6. Farmyard manure in relation to nutrient content

6.1 Nutrient Content of FYM

6.1.1 There is a large volume of literature on this subject, some of it contradictory, so the reader should not believe all that is printed is either the whole truth or nothing but the truth. Given the variability and complexity of FYM this is hardly surprising, and one should always remember that FYM is never homogeneous even from one animal on one type of bedding, and all we can hope to do is establish guidelines. The heterogeneity may actually serve the conservationist if not the farmer, given the niches it provides (see section 5.7.4). It has been said that FYM today is not the same today as that applied in the past, due to better animal feeding. However, today more care is taken over producing an appropriate ration related to the expected production of the animals to be fed, to avoid waste and uneconomic feeding. This with our better knowledge of feed constituents and the animal's dietary requirements enables the farmer who has his feed analysed to provide a balanced ration, which theoretically should mean that the animals manure contains less waste feed, particularly protein but also minerals, than may have occurred in the past. However, traditional farmers may ignore such science and maybe Management Agreements could both provide funds for analyses and farmers encouraged to feed a balanced ration to minimise wastage of feed which both costs them money and provides excess nutrients in the resultant manure. For a paper relating to diary cows on this topic see Tamminga (1992). It can also be argued that farmers today, by virtue of the ready availability of concentrate feeds, and other management changes have intensified their stocking rates, which increases the amount of manure they have to spread per acre or hectare. Traditional farmers are likely to have intensified to a lesser degree than others. However, by leaching of nutrients, loss of ammonia, poor timeliness of application, and other 'poor husbandry' or deliberate means it is possible to reduce the value of a manure to minimise the effect of increased manurial supply. Intensification remains a real possibility, necessitating a limit which can be monitored and enforced, if necessary, on the maximum amount of FYM that can be applied to a particular area. Some farmers argue that FYM is an essential factor in maintaining species diversity (Tallowin, pers. comm.). If evidence can support this then this might suggest on particular sites a minimum prescriptive limit on the amount of FYM which must be applied.

6.1.2 MAFF has recently (MAFF 1994a - pages 7-18; RB209) published the current definitive text on organic manure composition, production by different livestock, and utilisation. It is recommended that the values given are used whenever there is no possibility of using an actual analysis of the FYM available. However, it must be stressed that these averages may differ substantially from actual analyses, as can be seen from Appendix 2, and that individual analysis will always be a better guide, provided that it is truly representative.

6.1.3 ADAS can offer an analysis service for organic manures, hay, silage, grass, and soils (see Appendix 3).

6.1.4 Current advice (MAFF 1994) on organic manures includes typical nutrient content of FYM based on the analyses of large numbers of samples. Analysis can merely indicate some of the initial nutrients of the applied material, but climatic and soil influences, particularly microbes and to a certain extent invertebrates, can determine plant availability and different plants neither require nor extract the available nutrients to the same degree, and hence respond differently. Chemical analysis can indicate total nutrient content, and so provide a guide to what is added in a manure; but losses and immobilisation have to be estimated (see Sections 6.2 and 6.3 below), and soils differ in their ability to 'buffer' nutrient enrichment and to supply their own nutrients by weathering, eg potash from potash releasing clays (ADAS 1990). Consequently FYM application rates and frequency of applications should reflect these differences as far as possible to ensure appropriate inputs and management occurs.

6.1.5 The following authors have referred to the chemical composition of FYM: See Appendix 5.

Anon 1976b - p7 & 8, and p57-64; ADAS 1983a - p7; MAFF 1994a p8 &9- the current definitive text; Archer 1985 - p124 & p128; Bisset *et al* 1980 - p17; Cooke 1975 - p15 & 80; Dyson 1992 - p5; Garner 1957 - p23; Hunter 1931 - p356 & p361; Moore 1968 - p102; Smith 1991- p4; Weir 1936 - p396 (American); Wrightson c1875 - p112.

6.1.6 Not all authors agree on the chemical composition of FYM; and this may be due to experimental techniques or real changes with time, small numbers of samples, or variation in livestock rations. Appendix 2 gives previously unpublished ADAS data. The authors may attract criticism for indicating the range of results; but this is deliberate. To avoid leaving the reader confused, the MAFF (MAFF 1994a) text is stressed as giving typical current figures applicable to the UK (Tables 8 and 9).

