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FERTITEC

INNOVATIVE RECOVERY TECHNIQUES FOR ALTERNATIVE FERTILISERS

D2.3 FERTITEC Datasheets and EcoFerti tool Guidebook

AGRICULTURAL APPLICATIONS IKE (AgAp)

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FERTITEC
INNOVATIVE RECOVERY TECHNIQUES FOR ALTERNATIVE FERTILISERS

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Executive Summary

This deliverable (D2.3) presents the FERTITEC Datasheets and the EcoFerti tool Guidebook, produced under T2.3 of WP2. It documents two core outputs developed within the FERTITEC Knowledge Exchange Platform (KEP): the Datasheets and the EcoFerti decision-support tool, both of which were made publicly accessible in M17 of the project.

The Datasheets present the results of the technical, environmental, and socio-economic assessment of 30 case studies of existing installations recovering alternative fertilising products from secondary raw materials, covering six categories of secondary raw materials across five case regions in Europe and the African Union. Each datasheet is accessible through the KEP and provides structured information on the technology or technique, the secondary raw material, the alternative fertilising product, and key technical, environmental, and socioeconomic parameters.

The EcoFerti tool is a decision-support system that enables farmers and agricultural advisors to perform structured, parcel-level fertilisation planning incorporating both conventional and alternative fertilising products. At this stage, the tool operates as a transparent, rule-based system that calculates crop nutrient requirements for nitrogen, phosphorus, and potassium, and optimises fertiliser combinations to meet those needs while minimising over-application risks. Future development will introduce AI-enhanced capabilities under T3.3 (D3.3) by M36.

FERTITEC
INNOVATIVE RECOVERY TECHNIQUES FOR ALTERNATIVE FERTILISERS

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List of Terms and Definitions

Table 1. Terms and Definitions

Abbreviation	Definition
API	Application Programming Interface
AU	African Union
BAT	Best Available Technique
BBF	Bio-Based Fertiliser
CEC	Cation exchange capacity
D	Deliverable
DMP	Data Management Plan
DNS	Do No Significant Harm
DPLA	Data Protection Impact Assessment
DSS	Decision Support System

ESDAC	European Soil Data Centre
EU	European Union
GA	Grant Agreement
GDPR	General Data Protection Regulation
ha	Hectare
HI	Harvest Index
K	Potassium
KEP	Knowledge Exchange Platform
kg	Kilogram
LCA	Life Cycle Assessment
LUCAS	Land Use and Coverage Area frame Survey
M	Month
N	Nitrogen
NR	Nutrient Recovery
O	Objective
P	Phosphorus
PFC	Product Function Category
STL	Soil Test Level
STLt	Soil Test Level Threshold
SSL/TLS	Secure Sockets Layer/Transport Layer Security
T	Task
TRL	Technology Readiness Level
VPS	Virtual Private Server
WP	Work Package

1. Introduction

This document constitutes D2.3 of the FERTITEC project, which aims to accelerate the transition towards more sustainable agricultural practices by systematising knowledge on available technologies for recovering nutrients from secondary raw materials, identifying best available techniques, and making this knowledge accessible to a wide range of stakeholders across the EU and the African Union.

Within this framework, D2.3[1] presents two core outputs developed under T2.3 of WP2: the FERTITEC Datasheets and the EcoFerti tool. Both outputs have been developed and are hosted within the FERTITEC Knowledge Exchange Platform (KEP), making them freely accessible to farmers, advisors, industries, policymakers, and researchers.

The platform is publicly accessible at: https://kep.fertitec-project.eu

The document is structured as follows: **Section 1** provides an overview of T2.3, its positioning within the project, and the timeline of actions carried out; **Section 2** presents the Datasheets, covering their development process, technical implementation, and structure within the KEP; **Section 3** presents the EcoFerti tool, describing its methodology, computational logic, and user guidelines; **Section 4** addresses sustainability, data protection, and key performance indicators; **Section 5** outlines the next steps foreseen for both outputs in the remaining project period.

1.1 Description of T2.3 in Grant Agreement

T2.3 focuses on the development of two core outputs of WP2 (Technical & socioeconomic assessments to create alternative fertilisers' techniques datasheets): the Datasheets and the EcoFerti tool. Building on the results of the technical, environmental, and socio-economic assessments conducted in T2.1 and T2.2, the task produces 30 comprehensive datasheets for the techniques and technologies studied within the project. The Datasheets are developed using a common template agreed with the sister project FertiCovery, ensuring consistency and comparability across the broader knowledge base being built at EU level. In parallel, the task delivers the EcoFerti tool, a decision-support system that translates the information contained in the datasheets into practical, crop-specific fertilisation recommendations for farmers and advisors. Together, these two outputs form D2.3, which documents both the datasheets produced from the case study analyses and the guidelines for the use of the EcoFerti tool. Both outputs will subsequently be integrated into the KEP, making them accessible to a wide range of stakeholders across the EU and beyond. Following the selection of 30 case studies under T2.1, the partners produced one datasheet per case study, resulting in 30 datasheets, in line with the GA target.

[1] In the preparation of this deliverable, AI-assisted writing tools were used to support the refinement of texts in English, ensuring clarity and consistency of language throughout the document. All content, however, was reviewed, validated, and approved by the authors prior to submission.

1.2 Sitemap (within KEP)

The Datasheets page and the EcoFerti tool are hosted as dedicated pages within the KEP, the architecture of which is described in detail in D1.2 (Kalitsou et al. 2016)[2]. Both pages were completed and made visible to users in M17 of the project.

The platform includes the following sections:

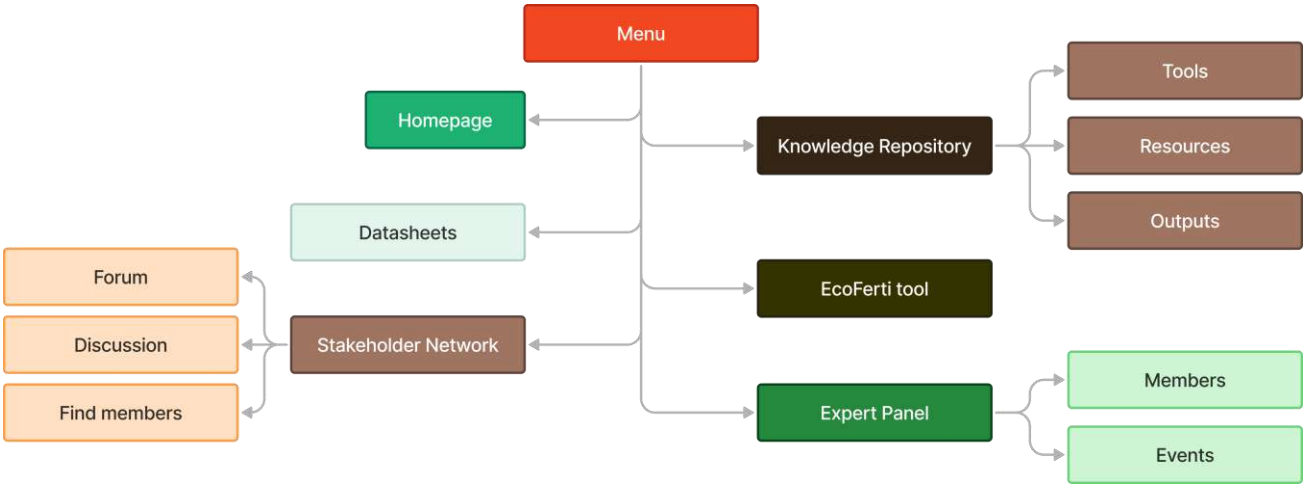

Figure 1 Platform Sitemap

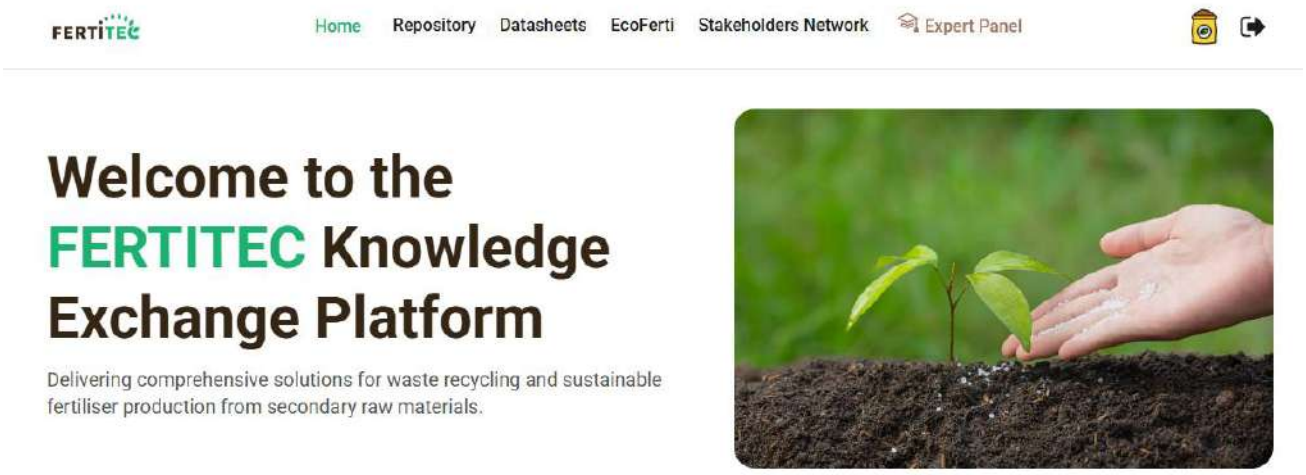

Figure 2 Screenshot of menu (login as Stakeholders' Network member)

[2] Kalitsou N., Ververis M., Kalisky T., D1.2 FERTITEC Knowledge Exchange Platform and Experts Panel, 2016, FERTITEC

1.3 Timeline of the actions

Over this section, the detailed action plan that was followed (and presented in the work packages and project operations meetings) throughout this period is highlighted.

Table 2 Timeline of the actions

#	Action	Who	By when
1	User requirements	AgAp, supported by all partners	February, 2025
2	Initial Mockups	AgAp	March 6th, 2025
3	Feedback received	All partners	March 14th, 2025
4	Updated mockups based on feedback	AgAp	April 10th, 2025
5	Feedback received	All partners	April 23rd, 2025
6	Meeting with RISE and LUKE for core functionalities & user registration/connection process	AgAp, RISE, LUKE	June 20th, 2025
7	Set up core functionalities and demo data	AgAp	October-December, 2025
8	Meeting for AI integration	AgAp, RISE	November 10th, 2025
9	Discussion and agreement of Datasheets template with FertiCovery project	AgAp, LUKE, RISE	December 15th, 2025
10	Demonstration of KEP with demo data	AgAp	January 20th, 2026
11	Datasheets and EcoFerti tool set up and data entry	AgAp, LUKE, RISE	March-May 2026
12	Finalisation of Datasheets template with FertiCovery	AgAp, LUKE, RISE	April 22nd, 2026
13	Demonstration of components to partners	AgAp	May 18th, 2026
14	Testing by partners	All partners	May 2026
15	D1.2 enriched with Datasheets section	AgAp, LUKE	May 26th, 2026
17	1st Quality Check of D2.3	AgAp, LUKE	June 3th, 2026
18	Address Comments & Re-Examination of D2.3	AgAp	June 12nd, 2026
19	2nd Quality Check of D2.3	LUKE	June 23th, 2026
20	Final Quality Check and Submission of D2.3	AgAp, RISE	June 30th, 2026

Through detailed planning and the active contribution of all partners, the objectives set for this stage have been successfully achieved, including the development of 30 datasheets as defined in O3 of the project. The EcoFerti tool and the Datasheets are now fully accessible to the public, and key user engagement metrics are already being tracked, including the number of visitors.

1.4 Dependencies with other tasks and Architecture overview

The Datasheets and the EcoFerti tool were developed as integral components of KEP, built within its architecture and made accessible through its dedicated pages. Their development therefore followed the establishment of the KEP infrastructure under T1.2, which provided the technical foundation and the overall framework within which both outputs are hosted and operated. The following figures present the overall architecture, illustrating how different project tasks and stakeholder groups contribute to each component, as well as the main user interactions within each section.

