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Edited by J L Jollans

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# 17 Technical factors affecting grassland output

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## DEFINITION OF GRASSLAND OUTPUT

Grassland output can be specified in a number of different ways. The conventional way of expressing cut herbage yields is as dry matter (DM) per unit area. Forages of different quality can be compared on the yield of digestible organic matter (DOM) which is the product of the DM yield and the digestible organic matter in the DM (D-value). An additional expression is the yield of digestible crude protein (DCP). Herbage yields from plots are generally reduced to translate them into field yields. A further deduction for utilisation allows for system losses during conservation and these range from 15% for tower silage and barn dried hay to 30% or over for field dried hay. Losses during utilisation by grazing are more difficult to estimate but are thought to be of the order of 25%.

Utilised output expressed as cow, beef and sheep grazing days are based on the actual or estimated intakes of DM by animals defined primarily in terms of liveweight (Baker, 1964). The performance of the animal in terms of milk production and/or liveweight gain can also be incorporated. Holmes (1968), in setting targets of four levels of animal production from grass, related DM and digestible crude protein yield to cow and beef grazing days and to the expected production, in a 180-day grazing season, of milk and liveweight gain at given stocking rates of dairy cows and beef cattle respectively.

The need for a more comprehensive definition of grassland output has now been met by the adoption of the metabolisable energy system (ARC, 1965; MAFF, 1975). Grass is used by a variety of livestock for different purposes and end products – maintenance, growth, milk and meat – and the only measure which combines these into a common unit of output is the energy used by all the livestock consuming grass on the farm. Production from grass also generally involves the use of a variety of feeds other than grass. The energy inputs from these sources can be deducted leaving a net value which represents the contribution from grass.

Forbes *et al.* (1980), working in the Joint GRI/ADAS Permanent Pasture Group, have studied factors affecting output on dominantly permanent grassland farms in England and Wales and have described in detail how this method can be used to arrive at a Utilised Metabolisable Energy (UME) output for the whole of the grassland on individual farms. This can then be expressed as UME per ha of the net grass area, calculated from the area of grassland and rough grazing with adjustments for areas in grass for part of the year. The method of calculation has the same drawback as the Starch Equivalent system previously used (Barker *et al.* 1955). Feeds other than home-grown grass are deducted at full energy value, on the assumption that they are utilised at full efficiency, and hence grassland output suffers the maximum penalty.

## EXAMPLES OF GRASSLAND OUTPUT AS UME

A range of possible UME values, derived from DM yields at various levels of utilisation efficiency and grass quality, is shown in Table 1. A range of 24–88 GJ per ha is shown but further extension is possible particularly at the higher end of the scale. Walsh (1979) has derived herbage yields from experimental data and expressed them in terms of UME for five levels of grass growing conditions, each at six levels of fertiliser nitrogen from 125–438 kg per ha. This calculation produced a range from 38 to 115 GJ per ha.

Table 1
**A range of theoretical UME outputs derived from DM yields**

| DM yield – kg per ha | 12 000 | | 6 000 | |
|---|---|---|---|---|
| Utilisation % | 70 | 50 | 70 | 50 |
| Utilised DM – kg per ha | 8 400 | 6 000 | 4 200 | 3 000 |
| ME – MJ per kg | 10.5 | 9.5 | 10.0 | 8.0 |
| UME output – GJ per ha | 88.2 | 57.0 | 42.0 | 24.0 |

A different approach is to start with the energy requirements of livestock. For example, Walsh (1979) has calculated the energy requirement of dairy cows at different milk yield levels, assuming that higher milk yields are associated with cows of higher body weights. Table 2 shows these ME requirements for cows of three different milk yields. The total ME requirement per ha is then shown at three different annual stocking rates for each milk yield level. For each of the nine stocking rate/milk yield combinations, the split of the total ME requirement into that obtained from concentrates and that obtained from grass is shown for six levels of concentrate feeding (including the nil level). These are defined in terms of weight (kg) of concentrates per litre of milk.

