A combination of sodium hydroxide and ammonia treatment are perceived to have potential for further improving the digestibility and utilization of roughages (Milligan *et al* 1995). There would be merit in evaluating the potential of such treatments to upgrade late cut hays so that optimum use may be made of such forages within extensive grassland systems.

Chemical oxidative treatments using, for example, sulphur dioxide or alkaline peroxides, although potentially very effective in improving the digestibility of mature forages are, at present, of limited practical use due to cost (Chesson *et al* 1995). Biological oxidative treatments using lignolytic fungi have, to date, proved largely unsuccessful. But it is possible that future developments in oxidative treatment could provide a more cost effective means of upgrading roughages such as mature hays than the hydrolytic treatments.

Potential for reducing losses at hay making

Loss of both dry matter yield and quality of hay occur during the hay-making process due to the effects of mechanical operations during harvesting and, less predictably, due to rain damage during field drying. Kirkham & Wilkins (1994a) found that about 20 percent of the dry matter yield and between 20-25 percent of the ME output was lost during the hay making process. There was tendency for the loss of ME output to be greater from unfertilized than from fertilized meadows which, in this case, may have reflected an effect of botanical composition. The unfertilized meadows had a higher proportion of broad-leaved species than the fertilized meadows (Mountford *et al* 1993; Mountford *et al* 1994) and this may have resulted in greater leaf shatter and loss of highly digestible leaf laminae than in more grass dominated hays.

The amount of loss during hay-making will depend upon factors such as the type of machinery used, the species composition of the grassland and swath structure. Work by Jones (1986) highlighted the risk of reducing the efficiency of drying of hays by using increasingly wider mowers that produce swathes of conventional size. The risk of increased losses arises from leaving such swaths undisturbed for even short periods of time. It appears that the use of mower-conditioners appropriate for rapid harvesting of silage may not be ideal for hay cutting. In order to reduce field losses of hays from semi-natural grasslands perhaps more attention should be paid to the type of machinery used. Some types of mower-conditioner may be more effective than others in improving the drying time.

Grazed semi-natural pastures

Livestock performance

The management of semi-natural grasslands often has a complex set of goals of which animal production is usually a minor one. Nevertheless where livestock are involved conditions under which the maintenance requirements of livestock are at least satisfied should be provided. On grasslands where either the amount and/or the nutritional quality of the forage is marginal for the maintenance requirements of livestock then considerable constraints are imposed on the type of livestock that can be used. This was shown by Wells (1976) on the chalk grasslands, CG2 and CG3 associations (Rodwell 1992), of the Aston Rowant National Nature Reserve. It was found that for the conservation management objectives to be achieved, which included effective control of scrub development, liveweight, physiological condition and possibly breed of sheep were important. On these chalk grasslands dry ewes or wethers with a liveweight of at least 50 kg were found to be most suitable for tolerating the nutritional stresses that were imposed on the animals, particularly during the winter months. As Wells (1976) pointed out utilization of these grasslands for lamb production systems would be untenable without supplementary feeding and the latter may be inappropriate for both economic and conservation reasons. Where winter grazing is required for conservation reasons, amelioration of nutritional stresses on livestock may be implemented by reducing grazing pressure and/or by supplementary feeding but, it needs to be established that these options do not compromise conservation interests. Where large areas of mesotrophic semi-natural grassland survive either a substantial part or possibly complete adapted livestock system may be based on them.Unfortunately there is a paucity of documented information on such systems that allow management options, such as the effects of supplementation, to be assessed with regard to livestock performance or on the utilization of the grassland and long-term sustainability of the system.

