THE THEORY OF FEED PLANNING

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Introduction

Over many years of scientific endeavour there has been much effort to define and refine the feed requirements of domestic livestock and to assess feeds in appropriate terms to allow calculation of the quantity of feed required Significant contributions to estimating the requirements of grazing animals was made in New Zealand (6) and Australia (3)

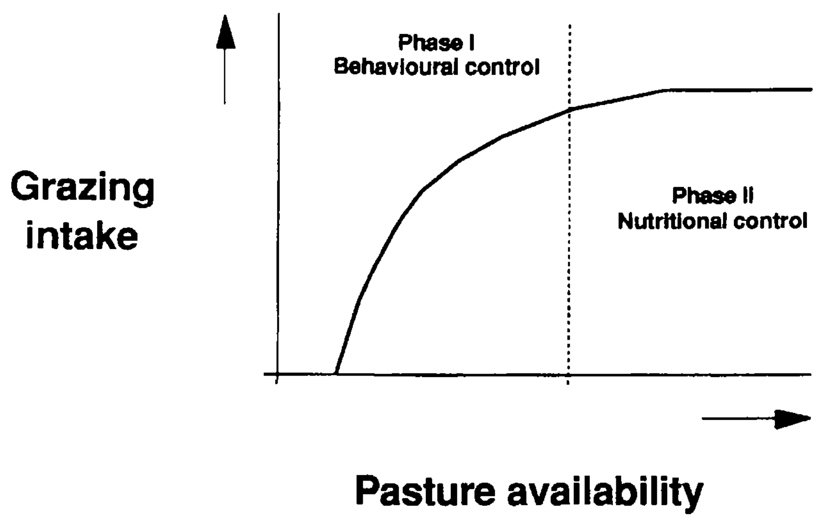
The outcome of this as far as New Zealand is concerned has been the adoption of the metabolisable energy system for estimating energy requirements and more recently assessing protein supply as the sum of the fed protein digested in the small intestine plus the rumen microbial protein supply These systems are now well described (1, 12) Similar levels of sophistication exist defining factors affecting the availability and requirements of minerals

It was soon clear to animal scientists, advisers and farmers trying to implement these feeding standards in pastoral farming, that a knowledge of feed requirements and feed values was not enough The results were variable and inconsistent The missing link was an understanding of the factors which influence/control the feed intake of the grazing animal There is little point in a highly precise definition of feed requirements if the animals consume more or less than they need

Grazing intake and pasture availability

The recognition that something was missing lead to a flurry of research actively in the 1970s and early 1980s, to quantify the relationship between animal intake (and performance) and pasture variables It was soon clear that a general relationship existed (Figure 1), which is arbitrarily described as consisting of two zones The first described by an increase in feed intake as pasture availability increases, the phase in which grazing behaviour controls intake It is in this zone in which almost all livestock production systems operate The second phase, where further increases in pasture available induce no further increase in intake, represents the stage at which the digestive characteristics of the feed limit intake or the maximum feed demand of the animal is met Operating animal production systems in this zone results in decline in pasture quality through under-grazing There are many factors of both animal and pasture origin which influence the specifics of the general relationship which will be considered later

Figure 1: The generic relationship between grazing intake and pasture availability



Behavioural control of intake

Academic research pursued explanations for the response of intake to pasture availability Grazing intake is the product of three basic components of grazing behaviour

Intake	=	bite size (g DM/bite)	x	biting rate (bites/min)	x	grazing time (hours)

It was soon identified that as pasture availability (defined most clearly as height but with a component of density) declined, bite weight (mg DM/bite) declines quite rapidly The grazing animal tries to compensate for this decline by increasing biting rate (bites/minute) and increase grazing time (hours/day) The combined rate at which biting rate and grazing time increase is not sufficient to compensate for the decline in bite size, and consequently total intake declines It is the interaction of these three factors with the pasture which determine grazing intake

