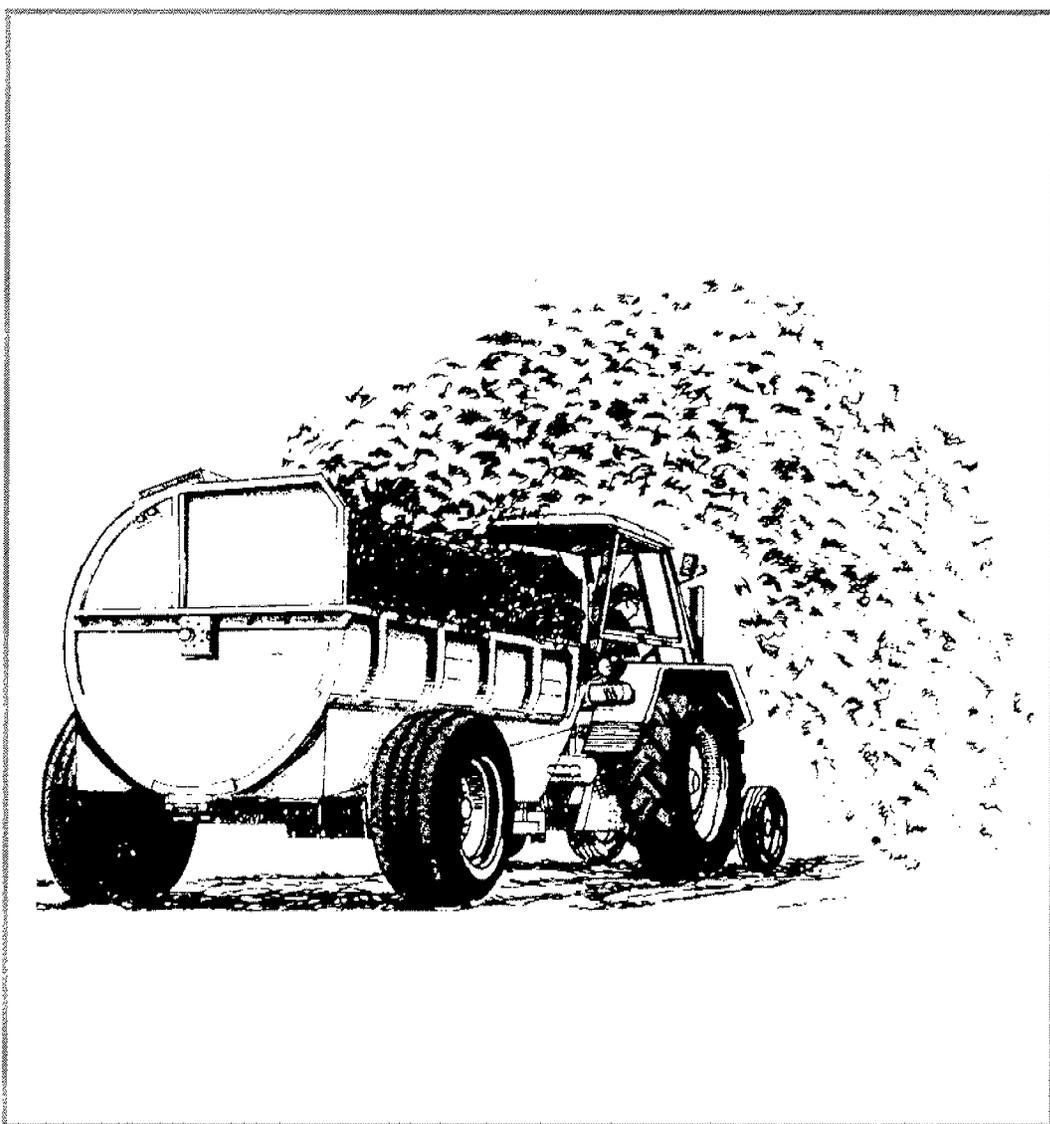


Use of farmyard manure on semi-natural (meadow) grassland

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**Use of farmyard manure on
semi-natural (meadow) grassland**