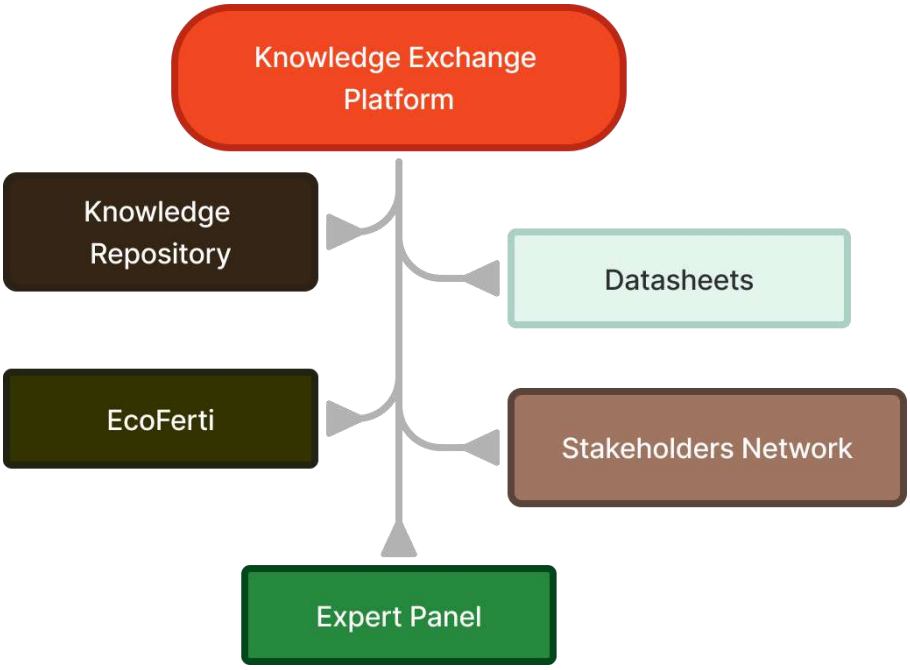

Figure 3 Knowledge Exchange Platform - Pillars Overview

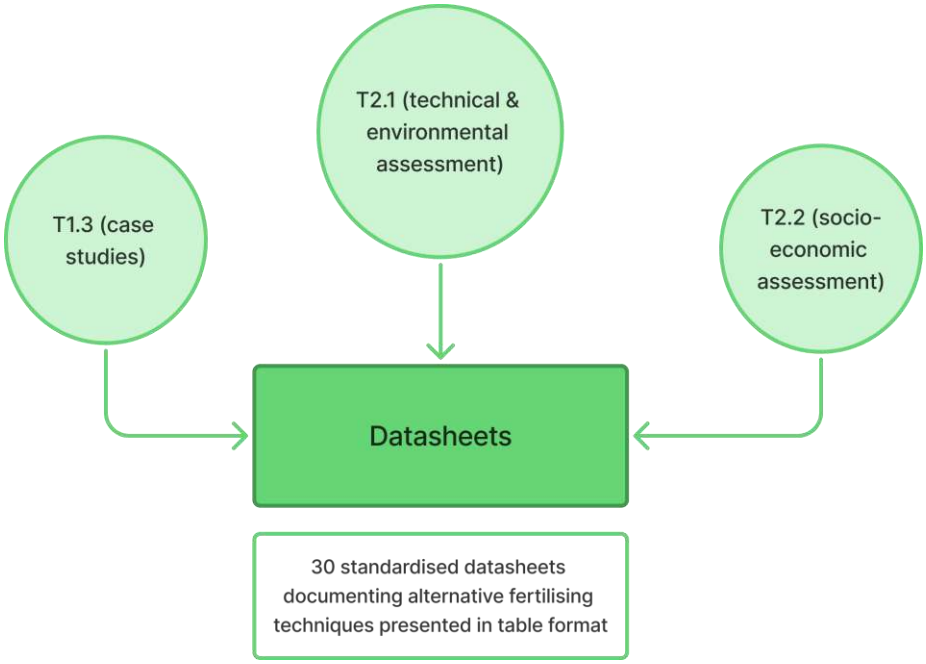

Figure 4 Datasheets Input Overview

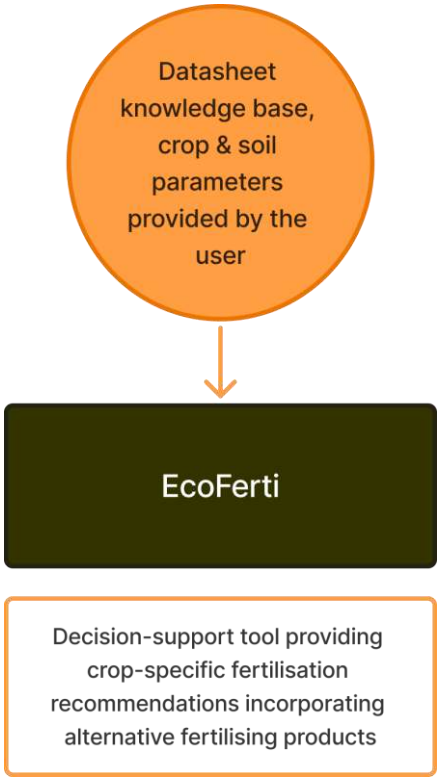

Figure 5 EcoFerti Tool Input Overview

From a technical perspective, while the KEP interface is built using Bubble.io, the EcoFerti tool operates through a dedicated Application Programming Interface (API) architecture, with its computational engine developed independently and integrated within the platform via API calls. Further details on the technical implementation are provided in Section 3.3.2.

2. Datasheets

2.1 Context and Scope

The FERTITEC datasheets present the results of the technical and socio-economic assessment of case studies of existing installations recovering alternative fertilising products from secondary raw materials. The process began with a broad collection of technologies, techniques, and practices from across Europe and African Union under T1.3, from which the 30 most relevant case studies were selected through T2.1 based on the criteria defined in the project, including geographical representation, diversity of secondary raw materials, scale of operations, and data availability.

The selected case studies were subsequently subjected to detailed technical, environmental, and socio-economic analysis under T2.1 and T2.2. Drawing on these assessments, the consortium identified the most important information categories to be presented to users through the KEP. The result is a structured table displaying, for each case study, five key pieces of introductory information: the technology or technique, the secondary raw material, the detailed raw material, the alternative fertilising product, the fertiliser type, and the region of operation. Each entry in the table links to a dedicated pop-up containing the full technical, environmental and socio-economic analysis of the respective case study, allowing users to access detailed information on demand.

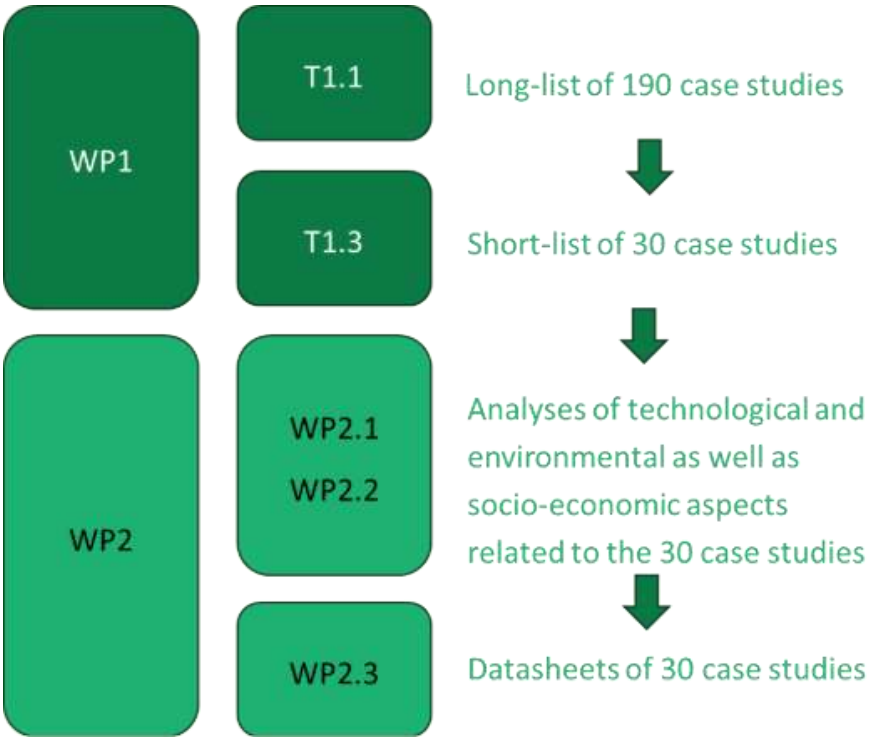

Figure 6 WP and Task interaction

2.2 Methodology

Building on the outcomes of T2.1 and T2.2, T2.3 focuses on the development of 30 comprehensive datasheets for the selected technologies. These datasheets are designed to provide a holistic overview of each case, including techno-economic characteristics, the level of innovation, and the

degree of circularity across the entire value chain. They also cover environmental impacts, scale-up potential as assessed in D2.1, market performance and insights from social perception and acceptance are derived from D2.2. Together, these elements provide a structured and comparable evidence base to support decision-making and knowledge exchange among stakeholders.

The datasheets are based on 30 selected cases, which were extracted from a comprehensive inventory of 190 technologies, case studies, and practices related to the production of circular fertilisers compiled within the T1.1 in FERTITEC project (Skowron et al., 2026a[3]). This dataset builds on information gathered from a wide range of national and EU-funded projects, including NUTRIMAN, FERPLAY, CiNURGi, SYSTEMIC, LEX4BIO, MainstreamBIO, P2GreeN, and SEA2LAND among others. The data collection was carried out collaboratively by FERTITEC project partners, following the methodology described in Skowron et al. (2026b[4]).

As part of T1.3, the project aimed to identify and select at least 30 representative case studies of installations that recover alternative fertilising products from secondary raw materials and are technically and commercially ready for practical application. To achieve this objective, the initial pool of 190 cases was systematically screened and reduced to a subset of 30 cases. These selected cases form the basis for more detailed analysis carried out in WP2, ultimately supporting the identification of Best Available Techniques (BATs) for converting secondary raw materials into alternative fertilising products.

The selection process was guided by a set of predefined criteria designed to ensure both representativeness and analytical robustness. These criteria included the geographical distribution of cases across Europe, the scale of operations, and the inclusion of both full-scale and pilot-scale installations. In addition, particular emphasis was placed on the availability and quality of environmental and technical data, as well as the existence of reliable information on mass and energy balances and associated environmental impacts. A regional approach was adopted to ensure adequate coverage across Europe, with project partners LUKE and RISE focusing on Northern Europe, IUNG on Central Europe, CET on South-Western Europe, AgAp together with QPL on South-Eastern Europe, and EAFF providing perspective across the AU. Where necessary, expert stakeholders with regional knowledge were consulted to validate and complement the selection, including input from the FERTITEC Expert Panel (EP).