Table 2

**Theoretical UME output from grass and ME from concentrates at three levels of annual milk yield per cow, three annual stocking rates and six levels of concentrate feeding**

| Annual milk yield – litres/cow | | 4 500 | | | 5 500 | | | 6 500 | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Total ME requirements[1] – GJ/cow | | 46.6 | | | 53.0 | | | 59.5 | | |
| Stocking rate – cows/ha | | 1.5 | 2.0 | 2.5 | 1.5 | 2.0 | 2.5 | 1.5 | 2.0 | 2.5 |
| Rate of concentrate feeding | Source of ME | UME outputs from grass and ME from concs, GJ/ha | | | | | | | | |
| 0.0 kg/litre | concs | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | grass | 70 | 93 | 116 | 80 | 106 | 133 | 89 | 119 | 149 |
| 0.1 kg/litre | concs | 7 | 10 | 12 | 9 | 12 | 15 | 10 | 14 | 18 |
| | grass | 63 | 83 | 104 | 71 | 94 | 118 | 79 | 105 | 131 |
| 0.2 kg/litre | concs | 15 | 19 | 24 | 18 | 24 | 30 | 21 | 28 | 35 |
| | grass | 55 | 74 | 92 | 62 | 82 | 103 | 68 | 91 | 114 |
| 0.3 kg/litre | concs | 22 | 29 | 36 | 27 | 35 | 44 | 31 | 42 | 52 |
| | grass | 48 | 64 | 80 | 53 | 71 | 88 | 58 | 77 | 97 |
| 0.4 kg/litre | concs | 29 | 39 | 48 | 36 | 47 | 59 | 42 | 56 | 70 |
| | grass | 41 | 54 | 68 | 44 | 59 | 74 | 47 | 63 | 79 |
| 0.5 kg/litre | concs | 36 | 48 | 60 | 45 | 59 | 74 | 52 | 70 | 87 |
| | grass | 34 | 45 | 56 | 35 | 47 | 59 | 37 | 49 | 62 |

*1* Taken from Walsh (1979).

The relationship between the ME from concentrates and from grass is clearly shown in Table 2. The two sources of energy are complementary to one another within the total ME requirement at any stocking rate/milk yield combination. A higher level of concentrate feeding automatically reduces grass UME output, unless compensated for by a higher stocking rate or a higher milk yield or both. This is illustrated in Table 3 for the 4 500 litre milk yield level using an extended stocking rate range from 1.25 to 2.50 cows per ha and the same range of concentrate use as in Table 2. The UME output of grass more than doubles across the concentrate usage range at any given stocking rate and it doubles at any given concentrate use across the stocking rate range. The increase from the lowest UME from grass (28 GJ per ha) to the highest (116 GJ per ha) is over 400% and is even higher at higher milk yields. What is very striking, however, is that similar levels of UME output from grass can be obtained from various combinations of stocking rate and concentrate use. For example, in Table 3 (based on a 4 500 litre cow milk yield) there are six different combinations producing similar UME values between 56 and 65 GJ per ha ranging from 1.25 cows per ha, at nil concentrate, to 2.50 cows per ha at 0.5 kg per litre. The difference is that, in the former instance, the amount of energy obtained from grass, within the total animal requirement, is 100% whereas, in the latter instance, it is only 48% falling to 44% with the 5 500 litre cow and 41% with the 6 500 litre cow.