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Contents

Acknowledgements	i
1. Executive summary	1
2. Terms of reference	3
3. Introduction	5
4. Literature search	13
4.1 Outline of Methodology	13
5. The use of farmyard manure on grassland	14
5.1 Summary of findings from the literature review	14
5.2 History of the use of FYM	14
5.3 Timing of FYM application	15
5.4 Application rates	17
5.5 Periodicity of application of FYM	18
5.6 Methods of application of FYM	20
5.7 Organisation	22
5.8 Impact of FYM on floristic composition	23
6. Farmyard manure in relation to nutrient content	28
6.1 Nutrient Content of FYM	28
6.2 Changes in storage	30
6.3 Changes in FYM nutrient content over historical time ..	32
6.4 Economic value of nutrients in cattle FYM (December 1995 prices)	32
6.5 Offtakes of nutrients in hay	33
7. The effects of farmyard manure on grassland productivity	35
7.1 Nutrient Effects of FYM (mainly nitrogen, phosphate and potash)	35
7.2 Liming	38
7.3 Physical/smothering effects of FYM	39
7.4 Introduction of plant species from seed by FYM	39

8.	Effects of farmyard manure on nature conservation interests	42
8.1	Nutrient effects and communities	42
8.2	The overall effects of FYM	45
9.	Current Practice on Certain Unimproved Hay Meadow SSSIs as found by a Survey of English Nature Local Teams	48
9.1	An outline of the methodology employed in the questionnaire survey	48
9.2	Survey of EN Local Teams	49
9.3	Results of Survey	49
9.4	Summary of comments from Tim Barfield	49
9.5	Notes regarding Arkle Beck Meadows from ADAS reports for English Nature	55
9.6	Current rates of FYM applied to unimproved meadow SSSI's where such information exists	56
9.7	Timing and periodicity of FYM applications	56
9.8	Storage of FYM	57
10.	Farmyard manure usage in relation to pollution management and farm economics	58
10.1	Avoiding pollution	58
10.2	Economics	61
11.	Suggested areas of further research	65
12.	Conclusions	68
13.	Bibliography	69

Appendices

1.	Glossary	85
2.	Typical analysis of farmyard manures - ADAS Database information	88
3.	Details and May 1995 prices of ADAS analytical services (for information)	90
4.	Hay yields from Cockle Park and Rothamsted	92
5.	Total nutrients supplied by cattle manure	93
6.	Survey of hay meadows questionnaire	94

List of Tables

	Page	
Table 1.	A guide to loading performance (tonnes hour ⁻¹)	20
Table 2.	Number of species in botanical analysis of unmanured and unlimed Park Grass Plot 3	23
Table 3.	Percentage of species by weight in hay in the botanical analysis of unmanured and unlimed Park Grass Plot 3	23
Table 4.	Number of species in botanical analysis of unlimed Park Grass Plot 2	24
Table 5.	Percentage of species by weight in hay in the botanical analysis of unlimed Park Grass Plot 2	24
Table 6.	Number of species in botanical analysis of unlimed Park Grass Plot 19	24
Table 7.	Percentage of species by weight in hay in the botanical analysis of unlimed Park Grass Plot 19	24
Table 8.	Typical nutrient content of animal manures	29
Table 9.	Percentage of total nitrogen available to the next crop following application of animal manures (% of total nitrogen)	30
Table 10.	Average nitrogen loss of outdoor compost piles of FYM during 4 months	32
Table 11.	Economic value of nutrients in cattle FYM (Dec 1994 price)	33
Table 12.	Total nutrients supplied by cattle FYM applied in February in kg ha ⁻¹ year ⁻¹	34
Table 13.	ADAS recommendations for a 5t ha ⁻¹ hay crop.	34
Table 14.	Averages and ranges of nutrient contents of sun-cured hay including trace elements	36
Table 15.	Comparison of various sun-cured hays made from old, average and young grasses - giving average DOMD, ME and nutrient contents	37
Table 16.	Analysis of hay from Snaper Farm Meadows, North Yorkshire	38
Table 17.	Respondents to a questionnaire survey of EN Local Teams regarding management of semi-natural grassland undertaken in 1994.	49
Table 18.	Results of Survey: Arkle Beck, Sutton Lane, Whitevine, Goldborough, Barrowburn, Barrow and Lee Farm	50
Table 19.	Results of Survey: Bradwell Meadows, Snaper Farm, Mottey Meadows, and Greenhaugh (The Bog)	53
Table 20.	Hay Yields at Arkle Beck	55
Table 21.	Adjusted hay yield at 85% DM from Field 1 at Arkle Beck from 1987 to 1992.	55
Table 22.	Rates of application of FYM found by the Survey	56
Table 23.	Timing and Periodicity of FYM applications: 1994 survey data	56
Table 24.	Storage of FYM: 1994 Survey Data	57

List of Figures

Figure 1	A simplified diagram of the soil N cycle	9
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1. Executive summary

Today traditional semi-natural hay meadows are recognised as a very rare habitat. Appropriate management and good communication is required to preserve, maintain and possibly improve such a scarce ecological resource for future human enjoyment and the survival of many plant and animal species, with their dependants. This study aims to assist those who manage hay meadows of a high nature conservation value. It has been written to convey the information which exists, beyond the experience of individual grassland managers, such that they may better judge what is appropriate management in their own situation and they may communicate it to others involved in the use of farmyard manure in the management of semi-natural hay meadows.

