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Impacts of grazing management on hill country pastures: principles and practices

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Abstract

Management of the balance of animal demand and feed supply is the result of a complex set of decisions. These decisions interact and are also variably affected by external drivers, including environmental. In particular, both pasture quantity and quality can be optimised by using appropriate grazing management, including stocking rate, livestock class, etc. In essence: apply sufficient grazing pressure at the appropriate time to maintain pasture covers at a level where the development of grass inflorescences is limited and pasture quality is maximised. The optimal grazing management strategy, however, may be different for each paddock and will change through the season. At a whole-farm scale, grazing management will be a set of trade-offs. Understanding the underlying ecological principles that drive the outcome of these grazing management decisions on pasture performance will have the greatest potential to drive the profitability and sustainability of hill country farms.

Keywords: Grazing management, pasture performance, pasture quality, hill country

Key messages

- Grazing management is a critical tool to improve the profitability of hill country farming systems
- Knowledge of the principles of pasture responses to defoliation will determine how best to achieve both quality and quantity in a farm forage supply
- The interaction between pasture management and animal performance will be driven by practitioner's decisions to deliver a compromise: the optimum local solution to the perennial problem of achieving an ideal pasture for maximum animal production while limiting the costs of realising it.

Introduction

The performance of hill country farms depends on a set of critical decisions that determine animal demand and feed supply. These include stocking rate, stock class, lambing/calving dates and selling policies as well as fertiliser use, pasture type/renewal and buying-in of feed. This balancing of demand and supply must be done with the knowledge that these decisions interact and will be also affected by external drivers such as farm topography, seasonal variation in weather and changing product prices.

Grazing management is a key method to improve the quality and quantity of pasture available and so drive better performance of breeding and finishing stock and improve farm profitability (Gray *et al.* 2004; Gray *et al.* 2005; Lambert *et al.* 2004). The productivity of grazing animals is driven by a wide range of factors but, from a pasture perspective, the key factors are pasture quantity and pasture quality (metabolisable energy (ME), and potential anti-quality factors). Poor quality pastures typically contain high levels of dead matter and stem, and may have low levels of clover (Lambert & Litherland 2000). The management of grazing animals interacts strongly with these factors (Chapman & Clark 1984).

Pasture management decisions may have both short and longer-term impacts on farm production. In particular, grazing intensity in spring has a strong influence on quality and quantity through late spring and summer (Clark 1994). Hill pastures are typically not well utilised in the spring because the whole-farm animal feed demand is insufficient to maintain optimum pasture covers. The effect of sub-optimal pasture management at this time is to allow the reproductive development of grasses with a consequent decline in pasture quality (Sheath *et al.* 1987). There are also impacts of grazing management on subsequent shifts in pasture botanical composition (Lambert *et al*. 1986a). For example, legumes, both perennial and annual, are strong drivers of pasture quality (Ulyatt 1978) and are affected by grazing management in previous seasons (Lambert *et al.* 1986b).

In the following sections, the impact of grazing management on the productivity of uncultivable hill country is reviewed, with a focus on the underlying principles and their practical implications. Much of the previous research in hill country was developed in a limited range of North Island hill country environments (especially at Whatawhata and Ballantrae) and this review will necessarily draw extensively from these important resources. The principles, however, will

ISSN 0110-8581 (Print) ISSN 2463-4751 (Online)

still be appropriate to the diverse array of hill country landscapes in both the North and South Islands, although the practical implementation of this knowledge may have to be adapted for local circumstance as appropriate. The aim of this review is to firstly identify the main principles that govern the key interactions at the pasture/animal interface, and then to identify farm management practices (other than fertilisation or the introduction of novel germplasm) that might be used to sustainably increase the quantity and quality of herbage produced on hill country farms. Grazing management decisions informed in this way have the greatest potential to enhance the performance of hill country farms.

Principles

Transformation of solar energy into carbohydrates is the fundamental driver of the pastoral agricultural system. Green growing leaf area along with the youngest fully expanded grass leaves are the most effective contributors to photosynthesis (Parsons *et al.* 1983) and maintenance of the sward for complete light interception by green lamina will allow the greatest energy input for plant growth. Through defoliation of pasture species, grazing animals reduce the available leaf area. Following defoliation rapid plant regrowth occurs with a delay in the corresponding rate of tiller death that allows for an increase in plant biomass. There are also a number of internal compensating processes that result in an animal-pasture-soil system that is in a state of dynamic equilibrium (Korte *et al.* 1987).