During the summer months it appears that the forage produced by most lowland semi-natural grasslands is adequate for the maintenance requirements and some growth in ruminant livestock such as dry or store animals or extensive suckler systems. The summer grazing of the chalk grasslands of Aston Rowant were found to be adequate for dry or wether sheep to regain body condition following the winter and indeed gain weight (Wells 1976). For more mesotrophic grasslands individual livestock growth rates can be comparable to the performance from agriculturally improved pastures, which would be expected to be greater than 0.7 kg per day (Tallowin *et al* 1990). Williams *et al* (1974) recorded liveweight gains of Galloway steers on mixed rush pasture and fen vegetation of Woodwalton Fen National Nature Reserve of *c* 0.85 kg/day during the summer. Grazing Woodwalton Fen during winter months the cattle showed little liveweight change indicating that the vegetation was adequate for the maintenance requirements of the animals. During the grazing periods on the fen the stocking density was *ca.* 2 steers per hectare. On species-rich meadows comprising a mixture of predominantly MG5 and MG8 associations on the Somerset Levels Hereford x Friesian steers (200-300 kg liveweight) grazing the regrowth following a hay crop attained an average daily liveweight gain of more than 1 kg (Kirkham & Wilkins 1994a). In this study a continuous variable stocking density (Tallowin *et al* 1990) was imposed to maintain a compressed sward height of between 5.5 and 6.5 cm. This sward height had been shown by previous work on agriculturally improved pastures not to restrict the performance of growing cattle and to provide an agronomically satisfactory level of pasture utilization (Wilkins *et al* 1983). On a lowland wet heath/fen meadow, comprising a mixture of M16, M23 and M24 communities (Rodwell 1991), Hereford x Friesian steers attained an average liveweight gain of less than 0.5 kg per day during May and June and less than 0.3 kg per day during July and August under a continuous variable stocking regime that achieved a compressed sward height of between 10-15cm period (Tallowin & Smith 1996).

On *Lolium perenne* dominated swards and agriculturally improved permanent pastures cattle, comparable in size and breed type to those used by Kirkham and Wilkins (1994a) and Tallowin and Smith (1996), under a comparable continuous grazing management, where a compressed sward height of *c* 5.0-6.0 cm was maintained, achieved an overall growth rate of *c* 0.7 kg per day, or more, during the summer months (Tallowin *et al* 1986; Tallowin *et al* 1990, Tyson *et al* 1992).

Where sward height was used as a management criterion for the semi-natural grasslands, in order to obtain a comparability with agriculturally improved pastures, it was not established whether these managements were in fact the most appropriate for maintaining the conservation interests of the grasslands. Indeed there was no clear definition of what constituted a good/optimum conservation structure for these grasslands. In all probability the definition would vary depending upon specific conservation objectives.

Utilization and structure of pastures

Through the expression of dietary preferences and/or selectivity grazing livestock will create structural heterogeneity in pastures. Temporal and spatial scales of heterogeneity will be influenced by type of management (whether rotational, continuous variable or continuous fixed grazing regimes), by stocking density and by the size, physiological state, species and possibly by the breed of livestock interacting with changes in the botanical composition of the pasture. In intensive livestock systems, where a principal goal is to achieve a high level of product output per unit area of grazed grassland, general principles that constitute an 'optimum' state of sward structure have been defined. For example, in order to achieve maximal intake of herbage by ewes per unit area of pasture (*Lolium perenne* dominated) a sward height of between 4 and 6cm should be maintained (Hodgson 1986). For dairy cows maximal intake per hectare occurs between a sward height of 6 and 8cm under continuous grazing (Leaver 1985), however, milk yield per cow increases with increasing sward height up to 9.0cm (Rook *et al* 1994). Because the goals involved with the management of semi-natural grasslands are probably more complex than those for intensively managed grass such management criteria as "the maintenance of an overall average sward height" may be inadequate. Perhaps more useful management criteria could take account of variability in sward height as demonstrated by the double normal distributions found in agriculturally improved pastures (Gibb & Ridout 1988). Although, as yet, this approach has had limited practical application further evaluation in semi-natural grasslands could be worthwhile.

In order to develop management criteria for different semi-natural grassland types information is needed on the foraging preferences that livestock may exhibit. A number of studies have examined occupancy of different associated vegetation types through the amount of dung voided onto each (Welch 1984; Pratt *et al* 1986; Bakker 1989). However, such an approach can be influenced by latrine effects, as Edwards & Hollis (1982) found. Another approach has been to develop a 'utilization factor/index' for semi-natural grasslands as defined by Bakker (1989). The technique was based on the use of exclusion cages to measure net herbage accumulation and assumed herbage consumption equated to the difference between adjacent grazed and caged areas. However, as Parsons *et al* (1983) demonstrated and as Bakker (1989) points out the caging technique can give rise to considerable inaccuracies compared with measured intake. A current approach developed for extensive land-use systems is based on the Ideal Free Distibution Theory (Sutherland 1983), uses the area, the biomass and nutrient contents or digestibilities of different associated vegetation types and predicts that animals will graze in a way that maximises their short-term digestible energy intake rate (Maxwell & Milne 1995). Models based on this approach such as the "Hill Grazing Management Model" (Milne *et al* 1995) could have considerable potential for developing management strategies for lowland semi-natural grasslands.

