Improving UK Fertiliser Statistics

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Department for the Environment, Food and Rural Affairs

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Executive summary

This project considered ways of improving statistics on fertiliser usage statistics on farms in the UK.

We have collected fertiliser statistics for many years through the British Survey of Fertiliser Practice (BSFP). This is an interviewer survey, which covers both manufactured and organic fertilisers. We explored whether this was the most appropriate method of collection, and whether it could be improved. We covered:

- improving data collection methods;
  - investigating the usefulness of using administrative farm records and electronic farm-recording systems; and
  - testing the feasibility of collecting data by postal questionnaire or telephone survey;
- improving the data on organic manure; and
- modelling manufactured fertiliser usage for holdings in the Farm Structure Survey.

We found that although there was considerable recording of fertiliser applications on farms in Nitrate Vulnerable Zones, this source did not provide reliable fertiliser statistics. The main reasons being that the coverage is not complete, the data is not collated centrally, the format and extent of record keeping varies substantially, the data required can vary over time with policy changes and that data on nutrients other than nitrogen is not collected.

We also explored the possibilities of using the data from commercial electronic record keeping systems. We found that around a third of farmers use such a system but that there is insufficient share of any one, or even a few, software packages to make collecting fertiliser data in this way feasible.

We investigated whether fertiliser data could be collected by postal or telephone questionnaire. We found that farmers were unwilling to supply the data in this way (only 15 per cent were willing to supply data by post). It may be possible to collect simple data by post or telephone. Just over 80 per cent were willing to submit their data within the confines of a 20 minute interview. However, there are accuracy concerns over collecting data by telephone (when compared with interviews) and we estimate that data from only 9 per cent of cereal holdings could be collected within a 20 minute interview (though this rises to over 50 per cent for livestock holdings).

We established that there were strong policy demands for data on manure, and that it was therefore important to collect information on the total nutrient use across the farm. The volume of manure generated, how it is stored and how it is applied to fields impacts on each of air, soil and water quality. There was little demand identified for data at sub-regional level.

We developed the questions on manure in the 2008 BSFP. This demonstrated that it was feasible to collect detailed data on manure use in a robust way. Almost 70 per cent of holdings applied some form of organic manure. We re-analysed historical manure data to produce results on a consistent basis. This showed that patterns of manure use haven’t varied considerably over the last five years.

Finally, we examined whether it was possible to model fertiliser usage at farm level, using nitrogen applications on wheat as our test data. We considered explanatory variable such as farm size and type, region, soil type, whether in an NVZ and livestock numbers. We found that it was not possible to produce a model using data available from the Farm Structure Survey to sufficient accuracy.

The reasons for our inability to model fertiliser use are probably threefold. Firstly, the explanatory data we have may be inexact, and we are not able to accurately capture their true impact. For example, we have only approximate information on soil types and the availability, and nitrogen content, of manure. Secondly, we are missing some explanatory data such as historical cropping patterns. Finally, we cannot model farmer behaviour, which may have a random element to it (because of limited information, for example).

Because we did not find it possible to use farm records or telephone or postal surveys instead of our current data collection method, and because of our limited success in modelling fertiliser use, the extent of this project was much reduced from that initially proposed.

Recommendations for collecting fertiliser data at EU level

There are strong demands for data on manufactured and organic fertiliser performance, for monitoring impacts on soil, water and air quality.

While it may be possible to collect very basic data on fertiliser usage through postal or telephone surveys, an interviewer survey is the only feasible way of collecting the complex data required.

The administrative cost of conducting the survey, the burdens on farmers and the policy demands suggest that the data need only be representative at national (or NUTS1) level.

There is only limited policy demand for sub-regional data. Modelling fertiliser usage at farm-level using Structure Survey variables is not possible. The demands for sub-regional data could be met by applying national crop averages at farm level.

Contents

1. Introduction

This report outlines the investigative work undertaken to improve statistics on fertiliser usage on farms in the United Kingdom. The purpose of the work is outlined in more detail below, along with a discussion of the policy uses of the data and a summary of the methodology we employed. The individual work areas are then discussed in more detail, and the full reports are annexed.

Purpose

This project has examined ways of developing the system for producing statistical estimates of manufactured and organic fertiliser usage in the United Kingdom. It has been funded by Eurostat, who have a requirement for consistent statistics on fertiliser usage across the EU to meet policy demands.

Fertiliser statistics have been produced in this country for many years through the British Survey of Fertiliser Practice (BSFP). The survey is primarily focussed on collecting data on manufactured fertiliser, though data on organic manure has also become routinely collected in recent years. Further information on this survey can be found at https://statistics.defra.gov.uk/esg/bsfp.htm.

We believe that the BSFP meets the vast majority of policy needs for data on fertiliser usage on farms. However, there are a number of features where we wanted to explore whether the methodology and/or efficiency of the survey could be improved, and identify the benefits of any alternative approaches for ourselves and other Member States. The main areas which we covered are:

- improving data collection methods;
    - investigating the usefulness of using administrative farm records (for example on Nitrate Vulnerable Zones) and electronic farm-recording systems; and
    - testing the feasibility of collecting data by postal questionnaire or telephone survey;
- improving the data on organic manure; and
- modelling manufactured fertiliser usage for holdings in the Farm Structure Survey.

Policy uses

There are a wide range of policy uses for data on fertiliser usage. These cover issues around both agronomic and environmental performance.

The use of data on manufactured fertiliser is fairly widespread. However, detailed data on organic manures has, until recently, not been routinely available although it forms an important part of the overall picture of nutrient use. To help understand the current uses and other demands for data on organic manure, Defra's Food and Research Agency (FERA) undertook an analysis of the policy requirements for data on manure usage. The results of this exercise are incorporated below and the full report is at Annex 1.

The need to increase food production and the pressures on farming incomes has led to more interest in investigating the efficiency of fertiliser usage. The BSFP allows for the monitoring of overall trends, as well as detailed investigations in to changing practices by crop. Using the data it is possible, though not straightforward, to compare actual usage at field level against recommended levels (by using information on soil type, rainfall, use of organic manures, previous crops, etc.).

The main interest in fertiliser data is, however, in monitoring environmental performance. Fertiliser usage impacts on each of air, water and soil quality.

Agriculture has a substantial impact on climate change, with greenhouse gas emissions from agriculture accounting for around 7.0 per cent of total United Kingdom emissions. Methane emissions, in particular, depend on the volume of manure generated, and how that manure is stored and applied to the land. The main agricultural source of emissions of nitrous oxides is from the oxidation of the nitrogen in fertilisers, accounting for around two thirds of all UK nitrous oxide emissions. In particular, the data on fertiliser is used to measure how well the UK was progressing towards the targets in the EU National Emissions Ceilings Directive.

Agriculture also accounts for over 90 per cent of UK ammonia emissions. Emissions arise predominately from livestock housing and from the spreading of animal manure. Urea fertiliser, in particular, is associated with much greater ammonia emissions than other fertiliser types.

The level, and method of application, of fertilisers can also impact on water quality. Data on both manufactured fertiliser and organic manure is used to inform progress against, and develop policies to support, the Water Framework and Nitrates directives. In particular, fertiliser data was used extensively in the evaluation of the NVZ Action Programme.

The importance of sustainable soil management and maintaining and enhancing carbon in agricultural soils is an increasingly important strategy. The use of manures is becoming more important as the availability, use and energy needs associated with producing manufactured fertilisers became subject to greater scrutiny.

Many of these policy issues are relevant (or indeed originated) at EU level. There is also demand for fertiliser data to populate the IRENA (Indicator Reporting on the Integration of Environmental Concerns into Agriculture Policy) indicators on the use of nitrogen and phosphate manufactured fertilisers in aggregate, and on selected crops (and also indirectly for the indicators on ammonia, methane and nitrous oxide emissions). The data for these is already available for GB (and is easily extended to the UK) at NUTS1 level from the British Survey of Fertiliser Practice.

The reasons for our inability to model fertiliser use are probably threefold. Firstly, the explanatory data we have may be inexact, and we are not able to accurately capture their true impact. For example, we have only approximate information on soil types and the availability, and nitrogen content, of manure. Secondly, we are missing some explanatory data such as historical cropping patterns. Finally, we cannot model farmer behaviour, which may have a random element to it (because of limited information, for example).

Methodology

The majority of the work in this project builds on the British Survey of Fertiliser Practice. This is an annual face-to-face survey conduced by dmrkynetec under contract to Defra. A summary of the methods used are given in the table below. More details are given in the appropriate section of the report.

Area	*Conducted by*	*Method*
Improving data collection methods	dmrkynetec	Develop questions on record keeping, collect through the 2008 BSFP and analyse (766 responses). Obtain data from those willing to submit. Identify willingness to complete by post and telephone. Pilot data collection (91 responses) using reduced questionnaire. Check sub-sample with follow-up visits.
Improving the data on manure use	Defra (Food and Environment Research Agency) Defra (Statistics) dmrkynetec	A small survey of policy contacts (10 responses) to identify policy requirements for manure data. Development of the BSFP questionnaire to provide better manure data. Collection of new data in the 2008 BSFP (not charged to this project). Analysis of historic manure data, producing results on an equivalent basis and publication with 2008 BSFP results.
Modelling manufactured fertiliser applications	dmrkynetec Defra (Farming Statistics)	Develop historical database to allow easier analysis. Attempt to model fertiliser applications for holdings in the Farm Structure Survey database, starting with nitrogen applications on wheat, by using responses to the British Survey of Fertiliser Practice.

2. Improving data collection methods

As noted, the British Survey of Fertiliser Practice already collects a wealth of information from farmers through face-to-face contact. This part of the project was aimed at seeing whether this was the most appropriate method of collection, and whether the efficiency of the operation could be improved by utilising farm records.

Use of farm records

The Nitrates Directive requires Member States to designate as Nitrate Vulnerable Zones (NVZs) all land draining to waters that are affected by nitrate pollution. The area of NVZs now covers around 70 per cent of England. Defra's Action Programme requires farmers to keep detailed records on applications of nitrogen (through both manufactured fertiliser and manure) on fields in these areas. Details of the records required can be found at http://www.defra.gov.uk/ENVIRONMENT/water/quality/nitrate/pdf/nvz-record-keeping-checklist.pdf.

While this data would be of considerable use in answering many of the policy questions identified above, we did not judge that this was a suitable source for providing reliable fertiliser statistics. The main reasons for this are that while the coverage is substantial (70 per cent of land) it is not complete, the data is not collated centrally (farmers need only have records available for inspection), the format and extent of record keeping varies substantially, the data required can vary over time with policy changes and that data on other nutrients (notably phosphate and potash) is not collected.

We also explored the possibilities of using the electronic farm records that farmers keep using commercial software packages. We asked dmrkynetec to include questions in the 2008 British Survey of Fertiliser Practice on the use of computerised records. They found that 31 per cent of farmers kept electronic records of their fertiliser applications. Around half of these held data on manufactured fertiliser only, with the remainder holding information on both manufactured and organic fertilisers. Electronic record keeping was greatest on cereal (48 per cent) and general cropping (50 per cent) farms, and on larger enterprises.

Six principal software packages were used to store the information. Of those who record manufactured fertiliser, around a quarter used their own system (generally Excel based) with the commercial packages Crop Manager (Farmplan) (at 24 per cent), Multicrop (Farmade) (at 18 per cent) and Muddy Boots (Crop Walker) (at 11 per cent) being the principals. Smaller farms tended to use their own systems (generally Excel) while there was little variation in the software package used across farm types.

Farmers with computerised record keeping were asked whether they were willing to submit their fertiliser data electronically. Around a quarter were willing to do so.

The use of electronic records is growing (from 24 per cent of farmers in 2004 to 31 per cent in 2008), but there is insufficient share of any one, or even a few, software packages to make collecting fertiliser data in this way feasible. The outputs from the software packages are in different formats and there are potentially high costs associated with developing common standards.

The comprehensiveness of information and detail entered by farmers also varies. So, even if the data can be collected in a common format, there will be gaps or incomplete data records. Farmers are also unwilling to submit data in this way (only 24 per cent of those able to do so were willing – this equates to 7 per cent of farmers overall). In some instances, agronomists hold the records on behalf of the farmer, which further complicates the issue.

The full detail of the findings by dmrkynetec can be found at Annex 2.

Postal and telephone surveys

We asked dmrkynetec to undertake a pilot study of farmers to identify whether they would be willing to submit data by telephone or post (details again in Annex 2). We initially asked the BSFP sample (766 responses) whether they would be willing to provide their data without an interviewer visit. Only 15 per cent were willing to do so. The reasons given for their unwillingness to consider self completion are given below:

Reasons for farmers being unwilling to consider self completion of fertiliser data

Reason	**Per cent**
Too much paperwork	45
Too busy	43
Too complicated	18
Can't be bothered	12
Wouldn't do without interviewer visit	11
Too much to read	7
Other	21

While we only considered farmers' willingness to supply the current level of detail on fertiliser applications (as collected in BSFP), this does given an indication that farmers value the interviewer collection and would be unlikely to submit data through postal or telephone methods.

Collecting data by telephone

We asked dmrkynetec to approach existing BSFP contributors to investigate the possibilities of collecting fertiliser-usage data by telephone. They received 91 responses across 9 robust types, with a range of different farm sizes. Details of the sample selected are in Annex 2.

We developed a reduced questionnaire based on that currently used by the BSFP. For each field (or blocks of fields with identical fertiliser applications) we asked for the size of the field, the current and past crop, and whether the field was in an NVZ. We then asked for information on the timing and content of manure applications, and then the timing and content of each application of manufactured fertiliser. At each stage in the process we recorded the time taken to complete. The interviews were stopped after 20 minutes.

On average, the questions on the field size and cropping took around 1 min 40 seconds, the questions on manure applications around 50 seconds in total, with around 40 seconds spent on providing information about each manufactured fertiliser application. There wasn't a substantial variation in the timings across farm types, but we did find that the average time taken to complete for each field got lower as the number of fields increased. It appears that as interviewers and respondents become more familiar with the process, the quicker it becomes.

We applied the average times taken to complete to the known details of the farm from previous BSFP responses. We judged that the maximum length of the telephone interview could be 20 minutes – after this time the quality of responses fell, farmers stopped supplying details and there was a reduced chance of farmers taking part in the survey in the future. We required a total of 5 minutes to introduce the survey, collect basic information on the farm and ask any supplementary questions (for example on imports or exports from the farm of manure). This left 15 minutes to collect the data on fertiliser applications. Based on the results of the survey we estimated the proportion of holdings for which data could be collected in 15 minutes or under, for each farm type. These are shown in the table below.

Proportion of holdings from BSFP sample from whom fertiliser application data could be collected in 15 minutes or under

Robust type	**Per cent collected in 15 minutes or under**
Cereals	9
General cropping	6
Horticulture	30
Pigs and poultry	57
Dairy	21
LFA	60
Sheep and cattle (lowland)	54
Mixed	21
Total	*27*

As can be seen from the table, it should be possible to collect more than half of responses from pigs and poultry, LFA, and lowland sheep and cattle farm types by telephone. However, these farm types make up only 1, 21 and 9 per cent respectively of the BSFP sample.

Farmers were asked how prepared they were to submit data by phone *within the confines of a 20 minute interview*. Just over 80 per cent were willing to submit their data in this way. This outcome did not seem to be influenced by farm type or the number of applications recorded.

The telephone interviewers were also asked their opinions on the process. Overall, more than three-quarters of interviews were thought to be fairly or very easy. This changed depending on the amount of data collected. When the number of fertiliser applications reached more than 15, only 50 per cent of interviews were thought to be fairly easy (and none very easy).

Farmers were asked about the accuracy of the data they supplied by telephone. Around two thirds thought it as good as a personal visit, while the remainder thought it probably not as good. The proportion was highest amongst sheep and cattle farmers, who generally make a small number of fertiliser applications.

We followed up around 20 of the telephone calls with personal visits to check the accuracy of the data supplied. In around two thirds of holdings the telephone data matched that collected by personal visit (although the telephone survey had often not collected data on all of the fields on the farm because the interview was ended after 20 minutes). The results from the remaining holdings all had some differences. Often these were minor, but on a couple of occasions there was very little correspondence between what had been provided by telephone and on the personal visit.

The dmrkynetec work identified that there is some scope for collecting simple fertiliser records by telephone. However, there are questions over the accuracy of the data collected by telephone, and this method introduces complexities disproportionate with the cost benefits.

Collecting data by post

To investigate further, dmrkynetec finally asked the 91 participants in the pilot collection about their willingness to submit data by post. Around one third of those contacted were not willing to submit their data by post, a third were not very willing to do so and the final third were very or fairly willing to submit their data.

Farmers with a small number (or no) fertiliser applications were more willing to submit their data by post (55 per cent fairly or very willing for those with no applications, 45 per cent for those with 1-5 applications and 20 per cent for those with 6-10 applications). There was also some limited variation by farm type, with specialist pig and poultry farms being more willing to submit postal data, although it was difficult to establish any firm pattern of responses amongst farm types.

The cost of collecting complex data by post (even if farmers could be persuaded of the benefits of taking part) can end up as much as telephone interviews when the cost of reminders and chasing postal returns are taken into account. Extensive notes to help farmers understand the data needed would also be required, which farmers are unlikely to read. We would therefore not recommend using postal surveys as a method for collecting robust, crop specific, data on fertiliser usage.

Our project proposal had included a large section on identifying the design options for a data collection method using telephone or postal surveys. Our work found that using these methods was not preferable to the existing interviewer survey. The extent of our project was therefore much reduced on our initial proposal.

3. Improving the data on manure use

This work had several strands. We asked our colleagues in the Food and Environment Research Agency to investigate the use of manure data for policy purposes through a small survey. We worked with dmrkynetec to improve the way in which fertiliser data was collected – we developed the questionnaire to include individual, rather than total, applications. This data was then collected, and published, in the 2008 BSFP report (only the developmental work from Defra statisticians has been charged to this project).

Finally, we also tasked FERA with re-analysing historic manure data from the BSFP (which has been collected in a variety of ways in recent years) to produce a consistent time series, which was subsequently published with the 2008 BSFP results.

Policy uses

The results of this analysis have already been incorporated in the introductory section above (and are given in full in Annex 1). The work showed that there were strong demands for data on manure usage to monitor environmental performance. This touched on each of air, water and soil quality.

As noted above, methane emissions, in particular, depend on the volume of manure generated, and how that manure is stored and applied to the land. Agriculture also accounts for over 90 per cent of UK ammonia emissions. Emissions arise predominately from livestock housing and from the spreading of animal manure.

In particular, manure data is used to measure how well the UK was progressing towards the targets in the EU National Emissions Ceilings Directive.

The level, and method of application, of manure (and manufactured fertilisers) can also impact on water quality. Data is required to inform progress against, and develop policies to support, the Water Framework and Nitrates directives.

The importance of sustainable soil management and maintaining and enhancing carbon in agricultural soils is an increasingly important strategy. The use of manures is becoming more important as the availability, use and energy needs associated with producing manufactured fertilisers became subject to greater scrutiny.

Developing the collection of manure data in the BSFP

Until recently, detailed information on manures has been collected infrequently in the British Survey of Fertiliser Practice. To reflect the increased interest in manure use, we have begun collecting data each year, although we have found the data difficult to collect because farmers do not always accurately record their applications. With the extension of Nitrate Vulnerable Zones and the increased awareness of the benefits of manure applications (particularly in times of high prices for manufactured fertilisers), farmers' knowledge, and record keeping, of applications has improved.

In 2007 we introduced the direct collection of weights in the BSFP, rather then the low/medium/high approximations that had previously been used. The TAPAS funding allowed this to be further refined in 2008 in consultation with farmers and industry experts. The data now collected is shown below (the full BSFP field sheet is at Annex 3).

Data collected on manure in the 2008 BSFP questionnaire

MANURE/SLURRY

7. *Please record all applications of manure/slurry made to this field. Refer to interviewer notes for guidance*
If more than 4 applications please start a new field sheet

Application number		1	2	3	4
(a) Month	*(e.g. 03)*				
Year	*(e.g. 08)*				
(b) Manure type	*(tick one per application)*				
Cattle FYM					
Pig FYM					

Sheep FYM				
Duck FYM				
Layer manure				
Broiler/turkey litter				
Cattle slurry				
Pig slurry				
Digested liquid sewage sludge				
Digested cake				
Thermally dried sewage sludge				
Lime stabilised sewage sludge				
Other (please specify below)				

(c) Application rate *(write in volume per application)*

Tonnes/tons				
M^3				
'000 litres				
Gallons				

(tick unit)

Per hectare				
Per acre				

(d) Incorporation time *(tick one per application)*

Within 6 hours of spreading				
Within 24 hours of spreading				
Within 1 week				
More than 1 week of spreading				
Applied but not incorporated				
Don't know				

(e) Contractor applied *(tick one per application)*

Yes				
No				

(f) Manure source *(tick one per application)*

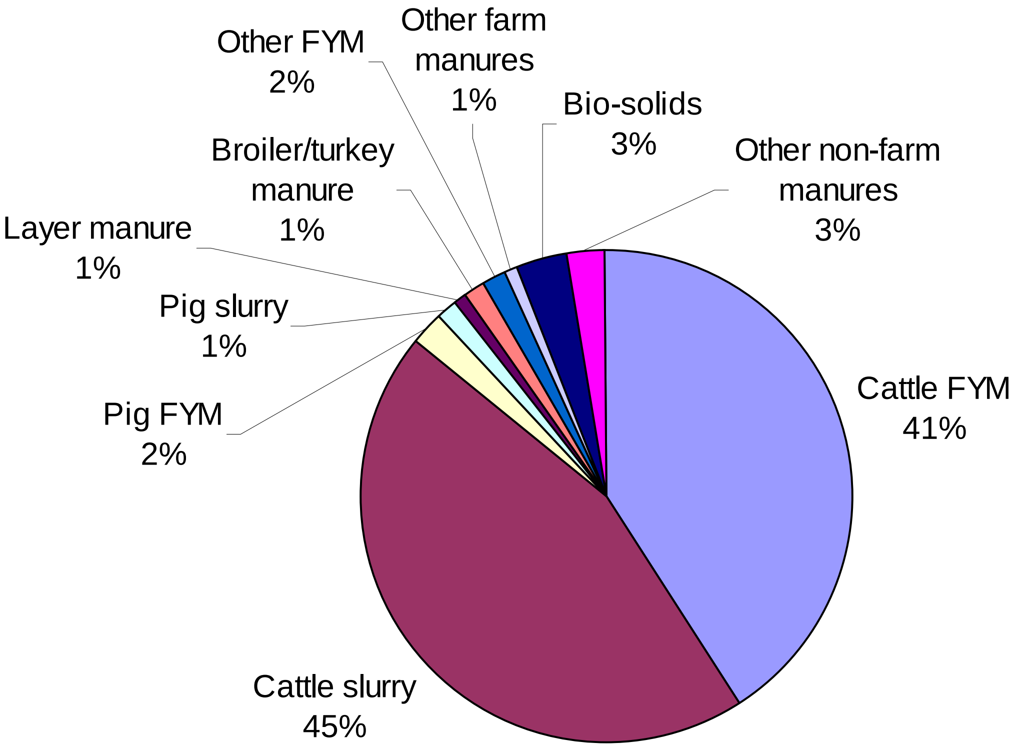
Own				
Imported				

(g) Slurry application method *(tick one per application)*

Broadcast				
Band spread				
Shallow injection				
Deep injection				
Rain gun				
Rotating boom				

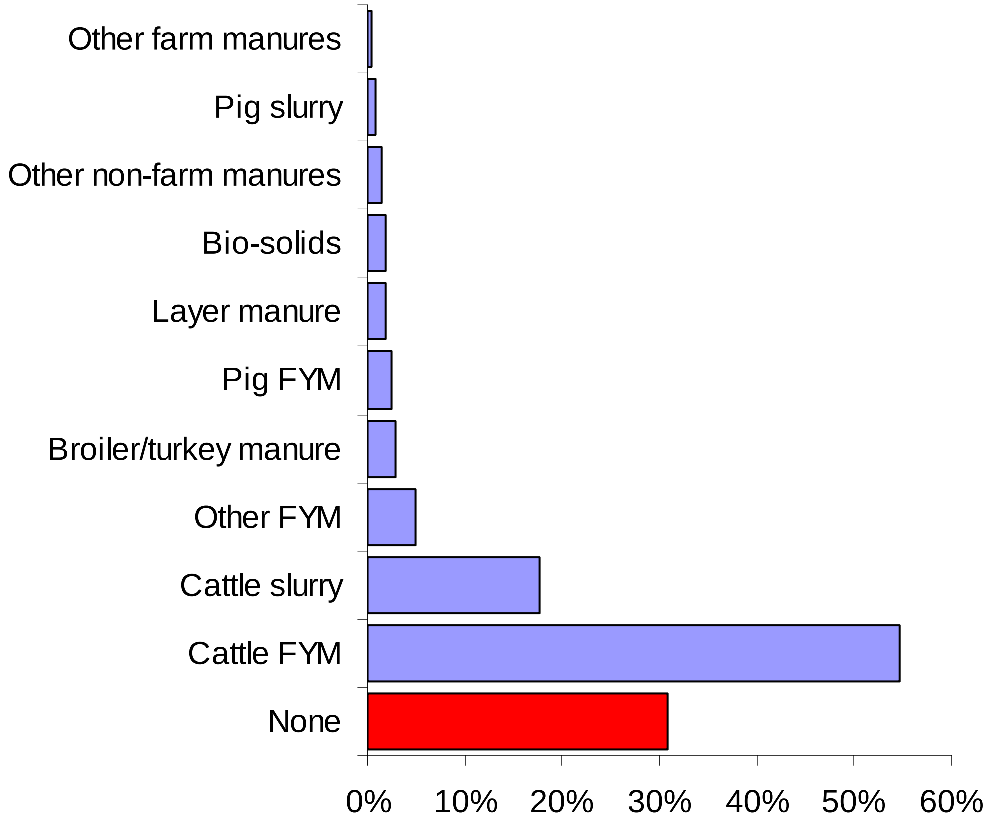
A full range of manure and slurry types have been used as these can have very different Nitrogen contents, and hence have very different implications for the environment. Similarly, the application method and incorporation timings substantially effect the environmental impacts. For example, if farmyard manure and poultry manure are left on the soil following land application, typically around 65 per cent and 35 per cent respectively of the readily available nitrogen they contain can be lost to the atmosphere as ammonia.

Proportion of manure applied by weight, Great Britain, 2008



This method of collection was found to work well, with the results being published in the 2008 BSFP report. The analysis showed that around 96 per cent of the manure applied by weight was cattle slurry or farmyard manure (see the chart above). Just over 30 per cent of holdings did not apply any manure, while less than 10 per cent of farms were applying some form of pig or poultry manure (see chart below).

Proportion of holdings applying organic manure, Great Britain, 2008



Analysing historic data on manure use

As noted above, the method of collection of manure data has evolved in recent years. Some of the questions have remained fairly similar since 2004, while others could be made consistent with some manipulation. Also, the data has only been weighted to be nationally representative since 2007 (unweighted figures had previously been presented).

We asked FERA to re-analyse the manure data since 2004, identifying where it was possible to present a consistent time series. This was then taken by dmrkynetec to produce a summary of the manure results, including time series where possible, which they published in the 2008 BSFP report (and is reproduced in Annex 4).

The analysis showed that the proportion of farms applying each type of manure has remained reasonably constant over the last five years (see the table below). This suggests that, unless identifying small annual changes are critical, there may be limited benefit in collecting this data each year.

Proportion of farms applying each type of manure, Great Britain

		Manure type							
Year	***None***	***Cattle FYM***	***Cattle slurry***	***Pig FYM***	***Pig slurry***	***Layer manure***	***Broiler/ turkey litter***	***Other FYM***	***Other***
2004	28	60	18	2	1	2	2	5	4
2005	31	58	19	1	1	2	3	4	3
2006	30	59	19	2	1	2	2	3	3
2007	33	56	20	1	1	2	2	2	3
2008	31	55	18	3	1	2	3	5	4

The analysis also identified that 1.1-1.7 per cent of holdings exported cattle farmyard manure each year, while only 0.2-0.6 per cent of holdings exported cattle slurry. Exports of other manures were zero or negligible. A slightly higher proportion of farms imported manures – these are shown in the table below.

Proportion of farms importing manure, Great Britain

			Manure type					
Year	***Cattle FYM***	***Cattle slurry***	***Pig FYM***	***Pig slurry***	***Layer manure***	***Broiler/ turkey litter***	***Other FYM***	***Other***
2004	1.3	0.5	0.4	0.2	0.4	1.8	0.0	2.4
2005	1.9	0.1	0.4	0.1	1.1	1.9	0.1	2.7
2006	2.1	0.1	0.4	0.0	0.8	2.1	0.3	3.3
2007	2.6	0.6	0.5	0.4	1.1	1.7	0.1	3.2
2008	2.8	0.4	0.5	0.2	1.4	2.0	0.4	3.3

The full analysis of manure data is presented at Annex 4.

4. Modelling manufactured fertiliser applications

Introduction

Eurostat's initial proposals for the Farm Structure Survey included a requirement for Member States to collect information on fertiliser usage at farm level. The UK, and some other Member States, argued strongly against this. We believe that there are only limited policy needs for data at this level, that accurate data cannot be collected through a postal survey (as the Structure Survey is in the UK) and that the administrative burden placed on farmers is unacceptable.

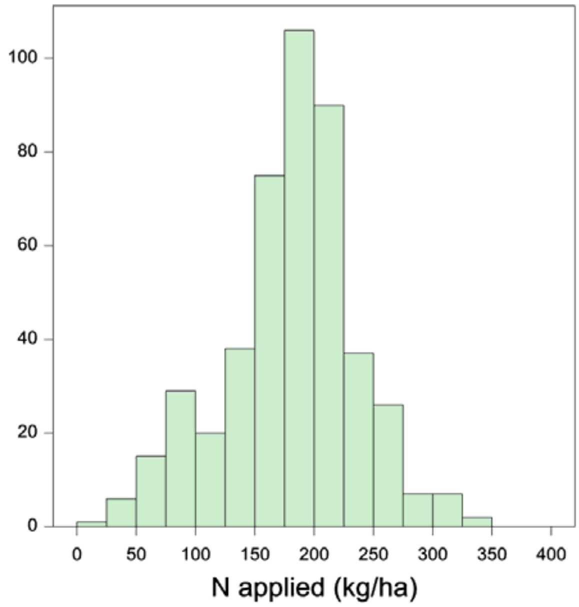
As an alternative, we suggested applying regional (NUTS1) or national application rates by crop to the Structure Survey data, which would allow estimates to be produced at sub-regional level. To further refine this method, we have investigated whether it is possible to use explanatory variables such as farm size and type, the number and type of animals on the holding, soil type or whether the farm was in an NVZ to produce more accurate estimates.

