The nitrate leaching tool: user guide

Chief Scientist's Group report

Date: May 2021

SC160010

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Professor Doug Wilson
Chief Scientist

Executive summary

This user guide accompanies the Environment Agency Nitrate Leaching Tool (NLT). The Nitrate Leaching Tool (NLT) is an Excel spreadsheet application the Environment Agency and Wood plc have developed to predict the amount of nitrate (NO3-) washed away (leached) from agricultural land each year. The tool is designed to be used on farms and fields, to identify fields and practices that present a high risk, and to help work with farmers and growers to reduce nitrate leaching.

The NLT calculates nitrate leaching using farm land use and management data that the user has entered, together with data on selected potential source of leaching (point sources). The calculation methods in the tool are simple, and it does not simulate every detail of nutrient management. It is intended to provide a simple, rapid assessment of nitrate leaching under typical local climatic conditions, rather than a detailed calculation of soil nitrogen cycling and losses throughout the year or from one year to the next.

The simple basis of the calculations means that the tool can easily and quickly calculate results in the field or on the go.

For catchment partnership work, we suggest that the NLT is used to complement existing models such as ADAS Farmscoper and that a tiered approach to assessing N losses is likely to be the most efficient.

- Tier 1: A catchment or sub-catchment scale assessment to determine the relative contribution of agricultural and non-agricultural sources of diffuse pollution. Suggested models include ADAS Farmscoper for agricultural contributions and the nitrogen and phosphorus (N&P) loading spreadsheet for non-agricultural inputs.
- Tier 2: In catchments where agriculture is likely to be a significant contributor to diffuse pollution, use Farmscoper at the farm scale to simultaneously assess multiple pollutant pressures and identify where farm advice may need to be targeted and measures can achieve cross-cutting benefits.
- Tier 3: Where a farm has been identified as a significant contributor to nitrate pollution and standard mitigation measures do not appear to reduce N losses sufficiently, the NLT can be used to determine any other options for change that may be effective enough to reduce the N losses to an acceptable limit.
- Tier 4: To optimise the quantity and timing of nutrient applications to avoid N losses and increase crop growth the Department for Environment, Food and Rural Affairs (Defra) has links to useful nutrient management tools such as MANNER-NPK on the ‘Planet4farmers’ website.

For further information about the NLT, please refer to the following publication:

- The Nitrate Leaching Tool - technical reference (2019) for a more detailed explanation of the calculations used within the tool.

Contents

1 Introduction

1.1 Purpose of this document

This user guide accompanies the Environment Agency Nitrate Leaching Tool (NLT). This section provides an introduction to the NLT, its purpose and intended use. Section 2 includes a 'Quick start guide' for new users. Section 3 provides a more comprehensive user guide and also describes the technical basis of the tool. Section 4 describes some assumptions and limitations of the tool, and provides additional guidance to users on the using the tool in non-typical situations.
A comparison of alternative tools is provided in the Appendices.

For further information, you should refer to the Nitrate Leaching Tool - technical reference (2019), which provides the sources of parameter values and a more detailed explanation of the calculations used within the tool.

1.2 The Nitrate Leaching Tool

The Nitrate Leaching Tool (NLT) carries out simple calculations of nitrate leaching using farm land use and management data that the user has entered, together with data on selected potential sources of leaching (point sources). The NLT can be used to estimate nitrate leaching from a farm, to identify high risk fields and practices, and to help work with farmers and growers to reduce nitrate leaching.

The calculation methods in the tool do not simulate every detail of nutrient management. It is intended to assess nitrate leaching under typical local climatic conditions, rather than provide a detailed, mechanistic calculation of soil nitrogen cycling and losses throughout the year. This means that the tool is not appropriate to use as the basis for recommending fertilisers.

The simple basis of the calculations mean that the tool easily and quickly produce results in the field or on the go. However, in order to do this the tool must make a number of assumptions and approximations. These are discussed in section 4.

1.3 Use of the NLT by external organisations

The Nitrate Leaching Tool is an Excel based application which is freely available to users from any external organisation. The tool and all supporting documentation is available to download via the Gov.uk website.

A GIS 'front end' has been developed for Environment Agency staff which facilitates the identification of fields and farms of interest and their associated environmental and climatic data, making it simpler to export this information to Excel to automatically populate the NLT. The complementary GIS component has been designed to work on the Environment Agency's systems and incorporates data obtained from nationally available datasets owned or licensed by the Environment Agency.

Due to restrictions licensing the 3rd party data in the GIS it is only possible to provide this component to Environment Agency staff and their contractors. If external organisations have the necessary soils (NSRI), climate (UK CEH CERF) and field (RPA CLAD) data licenses it may be possible to provide the GIS component subject to discussion with the Environment Agency.

1.4 Application of the Nitrate Leaching Tool

The Environment Agency uses two main tools for farm scale catchment partnership work. To date these have been the NLT (developed by the Environment Agency and Wood plc.) and ADAS Farmscoper (Gooday and others, 2014).

While the NLT assesses a farm at field scale for nitrate leaching, Farmscoper v.4 assesses at the farm scale. Within a catchment this can then be used to upscale the results from several farms to provide an overall catchment assessment at Water Framework Directive (WFD) waterbody scale.

In practical applications, on farms and in the Amec Foster Wheeler comparison report (Ref. 37918N018i1. November 2016a), it is concluded that at the farm scale, the nitrogen (N) loss predictions from both tools are 'similar for a range of reasonable input values'.

Therefore, while at the farm scale you may get similar results from both Farmscoper v4 and the NLT, it is advisable to consider the scale of the assessment you wish to carry out and the ultimate aim of the assessment. Appendix A summarises the pros and cons of several of the main N loss tools (ref. Environment Agency Nitrate Tools Comparison, November 2014).

During pilot trials, practically using the tools on farms has shown Farmscoper to be significantly less time consuming during the data input stage (20 to 30 minutes compared to two to three hours for the NLT, depending on farm details). Farmscoper also requires less skilled interpretation of input data to obtain a reasonable result. Time taken is an important factor and, with limited technical resources, Farmscoper offers the opportunity to maximise data capture for farm scale and catchment scale assessments.

Where an individual farm has high N losses and there is no significant over application of N, the NLT allows an in-depth field and crop assessment which may be used to inform future farm planning.

It is suggested that a tiered approach to the assessment of N losses is likely to be the most efficient.

- Tier 1: A catchment or sub-catchment scale assessment to determine the relative contribution of agricultural and non-agricultural sources of diffuse pollution. Use Farmscoper version 4 populated with agricultural census data to determine the agricultural contribution[1]. Farmscoper also allows the assessment of multiple pollutant pressures and can be used to run differing scenarios with varying catchment wide mitigation options. The nitrogen and phosphorus (N&P) loading spreadsheet can be used to estimate non-agricultural contributions (Entec, 2010).
- Tier 2: In catchments where agriculture is a significant contributor to diffuse pollution, use Farmscoper at the farm scale to simultaneously assess multiple pollutant pressures and identify where farm advice may need to be targeted and farm practices may need to change to benefit multiple diffuse pollutants. Farmscoper can be run under differing scenarios with varying mitigation options; this will indicate whether a broad approach can reduce the N losses to an acceptable limit. At this scale, site-specific farm data will need to be collected; this data can be fed back into the catchment scale assessment to refine the results previously based on census data.
- Tier 3: Where a farm has been identified as a significant contributor to nitrate pollution and the broad application of mitigation measures does not appear to reduce N losses sufficiently, the NLT can be used to determine any other options

[1] Farmscoper 'upscale' is populated with agricultural census data at Water Framework Directive waterbody or Natura 2000 site scale. If you are using the model at other scales, you will need to change to the input data (such as crop areas, livestock numbers)

for change that may be effective enough without having to totally change the type of farm to reduce the N losses to an acceptable limit. The field scale assessment of cropping and grazing will highlight those areas of the farm more vulnerable to nitrate leaching. For example, in those areas, it may be that winter crops such as wheat or barley are inappropriate or that fertiliser applications to certain crops may need to be altered; soil testing to determine the required fertiliser application may be appropriate. Grazing densities, grazing periods or animal type may need to change. Under sowing or cover crops scenarios may be run on fields with vulnerable soils to assess the likely effects of mopping up the excess N. The option to enter specific climatic and soil variables appears to make farmers less sceptical of the results.

In summary, this scale of assessment can be used as the basis of a discussion with the farmer about the changes he can make to the benefit of the environment without unacceptably compromising the economic viability of the farm.

- Tier 4: To optimise the quantity and timing of nutrient applications to avoid N losses and increase crop growth, the Department for Environment, Food and Rural Affairs (Defra) has links to useful nutrient management tools (http://www.planet4farmers.co.uk).

2 Quick start guide

This section provides a quick reference to the data entry requirements and possible sources of data necessary to run the NLT. You can find a more detailed explanation of each of the parameters can be found in section 3.

2.1 Software compatibility

The tool was developed in Microsoft Excel 2016 16.0.10730.20264.

2.2 Inputting field data

2.2.1 The ‘BaseData’ tab and data sources

1. Open the Excel workbook by agreeing to the ‘terms and conditions’. Enable macros (if they are not already enabled).
2. Open the ‘BaseData’ tab and enter the field data. Some columns are optional and not necessary for the tool to perform the calculations, such as ‘Field Name’, ‘Soil Series’ and ‘RPA Land Use’. Others, such as the ‘Field Number’ are simply a unique identifier that the user can set so that the tool can attribute the parameters and results.
3. The individual field data can be input from licensed data sources such as those outlined below or from local or farm specific data and knowledge.
    a. Farm scale information about land use is best obtained direct from the farmer, together with field areas. Alternatively, field areas can be estimated using the ‘measurement tool’ and freely available data on the Magic website: https://magic.defra.gov.uk/MagicMap.aspx (usage is protected under Crown copyright). The Rural Payments Agency (RPA) hold national scale field data, such as CPH number, field number, field size and land use (CLAD data), which can be licensed for discrete areas.
    b. Data on soil attributes can be purchased from the National Soils Research Institute (NSRI) at various scales. For high resolution site-specific data various private companies are able to carry out a soil survey. The parameters required for the running of the NLT are soil type, soil depth and stored water.
    c. The Standard Percentage Run off (SPR) can be crudely estimated using the table in section 4.7.2 based on the general soil type. If the land use is grassland this method is sufficient. However, more accurate figures for arable land calculations can be obtained from the National Soil Map NATMAP dataset (LandIS, 2013).
    d. Hydrologically effective rainfall (HER) can be estimated from local precipitation records and potential evaporation (PE). As a rule of thumb, in lowland areas, you can approximate HER as rainfall minus 0.9 x PE. Rainfall data is available from the Centre for Ecology and Hydrology (CEH) online: http://www. https://eip.ceh.ac.uk/rainfall and potential evaporation is also available; https://eip.ceh.ac.uk/chess
4. The ‘Intrinsic Risk’ column is automatically calculated from the ratio ‘HER’/’Stored Water’.
5. The ‘Parcel ID’ is the location of the field using national grid co-ordinates to 100,000 resolution (for example, SY7189). It is used by the spreadsheet to estimate the atmospheric

‘N’ deposition. If you don’t already know the grid co-ordinates of a field, you can calculate these online using the ‘Where am I’ tool on the Magic website: https://magic.defra.gov.uk/MagicMap.aspx

Figure 2-1: Base data tab to be completed with sourced data

2.2.2 Complete the ‘Actual Land Use’ tab

1. Open the Actual Land Use tab in the Excel spreadsheet.
2. Copy across the Field Number, Field Name, Agreed Area (Ha) and the Parcel ID from the BaseData Tab into the correct cells in the Actual Land Use tab.
3. For each field in turn:
    a. Click on the field number in column A
    b. EITHER

    Click the ‘Field data entry’ button (top left)

    Complete the details for cropping, fertiliser applications etc.