Table 8. Typical nutrient content of fresh animal manures (MAFF 1994a)

	% DM	Total nutrients			Available Nutrients [1]		
kg T^{-1} FYM	kg m^3 slurry	Nitrogen	Phosphate	Potash	Nitrogen	Phosphate	Potash
Cattle FYM [2]	25	6.0	3.5	8.0	See Table	2.1	4.8
Pig FYM [2]	25	7.0	7.0	5.0	overleaf	4.2	3.0
Dairy slurry[3]	6	3.0	1.2	3.5		0.6	3.2
Beef slurry[3]	6	2.3	1.2	2.7		0.6	2.4
Pig slurry[3]	6	5.0	3.0	3.0		1.5	2.7

1. Nutrients are available for the next crop. 2. Values for Nitrogen and Potash will be lower for FYM stored for long periods or in the open. 3. Undiluted animal slurry usually contains 10% DM; yet farm slurry is usually about 6%. Nutrient concentration rises or falls with slurry DM.

Table 9. Percentage of total nitrogen available to the next crop following applications of animal manures. (Percentage of total nitrogen). Slurries are included here for comparision with FYM (MAFF 1994a)

Timing		Autumn [1]	=Aug-Oct	Winter	=Nov-Jan	Spring =Feb-Apr	Summer use on grassland [2]
Soil type	DM %	Sandy/ Shallow	Other mineral [3]	Sandy/ Shallow	Other mineral [3]	All soils	All soils
Surface application							
Fresh FYM [4]	25	5	5	10	15	20	N/A
Dairy/beef slurry [5]	6	5	10	10	20	30	20
Pig slurry [5]	6	5	10	10	25	35	20

Notes

1. Total annual rainfall assumed to be 750 mm (30"); where average or actual winter rainfall is below 250 mm the values for autumn application should be increased to those given for winter application, which assumes 150 mm rainfall after application to end of March

2. The yield response to summer applications can be very variable according to soil and weather conditions. Later applications (July/August) are likely to be less effective.

3. For deep silt and clay soils assume higher percentage total nitrogen will be available for the next crop.

4. Values should be reduced by up to half for FYM materials that have been stored in the open under poor conditions or for long periods.

5. Ammonia loss decreases as slurries are diluted. The percentage of total N available to the next crop will therefore depend upon slurry dry matter, being greater for dilute slurries.

6.2 Changes in storage

6.2.1 It is important to distinguish between stockpiling manure (ie undisturbed storage) and composting (usually involving aeration by disturbance). FYM was by tradition a system of handling animal wastes together with straw and other litter as compost. In the opinion of Bisset *et al* (1980) opinion, (others have differing approaches - see Lampkin 1990; Russell 1936; Vogtmann & Besson 1978), "to achieve a good compost, the dungstead or midden requires careful construction and regular turning to allow air into the heap. In areas of high rainfall it was often roofed. Such composted FYM was a relatively dry and friable material, free from infective numbers of animal disease organisms and had a generally acceptable odour. Under present conditions, the FYM from cattle courts is seldom allowed to compost. It does not have the same texture as traditional FYM and may have relatively poor spreading characteristics", ie is prone to uneven spreading (Bisset *et al* 1980). The relative carbon losses are quoted as 17% and 26.4%, from stockpiling and composting respectively, and relative nitrogen gains of 25% and 32.7% respectively (Atallah et al 1995). They state that C/N ratios decrease with increasing time of storage and composting and they found that composting for 47 days seemed to generate a similar product to stockpiling for 330 days.

6.2.2 Vogtmann & Besson 1978 considered the following effects of composting of FYM as being of great importance:

1. Odour
2. Hygiene - loss of pathogenic organisms
3. Reduction of the germination of weed seeds
4. Fertiliser value
5. Effects on plants and soil-life
6. Leaching of nutrients
7. Loss of nutrients during treatment
8. Loss of nutrients during application
9. Cost of treatment: investment, labour and energy.

All the above change during and as a result of the storage conditions and storage period.

