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Nutrient release from cover crops Task 2 and 3: Quick scoping review and evaluation of the cover crop decision support tools available internationally

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1. Abstract

The overall aim of this project is to collate and review all existing evidence to inform the feasibility of creating a Decision Support Tool (DST) to help UK farmers predict nutrient release following the use of cover crops and provide recommendations for future development of the tool. This report covers Tasks 2 and 3 of the project and focuses specifically on evaluating DSTs available internationally that are capable of informing the adjustments needed to allow for nutrient release from cover crops to optimise cash crop nutrient management. This included an assessment of their applicability to the UK (and potential data requirements), and any change in user behaviour from usage of the tool.

A search of peer reviewed and grey literature identified seven potential tools, three of which had a focus on cover crop species selection and one was a greenhouse gas accounting tool. The remaining three tools predicted nutrient supply from cover crops: MERCI, CC-NCALC and Organic Fertilizer and Cover Crop calculator (OFCC), and were shortlisted for an in-depth review of all available supporting literature, test runs (where appropriate) and in the case of MERCI and CC-NCALC an interview with the tools providers. A SWOT (Strengths, Weaknesses, Opportunities and Threats) analysis was performed on the findings, focusing on their potential for use as a cover crop DST in the UK.

MERCI and CC-NCALC are both web-based tools that predict nitrogen release following cover crops for use by farmers and growers, that are easy to use and freely available, with good guidance and support. MERCI was developed for use in France, but has been extended to a number of other neighbouring European countries, whereas CC-NCALC is an American tool. OFCC is a spreadsheet-based tool, downloadable from the providers website (Oregan State University), which although intuitive and potentially straight forward to adapt for use in the UK, was not considered to be sufficiently robust in terms of the underpinning algorithms or validations. By contrast, both MERCI and CC-NCALC were considered to provide outputs that could be used for nutrient management planning purposes, having evolved from a rigorous and comprehensive programme of research, development, validation and user testing over many years, and underpinned by reputable modelling frameworks (the STICS and CERES-N models, respectively). It would be both onerous and potentially unnecessary to replicate this effort to create a similar, bespoke tool for the UK, if required by the industry. Both tool providers were interested in expanding to other countries, and responded positively to potential collaboration to develop and host a UK based tool from their existing DSTs.

MERCI models cover cropping scenarios which are much more reflective of UK practice than CCNCALC, with more similar crops, soils and climate (particularly rainfall). It has greater functionality (e.g. predicts P, K, Mg and S supply and allows for grazing of cover crops) and

potential accuracy (e.g. accounts for leaching post-destruction), and does not require laboratory test results to complete calculations. There are features within CC-NCALC that would be beneficial to include within a UK tool, such as the ability to generate an N balance from user entry of the following crop's N requirement (not currently in MERCI). However, it is recommended that if a web-based DST predicting cover crop nutrient availability is required, that adaptation of the MERCI model is explored with the tools providers. As a minimum this would require the creation of an English version of the tool (i.e. a UK 'landing page', to avoid confusion translating web-pages) and a programme of testing and validation work conducted under UK conditions. Initially, this is likely to include cross referencing UK cover crop measurements with the MERCI measurements reference database (providing nutrient values (N, P, K, Mg, S), UFL (feed energy from crop), carbon content and dry matter content) to check for similarities and gaps and establishing which locations within the UK can potentially be mapped across to the French simulated location. This is expected to require multiple measurements for each variety of cover crop grown in the UK to ensure that data measurements represent the UK's differing soil types and growing systems, locations and seasons. Given the limited number of pre-existing UK studies (see Task 1 report), it is envisaged that a more long-term, large scale and potentially costly programme of in field measurements, testing and STICS modelling runs will be required for those regions and cover crop scenarios within the UK that cannot be matched to those already held within the MERCI simulations.

2. Introduction

Nutrient management planning (NMP) is fundamental to economic and environmentally sustainable farming systems by helping farmers match inputs of nutrients to crop demand which minimises losses to the environment, reduces costs and optimises crop production. Indeed, NMP is a requirement of the Farming Rules for Water (FRfW) in England, and farmers can now get support through the SFI to help produce an NMP (NUM1).

A number of NMP tools are available for use by farmers and advisors in the UK, ranging from simple paper-based guidance to online tools and mobile applications. These help farmers take account of the supply of nutrients from the soil and any organic manure applications when calculating how much manufactured fertiliser to 'top up' with to meet crop demand, but very few, if any, make allowance for nutrient supply from cover crops. Tools assessing nutrient supply from cover crops are available elsewhere in other countries, however no industry-recognised tool is currently available for use in the UK. It is also uncertain as to whether the resources required to build such a tool in the UK, and changes in NMP that it might recommend, would be justified, and whether there is an appetite amongst farmers to make use of it.

Of particular relevance when assessing impact from cover crops, is the amount and timing of nitrogen release from cover crop residues and how this influences the nitrogen (N) fertiliser requirement of the following cash crop and subsequent nitrate leaching losses. This is further complicated by the range of cover crop species mixes available to growers, the diversity of agroclimatic conditions across the country (e.g. soil types, cropping, weather) and different management practices adopted (e.g. sowing and destruction dates and methods).

The overall aim of this project is to collate and review all existing evidence to inform the feasibility of creating a Decision Support Tool (DST) to help UK farmers predict nutrient release following the use of cover crops and provide recommendations for future development of the tool. Task 1 collated the existing evidence available on the timing and amount of nutrient released from cover crops and the methodologies used to predict this (Lloyd et al. 2025). A number of field assessment methodologies to measure potential N release were identified (e.g. direct measurement of cover crop N residues, soil mineral N and crop sensors), as well as three modelling approaches, one of which (STICS model; INRAE, 2022) has been incorporated into a cover crop DST for use by farmers and advisors. This report covers Tasks 2 and 3 of the project and aimed to build on the Task 1 findings, focusing specifically on evaluating DSTs available internationally that are capable of informing the adjustments needed to allow for nutrient release from cover crops to optimise cash crop nutrient management. This included an assessment of their applicability to the UK, and any change in user behaviour from usage of the tool.

2.1. Objectives

Upon researching for Task 2, it was decided outputs for Task 3 were interlinked, therefore Task 2 and Task 3 have been reported together.

The overall objective of Task 2 was to identify and evaluate the Decision Support Tools (DSTs) currently available relating to cover crop management with a focus on those related to nutrient release. This included an evaluation of the accessibility and uptake of these tools and any barriers to their use. Task 2 also aimed to discern whether the output of these DSTs had resulted in any behaviour change by the user.

The aim of Task 3 was to evaluate the approaches and methodologies used in existing models to understand the data requirements for the creation of a dataset and DST for the UK. In particular to determine:

1. The input requirements of existing models and if this data is available for the UK? Are there any gaps where certain data for the UK is missing?

2. The methodologies used by existing models and would these be applicable in a UK context?

2.2. Definitions and scope

Decision support tools are available in a range of formats, including:

- Paper-based: written guidance 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' DSTs 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 DSTs in the form of a spreadsheet, online calculator, desk-based or web-based software application; paper guidance and workbooks were excluded.

3. Materials and methods

3.1. Selection of DSTs for review

A Quick Scoping Review (QSR) was carried out to gather evidence on the DSTs currently available on an international scale to answer the following research question:

> What decision support tools are currently available to farmers to provide guidance on the use, management and subsequent impact of cover crops on nutrient release in temperate climates?

Of interest was the name of the tool, the objectives and outputs of the tool (e.g. to support cover crop choice, to predict N release, etc.), country of origin and relevance to UK climate, the accuracy of the tool, the data/input requirements, any shortcomings, ease of use and current uptake.

The systematic searches were conducted in Web of Science and Google Scholar to obtain peer reviewed published literature using the following search terms:

UK countries:
Search Term(s): (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 (cover crop OR catch crop Or green manure*) AND (UK or United Kingdom OR Ireland OR England OR Wales OR Scotland)

Temperate climate:
Search Term(s): (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 (cover crop OR catch crop Or green manure*) AND (Temperate)

In addition to peer reviewed literature, a search was completed through Google.com and ChatGPT, searches included:

- Cover crop decision support tools in the UK
- Cover crop decision support tools worldwide
- Tools focused on nutrient release from cover crops
- What decision support tools are currently available to farmers to provide guidance on the use, management and subsequent impact of cover crops on nutrient release in temperate climates?

- (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 (cover crop OR catch crop Or green manure*) AND (UK or United Kingdom OR Ireland OR England OR Wales OR Scotland)

Results of the data searches are presented in Section 4.1 below.

3.2. Review methodology

Search results went through a first phase review to see whether the search result provided a tool that was appropriate for further research. From the search results a shortlist of tools was created, this was further refined by assessing the results against some simple questions:

- Is it a decision support tool?
- Does it focus on cover crops?
- Does it provided nitrogen release values?
- Is it relevant to UK climate/production?

An in-depth review of the refined list of tools was then conducted by completing a proforma template 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), the available tools and online tutorials and where necessary, by interviewing the tool holders.

See Appendix for the completed review proforma.

3.3. Interview with tool providers

In addition to reviewing published papers and guidance documents online, developers of two of the tools included in the review (MERCI and CC-NCALC) were approached for more detailed information. Online workshops were completed for both tools to discuss the capabilities of the model, the extent to which it is used by farmers and the feasibility of adapting it for UK conditions. Further information on these tools can be found in Sections 4.2.1 and 4.2.2.

3.4. SWOT analysis

Following in depth analysis of three tools (MERCI, CC-NCALC, Organic Fertilizer and Cover Crop calculator) a SWOT analysis was completed to provide a cross analysis of the tools to support conclusions of Tasks 2 and 3. The SWOT analysis focused on the Strengths, Weaknesses, Opportunities and Threats for each of the shortlisted tools providing a summary of the benefits, knowledge and data gaps and opportunities for uptake of each tool within the UK.

Table 1: Review proforma

Criteria	Sub criteria
Description	Provider
	Brief description
	Format/Platform (excel/desktop/web-based) & how is it hosted?
	Date of last update
	Frequency of updates
	Cost & availability
	Intended user
	Country of origin
	Number of registered users
	Author & references
Scope	Relevance for UK
	Main purpose
	Geographical resolution (farm/field)
	Temporal resolution (single season/multiple seasons)
Functionality - Ability to:	*Predict:*
	Timing and amount of nutrient release (N & other nutrients)
	Fertiliser replacement value (N & other nutrients)
	Account for:
	Different cover crop species/mixes
	Destruction methods
	Destruction timings
	N losses (leaching, gaseous emissions)
	Capture and *store* data over multiple seasons
	Produce reports to integrate into NMP
Ease of use	Ease of use / look and feel of the tool
	Degree of user interaction/level of expertise required
	Input requirements
	Data sources
	Output format
	Ease of interpretation
	Level of user support/guidance available?
	User feedback/research
Design	TRL (Technology Readiness Level)
	Is there a design specification
	What is the coding language

	Is the code available
	IP rights
Data/adaption for use in the UK	Details of databases that would need to be created and adaptations made for potential use in the UK
Notes/other information	

4. Results

4.1. Overview of cover crop DSTs & selection of tools to review

Journal article results from the searches on Web of Science and Google Scholar using the two search strings (UK countries and temperate climate focused) detailed in Section 2.1 are presented in Table 2. From the journal article searches three tools were selected for further review.

Table 2: Searches from Web of Science and Google Scholar

Search site	Search string focus	Number of results	Number of results shortlisted for further review
Web of science	UK countries	12	0
	Temperate	23	1 (MERCI)
Google Scholar	UK countries	17 reviewed from first 10 pages (16,800 results within search)	1 (CC-NCALC)
	Temperate	7 reviewed from first 10 pages (17,100 results within search)	1 (COMET-Farm)

In addition to peer reviewed literature a search was completed through Google.com and ChatGPT. Results from search phrases used are presented in Table 3. A summary of each shortlisted tools is shown in Table 4. The 'Organic Fertilizer and Cover Crop Calculator' is not included in either table 2 or 3 but was found when searching for further information on CC-NCALC.

Table 3: Searches from Google.com and ChatGPT

Search string	Number of results	Number of results shortlisted for further review
Cover crop decision support tools in the UK	3	1 (Cover Crops Guide)
Cover crop decision support tools worldwide	5 (note 4 results were from the same suite of tools provided by Precision Sustainable Agriculture)	0
Tools focused on nutrient release from cover crops	3	2 (CC-NCALC; AgroDiversity Toolbox)
What decision support tools are currently available to farmers to provide guidance on the use, management and subsequent impact of cover crops on nutrient release in	4	3 (CC-NCALC; Cover crop decision support tool; MERCI)

Search string	Number of results	Number of results shortlisted for further review
temperate climates?		
(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 (cover crop OR catch crop Or green manure*) AND (UK or United Kingdom OR Ireland OR England OR Wales OR Scotland)	3	1 (Best4Soil Decision Support Tool)

Table 4: Summary of shortlisted tools

Tool name	Details	Shortlisted for in-depth review?
MERCI	MERCI is a DST that estimates availability of nitrogen from a wide range of cover crops to the next cash crop. The tool reports nutrients from 74 cover crops and has already been successfully expanded to other European countries (France, Belgium, Switzerland and Luxembourg).	Yes
COMET-Farm	Web based greenhouse gas accounting DST for assessment of farming operations in the US. The tool includes four cover crops scenarios as a fertiliser mitigation option but does not provide nutrient management decisions.	No
AgroDiversity Toolbox (formally Oscar Cover Crop and Living Mulch Toolbox)	Interactive web tool allowing users to identify suitable cover crops for their region and requirements (e.g. biomass production, nutrient supply etc). The tool helps with species selection, but only gives basic information on nutrient supply capability of the species - low , moderate, high; does not help with subsequent nutrient management decisions.	No
Cover Crops Guide	An online guide providing UK farmers with comprehensive information for the successful adoption of cover cropping. It offers insights into different cover crop species, their benefits, and management practices. The tool has a cover crop selection, with nitrogen fixing and nutrient storing as options to select, showing the species that are good at fixing N and capturing nutrients, but nothing about release.	No
CC-NCALC	This tool estimates the N release from cover crops and its uptake by subsequent cash crops over time. It's one of four tools provided by Precision Sustainable Agriculture in conjunction with four regional cover crops councils in the US (Southern, Northeast, Midwest and Western). Other tools include a cover crop species selector, a cover crop economic decision support tool and a cover crop seeding rate calculator.	Yes
Best4Soil	Best4Soil is developing a decision support tool to guide crop rotation and cover crop selection. Growers can input previous and planned crops for a field and the tool will identify potential diseases and nematodes that could be carried over, offering advice on mitigation techniques. This	No

Tool name	Details	Shortlisted for in-depth review?
	resource aims to assist in planning effective crop rotations and cover cropping strategies. Best4Soil provides information on the host status and damage sensitivity of crops for a large number of nematode species and soilborne pathogens.	
Organic Fertilizer and Cover Crop calculator	Spreadsheet tool developed for farmers in Oregon to predict N supply from cover crops and organic manures. Provides tools for larger farms on a per acre basis and smaller farms/gardens on a 1000 square foot basis.	Yes

4.2. DSTs reviewed

Three tools were shortlisted for in depth review, by filling out information in the review proforma (Table 1). The tools included:

- MERCI (French web-based tool)
- CC-NCALC (US web-based tool)
- Organic fertilizer and cover crop calculator (US spreadsheet-based tool)

Further information on each of the tools is included below.

4.2.1. MERCI

About the tool

MERCI is a free to use web based calculator providing cover crop nutrient and carbon characteristics based on the cover crop species and management practices as well as the location, soil 'reserve' (water holding capacity) and soil type (textural group) of the field. It is optimised to run on a computer, but can also be used on a range of devices (mobile phones, tablets, e-readers). It was developed for use mainly by farmers and advisors and can be found at: https://methode-merci.fr/.

The MERCI method is based on the coupling between field measurements (MERCI reference matrix) of a large number of cover crop species and reference values obtained by simulation with the STICS crop model (INRAE, version 9.0) to estimate nitrogen returns.

It provides results for cover crop dry matter (t/ha), total 'trapped' nitrogen from above ground biomass and roots (kg/ha), carbon storage in the soil (t/ha), evolution of soil organic matter (t/ha), as well as nitrogen, phosphorus (P2O5), potassium (K2O), sulphur (SO3) and magnesium (MgO) in kg/ha released from the cover crops. The mineralized nitrogen (N kg/ha) is presented in 30 day periods from 30 days up to 180 days. For some crops the tool also calculates the valorisation of

cover crops as animal forage (Forage Unit For Lactation - UFL and Total Nitrogenous Matter - MAT (g/kg or kg/t)) and methanization (energy yield Nm3 of CH4/ha).