    Click ‘Store Field Data’

    OR

    Click the ‘Use crop template’ button

    Select a crop from the list

    Creating and editing crop templates is covered in section 3.5.4.

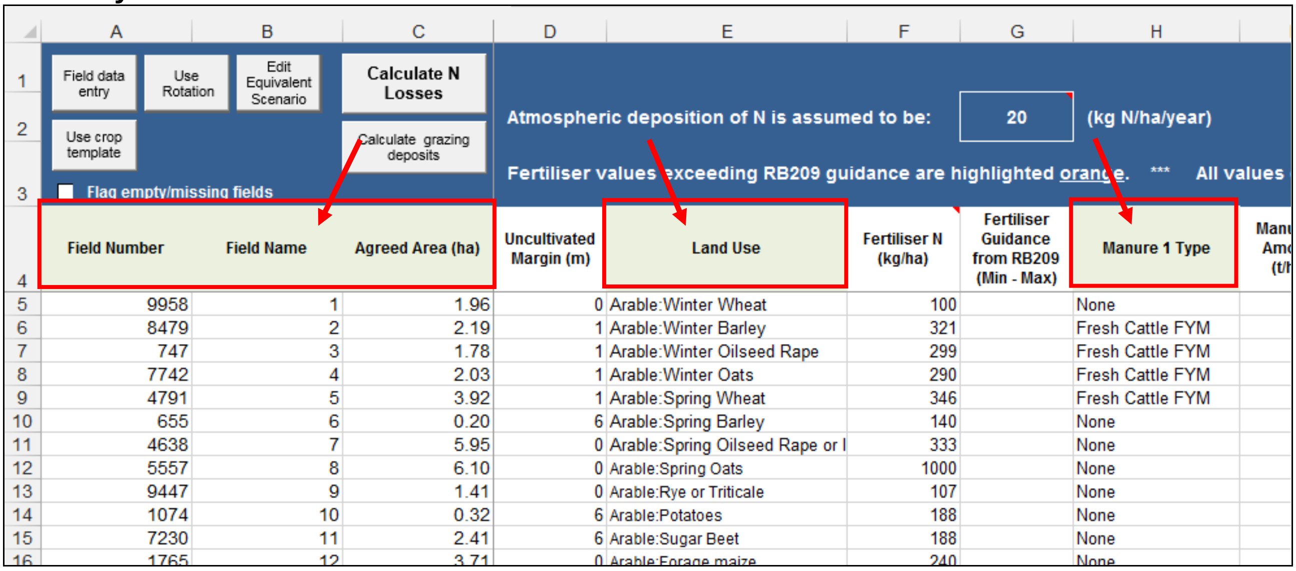
    OR

    Click the “Use Rotation” button

    Select a rotation and year from the list

    Note: This option only becomes available <u>after</u> a Rotation has been defined (see section 3.5.5.)
4. Check that all field data are complete. Field data can be manually amended and values supplied by the NLT can be overtyped. The columns marked with light green headers should be edited using the Field data entry form only and not manually (see Figure 2-1). These fields are mainly text fields, rather than quantities, which need to match available NLT options.
5. If you want to include point source calculations, complete the details in the ‘Point Sources’ tab.

Figure 2-2: Light green column headers indicate values that should only be changed using the Entry Form



	A	B	C	D	E	F	G	H
4	Field Number	Field Name	Agreed Area (ha)	Uncultivated Margin (m)	Land Use	Fertiliser N (kg/ha)	Fertiliser Guidance from RB209 (Min - Max)	Manure 1 Type
5	9958	1	1.96	0	Arable:Winter Wheat	100		None
6	8479	2	2.19	1	Arable:Winter Barley	321		Fresh Cattle FYM
7	747	3	1.78	1	Arable:Winter Oilseed Rape	299		Fresh Cattle FYM
8	7742	4	2.03	1	Arable:Winter Oats	290		Fresh Cattle FYM
9	4791	5	3.92	1	Arable:Spring Wheat	346		Fresh Cattle FYM
10	655	6	0.20	6	Arable:Spring Barley	140		None
11	4638	7	5.95	0	Arable:Spring Oilseed Rape or l	333		None
12	5557	8	6.10	0	Arable:Spring Oats	1000		None
13	9447	9	1.41	0	Arable:Rye or Triticale	107		None
14	1074	10	0.32	6	Arable:Potatoes	188		None
15	7230	11	2.41	6	Arable:Sugar Beet	188		None
16	1765	12	3.71	0	Arable:Forage maize	240		None

2.3 Calculating nitrate leaching

Click the ‘Calculate N Losses’ button (top left).

Any missing or empty field entries will be flagged with a warning pop-up message, unless the ‘Flag empty/missing fields’ tick box is unchecked (see Figure 2-2).

The results of the calculations are shown to the right of the field data in the ‘Actual Land Use’ tab (Figure 2-3).

The ‘Main Sheet’ tab includes charts of calculated nitrate losses from each land use.

Figure 2-3: Flag missing/empty fields tick box

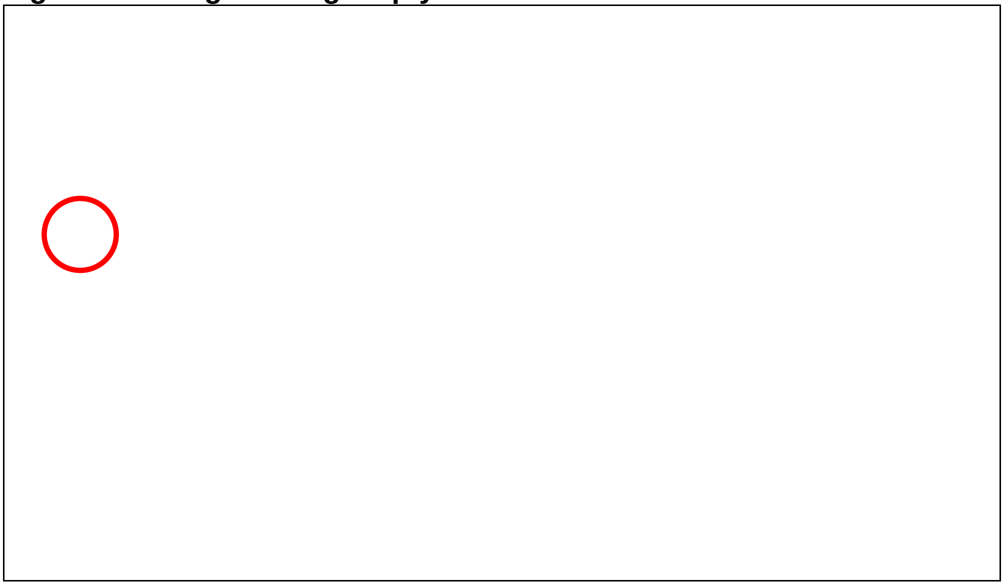
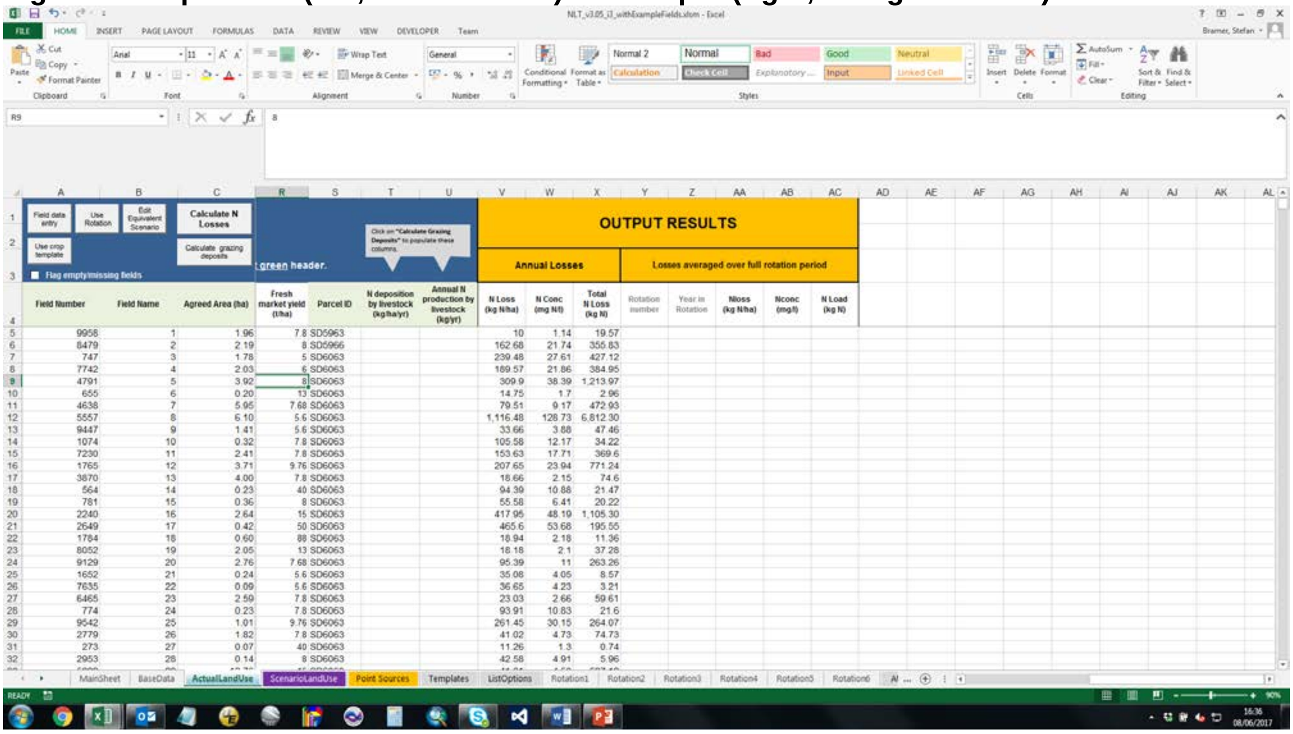


Figure 2-4:Input data (left, blue headers) and output (right, orange headers)



3 User guide

This section provides a guide to setting up and using the Nitrate Leaching Tool (NLT). For basic use, the details provided in the Quick start guide (Section 2) are likely to be enough. This section provides guidance on more advanced use of the tool.

3.1 Overview of technical basis

This section is intended to provide users with an overview of the technical basis of the NLT. For full details, please refer to the Technical Reference document.

In brief, there are five parts to the Nitrate Leaching Tool. These are summarised in Table 3.1.

Table 3.1: Nitrate Leaching Tool technical overview

Step	Function
Field data entry	The user must enter data for each field, such as field area, soil series, soil depth and field capacity, HER, cropping or land use and nutrient (fertiliser) applications.
Calculation of nitrate leaching (arable)	The NLT carries out a soil N budget calculation to estimate soil mineral nitrogen at risk of leaching, followed by a leaching calculation to estimate the nitrate load leached from each arable field.
Calculation of nitrate leaching (grass)	The NLT uses coefficients based on the N-CYCLE model to estimate the nitrate load leached from grassland field.
Calculation of nitrate leaching (sheep and outdoor pigs)	The NLT uses coefficients based on the Farmscoper model to estimate leaching from lowland sheep and outdoor pigs.
Assessment of mitigation	The NLT provides an indication of the reduction in nitrate leaching that might be achieved by applying mitigation measures.

Figure 3-2 shows the 'BaseData' tab and highlights the columns that make up the field data and are used by the NLT for nitrate predictions. To make sure the NLT takes fields into account, you need to replicate the field number (column A) and area (column C) in the 'Actual Land Use' tab in columns A and C respectively. Columns E to H contain the field specific soil properties that ultimately govern the proportion of residual N lost by leaching.

A field in the 'BaseData' tab is linked to its land use information in the 'Actual Land Use' tab via the Field Number in column A. Changes to the soil properties of a specific field will become effective once the calculation has been rerun by pressing the 'Calculate N Losses' button in the 'Actual Land Use' tab.