Exploratory data analysis

The following analysis (which is given in full in Annex 5) explores whether we can model the application rates of nitrogen on wheat fields by using data from the 2007 British Survey of Fertiliser Practice and Farm Structure Survey (ie. the June Survey in England). The assumption was made that if it is not possible to model the most commonly applied nutrient to the most widespread crop, then the possibilities for other crops and nutrients are severely limited.

The BSFP collects data on individual applications across each field on the holding. The data shows that nitrogen is usually applied in 2 to 4 separate applications, which averaged, in total, around 185 kg/ha on wheat in 2007. Because data on each field is collected, this can be further aggregated (weighted by the size of the fields) to get the farm-level estimate which would be required for the Farm Structure Survey. There were 450 wheat-growing farms in the dataset. As the chart below shows, there is considerable variation in nitrogen applications to wheat. The mean rate was 185 kg/ha, though the rates varied from 12 to 386 kg/ha.

Farm-level nitrogen application rates on wheat, BSFP, 2007



The exploratory analysis identified that there was little variation in applications by NUTS1 region. Even using Joint Character Areas (JCAs), which have been grouped together based on their physiogeographic, land-use, historical and cultural attributes, showed that there was considerable variation in application rates within these areas. Some substantial differences between JCAs were observed, but the sample sizes within areas were generally small (given there are 159 of them).

We also explored the variation by farm size. There was some variation between sizes, but no consistent pattern. See the table below.

Farm-level nitrogen application rates on wheat by farm size, BSFP, 2007

Farm size	Mean application rate (kg/ha)
Very small	175
Small	174
Medium	189
Large	180
Very large	184

Application rates are highest, and have least spread, on cereal farms (see table below). The application rates were lowest, and most variable, on dairy farms. In general, the application rates are lowest on farms with livestock, which is likely to be linked to the use of manures.

Farm-level nitrogen application rates on wheat by farm type, BSFP, 2007

Farm size	**Mean application rate (kg/ha)**
Cereals	191
General cropping	173
Dairy	152
Lowland livestock	155
Mixed	174

To further investigate the presence of livestock on application rates we calculated livestock units for each holding. There was little correlation between the number of livestock units and application rates on wheat.

Soil types were allocated to each farm in the dataset based on the National Soil Map. This is likely to provide only a broad indication of soil type, given that the exact type is likely to vary across the farm (and sometimes across the field). Only farms with deep fertile silt showed a substantially different application rate (173 kg/ha, compared with 185 – 190 kg/ha for the other soil types).

There was no difference in the application rates between farms inside Nitrate Vulnerable Zones (181 kg/ha) and those outside (182 kg/ha).

Farm-level modelling

Linear models using some of the variables examined above were fitted to the data. With the exception of JCA, none of the models containing a single explanatory variable were able to explain much of the variation in application rates. The main farm type (5.9 per cent) and the proportion of wheat on the holding (5.8 per cent, perhaps showing the benefits of economies of scale) explained most variation, but these figures are very low.

Even when a multiple model, containing 4 explanatory variables was fitted to the data, it was only able to explain 19 per cent of the variance within the observed application rates.

Linear models fitted to the data to try and explain nitrogen application rates on wheat

Model (constant +)	**Percentage variance explained**
Wheat area	4.5
Wheat % of the holding	5.8
RB 209 soil type	1.0
Log LU	0.6
Robust farm type	3.7
Simplified farm type	4.5
Main farm type	5.9
NUTS 1 region	0.8
JCA	14.6
JCA + Wheat % + Wheat area + Simplified farm type	19.3

It is clear that the models developed here are unable to explain a significant amount of variation in nitrogen application rates on wheat. Given this, it seems unlikely that the method could be expanded to other fertilisers and crops.

The reasons for our inability to model fertiliser use are probably threefold. Firstly, the explanatory data we have may be inexact, and we are not able to accurately capture their true impact. For example, we have only approximate information on soil types and the availability, and nitrogen content, of manure. Secondly, we are missing some explanatory data such as historical cropping patterns. Finally, we cannot model farmer behaviour, which may have a random element to it (because of limited information, for example).

While we have not been able to model usage using Structure Survey variables, the limited demands for sub-regional data on manufactured fertiliser could be met by applying national crop averages at farm level.

Policy Requirements for Data on Manure Use

Summary

Policy programmes within Defra and its agencies with an interest in manure management were identified. Key contacts were approached to explore which policies were supported by the data, and the respondents' experience of the British Survey of Fertiliser Practice (BSFP). Data on manure are relevant to a diverse number of programmes due to the agronomic benefits of using manure as a fertiliser, as well as the risks that its usage poses to the environment. Eleven contacts provided feedback, around three-quarters of which were aware of the BSFP.

The specific policies which were affected by manure usage were many and varied. We identified ten EU policy areas that were relevant. The Water Framework and Nitrates Directives cut across many Defra programmes and depended considerably on manure data for monitoring and policy development (particularly with regard to the Nitrate Vulnerable Zone (NVZ) Action Programme).

The use of manures is also relevant to climate change where the level of greenhouse gas emissions is affected by the volume of manure generated, and how that manure is stored and applied to the land. In particular, BSFP data was used to measure how well the UK was progressing towards the targets in the EU National Emissions Ceilings Directive.

Livestock housing and the spreading of animal manure contribute considerably to levels of ammonia emissions. The data informed the development of a strategy on ammonia reduction from agriculture based on manure management. The protection of designated conservation sites from ammonia deposition and from polluted run-off from land was also considered important.

The importance of sustainable soil management and maintaining and enhancing carbon in agricultural soils was an increasingly important strategy. The use of manures was becoming more important as the availability, use and energy needs associated with producing manufactured fertilisers became subject to greater scrutiny.

Overall, the BSFP was considered to be a very useful survey that covered all the necessary detail of manure usage in a useable format, and the data would continue to be of use in the future. Most respondents would prefer manure data to be collected annually so that the impact of policy changes and other drivers (such as fertiliser prices) could be evaluated. Others, particularly those who were investigating longer-term changes, would be happy to see the data collected less frequently.

Additional data requirements were identified including the total nutrients applied to each field (inorganic and organic), and the quantity of manure stored on each holding and the type and size of this storage (though some of this is already collected in the BSFP and Defra's Farm Practices Survey). Data by country, with the inclusion of Northern Ireland, was thought to be useful, well as regional detail for England.

Introduction

This survey was commissioned by Defra Farming Statistics to identify and summarise the main policy needs for data on manure use. A key source of information on manure use is the British Survey of Fertiliser Practice, which is now managed by Defra Statisticians in Food and Farming Group, although the fieldwork, data collation and tabulation are contracted out. The British Survey of Fertiliser Practice is a long running survey funded by Defra and the Scottish Government, which collects data on manufactured fertiliser. Organic fertilizer has been included as a regular part of the survey in recent years and the survey collects information on the volume and type of manure applied, the application method and the timings of incorporation. The survey also records the number and volume of movements of manures between farms. The volume of nitrogen applied to fields is estimated based on standard nutrient contents.

Published reports from the BSFP are available on the Defra InterNet site at: http://www.defra.gov.uk/farm/environment/land-manage/nutrient/fert/bsfp.htm

The survey was used to gather information on the main policy drivers, which were important to many areas within Defra and its agencies where manure use was relevant, with specific reference to the Department's Public Service Agreements, Departmental Strategic Objectives and associated Intermediate Objectives. Information was also to be collected on EU, UK and any other policy drivers that apply – e.g. Water Framework Directive, Nitrogen Vulnerable Zone policies, Waste Directive, Greenhouse Gas emissions, Air Quality (ammonia), etc. The aim was to understand what drives the requirements for data on manure. It was important to discover what other data sources were currently being used and to try and find any gaps in the available information. Comments from the respondents on the quality of the information available from the survey were sought and also how of it was being used.

Methods

Contacts

An initial search of the Defra website was done and possible contacts were identified from the Board and Group Programmes and Ongoing Functions information.

Programmes for which the manure data might be relevant were selected and the contact information was used to send a general email which stated the reason for the inquiry and asked if there was any relevance of the survey to the programme and if so, for the information to be passed onto anyone within that programme who might have an interest in data on manure usage and management. If there was no response a check of the corporate directory was made to ensure that the correct member of staff had been contacted and if this was so a further email or phone enquiry was made to ascertain the relevance of the data to that programme. Useful contacts were made through suggestions from Programme contacts and from using the Corporate Directory by following Group hierarchies. Once likely candidates had been identified either by self or delegated nomination, they were sent the questionnaire and briefing note. Telephone interviews were then arranged or completed questionnaires were submitted by e-mail.

Initial contact with Natural England (NE) was made via e-mail to personal contacts of members of the project team. These contacts passed on the detail of the enquiry to relevant personnel, which were also copied to the project team. The final sequence was the same as for Defra.

Contact with the Environment Agency (EA) was made via email to a personal contact of a member of the project team and also to a contact provided by Defra Statistics Team. These contacts passed on the information to more relevant members of Staff. A contact was also made through one of the telephone interviews with a member of NE. The final sequence was the same as for Defra.

The contact at the Institute of Grassland and Environmental Research (IGER) was provided by Defra Statistics Team. A telephone interview was arranged and completed.

Questionnaire

A questionnaire was developed to produce the desired information from the respondents. It was designed with the help of Defra's Statistics Team along with a detailed Briefing Note, which ensured that the respondents had all the required information about the survey before the questionnaire was carried out. The questionnaire was completed through telephone interviews though the respondents were given the choice of filling the form out themselves and then returning it to the project team. The responses were then collated.

Results

Tables 1 and 2 show the number of programs and the personnel contacted within Defra, and Table 3 shows the same for the EA, IGER and NE. These tables summarise their responses and the final outcome with regard to the receipt of questionnaires.

Annex 1

Table 1. Contacts and responses within Defra

Programme	Title	Response		Result
		Primary	Secondary	
Board	Biodiversity	No interest		No information
	CAP Reform and EU Strategy	Positive	Provided contact within the programme	1 Questionnaire
	National Climate Change and Energy	Not relevant	Provided contact in another programme	Not relevant
	Farming for the Future	Positive	Provided contacts within the programme	3 Questionnaires
	Floods	Not certain of relevance	Provided contact within the programme	Not relevant
	International Climate Change and Energy	Wrong contact	Provided contact within the programme	No response
	Rural Development Programme for England	Not relevant		Not relevant
	Waste	Not certain of relevance	Provided contact within the programme	Not relevant
	Water Availability and Quality	Positive	Provided contact within the programme	1 Questionnaire
Group	Environmental regulation	Not relevant	Provided contact within another programme	Not relevant
	Food Chain	No response		No Information
	Office of Climate Change	Not relevant		Not relevant
	Soils	Positive	Provided contact within the programme	1 Questionnaire
Ongoing Functions	Crops	Not relevant	Provided contact within another programme	Not relevant
Others	Natural Environment Strategic Unit	No response		No Information

Table 2. Defra Contacts

Name	Role	Programme	Result
Paul Bradley	Policy Advisor - Managing the Climate Change and Agriculture policy instruments project.	Farming for the Future	Telephone interview
David Brown	Head, Nutrient Management Unit	Farming for the Future	Completed Questionnaire
Lindsey Clothier	Statistician, Agricultural Change and Environment Observatory Programme	CAP Reform and EU Strategy	Completed Questionnaire
Simon Dawes	Policy Advisor – Nitrates Directive	Water Directorate WQ5: Non-agricultural diffuse water pollution and Nitrates Directive	Telephone interview
Maya de Souza	Head of Branch Soils policy	Soils	Completed Questionnaire
Dr Bruno Viegas	Manager of the Agriculture and Climate Change R&D Programme	Evidence and Knowledge Base Core Function (Food and Farming Group)	Telephone interview

Table 3. Contacts and responses within Environment Agency (EA), IGER and Natural England (NE)

Organisation	Name	Role	Response		Result
			Primary	Secondary	
EA	Jamie Letts	Policy Advisor	Positive		1 Questionnaire
IGER	Tom Misselbrook	Air and Climate Team Leader	Positive		1 Questionnaire
NE	Alan Brewer	Principal Advisor on Environmental Protection	Positive		1 Questionnaire
	Paul Arnold and James Grischeff	Catchment Sensitive Farming regional Advisors	Positive	Provided contact within EA	2 Questionnaires

The questionnaires produced a range of responses, which are detailed by question below. The questionnaire used is included at Annex A.

Q 4) Is manure management relevant to your policy area?

Positive responses were given for all 10 questionnaires. One Defra respondent gave reasons for its relevance, with usage required for the Greenhouse gas abatements committee, for carbon budgets for the UK, and for the cost-effectiveness of carbon usage.

Q 5) a) Specific policies for which organic manure management is relevant

The specific policies were many and diverse, demonstrating the many areas of policy, which are affected by manure usage. Table 4 shows the main policies that were mentioned by the respondents. Others include the EU Bathing Waters Directive and the EU Waste Framework Directive (composting and waste regulations), which were important for the EA respondent. Best practice for nutrient management, the preservation of biodiversity and the management of emissions of methane, CO_2 and ammonia were important for a Defra participant. Monitoring the environmental impacts of CAP reform and other key drivers were essential for another Defra respondent.

Table 4. Number of respondents within each organisation that mentioned a particular policy

Policy	Organisation		
	Defra	Environment Agency	Natural England
EU Nitrates Directive	3		1
EU Water Framework Directive	2	1	3
CAP Cross-Compliance	2		1
EU Groundwater Directive	2		
Climate Change: Mitigation and Adaptation	2	1	
NVZ	2		1
Catchment Sensitive Farming	1		2
Soil Management	2		
Environmental Stewardship	2		

The Climate change participant from the Defra Farming for the Future programme mentioned that they were at an early stage of policy cycle, creating and analysing up to 50 potential policy options, which must be reduced to 8-10. The main drivers were the minimization of manure usage and the optimisation of nutrients. There were also mitigation methods to reduce emissions and their cost including Climate Change Programs on Mitigation and Adaptation. This involves strategies on how to live with Climate Change and how agriculture must remain viable and sustainable under these changing conditions.

Another Defra respondent was clear that manure management was specifically relevant to two priority areas:

1) Climate change and soil, including the need to maintain and enhance the amount of carbon in soils, including agricultural soils.

2) Sustainable soil management in the agricultural sector, including the need to maintain and enhance soil organic matter in agricultural soils, and managing the use of nutrients to keep adverse environmental impacts to a minimum.

The interviewee from IGER was gathering data, which showed how well the UK was progressing towards the targets contained in the EU National Emissions Ceilings Directive.

Natural England respondents were also concerned with national policies driven by EU policies, including the development of the revised rules for farmers in Nitrate Vulnerable Zones, which are coming into force on 1 January 2009. There was also the revision of the existing three Codes of Good Agricultural Practice into one integrated Code, which is to be published soon. In addition, there was the development of a strategy on ammonia reduction from agriculture based on manure management. The protection of designated conservation sites from ammonia deposition and from polluted run-off from land was also considered important. The England Catchment Sensitive Farming Delivery Initiative (ECSFDI) was important for both of the organisations CSF Regional Advisors, as were Nitrate Vulnerable Zones (NVZ), the Soil Protection Review and the Codes of Good Agricultural Practice. The EA participant also mentioned these as well as anaerobic digestion and climate change.

b) Relationship with organisational/departmental objectives:

Departmental Public Service Agreements

Two Defra and the EA participants gave PSA 28[1] as the target that the policies feed into. The previous PSA 3, which included bringing into favourable condition 95% of important wildlife sites by 2010, was mentioned by two of the NE respondents.

Departmental Strategic Objectives

For Defra the important objectives were: (i) a society that is adapting to the effects of climate change; (ii) a healthy, resilient, productive and diverse natural environment; (iii) a thriving farming and food sector with an improving environmental impact; (iv) a sustainable, secure and healthy food supply. A NE respondent mentioned that an important objective of their organisation was to increase levels of farmer engagement with the regulations. For the EA respondent the organisation's objectives were to improve inland and coastal waters, improve and protect soil quality and to be ready to adapt to climate change.

[1] 'Secure a healthy natural environment for everyone's well being, health and prosperity, now and in the future'

Intermediate Outcomes

There were not many responses to this question. A NE respondent gave the relevant organisational outcomes as: (i) 'our rich biodiversity thrives across the landscape, with ecosystems and habitats resilient to climate change'; (ii) 'land is managed in a way that delivers environmental services alongside other benefits'. The EA participant mentioned water framework river basin planning cycles and that each water body should be at "Good ecological and chemical status".

c) Key indicators in use and sources

The main set of indicator for the Agricultural Change and Environment Observatory Programme were:

1) Nitrogen and phosphate application rates:
i) For tillage and grass (England & Wales);
ii) For key crops in England & Wales and by region.
see: https://statistics.defra.gov.uk/esg/ace/c4_data.htm
2) Cross compliance monitoring and evaluation:
Monitoring impact of NVZs: application rates (within/outside NVZs), timings of applications, planning, storage capacity.
See: https://statistics.defra.gov.uk/esg/ace/crosscompliance/index.htm

Another Defra respondent mentioned inventory data, the Greenhouse Gas Inventory (http://www.ghgi.org.uk/) and the National Atmospheric Emissions Inventory (http://www.naei.org.uk/) and economic data such as Farm Business surveys and data on land uses. A NE participant mentioned that Defra has a number of indicators for water quality, air quality (acidity and nutrient enrichment) and climate change (manure management can influence methane emissions and nitrous oxide emissions).

For the EA it was important to reduce diffuse pollution (reduce runoff), achieve healthy and protected soils (improve soil quality), utilise water frameworks, and standards for key chemicals in waters, and for heavy metals in soils.

d) Are there any EU policies where organic manure management is relevant e.g. Water Framework Directive?

The responses to this question are summarized in Table 5.

Table 5. Number of respondents within each organisation for which each of the listed EU policies were relevant

	Organisation			
Policy	Defra	Environment Agency	IGER	Natural England
Nitrates Directive	4			2
Water Framework Directive	4	1		3
CAP Cross-Compliance	2			
Groundwater Directive		1		
Integrated Pollution				1

Prevention and Control Directive			
Habitats Directive			1
Soil Framework Directive	1		
National Emission Ceiling Directive		1	
Waste Framework Directive	1		
Bathing Waters Directive	1		

e) Is anything emerging where organic manure management is going to be important?

Climate change was the most important emerging factor for two Defra participants. The importance of maintaining and enhancing carbon in soils, including agricultural soils, was also important for one of these, and the use and energy needs associated with producing and using fertilisers was crucial for the other. The development of Anaerobic Digestion processing facilities and the handling of the digestate was seen as important to another respondent. Climate change will alter cropping patterns, and it will be important to find out which crops are going to expand in the future and whether they will require different inputs. The IGER interviewee was concerned about the amount of organic manure spread and whether this was being offset against the farms' nutrient management plan. The methods of application were also considered important and at present there is not much legislation relating to the spreading of manure but it may be coming. The timing of the application and its incorporation thereafter were also factors whose importance was increasing.

For NE, a key issue was the new rules for NVZs, including a mandatory manure Nitrogen (N) efficiency index to be used in calculating compliance with a crop N limit (Nmax). It was suggested that this would push farmers towards more spring applications of manure. These N efficiency values will increase again from 1 January 2012. Another NE participant reported that the Bathing Waters Directive was increasing in importance. Failures to meet required levels of pollutants in coastal waters were quite often livestock related, and need to be reduced. Also there was an increased awareness for the need to control the usage and to manage the storage of manure.

NVZs and the storage of manure combined with the use of slurry/waste in anaerobic digestion were the most important factors emerging for the EA. There is pressure to reduce greenhouse gas emissions from agriculture. Farming must therefore become more efficient. Manure was spread as part of waste management in the past, but now it is considered to be a resource. There are financial environmental drivers now, which were not present before. Landfill tax and recycling requirements have also become important drivers along with the pressure to recycle.

Q6) & 7) Are you aware of the British Survey of Fertiliser Practice (BSFP)? (Yes/No) If yes, do you currently use data from the BSFP?

Table 6 summarises the responses to this question.

Table 6. Number of respondents within each organisation which were aware of the British Survey of Fertiliser Practice and the number that used it

Organisation	Aware of BSFP		If yes, do you use it?	
	Yes	No	Yes	No
Defra	5	1	4	1
EA		1		
IGER	1		1	
NE	2	1	1	1

8) Which data do you find useful?

All the data were considered important by three of the Defra participants, including both core data on inorganic fertiliser use and data on manure, and the long term trends and types of fertilisers being used that could be drawn from the survey were particularly important to one of these. Another utilized the manure application rates and methods, and the timings of the applications, as did the interviewee from IGER.

For one of the NE respondents, the month of application was important, although there was also interest in the 'big picture' for manure types regardless of crop type e.g. how much pig slurry is applied in each month. Slurry application technique was useful as well as the extent to which farmers make an allowance for manure nutrients, the use of contractors, and the average rates of application.

9) Are there any data that you don't find useful?

Three Defra respondents and the IGER interviewee replied that there were none, but a NE participant noted that the sampling regime distorts the influence of the pig and poultry sectors on organic manure exports. These are the main exporters rather than cattle farms. Another Defra participant mentioned that they had only made use of specified data, and only scratched the surface at present so was not able to comment fully on this. However they could see the potential for an Agricultural Change and Environment Observatory Programme project on fertiliser/pesticide use.

10) Is there any additional information not currently collected that you think would be useful?

One Defra interviewee mentioned that they don't use the report but instead take the raw data and process that to provide answers to specific questions. This data processing is done by ADAS and also by the Defra Statistics team in York, particularly with regard to policy questions.

There was also a query about precision spreading of fertilisers as part of survey data gathering. If this were not already done it would be useful to gauge how widespread precision spreading is on farms.

Defra are encouraging a change from mineral to organic manures, and there is a need to know the extent to which this is happening. There is also a need to improve the timing of manure application and it is therefore important to know when this happens. Greater knowledge of farmers' decision-making processes would also be useful, such as how do they decide how much fertiliser they need and the balance of mineral and manure fertilizers to apply? Emissions are dependent on local climate (e.g. wet conditions increase Nitrous oxide release) so regional data on issues such as the timing of application may be useful

IGER and NE require data on manure storage, methods and capacity, and NE thought it would be useful to identify the application techniques used by contractors. It may also be useful to have a breakdown of inputs on a Defra regional scale and, better still, for each river catchment area.

11) Is the information in a useable format?

Three of the Defra participants and the IGER interviewee thought that the format was useable, and one mentioned that that it was very clear and useable with the right level of detail, and the report was used to answer specific questions in negotiations with the European Commission, e.g. how much nitrogen was used on arable fields in GB. Another felt that it needed more information on application by crop type. However another thought that access to data for individual holdings or better geographical referencing would allow linkages with other key datasets and allow better use in analysis.

One of the NE respondents agreed but would have liked to see a fuller explanation of the data, and wanted more explanation of the table headings. It was felt that sometimes the language used was difficult to follow and needed re-reading more than once.

Q 12) & 13) Do you think it might be useful to you in the future? If yes, what data in the current survey might be useful to you?

Five participants from Defra, all three from NE and the respondent from EA and IGER all thought it might be useful in the future. Of these, only one from Defra and NE did not think it would all be useful. One Defra participant specified application rates and timings of applications by crop combined with geographical reference of field and the CPH number. The interviewee from IGER commented that it was a very useful survey now and would be in the future and it was a survey that the organisation had fought hard to keep. It's detail and comprehensiveness is the envy of many EU countries.

Q 14) Is there any additional information not currently collected that might be useful to you?

One respondent from Defra felt that presenting the data spatially might be useful. As well as the number of farms importing/exporting manure, including sludges, information on the distances involved would be useful. Temporal trends were required for the manure section, as provided for the inorganic fertiliser section. Another Defra interviewee wanted information on the storage of organic manure on farms: quantity stored, type and the size of storage. They also would have liked the total nutrient loads in soil (and whether these are what drives farmers), so total nutrients applied from fertilisers plus organic materials (manure, sludge, etc.) would be useful, even if this would have to make assumptions about nutrient content of organics. Data on month of application provide an indication about emissions to water and air, but some insight into how farmers decide the timing, type and amount of fertiliser would extremely useful.

The participant from IGER thought it would be useful if it incorporated data from Northern Ireland. It would also be useful if the data from England and Wales were separated, as data from these countries have to be reported separately. The ideal survey would have separate data for England, Wales, Scotland and Northern Ireland.

From both NE CSF participants there was a requirement for the breakdown of inputs by Defra region (county would be even better) and also by river catchment area. They need information for the farmers to use, such as the Phosphorus run-off from fields and in rivers. This would help to show the effect of the new regulations on nutrient levels in their catchment areas, to give them encouragement to continue. It would also be useful to know how much NPK is present in manure when applied and after that how much available to crops.

The EA interviewee felt that there was too much focus on quantity. There was very little calibration of application equipment and therefore little knowledge of rates of application to the land. Quantities of manure applied on upland versus lowland, and intensive versus non-intensive farmland would be useful as well as information on other waste products that are spread on holdings.

15) Is the survey report presented in a user-friendly manner for your purposes? If not, how could it be improved?

Some felt this question had already been answered but four from Defra were positive about the survey. An NE participant thought it would be useful to present the actual questionnaire used in the survey as an Appendix. The EA representative thought that average figures were not very meaningful. The whole publication needed to be more ‘user-friendly’ and it was felt to be too long at 91 pages. It required a good summary report covering the key issues. A Defra respondent wanted proper standard errors for the items within the report to ensure the proper interpretation of results. The presentation of overall totals for England was requested as well.

16) The survey is currently run every year. If it was only run every other year, would this affect your use of the data? Would it still be fit for purpose?

One Defra participant replied that changing to a biennial format would have an impact, as the state of implementation of the Nitrates Directive has to be reported to The European Commission on a specific year, so data were needed every year to make sure that they were available for the required year. The data show how the new regulations are affecting farmers' behaviour with regard to manure usage, but it is much easier to track trends and changes if continuous data are available. Another Defra respondent mentioned that historic year on year comparisons have been useful, particularly in respect of monitoring the impact of CAP reform. Another commented that with current price impacts and changes to NVZs, an annual survey was very important at the present time. This was supported by the IGER participant who was concerned about the collection of data on urea. Urea is a major contributor to the amount of ammonia being released by agriculture. There are large variations in the price of Urea between years, which affect its usage. These changes would be missed without annual reports.

The Pesticide Usage Survey is carried out every 2 years, and another Defra participant mentioned that there were good reasons to link the 2 surveys together as the questions could be asked of the same people. Another thought that every other year would be sufficient and this may allow a larger survey, which would produce more robust data. Every other year was fine as they were looking at very long-term trends, currently on a 40-year time line. Alternate years would be fine for calculating the carbon budget, as this was done every five years.

NE participants felt that information on manure management did not need to be collected every year, as changes usually take some time to be reflected in the data collected, but it would be better if it was collected every year, as this would make it easier to understand fluctuations, how prices were affecting fertiliser use, and how CSF was affecting farming practices.

The EA representative considered that there was no reason why the survey could not be biennial. It does need to tie in with the cycle of NVZ consultations.

17) Any other observations on the BSFP?

Two participants from Defra felt it was a very useful source of information. There would be a lot of negative impact if it were not carried out. The Nitrates Directive Policy team had asked for organic manure to be included in the BSFP for European Commission work and it also feeds into surveys of farmer behaviour. A Defra interviewee was more concerned that there was data collection and therefore a data series available. Data collected each time must be comparable. The interviewee also wanted to know if the sample was random each year, with different farms used. Soil type was very important when determining nutrient loads and it would be useful to have information on soil type along with manure information. It would also be useful to gather statistics on novel forms of bio-solids (e.g. anaerobic digestion from food waste). It would be helpful if the tables in section C had a column with total area for each crop, since this would allow a quick assessment of total amount of fertiliser used.

The IGER participant thought it did not cover the whole of the agricultural sector. There were reservations about the pig and poultry statistics because the sample was too small.

The three respondents from NE had no comment and the sole participant from EA commented that the survey adds to the evidence required. The survey must be tagged so that it is easy for users to find.

18) Do you use any other data sources? (What data, where from, why used, etc.)

Defra Farm Practice Surveys were mentioned by two Defra participants, the IGER and a NE interviewee, as well as the Agricultural Census. One Defra respondent also used more specific data from projects, for example SP0530 ‘Organic manure and crop organic carbon returns – effects on soil quality’. Another Defra participant mentioned publications from the Fertiliser industry, which are published through the Levy bodies. The Environment Agency has data on sewage sludge composition.

The IGER participant also used statistics from the Devolved Administrations such as livestock numbers and crop areas. A NE interviewee mentioned information from maize growers, the NFU, and Merchants such as the sales of fertiliser etc.