Effect of grazing management on pasture growth

The timing, frequency, intensity and selectivity of grazing directly affects pasture growth. The intensity of defoliation, as controlled by sward surface height or post-grazing residual, determines the remaining leaf area index (LAI) and leaf regrowth rate (Brougham 1956). This may be used to control the rate of re-growth and to some extent match animal demand to supply (Orr *et al.* 1988). However, it has been shown in farm systems trials that pasture growth and animal intake under different defoliation frequencies (rotational and continuous grazing by sheep) and indeed under different grazing severities is largely equalised by various compensatory mechanisms at the sward – animal interface (Bircham & Hodgson 1983b; Chapman & Clark 1984; Hodgson & Maxwell 1984).

A study of set stocked swards maintained at constant herbage masses of 500, 700, 1000 and 1700 kg organic matter DM/ha by variable stocking with sheep concluded that pasture growth remained greater than 90% of maximum over a range of herbage masses from 850 to 1850 DM/ha and a range of LAI from 2.3 to 4.1 (Bircham & Hodgson 1983a). Other studies showed a reduced pasture growth below 2.5 cm in height, while swards between 2.5 and 6.0 cm (approximately 1000 - 2500 kg DM/ha herbage mass) were largely insensitive to that variation (Grant *et al.* 1983).

Manipulation of defoliation frequency and intensity during the late spring can impact pasture quality and quantity in following seasons. Increasing the intensity of defoliation under continuous grazing from 7 cm to 3 cm sward surface height, for example, substantially reduced the drop in pasture quality over summer, and reduced the drop in pasture growth compared to a monthly cutting regime (Orr *et al.* 1988).

Effect of grazing management on tiller density

Tiller dynamics vary considerable through the year and will vary between and even within grass species. For example, ryegrass tillers turnover rapidly (~20 days) in spring (Matthew 1996) or early summer (Korte 1986) but much more slowly in winter (~80-100 days). There is a strong interaction between tiller dynamics and grazing. If severe and frequent defoliation is maintained (e.g. through continuous grazing) an increase in tiller density occurs that compensates for the reduction in LAI (Parsons *et al.* 1983; Bircham & Hodgson 1983b; Chapman & Clark 1984; Korte *et al.* 1984). High tiller numbers going into the summer may help the pasture survive the combination of grazing and additional heat and water stress and allow pasture growth to continue further into summer.

Tiller numbers are reduced under more lenient defoliation and also under infrequent defoliation, although leaf extension rates will increase to compensate (Chapman & Clark 1984). These compensatory mechanisms can reduce the effect of defoliation intensity and frequency variation on total pasture grown. A reduction in tiller populations over summer/autumn will occur following removal of continuous grazing pressure to allow accumulation of herbage in a rotation period when compared to continuously grazed plots (Parsons *et al.* 1984). Hard grazing during November-January on summer-dry slopes increased total pasture growth during the dry January-March period but reduced growth from winter to spring. Of greatest importance to summer-autumn pasture production was the maintenance of pasture tiller density and avoidance of dead herbage accumulation (Sheath & Boom 1985a).

Effect of grazing management on pasture quality

The natural life-cycle of leaves, tillers and stolons, sets a limit on the period in which they must be harvested if their potential contribution to a sward's herbage production is to be fully realised. The timespan this covers depends on many factors such as species of plant, time of year, climatic conditions and sward conditions (Korte *et al.* 1987).

The expression of reproductive growth is a key driver of the seasonality of herbage growth and of the quality of the sward as a whole: reproductive tissues are markedly lower in quality (Sheath *et al.* 1987; Buxton & Mertens 1995). In a grazing situation, the expression of reproductive growth can be restricted by defoliation. While most tillers in a sward will still show evidence of reproductive development through stem elongation, few of them will proceed to inflorescence emergence (Chapman *et al.* 1983). When reproductive development is interrupted early or after some inflorescence emergence, hard grazing has been shown to physically remove most reproductive stems. Subsequent regrowth is largely vegetative. By contrast, lax grazing mainly removed leaves from reproductive tillers - individual tillers continued to develop until seed ripening and subsequent tiller death (Korte *et al.* 1984).