Figure 3-1: 'BaseData' tab

Field Number	Field Name	Agreed Area (ha)	Soil Series	Soil Depth	Stored Water (mm)	HER (mm)	SPR	RPA Land Use	Intrinsic risk	Parcel ID	
9958	scenario 1	1.96	BELMONT	75	234	400.00	48	permanent grass in agri_env scheme	HIGH	SD5963	21/183/0001
8479	scenario 2	2.19	BRICKFIELD	150	480	500.00	40	permanent grass in agri_env scheme	HIGH	SD5966	21/183/0001
747	scenario 3	1.78	BELMONT	75	234	600.00	48	permanent grass in agri_env scheme	HIGH	SD6063	21/183/0001
7742	scenario 4	2.03	WILCOCKS	150	448	1000.00	59	permanent grass in agri_env scheme	HIGH	SD6063	21/183/0001
4791	scenario 5	3.92	BELMONT	75	234	807.18	48	forestry	HIGH	SD6063	21/183/0001
655	scenario 6	0.20	BELMONT	75	234	867.29	48	forestry	HIGH	SD6063	21/183/0001
4638	scenario 7	5.95	BRICKFIELD	150	480	867.29	40	permanent grass in agri_env scheme	HIGH	SD6063	21/183/0001
5557	scenario 8	6.10	BELMONT	75	234	867.29	48	permanent grass in agri_env scheme	HIGH	SD6063	21/183/0001
9447	scenario 9	1.41	BELMONT	75	234	867.29	48	forestry	HIGH	SD6063	21/183/0001
1074	scenario 10	0.32	BELMONT	75	234	867.29	48	forestry	HIGH	SD6063	21/183/0001
7230	scenario 11	2.41	WILCOCKS	150	448	867.29	59	permanent grass in agri_env scheme	HIGH	SD6063	21/183/0001
1765	scenario 12	3.71	BELMONT	75	234	867.29	48	permanent grass in agri_env scheme	HIGH	SD6063	21/183/0001
3870	scenario 13	4.00	BELMONT	75	234	867.29	48	permanent grass in agri_env scheme	HIGH	SD6063	21/183/0001
564	scenario 14	0.23	BELMONT	75	234	867.29	48	forestry	HIGH	SD6063	21/183/0001
781	scenario 15	0.36	BELMONT	75	234	867.29	48	permanent grass in agri_env scheme	HIGH	SD6063	21/183/0001
2240	scenario 16	2.64	BELMONT	75	234	867.29	48	permanent grass in agri_env scheme	HIGH	SD6063	21/183/0001

Field Number | Area | Soil Properties

MainSheet | BaseData | ActualLandUse | ScenarioLandUse | Point Sources | Templates | ListOptions | Rotation ...

The populated workbooks are now standalone files and can be renamed and moved to other folders as necessary.

3.2 Completing field data

The base data alone is not enough to calculate nitrate leaching, and you will need to provide additional field-level data. This section describes the NLT functionality to enter field data.

All additional data entry is carried out in the ‘**Actual Land Use**’ tab, and data is entered field-by-field. Several methods are available:

- the field data entry form
- default crop templates
- specifying a crop rotation

Whichever method is used, before entering field data **click on the field number of the field to be edited in column A**.

3.2.1 Field data entry form

Field data can be entered using a data entry form (Figure 3-3).

- Select a crop or land use for the field from the list.
- A default fertiliser rate for arable or horticultural crops will appear in the ‘Fertiliser N’ box. This can be overtyped as necessary.

- A default yield for arable crops will appear in the ‘Yield’ box. This can be overtyped as necessary. Make sure that the assumed yield is consistent with the fertiliser (inorganic and manure) application rate.
- Select the type, rate and month of application of up to two manure applications.
- Select a soil N index. If you do not know this, a value of 1 is a reasonable default. See Box 3.1.
- For grazed fields, select a stock type and stocking density, and grazing period.
- Specify the width of the field headland or unfertilised area.
- Enter a field name if required (this is optional).
- Select any applicable mitigation measures from the list.
- Once data entry is complete, click on ‘Store field data’ to close the form and enter data into the Excel workbook.

The fertiliser (kg/ha) amount (column F) will be highlighted orange if it is outside of the Fertiliser Guidance from RB209 (provided in column G and in the red section of the ‘Templates’ tab).

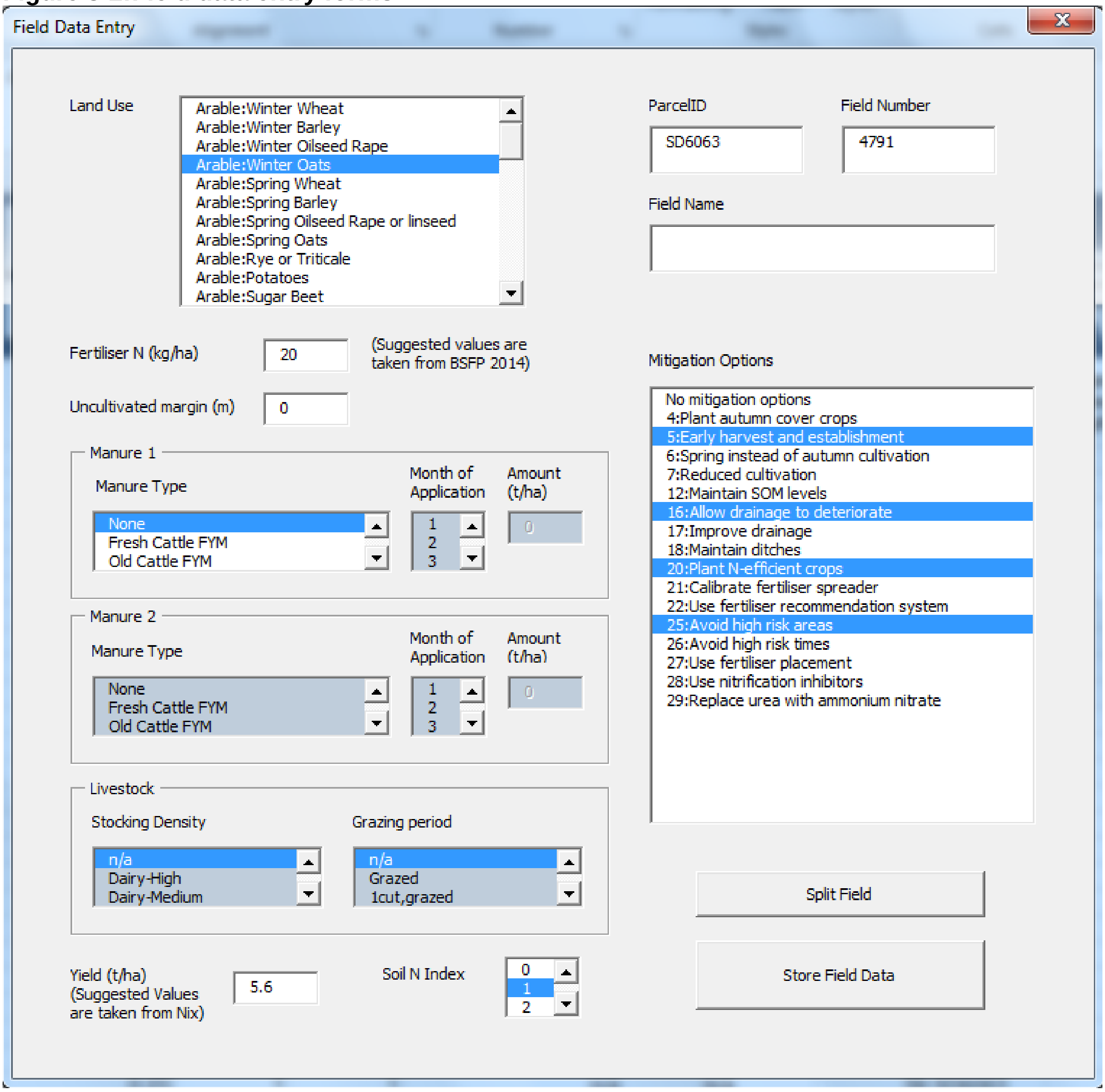
Box 3.1: Interpolating between SNS index values

There may be occasions when measurements of soil nitrogen supply (SNS) are available. It is preferable to use these more precise figures than to use an index value that limits you to one of about seven values of SNS.

The basis of the NLT is a simple soil nitrogen budget calculation. SNS is just one of the inputs of nitrogen to the soil budget, which will be added to calculate the total input term. All nitrogen source terms are treated equally in this calculation, for example 10 kilogram per hectare (kg/ha) from soil nitrogen supply is exactly the same as 10kg/ha of inorganic fertiliser. There is no reason, therefore, why precise measurements of SNS cannot be represented by adjustments to one of the other source terms, to represent the difference between the SNS corresponding to the entered index value, and the actual measured SNS.

For example, suppose a field receives 10kg-N/ha of inorganic fertiliser and has a measured SNS of 40 kg-N/ha. This value of SNS lies between an index value of 0 (0kg-N/ha) and 1 (60kg-N/ha). This can be represented in the NLT as an SNS index of 1, corresponding to a value of 60 kg-N/ha (that is, 20kg-N/ha more than measured), and a fertiliser input of 80kg-N/ha (20kg-N/ha less than was applied). In the NLT, the sum of the two inputs will be (60+80) =140kg-N/ha, which is the same as the actual inputs of (40+100)=140kg-N/ha.

Figure 3-2:Field data entry forms

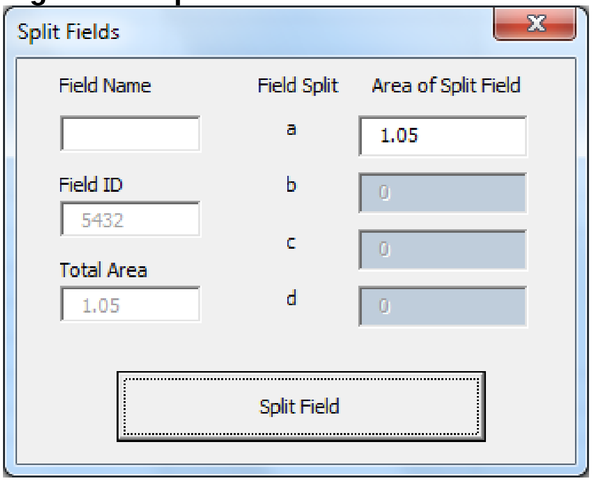


3.2.2 Splitting fields

Large fields may be split and managed as two or more smaller fields. In this case, extra fields can be created using the Field data entry form.

On opening the Field data entry form, click on ‘Split Field’. In the Split Fields form (Figure 3-4) enter the area of up to four sub-fields by overtyping the original values and pressing <Enter>. The total area of the sub-fields will equal the area of the original field. Sub-fields are numbered as the original field, appended with ‘a’, ‘b’ etc.

Figure 3-3:Split fields form



3.2.3 Calculating grazing deposits

Grassland fields with grazing animals will receive nitrogen in deposited dung and urine, the quantity of which will depend on the type of livestock (for example, dairy cattle, sheep) and the stocking density.

The NLT can calculate the rate of grazing deposits as a function of the livestock type and stocking density, and the default grazing period. Click on the ‘Calc grazing deposits’ button to calculate the default rate of nitrogen deposition by grazing animals (kg N/ha/yr).

The default figures may be modified by overtyping if required, and further guidance is provided in section 4.3. Note that it is not essential to calculate grazing deposits before calculating nitrate leaching; if column T is left blank the tool will calculate and use default values.

3.2.4 Crop templates

Templates are provided for a number of common crops and land uses. These provide a way of rapidly populating field data with default values for fertiliser and manure application data. Data can be amended later using the Field data entry form (section 3.5.1). Crop template data is held in the ‘Templates’ in the Excel workbook.

To use crop templates, click on the ‘Use crop template’ button in the ‘Actual Land Use’ tab, and select a crop or land use from the form (Figure 3-6).