Quality of grazed forages

Of the studies that have been conducted on the dietary components of livestock while grazing lowland semi-natural pastures few have included an examination of the digestible or mineral quality of the selected material.

Diet composition of the Galloway cattle and rabbits were examined in a notable study by Williams *et al* (1974) at Woodwalton Fen using a faecal fragment analysis technique. It was found that seasonal trends in the composition of the diet of the cattle occurred and that coarse grasses were often a dominant component of their diet. The prominence of coarse grasses in the diet was presumably a function of the availability of this type of forage and the ability of the cattle to graze such vegetation. The tall and/or coarse vegetation was 'unavailable' or avoided by the rabbits. As Williams *et al* (1974) point out the faecal fragment analysis technique may underestimate the contribution of highly digestible species or parts of plants if careful attention is not paid to staining procedures. It is also a laborious technique.

The use of oesophageally fistulated animals or hand-plucking samples of vegetation have been used for sampling both diet composition and quality. The limitations of oesophageal samples for assessing the nutritive quality of the diet are reviewed by Wallis de Vries (1994). A particular problem with oesophageal extrusa samples is that salivary contamination raises the contents of both sodium and phosphorus so as to preclude any accurate estimation of these constitiuents in the diet. Although time consuming the observation of grazing animals and the careful hand pluckingof vegetation similar to that being selected by the animals can yield valuable data on the quality of the diet. Wallis de Vries (1994; Ibid 1995) used a hand-plucked sampling technique in which the plucked sample size was weighted so as to correspond to the average bite size of the livestock being used. With this approach he obtained significantly close relationships for nutritive quality estimates (nitrogen and calcium content in the diet) between oesophageal extrusa and hand-plucked samples.

Wallis de Vries (1994; Ibid 1996) used the hand-plucking technique in diet quality studies on *Calluna vulgaris - Deschampsia flexuosa* heathland, akin to an H9 community (Rodwell 1991), and fertile riverine grasslands akin to MG6 communities (Rodwell 1992) in the Netherlands. On the riverine grassland and where animals could range freely between grassland types the cattle were able to consume more nutrients than were required for normal growth. On the heathland, however, intake of both sodium and phosphorus was 54% and 74%, respectively, below the animals metabolic requirements. Interestingly the heathland community could sustain a higher energy intake for the cattle than the riverine grassland. So, as Wallis de Vries (1996) suggests, where the animals had the freedom to range between the two habitats there appeared to be a trade-off between energy and mineral availability.

Deficiency of phosphorus in forage selected by cattle was found by Tallowin & Smith (1996) on a lowland wet heath/fen meadow, comprising a mixture of M16, M23 and M24 communities (Rodwell 1991). It appears that deficiency of phosphorus for ruminant nutrition is a widespread phenomenon in species-rich semi-natural pastures as indicated by the low content of this mineral in hays from a range of grassland types.

