10. Farmyard manure usage in relation to pollution management and farm economics

10.1 Avoiding pollution

10.1.1 The European Community has set a limit of 50 mg of nitrate (=11.3 mg N) per litre drinking water, along with limits on phosphate, coliform bacteria, and set other quality standards. In some area, especially where water is abstracted from boreholes in porous rock, nitrate concentrations have been increasing for some years. A major source of nitrate is nitrogen released from soil organic matter as a result of microbial activity. Lake (1982, quoted by Dowdwell 1986) pointed out that less than 10% of the nitrogen applied as fertiliser to UK crops is actually consumed by the UK population in its diet. The nitrogen balance for that part of agriculture based on grassland and ruminant production (as milk, beef and sheep) shows that these outputs only represent 13% of the total nitrogen consumed by ruminants (Royal Society 1983 quoted by Dowdwell 1986). (See the earlier section on the nitrogen cycle for details of how inorganic N is lost from the soil by denitrification, volatilisation and leaching.)

10.1.2 Similarly nitrates and phosphates can get into watercourses as a result of run-off, and drainage, which can enrich streams, rivers lakes, and eventually the sea. Some of the freshwater courses are used for drinking water supply, and the presence of nitrates increases the need and cost of treatment. In addition, over 100 SSSI's in England and 16 in Wales have been identified by English Nature, and the Countryside Council for Wales as having been affected by eutrophication. These are usually aquatic SSSIs polluted from outside the sites (Irving 1993); but there is always the risk of pollution caused by careless site management, so this section is included to alert the reader with a view to avoiding such problems.

10.1.3 Many crops use nitrogen inefficiently if more than the optimum amount is applied and this increases the amount of nitrate in soil at the end of the growing season. Thus it is essential to match fertiliser use to crop needs correctly, bearing in mind the expected yield, soil type and manure type. Organic manures are a rich source of nitrogen (N) but FYM especially from cattle or pigs release this N only slowly and if applied at the right time in the right amount constitute a relatively small risk of pollution, especially if run-off from manure heaps, or spreading on slopes is avoided. This risk of pollution is further reduced by the low application limits suggested for sites of high conservation value; however, one should be aware that there is legislation covering this topic, Codes of Good Agricultural Practice for the Protection of Water - known below as *the Water Code* (MAFF/WOAD 1991), and Air (MAFF/WOAD 1992), and in some areas Nitrate Sensitive Areas and Nitrate Vulnerable Zones, as well as ESA's and Management Agreements to which one must adhere. *The Water Code* is in the process of being revised and should be available in late 1995; until then RB209 (MAFF 1994) represents the latest data regarding the minimum land area needed for spreading wastes from different farm livestock.

10.1.4 Because 1988 regulations class commercial stable manure as industrial waste, there are different rules regarding waste disposal compared to that governing farms, and those concerned with commercial establishments (riding schools, livery yards, studs and racing yards) are advised to obtain a copy of *Waste Management - the Duty of Care, A Code of Practice*, published by HMSO.

10.1.5 For farmers the Acts which cover FYM and the avoidance of pollution are:

- ❑ Control of Pollution Act 1974
- ❑ Wildlife and Countryside Act 1981
- ❑ Agricultural Act 1986, Section 18
- ❑ Water Act 1989
  - Statutory Water Quality Objectives
- ❑ Water Resources Act 1991
  - Water Protection Zones
  - Nitrate Sensitive Areas (NSA)
- ❑ Control of Pollution (Silage, Slurry and Agricultural Fuel Oil) - covers slurry which by definition includes yard water and effluent from buildings. Whilst this report covers FYM many farms where this is produced must by definition also produce slurry. Slurry must be stored in a reception pit or slurry store; construction standards are based on British Standard 5502 Part 50 (1989) (Neilsen 1990).

These are apart from various European Directives (eg the EC Nitrate Directive 91/676) which are likely have some legal force in the future.

