95</td>
<td>540</td>
</tr>
<tr>
<td>4 November</td>
<td>139,140,143</td>
<td>60</td>
<td>MAF</td>
<td>0.912</td>
<td>0.832</td>
<td>1.55</td>
<td>7.06</td>
<td>4.72</td>
<td>1.25</td>
<td>740</td>
</tr>
<tr>
<td>5 Early December</td>
<td>154,161,166</td>
<td>60</td>
<td>MAF</td>
<td>0.905</td>
<td>0.819</td>
<td>1.35</td>
<td>6.15</td>
<td>4.19</td>
<td>1.24</td>
<td>570</td>
</tr>
<tr>
<td>6 Late December</td>
<td>172,179,181</td>
<td>60</td>
<td>MAF</td>
<td>0.852</td>
<td>0.726</td>
<td>4.18</td>
<td>7.54</td>
<td>7.30</td>
<td>1.90</td>
<td>650</td>
</tr>
<tr>
<td>1978</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7 Early January</td>
<td>186,192,193</td>
<td>59</td>
<td>MAF</td>
<td>0.610</td>
<td>0.372</td>
<td>-0.49</td>
<td>7.10</td>
<td>12.57</td>
<td>1.66</td>
<td>630</td>
</tr>
<tr>
<td>8 Late January - Early February</td>
<td>206,214,216,221</td>
<td>104</td>
<td>MAF</td>
<td>0.827</td>
<td>0.684</td>
<td>1.69</td>
<td>5.27</td>
<td>5.11</td>
<td>1.38</td>
<td>600</td>
</tr>
<tr>
<td>9 Late February</td>
<td>231,234,235</td>
<td>90</td>
<td>MAF</td>
<td>0.533</td>
<td>0.284</td>
<td>4.88</td>
<td>3.50</td>
<td>5.63</td>
<td>1.36</td>
<td>470</td>
</tr>
<tr>
<td>10 March</td>
<td>256,257,258</td>
<td>75</td>
<td>MAF</td>
<td>0.624</td>
<td>0.390</td>
<td>2.91</td>
<td>3.33</td>
<td>2.76</td>
<td>1.06</td>
<td>310</td>
</tr>
<tr>
<td>11 Early April</td>
<td>277,279,280</td>
<td>90</td>
<td>MAF</td>
<td>0.893</td>
<td>0.797</td>
<td>-1.91</td>
<td>8.14</td>
<td>5.99</td>
<td>2.02</td>
<td>680</td>
</tr>
<tr>
<td>12 Late April - Early May</td>
<td>300,301,312</td>
<td>90</td>
<td>MAF</td>
<td>0.853</td>
<td>0.727</td>
<td>4.57</td>
<td>4.38</td>
<td>4.46</td>
<td>2.60</td>
<td>390</td>
</tr>
<tr>
<td>Total 4 - 12</td>
<td></td>
<td>688</td>
<td>MAF</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.781</td>
<td>0.610</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.63</td>
</tr>
</tbody>
</table>

\* 1.7.77 = 1
Charlie to measure herbage water, although the correlation coefficients were generally lower when the herbage water ratio was below about 1.4 (i.e. DM > 40%). Nor did the 50% increase in the number of herbage samples taken from the end of January onwards improve the correlation coefficients because a single set of three cuts of one transect where herbage water was high but through operator or machine error was read low, could significantly affect the overall correlation due to the small range of meter readings obtained.

Differences in calibration technique were highlighted when the field data from season 1 (cuts from quadrats having the mean reading) and season 2 (herbage added to the box beneath the probes) were analysed together. The scattergram of \( w \) with \( mr \) computed by SPSS showed two independent clusters so that \( r_{w, mr} \) was -0.08. The samples from season 1 were of lower water content for the same meter reading than those of season 2 because the moisture in the stubble which could not be cut was nevertheless contributing to the capacitance reading.

The squares of the correlation coefficients indicate that in seven of the twelve seasons, variation in herbage water accounted for at least two thirds of the variation in capacitance readings. For the total of 688 herbage samples used to calibrate the MAF Charlie from November to May, \( r_{w, mr} \) was 0.78 and \( r^2 \) 0.61.

The \( w:DM \) ratios in Table 5 show that herbage was lowest in water content in spring and then again at the beginning of autumn. The ratio for season 1 is presumably influenced by standing dead matter from the previous growing season. In season 2 the spring flush had commenced but grazing in October on blocks 61 and 62 by sheep and cattle and lack of rainfall (see Figure 3d) caused the ratio to fall in mid-October. In summer the available herbage was most succulent in late December.
Rain in late March revived the pasture and in late autumn the largest herbage water ratios were recorded.

The ADM values in Table 5 are means of totals for the three blocks which in turn have been derived from land unit means weighted for area. There is no pattern relating changes in ADM and changes in $r_{W,MR}$, only evidence of independence.

7.17 A Comparison of Two Methods of Deriving Available Dry Matter

The w-mr regression equations for seasons 4 and 11 (Table 5) were used to predict the available herbage water at each transect with the mean capacitance reading for that transect as the independent variable (Appendix 8). The estimates of herbage water were then transformed, with accompanying standard errors, to dry matter estimates using the w:DM ratio for the appropriate season and transect. Seasons 4 and 11 were chosen for this investigation of a new technique because they have the best w:mr correlation for seasons of 60 and 90 herbage samples respectively. The long-term advantage of water-based prediction equations is to free herbage sampling from its quantitative requirement and so reduce the operation to the qualitative estimation of the herbage water to dry matter ratio on each land unit.

The second method in the comparison is the standard herbage-in-box calibration technique used from mid-September onwards to measure available dry matter. The final column in Appendix 8 lists these results for the two seasons examined, adjusted up or down according to the difference between the mean mr (column 2, Appendix 8) and the adjacent whole number mr which the herbage sample was cut to match. The standard errors of the sample cuts are also presented but because the cut herbage was not mixed as a whole before being drawn from for the individual samples, the ranges of ± s.e. obtained for the cuts are very variable.
In both seasons the actual dry matter was within one standard error of the predicted value at more than two thirds of the transects, thus the precision of the two techniques is similar. The mean dry matter beneath Charlie was 15.2g in season 4 and 13.8g in season 11. The predicted figures were 15.3 and 12.9g respectively.

7.18 Available Dry Matter on Each Block

The available dry matter on each land unit was totalled according to the effective area of the land unit (see Table 2) and the land units summed to give the total available intertussock herbage on the block. Figure 3a-c presents the graph of available dry matter on each sampling date for each block (note the amplified vertical scale used in 3a relative to b and c). On block 60 there were four periods when dry matter was accumulating, i.e. early September, October-November, early February and March. The main decline in (intertussock) herbage began about mid-November and continued through three samplings, despite the early removal of stock, until early February when 40mm of rain fell. Net regrowth was not sustained for long, however, and did not resume until late March when further rain fell.

Herbage did not accumulate on 61, the shady block, until late November, but thereafter about 900 kg ha\(^{-1}\) was available from the time stock were removed in late November through until mid-January. By mid-March the quantity on offer had halved after only a brief period of grazing. Autumn rain stimulated production so that 1.25 t ha\(^{-1}\) had accumulated by early April. This was the maximum for the growing season.

The available dry matter graph for block 62 (Figure 3c) shows the same trends as its counterpart 60 but the accumulation of herbage in spring is not interrupted by September grazing as happened on block 60.
Fig 3a: Block 60; grazing pressure, available dry matter, available herbage water and stocking rate
Fig 3b: Block 61; grazing pressure, available dry matter, available herbage water and stocking rate
Fig 3c: Block 62; grazing pressure, available dry matter, available herbage water and stocking rate.
Figure 3d: Daily soil moisture balance, daily rainfall and monthly moisture deficits for Tara Hills during the study period. Assumed soil moisture capacity = 25 mm. (Information supplied by N.Z. Meteorological Service)
The dry matter supply ranged between 700 and 200 kg ha\(^{-1}\) during the growing season compared to 900 and 280 kg ha\(^{-1}\) on 60 which is somewhat less exposed to the sun and northwest wind and was grazed less often.

7.2 GRAZING PRESSURE RESULTS

7.21 Stocking Load, Classes of Stock and Production

The study blocks include much of the best wintering country on Tara Hills and so they are used then, and at other times of the year for growing replacement hoggets for the merino ewe flock. Stocking loads and periods are graphed for each block in the top portion of Figure 3 a-c.

Block 60 had been grazed by 1160 hoggets since mid-July when they were shifted from 62. The hoggets were replaced by 830 ewes in mid-September and so stocking density (Kothmann, 1974) increased from 3.3 to 5.5 stock units ha\(^{-1}\). The block was spelled during October, then the hoggets were returned for six weeks and having grown somewhat, their stocking density became 3.81 s.u. ha\(^{-1}\). Again the block was spelled from mid-December to early March, and then stocked with 540 lambs or 1.52 stock units ha\(^{-1}\) until 1st May.

Block 61 was spelled from mid-April 1977 until the beginning of October when 240 ewes were grazed from lambing until the end of November. The block was not grazed from December until May except for one fortnight by 540 lambs (3.5 s.u. ha\(^{-1}\)). These returned as hoggets for an even shorter period in early May.

Block 62 was spelled from mid-July to the third week in September. Yearling and two year old heifers totalling 2.5 stock units ha\(^{-1}\) then grazed until the beginning of October and the yearlings for a further three weeks. Meanwhile 1160 hoggets were also put on this block for most of October so that a comparatively high stocking density of
6.6 s.u. ha$^{-1}$ ensued. In summer and autumn the density was reduced to 1.25 s.u. ha$^{-1}$. 349 hoggets were set stocked in effect, from mid-December to mid-March.

Production figures for 349 lambs born in 1976 and 620 in 1977 were obtained from Tara Hills staff. The weaning weights of the lambs were 20.0 kg in 1976 and 19.9 kg in 1977. In early winter, as hoggets, they weighed 25.0 kg and 28.6 kg in 1977 and 1978 respectively. At shearing in mid-September they weighed 24.3 and 29.9 kg respectively. However, the MAF selection trial hoggets (1976 lambs) were not shorn until early February 1978 when the 16 month fleeces weighed 4.1 kg each and bodyweights averaged 32.6 kg. The overall gain in liveweight of 12.4 kg from October 1977 to January 1978 inclusive was made by these hoggets while grazing on blocks 60 and 62.

7.22 Soil Moisture

Daily soil moisture data for Tara Hills provided by the Meteorological Service shows that the climate was considerably drier during the 1977/78 growing season than either the preceding or following season. For the 255 day period 28th August to 9th May chosen to match the time scale used throughout Figure 3, there were only 63 days when free soil moisture was present (see Figure 3d), assuming storage capacity of the soils is 25mm. This number was only increased by 20 days or 8% if the assumed storage was doubled to 50mm. There were 103 days of soil moisture in the 1976-77 growing season and 68 days for the 1978 portion of the 1978/79 season, i.e. the 126 day period for which results were then available (both figures are based on 25mm capacity). Given these conditions it is not surprising that the available dry matter at the beginning of winter 1978 was less on each block than at the end of winter 1977. The shortfalls were about 50%, 10% and 30% for blocks 60-62 respectively, assuming grazing management practices were
similar to the previous year. Any winter growth, particularly in August of species such as *Bromus tectorum* on sunny faces and in gullies under matagouri would help reduce the deficit.

Field measurements of soil moisture obtained from core sample to 10cm depth are presented in Appendix 2. This data is from two sources: routine measurements in the meteorological exclosures near the top of blocks 60 and 61 which represent sunny and shady aspects respectively, and cores collected at each of the ten transects (two per land unit) on block 60, as part of this project. All the land unit samples except 609 were taken from sites lower in altitude than the meteorological sites. Thus soil moisture at the shady land unit 602 is always less than that at the shady meteorological site for this reason, and probably because of reduced ground cover compared to the ungrazed exclosure.

Analysis of variance of the soil moistures recorded at the land units of block 60 from November to April established significant differences between dates but not between land units as a whole or between 601 (sunny aspect) and 602 (shady) in particular. Therefore assumptions such as soil moisture storage capacity used by the Meteorological Service to compute moisture deficits and runoff can be applied with greater confidence to the whole of block 60 and possibly to all land aspects and soils in the study area.

Daily rainfall >1mm during the study period is presented as a bar graph in Figure 3d. Only on two days was rainfall greater than 20mm although 57mm fell on 11/5/78 just two days after the last pasture measurement was made. The largest monthly total (including wet days, 0-1mm) was 53.8mm in December. Only 2.8mm was recorded in August and the October and January totals were both less than 20mm. From 1 August 1977 to 10 May 1978 229mm rainfall was recorded at Tara Hills, exactly nine inches.
Monthly totals of soil moisture deficit (storage = 25mm) are plotted on Figure 3d at the mid point of each month. The influence of the December rainfall is readily apparent. In August, despite only 2.8 mm rainfall, there were no deficit days which has been the case in the last 27 years. In May there was once again no deficit (historical deficit for May is only 1 mm). However, for the year July 1977 to June 1978 the total deficit was 658 mm and there were 183 deficit days. The 27 year means are 491 mm on 148 days. There was zero runoff predicted for the study period because adjacent rainfalls never exceeded the assigned water holding capacity of the soils.

7.23 Available Herbage Water

Available herbage water (AHW) is included in Figure 3 with grazing pressure and its component parameters because this was the basis on which pasture was measured and from which available dry matter was derived throughout the project.

On block 60, AHW was less than ADM until the early part of October but for the rest of the growing season the proportion of dry matter was always less than 50%. The herbage was most succulent in November and late December (after destocking), and most desiccated in mid-March.

On block 61 AHW and ADM were similar until December when the ewes had been removed and rainfall was sufficient for pasture growth and accumulation. Dry matter declined to 32%. In the new year AHW fell faster than ADM as the plants matured and in early March dry matter content was 50% following a short period of grazing. At the height of the subsequent autumn flush, which was quantitatively most marked on this block because of lighter grazing and less drying-off of pasture, ADM had increased from 0.46 t.ha\(^{-1}\) to 1.25 t and AHW from 0.44 t to 2.14 t.
in three weeks. Thereafter senescence, frost and grazing rapidly lowered the water content.

On block 62 AHW was substantially greater than ADM in September and April when there was adequate soil moisture and little or no grazing. At other times grazing pressure on this block was such that it clearly influenced the changes in AHW relative to ADM. In October heifers and hoggets consumed some of the accumulated dry matter from the previous growing season but ADM only decreased slightly because of spring growth, and AHW increased slightly as the new herbage replaced the old. In early December in the absence of stock AHW rose while ADM decreased through senescence of annuals and heat stress. Rain then enabled accumulative growth to resume under light grazing. However, water stress in February and continued grazing reduced ADM and AHW relative to ADM. At the end of March a flush of plant growth began so that ADM increased from 200 kg ha$^{-1}$ to 360 kg ha$^{-1}$ and AHW from 140 kg ha$^{-1}$ to 1000 kg ha$^{-1}$ in late April.

7.24 Grazing Pressure

Grazing pressure (GP) was calculated as the actual animal to forage ratio at a specific time (Kothmann, 1974) so that:

$$GP = \frac{\text{stock units}}{\text{tonnes of Available Dry Matter}}$$

The times chosen were the days when stock was put on to or taken off any of the study blocks and any days in between when the pasture on that block was measured. The graphs of grazing pressure for the three blocks are presented in the lower portion of Figure 3 a–c. Grazing pressure between the shaded areas was zero disregarding rabbits, insects and the occasional stray sheep.