Factors affecting the intake response relationship

There are many factors which influence the shape of the intake response curve The hypothesis that the specifics of the response are not important as long as the pasture conditions under which maximum intake is achieved is known is not valid In many production systems, it is necessary to restrict intake to below maximum, for example, pregnant hinds in September/October, so an understanding of factors affecting the response curve must be defined Illustrations of some of these will be given

- higher intake (~25%) and thus performance is achieved at the same pasture available on legumes compared to grasses because bulk density and bite size is higher with legumes (Figure 2)
- the same amount of pasture on a large area with a low pasture mass will promote lower intake (smaller bite size) than when offered as a higher mass on a smaller area (Figure 3)

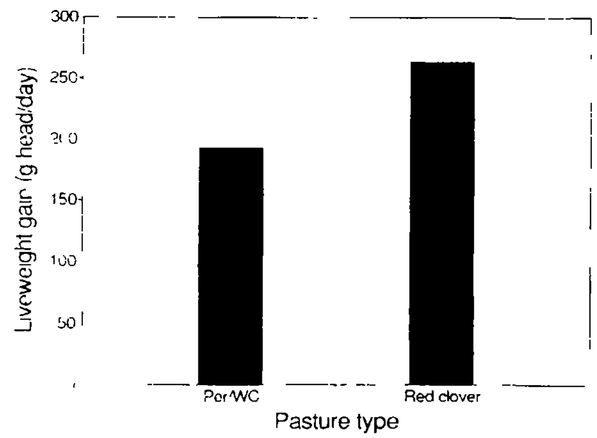


Figure 2: **Comparison of intake and growth rate of red weaner stags in autumn (from 14)**

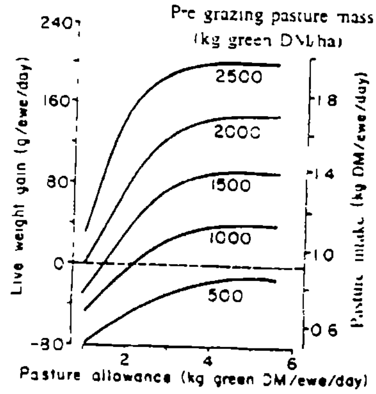


Figure 3: **Effect of pasture mass at equal pasture allowance on live- weight gain of ewes (from 11)**

- a high proportion of dead material or seed head in the pasture reduces intake at any pasture allowance, with sheep because bite size is reduced as they search for the green material, with cattle, because of the decline in diet quality

- for animals showing compensatory growth or seasonal changes in intake like deer similar pasture available results in higher liveweight gain in spring than in winter Indeed with weaner deer even very high pasture availability (post-grazing pasture mass of 1600 kg DM (8-10cm)), a liveweight gain of only 50-60 g/d has been achieved in red stags in June and July High allowances do affect deer growth rate in May and August (Table 2)

More details of factors affecting the basic intake/pasture relationship with deer have been given elsewhere (5)

Feed planning terminology

In tandem with research work to elucidate the mechanisms of and factors influencing the intake/pasture relationship was the development of techniques and terminology which would allow for the application of this knowledge at farm level to give some guarantee that desired feed intake could/would be achieved

In developing the concept of feed planning on pasture it was necessary to devise terms which would quantify the relative availability of pasture The best known of these are

- pasture height
- post-grazing pasture mass
- pasture allowance

Pasture height or more correctly, sward surface height is perhaps most commonly used under continuous grazing (set-stocking) and has been most widely applied in the UK Post-grazing pasture mass, (the dry matter, cut to ground level), remaining after grazing is a historical assessment of what has happened as a result of grazing while pasture allowance (kg dry matter, cut to ground level, on offer to the animal/day) is useful for forward planning These two latter terms are strictly NZ inventions Recommendations (see Table 1 for deer values) on appropriate values for animals of varying species and physiological conditions were brought together in 1989 by the New Zealand Society of Animal Production (9) Since then some more information, which is summarised in Table 2, has become available for deer

Table 1: Recommended (1989) post-grazing pasture mass for deer (4)

