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Review of Nutrient Management Planning tools available for use with forage crops in Northern Ireland

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EXECUTIVE SUMMARY

Nutrient management planning is fundamental to economic and environmentally sustainable farming systems by helping farmers match inputs of nutrients (in fertiliser and organic materials) to crop demand which minimises production costs and losses to the environment. A number of nutrient management planning NMP Tools (NMPT) are available to farmers and advisors in Northern Ireland. It is important that these tools are up-to-date and easily accessible to maximise uptake and ensure that nutrient management decisions are based on the most relevant scientific evidence base. The overall objective of this project was to conduct a comprehensive review of existing NMPTs for grassland and forage crops available for use in the UK or Ireland and provide recommendations for their future provision. The following, freely available NMPTs used in UK and Ireland were reviewed: CAFRE calculators, PLANET, MANNER-*NPK* and NMP-Online. In addition, selected tools were reviewed from countries with similar cropping conditions to Northern Ireland, including Overseer (New Zealand), MarkOnline (Denmark), CowVision (The Netherlands) and FAST (EU-wide).

The CAFRE nutrient calculators are the DAERA recommended free-to-use tools for use in NI and have an established user-base and support system. They perform similar calculations to those provided by PLANET for England, Wales and Scotland and NMP Online for Ireland. MANNER-*NPK* is a separate, stand-alone tool, applicable to the whole of the UK (including NI) specifically designed for predicting crop available nutrient supply from organic material applications and therefore only contributes to part of a NMP on farms where organic materials are used. The CAFRE calculators are underpinned by RB209 nutrient recommendations and the Nutrients Action Programme (NAP), PLANET is underpinned by RB209 and the NVZ action programme in England and Wales and the SAC Technical notes and NVZ action programme in Scotland. NMP-Online is underpinned by the Teagasc Green Book and the NAP.

The CAFRE tools are web-based tools, but dated and not very user-friendly, having not been updated since they were developed (apart from regular updates to the underlying recommendations in line with relevant RB209 updates). It is therefore recommended that these calculators continue to be the standard recommended tools for use in NI, with the aim of improving their functionality, accuracy and usability rather than seeking to produce anything 'new'. A number of potential improvements to the crop nutrient calculator include:

- Incorporation of MANNER-*NPK* algorithms.
- Inclusion of lime, SO_3 and MgO recommendations.
- Enable the recording of organic manure imports and exports.
- Include calculation of farmgate nutrient balances for N and P and K
- Inclusion of information on nutrient prices to adjust recommendations.
- Stream-line data entry as far as possible (for example data sharing between calculators)
- Enable users to download results into an excel workbook (or equivalent).

The addition of mapping functionality like that undertaken by NMP Online to enable easy targeting of fields which require attention is also potentially useful (possibly by incorporating mapping functions from the Soil Nutrient Health Scheme - SNHS). In contrast to the review of tools from other countries, none of the UK tools were available as mobile applications. Having the ability to update NMPs whilst in the field is a potentially useful function, although creating a full NMP 'on the go' is complex and likely to be difficult to achieve. If a mobile application is considered, a trial of the FAST App could give useful insights on how this might be achieved.

Crop nutrient recommendations are fundamentally dependent on the latest advice given by RB209, SAC technical notes, Teagasc Green Book or the NAP. It was outside the scope of this review to consider the accuracy and scope of these recommendation/guidance documents, other than to note

that further work is required to: improve our ability to account for N supplied by legumes and cover crops in the rotation; determine the nutrient requirements of herbal leys; understand how a NMP may change if abated fertiliser products are used. In addition, RB209 does not consider the potentially different availability of phosphate on basaltic soils which are found across about a third of Northern Ireland. A different approach may therefore be required for these soils.

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1 INTRODUCTION

1.1 Nutrient Management Planning

Nutrient management planning (NMP) is fundamental to economic and environmentally sustainable farming systems by helping farmers match inputs of nutrients (in fertiliser and organic materials) to crop demand which minimises losses to the environment. For ruminant livestock farmers in Northern Ireland effective nutrient management planning can:

- Minimise the use of manufactured fertilisers, which are both expensive and have a high carbon footprint.
- Make best use of organic manures and legumes, fully accounting for the nutrients they supply.
- Optimise the production of grazed and conserved grass and other forages.
- Minimise losses to the environment in the form of nitrate and phosphorus to water and ammonia and nitrous oxide to air.
- Ensure compliance with environmental legislation and farm quality assurance standards.

A number of nutrient management planning NMP Tools (NMPT) have potential for application for farmers and advisors in Northern Ireland, ranging from simple paper-based guidance to online tools and mobile applications (Apps). These include:

- CAFRE Nutrient Benchmarking tool: five separate nutrient calculators for ensuring compliance with the Nutrients Action Programme (NAP) in Northern Ireland (free to use tool in Northern Ireland).
- Teagasc NMP online: an online tool used for fertiliser planning and developing nutrient management plans on a field-by-field basis in Ireland for environmental and regulatory purposes (for use of Farm Advisors in ROI).
- PLANET (Planning Land Applications of Nutrients for Efficiency and the Environment): a computer based NMPT for field level nutrient planning and assessing and demonstrating compliance with the Nitrate Vulnerable Zone rules in England, Wales and Scotland.
- MANNER-NPK (MANure Nutrient Evaluation Routine): a stand-alone software tool for use by farmers and advisors throughout the UK to quantify crop available nutrient supply from applications of organic manures.

It is important that these tools are up-to-date and easily accessible to maximise uptake and ensure that nutrient management decisions are based on the most relevant scientific evidence base. Whilst the tools identified above meet many of these objectives, they are either out of date or fail to deliver all of the information needed to maximise nutrient use efficiency and comply with current regulations in a way that can be easily used by farmers and advisors in Northern Ireland.

1.2 Project objective

- To conduct a comprehensive review of existing NMPTs for grassland and forage crops available for use in the UK or Ireland.
- To provide recommendations for future provision of NMPTs in Northern Ireland

Following an initial stakeholder meeting (January 2023), the review was extended to include NMPTs used in other countries with similar climates/agricultural systems, including: The Netherlands, Germany and New Zealand. Although tools used in these countries are unlikely to be appropriate for direct use in Northern Ireland information on their scope and usability may give useful insights into how to improve uptake of NMPTs in Northern Ireland.

1.3 Definitions and scope

Nutrient Management Planning Tools are available in a range of formats, including:

- Paper-based: a written NMPT available in hard copy (i.e., book, manual or leaflet) and/or available to view/download on the internet.
- Spreadsheet: spreadsheet-based tool or workbook (i.e. Excel or similar).
- Software – desk-based: software which is installed on a computer.
- Software – web-based: software which requires a web-browser to run.
- Software – mobile application or 'app': software which runs on a smartphone or tablet.

These tools do not replace the need for 'human-based' NMPTs such as farm advisors, agronomists, workshops and meetings, but they are designed to help support and supplement 'human' advice.

This review focused on freely available digital NMPTs in the form of a spreadsheet, online calculator, desk-based or web-based software application; paper guidance & workbooks were excluded, although details of the key guidance documents and legislation on which many of the NMPTs reviewed are based are included in the sections below.

1.4 Nutrient management guidance documents

Northern Ireland uses the latest AHDB Nutrient Management Guide (RB209) for best practice guidance on the application of mineral fertilisers, manures and slurries to croplands and the Nitrate Action Plan (NAP) guidance for grassland. RB209 is used for all crops and grassland in England and Wales, whereas in Scotland, the SAC technical notes are used for this purpose. Ireland uses the Teagasc Green Book of Major and Micro-Nutrient Advice for Productive Agricultural Crops. These documents are recognised by the Industry as the standard recommendation systems for determining crop nutrient requirements within each of the Administrations/Countries, providing detailed guidance on when, where and how much nutrient to apply in the form of fertilisers and manures.

RB209 was first published in 1973 by the Ministry of Agriculture Fisheries and Food (MAFF) as the first comprehensive set of fertiliser recommendations for England and Wales. The latest (9th Edition) was published as 'The Nutrient Management Guide (RB209)' by AHDB in 2017. Since then, the recommendations have been revised on an annual basis in line with the latest research findings under the guidance of the UK Partnership for Crop Nutrition, with the most recent updates made to sections 1-4 in June 2023 and published as the 50th Anniversary Edition. It should be noted that it is unclear to what extent Sections 5-7 of the Guide (Potatoes; Vegetables and bulbs; Fruit, vines and hops) will be updated since the discontinuation of AHDB horticulture and potato sector groups in 2021.

RB209 (latest edition) is the basis for fertiliser recommendations given in the CAFRE Crop Nutrient Calculator for croplands whereas PLANET uses RB209 8th Edition recommendations for England and Wales. The latest edition of RB209 is also available in API format and is utilised by a number of commercial NMPTs (e.g. Farmplan (Gatekeeper), Navigate Pro & PearAgri). The SRUC Technical Notes are the basis for fertiliser recommendations given in PLANET Scotland and are currently being used as the basis to update the AHDB API to include fertiliser recommendations for Scotland. AHDB have committed to updating the API whenever recommendations in the AHDB Nutrient Management Guide are updated, ensuring that any third-party tool which uses the API will provide current up to date fertiliser recommendations.

The Teagasc Green Book promotes the use of NMP Online for producing fertiliser recommendations and complying with regulations. The latest edition includes revisions to grassland recommendations including N advice for grass-white clover swards. The Green book also adjusts P recommendations for

high organic matter soils (the NAP regulations in Ireland requires that the fertilization rates for soils which have more than 20% organic matter shall not exceed the amounts permitted for Index 3 soils).

1.5 Compliance with regulations

A number of the NMPTs are compliance tools that have been designed to assess and demonstrate compliance with nutrient management regulations, in particular the EU Nitrates Directive (Council Directive 91/676/EEC) which was adopted by the UK in 1991 to reduce water pollution caused by nitrates from agricultural sources. It requires that member states designate as Nitrate Vulnerable Zones (NVZs) areas of land that drain into polluted waters and to set up an Action Programme (AP) in these zones. The most recent iteration of the NVZ-AP in Northern Ireland is enforced in law under the Nutrient Action Programme Regulations (Northern Ireland) 2019 (NAP; SI 81, 2019) and applies to all agricultural land within the Administration.

If land on a farm falls within an NVZ there are a number of rules the land owner must follow in relation to the amount, timing and location of all nitrogen applications (fertilisers and organic manures), as well as the storage of organic materials (e.g. capacity and location of storage facilities).

2 APPROACH & METHODOLOGY

2.1 Selection of Nutrient Management Planning tools for review

A literature review was performed in 'Science Direct' using the following terms and restricting the search to the last 10 years (2013-2023):

(Decision support tool OR software tool OR Guidance tool OR Guidance software OR Decision support software OR Decision support system OR Decision management system OR Decision assistance tool OR Calculator OR Mobile App) AND (Nitrogen OR Nutrient*) AND (Grass OR Forage*) AND (UK or United Kingdom OR Ireland OR England OR Wales OR Scotland)*

This returned 5881 articles, which when filtered by subject area (agriculture/biology/environment) returned 4223 articles. These were sorted by 'relevance' and the first 300 titles were checked. From this, 5 papers were chosen. Two papers covered tools for grassland management, these were:

- 'GMOT' – a grass measurement optimisation tool (Murphy *et al.,* 2020);
- 'PastureBase' – a web-based grassland management tool (Hanrahan *et al.,* 2017).

One paper detailed results from a survey on nutrient management across c. 50 farms in Conwy, Wales (Gibbons *et al.,* 2014), whilst a similar paper produced farm-gate nutrient balances for c. 1500 Irish farms, using data collected by Teagasc (Thomas *et al.,* 2020). The final paper introduced a tool for carbon management in livestock production systems 'Carbon Navigator' (Murphy *et al.,* 2013). None of these papers were considered relevant to this review of NMPT tools.

The EU projects, 'SUPER-*G*' (Sagoo *et al.,* 2020) and 'Fairway' (Nicholson *et al.,* 2018) reviewed tools for managing grassland ecosystem service delivery and for water, nutrient and pesticide management, respectively. These projects identified no additional tools, relevant to nutrient management in forage production systems of Northern Ireland, over and above, those already identified within the project specification.

A meeting with Stakeholders (including representatives from Agrisearch, AFBI, DAERA, NIGTA, UFU & Dairy UK) was held in January 2023 at which it was agreed that the review would cover the following tools:

- **CAFRE Nutrient Calculators (5 separate tools)**
- **PLANET**
- **MANNER-*NPK***
- **Teagasc NMP online**

In addition, the stakeholder meeting recommended reviewing NMPTs used in other countries with similar climates and agricultural systems, including: The Netherlands, Denmark, Germany and New Zealand. These tools will potentially align with the individual countries cropping systems, agroclimatic conditions and legislative requirements, so are unlikely to be appropriate for direct use in Northern Ireland. However, information on their scope and usability may give useful insights into how to improve uptake of NMPTs in Northern Ireland.

Table 1 details some of the tools used in these countries (identified as part of the SUPER-*G* and Fairway projects, plus an initial search using google). The extent to which these tools can be reviewed will depend on whether they are freely available, if any guidance notes have been produced and whether the information can be easily translated into English. Following an Interim project meeting, the following tools were selected:

- **AgroMineral & CowVision**
- **Mark Online**
- **OVERSEER**

- **FAST**

Table 1. Nutrient Management planning tools used in other countries with similar cropping/agroclimatic conditions to Northern Ireland

Country	Tool	Purpose
The Netherlands	Annual Nutrient Cycle Assessment (ANCA)	Nutrient budget reporting tool
	AgroMineral & CowVision	Mineral accounting software covering all aspects of a farmgate nutrient balance on livestock farms. CowVision then uses data from this tool to plan manure import/export and fertilizer requirements
	Parcel Divider	Tool which helps dairy farmers plan manure applications
	Nitrogen dynamics in crop rotations in ecological agriculture (NDICEA)	Nitrogen budgeting tool
Denmark	Mark Online	Fertiliser planning and reporting tool, also covers wider aspects of crop management (tillage & crop protection)
Germany	Dungeplanung	Fertiliser planning programme
New Zealand	Nutrient Management Planner	Interactive form for nutrient management record keeping
	OVERSEER	Software tool modelling nutrient flows on farm. Used for nutrient budgeting purposes

2.2 Review methodology

A proforma template was used to collect information on each of the tools (

Table 1). These were completed as fully as possible by reviewing guidance documents, design specifications (where available), online tutorials and where necessary, by interviewing the tool holders.

Table 1. Review proforma

Criteria	Sub criteria
Description	Provider
	Brief description
	Format/Platform (e*xcel calculator / desktop / web based / mobile)*
	Date of last update
	Frequency of updates
	Cost & availability
	Intended user
	Country of origin
	Number of registered users
	Author & references
Scope	Relevance for NI *(e.g. UK tool, NI tool, Irish tool)*
	Main purpose (*e.g. fertiliser recommendation; record keeping; nutrient balance; manure storage requirements; compliance tool)*
	Geographical resolution *(farm/field)*
	Temporal resolution *(single/multiple seasons)*
Functionality	*Ability to account for:*
	organic manures
	legumes
	previous cropping history
	Capture and store data over multiple seasons
	Produce an accurate NMP
	Produce nutrient balances
	Adjust recommendations according to expected yield and quality requirements
	Account for manure imports & exports
	Adjust recommendations according to target pH
	Track and record inputs of fertilisers and manures, lime
	Track soil nutrient status over time
	Integrate data from NI soil nutrient health scheme
	Integrate data from precision software on fertiliser spreaders & tankers
	Ability to produce reports to meet requirements for:
	cross compliance
	NVZ/NAP regs
	Quality assurance schemes
	Benchmarking
Ease of use	Ease of use / look and feel of the tool
	Degree of user interaction/level of expertise required
	Input requirements
	Data sources *(does it use other data sets/models/realtime data)*
	Output format
	Ease of interpretation
	User support
	User feedback/research

3 EVALUATION OF CURRENT FREELY AVAILABLE NMP TOOLS IN THE UK

An overview of each of the freely available NMPTs tools identified by the review and stakeholder meeting is given in the sections below, with more detailed information included in Appendix 1.

3.1 CAFRE nutrient calculators

CAFRE host a suite of five, free online Farm Nutrient Calculators designed to help meet the requirements of the NAP and comprise:

- Crop nutrient calculator
- N loading calculator
- N max for grassland calculator
- Phosphorus balance calculator
- Manure storage calculator

These calculators were jointly developed by AFBI (coding) and CAFRE (input data) and are used for nutrient management planning (including fertiliser recommendations), reporting and demonstrating compliance. Each calculator is 'stand-alone' with no data-sharing facility between calculators. Although freely available, they can only be accessed via DAERA online services by users with a Northern Ireland business ID (farmer or agent). This prevented the authors of this report from having first-hand experience of using the calculators, with this review based on an interview and demonstration provided by CAFRE and a review of online guidance materials, webinars and youtube videos. Although all the calculators are intuitive, CAFRE recommend qualified farm advisors support users with the tools, and provide periodic training (online & in person) to support the use of the crop nutrient calculator in particular.