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Defra objectives

The business challenge for Defra is to optimise budget without loss of quality in the data collected for the annual BSFP. To achieve this, Defra recognise the need to:

- Investigate and evaluate the feasibility and practicality of employing alternative methodologies to collect the BSFP data in the future
- Understand the impact alternative methodologies could have on the quality of resultant data

Alternative methodologies under consideration are:

- Electronic download of data from proprietary software systems – Muddy Boots (Cropwalker); Gatekeeper (Farmade/Farmplan); Multi-crop (Farmade)/Crop Manager (Farmplan)
- Opportunities for telephone interview to collect data
- Postal/self completion data collection

Research objectives

- Evaluate the potential for electronic data collection
  - Estimate the percentage of farmers using software systems to record farm data, and the share of software brand by region, robust type and farm size
  - Estimate the percentage of farmers who might be willing to submit data relevant to BSFP by electronic download
  - Evaluate how comprehensively popular farm software reports can match the data fields required for BSFP
  - Compare the quality/variability of information input to popular software with the existing data collection method
  - Comment on the resource required to extract data from popular software to usable inputs

Research objectives

- Evaluate the potential for telephone data collection
  - Estimate current average interview time to complete a field sheet
  - Identify essential components of the survey and re-design a simplified field sheet/questionnaire guided by Defra
  - Pilot the new edited version among a representation of existing robust types recording field sheet times and compare to the existing face-to-face version
  - Collect interviewer assessment on the ease of administering by telephone
  - Collect farmer assessment on the perceived logic/content/inclusions and experience of participating by phone versus face-to-face

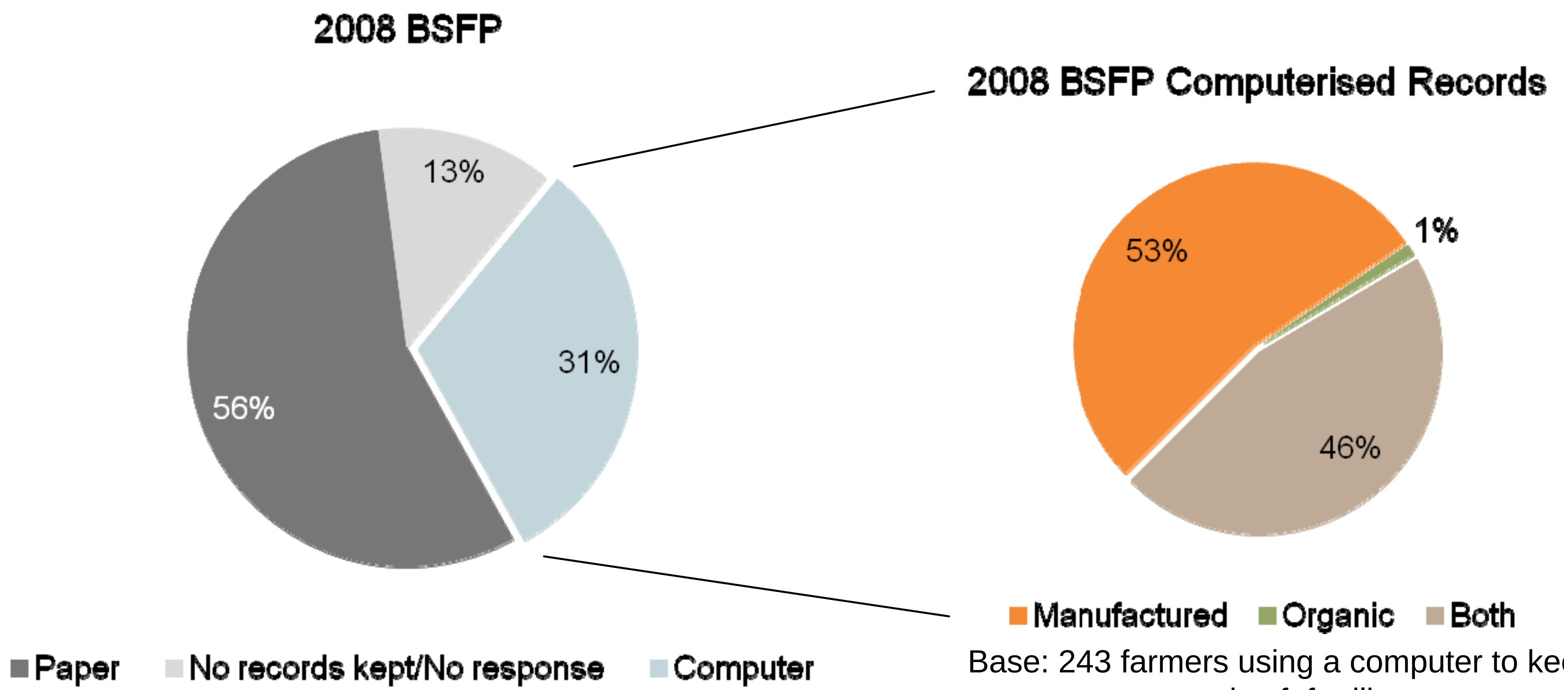
- Establish the willingness of a representation of existing robust types to consider completion of the telephone version by post as a self completion exercise

Section 1

Potential for Electronic Data Collection

2008 BSFP record keeping

Overall, 31% of farmers use some form of computerised record keeping, and just under half record both manufactured and organic applications

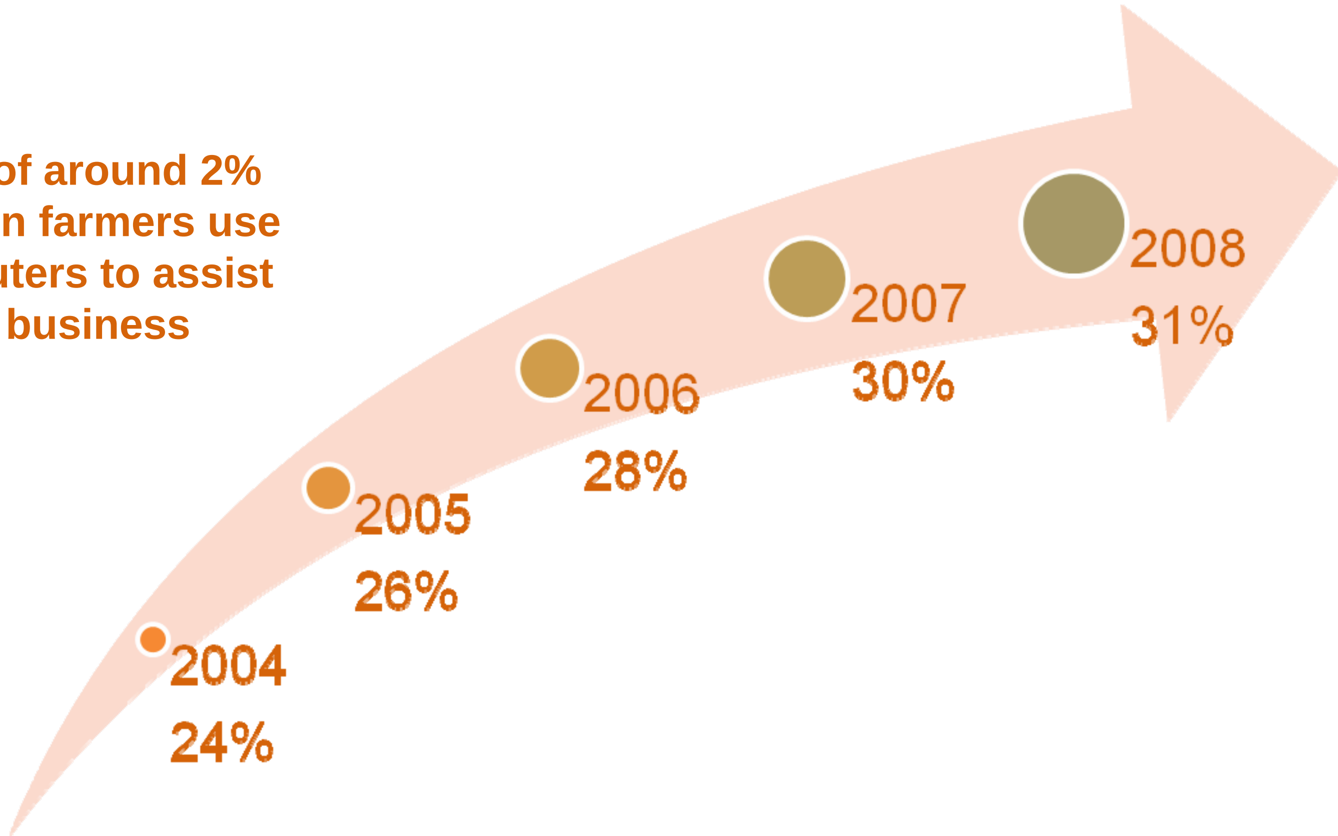


Base: 766 farmers responding to BSFP 2008 supplementary questionnaire

Base: 243 farmers using a computer to keep records of fertiliser

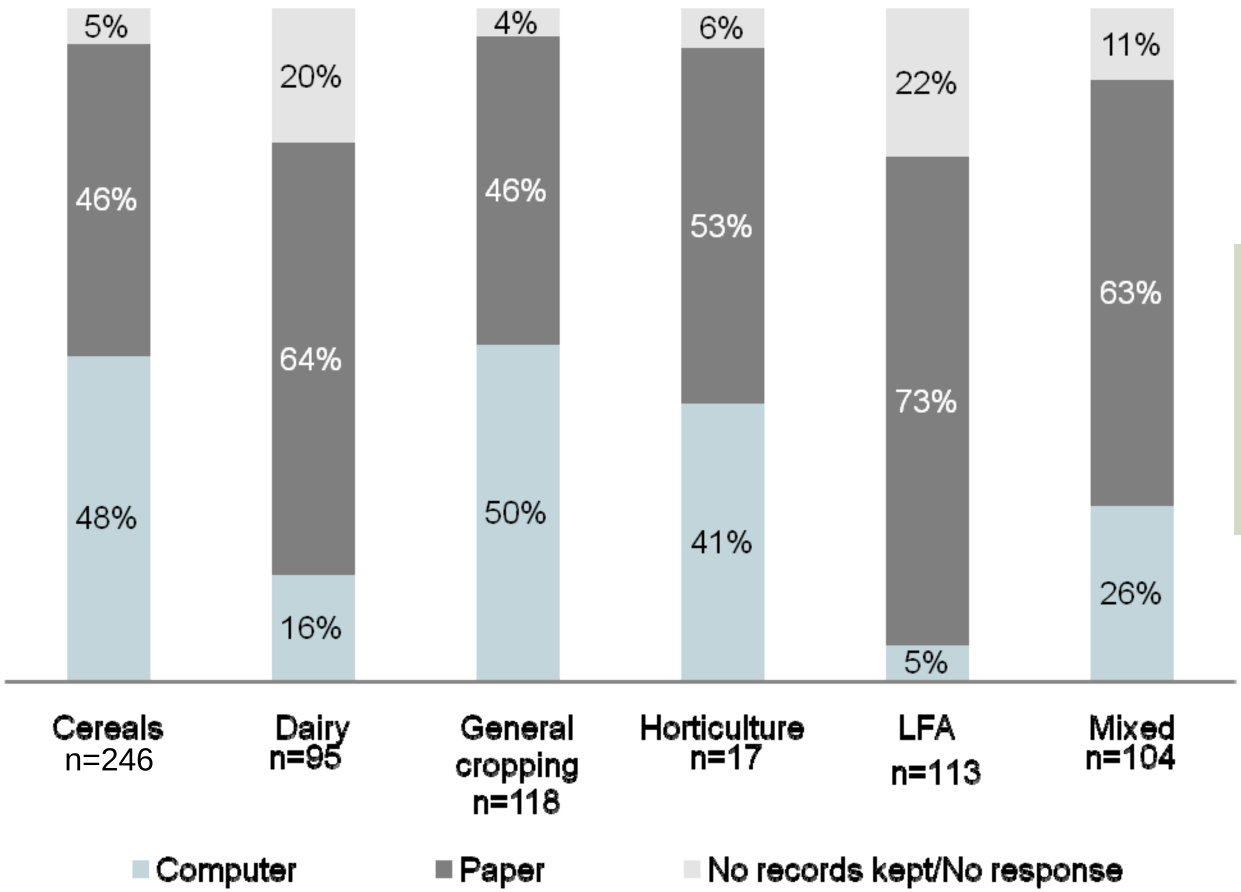
Trend in use of computers

Growth of around 2% per year in farmers use of computers to assist their business



Base: farmers responding to BSFP supplementary questionnaire

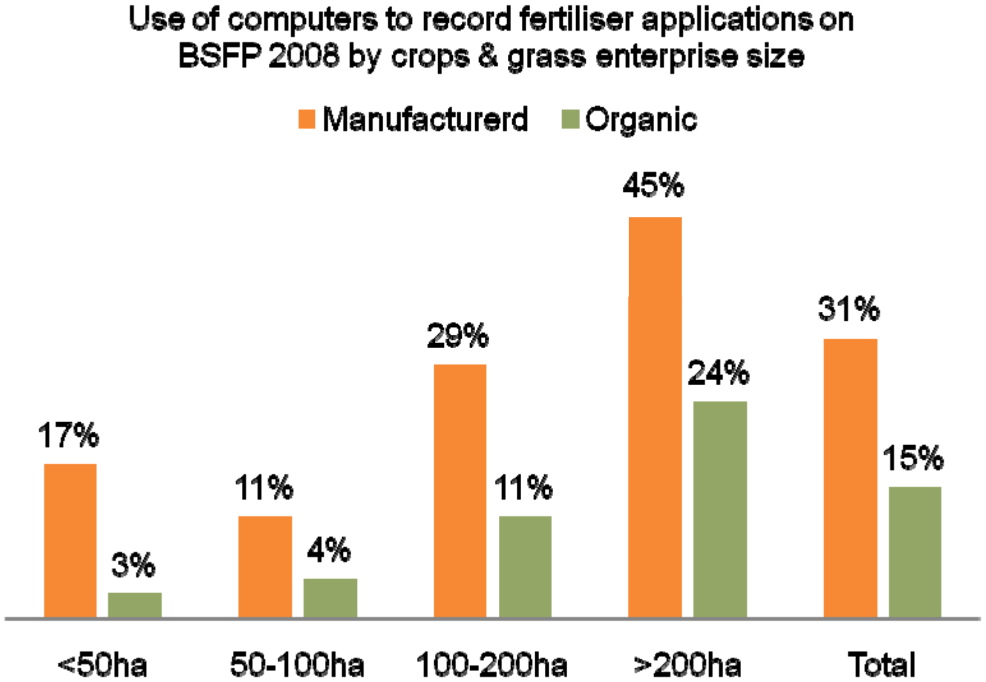
2008 BSFP record keeping by robust type



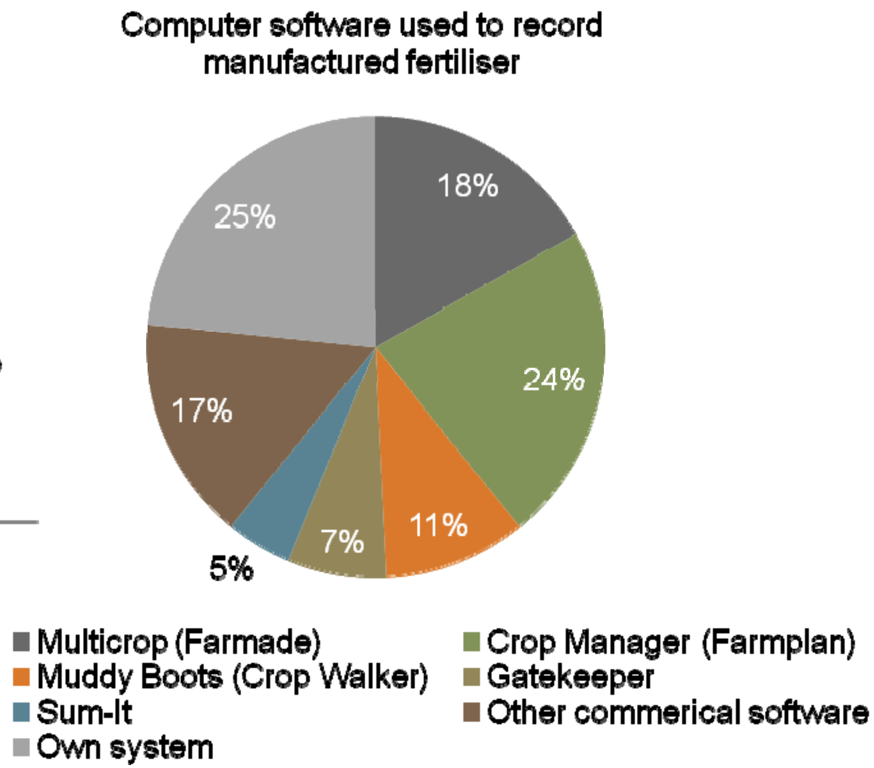
A higher incidence of computer record keeping is noted on farms with arable enterprise, and in horticulture (although the latter is a very low base for analysis)

Base: farmers recording manufactured fertiliser on computer

Use of computers



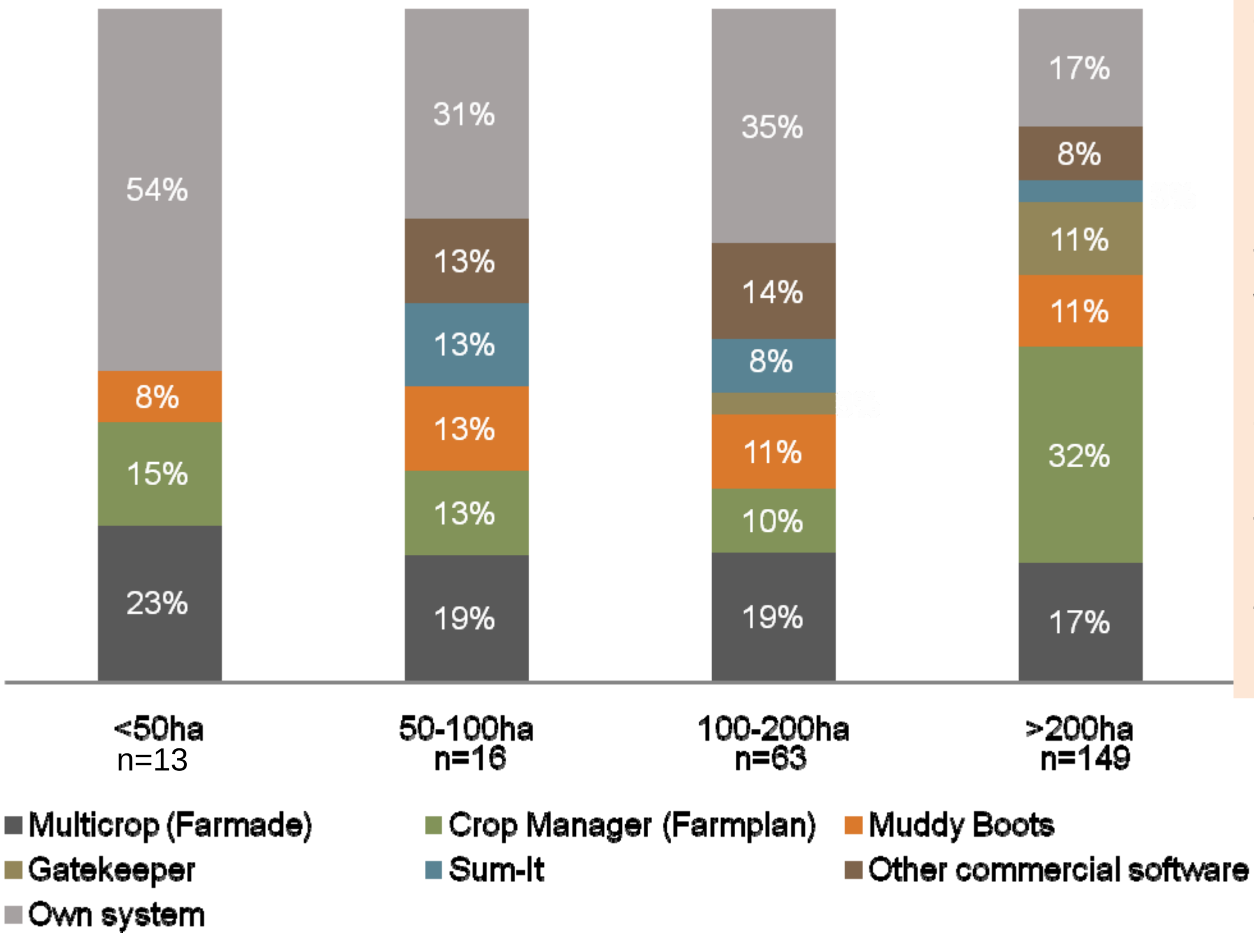
Base: 766 farmers participating in BSFP 2008



Base: 241 farmers using a computer to keep records of manufactured fertiliser

The larger the farm the greater incidence of keeping records on computer.

Share of software by crops & grass enterprise size

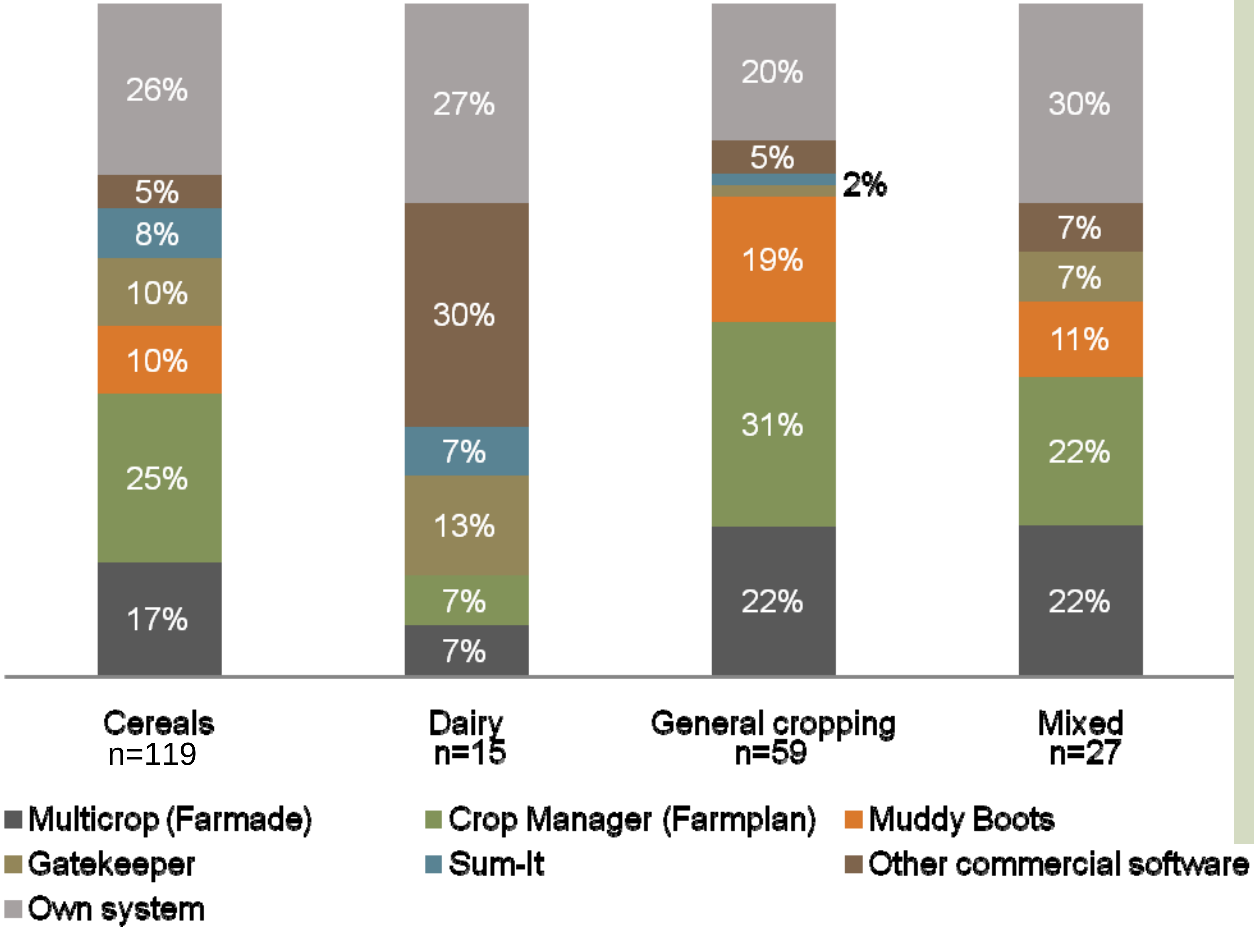


The 'share' of software used shows the smaller farms more inclined to manage with their own recording system, probably in Excel, until such time as the size of farm warrants a more professional or flexible approach.

The Farmade, Farmplan and Muddy Boots software account for 53% share of use in total (based on the total sample of farmers using a computer to record fertiliser records)

Base: farmers recording manufactured fertiliser on computer (farmers responding to 2008 BSFP supplementary questionnaire)

Share of software by robust type

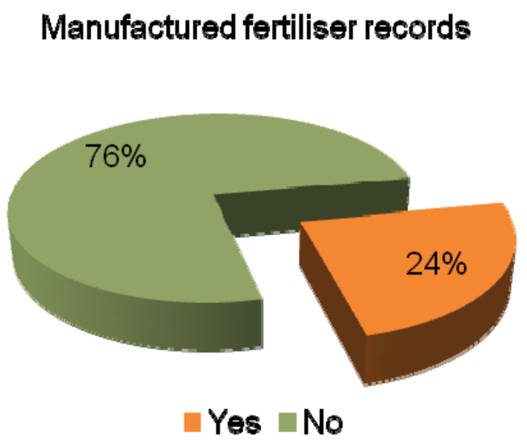


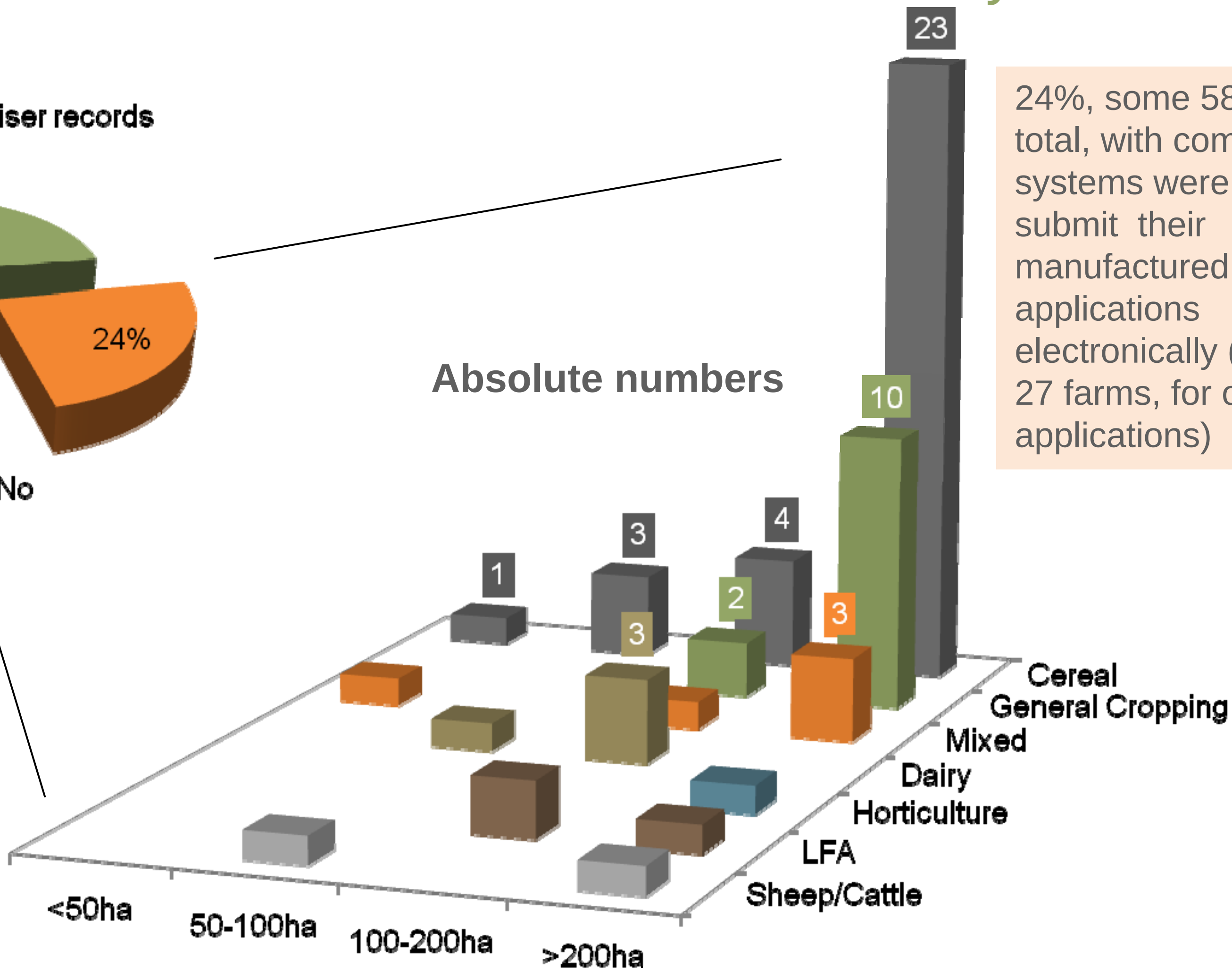
The ‘share’ of software used is **broadly** similar across different robust group types allowing for variation in sample size.

Outside of ‘cereals’ and ‘general cropping’ the bases for analysis are very low; and these ‘other‘ robust group types would probably tend to be smaller enterprises in any case, so we do see some skew toward ‘own systems’, or a function of the complexity of the agronomy required on farm. On dairy farms in particular, the ‘other’ commercial package is more often Adas – Planet.