The selection process was further strengthened through structured engagement with this EP. An initial draft list of selected cases was presented to the panel during a dedicated meeting in 8.9.2025, after which members were invited to provide feedback through a shared Teams workspace. Based on these comments, the list of cases was revised, including the addition of several cases proposed by panel members as well as project partners. At the same time, efforts were made to avoid duplication and maximise the overall impact of related research activities; therefore, cases overlapping with those analysed in the FERTITEC sister project FertiCovery were excluded, based on a review of their corresponding D2.1 (Klempetsani et al. 2025[5]). This iterative and consultative process ensured that

[3] Skowron, P., Karsznia, M., Wach, D., Witorożec-Piechnik, A., & Bibow, A. (2026). D1.1 Current available circular fertilising practices - TechPractice dataset (full table) (1.3) [Data set]. Zenodo. https://doi.org/10.5281/zenodo.20034997

[4] Skowron, P., Karsznia, M., Wach, D., Witorożec-Piechnik, A., Bibow, A. D1.1 Current available circular fertilising practises.2026, FERTITEC.

[5] Klempetsani, R., Kyriazi, M., Avramidi, M., Giouni, E-A. D2.1 List of existing/operating installations converting secondary raw materials into fertilizing products. 2025 FertiCovery.

the final selection was both comprehensive and strategically aligned with ongoing initiatives. The final set of 30 cases was subsequently presented again to the EP in a follow-up meeting in 30.10.2025.

The selected 30 cases constitute the analytical foundation for the assessments carried out in Task 2.1 (technical and environmental performance, Laakso et al. 2026[6]) and Task 2.2 (socio-economic performance, Kalisky et al. 2026[7]). The results of these analyses will be integrated into a coherent set of outputs, including case-specific factsheets to be disseminated via the KEP.

Table 3 Selected 30 cases recovering alternative fertilisers.

Technology	Tech no. in T1.1	Secondary raw material	Alternative fertilising product	Region
Hydrated ash of incinerated poultry manure	11	Agricultural biomasses	PK fertiliser	Central EU
Nutrient recovery via membrane stripping and calcium precipitation	120	Municipal wastewater fractions	Ammonium sulphate, amorphous calcium phosphate	North EU
Insect mealworm frass fertiliser via bioconversion of organic waste	17, 41, 108	Agricultural biomasses	NPK fertiliser	South EU
Insect black soldier fly frass compost via bioconversion of food waste	42, 184	Biowaste	Compost	Africa
Bokashi fermentation, drying, and pelletising of fish by products	44	Fisheries-aquaculture	Soil improver	North EU
Thermomechanochemical fracti onation of fish by products	19	Fisheries-aquaculture	NP fertiliser	Central EU
Anaerobic digestion of RAS fish sludge	159, 160	Fisheries-aquaculture	N fertiliser	North EU
Low temperature drying of poultry manure and pelletising	154	Agricultural biomasses	NPK fertiliser	North EU
Anaerobic digestion and solid liquid separation of pig slurry	118	Agricultural biomasses	Soil improver	North EU

[6] Laakso, J., Kiani, M., Tampio, E., Vikki, K. D2.1 Technical, environmental and scalability potential of case studies. 2026. FERTITEC.

[7] Kalisky T., Sylwan I., Cordeiro C., D2.2 Socioeconomic analysis of alternative fertilisers. 2026, FERTITEC

Incineration of dewatered sewage sludge and P recovery as calcium phosphate	178	Municipal wastewater fractions	P fertiliser	North EU
Precipitation and magnetic recovery of P as vivianite from anaerobic digestion	188	Municipal wastewater fractions	P fertiliser	Central EU
Ammonia stripping to ammonium sulphate and anaerobic digestion	123	Municipal wastewater fractions	Ammonium sulphate, digestate	South EU
Anaerobic digestion, N stripping with gypsum for ammonium sulphate and liming material recovery, fibre separation	125	Agricultural biomasses	Ammonium sulphate, digestate liquid fraction, liming substrate	Central EU
Urine nitrification, activated carbon filtration and concentration	127	Municipal wastewater fractions	NPK fertiliser	Central EU
Urine stabilisation, drying and granulation or pelletising	126	Municipal wastewater fractions	NP fertiliser	North EU
Hydrothermal carbonisation, solid liquid separation, drying	85, 168	Agricultural biomasses	Soil improver	North EU
Concentration of potato cell water by evaporation	151, 156	Industrial side-streams	K fertiliser	North EU
Mixing of compost and mineral nutrients, and pelletising	185	Agricultural biomasses	NPK fertiliser	Africa
Pyrolysis with additives for N binding, and recovery of mono ammonium phosphate	58, 59	Agricultural biomasses	Biochar and monoammonium phosphate	Central EU
Pig slurry separation and liquid fraction N recovery through stripping and scrubbing	60	Agricultural biomasses	Ammonium nitrate, ammonium sulphate	Central EU
Sludge drying, incineration, and P recovery as phosphoric acid	186	Municipal wastewater fractions	Phosphoric acid	North EU
N recovery of sludge liquid fraction as ammonium sulfate	177	Municipal wastewater fractions	Ammonium sulphate	North EU

Pelletising of food industry side streams	180	Industrial side-streams	NPK pellets	North EU
P recovery as struvite precipitation from digestate liquid of WWTP	49	Municipal wastewater fractions	P fertiliser	South EU
Composting of agricultural and wine production sidestreams	52, 54	Biowaste	Soil improver	South EU
Urine separation for fertiliser use from dry toilets	187	Municipal wastewater fractions	NPK fertiliser, soil improver	Africa
Pelletising of plant based digestate solid fraction	28	Agricultural biomasses	Fertiliser, soil improver	Central EU
Solid fraction of digestate	96	Agricultural biomasses	Soil improver	South EU
Composting of biowaste and plant biomass	189	Biowaste	Soil improver	Central EU
Algae cultivation and hydrolysis to biostimulant production	190	Industrial side-streams	NK fertiliser	South EU

2.3 Development of Datasheets within the KEP

The development of the Datasheets page within the KEP followed an iterative process closely aligned with the progress of the project's analytical work. During the initial phase of KEP development (M10–M15), a basic page structure was built using placeholder examples drawn from the case study tables, establishing the layout and the core fields to be displayed. Following the completion of the case study selection and the analytical work carried out under T2.1, LUKE provided five representative examples from the selected case studies, along with guidance on the fields to be displayed in the main table and the structure, order, and type of information to be presented in the detailed view. This input, received in M16, allowed the finalization of the page design and the integration of the full dataset (30 case studies), leading to the page going live in M17.

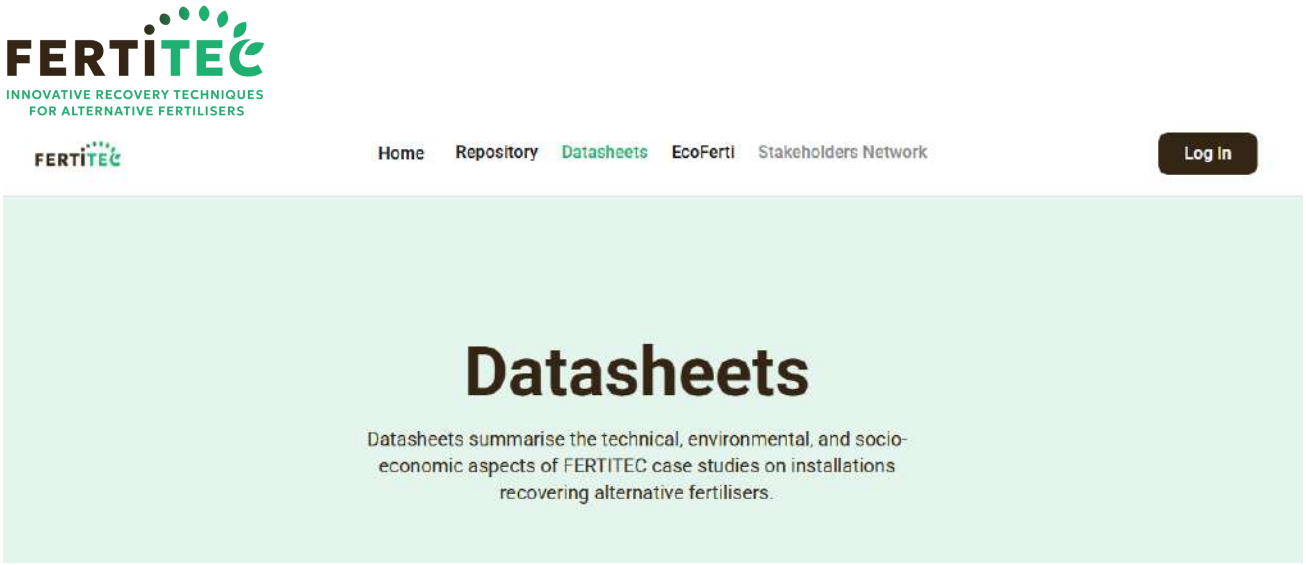

Figure 7 Datasheets Header overview

2.3.1 Technical Implementation of KEP

The KEP was developed using Bubble.io, a no-code platform selected following an evaluation of various development tools. Bubble.io was chosen for its flexibility, speed, and user-friendly architecture, which proved particularly well-suited to the project's need for iterative development and co-creation processes with consortium partners and stakeholders. A detailed description of the overall KEP architecture and technical implementation is provided in D1.2 (Kalitsou et al, 2026).