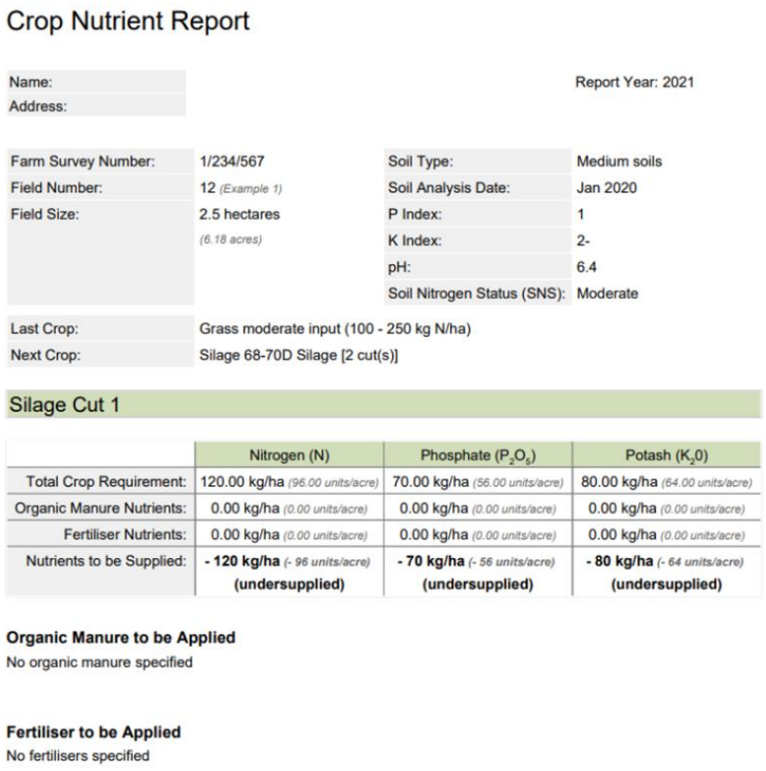
3.1.1 Crop nutrient calculator

This calculator produces a nutrient management plan for a farm, enabling the user to comply with nutrient limit requirements and plan applications (similar to the PLANET 'Field level records and recommendations' module for England, Wales and Scotland; section 3.2.1). Its core functions include:

- determination of the N, P_2O_5 and K_2O required by crops (but not MgO, SO_3 or lime)
- calculation of the amount of nutrients supplied by organic manures
- the ability for users to select the fertiliser and its application rate
- record keeping; production of a downloadable PDF report (e.g. Figure 1) and allowing users to retrieve records from previous seasons.

Nutrient recommendations are derived from RB209 (originally based on 7th Edition recommendations, published in 2000) for all crops except grassland, with the latter using recommendations as set out in the NAP regulations, particularly in relation to phosphate requirements (where soil Index 2 is split into 2- and 2+). The tool currently has *c.*1400 registered users and is actively promoted across Northern Ireland by CAFRE. The basic interface of the calculator has not changed since its launch in 2007, but the tool is regularly updated (manually by CAFRE) in line with changes to RB209 (as deemed appropriate for Northern Ireland) and the NAP. A recent addition includes the ability to pre-populate the 'Field and Soil Details' section with results from the 'Soil Nutrient Health Scheme' (SNHS) which commenced in 2022 and aims to sample all fields in Northern Ireland by 2026 (up to 700,000 fields). Future updates are considering the inclusion of a map viewer (to enable users to quickly identify fields with e.g. low or high P status), a pH adjustment and potentially linking to the RB209 API (for cropland recommendations).

Figure 1. Example crop nutrient report from the CAFRE crop nutrient calculator



Crop Nutrient Report

Name:
Address:

Report Year: 2021

Farm Survey Number:	1/234/567	Soil Type:	Medium soils
Field Number:	12 *(Example 1)*	Soil Analysis Date:	Jan 2020
Field Size:	2.5 hectares *(6.18 acres)*	P Index:	1
		K Index:	2-
		pH:	6.4
		Soil Nitrogen Status (SNS):	Moderate
Last Crop:	Grass moderate input (100 - 250 kg N/ha)		
Next Crop:	Silage 68-70D Silage [2 cut(s)]		

Silage Cut 1

	Nitrogen (N)	Phosphate (P_2O_5)	Potash (K_20)
Total Crop Requirement:	120.00 kg/ha *(96.00 units/acre)*	70.00 kg/ha *(56.00 units/acre)*	80.00 kg/ha *(64.00 units/acre)*
Organic Manure Nutrients:	0.00 kg/ha *(0.00 units/acre)*	0.00 kg/ha *(0.00 units/acre)*	0.00 kg/ha *(0.00 units/acre)*
Fertiliser Nutrients:	0.00 kg/ha *(0.00 units/acre)*	0.00 kg/ha *(0.00 units/acre)*	0.00 kg/ha *(0.00 units/acre)*
Nutrients to be Supplied:	**- 120 kg/ha** *(- 96 units/acre)* **(undersupplied)**	**- 70 kg/ha** *(- 56 units/acre)* **(undersupplied)**	**- 80 kg/ha** *(- 64 units/acre)* **(undersupplied)**

Organic Manure to be Applied
No organic manure specified

Fertiliser to be Applied
No fertilisers specified

3.1.2 Nitrogen loading calculator

This tool calculates the livestock manure nitrogen loading for a farm and highlights if the farm is above the 170 kg N per ha per year limit as required by the NAP or, if operating under a derogation, over the 250 kg N per ha per year limit. This is identical to the Livestock manure N farm limit module within PLANET (see section 3.2.3).

3.1.3 Manure storage calculator

This calculates the weekly slurry, dirty water, manure production and current storage capacity for a farm enabling the user to check they have sufficient capacity to meet the required 22 or 26 weeks' storage required by the NAP and where there is insufficient capacity details how much additional storage is needed. This is similar to the 'Manures storage capacity' module within PLANET (section 3.2.5).

3.1.4 Phosphorus balance calculator

If operating under a derogation, this tool calculates the phosphorus balance for a farm enabling the user to check that the NAP limit of 10 kg P per ha per year has not been exceeded. For all farms it helps with the management of phosphorus inputs and outputs to enable more efficient use of phosphorus. Note that this functionality is specific to Northern Ireland (and Ireland where NMP online, section 3.4, is used for this purpose); none of the tools reviewed from elsewhere in the UK include this calculation as it is not a requirement of regulations in England, Wales or Scotland.

3.1.5 N-max for grassland calculator

This tool checks that nitrogen applications to the whole grassland area on the farm do not exceed the NAP N max limits. This calculator is specific to grass, there is a 'N max checker' within the crop nutrient calculator for other crops. This is similar to the PLANET N Max module (section 3.2.2).

3.2 PLANET

PLANET (Planning Land Applications of Nutrients for Efficiency and the environmenT) is a nutrient management decision support tool for farmers and advisers in England, Wales and Scotland for field level nutrient planning and for assessing and demonstrating compliance with the Nitrate Vulnerable Zone Action Programme (NVZ) rules.

PLANET v1 was released in 2005 providing the first nationally available computer based nutrient management decision support tool in England and Wales. PLANET was updated in 2008 to include NVZ compliance 'modules' (v2) and in 2010 (v3) to incorporate the RB209 8th Edition fertiliser recommendations in England and Wales, and the Scottish Technical Note Fertiliser recommendations (PLANET Scotland; working with SAC) for the first time. Additional updates were made in 2012 and 2014 to reflect updates to the NVZ Action Programme rules. However, PLANET has not been updated since 2014, and it requires updating to reflect updated fertiliser recommendations (RB209 9th Edition, and updates to SRUC Technical Notes) and to improve general usability and functionality. In response to this need, Defra recently (January 2023) commissioned ADAS to develop and deploy a new 'industry standard' web-based free to use Nutrient Management Planning (NMP) platform to facilitate uptake of NMP on farms in England, Wales, and Scotland. It is envisaged the platform will provide a similar record keeping and nutrient planning functionality to the current PLANET software, with recommendations generated using the RB209 API provided by AHDB, and functionality to check and demonstrate compliance with NVZ and Farming Rules for Water (FRfW) regulations.

There are currently (March 2023) 18,898 registered users of PLANET England and 2,193 registered users of PLANET Scotland, and although PLANET is not specifically coded for Northern Ireland there are 101 registered users on the PLANET database from Northern Ireland. However only 8 of these are registered to use solely PLANET, with majority on the database registered to use MANNER-*NPK*, which is coded for use in Northern Ireland (Table 3). Note, each registered user has a unique email address, however it is not clear how many of these are active users.

Table 3. Download from the PLANET database of users (March 2023) showing the number of registered users for the PLANET and MANNER-*NPK* software

Details		Notes
Total number from Northern Ireland on the database	101	
Dates of registration [number registered]	2010 [1] - 2022 [11]	Most [22] in 2013
Number from Government/research institutes	18	Based on email addresses
Number from Businesses	24	Includes suppliers, AD plants, agronomists & farm businesses
Number with private email address	59	This likely to comprise farmers/farm businesses (some overlap with above)
Number using PLANET England only	19	
Number using PLANET Scotland only	10	
Number using both England & Scotland	16	
Total number PLANET users	**45**	
Total number MANNER users	**93**	
Number using PLANET only	8	4 PLANET England; 4 PLANET Scotland
Number using MANNER only	56	

PLANET includes a number of modules for either creating NMPs, record keeping or demonstrating compliance, some of which are linked (i.e. share data), whereas others are stand-alone (similar to the separate CAFRE calculators). Help guides are available within the software and on the PLANET website and a phone helpdesk was available up until 2017 for users in England and Wales. A helpline continues to be available for users in Scotland via the Farming Advisory Service.

3.2.1 PLANET Field level nutrient planning and recommendations

The PLANET 'Field level nutrient planning and recommendations' module gives fertiliser recommendations for all major nutrients and lime based on Defra's "Fertiliser Manual (RB209)" (8th Edition) in England/Wales and on SRUC "Technical Notes" in Scotland (similar to the CAFRE Crop Nutrient Calculator, section 3.1.1). Fertiliser recommendations take account of the crop nutrient requirement, the soil nutrient supply, laboratory soil analysis results, and the nutrients supplied from any organic material applications (calculated using the MANNER-*NPK* 'calculation engine'). Recommendations are then adjusted for (i) field level rolling phosphate and potash balance (where any surplus P or K supplied e.g. due to organic material applications, is carried over to the following crop), and (ii) Break even ratio adjustment for nitrogen fertiliser recommendations (to allow the user to adjust recommended N rates to cereal and oilseed rape crops in the light of fertiliser and crop prices). From this a nutrient application plan can be developed and updated during the season. Detailed field records can be kept of cropping, soil analyses, fertiliser and organic material applications. An example recommendations report produced by the tool is given in Figure 2. PLANET also produces a more detailed nutrient management plan showing the recommended nutrient addition rates and how these are planned over the season (see Appendix 3).

The PLANET fertiliser recommendations calculation engine was made available as a Dynamic Link Library (DLL) free of charge under licence to Defra. It was integrated into commercial tools produced by Farmade (now Farmplan) (Gatekeeper), MuddyBoots (Crop Water and later Greenlight Grower Management), and Pear Technology (now PearAgri). Farmplan and Pear Technology have switched from using the PLANET DLL to using the AHDB API for fertiliser recommendations. Muddyboots still use the PLANET DLL in their Greenlight Grower Management software. ADAS updated the PLANET DLL for Muddyboots to RB209 9th Edition recommendations for arable crops in 2018.

Figure 2. Example nutrient recommendation report produced by PLANET (PDF format)

Recommendations for Harvest year 2023

PLANET NUTRIENT MANAGEMENT

Hill Farm
Hill Farm
Long Road
Littlehampton
Midlands
CV10 9LS

CPH number
Single Business Identifier

Annual rainfall (mm) 670

Field name	Crop type	Cropped area (ha)	Nitrogen (N) (kg/ha)	Phosphate (P_2O_5) (kg/ha)	Potash (as K_2O) (kg/ha)	Magnesium (as MgO) (kg/ha)	Sulphur (as SO_3) (kg/ha)	Sodium (as Na_2O) (kg/ha)	Lime (as $CaCO_3$) (t/ha)
40 acres	Grass	9.60	54						
Far top	Grass	6.20	56						
Forest field	Grass	33.00	54	4					
Gates head	Grass	8.40	56						2
Long field	Grass	5.50	220	34	220		80		
Sunk field	For maize	12.00	13	66					

3.2.2 PLANET Nmax Calculator

The NVZ rules set mandatory limits for the maximum quantity of nitrogen (N max) that may be applied to specific crop types, over the whole area of the crop type grown on land within an NVZ on the farm.

The PLANET Nmax calculator is used to assess and demonstrate compliance with the NVZ Nmax rules in England, Wales and Scotland. This is similar to the CAFRE N max for grassland calculator (section 3.1.5).

3.2.3 PLANET Livestock manure N farm limit module

The NVZ rules set a mandatory limit on the loading of livestock manure on land. The Livestock manure N farm limit module calculates the N capacity and N loading of a farm and will help assess if the farm is compliant with the NVZ livestock manure N farm limit. This is a separate stand-alone module in PLANET and is similar to the CAFRE N loading calculator (section 3.1.2).

If a farm is part in and part out of an NVZ, the module calculates the livestock manure N farm limit using a limit of 170 kg N/ha for land inside an NVZ and 250 kg N/ha for land outside an NVZ. If the farm has an approved grassland derogation, the module calculates the limit based on 250 kg N/ha for the grassland area and includes additional P loading calculations required by farmers with a derogation.

3.2.4 PLANET Organic manures inventory and storage module

The Organic manures inventory and storage module calculates the monthly production of organic manures on the farm based on details of the livestock on the farm and allowing for any imports and exports of manure. It calculates the NVZ minimum storage requirement and the approximate nutrient content of the manures. This is a separate stand-alone module in PLANET and is not replicated in the CAFRE suite of calculators.

The Organic manures inventory provides a complete annual inventory of all livestock manure produced on the farm as well as the calculation of the NVZ minimum storage capacity; the NVZ requirement is only to calculate for livestock slurries and poultry manures (not other manures), and only for the period of October to March (for pig slurry and poultry manure), or October to February (for cattle slurry). The module also calculates the total amount of nutrients (N, P and K) in kilogrammes produced on the farm and the financial value of these nutrients based on default or user entered fertiliser prices.

3.2.5 PLANET Existing manure storage capacity module

The PLANET Existing Manure Store Capacity module calculates the capacity of a farms existing manure stores. This is a separate stand-alone module in PLANET and is similar to the CAFRE Manure storage calculator (section 3.1.3).

3.2.6 PLANET Organic manures imports and exports module

The PLANET Organic manures imports and exports module enables the user to record all details of imports and exports of manures. This module provides a single place to store all manure imports and exports records and to remove the need for repeat data entry of imports and exports to the 'Livestock manure N farm limit', 'Organic manures inventory' and 'Farmgate nutrient balance' modules. The Organic manure imports and exports module can record all import and export records from all years. The 'Livestock manure N farm limit', 'Organic manures inventory' and 'Farmgate nutrient balance' modules are all annual calculations, and all three modules allow import of data from the 'Organic manures imports and exports module' for the relevant 12 month period. This module is not replicated in the CAFRE suite of calculators.

3.2.7 PLANET Farmgate nutrient balance module

The PLANET Farmgate nutrient balance module calculates the quantity of nitrogen, phosphate and potash coming onto the farm through the farm gate (imported), balanced against those that are taken

off the farm (exported) during a 12 month period (assessment year). The difference between the quantity imported and exported is known as the 'Farmgate Nutrient Balance'. If more nutrient is imported onto the farm than is exported off the farm, then the farm has a surplus of nutrient (a positive value shown in red); if more nutrient is exported than imported, then there is a deficit (a negative value shown in green). The calculated balance is compared against benchmark values to indicate if the farm is typical compared to other farms of the same type. This module is not replicated in the CAFRE suite of calculators.

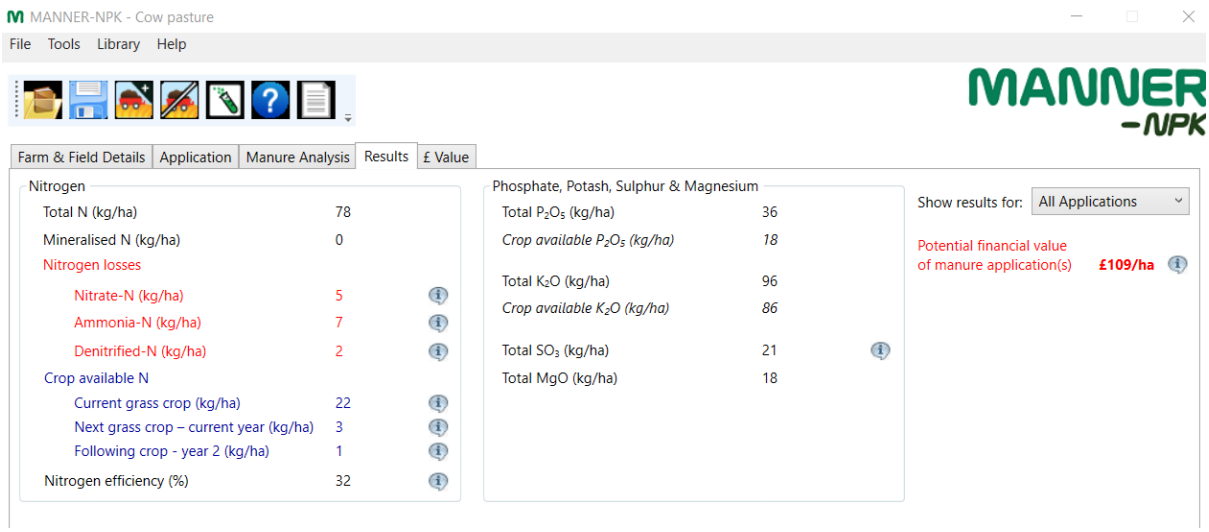
3.3 MANNER-*NPK*

MANNER-*NPK* (MANure Nutrient Evaluation Routine) is a software decision support tool for calculating crop available nutrient supply from applications of organic materials to land. The tool addresses factors affecting crop available nitrogen (N) supply from organic materials (i.e. nitrate leaching, ammonia (NH_3) volatilization, nitrous oxide (N_2O) loss and mineralisation of organic N). The MANNER-*NPK* outputs are based on algorithms developed from an extensive programme of national research experiments and have been validated against independently collected field experimental data (Nicholson *et al*., 2013).