Reproductive growth is linked with the formation of new tillers during early summer (Korte 1986). Allowing some reproductive growth can assist in the production of daughter tillers. Translocation of assimilate from parent tillers will increase the number and size of daughter tillers. However, when the parent tiller was removed entirely or translocation from parent to daughter was reduced through competition from the developing seedhead, tiller number and size was reduced (Matthew *et al.* 1991).

Effect of grazing management on senescence

In general, the amount of dead material in pasture swards – a key driver of pasture quality – is related directly to herbage cover. This has been demonstrated over a wide range of herbage masses from 700-2700 kg DM/ha (Binnie & Chestnutt 1994; Bircham & Hodgson 1983a; Grant *et al.* 1983). The rate of decay and disappearance of dead pasture material is regulated by moisture availability and temperature. Moist, warm conditions favour disappearance of dead leaves and stems; these conditions being suitable for bacterial and fungal growth, and for earthworm activity. In cold or dry conditions rates of decay are much reduced (Korte *et al.* 1987).

Animal-pasture interactions

The grazing animal can have a major effect on a pasture sward and its growth, not only through the quantity of herbage consumed, but also because of the selectivity of the animal. In a hill country system, sheep show a significant preference for green material and rejection of dead material (Clark *et al.* 1982; L'Huillier *et al.* 1986). The selected grazing of green material in a sward can have a disproportionately large impact on pasture re-growth. The ability of stock to be selective depends on stock class (especially cattle versus sheep) as well as stocking rate (Hodgson & Brookes 1999).

Effect of topography on pasture performance

Slope and aspect can have considerable effects on total annual pasture growth. The decrease in production ranges from about 100 to 400 kg DM/ha/yr per degree increase in slope (Gillingham 1974; Gillingham *et al.* 1984; Rowarth & Gillingham 1990; Lambert *et al.* 1983) and is largely related to a decline in soil moisture availability as surface slope increases (Gillingham & Bircham 1985). Aspect can influence annual pasture growth on steepland soils through the differences observed in soil moisture and temperature, and species composition (Gillingham 1974; Lambert & Roberts 1978). The proportion of areas in each slope and aspect class within the grazing area can also affect the utilisation of pasture through preferential grazing of different land classes (Sheath 1982).

Practices

Grazing management effects on pasture quantity and quality

Management of pasture resources in hill country is particularly concerned with maintaining control during periods of strong growth (especially spring) and controlling animal pressure through farm system-level decisions such as lambing date, and disposal of finished, tradable or cull stock (Clark 1994). Deferred grazing to transfer pasture growth from late spring into summer and autumn deficits is difficult due to detrimental effects on pasture quality, plant density and species composition (Sheath *et al.* 1987). Various grazing management models have been published to inform hill farmers of pasture management consideration during this period (Sheath & Bircham 1983; Sheath *et al.* 1987; Smith & Dawson 1977).

Declining pasture quality through late summer and autumn is an impediment to animal production. In steep hill country the only means of pasture control is through manipulation of grazing management. Herbage quality is generally higher in green leaf than in stem and dead material (Lambert & Litherland 2000). Quality decreases with plant age and with an increase in temperature, with the effect being minor in clover leaves, increased in grass leaves and is greatest in stem tissue (Buxton & Mertens 1995). Management of late spring surpluses to restrict reproductive growth will increase summer pasture quality through a reduction in accumulated stem and dead material and encourage the proliferation of clover that will increase pasture quality later in the season (Sheath *et al.* 1987). This can be achieved using severe and frequent defoliation through hard continuous grazing (Clark *et al.* 1982; Korte *et al.* 1984) or high frequency (short rotation) rotational grazing (Sheath *et al.* 1984). A greater degree of pasture control on steepland may be achieved with continuous grazing, although, compared to rotationally grazed systems, flexibility is reduced especially when under drought conditions or in summer-dry climates (Sheath *et al.* 1984).