This report concludes:

- FYM is applied to grassland to avoid nutrient depletion by crop removal which reduces potential hay yields.
- Conclusions about the effects of FYM on the species composition of semi-natural meadows are largely subjective and not verified. However, in general terms, as rates and frequency of application of FYM increase beyond a certain point (which varies according to background fertility), there is a decrease in the richness and abundance of dicotyledonous herbs and an increase in competitive grasses resulting in an overall reduction in species richness and diversity. This is consistent with research on the effects of inorganic fertilisers on species-rich grasslands.
- Annual high rates (> 30 t/ha) of FYM cause scorching and bare patches to reseeded grassland. These rates applied annually or even less frequently to semi-natural grassland would be very damaging, reducing species richness and diversity.
- There is little data in the agricultural or ecological literature which can help to provide a refinement of existing guidance on application of FYM to semi-natural meadows. **This report suggests that accurate measurement of FYM input and hay yields linked to analyses of well-rotted FYM, hay and soil nutrient content coupled with botanical monitoring may enable refinement of current guidance (Jefferson 1994 in Crofts & Jefferson eds.). This report does, however, indicate that current guidance is likely to represent good practice. Thus, if in doubt these guidelines should be followed.** It should be remembered that these rates supply nutrients at much lower quantities than the current MAFF/ADAS agricultural recommendations.
- If the current guidelines of 20 t/ha every 3-5 years provided in Jefferson 1994 represent good practice then it is likely that high rates (including those specified in some management prescriptions for semi-natural meadows in land management schemes) are too high for the long-term maintenance of species-rich meadows of high nature conservation value.
- FYM is a variable commodity with nutrient content dependent on many factors including handling, storage and weather conditions. Use of poorly rotted or inadequately composted manure on semi-natural meadows should be avoided. Where testing is practicable, FYM should not be applied until the C:N ratio is less than 18:1. In the absence of analyses, storage for a minimum of 12 months prior to spreading, is suggested.

- Records of FYM inputs and associated information in relation to semi-natural meadows are poor and should be improved.
- Current practice obtained from a small sample indicates, surprisingly, considerable variation in FYM application rates and periodicity of applications.
- Once an undesirable situation arises (eg due to nutrient enrichment) it may take many years to rectify, and recovery may not be possible when local extinction occurs. Thus, it is hoped that the warnings sounded in this report will be heeded, lessons learnt and appropriate action follows.
- There is no evidence for changes in the nutrient content of FYM over historical time (eg the last 50 years), but there is a suspicion that this may have occurred.
- Heavier (clay) soils lose nutrients less readily than light soils and as far as maintenance of hay yields are concerned, may require less frequent applications of FYM but these dressings may be heavier on light soils. Research work is needed to confirm this suggestion.
- If estimates of the nutrient content of FYM are required and analysis is not practicable, the values provided by MAFF 1994a (text Tables 8 & 9 and Appendix 3) should be used.
- The following areas of research would yield valuable information:
 - experimental trials investigating the impact of different rates of FYM compared to untreated controls on semi-natural swards preferably on representative sites, a variety of soils and differing rainfall regimes, under appropriate management regimes with consistent protocols. Ideally at least two cycles of FYM application should be allowed for (ie duration of experiment would need to be 6-10 years).
 - analysis of hay samples from semi-natural meadows for nutrient content and measures such as dry matter content, value and protein, together with changes in these measures over the season;
 - nutrient cycling (N & P) including grassland nitrification rates and factors which control it.
- Better, standardised recording and monitoring of FYM inputs, crop yields, management and botanical composition is required by those responsible for managing semi-natural meadows to assist researchers and future farmers/site managers, and ultimately those who make policy decisions. Such recording should allow appropriate analysis and be undertaken urgently.
- Updated management guidelines (beyond those of the Lowland Grassland Management Handbook) would follow from the above research and analysis of records.
- Changes to agricultural support that favour traditional cattle housing with straw bedding should be encouraged. This would help to ensure a ready supply of FYM in areas with concentrations of hay meadows and help to maintain traditional management which has conserved species-rich hay meadows, to date.