Tool history

Version 1 of the MERCI method was created as an excel model in 2009 by the Poitou-Charentes Regional Chamber of Agriculture. This first version was funded by the Loire-Bretagne and Adour-Garonne Water Agencies, the Poitou-Charentes Regional Council and France AgriMer.

In 2019, under the impetus of the Regional Chamber of Agriculture of Nouvelle-Aquitaine, a group of partners developed a new version of the MERCI method. The partners included Arvalis-Institut du Végétal, Bordeaux Sciences Agro, INRAE (UMR AGIR, Auzeville), the Chamber of Agriculture of Charente-Maritime and the Regional Chamber of Nouvelle Aquitaine. Version 2, was financed by CASDAR funds (Call for Projects ARPIDA 2018).

Improvements incorporated into version 2 included:

- Web-based application
- More cover crop species
- More precise and dynamic prediction of nitrogen (N) release
- Sulphur and magnesium
- Improvement in root estimates and partitioning of nutrients between root and shoot
- Estimation of forage value & methanogenic capacity & carbon storage
- Impact of export of residues
- Impact of not burying residues

Version 3 of the tool has just been published (March 2025) following further response from users adding:

- Additional cover crops species
- Adding dry biomass as a user input
- Optimising reporting
- Improving usability of the tool
- Adding grazing of cover crops as a method of destruction.
- Work is also currently under consideration to estimate aboveground biomass using satellite images.

How the tool works

MERCI is comprised of a large experimental database from France using the soil-crop model STICS to complete simulation experiments, these simulations experiments were used to create a background dataset which responds to inputs to the tool website; STICs simulations are not run

live through use of the tool. STICS is a soil-plant simulation mechanistic model which was developed at INRA, France in 1996. STICS simulates crop functioning at a daily time step at the field scale for an average plant, with input variables related to climate, soil and crop management. It simulates crop growth as well as soil water and nitrogen balances and is driven by daily climatic data (Brisson et al., 2003). It calculates both agricultural variables (yield, input consumption) and environmental variables (water and nitrogen losses). Residue decomposition in soil is simulated using three pools: fresh organic matter, microbial biomass and humified organic matter (which is divided into an active and an inert fraction). Nitrogen (and carbon) fluxes between these pools depend on their C:N ratio, soil temperature and water content (Nicolardot et al., 2001; Constantin et al., 2012).

Through a literature review of data from laboratory and in-field experiments in France, more than 16,000 measurements of 74 species of cover crops were collected to provide nutrient and dry matter characteristics. Using this data simulations were run through STICs to provide percentage of the nutrients mineralised and leached. STICS does not contain all the species of cover crops included within the MERCI model, therefore cover crops were characterised by their biomass and C:N ratio.

Simulations were run on nine dates of cover crop destruction, on each date the C:N ratio was different. It was found that location (temperature and soil type) of the cover crop within France had minimal impact on percentage of N mineralized, in comparison to the destruction date and outcome of the destroyed crops (e.g. incorporated or left on the surface), however percentage leached was sensitive to rainfall. Linear regression models, at the species, family or entire-database level depending on the data available, were built to predict dry biomass, nitrogen (N) amount and carbon (C):N ratio.

The ‘Intermediate Crop Return Estimation Method’ was configured and validated in 2020 across mainland France. A median climate was taken into account to calculate the risks of nitrogen leaching following the destruction of plant cover and thus make it possible to estimate nitrogen returns to the soil for 24 climatic stations distributed across metropolitan France. These simulations were carried out over 20 years (2006-2026) using the RCP8.5 scenario (http://www.drias-climat.fr/). The "soil" parameters, necessary for the simulations, were defined from the French soil database at 1:1,000,000 (INRAE Infosol Orléans).

Dynamics of N mineralized and leaching from cover crop residues were predicted for the 24 contrasting sites as a function of the biomass, C:N ratio and termination date. This is based on a mass balance equation (Figure 1).

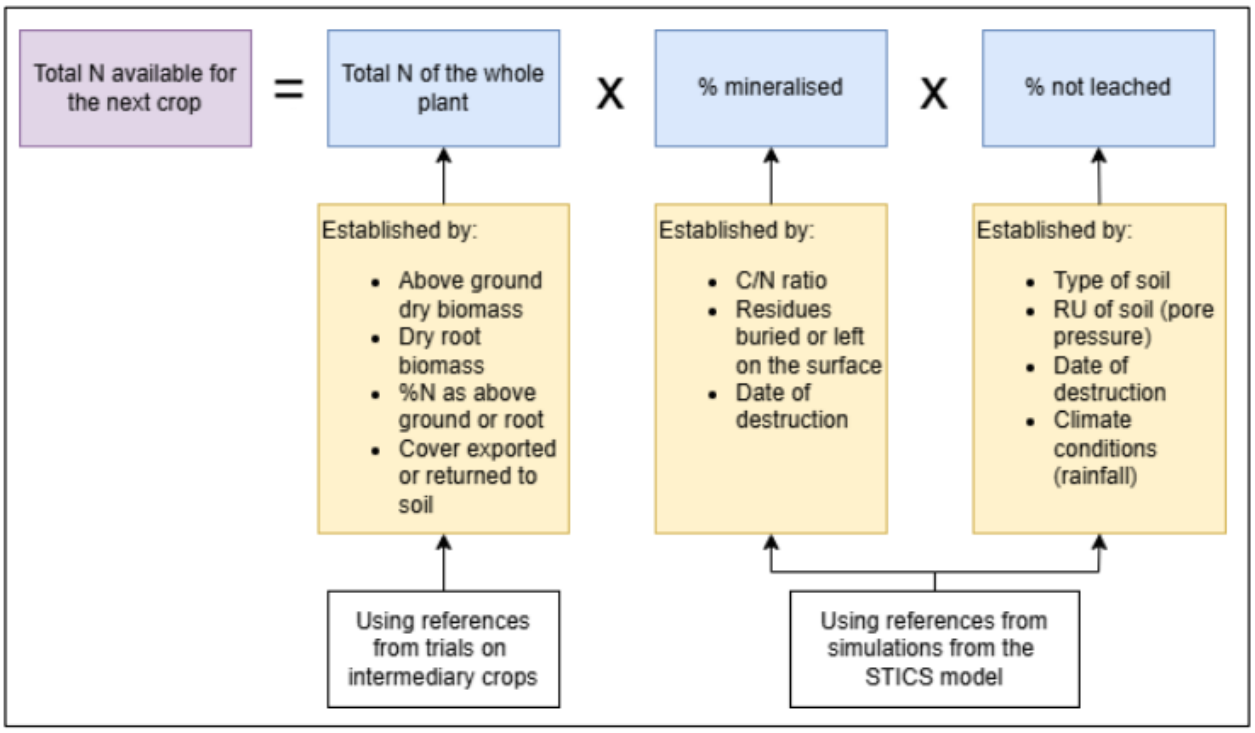


Figure 1: Nitrogen calculation methods for the MERCI model

Tool testing

A review was completed by Constantin et al. (2024) to assess their MERCI tool. Correlations between fresh biomass, dry biomass and N amounts in experimental data were strong (r = 0.80-0.96), and predicted N amounts in fresh shoot biomass were relatively accurate. Percentages of N mineralized and leached simulated by STICS were explained mainly by the C:N ratio, site and number of months after termination, but to different degrees.

The MERCI team stated that 15 trials recently run to assess the impact to yield from fertiliser reductions predicted by the MERCI model (on average 55kg N/ha reduction), observed no yield impacts, with a slight increase to yield in maize crops(interview conducted 25/2/25; Minette & Jordan-Meille, pers. Comm). One trial on sunflower fields showed no impact to yield following advice to remove additional fertiliser N input.

The MERCI team has plans for 20 trials a year to validate recommendations from the model.

User response

Minette (2021) stated that during a review of the original V1 model (from 600 users identified in metropolitan France in November 2019) they found that:

- The main advantage of the method for 85% of users being the ability to instantly obtain data on their plant cover.

- The calculation principles of the method were well understood by users and implementation in the field was considered simple and easy.
- The sampling time is, on average, 40-45 minutes for one plot. This was considered ‘fair’ by the majority of users, even if they recognized that this restrictive step was necessary and that no other method exists to date, especially for cover crops composed of several species. Note, to collect measurements for tool input it is advised to take samples on a dry day or with driedout cover, cuttings are then weighed by separate species and reported in grams.
- With a score of 7.1 (on a scale of 1 to 10), the results from the MERCI method are generally perceived as reliable by users. However, when questioning users, the vast majority considered that the results were very reliable for estimating the biomass produced and for the quantities of nitrogen, phosphorus and potassium trapped by the cover crop.
- Users were less unanimous on the reliability of the nitrogen, phosphorus and potassium return values indicated by the method, considering these values to be too high and fearing a drop in yield on the next crop (79% of users).
- The investigation revealed a lack of knowledge of the areas of validity of the MERCI 1 method (valid only for a period of destruction before February and buried residues).
- Only 16% of users integrated MERCI model results into their nutrient balance calculations. Users indicated that phosphorus and potassium releases from residues from the plant cover seemed too high, which could explain why they were only partially taken into account. The MERCI method is changing fertilisation management practices, but many users preferred to "play it safe" and integrate, for the time being, only a part of the values predicted by the method

Following feedback on the V1 method, and taking into account the changes in how cover crops are managed (e.g. remain on the field for longer, diversification of species, quais-systematic mixing) the new V2 calculator was developed to incorporate recent references on cover crops and improve areas based on user expectations.

A recent survey on use of V2 in 2024 has recently been published in the tool library (Sorel, 2024), reporting results from two surveys with 603 respondents in total, of which 3% were from outside of France. The survey found the following:

- 23% of users have been using the tool for more than 5 years, 35% were recent users of under 2 years. The main source of dissemination of the tool was through word of mouth.
- Generally, feedback around the tool was very positive:
    - 98-99% had complete to moderate confidence in the results calculated by MERCI (N, P and K results all achieved a similar level of confidence).

    - 95% were satisfied with the result formats provided. 86% easily understood the results.
    - 92% found the calculator interface easy to very easy to use.
    - 95% were willing to fill in additional fields to use the calculator and improve its functionality.
    - 98.5% were satisfied with the current MERCI interface.
- 82% of respondents performed less than 15 calculations a year.
- The majority of respondents stated that the tool was a popular method for estimating rapid nitrogen releases and just under 500 respondents used the tool to understand aboveground biomass produced by plant cover. Around two thirds of respondents also used the tool for P, K, S, Mg returns; carbon and organic matter; and the nitrogen release dynamics timeline.
- 54% of users synthesised the results through a PDF report, 27% on screen and 19% through a detailed excel file.
- Usage of the FAQ (used by 36% of respondents) and library page (used by 29% of respondents) was limited.
- The majority of respondents found sampling to be quick and easy, with the majority adhering the MERCI method guidelines.
- It was found that 73% of respondents took some samples with water on the plants which could provide a moderate to high risk of overestimation in some calculations. The document stated that sampling in humid conditions overestimates aboveground biomass by 15% to 45%. It is noted that Version 3 of the tool allows for dry biomass as a user input.
- Despite the confidence in the tool, only 62% of respondents stated that they strongly or partially trust the nitrogen fertilisation results, with 23% not taking the nitrogen release value into account when completing fertiliser requirement calculations for the next crop (Figure 2). Confidence in phosphorus and potassium results were lower than nitrogen results.
- To improve the consideration of nitrogen returns for fertilizing the following cash crop, "simple" trials will be conducted by the MERCI team on the following crop with one strip incorporating the value predicted by MERCI.

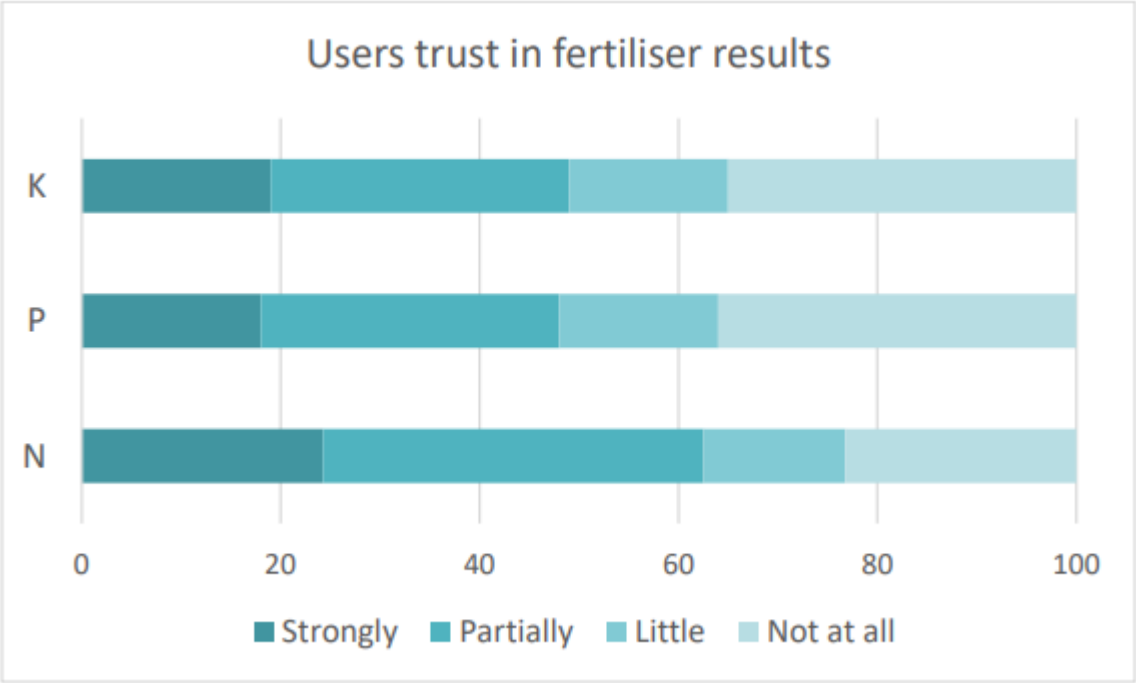


Figure 2: Confidence in N, P and K fertiliser results from the MERCI model as stated by respondents to the 2024 user survey.

User uptake

During a review of the tool over 600 users were identified in metropolitan France in November 2019. They stated that 'according to the testimonies of users, the number of beneficiaries is greatly underestimated. Many users know colleagues and/or farmers who use the method but who have not been listed', and that users of the tool not using a registered account are hard to identify (Minette, 2021).

Of the 600 tool users 28% were farmers and 63% were advisors. The tool has been implemented in various organisations (Chamber of Agriculture, Trade, Water Unions, etc.) and is being used in both conventional and organic farms (Minette, 2021).

During the workshop with the MERCI team they stated that more recently a survey of 4000 tool users was completed, of the farmers using the tool (around a third surveyed), 20% were fully using the results/advice from the model to adjust their field fertilisation (Minette, pers. comm.). It is possible that the number of users adopting the advice from the tool is higher, however the tool developers also noted that they had found farmers to be sensitive to nitrogen fertilisation meaning they were hesitant to reduce the amount of N applied. With some farmers continuing to apply fertiliser at the normal rate with the N retained from the cover crops assumed to be 'free N' to allow them to attain higher yields.

Some farmers are also using the carbon results from the tool to help understand their carbon balances from cover crops.

Using the tool

The tool is hosted on a French website: https://methode-merci.fr/calculateur. It is presented in French with no option within the webpage to translate the page to English, although dependent on the browser used this can translate the tool for you.

The tool is free for users to access, however to use the full features, including the ability to print the results page, and to save and export the results in a personal portal, users must register for a free account.

The calculator website includes a Frequently Asked Questions (https://methode-merci.fr/foire-aux-questions) section which provides further information on the MERCI method, field sampling methods, performing a calculation using the tool, interpretation of the results and references on plant cover. A library of resources (https://methode-merci.fr/bibliotheque) is also included providing tutorials (videos and PDF format), method documents and a summary of calculations completed as well as further information on cover crops. It is noted that the supplementary information and videos are provided in French.

The tool is simple to use with clearly defined user entry requirements, see Figure 3 for the user input screen. Users can input real farm data to understand the impact of the planted cover crops or simulation data which pulls from predefined model simulations allowing the user to assess different planting scenarios.

Users select the country of use and the municipality if the tool is used for French locations. Note that other countries included in the calculator (Belgium, Luxembourg and Switzerland) have not had simulations completed and as such the results are based on the most closely matched French pedoclimate dependent on the soil type selected. Related French simulation locations used are:

- Belgium: North; Pas de Calais; Ardennes
- Luxembourg: Moselle; Meurthe and Moselle
- Switzerland: Savoie; Haute Savoie

The country/municipality sets the ‘soil type’ drop down which is a dynamic list based on location selected, see Figure 4 for an example.