6.2.3 Aeration and exposure leads to greater losses of nitrogen due to volatilisation of ammonia than if manure is left undisturbed, compacted and covered, but convenience is usually the deciding factor (Garner 1957). Well made manure is often described as losing 10-16% of its total nitrogen by ammonia volatilisation compared to poorly packed, aerobically stockpiled manure losing up to 30-51% (Dyson 1992; Grundey 1960, Hunter 1931; Lampkin 1990; Russell 1936; Vogtmann & Besson 1978), with great lament for the latter, and all the range in between for the normal hybrid mix of aerobic and anerobically fermented cattle FYM. However, losses on spreading of anaerobic decomposition are greater and almost balance the losses from the spread product of aerobic decomposition. The actual loss depending on weather conditions; but in the case of surface applications to grassland much of the nitrogen applied is lost to the atmosphere. To avoid nutrient enrichment this may be desirable but from an agricultural, economic or pollution-prevention viewpoint it is wasteful.

6.2.4 ADAS data (in Powlson *et al* 1994) does indicate some transformation of ammonium nitrogen in fresh FYM into organic nitrogen in older FYM, thereby conferring a degree of protection. This protection appears to preserve 0.9 kg total nitrogen T^{-1}. However, given the loss of dry matter in storage and the potential for rain or excess liquid to cause leaching losses of nitrogen there is often associated nutrient loss. Such losses may result in a loss of 10-50% of nitrogen with a mean of perhaps 20%, phosphate 7% and potash 35% (see Lampkin 1990; Smith & Unwin 1983). This loss may be disguised by dry matter losses which cause apparent concentration of nutrients per unit weight, when compared before and after storage, see Appendix 5. Nitrogen may be made more soluble or more rapidly available to plants by composting; due to bacterial action on the nitrogenous compounds in dung and litter, by conversion of ammonium to nitrate and by altering the carbon to nitrogen ratio and thus making the manure 'rotten'. Fresh cattle manure in the literature may have a C:N ratio of 18-26.4, and after composting 11.7-15 (Atallah *et al* 1995; Castellanos & Pratt 1981; Chèneby *et al* 1994; Hébert, Karam & Parent 1991). **However, the previously unpublished ADAS database for ADAS analyses gives a range of 9-61, with a mean of 22 (see Appendix 2). This ADAS database may not be representative of the C:N ratio of FYM *in situ*, due to nitrogen losses during sample collection, transport**

and before analysis; given that a standard procedure for to minimise the effect of these variables does not exist compared to a standard laboratory procedure. For information fresh straw has a C:N ratio >200:1 (Smith pers. comm.). Powlson *et al*, 1994, quote ADAS, suggesting 13.7 as a typical C:N ratio for cattle FYM. Kirchmann (1985) suggested a C:N ratio of 15:1 may be critical, with N immobilisation occurring above and mineralisation below this level. This has been corroborated by Castellanos & Pratt (1981) and Beauchamp (1986). Table 10 is from Vogtmann & Besson (1978).

Table 10. Average nitrogen loss of outdoor compost piles of FYM during four months

	Average N content % of DM *1		Average N loss %	
Material	Total-N	NH3-N	Total-N	NH3-N
NOT TURNED				
Fresh FYM	2.09	2000	28	95
FYM,Compost	1.51	100		
TURNED - FOUR TIMES				
Fresh FYM	2.10	2024	31	94
FYM,Compost	1.45	120		

*1 Recalculated for total amount of dry matter (DM) and nitrogen (N) in the fresh material at the beginning

6.2.5 In Rothamsted experiments, (quoted in Garner 1957), moving freshly-made dung to a covered heap led to 30% loss of weight in three months and almost 60% loss in 11 months. He concludes, when these heaps are formed they should be placed on firm, level ground and made as deep and firm as possible. During storage manure changes according to the conditions under which it is kept and the period of storage. For fuller descriptions of the changes that occur during composting or rotting and alternative methods of composting see Atallah *et al* (1995), Hunter (1931), Lampkin (1990) and Vogtmann & Besson, (1978).

6.3 Changes in FYM nutrient content over historical time

Some may also believe that the nutrient content is likely to have changed over (say) the last 50 years; however, the evidence for any such trends in the UK is not available. It is a matter for conjecture what nutritional changes have occurred for the animals supplying manure to a given site, their comparative efficiency of feed utilisation, ie whether their diet is appropriate to the production required or if the type of animal fed is the same as previously.