Supplementation at pasture

It is general practice for livestock producers to use supplementary feeds to achieve high levels of individual animal performance (MLC 1995; ibid 1996). For example, for an average lowland beef suckler herd on agriculturally improved grassland receiving about 45 kg nitrogren/ha and at a stocking rate of about 1.7 cows/ha, about 157 kg of concentrate may be fed per cow and 67 kg per calf annually (MLC 1995). The suckler system aims to achieve a daily liveweight gain of the calves of 0.95-1.1 kg/day. For extensive early lambing systems based on lowland agriculturally improved pastures (receiving about 72 kg nitrogren/ha) and root crops, with an overall stocking rate of 13 ewes/ha, an average of 54 kg concentrate may be fed per ewe and 44 kg fed per lamb (MLC 1996). To gain some idea of the amount of a supplemented mineral, such as phosphorus, that might be fed in a concentrate ration an example is taken of the suggested composition of mineral-vitamin supplements in the concentrate portion of the diet for ewes in late pregnancy and early lactation. Mineral-vitamin supplements would amount to 2.5 % of the concentrate ration and, for example the phosphorus content of the concentrate ration would be 8.5% (MLC 1981). Therefore, at a stocking rate of 13 ewes /ha and a lambing percentage of 1.47 the amount of phosphorus added to the system from the mineral supplement alone could be over 3.0 kg/ha. Endogenous faecal loss of phosphorus from ruminant livestock will vary depending upon age and physiological state, for sheep the range could be between 12.3 and 40.6 mg/kg liveweight per day and for cattle, between 9.1

and 34.5 mg/kg liveweight per day (AFRC 1991). Depending upon the individual efficiency of absorption and retention a considerable part of the phosphorus in the supplementary feed could be recycled back to the pasture in dung and to a lesser extent in the urine. As discussed previously, mineral supplements of phosphorus that are not balanced with a high nitrogen availability, for example, may only allow an inefficient absorption and retention of the deficient mineral.

It is possible, therefore, that supplementary feeding on a semi-natural pasture, either with concentrates or in the form of a mineral block, could result in a net increase in the amount of phosphorus cycling within the pasture system. However, there is a lack of published information that could be used to quantify the risk that, with time, mineral supplementation could import sufficient phosphorus, or other minerals, to promote undesirable vegetational changes. Supplementary feeding may also cause substitution of the native forage for the feed supplement resulting in undesirable under-utilization of the semi-natural grassland. There is also the risk that supplementary feeding could, through concentrating livestock in feeding areas, cause localised soil structural damage (poaching). A paucity of published information on these subjects, highlights a need for research into the conservation risks (and possible benefits to livestock performance) of supplementary feeding as an integral part of managing some semi-natural grasslands.

Metabolizable energy output from semi-natural grasslands

The estimated metabolizable energy output, as hay, from unfertilized species-rich meadows (MG5/MG8 of the National Vegetation Classification (NVC) (Rodwell 1992)) on the Somerset Levels was *c*35 Giga Joules (GJ) per hectare (Kirkham & Wilkins 1994a; Tallowin & Smith 1994). From fen meadow/wet heathland communities in SW England (M23, M24 and M16 of the NVC (Rodwell 1991)) outputs ranged from less than 10 to *c*40 GJ/ha (Tallowin & Smith, unpublished). The average dry matter yield of hay from other unfertilized semi-natural grasslands of high conservation value was *c*3 tonnes/ha (Appendix table 1) and, assuming an ME value of the hay of 8.5MJ/ha, then an average ME output for such grasslands would be *c*25 GJ/ha.

The contribution made by the mid season hay crop to the total annual dry matter production can be derived for some semi-natural grasslands from the data in Appendix table 1. On the Somerset Levels the July hay crop comprised *c*70 percent of the total annual utilized metabolizable energy (UME) output (Kirkham & Wilkins 1994a). For other grassland types the mid-summer hay crop amounted to 60 percent, or more, of the total annual output. In the case of semi-natural grasslands and particularly those that are species-rich an upper limit for total annual ME output appears be about 40 GJ/ha; this figure takes no account of losses incurred during and as a result of feeding the hay to ruminant livestock. This upper limit is comparable to the estimated UME output recorded for some livestock systems on agriculturally improved grassland.

A national survey of non-suckler beef farms obtained an average UME output of 40.3 GJ/ha with an input of 66.2 kg nitrogen fertilizer/ha per year (Forbes *et al* 1980). In contrast more intensive systems, such as dairy farming, achieve considerably higher outputs. A survey of dairy farms in south-west England by Peel *et al* (1988) recorded a mean total UME output of 72 GJ/ha where the overall nitrogen fertilizer input was 232 kg /ha per year. Peel *et al* (1988) compared their results with a wider data set published by the Milk Marketing Board (Poole *et al* 1984) in which an average total UME output of 64 GJ/ha was recorded with an average nitrogen fertilizer input of 263 kg/ha per year. As Kirkham and Wilkins (1994a) observed the latter UME output was comparable to the output obtained from plots on species-rich meadows within the Tadham experiment that had received 200 kg of fertilizer nitrogen/ha per year. It has to be recognized, however, that the output obtained under experimental conditions is probably higher than under practical farming conditions due to the closer experimental control over the grassland management. Nevertheless, it appears that the total estimated UME output of unfertilized semi-natural grasslands cut for hay in mid summer and then either cut or grazed in the autumn may be, at best, only about 60 % of the output that is widely achieved from agriculturally improved and managed grasslands.