2. Terms of reference

2.1 The objectives of this study are to:

- a. Conduct a comprehensive search of the agricultural and ecological literature for information relating to the use and impact of farmyard manure (FYM) on the floristic composition of neutral grassland hay meadows, both unimproved and improved. The main NVC grassland types managed for hay are MG3-8 inclusive but occasionally MG11, 13 and M22, 23 and 24 when managed as meadow (Rodwell 1991 & 1992).
- b. Establish current practice on unimproved hay meadow SSSI's where FYM is used via a questionnaire to English Nature's Local Teams.
- c. Produce a brief summary review report which will be used to guide best practice and to highlight areas where further research is necessary.

2.2 The report makes the following assumptions which were determined by the authors:

- Since the advent of settled agriculture, the majority of hay meadows, (with the possible exception of alluvial flood meadows), have had a history of use of farmyard manure (FYM) and lime to maintain their productivity for producing winter keep.
- English Nature would ideally wish to see hay meadows of a high nature conservation value remain within the context of the farmed landscape. This requires meadows to be managed with a view to producing viable hay crops, which in the medium term (or foreseeable future) means the application of FYM.
- Traditional hay meadows will continue to be cut for hay, normally after the beginning of July, and if possible later on occasions, covered by management agreements where necessary, with specific management guidelines tailored to the site interest.
- Where FYM is applied to a meadow it is only applied as a precursor to the taking of a hay crop, at the next opportunity, and should be applied at an appropriate time with minimal damage to the site.
- Slurry, from whatever source, and pig and poultry manure are unsuitable for use on grasslands of high nature conservation value. However, it is accepted that more experimental information on the impact of slurry on species-rich grasslands would be desirable. Evidence for the damaging impact on such grasslands is anecdotal but a precautionary approach is justifiable. Brian Chambers and Ken Smith (pers. comm.) would contend that nutrients are nutrient wherever they arise from and would argue that the greater homogeneity of slurries compared to FYM with the minimal trash in most slurries one could argue that slurry is potentially a more conservation-friendly material as in future it will probably be easier to control uniformity and application rate using machinery currently under development. The authors suggest that the perceived difference in impact on the species composition of semi-natural swards between FYM and slurry may be due to the former releasing nutrients more slowly than the

latter by organic matter mineralisation (see also Smith 1994). However, this must be proved by research before appropriate doses of slurry can be sanctioned.

- ❑ Aftermath grazing is likely to be important in maintaining the species-richness of unimproved semi-natural meadows.
- ❑ Over-grazing and other undesirable practices are avoided, for example those described in Chapter 6 of the *Lowland Grassland Management Handbook* (Crofts & Jefferson 1994).
- ❑ Rates and periodicity of application of FYM, in the past have been variable due to factors such as soil type, distance from the farm holding, availability, accessibility, attitude of the farmer, etc.
- ❑ If a site is still mown and aftermath grazed, cessation of the use of FYM will ultimately lead to small standing crops. As fertility reduces through time, it is likely that species abundance will change with dicotyledonous herbs perhaps being favoured at the expense of some of the usually more competitive Gramineous species. The nature of any longer term changes in species composition and abundance which take place following cessation of FYM use will depend on factors such as geology, soil type, climate and management including whether lime application continues or not. The nature of nearby species source pools will determine whether any new stress-tolerant species (as described by Grime 1974, 1977 and Grime, Hodgson & Hunt 1988) will colonise given the altered environmental conditions. The above assumes change is directional; but in reality it can be random, or fluctuate according to seasonal influences.