6.4 Economic value of nutrients in cattle FYM (December 1995 prices)

6.4.1 If one takes the available nitrogen figure given by RB 209 (Anon 1994) as between 0.3-1.2 kg T^{-1} fresh weight of FYM, depending on time of application, and the total value of phosphate and potash, assuming all of this will be released over time:

Table 11. Economic value of nutrients in cattle FYM (December 1995 prices)

	Nutrient content	Nutrient value pence kg^{-1}	Nutrient value per tonne (pence)
N	0.3-1.2	36	11-43
P_2O_5	3.5	29	102
K_2O	8	20.3	162
TOTAL			275-307

6.4.2 Thus a 20t ha^{-1} application of FYM is equivalent to nutrients worth £55 ha^{-1} at current prices with an average value of £2.75 $tonne^{-1}$ fresh weight of FYM. Spreading of FYM by contractor might be estimated to cost up to £20 per hour, so @ 8 Tonnes per hour for a one man operation, this means a cost of £2.50 per tonne. If a large volume of manure needed spreading one might employ a separate loader @ up to £18 per hour, with several spreaders, and achieve work-rates of 50-100 tonnes $hour^{-1}$.

6.4.3 Given the relatively low value of nutrients applied relative to the application cost one can see why many farmers regard manure handling as waste disposal, rather than handling a valuable fertiliser. However, it must be remembered that farmers are required to manage manure produced and incur costs in doing so. Attempting to maximise the utilisation of manure adds little to the cost compared to waste disposal. Also because farmers must comply with relevant legislation whenever they store or handle or spread manure, it is recommended by the authors that they should maximise utilisation efficiency to help justify the costs of storage, handling or spreading.

6.5 Offtakes of nutrients in hay

6.5.1 The nutrients supplied in FYM, if applied, not only increase hay yields, depending on the rainfall and factors listed above; but can also increase the stock carrying capacity of aftermath grazing by 0-33 % (Lawes & Gilbert 1858).

6.5.2 When one reads the papers of Lawes and Gilbert one admires their vision and intelligence. They wrote in 1859 (Part I) "we come to consider the debtor and creditor account of certain constituents...the relation of the amounts removed in the produce to the amounts taken off in the increase of the first crop only, as most nearly representing the gain due to the supply in the manure employed." Today agriculturalists use nutrient balance sheets based on this principle, and it is the hope of the authors that this report will introduce the concept to ecologists and nature reserve managers, to enable them to communicate on the same level with farmers as well as to understand appropriate doses.

6.5.3 In another paper Lawes and Gilbert (1880) wrote " In the case of the hay crop the return of the constituents is by no means so regular," (as arable crops) "and the figures show how variable may be the amount of them in a given weight of crop according to the supply of them in the soil or by manure. Thus, whilst there is more nitrogen in a given weight of the hay grown without the manure than with the farmyard manure, there is one-and-a-half time as much phosphoric acid, and more than one-and-threequarters time as much potass (*sic*), in the hay grown by farmyard manure than in that without manure."

6.5.4 For a particular site an analysis of the hay, in each season after FYM application, will be a means of estimating the average off-take of nutrients, and the more seasons sampled, the less individual season rainfall and other variables will influence the calculation. Thus the following figures provided in Table 12 are only a guide.

Table 12. Total nutrients supplied by cattle FYM applied in February in kg ha^{-1} year^{-1}

	Estimated N*	P_2O_5	K_2O	S
20 t/ha/3 years	4.6 - 24 +*	23.3	53.3	46.6
20 t/ha/4 years	4.3 - 24 +*	17.5	40	35
20 t/ha/5 years	4.1 - 24 +*	14.0	32	28
12.5t/ha/year	15.0 + *	(26.25) - 43.75	(60) - 100	87.5

*Residual nitrogen will be available from previous FYM applications, depending on rainfall, temperature, and other variables; this is estimated by the authors as 4% of the applied dose in the year after the first hay crop, declining by 0.2% per year, after reading Van Dijk, Postmus & Prins (1990), which is not unreasonable (Smith, pers. comm., 1995).

(Figures in brackets above are the nutrients available in the first year; but given the annual repetition of FYM applications on to hay meadows, this lower figure in brackets is not normally appropriate.)

6.5.5 The above may be compared to ADAS recommendations for a 5t ha^{-1} hay crop and **average** phosphate and potash offtakes (ADAS 1985); excluding any nitrogen or potash for aftermath grazing:

Table 13. ADAS recommendations for a 5t ha^{-1} hay crop

	N	P_2O_5	K_2O	S
with low soil nitrogen supply	90	29.5	90	12.5
with moderate soil nitrogen supply	70	29.5	90	12.5
with high soil nitrogen supply	60	29.5	90	12.5

NB The above does not take account of soil phosphate and potash supply; which can be determined by soil analysis; therefore actual ADAS recommendations are normally adjusted accordingly.