On block 60 grazing pressure dropped from 5 to 3.5 s.u./t.ADM in early September but when the stocking density was increased from 3 to
5.5 s.u. ha\(^{-1}\) pasture was consumed faster than it was growing and GP increased to 10 s.u./t.ADM at closure. During the November-December grazing soil moisture became limiting to pasture growth soon after 14th November and GP, which had been falling slightly implying conservative or under stocking for late spring, began to slowly increase. Stocking density was less than half the preceding level during the final grazing within the 1977/78 growing season, but GP was 5 down from 7 s.u./t.ADM. This was appropriate to the condition of the herbage until the end of March when new growth would have supported more sheep for a month.

On block 61 the spring grazing was delayed until October when rabbit poisoning was completed. The initial grazing pressure (by 4 s.u. ha\(^{-1}\)) was 6.8 s.u./t.ADM. In late November it had eased to less than 4 s.u./t.ADM until lack of rainfall halted the accumulation of herbage. Grazing by lambs at 3.5 s.u. ha\(^{-1}\) was for a fortnight in both late summer and late autumn. On both occasions GP increased from 6 s.u./t.ADM but more so in May when new autumn grown herbage apparently suffered frost damage as well as grazing.

On block 62 grazing pressure was highest when the pasture was producing most vigorously which is as it should be in ordinary management. Thus GP in early October was 10.1 s.u./t.ADM and one month later it had only increased to 11.8. In November the remaining cattle on 62 had consumed the dense cocksfoot foottage in the water courses and high basins and were given access to the top of 61 also. Block 62 was then spelled for three weeks and hoggets at 1.25 s.u. ha\(^{-1}\) were introduced after substantial rainfall. Grazing pressure declined slightly in December and then stabilised at 2.5 s.u./t.ADM in January. These hoggets were removed for shearing for a week but GP remained similar after their return until the end of February, by which time the
established herbage was clearly suffering drought. There were 6.8 s.u./t.ADM when the hoggets were shifted on 13 March.

7.3 FORAGE RESULTS

7.3.1 Botanical Composition of Fresh Herbage

Three seasonal estimates of the botanical composition of inter-tussock herbage at each of the fifteen land units described for the study area are presented in Table 6 a-o. The information for late summer 1978 was obtained from 0.2 m² Charlie-frame estimates made at one metre intervals, as for machine readings, along each of the 30 transects between 31/1/78 and 22/2/78. Estimates for each species were made by eye to the nearest 5% of standing fresh weight. Blue tussocks plus small silver and fescue tussocks were included. The estimates for each transect have been averaged in accordance with the relative herbage production of each member of the pair and then expressed in Table 6 as kg ha⁻¹ and percentage of the total available fresh weight of herbage based on the ADM of the nearest sampling day.

The estimates for late autumn were made on 25, 26 and 29/4/78 at fifteen transects, one for each land unit (with two exceptions) chosen for their strategic value to grazing stock. The validity of excluding one replicate in late autumn was checked by applying an index of concordance of transect pairs to the late summer and early spring results, viz. the percentage of fresh weight accounted for in the second transect by species contributing five per cent and more in the first. This value was usually between 90 and 100% (16 of 30 cases) or between 80 and 89% (9 of 30 cases). Only on land unit 602 was their dissimilarity in both seasons because of the absence of cocksfoot from one of the transects (see Table 6f).
### TABLE 6(a): Land Unit 111, site description and seasonal estimates of fresh weight of intertussock herbage.

Location 601  
Effective area 45.9ha  
Aspect (°true) 338 (sunny)  
Slope 30°  
Soil Tara Steepland

<table>
<thead>
<tr>
<th>Location</th>
<th>Bare ground 20%</th>
<th>Litter 3%</th>
<th>Stones 20%</th>
<th>Tussocks 5% (Poa laevis)</th>
<th>Shrubs &lt;3% (Discaria townatou, Rosa rubiginosa, Hymenanthera alpina, Rubus sp., Coprosma sp.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective area</td>
<td>45.9ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aspect</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Tussocks</td>
<td>5%</td>
<td></td>
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</table>

#### Grasses

<table>
<thead>
<tr>
<th>Species</th>
<th>Late Summer kg ha⁻¹</th>
<th>Late Autumn kg ha⁻¹</th>
<th>Early Spring kg ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loliwm perenne</td>
<td>151</td>
<td>353</td>
<td>692</td>
</tr>
<tr>
<td>Daoustis glomerata</td>
<td>40</td>
<td>41</td>
<td>88</td>
</tr>
<tr>
<td>Poa laevis</td>
<td>20</td>
<td>2</td>
<td>108</td>
</tr>
<tr>
<td>Agropyron scabrum</td>
<td>4</td>
<td>&lt;2</td>
<td>58</td>
</tr>
<tr>
<td>Dichelachne orinita</td>
<td>4</td>
<td>&lt;2</td>
<td>2</td>
</tr>
<tr>
<td>Notodanthonia spp.</td>
<td>9</td>
<td>&lt;2</td>
<td></td>
</tr>
<tr>
<td>Bromus tectorum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poa colensoi</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Clovers

<table>
<thead>
<tr>
<th>Species</th>
<th>Late Summer kg ha⁻¹</th>
<th>Late Autumn kg ha⁻¹</th>
<th>Early Spring kg ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trifolium arvense</td>
<td>89</td>
<td>54</td>
<td>44</td>
</tr>
<tr>
<td>Trifolium repens</td>
<td>8</td>
<td>&lt;2</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Trifolium dubium</td>
<td>14</td>
<td>&lt;2</td>
<td></td>
</tr>
</tbody>
</table>

#### Other Herbs

<table>
<thead>
<tr>
<th>Species</th>
<th>Late Summer kg ha⁻¹</th>
<th>Late Autumn kg ha⁻¹</th>
<th>Early Spring kg ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echium vulgare</td>
<td>470</td>
<td>95</td>
<td>484</td>
</tr>
<tr>
<td>Rumex acetosella</td>
<td>55</td>
<td>217</td>
<td>120</td>
</tr>
<tr>
<td>Verbascum thapsus</td>
<td>5</td>
<td>27</td>
<td>2</td>
</tr>
<tr>
<td>Verbascum virgatum</td>
<td>5</td>
<td>&lt;2</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Crepis capillaris</td>
<td>4</td>
<td>&lt;2</td>
<td></td>
</tr>
<tr>
<td>Erodium cicutarium</td>
<td></td>
<td>14</td>
<td>54</td>
</tr>
<tr>
<td>Arenaria eeryllifolia</td>
<td></td>
<td></td>
<td>119</td>
</tr>
<tr>
<td>Plantago spathulata</td>
<td>14</td>
<td>&lt;2</td>
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</tr>
</tbody>
</table>

#### TOTAL

<table>
<thead>
<tr>
<th>Description</th>
<th>Late Summer kg ha⁻¹</th>
<th>Late Autumn kg ha⁻¹</th>
<th>Early Spring kg ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh weight</td>
<td>864</td>
<td>1304</td>
<td>3197</td>
</tr>
<tr>
<td>Dry weight</td>
<td>268</td>
<td>364</td>
<td>2005</td>
</tr>
</tbody>
</table>
TABLE 6(b): Land Unit 112, site description and seasonal estimates of fresh weight of intertussock herbage.

<table>
<thead>
<tr>
<th>Location 621</th>
<th>Bare ground 12%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective area 87.5ha</td>
<td>Litter 2%</td>
</tr>
<tr>
<td>Aspect (°true) 270 (sunny)</td>
<td>Stones 5%</td>
</tr>
<tr>
<td>Slope 28°</td>
<td>Tussocks 5% (Poa laevis, Poa colensoi)</td>
</tr>
<tr>
<td>Soil Tara Steepland</td>
<td>Shrubs &lt;1% (Discaria tournatou)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grasses</th>
<th>Late Summer kg ha(^{-1})</th>
<th>%</th>
<th>Late Autumn kg ha(^{-1})</th>
<th>%</th>
<th>Early Spring kg ha(^{-1})</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dactylis glomerata</td>
<td>640</td>
<td>81</td>
<td>628</td>
<td>89</td>
<td>1072</td>
<td>71</td>
</tr>
<tr>
<td>Poa colensoi</td>
<td>32</td>
<td>4</td>
<td>17</td>
<td>2</td>
<td>22</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Agropyron scabrum</td>
<td>18</td>
<td>2</td>
<td>10</td>
<td>&lt;2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notodanthonia spp.</td>
<td>13</td>
<td>2</td>
<td>13</td>
<td>2</td>
<td>37</td>
<td>2</td>
</tr>
<tr>
<td>Lolium perenne</td>
<td>11</td>
<td>&lt;2</td>
<td>25</td>
<td>4</td>
<td>37</td>
<td>2</td>
</tr>
<tr>
<td>Poa laevis</td>
<td>5</td>
<td>&lt;2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bromus tectorum</td>
<td>5</td>
<td>&lt;2</td>
<td></td>
<td></td>
<td>201</td>
<td>13</td>
</tr>
<tr>
<td>Bromus mollis</td>
<td>2</td>
<td>&lt;2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Clovers</th>
<th>Late Summer kg ha(^{-1})</th>
<th>%</th>
<th>Late Autumn kg ha(^{-1})</th>
<th>%</th>
<th>Early Spring kg ha(^{-1})</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trifolium arvense</td>
<td>66</td>
<td>8</td>
<td>5</td>
<td>&lt;2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trifolium dubium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>80</td>
<td>5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other Herbs</th>
<th>Late Summer kg ha(^{-1})</th>
<th>%</th>
<th>Late Autumn kg ha(^{-1})</th>
<th>%</th>
<th>Early Spring kg ha(^{-1})</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gnaphalium collinum</td>
<td>5</td>
<td>&lt;2</td>
<td></td>
<td></td>
<td>37</td>
<td>2</td>
</tr>
<tr>
<td>Rumex acetosella</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>9</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Arenaria serpyllifolia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| TOTAL Fresh weight | Late Summer | 790 | Late Autumn | 705 | Early Spring | 1495 |
| Dry Weight | Late Summer | 378 | Late Autumn | 188 | Early Spring | 943 |
TABLE 6(c): Land Unit 121, site description and seasonal estimates of fresh weight of intertussock herbage.

Location 603
Effective area 70.8ha
Aspect (true) 11 (sunny)
Slope 26°
Soil Tara Steepland

<table>
<thead>
<tr>
<th>Location</th>
<th>Bare ground 25%</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Litter &lt;1%</td>
</tr>
<tr>
<td></td>
<td>Stones 5%</td>
</tr>
<tr>
<td></td>
<td>Tussocks 1% (Poa laevis)</td>
</tr>
<tr>
<td></td>
<td>Shrubs &lt;5% (Hymenanthera alpina, Discaria townatou)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Late Summer</th>
<th>Late Autumn</th>
<th>Early Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg ha⁻¹</td>
<td>%</td>
<td>kg ha⁻¹</td>
</tr>
<tr>
<td><strong>Grasses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lolium perenne</td>
<td>171</td>
<td>19</td>
<td>155</td>
</tr>
<tr>
<td>Festuca rubra</td>
<td>38</td>
<td>4</td>
<td>45</td>
</tr>
<tr>
<td>Dactylis glomerata</td>
<td>13</td>
<td>&lt;2</td>
<td>15</td>
</tr>
<tr>
<td>Notodanthonia spp.</td>
<td>7</td>
<td>&lt;2</td>
<td></td>
</tr>
<tr>
<td>Bromus mollis</td>
<td>3</td>
<td>&lt;2</td>
<td>5</td>
</tr>
<tr>
<td>Poa laevis</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bromus tectorum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Clovers</strong></td>
<td>66</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Trifolium arvense</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trifolium repens</td>
<td></td>
<td></td>
<td>10</td>
</tr>
<tr>
<td><strong>Other Herbs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Echium vulgare</td>
<td>540</td>
<td>61</td>
<td>25</td>
</tr>
<tr>
<td>Achillea millefolium</td>
<td>38</td>
<td>4</td>
<td>185</td>
</tr>
<tr>
<td>Verbascum virgatum</td>
<td></td>
<td></td>
<td>45</td>
</tr>
<tr>
<td>Verbascum thapsus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL Fresh weight</strong></td>
<td>894</td>
<td></td>
<td>495</td>
</tr>
<tr>
<td><strong>Dry weight</strong></td>
<td>302</td>
<td></td>
<td>117</td>
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</tbody>
</table>
TABLE 6(d): Land Unit 122, site description and seasonal estimates of fresh weight of intertussock herbage.

Location 613  
Effective area 24.5ha  
Aspect (true) 68° (sunny)  
Slope 26°  
Soil Tara Steepland

<table>
<thead>
<tr>
<th>Location</th>
<th>Effective area</th>
<th>Aspect (true)</th>
<th>Slope</th>
<th>Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bare ground</td>
<td>20%</td>
<td>Litter &lt;1%</td>
<td>Stones 3%</td>
<td>Tussocks 2% (Poa laevis)</td>
</tr>
</tbody>
</table>

### Late Summer Late Autumn Early Spring

<table>
<thead>
<tr>
<th>Grasses</th>
<th>kg ha⁻¹</th>
<th>%</th>
<th>kg ha⁻¹</th>
<th>%</th>
<th>kg ha⁻¹</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lolium perenne</td>
<td>237</td>
<td>26</td>
<td>85</td>
<td>25</td>
<td>224</td>
<td>20</td>
</tr>
<tr>
<td>Dactylis glomerata</td>
<td>80</td>
<td>9</td>
<td>3</td>
<td>&lt;2</td>
<td>93</td>
<td>8</td>
</tr>
<tr>
<td>Notodanthonia spp.</td>
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<td>2</td>
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<td>&lt;2</td>
<td>42</td>
<td>4</td>
</tr>
<tr>
<td>Agrostis tenax</td>
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<td>2</td>
<td></td>
<td></td>
<td>54</td>
<td>5</td>
</tr>
<tr>
<td>Agropyron scabrum</td>
<td>15</td>
<td>2</td>
<td></td>
<td></td>
<td>6</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Poa laevis</td>
<td>11</td>
<td>&lt;2</td>
<td>17</td>
<td>5</td>
<td>364</td>
<td>32</td>
</tr>
<tr>
<td>Bromus mollis</td>
<td>9</td>
<td>&lt;2</td>
<td></td>
<td></td>
<td>30</td>
<td>3</td>
</tr>
<tr>
<td>Bromus tectorum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Clovers</th>
<th>kg ha⁻¹</th>
<th>%</th>
<th>kg ha⁻¹</th>
<th>%</th>
<th>kg ha⁻¹</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trifolium arvense</td>
<td>147</td>
<td>16</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trifolium repens</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>&lt;2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other Herbs</th>
<th>kg ha⁻¹</th>
<th>%</th>
<th>kg ha⁻¹</th>
<th>%</th>
<th>kg ha⁻¹</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achillea millefolium</td>
<td>352</td>
<td>38</td>
<td>225</td>
<td>66</td>
<td>310</td>
<td>27</td>
</tr>
<tr>
<td>Echium vulgare</td>
<td>31</td>
<td>3</td>
<td>3</td>
<td>&lt;2</td>
<td>12</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Cerastium holosteoides</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Rumex acetosella</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>6</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Arenaria serpyllifolia</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

TOTAL Fresh weight 916 336 1171  
Dry weight 382 98 623
TABLE 6(e): Land Unit 123, site description and seasonal estimates of fresh weight of intertussock herbage.