MANNER was developed by ADAS in 1996 and first released to farmers on CD in 2000. The MANNER-*NPK* calculations were updated in 2004 and 2010 to incorporate advances in our understanding of nitrogen transformation and loss processes following the land application of organic materials. The latest version – MANNER-*NPK* included improvements to usability and functionality and was released to farmers in 2013. The MANNER-*NPK* 'calculation engine' is incorporated into PLANET and included in the PLANET DLL which is still used in the commercial software tool produced by Muddyboots.

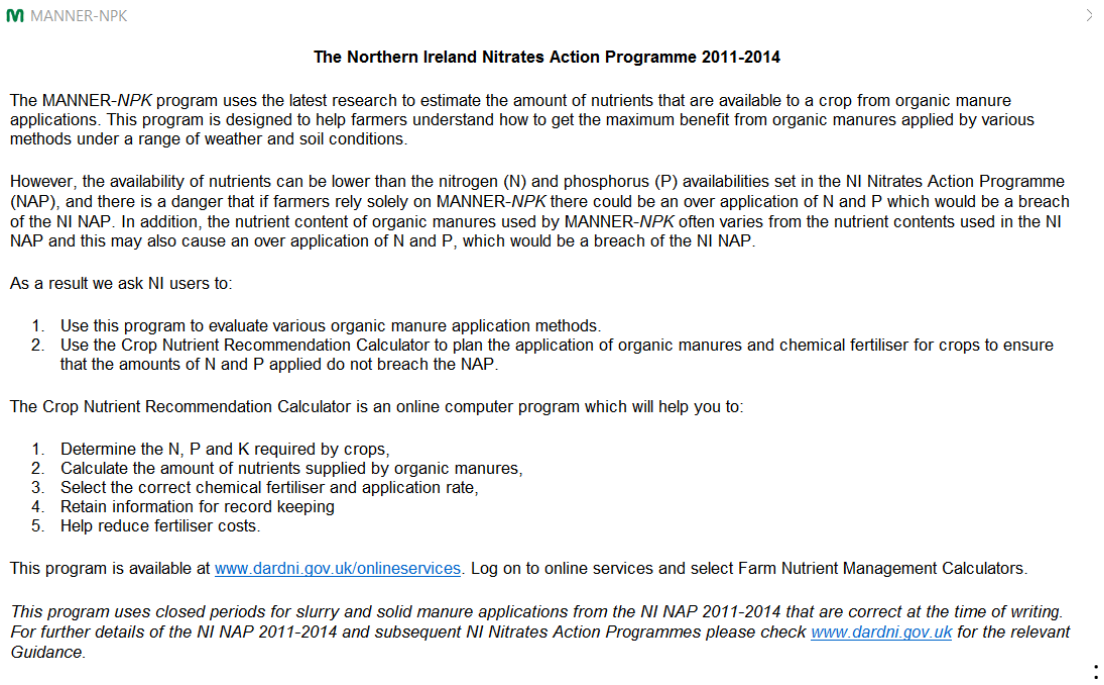
As well as estimating crop nutrient supply from a wide range of organic materials applied to land, it also gives estimates of N losses to the environment, via nitrate leaching, NH_3 volatilisation and denitrification, as well as the potential financial value of the crop available nutrients (see figure 3 for a screenshot of the results page and Appendix 4 for an example PDF report). It can therefore be used to not only adjust manufactured fertilizer application rates (to account for the organic material nutrient supply), but also to support compliance with NVZ rules and test the impact of changes in manure management on losses to the environment. The algorithms N loss/N cycling algorithms in the model are based on the results of a large number of Defra funded R&D projects, as such it provides the most accurate information on crop available N supply from applications of organic materials in the UK, and underpins the guidance given in Nutrient Management Guide-RB209 section 2 (AHDB 2021) and the SRUC Technical Note TN736 (SRUC, 2020).

Figure 3. Screenshot of MANNER-NPK results page



There are currently (March 2023) 6,388 registered users of MANNER-*NPK*, including 93 from Northern Ireland (Table 3). Unlike PLANET, MANNER-*NPK* has been coded for use in Northern Ireland (i.e. uses NI climate data), however an initial warning message is given for users in NI, instructing users to use MANNER-NPK to evaluate the effect of application method, but the CAFRE Crop Nutrient Calculator (section 3.1.1) to plan applications (see figure 4). Note also that the software is coded in line with the NAP 2011-2014 regulations for closed spreading periods, and therefore requires updating to reflect the new NAP where appropriate.

Figure 4. Guidance for users of MANNER-*NPK* in Northern Ireland



MANNER-NPK

The Northern Ireland Nitrates Action Programme 2011-2014

The MANNER-*NPK* program uses the latest research to estimate the amount of nutrients that are available to a crop from organic manure applications. This program is designed to help farmers understand how to get the maximum benefit from organic manures applied by various methods under a range of weather and soil conditions.

However, the availability of nutrients can be lower than the nitrogen (N) and phosphorus (P) availabilities set in the NI Nitrates Action Programme (NAP), and there is a danger that if farmers rely solely on MANNER-*NPK* there could be an over application of N and P which would be a breach of the NI NAP. In addition, the nutrient content of organic manures used by MANNER-*NPK* often varies from the nutrient contents used in the NI NAP and this may also cause an over application of N and P, which would be a breach of the NI NAP.

As a result we ask NI users to:

1. Use this program to evaluate various organic manure application methods.
2. Use the Crop Nutrient Recommendation Calculator to plan the application of organic manures and chemical fertiliser for crops to ensure that the amounts of N and P applied do not breach the NAP.

The Crop Nutrient Recommendation Calculator is an online computer program which will help you to:

1. Determine the N, P and K required by crops,
2. Calculate the amount of nutrients supplied by organic manures,
3. Select the correct chemical fertiliser and application rate,
4. Retain information for record keeping
5. Help reduce fertiliser costs.

This program is available at www.dardni.gov.uk/onlineservices. Log on to online services and select Farm Nutrient Management Calculators.

This program uses closed periods for slurry and solid manure applications from the NI NAP 2011-2014 that are correct at the time of writing. For further details of the NI NAP 2011-2014 and subsequent NI Nitrates Action Programmes please check www.dardni.gov.uk for the relevant Guidance.

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3.4 NMP Online

Teagasc have produced a web-based nutrient management planning tool – 'NMP Online' for use by farm advisors to assist them in producing fertiliser recommendations for their clients and demonstrate compliance with the Nitrates Action Programme in Ireland (NAP, 2022-25). The tool has been included in this review as Ireland has a very similar pattern of landuse to NI in that 90% of farms have some degree of livestock farming, with beef production the dominant enterprise.

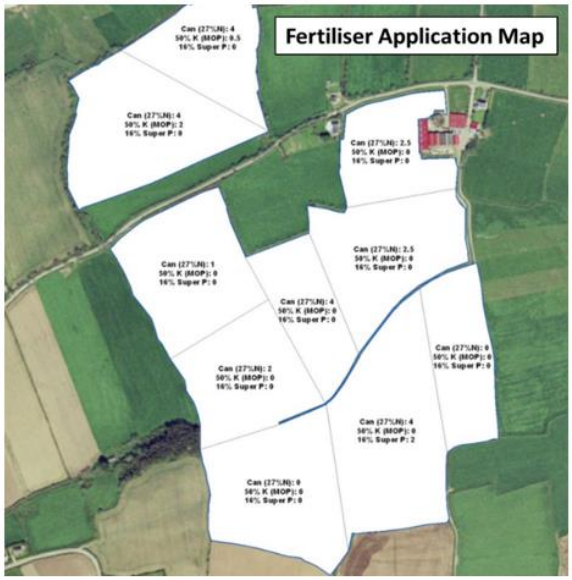
The tool is specifically for use by agricultural professionals, not farmers, with access only given to Teagasc farm advisors or registered external agricultural consultants by logging onto the system using 'Teagasc ConnectEd online'. This is free to Teagasc employees, but external advisors are required to pay an annual subscription fee which varies depending on the number of NMPs the advisor needs to produce (ranging from €250/yr to €450/yr for 50 to 150 clients). The system is only for use in Ireland and is underpinned by Teagasc Green Book (5th Edition, July 2020). Note because of the restricted access, this review is based on online guidance materials and youtube video demonstrations.

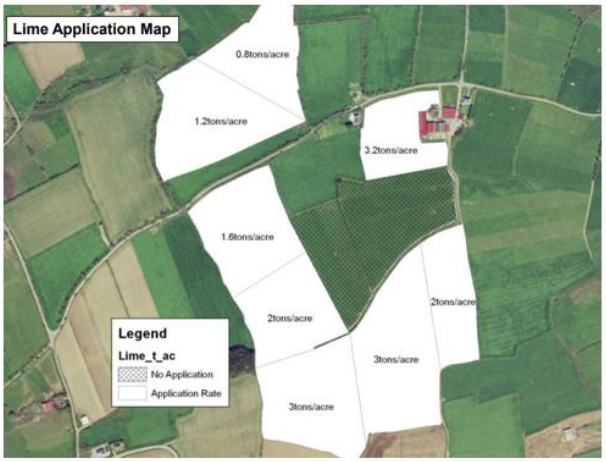
A key feature of NMP Online (which distinguishes the tool from both the CAFRE tools and PLANET) is the use of mapping for both data entry and reporting. This was updated in 2021 and uses ESRI's ArcGIS mapping API. This, together with the ability to import basic field data from DAFM's Land Parcel Identification System (LPIS), animal numbers/types from the Animal Identification and Movement (AIM) database and soil analysis results direct from the laboratories, simplifies the creation of the NMP for a farm. The output is also available in both map form and as tables (with the tool promoted using the strapline '*maps for farmers, tables for regulators*'). The use of mapping enables the user to quickly identify where nutrients and lime are required across the farm (see Figure 5 for an example).

There are comprehensive training materials online, including video tutorials and webinar recordings as well as a detailed user manual and regular bulletins together with 'tool tips' embedded within the application itself. There is also an email and telephone help line. Despite this, it is not a tool that could be used intermittently by a farmer, rather it has been designed specifically for advisors who are likely to be producing multiple plans for numerous clients.

As well as producing an NMP the tool also calculates manure production and storage requirements in a similar way to the separate CAFRE calculators and PLANET modules.

Figure 5. Typical output from NMP Online (map format); *source: presentation given by P. Murphy at the Teagasc Soil Fertility Conference in 2015*





4 EVALUATION OF SELECTED NON-UK TOOLS

An overview of selected NMPTs tools from countries with similar climate and cropping conditions to Northern Ireland as agreed with AgriSearch is given in the sections below, with more detailed information included in Appendix 2. The purpose of this part of the review was to determine whether any lessons could be learnt from these tools that could be useful for the further development of NMPTs in Northern Ireland.

4.1 OVERSEER

OVERSEER® is a nutrient budgeting desktop and web-based computer model that is widely used in New Zealand (and is required to be used in some regions). It models seven nutrients: N, P, K, S, Ca, Mg, Na and the pH of pastoral blocks. It can assist farmers and regulators with:

- Calculating on-farm budgets for a range of nutrients and farming systems (pastoral, arable/vegetable and fruit crops) based on data inputs readily available from the farm.
- Understanding the fate of these nutrients (an important precursor to developing a Nutrient Management Plan).
- Calculating and reporting farm-level GHG emissions.
- Identifying major emission sources on farms and testing mitigation strategies.
- Calculating maintenance nutrient and lime applications for pastoral farms, i.e. levels of nutrients required to maintain current soil test values.

Information provided by OVERSEER can support farmers and their advisors in planning nutrient use and assessing potential environmental losses, as well as supporting environmental policy development. It is a model rather than a 'day-to-day' nutrient management tool (see Figure 6 for a schematic of the model components, which suggests a high level of complexity and heavy data requirement), although it does demonstrate the fate of any applied N and estimates maintenance P, K and Mg as well as lime rates based on soil analysis results. It does not include economic analysis, so outputs need to be combined with other economic models/tools to assess impacts of options on the farm business.

A dedicated website provides a full explanation of the model, how to use it, benefits of use, and a range of publications and science papers. https://www.overseer.org.nz/

Uptake: Development of a fertiliser advice tool for New Zealand started in 1982-84; there are currently over 14,000 registered users.

Useful features: Regular updates allow timely incorporation of new science and functionality; users can request new features. Extensive user support and training materials are available via the website and Helpdesk service, including videos showing farmer/advisor/regulator experiences of using OVERSEER. There is a roadmap for future developments (including "international opportunities").

Lessons: There have been some misconceptions about what it can and can't do, highlighting the need for clarity and communication. It can be used as a regulatory tool to enforce environmental standards, which could discourage its use by farmers for nutrient planning.

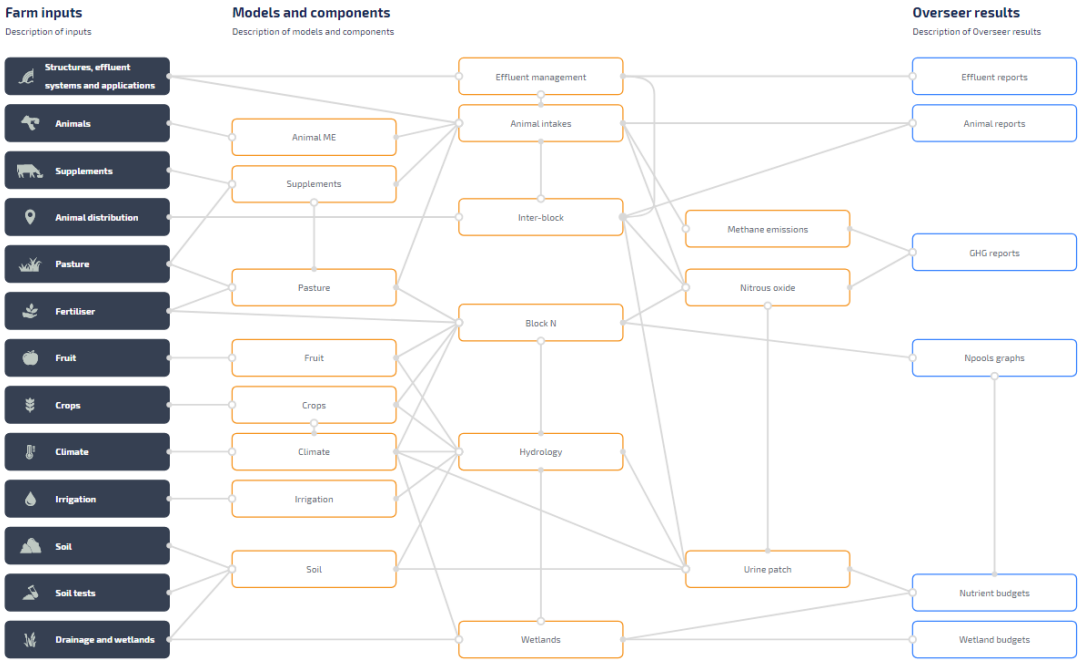


Figure 6. Simplified diagram showing OVERSEER model inputs, components and outputs

4.2 Farm Sustainability Tool for Nutrient Management (FaST)

Supported by the European Commission's DG Agriculture and Rural Development, the EU Space Programme (DG DEFIS) and the EU ISA2 Programme (DG DIGIT), the FaST mobile App and web-based tool aims to support the agronomic, economic and environmental performance of EU farms by providing information on nutrient (N, P and K) management. The main functions for farmers and advisors are:

- fertiliser advice
- nutrient (NPK) balances at field and farm scale
- assistance with developing an efficient and compliant Nutrient Management Plan
- a record proving compliance with CAP
- improved agronomic performance
- reduced costs and environmental impact

The FaST website provides further explanation of the model, the data it uses, the project timeline and other project documentation: https://fastplatform.eu/. Figure 7 gives an example of the mobile application and figure 8 the web portal.

Uptake: Currently being used in Spain (2 regions), Italy (1 region) and Estonia, with plans to expand the reach to Bulgaria, Belgium, Greece, Slovakia and Romania. No information could be located on the current number of users, but the aim is to eventually reach all farmers across the EU.

Useful features: A single EU wide tool could reduce digitisation costs, whilst being customisable for specific local administrative, agricultural and regulatory requirements. EU satellite data (Copernicus and Galileo) is integrated into the tool. All the software is open source and free, and the modular design offers flexibility.

Lessons: A slow and complex process to customise and roll out a single tool across many countries with very different requirements.