However, it is also important to realise that MAFF P and K recommendations, as in RB209 (MAFF 1994a), are not as the same as ADAS recommendations and consequently differ from those produced by the reasoning used in this report. MAFF recommendations have been based on many trials in agricultural situations where yield responses to individual nutrients indicate appropriate fertiliser dressings; whilst this report, and ADAS generally, aims to maintain a nutrient balance where appropriate, and also take into account potash release from potash-releasing clays (see ADAS 1990), target yield and soil analyses. Each method has different aims, and consequently produce different recommendations.

7. The effects of farmyard manure on grassland productivity

7.1 Nutrient Effects of FYM (mainly nitrogen, phosphate and potash)

7.1.1 One of the reasons why farmers apply FYM to hay meadows is to avoid nutrient depletion by crop removal which reduces potential hay yields. Obviously FYM has the potential to increase grassland productivity, providing adequate rainfall occurs and smothering effects or other negative influences are avoided or are not overwhelming.

7.1.2 Potential is transformed into reality by resources, opportunity, chance, and constraints. Constraints may be include the nature of the manure or other factors. In particular FYM is not necessarily the ideal input from an agricultural standpoint, to replace the nutrients required or removed by a hay crop. However, given the relatively slow nutrient-release characteristics of manure, and the way it feeds the soil, and not the plant directly, it can be appropriate in certain circumstances. Moreover, the transformation and losses of nutrients during storage and application to grassland by surface application, can also affect the fertiliser value of FYM, usually reducing its value in agricultural terms but possibly enhancing it in conservation terms.

7.1.3 Grassland productivity in terms of hay yield can be measured in terms of the weight put into store. So grassland productivity is by convention taken as either dry matter yield, or fresh weight yield. Fresh weight is subject to variation in moisture content but does not need analysis to give an estimate of production. These parameters are relatively immediately capable of measurement; with animal production and economic return are measured separately and whilst related to grassland productivity are not directly linked due to losses in store, in utilisation and in potential.

7.1.4 On cutting a grass sward, losses of dry matter occur during hay-making; both due to the respiration of cut grass, leaching losses and due to leaf shatter and the inability of farmers to bale all the cut material. Then during storage and subsequent feeding further losses occur; depending on the farmers' management. In addition, other lost potential accrues due to timeliness of operations.

7.1.5 For example, Fleury, Jeannin & Dorioz 1987 wrote "Yield increases resulting from high dressings of organic manures have as a corollary a decrease in flexibility of cutting opportunities and in particular earlier mowing in order to obtain herbage with the same nutritional value: the 65% OMD (= organic matter digestibility) limit is reached 15 days earlier on heavily fertilised meadows than on poor meadows". This implies that, if this date is missed, animal production may be lower either side of the optimum date of cutting given that the purpose of conserving forage as hay is to feed animals, although grass yield may go on rising with later cutting.

7.1.6 Efficient utilisation of grass if cut at the time of optimum dry matter yield with optimum digestibility gives the highest animal production potential and therefore highest economic return. It is worth remembering that a

higher grass dry matter yield with lower digestibility **can be inferior** to a farmer in economic terms and also inferior to a farm animal if its overall diet is not appropriate. So farmers should not only compare yield but performance. Different grass species and varieties vary both in their amount of yield but also in the time at which they reach peak dry matter yield and their D values both at this time and at other dates. Consequently a semi-natural sward will reach its optimum date of cutting at a different (usually later) date compared to an improved rye-grass sward even in the same area in the same year. Nutrient additions will also influence both total yield and date of flowering and therefore, D values.

7.1.7 Thomas, Holmes & Clapperton (1955 a & b) found effects not just on digestibility; but the percentage composition of a whole range of nutrients were altered by changing date of cutting. This has a big influence on nutrient removal by herbage; but not directly on animal production. Whilst any nutrient in an animals diet can be limiting the most usual limits on animal production are energy or protein in the diet, the animals' environment or the management of the animal to overcome other adverse influences such as stress, disease or pest attack.