<table>
<thead>
<tr>
<th>Location 623</th>
<th>Bare ground 20%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective area 66.7ha</td>
<td>Litter &lt;1%</td>
</tr>
<tr>
<td>Aspect (true 0) 0 (sunny)</td>
<td>Stones 2%</td>
</tr>
<tr>
<td>Slope 18°</td>
<td>Tussocks 1% (Poa laevis)</td>
</tr>
<tr>
<td>Soil Tara Steepland</td>
<td>Shrubs &lt;1% (Carmichaelia monroi, Rosa rubiginosa)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grasses</th>
<th>Late Summer</th>
<th>Late Autumn</th>
<th>Early Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg ha⁻¹</td>
<td>%</td>
<td>kg ha⁻¹</td>
<td>%</td>
</tr>
<tr>
<td>Lolium perenne</td>
<td>175 39</td>
<td>970 66</td>
<td>603 48</td>
</tr>
<tr>
<td>Dactylis glomerata</td>
<td>52 12</td>
<td>103</td>
<td>142 11</td>
</tr>
<tr>
<td>Notodanthonia spp.</td>
<td>32 7</td>
<td>44 3</td>
<td>18 &lt;2</td>
</tr>
<tr>
<td>Poa colensoi</td>
<td>9 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agropyron scabrum</td>
<td>8 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poa laevis</td>
<td>6 &lt;2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bromus mollis + Bromus tectorum</td>
<td>5 &lt;2</td>
<td>44 3</td>
<td>191 15</td>
</tr>
<tr>
<td>Poa pratensis</td>
<td></td>
<td></td>
<td>27 2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Clovers</th>
<th>Late Summer</th>
<th>Late Autumn</th>
<th>Early Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg ha⁻¹</td>
<td>%</td>
<td>kg ha⁻¹</td>
<td>%</td>
</tr>
<tr>
<td>Trifolium arvense</td>
<td>58 13</td>
<td>29 2</td>
<td>63 5</td>
</tr>
<tr>
<td>Trifolium repens</td>
<td>59 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trifolium dubium</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Other Herbs</th>
<th>Late Summer</th>
<th>Late Autumn</th>
<th>Early Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg ha⁻¹</td>
<td>%</td>
<td>kg ha⁻¹</td>
<td>%</td>
</tr>
<tr>
<td>Echiium vulgare</td>
<td>74 17</td>
<td>73 5</td>
<td>41 3</td>
</tr>
<tr>
<td>Gnaphalium collinum</td>
<td>16 4</td>
<td>147 10</td>
<td>63 5</td>
</tr>
<tr>
<td>Achillea millefolium</td>
<td>10 2</td>
<td>44 3</td>
<td></td>
</tr>
<tr>
<td>Hypochaeris radicata</td>
<td></td>
<td>15 &lt;2</td>
<td>11 &lt;2</td>
</tr>
<tr>
<td>Verbasum thapsus</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>TOTAL</th>
<th>Late Summer</th>
<th>Late Autumn</th>
<th>Early Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg ha⁻¹</td>
<td>%</td>
<td>kg ha⁻¹</td>
<td>%</td>
</tr>
<tr>
<td>Fresh weight</td>
<td>445</td>
<td>1469</td>
<td>1218</td>
</tr>
<tr>
<td>Dry weight</td>
<td>176</td>
<td>310</td>
<td>721</td>
</tr>
</tbody>
</table>
**TABLE 6(f): Land Unit 211, site description and seasonal estimates of fresh weight of intertussock herbage.**

**Location 602**
- Effective area 46.8ha
- Aspect (true) 79 (shady)
- Slope 33°
- Soil McIay Steepland

**Bare Ground 15%**
- Litter 5%
- Stones 30%
- Tussocks 5% (*Poa laevis, Poa colensoi*)
- Shrubs 1% (*Rosa rubiginosa, Muehlenbeckia axillaris, Hymenanthera alpina, Carmichaelia petriei*)

<table>
<thead>
<tr>
<th></th>
<th>Late Summer</th>
<th>Late Autumn</th>
<th>Early Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg/ha⁻¹ %</td>
<td>kg/ha⁻¹ %</td>
<td>kg/ha⁻¹ %</td>
</tr>
<tr>
<td><strong>Grasses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Dactylis glomerata</em></td>
<td>643 60</td>
<td>476 28</td>
<td>989 30</td>
</tr>
<tr>
<td><em>Poa colensoi</em></td>
<td>85 8</td>
<td>238 14</td>
<td>403 12</td>
</tr>
<tr>
<td><em>Lolium perenne</em></td>
<td>85 8</td>
<td>102 6</td>
<td>284 9</td>
</tr>
<tr>
<td><em>Notodanthonia spp.</em></td>
<td>39 3</td>
<td>51 3</td>
<td>131 4</td>
</tr>
<tr>
<td><em>Poa laevis</em></td>
<td>36 3</td>
<td>68 4</td>
<td>29 &lt;2</td>
</tr>
<tr>
<td><em>Agropyron scabrum</em></td>
<td>32 3</td>
<td>459 27</td>
<td>713 22</td>
</tr>
<tr>
<td><em>Bromus mollis + Bromus tectorum</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Holcus lanatus</em></td>
<td>17 &lt;2</td>
<td>72 2</td>
<td></td>
</tr>
<tr>
<td><em>Deyeuxia sp.</em></td>
<td>51 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Clovers</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Trifolium pratense</em></td>
<td>25 2</td>
<td></td>
<td>15 &lt;2</td>
</tr>
<tr>
<td><em>Trifolium arvense</em></td>
<td>21 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Trifolium repens</em></td>
<td>18 2</td>
<td>17 &lt;2</td>
<td>53 2</td>
</tr>
<tr>
<td><strong>Other Herbs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Echium vulgare</em></td>
<td>28 3</td>
<td>51 3</td>
<td>18 &lt;2</td>
</tr>
<tr>
<td><em>Crepis capillaris</em></td>
<td>28 3</td>
<td>51 3</td>
<td></td>
</tr>
<tr>
<td><em>Rumex acetosella</em></td>
<td>18 2</td>
<td>119 7</td>
<td>105 3</td>
</tr>
<tr>
<td><em>Senecio sp.</em></td>
<td>7 &lt;2</td>
<td></td>
<td></td>
</tr>
<tr>
<td><em>Cerastium holosteoides</em></td>
<td>4 &lt;2</td>
<td>417 13</td>
<td></td>
</tr>
<tr>
<td><em>Arenaria serpyllifolia</em></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL Fresh weight</strong></td>
<td>1069</td>
<td>1700</td>
<td>3229</td>
</tr>
<tr>
<td><strong>Dry weight</strong></td>
<td>392</td>
<td>605</td>
<td>2312</td>
</tr>
</tbody>
</table>
TABLE 6(g): Land Unit 221, site description and seasonal estimates of fresh weight of intertussock herbage.

Location 612
Effective area 31.3ha
Aspect (true) 101 (shady)
Slope 30°
Soil McLay Steepland

Bare ground 15%
Litter 20%
Stones 2%
Tussocks 30% (Poa colensoi, Festuca novae-zealandiae, Festuca matthewsii)
Shrubs <1% (Carmichaelia monroi)

<table>
<thead>
<tr>
<th></th>
<th>Late Summer kg ha⁻¹</th>
<th>Late Autumn kg ha⁻¹</th>
<th>Early Spring kg ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grasses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poa colensoi</td>
<td>600</td>
<td>548</td>
<td>988</td>
</tr>
<tr>
<td>Dactylis glomerata</td>
<td>278</td>
<td>168</td>
<td>306</td>
</tr>
<tr>
<td>Festuca novae-zealandiae</td>
<td>115</td>
<td>168</td>
<td>321</td>
</tr>
<tr>
<td>Agropyron scabrum</td>
<td>61</td>
<td>67</td>
<td>51</td>
</tr>
<tr>
<td>Anthoxanthum odoratum</td>
<td>59</td>
<td>78</td>
<td>57</td>
</tr>
<tr>
<td>Agrostis tenue</td>
<td>57</td>
<td>6</td>
<td>80</td>
</tr>
<tr>
<td>Holcus lanatus</td>
<td>16</td>
<td>&lt;2</td>
<td>46</td>
</tr>
<tr>
<td>Bromus mollis + Bromus tectorum</td>
<td>11</td>
<td>&lt;2</td>
<td>29</td>
</tr>
<tr>
<td>Poa laevis</td>
<td>110</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Lolium perenne</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Clovers</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trifolium repens</td>
<td>54</td>
<td>45</td>
<td>29</td>
</tr>
<tr>
<td>Trifolium pratense</td>
<td>8</td>
<td>4</td>
<td>&lt;2</td>
</tr>
<tr>
<td><strong>Other Herbs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rumex acetosella</td>
<td>8</td>
<td>34</td>
<td>49</td>
</tr>
<tr>
<td>Achillea millefolium</td>
<td>8</td>
<td>3</td>
<td>12</td>
</tr>
<tr>
<td>Cerastium holostoeides</td>
<td>8</td>
<td>&lt;2</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Carex spp.</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Luzula rufa</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>TOTAL Fresh weight</strong></td>
<td>1264</td>
<td>1119</td>
<td>2100</td>
</tr>
<tr>
<td><strong>Dry weight</strong></td>
<td>709</td>
<td>547</td>
<td>1208</td>
</tr>
</tbody>
</table>
TABLE 6(h): Land Unit 222, site description and seasonal estimates of fresh weight of intertussock herbage.

<table>
<thead>
<tr>
<th>Location 628</th>
<th>Effective area 5.7ha</th>
<th>Aspect (°true) 202 (shady)</th>
<th>Slope 20°</th>
<th>Soil Berwen Hill</th>
<th>Bare ground 40%</th>
<th>Litter &lt;1%</th>
<th>Stones 1%</th>
<th>Tussocks 10% (Festuca novae-zelandiae, Poa colensoi, Poa laevigata)</th>
<th>Shrubs none</th>
</tr>
</thead>
</table>

**Table 6(h):**

<table>
<thead>
<tr>
<th>Location 628</th>
<th>Effective area 5.7ha</th>
<th>Aspect (°true) 202 (shady)</th>
<th>Slope 20°</th>
<th>Soil Berwen Hill</th>
<th>Bare ground 40%</th>
<th>Litter &lt;1%</th>
<th>Stones 1%</th>
<th>Tussocks 10% (Festuca novae-zelandiae, Poa colensoi, Poa laevigata)</th>
<th>Shrubs none</th>
</tr>
</thead>
</table>

**Location 628**
- **Effective area** 5.7ha
- **Aspect (°true)** 202 (shady)
- **Slope** 20°
- **Soil Berwen Hill**

**Bare ground 40%**
- Litter <1%
- Stones 1%
- Tussocks 10% (Festuca novae-zelandiae, Poa colensoi, Poa laevigata)
- Shrubs none

<table>
<thead>
<tr>
<th>Grasses</th>
<th>Late Summer kg ha(^{-1})</th>
<th>Late Summer %</th>
<th>Late Autumn kg ha(^{-1})</th>
<th>Late Autumn %</th>
<th>Early Spring kg ha(^{-1})</th>
<th>Early Spring %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthoxanthum odoratum</td>
<td>294</td>
<td>32</td>
<td>660</td>
<td>40</td>
<td>600</td>
<td>28</td>
</tr>
<tr>
<td>Poa colensoi</td>
<td>212</td>
<td>23</td>
<td>363</td>
<td>22</td>
<td>533</td>
<td>25</td>
</tr>
<tr>
<td>Dactylis glomerata</td>
<td>158</td>
<td>17</td>
<td>264</td>
<td>16</td>
<td>564</td>
<td>26</td>
</tr>
<tr>
<td>Festuca novae-zelandiae</td>
<td>104</td>
<td>11</td>
<td>116</td>
<td>7</td>
<td>274</td>
<td>13</td>
</tr>
<tr>
<td>Agropyron scabrum</td>
<td>37</td>
<td>4</td>
<td>132</td>
<td>8</td>
<td>42</td>
<td>2</td>
</tr>
<tr>
<td>Agrostis tenuis</td>
<td>13</td>
<td>&lt;2</td>
<td>17</td>
<td>&lt;2</td>
<td>42</td>
<td>2</td>
</tr>
<tr>
<td>Holcus lanatus</td>
<td>7</td>
<td>&lt;2</td>
<td>21</td>
<td>&lt;2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Notodonthonia spp.</td>
<td>7</td>
<td>&lt;2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Clovers**
- Trifolium repens 7 <2
- Trifolium pratense 3 <2

**Other Herbs**
- Hieracium praealtum 29 3
- Cerastium holosteoides 26 3
- Rumex acetosella 10 <2
- Hypochaeris radicata 7 <2
- Echium vulgare

**TOTAL Fresh weight**
- Dry weight 437

**TOTAL Fresh weight**
- Dry weight 914

**TOTAL Fresh weight**
- Dry weight 1636

**TOTAL Fresh weight**
- Dry weight 2123

**TOTAL Fresh weight**
- Dry weight 1257
TABLE 6(i): Land Unit 311, site description and seasonal estimates of fresh weight of intertussock herbage.

<table>
<thead>
<tr>
<th>Location 626</th>
<th>Bare Ground 2%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective area 9.8ha</td>
<td>Litter 1%</td>
</tr>
<tr>
<td>Aspect (°true) 270 (sunny)</td>
<td>Stones 1%</td>
</tr>
<tr>
<td>Slope 8°</td>
<td>Tussocks 5% (Poa laevis, Poa colensoi, Festuca novae-zelandiae)</td>
</tr>
<tr>
<td>Soil Berwen Hill &amp; Tara Steepland</td>
<td>Shrubs &lt;5% (Carmichaelia monroi, Muehlenbeckia axillaris, Discaria tomatou, Rosa rubiginosa)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Late Summer kg ha⁻¹</th>
<th>Late Autumn kg ha⁻¹</th>
<th>Early Spring kg ha⁻¹</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grasses</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dactylis glomerata</td>
<td>1944</td>
<td>78</td>
<td>1669</td>
</tr>
<tr>
<td>Lolium perenne</td>
<td>68</td>
<td>3</td>
<td>162</td>
</tr>
<tr>
<td>Poa laevis</td>
<td>68</td>
<td>3</td>
<td>89</td>
</tr>
<tr>
<td>Agrostis tenuis</td>
<td>56</td>
<td>2</td>
<td>113</td>
</tr>
<tr>
<td>Festuca novae-zelandiae</td>
<td>11</td>
<td>&lt;2</td>
<td>163</td>
</tr>
<tr>
<td>Bromus tectorum</td>
<td>68</td>
<td>&lt;2</td>
<td>114</td>
</tr>
<tr>
<td>Poa colensoi</td>
<td>68</td>
<td>3</td>
<td>65</td>
</tr>
</tbody>
</table>

| **Clovers** |                      |                      |                      |
| Trifolium repens | 53 | 2 | 22 | <2 | 91 | 2 |
| Trifolium pratense | 11 | <2 | 122 | 2 |
| Trifolium dubium |                      |                      |                      |

| **Other Herbs** |                      |                      |                      |
| Achillea millefolium | 260 | 10 | 378 | 17 | 44 | <2 |
| Rumex acetosella |                      |                      |                      |
| Arenaria serpyllifolia |                      |                      |                      |
| Hieracium praesaltum |                      |                      |                      |

| **Shrub** |                      |                      |                      |
| Carmichaelia monroi | 11 | <2 | 31 | <2 |                      |

| **TOTAL Fresh weight** | 2482 | 2202 | 5102 |
| **Dry weight** | 1100 | 681 | 3730 |
TABLE 6(j): Land Unit 321, site description and seasonal estimates of fresh weight of intertussock herbage.