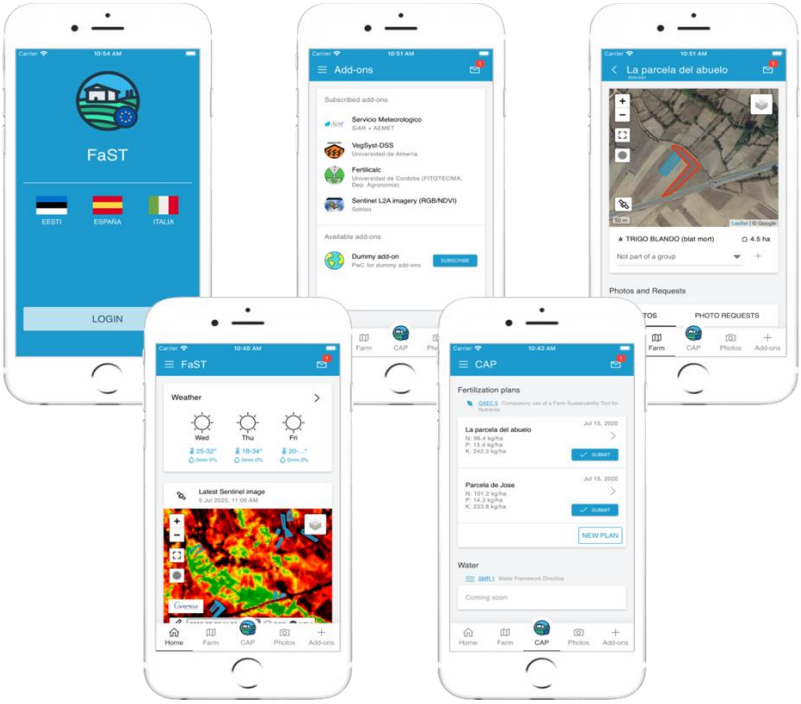


Figure 7. Examples of the FAsT tool phone App used by farmers

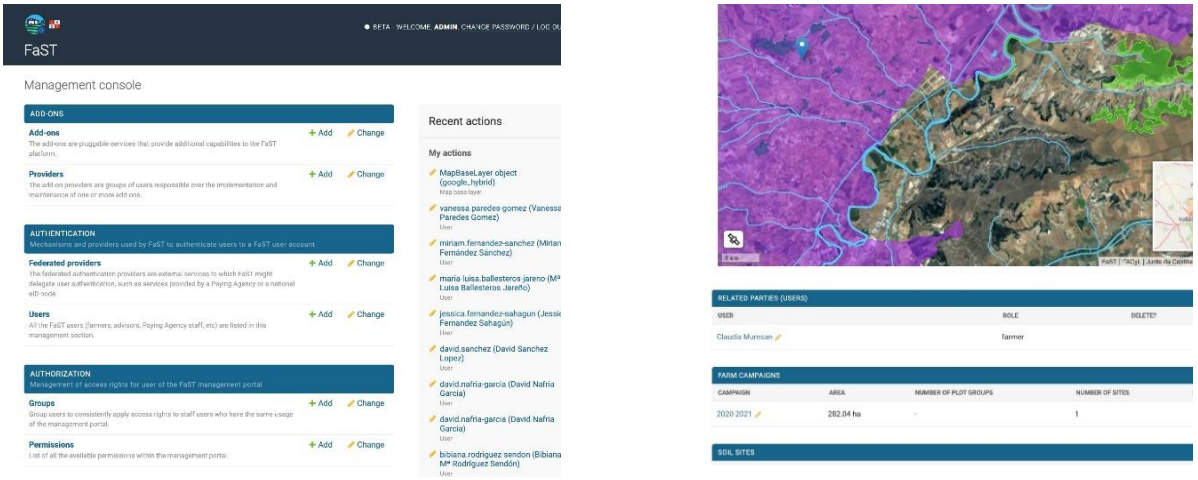


Figure 8. Examples of the web portal used by Paying Agencies

4.3 Mark Online

Mark Online is the most widely used farm management system in Denmark, with desktop and mobile App interfaces. Developed by SEGES, it is used by farmers and advisors for fertiliser (N, P and K) planning, optimisation and documentation, and covers all aspects of crop management including soil tillage and crop protection. Mitigation of environmental impacts is included by economic optimisation of fertiliser (and pesticide) inputs with respect to national rules and regulations.

The main outputs for farmers (and advisors) include:

- Farm fertiliser plans (arable and grassland) e.g. Figure 9
- Nutrient balances at field and farm scale
- Ensuring that nutrients and pesticides use is in accordance with legislation

It was difficult to fully assess this tool as limited documentation was available and most of this was in Danish.

The SEGES website has further information (mostly in Danish) about Mark Online, including videos and user guides: https://www.seges.dk/software/plante/mark-online

Uptake: Actively used on 2.2 m ha or 85 % of all land in Denmark (25,000 farms) by approx. 350 advisers and 2,500 farmers (Data from the EU FAIRWAY project, 2018).

Useful features/lessons: Feedback from farmers in Germany who used Mark Online (in a Case Study as part of the EU FAIRWAY project) was that whilst they liked the modular design, they found it complex and advisory assistance was needed to use it.

Kontroller			**N-regnskab**		
Harmonikravet er overholdt			Overskridelse af N-kvoten	-1,633 kg	-44.6 kg/ha
N-kvote overholdt			Overdraget forbrug af N	kg	
Lagerreglen er overholdt			Forbrug af N i handelsgødning	3,369 kg	92.0 kg/ha
Interne overførsler stemmer			Max forbrug af N i handelsgødning	5,003 kg	136.5 kg/ha
Harmoni			Forbrug af N (udnyttet) org. gødn.	2,045 kg	55.8 kg/ha
Harmoniareal:	36.64 ha		**P-regnskab**		
Dyreenheder og harmoni			Pt for alle harmoniarealer:		Nej
Forbrug af DE:	32.77 DE	52.73 Max	**N-kvote**		
Lageropbygning	1.21 DE		N-prognose:	-71 kg	
Forbrug af DE pr. ha:	0.89 DE/ha	1.44 Max	Anvendt forhøjet udbytte	0.0 kg	Nej
Forbrug af total N i org. gødning	86.3 kg/ha	Max	N-kvote efter korrektioner	7,048 kg	192.3 kg/ha
			Max N i handelsg. + N i org.gødn.	6,394 kg	174.5 kg/ha
			Planlagt N-behov	7,750 kg	211.5 kg/ha

Figure 9. Example of a Mark Online fertiliser plan.

4.4 CowVision (including AgroMineraal)

CowVision is an online application platform (with a mobile App interface) developed by AgroVision in the Netherlands, which provides an overview of a dairy farmer's business and opportunities for improvement. It comprises 5 modules namely, animal management (e.g. pedigree, milk production), feed (rations and feed calculation), minerals, soil and crops (fertilization production and plan) and financial (Figure 10). AgroMineraal is the module used for mineral accounting for meeting legal requirements; it summarizes all aspects of the farm gate nutrient balance and nutrient flows of the crops, soils and livestock on the farm. Phosphate Monitor (for tracking annual P production; see Figure 11 for an example), Fertilizer Planner and Manure Planner are available as optional add-ons.

CowVision provides information on the quantity of manure available throughout the year, taking into account disposal, supply production, grazing, cutting and yield potential. It uses data from AgroMineraal to create a field specific fertilizer plan based on the needs of the soil, the crop and the available fertilisers. The tool can be used to plan how much manure must be exported (if needed) and how much fertiliser needs to be purchased and when to be applied. Through the year the plan can be changed so that the farm stays within legal application limits.

Further information about CowVision and Agro MIneraal (mostly in Dutch) can be found on the AgroVision website: https://www.agrovision.com/nl/producten/melkvee

Uptake: No information could be located on uptake or number of users. However, the software is customisable and is available in 30 countries worldwide.

Useful features: Modules can be purchased separately or as a whole suite.

Lessons: Difficult to assess as not very much information available is online and most is in Dutch.

Figure 10. Schematic overview of the CowVision software modules

Figure 11. Example of an Agro Mineraal phosphate report screen

5 DISCUSSION

5.1 Free to use NMPTs in the UK and Ireland

Fertiliser recommendations and nutrient management legislation differ slightly between the countries of the UK, and consequently the NMPT tools reviewed have different geographical scopes. The CAFRE nutrient calculators are the DAERA recommended free-to-use tools for use in Northern Ireland and perform similar calculations to those provided by PLANET for England, Wales and Scotland and NMP Online for Ireland. MANNER-*NPK* is a separate, stand-alone tool, applicable to the whole of the UK (including Northern Ireland) specifically designed for predicting crop available nutrient supply from organic material applications and therefore only contributes to part of a NMP on farms where organic materials are used. CAFRE recognise that the 'look and feel' of the calculators could be improved as, similar to PLANET, they appear 'dated' and cumbersome to navigate. It is therefore recommended that these calculators continue to be the standard recommended tools for use in NI, with the aim of improving their functionality, accuracy and usability rather than seeking to produce anything 'new'.

5.1.1 Format

Both the CAFRE calculators and NMP Online have the benefit of being web-based tools, compared to PLANET and MANNER-*NPK* which are desk-based software tools. Web-based tools reduce compatibility and systems issues compared to installed software tools, for example PLANET and MANNER-*NPK* are Windows based tools and therefore cannot be loaded onto an Apple machine. The planned development by Defra of a new nutrient planning and compliance tool to replace and build on existing PLANET functionality in a web-based format and linked to the AHDB API represents a significant improvement on the current free to use NMPTs in England, Wales and Scotland.

None of the tools reviewed are available as a mobile application, although the web-based tools could be accessed by a phone using data roaming services. The ability to see and make changes to a NMP 'on-the-go' is a potentially useful feature that farmers could use whilst out in the field in order to record accurately what nutrients are spread and where and make adjustments to the plan in the light of what is actually done in the field. However, this is reliant on there being good mobile phone connectivity across the country. Given the complexity of nutrient management planning and the requirements required for compliance reporting the core tasks associated with creating a plan (field records – soil type, cropping history etc) are likely to be more easily undertaken on a desk/laptop in the office. However, having the facility to access and update a plan whilst in the field, even if it is 'off-line' (to be uploaded when there is a connection) would be a useful facility.

5.1.2 Functionality

The CAFRE calculators perform all the necessary functions to produce a NMP for farmers in Northern Ireland and enable the user to demonstrate compliance with the NAP. Incorporation of data from the new Soil Nutrient Health Scheme is a useful recent addition to the tool, although only the soil P and K status is used for generating recommendations. Lime recommendations have to be taken from the soil analysis report, they are not produced by the calculator. The calculator does not produce recommendations for S or Mg.

All tools calculate crop nutrient requirements based on soil analysis results and take account of nutrients supplied by organic materials. The latter is determined using standard values by the CAFRE calculators and NMP Online, whereas PLANET uses the MANNER-*NPK* algorithms. The use of MANNER-*NPK* alongside the CAFRE nutrient calculator (or incorporation of the MANNER algorithms into the

calculator, as in PLANET) would give a more accurate NMP. The CAFRE calculator currently uses the standard organic material crop nutrient availabilities given by the look up tables in RB209. Although these were calculated from MANNER-*NPK* (rounded to the nearest 5%), only selected combinations of organic material application date (e.g. autumn, winter, spring, summer for cattle slurries), application method (e.g. surface applied, band spread, injected) and incorporation timing (not incorporated/incorporated within 24 hours) are given within RB209 (and hence used by the CAFRE Calculator). MANNER-*NPK* however models a wider range of application methods and timings, as well as a broader range of materials than those given in RB209, it also takes into account weather conditions following application to refine predictions based on the actual date of application (rather than season). If the model is run in advance, it would also enable the user to see the environmental impact of any planned organic material application, potentially enabling adjustments to be made to the NMP so that nutrients are used more efficiently, and losses reduced (e.g. by changing the date or method of application).

Expected yield is also accounted for by all of the tools (for certain crops and in line with NAP/NVZ N max requirements). However, only PLANET enables an adjustment based on fertiliser nutrient (P, K, K) and crop prices, using a 'break even ratio' calculation. PLANET also calculates a P and K balance, carrying forward any surplus P and K supplied by organic materials to adjust recommendations for the field in the following season/s. Moreover there are additional modules within PLANET that are not replicated within the CAFRE suite of calculators. Most notably the ability to record organic manure imports and exports and calculate an annual inventory of livestock manure produced on the farm, and to produce a farmgate nutrient (N, P, K) balance.

Both the CAFRE crop nutrient calculator and NMP Online allow the user to select the type of fertiliser product applied, based on the nutrient ratio in the material (e.g. '20 10 10'), rather than the name of the product. Further development of the fertiliser selection component of the CAFRE calculator could include an assessment the economic implications of using different nutrient sources (price of fertiliser, value of organic materials), as well as the carbon footprint. None of the tools make adjustments to the NMP as a result of using abated products (e.g. use of urease or nitrification inhibitors).

None of the tools reviewed enabled the integration of precision software on fertiliser spreaders and tankers. However, the use of mapping in NMP Online would potentially make this a simpler upgrade task for this tool compared to the CAFRE crop nutrient calculator and PLANET.

Recommendations given by all of the tools are fundamentally dependent on the latest advice given by RB209, SAC Technical Notes, Teagasc Green Book or the NAP. It is outside the scope of this review to consider the accuracy and scope of these recommendation/guidance documents, other than to note that the further work is required to:

- Improve our ability to account for N supplied by legumes and cover crops in the rotation.
- Determine the nutrient requirements of herbal leys.
- Understand how a NMP may change if abated products are used.

In addition, RB209 does not consider the potentially different availability of phosphate on basaltic soils which are found across about a third of Northern Ireland, with Olsen P analysis (which underpins the P Index system in RB209) shown to be an inadequate predictor of plant available P in these soils (Bell et al. 2006). A different approach may therefore be required for these soils.

5.1.3 Usability

Both the data entry screens and reports produced by the CAFRE crop nutrient calculator (and PLANET) have been described as 'dated' and 'clunky'. Both tools have not been updated for a number of years, and would benefit from a 'refresh' to streamline data entry and reporting (e.g. to avoid users having to swap between multiple screens or enter the same data several times). Reports produced by the

CAFRE calculators are only available in PDF format. The ability to export data in other formats (e.g. excel) would enable the user to undertake further analysis (e.g. to explore trends in nutrient use, soil properties etc.) or use the data generated by the tool in other applications (e.g. carbon calculators).

NMP Online uses a different data entry & reporting approach to the CAFRE crop nutrient calculator and PLANET, using mapping to select fields and demonstrate results (with tabular data entry tables 'behind' the maps and tabular reporting options available for demonstrating compliance). Although 'drawing' field boundaries/management areas requires some dexterity with a computer mouse, the ability to select fields and report results on a map is an attractive feature, enabling a farmer to quickly identify what nutrients are required and where. Mapping soil nutrient status in this way also enables a farmer to target organic material applications appropriately across the farm thereby avoiding excess nutrient accumulation.

5.1.4 Uptake

The CAFRE calculators, PLANET and NMP Online are the recommended 'industry standard' NMPTs to use in the country they were developed for and have an established user-base.

In order to improve the uptake of nutrient management planning and NMPTs, farmers need to see them as being useful (beneficial e.g. in terms of improving productivity and gross margins) as well as easy to use. User research of NMP Online undertaken by McCormack *et al.,* (2021) describes these two key factors as 'Perceived Usefulness' (PU) and 'Perceived Ease of Use' (PEOU). They reported that if a farmer perceives a NMP to be useful and easy to use there is a higher likelihood of adoption. Results from a survey of farmers participating in the Agricultural Catchments Programme (358 farms in Ireland) indicated that the strongest factor influencing future intentions to adopt a NMP was the farmer's PU of a NMP to their overall farming business, suggesting that in order to create a positive attitude towards the adoption of a NMP the usefulness of the technology in terms of increased profitability, improving nutrient management practices, labour and time saving advantages should be highlighted and clearly communicated to farmers. While the PU was the most important factor, PEOU which reflects farmer perceptions in relation to their own ability to adopt the technologies, was also considered to be significant.

All of the tools reviewed had a guidance and training materials, including (in some cases) video walk-throughs of the tools, in person training (workshops/webinars) and the provision of a helpline.

5.2 Lessons from selected non-UK tools

Most of the non-UK tools reviewed aligned with the individual countries cropping systems, agroclimatic conditions and legislative requirements, so were not appropriate for direct use in Northern Ireland. The exception to this is the FaST tool which has been designed with the specific goal of being customizable for countries in the European Union. This tool is available both as a web and mobile application linked to satellite data, able to produce maps and display real-time data (e.g. weather), which are all attractive features. However, it has only been customized for three countries to date and is likely to require significant resource to align it to Northern Ireland, particularly as it is aligned with the Common Agricultural Policy (CAP). Given the CAFRE calculators are already widely used and regularly updated (in line with RB209 as appropriate) customization of FaST for use in NI is not considered to be necessary. However, it would be useful to follow the progress of this tool to see how well it is used within the existing countries and if it is more widely adopted across Europe. Moreover, if a mobile Application is to be developed for NI it would be worth trialing the FaST mobile App to inform its design and functionality. Both MarkOnline (Danish NMPT) and CowVision (Dutch NMPT) are available as mobile Applications, indicating that there is demand for tools to be provided in this format across Europe and therefore potentially in Northern Ireland in the future.

CowVison is more than an NMPT and integrates other (dairy) farm management planning such as feed requirements and milk production into one platform. Understanding how much feed is required, what can be produced on farm and how much needs to be bought-in, is an important aspect of nutrient management planning, with bought-in feed a significant component of an intensive livestock farm nutrient balance. Moreover, linking grass performance to nutrient requirements in a real-time and adaptive manner is likely to improve nutrient use efficiency. However, there are separate tools which can help a farmer do this within NI (e.g. 'grass check'), and the Stakeholder workshop held in February 2023 concluded that these tools should be used alongside a NMPT, rather than be integrated into it.

Overseer is a nutrient budgeting model, not designed for giving day-to-day nutrient recommendations, although a useful tool to demonstrate to farmers the fate of nutrients used on farm and their environmental impact. This information could potentially help farmers use nutrients more effectively, although user research with Overseer suggests that use of this information to enforce environmental standards could discourage use by farmers for nutrient planning.

6 CONCLUSIONS & RECOMMENDATIONS

The CAFRE nutrient calculators are the recommended 'industry standard' NMPTs to use in Northern Ireland and have an established user-base and support system. They are web-based, but dated, having not been updated since they were developed (apart from regular updates to the underlying recommendations in line with relevant RB209 updates).