7.1.8 Nutrient removal in herbage not only has an immediate effect on the available nutrients for aftermath growth but also over a period of years an overall effect on the nutrients available for earlier growth before cutting. Hence the need to supply nutrients to avoid nutrient depletion is acknowledged but the actual nutrients required will vary according to yield, botanical composition and date of cutting which all interact.

7.1.9 Average phosphate and potash offtakes in hay (not specifically taken from the semi-natural swards) are quoted in section 6.5 of this report, and can give estimated offtakes when multiplied by hay yield. Other nutrients have been found by analysis of sun-cured hay samples; but these were not from semi-natural meadows, so are only given here for comparison in the future with hay from such meadows. Please note that not all the analyses were taken from an equal number of samples and that the maximum and minimum figures are ranges and not to be compared across the table (Table 14):

Table 14. Averages and ranges of nutrient contents of sun-cured hay (Givens *et al*, 1990) including trace elements

g		g kg^{-1} dry matter						mg kg^{-1} dry matter			
	DM	CP	Ca	Mg	Na	K	P total	Mn	Zn	Cu	No of samples
Mean	864	98.5	5.0	1.5	1.9	20.1	2.5	56.1	20.8	5.8	6 - 77
Min	791	52	1.9	0.7	0.1	11	1.1	31	15	5	
Max.	914	199	25	4.8	9.2	32	7.8	94	25	7	

Conversion Factors which may be useful when calculating equivalent fertiliser or farmyard manure dressings:

To convert CP (Crude Protein) to nitrogen divide by 6.25
To convert P to P_2O_5 multiply by 2.29
To convert K to K_2O multiply by 1.205

Other conversion factors (Anon, 1967):

To convert Na to NaCl multiply by 2.542
To convert Mn to $MnSO_4$ multiply by 2.749

7.1.10 Many of the hays which gave the above were split into different groups according to their digestibility of organic matter in a previous publication (Givens, 1986) which given the fall in digestibility, as measured by digestibility of organic matter (DOMD), with age of grass enables some broad conclusions to be drawn on changes in nutrient content of hay with time of cutting (Table 15 (DOMD if low indicates low digestibility)

Table 15. Comparison of various sun-cured hays giving the following averages and ranges of nutrient contents including digestibility of organic matter (DOMD), metabolisable energy (ME) (Givens, 1986) to illustrate change over time during the grass growing season

		g	$g\ kg^{-1}$ dry matter						
DOMD $g\ kg^{-1}$	ME MJ kg^{-1} DM	DM	CP	Ca	Mg	Na	K	P total	No of samples
602 = Overall Mean	9.2	858	122	5.5	1.5	2.5	-	2.8	68
<450 Old grass (Mean 416)	6.1	870	90	3.7	1.6	3.8	-	2.0	2
>700 Young grass (Mean 724)	11.5	863	140	5.0	1.3	2.3	-	3.1	5

7.1.11 Spedding & Diekmahns (1972) report that the main factors affecting P and K content of herbage are stage of maturity and supply of P from the soil. P contents decline with advancing maturity, as can be seen from Table 15 above, and they report K content also declines with age, although rain can also leach K from young cut herbage and fertiliser can maintain K levels. Other factors affecting P content are water supply and application of N and K fertilisers and lime, ie at the extreme of pH phosphate is less available; whilst N tends to increase K content when K supplies are plentiful and decrease it when K supplies are limited. Other inter-relationships between nutrients also exist and may result from FYM applications.

7.1.12 From gaps in the literature research the authors can suggest that **a very useful and cost-effective area of future research** could be to take hay samples from semi-natural meadows to be routinely analysed for nutrient content and the results collated for each site in a database with relevant management details and hay cutting date. The results of recent analysis of hay from Snaper Farm Meadows SSSI, an MG5 semi-natural meadow receiving FYM (see Table 22), are provided in Table 16. This suggests that hay from semi-natural sites where FYM is applied, albeit in this case at slightly higher rates than recommended by Jefferson (1994) in Crofts & Jefferson 1994, can provide satisfactory hay for livestock with a good energy level. Changes in yield, dry matter, D value, mineral and protein levels over time in various seasons might also be useful with a view to looking at optimum cutting dates from an agricultural viewpoint with a view to examining the scope for marrying conservation and agricultural objectives for meadows.