<table>
<thead>
<tr>
<th>Location 604</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective area 34.9ha</td>
</tr>
<tr>
<td>Aspect (°true) 23 (Sunny)</td>
</tr>
<tr>
<td>Slope 8°</td>
</tr>
<tr>
<td>Soil Corbies &amp; McLay</td>
</tr>
<tr>
<td>Steepland</td>
</tr>
<tr>
<td>Bare ground 5%</td>
</tr>
<tr>
<td>Litter 2%</td>
</tr>
<tr>
<td>Stones &lt;1%</td>
</tr>
<tr>
<td>Tussocks &lt;5% (Poa laevis)</td>
</tr>
<tr>
<td>Shrubs 5% (Rosa rubiginosa, Discaria townatou, Hymenanthera alpina)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Late Summer kg ha⁻¹</th>
<th>Late Summer %</th>
<th>Late Autumn kg ha⁻¹</th>
<th>Late Autumn %</th>
<th>Early Spring kg ha⁻¹</th>
<th>Early Spring %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grasses</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loliwm perenne</td>
<td>397</td>
<td>30</td>
<td>554</td>
<td>37</td>
<td>2284</td>
<td>35</td>
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<tr>
<td>Dactylis glomerata</td>
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<td>15</td>
<td>30</td>
<td>2</td>
<td>747</td>
<td>12</td>
</tr>
<tr>
<td>Bromus tectorum</td>
<td></td>
<td></td>
<td>15</td>
<td>&lt;2</td>
<td>2059</td>
<td>32</td>
</tr>
<tr>
<td>Poa laevis</td>
<td></td>
<td></td>
<td>21</td>
<td>&lt;2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clovers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trifolium arvense</td>
<td>122</td>
<td>9</td>
<td>30</td>
<td>2</td>
<td>150</td>
<td>2</td>
</tr>
<tr>
<td>Trifolium repens</td>
<td>33</td>
<td>3</td>
<td>15</td>
<td>&lt;2</td>
<td>89</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Trifolium pratense</td>
<td>97</td>
<td>7</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Other Herbs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Echium vulgare</td>
<td>399</td>
<td>30</td>
<td>674</td>
<td>45</td>
<td>569</td>
<td>9</td>
</tr>
<tr>
<td>Rumex acetosella</td>
<td>32</td>
<td>2</td>
<td>60</td>
<td>4</td>
<td>21</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Crepis capillaris</td>
<td>28</td>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achillea millefolium</td>
<td>13</td>
<td>&lt;2</td>
<td>60</td>
<td>4</td>
<td>82</td>
<td>&lt;2</td>
</tr>
<tr>
<td>Chenopodium album</td>
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<td>&lt;2</td>
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</tr>
<tr>
<td>Erodium cicutarium</td>
<td>60</td>
<td>4</td>
<td>269</td>
<td>4</td>
<td>331</td>
<td>5</td>
</tr>
<tr>
<td>Arenaria serpyllifolia</td>
<td>363</td>
<td>5</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>TOTAL Fresh weight</td>
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<td>1498</td>
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<td>Dry weight</td>
<td>462</td>
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<td>289</td>
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<td>4027</td>
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</tr>
</tbody>
</table>
TABLE 6(k): Land Unit 322, site description and seasonal estimates of fresh weight of intertussock herbage.

<table>
<thead>
<tr>
<th>Location 614</th>
<th>Effective area 11.3ha</th>
<th>Aspect (°true) 23 (flat)</th>
<th>Slope 3</th>
<th>Soil Corbies &amp; Tara Steepland</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Bare ground &lt;1%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Litter 2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Stones 2%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Tussocks &lt;5% (Poa laevis)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Shrubs 5% (Rosa rubiginosa, Discaria townatou, Hymenanthera alpina, Muehlenbeckia sp.)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Late Summer</th>
<th>Late Autumn</th>
<th>Early Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kg ha⁻¹</td>
<td>kg ha⁻¹</td>
<td>kg ha⁻¹</td>
</tr>
<tr>
<td>Grasses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lolium perenne</td>
<td>268 18</td>
<td>447 24</td>
<td>935 28</td>
</tr>
<tr>
<td>Dactylis glomerata</td>
<td>89 6</td>
<td>149 8</td>
<td>307 9</td>
</tr>
<tr>
<td>Poa laevis</td>
<td>85 6</td>
<td>112 6</td>
<td>90 3</td>
</tr>
<tr>
<td>Notodanthonia spp.</td>
<td>9 &lt;2</td>
<td>149 8</td>
<td>1177 35</td>
</tr>
<tr>
<td>Bromus tectorum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clovers</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trifolium pratense</td>
<td>51 3</td>
<td>56 3</td>
<td>18 &lt;2</td>
</tr>
<tr>
<td>Trifolium repens</td>
<td>44 3</td>
<td>130 7</td>
<td>99 3</td>
</tr>
<tr>
<td>Trifolium arvense</td>
<td>27 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Herbs</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achillea millefolium</td>
<td>574 39</td>
<td>373 20</td>
<td>106 3</td>
</tr>
<tr>
<td>Arrhenatherum vulgare</td>
<td>224 15</td>
<td>280 15</td>
<td>306 9</td>
</tr>
<tr>
<td>Marrubium vulgare</td>
<td>41 3</td>
<td>56 3</td>
<td>90 3</td>
</tr>
<tr>
<td>Coprosma sp.</td>
<td>36 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cirsium arvense</td>
<td>10 &lt;2</td>
<td>93 5</td>
<td>106 3</td>
</tr>
<tr>
<td>Verbascum thapsus</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arenaria serpyllifolia</td>
<td></td>
<td></td>
<td>115 3</td>
</tr>
<tr>
<td>Erodium cicutarium</td>
<td></td>
<td></td>
<td>50 &lt;2</td>
</tr>
<tr>
<td>TOTAL Fresh weight</td>
<td>1458</td>
<td>1845</td>
<td>3399</td>
</tr>
<tr>
<td>Dry weight</td>
<td>496</td>
<td>658</td>
<td>1767</td>
</tr>
</tbody>
</table>
TABLE 6(1): Land Unit 323, site description and seasonal estimates of fresh weight of intertussock herbage.

<table>
<thead>
<tr>
<th>Location 624</th>
<th>Effective area 6.9ha</th>
<th>Aspect (true) 23 (flat)</th>
<th>Slope 40</th>
<th>Soil Corbies &amp; Tara Steepland</th>
<th>Bare ground &lt;1%</th>
<th>Litter &lt;1%</th>
<th>Stones 5%</th>
<th>Tussocks 2% (Poa laevis)</th>
<th>Shrubs 5% (Coprosma sp., Muehlenbeckia sp., Disocaria townia, Rosa rubiginosa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grasses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lolium perenne</td>
<td>116 20</td>
<td>563 30</td>
<td>892 24</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dactylis glomerata</td>
<td>102 17</td>
<td>150 8</td>
<td>633 17</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bromus mollis</td>
<td>30 5</td>
<td>94 5</td>
<td>73 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Holcus lanatus</td>
<td>24 4</td>
<td>19 &lt;2</td>
<td>19 &lt;2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poa laevis</td>
<td>22 4</td>
<td>94 5</td>
<td>57 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agrostis tenuis</td>
<td>12 2</td>
<td>4</td>
<td>146 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poa pratensis</td>
<td>8 &lt;2</td>
<td></td>
<td>75 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bromus tectorum</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Festuca rubra</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Clovers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trifolium repens</td>
<td>34 6</td>
<td>19 &lt;2</td>
<td>147 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trifolium arvense</td>
<td>12 2</td>
<td></td>
<td>278 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trifolium dubium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other Herbs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Achillea millefolium</td>
<td>166 28</td>
<td>919 49</td>
<td>745 20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Cirsium arvense</td>
<td>30 5</td>
<td>19 &lt;2</td>
<td>19 &lt;2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rumex acetosella</td>
<td>10 2</td>
<td></td>
<td>19 &lt;2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Juncus sp.</td>
<td>12 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypochaeris radicata</td>
<td>2 &lt;2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arenaria serpyllifolia</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Erodium cicutarium</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbascum thapsus</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTAL Fresh weight</td>
<td>580</td>
<td>1877</td>
<td>3611</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry weight</td>
<td>250</td>
<td>240</td>
<td>2134</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE 6(m): Land Unit 411, site description and seasonal estimates of fresh weight of intertussock herbage.

<table>
<thead>
<tr>
<th>Location 615</th>
<th>Bare ground 8%</th>
<th>Effective area 24.6ha</th>
<th>Litter 10%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aspect</td>
<td>(true) 135 (shady)</td>
<td>Stones 3%</td>
<td>Tussocks 5% (Poa colensoi, Poa laevis, Festuca novae-zelandiae)</td>
</tr>
<tr>
<td>Slope</td>
<td>29°</td>
<td>Shrubs 2% (Carmichaelia monroi, Hymenanthera alpina)</td>
<td></td>
</tr>
</tbody>
</table>

**Soil** McLay Steepland

<table>
<thead>
<tr>
<th>Late Summer</th>
<th>Late Autumn</th>
<th>Early Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg ha⁻¹</td>
<td>kg ha⁻¹</td>
<td>kg ha⁻¹</td>
</tr>
<tr>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
</tbody>
</table>

**Grasses**

<table>
<thead>
<tr>
<th>Species</th>
<th>Late Summer</th>
<th>Late Autumn</th>
<th>Early Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agrostis tenuis</td>
<td>618 49%</td>
<td>1118 62%</td>
<td>1138 58%</td>
</tr>
<tr>
<td>Poa colensoi</td>
<td>80 6%</td>
<td>18 &lt;2%</td>
<td>72 4%</td>
</tr>
<tr>
<td>Dactylis glomerata</td>
<td>72 6%</td>
<td>126 7%</td>
<td>40 2%</td>
</tr>
<tr>
<td>Festuca rubra</td>
<td>62 5%</td>
<td>72 4%</td>
<td>188 10%</td>
</tr>
<tr>
<td>Anthoxanthum odoratum</td>
<td>43 3%</td>
<td>72 4%</td>
<td>43 2%</td>
</tr>
<tr>
<td>Holcus lanatus</td>
<td>9 &lt;2%</td>
<td>72 4%</td>
<td>22 &lt;2%</td>
</tr>
<tr>
<td>Poa laevis</td>
<td>9 &lt;2%</td>
<td>72 4%</td>
<td>22 &lt;2%</td>
</tr>
<tr>
<td>Notodanthonia spp.</td>
<td>8 &lt;2%</td>
<td>35 2%</td>
<td>107 5%</td>
</tr>
<tr>
<td>Lolium perenne</td>
<td>4 &lt;2%</td>
<td>54 3%</td>
<td>54 3%</td>
</tr>
<tr>
<td>Festuca novae-zelandiae</td>
<td></td>
<td>54 3%</td>
<td>63 3%</td>
</tr>
<tr>
<td>Bromus mollis + Bromus tectorum</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Clovers**

<table>
<thead>
<tr>
<th>Species</th>
<th>Late Summer</th>
<th>Late Autumn</th>
<th>Early Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trifolium repens</td>
<td>136 11%</td>
<td>180 10%</td>
<td>116 6%</td>
</tr>
<tr>
<td>Trifolium arvense</td>
<td>13 &lt;2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Trifolium pratense</td>
<td>8 &lt;2%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Other Herbs**

<table>
<thead>
<tr>
<th>Species</th>
<th>Late Summer</th>
<th>Late Autumn</th>
<th>Early Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Achillea millefolium</td>
<td>171 14%</td>
<td>126 7%</td>
<td>27 &lt;2%</td>
</tr>
<tr>
<td>Arrhenathera sp.</td>
<td>17 &lt;2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crepis capillaris</td>
<td>8 &lt;2%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Arenaria serpyllifolia</td>
<td></td>
<td></td>
<td>45 2%</td>
</tr>
</tbody>
</table>

**TOTAL Fresh weight**

<table>
<thead>
<tr>
<th>Late Summer</th>
<th>Late Autumn</th>
<th>Early Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>kg ha⁻¹</td>
<td>kg ha⁻¹</td>
<td>kg ha⁻¹</td>
</tr>
<tr>
<td>%</td>
<td>%</td>
<td>%</td>
</tr>
<tr>
<td>1266 1766</td>
<td></td>
<td>58 40 2%</td>
</tr>
<tr>
<td>1972</td>
<td>1302</td>
<td></td>
</tr>
<tr>
<td>Location 627</td>
<td>Bare ground 15%</td>
<td></td>
</tr>
<tr>
<td>--------------</td>
<td>-----------------</td>
<td></td>
</tr>
<tr>
<td>Effective area 18.9ha</td>
<td>Litter 1%</td>
<td></td>
</tr>
<tr>
<td>Aspect (true) 158 (shady)</td>
<td>Stones 1%</td>
<td></td>
</tr>
<tr>
<td>Slope 4</td>
<td>Tussocks 10% (<em>Festuca novae-zelandiae, Poa colensoi</em>)</td>
<td></td>
</tr>
<tr>
<td>Soil Berwen</td>
<td>Shrubs &lt;1% (<em>Carmichaelia monroi</em>)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Location</th>
<th>Late Summer kg ha(^{-1})</th>
<th>Early Spring kg ha(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grasses</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agrostis tenuis</td>
<td>2372</td>
<td>2099</td>
</tr>
<tr>
<td>Poa colensoi</td>
<td>247</td>
<td>105</td>
</tr>
<tr>
<td><em>Festuca novae-zelandiae</em></td>
<td>66</td>
<td>118</td>
</tr>
<tr>
<td>Anthoxanthum odoratum</td>
<td>47</td>
<td>23</td>
</tr>
<tr>
<td><em>Festuca rubra</em></td>
<td></td>
<td>&lt;2</td>
</tr>
<tr>
<td>Holcus lanatus</td>
<td></td>
<td>13</td>
</tr>
</tbody>
</table>

| Other Herbs |
|-------------|-----------------|-----------------------------|
| Hieracium praelatum | 76 | 23 |
| Rumex acetosella | 10 | 13 |
| Achillea millefolium | 10 | <2 |
| Hypochaeris radicata | 10 | <2 |

<table>
<thead>
<tr>
<th>TOTAL Fresh weight</th>
<th>Late Summer</th>
<th>Early Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dry weight</td>
<td>2838</td>
<td>2393</td>
</tr>
<tr>
<td></td>
<td>1609</td>
<td>1378</td>
</tr>
</tbody>
</table>
### TABLE 6(o): Land Unit 511, site description and seasonal estimates of fresh weight of intertussock herbage.