3. Introduction

- 3.1 Semi-natural grassland has not usually been sown but rather usually reclaimed from woodland or wetland sometimes via a period of arable cropping and then managed over many centuries to create grassland for feeding farm livestock. Traditional management has often divided grassland into two main types - meadow and pasture (Rackham, 1986). Until traction engines and tractors replaced horses and oxen every parish had grassland for its 'animal motive power' as well as for any sheep, cattle, geese or other grazing livestock. Livestock can graze for much of the year but hay is useful or indeed often essential, during the winter when grass growth is limited and there is the risk of damage to the sward from grazing wet pastures. The performance of working livestock can be improved by good feeding so the best hay was often fed to these but hay also enhanced the output of productive animals. In the days of town dairies, canal transport and before the car, lorry and electric milk float replaced the horse hay was also needed by townsfolk, travellers and tradesmen to feed their animals. So farmers in some areas also grew hay as a cash crop. Thus, hay meadows were a common feature of the English landscape. Archaeological evidence suggests that neutral grassland communities similar to those currently described were present in the landscape from at least the Bronze Age period. Evidence for hay making has been found in Roman deposits but this practice could conceivably pre-date this era (Greig 1988).
- 3.2 Just as farmers were keen to keep their animals alive and fed over the winter, so they came to realise the value of manures to fertilise their crops and grassland. Indeed they recognised that hay which removes nutrients is like any other crop, and to maintain its productivity these nutrients need to be replaced. So a traditional form of management evolved. It would also be fair to say that farmers varied their motives for using FYM - some regarded it as too precious for grassland preferring to apply it to arable land; others regarded it as a waste product and their fields varied in their convenience.
- 3.3 Until the 1960s, the typical management of many agriculturally unimproved lowland hay meadows was a summer hay cut followed by aftermath grazing, together with occasional dressings of well-rotted farmyard manure (FYM) and lime. FYM was applied to hay meadows; not necessarily consistently; but as the availability and farmers individual approach to their own resources allowed, or seemed best. This system was wholly consistent with the maintenance of botanical diversity in hay meadows unlike silage-making which relies on earlier cutting, is usually combined with inorganic fertiliser inputs, possibly with re-seeding.
- 3.4 Conservation organisations and others running countryside incentive schemes wish to continue this 'traditional' system in both statutory sites and the wider countryside to maintain the botanical richness of hay meadows valued for nature conservation. For example, "The retention of the flower-rich hay meadows, one of Britain's rarest and most fragile habitats, is a key objective of the ESA (Environmentally Sensitive Area) Scheme in many of the designated areas. Farmers are encouraged to manage their hay meadows using traditional practices"... "In this way, the variety of plants in the flower-rich hay is maintained" (MAFF 1994a).
- 3.5 "Whereas the ecologist studies the factors which, on the one hand, maintain a particular plant association in a defined habitat, and on the other, lead to

botanical change, the agriculturalist adopts measures which may entirely alter the herbage in a comparatively short space of time although no recourse may be had to methods of soil cultivation or the sowing of seeds. It has been found that controlled and periodic grazing or cutting and the application of lime and fertilisers will alter the proportions of the species which comprise the original swards by encouraging those grasses of most value in terms of grazing or as hay" (Milton & Davies 1947).

- 3.6 By continuing the traditional management of certain hay meadows we wish to conserve, the species present, whether plant, animal, fungal or microbial, because we believe that these species are adapted to an environment where cutting, grazing and FYM input has been provided. To minimise deleterious change, continuation of the traditional management system including FYM application at appropriate levels is desirable, within certain constraints and making a flexible response when undesirable change is noted. However, to be flexible involves knowledge, experience, and communication so the mistakes and lessons of the past are not repeated too often.
- 3.7 The first difficulty when prescribing use of FYM, as used 'traditionally' to compensate for the nutrient removal in hay, is the lack of data on appropriate rates of FYM application to semi-natural grassland and the time intervals of application. Current advice (Jefferson 1994 in Crofts & Jefferson (eds) 1994) suggests one dressing of up to 20 tonnes ha⁻¹ every three to five years on grasslands of high nature conservation value, which include agriculturally unimproved, semi-natural meadows; whilst the rules for farms managed under ESA Agreements state a maximum of 12.5 t ha⁻¹ per year (ie two to three times Jefferson's advice). The second difficulty relates to the nutrient content of FYM which varies according to:
1. the species of animal producing it;
 2. the age and condition of the animal (which is always changing);
 3. the food of the animal (which is widely variable);
 4. the accommodation of the animal;
 5. the amount and quality of the litter supplied (which in itself is widely variable);
 6. the management of the manure during its accumulation;
 7. its 'after-treatment' (ie storage period, timing and method of application).
- 3.8 This list (with the current authors comments in brackets) was written about 1875 (Wrightson, unknown date). Given the above factors, any overall trends are likely to be insignificant compared to the substantial impact of relevant changes relating to a specific site, the management of it and any associated livestock.
- 3.9 When commissioning this study it was said that "further information on these topics is vital if English Nature (EN) are to provide accurate best practice advice to land managers and advisors within Sites of Special Scientific Interest (SSSIs) and the wider countryside (for example meadows in ESAs or targeted by Countryside Stewardship).