A much larger divergence in output is probably the case for semi-natural grasslands that are extensively managed by grazing alone. For example, grazed lowland wet heaths and fen meadows (M16, M23 and M24 of the NVC, Rodwell 1991)) that had an estimated UME output of only *c*15 GJ/ha (Tallowin & Smith 1996) would have produced only *c*20-25 percent of the output achievable from intensively managed permanent pastures (Tallowin *et al* 1990).

Financial implications of managing semi-natural grasslands

The financial impetus to farmers to improve grasslands and boost livestock output has a long history, as exemplified by the classic Park Grass experiment at Rothamsted (Lawes & Gilbert (1859) and the Cockle Park experiment in Northumberland (Pawson 1972). In the Cockle Park experiment the liveweight gain produced by sheep on an unfertilized grassland of what appears to have been a *Festuca-Agrostis-Galium* type, U4 of the NVC (Rodwell 1992), was only 30 percent of the production achieved on plots that received an application of 1.25 tonnes basic slag /ha at the beginning of a six year experimental period, 1897-1902 (Pawson 1972). The fertilizer treatment increased the stock-carrying capacity three to fourfold and increased the rental value of the land by five to six times. The botanical composition of the fertilized plots changed and, with time, appeared to be more akin to the MG6b *Lolio-Cynosuretum*, *Anthoxanthum odoratum* sub-community, (Rodwell 1992), which is typical of much of the productive improved grassland in the UK. The long tradition of grassland improvement in the UK has encouraged the evolution of high input/ high output livestock systems today and its against this background that the economics of managing unimproved semi-natural grasslands tend to be judged.

Financial burdens imposed on farmers for implementing managements to conserve semi-natural grasslands are, or can be, mitigated to a large extent by grant payments under various agri-environmental schemes. In order to be sustainable extensive livestock systems that integrate nature conservation objectives within a contemporary productive farming framework need support (Nosberger *et al* 1994). The overall cost of these schemes should, however, be offset against the considerable financial support that production orientated livestock systems currently attract. Financial evaluation of management costs for maintaining semi-natural grasslands need to accommodate the wider socio-economic benefits of their existence notwithstanding the fact that such additionality factors are by their very nature qualitative and difficult to give a monetary value to. That semi-natural grasslands have an existence value was shown by the studies of Brown (1995) and Giles (1995). It is evident, therefore, that assessments of costs and benefits of managing semi-natural grasslands based solely on agronomic parameters risk undervaluing their existence in landscapes. Adoption of more holistic economic evaluations are now needed, to include, where possible, hitherto less tangible benefits, such as societal perceptions of quality of life, that accrue from maintaining or re-establishing semi-natural grasslands in landscapes. This is an area of socio-economic research that merits further attention.

Unfortunately there is at present a paucity of published accounts of the costs/economic implications of managing semi-natural grasslands in the UK. There has been a grave lack of research on the impact of extensive grassland management for the maintenance or enhancement of biodiversity on farm output and livelihood (EGRO 1996). Indeed it is rare to have information on geo-climatic conditions, vegetation composition of the grassland, environmental value and the livestock output all together in one piece of work. Hitherto few studies have addressed these points in an integrated way.