Priority control of late spring-early summer surpluses on steepland is recommended due to longer term benefits to pasture composition, density and production. In contrast, gentler slopes are less likely to deteriorate in botanical composition or production once pasture control has been lost. However, the advantages to animal production are often not seen until winter or spring following pasture recovery (Sheath & Bircham 1983). The animal liveweight cost of pasture control to ensure high quality late-summer pasture can be compensated by slightly superior flushing liveweight gain in ewes although wool production may suffer (Smeaton *et al.* 1984). Good pasture and animal performance occurred where pasture residuals were 1800 and 1500 kg DM/ha for easy and steep land, respectively. This approach ensures availability of quality pasture for priority stock (weaned lambs or cattle near finishing) (Sheath *et al.* 1984).

Long rotations achieve higher utilisation and are the most suitable way to clean up uncontrolled pasture accumulated following deferred grazing. Non-priority stock, for instance cows and unweaned calves, can utilise pastures with up to 5000 kg DM/ha with no detrimental effect on calf liveweight gains, minimal effect on cow liveweight, and increased facial eczema protection (McCall *et al.* 1988). Such pastures allow transfer of late spring/summer surplus as a valuable buffer against late summer-autumn droughts (Clark 1994). Deferred grazing from October to December does reduce tiller population density, although increasing the duration to 7 months does not further increase tiller mortality (Nie *et al.* 1997). Advantages of deferred grazing include increased legume content, nitrogen fixation and pasture growth in the following summer although during the fallow there is a reduction in nitrogen fixation possibly through nitrogen recycling (Mackay *et al.* 1991). If a deferred surplus can be suitably removed to regain control of the sward, pasture quality can be recovered to a similar level to well-maintained pasture (Rennie *et al.* 2014), although reductions in pasture growth should be expected.

Pasture utilisation in hill country is influenced by many factors including: proportion of different land classes, grazing duration, herbage palatability, ease of harvesting, pasture density and height, potential for selective grazing, manageability, and grazing animal species/class (Lambert *et al.* 2000a). Stock generally prefer to graze easy rather than steep land. More uniform pasture utilisation is a reflection of paddocks with a higher preferred to rejected area ratio (Sheath 1982). A range of grazing management strategies have been developed to ensure that a high level of pasture utilisation was achieved on all slopes and aspects. Of these, the 3-day per paddock, high stocking rate regime (Smith & Dawson, 1977) has been adopted by many hill country farmers.

Leaf death rates and longevity are largely unaffected by grazing management and the number of live leaves per tiller or stolon does not differ greatly between management regimes (Chapman *et al.* 1984). Leaf longevity is least in spring and summer when leaf death rates are fastest, and is greatest in winter when leaf death rates are slowest. In autumn, spring, and summer, mortality of leaves occurs within 3 weeks of their appearance, resulting in the loss of up to 28% of leaves which are formed soon after one grazing, and before the next grazing, under rotational management. A long rotation in winter (63 days) resulted in the death of many leaves before they had a chance to be grazed (Chapman *et al.* 1984). Leaf utilisation data showed that 20-46% of ryegrass leaf tissue, 45-63% of browntop leaf tissue, and 34-60% of white clover leaf production was ungrazed and subsequently died and decayed. Grazing pressure is critical in determining the amount of leaf tissue entering the litter pool, and has a considerable influence on tiller and stolon death.

Impact of treading damage on pasture quantity and quality

Animal treading can also indirectly affect pasture growth by altering soil physical and biological properties. Reduced growth, tiller numbers, plant cover and changes in botanical composition have been observed with increased grazing pressure on both cattle and sheep grazed pastures in hill country (Betteridge *et al.* 1998; Pande *et al.* 2000; Sheath & Boom 1997; Sheath & Carlson 1998). The initial effect of treading is to reduce pasture growth (Finlayson *et al.* 2002) but the longer term impact of treading damage is harder to quantify (Drewry *et al*. 2008). Subsequent pasture growth can increase as a result of treading due to shifts in species composition. For example, legumes and some high fertility tolerant grasses such as ryegrass species are better able to tolerate treading damage than less productive species such as browntop, and farmers can use this to manipulate sward species composition to some extent (Edmond 1958; Brown 1968; Brown 1971).