- 3.10 Management objectives for neutral lowland (enclosed and under 300m) hay meadows are as follows (Jefferson 1994 in Crofts & Jefferson 1994):
- a. to maintain grassland communities valued for nature conservation with their component species of flora and fauna;
 - b. to continue, where practicable, the traditional hay cutting (and grazing) management within a farming system;
 - c. to prevent the establishment of undesirable robust competitive grasses and herbs;
 - d. to prevent the establishment of shrubs and trees.
- 3.11 Consistent with these objectives the use of light well distributed dressings of well-rotted farmyard manure (ie where stored outdoors for a minimum of four months) from cattle is acceptable where the following circumstances are satisfied:
- on grasslands mown for hay on neutral (mesotrophic) soils (eg NVC communities MG3, MG4, MG5, MG11 and MG13, after Rodwell 1992); and
 - on grasslands where there is a proven history of use of FYM and no evidence of damage to its nature conservation value; or
 - Where management of grassland is required to support breeding waders and wildfowl, application must be made outside the breeding period (15 March- 5 July) (Jefferson 1994 in Crofts & Jefferson (eds.) 1994).
- 3.12 **FYM use may be allowed in the above circumstances; but before each and every application further advice should always be sought from a relevant authority unless FYM application details are already prescribed in a management agreement.**
- 3.13 This report aims to ensure the advice relating to hay meadows is appropriate. **Semi-natural hay meadows are one of England's scarcest habitats and are a high priority for conservation by English Nature and others (see Moffat 1994).**
- 3.14 Fuller (1987) estimated that in 1984 there were only 200,000 ha of unimproved lowland semi-natural grassland in England and Wales (at the time, about 4 % of the total agricultural grass, and 5 % of the grass over five years old excluding rough grazings), and according to Hopkins & Hopkins (1993) less can be expected in Scotland and N. Ireland. Of this, lowland unimproved neutral hay meadows now cover less than 10,000 ha in England.
- 3.15 **The nitrogen (N) cycle (See Figure 1)**
- 3.15.1 The following sections are intended to provide an introduction to the nitrogen cycle which it is hoped will help achieve a greater understanding of the complexity of the subject covered by this report. There is insufficient space here for a full appreciation of the topic but the references cited should assist the reader to further study, where required.

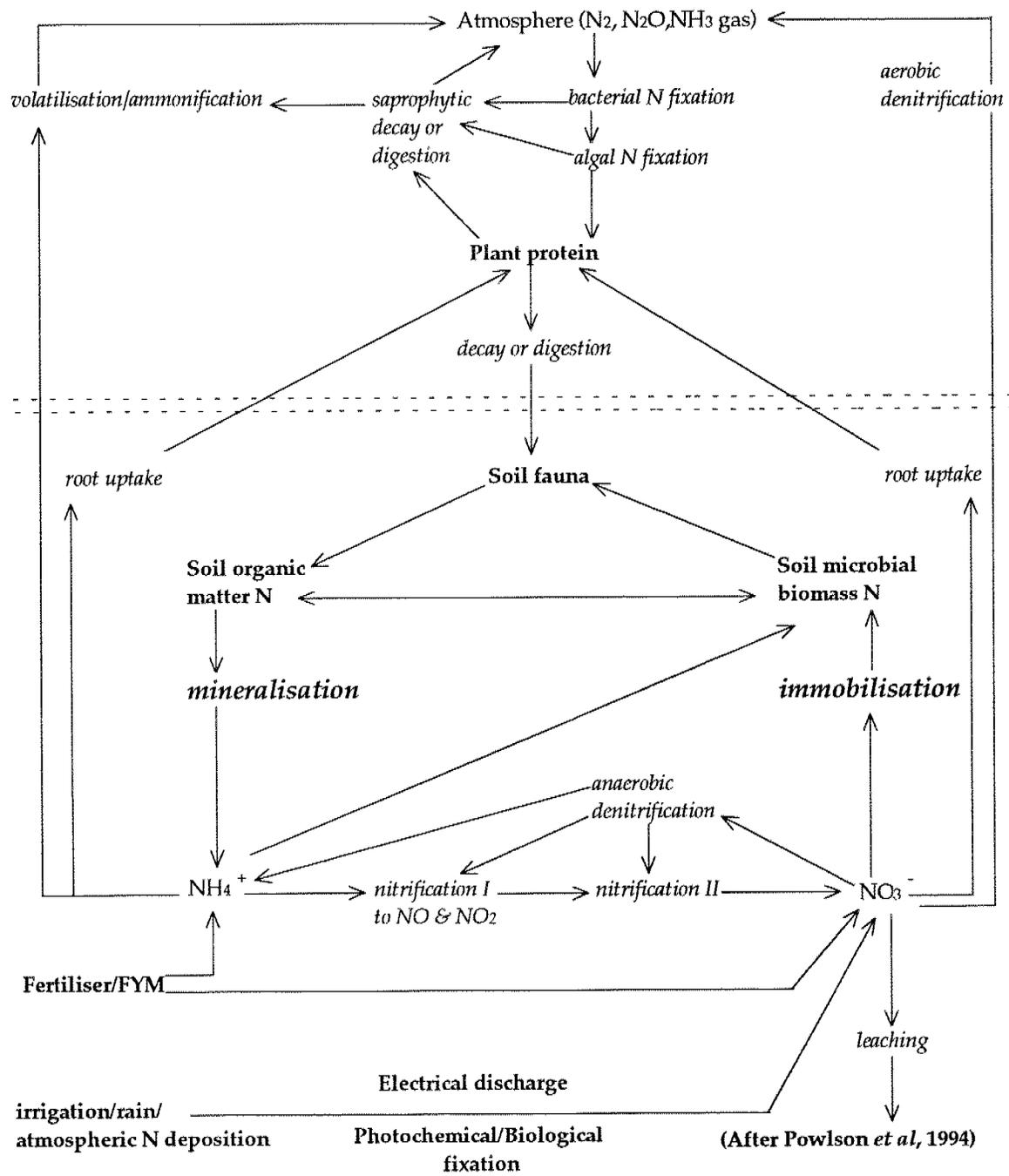
3.15.2 The single most important nutrient to plants is nitrogen (N); because, of all the nutrients, a relative shortage of this nutrient most commonly limits growth, and hence biomass. The ratio of C to N is also important because if the soil carbon supply is high relative to nitrogen availability this will 'lock up' any free nitrogen. This situation can occur when undecomposed straw or unrotted FYM is applied. In addition to soil nitrogen supply some plants have associated symbiotic bacteria (eg *Rhizobia*, *Granulobacter*, *Radiobacter*, *Azobacter*, *Costridium* species, *Bacillus* species) or blue-green algae (eg *Nostoc*), which are capable of fixing atmospheric nitrogen. However, most plants in their natural habitat receive nitrogen as provided by atmospheric dry or rain deposition, or by break-down of organic matter in the soil.