Wilkins (1991) examined the economic implications of restricting fertilizer use on species-rich meadows, MG5 and MG8 communities of the NVC (Rodwell 1992), on the Somerset Levels. The study was initially based on a beef cattle production system with hay cut in mid-summer followed by grazing the regrowth from the hay cut. Financial margins were derived that allowed for the costs of purchase of beef cattle, fertilizer, contract charges for fertilizer application and hay making and interest on working capital. The margins for meadows with no fertilizer input were £170/ha. Meadows that received100 kg N/ha together with sufficient P and K to replace that removed in hay, achieved a margin of £223/ha. The margin with an application of 200 kg N/ha and higher rates of P and K was £256/ha. A second scenario involved calculating margins for milk production allowing for costs of fertilizer, contract charges for fertilizer application and hay making, concentrate feeds, other variable costs and interest on working capital. For milk production there was an increase from £668/ha without fertilizers to £936/ha with 100 kg N/ha and £1231/ha for 200 kg N/ha with added P and K. When allowance was made for the cost of leasing extra milk quota to sustain the systems involving fertilizer then the margins at 100 kg N/ha and 200 kg N/ha with added P and K were reduced to £803 and £904/ha respectively (Wilkins 1991). However, as Wilkins (1991) points out the payments under the Environmentally Sensitive Area (ESA) scheme would have been adequate to compensate livestock farmers at the time for income lost due to restricting fertilizer use. Such studies, albeit with their limited economic scope, are urgently needed.

Potential for integrating the management of semi-natural grasslands into productive livestock systems

It is recognised at the outset that what constitutes 'good' agricultural management does not necessarily also constitute 'good' conservation management, as emphasized in early studies on the management of chalk grassland (Wells 1969; Ibid 1976) and outlined in Crofts & Jefferson (1994). The studies by Wells (1976) on CG2 and CG3 associations (Rodwell 1992) at Aston Rowant National Nature Reserve showed that in order to achieve conservation objectives, such as effective control of scrub development by grazing livestock, animal performance was compromised. It was also apparent that the nutritional limitations of these chalk grasslands made them inappropriate for use in lamb production systems, as subsequent studies by Large & King (1978) endorsed. These studies also indicated that for effective control of coarse grasses and for resilience to stresses imposed by this semi-natural grassland environment both size and breed of sheep were important. The studies by Wells (1976) and earlier work by Kydd (1964) showed that the botanical composition of chalk grasslands, such as CG2 associations, change little, at least in the short term, in response to a wide range of grazing managements. The principle was thus established that, providing no fertilizer is applied, semi-natural grasslands have considerable resilience to withstand occasional high grazing pressures. What was also demonstrated was that room for compromise between achieving conservation objectives and using semi-natural grasslands for modern productive livestock systems is limited. Nevertheless, as subsequent studies by Treweek and Watt (1994) demonstrated, investigating ways of achieving the least negative effect on productive livestock in the management of semi-natural grasslands could be worthwhile.

It is probable that survival of much of the lowland semi-natural grassland in the UK outside nature reserves will depend upon continued management by farmers who will wish to use the forage for productive livestock. The use of the forage should thus involve some form of integration into sustainable/profitable livestock system(s). Lack of incentives for farmers to use semi-natural grassland forages in a way that is appropriate for the maintenance of their conservation interests will result in them being either abandoned, mismanaged or agriculturally improved.

Unfortunately few studies have examined the potential for integrating the management of semi-natural grasslands into productive livestock systems. One such study was conducted by Tallowin & Smith (1996) on lowland wet heaths and fen meadows, M16, M23 and M24 associations (Rodwell 1991). Traditionally these grasslands were grazed with heavy store cattle at low stocking densities. However, low output per ha and poor performance of livestock marginalizes their value to the agricultural sector and this has led to either their abandonment or improvement. Tallowin & Smith (1996) examined the potential of using short duration high stocking density grazing treatments with store cattle (2-300 kg liveweight) to control successional change, dominance by *Molinia caerulea* and to limit the time that productive livestock were exposed to mineral deficiencies. The study indicated that grazing for one - two month periods in the summer achieved the conservation objective of allowing enhanced botanical richness. It would also have allowed the release of intensively managed grassland for silage and the UME output that could be achieved from the silage would have compensated for the reduced output by the livestock while on the semi-natural grassland. Whether such intensive short-duration treatments if imposed on a rotational basis on these grasslands would have a long-term impact on the populations of key fauna, particularly among invertebrates, was not established. The need to accommodate entomological interests, for example, as earlier work on chalk grassland showed (Morris 1971), serves to emphasize that potential integrative management studies should be long-term and multidisciplinary.