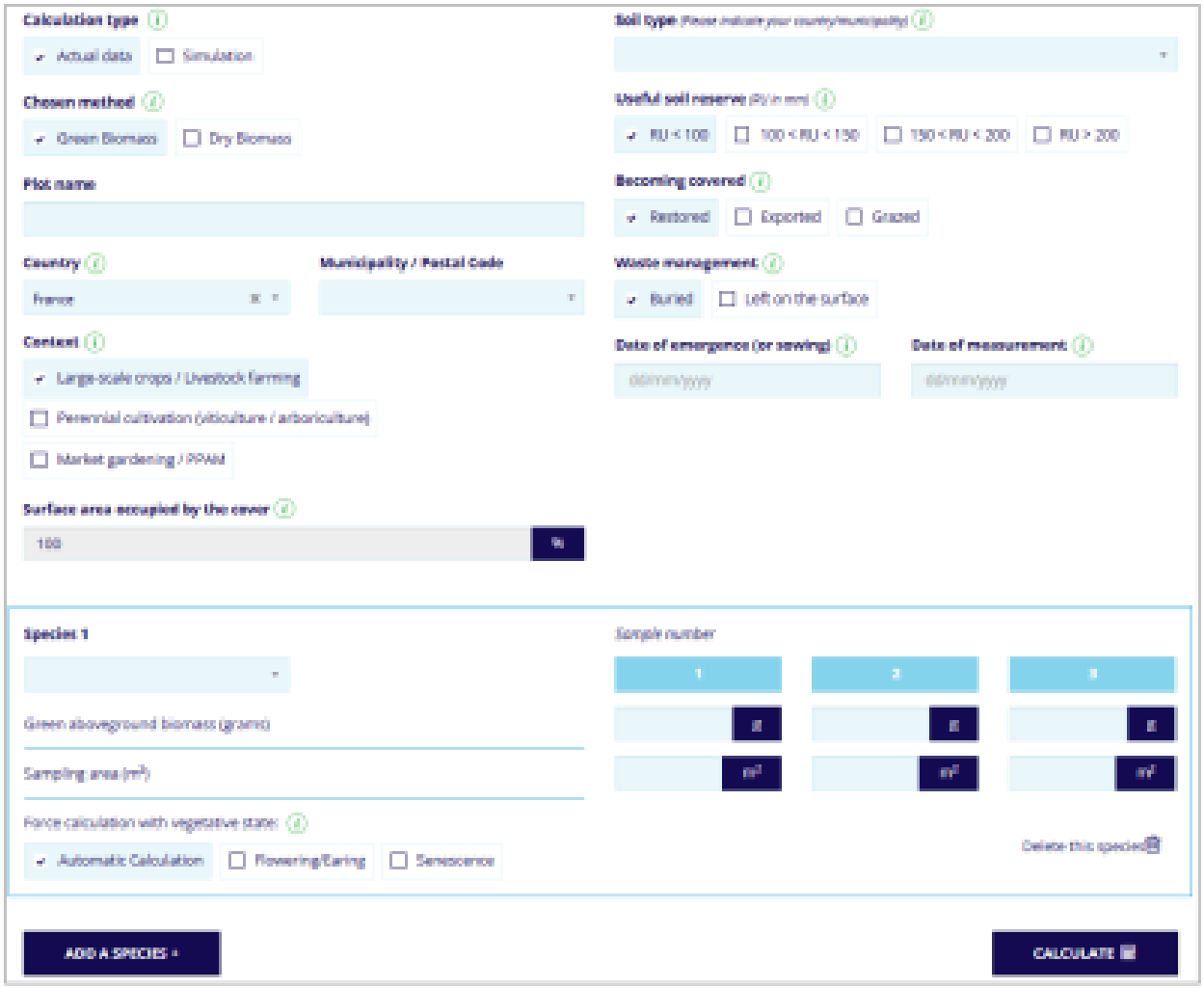


Figure 3: MERCI calculator input page

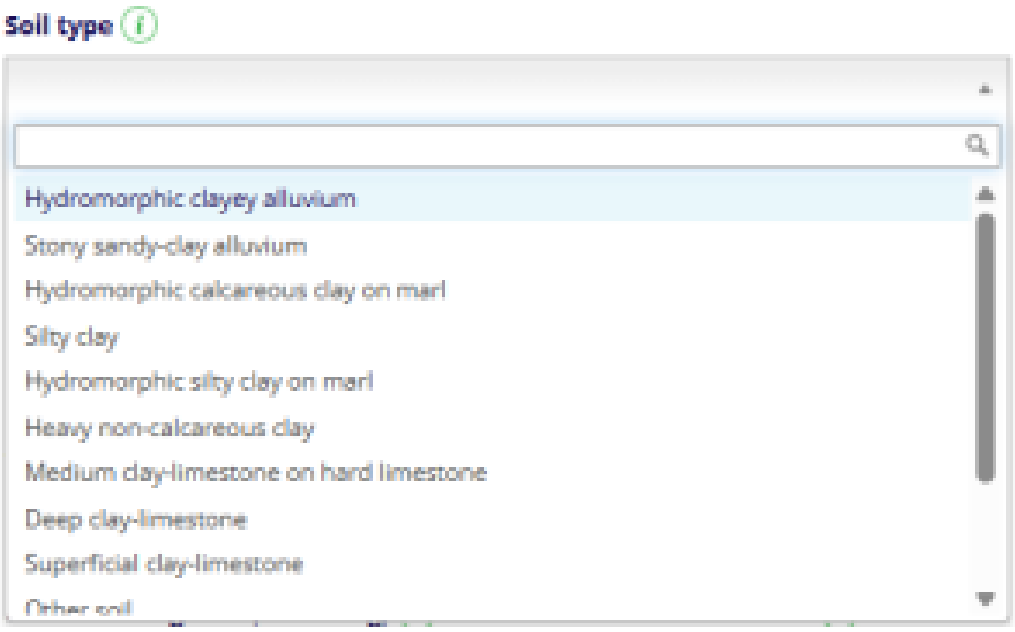


Figure 4: MERCI calculator dynamic soil type selection

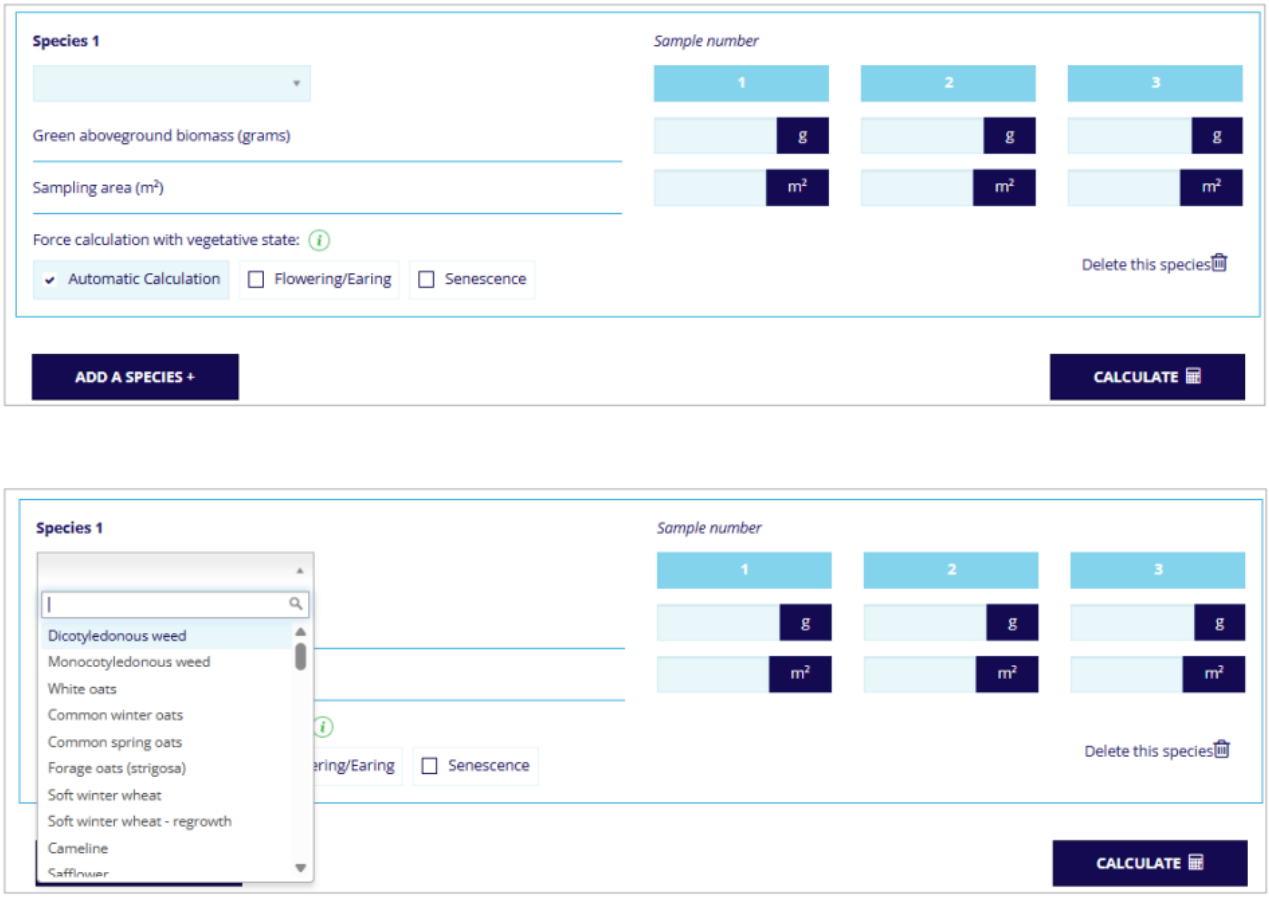


Figure 5: MERCI calculator species input section (top) and showing the cover crop species list (bottom)

UK requirements

The MERCI team are keen for an expansion of the tool to other countries and have stated that benefits would be achieved for the MERCI creators through the increased dataset of cover crops and simulated model runs. They state that the tool is funded by the French public and would be free for UK users to use. Due to licensing in place the tool (databases and equations) cannot be copied but the team are happy for the tool to evolve using the MERCI name and website.

The tool website and the information pages (Frequently Asked Questions and Library) are all provided in French. There is currently no option to translate the tool within the website and as such work would need to be completed to provide an English language version of the tool and its supplementary information.

The MERCI creators have suggested that for southern regions of the UK a similar approach could potentially be adopted to other countries using the tool i.e. utilising the most closely matched French pedoclimate dependent on the soil type selected. However, this is unlikely to be accurate for more northern regions of the UK, so to fully adapt the tool for the UK, the STICS model (or a similar model that would produce C:N ratio and N loss through leaching) would need to be run for each area considered to have different rainfall, e.g. at a minimum north, south, east, west. Monthly

results would need to be calculated to align with the MERCI tool inputs. The MERCI team have suggested that they could provide assistance for the calculation stage, such as having a UK modeller shadow the MERCI modelling team. The calculations stage was suggested to take around 2-3 years for the latest version 3 model.

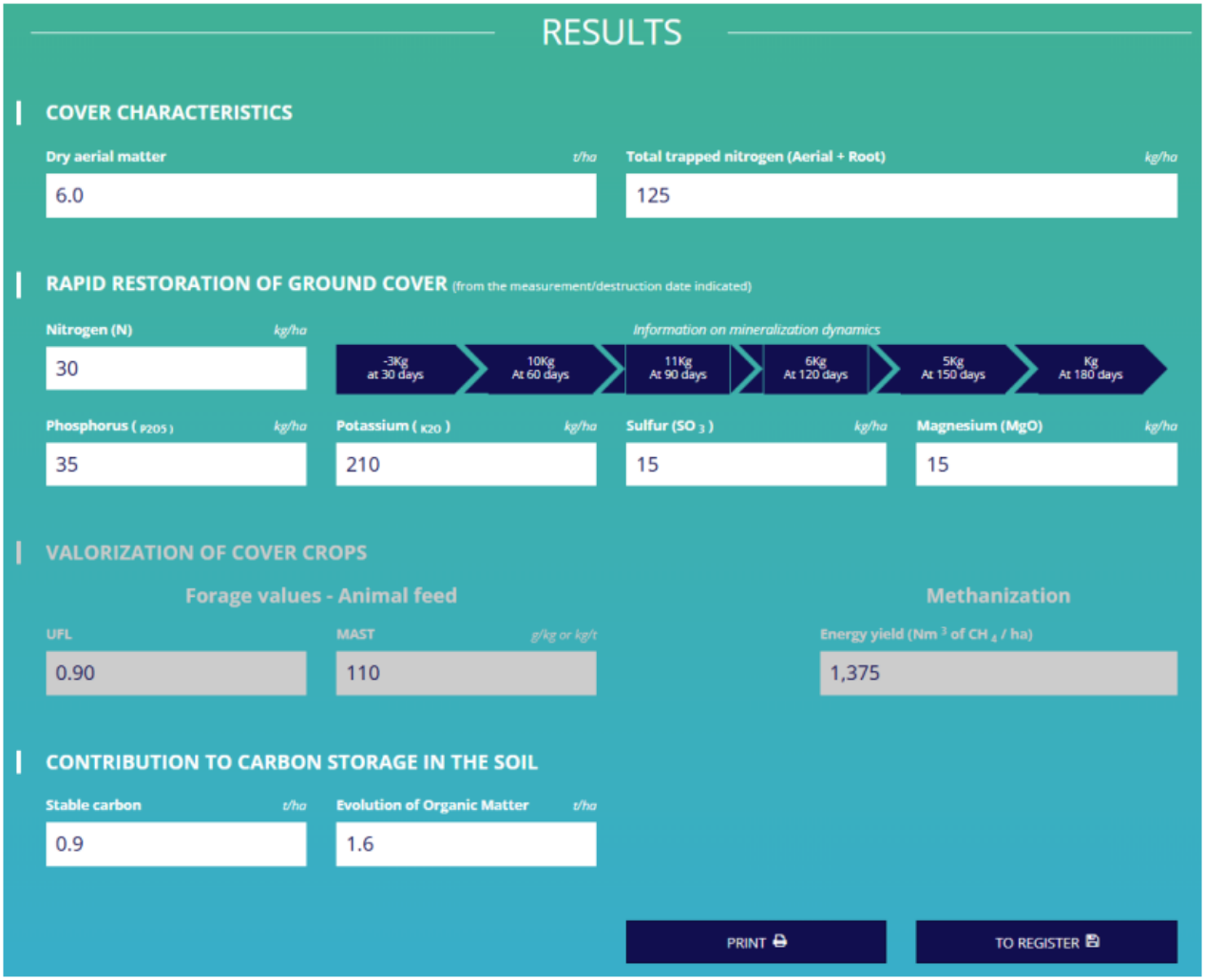


Figure 6: MERCI calculator results page

A crop database would also need to be constructed using measured data (e.g. field trials, laboratory analysis) of cover crops, providing nutrient values (N, P, K, Mg, S), UFL (feed energy from crop), carbon content and dry matter content. The MERCI cover crop database currently contains over 16,000 rows of cover crop data. There is the potential to compare UK cover crop values to those included in the MERCI database to see if the French values are applicable for UK use, allowing for potential reductions to the collection of cover crop data. However, it is expected that UK measurements would need to be undertaken, which would require multiple measurements (expected to be double digits and above) for each variety of cover crop grown in the UK to ensure that data measurements represent the UK's differing soil types and growing systems, locations and seasons.

To replicate the French database in full with UK data would require a considerable amount of measurement data. Cover crop measurements could be attained through existing literature, field trials, laboratory trials or through a 'Citizen Science' approach where growers of cover crops could submit measurements on the cover crops they have grown. Given the limited number of pre-existing UK studies (see Task 1 report), it is envisaged that a more long-term, large scale and potentially costly programme of in field measurements, testing and STICS modelling runs will be required for those regions and cover crop scenarios within the UK that cannot be matched to those already held within the MERCI simulations.

4.2.2. CC-NCALC

About the tool

The cover crop N calculator (CC-NCALC) is a free-to-use, open-source, web-based application which estimates how much nitrogen a cover crop will release and how much is available for the following crop in order to offset N fertiliser inputs. It is one of a suite of cover crop DSTs provided by Precision Sustainable Agriculture in collaboration with four regional cover crop councils in the United States. The tool is intended to be used by farmers and their advisors and shows how much N a cover crop will release and how much the following cash crop will take up over time. It can be found at https://covercrop-ncalc.org/.