In places where no data is currently available (for example, yield of asparagus) or parameters are not applicable for certain land uses, such as stocking density for arable land uses, the term ‘n/a’ is used.

Crop templates can be modified directly in the ‘Templates’ tab of the workbook by selecting a land use in column B and pressing the ‘Define/Edit Template’ button (top left) or by directly overtyping certain values. However, it is recommended that you use the ‘Template Edit Form’ (see Figure 3-5, left side) called by using the ‘Define/Edit Template’ button as it will provide the expected ranges for input variables. The applied changes should be restricted to the green section of the sheet ‘TEMPLATES: User defined values (editable)’. The red section represents guidelines and literature values and their various literature sources. All crop templates were initially set up to reflect the literature values (red section) and any changes to the templates (green section) that differ from literature recommendations will be highlighted red. The red section is a protected area of the

‘Templates’ tab and any changes will be flagged by a pop-up warning and you then need to confirm them. NLT currently includes a total of 46 predefined land uses.

As of NLT version 3.5, the option to create up to three miscellaneous land uses is available in the ‘Templates’ tab. Miscellaneous land uses are created by selecting one of the three miscellaneous slots in column B (bottom of the template list, row 49 – 51) and pressing the ‘Define/Edit Template’ button (top left). This will open the ‘Template Edit Form’, as described above, which will now have the ‘Miscellaneous Landuse Options’ on the right side of the form enabled. This will prompt you to first specify the type of land use (arable, vegetables, grassland or other) and then, depending on the land use, provide the following additional information:

- arable:
    - N Coefficient (kg N/t), for reference see Eurostat Crop N Coefficients (2011)
- vegetables:
    - FW/DW (Ratio of fresh weight yield to total dry matter), for reference see RB209 appendix 10
    - ‘a’ parameter (Relation N% and dry matter yield), for reference see RB209 appendix 10
    - ‘b’ parameter (Relation N% and dry matter yield), for reference see RB209 appendix 10
- grassland:
    - livestock (dairy, beef, sheep, pigs, other)
    - N production (kg N/a/animal)
    - stocking density (animals/ha) high/medium/low

The miscellaneous land use can be specified with a user defined name and saved by pressing ‘Update this template’. Note: A miscellaneous land use can only be used <u>after</u> it has been set up in ‘Templates’ in the way described above.

Figure 3-4: Template edit form

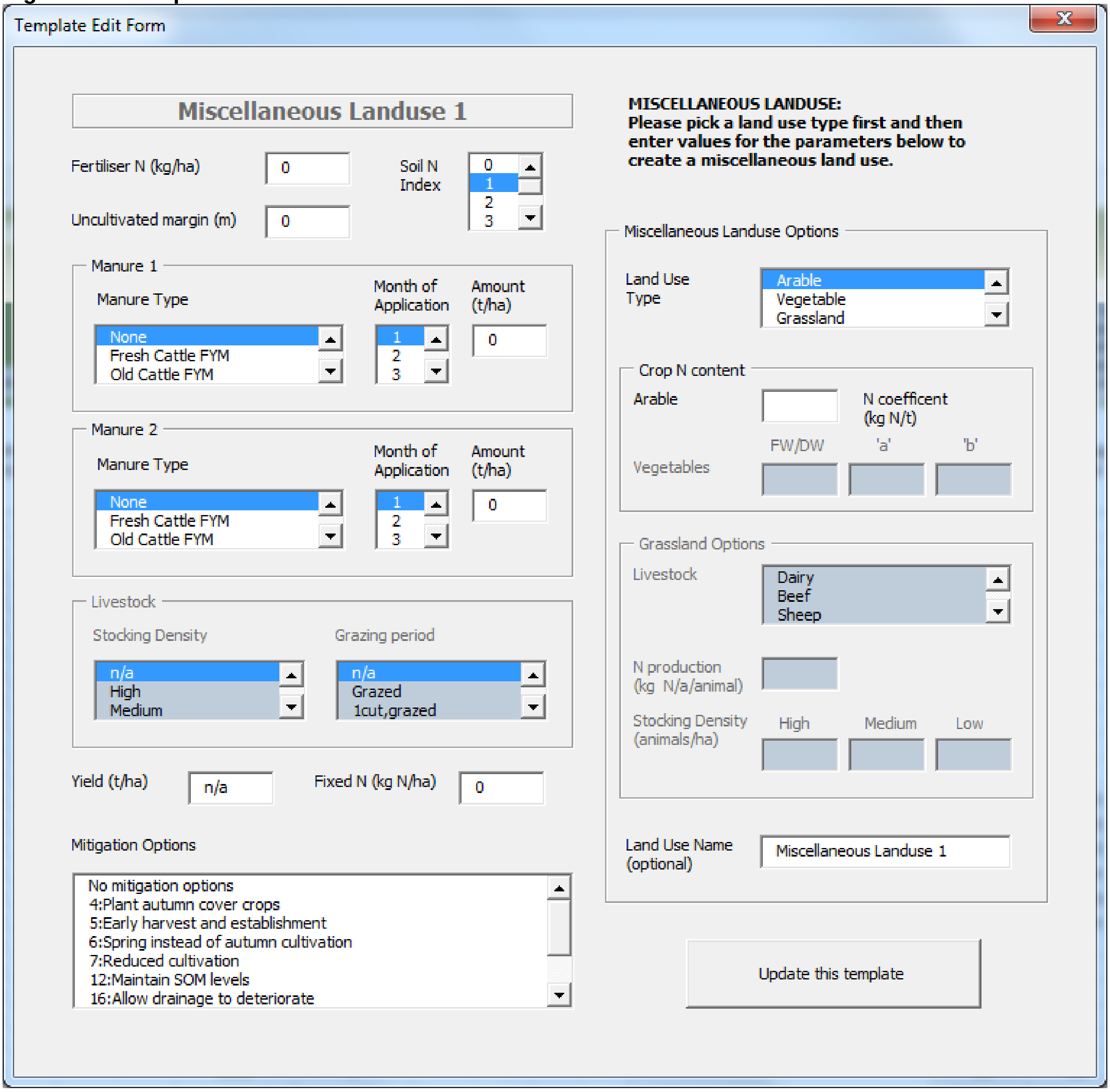
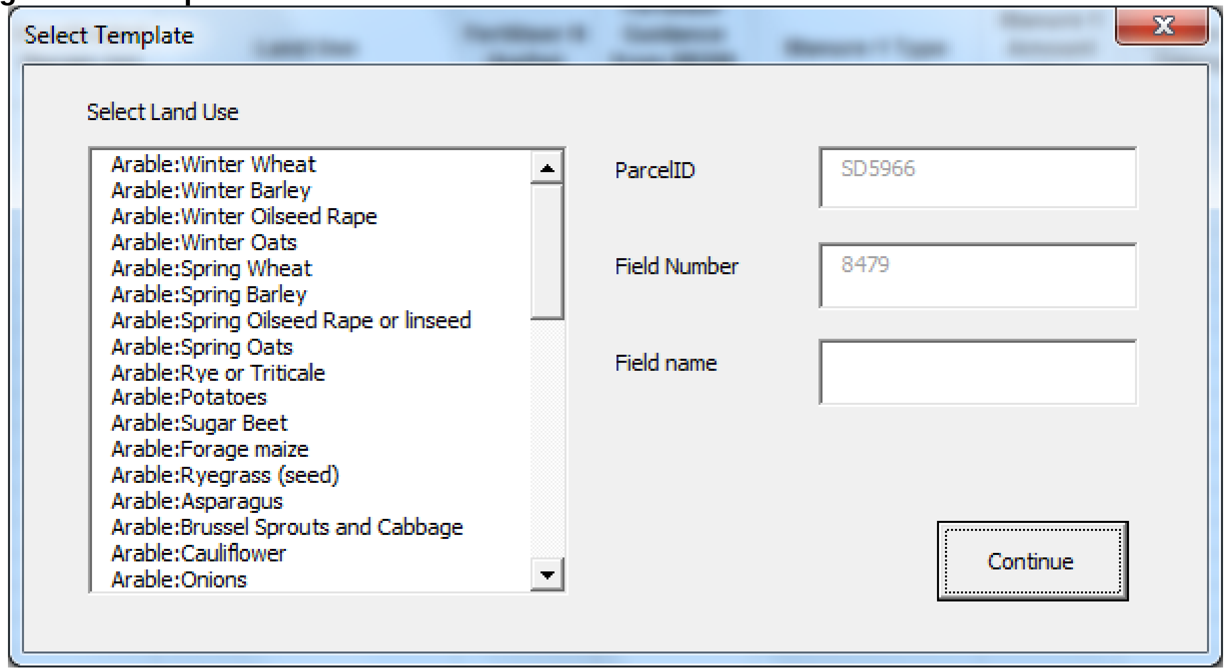


Figure 3-5:Template selection form



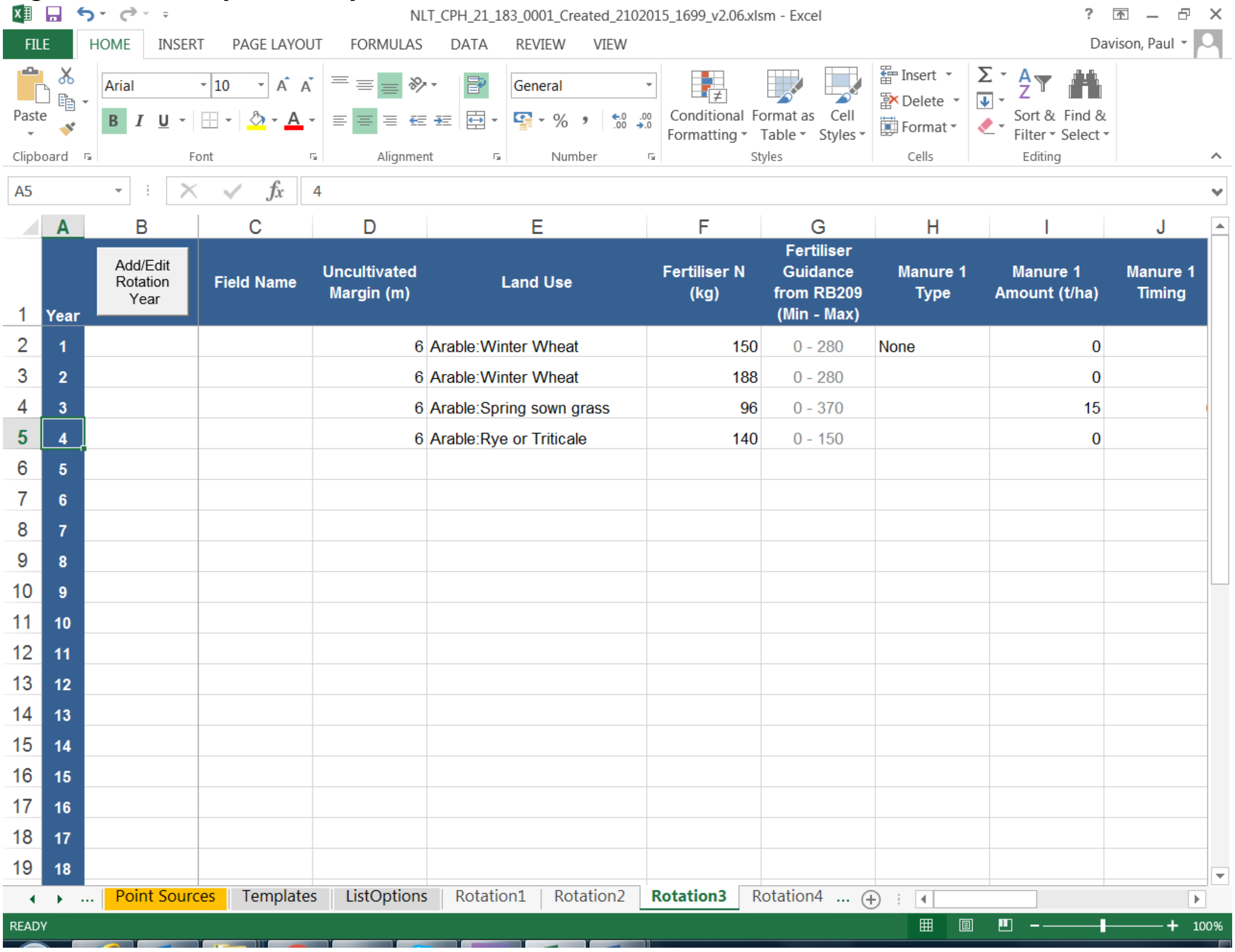
3.2.5 Crop rotations

A number of crop rotations may be defined in the NLT, and used as the basis of field data entry. Rotations are defined in the Rotation1, Rotation2 etc. tabs of the workbook. Each line of each Rotation tab specifies a crop or land use for one year. An example of a hypothetical 4-year rotation is shown in Figure 3-7.