	Post-grazing pasture mass (kg DM/ha)	**Liveweight change**
Autumn		
Stags	**1200**	**Losing weight (rut)**
Hinds	**1200**	**50 to 80 g/day**
Young stock (weaners)	**1400**	**150 to 200 g/day**
Winter		
Stags	**600**	**Maintenance**
Hinds	**600**	**-50 to 0 g/day depending on body condition**
Young stock	**1000**	**50 to 100 g/day**
Spring		
Stags	**1200-1400**	**200 to 300 g/day**
Hinds	**800**	**50 g/day**
Yearlings	**1500**	**200 to 300 g/day**
Summer		
Stags	**1400**	**200 to 300 g/day**
Hinds	**1400**	**Lactation + 140 g/day**
Yearlings	**1500**	**200 to 300 g/day**

Table 2: Recent data on weaner/yearling stag response to pasture availability (post-grazing pasture mass)

Season	Liveweight gain (g/d)	Genotype	Post-grazing pasture mass (kg DM/ha)	Pasture type	Period	Supple-ment fed	Source
Winter	140	Red	1600	Perennial ryegrass/WC	Mid-May to	None	(2)
	165	Red	1600	Moata	End Aug		
	30	Red/hybrids	650	Per Rye/WC	Jun/Jul	None	(7)
	45	" "	1200	" "	" "	"	
	45	" "	1800	" "	" "	"	
	60	" "	2500	" "	" "	"	
	150	Red	1750	Per Rye/WC	100 days	"	(8)
	170	Hybrids (¼)	1750	" "	"		
	104	Reds	1100	Per Rye/WC	Mid May-Mid-Aug	0 5 kg hay DM/head	(14)
	245	Hybrids (?)	1300	Not stated	Not stated	None	(13)
Spring	220	Red	1600	PRG/WC	Sept/Nov	None	(2)
	235	Red	1000	Moata	"		
	40	Red	1300	PRG/WC	Oct/Nov		(7)
	235	Red	2400	PRG/WC	"		
	260	Red	3800	PRG/WC	"		
	270	Red	4800	PRB/WC	"		
	200	Hybrid (¼)	1300	PRG/WC	"		
	240	Hybrid (¼)	2400	PRG/WC	"		
	325	Hybrid (¼)	3800	PRG/WC	"		
	360	Hybrid (¼)	4800	PRG/WC	"		
	260	Red	2080	PRG/WC	Oct/Dec		(8)
	255	Red	2635	Chicory	"		
	270	Hybrid (¼)	2080	PRG/WC	"		
	310	Hybrid (¼)	2635	Chicory	"		
	340	Red	1850	PRG/WC	Sept/Nov		(14)
	355	Red	2800	Red clover	"		

Short-term feed planning

These data on allowances and post-grazing pasture mass allow farmers to quantify much of their short feed planning such as

- the length of time a particular paddock will last a particular mob of stock (pasture allowance) or
- when to shift a mob of stock (post-grazing pasture mass)
- adjustments in stocking rate on set stocked pastures

In many ways, pasture allowance or post-grazing pasture mass are simply alternatives to achieving the same end (see Table 3), although each has its strengths and weaknesses (Table 4)

Table 3: Illustration of the use of pasture allowance and post-grazing pasture mass methods in devising short term feed plans

Residual method

Given . 2.4 ha with pre-grazing mass 2600 kg DM/ha
200 yearling stags (60 kg), 200 g/day
Intake 2.0 kg DM, PGPM, 1600 kg DM/ha

Calculation·

$$\textbf{Days} = \frac{((2600 - 1600) \times 2.4)}{(200 \times 2.0)} = 6.2 \textbf{ days}$$

Pasture allowance method

Given 2.4 ha with pre-grazing mass 2600 kg DM/ha
200 yearling stags (60 kg), 200 g/day
Allowance 5 kg DM/head/day

Calculation

$$\textbf{Days} = \frac{(2.4 \times 2600)}{(200 \times 5)} = 6.2 \textbf{ days}$$

Table 4: Advantages and disadvantages of pasture allowance and post-grazing pasture mass methods.