3.15.3 It is important to realise that when fertiliser nitrogen, either from inorganic or organic sources, is applied, most of this nitrogen does not enter the plant directly but enters the soil 'pool of nitrogen', some of which is mobile (sometimes called 'labile') and most is relatively immobile, in soil organic matter, ie 'humus'. This nitrogen pool constitutes a massive residual nitrogen resource, used by a whole host of organisms, which can then indirectly release nitrogen to be used by plants or lost by atmospheric volatilisation or lost through leaching in excess drainage. The buffering effect of soil organisms ensure that even if N gains equal N losses, then the soil 'nitrogen cycle' is not static. Soil organisms have a great stabilising influence on the whole ecosystem by cycling the nitrogen

3.15.4 Paraphrasing and interpreting the summary of Powlson *et al* 1994:

- The soil microbial biomass is the main agent of soil N mineralisation (ie the release of N from organic matter in inorganic forms) and N immobilisation (i.e. the assimilation of N into organic forms in the soil) and have a major impact on N losses and utilisation efficiency by plants. They are greatly influenced by temperature, the amount of soil organic matter, and grass (meadow) uptake.
- Animal manures vary in the forms and amounts of N, interacting and stimulating the soil microbes and these interactions affect the timing of N release from manure pools and the persistency of residual effects.

Figure 1. A simplified diagram of the Soil N cycle



- It is difficult to measure mineralisation of N in soil. Powlson *et al*, (1994) believe that modelling is the only way to bring together the different parts of the N cycle in a way that can be used to predict effects and to make recommendations which take account of N mineralisation, N losses and N immobilisation.
- Key strategic research is needed, and is being funded by MAFF. Nitrification is a key process which produces highly mobile forms of inorganic N (nitrate and nitrite) from an immobile form (ammonium), much of which is derived from mineralisation. A reassessment of nitrification rates and the controlling factors in grassland would be timely.