Tool history

The N calculator is adapted from the original CERES-N (N subroutine of the Crop Environment REsource Synthesis) sub-model (Quemada and Cabrera, 1995). The CERES suite of models are process-based models which simulate the whole crop-soil system, including N transformations. Woodruff et al. (2018) adapted the CERES-N subroutine into a web-based calculator, linking it to weather station data and specific cover crop chemistry, calibrating it using published mineralisation studies and validating it using field studies investigating the decomposition of surface applied or incorporated crimson clover or rye residues over a three year period. Gaskin et al. (2020) also reported on a number of advances to the calculator to make it more practical for use by farmers, including the use of Near Infrared Reflectance Spectroscopy (NIRS) results to predict the cover crop quality parameters required to run the model, and linkage to automated weather stations.

The interview with the tool providers found that they are currently working on adding a geospatial element to the tool, enabling users to avoid the need for biomass sampling and linking the tool output directly to precision fertiliser spreading equipment (pers. Comm. S. Mersky, USDA & A. Smith, North Carolina State University). This new phase is developing and testing a 3-D species mapping tool ('PlantMap3D) which will map cover crop species mixtures in real time, using image recognition software and scanning techniques to determine the species present and biomass, which together with databases of cover properties (look up tables of %N content & NIRS

predictions) can be directly inputted into the calculator to create a map of cover crop N supply for use on variable N rate spreaders. The imaging software is being tested across the USA both manually (low cost cameras) and automatically (tractor mounted devices) in 2025, with the aim of rolling it out at scale during 2026 and having a commercial product released in 2027.

Note that the current version of the tool online predicts N release from surface applied residues only; the version which also predicts N release from incorporated residues has yet to be released online.

How the tool works

The CERES-N subroutine underpins the calculator. This sub-routine simulates soil N transformations, including mineralization, immobilization, nitrification, and denitrification. The mineralization and immobilization subroutine simulates the decay of two types of organic matter: Fresh organic matter (FOM) and humus (HUM). The calculator uses the FOM simulation to estimate N release. Here, FOM is divided into three pools: carbohydrate, cellulose and lignin, split by default 20%, 70% and 10%, respectively, although the user can change these either with their own direct analyses or from NIRS predictions based on the residue N content. The three pools decompose simultaneously, each one having a decay rate constant under nonlimiting conditions (Quemada & Cabrera, 1995); these are: 0.14, 0.00255 exp(−12*lignin content), and 0.00095 day−1, for the carbohydrate, cellulose and lignin respectively (Gaskin et al., 2020). The decay rates are then modified by soil water content, temperature, and C:N ratio of the residue. Depending on residue placement (surface or soil- incorporated), the calculator uses soil moisture and soil temperature (for incorporated residues) or residue water potential (i.e. the energy required to extract water from a residue) and air temperature (for surface residues) to adjust decomposition rates. Five year average daily soil moisture and temperature from local weather stations are used to predict the daily release of N from each pool which is calculated as the product of the modified decay rate multiplied by the size of the pool. The model assumes that 25% of the N mineralized is incorporated into HUM pool when the residue is incorporated or 12.5% when the residues is left on the soil surface (Gaskin et al., 2020), the rest enters the soil inorganic pool and could be available to be taken up by plants. Note, the tool does not take into account of the onward fate of N such as N loss via leaching following destruction. The predicted available N only includes N mineralised from above ground cover crop biomass and does not include N mineralised from the roots or inherent soil organic matter. The tool only predicts cover crop N supply, not any other nutrients.

Tool testing

Initial testing of the calculator by Woodruff et al. (2018) using both lab and field studies measuring changes in soil mineral N indicated that the model simulations for incorporated residues were ‘acceptable’, but that the model tended to over-predict N mineralized from surface residues, stating

that this was most likely due to the use of soil temperature and water content. The model has since been adapted to use residue water potential and air temperature for surface residues. There has also been a considerable number of studies evaluating the underpinning CERES model, with many suggesting that the model did not simulate N dynamics particularly well, although most of this work was conducted over 20 years ago before the web-based calculator was developed (e.g. Hasegawa et al., 1999, 2000; Schomberg & Cabrera, 2001; Nain & Kersebaum, 2007).

The team currently working on the tool (S. Mersky, USDA & A. Smith, North Carolina State University) stated that the underpinning algorithms and final tool has been derived from 'decades of research', including laboratory incubation studies, decomposition studies in the field using litter bags and on-farm calibration and validation with farmers. A number of papers have been published from these studies e.g. Thapa et al., (2022, 2023). However, the literature search undertaken for this report only found one published study which directly evaluated the calculator's prediction of N availability to the following crop (or 'N credit') in terms of its nitrogen fertiliser replacement value (NFRV) and impact on crop yield (Gaskin et al., 2020). Here, the N credit from a summer cover crop (cowpeas) ahead of autumn-sown broccoli was evaluated at one site in south eastern USA for three consecutive years and a second site for 2 consecutive years; at a third site Sunn hemp (a legume) was used as the cover crop for two consecutive years. The cover crops were mown and incorporated and a N response experiment was used to predict the N supply from the cover crop for comparison with the calculator's predictions. The results were variable, whereby in one season the calculator underestimated (by c. 30 kg/ha) the average N credit (or NFRV) and in another it over-estimated it (by c. 20 kg/ha). However, the authors reported that measured NFRVs (i.e. from the N response curves) were 'within the range' of the predicted N credits in both seasons and there was no significant difference in yield between no cover crop and cover crop treatments where N rates had been adjusted using the calculator. The discrepancies in predicted N supply were attributed to the contribution of N mineralised from the roots or soil organic matter and differences in actual weather conditions compared to the 5 year averages used by the model. Gaskin et al. (2020) also commented that a potential 'drawback' to the approach was the need for field measurement of cover crop dry biomass.

User response and uptake

The calculator has been user tested across multiple states and although the tool providers indicate it has been well received, the need for taking a biomass sample has caused some reluctance to use the tool, and farmers do not necessarily 'trust' the results to make an adjustment to their fertiliser application rates (S. Mersky, pers. comm.). The new phase of work aims to remove the need for taking a biomass sample and, by funding farmers to use the tool, build confidence in its use (i.e. that they will not suffer a yield penalty by adjusting N applications in line with the tool's output).

Using the tool

The tool is hosted on an American website: https://covercrop-ncalc.org/, which is free for users to access. Any information entered into the tool is stored on the users own computer (and not uploaded onto a server). The tool is intuitive and simple to use with clearly defined user entry requirements (Figure 7).

Figure 7: CC-NCALC home page

Users are taken through a series of tabs (Figure 8) and asked to input the following data detailing:

- Field location (enter address or zip code and select field from satellite map of the location - fields in the USA only). Fields can be named at this point (for future reference). The calculator uses this location to access: daily soil moisture and soil temperature from 'Iteris' (a Soil Conditions API developed by 'ClearAg' – this API suggests it can provide endpoints for any location in the world); hourly weather data (air relative humidity, air temperature, and rain) from a weather API (specific to North America); and soils data (see below). Note the calculator uses real-time weather data and where this isn't available, 5 year historical averages.
- Soil – the tool uses the location selected in the previous step to 'pull' data on local soil properties (organic matter, bulk density & inorganic N in the top 10cm) from the NRCS's Soil Survey Geographic database (SSURGO). These can be over-written by the user if they have their own soil analyses.
- Cover crop - the user can select from up to 36 different cover crop species and add multiple species to create a mix from a drop down list. A termination date for the cover crops should be given, as well the dry biomass and (optionally) the fresh biomass and cover crop water content at termination. A second screen on the cover crop tab then asks for details of the cover crop quality. As a minimum the user is required to enter the N content. The

carbohydrate, holo-cellulose and lignin are then pre-populated which the user can adjust if they have their own analyses.

- Cash crop - the following cash crop is then selected from a very long list which includes flowers, herbs, turf, nursery stock, vines and trees as well as arable crops – all tailored to those used in USA rotations. A planting date and target N rate should also be entered. Finally the expected N fertiliser rate for the cash crop is inputted (to enable the user to see how much of this could potentially be supplied from the cover crop).

Data can be 'saved' under different field names and selected from a drop down list the next time the tool is used. This data is stored on the users own web-browser's cache, so if this is cleared then the data will be lost.

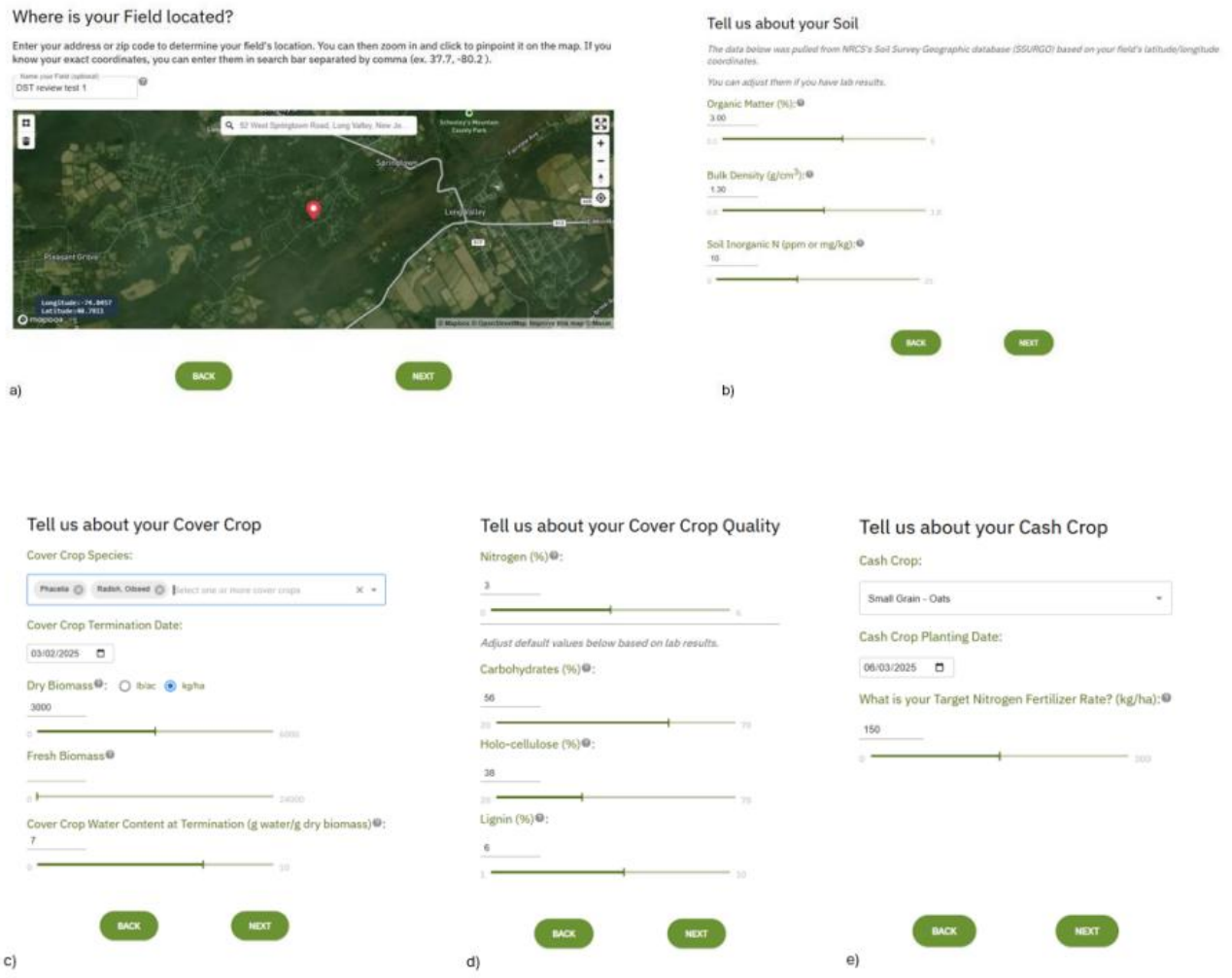


Figure 8: CC-NCALC data input screens: a) field location; b) soil details; c) & d) cover crop details; e) cash crop details. Note most of the inputs have ? beside them giving guidance on what is required.

The output is simple to interpret (Figure 9). As well as showing the total N available from the cover crop for the next cash crop ('N credit') on a bar chart, users can hover their mouse across different dates on the graph and see the N released at that point in time and change the number of weeks to find the cumulative N released over different periods of time. For example, in Figure 9, a change from 4 weeks to 8 weeks increased the cumulative N release from 4 to 11 kg/ha.

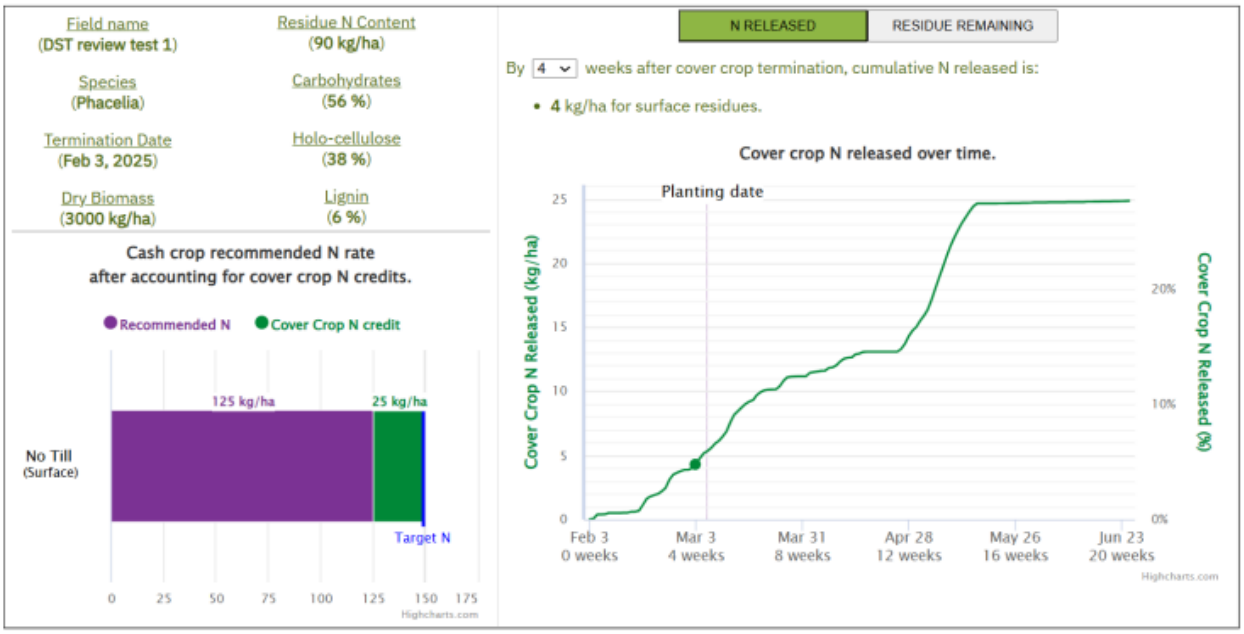


Figure 9: Typical CC-NCALC output (test run had a phacelia and oil radish cover crop terminated in February followed by spring oats with an N recommendation of 150 kg/ha).

A number of alternative output views are available, including a graph of the residue remaining (Figure 10), and more detail (generated by clicking on 'advanced') on the various fractions, decay rates and adjustments (Figure 11).

Figure 10: Additional CC-NCALC output detailing the amount of residue remaining.