Table 3

**UME output from grassland (GJ per ha) at six stocking rates and six levels of concentrate use at a milk yield of 4 500 litres per cow per year**

| Concentrate use kg per litre milk | Stocking rate – cows per ha | | | | | |
|---|---|---|---|---|---|---|
| | 1.25 | 1.50 | 1.75 | 2.00 | 2.25 | 2.50 |
| 0.0 | 58 | 70 | 82 | 93 | 105 | 116 |
| 0.1 | 52 | 63 | 74 | 83 | 95 | 104 |
| 0.2 | 46 | 55 | 65 | 74 | 83 | 92 |
| 0.3 | 40 | 48 | 56 | 64 | 72 | 80 |
| 0.4 | 34 | 41 | 48 | 54 | 61 | 68 |
| 0.5 | 28 | 34 | 40 | 45 | 51 | 56 |

The UME outputs in Table 2 relate only to the dairy cow situation. In practice, on dairy farms, there are generally followers for dairy replacements and possibly also for beef production. Occasionally there are sheep as well.

The effect of these other stock, on UME output of grass, depends on management but is likely to reduce the overall level. Similarly, on some dairy farms, foods other than home-grown grass and concentrates are fed. The ME content of these has to be deducted from total requirements with the effect of further reducing UME output from grass.

In practice, it is doubtful whether some of these high grass UME output figures, derived from combinations of high milk yield and low concentrate use (Table 2), have yet been obtained. Hutchinson (1979) quoted an example of an autumn calving herd in south-west England averaging 5 959 litres per cow, at 0.30 kg of concentrates per litre and at 2.91 cows per ha, producing a UME from forage (including some kale) of 95 GJ per ha. He also specifies a similar result of 93 GJ per ha at the same location from a spring calving herd at a slightly higher milk yield, a lower concentrate use and a stocking rate of 2.64 cows per ha. Evans (1979), working at Trawscoed EHF, has shown that the spring calving dairy herd averaged 4 610 litres at 0.13 kg per litre and at a stocking rate of 2.5 cows per ha. Reference to Table 1 indicates that the UME output from grassland is of the order of 100 GJ per ha. Gordon (1979) has described a spring calving system in Northern Ireland, based on a very high stocking rate of 2.9 cows per ha with a yield of 5 344 litres at 0.1 kg per litre. Using an extrapolation from the stocking rates shown in Table 1, the UME output from grassland would be about 134 GJ per ha.

The grassland output on dairy farms reported by Forbes *et al.* (1980) averaged some 44 GJ per ha. This was obtained at a stocking rate of 1.8 cow equivalents per ha and a dairy cow performance of 4 500 litres per cow at 0.34 kg per litre concentrate use. However, the top third of dairy farms based on UME output averaged 57 GJ per ha which was about double the output of the bottom third at 31 GJ per ha. The difference was due to the top third having a higher stocking rate, a higher milk yield and a lower concentrate use.

Information on dairy herd performance on farms fully costed by the Milk Marketing Board (Amies *et al.* 1979) shows that the top 25%, selected on gross margin per ha, had a UME from forage of 80 GJ per ha in comparison with the 42 GJ per ha from the bottom 25%. These outputs are closely in line with the predicted values in Table 2 given milk yields of 5 590 and 4 863 litres per cow, concentrate use of 0.33 and 0.40 kg per litre and stocking rates of 2.43 and 1.49 livestock units per ha for the top and bottom quartiles respectively. These results emphasise the overall close link between a high gross margin per ha and a high UME output per ha. However, at any given level of grassland UME output there is a range of possible financial margins derived from the various combinations of milk yield, stocking rate and concentrate use.

Examples of UME output from grassland utilised by beef and sheep are as yet uncommon. Forbes *et al.* (1980) have compared dairy farms with both non-suckler and suckler beef farms and showed that the average UME output of the beef farms was some 9 and 14% respectively lower than that of the dairy farms. However, this difference was less than might be expected from the 33% lower stocking rate and 66% lower fertiliser nitrogen use on the beef farms than on the dairy farms. The top third of the beef farms in both groups produced a UME output from grass of over 50 GJ per ha which was twice as high as the bottom third.

Elliott *et al.* (1978) reported an average output of 60 GJ per ha from permanent pasture under a fattening beef system but with the output from fertilised grass more than double that from unfertilised grass at 69 and 30 GJ per ha respectively.