Method	Advantages	Disadvantages
Pasture allowance	easy calculation good for planning better for low intake	only a plan confused with intake useless for set-stocking
Post-grazing pasture mass	defines an end point easy to "see" better in lax-grazing	historical more calculations

This level of feed planning is also useful from a diagnostic prospective Clearly if the farmers' claims or expectations for a particular level of stock performance is not matched by the appropriate pasture availability then their expectations are unlikely to be met For example, a target liveweight gain of 300 g/d for yearling stags in September will not be achieved if post-grazing pasture mass is below 1200 kg DM/ha Similarly, a markedly lower than expected animal performance at any particular pasture feeding level is likely to be indicative of other micro-nutrient deficiencies or health problems So clearly it is important that the practising veterinarian has a good knowledge of these guidelines if he/she is to accurately assess the relative importance of level of nutrition to clinical cases

Use of pasture availability as a diagnostic tool must take into consideration any supplementary feeding involved A post-grazing pasture mass of 800 kg DM/ha could be adequate for stags in the winter where supplementary feed was making up more than 80% of requirements but inadequate of supplementary feed made up less than 15% of requirements

Feed Flows

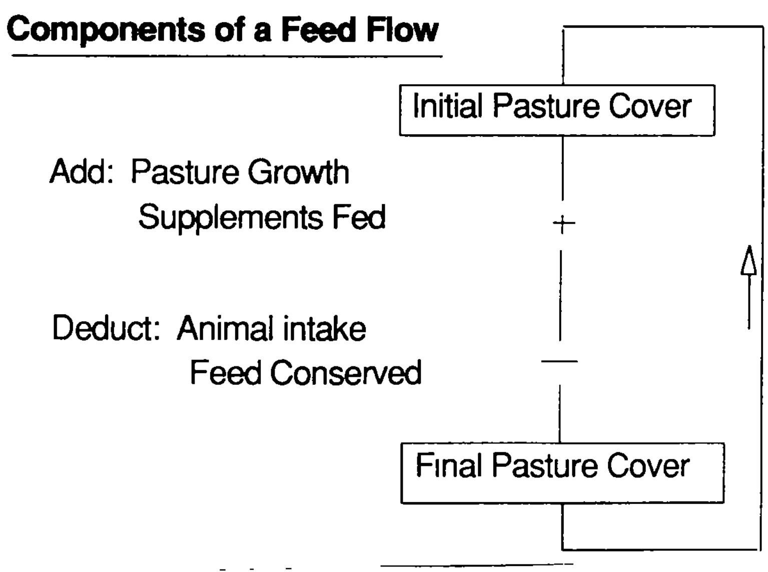
A logical extension to the use of quantitative measures of pasture availability for short-term (days to a few weeks) feed planning is to maintain a running balance of the feed supply and demand on any farm over time Such a feed budget or more correctly a "feed flow" since it, like a cash flow, shows the dynamics of the balance between income (feed supply) and expenditure (feed demand) rather than just an overall annual summary, is now a common feature of pasture feed planning

The components of a feed flow are

- initial pasture cover (kg DM/ha)
- pasture growth (net pasture production), kg DM/ha/day
- feed requirements (kg DM/day) of number of stock in each class
- supplementary feed used (kg DM)
- pasture conserved (kg DM)

The starting point for a feed flow is the initial "pasture cover", another new term coined to refer to the average pasture mass over the whole farm (an amalgam of pasture masses over a range from immediately pre-, to immediately post-grazing and variable paddock sizes) In crude terms the mean pasture cover represents the average of the pre- and post-grazing pasture mass The expected pasture growth rate over a predetermined time period (usually 1 month) is added to initial pasture cover and any supplementary feed used is included to give the total feed available A deduction of the total feed demand (the sum of the requirements of the various stock classes involved) plus any conservation made gives the pasture cover at the end of the period This process is iterated for the entire period, usually 12 months (see Figure 3)