Base: farmers recording manufactured fertiliser on computer

Willingness to submit fertiliser data electronically





24%, some 58 farms in total, with computerised systems were willing to submit their manufactured fertiliser applications electronically (and 23%, 27 farms, for organic applications)

Base: 241 farmers recording manufactured fertiliser on computer

Example reports are shared with Defra under the MRS Code of Conduct and complete confidentiality of these farmers must be respected

Reports available in proprietary software packages

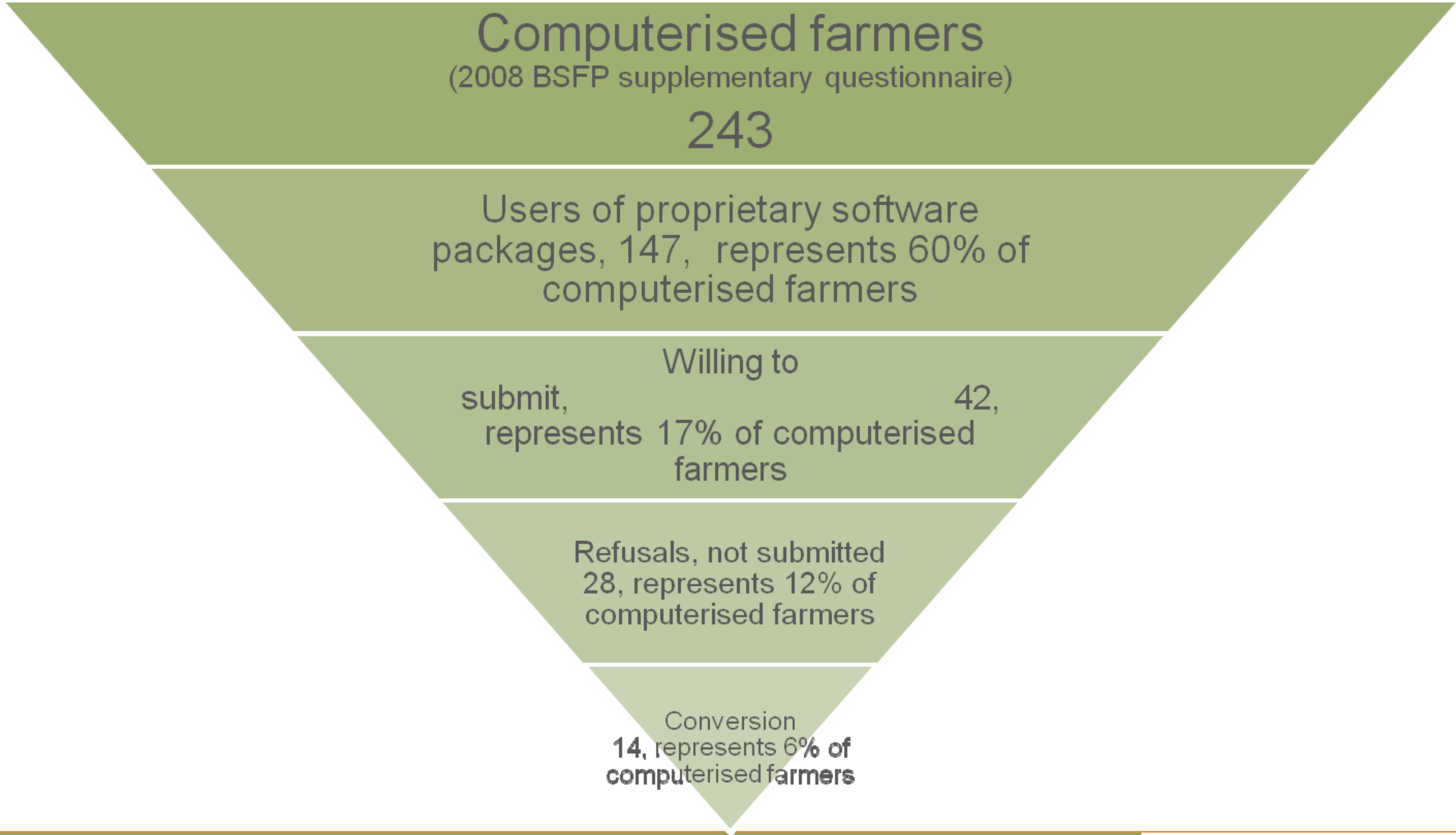
Multicrop (Farmplan) & Crop Manager (Farmade) have been considered jointly as the two programmes are known to be very similar

Gatekeeper (Farmade/ Farmplan's upgrade to Multicrop and Crop manager)

Crop Walker (Muddy Boots)

- Use of software to keep records is growing, but there is insufficient share of any one, or even a few, software packages to allow a practical change in the way BSFP data is collected
- Reports from different packages are in different formats
  - Potential costs (time and resource) to develop download from these formats to a common format
- Packages are inconsistent in the data recorded
- The comprehensiveness of information and detail entered by farmers varies
  - Even if data can be collated into a common format, there will be gaps/incomplete data records,
- Farmers are reluctant to submit data in this way
- Agronomists keeping records on behalf of the farmer further complicates the issue

Converting willingness to submit into submission



Recruitment of 2008 BSFP 'Electronic Pilot'

Ease of exporting data

- 10 of the farmers found it easy
- 1 struggled because of pressure of work
- 4 found the instructions insufficient for their needs
- Muddy Boots will not export in Excel, only pdf format

Assistance required

- 7 needed no assistance and completed the task from the written instructions
- 5 phoned the office and were talked through the process (about 2 hours of man time)
- 2 farmers delegated the task, one to their agronomist, the other to the farm secretary

Prepared to submit

- All 14 farmers were prepared to help in supply information in this way in the future

Base: 14 submitting data for the 'electronic pilot'

Interviewer's perspective and time

- There were no specific problems encountered, only those one might normally come across in recruiting farmers for survey work
  - Busy with crops, drilling
  - Son/secretary/other person does all the computer work

- **Average number of times the interviewer called before data was received was 4**
- Ranging from 1 to 12 times

- **Average time spent calling each farm before data was received was 22 minutes**
- Ranging from 10 to 45

Electronic data collection

- At the present time, data collection electronically on any reasonable scale does not appear a viable option

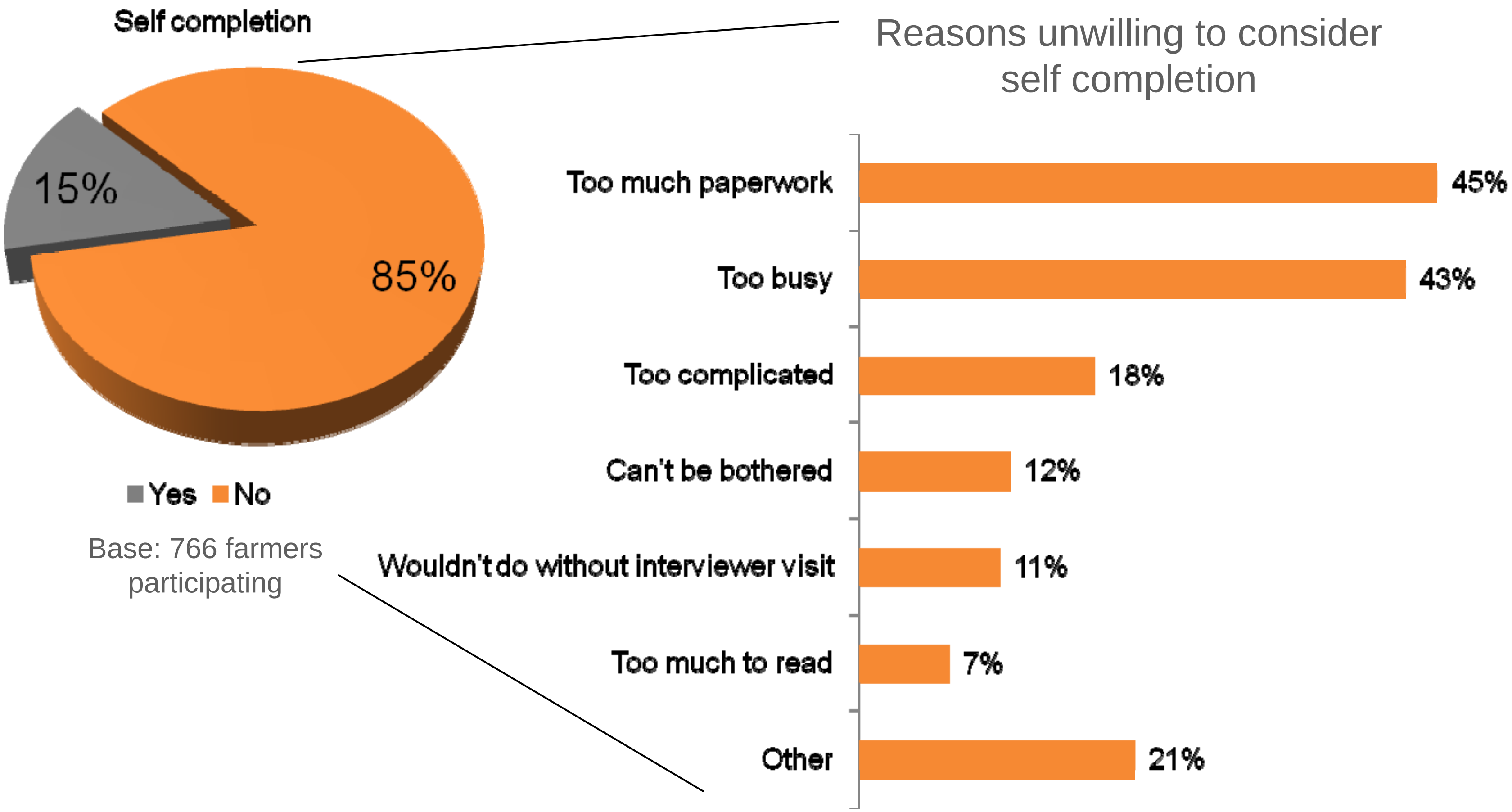
- Monitor growth in usage and share of farm software with a view to adopting this methodology when it becomes more practical to do so

- Lack of harmonization in what/how information is recorded between the different packages
- Insufficient share among software market leaders to eliminate survey bias
- Time and resource required to develop this methodology is likely, at this time, to outweigh any saving in costs
- There is a reluctance to submit data in this way at the present time
- There are likely to be gaps in any data because farmers won't enter all the details, and won't necessarily have records completely up to date

Section 2

Potential for Postal Returns

Willingness to self complete – panel view

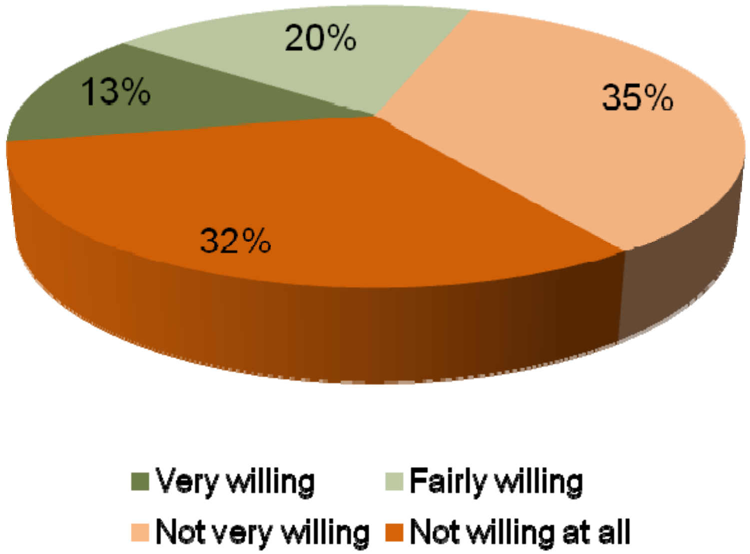


Base: 766 farmers participating

Base: 649 farmers unwilling to self complete (multiple responses)

BSFP Alternative Methodology Pilots

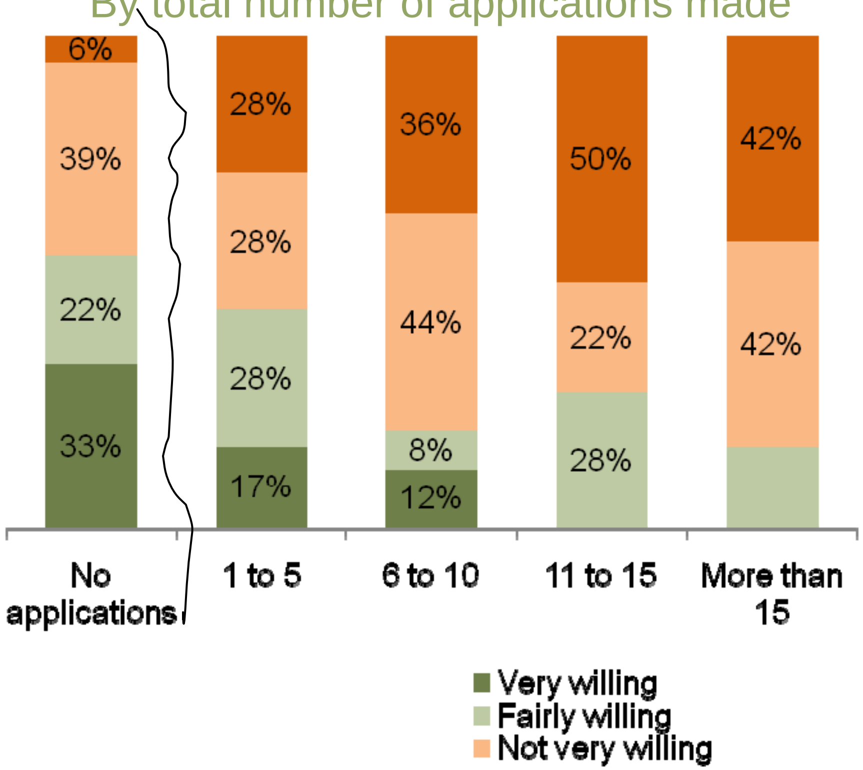
Willingness to self completion – telephone pilot view



Only a small number of those taking part in the telephone pilot would be very willing to give the same information by post.
By robust type, it might be an option for specialist pig/poultry and perhaps some livestock, but it is difficult to be conclusive about any 'pattern'.

Where no (or maybe up to 5) applications are made there is some willingness to submit by post, however in reality it is unlikely to offer a viable cost benefit option.

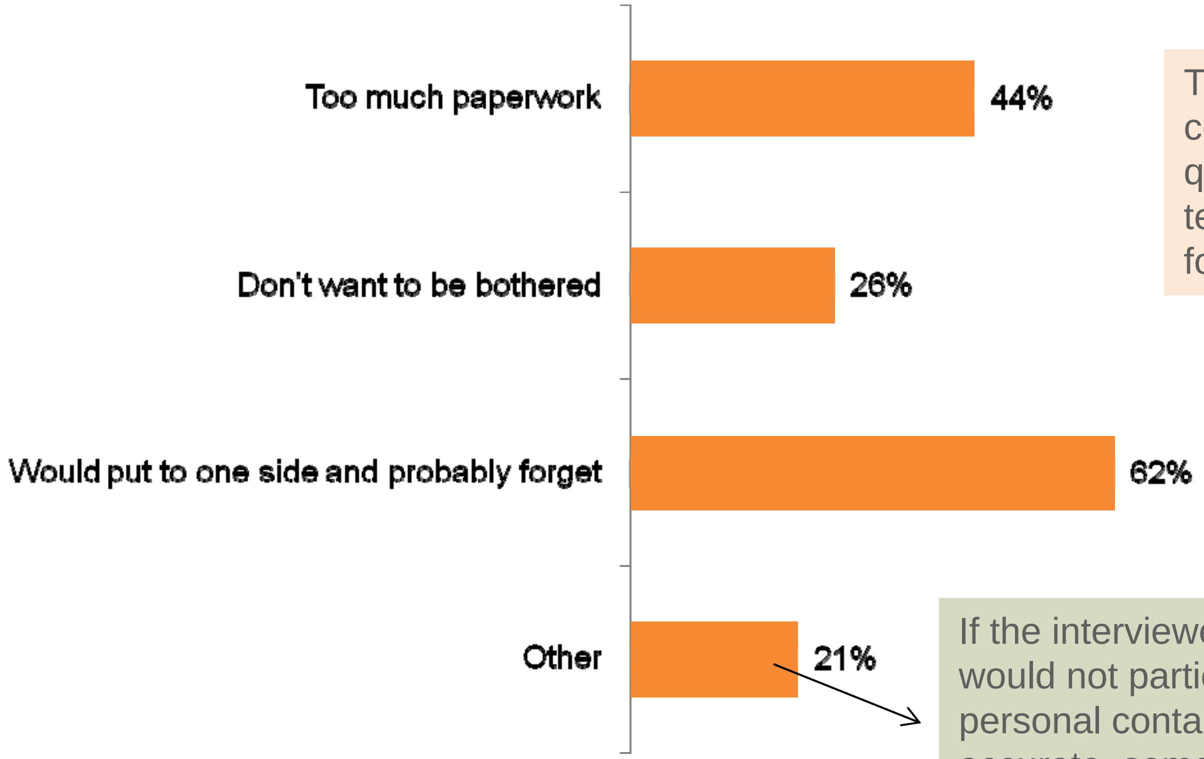
By total number of applications made



Base: 91 farmer telephone pilots

Europe • Asia • Americas

Reasons unwilling to complete telephone pilot by post



The reasons against postal data collection of the shorter questionnaire used in the telephone pilot are the same as for the main panel.

If the interviewer did not call, most said they would not participate. Some appreciate the personal contact, others feel the data is more accurate, some that it would be too difficult to look up records whilst on the phone. Indeed the collection of the data is often a joint task, and interviewers do a lot of writing up after the visit from various print-outs and notes.

Base: 61 farmers unwilling to submit their telephone pilot data by post

Postal data collection

- Data collection by post on any reasonable scale is not an appropriate option

- Resistance to submit data by post
  - Too much paperwork
  - Too busy
  - Likely to be lost /put to one side and forgotten
- Cost of reminders and chasing postal returns can end up as much as telephone interviews
- Significant re-design of paperwork would be required to enable and encourage farmers to fill in
- Extensive notes would be required to offer help in accurate completion which farmers just won't read

Section 3

Potential for Telephone Data Collection

Telephone Pilot > Process

Approached existing BSFP members explaining that we had been tasked to look at different ways of collecting the information normally given, to make sure Defra were delivering against their duty to collect data cost effectively.
Farmers were asked to have their fertiliser records to hand during the interview.

Identified a sample of 10 farms in each of 9 robust types, and within those a range of different farm sizes. The data in this report on the telephone pilot are robust when analysed as a total, but should be viewed qualitatively when analysed by robust type (despite the use of percentages to create graphic/visual illustration of the data).

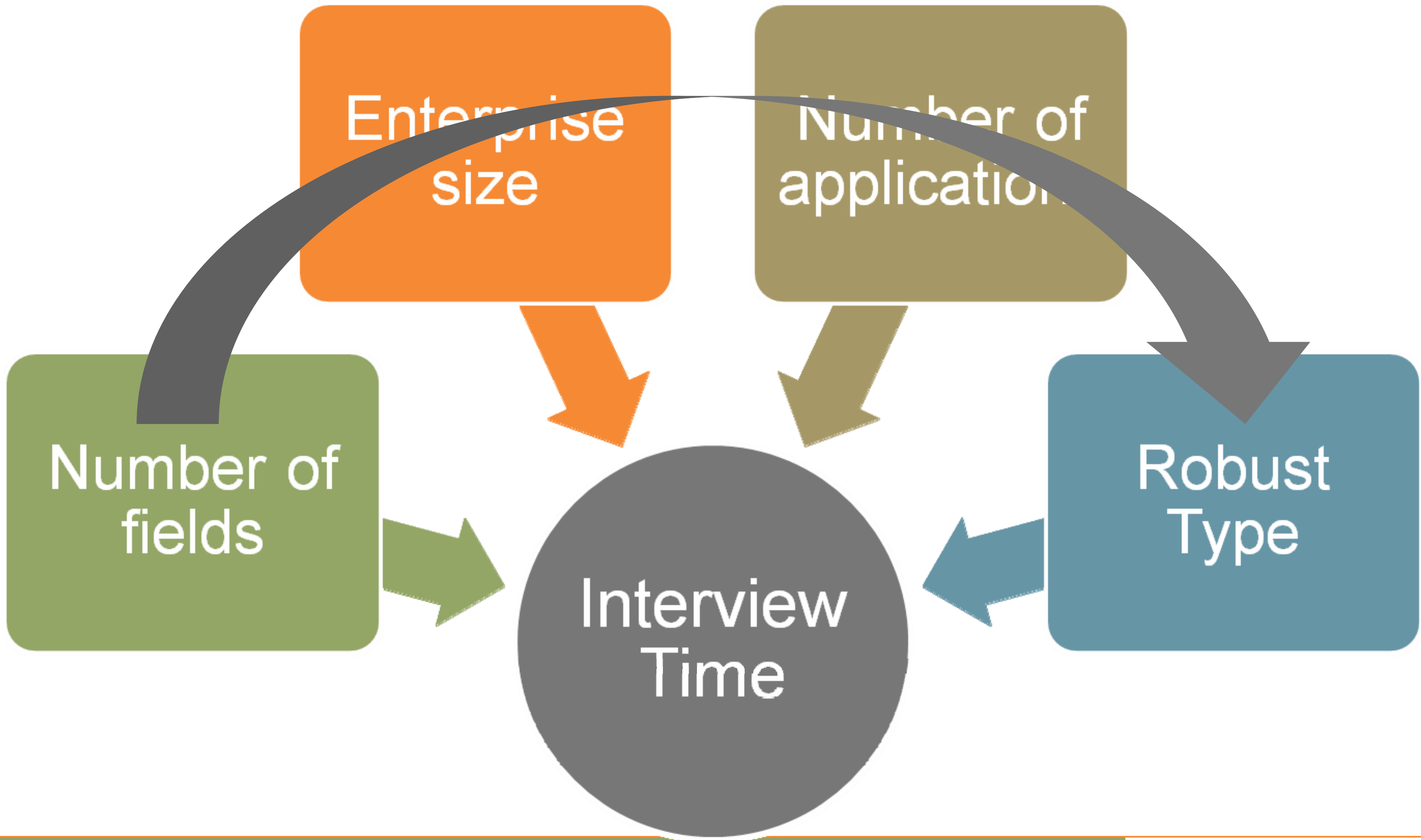
Defra reviewed and deleted superfluous questions from the Farmer Questionnaire, Field Sheet and Application records.
Field interviewers used on the current BSFP were used to conduct the pilot telephone survey, and farmers and interviewers were asked to give their opinion on the concept (and that of a postal survey) at the end of the interview.

Sample structure

	Pilot Sample	BSFP sample
Cereals	21	
General cropping	14	
Horticulture	7	
Specialist Pigs	4	
Specialist Poultry	5	
Dairy	10	
LFA	10	
Sheep & Cattle LA	10	
Mixed	10	

The plan was to achieve 10 pilots in each robust type.
This proved almost impossible in specialist pigs and poultry and difficult in horticulture so a decision was made to accept this because these sectors were less significant in any case and to use the budget to 'top up' the larger groups.

Estimating interview time



Farmer questionnaire – telephone pilot

FARMER QUESTIONNAIRE

BSFP 080481 Evaluation of data collection methods (Telephone)

Farmer's Name			
Farm Ref No		Reserve No	
CPH No		Telephone No	

Please give areas for the following to ONE decimal place. *(please circle one)*

1. **Total area of crops and grass (excluding rough grazing)** . Ha/Ac

2. **What percentage of your land is in a Nitrate Vulnerable Zone** % *(If 0% start field sheets)*

3. **For field areas in Nitrate Vulnerable Zones, do you record...** *(read out)***?**

Just manufactured N (Nitrogen)	1
Manufactured N, P and K (Nitrogen, Phosphorous, Potash)	2
Type of manure applied	3
and, analysis of nitrogen content **of manure** (where available)	4
Quantity of manure applied	5
% manure that is dry matter (if slurry)	6
Other information recorded: Please state	
Do not keep any records of fertiliser applications	00

Record interview time to this point mins

Now complete the necessary field sheets and then continue with the questionnaire

Defra asked only key information criteria regarding NVZ's on the farmer questionnaire for the telephone pilot.

The **average time taken** to complete these questions was a fraction over **2 minutes.**

This 2 minutes interview time is not included in the estimates later in this report for '*total interview time*' taken to complete the sheets i.e. field information and application records.

BSFP

BSFP Alternative Methodology Pilots

Field sheet Questions

FARM

FIELD SHEET

1.(a) What is the total field size, including headlands? *please circle unit* Ha/Ac

(b) What is the total sown area? Ha/Ac

(c) When was this field designated a Nitrate Vulnerable Zone (NVZ)?

(year) Not in NVZ

(d) How many actual fields are there in this block?

(e) What is the 2008 crop? (For cereals, pulses or OSR specify 'winter' or 'spring' crop)

(f) What was the previous (2007) crop? (For cereals, pulses or OSR please specify 'winter' or 'spring' crop)

2. Is this field farmed organically?

Yes No

Record Interview time to this point mins

The interviewer records the interview time after Q2, Q3 and at the bottom of each field application sheet

MANURE/SLURRY

3. *Please record all applications of manure/slurry made to this field. Refer to interviewer notes for guidance*

If more than 4 applications please start a new field sheet

Application number 1 2 3 4

(a) Month (e.g. 03)

Year (e.g. 08)

(b) Manure type

Cattle FYM

Pig FYM

Sheep FYM

Duck FYM

Layer manure

Broiler/turkey litter

Cattle slurry

Pig slurry

Digested liquid sewage

Digested cake

Thermally dried sewage

Lime stabilised sewage

Other (please specify below)

(c) Application rate

Tonnes/tons

M^3

'000 litres

Gallons

Per hectare

Per acre

Record Interview time to this point mins

4. Please detail the fertilisers that have been used on this field including sulphur nutrient sprays and sulphur granules.
Start with the first dressing used for this crop (check definition of Survey Year for crop grown).

If milling wheat, was extra N applied for to boost grain protein? Yes No **If 'Yes', also tick 'Late N for milling wheat'**

D1 ANALYSIS / CONTENT (please enter to one decimal place) Month Year

N (nitrogen) % Late N for milling wheat P_2O_5 (phosphate) % K_2O (potash) % SO_3 (sulphur as SO_3) % Other

(please tick one formulation only) (please tick one measurement unit only)

OR Liquid Solid RATE Kg (nutrient) Kg (product) Units Cwt Per hectare? Litres Gallons Per acre?

Method

Combined drilled In Seedbed Top dressed Placement

D2 ANALYSIS / CONTENT (please enter to one decimal place) Month Year

N (nitrogen) % Late N for milling wheat P_2O_5 (phosphate) % K_2O (potash) % SO_3 (sulphur as SO_3) % Other

(please tick one formulation only) (please tick one measurement unit only)

OR Liquid Solid RATE Kg (nutrient) Kg (product) Units Cwt Per hectare? Litres Gallons Per acre?

Method

Combined drilled In Seedbed Top dressed Placement

PROMPT: Are there any more dressings you applied or intend to apply on this field during the survey year?

Tick here if you are continuing onto another sheet for this field

REMEMBER TO WRITE FARM, FIELD AND SHEET NUMBER ON TOP OF ALL NEW FIELD SHEETS

Record Interview time to this point mins

Europe • Asia • Americas

dmrkynetec

Average times recorded by robust type

	Q1-2 Field details	Q3 Manure/Slurry	Per application
Cereals	1 min 48 sec	0 min 36 sec	0 min 36sec
Sheep & Cattle LA	2 min 12 sec	0 min 42 sec	1 min 6 sec
General cropping	1 min 48 sec	0 min 54 sec	0 min 54 sec
Dairy	[illegible]	[illegible]	0 min 30 sec
Horticulture	[illegible]	[illegible]	0 min 54 sec
LFA	1 min 54 sec	0 min 54 sec	1 min 0 sec
Mixed	1 min 24 sec	0 min 48 sec	0 min 30 sec
Specialist Poultry	1 min 30 sec	1 min 18 sec	1 min 30 sec
Specialist Pigs	1 min 36 sec	1 min 24 sec	0 min 36 sec
Grand Total	1 min 42 sec	0 min 48 sec	0 min 42 sec

By robust type, the average times are quite similar, so we decided to look at the more direct influence on time, the number of field sheets.

Average times recorded by number of fields (field sheets)

	Q1-2 Field details	Q3 Manure/Slurry	Per application
1	3 min 48 sec	1 min 0 sec	3 min 30 sec
2	3 min 0 sec	1 min 18 sec	0 min 54 sec
3	2 min 12 sec	1 min 0 sec	1 min 0 sec
4	2 min 12 sec	1 min 0 sec	0 min 48 sec
5	1 min 36 sec	1 min 0 sec	0 min 54 sec
6	1 min 24 sec	0 min 48 sec	0 min 30 sec
7	1 min 0 sec	0 min 48 sec	0 min 36 sec
8	1 min 18 sec	0 min 42 sec	0 min 42 sec
9	1 min 0 sec	0 min 42 sec	0 min 12 sec
10	1 min 0 sec	0 min 18 sec	0 min 18 sec
12	0 min 54 sec	0 min 30 sec	0 min 30 sec
13	0 min 42 sec	0 min 6 sec	0 min 12 sec
Grand Total	1 min 42 sec	0 min 48 sec	0 min 42 sec

What we see, broadly, is an economy in time the greater the number of fields. The more familiar interviewer and respondent are or become, the quicker the process.