Within this environment, the Datasheets page was designed and built incrementally, taking advantage of Bubble.io's visual drag-and-drop interface to enable rapid prototyping and iterative adjustments as the analytical content progressively became available. The component-based logic of the platform allowed the structured presentation of case study data to be refined in response to partner feedback and the evolving requirements of the datasheet template. Particular attention was paid to visual design and colour schemes to ensure consistency with the project's identity and official website, maintaining a coherent user experience across the platform. The platform is configured exclusively in English.

2.3.2 Collaboration with FertiCovery

The FertiCovery[8] project, funded under the same Horizon Europe topic (HORIZON-CL6-2024-ZEROPOLLUTION-01-2), focuses on the assessment of best available technologies for recovering and recycling fertilising products from secondary raw materials. The project analyses over 25 nutrient recovery and bio-based fertiliser technologies, evaluating their technical performance, environmental impacts, market viability and scalability, with the aim of producing detailed datasheets and multicriteria analyses to support policymakers, technology providers and end users in the adoption of alternative fertilising products.

In line with the GA commitment, an initial discussion on the common datasheet template was held with FertiCovery in December 2025 (M12), establishing the foundational framework for collaboration. The template was subsequently presented and further discussed during the FERTITEC Plenary Meeting in Cartagena, Spain (January 20–21, 2026), where a common session between the two projects was held. The two projects exchanged views on the similarities and differences between their respective approaches, identifying areas of alignment as well as points of divergence. A key

[8] FertiCovery is supporting farmers, bio-based fertiliser producers and policymakers to remove barriers and promote nutrient recovery and the application of bio-based fertilisers, from secondary raw materials such as biowaste, manure, and wastewater (ID 101181936)

distinction emerged between the two platforms: while FertiCovery focuses on the presentation of products, FERTITEC's datasheets centre on technologies and techniques.

Following this meeting, in M17, both projects shared their finalised page setups and jointly refined a number of common fields, contributing to a degree of harmonisation between the two platforms in line with the broader objective of building a coherent and interoperable knowledge base at EU level.

2.3.3 Datasheets analysis

The datasheets describe the technical, environmental, and socio-economic aspects of case studies on existing installations for recovering alternative fertilisers analysed within FERTITEC. The information regarding technical and environmental aspects is collected from the literature, while socio-economic aspects were based on both desk research and interviews. The full analysis of the cases and the list of background literature is available via the FERTITEC Deliverables D2.1 and D2.2.
Click on "**More Details**" **icon** to see full information

Technology/Technique/Practice	Secondary raw material	Detailed raw material	Alternative fertilising product	Fertiliser type	Region	More Details
Hydrated ash of incinerated poultry manure	Agricultural biomasses	Poultry manure	PK fertiliser	Powder, granular/pellet	Central EU	ⓘ
Nutrient recovery via membrane stripping and calcium precipitation	Municipal wastewater fractions	Wastewater, reject water	Ammonium sulphate, amorphous calcium phosphate	Liquid, solid (bulk)	North EU	ⓘ
Insect (Mealworm) frass fertiliser via bioconversion of organic waste	Agricultural biomasses	Feed for insect: wheat bran	NPK fertilizer	Solid (powder)	South EU	ⓘ
Insect (Black soldier fly) frass compost via bioconversion of food waste	Biowaste	Coffee pulp, food waste, organic waste	Compost	Solid	Africa	ⓘ
Bokashi fermentation, drying, and pelletising of fish by-products	Fisheries-aquaculture	Fish by-products, tree leave, ash	Soil improver	Pellet	North EU	ⓘ
Thermomechanochemical (TMC) fractionation of fish by-products	Fisheries-aquaculture	Fish by-products	NP fertilizer	Solid (bulk)	Central EU	ⓘ
Anaerobic digestion of RAS fish sludge	Fisheries-aquaculture	Fish sludge from RAS system	N fertilizer	Liquid	North EU	ⓘ
Low temperature drying of poultry manure and pelletising	Agricultural biomasses	Poultry manure	NPK fertilizer	Pellet	North EU	ⓘ
Anaerobic digestion and solid–liquid separation of pig slurry	Agricultural biomasses	Pig slurry	Soil improver	Solid	North EU	ⓘ
Incineration of dewatered sewage sludge and P recovery as calcium phosphate	Municipal wastewater fractions	Dewatered wastewater sludge	P fertilizer	Solid	North EU	ⓘ
Precipitation and magnetic recovery of P as vivianite from anaerobic digestion	Municipal wastewater fractions	Wastewater sludge containing P–Fe precipitates	P fertilizer	Solid	Central EU	ⓘ
Ammonia stripping to ammonium sulphate and anaerobic digestion	Municipal wastewater fractions	Municipal sewage sludge, sewage sludge from the agro-food industry	Ammonium sulphate, digestate	Liquid	South EU	ⓘ
Anaerobic digestion, N stripping with gypsum for ammonium sulphate and liming material recovery, fibre separation	Agricultural biomasses	Crop biomasses, manure	Ammonium sulphate, digestate liquid fraction, liming substrate	Liquid, solid	Central EU	ⓘ
Urine nitrification, activated carbon filtration and concentration	Municipal wastewater fractions	Source-separated urine	NPK fertilizer	Liquid	Central EU	ⓘ
Urine stabilisation, drying and granulation/pelletising	Municipal wastewater fractions	Source-separated urine	NP fertilizer	Solid	North EU	ⓘ
Hydrothermal carbonisation, solid-liquid separation, drying	Agricultural biomasses	Agricultural biomass, food waste, blue biomass	Soil improver	Solid	North EU	ⓘ
Concentration of potato cell water by evaporation	Industrial side-streams	Potato cell water	K fertilizer	Liquid	North EU	ⓘ
Mixing of compost and mineral nutrients, and pelletising	Agricultural biomasses	Crop residues, animal manure	NPK fertilizer	Solid	Africa	ⓘ
Pyrolysis with additives for N binding, and recovery of mono-ammonium phosphate	Agricultural biomasses	Solid manure (cattle)	Biochar (and monoammonium phosphate)	Solid	Central EU	ⓘ
Pig slurry separation and liquid fraction N recovery through stripping–scrubbing	Agricultural biomasses	Pig slurry manure	Ammonium nitrate, ammonium sulphate	Solid	Central EU	ⓘ
Sludge drying, incineration, and P recovery as phosphoric acid	Municipal wastewater fractions	Dewatered wastewater sludge	Phosphoric acid	Liquid	North EU	ⓘ
N recovery of sludge liquid fraction as ammonium sulphate	Municipal wastewater fractions	Reject water of wastewater sludge	Ammonium sulphate	Liquid	North EU	ⓘ
Pelletising of food industry side streams	Industrial side-streams	Animal by-products, vinasse	NPK Pellets	Solid	North EU	ⓘ
P recovery as struvite precipitation from digestate liquid of WWTP	Municipal wastewater fractions	Wastewater, reject water	P fertilizer	Solid	South EU	ⓘ
Composting of agricultural and wine production sidestreams	Biowaste	Green landscape waste, ligno-cellulosic plant residues	Soil improver	Solid	South EU	ⓘ
Urine separation for fertiliser use from dry toilets	Municipal wastewater fractions	Urine and faeces	NPK fertiliser, soil improver	Solid	Africa	ⓘ
Pelletising of plant-based digestate solid fraction	Agricultural biomasses	Agricultural processing residues, crop residues	Fertiliser, soil improver	Liquid, pellet	Central EU	ⓘ
Solid fraction of digestate	Agricultural biomasses	Crop residues, animal manure	Soil improver	Solid	South EU	ⓘ
Composting of biowaste and plant biomass	Biowaste	Biowaste, green waste	Soil improver	Solid	Central EU	ⓘ
Algae cultivation and hydrolysis to biostimulant production	Industrial side-streams	Vinasse from ethanol industry	NK fertiliser	Liquid	South EU	ⓘ