## FACTORS AFFECTING UME OUTPUT OF GRASSLAND

It is evident that there are a number of technical and environmental factors (as well as sociological and financial ones) which may affect UME output of grassland. The National Farm Study reported by Forbes *et al.* (1980) was designed to study the relationships between UME output and many of these factors, first by correlation and then by a multiple regression analysis. The problem of high correlations between the independent variables necessitated the determination of partial correlations to ascertain real effects. The proportion of variation between farms accounted for by single variables was also calculated.

### Stocking rate

This was the variable most highly and consistently correlated with UME output in the National Farm Study. A degree of correlation was to be expected since stock numbers were involved in the calculation of total ME requirements. Stocking rate accounted for a smaller proportion (up to 53%) of the variation in output on dairy farms than on beef farms (up to 51% on non-suckler and up to 84% on suckler beef farms) which reflects the heavier dependence on feed, other than home-grown grass (FME), on dairy farms. At the same level of UME output, the stocking rate on beef farms was some 40% lower than on dairy farms. Similarly at the same stocking rate, the UME output on the beef farms was about 50% higher than for the dairy farms. Stocking rate itself is influenced by many of the technical factors which influence UME output and these will be mentioned under subsequent headings. The relationship between FME and UME has already been described. A higher stocking rate on all farm types was significantly associated with a higher FME per cow equivalent.

At any given level of inputs, increasing stocking rate may reduce animal performance but will increase output per unit area up to an optimum point beyond which output falls (Mott, 1961). It is not possible to say whether the much higher stocking rates achieved by the top third (based on UME) of farms in both beef groups in the National Farm Study have resulted in poorer animal performance. This was certainly not the case, however, in the dairy group, where the average milk yield tended to be higher for the top third of farms. Holmes (1974) considered that improvement in grass utilisation has been made largely by the fuller appreciation of the importance of attaining an adequate stocking rate, to make full use of the pasture potential, and the discrepancies which still occur between potential and actual performance stem primarily from a failure to achieve optimal stocking rates.

However, it is clear that, on grassland farms where there is little opportunity for alternative crops, the number of animals kept is influenced very considerably by the amount of labour, buildings and capital available. For example, farmer co-operators in the National Farm Study were asked whether the grassland on their farms was stocked to potential and about two-thirds recognised that more stock could be carried. Of these, rather more than half had decided that they would not increase stock numbers and gave, as their prime reason, lack of incentive followed by buildings, labour and capital. Hence about one-third of all farmers in the Study have accepted a ceiling of stocking rate which is determined not by the capabilities of the land but by other constraints. Increased output from these farms may come from better animal performance but, for many, economic survival depends on keeping inputs down to low levels.

**Fertiliser N use**

This was also highly correlated with UME output in the National Farm Study and it remained so after the effect of 'preferred' species content had been removed by partial correlation. In regression analyses which included stocking rate, fertiliser N accounted for little or none of the variation in UME output. When stocking rate was excluded, fertiliser N was either first in importance or second to FME in most year x farm type analyses and it accounted for up to 22% of variation on dairy farms.

Input of fertiliser N was also strongly correlated with stocking rate. The relationship of nitrogen with stocking rate appeared to be stronger than the direct effect of nitrogen on UME output and it accounted for up to 27% of variation on dairy farms.

The importance of the fertiliser nitrogen effect is of course not unexpected. Morrison *et al.* (1980), reporting on 21 sites in England and Wales over four years from 1971–1975, using S23 perennial ryegrass swards cut monthly, have shown that the response to nitrogen is linear up to 300 kg per ha with an overall mean response of 23 kg DM per kg N. Apart from nitrogen, the factors affecting yield were the summer rainfall and soil available water capacity. On a mixed sward of 22 different species, cut monthly throughout six growing seasons, Mudd (1971) obtained responses of 22 kg DM per kg N between nil and 250 kg N per ha and 14 kg DM per kg N from 250 to 500 kg N per ha.