10.1.6 The following recommendations, which are all good advice, have been taken from the Water Code referred to above:

- ❑ Do not apply more available nitrogen than the crop (including grass) needs (from inorganic or organic manures).
- ❑ Keep a record of the amounts and dates of inorganic and organic fertilisers.
- ❑ Take into account how much nitrogen may be already in the soil before applying more.
- ❑ Ensure the correct amount of fertiliser is distributed by spreaders accurately without overlapping or applying it to uncropped areas, hedges or watercourses.
- ❑ Leave an untreated strip at least 10m wide next to all watercourses. and 50 m next to boreholes, well, or spring to be used for human consumption or dairy washing.
- ❑ Do not apply more than 250 kg ha^{-1} of total nitrogen in organic manure in any 12 months (less if within NSA's or Nitrate Vulnerable Zones

(NVZ's); by 1999, falling to 170 kg N ha^{-1} yr^{-1} equivalent to 1.8 dairy cows ha^{-1} or 5 fattening bullocks ha^{-1} within NVZ's).

- ❑ Do not apply to fields:
  - likely to flood in the month of application;
  - frozen hard,
  - next to a watercourse, spring or borehole where the surface is severely compacted;
  - next to a watercourse, spring or borehole with a steep or moderate slope and soil is at field capacity (i.e. when the soil is fully wetted and more rain would cause water loss by drainage).

10.1.7 Smith & Chambers 1993, Smith, Chambers & Johnson 1994 and Chambers 1994 indicate that straw based FYM have lower ammonium (available) N content than slurry so constitute a relatively low risk of pollution during autumn and winter. Their results support the recommendation in the Code of Good Agricultural Practice for the Protection of Water (MAFF 1991) that autumn/early winter applications of manures containing available N should be avoided wherever practically possible. This does not apply to FYM from pigs and cattle.

10.1.8 For commercial horse stables, the following legislation currently applies:

- ❑ Control of Pollution 1974.
- ❑ Collection and Disposal of Waste Regulations 1988 (this allows spreading on agricultural land as a fertiliser, providing the local authority has been notified beforehand; but farmers must either have or use someone who has a waste carrier and disposal licence, if carting it from off their holding).
- ❑ Control of Pollution (Amendment) Act 1989.
- ❑ Environmental Protection Act 1990.

10.1.9 In addition to nutrient pollution, disease can also be spread by animal manures, both in water and by air, and also by livestock eating contaminated herbage. Carbon dioxide, ammonia and hydrogen sulphide derived from slurry are dangerous in high concentrations for humans and animals; but odours, particularly where manure has been stored under anaerobic conditions can be offensive, and cause local Environmental Health Officers to investigate complaints and can threaten prosecution to force farmers to prevent or reduce such pollution. ADAS currently (May 1995) offer to visit and advise farmers on Pollution Control, with such advice paid for by MAFF. Local ADAS Offices have details. (Please note that ADAS offer a separate commercial consultancy service to ensure appropriate fertiliser inputs are applied, with appropriate analytical services as set out in Appendix III).

10.2 Economics

10.2.1 It has been shown by the experience of many farmers, and scientific studies such as those by Lawes & Gilbert (1859a & b 1880); MacDonald (1908); Smith (1924);Warren & Johnston (1964) using the Park Grass Plots at Rothamsted and Elliott & Thomas (1934); Coleman, Shiel & Evans (1987) from the Cockle Park Experiment that hay yield can be increased by application of FYM. We are unable to predict the yield effect in any one season from any one application; but various workers have explained some of the variation in yield effects as shown in Section 5.8.4. Thus we are forced to look at average responses, from the records that we do have; but almost always the original soil analyses and nutrient content of the FYM have not been measured even if the actual amounts of FYM applied have been measured. The economic effect of using FYM is also complicated by the fact that hay is rarely sold as a cash crop from many sites of high conservation value. More usually hay is fed to various forms of livestock, with other dietary components under differing management and housing regimes with differing climatic conditions both during the hay growing season, and livestock feeding. Grazing outside the "shutting-up" period for hay is rarely well recorded, and certainly there is a lack of economic appraisals comparing the effect of applying FYM to an untreated meadow over one year let alone a run of years to take out seasonal price fluctuations. So all in all one has to simplify one's assumptions to estimate the economic effects of FYM usage. The primary assumption used below is that hay has a cash crop value, which may or may not reflect its nutritional value to the animal, depending on its analysis, and the quality of the rest of the animal's diet. If others are able to use values from animal production in particular situations then this may improve on the information given here; but such data will always be unique and comparison between sites less easy than comparisons based on hay valued as a cash crop.