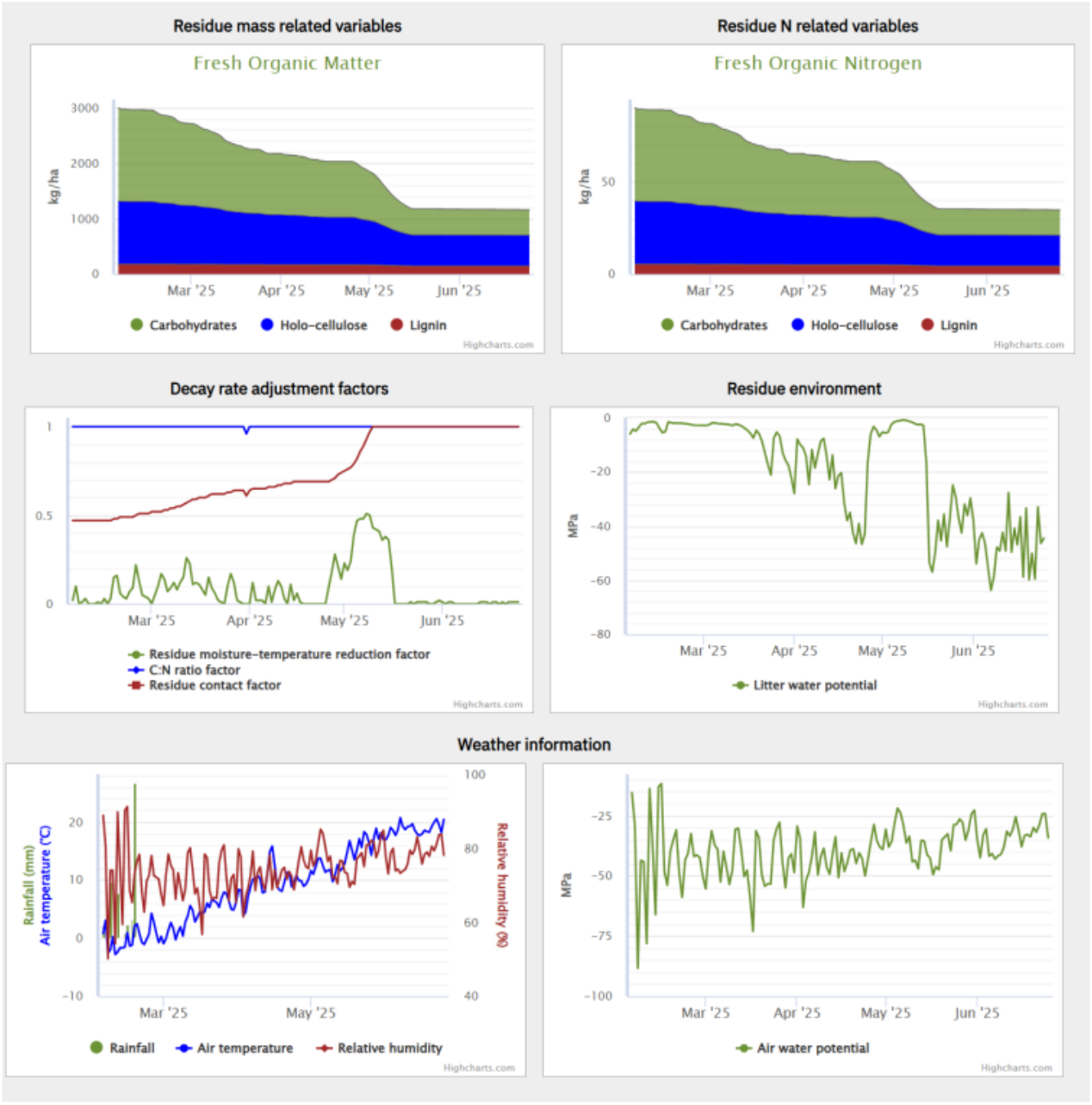


Figure 11: CC-NCALC 'Advanced' output

The tool does not provide a printout of results or results in an exportable format, instead users would be required to screenshot or copy relevant information. However, A. Smith (pers. comm.) suggested this would be an easy addition to incorporate and deploy.

User support is provided throughout the user journey through tool tips (presented by a question mark) alongside the different input tabs giving in-tool guidance or links to other websites). There is also a contact form on the home page for feedback and help. The authors of this report were able

to schedule a call with the CC-NCALC team by completing this form, with a response given within a few days of making contact.

UK requirements

The tool is hosted on a US server and links into soils databases and a weather API which are specific to the US. Although it is hosted on a US website, the providers suggested that using a UK domain name to access the tool would not be problematic. They envisage the tool to be available for use globally and are in conversation with researchers in Spain and Brazil to adapt it for these locations. For the use in the UK, the following would be required:

- Link into a UK soils database of the relevant parameters – although the providers suggested soil type was not an important factor determining N release and felt that similar agroclimatic conditions and soil types were present in the US, that could potentially match UK conditions.
- Link into a UK weather API
- Run a series of calibration trials including in-field decomposition studies (litter bags)
- Add new cover crop species and cash crops as appropriate (to reflect those used in the UK)
- Create an inventory of NIRS analysis data for UK specific cover crops.

4.2.3. Organic Fertilizer and Cover Crop calculator

About the tool

The Organic Fertilizer and Cover Crop Calculator is a freely available excel based tool created by Oregon State University (OSU) to assist with pre-plant N input decisions. There is no requirement for users to make an account to access the tool.

The tool calculates at field scale for single seasons. By using the calculator, users can gain an understanding of the appropriate amount of plant-available nitrogen (PAN) for their crops. The calculator predicts how much of the total N present in an organic material will transform to PAN during the first growing season after application in the field. It forecasts the quantity of PAN provided by inputs such as fresh organic materials, cover crop residues, and compost. The tool also compares the nutrient value and cost of cover crops, compared to organic fertilisers, synthetic fertilisers, and compost.

Version 5, released in 2022, is downloadable as two spreadsheet tools for either larger farms (acres), or small farms and gardens (1000 sq. ft. and under). The tool is available through the Oregon State University website (https://smallfarms.oregonstate.edu/calculator).

Tool history

Version 1 was released in 2012 through a Sustainable Agriculture Research and Education (SARE) project (FW09-328, available at: https://projects.sare.org/sare_project/fw09-328/). Through the project OSU conducted two years of cover crop trials on participating farms and at the North Willamette Research and Extension Centre. Cover crops in Western Oregon are normally drilled in the autumn and destroyed in the spring, prior to a sowing of a summer vegetable crop. Measurements of cover crop biomass, N content and aspects of soil quality were used to validate N mineralization estimates provided by the Calculator.

How the tool works

To use the cover crop calculator users need to specify:

- Area sampled (ft2).
- Fresh weight of field sample (lb).
- Percentage of dry matter (DM) - requires laboratory analysis.
- Total N analysis (% of N in dry matter) - requires laboratory analysis.
- Fertiliser recommendation for the field (to calculate the nutrient balance).

The calculator estimates PAN at 4 weeks and 10 weeks after the application of organic amendments (cover crops and organic materials). The 4 week and 10 week PAN value calculations are based on prediction equations developed from segmented linear regression analysis from laboratory analysis of residues from local cover crops (Figure 12).

The calculator does not forecast long-term plant available nitrogen via mineralization from organic amendments. After the application year, only rough estimates of PAN release are possible. OSU suggest that research shows that approximately 5% to 10% of the total N provided by an organic input is converted to PAN during the second year after application.

The tool does not consider destruction method of the cover crop, or destruction timings. The calculator does not consider cover crop roots in the calculations, due to local research finding that cover crop roots only contribute a small amount of PAN for the following crop.

The tool does not require location information, and does not include climate or temperature data within calculations.

The relationship documented between total N and PAN is as follows:

- At 4 weeks after application
    - When total N is less than 2.34%: PAN = −31 + [(total N−1.03) × 43.3]
    - When total N is more than 2.34%: PAN = 25.8 + [(total N−2.34) × 11.7]

- At 10 weeks after application
    - When total N is less than 2.26%: PAN = –11 + [(total N−1.03) × 37.9]
- When total N is more than 2.26%: PAN = 35.6 + [(total N−2.26) × 8.5]

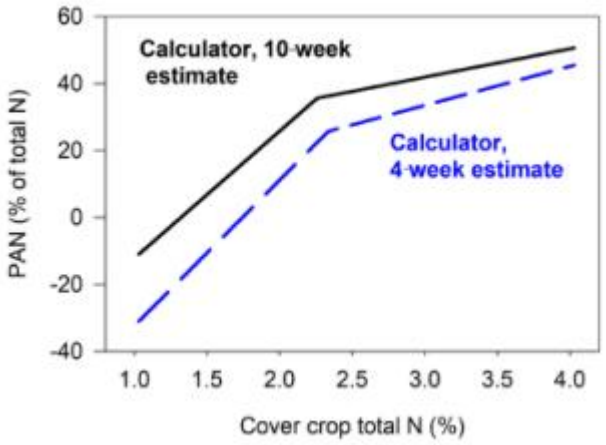


Figure 12: Relationship between the total N analysis of cover crop residues and predicted PAN produced at 4 and 10 weeks after application to soil. Ten-week estimate is a solid line, 4-week estimate is a dashed line. Source: OSU calculator

Tool testing

Sullivan et al. (2019) provides information on the PAN prediction equations for cover crop residues developed from OSU laboratory incubation experiments. PAN was also measured in selected field trials following ploughing of cover crop residues. Cover crop biomass samples were harvested from field plots in April at vegetative growth stage or in May at early reproductive growth stage. Cover crop species included legumes (common vetch, clovers), cereal rye, and phacelia.

After 4 and 10 weeks of incubation of the cover crops in bags with soil at 72°F (22°C), soil from the incubation bags was subsampled and nitrate-N was determined. Cover crop PAN was determined by difference, by subtracting the nitrate-N present in the no-cover-crop control bags.

A combined dataset from three laboratory incubations was used in the development of the calculator equations to predict PAN from cover crop residues. Segmented linear regression was used to develop prediction equations for cover crop PAN. This regression technique represents the relationship between cover crop N (% in DM) and PAN (% of total N) as two lines that come together at a change point where the slope of the regression line changes.

The regression equations developed as a replacement for the cover crop prediction equation present in the original (2010) version of the calculator. The original calculator equation was

adopted from PAN data for Kansas crop residues (Vigil and Kissel, 1991) with an unspecified time interval after crop residue incorporation for PAN prediction. The OSU cover crop PAN predictions were in general agreement with a recent PAN model developed by the University of Georgia (Gaskin et al., 2020). It is noted that Gaskin et al. (2020) refers to the CC-NCALC too, showing the interlinkages in theory and equations between the American tools found within the Task 2 review.

User response

Limited information can be found online for the user response to the tool.

At the end of 2010, 19 agricultural professionals provided feedback on the calculator for the final report of the SARE project (FW09-328, available at: https://projects.sare.org/sare_project/fw09-328/?ar=2010). The main users were extension faculty and conservation planners. They rated the overall helpfulness of the calculator at 4.4/5. Eight used it in their teaching, 11 in their extension work and seven in their research.

User uptake

Limited information can be found online for recent usage of the calculator, however, a report published in 2012 (SARE project - FW09-328) stated that from 2010-2012 more than 620 people had registered to use the calculator. This accounted for over 52,000 acres managed by registered calculator users. In addition to farmers, agricultural professionals were known to use the calculator.

Using the tool

The tool is an excel model, with five user input sheets:

- Fertilizer Analysis (Figure 13)
- Cover Crop Analysis (Figure 14)
- Your Costs (Figure 15Figure 14: 'Cover Crop Analysis' input page of the Organic Fertilizer and Cover Crop Calculator (input cells are highlighted yellow, green cells are populated with information).
- Cost Comparisons (Figure 16)
- Nutrients Provided (Figure 17)

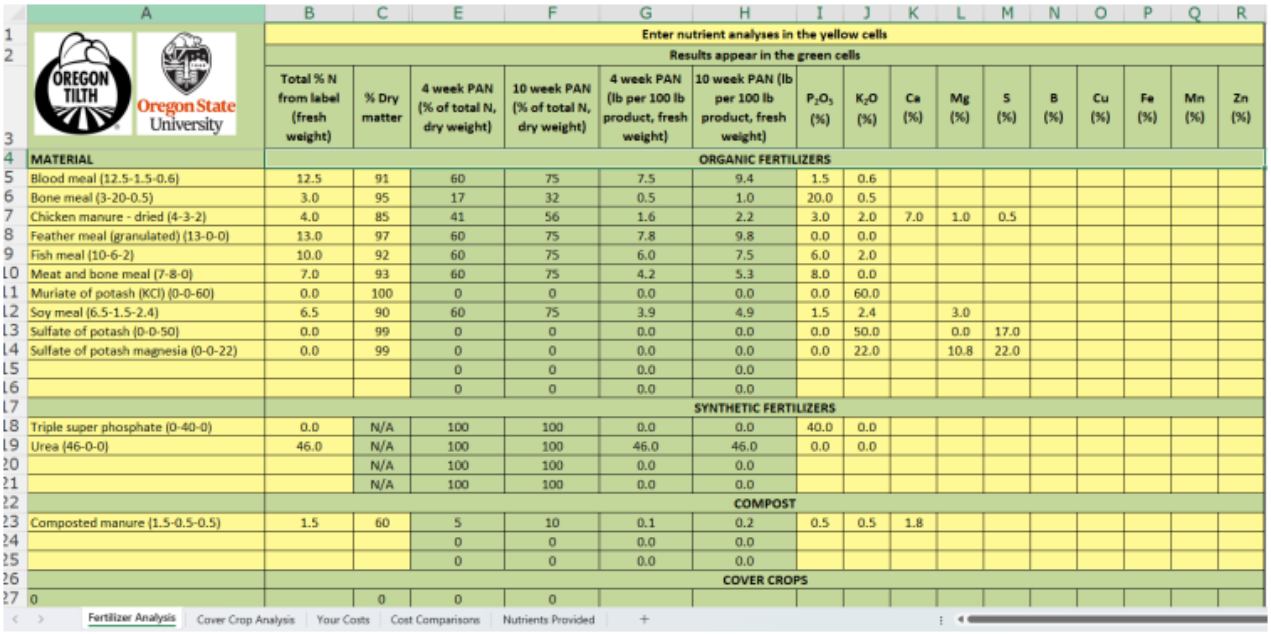
Each sheet has locked cells, with user entry cells unlocked in yellow, however, the tool provides the password to unlock each sheet if required.

Both the Larger Farm Calculator (Acres) and the Small Farms and Garden Calculator follow the same layout. A seeder calibration worksheet can also be downloaded from the OSU website to help calculate the application rate of cover crop seed.

The calculator does not included any predefined information on cover crops, e.g. species, all information on cover crops is required as a user input.

Nutrient balance outputs are presented within the 'Nutrients Provided' tab. The calculator assumes that users have a target value for crop N requirements.

The tool does not provide a printout of results, instead users would be required to screenshot or copy relevant information. There is minimal guidance within the calculator on how to input information to each sheet and how to understand the outputs provided, but overall the tool is relatively easy to use and requires a low level of expertise. The calculator does however, require information to be provided in the correct format, which includes laboratory analysis of in field samples taken by the user.



	A	B	C	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1		Enter nutrient analyses in the yellow cells															
2		Results appear in the green cells															
3		Total % N from label (fresh weight)	% Dry matter	4 week PAN (% of total N, dry weight)	10 week PAN (% of total N, dry weight)	4 week PAN (lb per 100 lb product, fresh weight)	10 week PAN (lb per 100 lb product, fresh weight)	P_2O_5 (%)	K_2O (%)	Ca (%)	Mg (%)	S (%)	B (%)	Cu (%)	Fe (%)	Mn (%)	Zn (%)
4	MATERIAL	ORGANIC FERTILIZERS															
5	Blood meal (12.5-1.5-0.6)	12.5	91	60	75	7.5	9.4	1.5	0.6								
6	Bone meal (3-20-0.5)	3.0	95	17	32	0.5	1.0	20.0	0.5								
7	Chicken manure - dried (4-3-2)	4.0	85	41	56	1.6	2.2	3.0	2.0	7.0	1.0	0.5					
8	Feather meal (granulated) (13-0-0)	13.0	97	60	75	7.8	9.8	0.0	0.0								
9	Fish meal (10-6-2)	10.0	92	60	75	6.0	7.5	6.0	2.0								
10	Meat and bone meal (7-8-0)	7.0	93	60	75	4.2	5.3	8.0	0.0								
11	Muriate of potash (KCl) (0-0-60)	0.0	100	0	0	0.0	0.0	0.0	60.0								
12	Soy meal (6.5-1.5-2.4)	6.5	90	60	75	3.9	4.9	1.5	2.4		3.0						
13	Sulfate of potash (0-0-50)	0.0	99	0	0	0.0	0.0	0.0	50.0		0.0	17.0					
14	Sulfate of potash magnesia (0-0-22)	0.0	99	0	0	0.0	0.0	0.0	22.0		10.8	22.0					
15				0	0	0.0	0.0										
16				0	0	0.0	0.0										
17		SYNTHETIC FERTILIZERS															
18	Triple super phosphate (0-40-0)	0.0	N/A	100	100	0.0	0.0	40.0	0.0								
19	Urea (46-0-0)	46.0	N/A	100	100	46.0	46.0	0.0	0.0								
20			N/A	100	100	0.0	0.0										
21			N/A	100	100	0.0	0.0										
22		COMPOST															
23	Composted manure (1.5-0.5-0.5)	1.5	60	5	10	0.1	0.2	0.5	0.5	1.8							
24				0	0	0.0	0.0										
25				0	0	0.0	0.0										
26		COVER CROPS															
27	0		0	0	0												

Fertilizer Analysis | Cover Crop Analysis | Your Costs | Cost Comparisons | Nutrients Provided | +

Figure 13: 'Fertilizer Analysis' input page of the Organic Fertilizer and Cover Crop Calculator (input cells are highlighted yellow, green cells are populated with information).