Estimating interview time

Timed interview sections:

Farmer questionnaire
Field sheet, field questions
Field sheet, applications

Calculated the average time by the number of field sheets to complete various sections, and the average time to complete a single application record

Applied those averages by field sheets, to the field and applications profile of the 1,328 current panel members

- Actual number of fields on 2008 panel
- Multiplied by the average time, by field averages, to complete Q1-2

Sum time Q1-2 Pilot FS

Sum time Q3 Pilot FS

- Actual number of fields on 2008 panel
- Multiplied by the average time, by field averages, to complete Q3

- Actual number of total applications on 2008 panel
- Multiplied by the average time per application, by field averages

Sum time all applications

Potential for telephone interviews on BSFP

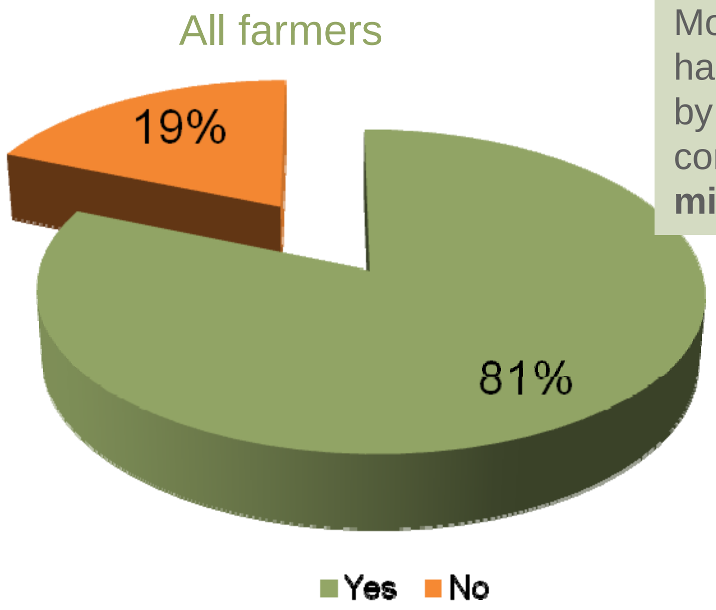
Farmer Questionnaire
Av. **2 mins** of interview time

Field sheet and applications
Up to **15 min** of the interview time

Limited time allocation for any supplementary questions, or to collect more data on the Farmer Questionnaire
3 min

Absolute numbers	< or = to 15 min	>15 min	BSFP
Cereals	34	365	399
General cropping	11	164	175
Horticulture	8	19	27
Pigs	1	2	3
Poultry	3	1	4
Dairy	36	135	171
LFA	166	109	275
Sheep & Cattle LA	65	55	120
Mixed	32	121	153
Grand Total	356	971	1327

Preparedness to submit data by telephone

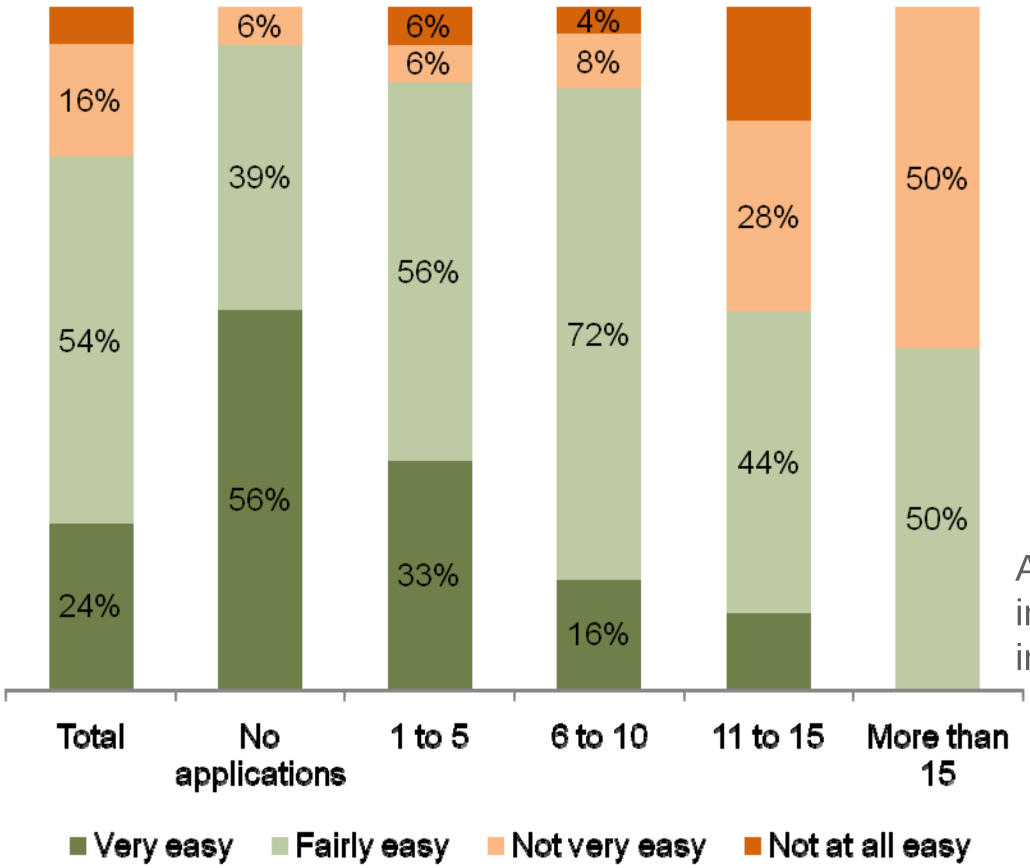


Most farmers are happy to submit data by phone within the confines of a **20 minute** interview

The outcome in terms of preparedness to submit data by phone was not influenced by robust type, number of applications recorded or other variables. It is more to do with personal attitude to giving data in this way, and to the understanding they were answering assuming BSFP interviews in future will last a **maximum** 20 minutes

Base: 91 farmer telephone pilots

Interviewers perception - ease of administering the interview

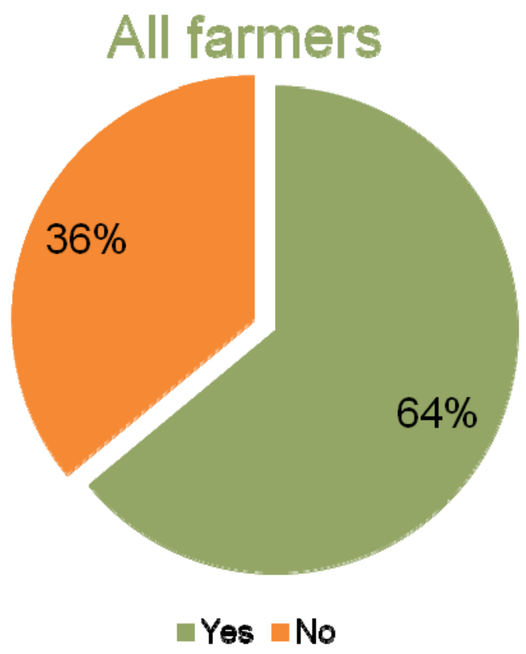


As the number of applications recorded increases the ease of administering the interview becomes more difficult

Base: 91 farmer telephone pilots

BSFP Alternative Methodology Pilots

Reference to records during the interview

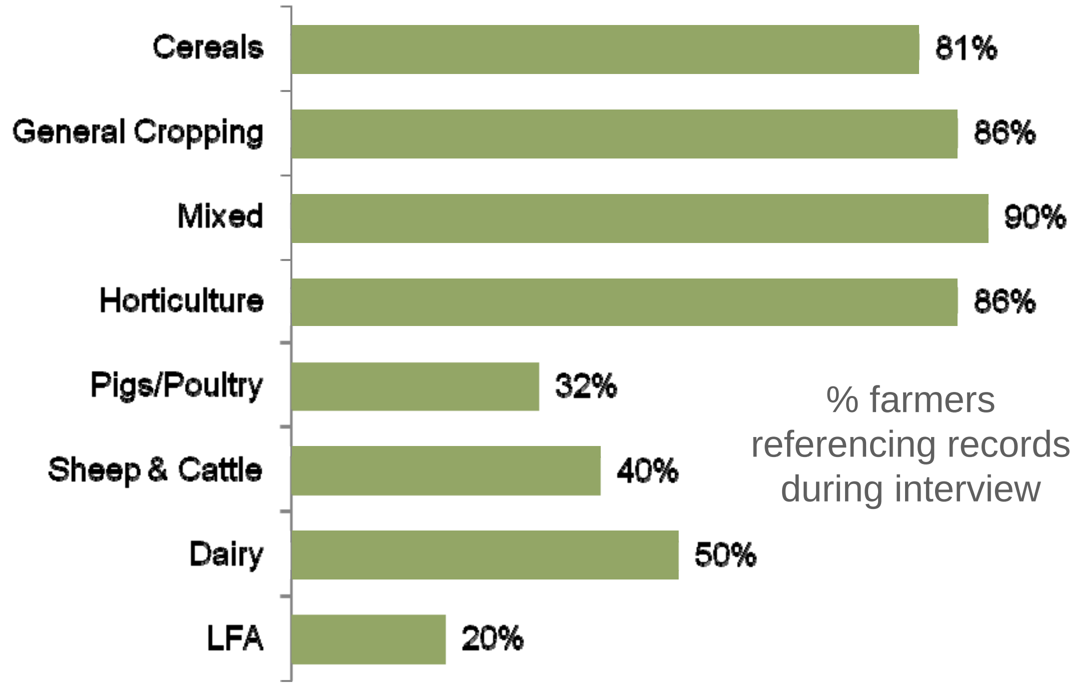


Farmers on smaller enterprises and/or livestock associated enterprises show a greater propensity to rely on memory than reference their records during the interview

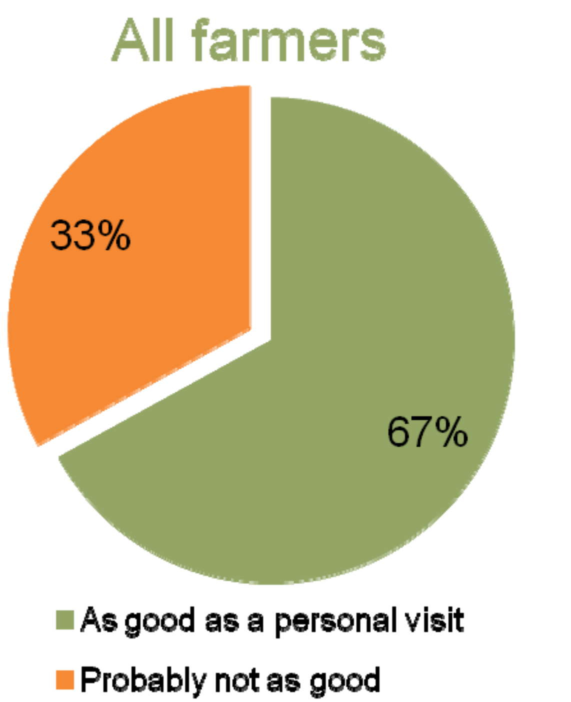
Base: 91 farmer telephone pilots

By robust group, farmers with arable or horticulture are more inclined to reference their records during the interview.

By number of applications, the incidence of referring to their records is much lower where there are 9 or fewer applications made in total

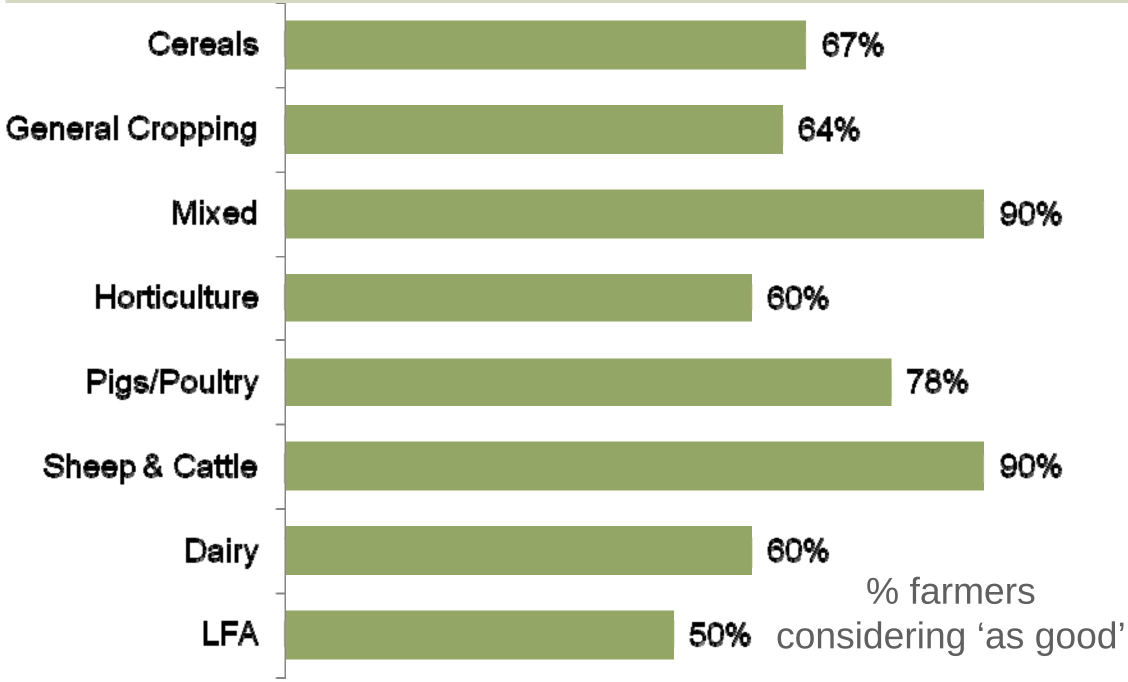


Farmers perception of accuracy of information given by telephone versus farm visit



By robust group, there was greater confidence among Mixed and Sheep & Cattle LA robust farmer groups.

The perception of accuracy is 80% considering the information they gave 'as good' where there are up to 10 applications made in total; once the number of applications goes over that level confidence in accuracy reduces to just 20%



It is likely information given by telephone will be 'as good' as when an interviewer visits the farm on farms where there are up to 10 applications made in total

Base: 91 farmer telephone pilots

Europe • Asia • Americas

Interviewer's perspective

- When the fertiliser applications are simple and/or few in number it is perfectly feasible over the telephone,
- The telephone does not allow for the practical reality of the interview,
- Farmers do not necessarily think in the way the interview is structured,
- Many interviewers take notes or take away print outs to write up the information later.

This farm manager spoke very quickly and I had to ask him the same question twice before I got it written down. He gave information about winter barley without realising some had FYM and some not. 165.9 acres were unaccounted for. Couldn't see need for us to know the number of fields of a crop or if they were organic because DEFRA already have this information.

I've timed this one as if I filled it all in at the time. There is a problem doing this especially they suddenly back track or forget something and then you have so many changes so even when I do fill in the farm as I go it's done in pencil to be safe. Office need to know about write up time.

Usual problem - you ask was all this barley treated the same and he says yes so you write in 3 fields 30ac then say did it have muck on it and he says yes, so you ask how much? 2 of the fields, so you cross out 30 & 3 & write 20 & 2 and then have to go to next sheet. This can be tricky and messy and your missing vital information. This was relatively easy to do by phone because all the cereal fields, bar one had had virtually the same NPK, even so I did not finish and am not certain all the acreages are accurate.

Interviewer’s perspective and feedback

The farmer said because he had done this interview before face to face he knew already basically what the format was so found it quite easy over the phone, but had he not done it before and I had phoned "out of the blue“ he would not have been so happy and although he would have done it may have lied as " you can tell them anything over the phone".

The biggest problem is when the farmer tries to give you information on 2 crops at the same time it all had the same as the 2 fields following but one had muck & the other 2 had slurry & you are having to write on 2 sheets at the same time. Again the acreage doesn't tie up with the DEFRA figure & I had no time to check this. There is a lot of tidying up to do after, it’s OK if everything is simple, disastrous if its not .

Difficult to add up field sheets on phone & see if anything missing. Often at face to face interview they say "rest in perm pasture" and you add it up 7 say so that's "X" acres & they then realise they've forgotten a field of corn. This might not get sorted out on phone for larger or complicated farms so perhaps need to allow for a second call to farmer if there's a problem.

This was not a difficult farm but we did not finish all the fields. There was a problem when it came to FYM on fields when it was found that some did and some didn't have FYM. We then had to re calculate the sizes and number of the fields

Examples of difficulties highlighted by farmers

Q1a: Total field size. Q1d: Field Blocks.	Difficult to think about number of fields and averages when you are on the phone. Better if you and the interviewer are together.
Q1c: NVZ	Unsure of NVZ year but thinks 2002
Q1d: Field blocks.	Couldn't see need for us to know the number of fields of a crop or if they were organic because DEFRA already have this information.
Q1a: Total field size. Q1b: Total sown area	Farmer felt that some of the acreages he gave were possibly not right.
Q1f: 2007 Crop	Remembering what crop was in a field the year before last - I'm thinking about what's being planted now!
Q3c: Manure rates	Farmyard manure rates
	Time consuming as information is in different books , so looking in one place for sown and total areas, another for manure and fertiliser and another for sewage records. Took a while looking at records to see if any fields could be blocked together but decided easier to carry on doing one field at a time.

Comparison of telephone data with BSFP visit

It was not possible to be 100% certain of comparing like for like in this exercise. The BSFP does not record the name of fields and it was not possible to be 100% sure the field on the telephone pilot was indeed the same field as in the BSFP main survey, a ‘guess’ was made based on the cropping and field area. Given this, the quality of data is a difficult comparison to make but we feel the quality of information collected by telephone was not compromised by the methodology.

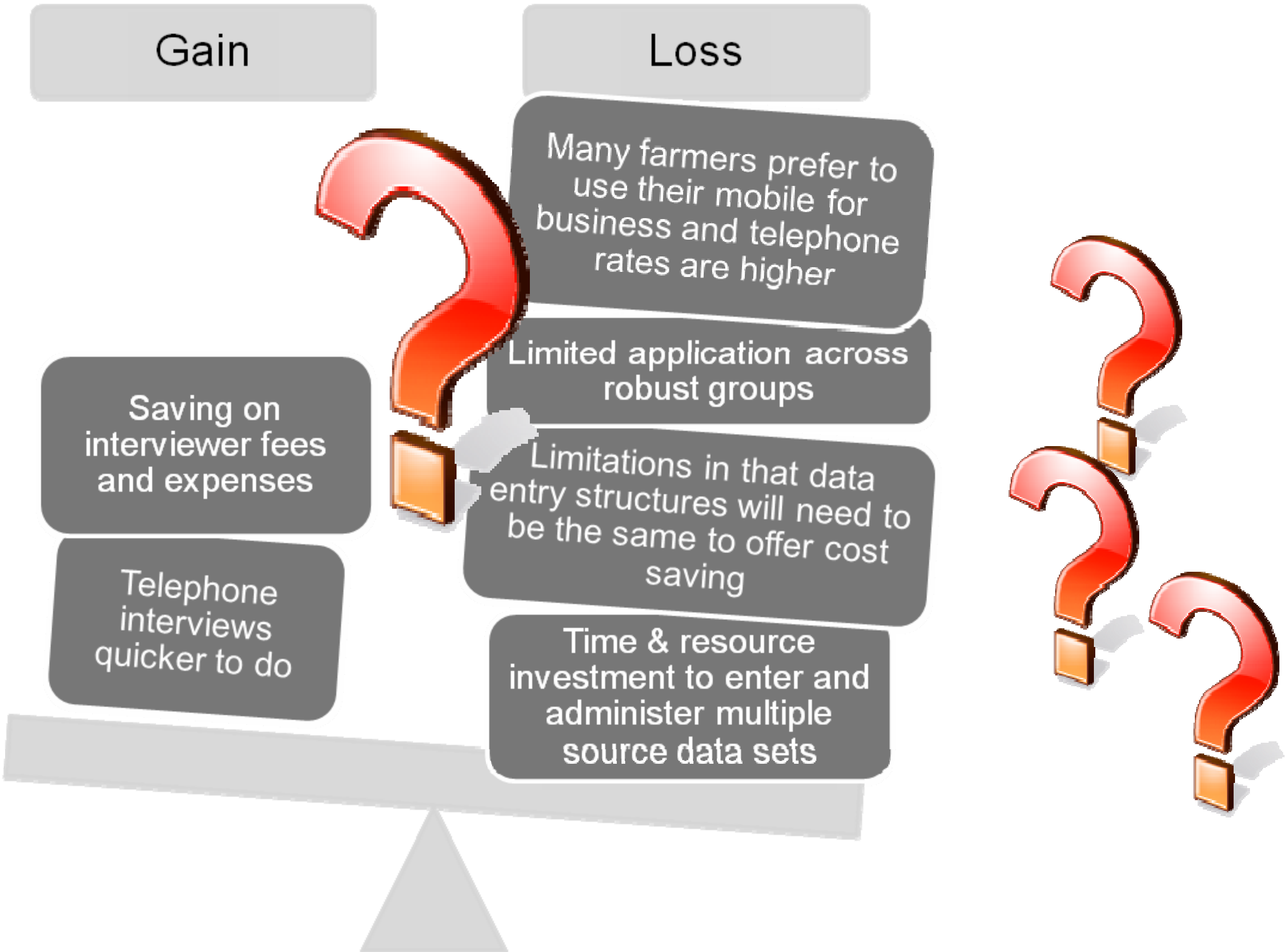
Robust	BSFP Field Sheets	Telephone Field Sheets	Comments
1	13	4	Out of the 4 fields in the telephone survey the first 2 fields are the same, the 3rd field has an extra fertiliser application and the 4th ran out of time
1	7	3	First 2 fertiliser applications are different and the 3rd is OK
2	11	5	These don't match because on the telephone interview the fields have not been blocked.
2	6	5	Fertiliser application rates are different on fields 1 to 3. Field 4 first application OK and second application different. Field 5 no match.
3	7	8	Fields 1 & 2 no fertiliser applications but BSFP has applications. Fields 3-5,8 are OK. Fields 6 & 7 are different.
3	11	5	Fields 1-4 are the same, field 5 has 1 extra fertiliser application than BSFP
4	7	4	All fields slightly different
4	16	5	Field 1 is OK, fields 2-5 are different
5	3	3	100% perfect but there were no fertiliser applications!
5	17	4	BSFP has 94.1 acs grass, telephone has 340 acs grass

Comparison of telephone data with BSFP visit

Robust	BSFP Field Sheets	Telephone Field Sheets	Comments
6	6	6	Fields 1,2 & 6 are OK. 3-5 are different
6	7	5	These don't match because on the telephone interview the fields have not been blocked.
7	10	8	Fields 1,4 & 5 are the same. Fields 2,3,6 & 7 are different. Field 8 ran out of time.
7	3	2	These don't match at all
8	4	5	Fields 1,4 & 5 are different. Fields 2 & 3 are the same
8	4	4	Fields 1-3 are the same. Field 4 is different
9	8	4	Fields 1-3 are the same. Field 4 ran out of time
9	6	6	100% perfect but no fertiliser applications!

Around two-thirds of the telephone pilot field sheets matched against the data collected on the personal visit.
The remainder were slightly different in some way, and one would expect this to be the case, because additional applications may have been made since; rates may be remembered differently, or additional reference records consulted, etc.

Cost benefit considerations



Conclusions and Recommendations

Conclusions and recommendations

- The current face to face methodology offers the best option in terms of efficiency and accuracy
- There is potential for a nominal cost saving by moving some of the farms with fewer records to telephone, but there is question over accuracy
- Moving to telephone is likely to introduce complexity disproportionate with the benefit
- Postal data collection is not an appropriate option at all, and there is high resistance to this among farmers
- Electronic data collection will undoubtedly be the future, however at the present time there is insufficient market share or consistency in the data recorded by proprietary software providers to warrant the investment, and at this time high resistance to the concept of electronic data submission among farmers

Conclusions and recommendations

- Continue with the current face to face methodology of data collection
- Consider a review of the field sheets, the format and order for collecting the data, to see if there is an obvious solution to making it more aligned to the way farmers think about their fertiliser applications
  - Many of the problems and complications in the interview stem from having blocked fields and then realising later in the interview they can't be blocked because
    - The previous years cropping was different
    - There were manure or other organic fertiliser applied to some of the area
- As part of the panel's standard questionnaire, on a yearly basis, monitor the use of computers to record manufactured and organic fertiliser applications and the software package used by the farm

BSFP

Project contact:

Lesley Selby/Kate Benford, West Europe Region & UK, lesley.selby@dmrkynetec.com / kate.benford @dmrkynetec.com

WEST EUROPE REGION AND UK
dmrkynetec
Weston Court
Weston, Newbury
Berkshire, RG20 8JE, UK
Tel. + 44 (0)1488 649 130

AMERICAS REGION AND US
dmrkynetec
1807 Park 270 Drive, Suite 300
St. Louis, Missouri 63146
USA
Tel. + 1 314 878 7707

ASIA REGION AND MALAYSIA
dmrkynetec
E-1-45 Aman Suria
Jalan PJU1/45
47301 Petaling Jaya, Malaysia
Tel. +60 3 7880 6752

FRANCE
dmrkynetec
Immeuble Le Gemellyon Sud
59 Bd Vivier Merle
FR-69003 Lyon, France
Tel. + 33 (0)4 78 53 04 79

GERMANY
dmrkynetec
Kiebitzreihe 9
24837 Schleswig,
Germany
Tel. + 49 462 1301 4336

EASTERN EUROPE AND POLAND
dmrkynetec
ul. Janickiego 20 b
60-542 Poznan
Poland
tel.: +48 (0)61 663 1977

CHINA
dmrkynetec
Kelun Building A
No 12. Guanghualu
Chaoyang District, Beijing, China
Tel. + 86 1065 814 109

SATELLITE OFFICES
Cleveland, OH, USA
Fresno, CA, USA
Raleigh, NC, USA
Nuremberg, Germany
Cork, Ireland
Singapore

ASSOCIATED OFFICES
Tokyo, Japan
Sydney, Australia

m2A OFFICE
Paris, France

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BRITISH SURVEY OF FERTILISER PRACTICE 2008 **FIELD SHEET**

FARM [ ]

FIELD [ ] SHEET [ ]

1. (a) What is the total field size, including headlands? *please circle unit*
   [.] Ha /Ac

   (b) What is the total sown area? [.] Ha /Ac

   (c) When was this field designated a Nitrate Vulnerable Zone (NVZ)?

   ___________________(year) Not in NVZ [ ]

   (d) Which definition below best describes the *main* soil type of this field?

   Sandy [ ] Shallow [ ] Neither [ ]

   (e) How many *actual* fields are there in this field 'block'? [ ]

2. (a) What is the 2008 crop?
   For cereals, pulses or osr specify 'winter' or 'spring' crop

   [ ]

   Crop Code [ ] Sowing Date Month [ ] Year [ ]

   (b) If CEREAL, how many consecutive years in cereal for this field including 2008? (*if 'don't know', write* '**DK**') [ ]

3. (a) What was the previous (2007) crop?
   For cereals, pulses or osr specify 'winter' or 'spring' crop

   [ ]

   Crop code [ ]

   (b) If previous (2007) crop was a CEREAL, was the straw (*tick one only*)

   Chopped up/incorporated? [ ]

   Baled and removed from field? [ ]

GRASS

4. If grass in the 2008 Survey Year, was the grass
   (*please answer all questions*)

   (a) Grazed? Yes [ ] No [ ]

   (b) Mown for hay? Yes [ ] No [ ]

   If 'Yes', specify the number of times [ ]

   (c) Mown for silage? Yes [ ] No [ ]

   If 'Yes', specify the number of times [ ]

   (d) Put to other use Yes [ ] No [ ]

   If 'Yes', specify what other use [ ]

LIME

5. (a) On average, how many years are there between lime applications to this field, if any?
   (*if 'never', write* '**0**', *if 'don't know write* '**DK**') [ ]

   (b) Was lime applied to the field for the current season?

   Yes [ ] No [ ]

   If 'Yes', what type?

   Grounded limestone [ ] Ground chalk [ ]

   Magnesian limestone [ ] Sugarbeet lime [ ]

   Other [ ]

   If other, please specify: [ ]

   At what rate was this applied?

   [.] Tonnes/Ha

   [.] Tons/Acre

6. (a) Is this field farmed organically?
   Yes [ ] No [ ]

MANURE/SLURRY

7. *Please record all applications of manure/slurry made to this field. Refer to interviewer notes for guidance*
   If more than 4 applications please start a new field sheet

Application number	1	2	3	4
(a) Month *(e.g. 03)*				
Year *(e.g. 08)*				
(b) Manure type *(tick one per application)*				
Cattle FYM				
Pig FYM				
Sheep FYM				
Duck FYM				
Layer manure				
Broiler/turkey litter				
Cattle slurry				
Pig slurry				
Digested liquid sewage sludge				
Digested cake				
Thermally dried sewage sludge				
Lime stabilised sewage sludge				
Other (please specify below)				

[ ]

(c) Application rate *(write in volume per application)*				
Tonnes/tons				
M^3				
'000 litres				
Gallons				
(tick unit)				
Per hectare				
Per acre				
(d) Incorporation time *(tick one per application)*				
Within 6 hours of spreading				
Within 24 hours of spreading				
Within 1 week				
More than 1 week of spreading				
Applied but not incorporated				
(e) Contractor applied *(tick one per application)*				
Yes				
No				
(f) Manure source *(tick one per application)*				
Own				
Imported				
(g) Slurry application method *(tick one per application)*				
Broadcast				
Band spread				
Shallow injection				
Deep injection				
Rain gun				
Rotating boom				

PLEASE ENSURE <u>ALL</u> USES OF STRAIGHT N OR NS PRODUCTS HAVE 'TYPE' SPECIFIED IN SHADED BOX

7. Please detail the fertilisers that have been used on this field including sulphur nutrient sprays and sulphur granules.
Start with the first dressing used for this crop (check definition of Survey Year for crop grown).