Table 16. Analysis of hay from Snaper Farm Meadows, North Yorkshire

Metabolisable Energy (ME) MJ kg^{-1} DM	9.3
Digestibility (D)	61
Digestable Crude Protein g/kg^{-1} DM	48
Dry matter content (%)	83.7
Total Crude Protein (%)	9.4

Analysis by ADAS Wolverhampton.
Source: Dave Clayden, English Nature

7.1.13 The literature search revealed little information on the nutrient content and changes in nutrient content with time of cutting of individual plant species which are relevant to semi-natural grasslands; although Spedding & Diekmahns (1972) mentioned earlier has relevant information on grasses and legumes. **Nutrient contents of plant species could prove an area for further research but this would depend on the usefulness of such information, and its cost-effectiveness and priority compared to data on the nutrient content of hay from different sites or other potential research areas.** Lack of priority may explain the paucity of existing data, or it may be a matter of looking in the right place to find it. However, if understanding of what causes the variation of nutrient content of hay from particular sites, then details on the nutrient content of individual plant species and changes over time would enable interpretation. Where possible, students and researchers could be asked to make relevant measurements and forward relevant records to English Nature, if in the course of studying semi-natural hay meadow sites, they are willing and able to do so.

7.2 Liming

Rodwell (1992) indicated that liming was a traditional treatment associated with meadows. Lime would have been applied to offset losses of calcium by leaching and cropping of herbage as increased acidity can limit grass growth. Liming would have been especially prevalent on grassland overlying base-poor soils and in areas with high rainfall. Use of FYM and lime were likely to have proceeded in tandem as increases in vegetation biomass and offtake as a result of FYM use would cause enhanced depletion of base cations from the soil. Although it should be noted that FYM is in itself alkaline (eg cattle FYM has a mean pH = 8.6; range 7.7-9.48) see pH's given in Appendix II and Atallah et al 1995. This buffers the effect of cation removal in increased biomass resulting from FYM application. However, additional lime may also be needed in certain situations to maintain diversity or to avoid altering pH and consequently the proportion of plant species. Liming practice may have been a key influence on the current vegetation composition of semi-natural meadows. Its continuation may be appropriate in many circumstances (see Crofts & Jefferson 1994). A soil pH test or grid sampling is recommended on all semi-natural hay meadows every four years to indicate if lime may be needed.

7.3 Physical/smothering effects of FYM

7.3.1 Obviously this is related to the application rate, the consistency of the manure and the timing of applications relative to rain or other weather influences. The more manure applied or due to uneven spreading the greater the physical/smothering effects. If the manure is well rotted and shredded by the manure spreader during application, at a relatively low dose rate, applied in winter when conditions are relatively cool and wet to a sward which is short and possibly thin due to aftermath and winter grazing then little smothering or physical scorch of herbage occurs. FYM is said to improve the water-holding capacity of soils, particularly sands, (eg Hunter 1931) so having a physical effect on the soil due to its humus content, which may affect the survival of some plants in a drought. FYM may improve the efficiency of water use by plants and to decrease water loss by evaporation and run-off on slopes (Rabotnov 1977). FYM may also have other effects due to the organic content affecting the cation exchange capacity of the soil (see Marschner 1990).

7.4 Introduction of plant species from seed by FYM

7.4.1 It has long been known that manure can introduce plant seeds. Korsmo (1938) indicated 6 tonnes of manure contain approximately 50,000 seeds. Dastgheib (1989) found that spreading sheep manure could contribute as many as 10 million seeds per hectare. However, it has also been thought (eg Candolle 1855) that seeds which passed through the digestive tract lost their germinative power. This is only partially true, depending on the species and the length of time in the digestive tract (Müller-Schneider 1986, Simao Neto & Jones 1987 and Blackshaw & Rode 1991). Weeds and their seeds may derive from the litter used for animal bedding or the food either missed or passed through after eating by the animals, or may arrive as other waste added by a farmer or as opportunistic colonisers of an undisturbed muck heap, and then be spread with the manure. Gill & Vear, 1968 wrote (p372)" the extent to which FYM may be a source of weed seeds depends largely on the method of making. Fresh dung may contain large numbers of viable weed seeds; germination of these is, however, very much reduced by storage for two months, providing that the manure is managed in such a way that fermentation takes place and temperatures of 150° F (65.5° C) are reached in the heap. Field bindweed *Convolvulus arvense* is an example of a very resistant species. Storage in loose, dry manure has little effect in reducing the viability of weed seeds, an d old, neglected manure heaps may, in fact, be a further source of more weed seeds if they are allowed to become overgrown with such weeds as fat hen *Chenopodium album*."