<table>
<thead>
<tr>
<th>Location 609</th>
<th>Bare ground 40%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Effective area 14.6ha</td>
<td>Litter 2%</td>
</tr>
<tr>
<td>Aspect (true) 293 (sunny)</td>
<td>Stones &lt;1%</td>
</tr>
<tr>
<td>Slope 13°</td>
<td>Tussocks 10% (<em>Poa colensoi</em>, <em>Festuca novae-zelandiae</em>)</td>
</tr>
<tr>
<td>Soil Berwen</td>
<td>Shrubs 1% (<em>Carmichaelia monroi</em>)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Late Summer</th>
<th>Late Autumn</th>
<th>Early Spring</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grasses</strong></td>
<td>kg ha⁻¹</td>
<td>%</td>
<td>kg ha⁻¹</td>
</tr>
<tr>
<td><em>Poa colensoi</em></td>
<td>654</td>
<td>61</td>
<td>1885</td>
</tr>
<tr>
<td><em>Festuca novae-zelandiae</em></td>
<td>241</td>
<td>22</td>
<td>209</td>
</tr>
<tr>
<td><em>Agropyron scabrum</em></td>
<td>50</td>
<td>5</td>
<td>26</td>
</tr>
<tr>
<td><em>Anthoxanthum odoratum</em></td>
<td>22</td>
<td>2</td>
<td>105</td>
</tr>
<tr>
<td><em>Poa laevis</em></td>
<td>157</td>
<td>6</td>
<td>70</td>
</tr>
<tr>
<td><em>Bromus mollis</em> + <em>Bromus tectorum</em></td>
<td>79</td>
<td>3</td>
<td>39</td>
</tr>
</tbody>
</table>

**Clovers**

| Trifolium repens | 16 | <2 | 105 | 4 | 10 | <2 |
| Trifolium arvense | 11 | <2 |  |  |  |  |

**Other Herbs**

| Hieracium praealtum | 44 | 4 | 9 | <2 |
| Rumex acetosella | 11 | <2 | 52 | 2 | 29 | 2 |
| Hypochaeris radicata | 11 | <2 |  |  |  |
| Crepis capillaris | 11 | <2 |  |  |  |
| Hieracium pilosella | 6 | <2 |  |  |  |

**TOTAL**

| Fresh weight | 1077 | 2618 | 1835 |
| Dry weight | 555 | 1602 | 1020 |
Botanical information obtained in spring 1977 was qualitative only, so estimates for the thirty transects were repeated in the period 3/10 to 8/10/78. Charlie readings were available from the comparison of permanent with random transects carried out at the same time. Estimates of total fresh weight at each transect were then made from the season 4 w-mr regression equation of Table 5 and per cent dry matter data from September 1977.

The components of ground cover listed in Table 6 as part of each representative site description were estimated in the 100 m² temporary relevés used to obtain the broad measurement of plant communities which is presented in Table 3. The shrubs were listed from a much wider area in each case.

7.32 The Diet of Sheep on the Study Area

Four estimates of the botanical composition of the diet of lambs and hoggets grazed on the study blocks in late summer and autumn are presented in Table 7. No other class of stock was grazed on the study area after November.

The dung sample from block 62 was collected from lightly stocked hoggets 2½ weeks after they had returned from shearing. Estimates of botanical composition had been completed 12 days earlier and ADM was also measured on 20 February. Grazing pressure was almost constant. The sample from block 62 was taken when grazing pressure was increasing. Botanical composition and ADM measurements were made a week earlier when the lambs were introduced to this block. The first dung sample from block 60 was taken two weeks after the lambs came on to the block and five weeks after botanical composition (in the absence of stock) was recorded. The second sample was collected when the stock were moved on the day they became hoggets. ADM and botanical composition were measured a few days earlier. Grazing pressure was slowly falling at
### TABLE 7: Botanical composition of sheep diet in late summer and autumn 1977 (based on 200 plant cuticle identifications per faecal sample by Miss L. Budgeon, T.G.M.L.I.)

<table>
<thead>
<tr>
<th>Block Rank</th>
<th>Date</th>
<th>Stock (s.u. ha(^{-1}))</th>
<th>g.p. (s.u. tADM(^{-1}))</th>
<th>Grasses</th>
<th>Other Herbs</th>
<th>Shrubs</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>20.2.78</td>
<td>349 hoggets</td>
<td>2.8</td>
<td>Dactylis glomerata 36.5</td>
<td>Rumex acetosella 14.5</td>
<td>Muehlenbeckia axillaris 0.5</td>
</tr>
<tr>
<td></td>
<td>27.2.78</td>
<td>426 lambs</td>
<td>6.5</td>
<td>Lolium perenne 9.5</td>
<td>Echium vulgare 1.5</td>
<td>Discaria tournatou 0.5</td>
</tr>
<tr>
<td></td>
<td>21.3.78</td>
<td>540 lambs</td>
<td>5.0</td>
<td>Anthoxanthum odoratum 22.5</td>
<td>Trifolium spp. 1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.5.78</td>
<td>540 hoggets</td>
<td>4.9</td>
<td>Poa laevis 7.5</td>
<td>Hieracium spp. 1</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Poa colensoi 13</td>
<td>Crepis capillaris 1.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Festuca spp. 11.5</td>
<td>Carex spp. 2</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Agropyron scabrum 2.5</td>
<td>Soleranthus uniflorus 0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Notodonothia spp. 1</td>
<td>Cerastium holosteoides 0.5</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Dichelachne crinita 0.5</td>
<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Notes:**
- s.u. = stocking unit
- tADM = true area of management
- Blocks 62, 61, 60
- Mean rank calculated for each species
- Percentages rounded to one decimal place
21/3/78 and slowly rising at 1/5/78.

The analyses in Table 7 were based on 200 positive cuticle identifications which were proved by Stevens, Rogerson and O'Connor (TGML1, unpubl. manuscript) to be the optimal compromise between statistical accuracy and operator fatigue. However, only tentative assumptions can be made about selection or rejection of species constituting less than 20% of any one analysis.

7.33 Abundance of Pasture Species in the Diet Compared to the Field

Figure 4 a-d illustrates the abundance of the intertussock pasture species on the basis of freshweight and changes from field abundance rank to diet abundance rank. The parts a to d are ordered according to the time sequence of faecal sampling as indicated in Table 7.

On block 62 in February the most abundant species, *Dactylis glomerata* (0) was most eaten. *Lolium perenne* (0) was likewise consumed in the measure that it was available, but *Rumex acetosella* (+12) was eaten as often as ryegrass although only 2 kg ha\(^{-1}\) were available. Land unit comparisons from Table 6 suggest the water courses on block 62, (323) and the shady face (222) were the best sources of sheep sorrel and were therefore grazed more heavily. Selection for *Anthoxanthum odoratum* (+5) was further evidence of the usefulness of land unit 222 at that time of the year.

On block 61 *Poa colensoi* (-1) was much more abundant than on 62 but only a little more was consumed (Table 7). There was less than half as much *Dactylis glomerata* (+3) on this block but this grass was sought after and so remained the most important component of diet. Cocksfoot was most abundant on land unit 221 (Table 6g) as was *Rumex acetosella* (+12). *Lolium perenne* was most common on the sunny land unit 122, and the water courses 322. *Anthoxanthum odoratum* (+3) was found on 221 and 411.
Figure 4a: Changes in relative abundance of intertussock herbage species from field to diet, block 62, late summer 1978.
Figure 4b: Changes in relative abundance of intertussock herbage species from field to diet, block 61, late summer 1978.
Figure 4c: Changes in relative abundance of intertussock herbage species from field to diet, block 60, late summer 1978.
Figure 4d: Changes in relative abundance of intertussock herbage species from field to diet, block 60, late autumn, 1978.
On block 60 at the end of summer 1978 *Lolium perenne* (+2) was the largest component of diet, followed by *Dactylis glomerata* (0). By the end of autumn these positions were reversed so that *Dactylis glomerata* (+4) was 31% of diet and *Lolium perenne* (-1) although more abundant then, was down to 15.5% of diet (possibly due to fungal rust infection). Ryegrass was most abundant on land unit 321 in March, and 321 and 121 in May. Cocksfoot dominated 211, the opposing aspect. *Anthoxanthum odoratum* (+9, +12) was restricted to land unit 511. *Rumex acetosella* (+4, +1) was not so highly favoured as on the other blocks and stocks increased ahead of demand on the four land units where it grew in quantity.

7.34 **Specific Selection Pressure**

The rates of consumption of intertussock herbage species relative to the amounts available are expressed for three particular days in Table 8. These daily consumption percentages were calculated thus:

\[
\text{Specific Selection Pressure (SSP) of species A} = \frac{\text{no. of animals} \times \text{daily intake of fresh herbage} \times \% \text{of diet of sp. A}}{\text{Available fresh weight of sp. A}}
\]

Late summer feed requirements were obtained from Harris (1979). *Rumex acetosella* made a similar contribution to diet on all three blocks in late summer (Table 7) but it was ten times more abundant on block 60 (Figure 4 a-c). At 20/2/78 on block 62 the supply would have been exhausted in two days if both demand and supply estimates were accurate. A similar stress was imposed on *Anthoxanthum odoratum* on block 60 where quantities were very much less than on 61 and 62.

*Dicliochne ornita* is clearly palatable but poorly adapted to close grazing. This species was commonly found growing adjacent to or within tussock crowns so production would be difficult to measure by
**TABLE 8:** Specific Selection Pressure (SSP) in late summer, 1978, ranked by means from three blocks. (SSP is expressed as the percentage eaten daily of that which is available.)

<table>
<thead>
<tr>
<th>Block</th>
<th>60</th>
<th>61</th>
<th>62</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stock</td>
<td>540 lambs</td>
<td>426 lambs</td>
<td>349 hoggets</td>
</tr>
<tr>
<td>Date</td>
<td>21.3.78</td>
<td>27.2.78</td>
<td>20.2.78</td>
</tr>
<tr>
<td>Overall grazing pressure (s.u.t.ADM⁻¹)</td>
<td>5.0</td>
<td>6.5</td>
<td>2.8</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Rank Species</th>
<th>SSP%</th>
<th>SSP%</th>
<th>SSP%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Rumex acetosella</td>
<td>3.3</td>
<td>29.6</td>
<td>38.9</td>
</tr>
<tr>
<td>2 Anthoxanthum odoratum</td>
<td>39.4</td>
<td>1.7</td>
<td>3.3</td>
</tr>
<tr>
<td>3 Dichelachne arinita</td>
<td>3.6</td>
<td>14.7</td>
<td>5.4</td>
</tr>
<tr>
<td>4 Muehlenbeckia axillaris</td>
<td>12.5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5 Crepis capillaris</td>
<td></td>
<td>5.2</td>
<td>6.5</td>
</tr>
<tr>
<td>6 Hieracium spp.</td>
<td>2.7</td>
<td>6.9</td>
<td>0.53</td>
</tr>
<tr>
<td>7 Saleranthus uniflorus</td>
<td>6.9</td>
<td>6.9</td>
<td>2.2</td>
</tr>
<tr>
<td>8 Cerasium holosteoides</td>
<td></td>
<td>6.9</td>
<td></td>
</tr>
<tr>
<td>9 Notodanthonia spp.</td>
<td>0.49</td>
<td>3.4</td>
<td>0.64</td>
</tr>
<tr>
<td>10 Agropyron scabrum</td>
<td>1.4</td>
<td>0.74</td>
<td>0.91</td>
</tr>
<tr>
<td>11 Lolium perenne</td>
<td>0.81</td>
<td>0.72</td>
<td>0.78</td>
</tr>
<tr>
<td>12 Poa colensoi</td>
<td>0.84</td>
<td>0.40</td>
<td>0.87</td>
</tr>
<tr>
<td>13 Dactylis glomerata</td>
<td>0.49</td>
<td>1.2</td>
<td>0.39</td>
</tr>
<tr>
<td>14 Echium vulgare</td>
<td>0.05</td>
<td>0.16</td>
<td>0.26</td>
</tr>
<tr>
<td>15 Trifolium spp.</td>
<td>0.03</td>
<td>0.13</td>
<td>0.13</td>
</tr>
</tbody>
</table>
any method. *Agropyron secalinum* and *Notodanthonia* spp. were the other small native grasses. Both were present on each block at 8 to 32 kg ha\(^{-1}\) fresh weight. Blue wheat grass was always selected for, but mean SSP for *Notodanthonia* is higher because on block 61 when GP was 6.5 it was being depleted rapidly despite the record of indifference (-1) in Figure 4b (cf. 4a, +2 and 4c, -2).

Specific Selection Pressures for the two most important species, *Dactylis glomerata* and *Lolium perenne* were uniformly low on all blocks implying grazing pressure was nowhere severe. The very low SSP values for the pooled legumes, mainly *Trifolium repens* and *T. arvense*, are a reflection of the rejections recorded in Figure 4a-c (but not 4d). Haresfoot trefoil may well have been unpalatable in late summer for morphological reasons, white clover possibly for chemical reasons, or else the cuticle of this genus is still underestimated even by the improved TGMLI techniques.
CHAPTER VIII

DISCUSSION AND CONCLUSIONS

This chapter first considers whether the stratification process adequately represented the landscape. Then the capacitance technique is evaluated with respect to the steep and semi-arid environment of Tara Hills. The next section interprets the grazing pressure results with a view to the improved utilization of available dry matter; the pattern and extremes of grazing pressure are compared with Harris' (1978) results from an unimproved summer range; and the species preference exhibited by the sheep is discussed with reference to four other hill and high country sites. The final section discusses parameters proposed by other workers which discriminate in favour of forage at the expense of total herbage, unlike available dry matter, and which can be suitably derived from the capacitance method.

8.1 THE STRATIFICATION METHOD OF REPRESENTING THE LANDSCAPE

Were the four criteria of Chapter V easily applied? The system of parallel hill faces and gullies was readily mapped in these terms. Some riparian areas and side gullies enjoyed enhanced soil moisture conditions only in spring when the land units were described. The fourth criteria "land-form elements" was partly encompassed by the first and proved almost unnecessary.

Were the land units too big? The size of the land units designated for this study area of 500.1 ha was suitable with respect to the size of blocks, the desire for replication within land units, and
the heterogeneity of the vegetation. Several of the land units have
direct counterparts in one or both the other blocks so that hierarchical
analysis (Table 4) was relevant and furthermore those analogous land
units are members of land systems, applicable to mapping the run or the
district.

Were the land units too small? Most of the smallest land units
were riparian areas or areas of converging drainage which were isolated
by the first of the mapping criteria, "contour concavity". Land units
604, 614 and 624 ran almost the length of the main hill faces on their
respective block and so were readily accessible despite their small
area. These small land units were also important because the various
water sources were all located there. Although it is not known if the
merinos required water regularly, the herbage of the water courses
remained high in moisture content after the streams dried up. (Watering
behaviour by halfbreds on unimproved range at Glenthorne was observed
not to occur by Harris (1978) although some movement to stream and
drinking was observed following topdressing (P.S. Harris, pers. comm.).)

Sheltering was very prevalent on hot days in summer. Shelter
bushes of Discaria tomatou and Rosa rubiginosa were most common on
land units 604, 614 and 624 although rock outcrops were utilized
elsewhere.

Finally the riparian areas were most important to the yearling
and two-year heifers grazed on the study blocks in early spring. The
rank vegetation was removed by the cattle, allowing effective grazing
by sheep during the growing season.

Were some of the land units irrelevant to pastoral production?
Under the present system this seems to be the case. The land units
which appeared to be least utilized by the stock were 609 - Poa colensoi
with minimal intertussock herbage at the crest of this block; 615 -
south east spur faces in rank and dense browntop; and 627 - the southerly crest on block 62 similarly covered with browntop. Herbage sampling at the transects on these land units involved cutting long-standing vegetation rather than new season's regrowth of varying stages. It seems probable these areas are under-used because of their exposure, or, in the case of 615, its shadiness, and because of the rankness of vegetation which has consequently developed.