If milling wheat, was extra N applied for to boost grain protein? Yes ☐ No ☐ **if 'Yes', also tick 'Late N for milling wheat'**

D1 ANALYSIS / CONTENT (please enter to one decimal place) Month ☐☐ Year ☐☐

N (nitrogen) % ☐☐.☐ | Late N for milling wheat ☐ | P_2O_5 (phosphate) % ☐☐.☐ | K_2O (potash) % ☐☐.☐ | SO_3 (sulphur as SO_3) % ☐☐☐.☐ | Other ☐☐☐

Straight N or NS products (tick one)
Ammonium Nitrate ☐
Urea Ammonium Nitrate (UAN) (liquid) ☐
Calcium Ammonium Nitrate (CAN) ☐
Urea ☐
Other Straight N ☐

(please tick one formulation only) OR Liquid ☐ Solid ☐ Kg (nutrient) ☐ Kg (product) ☐
(please tick one measurement unit only) Units ☐ Cwt ☐ Litres ☐ Gallons ☐
RATE ☐☐☐.☐ Per hectare? ☐ Per acre? ☐
Method
Combined drilled ☐ In Seedbed ☐ Top dressed ☐ Placement ☐

D2 ANALYSIS / CONTENT (please enter to one decimal place) Month ☐☐ Year ☐☐

N (nitrogen) % ☐☐.☐ | Late N for milling wheat ☐ | P_2O_5 (phosphate) % ☐☐.☐ | K_2O (potash) % ☐☐.☐ | SO_3 (sulphur as SO_3) % ☐☐☐.☐ | Other ☐☐☐

Straight N or NS products (tick one)
Ammonium Nitrate ☐
Urea Ammonium Nitrate (UAN) (liquid) ☐
Calcium Ammonium Nitrate (CAN) ☐
Urea ☐
Other Straight N ☐

(please tick one formulation only) OR Liquid ☐ Solid ☐ Kg (nutrient) ☐ Kg (product) ☐
(please tick one measurement unit only) Units ☐ Cwt ☐ Litres ☐ Gallons ☐
RATE ☐☐☐.☐ Per hectare? ☐ Per acre? ☐
Method
Combined drilled ☐ In Seedbed ☐ Top dressed ☐ Placement ☐

D3 ANALYSIS / CONTENT (please enter to one decimal place) Month ☐☐ Year ☐☐

N (nitrogen) % ☐☐.☐ | Late N for milling wheat ☐ | P_2O_5 (phosphate) % ☐☐.☐ | K_2O (potash) % ☐☐.☐ | SO_3 (sulphur as SO_3) % ☐☐☐.☐ | Other ☐☐☐

Straight N or NS products (tick one)
Ammonium Nitrate ☐
Urea Ammonium Nitrate (UAN) (liquid) ☐
Calcium Ammonium Nitrate (CAN) ☐
Urea ☐
Other Straight N ☐

(please tick one formulation only) OR Liquid ☐ Solid ☐ Kg (nutrient) ☐ Kg (product) ☐
(please tick one measurement unit only) Units ☐ Cwt ☐ Litres ☐ Gallons ☐
RATE ☐☐☐.☐ Per hectare? ☐ Per acre? ☐
Method
Combined drilled ☐ In Seedbed ☐ Top dressed ☐ Placement ☐

D4 ANALYSIS / CONTENT (please enter to one decimal place) Month ☐☐ Year ☐☐

N (nitrogen) % ☐☐.☐ | Late N for milling wheat ☐ | P_2O_5 (phosphate) % ☐☐.☐ | K_2O (potash) % ☐☐.☐ | SO_3 (sulphur as SO_3) % ☐☐☐.☐ | Other ☐☐☐

Straight N or NS products (tick one)
Ammonium Nitrate ☐
Urea Ammonium Nitrate (UAN) (liquid) ☐
Calcium Ammonium Nitrate (CAN) ☐
Urea ☐
Other Straight N ☐

(please tick one formulation only) OR Liquid ☐ Solid ☐ Kg (nutrient) ☐ Kg (product) ☐
(please tick one measurement unit only) Units ☐ Cwt ☐ Litres ☐ Gallons ☐
RATE ☐☐☐.☐ Per hectare? ☐ Per acre? ☐
Method
Combined drilled ☐ In Seedbed ☐ Top dressed ☐ Placement ☐

D5 ANALYSIS / CONTENT (please enter to one decimal place) Month ☐☐ Year ☐☐

N (nitrogen) % ☐☐.☐ | Late N for milling wheat ☐ | P_2O_5 (phosphate) % ☐☐.☐ | K_2O (potash) % ☐☐.☐ | SO_3 (sulphur as SO_3) % ☐☐☐.☐ | Other ☐☐☐

Straight N or NS products (tick one)
Ammonium Nitrate ☐
Urea Ammonium Nitrate (UAN) (liquid) ☐
Calcium Ammonium Nitrate (CAN) ☐
Urea ☐
Other Straight N ☐

(please tick one formulation only) OR Liquid ☐ Solid ☐ Kg (nutrient) ☐ Kg (product) ☐
(please tick one measurement unit only) Units ☐ Cwt ☐ Litres ☐ Gallons ☐
RATE ☐☐☐.☐ Per hectare? ☐ Per acre? ☐
Method
Combined drilled ☐ In Seedbed ☐ Top dressed ☐ Placement ☐

PROMPT: Are there any more dressings you applied or intend to apply on this field during the survey year?
Tick here if you are continuing onto another sheet for this field ☐

REMEMBER TO WRITE **<u>FARM</u>**, **<u>FIELD</u>** AND **<u>SHEET</u>** NUMBER ON TOP OF **<u>ALL</u>** NEW FIELD SHEETS

USE OF ORGANIC MANURES – GREAT BRITAIN, 2008

Introduction

Whilst the British Survey of Fertiliser Practice has focussed historically on the application of manufactured fertilisers, in recent years it has also collected increasingly detailed information on the use and movement of organic manures. In previous years, farmers were asked where their manure applications fall within pre-specified 'high', 'medium' and 'low' ranges. In 2007, in an effort to better quantify the organic manure data, farmers were asked to provide a specific rate of application which could then be weighted in the same way as the manufactured fertiliser data to deliver a national picture of organic manure usage. However, it should be remembered that the underlying sample design is constructed to measure manufactured fertiliser usage and may not wholly represent the population of farmers using organic manures.

D1 FARMS HANDLING ORGANIC MANURES

Organic manures applied to agricultural land may be produced on farm by livestock as slurries, farmyard manure (FYM) and poultry manures or imported from other sources such as treated sewage sludges (also called bio-solids) and some industrial 'wastes' such as paper waste or brewery effluent.

Of the 1327 farms in the survey, around two thirds (907) used organic manures on at least one field on the farm, the details are shown in Table D1.1a.

Table D1.1a Numbers and percentage (%) of farms using each type of manure in Great Britain, 2008

	none	*cattle FYM*	*cattle slurry*	*pig FYM*	*pig slurry*	*layer manure*	*broiler/ turkey litter*	*other FYM*	*other farm*	*bio-solids*	*other non-farm*
Farms in sample	420	708	256	38	15	29	42	52	7	41	22
Farms in population	27424	48806	15740	2239	680	1709	2607	4348	457	1659	1278
Farms in population %	31%	55%	18%	3%	1%	2%	3%	5%	1%	2%	1%
Volume ('000,000 t; m^3)	n/a	31.7	34.7	1.8	1.0	0.7	1.0	1.3	0.7	2.5	2.0
Volume %	n/a	41%	45%	2%	1%	1%	1%	2%	1%	3%	3%

Note: some farmers may use more than one type of manure

Table D1.1b Percentage (%) of farms using each type of manure in Great Britain, 2004 - 2008

	none	*cattle FYM*	*cattle slurry*	*pig FYM*	*pig slurry*	*layer manure*	*broiler/ turkey litter*	*other FYM*	*other*
2004	28	60	18	2	1	2	2	5	4
2005	31	58	19	1	1	2	3	4	3
2006	30	59	19	2	1	2	2	3	3
2007	33	56	20	1	1	2	2	2	3
2008	31	55	18	3	1	2	3	5	4

Cattle manure from beef and dairy farms is by far the largest volume of manure type generated in Great Britain. The percentage of farms using cattle FYM has declined by 5% since 2004, whereas the use of cattle slurry has remained more consistent, and is at 18% of farms in 2008. Not all the manure generated by a farm is retained for use by that farm and excess manure/slurry can be exported for use elsewhere. Details of estimates of manure exports are given in Table D1.2a.

Table D1.2a Estimated volume of exported manures, Great Britain 2008

	cattle FYM	cattle slurry	pig FYM	layer manure	broiler/ turkey litter	other	total
Farms in sample	19	7	2	3	1	0	30
Farms in population	1498	452	-	-	-	-	2579
Exported volume ('000,000 t; m^3)	0.5	0.1	-	-	-	-	0.7
Average volume per farm (t;m^3)	340	264	-	-	-	-	284

Note: some farmers exported more than one type of manure

This indicates that only about 2% of the farmers surveyed exported manures and that cattle FYM is exported by more farms than any other manure. Data on manure types other than cattle FYM should be treated with caution due to the small numbers in the sample.

Table D1.2b Percentage (%) of farms exporting manures of each type, Great Britain 2004 - 2008

	cattle FYM	cattle slurry	other	farms in population
2004	1.1	0.4	0.5	108140
2005	1.7	0.5	0.3	90787
2006	1.6	0.2	0.2	90549
2007	1.3	0.6	0.3	91361
2008	1.7	0.5	1.0	89241

The percentage of farms exporting cattle manures is reasonably consistent over the five year period 2004 – 2008. Exports of other types of manures have increased over the same period, although this remains at a low level at just 1% of farms.

Of the farms surveyed, 907 reported use of either farm or non-farm manure and, of these, 170 had imported some/all of it. The details are given in Tables D1.3a/b.

Table D1.3a Number of farms importing farm manures (solids and liquids), showing quantity imported, Great Britain 2008

	cattle FYM	cattle slurry	pig FYM	pig slurry	layer manure	broiler/ turkey litter	other FYM	other farm manure	total
Farms in sample	32	6	10	6	23	33	8	1	106
Farms in population	2502	372	439	213	1291	1756	360	-	6624
Imported volume ('000,000 t; m^3)	0.7	0.1	0.4	0.2	0.2	0.6	0.1	-	2.3
Average volume per farm (t; m^3)	283	273	876	948	178	326	199	-	348

Table D1.3b Number of farms importing non-farm manures (solids and liquids), showing quantity imported, Great Britain 2008

	bio-solids	other non-farm manure	total
Farms in sample	42	24	64
Farms in population	1668	1211	2803
Imported volume ('000,000 t; m^3)	1.5	3.9	5.4
Average volume per farm (t; m^3)	898	3255	1941

Note: some farmers imported more than one type of manure

The amount of imported non-farm manures has increased each year since 2003 to 5.4 million tonnes in 2008. This is attributable to both an increase in usage per farm (1941 tonnes;m^3 compared with 1070 tonnes;m^3 in 2003) and to a substantial increase in the number of farms importing (64 compared with 23 in

2003). Cattle FYM and poultry manure continued to be the farm produced manures most likely to be imported.

Table D1.3c Percentage (%) of farms importing manures of each type, Great Britain 2004 - 2008

	cattle FYM	cattle slurry	pig FYM	pig slurry	layer/hen manure	broiler/ turkey litter	other FYM	other	farms in population
2004	1.3	0.5	0.4	0.2	0.4	1.8	0.0	2.4	108140
2005	1.9	0.1	0.4	0.1	1.1	1.9	0.1	2.7	90787
2006	2.1	0.1	0.4	0.0	0.8	2.1	0.3	3.3	90549
2007	2.6	0.6	0.5	0.4	1.1	1.7	0.1	3.2	91361
2008	2.8	0.4	0.5	0.2	1.4	2.0	0.4	3.3	89241

The percentage of farms importing cattle FYM and other manures have gradually increased since 2004 to just under 2.8% and 3.3% of farms respectively in 2008. Other types of manure are imported to a lesser degree and show greater fluctuations across the period.

The number and percentage of farms using each type of slurry application method in Great Britain are shown in Table 1.4. These data serve as a guide only and are calculated as an expression of the number of farms adopting a proportion of each application method, where slurry was applied. The data do not account for the proportion of each farm's total cultivatable area receiving slurry, or any variation in the rate at which slurry may have been applied using different application methods. Notwithstanding these considerations, it is clear that broadcast application is by far the most widespread method adopted across all farm robust types for both types of slurry.

Table D1.4 Number and percentage (%) of farms using each type of application method by slurry type and robust farm type, Great Britain 2008

			percentage of farms					
robust farm type	farms in sample	farms in population	broadcast	band spread	shallow injection	deep injection	rain gun	rotating boom
Cattle slurry								
Cereals	4	222	-	-	-	-	-	-
General cropping	6	217	70	25	25	0	0	0
Dairy	139	9017	90	8	7	2	2	2
Other livestock	78	4954	89	9	2	0	1	0
Pigs and poultry	1	52	-	-	-	-	-	-
Mixed	28	1278	84	6	2	0	4	0
TOTAL	256	15740	89	8	5	1	2	1
Pig slurry								
Cereals	4	112	-	-	-	-	-	-
General cropping	3	97	-	-	-	-	-	-
Dairy	1	103	-	-	-	-	-	-
Other livestock	2	218	-	-	-	-	-	-
Pigs and poultry	1	24	-	-	-	-	-	-
Mixed	4	126	-	-	-	-	-	-
TOTAL	15	680	96	0	0	0	0	4
Both	2	218	-	-	-	-	-	-
Grand Total	269	16202	89	8	5	1	2	2

Whilst some of these application methods (e.g. shallow injection or deep injection) apply slurry below the surface of the field, the majority require secondary cultivation to incorporate the manure/slurry into the soil. Assessment of how often organic manures are incorporated into the soil is complicated by the fact that some farmers make more than one application or apply more than one type of manure and may incorporate each of these differently. As manure on grass fields is seldom incorporated (unless they are destined for re-seeding), grass fields have been excluded from the incorporation analysis.

Table D1.5 gives estimates of the volume and area of manure/slurry incorporation on tillage fields by manure type and immediacy of incorporation. Farm yard manure is the most extensively incorporated at 94% of the area with 78% of it incorporated within a week of spreading on tillage fields. Cattle slurry is less likely to be incorporated at 85% of the volume and this incorporation tends to be later than for FYM, with 23% of the volume incorporated after one week.

Table D1.5 Percentage of incorporated of organic manure volume and area on tillage fields by incorporation time and manure/slurry type, Great Britain 2008

	incorporation time after spreading										*total*	
	not incorporated		*within 6 hours*		*between 6 and 24 hours*		*between 1 and 7 days*		*more than 1 week*		*applied area*	*volume applied*
	%area	*%vol*	*%area*	*%vol*	*%area*	*%vol*	*%area*	*%vol*	*%area*	*%vol*	*'000 ha*	*'000,000t;m* ^{3}
FYM	6	7	6	6	20	19	52	53	15	16	652	16.2
Cattle slurry	22	15	4	3	21	26	29	34	23	23	117	3.7
Pig slurry	12	7	6	3	6	5	48	45	28	39	24	0.5
Poultry FYM	13	18	16	12	40	35	28	33	3	2	159	1.6
Other	3	0	23	22	38	30	36	48	0	0	127	4.0

Farmers were asked to indicate what proportion of their livestock manures had been spread by a contractor (Table D1.6). Farmers with pig slurry were the least likely to use a contractor to apply at least some of their manure at 10% of farms, with other main manure and slurry types sitting between 26-33% of farms using a contractor. Where contractors were used they were applying between 84 and 100% of the manure.

Table D1.6 Use of contractors to spread manure/slurry in current season, Great Britain 2008

	% of farms using a contractor	*% volume applied by contractor*	*average % of contractor-applied manure, where contractor is used*
FYM	27	23	90
Cattle slurry	33	24	84
Pig slurry	10	7	100
Poultry manure	26	32	100
Other	65	71	98

Note: care should be taken with slurry figures here as the bases are small.

D2 USE OF ORGANIC MANURES

The proportion of fields receiving each of the main types of manure is shown in Table D2.1a, with cattle FYM and cattle slurry being the most commonly applied manures.

Table D2.1a Percentage of fields receiving each organic manure type, Great Britain 2008

	cattle FYM	cattle slurry	pig FYM	pig slurry	sheep FYM	layer manure	other FYM	other farm manure	bio-solids	other non-farm	total
% of all fields	20	9	1	0	1	1	1	0	1	1	32
% of all fields where organic manure is applied	62	26	4	1	2	4	4	1	3	2	100

Note: some fields may receive more than one type of manure

Table D2.1b Percentage of all fields receiving each organic manure type, Great Britain 2004 - 2008

	cattle FYM	cattle slurry	pig FYM	pig slurry	layer hen manure	broiler/ turkey litter	other FYM	other
2004	23	9	1	1	0	1	1	1
2005	21	9	0	0	1	1	1	1
2006	23	9	0	1	1	1	1	1
2007	20	9	0	0	1	1	0	1
2008	20	9	1	0	1	1	1	2

Table D2.1c Percentage of all fields where organic manure is applied receiving each organic manure type, Great Britain 2004 - 2008

	cattle FYM	cattle slurry	pig FYM	pig slurry	layer hen manure	broiler/ turkey litter	other FYM	other
2004	72	27	2	2	1	2	4	3
2005	69	28	1	1	2	4	4	5
2006	70	28	1	2	2	2	3	5
2007	68	32	2	1	2	2	2	3
2008	62	26	4	1	2	4	4	5

The percentage of all fields receiving an application of cattle FYM has declined slightly since 2004 to 20%. Looking across all fields where an organic manure has been applied the trend for cattle manure and slurries is for declining applications, and increased applications for pig FYM, broiler and turkey litter and other manure types (Table 2.1c).

The levels of nutrient within organic manures vary according to which type of manure is being applied as well as factors such as the size, age, gender, and market for the animals being farmed. Furthermore, the concentration of nutrients is dependent on the proportion of bedding, the length of time that the manure has been stored and, in the case of slurries particularly, diluting factors such rainwater or dirty water which affect the proportion of dry matter. The British Survey of Fertiliser Practice does not ask detailed questions on the animals producing manures or the nutrient analysis of any organic applications made, but it is possible to use typical values for different manure types to estimate the likely nutrient levels delivered. Details of these values are given in Table D2.2.

Table D2.2 Typical dry matter and nutrient content of different organic manure types[1]

	dry matter (%)	*total N (kg/t; kg/m^3)*	*total P_2O_5 (kg/t; kg/m^3)*	*total K_2O (kg/t; kg/m^3)*
Cattle FYM	25	6.0	3.5	8.0
Pig FYM	25	7.0	7.0	5.0
Sheep FYM	25	6.0	2.0	3.0
Duck manure	25	6.5	5.5	7.5
Layer hen manure	30	16.0	13.0	9.0
Broiler/turkey litter	60	30.0	25.0	18.0
Cattle slurry	6	2.7	1.2	3.1
Pig slurry	4	4.0	2.0	2.5
Digested liquid sewage sludge	4	2.0	1.5	-
Digested cake	25	7.5	9.0	-
Thermally dried	95	35.0	45.0	-
Lime stabilised	40	6.0	8.0	-
Composted green manure	65	7.0	2.8	5.3

Using these typical values it is possible to estimate the average application rate for nitrogen on fields receiving manures. In Table D2.3, crops receiving manure applications have been classified as either "winter sown", "spring sown" or "grass" (details given in Table D2.5) and their average application of nitrogen calculated accordingly.

Table D2.3 Estimated average rates of total nitrogen from organic manure applications to winter sown and spring sown crops and grassland by manure type, Great Britain 2008

	cattle FYM	*cattle slurry*	*pig FYM*	*pig slurry*	*layer manure*	*broiler/ turkey litter*	*other FYM*	*other farm manure*	*bio-solids*	*other non-farm*
Winter sown										
Treated area %	7.4	1.0	1.1	0.4	1.0	2.4	0.6	-	1.9	1.2
Avg manure rate (t; m^3/ha)	25	30	19	20	12	8	20	-	28	39
Volume ('000,000 t ; m^3)	5.7	0.9	0.7	0.2	0.4	0.6	0.3	-	1.6	1.4
Fields in sample	312	39	41	19	31	50	23	4	62	26
Spring sown										
Treated area %	23.1	2.2	1.8	0.9	0.8	2.0	-	-	1.3	0.6
Avg manure rate (t; m^3/ha)	23	19	33	21	5	8	-	-	21	41
Volume ('000,000 t ; m^3)	4.8	0.4	0.5	0.2	0.0	0.1	-	-	0.3	0.2
Fields in sample	277	35	28	12	11	21	4	1	11	11
Grass										
Treated area %	23.2	24.3	0.5	0.7	0.4	0.6	2.1	0.5	0.6	0.3
Avg manure rate (t; m^3/ha)	15	26	12	12	4	5	8	32	13	8
Volume ('000,000 t ; m^3)	17.2	31.0	0.3	0.4	0.1	0.1	0.8	0.7	0.4	0.1
Fields in sample	598	538	19	17	9	22	47	12	19	6

[1] Anon. (2000). *Fertiliser Recommendations for Agricultural and Horticultural Crops.* MAFF Reference Book 209 (Seventh edition). The Stationery Office, London.

The majority of cattle manure and slurry applications were made to grassland, reflecting the practice of utilising the manure within the farm on which it is produced. Conversely, non-farm manures such as biosolids appear to be favoured on winter sown tillage land.

The time of year when manure was applied is shown in Table D2.4. as a proportion of fields receiving manure applications. Once again the crops have been classified as either “winter sown”, “spring sown” or “grass”. This segmentation highlights the prevalence of applications in August and September for winter sown crops (prior to drilling), whereas spring sown and grass fields are predominantly treated between November and April.

Table D2.4 Percentage of fields receiving each organic manure type by sowing season and timing, Great Britain 2008

	cattle FYM	*cattle slurry*	*pig FYM*	*pig slurry*	*layer manure*	*broiler/ turkey litter*	*other FYM*	*other farm manure*	*bio-solids*	*other non-farm*
Winter sown										
August	20	23	53	26	35	44	37	-	31	25
September	61	41	33	19	59	30	58	-	53	60
October	11	5	4	8	2	2	5	-	13	15
Winter (Nov, Dec, Jan)	2	10	0	3	0	0	0	-	3	0
Spring (Feb, Mar, Apr)	3	15	1	15	2	24	0	-	0	0
Summer (May, Jun, Jul)	2	6	8	29	2	0	0	-	0	0
Spring sown										
August	0	0	0	0	6	0	-	-	9	0
September	2	1	3	0	0	0	-	-	3	0
October	5	0	24	5	11	0	-	-	23	0
Winter (Nov, Dec, Jan)	26	24	28	32	40	23	-	-	58	0
Spring (Feb, Mar, Apr)	66	75	44	63	43	77	-	-	7	100
Summer (May, Jun, Jul)	1	0	0	0	0	0	-	-	0	0
Grass										
August	9	5	2	2	8	6	11	30	0	0
September	5	1	6	0	0	0	5	45	14	18
October	8	4	0	2	0	14	17	0	40	0
Winter (Nov, Dec, Jan)	22	18	34	9	0	8	13	1	0	0
Spring (Feb, Mar, Apr)	39	47	45	51	85	68	29	17	39	71
Summer (May, Jun, Jul)	16	24	13	37	7	4	26	7	7	11

Table D2.5 Classification of “winter sown”, “spring sown” and “grass” crops

crop group	*crops included*						
Winter sown	Rye/triticale (for grain)		Winter barley	Winter oats	Winter oilseed rape		Winter wheat
Spring sown	Beans for human consumption (broad, french, runner etc.)				Beetroot	Broccoli	Cabbage
	Calabrese/broccoli		Carrots	Cauliflower	Courgette/marrows		Peas
	Flax	Forage maize	Leeks	Lettuce	Linseed	Mangolds/fodderbeet	
	Onions	Other outdoor vegetables		Parsnips	Potatoes	Spring barley	Spring oats
	Spring oilseed rape		Spring wheat	Sugar beet	Swedes/turnips		Sweetcorn
Grass	Grass five years and over		Grass less than five years old				

D3 FERTILISER VALUE OF ORGANIC MANURES

Organic manures are valuable sources of the major plant nutrients (nitrogen, phosphorus and potassium) and, where used, applications of manufactured fertiliser can usually be reduced[2]. In the survey, farmers were not asked directly whether they had made an adjustment to fertiliser inputs because of manure use, however an indication of possible adjustments has been derived by comparing fields that received manure with those that did not. Organic fields, which use no mineral fertilisers, have been excluded from these comparisons, since they would distort the influence of manures on mineral application rates. Table D3.1a shows the overall fertiliser rates for the main tillage crops in Great Britain, with and without manure inputs.

Table D3.1a Overall field rate of manufactured fertiliser application to tillage crops in Great Britain, with and without applications of organic manure, 2008

	nitrogen		*phosphate*		*potash*		*fields in sample*	
	with manure	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*
Winter wheat	161	183	17	30	31	37	356	1596
Spring barley	88	101	39	33	48	48	252	460
Winter barley	122	137	25	37	41	53	120	489
Potatoes (maincrop)	154	156	140	127	260	227	39	57
Sugar beet	80	89	15	39	84	93	46	88
Spring oilseed rape *	161	108	0	55	48	65	1	17
Winter oilseed rape	159	197	14	31	25	36	68	495
Peas - animal consumption *	0	1	20	23	75	34	2	37
Beans - animal consumption *	2	1	9	24	29	25	16	140
Forage maize	44	48	34	31	29	67	172	20

* Note: small number of fields receiving manures

For all the major tillage crops, except spring oilseed rape, where we have very few fields, the overall rate of nitrogen from manufactured mineral fertiliser is consistently higher on fields where organic manures were not applied. Application rate increases in nitrogen ranged from 1% for potatoes through to 24% for winter oilseed rape. This is also predominantly the case for phosphate and potash fertiliser application rates. This was most dramatically illustrated by a 62% decrease in the rate of phosphate on manured sugar beet fields. Maincrop potatoes showed a reduction in the overall rates of phosphate and potash on un-manured land, although the number of fields in the sample is quite low. The survey does not collect reasons why manufactured fertiliser application rates may vary when used with or without organic manures. It is possible that certain fields are being managed to achieve a desired nutrient status and a strategy of this sort may require unusually high or low applications of specific nutrients. Where only a small number of fields are surveyed, such a strategy may exert an influential bias on the overall figures for a crop.

[2] Anon. (2000). *Fertiliser Recommendations for Agricultural and Horticultural Crops.* MAFF Reference Book 209 (Seventh edition). The Stationery Office, London.

Table D3.1b Overall field rate from manufactured fertiliser application to tillage crops in Great Britain, with and without applications of organic manure, 2004 - 2008

	2004		*2005*		*2006*		*2007*		*2008*	
nitrogen	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*
Winter wheat	191	199	177	199	167	197	168	194	161	183
Spring barley	93	109	87	112	102	101	94	103	88	101
Winter barley	133	147	120	150	114	141	108	141	122	137
Potatoes (maincrop)	172	149	148	186	136	152	109	144	154	156
Sugar beet	98	95	88	101	83	109	79	99	80	89
Winter oilseed rape	177	215	180	209	181	193	181	191	159	197
Forage maize	46	93	58	89	52	58	51	61	44	48
	2004		*2005*		*2006*		*2007*		*2008*	
phosphate	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*
Winter wheat	30	40	31	38	19	37	21	33	17	30
Spring barley	46	44	38	42	49	33	41	36	39	33
Winter barley	50	45	42	43	35	38	34	36	25	37
Potatoes (maincrop)	125	128	116	188	90	156	91	151	140	127
Sugar beet	22	41	23	46	19	45	11	50	15	39
Winter oilseed rape	23	41	27	44	25	35	19	32	14	31
Forage maize	39	56	42	64	43	20	40	28	34	31
	2004		*2005*		*2006*		*2007*		*2008*	
potash	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*
Winter wheat	49	48	44	44	37	42	36	40	31	37
Spring barley	53	59	48	55	60	61	51	49	48	48
Winter barley	65	62	54	58	51	54	46	62	41	53
Potatoes (maincrop)	243	188	204	306	174	225	141	230	260	227
Sugar beet	94	108	77	135	76	128	81	110	84	93
Winter oilseed rape	34	48	31	44	37	37	39	37	25	36
Forage maize	42	72	62	128	38	84	33	25	29	67

Differences in field rates with and without manures for nitrogen, phosphate and potash for the period 2004 to 2008 are shown in table D3.1b above. The trend for higher rates on unmanured fields holds true for nitrogen and phosphate on winter wheat throughout the period. The increased rates are most consistent for nitrogen on winter wheat at between 4% and 18% increase over manured fields. Winter oilseed rape application rates for all three nutrients were consistently higher on unmanured crops over the five year period. Other crops show greater variability between manured and unmanured field rates for the different nutrients across the five year period which may in part be due to the lower number of fields of each of these crops in the survey causing higher statistical variability.

Data for grassland are presented separately because grass is managed differently according to the amount of production required. Thus, intensive milk production requires large volumes of grass and is likely to receive higher inputs of both manure and mineral fertilisers than beef or sheep systems. Table D3.2 shows the average field rate of fertiliser applied to grassland in different management systems (as defined by Robust farm type groups) with and without applications of manure. Average field rates have been used for grassland because grass fields often receive no mineral fertiliser, not because of manure use, but because the amount of grass production required does not warrant fertiliser input.

Table D3.2 Average fertiliser application rate on grassland with and without applications of organic manure by robust type group, Great Britain 2008

	nitrogen		*phosphate*		*potash*		*fields in sample*	
	with manure	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*
Cereals								
Grass under 5 years old *	100	112	32	37	41	56	20	119
Grass 5 years and over *	61	72	29	27	58	34	19	351
All grass	86	84	31	31	44	43	39	470
Dairy								
Grass under 5 years old	166	118	33	26	59	34	144	45
Grass 5 years and over	133	128	26	26	39	33	257	167
All grass	143	126	28	26	45	33	401	212
General cropping								
Grass under 5 years old *	109	114	22	40	37	50	22	70
Grass 5 years and over *	71	71	17	24	18	29	12	163
All grass	90	86	19	31	26	38	34	233
Mixed								
Grass under 5 years old	168	101	48	28	92	36	48	116
Grass 5 years and over	88	80	26	25	34	31	40	230
All grass	130	87	36	26	62	32	88	346
Other livestock								
Grass under 5 years old	96	94	31	25	37	35	128	140
Grass 5 years and over	71	61	20	17	23	19	357	532
All grass	75	66	22	19	26	22	485	672
All farm types								
Grass under 5 years old	141	104	33	29	53	40	363	493
Grass 5 years and over	101	77	23	21	31	24	685	1447
All grass	112	83	25	23	36	28	1048	1940

Note: all farm types exceeds the sum of the other in the table as it includes pig and poultry farms
* Note: small number of fields receiving manures

When looking at all farm types taken together, the rates of nitrogen, phosphate and potash fertiliser were higher on fields where manures were also used. Mineral fertiliser rates were also consistently higher on short term grass than permanent grassland.

As so many fields on dairy farms receive manure, a separate analysis was carried out to examine the influence of grass management (Table D3.3a).

Table D3.3a Average fertiliser application rate on dairy grassland with and without applications of organic manure, Great Britain 2008

	nitrogen		*phosphate*		*potash*		*fields in sample*	
	with manure	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*
All cut for hay	75	74	18	26	18	32	144	352
All cut for silage	126	110	29	30	45	43	631	476
All grazings	108	81	24	22	34	26	945	1742

Application rates of mineral fertilisers are consistently higher for grass to be cut for silage and on fields that also receive a dressing of manure.

Table D3.3b Average fertiliser application rate on dairy grassland with and without applications of organic manure, Great Britain 2004 – 2008

	nitrogen		*phosphate*		*potash*		*fields in sample*	
all cut for hay	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*
2004	117	116	29	54	44	66	44	22
2005	89	120	24	54	37	45	33	15
2006	86	84	30	21	41	24	42	15
2007	85	78	31	29	36	37	131	347
2008	75	74	18	26	18	32	144	352
	nitrogen		*phosphate*		*potash*		*fields in sample*	
all cut for silage	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*
2004	163	187	30	54	60	77	301	68
2005	165	148	33	30	57	51	225	75
2006	139	118	30	26	50	38	246	55
2007	133	120	31	33	48	49	657	542
2008	126	110	29	30	45	43	631	476
	nitrogen		*phosphate*		*potash*		*fields in sample*	
all grazings	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*	*with manure*	*without manure*
2004	152	163	29	32	47	42	457	221
2005	153	157	30	29	47	38	330	175
2006	136	129	28	25	43	27	383	169
2007	117	83	26	25	37	30	1028	1810
2008	108	81	24	22	34	26	945	1742
Note: Figures for 2004-2006 are for England & Wales, figures for 2007 onwards are for Great Britain								

Mineral fertiliser application rates of nitrogen on grass cut for hay have in general declined over the 5 year period 2004-2008. For phosphate and potash significant reductions were not seen until this year and these were most marked in fields receiving manure. There is a similar pattern of reducing nitrogen and potash on grass cut for silage since 2004. Phosphate rates on grass for silage have held more steady since 2005 in the range of 26-33 kg/ha.