Output in terms of dairy cow grazing days (CGDs) per ha in relation to fertiliser nitrogen use has been reviewed by Holmes (1968) who showed a highly significant linear relationship between production per ha, expressed as CGDs, and nitrogen level up to 450 kg N per ha. Gordon (1974) has shown a close correlation between grass dry matter responses and those measured through the dairy cow. Holmes (1974) has assessed the response of pastures, grazed by beef cattle, to N fertiliser and concluded that there was a significantly linear response with applications up to 200 kg per ha. However, he does make the point that it is possible to obtain over 1 000 kg per ha liveweight gain from clovery swards with little or no nitrogen.

Kilkenny & Lloyd (1979) have reviewed the relationship between fertiliser nitrogen use and utilised output, expressed as Livestock Unit Grazing Days (LUGDs), over five years on beef/sheep farms recorded by the Meat and Livestock Commission. The pattern for each year was similar and best expressed as a curve which, in all cases, flattened off after 200 kg per ha of nitrogen. Below that level there was a clear and marked response in number of LUGDs to increasing fertiliser nitrogen levels, but at each level there was considerable variation in utilised output.

The 'average' beef farmer in the National Farm Study was using about 55 kg per ha of nitrogen and the 'average' dairy farmer about 160 kg per ha per annum. Hence even the few high nitrogen dairy farms were unlikely to be beyond the linear response level and many of the beef farmers were relying on soil and clover nitrogen rather than fertiliser N for production.

**'Preferred' species content of swards**

In the National Farm Study, when the effect of fertiliser N was removed by partial correlation, there was no significant correlation between the 'preferred' species content and the UME output on dairy farms. However, it remained significant on both types of beef farms. In regression analyses excluding stocking rate, 'preferred' species content was not among the significant variables on dairy farms. However, on beef farms it was an important variable and, together with nitrogen, accounted for up to 42% of the variation. 'Preferred' species content was also significantly related to stocking rate on beef farms and, together with nitrogen, it accounted for up to 42% of variation. It might be that the proportion of 'preferred' species is very important in the less intensive situations where inputs of fertiliser N and FME are low. It is also likely that the importance of the 'preferred' species on suckler beef farms stems from the larger proportion of farms in this group with grassland of a low potential, due to soil and sward type. Not only is the actual output of this land low but the UME output per ha is reduced by the method of calculation in which the enclosed rough grazing counts in full in the total grassland area.

Evidence of effect of sward changes on yield has been reviewed by Dibb & Haggar (1979) who concluded that some other grass species are capable of production comparable with perennial ryegrass under a certain range of environments and treatments. They considered that output is associated with environment and fertility and that the type of sward reflects these conditions rather than itself being the prime cause of increased production.

It is relevant to note that the botanical composition of enclosed grassland has changed remarkably in the past forty years. In the 1930s the first-grade pastures (more than 30% perennial ryegrass), as defined by Davies (1941), accounted for less than 2% of the permanent grassland area of England and Wales. In the National Farm Study at least 40% of the grassland qualified as first grade by the same definition (Hopkins, 1979). Over the whole sample of farms the 'preferred' species content averaged 43% ranging from 39% on suckler beef farms to 48% on dairy farms.

**Clover content of swards**

Clover (nearly always white clover) is included amongst 'preferred' species but, because of its special importance as a high-quality feed and source of nitrogen, it was also included separately amongst the independent variables in the National Farm Study. There was, however, no relationship between clover content of the sward and UME output on dairy farms. There was a significant negative correlation with stocking rate which probably reflects the difficulty of maintaining clover in swards under intensive dairy situations. Indeed, the amount of clover found on dairy farms was limited, with less than 10% of fields having a good clover content. This contrasted with the beef farms where about one in three fields had a good clover content. Nevertheless, clover was not correlated with UME output or stocking rate on a whole-farm basis on beef farms. This is surprising, as many workers have shown the value of white clover as a source of nitrogen. For example, Brockman (1974) calculated that the quantity of fertiliser N that it would be necessary to apply to a clover-free sward to get the yield obtained from a grass/clover sward receiving no fertiliser N was 139 kg per ha with a range from 40 to 220 over 29 site years of grazed experiments.