Figure 3: Feed flow model



Target Pasture Cover

Each feed flow has an associated monthly "target" pasture cover or at least a band of pasture cover within which the feed flow should operate For example, in most feed flows, if mean pasture cover is likely to exceed 2500 kg DM for more than 1 month then steps need to be taken to increase feed demand (more animals) or remove areas for conservation At a mean pasture cover of over 2500 kg DM/ha pasture control is likely to be lost through lax grazing Each farm or livestock system has a minimum pasture cover below which the sustainability of the system is at risk, usually through an insufficient proportion of the farm with a sufficiently high pre-grazing pasture mass The absolute value of this minimum depends on the production system involved and the management system adopted For example for a ewe flock lambing in late September in a Southland all grass wintering system, pasture cover may be safely "wound down" to as low as a 1000 kg in mid winter whereas for the same farm wintering only weaner stags a minimum cover of about 1600 kg DM would be set Target pasture cover must not be confused with post-grazing pasture mass

In addition to acting as critical "trigger" point, pasture cover, or at least changes in pasture cover are yet another feed resource Accumulating pasture cover in autumn and depleting this in winter contributes as much as 40% of the pasture supply in winter Increasing pasture cover in spring is not only essential if high allowances, post-grazing pasture mass and thus high animal performance is to be achieved, but it also acts as the platform on which feed conservation or winter feed crops are based

The feed flow lends itself to computerisation and many variations on the theme exist with different levels of sophistication, but basically all follow the approach outlined above The more sophisticated models predict pasture growth rate from soil temperature and soil moisture, account for decay of senescent pasture and losses due to conservation and trampling However, these models quickly become cumbersome to use and there is a tendency to expect them to accurately predict rather than act as useful guide to likely outcomes A feed budget or feed flow is an expectation not a statement of fact (a set of accounts)

Use of Feed Planning

Formal feed flows are widely used in designing and fitting animal production systems to feed supplies and *vice versa* They are also useful in testing the robustness of systems by comparing "what-if" scenarios What-if pasture growth rate is reduced by 50%, lambing % increases by 20%, 60% less/more silage is made?

To be useful for day-to-day feed planning, feed flows must be updated very regularly to adjust for "actual" versus expected outcomes, particularly in terms of pasture growth rate and pasture cover Feed flows do not replace the short term feed plan as a day-to-day monitoring tool Neither do feed plans replace the regular monitoring of stock to determine that target performance levels are being achieved

Many experienced livestock farmers farm quite satisfactorily without formal feed planning They know on the basis of their experience and records, when to shift a mob of stock, how much hay they need to make and when the season is not typical The value of formal feed planning is in the unfamiliar situation, the young farmer, the student, the farmer changing his enterprise (sheep to dairy), the advisor looking at alternatives, to help decision making in unusual situation (for example, a feed flow may convince a farmer to sell stock or buy extra feed, before everybody else does, to give him or her a marketing advantage)

Detailed feed budgets are also used at the top end of the productivity distribution when getting feed planning right really counts For example all managers and share milkers of corporate dairy farms report on their feed flows

Understanding where a farm(er) is in relation to a feed flow is as important in identifying problems and solutions as is the short-term feed plan For example, there is little point, advising a client that his or her yearling cattle require a higher pasture intake in September, when a feed flow shows that as much pasture area as possible must be allocated to ewes and lambs over this period All factors must be considered when giving advice

It is only by considering feed flows and their systematic match of feed supply and demand, that practitioners can appreciate the significance of the correct timing of events such as calving and stock sales, the implication of changing production targets and the compromises that have to be made between what should be done and what can be done in the pasture feeding of livestock

Summary

Feed planning on pasture has required the establishment of procedures to ensure that animal requirements are met by the availability of a suitable quantity of pasture These guidelines can also be useful diagnostically Quantification of feed planning has allowed for the systematic sequential accounting of feed demand and supply which is an important component of the monitoring of, and advise on, pastoral farming systems

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