Figure 8 Datasheets Table overview

The main table was designed to provide users with a quick and accessible overview of each case study, displaying only the most essential information needed to identify and compare technologies at a glance. The fields presented in the table were selected to reflect the key dimensions by which a user would typically search for or evaluate an alternative fertilizing technique: the type of technology or practice, the secondary raw material it processes, the specific input material used, the fertilising product it generates, the physical form of that product, and the region where the installation operates.

The fields included in the main table were selected to provide a clear and comparable overview of the selected case studies, covering the key aspects of the systems. The “Technology/Practice” field identifies the process technologies applied, while “Secondary raw material” and “Detailed raw material” describe the origin and specificity of the input feedstock. The “Alternative fertilising product” and “Fertiliser type” fields briefly describe the nature and physical form of the output, which are essential for evaluating usability and market potential. Finally, the “Region” field reflects geographical context, allowing consideration of regional conditions and scalability. Together, these fields enable a structured comparison of different approaches from feedstock to final product.

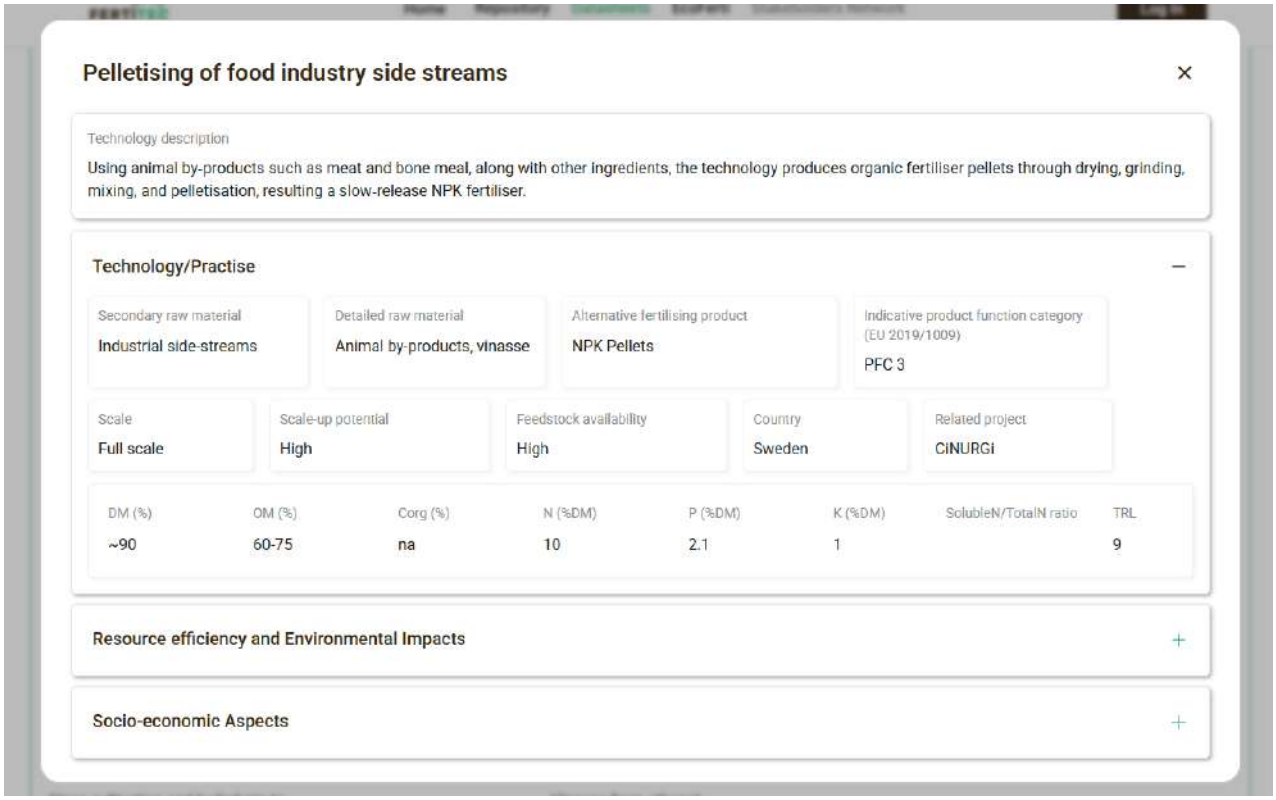

Figure 9 Datasheets Popup overview

Upon clicking the information icon, a detailed pop-up opens displaying the full datasheet for the selected case study. The pop-up is organized into three distinct sections to facilitate readability and the structured presentation of information.

At the top of the pop-up, the title of the technology or technique is displayed alongside a brief technology description providing an overview of the process.

The **first** section, **Technology/Practice**, is expanded by default and presents the core technical and product-related information across two groups of fields. The first group covers the qualitative

characteristics of the case study: secondary raw material, detailed raw material, alternative fertilising product, indicative product function category, scale, scale-up potential, feedstock availability, country, and related project. The second group presents the key compositional and nutrient data of the fertilising product: dry matter content (DM %), organic matter content (OM %), organic carbon (Corg %), nitrogen content (N %DM), phosphorus content (P %DM), potassium content (K %DM), soluble nitrogen to total nitrogen ratio (SolubleN/TotalN), and Technology Readiness Level (TRL).

The data were sourced from a range of literature, including scientific articles, project reports, and online sources. Where necessary, nutrient characteristics were converted from fresh mass to dry mass based on the available information. Product Function Categories (PFCs) under the EU Fertilising Products Regulation (EU) 2019/1009 were assigned based on the main characteristics of the end products. However, these classifications were used solely for comparison purposes; the products are not necessarily CE-marked or formally classified under the regulation.

Information on scale, scale-up potential, feedstock supply, and technology readiness levels (TRLs) was based on analyses conducted as part of Task 2.2, with more detailed results reported in D2.1 (Laakso et al., 2026).