It should be recognised that the present wastage on these land units is a small price to pay if the balance of the blocks can be successfully grazed. Certainly the overall utilization of the study area has improved since 1963 when the largest sunny and shady faces were fenced to form blocks 62 and 61 respectively. When controlled grazing became possible, differences in the herbage composition of these faces and those of block 60 where grazing distribution remained uncontrolled were studied (Ludecke and Molloy, 1966). After fencing there was much better utilization of fodder on block 61 than on the equivalent dark face on block 60. On both 61 and 62 there was a decrease in the amount of bare ground and an increase in cover of native and introduced grasses, clovers and other herbs.

Are the differences between land units real in terms of grazing management? No particular patterns were found when the weight of herbage water was correlated with capacitance values at either the transect, land unit, "community" or "terrain" levels of Table 4. There was no duplication of relevés within land units when the field lists for Table 3 were drawn up so although vegetation phases on the basis of analogous land units (between blocks) were suggested by the data, only the clearest distinction into phases A and B was made and circular reasoning was avoided.
It is interesting to note from the clustering of abundance indices in Table 3 that the flora of the water-courses more closely matches that of the sunny faces and the flora of the crests that of the cold faces. These riparian land units were dominated by the improved grasses *Lolium perenne* and *Dactylis glomerata* and by the dryland species *Echium vulgare, Achillea millefolium* and *Bromus tectorum*.

The water content of the herbage from the riparian land units averaged 59% over the whole study period and 64% from November, after cattle had grazed the rank growth. The sunny land units also averaged 59% herbage water during the study. The shady land units had herbage of 53% average moisture. The browntop and blue tussock of the cold/crest land units had only 43% moisture. Moisture contents of herbage are the reverse of what might be expected from evaporative regimes of the aspects involved. These herbage moisture differences reflect the higher utilization of vegetation on sunny and riparian land with consequent lower accumulation of dead material of low moisture content.

Not surprisingly, the water courses and sunny faces are dissimilar in terms of floristic diversity. The land unit with the greatest number of species was 624, a riparian area. The northerly faces on each block and the main northwest face of block 62 contained the fewest herbage species.

Was the location of transect pairs in each land unit for sampling purposes consistent with the subsequent expression of available dry matter on a land unit rather than single transect basis? The members of each transect pair were treated as replicates so that available dry matter results for the land unit were the mean of the transect values. Standard errors ordinarily assume randomly located sampling sites within land units. The standard errors presented in Appendix 5 are of means of two transects which were located, with access in mind, so as to reflect
the range of altitude, space and floristic diversity of the land unit (see section 5.32). On the hill faces the transects were matched to the predominant aspect and slope where possible. This subjective "sub-stratification" might have been expected to lead to high standard errors for the mean of each land unit. The fact that most of the standard errors are not unduly high suggests that the land units are well conceived and that the mean of two transects represents each fairly.

Steiger (1930) published analyses of the structure of prairie vegetation on which several workers subsequently based theoretical investigations concerning the random or non-random nature of the distribution of plant individuals in plant communities. At his lowland site, Steiger read 1 m² quadrats at regular intervals on a random line but at his upland site a similar number of quadrats were selected "with the express purpose of including various portions of the tract upon which the vegetation was much more diversified." For this reason Curtis (1955) published a warning note which exposed the pitfall of studying artificial populations which are not truly random: "Almost any spatial pattern (of plants) can be made to appear regular, random or aggregated if areas of great local concentration are either favoured or avoided in the sampling."

Although the transects were subjectively located insofar as representativeness was concerned, their specific location was at random within the conceptual "sub-stratum". By the close of spring 1977 some transects were observed to be less representative of the whole land unit as used by stock. These anomalies were then corrected by the creation of one new land unit and the relocation of some transects (see section 5.34). The experience of the year's observations was used to select relevés in spring 1978 for the phytosociologic analysis (Table 3). A chosen relevé was in some cases adjacent to one of the transects
rather than at some intermediate position. By this time evidence was probably sufficient to allow omission of some transects if periodic, low-precision measurements of available dry matter were to continue. To achieve greater precision and confidence, more transects could then have been randomly located within land units.

Estimates of the number of transects that would be required on each land unit to reduce the present pooled coefficients of variation to 20% are presented in Appendix 10. This information suggests at least one of the existing transect pair on land units 621 and 623 should be relocated. The same is probably true of land units 615, 627, 604 and 628 although the exceptionally dry season encountered is a mitigating circumstance. In a normal year three or four transects on most land units could be expected to provide a reliable mean for available dry matter. New transects would be located bearing the inferred grazing distribution of the sheep in mind. Land units 609, 615 and 627 are low priority areas from which information could be foregone under the present management if any one block was to contain more than 15 transects - a day's work to measure on this terrain.

Despite the dryness of the growing season and the non-random element in transect location, trebling of the number of transects is in the majority of cases sufficient to ensure a reliable mean value for available dry matter on each land unit.

8.2 THE CAPACITANCE TECHNIQUE IN A SEMI-ARID AND STEEP ENVIRONMENT

Was sufficient green herbage present to allow measurement by a water-based technique? The rainfall at Tara Hills in 1977 was 384 mm compared to the 27 year mean of 515 mm. This was the driest year since formal recording began. The dry season continued until the end of the
growing season in May 1978. According to Penman potential evapotranspiration calculations, there were only 63 days out of 312 during the study period when there was soil moisture in the rooting zone freely available for plant growth. However, it is assumed that actual evaporation continues at the potential rate until the available soil moisture is used up (Coulter, 1973). In fact, evapotranspiration from dry soil surfaces is considerably less than the potential rate, e.g. 90% at a leaf area index of four and 40% at LAI = 1 (R.W. Heine, pers. comm.). Transpiration by plants may occur independently of evaporation from the soil surface. Growth is impeded before the bank of standing herbage is degraded by drought. By March 1978, scorching of green cocksfoot leaves was evident at some sites.

The chief disadvantage of the capacitance probe commissioned in November 1977 was the insensitivity of its circuitry in relation to the low levels of available dry matter encountered over much of Tara Hills. However, the problem was the environment. From November to May, 590 of about 700 mean meter readings at Tara Hills were in the range 0.5 to 5.0 µA. Of the fifty meter readings from pasture and waste places at Lincoln College which contributed to Appendix 9, the four lowest were in the range 5-10 µA as recorded by a similar instrument. At Tara Hills 24 cuts at 5 µA contained an average of 29g water. At Lincoln, the one cut at this meter reading contained 26g of herbage water.

The water content of herbage averaged 40% at the end of August (the beginning of the growing season); 51% in November; 58% in December and January; 45% in March; and 58% in April. Broadly similar values were obtained by Harris (1978) from unimproved range in a humid environment: 51% moisture in November; 59% in December; only 40% in January; 55% in February and March; and 49% in April.

It must be noted that although levels of standing herbage were
too low to be effectively measured at some sites at the end of summer, extraneous water rather than drought is more limiting to the application of the capacitance technique to tussock grasslands. It was found even in the semi-arid environment of Tara Hills that in autumn dew and rain remained too long on the vegetation of the shady faces to permit routine capacitance-based sampling. On 27th April 1978 dew was still present on transect 604b at 2.30 p.m. On block 66, which faces northwest, however, it was possible to record with Charlie through the winter (B.E. Allan, pers. comm.).

Although the literature does not regard dew as a major problem (e.g. Johns and Watkin, 1965) it is, when present, a very variable "contaminant" depending on aspect, plant cover and phenology, and elapsed time from the cutting of herbage samples.

The loss of herbage water from samples was assumed to be matched by the loss of dry matter due to continued respiration of the cut herbage inside the paper bag. The conditions of storage were considerably less rigorous than those described by Edwards (1965) of containment by polythene and exposure to the sun, whereupon, however, significant changes in per cent dry matter were not recorded over 23 hours.

Was the instrument sufficiently robust for measuring steep country? The structural strength of the capacitance probe used for most of the study was acceptable for hill work although the stability of the instrument on slopes greater than 25° was marginal when unattended. An ideal design for a hill country Charlie would seem to be a main frame like a pack frame supporting aluminium alloy probes, perhaps spring loaded. The meter would be recessed or folding so as to lower the centre of gravity and allow the instrument to be worn on the back. Alternatively, the current Charlie could be clamped to a pack
frame rather than worn from a diagonal sling.

The speed of obtaining capacitance readings is not under question. The author and co-worker obtained 1350 readings from a total of six scattered locations on steep country in one day on Longslip Station. The stability of the needle is such that a reading is possible as soon as the machine is on the ground. However, the vagaries of range picotopography are such that repeatability of reading for reading upon making two passes along the same transect at the same pace is not good. Slowing the process or shuffling the instrument in a test for repeatability increases compression of the vegetation and constitutes a departure from the routine technique. If individual readings are unrepeatable their value for deriving quantitative information about the botanical composition of the transects as in Table 6, comes under question.

Were the transects satisfactory? The worth of transects on steep slopes rather than sampling at random throughout 20m x 20m plots was established in terms of both operator-convenience and limiting human interference to the vegetation. It was not always possible for all the probes to be placed close to the ground at each of the 25 positions because of rocks and scarplets. Capacitance instruments of smaller measuring area should be considered. This study required the assumption that hillocks and hollows were self-cancelling over-all in terms of interference.

Was the new calibration technique reliable? The validity of placing cut herbage between enclosed probes rather than cutting a quadrat of the desired capacitance is suggested by comparing the $r^2$ values of 0.87 and 0.77 from Appendix 9. At Tara Hills the boxed herbage was gathered randomly, often from several square metres, and so the herbage water to dry matter ratio of the samples was more
representative than most placements of a 0.2 m² quadrat would have obtained. The contribution of that component of tufted grasses below reasonable grazing and cutting height to capacitance readings has not been adequately assessed. The chief disadvantage of the box technique is that such a contribution would be substituted by cuttable herbage of presumably higher moisture content (but therefore less dry matter) and this material would represent the measured, but unavailable component in the derivation of ADM.

8.3 GRAZING PRESSURE, UTILIZATION AND PREFERENCE

At constant stocking rate, the trend of grazing pressure as defined in this study is the mirror image of available dry matter when both parameters are graphed as in Figure 3. The magnitude of grazing pressure is ordered by the stocking rate.

Annual stocking rates calculated for the year July 1977 - June 1978 were all significantly less than the traditional carrying capacities of these blocks (Musgrave, 1977). Seasonal set stocking on block 60, which is 79% sunny, was equivalent to 1.64 s.u. ha⁻¹ which was 83% of normal. Block 61 (28% sunny) was stocked at 0.84 s.u. ha⁻¹ or 42% of normal. Block 62 (91% sunny) was stocked at 1.14 s.u. ha⁻¹ or 77% of normal.

With hindsight, some stock could have remained on block 60 after 12th December for up to a month (Figure 3a). Part of the herbage stock senesced during the period and was lost, but rainfall in this month boosted the water content of the younger material.

The delayed commencement of grazing on block 61 relative to the other two was appropriate. However, grazing was foregone in December and January so that 200 kg ha⁻¹ of ADM was lost through senescence and
the dry matter of the herbage increased from 34% in December to 50% in February when grazing finally commenced. Despite this loss of ADM through spelling, the potential for improving cover through seeding and spelling should not be overlooked - the three largest land units on this block contained 15%, 20% and 8% bare ground. White clover composition in the following spring was estimated as <2%, <2% and 6% respectively for those same land units, the latter situation being the most shaded.

In April a more dramatic rise and fall of ADM on block 61 is suggested by Figure 3b, beyond the consumption of forage by 540 hoggets in early May. Ground frosts were recorded each week in April on this block.

Figure 3c suggests that the pasture production of block 62 was adequately utilized during the particularly dry growing season of the study. Available dry matter was usually less than 500 kg ha⁻¹ after November. Reserves were thus inadequate for much winter grazing in 1978 although the strategic value of this block in terms of short lived snow cover is largely independent of plant cover. Normally about 1150 hoggets would graze block 62 from mid-April to mid-July and then move to block 60 until spring.

Average available dry matter at Glenthorne from six dates between November 1976 and April 1977 on the most widely used land units ranged from 270 to 670 kg ha⁻¹ (Harris, 1978). Grazing pressure indices for the season were 11.2 s.u./t.ADM in the swamp, 7.0 on the nearby knob and between 1.1 and 2.3 on the other land units. However, the overall grazing pressure on the Glenthorne study area was over 10.0 in early April, which is high compared to the maxima recorded on the smaller Tara Hills blocks. At the preferred swamp and knob sites at Glenthorne, grazing pressures then reached 73 and 45 respectively. Grazing pressures
on individual land units were not established in the present study, but palatable pasture species were widely distributed within each block. Although stock did not have the option of regulating grazing pressure by migration as was possible at Glenthorne, under normal management maxima were only 12 or 14 overall. Grazing pressure was probably never excessive on any one land unit. Merinos are well adapted to the dry environment of Tara Hills. The hoggets grew well during the study period.

The most sophisticated of the grazing management parameters used in this study, Specific Selection Pressure, is also the least firmly grounded in sound contributing data. As expressed in Table 8 however, this parameter indicates very practically just how fast the stocks of the most preferred species were being consumed at the time dung sampling (less two or three days for time-of-passage) and botanical composition measurements were carried out.

The point analysis method of quantifying faecal cuticle gives an estimate of the relative area of surface of different plant species ingested by the sheep. It does not directly indicate the relative weights of different species eaten (Hughes, 1975), nor does it compensate for possible differential digestion of cuticle or damage during preparation. The current method used (Rogerson et al., 1976) appears to rank diet components avoiding the loss of sensitive cuticle in preparation such as was suffered by Hughes (1975).

Strictly speaking it is incorrect to claim that differences in acceptability of forage species are the reason for differences in relative intake when the species are of different availability (Hughes, 1975). For an animal to continue to exhibit the same degree of preference for a species, the preferred parts of it must remain available in the same quantity and without changes in chemical quality. Therefore information about individual plant species in Figure 4 and Tables 7 and 8 must be
interpeted in relation to the level of supply of other species on the same block. With respect to the warning at the end of section 7.32, *Dactylis glomerata* and *Lolium perenne* are the only components of diet large enough to allow firm assumptions as to preference by young merinos.

The following additional information concerning sheep preference for high country forage species was obtained from a developed sub-humid block on Ribbonwood Station (Hughes, 1975); a partly improved humid block on Brooksdale (Stevens, 1977); a developed humid paddock at Cooper's Creek (Stevens, *ibid*); and an undeveloped humid summer range on Glenthorne Station (Harris, 1978). The Ribbonwood results carry the rider that *Trifolium repens* and *Anthoxanthum odoratum* cuticle was partially destroyed during the preparation of dung samples for point analysis.

*Dactylis glomerata* was the major component of diet on the Tara Hills hogget block during late summer and autumn. Figure 4 indicates indifference and positive selection by young sheep in late summer and autumn. At Ribbonwood, cocksfoot was 7th in abundance and 2nd in overall preference. At Brooksdale and Cooper's Creek it was a consistently preferred minority species and both leaf and stem were ingested. At Glenthorne it was not among the twelve most abundant species but comprised 2-7% of cuticle identifications for the February-April period.

*Lolium perenne* at Tara Hills was also grazed in the measure of its abundance. At Ribbonwood it was the most preferred species but ranked 12th in abundance. At Cooper's Creek it was somewhat rejected, particularly during times of lower grazing pressure in spring and autumn. At Glenthorne it was a minority species.