Each line (year of the rotation) may be edited by clicking on the year number, in column A, followed by the 'Add/Edit Rotation Year' button. Additional years may be added to the rotation in the same way. The rotation data entry form is shown in Figure 3-8.

Note that, at this stage, rotations are not attached to any particular field or fields on the farm. They are simply a specification of management data. Fields are associated with a rotation in the 'Actual Land Use' tab, by clicking the Use Rotation' button.

Figure 3-6:Example of crop rotation data



Year	Add/Edit Rotation Year	Field Name	Uncultivated Margin (m)	Land Use	Fertiliser N (kg)	Fertiliser Guidance from RB209 (Min - Max)	Manure 1 Type	Manure 1 Amount (t/ha)	Manure 1 Timing
1			6	Arable:Winter Wheat	150	0 - 280	None	0	
2			6	Arable:Winter Wheat	188	0 - 280		0	
3			6	Arable:Spring sown grass	96	0 - 370		15	
4			6	Arable:Rye or Triticale	140	0 - 150		0	
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
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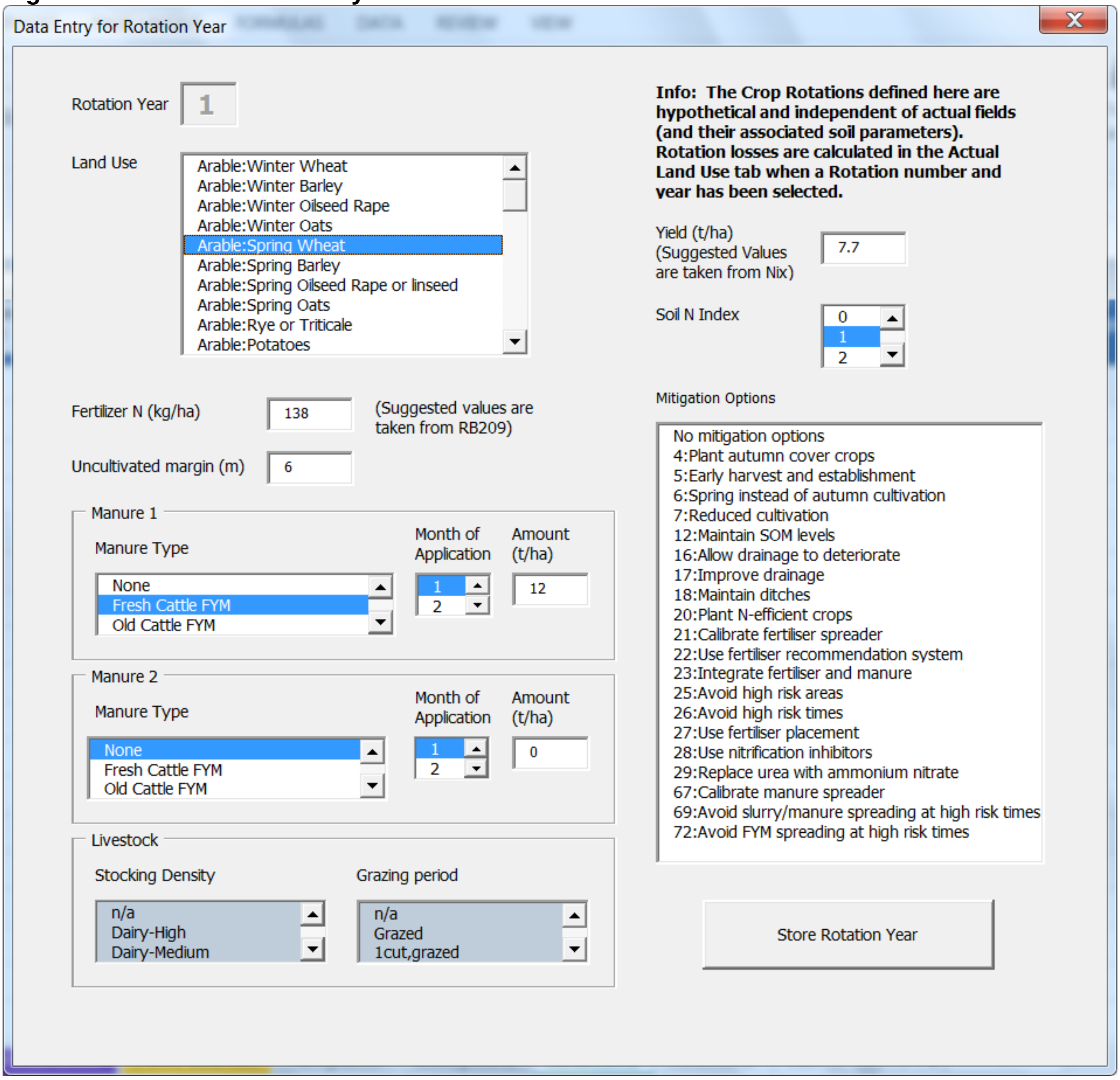
17									
18									

Figure 3-7:Rotation data entry form



3.3 Atmospheric deposition

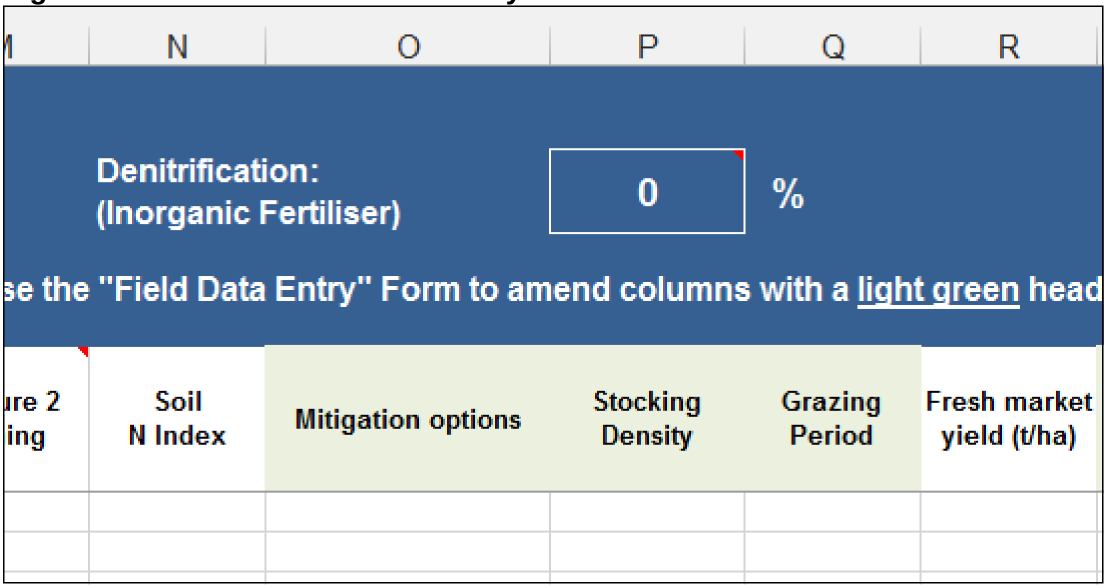
The rate of atmospheric nitrogen deposition used by the NLT is estimated based on 2011 data published by Defra (2012). A rate is estimated automatically based on the OS 100km square in which the farm being modelled is located. A map of deposition rates and the rate associated with each 100km square are shown in the 'Atmospheric deposition' tab in the workbook.

The selected rate of deposition used in the calculations is shown at the top of the 'Actual Land Use' tab, and may be overtyped if necessary. Regular updates of atmospheric N deposition data for single years and as 3-year average deposition values (CEH, 2016) are available from: http://www.pollutantdeposition.ceh.ac.uk/data

3.4 Denitrification

To account for the fact that nitrate can be denitrified and lost to the atmosphere, a term for denitrification of the inorganic fertiliser was introduced with NLT version 3.5. The rate of denitrification (%) can be specified at the top of the ‘Actual Land Use’ tab (see Figure 3-9) and has a default value of 0%. Dunn and others (2004) gives a guidance range of ‘little’ (0%) denitrification for light sandy, freely drained soils, around 20% for sandy loam soils and up 35% for heavy clay loam textured soils. The denitrification value (%) will be applied to all fields. Denitrification rates can be highly variable and difficult to determine. Without evidence suggesting otherwise, it is conservative to assume that no denitrification occurs (that is, to retain the default value of 0%). Alternatively, you may decide what figure may be appropriate, on average, across the catchment.

Figure 3-8: Denitrification value entry box

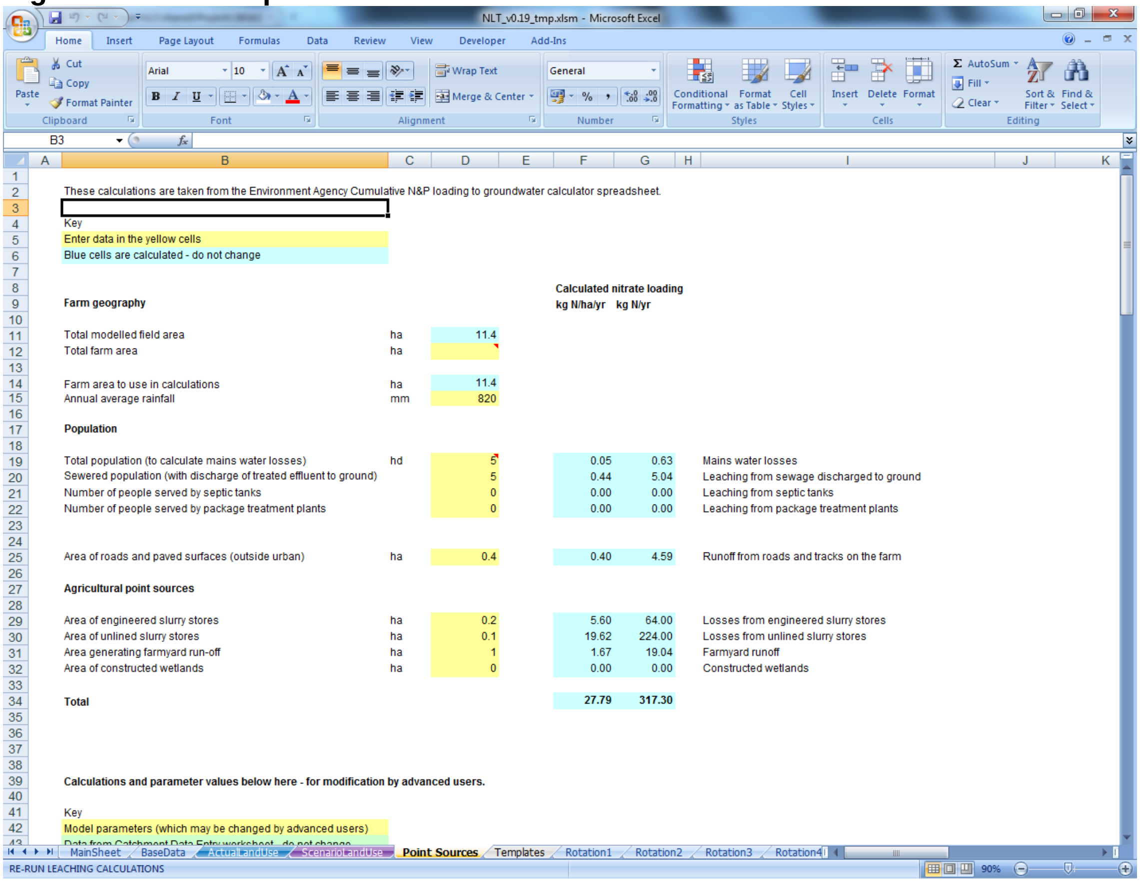


3.5 Point sources

The main aim of the NLT is to estimate nitrate leaching from inorganic fertiliser and manure applied to agricultural land. However, there are other potential point sources of nitrate leaching on farms, such as slurry stores, run-off from farmyards and tracks, and sewage discharges such as septic tanks. The ‘Point Sources’ tab in the workbook allows you to estimate the nitrate loading from these sources. These calculations are optional and not including them will not affect the calculation of leaching from agricultural land.