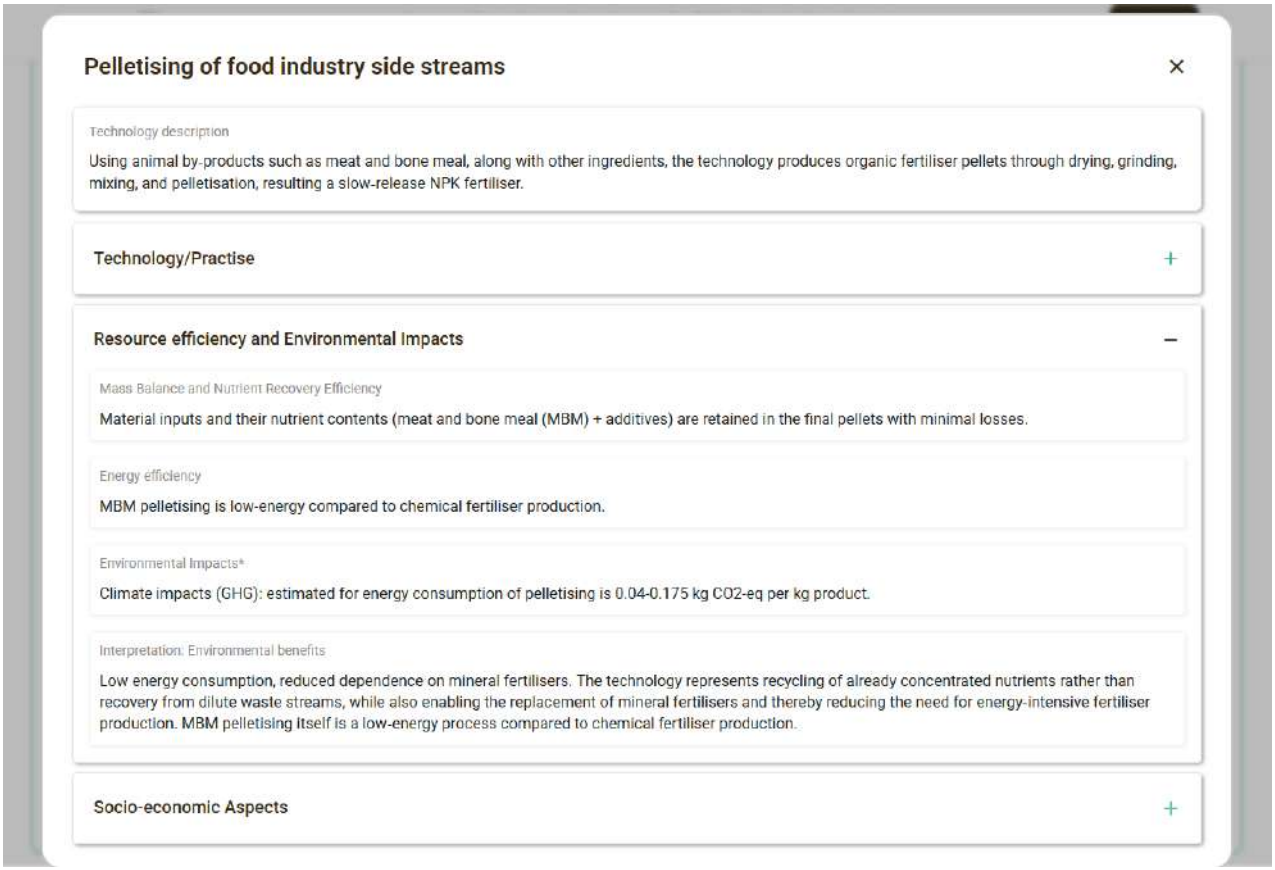

Figure 10 Datasheets Popup second section

The **second** section, **Resource efficiency and Environmental Impacts**, and the **third** section, **Socio-economic Aspects**, are collapsed by default and can be expanded or hidden by the user through the + and − controls. The Resource efficiency and Environmental Impacts section covers mass balance and nutrient recovery efficiency, energy efficiency, and environmental impacts. The Socio-economic Aspects section addresses market performance, regulation and standards, social perception and acceptance, market status, and regulation status.

The recovery and environmental impacts section describes more detailed aspects on the technologies, from the mass balances and nutrient recovery efficiency to energy efficiency and environmental impacts. These aspects were assessed using literature sources, such as previous life-cycle assessments (LCAs) and related studies. The analysis focused on two key life cycle stages: material processing and field application of circular fertilisers. Emphasis was placed on identifying major environmental hotspots, particularly greenhouse gas, eutrophication, ecotoxicity and acidification. Where possible, additional impacts, such as on soil health, biodiversity, and were included, if such data was available. The methodology and more thorough analysis of the impacts have been conducted as part of T2.2, with more detailed results reported in D2.1 (Laakso et al., 2026).

Within the **Social Economics Analysis** section, the field **market performance** summarises the economic viability and business-related characteristics of the technology or product, including indicative production costs, competitiveness in relation to conventional fertilisers, and relevant opportunities or constraints affecting commercial uptake. **Regulation and standards** describes the legal and normative framework relevant to the product or process, such as compliance with fertiliser legislation, waste or by-product regulation, end-of-waste considerations, and applicable technical or quality standards. **Social perception and acceptance** reflects how the technology or fertilising product is perceived by relevant stakeholder groups, including farmers, advisors, authorities, industry actors, and local communities, with particular attention to trust, usability, perceived safety, and willingness to adopt. The field **market status** indicates the current stage of market maturity, such as whether the product is already commercialised, demonstrated at pilot scale, regionally available, or still emerging. Finally, **regulation status** summarises the practical status of regulatory approval or market authorisation, for example whether the product is CE-marked, nationally approved, under assessment, or currently facing regulatory barriers. Together, these fields provide a structured overview of the non-technical factors influencing the uptake and scalability of the assessed solutions.

3. Development of the EcoFerti Tool

3.1 Background and Motivation

Fertilisation management lies at the core of agricultural productivity, yet it remains one of the most significant sources of environmental pressure within modern farming systems. The production and use of mineral fertilisers are inherently resource-intensive, relying on finite raw materials and energy-demanding industrial processes, while their misapplication contributes substantially to greenhouse gas emissions, nutrient losses, and the degradation of water bodies. Global evidence highlights the scale of inefficiency in current fertilisation practices.

On average, only around **30–50% of applied nitrogen globally is effectively taken up by crops**, meaning that up to **two-thirds of nitrogen inputs can be lost to the environment** through leaching, volatilization, and runoff. For phosphorus, it is estimated that **more than 50% of applied inputs accumulate as surplus**, often remaining in soils or being transported to aquatic systems over time. These inefficiencies result in substantial nutrient surpluses at the system level. In many intensive agricultural regions, nitrogen surpluses exceed **50–100 kg/ha**, while in some countries they can reach **over 200 kg/ha**, reflecting significant over-application relative to crop needs (Ritchie, 2021)[9]. Such excesses are directly linked to environmental impacts, including eutrophication, groundwater contamination, and broader ecosystem degradation. At the same time, global patterns reveal strong disparities: while some regions operate under nutrient deficits that limit productivity, others experience chronic over-application with diminishing agronomic returns. This imbalance underscores the need for improved nutrient management strategies that can simultaneously address productivity and environmental objectives.

In Europe and other highly intensive agricultural systems, these challenges have driven increasingly stringent regulatory frameworks aimed at reducing nutrient losses and improving input efficiency. Rising fertiliser costs and market volatility further reinforce the need for more precise, targeted, and economically viable fertilisation practices.

[9] Hannah Ritchie (2021) - “Excess fertilizer use: which countries cause environmental damage by overapplying fertilizers?” Published online at OurWorldinData.org. Retrieved from: 'https://archive.ourworldindata.org/20260518-083815/excess-fertilizer.html' [Online Resource] (archived on May 18, 2026).