*Rumex acetosella* was the 3rd-ranked component of diet in the latter part of the growing season at Tara Hills. In the other, wetter study areas it was not an important forage species although positive
selection was recorded under lower and higher grazing pressures at Brooksdale.

* Anthoxanthum odoratum * was selected on each of the Tara Hills blocks, particularly on block 60 where least was available. This species was inadequately measured by the faecal cuticle method then used with the Ribbonwood samples. At Brooksdale it was treated with indifference by the sheep. At Cooper's Creek it was also an important species, consistently preferred and ranking 2nd or 3rd in all seasons. At Glenthorne it was the most abundant species and the most eaten, making up 19-25% of the diet.

* Poa laevis * made a surprisingly large contribution to diet during the driest period on Tara Hills. Lambs on blocks 60 and 61 apparently made up 13 and 14% of their diet with this grass. Silver tussock was unimportant at Brooksdale and Cooper's Creek but it was recorded in the diet. The stems appeared relatively palatable.

* Poa colensoi * was the most consistently eaten tussock at Tara Hills, the response seeming to reflect supply on each block. Note however the different expressions of this situation by Figure 4 and Table 8. Blue tussock was present only in small quantities at Ribbonwood. It was 15th preference on the developed block (and 5th on the undeveloped).

* Poa * species were not important at Glenthorne.

* Festuca * species, which were often recorded in the diet at Tara Hills, were probably both * Festuca novae-zelandiae * and * F. rubra * which is smaller than the tussock but also somewhat fibrous. These species were 5th and 6th respectively in abundance at Ribbonwood but were unranked and 16th in the diet. At Glenthorne * Festuca * species were ranked 9th preference, being somewhat rejected; * F. novae-zelandiae * was there ranked 3rd in abundance.

* Agropyron scabrum * was a consistently favoured minority component
of the Tara Hills diet. Indifference was found in February at Ribbonwood and selection in May. At Cooper's Creek it appeared in the diet of early summer and late autumn. At Glenthorne it was ranked 6th in preference.

*Notodonanthonia* species were ranked 9th equal preference at Tara Hills, similar to *N. clavata* at Ribbonwood, which was most utilized in late winter. *Notodonanthonia/Cynosurus* leaf was the most abundant component of dung samples from the sunny aspect at Cooper's Creek. Selection within months was neutral or positive. At Glenthorne *Notodonanthonia* was jointly 4th ranked in preference and 8th ranked for abundance.

*Echium vulgare* was apparently consumed under duress or out of curiosity by lambs in March when it was the most abundant plant on block 60. This species was a very small component of herbage at Ribbonwood but was strongly selected in spring when it is in the rosette stage.

*Trifolium* species (mainly *T. repens*) were rejected at Tara Hills except in late autumn on block 60. At Brooldale *T. repens* was the only abundant species which was consistently and markedly preferred. At Cooper's Creek *Trifolium* species were 5th and 6th ranked components of diet on shady and sunny faces respectively. At Glenthorne this genus was 2nd preference and 5th in abundance.

*Agrostis tenuis* appears in parts a and b of Figure 4 although it was never identified in the dung samples. At Ribbonwood it was 2nd in abundance in February and May but only slight rejection was exhibited. At Brooldale and Glenthorne browntop was also abundant and the response neutral. Apparently the Tara Hills stock were free to reject this grass because it was a minority component or absent on all except two land units where it was highly available in late summer at 190 and 230 kg ha⁻¹ fresh weight.

Similarly *Achillea millefolium* was not recorded during faecal cuticle analysis but was available in quantities ranging from 15 to 170
\(135\) kg ha\(^{-1}\) fresh weight. Yarrow at Ribbonwood was ranked similarly for both abundance and diet: 9th and 11th respectively. At the three humid localities this species was not significant.

Finally it should be noted that the Ribbonwood, Cooper's Creek and Glenthorne studies of the grazing preference of sheep lasted most or all of one year, and each indicated the rather consistent way in which sheep prefer some species and select against others at virtually all times regardless of their abundance.

### 8.4 PARAMETERS WHICH EMPHASIZE FORAGE

This study indicates that available dry matter should no longer be assumed the logical parameter to be derived from capacitance-based pasture measurements. This observation is particularly pertinent to the high country where stock seek out forage species from the herbage on offer and then where possible seek green forage ahead of senescent material. Such dilution factors can often be eliminated if improved pasture species can be established and grazed promotionally, but the variation in aspect, altitude and soil moisture in mountainous terrain is such as to preclude complete uniformity and utility of swards across any one grazing block.

The apparent maximum rate of intake by hungry young sheep of both green and dry herbage was related to grazing time and herbage availability by Allden and Whittaker (1970). There was a steady and consistent increase in the herbage moisture content associated with increasing herbage availability so that the rate of dry matter intake was constant at ADM levels above 1800 kg ha\(^{-1}\) but the rate of intake of fresh material did not stabilize until at least 3000 kg of dry matter was available. Grazing time became constant at about 400 minutes day \(^{-1}\) at this same threshold.
The relationship between water content of herbage and the overall quality of the vegetation measured by in vitro digestibility was examined by Harris (1978) for samples taken from most of the Glenthorpe sites in December, February and March. The pooled results gave a correlation coefficient of 0.78 between the two parameters (a similar relationship to that of water content and capacitance reading at Tara Hills). Harris then inferred the digestibility of the ADM at each sampling date using the linear prediction equation and calculated grazing pressure both as GP\text{dm} and GP\text{ddm}. The latter index was always somewhat larger, particularly in January when stocks of actively growing herbage were minimal.

Stevens (1977) had earlier proposed this digestibility-based parameter and named it Feeding Pressure. Using Joan Radcliffe's data from Cooper's Creek, Stevens presented indices of feeding pressure and grazing pressure for the period September 1973 to June 1974. Grazing pressures on the shady face were very much higher than on the sunny, but feeding pressures suggested the differences were not so marked.

Clarke (1977) reported preliminary investigation of the possibility of predicting digestible dry matter directly from capacitance readings. This method seems to offer a more sensitive assessment of the worth of different plant communities on the same range to stock. Prediction equations for available dry matter such as the examples in Appendix 8 were derived from capacitance readings and herbage samples taken on three days falling within a week or two, from three blocks being variously grazed or spelled. Such functions, whether for available or digestible dry matter, can be applied to capacitance readings made at a similar time in subsequent years which are supported by strategic qualitative sampling of the herbage.
CHAPTER IX

SUMMARY

9.1 Pasture production on 500 ha of improved semi-arid high country was measured by a capacitance probe instrument for one growing season at Tara Hills High Country Research Station. The capacitance technique itself was under evaluation because some earlier work in the tussock grasslands was frustrated as herbage samples cut to calibrate the instrument were unrepresentative in terms of herbage water to dry matter ratio. The following parameters relating to grazing management were studied to determine if the forage on the three blocks involved was adequately utilized without detriment to the most useful species and most preferred grazing areas: available dry matter; available herbage water; soil moisture deficit; grazing pressure; botanical composition as fresh weight; diet (during the latter part of the growing season) and specific selection pressures (for the same period).

9.2 Blocks 60, 61 and 62 were chosen because of the hillsides of complementary aspect which they contained; somewhat complementary seasonal set-stocking and good access to top and bottom. These blocks are steep sided ridges arising from the Omarama Basin and leading south-west to the crest of the lower Ewe Range. The main soils are dry subhygrous and subhygrous yellow grey earths derived from non-foliated semi-schist.

Block 60 was mapped with respect to rock outcrops and slopes and the effective (grazable) area estimated to be 213.0 ha. Seventy-nine per cent of the block is sunny country facing north or north-west.
Five land units were mapped on this block by applying the following criteria in descending order: contour concavity (land unit 604); aspect (601, 602); vegetation (603, 609); and land-form elements.

Most of this block comprises both sides of a large gully.

Block 61 is 91.7 ha effective area and 28% sunny. Four land units were mapped: 614 (contour concavity); 613 (aspect); 612 and 615 (vegetation).

Block 62 is 195.4 ha and 91% sunny, being mainly the north-west face opposite block 61. Six land units were mapped: 624 (contour concavity); 621, 628 (aspect); 623, 627 (vegetation); and 626 (vegetation and landform elements).

Two permanent 25m transects were located on each land unit to allow replication and reflect variation within each unit.

9.3 Available dry matter was measured at each transect twelve times between 31st August 1977 and 9th May 1978. The mean of 25 capacitance readings at 1m intervals was calculated by an assistant, and random close-cut herbage from nearby was introduced to a cardboard box enclosing a subset of the probes so that the mean capacitance was matched. Two or three such samples per transect were measured for water and dry matter content. Composite ADM derived for block 60 ranged from 300 to 900 kg ha\(^{-1}\); block 61, 480-1280 kg ha\(^{-1}\); 62, 200-720 kg ha\(^{-1}\). The lowest quantities were each recorded in mid-March.

9.4 The capacitance reading, water content and dry weight of 688 herbage samples were analysed in 64 groups based on 12 "seasons", 15 land units, and hierarchical combinations of land units based on increasingly broad similarities. Overall, changes in water content of the samples explained 61% of the variation in capacitance. Seasonal correlation coefficients ranged from 0.53 to 0.91. Analysis of herbage water to dry matter ratios
of samples where the former parameter was poorly correlated with capacitance sustained the thesis that capacitance probes respond to plant water only without undue influence from senescent or dried material. Further development of the capacitance technique is suggested to simplify herbage sampling and capitalise on the relevance of the water content of forage. Two seasonal prediction equations based on capacitance were compared with known calibration samples.

9.5 Rainfall was very low during the study period so that with an assumed soil storage capacity of 25mm, there were only 63 days in 255 when free soil moisture was available for plant growth.

9.6 Grazing pressure on block 60 reached a maximum of 14 stock units/tonne ADM and was usually between 5 and 7 s.u./t.ADM. The range on block 61 was similar and the maximum about 9 s.u./t.ADM. Block 62 was grazed for a greater proportion of the growing season: in early November there were 12.5 s.u./t.ADM but at most other times the grazing pressure was less than 4.

Annual stocking rates for the year July 1977 to June 1978 were 1.64, 0.84 and 1.14 s.u. ha\(^{-1}\) for blocks 60-62 respectively. Usage was thus estimated as 83%, 42% and 77% of normal, in terms of the historical stocking rate since oversowing. Some eligible grazing was foregone in early summer and late autumn, particularly on block 61.

9.7 Botanical composition of the herbage at each capacitance reading site was estimated by eye to the nearest 5% on two or three occasions and quantitative estimates, also on a fresh weight basis, determined from the appropriate set of 750 capacitance readings. The most abundant intertussock species in the latter part of the growing season were *Dactylis glomerata*, *Poa colensoi*, *Agrostis tenuis*, *Lolium perenne*, *
Trifolium spp., Achillea millefolium, Echium vulgare, Bromus spp. and Rumex acetosella.

In early spring 1978 estimates of bareground, shrubs and tussocks were made on each land unit as well as supplementary records of abundance and sociability of the herbs and grasses. Vegetation of the sunny faces was thus found to be broadly similar to that of the watercourse land units and the species of the shady faces were also found on the crests.

9.8 The diet of merino lambs and hoggets on the study area was estimated by faecal cuticle analysis of samples collected between late February and late April. On each of four occasions the diet was very varied. Only Dactylis glomerata (and Lolium perenne in one case) ever contributed more than 20% of the cuticle fragments identified. Trifolium species were apparently discriminated against.

9.9 The specific selection pressures imposed on fifteen plants were estimated as the percentage of the species eaten daily of that which was available to the stock. In terms of this parameter Rumex acetosella, Anthoxanthum odoratum and Dichelaehne crinita were often highly sought after by sheep in late autumn.

9.10 It was concluded that the criteria used to stratify the study area were relevant and easily applied. The land units so derived were of suitable size, and differences in utilization were apparent between groups of analogous land units from the three blocks.

The number and location of transects within land units are reviewed and suggestions made on statistical grounds and with reference to the present results.

The capacitance technique as calibrated in this study was found adequate even in the very dry conditions of 1977/78.
Some conclusions of other workers in the high country regarding the plant species preferred by sheep are affirmed. Parameters which emphasize forage appear to be suitable alternatives to available dry matter for the grazing management of tussock grassland.
ACKNOWLEDGMENTS

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I thank Professor Kevin O'Connor for his willingness to reinstate the vision when on occasion it had receded, and for the support which the Tussock Grasslands and Mountain Lands Institute afforded through him.

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REFERENCES


APPENDIX 1: Meteorological data from a sunny exclosure at 850m, block 60, and a shady exclosure at 830m on block 61.

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Information supplied by MAF, Tara Hills.
APPENDIX 2: Soil moisture, 0 - 10cm (per cent of oven dry weight).

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<td>19/4</td>
<td>7.0</td>
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<td></td>
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1 Information supplied by MAF, Tara Hills.

2 Mean of samples at two locations, each of six cores.
APPENDIX 3: Comparison of mean Charlie capacitance (mr) at permanent transects with three adjacent random transects.

<table>
<thead>
<tr>
<th>Location</th>
<th>Permanent Transect</th>
<th>Random Transects</th>
<th>Mean</th>
<th>% Difference from Mean</th>
</tr>
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<td></td>
<td>Location</td>
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<td>s.e.</td>
<td>Mr.</td>
</tr>
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<td>626a</td>
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<td>628a</td>
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<td>0.6</td>
<td>0.58</td>
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<tr>
<td>2 Early Spring (13.9.78)</td>
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### APPENDIX 4: Mean Charlie capacitance (mr, n=25) and standard error for each transect on each sampling date.