It is therefore recommended that these calculators continue to be the standard recommended tools for use in NI, with the aim of improving their functionality, accuracy and usability rather than seeking to produce anything 'new'.

A number of potential improvements to the CAFRE tools include:

- **Account for nutrients supplied by organic materials more accurately** by incorporating MANNER-*NPK* algorithms into the crop nutrient calculator to allow adjustments to manure nutrient availability based on method of incorporation, delay to incorporation, rainfall, wind speed etc. Allow users to enter their own livestock manure analysis results more simply (they can currently only do this by selecting 'other organic material')
- **Inclusion of lime, SO_3 and MgO recommendations** - the soil nutrient health scheme includes measures of soil pH, Mg, S and organic matter content which are automatically uploaded onto the calculator, but not used by the tool.
- **Include information on the import and export of organic manures** – to provide a single place to store all manure imports and exports records in a similar way to the Organic Manures Imports and Exports module in PLANET.
- **Include calculation of farmgate nutrient balance for N, P and K** – to allow the user to calculate the quantity of nitrogen, phosphate and potash coming onto the farm through the farm gate (imported) and compare this with the quantity taken off the farm (exported) during a 12 month period, in a similar way to the Farmgate Nutrient Balance module within PLANET.
- **Inclusion of information on nutrient prices** – to allow users to make adjustments to fertilizer recommendations in a similar way to the 'break even ratio' adjustment in PLANET, and to see the value of their organic material additions.
- **Stream-line data entry as far as possible** – so that users don't have to 'switch' between 'pages', data is automatically saved and that common data shared between the five separate calculators does not have to be entered twice.
- **Consider linking the calculators to the NI Food Animal Information System (NIFAIS)** - to enable automatic uploading of data on livestock held on the farm (e.g. numbers, age etc) to assist with livestock manure calculations.
- **Enable users to download results into an excel workbook** (or equivalent), rather than just in PDF format. This will allow data to be further manipulated by the user or potentially imported into other tools.
- **Consider mapping functionality** - allowing results to be displayed on a map for easy targeting of fields which require attention. NMP Online is a good example of how this may be achieved.
- **Consider a mobile application** – as a minimum to allow users to enter data/notes whilst in the field as a record of what was actually done (if different to the plan). A trial of the FaST app could give useful insights on how this might be achieved.

7 KNOWLEDGE GAPS

Crop nutrient recommendations are fundamentally dependent on the latest advice given by RB209, SAC Technical Notes, Teagasc Green Book or the NAP. It is outside the scope of this review to consider the accuracy and scope of these recommendation and guidance documents, other than to note that the further work is required to:

- Improve our ability to account for N supplied by legumes and cover crops in the rotation.
- Determine the nutrient requirements of herbal leys.
- Determine the optimum pH for different types of grassland
- Understand how a NMP may change if abated products are used.

In addition, RB209 does not consider the potentially different availability of phosphate on basaltic soils which are found across about a third of Northern Ireland, with Olsen P analysis (which underpins the P Index system in RB209) shown to be an inadequate predictor of plant available P in these soils (Bell et al. 2006). A different approach may therefore be required for these soils.

None of the tools reviewed enabled the integration of precision software on fertiliser spreaders and tankers. Likewise, there may be scope to link the output from a NMPT to a carbon calculator (given fertiliser usage can form a large part of a farm's carbon footprint). Further work would be required in order to determine the demand for this type of functionality and its feasibility.

8 REFERENCES

Bell, A.A.W., Bailey, J.S. and Smith, R.V. (2006) An evaluation of the Olsen test as a measure of plant available phosphorus in grassland soils derived from basalt parent material. Soil Use and Management, 21 (3) 322-329.

Gibbons, G.M., Williamson, J.C., Williams, A.C., Withers, P.J.A., Hockley, N., Harris, I.M., Hughes, J.W., Taylor R.L., Jones, D.L. and Healey, J.R. (2014) Sustainable nutrient management at field, farm and regional level: Soil testing, nutrient budgets and the trade-off between lime application and greenhouse gas emissions. Agriculture Ecosystems & Environment, 188, 45-56. https://doi.org/10.1016/j.agee.2014.02.016.

Hanrahan, L., Geoghegan, A., O'Donovan, M., Griffith, V., Ruelle, E., Wallace, M. and Shalloo, L. (2017) PastureBase Ireland: A grassland decision support system and national database. Computers and Electronics in Agriculture, 136, 193-201. https://doi.org/10.1016/j.compag.2017.01.029.

McCormack, M., Buckley, C., Kelly, E. (2021) Using a Technology Acceptance Model to investigate what factors influence farmer adoption of a nutrient management plan. Irish Journal of Agricultural and Food Research, 60 (1) 142-151.

Murphy, D.J., O'Brien, B. and Murphy, M.D. (2020) Development of a grass measurement optimisation tool to efficiently measure herbage mass on grazed pastures. Computers and Electronics in Agriculture, 178, 105799 https://doi.org/10.1016/j.compag.2020.105799.

Murphy, P., Crosson, P., O'Brien, D. and Schulte, R.P.O. (2013) The Carbon Navigator: a decision support tool to reduce greenhouse gas emissions from livestock production systems. Animal, 7 (2) 427-436. https://doi.org/10.1017/S1751731113000906.

Nicholson, F.A., Bhogal, A., Chadwick, D., Gill, E., Gooday, R.D., Lord, E., Misselbrook, T., Rollett, A.J., Sagoo, E., Smith, K.A., Thorman, R.E., Williams, J.R. and Chambers, B.J. (2013). An enhanced software tool to support better use of manure nutrients: MANNER-*NPK*. Soil Use and Management 29 (4) 473-484.

Nicholson, F.A. Williams, J.R., Cassidy, R., Doody, D., Ferriera, A. Jamsek, A., Kaste, Ø., Langas, S., Laursen, R.K., Surdyk, N., Schipper, P. Tendler, L. Van Vliet, J. and Verloop K. (2018) Survey and Review of Decision Supports Tools. FAIRWAY Project 5.1 report. www.fairway-project.eu

Thomas, A., Buckley, C., Kelly, E., Dillon, E., Lynch, J., Moran, B., Hennessy, T. and Murphy, P.N.C. (2020) Establishing nationally representative benchmarks of farm-gate nitrogen and phosphorus balances and use efficiencies on Irish farms to encourage improvements. Science of the Total Environment, 720, 137245, https://doi.org/10.1016/j.scitotenv.2020.137245.

Sagoo, L., Dowers, J., Lively, F. and Rankin, J. (2020) Review of existing tools available for use on permanent grassland. Super-G Task 5.1 Final report https://www.super-g.eu/

APPENDIX 1 NMPTS IN THE UK AND IRELAND

List of Nutrient Management Planning Tools in the UK & Ireland

Number	Provider	NMPT name/module
1	CAFRE	Crop Nutrient Calculator
2	CAFRE	Nitrogen Loading Calculator
3	CAFRE	N max for grassland
4	CAFRE	Phosphorus balance
5	CAFRE	Manure Storage
6	ADAS/SAC	PLANET Field level nutrient planning and recommendation
7	ADAS/SAC	PLANET N max calculator
8	ADAS/SAC	PLANET Livestock manure N farm limit module
9	ADAS/SAC	PLANET Organic manures inventory and storage module
10	ADAS/SAC	PLANET existing manure storage capacity module
11	ADAS/SAC	PLANET Imports and exports module
12	ADAS/SAC	PLANET Farmgate nutrient balance module
13	ADAS	MANNER-*NPK*
14	Teagasc	NMP Online
15	AHDB	RB209 - API

NMPT 1 CAFRE Crop nutrient calculator	
Provider/funder	Developed by AFBI for CAFRE, funded by DAERA
Brief Description	Tool which helps draw up a NMP for a farm in Northern Ireland (fertiliser recommendations) & comply with nutrient limit requirements. It is used to determine the N, P & K required by crops and compares this to the nutrients applied, advising of any surplus or deficit
Main purpose	Nutrient management planning, fertiliser recommendations, record keeping & demonstration of compliance (field plan produced which satisfies the requirements for a non-derogated fertilisation plan within NAP)
If a compliance tool, what regulations can it be used for?	Nutrients Action Programme (NAP) 2019-2022, Northern Ireland
Links & references	CAFRE online nutrient calculators
Date of first release	2007
Date of last update	Originally coded using 8th Edition of RB209; Updates to RB209 since then are scrutinized for applicability to Northern Ireland and then the calculator is manually updated as appropriate
Planned future updates	Updates in line with RB209 updates where applicable to Northern Ireland; currently considering an update to include map viewer functionality and pH adjustment. Also the potential for using the RB209 API; There has been some discussion on streamlining the UI to reduce number of steps involved in entering data (as well as modernising to support greater range of devices) to make it more user friendly.
Format/platform	Web-based.
Available on	PC
Cost	Free online service for farm businesses with a business ID
Availability & user credentials	Access via DAERA online services a farm business with a NI business ID (farmer or agent); https://www.daera-ni.gov.uk/services/daera-online-services; need a government gateway account & verification from a DAERA office
Intended user	Farmer & Advisor
Number of registered users	1400 (April 2023)
Country of origin	Northern Ireland
Scope	Northern Ireland, specific to Northern Ireland NAP requirements
Geographical resolution	Farm (user can enter multiple fields as separate entries, or if same management & soil type create a single plan for multiple fields)
Temporal resolution	Stores data for multiple seasons enabling the user to import fields from previous years and edit accordingly
Data input requirements	Field details (name, size), soil (type, analysis - P, K, pH), cropping (includes details like number of cuts for silage, aftermath grazing type, previous cropping), manure (type & volume, method of application and date), planned fertiliser applications if known (type of fertiliser and quantity applied); some of this information can be pre-populated from the NI soil health sampling scheme

Data sources	RB209 (8th edition & updates as appropriate to NI); NI fertiliser list (Daera); single farm payment application details & NI Soil health sampling scheme (following participation to the scheme)
Data export	User can download a report (PDF). No facility to export in spreadsheet format
Data storage	Data is stored on the calculator; The user can select a cropping year and bring up previous plans for a field
Degree of user interaction/level of expertise required	Intended to be used by farmers & is intuitive, although most 'need help'
Ability to account for:	
Organic manures	Uses default values for livestock manures & user can enter lab analysis for other materials; Default nutrient contents are taken from NAP 2011-2014 guidance & availability from the NAP or RB209 8th edition, whichever is highest.
Legumes	Previous cropping tab splits out low, moderate and high input grass (grass/clover included in the moderate category), but no further breakdown for e.g. herbal leys
Previous cropping history	yes
Expected yield	Yes, with N-max checker
Target pH	No, pH is not used by the tool
Ability to:	
Track soil nutrients over time	yes
Integrate data from NI soil nutrient scheme	yes
Integrate data from precision spreaders	no
Any user feedback/research on its use	Small survey carried out in 2022 sent to CAFRE and UFU staff; due to be published this year
User support?	Help button on the calculator takes the user to a help document; Also a separate guidance doc (series of slides) on the website; CAFRE give periodic training on using the calculator (webinar/meetings)
Other DST with similar purpose	• PLANET Field level records and recommendations module
Other notes	Tool uses RB209 (8th Edition), but not for grassland recommendations (which uses recommendations from the NAP, particularly for P); Cannot over-write manure analysis results from drop-down box of livestock manures, so if have own analysis need to add this as 'other organic material'. Doesn't give S, Mg or lime recommendations; Doesn't take into account as many factors as MANNER for calculating manure nutrient supply (e.g incorporation method and timing, weather on application). User can state exactly what fertiliser they will be using (nutrient ratios). Described as 'clunky' by CAFRE; No cost calculator for the value of manures.
Updates required	Northern Ireland was due to have a review of NAP however this has been delayed, and therefore farms will continue to work with the 2019-2022 NAP until such time as the review takes place and a new 2022-2025 NAP is released. The Crop Nutrient Calculator will be updated to include any changes to the NAP as they happen.

NMPT 2 CAFRE Nitrogen loading calculator	
Provider/funder	Developed by AFBI for CAFRE, funded by DAERA
Brief Description	Tool to check if a farm in Northern Ireland is below the 170 kg/ha/yr N limit or if operating under a derogation to the 250 kg/ha/yr N limit; Estimates N loading based on livestock numbers, imports/exports of manure and land area
Main purpose	Demonstrate compliance with the NAP N loading limit
If a compliance tool, what regulations can it be used for?	Nutrients Action Programme (NAP) 2019-2022, Northern Ireland
Links & references	CAFRE online nutrient calculators
Date of first release	2007
Date of last update	Updated with start of last NAP (2019)
Planned future updates	Updated in response to changes to NAP; No updates currently planned -although new NAP is imminent
Format/platform	Web-based.
Available on	PC
Cost	Free online service for farm businesses with a business ID
Availability & user credentials	Access via DAERA online services a farm business with a NI business ID (farmer or agent); https://www.daera-ni.gov.uk/services/daera-online-services; need a government gateway account & verification from a DAERA office
Intended user	Farmer & Advisor
Number of registered users	5600 (April 2023)
Country of origin	Northern Ireland
Scope	Northern Ireland, specific to Northern Ireland NAP requirements
Geographical resolution	Farm
Temporal resolution	Annual
Data input requirements	Eligible land area (from BPS declaration); Number livestock (broken down by type and age); imported/exported manure
Data sources	No external data sources used.
Data export	User can download a report (PDF) which will detail total N loading, broken down by livestock type & manure import/export; Will also give P produced by each group (needed if operating under a derogation); If over the limit the numbers will be highlighted in red; No facility to export in spreadsheet format
Data storage	Data is stored on the calculator; The user can select a cropping year and bring up previous plans
Degree of user interaction/level of expertise required	Intended to be used by farmers & is intuitive
Any user feedback/research on its use	No
User support?	Help button on the calculator takes the user to a help document. Also a separate guidance note (series of 'how to' slides) on the website plus a 'How to' video

Other DST with similar purpose	PLANET Livestock manure N farm limit
Other notes	None
Updates required	Northern Ireland was due to have a review of NAP however this has been delayed, and therefore farms will continue to work with the 2019-2022 NAP until such time as the review takes place and a new 2022-2025 NAP is released.

NMPT 3 CAFRE Nmax for grassland calculator	
Provider/funder	Developed by AFBI for CAFRE, funded by DAERA
Brief Description	Tool to check that N applications to the whole of the grassland area on a farm in NI do not exceed NAP limits.
Main purpose	Demonstrate compliance with the NAP N application limits to grassland
If a compliance tool, what regulations can it be used for?	Nutrients Action Programme (NAP) 2019-2022, Northern Ireland
Links & references	CAFRE online nutrient calculators
Date of first release	2007
Date of last update	Updated with start of last NAP (2019)
Planned future updates	Updated in response to changes to NAP; No updates currently planned -although new NAP is imminent
Format/platform	Web-based.
Available on	PC
Cost	Free online service for farm businesses with a business ID
Availability & user credentials	Access via DAERA online services a farm business with a NI business ID (farmer or agent); https://www.daera-ni.gov.uk/services/daera-online-services; need a government gateway account & verification from a DAERA office
Intended user	Farmer & Advisor
Number of registered users	1800 (April 2023)
Country of origin	Northern Ireland
Scope	Northern Ireland, specific to Northern Ireland NAP requirements
Geographical resolution	Farm
Temporal resolution	Annual
Data input requirements	Eligible Land area; fertiliser applied (type and rate); Manure (type, rate and N content)
Data sources	No external data sources used.
Data export	User can download a report (PDF). No facility to export in spreadsheet format
Data storage	Data is stored on the calculator for previous years but a new report has to be produced for each year
Degree of user interaction/level of expertise required	Intended to be used by farmers & is intuitive
Any user feedback/research on its use	No
User support?	Currently no help documents available for this calculator
Other DST with similar purpose	PLANET Nmax module
Other notes	None
Updates required	Northern Ireland was due to have a review of NAP however this has been delayed, and therefore farms will continue to work with the 2019-2022 NAP until such time as the review takes place and a new 2022-2025 NAP is released.

NMPT 4 CAFRE Phosphorus balance calculator	
Provider/funder	Developed by AFBI for CAFRE, funded by DAERA
Brief Description	Tool which calculates the P balance of a farm in NI to help manage P inputs and outputs to meet the limit of 10 kg P/ha/yr.
Main purpose	Demonstrate compliance; manage P inputs; use P efficiently
If a compliance tool, what regulations can it be used for?	Nutrients Action Programme (NAP) 2019-2022, Northern Ireland
Links & references	CAFRE online nutrient calculators
Date of first release	2007
Date of last update	Updated with start of last NAP (2019)
Planned future updates	Updated in response to changes to NAP; No updates currently planned
Format/platform	Web-based.
Available on	PC
Cost	Free online service for farm businesses with a business ID
Availability & user credentials	Access via DAERA online services a farm business with a NI business ID (farmer or agent); https://www.daera-ni.gov.uk/services/daera-online-services; need a government gateway account & verification from a DAERA office
Intended user	Farmer & Advisor
Number of registered users	1300 (April 2023)
Country of origin	Northern Ireland
Scope	Northern Ireland, specific to Northern Ireland NAP requirements
Geographical resolution	Farm
Temporal resolution	Annual
Data input requirements	Eligible land area, P bought onto farm (fertiliser, feedstuff, manures & livestock - number and liveweight), P leaving farm (crops, manure and livestock)
Data sources	No external data sources used.
Data export	User can download a report (PDF). No facility to export in spreadsheet format
Data storage	Data is stored on the calculator; The user can select a cropping year and bring up previous plans for a field
Degree of user interaction/level of expertise required	Intended to be used by farmers & is intuitive, although most 'need help'
Any user feedback/research on its use	None
User support?	Currently no help documents available for this calculator
Other DST with similar purpose	None Note: Great Britain doesn't have the same restrictions within NVZ rules on phosphate application that the NAP has
Other notes	None
Updates required	Northern Ireland was due to have a review of NAP however this has been delayed, and therefore farms will continue to work with the 2019-2022 NAP until such time as the review takes place and a new 2022-2025 NAP is released.