10.2.2 From the above it is hoped that the reader will treat the following remarks with caution, as being a starting point for future research.

10.2.3 **Output assumptions from hay-making**

a. FYM increases hay yield, the actual response depending on the initial soil fertility, the nutrient content of the manure, its time of application, rainfall, and other factors. At relatively high rates of FYM, 1 tonne of FYM on a 4 year cycle of application has produced a yield benefit of 240 kg ha^{-1} $cycle^{-1}$ taking a crude average of the Cockle Park and Rothamsted results quoted below. However, it must be remembered that the yield response to fertiliser is not usually linear over a wide range of inputs, and the amounts of maximum amounts of FYM recommended for sites with a high conservation value by Jefferson (1994 *in* Crofts & Jefferson 1994) are roughly **half** of the amounts applied on a 4 year cycle in the experiments quoted. Yet if one applies half the amount of fertiliser this does not usually produce just half the response, it often produces more - up to maybe two-thirds, depending on the rainfall. However, the experiments do provide a guide to the yield responses that could be expected under the ESA management guidelines:

At Palace Leas, Cockle Park over the period 1897-1980 by an average of :

197.1 kg hay ha^{-1} cycle^{-1} per t of FYM applied in annual cycle;

227.0 kg hay ha^{-1} cycle^{-1} per t of FYM applied in a two year cycle; or

256.6 kg hay ha^{-1} cycle^{1} per t of FYM applied in a four year cycle (using results published in Coleman, Shiel & Evans 1987) as given in Appendix IV.

At Rothamsted, a drier site (median max. Soil Moisture Deficit-SMD, 111 mm, than at Palace Leas, 80 mm; MAFF 1976), over the period 1920-1959 by an average of :

223.3 kg hay ha^{-1} (=189.8 kg DM ha^{-1}) cycle ^{1} per t of FYM applied in a 4 year cycle (using results published in Warren & Johnston 1964) as given in Appendix IV.

One might extrapolate from these results to say that for every ±1 mm change in SMD the change in hay yield is equivalent to ±1.074 kg ha^{-1} cycle ^{1} per t FYM applied per four year cycle

i.e (256.6 -223.3 =) 33.3 kg ha^{-1} year^{-1} per t FYM applied ÷ (111-80 =) 31 mm SMD.

Taking the various Cockle Park cycles of manure application an exponential response curve can be drawn to indicate the effect of varying the period between FYM dressings. This predicts for a site with an SMD of 80 mm per t FYM applied per hectare:

For a three year cycle a yield of 245 kg ha^{-1} cycle $^{-1}$
For a five year cycle a yield of 264 kg ha^{-1} cycle $^{-1}$
For a six year cycle a yield of 270 kg ha^{-1} cycle $^{-1}$

Obviously such extrapolation is simplistic and may be carried too far; but in the absence of better information could be a working guide. Research to test such effects based on sites of high conservation value with lower amounts of FYM would be valuable to quantify the variables. Higher yield increases per tonne of FYM might be expected if less FYM is applied.

b. Say, hay is worth £40 per tonne; obviously variation in quality and scarcity will affect the price; so a rough estimate has been used here; but it is equivalent to four pence per kg hay.

c. From these assumptions an increase in hay output is 240 x 4p ha^{-1} cycle ^{1} worth £9.60 per tonne FYM applied, might apply when ESA Management Rules are followed for nutrients valued at £2.61 - £2.88 per tonne (see Section 6.4.1).