3.16 Recycling from plant residues and manures

- 3.16.1 Recycling provides a source of many nutrients, not just N. N recycling is dependent on N mineralisation, which may lead to production of nitrate that is at risk of loss from denitrification or leaching (Powlson *et al* 1994). So in addition to consideration of nutrient enrichment one should also consider the risk of nutrient loss, which may have economic and pollution implications but may also reduce the risk of altering a desirable plant community. We can influence these losses, bearing in mind that grassland constitutes a continuous crop which reduces the potential losses; but with the possibility of relatively large influxes of nutrients from time to time which cannot be all taken up at once by plants. Powlson *et al* 1994 recognised that: "A sound understanding of the amounts and timing of N release" (from manures) "is necessary so that they can be used efficiently in ways which maximise the benefit to the agricultural system but minimise the environmental hazards."
- 3.16.2 "Most of the N in soils, at least 90% of the total content, is in organic compounds as a residue of plants (roots and shoots) and animals, and the products of microbial decomposition. Decomposition and mineralisation are the means by which N held in the structure of such residues is released into the soil as inorganic (often referred to as mineral) forms either for subsequent recycling or utilisation by plants or micro-organisms or to be lost to the system. Mineralisation is the transformation process whereby ammonium (NH_4^+) or ammonia (NH_3) is released by soil micro-organisms as they utilise organic N compounds as an energy source (Jansson & Persson 1982; Royal Society 1983 quoted in Powlson *et al* 1994). The process is complex and depends on the activities of non-specific heterotrophic soil micro-organisms under both anaerobic and aerobic conditions..... Invertebrate fauna also make an important contribution by
- i. redistributing organic materials over a range of spatial scales;
 - ii. enhancing the rate of cycling through chemical change during metabolism; and
 - iii. having an effect on microbial populations themselves by creating or removing appropriate conditions for their various activities." (Powlson *et al* 1994)

- 3.16.3 N mineralisation is always coupled with N immobilisation by soil microbes: the two processes are intimately connected and dependent:
- 3.16.4 N immobilisation by soil microbes has been shown to occur predominantly from the NH_4^+ pool (Jansson 1958; Recous *et al*, 1988, quoted in Powlson *et al* 1994). Where NH_4^+ is not readily available, NO_3^- is assimilated by the soil microbial biomass (Azam *et al* 1986; Recous *et al*, 1988, quoted in Powlson *et al*, 1994). The continuous transfer of mineralised N into synthesised organic matter and the release of immobilised N back into the inorganic pool is known as the 'Mineralisation- Immobilisation- Turnover' or MIT (Jansson & Persson 1982 quoted in Powlson *et al* 1994). The MIT assumes that immobilisation of inorganic N as NH_4^+ or NO_3^- is the only means of N immobilisation. However, it has also been proposed and shown that immobilisation of amino acids can occur, this is known as the 'Direct Hypothesis' (Hadas *et al* 1987; Drury *et al* 1991 and Barak *et al* 1990 quoted in Powlson *et al* 1994).
- 3.16.5 It is important to realise that in addition to immobilisation by the soil microbial biomass, some also refer to the long-term accumulation of organic N by plant shoot and root residues in soils as 'immobilisation'. In undisturbed grassland soils, there is a long term accumulation of organic N through this means, and it is a means of buffering excess nutrients where the removal exceeds the offtake in hay. By the same token mineralisation of this organic matter provides nutrients when they become available and required at a later date.
- 3.16.6 Paraphrasing Powlson *et al* 1994: the balance between mineralisation and immobilisation influences the extent of N available for uptake, or loss to waters or the atmosphere. Gross mineralisation of FYM is linked to its individual properties and its interaction with the ambient environment; yet gross mineralisation is more difficult to measure than immobilisation. It is important to realise that even if one applies the same homogeneous manure to different sites with different soil textures mineralisation will occur at different rates, and will especially change due to temperature and soil moisture if comparing different times of application or measurement. Beyond this manures are rarely, if ever, homogeneous, and usually come from differing sources, resulting in an infinite variety of effects.
- 3.16.7 "The ratio of carbon to nitrogen (C:N) influences the relative availabilities of nutrients and therefore the nature and rate of degradation/ mineralisation processes". The C:N ratio of" FYM or any other nitrogenous "material provides an indication of the likely balance between mineralisation and immobilisation ..which will occur when added to the soil" (Powlson *et al* 1994). In general, as a substrate C:N increases, mineralisation decreases until some critical point is reached (Marstorp & Kirchmann 1991 quoted in Powlson *et al* 1994). Thus, the more straw bedding found in a FYM the higher the initial C:N ratio. This will tend to reduce the initial availability of nitrogen until respiration losses of carbon and possibly nitrogen from other sources during decomposition enables subsequent nutrient release and a lower equilibrium C:N ratio to be reached. However, it is important to recognise that C:N ratio is not a simple reliable guide which can be used to predict effects accurately largely because organic matter comprises a wide range of chemical components, and there are differences in soil

microbial populations. Increasingly it will be important to be able to better define resource quality in terms of nutrient supplying potential rather than chemical composition). The interaction of manure and bedding will have important effects on N mineralisation patterns (Powlson *et al* 1994).