Calculations are based on the coefficients derived by AMEC in 2010 (ref 27510rr032i3) for the project ‘Cumulative N and P loadings to groundwater’. Figure 3-10 shows the Point Sources calculation tab.

Figure 3-9: Nitrate point source calculation



Data should be entered in the yellow cells. The calculated nitrate loading from each potential point source is shown to the right in the blue cells. Data entries are required as follows:

- the total farm area (used to calculate area-specific nitrate loading). This defaults to the total area of all modelled agricultural fields, but the total farm area, including hardstandings and non-productive land, will be greater than this. Enter the total farm area if known, or leave blank to use the default value
- population. Enter the number of people living on the farm. This is used to calculate mains water nitrate losses. Enter zero if the farm has a private water supply
- sewage arrangements. Enter the number of people living on the farm served by mains sewers (with discharge of effluent to ground), septic tanks, a package treatment plant
- area of roads and paved surfaces. This includes all farm tracks and other impermeable areas, but not farmyards or cattle hardstandings
- area of slurry stores, farmyards and hardstandings, and constructed wetlands, if applicable

The details of the nitrate calculations from these sources are provided further down in the worksheet. We do not recommend that you change the coefficients unless there is evidence is to support you doing this.

The total calculated nitrate loading from point sources (kg/N) is displayed on the bottom figure in the ‘Main Sheet’. It is plotted next to the total loading from the four main land uses (Actual Land Use) for comparison.

3.6 Creating scenarios

The potential impact of changes in management can be assessed by creating scenarios based on current field data. Scenario calculations are carried out in the ‘Scenario Land Use’ tab.

Click on ‘Copy across Actual Land Use’ to create a copy of the data in the ‘Actual Land Use’ tab. Select a field to modify by clicking on the field number in column A and then on the ‘Edit Scenario’ button. Once you have made all modifications to the scenario field data, click on ‘Calculate N Losses’ to estimate nitrate leaching from the scenario fields. The results are displayed to the right in the ‘Scenario Land Use’ tab, and also in the ‘Main Sheet’ tab in bar charts on the left.

3.7 Viewing results

The Nitrate Leaching Tool calculates nitrate leaching from each field for which data has been entered as:

- a loading of nitrate (kg N)
- an area-specific loading (kg N/ha)
- a concentration of nitrate in soil drainage (mg N/l)

Calculations are carried out for baseline conditions and for scenarios. For fields that are in defined rotations, the average nitrate loss across all years in the rotation is also calculated. Nitrate losses from point sources such as slurry stores may also be estimated.

Results are displayed numerically in the various data entry tabs in the workbook, and also graphically in the ‘Main Sheet’ tab.

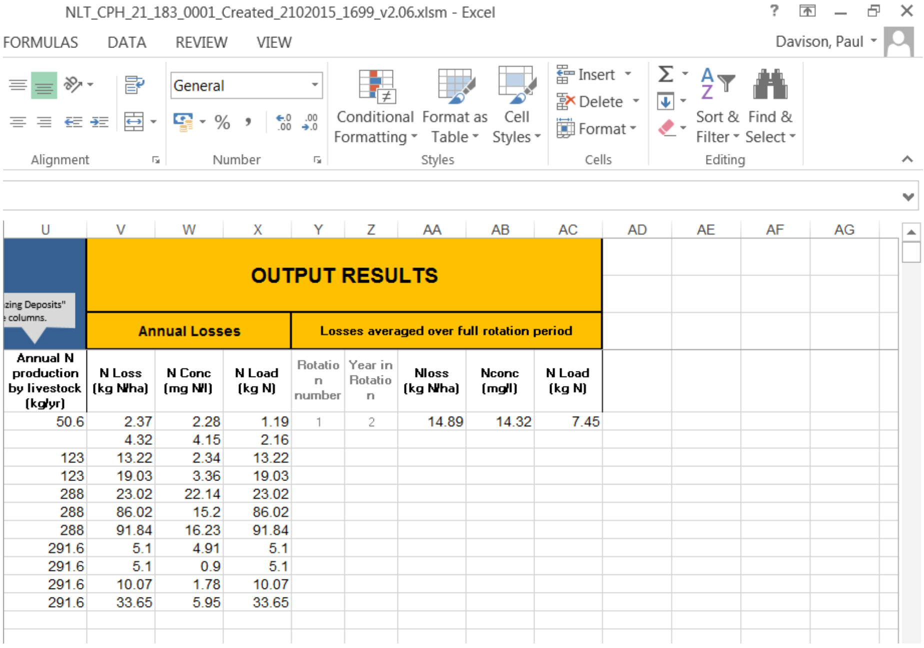
Note that if you change input (field) data, the results do not automatically update, i.e. the calculation routine must be manually re-run.

3.7.1 Calculated field nitrate losses

The calculated nitrate leached from each field is shown in the ‘Actual Land Use’ tab to the right of the field data, in columns with orange headers (Figure 3-11). The nitrate loading and concentration in soil drainage are shown for each field.

For fields that are in defined rotations, the average loading and concentration over the full rotation period is also shown. It should be noted that the average rotational concentration values should be treated with caution as they may not be representative for fast reacting catchments (in which the rotation length may be greater than travel time through the unsaturated zone).

Figure 3-10: Output of field-by-field calculations



U	V	W	X	Y	Z	AA	AB	AC
	OUTPUT RESULTS							
	Annual Losses			Losses averaged over full rotation period				
Annual N production by livestock (kg/yr)	N Loss (kg N/ha)	N Conc (mg N/l)	N Load (kg N)	Rotation number	Year in Rotation	Nloss (kg N/ha)	Nconc (mg/l)	N Load (kg N)
50.6	2.37	2.28	1.19	1	2	14.89	14.32	7.45
	4.32	4.15	2.16					
123	13.22	2.34	13.22					
123	19.03	3.36	19.03					
288	23.02	22.14	23.02					
288	86.02	15.2	86.02					
288	91.84	16.23	91.84					
291.6	5.1	4.91	5.1					
291.6	5.1	0.9	5.1					
291.6	10.07	1.78	10.07					
291.6	33.65	5.95	33.65					

3.7.2 Scenario predictions

Results of scenario calculations are displayed in the ‘Scenario Land Use’ tab, in the same way as baseline results: to the right of the field data in columns with orange headers. As for the baseline calculations, the predicted nitrate loading and concentration in soil drainage are shown for each field.

3.7.3 Log files

Each ‘run’ of the NLT will create a log file. These text files are created in the folder containing the NLT workbook and have names, which include a date and time stamp.

The files contain a record of all the input values used in the calculations, and all the outputs from them.

4 Assumptions and limitations

The NLT uses a simple soil N balance calculation to estimate nitrate at risk of leaching. This simplistic tool requires little data, but this does mean that it cannot represent some aspects of nutrient management. The onus is on the user to ensure that all data and parameter values entered into the tool are internally consistent and appropriate. This section describes some points to consider when selecting data values.

4.1 Timing of manure and inorganic fertiliser applications

The tool assumes that manure and inorganic fertiliser are applied at the ‘correct’ times of the year to maximise the availability of nutrients to the crop and minimise leaching. In practice, this typically means spring applications.

Late summer or autumn applications are at risk of leaching during the winter, and you will need to consider this when assessing output from the NLT. The ADAS MANNER[2] tool can provide guidance on the likely leaching of nitrogen from autumn applications of manure. Of course, there may be other factors to consider when planning manure applications, such as the requirements of the Nitrate Vulnerable Zones (NVZ) Action Plan.

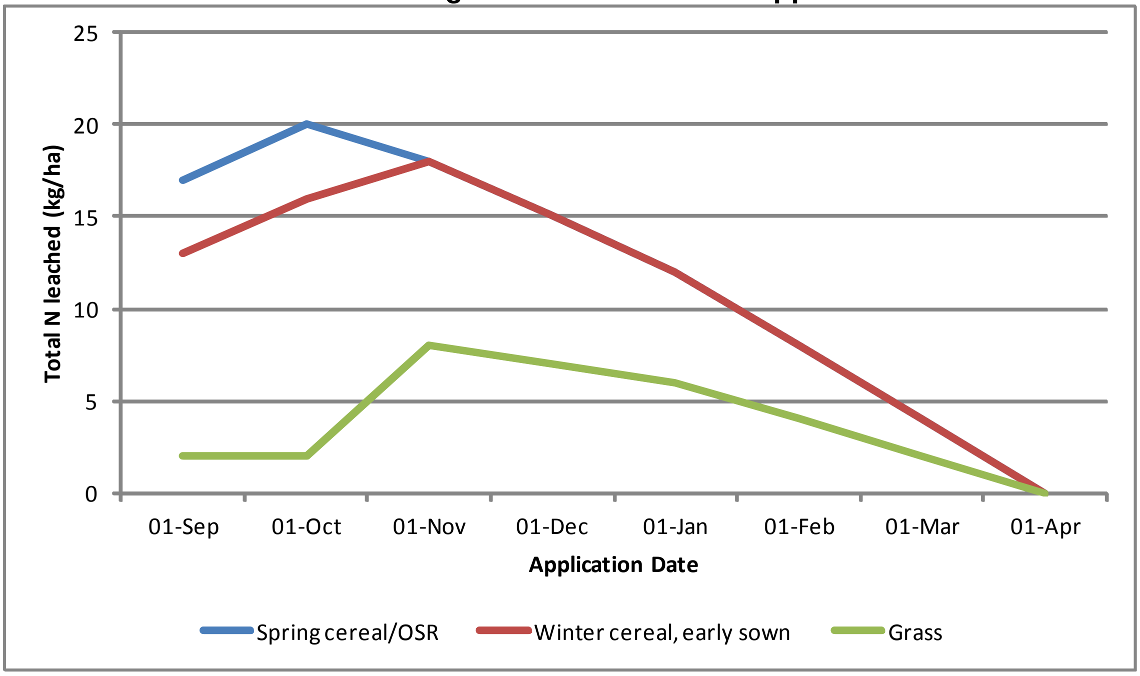
Figure 4-1 shows nitrate leaching from an application of cattle slurry at $50m^3$/ha as predicted by the MANNER model, as a function of application date, for autumn crops, spring crops and grass. In general, and all else being equal:

- spring crops will allow more leaching than autumn crops or grass. This is because autumn sown crops will take up some nitrogen in the autumn, reducing the amount of nitrate at risk
- the risk of nitrate leaching decreases for later applications
- applications in April or later are predicted, in this case, to result in no leaching and maximum availability of nutrients to the crop

There are other factors that can influence nitrate leaching from applications of manure, such as the method of spreading and the weather conditions during and after spreading. The MANNER tool can provide further guidance on these factors.