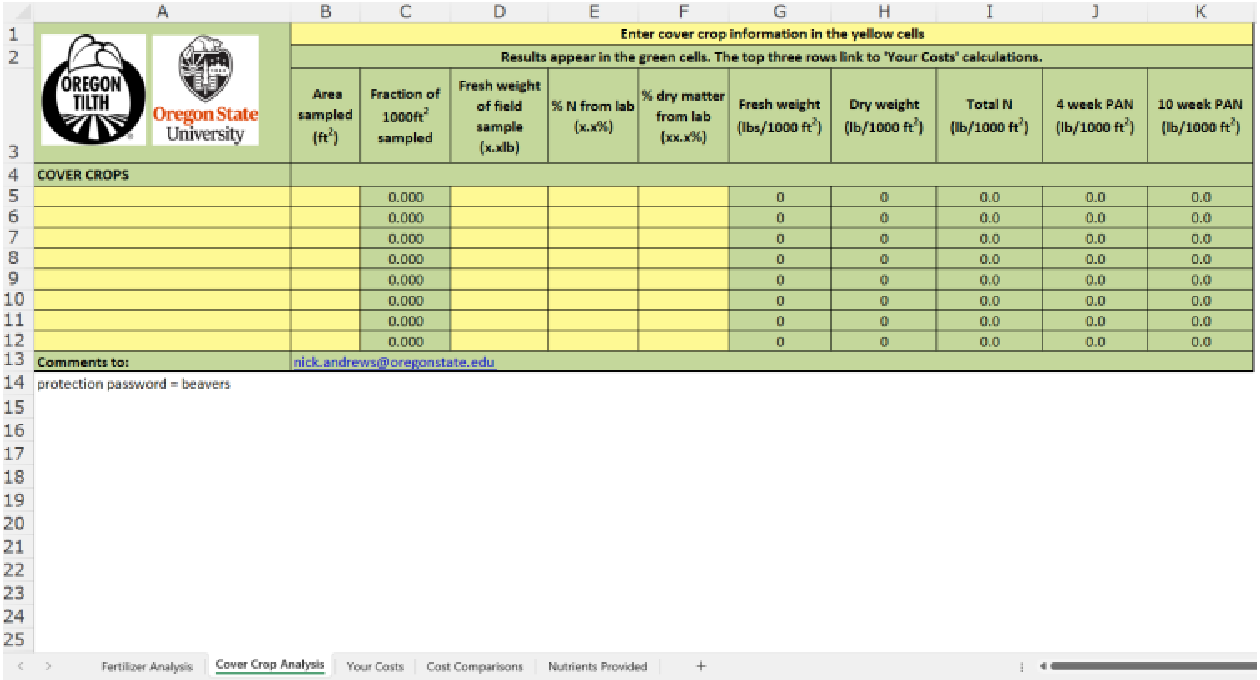


Figure 14: 'Cover Crop Analysis' input page of the Organic Fertilizer and Cover Crop Calculator (input cells are highlighted yellow, green cells are populated with information).

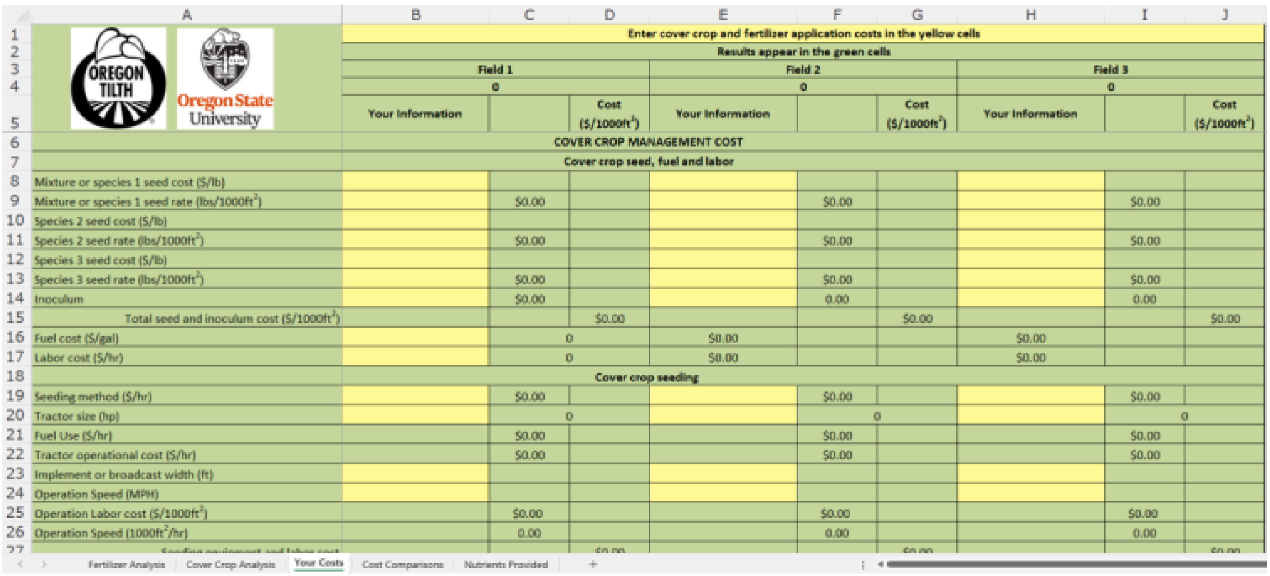
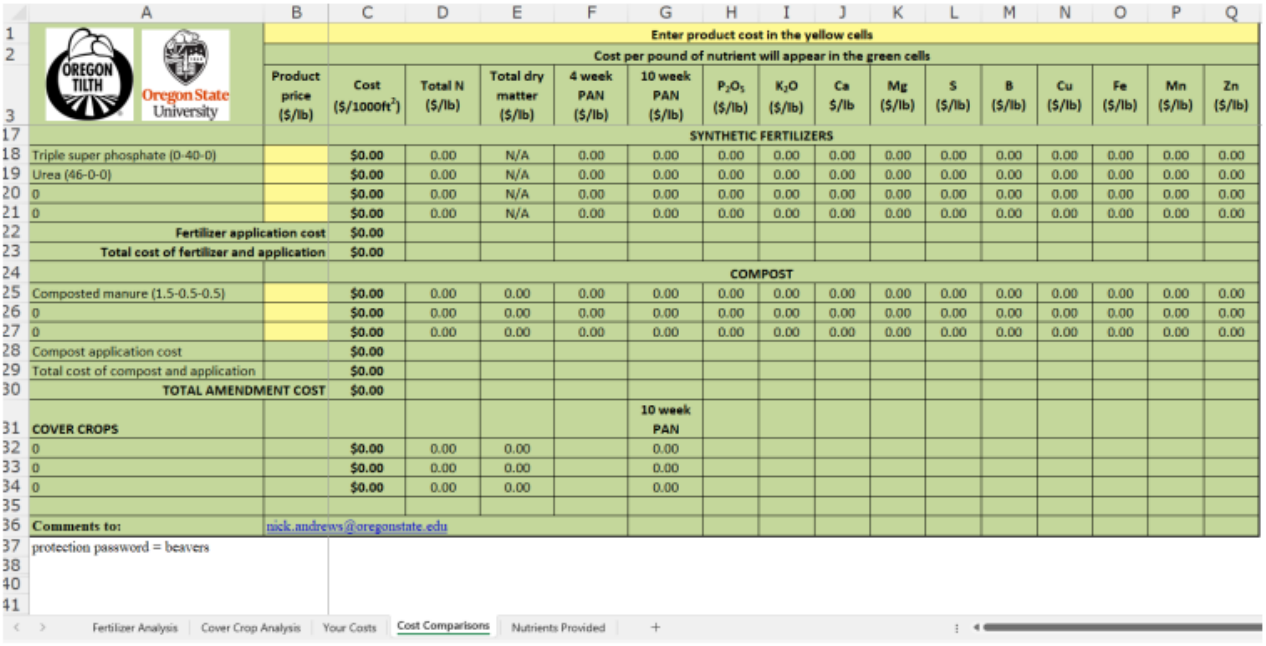


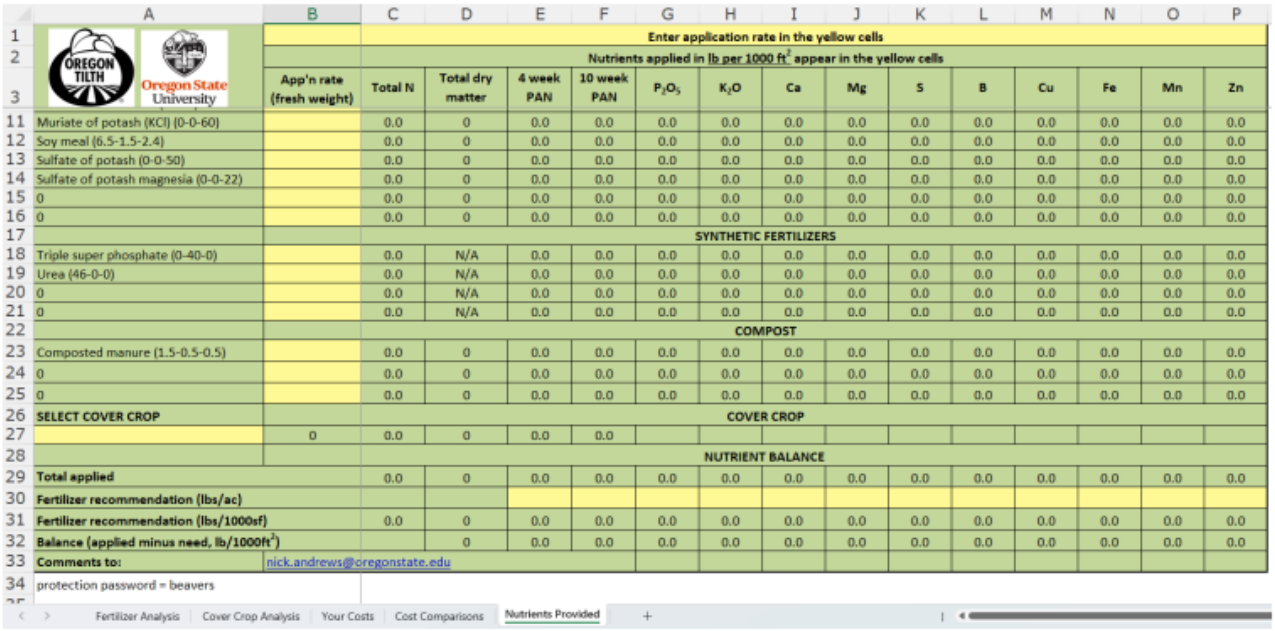
Figure 15: 'Your Costs' input page of the Organic Fertilizer and Cover Crop Calculator (input cells are highlighted yellow, green cells are populated with information).



	Product price ($/lb)	Cost ($/1000ft²)	Total N ($/lb)	Total dry matter ($/lb)	4 week PAN ($/lb)	10 week PAN ($/lb)	P_2O_5 ($/lb)	K_2O ($/lb)	Ca $/lb	Mg ($/lb)	S ($/lb)	B ($/lb)	Cu ($/lb)	Fe ($/lb)	Mn ($/lb)	Zn ($/lb)
		Enter product cost in the yellow cells														
		Cost per pound of nutrient will appear in the green cells														
SYNTHETIC FERTILIZERS																
Triple super phosphate (0-40-0)		$0.00	0.00	N/A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Urea (46-0-0)		$0.00	0.00	N/A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0		$0.00	0.00	N/A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0		$0.00	0.00	N/A	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Fertilizer application cost		$0.00														
Total cost of fertilizer and application		$0.00														
COMPOST																
Composted manure (1.5-0.5-0.5)		$0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0		$0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
0		$0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Compost application cost		$0.00														
Total cost of compost and application		$0.00														
TOTAL AMENDMENT COST		$0.00														
COVER CROPS						10 week PAN										
0		$0.00	0.00	0.00		0.00										
0		$0.00	0.00	0.00		0.00										
0		$0.00	0.00	0.00		0.00										
Comments to:	nick.andrews@oregonstate.edu															
protection password = beavers																

Fertilizer Analysis | Cover Crop Analysis | Your Costs | Cost Comparisons | Nutrients Provided

Figure 16: 'Cost Comparisons' input page of the Organic Fertilizer and Cover Crop Calculator (input cells are highlighted yellow, green cells are populated with information).



	App'n rate (fresh weight)	Total N	Total dry matter	4 week PAN	10 week PAN	P_2O_5	K_2O	Ca	Mg	S	B	Cu	Fe	Mn	Zn
	Enter application rate in the yellow cells														
	Nutrients applied in lb per 1000 ft² appear in the yellow cells														
Muriate of potash (KCl) (0-0-60)		0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Soy meal (6.5-1.5-2.4)		0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sulfate of potash (0-0-50)		0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sulfate of potash magnesia (0-0-22)		0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0		0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0		0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SYNTHETIC FERTILIZERS															
Triple super phosphate (0-40-0)		0.0	N/A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Urea (46-0-0)		0.0	N/A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0		0.0	N/A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0		0.0	N/A	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
COMPOST															
Composted manure (1.5-0.5-0.5)		0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0		0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
0		0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SELECT COVER CROP		COVER CROP													
	0	0.0	0	0.0	0.0										
NUTRIENT BALANCE															
Total applied		0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Fertilizer recommendation (lbs/ac)															
Fertilizer recommendation (lbs/1000sf)		0.0	0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Balance (applied minus need, lb/1000ft²)			0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Comments to:	nick.andrews@oregonstate.edu														
protection password = beavers															

Fertilizer Analysis | Cover Crop Analysis | Your Costs | Cost Comparisons | Nutrients Provided

Figure 17: 'Nutrients Provided' output page of the Organic Fertilizer and Cover Crop Calculator (input cells are highlighted yellow, green cells are populated with information).

UK requirements

The tool provides a simplistic calculation of plant available nitrogen from cover crops, relying on user inputs for specific cover crop information. A simple calculator of this format would be easy to reproduce for UK usage.

The tool is based in Oregon, but the majority of localised information could be updated to reflect UK practices, e.g. pre-populated fertiliser and cost information. However, the 4-week and 10-week PAN value calculations are based on prediction equations developed from segmented linear regression analysis from laboratory analysis of residues from local cover crops (Figure 12). OSU have stated that they expect a strong relationship between cover crop %N and %PAN in most locations, however, they expect PAN release timings to differ outside of Western Washington and Oregon. As such, it is expected similar experiments and analysis would be required for UK crops, these may be available within published literature.

4.3. SWOT analysis

Table 5 summarises the Strengths, Weaknesses, Opportunities and Threats of MERCI, CC-NCALC and the Organic Fertilizer and Cover Crop calculator for their potential use as cover crop decision support tools in the UK, based on the findings of this review and associated proforma (Appendices).