NMPT 5 CAFRE Manure storage calculator	
Provider/funder	Developed by AFBI for CAFRE, funded by DAERA
Brief Description	Tool which calculates the weekly slurry, dirty water, manure production and current storage capacity of a farm in Northern Ireland.
Main purpose	Demonstrate compliance with NAP
If a compliance tool, what regulations can it be used for?	Nutrients Action Programme (NAP) 2019-2022, Northern Ireland
Links & references	CAFRE online nutrient calculators
Date of first release	2007
Date of last update	Updated with start of last NAP (2019)
Planned future updates	Updated in response to changes to NAP; No updates currently planned
Format/platform	Web-based.
Available on	PC
Cost	Free online service for farm businesses with a business ID
Availability & user credentials	Access via DAERA online services a farm business with a NI business ID (farmer or agent); https://www.daera-ni.gov.uk/services/daera-online-services; need a government gateway account & verification from a DAERA office
Intended user	Farmer & Advisor
Number of registered users	2300 (April 2023)
Country of origin	Northern Ireland
Scope	Northern Ireland, specific to Northern Ireland NAP requirements
Geographical resolution	Farm
Temporal resolution	Annual
Data input requirements	Slurry producing livestock by animal type and age (No over winter period); % separated; bedded livestock; outwintered livestock & land area; slurry exported for processing by livestock type; poultry litter production & export; dirty water produced (yard area, roof area, tank area, parlour washings etc); tank size
Data sources	No external data sources used.
Data export	User can download a report (PDF). No facility to export in spreadsheet format
Data storage	Data is stored on the calculator; The user can select a cropping year and bring up previous plans for a field
Degree of user interaction/level of expertise required	Intended to be used by farmers & is intuitive, although most 'need help'
Any user feedback/research on its use	None
User support?	Help button on the calculator takes the user to a help document (series of 'how to' slides);'How to video online
Other DST with similar purpose	PLANET Organic manure inventory module
Other notes	None

Updates required	Northern Ireland was due to have a review of NAP however this has been delayed, and therefore farms will continue to work with the 2019-2022 NAP until such time as the review takes place and a new 2022-2025 NAP is released.

NMPT 6 PLANET Field level nutrient planning and recommendations	PLANET NUTRIENT MANAGEMENT
Provider/funder	Produced by ADAS and SAC with funding from Defra and Scottish Government
Brief Description	PLANET (Planning Land Applications of Nutrients for Efficiency and the environmenT) is a nutrient management decision support tool for use by farmers and advisers in England/Wales and Scotland for field level nutrient planning and for assessing and demonstrating compliance with the Nitrate Vulnerable Zone (NVZ) rules. The PLANET 'Field level nutrient planning and recommendations' module gives fertiliser recommendations for all major nutrients and lime based on Defra's "Fertiliser Manual (RB209)" (8th Edition) in England/Wales and on SRUC "Technical Notes" in Scotland. Fertiliser recommendations take account of the crop nutrient requirement, the soil nitrogen supply, laboratory soil analysis results, and the nutrients supplied from any organic material applications (calculated using the MANNER-*NPK* 'calculation engine'). A nutrient application plan can be developed and updated during the season. Detailed field records can be kept of cropping, soil analyses, and fertiliser and organic material applications.
Main purpose	• Fertiliser recommendations • Nutrient management planning and record keeping • Compliance tool (demonstrates compliance with NMP requirements)
If a compliance tool, what regulations can it be used for?	Nitrate Vulnerable Zone regulations in England and Scotland
Links & references	PLANET website (includes links to audio visual tutorials and help guides)
Date of first release	2005
Date of last update	2014 (v.3.3)
Planned future updates	The current Defra NMPT project plans to update existing PLANET functionality to a new web-based NMPT
Format/platform	Software – desk based
Available on	Windows PC
Cost	Free
Availability & user credentials	Users must register to be able to download the software. User registration is available to anyone.
Intended user	Farmer & Advisor
Number of registered users	There are currently (July 2023) 18,898 registered users of PLANET England and 2,193 registered users of PLANET Scotland. Each registered user has a unique email address; however it is not clear how many of these are active users.
Country of origin	England
Scope	England, Wales and Scotland
Geographical resolution	The 'Field level nutrient planning and recommendations' module is field level.
Temporal resolution	Data is entered for a 'harvest year'. Data can be entered and saved for any number of harvest years.

Data input requirements	Farm and field details including location (postcode to retrieve location specific rainfall data), soil type, past cropping, soil analysis, planned cropping and planned manure use. Users can also record details of actual fertiliser and lime applications.
Data sources	PLANET uses postcode specific long term average (1971-2001) climate data to (i) identify the farms average annual rainfall which is used to calculate Soil Nitrogen Supply, and (ii) for use in the MANNER-*NPK* model to calculate crop available N supply from organic materials.
Data export	Data can be exported in excel format.
Data storage	Data entered into the tool can be saved. Multiple 'files' can be saved within the tool. Files are saved as MS Access files. The DST can generate reports which can be saved in PDF format.
Degree of user interaction/level of expertise required	ADAS recommend reading the Quick start guide before using the tool. The flow of data input follows the steps required to created a NMP, so should be familiar to those who understand or are experienced with Nutrient Management Planning.
Ability to account for:	
Organic manures	Yes – uses MANNER-NPK algorithms
Legumes	PLANET is based on RB209 8th Edition and includes two options for clover (low and high) in 'grassland management'. If these are selected the N fertiliser recommendation becomes zero and a guidance note is given
Previous cropping history	yes
Expected yield	yes
Target pH	yes - lime recommendations are given for target pH, based on RB209 8th Edition
Ability to:	
Track soil nutrients over time	user can enter soil analysis results (or upload directly from lab report in csv format) and is reminded if these are out of date; all data entered into PLANET can be exported to excel. Soil analyses from different years are saved separately, with fertiliser recommendations coded to use the most recent analyses
Integrate data from NI soil nutrient scheme	No
Integrate data from precision spreaders	No
Any user feedback/research on its use	PLANET user surveys were carried out for Defra in 2006 and 2012. More recently, the Defra Farm Practice Survey (2022) showed that 54% of farms had a nutrient management plan and about 35% used either Planet or Muddy boots.
User support?	User guide (PDF) and video tutorial available in PLANET. Email and telephone helpline support was provided between 2005 and 2017, and continued unofficially by ADAS until July 2021. The PLANET England helpline has now been discontinued. The PLANET Scotland helpline is now supported via the Scottish Farming Advisory Service.
Other DST with similar purpose	Fertiliser recommendations based on RB209 9th Edition recommendations are provided by the AHDB API CAFRE Crop nutrient calculator

Other notes	None
Updates required	PLANET provides fertiliser recommendations for users in England and Wales based on RB209 8th Edition. These needs updating to RB209 9th Edition. PLANET provides fertiliser recommendations for users in Scotland based on SRUC Technical Notes and was last updated in 2013. Since then, there have been a number of updates (most significantly the introduction of phosphorus sorption capacity classes for soils) which needs updating in the software. Note that the AHDB API provides fertiliser recommendations based on RB209 9th Edition, and is currently being updated to provide recommendations for users in Scotland based on guidance given in the current SRUC Technical Notes. PLANET is a desk-based tool which was last updated in 2013. It needs updating to web-based, and where possible improvements made to it's general usability and functionality.

NMPT 7 PLANET N max calculator	
Provider/funder	Produced by ADAS and SAC with funding from Defra and Scottish Government
Brief Description	The NVZ rules set mandatory limits for the maximum quantity of nitrogen (N max) that may be applied to specific crop types, over the whole area of the crop type grown on land within an NVZ on the farm. The PLANET Nmax calculator is used to assess and demonstrate compliance with the NVZ Nmax rules in England, Wales and Scotland.
Main purpose	Compliance tool (demonstrates compliance NVZ Nmax rules)
If a compliance tool, what regulations can it be used for?	Nitrate Vulnerable Zone regulations in England and Scotland
Links & references	PLANET website (includes links to an Nmax audio visual tutorial and help guide)
Date of first release	2008 (Nmax was included in PLANET v2 released in 2008)
Date of last update	2014 (v.3.3) Updates to Nmax calculations to reflect updates to Nmax rules from 01/01/2014 including new Nmax limits for vegetable crops and grass for protein, and an increase in the minimum livestock manure N efficiency values for pig and cattle slurry.
Planned future updates	The current Defra NMPT project plans to update existing PLANET functionality to a new web-based NMPT.
Format/platform	Software – desk based
Available on	Windows PC
Cost	Free
Availability & user credentials	Users must register to be able to download the software. User registration is available to anyone.
Intended user	Farmer & Advisor
Number of registered users	See 'PLANET Field levels nutrient planning and recommendations module'
Country of origin	England
Scope	England, Wales and Scotland
Geographical resolution	N max is calculated over the whole area of the crop type grown on land within an NVZ on the farm
Temporal resolution	The Nmax calculation should be carried out annually, and uses data entered into the PLANET Field level records and recommendations module.
Data input requirements	Uses cropping data entered into the PLANET Field level nutrient planning and recommendations module, including crop type, yield, fertiliser and manure use.
Data sources	No external data used
Data export	N max reports can be saved and printed.
Data storage	See 'PLANET Field levels nutrient planning and recommendations module'
Degree of user interaction/level of expertise required	ADAS recommend reading the Quick start guide before using the tool. The flow of data input follows the steps required in NVZ rules to calculate Nmax compliance, so should be familiar to those who understand or are experienced with NVZ rules.

Any user feedback/research on its use	A PLANET user survey which included Nmax was carried out for Defra in 2012.
User support?	See 'PLANET Field levels nutrient planning and recommendations module'
Other DST with similar purpose	CAFRE Nmax checker for grassland and Crop Nutrient Calculators
Other notes	Problems calculating Nmax for 'recorded' fertiliser and manure applications has been one of the most common reasons for helpline calls. This is mainly due to requirements of the tool for users to have (i) entered fertiliser information for all fields they want to calculate N max for, (ii) have confirmed all field/cropping information, and/or (iii) have cropping information for all fields they want to calculate N max for in the previous harvest year.
Updates required	• There have been no changes to the NVZ Nmax rules since PLANET Nmax was last updated in 2014. • PLANET is a desk-based tool which was last updated in 2013. It needs updating to web-based, and where possible improvements made to it's general usability and functionality.

NMPT 8 PLANET Livestock manure N farm limit	PLANET NUTRIENT MANAGEMENT
Provider/funder	Produced by ADAS and SAC with funding from Defra and Scottish Government
Brief Description	The Livestock manure N farm limit module calculates the N capacity and N loading of a farm and will help assess if the farm is compliant with the NVZ livestock manure N farm limit.
Main purpose	Compliance tool (demonstrates compliance NVZ Livestock Manure N Far limit)
If a compliance tool, what regulations can it be used for?	Nitrate Vulnerable Zone regulations in England and Scotland
Links & references	PLANET website (includes links to a help guide for this module)
Date of first release	2009 (the Livestock manure N farm limit module was included in PLANET v2 released in 2009)
Date of last update	2010 (v.3) Change from VB to .NET coding language as part of v3 update. Addition of functionality to allow the user to load existing livestock manure import/export data already entered within the 'Organic manures imports and exports' module.
Planned future updates	The current Defra NMPT project plans to update existing PLANET functionality to a new web-based NMPT
Format/platform	Software – desk based
Available on	Windows PC
Cost	Free
Availability & user credentials	Users must register to be able to download the software. User registration is available to anyone.
Intended user	Farmer & Advisor
Number of registered users	See 'PLANET Field levels nutrient planning and recommendations module'
Country of origin	England
Scope	England, Wales and Scotland
Geographical resolution	Livestock manure N loading is calculated for the whole farm.
Temporal resolution	The calculation is performed annually. The user can save one set of data (for the current calendar year). If the user wishes to save information for past years, then they are advised to save a copy of the report before overwriting any data.
Data input requirements	Farm area, livestock details, imports and exports of organic manures
Data sources	No external data used
Data export	Data can be exported in excel format.
Data storage	See 'PLANET Field levels nutrient planning and recommendations module'
Degree of user interaction/level of expertise required	The flow of data input follows the steps required in NVZ rules to calculate the Livestock Manure N farm limit, so should be familiar to those who understand or are experienced with NVZ rules.
Any user feedback/research on its use	A PLANET user survey which included this module was carried out for Defra in 2012.
User support?	See 'PLANET Field levels nutrient planning and recommendations module'

Other DST with similar purpose	CAFRE Nitrogen loading calculator
Updates required	• There have been no changes to the Livestock manure N farm limit NVZ rules since PLANET was last updated. • PLANET is a desk-based tool which was last updated in 2013. It needs updating to web-based, and where possible improvements made to it's general usability and functionality.

NMPT 9 PLANET Organic manures inventory and storage	
Provider/funder	Produced by ADAS and SAC with funding from Defra and Scottish Government
Brief Description	The Organic manures inventory and storage module calculates the monthly production of organic manures on the farm based on details of the livestock on the farm, and allowing for any imports and exports of manure. It calculates the NVZ minimum storage requirement and the approximate nutrient content of the manures.
Main purpose	Compliance tool (demonstrates compliance with the NVZ requirement to calculate the minimum storage requirement for livestock slurries and poultry manure).
If a compliance tool, what regulations can it be used for?	Nitrate Vulnerable Zone regulations in England and Scotland
Links & references	PLANET website (includes links to a help guide for this module)
Date of first release	2009 (the Organic manures inventory and storage module was included in PLANET v2 released in 2009)
Date of last update	2010 (v.3) Change from VB to .NET coding language as part of v3 update. Addition of functionality to allow the user to load existing livestock manure import/export data already entered within the 'Organic manures imports and exports' module.
Planned future updates	The current Defra NMPT project plans to update existing PLANET functionality to a new web-based NMPT
Format/platform	Software – desk based
Available on	Windows PC
Cost	Free
Availability & user credentials	Users must register to be able to download the software. User registration is available to anyone.
Intended user	Farmer & Advisor
Number of registered users	See 'PLANET Field levels nutrient planning and recommendations module'
Country of origin	England
Scope	England, Wales and Scotland
Geographical resolution	The organic manures inventory is calculated for the whole farm.
Temporal resolution	The calculation is performed annually. The user can save one set of data (for the current calendar year). If the user wishes to save information for past years, then they are advised to save a copy of the report before overwriting any data.
Data input requirements	Manure stores and rainfall collection areas draining to stores, livestock details, wash water use, and imports and exports of organic materials.
Data sources	No external data used
Data export	Data can be exported in excel format.
Data storage	See 'PLANET Field levels nutrient planning and recommendations module'
Degree of user interaction/level of expertise required	The flow of data input follows the steps required in NVZ rules to calculate the Organic manures inventory, so should be familiar to those who understand or are experienced with NVZ rules.

Any user feedback/research on its use	A PLANET user survey which included this module was carried out for Defra in 2012.
User support?	See 'PLANET Field levels nutrient planning and recommendations module'
Other DST with similar purpose	None (in this review)
Updates required	• There have been no changes to the NVZ minimum livestock manure storage requirements since PLANET was last updated. • PLANET is a desk-based tool which was last updated in 2013. It needs updating to web-based, and where possible improvements made to it's general usability and functionality.

NMPT 10 PLANET Existing manure storage capacity module	PLANET NUTRIENT MANAGEMENT
Provider/funder	Produced by ADAS and SAC with funding from Defra and Scottish Government
Brief Description	The PLANET Existing Manure Store Capacity module calculates the capacity of a farms existing manure stores. The calculation includes the allowance for 'freeboard' specified in the NVZ rules.
Main purpose	Compliance tool (demonstrates compliance with the NVZ requirement to calculate the farms storage capacity in order to demonstrate sufficient capacity).
If a compliance tool, what regulations can it be used for?	Nitrate Vulnerable Zone regulations in England and Scotland
Links & references	PLANET website (includes links to a help guide for this module)
Date of first release	2009 (the Existing manure store capacity module was included in PLANET v2 released in 2009)
Date of last update	2010 (v.3) Change from VB to .NET coding language as part of v3 update.
Planned future updates	The current Defra NMPT project plans to update existing PLANET functionality to a new web-based NMPT
Format/platform	Software – desk based
Available on	Windows PC
Cost	Free
Availability & user credentials	Users must register to be able to download the software. User registration is available to anyone.
Intended user	Farmer & Advisor
Number of registered users	See 'PLANET Field levels nutrient planning and recommendations module'
Country of origin	England
Scope	England, Wales and Scotland
Geographical resolution	Whole farm
Temporal resolution	The calculation is performed once and then updated if the storage capacity changes.
Data input requirements	Details of existing manure stores (store type, stored material, store dimensions)
Data sources	No external data used
Data export	Data can be exported in excel format.
Data storage	See 'PLANET Field levels nutrient planning and recommendations module'
Degree of user interaction/level of expertise required	This is a simple calculation module.
Any user feedback/research on its use	A PLANET user survey which included this module was carried out for Defra in 2012. Another more detailed user survey has been carried out as part of this project.
User support?	See 'PLANET Field levels nutrient planning and recommendations module'
Other DST with similar purpose	CAFRE Manure Storage calculator

Updates required	• There have been no changes to the NVZ rules affecting storage calculations since PLANET was last updated. • PLANET is a desk-based tool which was last updated in 2013. It needs updating to web-based, and where possible improvements made to it's general usability and functionality.