In recent years there has been a great deal of promotional activity aimed at encouraging farmers to make adjustments to fertiliser inputs where manures are used. When making comparisons of the data presented in this report a number of factors should be taken into account:

- the extent to which individual farmers have accounted for the nutrients in the manures cannot be judged from these data,
- the data presented for 'with/without' manure are not a paired comparison of otherwise identical fields,
- fields which have not received manures may be on farms which have no manure and are thus managed in a different way,
- in grassland systems, fields which have not received manures may be managed differently (e.g. grazed only) compared with manured fields which may be cut more than once as well as grazed,
- for tillage crops, the overall fertiliser rate means that some fields are included which have received no fertiliser. For the 'with manure' data, it may indicate that the manure was judged to supply all the fertiliser which was required,
- for grassland, the average fertiliser rate has been used so as to avoid distorting the data by inclusion of 'unmanaged' grass, which receives no fertiliser, although this has the effect of excluding any fields on which no fertiliser was applied because the manure was considered sufficient, thus obscuring a substitution effect,
- the dataset of fields where manures are used includes fields which may have received only a very small amount of manure (see section D2). On those fields receiving large dressings, there may be a greater adjustment in mineral fertiliser,
- where reductions in phosphate and potash fertiliser have not been made, this may indicate a desire to build up soil reserves of these nutrients.

Modelling BSFP data to provide holding level inputs to the EU Farm Structure Survey

1. Project aim

This report provides a short summary of a modelling study using data from the British Survey of Fertiliser Practice. The aim was to investigate the feasibility of using BSFP and additional survey data to model farm level fertiliser inputs. This could then be refined to provide data for the EU Farm Structure Survey to avoid the need to collect fertiliser information directly (for each farm in the UK) as part of the survey.

To test the feasibility of the modelling, this analysis focused on Nitrogen (N) applied to English wheat fields, across all farm types, in 2007. At the time of analysis this was the most recent BSFP data available. The assumption was made that if it is not possible to model the most commonly applied nutrient to the most widespread crop, then the possibilities for other crops and nutrients are severely limited.

2. Exploratory data analysis with BSFP variables

The BSFP data is collected at the application level for each individual field[1]. Thus individual applications need to be summed to give total field inputs. Average field applications then form farm level inputs.

Individual applications

Considering first the individual N applications (Figure 1)[2]. The majority of fertiliser applications made to wheat fields (83%) contain some N. Most applications were between 25 and 100 kg/ha with an average of 72 kg/ha (Table 1). The distribution has a long upper tail with a maximum application rate of 266 kg/ha but only a quarter of applications exceeded 88 kg/ha.

In most cases a field will receive more than 1 fertiliser application each year. This allows the crop to take on board the nutrients at key growth stages as well as minimising the quantities lost through leaching. In 2007 some wheat fields received as many as 7 individual applications (Figure 2). Above 3 applications, the application rate tended to be lower and less variable. Three nitrogen applications was the most common scenario and occurred on almost 40% of wheat fields (700 fields), although 2 and 4 applications were also quite common (Figure 3).

[1] In BSFP a field is defined as any single area of land measuring more than 0.2 ha (half an acre) which had a uniform cropping and fertiliser history from autumn 2006 to summer 2007. For data collection and processing purposes, separate fields with identical cropping and fertiliser management on the same farm are blocked together as one ‘field’, to represent the total combined area of those fields. Areas within the same natural boundary with different crops or receiving different fertiliser treatments were recorded separately.

[2] Note that both straight and compound N fertilisers have been included.

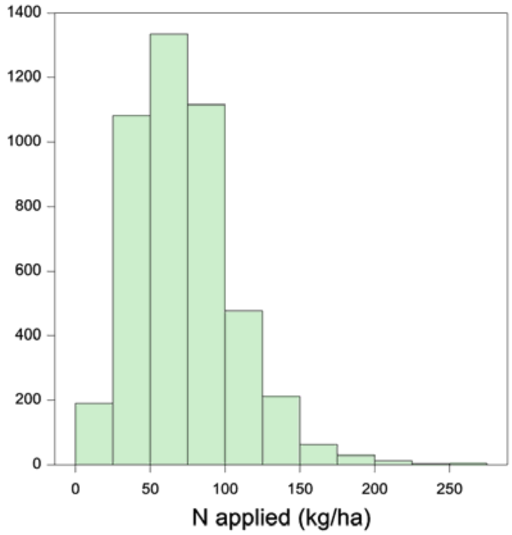

Table 1: Nitrogen applications on wheat in 2007. There were 4,526 individual applications. Application rates above 300 kg/ha were excluded from analysis

	N applied (kg/ha)
Mean	72
Median	67
Minimum	4
Maximum	266
Range	263
Lower quartile	46

Figure 1: Nitrogen applications on wheat in 2007.

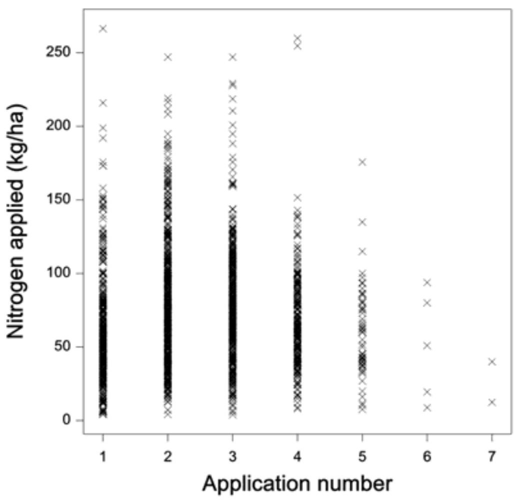

Figure 2: Nitrogen applied to wheat fields by application number in 2007.

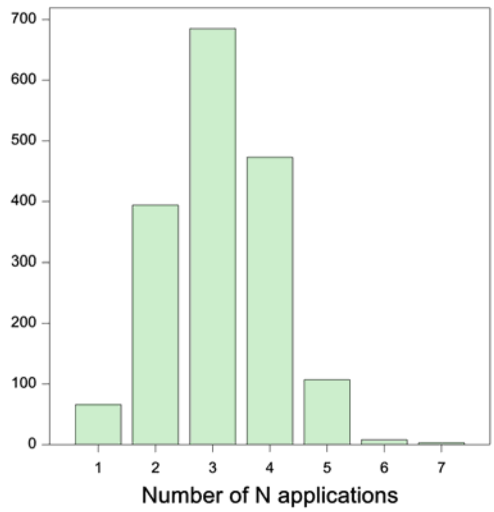

Figure 3: The number of nitrogen applications to wheat fields in 2007.

Field level application rates

For this project there is no need to differentiate between a single N application of 100 kg/ha or two separate 50 kg/ha applications to the field. So the rest of the analysis focuses on the field and average farm levels application rates.

Only 5 (of 1,750) wheat fields received no nitrogen. When individual applications were summed about 10 wheat field applications exceeded 400 kg/ha. This level was deemed unreasonable and these data points have been omitted[3]. The mean and median field application rates were both 190 kg/ha (Table 2) and their distribution (Figure 4) was closer to normal than for the individual application rates. Half of the wheat fields had N

[3] The Nitrogen response curve on P8 of Fertiliser Recommendations for Agricultural and Horticultural Crops RB209) shows that yield will tend to increase with increased N up to 190 kg/ha after which point it levels off as the nitrate leaching losses increase. At rates above 280 kg/ha the yield decreases with increased N and substantial quantities of N are left in the soil after harvest and are a potential pollution hazard. RB209 is available on the Defra web site at: http://www.defra.gov.uk/FARM/environment/land-manage/nutrient/fert/rb209/.

application rates between 160 and 220 kg/ha. As previously stated this N will normally have been applied in 2 to 4 separate applications and typically the greater the number of applications the greater the total amount of N added to the field (Table 3). The range of application rates also tended to increases with further applications.

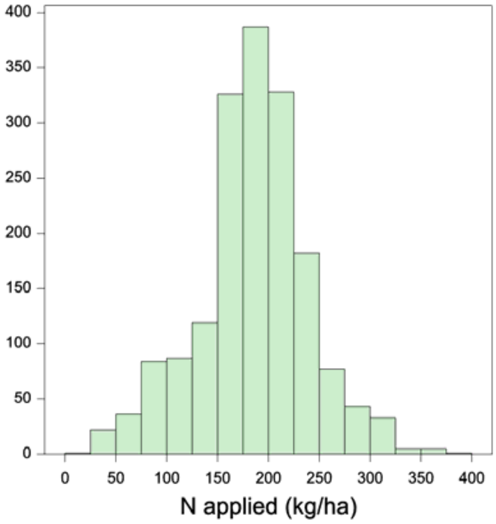

Figure 4: Field level nitrogen applications

Table 2: Field level nitrogen applications on wheat in 2007. Field application rates above 400 kg/ha were excluded from the analysis leaving 1,736 wheat fields that received some nitrogen.

	N applied (kg/ha)
Mean	185
Median	188
Minimum	12
Maximum	386
Range	374
Lower quartile	160
Upper quartile	218

Table 3: Summary statistics for field level nitrogen applications (kg/ha) broken down by the number of separate applications. As previously, field application rates above 400 kg/ha were excluded. There is insufficient data to produce robust estimates for 6 and 7 applications (n=8 and 3 respectively).

	Number of applications				
	1	2	3	4	5
Number of fields	66	394	685	473	107
Mean	94	161	189	203	223
Median	87	165	189	203	220
Range	204	262	319	340	264
Lower quartile	54	130	167	181	200
Upper quartile	123	188	217	224	249

The N requirements for wheat (like any other crop) are related to a number of factors including the soil characteristics, the climate and the quantity of nutrients that the previous crop removed from (or added to) the soil. If the preceding crop has removed significant quantities of N from the soil or cereals have been grown several years in succession, N application rates will usually need to be higher. Conversely, a spring sown crop usually requires a lower N input. The impact of these three factors was examined at the field level.

There was no evidence to suggest that the number of years cereals are grown in the field impacts upon fertiliser application rates (Table 4), although 90% of the wheat fields receiving N fertiliser were in consecutive cereals for two years or less. The BSFP collects the previous crop for each field in the survey and the dataset contains a value for the maximum recommended N application for each crop. Using these maximum recommended N values for the previous crop as a proxy for the actual N applied showed that there was little relationship between the maximum N for the 2006 crop and actual applications on the 2007 crop (Figure 5).

As anticipated fertiliser applications on spring wheat were lower than for winter wheat (average 150 kg/ha compared to 190 kg/ha) and they had a range of only 200 kg/ha (Table 5). However, spring wheat was only recorded in 21 fields in 2007 (just over 1% of wheat fields).

Table 4: Summary statistics for field level nitrogen applications (kg/ha) broken down by the number consecutive years of cereal growth. As previously, field application rates above 400 kg/ha were excluded.

	Number of years of continuous cereals						
	1	**2**	**3**	**4**	**5**	**6**	**20**
Number of fields	1,204	342	77	34	17	9	53
Mean	184	196	177	170	175	185	193
Median	185	201	185	176	193	195	201
Range	374	344	258	234	224	126	320
Lower quartile	158	173	130	130	130	172	173
Upper quartile	214	225	214	213	219	217	232

Table 5: Summary statistics for field level nitrogen applications (kg/ha) on winter and spring sown wheat. As previously, field application rates above 400 kg/ha were excluded.

	Season	
	Winter	**Spring**
Number of fields	1,715	21
Mean	186	150
Median	189	151
Minimum	13	48
Maximum	386	237
Range	374	189
Lower quartile	160	100
Upper quartile	218	203
Standard deviation	55	55

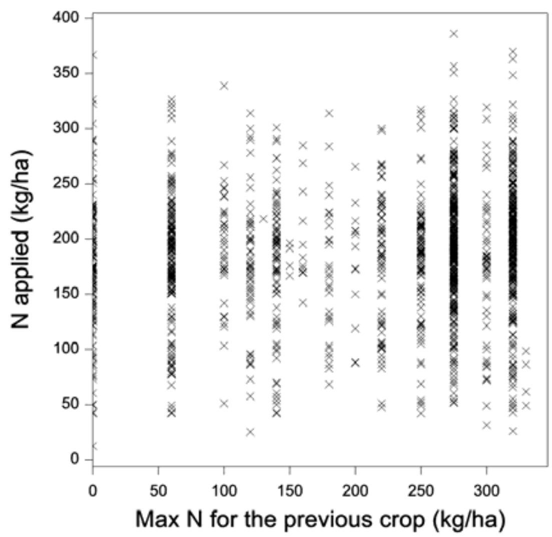

Figure 5: Field level nitrogen applications by recommended maximum nitrogen for the previous crop.

3. Exploratory data analysis with June Survey variables

Of course the variables used so far are only available as part of the BSFP. For the modelling to be a success, it needs to use variables that are readily available for the full population. These could come from the June Survey (which is the main source for the EU Structure Survey) or a dataset that can be readily matched to the full June Survey population. Such variables that might be related to fertiliser input are farm size and farm type, livestock units or a geographical variable. Almost 1,500 of the fields analysed in the previous sections could be matched to the information available from the June Survey.

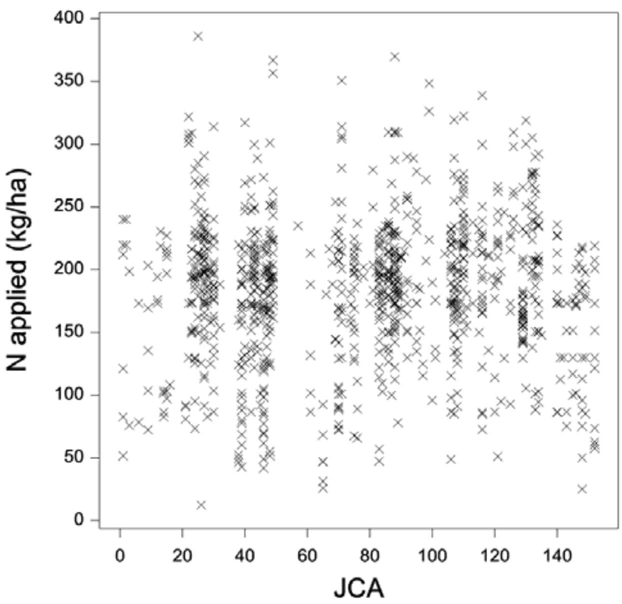

Figure 6: Field level Nitrogen applications by JCA number.

Starting with geographical variables, there was little variation in the average field application by NUTS 1 region (Table 6). The median application was approximately 190 kg/ha in all regions except the NW (which had a very small sample size). With the exception of fields in the north (NE or NW), half of the fields received between 160 and about 220 kg/ha of N fertiliser. Joint Character Areas (JCAs[4]) could provide a better predictive variable. These units are much smaller than NUTS 1 regions and are composed of areas with similar landscape characteristics. If fertiliser use within JCAs is consistent, JCAs might provide a proxy for a range of environmental factors. Unfortunately, as Figure 6 shows there was considerable variation within the application rates in each JCA. Considering just the 15 JCAs with more than 30 fields (Table 7), showed that: (a) the difference in average N application rates is quite small; and (b) on average, the central 50% of the data for each region varied by 55 kg/ha (which is more than 25% of the average application rate). This initial analysis suggested that relatively simple geographical breakdowns will not yield suitable predictor variables.

[4] England has been divided into 159 JCAs based on their physiogeographic, land-use, historical and cultural attributes . See http://p1.countryside.gov.uk/LAR/Landscape/CC/jca.asp for more details on JCAs.

Table 6: Summary statistics for field level nitrogen applications (kg/ha) broken down by NUTS 1 region. As previously, field application rates above 400 kg/ha have been excluded.

	Region							
	NE	NW	YH	EM	WM	E	SE	SW
Number of fields	71	15	278	344	88	242	198	239
Mean	175	147	185	182	184	188	196	182
Median	197	154	188	186	190	194	193	188
Lower quartile	104	91	160	158	158	160	163	152
Upper quartile	220	188	220	207	217	220	234	213

Table 7: Summary statistics for field level nitrogen applications (kg/ha) for each of the JCAs with more than 30 data points. JCA numbers as used on Figure 6 are given in brackets after the JCA name. As previously, field application rates above 400 kg/ha were excluded.

JCA	Number of fields	Mean	Median	Lower quartile	Upper quartile
Vale of Mowbray (24)	36	187	192	169	214
Yorkshire Wolds (27)	54	194	197	173	224
Southern Magnesium Limestone (30)	41	197	188	163	226
Humberhead Levels (39)	45	146	170	101	177
Lincolnshire Wolds (43)	43	200	200	175	221
The Fens (46)	68	143	126	98	182
Trent and Belvoir Vales (48)	48	176	180	126	200
Kesteven Uplands (75)	35	176	198	141	206
South Suffolk and North Essex Clayland (86)	34	198	196	180	221
Bedfordshire & Cambridgeshire Claylands (88)	47	203	200	173	217
Severn & Avon Vales (106)	40	191	200	174	223
Cotswolds (107)	36	195	176	160	235
Chilterns (110)	40	230	228	209	253
Berkshire & Malborough Downs (116)	41	189	195	172	217
Thames Basin Heaths (129)	42	172	164	156	181

Given that livestock farmers have greater access to organic manures to supplement their inorganic fertilisers, application rates may differ with farm type. Specialist cereal farmers tended to have the largest application rates, whilst mixed farms had the most variable (Table 8). The average application rates for dairy were pulled down by a few kg/ha due to the presence of a handful of fields which were within Less Favoured Areas (LFAs), where application rates were only 90 kg/ha.

Table 8: Summary statistics for field level nitrogen applications (kg/ha) for each (robust) farm type. As previously, field application rates above 400 kg/ha were excluded.

	Number of fields	Mean	Median	Lower quartile	Upper quartile
Cereals	833	192	197	169	221
Dairy	57	165	170	129	201
General Cropping	320	177	182	154	208
Lowland Livestock	44	164	173	126	190
Mixed	178	183	180	130	226

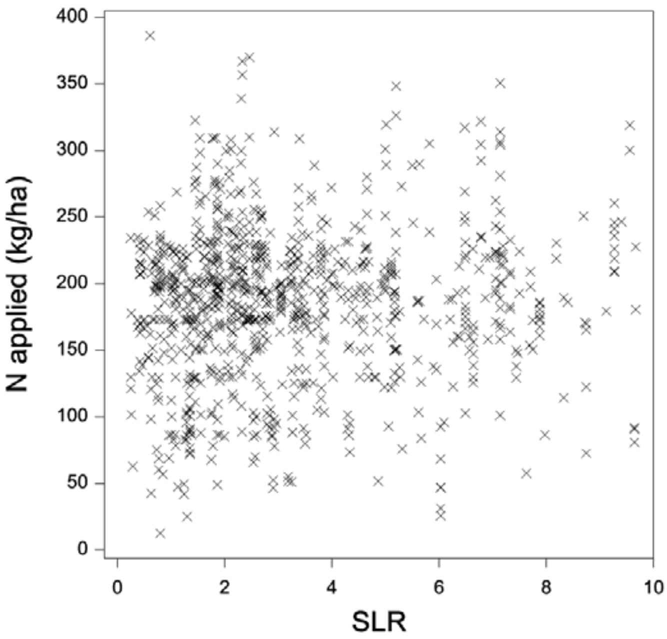

Figure 7: Field level nitrogen applications by Standard Labour Requirements (SLR). On this chart the SLR axis has been truncated at SLR 10,

In general, average rates were higher on farms where the dominant enterprise is cropping than those where the dominant enterprise is livestock based. The robust farm types used in (Table 8) can be broken down into a more detailed list known as main farm types (Appendix 1). The highest median application rate was on the 'cropping & dairy' main farm type (220 kg/ha). On average, for these 25 farms, wheat accounted for 30% of the total farm area. If these farms were growing a second wheat as feed wheat[5] the extra fertiliser may have been needed to obtain the desired high yields.

Farm size was also considered as a predictor. Smaller farms had the lowest application rates, but application rates were not largest on very large farms (Table 9). In general, there was no clear link between the Standard Labour Requirements (SLR)[6] for a holding and the N application rates (Figure 7).

This section has highlighted that at the field level we do not have any obvious predictor variables for fertiliser use.

Table 9: Summary statistics for field level nitrogen applications (kg/ha) by farm size – farm size very small (spare time) has been omitted from the table. As previously, field application rates above 400 kg/ha were excluded.

	Number of fields	Mean	Median	Lower quartile	Upper quartile
Very small (P/T)	102	174	190	13	144
Small	347	177	188	25	138
Medium	303	194	195	47	170
Large	324	188	194	51	172
Very large	367	185	182	26	151

[5] Often when the rotation includes wheat for two consecutive years, the first wheat following a fallow year or peas/beans will often be a feed wheat. The aim being to take advantage of the higher soil nitrogen and achieve bigger yields. The second wheat, when the anticipated yields are lower, will often be a milling wheat. These offer a price premium to offset the lower yields. Farmers with livestock will often only be growing feed wheat with their aim to grow enough to avoid the need to buy in grain over the winter. The cost of this grain (or pre-mixed feed) is more than the sale value of their grain, hence their economic optimum fertiliser rate will be higher.
[6] SLR is an estimate of farm size. It is estimated using the theoretical labour requirements for the holding based on its land-use and livestock.

4. Variance modelling

Before attempting any modelling at the farm level it is useful to investigate the scale at which the variation in fertiliser application rates occurs. Linear mixed models[7] were fitted to the data using restricted maximum likelihood (REML) to allow multiple random terms. Data from the BSFP is in a hierarchical structure in which there is variation within:

(1) fields on individual farms within counties;
(2) farms within counties; and
(3) counties (within England).

This leads to a mixed model with a constant for the fixed component and 3 random components. This model was fitted to the data and the variance of the separate components examined. The analysis showed that there was some field-to-field variation within farms (intra-farm variation), which suggests that some farmers take greater account of local variations across their farm. The larger the farm the more likely it is for conditions to change necessitating a different application rate. The vast majority of the variation in application rates was between farms. Inter-farm variation was at least 3 times as important as intra-farm variation. This is not surprising given that inter-farm variation is influenced by both environmental conditions and farmer behaviour[8]. There was little variation in N applications on wheat at the county level.

In summary, the variance modelling has shown that it is the local (inter-farm) scale variation that is important not the micro (field) or macro (county) scale variations.

5. Farm level exploratory analysis

To permit modelling at the farm level, the average nitrogen application rate across all 2007 wheat fields was calculated for each farm. A large number of farms in the data set had more than one field and in most cases the field size varied. Thus the farm level application rate was calculated as a weighted average based on the field size. The farm level average N application rate had a median of 190 and a mean of 180 kg/ha, but the distribution had quite long tails (Figure 8 and Table 10). Half of farms had an average application rate between 150 and 210 kg/ha but farmers in the upper and lower 2% of the distribution applied more than 300 kg/ha and less than 50 kg/ha respectively.

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[7] Models that contain both fixed and random terms

[8] There are many things outside the environmental conditions that influence a farmers choice of application rates. Many of these relate to the farmer such as their knowledge and experience, their willingness to seek advice on application rates and their attitude towards maximising yield or minimising expenditure – particularly if they bought inputs at the wrong time.

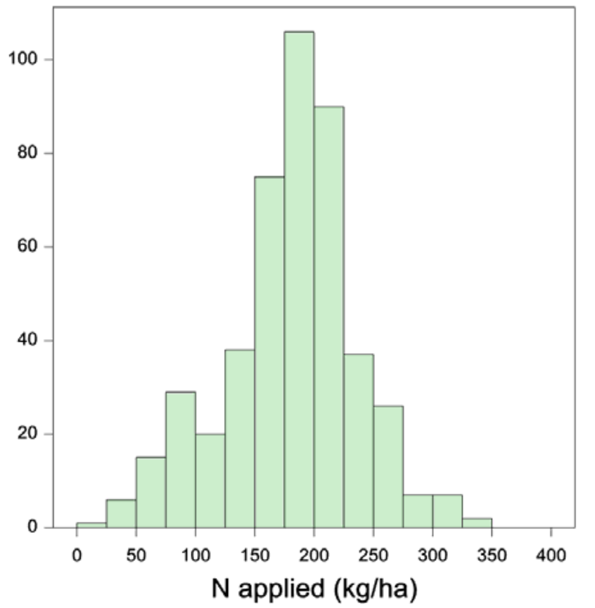

Figure 8: Weighted farm level nitrogen applications.

Table 10: Weighted average nitrogen applications rates on wheat in 2007. Application rates above 400 kg/ha were excluded from the analysis leaving 459 farms with wheat fields that received some nitrogen.

	N applied (kg/ha)
Mean	181
Median	188
Minimum	8
Maximum	334
Lower quartile	154
Upper quartile	213

Since the previous section revealed the importance of inter-farm variation it is useful to consider the variation in average farm level N application rates within JCA, farm size and farm type. Using weighted averages for each farm will smooth some of the variation within JCAs, farm sizes and types which might make patterns clearer. Even at farm level there is still no clear relationship between JCA and N applications (Table 11 and Figure 9). There is still considerable variation within JCAs. For example in the Cotswolds JCA, the 11 farms had an inter quartile range of 84 and the farm with the highest application rate (303 kg/ha) was more than double the lowest application rate (134 kg/ha). Despite this variation within the JCAs, differences between the JCAs can still be observed.

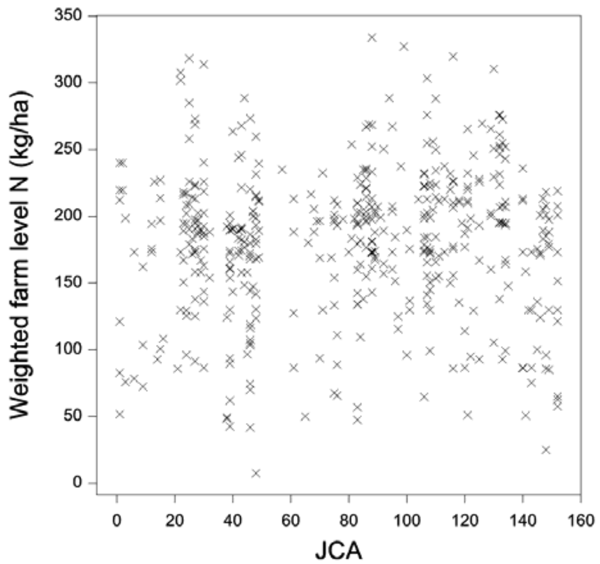

Figure 9: Farm level nitrogen applications by JCA.

Consider the Fens and the Bedfordshire & Cambridgeshire Claylands, which are two adjacent JCAs that share a NW/SE boundary that runs from Peterborough to Cambridge. In the former, the median application rate is 132 kg/ha and 75% of farmers applied less than 175 kg/ha whereas in the latter, the median application rate is 190 kg/ha and 75% of farmers applied more than 175 kg/ha.

The variation in fertiliser inputs with farm size was similar at the farm level to that at the field level (Table 12 and Table 9). Although, the farm size with the smallest median input was the very large farms. Unlike at the field level, the upper and lower quartile values (and hence the inter quartile range) was similar across all farm sizes. Notice that the mean SLR is considerably smaller for cereal farms that for other farm types (Table 13), which suggests that most of the small farms on BSFP are cereals farms. Also any farms with less than 20 ha are excluded from the survey. This gives a slightly biased distribution of SLRs relative to the larger population and might explain why SLR is such a poor predictor variable.

Table 11: Summary statistics for weighted average farm nitrogen applications (kg/ha) for each of the JCAs with more than from that have more than 10 farms. JCA numbers as used on Figure 9 are given in brackets after the JCA name. Application rates above 400 kg/ha were excluded.

	Number of farms	Mean	Median	Lower quartile	Upper quartile
Yorkshire Wolds (27)	15	188	191	162	220
Southern Magnesium Limestone (30)	13	190	188	158	221
Humberhead Levels (39)	16	144	161	112	182
The Fens (46)	16	141	132	104	176
Trent and Belvoir Vales (48)	13	173	183	139	215
South Suffolk and North Essex Clayland (86)	13	212	215	197	230
Bedfordshire & Cambridgeshire Claylands (88)	14	207	190	173	233
Severn & Avon Vales (106)	12	188	191	174	223
Cotswolds (107)	11	201	185	158	244

Table 12: Summary statistics for farm level nitrogen applications (kg/ha) by farm size – farm size very small (spare time) has been omitted from the table. As previously, application rates above 400 kg/ha were excluded.

	Number of farms	Mean	Median	Lower quartile	Upper quartile
Very small (P/T)	38	175	187	156	212
Small	115	174	186	138	211
Medium	99	189	195	163	221
Large	104	180	190	162	210
Very large	88	184	182	154	219

Table 13: Summary statistics for farm level nitrogen applications (kg/ha) for each farm type. As previously, field application rates above 400 kg/ha were excluded. Percentage wheat is the median proportion of the holding area accounted for by wheat.

	Number of farms	Mean	Median	Lower quartile	Upper quartile	% wheat	Mean SLR
Cereals	251	191	197	170	221	47	2.4
Dairy	29	152	148	96	188	15	4.9
General Cropping	96	173	182	144	203	37	4.6
Lowland Livestock	18	155	166	107	177	17	4.8
Mixed	58	174	177	130	216	29	4.9

As was the case at the field level, average farm level application rates were highest and had least spread on cereals farms (Table 13). The application rates were lowest and most variable on dairy farms which was the farm type where wheat accounts for the smallest proportion of the farm area. Considering main farm types instead, revealed that two types of mixed farm fell at either end of the spectrum. The average application rate was greatest on the ‘cropping and dairy’ farms and lowest on the ‘cropping, cattle and sheep’ main farm type.