Table 5: SWOT analysis of the reviewed tools

	MERCI	**CC-NCALC**	**Organic Fertilizer and Cover Crop calculator**
Strengths	• Very easy to use and to obtain results. • Contains good support information through a tool library. • Freely available. • Based on the well-established and validated STICS model. • Does not require users to complete any laboratory analysis. • Based on a large experimental database of more than 25,000 measurements which cover 74 species of cover crops. The database includes root data, although this is minimal. • Version 3 includes the option to destroy covers by grazing animals • In addition to nitrogen the tool calculates other nutrients (P_2O_5, K_2O, SO_3, MgO) returns to the soil. • A statistical review of the model found that MERCI is a robust DST for predicting N release in field (Constantin *et al*., 2024) • The tool providers are keen to extend the use of the tool into the UK.	• Very easy to use & intuitive. • Contains good guidance and support. • Freely available. • Based on the well-established and validated CERES model. • Produces advanced calculations based on NIRS measurements from 100s of locations across the US. • Includes real time weather data (using a web-based API with a projection using 5-year averages). • Performs the fertiliser adjustment calculation, based on N returned by the cover crop. • Currently under development to account for spatial variation and use with precision software, including a comprehensive programme of validation and testing. • The tool providers are keen to extend the use of the tool into the UK	• Easy to use (but not as intuitive as MERCI and CC-NCALC). • Freely available. • Experiments to attain data for regression equations would be easy to replicate to cover UK applications (Note: the task 1 QSR, identified 58 individual measurements from laboratory experiments across 8 studies; Lloyd et al. 2025).
Weaknesses	• The website and all documentation is in French. An English version would need to be created • N fertiliser recommendations are not provided within the outputs.	• The tool only assesses N, it does not consider other nutrients. • Does not include N leaching, assumes all N is available. • The current tool online is only for surface, not incorporated residues. A	• Does not include N leaching, assumes all N is available. • Requires users to complete laboratory analysis of cover crops to attain %DM and %N. • Reliant on non-crop specific regression

	MERCI	CC-NCALC	Organic Fertilizer and Cover Crop calculator
	• In-field samples of cover crop biomass (fresh weight) are required which are reported to take around 45 minutes per field area. This could be onerous if lots of samples are required. • If none of the 24 French sites mapped within MERCI match UK climatic conditions then extensive modelling of STICS would be required. • Estimating the percentage of N available is dependent on the nearest simulated site. Soil type, depth and climate can vary greatly over short distances. N mineralized was found to be less sensitive to site selected, whereas N leaching was highly sensitive. This is likely to be exacerbated if UK sites are mapped to relevant French locations. • The current cover crop database would need to be validated to check relevance for the UK. It is envisaged that an extensive programme of cover crop measurements would be required to create a UK specific version. • The experimental database contains little data on roots increasing the uncertainty of predictions of root N. N in roots is a relatively small percentage of total N so the uncertainty has less influence except for exported residues.	newer release (expected by 2027) will include incorporated residues. • Requires users to complete laboratory analysis of cover crops for dry biomass (kg/ha) and N (%); other preset inputs can be adjusted by the user. • Reliant on measurement of or predicted carbohydrate, cellulose and lignin contents. • Specific to the US; cover and cash crop databases are not easily transferrable to UK. • Doesn't include roots. • There are currently minimal (published) assessments of in-field accuracy of results, it is unclear how accurate the outputs of the tool are. • Minimal (published) information on user uptake and response. • An extensive programme of cover crop measurements would be required to create a UK specific version. • The tool links to a US soils database, this would need to be updated for the UK.	equations, based on total N content. • The regression equations are based on lab incubation studies, the tool does not include any assessment of in-field measurements. Therefore, calculations are not location, soil type, climate, or crop specific. • There is little guidance included within the tool, and a user guide could not be found online. • The outputs of the tool are limited, and the majority of the tool is based on cost implications of cover crops. However, it does provide an N recommendation, though this requires the user to state the N requirements for the field/next crop.
Opportunities	• The tool has currently been used in other European countries, based off	• The CC-NCALC team are keen for collaboration. They envisage the tool being available for use globally and are	• The tool is simplistic in nature, with the majority of the tool based on user inputs. This would be relatively easy to replicate

	MERCI	CC-NCALC	Organic Fertilizer and Cover Crop calculator
	data from the closest matching French location based on climatic conditions • The STICS model is now calibrated for soils and climates that are representative for much of Europe. • The MERCI team are keen for collaboration with other European countries, with a view that further sites will strengthen the tool's analysis. They have also suggested that they would be happy for their STICS modeller to help with UK modelled scenarios. • The team have aspirations to include satellite/remote sensing analysis within future developments.	in discussion with adapting the tool to other locations. • The tool is under development adding in a geospatial element for precision analysis and the team are open to further adjustments dependent on user requirements. • The model team are focused on precision agriculture and there is the potential opportunity for satellite analysis based on the NIRS data held within the tool. However, this is expected as a longer term opportunity.	for UK usage. • The tool adds different elements to the analysis such as cost of production as well as other organic materials.
Threats	• If there are no French sites (of the 24) within the currently modelled data which match UK climate then it could be costly to run experiments and STICS modelling to produce UK relevant sites. • Potential issues with using the tool hosted through the owners website. Further clarifications and reassurances would be required to understand the implications of any change in funding, support, government etc. It is expected a formal agreement would be required. • Although the tool owner are open to collaboration, there is the potential for complex IP issues dependent on legal arrangements made. However, the tool is currently successfully being used in other EU countries, through the French	• Potential requirement to complete field experiments to produce cover crop and cash crops NIRS database and rerun CERES modelling to produce UK relevant sites. • Potential issues with using the tool hosted through the owners website. Further clarifications and reassurances would be required to understand the implications of any change in funding, support, government etc. It is expected a formal agreement would be required. • Although the tool owner are open to collaboration, there is the potential for complex IP issues dependent on legal arrangements made. • Only Version 1 is currently available online, with on-going development expected to be completed by 2027.	• Outputs from the tool are based on regression equations, which are not dynamic to individual cover crops, but instead user percentage of total N. • The tool is considered less robust than MERCI or CC-NCALC.

	MERCI	CC-NCALC	Organic Fertilizer and Cover Crop calculator
	hosted website. • Simulations were run under a RCP8.5 climate scenario for a 20 year projection (2006 to 2026), which might mean that real world measurements differ dependent on the alignment to the scenario climate and current climate conditions. • Farmer confidence in the results from the tool is still perceived to be low.	• Limited information on user uptake, however the tool providers suggested farmers are reluctant to adjust fertiliser recommendations.	

5. Discussion

This review identified two web-based DSTs (MERCI & CC-NCALC) that predict nitrogen release following cover crops for use by farmers and growers, that were both were both easy to use and freely available, with good guidance and customer support provided. A third, spreadsheet based tool, downloadable from the providers website (Organic Fertiliser and Cover Crop calculator - OFCC) was also identified, which although intuitive to use and potentially straight forward to adapt for use in the UK, was not considered to be sufficiently robust in terms of the underpinning algorithms or validations to be a viable tool for use in the UK. By contrast, both MERCI and CC-NCALC were considered to provide outputs that could be used for nutrient management planning purposes, with both tools underpinned by a rigorous programme of research, development, validation and user testing.

5.1. Format

MERCI and CC-NCALC are both web-based tools compared to the downloadable OFCC spreadsheet. Web-based tools reduce compatibility and systems issues compared to installed software tools (such as the MANNER-NPK tool produced and used in the UK for predicting crop available nutrients from organic manure additions; Nicholson et al., 2013). None of the tools were available as a mobile application, although the web-based tools could be accessed by a phone using data roaming services.

The ability to enter data and see results 'on-the-go' is a potentially useful feature that farmers could use whilst out in the field assessing their cover crops. However, this is reliant on there being good mobile phone connectivity across the country. Moreover, all three tools required users to input either laboratory analyses or weights of cover crop material, and although the latter can be performed in the field (fresh weight only – as required by MERCI), a mobile application is not likely to improve the usability and uptake of a DST predicting cover crop nutrient supply. The current programme of development of CC-NCALC aims to remove the need for biomass samples through the use of crop scanning linked to precision application software (expected in 2027). This is a potentially attractive feature, particularly for large-scale farming operations, but is likely to have a large equipment cost associated with it, which may not be offset by the potential savings in fertiliser.

MERCI and all associated supporting documents are in French, so an English version of the tool and translate all documentation would be required for use in the UK. CC-NCALC website is hosted in English.

5.2. Underpinning science and accuracy

Both MERCI and CC-NCALC provide a projection of N release/availability over time after cover crop destruction, with the OFCC spreadsheet only providing details of PAN at two fixed points. The OFCC has a very different approach underpinning these projections, relying on algorithms derived from laboratory incubation studies of the relationship between total N in the cover crop material and inorganic N in the soil, with no adjustments made for cover crop type, temperature or moisture conditions. This is a much cruder and less sensitive approach to that of MERCI and CC-NCALC, and is therefore likely to produce inaccurate results. MERCI and CC-NCALC, by contrast are underpinned by the outputs from process-based models of N cycling within soils (STICS and CERES models, respectively), taking into account differences in cover crop 'quality' as well as the impact of temperature and moisture on N mineralisation. The broad approach is similar between the two tools, with the decomposition of cover crop N (and C) allocated to different pools within the soil (e.g. biomass and humus pools), but the cover quality parameters are different, with MERCI using a database of cover crop C:N ratios as a key driver, whereas CC-NCALC uses carbohydrate, cellulose and lignin (either inputted by the user, or derived from NIRS predictions). It is impossible to conclude which approach is the most accurate, as there appears to have never been a direct comparison of the outputs (i.e. N prediction) of two DSTs, indeed this would be difficult to achieve given the climates, soil types and crop rotations they have been set up for. However, a key component missing from the CC-NCALC calculations is the potential nitrate leaching that may occur following cover crop destruction, which MERCI includes. This could lead to an over-estimation of N supply by CC-NCALC, particularly under UK climatic conditions where leaching post-destruction is likely to occur in some circumstances. MERCI also attempts to include the contribution of root-derived N for some cover crops where data is available, although further work is required in this area.

5.3. Functionality

MERCI has much greater functionality than either CC-NCALC or OFCC, enabling users to not only predict cover crop N supply, but also other nutrients (P, K, S, Mg) as well as forage value and potential energy yield (methane production if used as a feedstock for anaerobic digestion). It also considers the carbon storage benefits. The main feature that is missing from the tool, that the others provide, is a final calculation of N fertiliser requirement of the following cash crop. Both CC-NCALC and OFCC allow the user to enter details of the following cash crop and its recommended N requirement, and then performs the calculation to show users much of this requirement can be fulfilled by supply of N from the preceding cover crop. This is considered to be an attractive feature to include in a cover crop DST.

MERCI also considers a wider suite of cover crop destruction and incorporation options, with the latest (V.3; March 2025) version including a grazing option, as well as no till (not incorporated) and tilled (incorporated) options. CC-NCALC is reported to account for tillage, but the current version online only simulates no-till situations. OFCC does not consider how cover crops are destroyed and incorporated. The inclusion of grazing within MERCI is considered to be an attractive feature, given the rise in this practice within the UK.

As a European DST, the cover crop species within the MERCI database more closely align with UK cover crops, compared to CC-NCALC, which lists many species that cannot grow under UK conditions. Moreover, the CC-NCALC database of cash crop types (not required by MERCI) is very different to those grown in UK crop rotations.

CC-NCALC seems to be under a large update, which could change the model requirements/outputs compared to the current published model.

5.4. Usability and uptake

All of the tools were considered to be easy to use. The OFCC provided no guidance materials, but as a simple spreadsheet-based tool was intuitive to use. By contrast both MERCI and CC-NCALC included 'tool tips' ("i" or "?" buttons alongside data entry tabs) throughout the user journey. MERCI also provide a comprehensive list of 'Frequently Asked Questions' and a library of resources detailing the background to the tool, testing undertaken and tutorial videos. Similar materials were not provided by CC-NCALC, but the website did have a contact page (not provided by MERCI), where users could ask for direct help from the tool providers.

OFCC provided no information on how it is being used. Both MERCI and CC-NCALC had at least one refereed academic paper published which included an evaluation of the ability of the tool to either predict cover crop properties (MERCI; Constantin et al., 2024) or fertiliser N replacement value (CC-NCALC, Gaskin et al., 2020), with numerous studies published on the science and modelling underpinning the tools (i.e. STICS and CERES). The MERCI library of resources also included a number of reports and surveys on the use of the tool, which was not the case for CC-NCALC, although the tool providers described (during an online workshop) a very comprehensive programme of on-going validation and user testing, covering the whole of the US.

In order to improve the uptake of nutrient management planning tools, farmers need to see them as being useful and beneficial (e.g. in terms of reducing inputs and improving productivity and gross margins) as well as easy to use. It is clear that both MERCI and CC-NCALC are aimed at farmers and advisors, with the goal of making them simple to use and reliable enough that farmer will adjust their nutrient management plans based on the outputs. However, it is notable that both

the MERCI and CC-NCALC teams described a reluctance by farmers to trust the DST outputs enough to make adjustments to their fertiliser inputs.

6. Conclusions and recommendations

This review has identified two web-based DSTs, MERCI and CC-NCALC, which are actively supported and in use within their host countries (and in the case of MERCI, a number of neighbouring countries) to guide farmers in their nutrient management planning following cover crops. A third, spreadsheet based tool was also identified (OFCC) but was considered to be not as robust in terms of its underpinning algorithms as well as its overall functionality and accuracy, although it's approach could be relatively easily replicated in the UK, as it is heavily reliant on user inputs rather than a background dataset of cover crops.

Both MERCI and CC-NCALC have evolved from a rigorous and comprehensive programme of research, development and validation over many years, which would be onerous (in terms of time and investment) and potentially unnecessary to replicate in order to create a similar, bespoke tool for the UK, if required by the industry. The STICS and CERES model framework provide reputable underpinning models from which a UK tool could be based on, and both tool providers were interesting in expanding their tools to other countries, responding positively to the potential collaboration to develop and host a UK based tool from their existing DSTs.

MERCI models cover cropping scenarios which are much more reflective of UK practice than CC-NCALC, with more similar crops, soils and climate (particularly rainfall). It has greater functionality and potential accuracy (e.g. inclusion of leaching post destruction), and does not require laboratory test results to complete calculations. There are features within CC-NCALC that it would be beneficial to include within a UK tool, such as the ability to generate an N balance from user entry of the following crop's N requirement. However, it is recommended that if a web-based DST predicting cover crop nutrient availability is required, that adaptation of the MERCI model is explored with the tool's providers. This tool has been successfully expanded outside of France to other countries in Europe (Belgium, Switzerland and Luxemburg) based on the most closely matched French pedoclimate dependent on the soil type selected. However, no information on user uptake and response in countries outside of France was provided to show how successful the adoption to other countries has been.

In order to adapt MERCI for UK purposes, as a minimum it would be recommended that a UK landing page is produced for the tool (to avoid confusion translating webpages) and a programme of testing and validation work is undertaken under UK conditions. Initially, this is likely to include cross referencing UK cover crop measurements with the MERCI database to check for similarities and gaps and establishing which locations within the UK can potentially be mapped across to the

French simulated locations. However, Task 1 of this project has indicated that current UK based experiments on nutrients from cover crops are limited (Lloyd et al., 2025); for example, the majority of evidence on N availability to the following crop is from non-UK studies; with only 22 individual measurements (4 studies) originating from the UK. It is therefore envisaged that a more long-term, large scale and potentially costly programme of in-field measurements, testing and STICS modelling runs will be required for those regions and cover crop scenarios within the UK that cannot be matched to those already held within the MERCI simulations.

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8. Appendices

Table 6: Completed review proforma containing in-depth information on each of the shortlisted tools.

Criteria	Sub criteria	MERCI	COVER CROP N CALCULATOR (CC-NCALC)	ORGANIC FERTILISER & COVER CROP CALCULATOR
Description	Provider	Nouvelle-Aquitaine Regional Chamber of Agriculture	Precision Sustainable Agriculture	Oregon State University
	Brief description	The MERCI (Méthode d'Estimation des Restitutions par les Cultures Intermédiaires) method is based on the coupling between "field" references allowing the estimation of N, P, K and S and Mg contents of the majority of intermediate crop species and references obtained by simulation with the INRAE STICS crop model to define, after destruction, the quantity of nitrogen available for the following crop in different pedoclimatic contexts of Metropolitan France. The user proceeds in 2 steps: - taking and weighing a sample in the field	The Cover Crop N Calculator (CC-NCALC) estimates how much N a cover crop will release and how much is available for the following crop in order to offset N fertiliser inputs. It is one of a suite of cover crop DSTs provided by Precision Sustainable Agriculture in collaboration with four regional cover crop councils in the United States	The OSU Organic Fertilizer and Cover Crop Calculator is a excel based tool to assist with preplant N input decisions. It forecasts the quantity of plant-available nitrogen (PAN) provided by inputs such as fresh organic materials, cover crop residues, and compost.

Criteria	Sub criteria	MERCI	COVER CROP N CALCULATOR (CC-NCALC)	ORGANIC FERTILISER & COVER CROP CALCULATOR
		- entering information into the internet application to obtain the results		
	Format/Platform	Web-based https://methode-merci.fr/calculateur	Web-based https://covercrop-ncalc.org/	The calculator is an Excel-based worksheet available via the OSU Small Farms Program website. https://smallfarms.oregonstate.edu/calculator
	Date of last update	Version 3 was updated in 2025.	Unknown	2022 (Version 5)
	Frequency of updates	Not available (Version 1 was produced in 2010)	Unknown	Unknown, but originally produced V1 in 2012
	Cost & availability	Free to use without any registration requirements with limited access to library documents and no ability to export or save calculations. Free to create an account to record data in a 'personal' space, with authorised access to extra features.	Free to use, open source. Data is stored on the users own computer (linked to the websites cache - if this is cleared the data needs to be entered again)	Free to use based on a free download of the excel based tool. Downloadable tools include: - Larger Farms Calculator: Acre units - Small Farms and Garden Calculator: 1000 sq. ft units - Seeder Calibration Worksheets (to help calculate application rate of seed)
	Intended user	Farmers and agricultural advisors	Farmers and agricultural professionals.	Farmers/ranchers and agricultural professionals.
	Country of origin	France	USA	USA

Criteria	Sub criteria	MERCI	COVER CROP N CALCULATOR (CC-NCALC)	ORGANIC FERTILISER & COVER CROP CALCULATOR
	Number of registered users	Cannot find an exact value, but user surveys with 603 respondents were completed.	No registration procedure	No registration procedure
	Author & references	Constantin, J., Minette, S., Vericel, G., Jordan-Meille, L. and Justes, E., 2024. MERCI: a simple method and decision-support tool to estimate availability of nitrogen from a wide range of cover crops to the next cash crop. Plant and Soil, 494(1), pp.333-351.	1. Vigil MF and Kissel DE (1991) Equations for estimating the amount of nitrogen mineralized from crop residues. Soil Science Society of America Journal 55, 757–761. 2.Woodruff LK, Kissel DE, Cabrera ML, Hitchcock R, Gaskin J, Vigil M, Sonon L, Saha U, Habteselassie MY and Rema J (2018) A web based model of N mineralization from cover crop residue decomposition. Soil Science Society of America Journal 82, 983–993. 3.Gaskin JW, Cabrera ML, Kissel	Developed by Nick Andrews, Dan Sullivan, Jim Julian and Kristin Pool for SARE in 2012. Final project report: Increasing Grower Adoption of Adaptive Cover Cropping Systems: Effects on Vegetable Production and Nitrogen Cycling. Available at: https://projects.sare.org/project-reports/fw09-328/ Original cover crop equations in V1 calculator based on: Vigil, M.F. and D.E. Kissel. 1991. Equations for estimating the amount of nitrogen mineralized from crop residues. Soil Sci. Soc. Am. J. 55:757-761. Equations in current calculators have been updated based on laboratory experiments and regression analysis.