Influence of grazing management on pasture species composition

Although climate and soil fertility are the main determinants of species diversity in pastures (Levy 1970; King *et al.* 2006), some manipulation can be achieved through grazing management. Grazing pressure during the reproductive and establishment phase of annual plants has a marked effect on pasture composition on summer-dry hills (Sheath & Boom 1985b). Annual legume content increased with lenient grazing during flowering and hard grazing before germination (Suckling 1959; Sheath & Boom 1985b). This grazing management is in contrast to that required to encourage white clover and therefore would be less important in more moist climates (especially summer-moist) where production from winter annuals is less critical.

White clover is strongly affected by grazing management, with late spring/early summer management critical in determining its relative content. Pastures grazed low allow white clover to exploit free space during their active growing period. Further, white clover stolons become elevated in leniently grazed swards, increasing their vulnerability to subsequent grazing (Sheath & Boom 1985b). Summer spelling of dry northerly faces and either lenient or less frequent severe defoliation of south eastern aspects will increase clover contents (Bircham 1977). In addition, the use of rotationally grazed cattle, rather rotationally grazed or set stocked sheep, has been shown to increased white clover content in systems trials (Lambert *et al.* 1986).

The impact of grazing management on the botanical composition of a ryegrass-browntop association is less clear. An increase in ryegrass and a decrease in browntop tiller numbers in summer has been demonstrated with lenient grazing in late spring (Bircham 1977). Less frequent grazing and the use of rotationally grazed cattle can increase ryegrass content (Lambert *et al.* 1986). Increasing grazing pressure throughout the year has been shown to increase ryegrass content (Radcliffe 1972) and avoiding accumulation of high herbage mass pastures in summer has been shown to favour a sward with more ryegrass and less browntop (Sheath & Boom 1985b).

Impact of grazing regime on nutrient return in hill country

In hill country, where grazing systems are often extensive, animals have greater opportunity to show preference in choosing grazing, resting and excreting sites. Animals tend to graze the easier slopes and warmer and more sheltered aspects before there is pressure for them to graze the steeper and/or more exposed country. While animals will graze steeper and more exposed hill areas out of necessity, areas of ruminating, resting, and social interaction as well as excreting are generally confined to the easier slopes and sheltered aspects (Gillingham & During 1973; Saggar 1990; Saggar *et al.* 1990; Betteridge *et al.* 2010a; Betteridge *et al.* 2010b). Over time, there is therefore a depletion of nutrients on steeper slopes and on shadier aspects and on aspects that are exposed to prevailing wind and rain. Conversely, there is a concentration of nutrients in flatter, sunnier and more sheltered areas.

The relationship between slope class and/or aspect and the harvesting and excreting of nutrients is not a simple one (Sheath 1982; Gillingham 1982). Although patterns of animal behaviour that determine where an animal eats and where it excretes are determined by interactions between slope, aspect, other topographic features and current weather, there are additional farm management factors such as stocking rate, grazing regime and size and shape of a paddock which also influence animal behaviour.

Stock excretal returns on a range of slope classes and aspects have been calculated as 60, 30 and 19% of dung and 55, 31 and 14% of urine deposited on low slope (LS) (0-12°), medium slope (MS) (13-25°) and high slope (HS) (>25°) areas, respectively (Saggar *et al.* 1990). Soil total nitrogen (N), organic carbon ©, Olsen P, sulphate-S and nitrate-N (NO_3-N) were all higher in LS than MS and HS soils and soil ammonium-N (NH_4-N) was higher in LS and MS than in HS soils (Lambert *et al.* 2000b; Lopez *et al.* 2003).

There was a strong correlation between the time that sheep and cattle spent in an area and the number of urination events in that area (Betteridge *et al.* 2010a; Betteridge *et al.* 2010b). In addition, the urination data confirmed that stock camps received a disproportionate amount of urine compared to the rest of the paddock. Stock camps were also found to contain more soil organic C, organic and inorganic P and S, and a higher pH, water soluble organic C, microbial biomass, and basal respiration than nearby grazing areas (Haynes & Williams 1999). The transfer of nutrients and organic matter from the main grazing areas to stock camps by grazing animals not only resulted in a decrease in nutrient status of the main grazing area, but also in a decline in soil biological activity relative to that in the camp area.