[2] http://www.planet4farmers.co.uk/manner

Figure 4-1:Variation in nitrate leaching with date of manure application



In assessing leaching from manure applications, the NLT considers only the readily available N content of the manure, not the total N content. The total N content of a manure application will be higher than the readily available N content, as it will include organic N that might become available to the crop during the course of the growing season. In practice, the total N available to the crop from a manure application will usually lie somewhere in between the readily available and total N content, and this represents a source of uncertainty in the leaching calculation.

4.2 Nitrogen content of manure

The NLT calculates the addition of nitrogen in manure based on the volume applied and the readily available nitrogen content of the manure. This will overestimate the nitrogen applied that is at risk of leaching, since some losses through volatilisation of ammonia are likely, which will reduce the overall nitrogen content. Losses from volatilisation are highly variable and depend on the type of manure, method of application, whether the manure is incorporated into the soil, the type of soil and other factors. The MANNER tool can provide further guidance.

4.3 Utilisation of nutrients by the following crop

The NLT soil N balance calculations span a period of one agricultural year, from (typically) September to August. The tool estimates the soil mineral nitrogen (SMN) at risk of leaching in the autumn, post-harvest, as the excess N above that taken up by the crop.

However, depending on how the land is managed following crop-harvest, much of this SMN may not be at risk. For example, a following autumn-sown arable crop may take up a significant quantity of nitrate that the NLT cannot account for. This would result in nitrate leaching being significantly over predicted. When Amec Foster Wheeler (Ref. 37198N019i1. November 2016b) compared the NLT with porous pot data provided by Wessex Water it was found that 'the NLT generally overestimates leaching compared with porous pot data which can partly be attributed to the effect of following crops and their autumn nitrate uptake'.

In particular, this must be accounted for when assessing potential leaching from fields where the soil nitrogen supply has been deliberately built up, for example outdoor pigs in an arable rotation, or the use of legumes in rotational grass. In these cases, the NLT will predict a very high rate of nitrate leaching because the excess nitrogen applied during the crop year for which calculations are carried out will be substantial. However, you will need to consider whether this is realistic or whether, in fact, the subsequent management of the field will utilise this soil nitrogen and reduce rates of leaching. Subsequent sections deal with these specific examples in more detail.

4.4 Outdoor poultry, horses and other livestock

Current Defra guidance[3] provides figures for the quantity of nitrogen produced by grazing livestock. These figures, reproduced in Table 4.1, can be used to estimate the approximate equivalent nitrogen loading to land from grazing livestock, recognising that this will represent a major simplification of nitrogen cycling processes on grassland.

It is notable that a horse produces approximately one fifth of the nitrogen produced by a dairy cow. The nitrogen loading to soil from horses at typical stocking densities will, therefore, be well below that of dairy cattle.

Table 4.1: Nitrogen production by grazing livestock (from Defra NVZ guidance, 2019)

Livestock type	**Total N produced (kg/yr)**
1 calf (all categories) younger than 2 months	1.4
1 dairy cow from 2 months and less than 12 months	29
1 dairy cow from 12 months up to first calf	61
1 dairy cow after first calf (over 9,000 litres milk yield)	115
1 dairy cow after first calf (6,000 to 9,000 litres milk yield)	101
1 dairy cow after first calf (up to 6,000 litres milk yield)	77
1 beef cow or steer (castrated male) from 2 months and less than 12 months	28
1 beef cow or steer from 12 months and less than 24 months	50
1 beef cow or steer for slaughter 24 months and over	50
1 beef cow for breeding 24 months and over weighing up to 500kg	61

[3] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/403382/nvz-guidance-blank-completion-data-tables-201312.xlsm (accessed March 2019)

1 beef cow for breeding 24 months and over weighing over 500kg	83
1 non-breeding bull 2 months and over	54
1 bull for breeding from 2 to 24 months	50
1 bull for breeding 24 months and over	48
1 lamb, 6 to 9 months	0.5
1 lamb, 9 months and over, to first lambing, first tupping or slaughter	0.7
1 sheep, less than 60 kg, after lambing or tupping. For ewes, this includes one or more suckled lambs up to 6 months	7.6
1 sheep, over 60 kg, after lambing or tupping. For ewes, this includes one or more suckled lambs up to 6 months	11.9
1 goat	15
1 deer for breeding	15.2
1 deer, other	12
1 horse	21
1,000 laying hen places, free range, 17 weeks and over	530
1,000 turkey places (male)	1,230
1,000 turkey places (female)	910
1,000 duck places	750
1 ostrich	1.4

Note: For poultry figures, N produced in excreta is per 1,000 poultry places (except ostriches) and includes an allowance for N losses from livestock housing and manure storage.

4.5 Clover in grassland systems

In the NLT, the fixing of nitrogen by clover in grass swards is represented by using clover as a grassland mitigation option, which will simply reduce residual N to 80% of the original value. However, clover will increase the pool of organic nitrogen available to mineralise, therefore potentially increasing the risk of nitrate leaching if the sward is ploughed out. You will need to account for this when considering predictions of nitrate leaching from rotational grass. Further guidance on the potential soil nitrogen supply from clover is provided in RB209 (AHDB, 2019). In terms of a soil N budget on arable land, soil nitrogen supply from clover can be represented in the NLT as an elevated SNS index or as a fertiliser input.

4.6 N-fixing legumes

The crop type peas and beans with their N-fixing properties are now available in the NLT. Leaching from N-fixing crops is calculated by applying a fixed N amount as additional input to the Soil N Budget calculation. The amount can be viewed and changed in the 'Templates' tab (Col P). The default values for beans and peas used in the NLT are 224.6kg N ha^{-1} and 140.7kg N ha^{-1} respectively (Baddeley and others, 2013).

4.7 Under sowing of arable crops

This cannot be represented in the NLT mechanistically. However, for the under sowing of maize a mitigation measure has been added. The reduction in leaching that this measure will cause has been taken from Whitmore and Schroeder (2007).

4.8 Selecting appropriate parameter values for grassland fields

The NLT uses the N-Cycle model to estimate nitrate leaching from grassland fields. Estimates are based on N-Cycle predictions of nitrate leaching from cut grass, which are a function of soil type, climate and fertiliser/manure application rate. Predicted leaching rates are then modified to account for cycling of nitrogen by grazing livestock. Full details are provided in the Technical Basis document, and the following information is provided here to help use the tool and select appropriate parameter values.

4.8.1 Climate zone

The N-Cycle climate zone (1, 2 or 3) is automatically selected based on the grid reference of the first field in the 'Base Data' sheet. The selected value is displayed in the 'Actual Land Use' sheet, and can be overtyped if required.

4.8.2 Soil type and drainage class

Three combinations of soil type and drainage class are available. Since soil data is not currently imported to the tool, soil type and drainage class are estimated based on standard percentage runoff (SPR), as shown in Table 4.2. It is recognised that this is rather crude and would benefit from refinement.

Table 4.2: Estimated soil type and drainage class as a function of SPR

SPR (%)	***Soil type – drainage class***
< 30	*Sand – Good*

30 < SPR < 60	*Loam – Moderate*
> 60	*Clay - Poor*

4.8.3 Estimation of grazing deposits

The rate of N deposition by grazing livestock is calculated according to the livestock type and stocking density entered by the user, the estimated length of the grazing season and annual rates of N production by livestock (Defra NVZ guidance). The figures for annual N production by livestock are provided in the ‘Templates’ tab and may be overtyped if required.

Grazing deposits (kg N/ha/yr) are calculated as:

Annual N production per head of livestock x No. of livestock per ha (stocking density) x Length of grazing season (fraction of year)

Values are as shown in Table 4.3.

Table 4.3: Default grassland parameter values

Livestock type/ stocking density	**Length of grazing season (months)**	**Stocking density (head/ha)[4]**	**Annual N production (kg N/head)[5]**
Dairy-High	7, 5 or 4[1]	3.1	117
Dairy-Medium	7, 5 or 4[1]	2.6	117
Dairy-Low	7, 5 or 4[1]	2.0	117
Beef-High[2]	7, 5 or 4[1]	3.17	92
Beef-Medium	7, 5 or 4[1]	2.0	92
Beef-Low	7, 5 or 4[1]	0.83	92
Sheep-High[3]	12 (All Year)	10	12.3[6]
Sheep-Medium	12 (All Year)	4.12	12.3
Sheep-Low	12 (All Year)	0.59	12.3
Outdoor pigs-High	12 (All Year)	25[7]	18[6]
Outdoor pigs-Medium	12 (All Year)	16[8]	18
Outdoor pigs- Low	12 (All Year)	7[8]	18

1. 7 months for grazed fields, 5 months for 1 cut then grazed, 4 months for 2 or 3 cut then grazed
2. 1 Beef cow = 0.6 LU
3. 1 Sheep = 0.17 LU
4. Stocking Density for good conditions as upper bound. Source: RB209 (Tables 8.1 to 8.8)
5. Source: Nitrates Consultation Supporting Paper F2 (Tables 26 - 28)

6. Value derived from Farmscoper
7. Recommendation for ideal sites, from: The Defra Code of Recommendations for the Welfare of Livestock
8. Estimated value

The figures above will result in an estimate of, for example, 211kg N/ha/yr in dung and urine from dairy cattle with high stocking density, on a grazed field (7 months grazing season). It is assumed that dung and urine produced during the remainder of the year is managed as manure or slurry and, by default, the NLT assumes that this manure is spread elsewhere or exported off the farm. If the manure is spread to the grazed field, it must then be included in the NLT as a manure (or fertiliser) application.

Note that the onus is on the user to make sure that the fertiliser rate and stocking density selected for each field are consistent (that is, that the selected fertiliser rate is sufficient to produce enough herbage to feed the selected stocking rate).

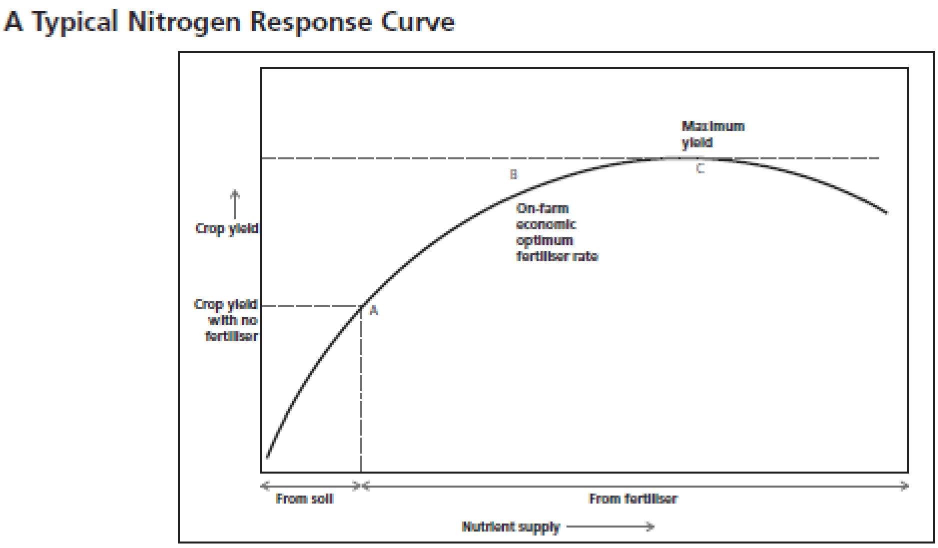
4.9 Relationship between fertiliser application rate, crop yield and offtake

The NLT uses fixed parameter values of the nitrogen content of harvested arable crops derived from Eurostat Crop N Coefficients (2011). For specific crop types that weren't included in Eurostat, the value of the associated group crop was used instead (for example, onion = root crops). The calculated offtake is the fresh weight yield (as entered by the user) multiplied by the crop N content.

The onus is on the user to make sure that all field parameters are consistent: fertiliser application rate, crop yield and crop N content.