Farms with livestock will tend to have greater access to organic manures and this can be used to supplement their fertiliser applications[9]. Livestock Units (LU)[10] were calculated for each of the farms in the data set. The distribution was very skewed and around a third of the farms had no livestock. When logs of the data were taken (Figure 11) a more useful distribution was achieved, but there was little relationship (Figure 10) between this transformed variable and average N application rates.[11]

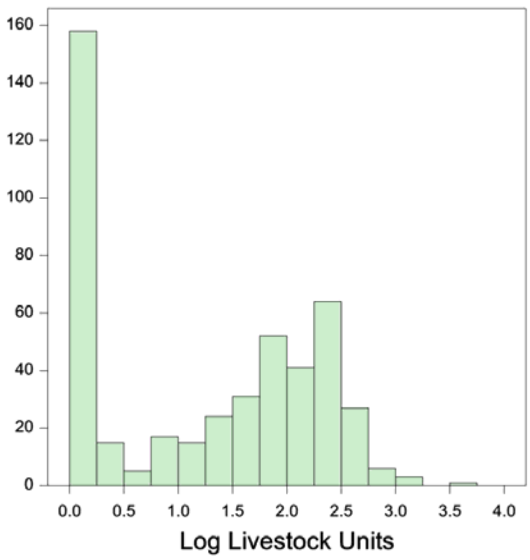

Figure 11: The distribution for livestock units (LU) on the 459 farms in the data set. The data has been transformed as follows: $\log_{10}$ (LU+1)

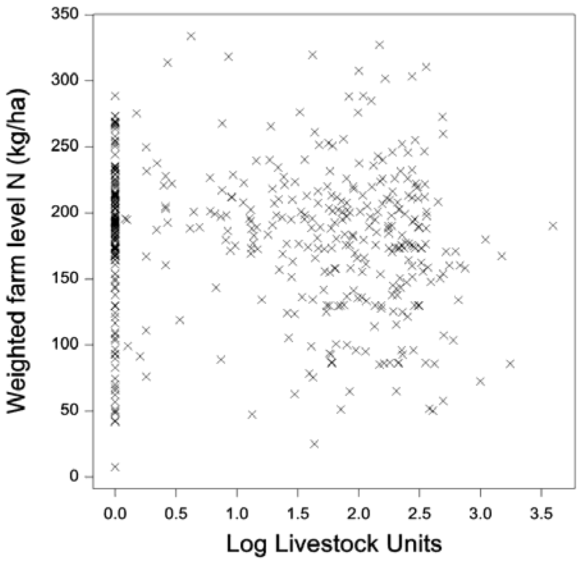

Figure 10: Farm level nitrogen applications by Log LU

Soil types were assigned to each of the 450 wheat growing farms in the data set. These soil types reflect those used in RB209 but are based on the more detailed classification available in the National Soil Map. Most farms in the sample were soil type 3 – medium soils (Figure 12). Considering just the soil types that occurred on at least 15 farms, revealed that average N application rates and the variability in application rates was similar on shallow soils, medium soils and those with clay to depth (Table 14). On deep fertile silts, the average application rates were lower but they had a greater spread.

The average farm level N application rates were grouped based on the area of wheat grown on the farm. As the wheat area increased the average N application rate tended to increase (Figure 13). Also as wheat area increased it tended to account for a larger proportion of the holding; but a ceiling seemed to be reached at 100ha of wheat beyond which wheat did not account for more than 50% of the holding (Figure 14). As a holding increases its wheat area it achieves greater economies of scale. As the quantity of

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9 Organic manures will normally only be applied to grassland used for silage or hay production, not grazing land, so the remainder can be applied to any arable land.

10 One Livestock Unit is defined as the grazing equivalent of one adult dairy cow. Other livestock types receive a smaller value such as 0.1 units for sheep or 0.7 per hundred broilers.

11 The correlation between the average N applied and Log LU was -0.15 (based on the 306 farms with livestock). This is marginally higher than the -0.1 achieved before the transformation.

fertiliser purchased increases the cost per tonne will generally fall. So a farmer purchasing more fertiliser at a cheaper rate may have a higher economic optimum nitrogen rate (and a lower break even rate).

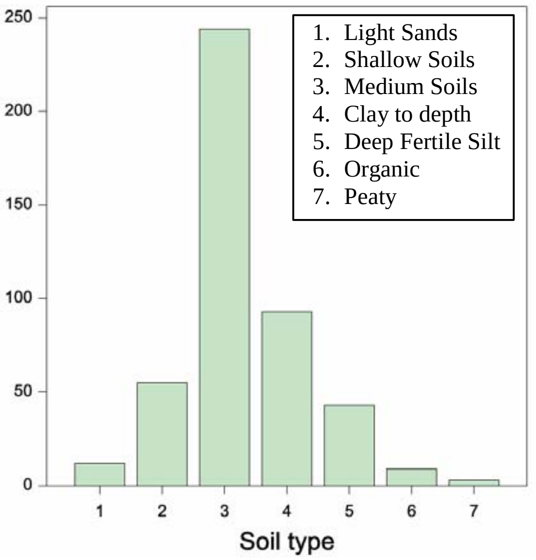

Figure 12: The distribution of soil types for the 459 farms in the data set.

Table 14: Summary statistics for farm level nitrogen applications (kg/ha) for each farm type. As previously field application rates above 400 kg/ha have been excluded. Only includes soil types that occurred on at least 15 farms.

	Mean	Median	Lower quartile	Upper quartile
Shallow Soils	184	190	156	222
Medium Soils	182	189	159	215
Clay to depth	186	185	156	212
Deep Fertile Silt	172	173	132	204

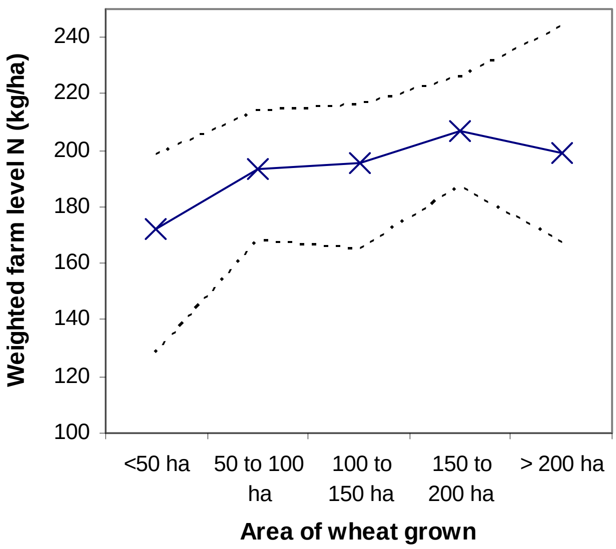

Figure 13: Median nitrogen applications for 5 wheat area bands. The dashed lines mark the upper and lower quartile values for the area bands.

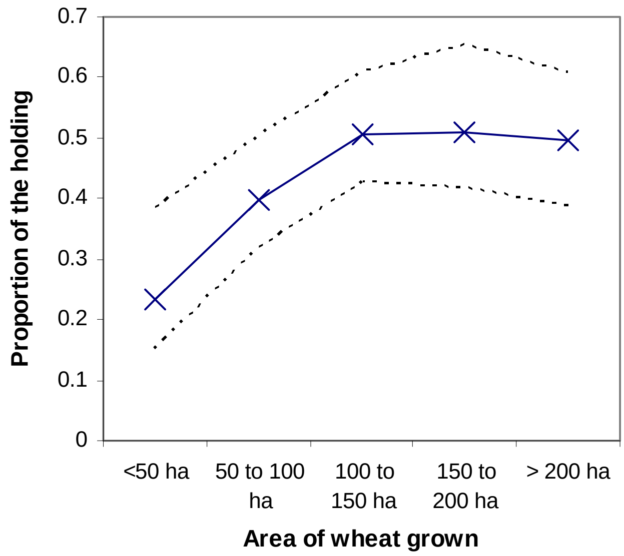

Figure 14: Median proportion of the farm accounted for by wheat. The dashed lines mark the upper and lower quartile values for the area bands.

A Nitrate Vulnerable Zone (NVZ) is an area of land that drains into nitrate polluted waters, or waters which could become polluted by nitrates. Around 68% of agricultural land in England is within a NVZ. Within such areas, farmers can not apply manufactured N fertiliser between 1 September (15 for grassland) and 15 January and for winter wheat the total nitrogen supplied from manufactured fertilisers and manures should not exceed the N max limit of 220 kg/ha[12]. It could be anticipated that N application rates within NVZs are lower than outside them. The data in Table 15 suggests than this is not the case. Average application rates and their spread were almost identical on wheat fields in 2007.

Table 15: Summary statistics for farm level nitrogen applications (kg/ha) for each farm type. As previously, field application rates above 400 kg/ha were excluded.

	Number of farms	Mean	Median	Lower quartile	Upper quartile
Farm in NVZ	301	181	188	154	212
Farm not in NVZ	158	182	189	144	216

6. Farm level modelling

Linear models using some of the variables examined above were fitted to the data (Table 16). With the exception of JCA, none of the models containing a single explanatory variable were able to explain much of the variance within the farm level application rates. Disappointingly, the model using soil types was only able to explain 1% of the observed variation in average N application rates. When the soil classification was simplified by grouping similar categories together, the model performance was even worse. A similar exercise was tried with farm types, which were collapsed into the following 3 categories: cereals, cropping/mixed and livestock. However, the increase in model performance was minimal.

Although the JCA model would appear the most promising, the number of farms in the data set (approximately 450) means that there are relatively few farms within most of the 99 JCAs in the data set. Only a few have more than 10 farms. The model, therefore, is really over-fitted for the amount of data available. The model is tuned to, and has some success in replicating the variation in, this small data set but this does not mean that it will be able to represent the variations in the full population.

Table 16: Linear models fitted to the data and the proportion of the variance that they were able to explain.

Model (constant +)	Percentage variance explained
Wheat area	4.5
Wheat % of the holding	5.8
RB 209 soil type	1.0
Log LU	0.6
Robust farm type	3.7
Simplified farm type	4.5
Main farm type	5.9
NUTS 1 region	0.8
JCA	14.6
JCA + Wheat % + Wheat area + Simplified farm type	19.3

[12] Exceptions to N max are: (a) an additional 20 kg N/ha is permitted on fields with a shallow soil type (not shallow soils over sandstone); (b) an additional 20 kg N/ha is permitted for every tonne that the expected yield exceeds the standard yield; and (c) an additional 40 kg N/ha is permitted to milling wheat varieties. Source: Guidance for farmers in NVZs leaflet 3 (http://defraweb/environment/water/quality/nitrate/pdf/leaflet3.pdf).

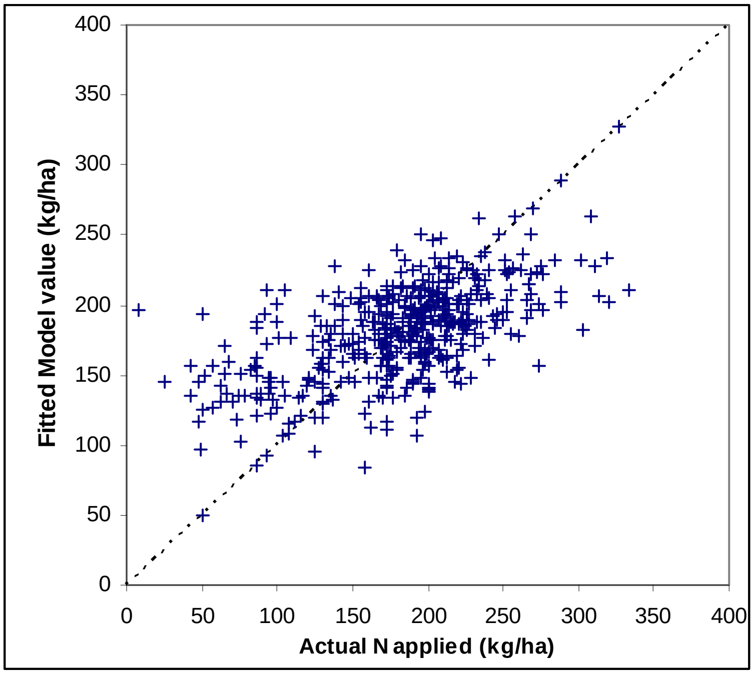

Figure 15: Actual N applied and the corresponding fitted values for the following model: Constant + JCA + Wheat % + Wheat area + Simplified farm type. The dashed line marks the 1:1 line.

Even when a multiple model, containing 4 predictive variables[13], was fitted to the data it was only able to explain 19% of the variance within the observed application rates and modelled application rates. Some farms have very large residuals and the model will tend to (almost exclusively) overestimate application rates beneath 150 kg/ha and (almost exclusively) underestimate application rates above 250 kg/ha (Figure 15). Given such a relatively complex linear model (for the size of the data set) was unable to capture even a fifth of the variability (and most of this skill came from the over fitted JCA parameter) there seems little benefit in trying to refine or improve the linear models fitted to the data. Further details of this multi parameter model can be found in Appendix 2.

[13] The 4 predictive variables chosen were those that achieved the best performance in the single variable models.

7. Conclusions

It seems clear that the models developed here are unable to explain a significant amount of variation in fertiliser application rates. Whilst one could try and improve with the models by considering alternative variables such as grazing livestock numbers, total arable areas or even the quantity of fertiliser held in stock on 1 December (from the December Survey of Agriculture) or the newer 2008 BSFP data, none of this is likely to improve model skill significantly.

The problem is that fertiliser applications are a complex stochastic process14 that involves many factors. Whilst simple linear models might be able to capture the variations in application rates caused by factors which vary in a predictable or controllable manner, such as rainfall or soil types they can not capture the random element induced by farmer behaviour. The 2007 Farm Practices Survey (FPS) asked farmers how they calculate nutrient requirements. Whilst RB209 was used to calculate N requirements on nearly 40% of farms less than 10% of livestock farms used this guide (Figure 16). Similarly, whilst more than three-quarters of cropping farms sought professional advice for their fertiliser requirements, significantly fewer livestock farmers consult such experts. Livestock farmers tend to rely heavily on their own experience, which will be different for each farmer, which makes predicting their application rates difficult.

[14] A stochastic process is one whose behavior is non-deterministic, *i.e.* any subsequent state is determined both by the process's predictable actions and by a random element.

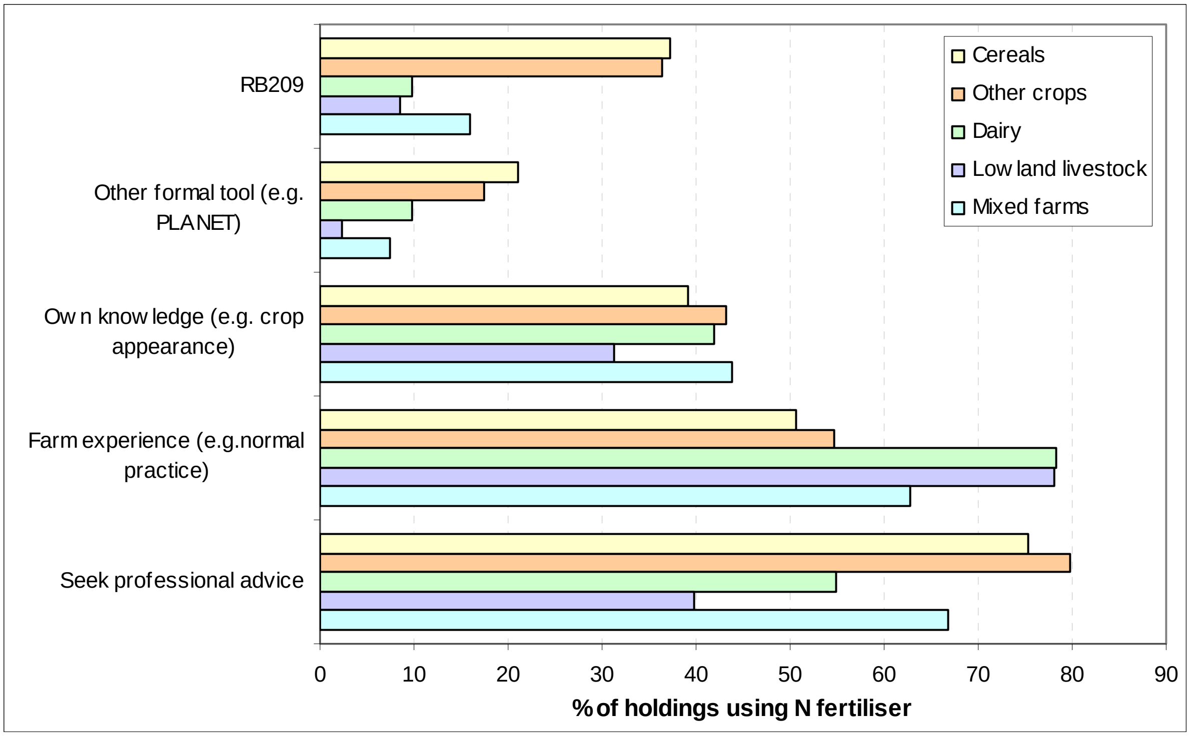

Figure 16: Nitrogen fertiliser calculation methods across a range of farm types (Farm Practices Survey 2007[15]). All farm types included are based on at least 150 responses. Farmers could tick multiple responses.

To predict fertiliser applications with any degree of accuracy a much more complex model with more detailed and specialised input data would be required. This model would also need some way of accounting for this random element introduced by the behaviour of the farmer. One way of incorporating this might be through farmer attitudinal questions16 or applying the Defra farmer segmentation model17 to the entire Structure Survey Population.

[15]Farm Practices Survey results are available of the Defra web site: https://statistics.defra.gov.uk/esg/publications/fps/default.asp

[16] On the 2008 Farm Practices Survey farmers were asked a series of attitudinal questions. Fifty of the respondents to this survey were also respondents to the 2007 BSFP. Two such questions asked: (1) I want to be sensitive to the environmental impacts of farming and (2) Maintaining the environmental assets of the farm for the future is a priority. For both questions, the group of farmers who agreed strongly have lower average N applications than the group who agreed. Unfortunately, there were insufficient farmers in this small sample who disagreed to draw any conclusions from that data. This would suggest that if data on farmers attitudes to the environment, and possibly their attitude towards business were available for a larger sample they might provide useful model inputs.

[17] https://statistics.defra.gov.uk/esg/ace/research/pdf/ACEO%20Behaviours%20Discussion%20Paper%20(new%20links).pdf

Appendix 1 Main farm types and their corresponding robust farm types

Robust Farm Type	Main Farm Type
Cereals	Cereals
General cropping	General cropping
Horticulture	Specialist fruit Specialist glass Specialist hardy nursery stock Other horticulture
Specialist pigs	Specialist pigs
Specialist poultry	Specialist poultry
Dairy	Dairy (LFA[18]) Dairy (lowland)
LFA grazing livestock	Specialist sheep (SDA[19]) Specialist beef (SDA) Mixed grazing livestock (SDA) Various grazing livestock (DA[20])
Lowland grazing livestock	Various grazing livestock (lowland)
Mixed	Cropping and dairy Cropping, cattle & sheep Cropping, pigs & poultry Cropping & mixed livestock Mixed livestock
Other	Specialist set-aside Specialist grass & forage Specialist horses Non-classifiable holdings - fallow Non-classifiable holdings - other

[18] Less Favoured Areas
[19] Severely Disadvantaged Areas
[20] Disadvantaged Areas

Appendix 2 Genstat model output

Regression analysis

Response variate: Weighted_N_kg_ha
Fitted terms: Constant + jca + wheat_prop + Wheat_area + Simp_farm_type

Summary of analysis

Source	d.f.	s.s.	m.s.	v.r.	F pr.
Regression	103	529919.	5145.	2.06	<.001
Residual	355	885083.	2493.		
Total	458	1415001.	3090.		

Percentage variance accounted for 19.3
Standard error of observations is estimated to be 49.9.

Message: the following units have large standardized residuals.

Unit	Response	Residual
3	7.6	-4.01
12	51.1	-3.06

Message: the error variance does not appear to be constant: intermediate responses are less variable than small or large responses.

Message: the following units have high leverage.

Unit	Response	Leverage
10	50.2	1.00
30	85.8	1.00
42	92.8	1.00
61	108.3	1.00
85	129.9	1.00
110	147.8	1.00
153	169.2	1.00
170	173.2	1.00
206	180.3	1.00
263	194.9	1.00
274	196.5	1.00
282	197.9	1.00
284	198.3	1.00
290	199.3	1.00
321	207.2	1.00
344	212.8	1.00
359	216.5	1.00
383	225.9	1.00
404	235.0	1.00
408	237.5	1.00
442	269.5	1.00
452	288.7	1.00
460	327.4	1.00

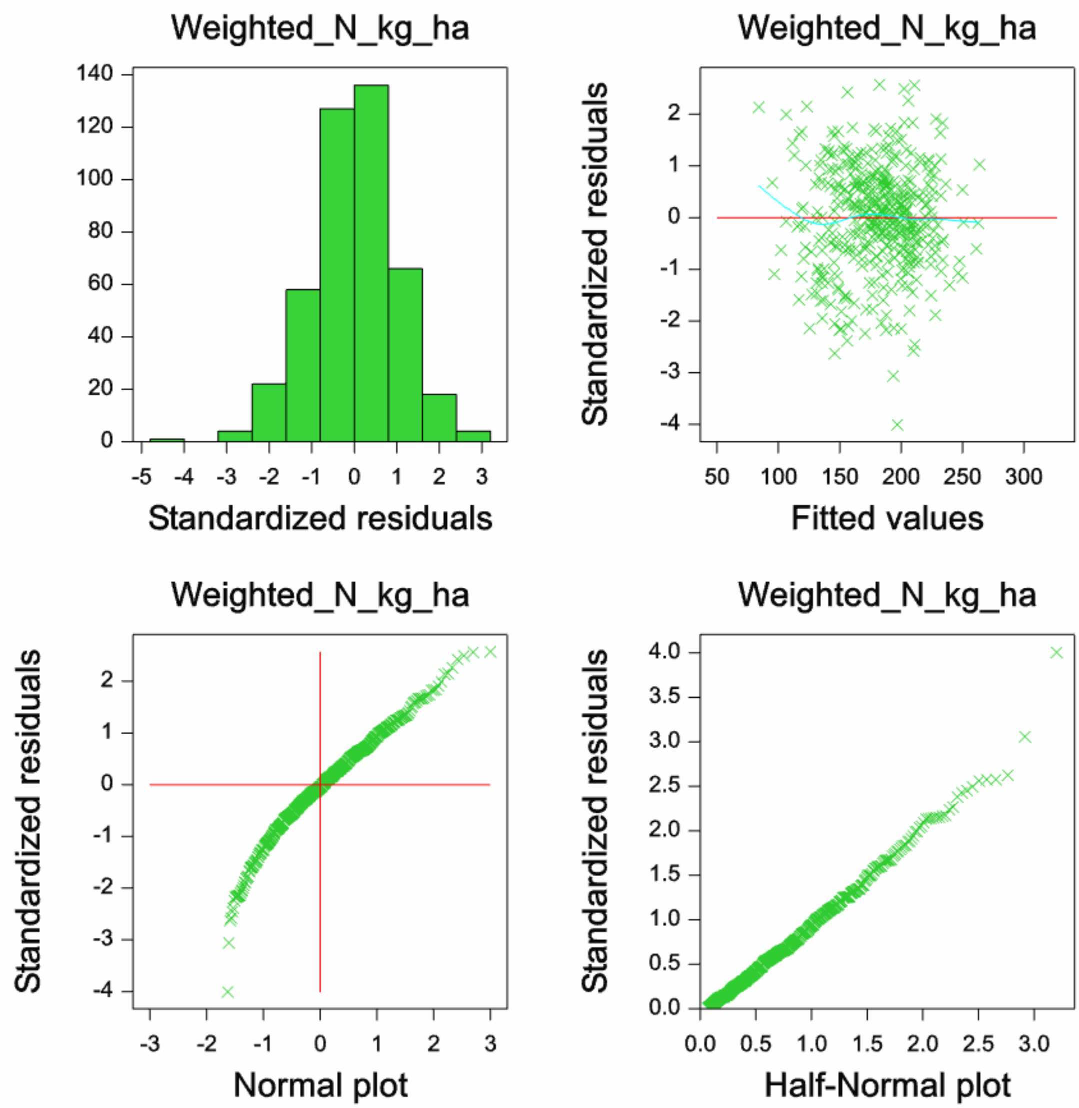

Figure 17: Plot of model residuals

Estimates of parameters

Parameter	estimate	s.e.	t(355)	t pr.
Constant	132.8	21.4	6.21	<.001
jca 2	85.2	40.9	2.08	0.038
jca 3	-23.0	40.9	-0.56	0.575
jca 6	-4.3	41.3	-0.10	0.917
jca 9	-11.6	36.7	-0.32	0.752
jca 12	39.0	35.5	1.10	0.272
jca 13	70.2	54.2	1.29	0.196
jca 14	-65.3	54.0	-1.21	0.227
jca 15	29.5	32.3	0.91	0.361
jca 16	-44.5	54.4	-0.82	0.414
jca 21	-49.3	54.9	-0.90	0.370
jca 22	89.4	32.7	2.73	0.007

jca 23	42.6	28.9	1.47	0.142
jca 24	19.3	28.1	0.68	0.494
jca 25	91.5	27.8	3.29	0.001
jca 26	33.6	35.4	0.95	0.343
jca 27	33.1	24.3	1.36	0.174
jca 28	41.2	30.5	1.35	0.178
jca 29	23.8	35.5	0.67	0.503
jca 30	37.0	24.7	1.50	0.135
jca 32	47.9	36.1	1.33	0.185
jca 38	-49.9	32.3	-1.55	0.122
jca 39	-13.1	24.2	-0.54	0.590
jca 40	38.3	32.3	1.19	0.236
jca 42	39.2	30.2	1.30	0.196
jca 43	42.1	26.4	1.59	0.112
jca 44	44.1	32.2	1.37	0.172
jca 45	-15.7	41.1	-0.38	0.703
jca 46	-15.1	24.4	-0.62	0.537
jca 47	20.3	32.5	0.62	0.533
jca 48	16.8	24.8	0.68	0.498
jca 49	51.1	30.4	1.68	0.093
jca 57	62.3	55.1	1.13	0.259
jca 61	16.0	32.7	0.49	0.624
jca 65	-92.5	54.2	-1.71	0.089
jca 66	39.0	54.2	0.72	0.472
jca 67	58.8	54.3	1.08	0.279
jca 68	60.2	41.1	1.46	0.144
jca 69	37.0	54.1	0.68	0.495
jca 70	-0.6	35.4	-0.02	0.986
jca 71	25.1	41.4	0.61	0.544
jca 74	17.8	54.0	0.33	0.742
jca 75	-1.8	28.0	-0.06	0.950
jca 76	-25.7	30.4	-0.84	0.399
jca 78	58.7	54.3	1.08	0.280
jca 80	35.2	54.3	0.65	0.517
jca 81	59.0	40.9	1.44	0.150
jca 82	40.7	54.1	0.75	0.452
jca 83	10.7	24.7	0.43	0.665
jca 84	18.1	30.3	0.60	0.551
jca 85	46.0	41.2	1.12	0.265
jca 86	47.0	24.9	1.89	0.060
jca 87	60.6	41.6	1.46	0.146
jca 88	38.9	24.6	1.58	0.116
jca 89	7.9	29.3	0.27	0.786
jca 90	35.8	54.1	0.66	0.509
jca 91	34.6	54.4	0.64	0.525
jca 92	28.5	32.3	0.88	0.379
jca 94	139.0	56.2	2.47	0.014
jca 95	54.6	30.3	1.80	0.073
jca 96	14.6	40.8	0.36	0.720
jca 97	-17.2	41.2	-0.42	0.676
jca 98	88.9	54.2	1.64	0.102
jca 99	182.5	54.2	3.37	<.001
jca 100	5.4	41.2	0.13	0.895
jca 101	-3.5	35.3	-0.10	0.921
jca 104	46.2	54.0	0.86	0.393
jca 106	30.7	25.3	1.21	0.226

jca 107	51.7	25.4	2.04	0.043
jca 108	20.6	25.9	0.80	0.426
jca 109	85.7	40.9	2.10	0.037
jca 110	43.5	27.3	1.59	0.112
jca 111	21.8	35.5	0.61	0.540
jca 113	49.4	35.6	1.39	0.166
jca 115	44.8	35.4	1.26	0.207
jca 116	42.4	26.3	1.61	0.108
jca 118	46.4	35.6	1.31	0.193
jca 119	37.7	54.3	0.69	0.488
jca 120	-1.2	32.4	-0.04	0.971
jca 121	42.1	27.0	1.56	0.120
jca 122	-9.3	40.8	-0.23	0.820
jca 123	28.4	40.9	0.69	0.488
jca 125	33.8	30.3	1.12	0.266
jca 126	115.3	54.0	2.14	0.033
jca 129	50.3	32.4	1.55	0.121
jca 130	56.3	32.5	1.73	0.084
jca 132	72.3	25.0	2.89	0.004
jca 133	55.0	28.9	1.90	0.058
jca 134	45.7	26.4	1.73	0.085
jca 135	31.0	54.9	0.57	0.572
jca 140	30.6	29.4	1.04	0.298
jca 141	-39.5	41.1	-0.96	0.337
jca 142	7.3	54.9	0.13	0.895
jca 143	-16.5	32.7	-0.51	0.614
jca 145	-4.2	35.5	-0.12	0.906
jca 146	22.1	32.5	0.68	0.498
jca 147	62.0	32.6	1.90	0.058
jca 148	4.8	28.0	0.17	0.864
jca 149	33.9	29.8	1.14	0.256
jca 152	10.2	25.9	0.40	0.693
wheat_prop	36.5	16.7	2.18	0.030
Wheat_area	0.0860	0.0315	2.73	0.007
Simp_farm_type LIVESTOCK	-17.5	10.8	-1.62	0.106
Simp_farm_type MIXED & CROPPING	-3.54	6.43	-0.55	0.582

Parameters for factors are differences compared with the reference level:

Factor	Reference level
jca	1
Simp_farm_type	CEREALS

Accumulated analysis of variance

Change	d.f.	s.s.	m.s.	v.r.	F pr.
+ jca	99	467804.	4725.	1.90	<.001
+ wheat_prop	1	37100.	37100.	14.88	<.001
+ Wheat_area	1	18463.	18463.	7.41	0.007
+ Simp_farm_type	2	6551.	3275.	1.31	0.270
Residual	355	885083.	2493.		
Total	458	1415001.	3090.		

1283 RWALD

Wald tests for dropping terms

Term	Wald statistic	d.f.	F statistic	F pr.
jca	159.73	99	1.61	<0.001
wheat_prop	4.77	1	4.77	0.030
Wheat_area	7.43	1	7.43	0.007
Simp_farm_type	2.63	2	1.31	0.270

Residual d.f. 355