NMPT 11 PLANET Organic manures imports and exports module	PLANET NUTRIENT MANAGEMENT
Provider/funder	Produced by ADAS and SAC with funding from Defra and Scottish Government
Brief Description	The PLANET Organic manures imports and exports module enables the user to record all details of imports and exports of manures.
Main purpose	Support compliance by recording details of all imports and exports of organic manures
If a compliance tool, what regulations can it be used for?	Nitrate Vulnerable Zone regulations in England and Scotland
Links & references	PLANET website (no specific help guide for this module)
Date of first release	2010 (the Organic manures imports and exports module was included in PLANET v3 released in 2010)
Date of last update	2010 (v.3) Change from VB to .NET coding language as part of v3 update.
Planned future updates	The current Defra NMPT project plans to update existing PLANET functionality to a new web-based NMPT
Format/platform	Software – desk based
Available on	Windows PC
Cost	Free
Availability & user credentials	Users must register to be able to download the software. User registration is available to anyone.
Intended user	Farmer & Advisor
Number of registered users	See 'PLANET Field levels nutrient planning and recommendations module'
Country of origin	England
Scope	England, Wales and Scotland
Geographical resolution	Whole farm
Temporal resolution	The module can store data from any time period.
Data input requirements	Details of manure imports and exports including date, manure type, quality, analysis, and supplier or recipient details.
Data sources	No external data used
Data export	Data can be exported in excel format.
Data storage	See 'PLANET Field levels nutrient planning and recommendations module'
Degree of user interaction/level of expertise required	This is a simple record keeping module.
Any user feedback/research on its use	No
User support?	See 'PLANET Field levels nutrient planning and recommendations module'
Other DST with similar purpose	None in this review
Other notes	This module was added to PLANET v3 to provide a single place to store all manure imports/exports records and to remove the need for

	repeat data entry of imports/exports to the 'Livestock manure N farm limit', 'Organic manures inventory' and 'Farmgate nutrient balance' modules. The Organic manure imports and exports module can record all import/export records from all years. The 'Livestock manure N farm limit', 'Organic manures inventory' and 'Farmgate nutrient balance' modules are all annual calculations, and all three modules allow import of data from the 'Organic manures imports and exports module' for the relevant 12 month period.
Updates required	PLANET is a desk-based tool which was last updated in 2013. It needs updating to web-based, and where possible improvements made to it's general usability and functionality.

NMPT 12 PLANET Farmgate nutrient balance module	
Provider/funder	Produced by ADAS and SAC with funding from Defra and Scottish Government
Brief Description	The PLANET Farmgate nutrient balance module calculates the quantity of nitrogen, phosphate and potash nutrients coming onto the farm through the farm gate (imported), balanced against those that are taken off the farm (exported) during a 12 month period (assessment year). The difference between the quantity imported and exported is known as the 'Farmgate Nutrient Balance'.
Main purpose	Calculates Farmgate nutrient balance to improve farm level nutrient management.
If a compliance tool, what regulations can it be used for?	This module is not a compliance tool. Calculation of a farmgate nutrient balance is not required under any existing legislation.
Links & references	PLANET website (includes links to a help guide for this module)
Date of first release	2009 (the Farmgate nutrient balance module was included in PLANET v2 released in 2009)
Date of last update	2010 (v.3) Change from VB to .NET coding language as part of v3 update.
Planned future updates	The current Defra NMPT project plans to update existing PLANET functionality to a new web-based NMPT
Format/platform	Software – desk based
Available on	Windows PC
Cost	Free
Availability & user credentials	Users must register to be able to download the software. User registration is available to anyone.
Intended user	Farmer & Advisor
Number of registered users	See 'PLANET Field levels nutrient planning and recommendations module'
Country of origin	England
Scope	UK
Geographical resolution	Whole farm
Temporal resolution	The calculation is performed annually. The user can save one set of data (for the current calendar year). If the user wishes to save information for past years, then they are advised to save a copy of the report before overwriting any data.
Data input requirements	Farm and cropping details (farm type and area of main crop groups), imports of livestock, animal feeds, bedding, organic manures, and inorganic fertiliser, and exports of livestock products, harvested crops, organic manures and inorganic fertiliser.
Data sources	No external data used
Data export	Data can be exported in excel format.
Data storage	See 'PLANET Field levels nutrient planning and recommendations module'
Degree of user interaction/level of expertise required	The layout of the module and type of data entry should be familiar to existing PLANET users with experience of other PLANET modules. New users may need to read the User guide or rely on the tool-tips. Unlike the other PLANET NVZ compliance modules, the Farmgate

	nutrient balance calculation is not one that is routinely carried out by all farmers.
Any user feedback/research on its use	A PLANET user survey which included this module was carried out for Defra in 2012.
User support?	See 'PLANET Field levels nutrient planning and recommendations module'
Other DST with similar purpose	None of the other tools reviewed include these Farmgate nutrient balance calculations.
Other notes	
Updates required	PLANET is a desk-based tool which was last updated in 2013. It needs updating to web-based, and where possible improvements made to it's general usability and functionality.

NMPT 13 MANNER-*NPK*	
Provider/funder	Produced by ADAS & North Wyke (Rothamsted Research) funded by AHDB, CSF, DARD, Defra, Environment Agency, Natural England, Scottish Government, Tried and Tested and WRAP.
Brief Description	MANNER-*NPK* (MANure Nutrient Evaluation Routine) is a practical software tool that provides farmers and advisers with a quick estimate of crop available nitrogen (N), phosphate (P_2O_5) and potash (K_2O) supply from organic manure applications. It has drawn together the latest research information on factors affecting organic manure N availability to crops and N losses to the environment, via nitrate leaching, ammonia volatilisation and denitrification.
Main purpose	Estimates crop nutrient (N, P, K, S and Mg) availability following organic material applications, the potential value (£) of those nutrients and provides warning messages highlighting potential breaches of NVZ rules in England, Wales, Scotland and Northern Ireland. It can also be used to test the impact of changes in manure management on losses to the environment.
If a compliance tool, what regulations can it be used for?	MANNER-NPK can be used to support compliance with NVZ and FRfW requirements to plan nutrient use taking into account the nutrient supply from organic materials. MANNER includes NVZ warning messages to highlight non-compliance with the NVZ organic manure N field limit and the Closure spreading period for high readily available N manures.
Links & references	• A 'User guide' and 'Technical guide' are available form the Help menu in the software. • Published paper: Nicholson *et al*. (2013) https://bsssjournals.onlinelibrary.wiley.com/doi/abs/10.1111/sum.12078
Date of first release	2000
Date of last update	2013
Planned future updates	The current Defra NMPT project plans to update existing MANNER-*NPK* functionality to a new web-based NMPT
Format/platform	Software – desk based
Available on	Windows PC
Cost	Free
Availability & user credentials	Users must register to be able to download the software. User registration is available to anyone.
Intended user	Farmer & Advisor
Number of registered users	6388 registered users (July 2023)
Country of origin	England & Wales
Scope	UK
Geographical resolution	Individual field
Temporal resolution	The calculation is performed annually and will give crop available P, K, Mg and S for the year of application and crop available N for the current and

	following year (next crop); users can add multiple applications to the same field.
Data input requirements	Farm and field details (location from postcode, crop type and soil type). Details of the organic manure application including manure type, application data, application rate, method of application and manure analysis (if available).
Data sources	MANNER-*NPK* uses postcode specific long-term average (1971-2001) climate data.
Data export	PDF report with user entered data and results which can be saved as .pdf document and printed
Data storage	Data entered into the tool can be saved as a XML file. Multiple 'files' can be saved within the tool. The report can be saved in PDF format including all input data and results.
Degree of user interaction/level of expertise required	Intuitive; The majority of farmers and farm advisors with a basic level of computer literacy should be able to use MANNER without any training or additional support. A help guide is available from within the software.
Any user feedback/research on its use	The Defra Farm Practice Survey (2022) showed that 54% of farms had a nutrient management plan and about 35% used either Planet or Muddy boots which integrates the MANNER-*NPK* calculations; Feedback on the usability and functionality of the tool has been actively sought from users on two occasions – following the release of MANNER in 2000 and prior to release of MANNER-*NPK* in 2013.
User support?	User guide and technical guide are available from the help menu. Email and telephone helpline support was provided as part of the PLANET helpline between 2005 and 2017, and continued unofficially by ADAS until July 2021. The helpline has now been discontinued.
Other DST with similar purpose	Farm crap app (not reviewed as part of this project)
Updates required	• Update NH_3 and N_2O loss algorithms; updated algorithms have been recommended as part the Defra NMPT project. • MANNER-*NPK* is a desk-based tool which was last updated in 2013. It needs updating to web-based, and where possible improvements made to it's general usability and functionality.

NMPT 14 NMP-Online	
Provider/funder	Teagasc
Brief Description	A tool for developing nutrient/fertiliser management plans to optimise soil fertility and ensure compliance with the NAP in Ireland
Main purpose	Nutrient management planning, fertiliser recommendations, record keeping & demonstration of compliance
If a compliance tool, what regulations can it be used for?	Nutrients Action Programme (NAP, 5th Edition) 2022-2025, Ireland
Links & references	https://www.teagasc.ie/environment/soil/nmp/
Date of first release	2015
Date of last update	Underpinned by Teagasc Green Book of Major and Micro Nutrient Advice for Productive Agricultural Crops (last revised July 2020) and NAP (2022-25); full user update given in September 2022 with main changes to the mapping functionality
Planned future updates	Updates in line with changes to regulation and regulations; typically 2 bulletins are produced per year detailing any changes
Format/platform	Web-based.
Available on	PC
Cost	Free online to Teagasc advisors; annual registration fee for other advisors depending on the number of NMP's produced
Availability & user credentials	Teagasc ConnectEd Online Plan, which users must 'sign up' or pay in order to gain full access to the programmes (user name and password given); restricted to use with Irish farms only (farm ID needed)
Intended user	Advisor
Number of registered users	?
Country of origin	Ireland (Teagasc, johnstone Castle, Wexford)
Scope	Ireland, specific to Irish NAP requirements
Geographical resolution	Farm
Temporal resolution	Annual, but the tool stores data for multiple seasons enabling the user to import fields from previous years and edit accordingly
Data input requirements	Stocking rate, soil analysis results, concentrate use, farm size, cropping, housing and storage facilities, manure imports/exports
Data sources	Department for Agriculture Food & Marine (DAFM) land parcel identification (LPIS) & animal numbers, OS and mapping layers, Teagasc Green Book; farm input data, soil analysis results (labs)
Data export	Produces colour coded maps as well as various reports which can be downloaded. Maps as PDF, data in a format which can be exported into excel (e.g. soil analysis results)
Data storage	Data is stored on the cloud; The user can select a cropping year and bring up previous plans for a field
Degree of user interaction/level of expertise required	For use by an advisor but training is needed; The tool is a bit 'fiddly' if working with split fields or editing field management boundaries by drawing manually & requires more than just basic computing skills
Ability to account for:	
Organic manures	yes (standard values for nutrient content and availability from NAP or user entered values from certified lab)

Legumes	Takes some account of clover content of the sward (split low-normal <20% sward and normal-high > 20% of sward)
Previous cropping history	yes (N Index of a soil)
Expected yield	Yes ('crop yields adjustment tab')
Target pH	Yes (lime)
Ability to:	
Track soil nutrients over time	Yes
Integrate data from NI soil nutrient scheme	No
Integrate data from precision spreaders	No
Any user feedback/research on its use	McCormack et al., (2021)
User support?	Email helpdesk and telephone number; how to videos, regular bulletins giving guidance on new features; help button on each page users can click on (? Symbol) - tool tips; detailed user manual (2016); post 2016 guidance given in the bulletins
Other DST with similar purpose	CAFRE Crop Nutrient Calculator PLANET Field level records and recommendations module
Other notes	Potential problem identified if upgrades to the Mapping API mean it is unsupported on old browsers
Updates required	

NMPT 15 AHDB RB209 Web API	
Provider/funder	Produced by AHDB
Brief Description	The API is used to run nutrient management calculations as set out in the AHDB Nutrient Management Guide (RB209) for England and Wales. Behind the application is a set of industry wide standardised calculations and formulae which can be called, which will then return corresponding calculated values and supplementary guidance. The API will be updated in line with the changes in the AHDB Nutrient Management Guide (RB209). The recommendations from the Scottish Technical Notes will be incorporated in 2023.
Main purpose	To calculate nutrient recommendation values
If a compliance tool, what regulations can it be used for?	Not a compliance tool. However the API generates 'advice notes' if fertiliser N recommendations exceed Nmax limits for some cereal crops.
Links & references	https://ahdb.org.uk/rb209
Date of first release	2016
Date of last update	18/10/2022 (security fix, no change to recommendations)
Planned future updates	Addition of Scotland recommendations, along with migrating the software to .net6, and changing the authentication method from basic to token based. The API is typically updated every other year when RB209 is updated.
Format/platform	Web based
Available on	Web
Cost	There is no fee for licensees who incorporate the API in nutrient management planning software that is free to users. For other licensees that use the API in paid for software, an annual licence fee of £500 is applicable.
Availability & user credentials	Developers need to register, and the request must be approved by AHDB to grant access.
Country of origin	England & Wales
Scope	England & Wales, with Scotland due summer 2023
Geographical resolution	Field
Temporal resolution	Annual
Data input requirements	Crop type (arable/grassland), Soil type, Site class, Crop type, Additional RB209 crop information (crop specific), Grass growth class, Grass SNS, Grass season, Grass crop type, Grass sequence, Grass yield, Grass crop material, Crop height, GAI, Shoot number, Measurement season, Previous cropping, Organic materials applied, Soil type, NVZ Action programme
Data sources	The API doesn't import or use any external data sources. RB209 guidance documents are the original source data.
Data export	N/A
Data storage	None

Degree of user interaction/level of expertise required	Software providers to implement their own UI in front of API for users.
Any user feedback/research on its use	No
User support?	Developer support published https://rb209-api-v1.ahdb.org.uk/ Ad hoc email support is provided as requested. Contact details are provided on the website.
Other notes	Currently working on Scottish API
Updates required	• The API is updated every 2 years as RB209 is updated. • ADAS recommend integration of the MANNER-NPK calculation engine into the API

APPENDIX 2: NMPTS IN SELECTED NON-UK COUNTRIES

NMPT 16 Overseer	
Provider/funder	Jointly owned by Ministry for Primary Industries, AgResearch Limited & New Zealand Phosphate Company.
Brief Description	An agricultural management tool which assists in examining nutrient use and movements within a farm. OVERSEER calculates and estimates the nutrient flows in a farming system and can be used to identify potential risks of environmental impacts through the calculation of nutrient loss such as run-off, leaching and GHG emissions. It models seven nutrients: N, P, K, S, Ca, Mg, Na and for pastoral blocks acidity, which is linked to maintenance lime requirements.
Main purpose	To construct nutrient balances to provide information on nutrient losses from farms and support decision making. Also used for maintenance fertiliser recommendations, environmental footprinting, scenario testing of management changes, benchmarking, (can also be used as a policy tool, for education and for scientific research).
Links & references	https://www.overseer.org.nz/our-science
Date of first release	?
Date of last update	OverseerFM version 6.5.1 released April 2023 (improved crop modelling capability).
Planned future updates	Updated at regular intervals to fix known problems, add in new science, to improve existing features or add new features.
Format/platform	Web-based & stand alone desk top
Available on	PC
Cost	NZ$680 for 12 months for each farm account. Can be multiple users per farm, and results can be shared.
Intended user	Farmers and advisors; Education establishments; Policy developers and implementers; scientists and researchers
Number of registered users	Over 14,000
Country of origin	New Zealand
Relevance for NI	Agroclimatic conditions in NZ are reasonably similar to NI, however cropping, fertiliser recommendation and legislation will be different. Overseer has inbuilt databases for NZ cropping, fertiliser composition, climate and soils which could be replaced with local NI versions.
Geographical resolution	Annual average nutrient budgets (kg/ha/yr) can be constructed at the farm, block or paddock level.
Temporal resolution	Can be used to estimate long-term nutrient losses, or those for a specifc year. Data for multiple years can be stored allowing monitoring of changes in nutrient losses over time.
Data input requirements	Uses information readily-available to farmers (suitable defaults have been built in). Takes a three-tiered approach viz. Compulsory inputs, Optional inputs and Default values (which can be overridden). Some inputs are required at farm level and some at block level. Crop rotations are modelled over a 2-year time period, so the input

	information required for crop blocks can be significant. Data can be uploaded
Data sources	As well as farmer inputs, has inbuilt databases for NZ cropping, fertiliser composition, climate and soils.
Data export	Reports and graphs (not clear if these are pdf, Excel or other format)
Data storage	Yes
Degree of user interaction/level of expertise required	By following the video guides, it is possible to set up a farm and produce a simple analysis in 20 minutes. The tool seems easy to use but there is a lot of data required - this will be less in subsequent years once a farm has been set up, but still considerable.
Ease of interpretation	The software documentation states that "OVERSEER should be frequently used in conjunction with other models, farm or nutrient management plans and rural professionals to fully interpret the outputs".
Any user feedback/research on its use	There is an indication (on the News pages of the website) that Overseer has attracted criticism in the past, which may have been due to misconceptions about what it can and can't do. One of the criticisms has been that some regional councils are using it as a regulatory tool to enforce environmental standards. Other information may be available in the published scientific papers and on the News section of the website https://www.overseer.org.nz/our-news.
User support?	Website provide access to various information sources, including: Helpdesk service. Video Guides. Release notes. Best practice. Data Input Standards. Technical notes and technical manual chapters. Science papers and reports. OVERSEER news.
Other notes	“The model was not developed as a day-to-day management tool, nor was it developed to make fertiliser recommendations.” However reports are produced which could provide useful information e.g. a graph of N pools (i.e. changes over the calendar year to the soil N pool; for crop blocks - arable and vegetable, fruit, cut and carry systems; also shows changes to plant N, residue root N and residue stover N). Maintenance fertiliser nutrient (estimated fertiliser and lime rates for each nutrient, except N, to maintain soil test levels - pasture only). Relative yield (Predicted relative yield for each nutrient - pasture only).