7.4.2 Sarapatka, Holub & Lhotska (1993) studied the effect of anaerobic treatment of FYM on weed seed viability, stating this was one method for eliminating weed seed germination, with a simultaneous production of biogas, the so-called 'Olomouc method'. They found different species had differing abilities to germinate after treatment for different periods of time. They found that of the 11 species studied using **non-dormant** seeds that cockspur *Echinochloa crus-galli*, fat-hen *Chenopodium album*, broad-leaved dock *Rumex obtusifolius* and common amaranth or pigweed *Amaranthus retroflexus* had the ability to survive one month of anaerobic fermentation at 400 mm depth in the manure but did not survive a similar period at 1800 mm. These weeds are commonly associated with spreading of FYM. Jeyananyagam & Collins, 1984 studying Johnson-grass *Sorghum halepense* and fall panicum *Panicum dichotomoflora* seeds found anaerobic fermentation was more effective in destroying non-dormant seeds than dormant seeds. They also found greater seed destruction by 20 days compared to 15 days of anaerobic digestion.

7.4.3 In the literature, deliberate addition of weeds was even suggested by one author in the past (Wrightson *c*1875) as a means of soaking up excess liquor from manure! Some authors have suggested 25% of weed seeds in manure could emanate from straw used as litter (Duchon 1948) and whilst any amount of weeds could derive from this source depending on the hay or straw source, Arkle Beck meadow in North Yorks (an SSSI) seems to have had such an experience in 1990-1 (see Section 9.3) bringing in chickweed *Stellaria media*, soft brome *Bromus mollis* and docks *Rumex* spp. from bought-in fodder which may have been fed in-field.

7.4.4 Obviously weed seeds can also emanate from other sources - on vehicles, by feeding weedy forage, by cleaning out ditches, and by other means; but we do not wish to add undesirable species to semi-natural grassland or increase their quantity, so care is needed to avoid FYM adding to the weed burden of a soil or disastrously changing the vegetation. Once introduced in to a site seeds can remain dormant for considerable periods (Brenchley 1918), so such seeds may cause change long after introduction when conditions for germination are favourable, providing these seeds are not easily found by predators such as rodents (Hulme 1994) or ants (Reader 1993) or birds. This potential problem could be minimised by ensuring that the niches favoured by weed species (bare ground) are not created by inappropriate management practices. Litter quantity will also have a major effect on species richness and abundance (Carson & Peterson 1990).

7.4.5 It is unlikely that FYM would act in a deliberately positive way by introduction of new seeds. Some incidental and accidental introductions may occur. If manure derives from the hay of a particular site, then a closed system, which returns the nutrients from whence they came, may also return some weed seeds to the same source; but almost certainly not in the same proportion as they were removed. If vegetation change in a site is noted it would be worthwhile distinguishing the cause.

7.4.6 Apart from introduction of weed seeds, FYM could cause 'successional sequences', ie botanical change by:

- ❑ inducing greater competition proportional to the nutrient-use efficiencies of different plants (Berendse & Elberse 1990);
- ❑ smothering or suppression of desirable plants;
- ❑ by sward damage during handling operations providing gaps for weed ingress (for example wheel rutting in wet conditions).

7.4.7 However, there are also many other causes of vegetation change including under- or over-grazing, hay cutting dates and heights, sward poaching in wet conditions, apart from influences beyond a manager's control, so a blanket ban on the use of FYM in semi-natural meadows due to the risk of weed introduction is not generally appropriate. However, a specific ban on the use of poorly rotted or inadequately composted manures (eg a ban on those with a C:N ratio greater than, say, 18 if one was confident that the sample was representative and no change occurred in the time from sampling to analysis), and from sources where undesirable weeds are known to exist is probably prudent. Careful choice, observation and recording of operations relating to FYM production and spread, should minimise harm from this source, provide positive benefits and provide accurate information for future decisions. This is recommended because we do not know what is 'normal' practice or how often poorly rotted manure has been used in the past. In the absence of an analysis of C:N ratio one might suggest that muck should be stored 12 months prior to spreading (see Malgeryd 1994).