d. It is not known what response a lower total FYM dressing would produce; but it is estimated here that the response per t of FYM will be on average 33% higher than when larger dressings are applied.

e. However, hay costs money to make, and cart. Storage can also be costly but if the hay value/price of £40 per tonne is assumed before storage this removes this variable.

f. Say a yield of 3.484 t ha^{-1} is expected where FYM is allowed; yet only 1.884 t ha^{-1} is produced when no FYM is applied (taking a crude average of the untreated yield from Appendix IV, then adding the result of multiplying 20t x 320 kg hay ha^{-1} $cycle^{-1}$ (ie 240 x 1.33 to allow for a higher response to a lower overall FYM dressing) ÷ 4 years = 6400 ÷ 4 = 1600 kg ha^{-1} yr^{-1}). Please note that the estimated **(rather than measured)** average hay yields from seven hay meadows which receive FYM regularly in Section 9.3 is 4.2t ha^{-1} which probably reflects their rainfall and relatively low soil moisture deficit.

10.2.4 Variable Costs of Hay-making on a meadow which receives FYM

Cost of mowing = £29.76 hour-1 -(Anon, 1994c):
cutting say 1.14 ha $hour^{-1}$ = £26.10 ha^{-1}
÷ 3.484t ha-1 = £ 7.49 t^{-1}

Cost of swath turning @ £11.25 ha^{-1} (Nix 1994) x 3 turns @
£33.75 ha^{-1} ÷3.484t ha^{-1}= £9.68 t^{-1}

Cost of baling - big bales £1.50/bale - 4.4 big bales @
4 foot x 4 foot t^{-1} =£22.99 ha^{-1}
(Which is roughly the same as £2.00/bale @ 3.3 big bales @
5 foot x 4 foot t^{-1} = £6.60 t^{-1}

Haulage to farm eg 20 bales/trailer if 5 x 4 foot = 13.3 t/trailer to haul up to two miles with time to load and drop off - one hour per trailer load @ £20 $hour^{-1}$.
£20 ÷ 13.3 = £1.50 t^{-1}

Variable costs = £23.27t^{-1} but this excludes grass rent.

Where owners make hay on their own land a rental equivalent of £21.54/acre may be assumed as attributable to the hay-making. This is equivalent to £30 per acre per year, but with roughly two-thirds (71.8% actually) of the benefit from the grass being taken off in the hay, with the rest of the benefit in grazing: this figure has been derived from the authors experience coupled with the results of the unmanured, unlimed Plot 19 as reported by Warren & Johnston 1964:

£21.54/acre x 2.4711 = £53.23 ha^{-1} ÷ 3.484 t ha^{-1} = £15.28t^{-1}

Hay costs = £15.28 in rent + £23.27 to make/cart = £38.55t^{-1}

Net margin from hay making = £1.45t^{-1} (ie £40 - 38.55t^{-1})

However, if unfertilised the hay costs even more to make per tonne; because the costs are spread over less bulk.

10.2.5 Variable Costs of Hay-making on a meadow which does not receive FYM

Cost of mowing = £29.76 $hour^{-1}$ = cutting 1.25 ha $hour^{-1}$ given lighter grass crop of say 1.884t/ha
= £12.63t^{-1}

Cost of swath turning @ £11.25 ha^{-1} x 2 turns if lighter crop providing no rainfall falls during hay-making.
= £22.50/ha
1.884= £11.94t^{-1}

Cost of baling big bales @ £1.50/bale = 4.4 big balest^{-1} = £6.60 t^{-1}

Haulage to farm - as previously £1.50t^{-1}

Total costs of hay = £32.67t^{-1} excluding rent

Assuming rent @ £21.54/acre = £53.23 ha^{-1} on average - gives total cost of:

£32.67 + (53.23 1.884) = £60.92t^{-1} .