NMPT 17 Farm Sustainability Tool for Nutrient Management (FaST)	
Provider/funder	European Commission: DG DEFIS with DG AGRI and DG DIGIT
Brief Description	Supported by the EC's DG DEFIS and DG DIGIT, the FaST mobile App and web-based tool aims to support the agronomic, economic and environmental performance of EU farms by providing information on nutrient (N, P and K) management via a user friendly interface
Main purpose	To support the agronomic, economic and environmental performance of farms by providing information on nutrient management. The main functions (for farmers and advisors) are nutrient (NPK) balances and assistance to develop an efficient and compliant NMP.
Links & references	https://fastplatform.eu/
Date of first release	FaST v1.0 released in 2021. FaST v1.0 available in participating countries - Spain (2 regions), Estonia and Italy (1 region).
Date of last update	FaST stage 2 is currently in progress; FaST stage 2 will expand the reach to Belgium (Wallonia), Bulgaria, Greece, Romania and Slovakia.
Planned future updates	?
Format/platform	Mobile app (iOS and Android versions) and web based tool
Available on	PC, Tablet & Mobile
Cost	Not clear. Documentation states that the tool will be "made available by Member States to farmers".
Intended user	Farmers, EU Member State Paying Agencies, farm advisors and researchers
Number of registered users	Not known. Currently only being used in (regions of) Spain, Italy and Estonia
Country of origin	EU
Relevance for NI	The rollout involves customisation of the FaST tool for different EU countries. Can be adapted for local specific requirements (adminstrative, agricultural and regulatory).
Geographical resolution	Field scale nutrient balances. Nutrient management plan at field and farm scale. GHG emissions and removals assessments are at the farm scale
Temporal resolution	Farmers can input multiple 'campaigns' which seem to be related to cropping years. Data inputs can be on a daily, seasonal or annual basis.
Data input requirements	Farmer entered information - sensible default values (overridable) provided to reduce the need for user inputs.
Data sources	As well as farmer inputs, has inbuilt databases for soils, surface waters, NVZs, Natura2000 areas, plant species, fertiliser products, legal N limits, custom maps. One of the key selling points is the integration of satellite data and services. The FaST platform also integrates multiple heterogeneous data sources from participating Member States
Data export	Fertilization plan can be downloaded by the user as a pdf (custom format for each algorithm) either at the parcel level or at the campaign level.

Data storage	Yes. The documentation states that farmers will have a record proving compliance with CAP.
Degree of user interaction/level of expertise required	Mock ups of the mobile App look very clear and simple to use.
Ease of interpretation	Mock ups of the mobile App look very clear and simple to use. "Fertilization advice is provided through a user-friendly interface"
Any user feedback/research on its use	None (publically) available. May be more information available for registered users.
User support?	A Quickstart guide is available for mobile App users and User Documentation can be accessed via an Administration Portal. Documentation for Paying Agency staff is also available - the Paying Agencies access the platform through a web portal, where they can, amongst other things, manage users and directly communicate with them. There is a ticket-based service desk.
Other notes	Need to register to get full access to documentation, trial the App etc.

NMPT 18 Mark Online	
Provider/funder	SEGES (Denmark)
Brief Description	The most widely used DST/ Farm Management Information System for fertilizer (N, P and K) and pesticide planning, optimization and documentation in Danish crop production. It covers all aspects of crop management including soil tillage and crop protection.
Main purpose	Farm fertilizer plans (for arable and grassland crops) to be directly used by farmers, and nutrient balances at both field and farm scales.
Links & references	Jens Bligaard, 2014. Mark Online, a Full Scale GIS-based Danish Farm Management Information System, Int. J. Food System Dynamics 5 (4), 190-195.
Date of first release	First version developed approx. 1991.
Date of last update	Updated when required - programs are updated automatically
Planned future updates	Updated when required - programs are updated automatically
Format/platform	Information is stored on a centralized Microsoft SQL database. Based on a MS .NET framework a number of multi-tier client-server applications have been developed. Most of the desk top applications are based on Win forms. HTML5 apps and Android/IOS native apps are used for the mobile platform.
Available on	PC, Tablet & Mobile
Cost	From 180 Euro per year. Free 2 month trial available.
Intended user	Farmers & Advisors
Number of registered users	Actively used on 2.2 m ha = 85 % of all land in DK (25,000 farms) by approx. 350 advisers and 2,500 farmers (Data from Nicholson et al., 2018)
Country of origin	Denmark
Relevance for NI	Agroclimatic conditions in DK are reasonably similar to NI, however cropping, fertiliser recommendation and legislation will be different. Based on legal pesticides, quotas for N application and minimum utilization of N in animal manure in DK. Not designed for use in other countries.
Geographical resolution	Field scale (outputs can be scaled up to farm level)
Temporal resolution	Daily and annual
Data input requirements	Field specific information on field size, soil type, crops, varieties, soil tillage, sowing, fertilization, pesticide usage, precipitation, prices. etc is held in a GIS based system.
Data sources	Based on 30 years of SEGES R&D and Landsforsøgene ® data
Data export	Fertiliser schedules and field maps can be printed as pdfs
Data storage	Yes. Field information can be copied from previous years and updated.
Degree of user interaction/level of expertise required	Difficult to assess from limited information available. Example of data entry screens seem relatively simple. Participating farmers in the FAIRWAY case study area liked the modular design and the possibility to compile useful management information within the software.
Ease of interpretation	Can be used by trained farmers and advisors. Feedback from the FAIRWAY Case Study in Lower Saxony was that it was complex and advisory assistance was needed.

Any user feedback/research on its use	Tested in real life on 80% of the farms and 100% reporting to the authorities. It was tested in Lower Saxony as part of a FAIRWAY Case Study.
User support?	A series of tuturials are available on the SEGES website. SEGES provide a 'customer centre'. A guide for field and fertiliser planning is available (in Danish). https://help-seges-dk.translate.goog/mark-online?_x_tr_sl=da&_x_tr_tl=en&_x_tr_hl=en&_x_tr_pto=sc
Other notes	Most information is only availble in Danish so it was difficult to fully assess this tool. Some information was taken from that provided to the FAIRWAY project by SEGES in 2018/19 and some from Bligaard (2014).

NMPT 19 CowVision (AgrroMineral)	
Provider/funder	AgroVision (Netherlands)
Brief Description	An online application platform providing an overview of a dairy farmer's business and opportunities for improvement. It comprises 5 modules namely, animal management (e.g. pedigree, milk production), feed (rations and feed calculation), minerals, soil and crops (fertiliser production and plan) and financial. AgroMineral is the module for mineral accounting to meet legal requirement.
Main purpose	AgroMineral provides a farmer with an overview of nutrient use in relation to current legislation. It can be expanded by using PhosphateMonitor to track annual P production and a Fertilser Planner and Manure Planner.
Links & references	https://www.agrovision.com/nl/producten/melkvee
Date of first release	Not known. Commerical software so presumably updated regularly.
Date of last update	Not known. Commerical software so presumably updated regularly.
Planned future updates	Not known. Commerical software so presumably updated regularly.
Format/platform	Software application platform; big data; data analytics; mobile app. Modules can be purchased separately or as the whole suite.
Available on	PC, Tablet & Mobile
Cost	Not Known
Intended user	Farmers
Number of registered users	Not known.
Country of origin	Netherlands
Relevance for NI	The software is available in 30 locations worldwide, so could probably be customised for NI.
Geographical resolution	Fertiliser advice per plot and per cut
Temporal resolution	Can access previous years data.
Data input requirements	Significant input data required, particularly if all modules are being used.
Data sources	Farmer data. Works with secured data from the Kringloopwijzer (a program available from Wageningen Livestock Research which charts mineral cycles for a specific company. Currently deals with N and P only)
Data export	Graphs show how much fertiliser should be applied and how much is available monthly.
Data storage	Yes.
Degree of user interaction/level of expertise required	Sample screenshots provided on the website look clear (although all in Dutch).
Ease of interpretation	Probably requires support from an advisor to interpret the results.
Any user feedback/research on its use	Not known
User support?	Not known
Other notes	Not very much information available online and much is in Dutch. A demo can be requested by calling a telephone number provided on the website

APPENDIX 3 EXAMPLE DETAILED NMP FROM PLANET

Example of the detailed NMP report (PDF format) produced by PLANET for two example fields (Long field: grass silage & Sunk field: maize).

Detailed nutrient application plan for 2023

PLANET NUTRIENT MANAGEMENT

Hill Farm
Hill Farm
Long Road
Littlehampton
Midlands
CV10 9LS

CPH number
Single Business Identifier

Annual rainfall (mm) 670

Long field

Crop type	Cropped area (ha)	Nutrient	Soil Index	Recommendations (kg/ha)			Planned fertiliser and lime applications (kg/ha)								
				Crop need	From manures	From fertilisers or lime	Aug-Sep	Oct-Dec	Jan-mid Feb	mid Feb-early Mar	mid Mar-early Apr	mid Apr-early May	mid May - early Jun	mid Jun-Jul	Total
		N	Mod	113	4	109				100					100
		P2O5	2	40	0	9				50					50
Defoliation 1: /	5.50	K2O	2-	80	0	70				50					50
		SO3		40		40				40					40
		Lime	6.1	0		0									

Crop type	Cropped area (ha)	Nutrient	Soil Index	Recommendations (kg/ha)			Planned fertiliser and lime applications (kg/ha)								
				Crop need	From manures	From fertilisers or lime	Aug-Sep	Oct-Dec	Jan-mid Feb	mid Feb-early Mar	mid Mar-early Apr	mid Apr-early May	mid May - early Jun	mid Jun-Jul	Total
		N	Mod	99	0	99					100				100
		P2O5	2	25	0	25									
Defoliation 2: /	5.50	K2O	2-	90	0	90					100				100
		SO3		40		40					40				40
		Lime	6.1												
		N	Mod	12	0	12									
		P2O5	2	0	0	0									
Defoliation 3: /	5.50	K2O	2-	60	0	60									
		SO3		0		0									
		Lime	6.1												

Cropping and soil details

Crop	Yield (t/ha)	Crop info 1	Crop info 2	Defoliation	Utilisation 1	Utilisation 2
Grass				1	Cut	Silage
Grass				2	Cut	Silage
Grass				3	Grazing	Beef Sheep

Soil type	Medium	Starting P balance (kg/ha)	+31
K releasing clay	No	Starting K balance (kg/ha)	+10
Sulphur deficient	Yes	SNS (kg/ha)	
Last soil analysis	05/02/2020	SNS Index	

Planned organic manures

Application date	Manure type	Application rate t/ha or m^3/ha	Applic method	Method of incorp	Delay to incorp	Total N (kg/ha)	Total Phosphate (P_2O_5) (kg/ha)	Available Phosphate (P_2O_5) (kg/ha)	Total Potash (as K_2O) (kg/ha)	Available Potash (as K_2O) (kg/ha)

Recommendations advice

The recommendations are based on providing home-grown forage to achieve growth rate targets of 0.95 kg/head/day (Intensively grazed), 0.85 kg/head/day (Moderately grazed) or 0.6 kg/head/day (Extensively grazed), depending on the use of concentrates fed through the winter housing season. If your system is markedly different from this, you may need to seek advice from a FACTS qualified adviser.

In mild areas and on land where early grazing is possible, nitrogen may be applied from early-mid February. In upland areas, apply from mid-late March. Typically apply N around one month before turn-out. Nitrogen for 1st cut could be split with 30-40 kg N/ha applied in February/March, and the balance in early April. In intensive grazing systems, application of N after mid August is usually not justified.

If grass growth is restricted due to drought, reduce or omit the use of N once growth restarts following rain. As a guide, if there is no growth for 2 weeks the annual grass yield may be reduced by 1 t/ha of dry matter and there will be about 40 kg/ha of unused N in the soil.

Cutting:- Apply potash for each cut but do not apply more than 80-90 kg/ha in spring; apply the balance in the previous autumn. In one and two cut systems, the recommendations for the last one or two defoliations include the extra 60 kg/ha as recommended in RB209 to balance the potash offtake during the season, or the extra 30 kg/ha recommended for three cut systems. This extra potash may alternatively be applied in the autumn after the last defoliation. No extra potash is needed for 4 cut systems.
Organic manures can supply some sulphur for crop uptake but probably insufficient to meet a significant crop sulphur requirement.
The lime recommendation may be higher in mixed grass/arable rotations (see the Fertiliser Manual). Grass/clover swards are less tolerant of soil acidity than all-grass swards. Lime may not be fully effective for some months.

NVZ warning messages – the planned application(s) may not comply with the following mandatory NVZ Action Programme rules

Sunk field

Crop type	Cropped area (ha)	Nutrient	Soil Index	Recommendations (kg/ha)			Planned fertiliser and lime applications (kg/ha)								
				Crop need	From manures	From fertilisers or lime	Aug-Sep	Oct-Dec	Jan-mid Feb	mid Feb-early Mar	mid Mar-early Apr	mid Apr-early May	mid May - early Jun	mid Jun-Jul	Total
For maize	12.00	N	2	50	37	13					50				50
		P2O5	1	85	24	66					25				25
		K2O	2+	145	128	0					25				25
		SO3													
		Lime	6.5	0		0									

Cropping and soil details

Crop	Yield (t/ha)	Crop info 1	Crop info 2	Defoliation	Utilisation 1	Utilisation 2
For maize	40.0					

Soil type	Medium	Starting P balance (kg/ha)	-5
K releasing clay	No	Starting K balance (kg/ha)	+343
Sulphur deficient	Yes	SNS (kg/ha)	
Last soil analysis	05/02/2020	SNS Index	

Planned organic manures

Application date	Manure type	Application rate t/ha or m³/ha	Applic method	Method of incorp	Delay to incorp	Total N (kg/ha)	Total Phosphate (P_2O_5) (kg/ha)	Available Phosphate (P_2O_5) (kg/ha)	Total Potash (as K_2O) (kg/ha)	Available Potash (as K_2O) (kg/ha)
01/03/2023	Cattle slurry	40	Band spreader - trailing hose	Not incorporated	Not Incorporated	104	48	24	128	115

Recommendations advice

Up to 10-15 kg N/ha may be placed below the seed at drilling and the balance top-dressed after emergence.
All of the phosphate may be placed below the seed at drilling.
The soil P Index is low/deficient.
Organic manures can supply some sulphur for crop uptake but probably insufficient to meet a significant crop sulphur requirement.
Lime may not be fully effective for some months. Apply well before growing sensitive crops.
The lime recommendation may be different in mixed grass/arable rotations (see the Fertiliser Manual).

NVZ warning messages – the planned application(s) may not comply with the following mandatory NVZ Action Programme rules

APPENDIX 4 EXAMPLE MANNER-NPK REPORT

Agrisearch

MANNER-NPK

Field name: Cow pasture	Grass
Postcode: BT26 6DR	Autumn crop N uptake: N/A
Average annual rainfall: 903 mm	Topsoil texture: Clay loam
Field in a NVZ	Subsoil texture: Clay loam
Comments:	

Application details

	Application 1
Manure type	Cattle slurry
Application date	15/02/2023
Application rate (t/ha or m^3/ha)	30
Application method	Band spreader - trailing shoe (short grass i.e. <=7cm)
Method of soil incorporation	Not incorporated
Delay to soil incorporation	Not incorporated
End of soil drainage	31/03/2023
Rainfall post application (mm)	102
Windspeed at application	Calm/gentle (0-3 Beaufort scale)
Rain within 6 hours of application (mm)	No rainfall within 6 hours of spreading
Topsoil moisture	Moist

Manure analysis

Application	DM (%)	Total N	NH_4-N	Uric acid-N	Nitrate-N	Total P_2O_5	Total K_2O	Total SO_3	Total MgO
		kg/t or kg/m^3							
App 1	6	2.6	1.2	0	0	1.2	3.2	0.7	0.6

MANNER-*NPK* Results

			Nitrogen losses (kg/ha)			Crop available N (kg/ha)			
Application	Total N (kg/ha)	Mineralised N (kg/ha)	Nitrate-N	Ammonia-N	Denitrified-N	Current grass crop	Next grass crop - current yr	Following crop year 2	N use efficiency (%)
App 1	78	0	5	7	2	22	3	1	32

Application	Total P_2O_5 (kg/ha)	Available P_2O_5 (kg/ha)	Total K_2O (kg/ha)	Available K_2O (kg/ha)	Total SO_3 (kg/ha)	Total MgO (kg/ha)
App 1	36	18	96	86	21	18

Potential financial value of all manure applications £109/ha

	Application 1
Crop available N (£/ha)	£23
Total P_2O_5 (£/ha)	£29
Total K_2O (£/ha)	£58
Grand total (£/ha)	**£109**

* Based on 90 p/kg N, 80 p/kg P_2O_5 & 60 p/kg K_2O