While the effects of fertiliser application on hill country pasture production are beyond the scope of this article, it is important to note here that soil fertility both directly and indirectly affects a pasture's productive potential and quality and that grazing, in turn, interacts with soil fertility. Therefore, withholding maintenance and capital fertiliser applications over the long term has the potential to severely compromise a hill country farm's potential for growing and finishing stock. On large tracts of low fertility, grass-dominant hill land with low soil moisture and N status there may be a need to look beyond current approaches to both nutrient and lime inputs. Opportunities may exist for tactical application of fertilisers in response to specific conditions (e.g. soil moisture) and in specific locations (e.g. slope, aspect) as suggested by Gillingham *et al.* (2007).

Impact of grazing regime on soil physical and biological properties

When grazing frequency and intensity are increased the resultant increase in hoof action by grazing animals can lead to degradation of soil physical properties (Lambert *et al.* 1985; Betteridge *et al.* 1999; Russell *et al.* 2001; Elliot *et al.* 2002; Drewry *et al.* 2008; Houlbrooke *et al.* 2009) and soil biological properties (Lambert *et al.* 1996; Rook & Tallowin 2003; Dawson *et* al. 2003; Parfitt *et al.* 2010; Schon *et al.* 2011). Cattle exert greater static pressure (160-192 kPa) on soil than sheep (83 kPa), and these pressures are known to at least double when animals are walking (Willatt & Pullar 1984). When soils are excessively wet, the hoof pressure of sheep and cattle can cause soil compaction and soil homogenisation through shearing or pugging and poaching. Treading induced damage includes reduced soil permeability through reduced pore space size and disrupted soil pore networks, and increased bulk density.

Changes in grazing management may also have an impact on soil biology. For example, in a study comparing the impact of farm management intensity (via P fertiliser and stocking rates) on sheep grazed summer-moist southern North Island hill country, earthworm densities were highest in the most intensive system, with the exception of the endemic species *Ochtochaetus multiporous*. In contrast, the lower intensity farm system, where the soil C:N ratio was higher, supported a greater density and diversity of soil mesofauna and *Orbibatida*, which were concentrated in the top soil (0-75 mm depth) (Schon *et al.* 2008). The interactions between soil biology, pasture growth and whole-farm performance are not well understood but they will come under increasing scrutiny as part of a wider focus on the sustainability of hill country farming systems.

Conclusions

Pastures in hill country are a key agricultural asset that face rising expectations to increase productivity and contribute to export growth. They are, however, difficult to substantially alter and hugely variable in potential productivity. Nevertheless, there are opportunities to drive improvements through a better understanding of the state of the resource and the dynamics of the system. The body of foundation research knowledge of these systems is of great value and deserves a wider readership. In particular, the relationship between grazing timing and intensity and pasture quality has been much studied and the principles behind the observed responses well understood. In essence: apply sufficient grazing pressure at the appropriate time to maintain pasture covers at a level where the development of grass inflorescences is limited and pasture quality is maximised. This single objective, however, obscures the array of factors that routinely compromises farmers' abilities to achieve this goal. These include many factors that farmers have little or no control over such as seasonal conditions. However, future improvements in the grazing management of hill country farms could be driven by further investment in stock and paddock subdivision. Such a strategy may result in improved farm profitability, but it would not eliminate the impact of external factors and the return on investment will depend on individual farm circumstances and individual farmers' appetite for risk. In addition, the environmental impact of any change in grazing management will need to be considered.

While there has been less research focus on hill country pastures lately, some recent initiatives have the potential to enable improvements in grazing management by using new tools to assess pasture quality and quantity remotely. Available at whole-farm scale, and in near real-time, these data could be used to inform better decisions around timing and intensity of grazing. More timely decision making around stocking policy (including stock disposal) at farm, region and industry scale has value but further research is needed to assess its potential. Realising the full value of the existing research as well as exploiting new technologies will be needed to drive large improvements in the profitability of hill country while simultaneously addressing sustainability issues in a changing social and biophysical environment.

ACKNOWLEDGEMENTS

We are grateful for the thoughtful comments of referees and helpful discussions with numerous colleagues. The original report that formed the basis of this paper was funded by the Pastoral 21 consortium, a collaborative venture between DairyNZ, Fonterra, Dairy Companies Association of New Zealand, Beef + Lamb New Zealand and the Ministry of Business, Innovation and Employment.

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