The study by Tallowin & Smith (1996) indicated that grazing lowland heath and fen-meadow communities for longer periods over the summer provided little agronomic advantage over the short duration treatments and caused individual animal performance to suffer for longer. Poor performance and health of livestock is an unacceptable consequence of restricting animals to nutritionally deficient pastures for prolonged periods of time.

Studies by Wallis de Vries (1994; ibid 1996) in the Netherlands indicated that nature conservation management of such nutritionally deficient communities as lowland heathlands can, through combining these habitats with others of different/better nutritional qualities, provide grazing animals with more optimal foraging conditions that might sustain agronomically acceptable performance. A challenge in developing such free-range systems that allow livestock to move between different grasslands to obtain mineral and energy supplies for good performance may be in obtaining sufficient utilization of the semi-natural grassland to control successional change. It may be that mixtures of livestock species and/or mixtures of breed types, including rare or traditional breeds, may be more appropriate to such free-range systems. It also needs to be ascertained that over the long-term such free-range grazing will not lead to a significant transfer of nutrients, through dung and urine deposition, into the unimproved grassland which could promote undesirable vegetational change.

A basis for examining the potential of different breeds for use in the management of semi-natural grasslands comes from evidence that intake requirement of cattle differ between breeds (Petit *et al* 1995) and particularly as animals approach their mature weight (ARC 1980). For traditional beef breeds, such as Herefords and Aberdeen Angus, that mature at a lower liveweight than dairy breeds such as Holstein or Friesian or continental breeds such as Charolais, forage consumption may be as much as 5 to 10 percent lower for similar weight but physiologically different aged animals. Thus for set-stocked grasslands where forage mass declines towards the end of the grazing season there appears to be some rationale for using earlier maturing traditional beef breeds. In addition where resilience to harsh/stressfull environmental conditions is required some traditional breeds appear to have advantages over breeds selected for highly productive systems. For example, the Galloway breed of cattle was selected for grazing a lowland wet fen where its resilience to insect pests was considered a useful attribute (Williams *et al* 1974). Where the grassland contains mature vegetation such as coarse grasses there appear to be differences between breed types in their selection of such material (Petit *et al* 1995), that could be exploited in the management of semi-natural grasslands. The energy requirements associated with the process of grazing will vary between the type of grassland forages provided. Baker (1982) suggests that this energy requirement may be considerably increased for livestock in extensive grazing systems, which would include most semi-natural grasslands. There appear to be differences in the ability of different breeds to walk and thus exploit grasslands (Herbel & Nelson 1966), which again could be a trait that could be exploited in the management of extensive and varied habitats.

A re-examination of livestock breed attributes that might offer advantages over modern/conventional breeds in the management of different semi-natural grassland associations could prove worthwhile.

Future research requirements

- Extend the agronomic data base for semi-natural grassland associations (yield and quality of hays and/or liveweight carried should, at the very least, be routinely collected for semi-natural grasslands on National Nature Reserves).
- Examine further the contention that biomass variability is lower in more species-rich grassland than in species-poor communities.
- Validate/examine the contention that the soil organic matter mineralization processes that result in low nutrient availability in the spring/early summer is a key factor allowing high species-richness to be maintained.
- Long-term ecological and agronomic studies on effects of occasional inputs of either farmyard manures or inorganic fertilizers: to develop sustainable management systems for semi-natural meadow communities.
- Evaluation of treatments for upgrading the quality of late cut hays which should also include an assessment of effects on intake, performance and health in ruminant livestock.
- Evaluation of rare/traditional breeds for potentially useful attributes for managing semi-natural grasslands, such as resilience/tolerance of periodic nutritional deficiency, behavioural traits and adding value to livestock products.
- Evaluation of mower-conditioners for mature species-rich hays to ensure rapid drying time and reduce losses of quality.
- Develop and evaluate models to assist in achieving sound grazing management strategies for lowland semi-natural grasslands.
- Quantify the risk of supplementary feeding and/or free-range grazing causing long-term damage through nutrient import into semi-natural grasslands.
- Evaluation of socio-economic benefits of maintaining semi-natural grasslands.