10.2.6 Whilst the above is only a budget based on the assumptions given, if the product is only worth £40 $^{-1}$ and yet costs £60.92 $^{-1}$ to make the less hay made by the farmer the better, if it is uneconomic. Using the above methodology, the average cost per tonne of hay is £35t^{-1} if the average hay yield of 4.2t ha^{-1} (as estimated from meadows in Section 9.3 where FYM is regularly used). These sites have not measured nil FYM plots for comparison; but if one accepts 4.2t ha^{-1} is 20% higher that the figure of 3.484t ha^{-1} used above; then a 20% increase on 1.884t ha^{-1} gives a yield of 2.27t ha^{-1}. This would give a cost of £51.75 per tonne of hay. Avoidance of use of FYM would clearly have great implications for the cost of supporting farmers constrained by management agreements of similar arrangements. For each meadow it should be possible to do similar calculations using realistic local data to indicate the consequences of alternatives. **The budgets given above are not intended to be used on individual sites where records are inadequate; but are merely a model which may be used to show what data is required.**

10.2.7 One recognises the reality that making hay without using FYM (or some other fertiliser) is usually uneconomic from a farmer's point of view; that is why it is done. Buying-in hay is not a viable option because it may import weeds and nutrients onto meadows which have a high nature conservation value, and hay is an intrinsic part of the traditional management which has maintained the desirable flora of such meadows. Thus on economic and conservation grounds the continued use of FYM can be argued.

11. Suggested areas of further research

11.1 Obviously many of the areas covered by this report could benefit from further research.

11.2 The authors do not intend to prioritise such potential work, given that a consensus will need to be achieved between English Nature and other organisations with an interest in the topic. However, useful information on some topics seems lacking, particularly at the individual site level.

11.3 It may be that the most cost-effective and relevant areas of research would be on individual sites managed by English Nature or other conservation organisations, where staff are on-hand already and are willing and able to look at what is done more closely than hitherto. Useful records of what is done is essential - to communicate with others and to help their successors. Examples of what needs to be recorded can be seen from the questions and answers to the survey quoted in this report. (Section 9 and Appendix 6.)

11.4 Only 11 sites (out of a 'guesstimated' 240 relevant meadows) are covered by the questionnaire survey replies. This means that at present there is little information in this report available to readers on over 95% of the hay meadows currently estimated to be of high nature conservation value.

11.5 Research starts with current knowledge, so we need to start recording, collecting and sharing our knowledge. As was indicated in Section 4.1.4, it is suggested that the bibliography in Section 13. offers an excellent starting point for future researchers.

11.6 Key strategic research is needed into nutrient cycling; not only nitrogen but also phosphate. MAFF is already sponsoring some; but grassland nitrification rates and the factors which control them would be of value. Lack of availability of FYM due to economic pressures, intensification and changes in housing means that FYM is becoming a rarer commodity; but if only slurry is available in certain areas, research is needed into ways of combining separated solids from the slurry with straw or other organic materials to maintain the current diversity of species and hay yields. There is some evidence to suggest that slurry releases nutrients rapidly, particularly nitrate, and this can reduce grassland biodiversity. Research into the impact of slurry on the species composition of semi-natural meadows may be appropriate. In relation to the latter topic, simple laboratory research into the effects of enhanced $C0_2$ levels of known nutrient concentrations on the growth of selected meadow species (see section 8.2d) may prove instructive. Should significant growth effects be detected, then field experiments could be conducted to see whether there were differences in plant responses to FYM, slurry and a control, aside from differences in N, P and K.

11.7 FYM is a notoriously variable commodity, incomplete mixing and the relatively low application rates suggested for meadows of high conservation value are difficult to achieve without overlapping and uneven spreading, given that application machinery has been developed using agricultural rather than conservation criteria and users may not be proficient at achieving targets for application rate or evenness of spread. Research linked to manufacturers (or contractors) setting up and demonstrating their differing equipment may complement attendance by site managers at the annual Muck event held at the

National Agricultural Centre, Stoneleigh. An information note could be produced for the benefit of all who could not attend such events and for future reference.