Figure 4-2 shows a typical yield response curve (from RB209, AHDB, 2019).

Figure 4-2:Nitrogen response curve



The N offtake is calculated in the NLT as the product of the yield and the crop N content (as a percentage of yield). The NLT provides 'standard' figures for fertiliser application rates, crop N content and yield. However, the user may wish to override these default figures in particular circumstances. For example, additional fertiliser applications may be made to milling wheat crops to increase grain protein content. In this case, the crop N content, and therefore offtake, should also be increased. Not accounting for this would result in a predicted soil N surplus and overestimated risk of leaching.

Similarly, crops with low fertiliser application rates (for example, organic crops that do not receive any inorganic N) may achieve low yields and, therefore, lower N offtake. Not reducing the yield value in the tool will result in an overestimate of crop N offtake and underestimate of risk of N leaching.

In particular, it should be noted that there is additional uncertainty around the ‘standard’ figure for the yield of spring sown grass, which has been estimated on the basis of a dry-matter yield of 9.5 t/ha and 25% dry matter content (after the figures provided in RB209, AHDB 2019), and in the N content of radish crops, for which parameters have been estimated from data in Nendel and others (2009). It is, therefore, not appropriate to adjust the ‘a’ and ‘b’ coefficients for radish to account for variations in yield.

4.10 Mitigation measures on grassland

For grasslands, mitigation measures reduce the amount of leached N calculated by the N-Cycle model. Unlike for arable and vegetable crops where some measures can be applied pre- and post-harvest, these measures are applied only once. This is a limitation of the NLT, in that because leached N is calculated directly for grassland with no intermediate calculation of residual N at risk, it is not possible to apply mitigation coefficients to the calculated residual N before calculating leaching.

4.11 Scale of application

The NLT is intended mainly as a tool for estimating the risk of nitrate leaching from productive land across a farm, although as noted in section 3.8, some point sources of nitrate such as septic tanks can also be included. The natural scale of operation of the NLT is, therefore, a single farm, with outputs at the field scale.

In order to estimate the nitrate loading to groundwater at a larger scale, for example a river catchment, it would be necessary to combine the estimated loading from all the sources of nitrate in the catchment. This will include all the farms in the catchment and also all other potential sources such as landfill sites (current and historic) and sewer leakage. There will also be significant areas of non-agricultural land in the catchment that will exhibit lower levels of nitrate leaching, such as amenity land. The effect of soil drainage from these areas will be to ‘dilute’ the leaching from higher risk areas.

It is nonetheless possible to estimate the nitrate loading from all agricultural land in a sub-catchment or even a larger river catchment by carrying out leaching calculations for all the fields in the catchment. This will be likely to overestimate nitrate concentrations at the water table since drainage from non-agricultural land, which will generally have a lower nitrate concentration, will not be accounted for. This may still be useful for identifying particularly high risk areas within a catchment, or catchment scale source apportionment within the agricultural sector.

Note that unlike the Farmscoper tool, the NLT does not include any agricultural census data or model farm type information. There is, therefore, no facility to ‘upscale’ from individual farm to catchment scale using pre-populated databases.

At larger spatial scales, the number of fields selected for modelling will be likely to prohibit detailed field data collection and entry, for example it would be difficult to collate and enter detailed data on cropping, manure applications and mitigation methods in place for hundreds of fields. It will also be necessary to use average values for the major crops and livestock sectors present in the catchment, such as those included in the NLT crop templates. This inevitably introduces some uncertainty. However, in parts of the country that reflect general land management practices or at increasing spatial scale, using default ‘average’ values will result in less uncertainty than at smaller scales.

In practice, it is likely that the main constraint on using the NLT at larger spatial scales will be the effort and time required to populate the ‘Actual Land Use’ fields for a very large number of fields.

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Appendix A

Field scale Nitrate source apportionment tools. Key similarities and differences.

Parameter	Catchment Change Matrix (CCM)	FARMSCOPER	NLT
Developer	EA Risk & Forecasting	ADAS	EA Land Research
Intended User	Risk & Forecasting	Farm advisor, EA Ops, E&B	Farm advisor, EA Ops, Water Companies
Purpose	Used as a national scale tool and simulates losses and mitigation effectiveness nationally	A farm mitigation planning tool for nutrients.	Engage with farmers to identify measures to minimise nitrate losses to groundwater
Platform	PC	PC & Laptop	PC & Laptop
Scale	Farm (Many farms per run)	Farm (Single farm per run*) *in standard configuration	Field or Farm (Single farm per run*) *in standard configuration.
(Non Farm) Input data	Farm data (see below); suite of measures (real or scenario based); measure implementation rates (or audited farm measure data); catchment or management unit boundary; user can supply information on prior implementation of measures (optional)	Farm data (see below); suite of measures (real or scenario based); suite of prior implemented measures (optional)	Location, climatic region, Hydrologically Effective Rainfall (HER), soil properties, Atmospheric N deposition, Farmer supplied data (see below)
Farm input data	Defra Agricultural Census holding level data; RLR-CLAD data may be needed when setting up new area for first time	Input manually by user (could range from Agricultural Census holding level data to pre-defined model farm type)	Input manually by user: • ADAS mitigation measures.
Output	Baseline and pollutant	Baseline and pollutant	N concentration

	farm loadings at farm scale and aggregated to catchment or management unit scale; a detailed set of measure implementation rates that are specific to CSF; lists of 'most effective' measures per scenario	farm loadings at farm scale; optimised suite of measures; Cost estimates are associated with each mitigation measure, so the user will be able to produce estimates of the cost of modelled measure suites.	(mg/l) at base of soil zone in Autumn (i.e. available for winter recharge to groundwater). Calculated for baseline (actual practice) and scenario measures at the field and farm scale
Assumptions/ Caveats	Prior mitigation is based on national assumptions, as featured in Farmscoper, moderated to include basic information on ES and NVZ. Future scenarios include CSF mitigation as part of the 'prior mitigation'.	Farmscoper makes assumptions on the prior implementation of measures; for example if a farm is in an NVZ Farmscoper will implement measures corresponding to the Nitrates directive action plan. It also assumes some basic measures are applied on all farms. These prior mitigation measures are applied when the baseline is calculated.	Tool assumes timing of manure/slurry application follows good practice. (*Use Manner if this is not the case)
Basis	Uses export coefficients from Farmscoper for nutrients and sediment. FIO losses are calculated using an EA model. The CCM uses very similar information to Farmscoper for mitigation measure effectiveness. There are some differences where expert judgement has been used to complete gaps in the literature, or where adjustments have been made to account for specific computing operations (Burgess 2011)	Losses are expressed as export coefficients. These are derived from a suite of process based mathematical models (Anthony 2006). The export coefficients used are dependent upon climate region and soil type. The user may override the default losses where appropriate field scale empirical evidence is available. Mitigation measure effectiveness is based upon the DPI Manual (Newell Price et al. 2011), the Ammonia mitigation manual (Misselbrook et al. 2009) and the Review of Research to Identify Best Practice for Reducing Greenhouse Gases from Agriculture	Losses are expressed as export coefficients. Crop calculations based on MAGPIE and NEAP-N (Lord &Anthony). Grassland losses based on NCYCLE (Schofield) The export coefficients used are then used for outputs dependent upon bespoke input data from farmer on crop and field management at the field scale. Also, climate region and soil type. Mitigation measure effectiveness is based upon the DPI Manual (Newell Price et al. 2011)

		and Land Management (Moorby et al. 2007). In some cases expert judgement is used to complete gaps or where s using the literature figures would lead to errors or inaccurate outputs (Gooday et al. 2013).	
Baseline Approach	Uses very detailed, spatially explicit (Ag Census) farm data for the whole of England. The CCM uses a similar coordinate apportionment system to Farmscoper.	Uses a coordinate system to identify the source, area (landuse) and pathway of farm losses. Farm data (land use, livestock) is multiplied by the export coefficients to generate baseline farm losses. The apportionment information is used to assign losses to the Farmscoper coordinate system.	Used at the field or holding scale. Takes RPA data to identify individual fields associated with a particular holding and farmer derived data on land use (crop etc) and management practices (eg buffer strip size). Measures can be applied in the baseline if they are being implemented already.
Mitigation Measures Approach	Each measures acts upon one or more coordinates. The effectiveness rates for each measure may vary across multiple coordinates. The overall measure effectiveness rate in the CCM is a function of: • the base DPI manual effectiveness, • the measure areal coverage, • prior mitigation rates • the observed implementation rate. The CCM alters the portion of the coordinate each	Each measures acts upon one or more coordinates. The effectiveness rates for each measure may vary across multiple coordinates. Effectiveness of multiple measures uses a simple multiplicative reduction. Farmscoper can also implement farm scale mitigation measures optimisation that aims to maximise reductions and minimise cost (Gooday & Anthony 2010).	NLT uses some ‘sense checks’ and expert assumptions to avoid double counting of losses between measures types and prevent situation where measures 100% effective. For arable cropping, the tool distinguishes between pre-mitigation options – those actions which act before crop harvest; and post-mitigation options which act post-harvest. The tool implements multiple mitigations options in a simple multiplicative way. Thus if 2 options are selected which reduce residual N by 70 and 50% respectively, their combined effect is taken as 70*50/10000=35%.

	measure is effective against based on the estimated areal coverage of the measures taken from the DPI manual (Newell Price 2011). The CCM produces a cascading set of measure implementation rates based on CSF audit data. Where there are multiple implementation rates for each measure, the CCM will use the implementation rate from the most detailed available level of the cascade. The cascade has four levels: global > mitigation measure > farm type > region. There must be at least 30 measures at a given level for the implementation rate to be considered robust. If there is not 30 measures at the most detailed level then the implementation rate from one level up the cascade is used and so on (Burgess 2011). The base measure effectiveness is also subject to alteration based on the observed implementation rate of each measure. The CCM allows for two methods of combining multiple measures on the same co-ordinate. • The first is a simple multiplicative reduction, similar to Farmscoper. • The second purposefully		The tool sets a minimum limit on the residual N achievable through the application of multiple pre-harvest mitigation options. At present, this is set as 20 kgN/ha based on a data set supplied by ADAS. post-harvest options such as the planting of autumn cover crops can reduce levels below 20 kg N/ha.

	biases against subsequent measures so that the base effectiveness of up to 5 measures is altered as follows 100% (effective), 80%, 60%, 40%, 20% all subsequent measures have zero effectiveness.		
Uncertainty	The CCM is a deterministic model, however it does produce multiple outputs to represent the uncertainty in mitigation measure effectiveness and implementation.	There are two (quantified) sources of uncertainty in Farmscoper, the baseline losses and the mitigation measure effectiveness. Farmscoper uses latin-hypercube sampling to estimate the combined uncertainty in the estimated losses (Gooday et al. 2013)	Unquantified uncertainty around effectiveness of combinations of measures.
User expertise	If licensing issues addressed...new users would face a steep learning curve, but those with a decent knowledge of MS Access and of diffuse water pollution from agriculture mitigation methods should be able to run the model.	Well documented, should be fairly easy for competent users of MS Excel to use the model.	Should be fairly easy for competent users of MS Excel to use the model. Intended for farm advisors/agronomist who understand farm practices and mitigation measures.
Data input time			< 1hr depending on farm size
Run time	As the CCM is generally run as a national scale (c. 200k farms) model run times can be long.	Farmscoper is generally run for a single farm so run times are very short.	Quick for individual farms (<1min).
Software	MS Access, ESRI ArcGIS (optional - to plot results spatially)	MS Access, MS Excel, ESRI ArcGIS (optional)	MS Excel, ESRI ArcGIS
Accessibility	Due to the use of farm scale Ag Census data each use of the CCM requires a licence from Defra, therefore the CCM is not easily accessible to new users.		Current licenses only cover use of data in tool for Pilot EA projects. National roll out options are being explored.

	Currently the CCM may only be applied by the EA for specific Defra projects.		

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