Criteria	Sub criteria	MERCI	COVER CROP N CALCULATOR (CC-NCALC)	ORGANIC FERTILISER & COVER CROP CALCULATOR
			DE, Hitchcock R (2020). Using the cover crop N calculator for adaptive nitrogen fertilizer management: a proof of concept. Renewable Agriculture and Food Systems 35, 550–560.	
Scope	Relevance for UK	MERCI currently covers France, Belgium, Luxembourg and Switzerland. Dynamic lists dependent on country/municipality selected. French results are from simulations of the STICS model, other countries have not had simulations completed but are instead based on French pedoclimates. Relevance for the UK would depend on whether the database of cover crops is relevant to the UK, as these are dependent on the climate and soils within the experiments (current tool represents conditions of temperate	USA The tool links to a soil survey database (USA only) an API for soil moisture and temperature (ClearAg - global) and a weather API (USA only). It includes 36 cover crop options and a long list of cash crop options. The CERES model is used to predict N release and availability within the tool.	USA based tool, however background information behind the tool could be updated to be UK specific, e.g. fertiliser types, costs and units. Field data from the Willamette Valley cropping systems (Western Oregon) was used to support the calculators predictions for PAN from organic inputs and support recommendations. The tool creators suggest that they expect a strong relationship between cover crop %N and PAN in most locations, however they expect the timing of PAN release to differ outside of Western Washington and Oregon. Majority of the model is based on user input

Criteria	Sub criteria	MERCI	COVER CROP N CALCULATOR (CC-NCALC)	ORGANIC FERTILISER & COVER CROP CALCULATOR
		countries in western and southern Europe). The database covers 78 species of cover crops from seven botanical families (34% Brassicaceae, 33% Fabaceae, 25% Poaceae, 6% Hydrophyllaceae and 1% or less each Asteraceae, Polygonaceae and Linaceae). The STICS model (version 9.0) is used to predict N release and availability within the MERCI tool. STICS is now calibrated for soils and climates that are representative of much of Europe.		values, however the 4 week and 10 week PAN value calculations look to be based equation dependent %N of the cover crop (see equation B in cell to right). Segmented linear regression was used to develop prediction equations for cover crop PAN. Based on laboratory analysis of incubation of cover crop residues, regression analysis was completed to represent the relationship between cover crop N (% in DM) and PAN (% of total N) as two lines that come together at a change point where the slope of the regression line changes.

Criteria	Sub criteria	MERCI	COVER CROP N CALCULATOR (CC-NCALC)	ORGANIC FERTILISER & COVER CROP CALCULATOR
	Main purpose	MERCI is a “field” method that is intended to be easy to use and quickly operational. The MERCI method, developed in 2010 by the Nouvelle-Aquitaine Regional Chamber of Agriculture, contributes, through a simple and rapid measurement in the field, to demonstrating the agronomic, economic and environmental interest of multi-service intermediate crops on the recycling and provision of mineral elements. Simple to implement, it will allow the user to concretely assess the benefit of planting a plant cover and reduce, if necessary, the fertilization of the following crop (or in place in the case of vines).	Calculate cover crop N supply to the following cash crop and N fertiliser replacement value. Includes an estimation of the amount and timing of N release	To compare the nutrient value and cost of cover crops, organic and synthetic fertilizers and compost in acre and 1,000 ft2 units. To estimate nitrogen supplied by cover crops and organic fertilisers, and develop well balanced and cost effective nutrient management programs at farm scale.
	Geographical resolution	Field	Field	Field

Criteria	Sub criteria	MERCI	COVER CROP N CALCULATOR (CC-NCALC)	ORGANIC FERTILISER & COVER CROP CALCULATOR
	Temporal resolution	Single season	Single season	Single season
Functionality - Ability to	*Predict:*			
	Timing and amount of nutrient release (N & other nutrients)	Provides N, P2O5, K2O, SO3 and MgO release (kg/ha) at 30, 60, 90, 120, 150 and 180 days	N release up to 20 weeks in 2 weekly intervals	The OSU calculator does not forecast long-term plant available nitrogen (PAN) via mineralization from organic amendments. The calculator estimates PAN only during the first 10 weeks after the application of organic amendments. After the application year, only rough estimates of PAN release are possible. Research shows that approximately 5% to 10% of the total N provided by an organic input is converted to PAN during the second year after application. Also provides information on P2O5, K2O, Ca, Mg, S, B, CU, Fe, Mn, Zn. These are provided as single values and not projected over time.

Criteria	Sub criteria	MERCI	COVER CROP N CALCULATOR (CC-NCALC)	ORGANIC FERTILISER & COVER CROP CALCULATOR
	Fertiliser replacement value (N & other nutrients)	N/A	Yes a user can enter the cash crop N recommendation & the tool will show how much of the recommendation will be supplied by the cover crop	Yes, user can add cover crops to the 'Cover Crop Analysis' tab of the calculator, along with the area sampled, fresh weight of field sample, %N from lab and % dry matter from lab. Users can then state which fertilisers are applied and fertiliser recommendation of the field in the 'Nutrients Provided' tab, this then calculates the balance of fertiliser.
	Account for:			
	Different cover crop species/mixes	Yes contains 74 species of cover crops, although mixes are limited	Yes a user can choose from 36 different cover crop species and add multiple species (but not the % composition)	The user enters their own crops/species with details of the area samples, fresh weight of field sample, %N from lab analysis and % dry matter from lab analysis.
	Destruction methods	Not included, accounts for outcome of waste (e.g. buried or left on surface) but not the destruction method	Published papers suggest that the tool can model either residues left on the surface (no till) or incorporated; however the online version only seemed to simulate no till situation. No option for method of	Not included

Criteria	Sub criteria	MERCI	COVER CROP N CALCULATOR (CC-NCALC)	ORGANIC FERTILISER & COVER CROP CALCULATOR
			destruction	
	Destruction timings	Not included. Timings in the tool are for date of emergence or sowing and date of measurement	Yes a user can enter when the cover crop was destroyed ('termination date')	Not included
	N losses (leaching, gaseous emissions)	N losses are calculated within the tool methodology through the STICS simulations at the 24 locations.	The tool does not estimate or account for potential N losses following destruction	Not included
	Capture and *store* data over multiple seasons	Can recalculate and save data reports, but cannot calculate data for multiple seasons on one webpage instead it would require rerunning the tool	Only estimates N supply for a single season (cash crop immediately following the cover crop); data is stored on the users computer (website cache - if the cache is cleared the data is lost)	Only estimates for the single season, the user would need to rerun the model to analyse for multiple seasons.
	Produce reports to integrate into NMP	Webpage report can be printed/saved	Does not produce a downloadable report; user would have to take a screen shot of the output	Does not produce a report, users would need to take a screen shot of the nutrient balance.
Ease of use	Ease of use / look and feel of the tool	Tool is very easy to use, with one web page to add information to in a user-friendly format	Very easy to use and intuitive; user taken through a series of webpages, with clear instructions and help buttons	The tool is easy to use. There is a slight risk of entry error as there does not appear to be checks included (e.g. suggested ranges) on most pages. The majority of the spreadsheet

Criteria	Sub criteria	MERCI	COVER CROP N CALCULATOR (CC-NCALC)	ORGANIC FERTILISER & COVER CROP CALCULATOR
				is locked with user entry in editable yellow cells, however the each page can be unlocked with the password included on each sheet.
	Degree of user interaction/level of expertise required	Low level of expertise required, however, some specific information is required (like soil reserve in RU in mm)	Low level of expertise required	Low level of expertise required, however there is a requirement for information to be in the correct format e.g. $/lb. The tool includes minimal information on how to use the tool, so may be confusing for some users during the first use.
	Input requirements	Required in field sampling of biomass to produce fresh weight or dry weight. User input for: - Calculation type - Wet or dry biomass value - Plot name - Country and municipality - Main farm/cover crop use type - Surface area occupied by the cover - Cover restored, exported or grazed	Requires dry biomass weight. User input for: - Location (select from map (google satellite) - Soil information (defaults from soil survey database can be overwritten with users own results): SOM, bulk density and inorganic N in the top 10cm of soil	Requires laboratory analysis by the user to provide N% values. User input for fertiliser analysis: - Ability to change the preset input values around fertiliser %N, % DM and nutrient profile User input for cover crop analysis: - Crop variety - Area sampled (ft2) - Fresh weight of field sample (lb)

Criteria	Sub criteria	MERCI	COVER CROP N CALCULATOR (CC-NCALC)	ORGANIC FERTILISER & COVER CROP CALCULATOR
		- Soil type - Soil reserve (RU in mm) - Management of cover crop residues (buried or left on surface) - Date of emergence/sowing - Date of measurement - Species - Green above ground biomass (g) - Sampling area (m2) - Vegetative state (e.g. flowering/earing, senescence, or not required)	- cover crop species & termination date - cover crop dry biomass (required) - Cover crop fresh biomass and moisture content (at least one of these have to be given) - Cover crop N content (required) - Cover crop carbohydrate, cellulose and lignin content (optional - tool will calculate this from N content) - Cash crop & planting date - target N fertiliser rate	- % N from lab % dry matter from lab User input for costs: - Seed cost ($/lb) - Seed rate (lbs/A) - Other costs include fuel, labour, sowing costs, irrigation, tillage User input for cost comparisons: - Product price ($/lb) for organic fertilisers, synthetic fertilisers and composts User input for nutrients provided: - Fertiliser application rate (fresh weight) - Selection of the cover crop - Fertiliser recommendation of the field (lbs/ac)

Criteria	Sub criteria	MERCI	COVER CROP N CALCULATOR (CC-NCALC)	ORGANIC FERTILISER & COVER CROP CALCULATOR
	Data sources	- STICS model version 9.0 - Crop database from 48 research and development partners	The tool is underpinned by the CERES model and links to a soil survey database (USA only) an API for soil moisture and temperature (ClearAg - global) and a weather API (USA only).	Based on two year of cover crop trials in Western Oregon, for a report for SARE in 2012. https://projects.sare.org/project-reports/fw09-328/ Original cover crop equations in V1 calculator based on: Vigil, M.F. and D.E. Kissel. 1991. Equations for estimating the amount of nitrogen mineralized from crop residues. Soil Sci. Soc. Am. J. 55:757-761. Equations in current calculators (V5) have been updated based on laboratory experiments and regression analysis.

Criteria	Sub criteria	MERCI	COVER CROP N CALCULATOR (CC-NCALC)	ORGANIC FERTILISER & COVER CROP CALCULATOR
	Output format	A simple output report on the calculation webpage providing information on the following: - Cover characteristic + Dry air matter (t/ha) + Total trapped nitrogen - aerial + root (kg/ha) - Restoration of ground cover + Nitrogen (kg/ha) + Phosphorus (kg/ha) + Potassium (kg/ha) + Sulphur (kg/ha) + Magnesium (kg/ha) - Valorisation of cover crops + UFL (g/kg or kg/t) + MAST (g/kg or kg/t) + Energy yield (Nm3 of CH4 / ha) - Contribution to carbon storage in soil + Stable carbon (t/ha) + Evolution of organic matter (t/ha)	Simple output is given on screen. This cannot be downloaded or exported. Report views can be changed to see either the N released or the residue remaining (kg/ha or %); user can hover over different dates to see the actual predicted release for that date or give the number of weeks for a cumulative estimate	Simple output is given on the 'Cost comparisons' and 'Nutrients Provided' tabs of the downloadable excel models.

Criteria	Sub criteria	MERCI	COVER CROP N CALCULATOR (CC-NCALC)	ORGANIC FERTILISER & COVER CROP CALCULATOR
	Ease of interpretation	Relatively easy, the web page produces a simple output page	Easy to interpret in terms of how a farmer might adjust N fertiliser applied	Relatively easy to interpret, although the spreadsheets to not specify which areas are result outputs.
	Level of user support/guidance available?	- 39 page methodology report - FAQ page on the website supporting the tool	There is a feedback tab on the webpage for email support); Initial page gives an overview of the tool and what the user will require.	An email for a member of the Oregon State University is provided within the model to submit comments and questions.
	User feedback/research	Not found online	Unknown	During the initial report for V1 of the tool (2012 report) 620 people had registered to use the calculator, rating the overall helpfulness of the calculator at 4.4/5. At the time the main users were extension faculty and conservation planners.
Design	TRL	TRL 9	TRL 9	TRL 9
	Is there a design specification	There is a calculation methods report in French	There are links to a confluence page on the precision farming website. This page documents various aspects of the tool	Minimal information on tool design specification, majority of information covers the field trials and user guides for field sampling techniques. Methods information included in this report: Sullivan, D.M., Andrews, N., Sullivan, C.S. and

Criteria	Sub criteria	MERCI	COVER CROP N CALCULATOR (CC-NCALC)	ORGANIC FERTILISER & COVER CROP CALCULATOR
				Brewer, L.J., 2019. OSU organic fertilizer & cover crop calculator: predicting plant-available nitrogen. Oregon State University Extension Service.
	What is the coding language	Using R software, analysis of variance (ANOVA) were performed on the experimental and simulation results to estimate the percentage of variance explained by the factors for each variable of interest	Unknown	Simple excel based equations
	Is the code available	Not available online	Unknown	Not applicable
	IP rights	IP rights lie with Nouvelle-Aquitaine Regional Chamber of Agriculture	Open source - anyone can use	Open source - anyone can use. Unsure on IP for extending the tool to UK usage.

Criteria	Sub criteria	MERCI	COVER CROP N CALCULATOR (CC-NCALC)	ORGANIC FERTILISER & COVER CROP CALCULATOR
Data/adaption for use in the UK	Details of databases that would need to be created and adaptations made for potential use in the UK	A crop database would also need to be constructed using field trial data of cover crops, providing nutrient values (N, P, K, Mg, S), UFL (feed energy from crop), carbon content and dry matter content. The MERCI cover crop database currently contains over 16,000 rows of cover crop data. There is the potential to compare UK cover crop values to those included in the MERCI database to see if the French values are applicable for UK use, allowing for potential reductions to the collection of cover crop field data. The STICS model (or a similar model that would produce C:N ratio and N loss through leaching) would need to be run for each area considered to have different rainfall, e.g. at a minimum north, south, east, west,	Link into a UK soils database of the relevant parameters – although the providers suggested soil type was not an important factor determining N release and felt that similar agroclimatic conditions and soil types were present in the US, that could potentially match UK conditions. Link into a UK weather API Run a series of calibration trials including in-field decomposition studies (litter bags) Add new cover crop species and cash crops as appropriate (to reflect those used in the UK)	A simple calculator of this format would be easy to reproduce for UK usage. The tool is based in Oregon, but the majority of localised information could be updated to reflect UK practices, e.g. pre-populated fertiliser and cost information. However, the 4-week and 10-week PAN value calculations are based on prediction equations developed from segmented linear regression analysis from laboratory analysis of residues from local cover crops. it is expected similar experiments and analysis would be required for UK crops, these may be available within published literature.

Criteria	Sub criteria	MERCI	COVER CROP N CALCULATOR (CC-NCALC)	ORGANIC FERTILISER & COVER CROP CALCULATOR
		which does not have a similar French region already simulated within the MERCI tool. Translation of the tool website and the information pages (Frequently Asked Questions and Library) which are all provided in French.	Create an inventory of NIRS analysis data for UK specific cover crops.	