11.8 As suggested in Section 7.1.12, hay samples from semi-natural meadows could be routinely analysed for nutrient content and the results collated for each site on a database with relevant management details such as hay cutting date, time taken to baling, and storing, weather during hay-making and storage conditions. Before cutting changes in yield, dry matter, D value, mineral and protein contents might also indicate optimum cutting dates from an agricultural viewpoint.

11.9 Nutrient content of individual plant species would complement such data as suggested above. Such work would complement the work already done by the NERC Unit of Comparative Plant Ecology at the University of Sheffield, as published in Grime, Hodgson & Hunt (1988) or could form part of the Ecological Flora Database (see Fitter & Peat 1994).

11.10 As was stated in Section 8.1.8, there is a need to define and standardise the sampling, transport and storage of samples for measurement of the C:N ratio of organic manures.

11.11 Pro-forma or checklists could be drawn up by English Nature to assist in record keeping relevant to meadows of a high conservation value. These could be completed during site visits. A survey of staff might indicate what records would be useful. Such records could then be used by researchers in future.

11.12 As was said in Section 5.1 generally the proportion of grasses and the extent of floristic change increases with increasing FYM rate and frequency of application. However, directional change, cyclical change and stability are also influenced by other factors to the extent where the results are not entirely predictable. It should also be remembered that one may use good information to set **appropriate** limits on the use FYM, linked to expected hay yields and the sensitivity of the desirable species present, to try to maintain the traditional appearance of a site as well as achieving the farmer's aim of economic hay yields. If the balance seems to tilt in favour of the nature conservation aims over those of a farmer's in terms of yield, cutting date, and consequently economics, then the variables might then be given an economic value which is acceptable to all parties. However, this necessitates good information and this is currently lacking in most field situations. Thus it is recommended that practices are not changed until monitoring provides the relevant base line data. Experimental trials then need to be undertaken, following appropriate protocols, collecting all the relevant data which then needs to be intelligently analysed to explain the causes and effects. This report review much of the existing literature but it also highlights the lack of recorded information in most field situations. For everyone's benefit it is recommended that the right questions are asked and answered by monitoring, this will result from and lead to good communication.

11.13 Where there is a need and funds allow, the dose response of each site to FYM could be quantified. Snaper Farm Meadows (North Yorkshire) was suggested by Dave Clayden as an excellent research opportunity in this context where FYM is being applied for the first time in 20 years.

11.14 It cannot be overstated that monitoring and analysis should be given the highest priority on sites where change is contemplated. Where no change in management is currently contemplated but could occur in the future it is also important that base line figures are collected to enable monitoring of the effects on a trial basis of the consequences of any changed practices. Otherwise illogical decisions with uneconomic consequences which cause frustration and the loss of floral and faunal communities will beg the question what could have been done differently?

12. Conclusions

12.1 Much work remains to be done; both formal experimental research and, more fundamentally, collection and analysis of data from existing meadows to establish a benchmark against which further change can be measured. From these better management guidelines can then be issued, which will be recognised as appropriate and therefore more likely of commanding support and resources from interested parties. A plea that economic margins are quantified, in the near future is made, modelled on farm management budgeting, as exemplified in Section 10.2

12.2 This report aims to increase understanding of the subject with a view to individual site managers and others conservation advisors drawing up their own guidelines which are tailored to the needs of their own particular site(s). Similarly appropriate research must begin from current knowledge to avoid duplication, wastage and unnecessary delay - so thus report aims to 'kindle' ideas, and highlight gaps in our knowledge. Without the work begun in the 19th Century this report would have much less data to report. New initiatives relevant to hay meadows, with the exception of the work on nutrient cycling, have been lacking in the 20th Century. Let us hope that as we enter the 21st Century that the recognition of the scarcity of this precious floral resource encourages a better focus of what is needed for the future. By both the nature of hay meadows and the changes we induce, long-term research will be needed, at a time when financial resources need justification.

12.3 At an individual site level, poor management will usually reduce the incidence of desirable communities and species as well as providing suitable conditions for a predominance of undesirable species. 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 by this report will be heeded, the lessons learned and appropriate action followed.