**Age of sward**

The farms in the National Farm Study excluded those with large proportions of short-term leys in arable rotation. Hence comparisons are between farms with different ratios of grass above and below 20 years old. No evidence was found that the age of grass itself affected output. While a high proportion of old swards was frequently associated with low output, the latter was a result of low input of fertiliser nitrogen and low stocking rates. Old grass, low stocking rates and land classified as difficult to manage often went together. Although old swards had a relatively low content of 'preferred' species, there was no indication that the proportion of old grass on a farm affected animal performance or the level of FME supplementation or the quality of hay or silage.

**Phosphate, potash and pH levels**

The only significant relationship in the National Farm Study was that of a low soil phosphate index with UME output on dairy farms. The reason for this is difficult to pinpoint. Hopkins & Green (1979) have suggested that there is a relationship between phosphate index and perennial ryegrass content but the latter is not associated with output on dairy farms. In some regions there is a tendency for dairy farms to be located on the heavier and wetter soils of a naturally low phosphate index; perhaps a low index is reflecting poorer conditions for grass growth and utilisation.

**Quality of conserved grass**

There was no discernible effect of quality, as measured by D value, on the UME output in any of the farm type groups in the National Farm Study. It was noticeable, however, that the average quality was in the upper fifties or low sixties D value. Corrall & Treacher (1976), comparing D values from 61–70, have shown that the production of dry matter is maximised at 61 D. The highest yields of ME were achieved at 61 or 64 D but when liveweight gains of young cattle were predicted, the highest gain was obtained from 67 D silage. Other theoretical studies on silage for milk production (ADAS, 1976; Adamson & Brooke, 1976) have shown that, if cow numbers cannot be increased and land cannot be used in some other more profitable enterprise, then lower yield, high D value silage might be the best economic strategy. Where land area is limited, or cow numbers can be expanded, higher yield/low D value systems might be best.

**Pests and diseases**

These have not been recorded in the National Farm Study. However, Henderson & Clements (1977) have concluded that the growth of ryegrass swards is adversely affected by the activities of insects and other invertebrates, even when no damage is evident, and pesticide treatment can increase the annual DM output by up to 32%. Italian ryegrass, and to a lesser extent perennial ryegrass, on lowland swards are particularly susceptible to attack by normal populations of stem-boring *Diptera* larvae. Permanent pastures in upland regions of England and Wales did not seem to respond in a consistent way to insecticide treatment (Clements, 1979).

Carr (1979) has pointed out that diseases caused by fungi and viruses are widespread and often damaging in grass/clover swards. For example, losses of up to 20% DM can result from crown rust infection of ryegrass. Ryegrass mosaic virus infection reduces Italian ryegrass yield by up to 30% and accentuates winter kill. Clover rot is lethal to red and white clover, although resistant cultivars are now available. More recently, bacterial wilt has been recognised as damaging to Italian and perennial ryegrasses (A J Heard, personal communication).

## CONCLUSIONS

Within the overall constraints of land, labour and capital resources and within the abilities and ambitions of the farmer, there are a number of technical factors which influence utilised output from grassland. Stocking rate and fertiliser nitrogen use are important on all farm types. The role and significance of 'preferred' species is less clear and is dependent on type of farm and the potential of the soil and indigenous sward. Clover is now noticeably absent from much grassland and appears to be exerting little influence on output in spite of its high potential for nitrogen contribution. There is experimental evidence that unseen and hitherto unsuspected pests and diseases, causing losses of yield, are endemic in some swards.

Other technical factors possibly affecting utilised output, such as drainage, irrigation, animal nutrition and animal health, have not been discussed in this paper.

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