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<th>139</th>
<th>166</th>
<th>179</th>
<th>192</th>
<th>216</th>
<th>231</th>
<th>258</th>
<th>279</th>
<th>300</th>
</tr>
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<td>10.10.77</td>
<td>17.11.77</td>
<td>14.12.77</td>
<td>27.12.77</td>
<td>9.1.78</td>
<td>2.2.78</td>
<td>17.2.78</td>
<td>16.3.78</td>
<td>6.4.78</td>
<td>27.4.78</td>
</tr>
<tr>
<td>Transect</td>
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<td>mr s.e.</td>
<td>mr s.e.</td>
<td>mr s.e.</td>
<td>mr s.e.</td>
<td>mr s.e.</td>
<td>mr s.e.</td>
<td>mr s.e.</td>
<td>mr s.e.</td>
<td>mr s.e.</td>
<td>mr s.e.</td>
<td>mr s.e.</td>
</tr>
<tr>
<td>601a</td>
<td>14.6</td>
<td>5.3</td>
<td>6.9</td>
<td>4.5</td>
<td>0.9</td>
<td>1.6</td>
<td>3.0</td>
<td>1.2</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
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<td>6.9</td>
<td>4.5</td>
<td>0.9</td>
<td>1.6</td>
<td>3.0</td>
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<td>5.3</td>
<td>6.9</td>
<td>4.5</td>
<td>0.9</td>
<td>1.6</td>
<td>3.0</td>
<td>1.2</td>
<td>0.8</td>
<td>0.8</td>
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<td>0.8</td>
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<tr>
<td>602b</td>
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<td>6.9</td>
<td>4.5</td>
<td>0.9</td>
<td>1.6</td>
<td>3.0</td>
<td>1.2</td>
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<td>6.9</td>
<td>4.5</td>
<td>0.9</td>
<td>1.6</td>
<td>3.0</td>
<td>1.2</td>
<td>0.8</td>
<td>0.8</td>
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<tr>
<td>603b</td>
<td>14.6</td>
<td>5.3</td>
<td>6.9</td>
<td>4.5</td>
<td>0.9</td>
<td>1.6</td>
<td>3.0</td>
<td>1.2</td>
<td>0.8</td>
<td>0.8</td>
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</tr>
<tr>
<td>604a</td>
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<td>5.3</td>
<td>6.9</td>
<td>4.5</td>
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<td>1.6</td>
<td>3.0</td>
<td>1.2</td>
<td>0.8</td>
<td>0.8</td>
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<tr>
<td>604b</td>
<td>14.6</td>
<td>5.3</td>
<td>6.9</td>
<td>4.5</td>
<td>0.9</td>
<td>1.6</td>
<td>3.0</td>
<td>1.2</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
<tr>
<td>605a</td>
<td>14.6</td>
<td>5.3</td>
<td>6.9</td>
<td>4.5</td>
<td>0.9</td>
<td>1.6</td>
<td>3.0</td>
<td>1.2</td>
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<td>0.8</td>
<td>0.8</td>
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<tr>
<td>605b</td>
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<td>5.3</td>
<td>6.9</td>
<td>4.5</td>
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<td>1.6</td>
<td>3.0</td>
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<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
<td>0.8</td>
</tr>
</tbody>
</table>

| Block 60 | 602a | 14.6 | 5.3 | 6.9 | 4.5 | 0.9 | 1.6 | 3.0 | 1.2 | 0.8 | 0.8 | 0.8 | 0.8 |
| Block 61 | 604a | 14.6 | 5.3 | 6.9 | 4.5 | 0.9 | 1.6 | 3.0 | 1.2 | 0.8 | 0.8 | 0.8 | 0.8 |
| Block 62 | 606a | 14.6 | 5.3 | 6.9 | 4.5 | 0.9 | 1.6 | 3.0 | 1.2 | 0.8 | 0.8 | 0.8 | 0.8 |

() - Coarse meter scale
APPENDIX 5: Available dry matte r (kg ha\(^{-1}\)) for each land unit on each date expressed as the mean and standard error of two transects.

<table>
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<th>Season</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>6th</th>
<th>7th</th>
<th>8th</th>
<th>9th</th>
<th>10th</th>
<th>11th</th>
<th>12th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land unit</td>
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<td>ADM s.e.</td>
<td>ADM s.e.</td>
<td>ADM s.e.</td>
<td>ADM s.e.</td>
<td>ADM s.e.</td>
<td>ADM s.e.</td>
<td>ADM s.e.</td>
<td>ADM s.e.</td>
<td>ADM s.e.</td>
<td>ADM s.e.</td>
<td>ADM s.e.</td>
</tr>
<tr>
<td>601</td>
<td>739 -</td>
<td>1176 -</td>
<td>461 -</td>
<td>788 -</td>
<td>248 -</td>
<td>138 -</td>
<td>86 -</td>
<td>157 -</td>
<td>24 -</td>
<td>190 -</td>
<td>41 -</td>
<td>350 -</td>
</tr>
<tr>
<td>602</td>
<td>1065 -</td>
<td>181 -</td>
<td>314 -</td>
<td>353 -</td>
<td>515 -</td>
<td>33 -</td>
<td>559 -</td>
<td>384 -</td>
<td>412 -</td>
<td>350 -</td>
<td>610 -</td>
<td>26 -</td>
</tr>
<tr>
<td>603</td>
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<td>120 -</td>
<td>346 -</td>
<td>11 -</td>
<td>91 -</td>
<td>257 -</td>
<td>219 -</td>
<td>48 -</td>
<td>34 -</td>
<td>191 -</td>
<td>4 -</td>
<td>271 -</td>
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<td>850 -</td>
<td>518 -</td>
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<td>1181 -</td>
<td>619 -</td>
<td>308 -</td>
<td>998 -</td>
<td>417 -</td>
<td>479 -</td>
<td>315 -</td>
<td>552 -</td>
<td>183 -</td>
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<td>609</td>
<td>413 -</td>
<td>1159 -</td>
<td>-</td>
<td>670 -</td>
<td>843 -</td>
<td>981 -</td>
<td>17 -</td>
<td>1432 -</td>
<td>213 -</td>
<td>1170 -</td>
<td>189 -</td>
<td>555 -</td>
</tr>
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<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
<td>8</td>
<td>9</td>
<td>10</td>
<td>11</td>
<td>12</td>
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</table>
APPENDIX 6a: Water to dry matter ratio (w:DM) and mean ADM at nine transects where herbage water was a poor correlate of capacitance (r<0.7). (Data is from seasons 4 to 11)

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<tr>
<th>Transect</th>
<th>Hierarchical name</th>
<th>Location</th>
<th>(r_{w, \text{mr}})</th>
<th>w/DM</th>
<th>ADM_1 kg ha⁻¹</th>
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<tbody>
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<td>2112</td>
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<td>613a</td>
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<td>1122</td>
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<td>603b</td>
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<td>0.98</td>
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APPENDIX 6b: Water to dry matter ratio and mean ADM on the other transects (seasons 4 to 11).

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<th>w/DM</th>
<th>$\bar{ADM}_{1 \text{ kg ha}^{-1}}$</th>
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<td>471</td>
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<td>924</td>
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<td>614a</td>
<td>0.948</td>
<td>2.89</td>
<td>183</td>
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</tbody>
</table>
APPENDIX 7: Water to dry matter ratio (w:DM) and mean ADM at nine transects where herbage water was not the best correlate of capacitance. (Data is from seasons 4 to 12)

<table>
<thead>
<tr>
<th>Transect</th>
<th>Hierarchical name</th>
<th>Location</th>
<th>$r_{fw, mr}$</th>
<th>$r_{w, mr}$</th>
<th>w/DM</th>
<th>ADM kg ha$^{-1}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1111</td>
<td>5111</td>
<td>601a</td>
<td>0.931</td>
<td>0.917</td>
<td>1.89</td>
<td>331</td>
</tr>
<tr>
<td>5111</td>
<td>6111</td>
<td>609a</td>
<td>0.888</td>
<td>0.872</td>
<td>0.59</td>
<td>1132</td>
</tr>
<tr>
<td>2212</td>
<td>612b</td>
<td>612b</td>
<td>0.883</td>
<td>0.872</td>
<td>1.16</td>
<td>1169</td>
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<tr>
<td>1222</td>
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<td>613b</td>
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<td>0.754</td>
<td>2.37</td>
<td>384</td>
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<tr>
<td>4112</td>
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<td>615b</td>
<td>0.797</td>
<td>0.789</td>
<td>1.13</td>
<td>781</td>
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<td>3212</td>
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<td>604b</td>
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<td>0.786</td>
<td>1.97</td>
<td>609</td>
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<tr>
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<td>615a</td>
<td>0.654</td>
<td>0.614</td>
<td>0.98</td>
<td>1734</td>
</tr>
<tr>
<td>5112</td>
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<td>609b</td>
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<td>0.622</td>
<td>0.75</td>
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<td>602b</td>
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<tr>
<td>Mean nine</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.37±0.20</td>
<td>856±151</td>
</tr>
<tr>
<td>Mean 20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.75±0.16</td>
<td>542±85</td>
</tr>
<tr>
<td>Mean 29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.63±0.13</td>
<td>639±79</td>
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</table>
APPENDIX B: Dry matter predicted via w-mr regression equation compared with cut samples.

Season 4, sampling days 139, 140 & 141.

w = 1.55 + 7.0E mr. (computed from 60 samples).

From the table, 67% of the sample fall within one s.e. of the predicted DM value.

<table>
<thead>
<tr>
<th>Transect</th>
<th>nr(n=25)</th>
<th>( w_{est}(g) )</th>
<th>( w_{DM} )</th>
<th>( DM_{est.} )</th>
<th>s.e.(g)</th>
<th>( DM_{cut}^2 )</th>
<th>s.e.((g) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>601a</td>
<td>2.96</td>
<td>22.46</td>
<td>1.18</td>
<td>15.0</td>
<td>4.0</td>
<td>17.3</td>
<td>3.7</td>
</tr>
<tr>
<td>601b</td>
<td>1.68</td>
<td>22.41</td>
<td>1.24</td>
<td>10.9</td>
<td>3.8</td>
<td>12.6</td>
<td>3.1</td>
</tr>
<tr>
<td>602a</td>
<td>3.76</td>
<td>28.11</td>
<td>1.61</td>
<td>17.5</td>
<td>2.9</td>
<td>15.7</td>
<td>2.4</td>
</tr>
<tr>
<td>602b</td>
<td>0.92</td>
<td>8.54</td>
<td>1.69</td>
<td>5.1</td>
<td>2.8</td>
<td>5.4</td>
<td>2.5</td>
</tr>
<tr>
<td>603a</td>
<td>1.32</td>
<td>10.67</td>
<td>1.70</td>
<td>6.4</td>
<td>2.8</td>
<td>7.8</td>
<td>0.2</td>
</tr>
<tr>
<td>603b</td>
<td>0.40</td>
<td>4.40</td>
<td>1.66</td>
<td>2.7</td>
<td>2.9</td>
<td>1.9</td>
<td>0.2</td>
</tr>
<tr>
<td>604a</td>
<td>1.79</td>
<td>14.19</td>
<td>1.62</td>
<td>8.8</td>
<td>2.9</td>
<td>13.2</td>
<td>6.5</td>
</tr>
<tr>
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<td>4.08</td>
<td>30.37</td>
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<td>0.36</td>
<td>8.33</td>
<td>0.71</td>
<td>11.7</td>
<td>6.7</td>
<td>15.9</td>
<td>6.9</td>
</tr>
<tr>
<td>605b</td>
<td>0.16</td>
<td>2.68</td>
<td>1.04</td>
<td>2.6</td>
<td>4.6</td>
<td>6.2</td>
<td>0.1</td>
</tr>
<tr>
<td>612a</td>
<td>3.56</td>
<td>26.68</td>
<td>1.14</td>
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<td>15.5</td>
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</tr>
<tr>
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<td>11.8</td>
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</tr>
<tr>
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<td>2.40</td>
<td>18.49</td>
<td>1.11</td>
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<td>34.4</td>
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<td>22.7</td>
<td>0.8</td>
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</tbody>
</table>

| Overall means | 15.3 | 15.2 |

1 Means derived from three samples/transect. 2 Scaled from samples at whole no. capacitance.
APPENDIX B: Dry matter predicted via w-nr regression equation compared with cut samples.

8b. Season 11, sampling days 279, 277 & 280.

\[
w = 8.14 \text{ nr} - 1.91 \text{ (computed from 90 samples)}
\]

From the table, 67% of the sample fall within one s.e. of the predicted DM values.

N.B. Six of the transects on block 61 were affected by dew.

<table>
<thead>
<tr>
<th>Transect</th>
<th>mr(n=25)</th>
<th>w_est. (g)</th>
<th>w/DM</th>
<th>DM_est.</th>
<th>s.e.(g)</th>
<th>DM^2cut</th>
<th>s.e.(g)</th>
</tr>
</thead>
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<td>2.10</td>
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<tr>
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<td>12.42</td>
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<td>8.6</td>
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<td>10.5</td>
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<td>8.8</td>
<td>0.9</td>
</tr>
<tr>
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<td>0.1</td>
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<td>48.4</td>
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</tr>
<tr>
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<td>1.41</td>
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<td>4.1</td>
<td>1.3</td>
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<td>17.95</td>
<td>3.30</td>
<td>5.4</td>
<td>1.8</td>
<td>4.9</td>
<td>0.1</td>
</tr>
<tr>
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<td>3.7</td>
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<td>17.4</td>
<td>4.8</td>
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<td>6.7</td>
<td>6.3</td>
<td>1.4</td>
</tr>
</tbody>
</table>

Overall means

1 Means derived from three samples/transect.
2 Scaled from samples at whole no. capacitance.

A direct comparison of two methods of calibrating "Charlie" was carried out by E.J. Costello of TGMLI assisted by the author. In one, herbage was cut from a measured quadrat enclosing the probes. In the other method cut herbage from the same quadrat was introduced to a corrugated cardboard box beneath the probes.

Fifty quadrats were cut over three dates, 30.10.78, 3.11.78 and 14.11.78. The quadrats were chosen to represent a wide range of yields and pasture species so the full range of the capacitance meter was employed, which was almost never the case at Tara Hills. Other noteworthy differences from the Tara Hills experience in this exercise were flat ground and, except in "waste places", the absence of bare ground.

The statistical table below includes the elements of five linear regression equations of the form \( w = a + b \cdot mr \); where \( w \) is the weight of water in the cut herbage; DM is the weight of dry matter; and \( mr \) is the Charlie reading of (i) standing herbage; (ii) the stubble after cutting and (iii) the cut herbage, loosely arranged among the probes and contained by the box.

<table>
<thead>
<tr>
<th></th>
<th>( x )</th>
<th>( y )</th>
<th>( a )</th>
<th>( b )</th>
<th>s.e.</th>
<th>( r )</th>
<th>( r^2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i)</td>
<td>Quadrat mr</td>
<td>w</td>
<td>-57.5</td>
<td>5.61</td>
<td>9.8</td>
<td>0.82</td>
<td>0.67</td>
</tr>
<tr>
<td>(i)</td>
<td>Quadrat mr</td>
<td>DM</td>
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<td>1.36</td>
<td>9.8</td>
<td>0.87</td>
<td>0.77</td>
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<tr>
<td>(ii)</td>
<td>Stubble mr</td>
<td>w</td>
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<td>6.34</td>
<td>8.7</td>
<td>0.83</td>
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<tr>
<td>(iii)</td>
<td>Box</td>
<td>mr</td>
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<tr>
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<td>1.40</td>
<td>10.2</td>
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<td>0.87</td>
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</tbody>
</table>
APPENDIX 10: Estimation of the number of sampling transects required in each land unit for the coefficient of variation to be 20%.

\[ n = \frac{(1.96 \text{ (s.e.)})}{L^2} \]

- \( n \) is no. of samples required
- s.e. is known standard error from 2 samples on 7-12 dates.
- L is 95% confidence limit of the mean ADM.

<table>
<thead>
<tr>
<th>Land unit</th>
<th>kg ha(^{-1})</th>
<th>s.e.</th>
<th>CV actual</th>
<th>L actual</th>
<th>s.e. req'd (CV = 20%)</th>
<th>L required</th>
<th>n</th>
</tr>
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<tbody>
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<td>221</td>
<td>58</td>
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<td>80</td>
<td>44</td>
<td>61</td>
<td>3</td>
</tr>
<tr>
<td>603</td>
<td>188</td>
<td>58</td>
<td>31%</td>
<td>81</td>
<td>38</td>
<td>52</td>
<td>5</td>
</tr>
<tr>
<td>613</td>
<td>352</td>
<td>112</td>
<td>59%</td>
<td>155</td>
<td>71</td>
<td>98</td>
<td>5</td>
</tr>
<tr>
<td>621</td>
<td>342</td>
<td>246</td>
<td>72%</td>
<td>341</td>
<td>68</td>
<td>95</td>
<td>26</td>
</tr>
<tr>
<td>623</td>
<td>222</td>
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<td>64%</td>
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<td>44</td>
<td>62</td>
<td>21</td>
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<tr>
<td>604</td>
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<td>419</td>
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<td>11</td>
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<td>624</td>
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<td>67</td>
<td>6</td>
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