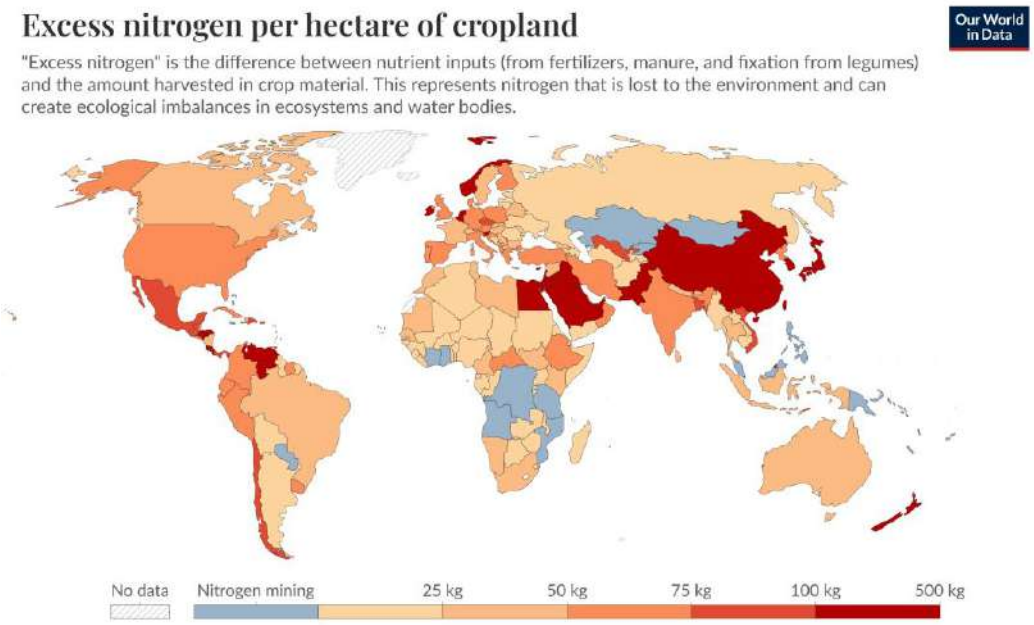

Figure 11 Excess of nitrogen application per ha of cropland.

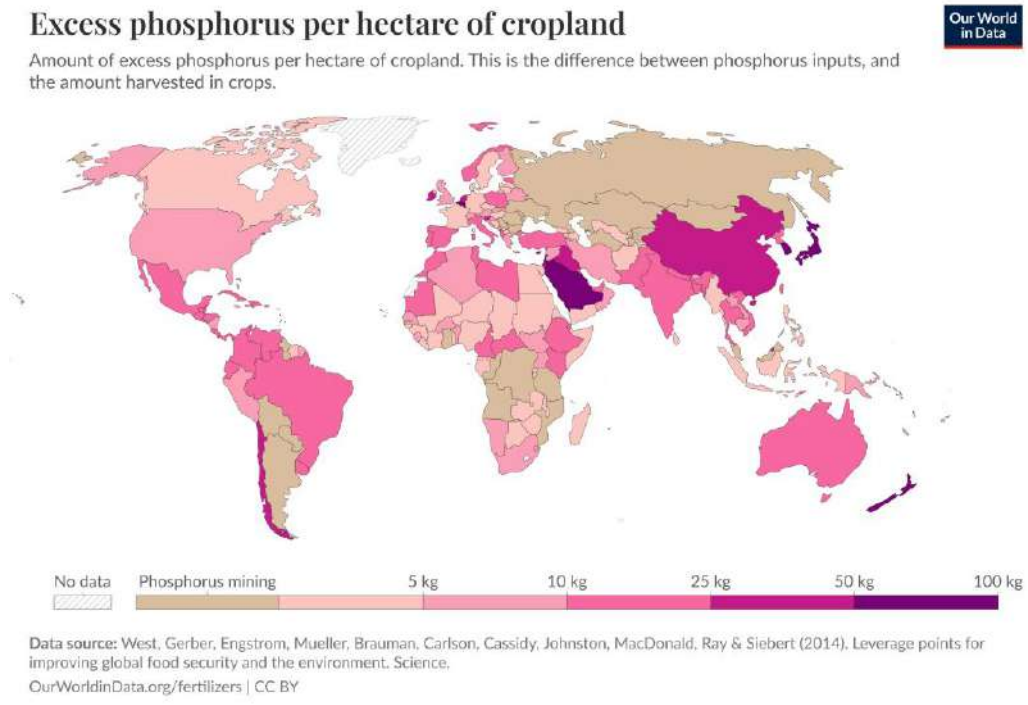

Figure 12 Excess of phosphorus application per ha of cropland

Despite these challenges, fertilisation decisions at farm level are still often based on simplified assumptions, generic recommendations, or incomplete data, rather than on a precise understanding of crop requirements and soil nutrient dynamics. This frequently results in over-application or imbalanced nutrient supply, reducing input efficiency while increasing environmental risks. The transition towards sustainable and climate-resilient agriculture therefore requires tools capable of

integrating agronomic knowledge, site-specific data, and practical decision-making processes into coherent, actionable recommendations.

Within this context, the EcoFerti tool has been developed as Decision Support System (DSS) designed to enable data-driven, transparent, and optimized fertilisation planning at parcel level. The tool addresses the gap between complex agronomic modelling and real-world usability by translating heterogeneous inputs, such as crop characteristics, soil properties, and management choices, into clear and actionable fertilisation strategies. By combining established agronomic principles with a structured computational framework, EcoFerti supports both the accurate estimation of crop nutrient requirements and the efficient allocation of fertilisers to meet these needs.

A key feature of EcoFerti is its ability to balance agronomic performance with environmental safeguards. The system not only estimates the quantities of nutrients required to achieve target yields, but also incorporates constraints related to nutrient excess, soil fertility status, and upper allowable thresholds. In doing so, it ensures that recommendations remain both productive and environmentally responsible, aligning with broader policy objectives related to nutrient management, climate mitigation, and sustainable resource use.

Furthermore, EcoFerti is designed to accommodate the diversity of real-world farming practices. It supports multiple fertilisation strategies, ranging from conservative sufficiency approaches to yield-maximizing schemes, and allows users to work with both conventional and alternative fertiliser products. The tool also integrates practical considerations, such as the use of liquid fertilisers and mixed fertilisation plans, ensuring that outputs are directly applicable under field conditions.

This deliverable presents the EcoFerti tool as a core component of the project's digital framework for sustainable agriculture. It provides a comprehensive overview of its methodological foundations, computational logic, and user-oriented functionalities. The document aims to demonstrate not only how EcoFerti operates, but also how it contributes to improving fertilisation practices by enhancing efficiency, transparency, and decision-making capacity at farm level. Core principles of the tool, such as the nutrient uptake and leaching are based on the Principles of Agronomy for Sustainable Agriculture.

By bridging scientific knowledge and practical implementation, EcoFerti supports the transition towards more sustainable nutrient management systems, enabling stakeholders to optimize inputs, reduce environmental impacts, and strengthen the resilience of agricultural production systems.

3.1.1 Role of the EcoFerti tool in FERTITEC

Within the FERTITEC project, EcoFerti constitutes a key operational tool that bridges knowledge generation with practical decision-making, enabling the translation of complex technical information on alternative fertilising products into actionable recommendations for end-users. FERTITEC is designed to accelerate the uptake of alternative fertilisers derived from secondary raw materials, by consolidating knowledge from previous EU projects, analysing real-world case studies, and delivering practical tools and guidelines through a dedicated KEP. In this broader framework, EcoFerti plays a central role in ensuring that the knowledge produced does not remain descriptive, but becomes directly usable in real agricultural decision-making contexts.

3.1.2 Positioning within the FERTITEC Architecture

EcoFerti is developed under T2.3 as a core output alongside the production of case-study datasheets, forming a critical component in bridging knowledge generation and practical application within the FERTITEC architecture. At this stage, its primary role is to function as a **translation and operationalization layer**, transforming the technical, environmental, and economic insights derived from the analysis of alternative fertilizing technologies into **crop-specific, actionable fertilisation recommendations**. While the datasheets systematically capture structured information on alternative fertilisers, including their performance under different conditions, scalability potential, environmental footprint, and market and regulatory context, such knowledge, in isolation, remains largely descriptive and difficult to operationalise at farm level. This challenge is well recognized in the literature, where the gap between agronomic knowledge and its effective on-farm implementation is identified as a key barrier to improving nutrient use efficiency and reducing environmental impacts (Cassman et al., 2003)[10].

EcoFerti directly addresses this gap by converting these datasets into a **decision-support framework**, enabling users to translate static information into dynamic fertilisation strategies. Specifically, the tool operationalises the knowledge embedded in the datasheets into: (i) nutrient-based fertilisation planning aligned with crop requirements and soil conditions, (ii) the selection and optimization of fertiliser combinations, including alternative products derived from secondary raw materials, and (iii) practical, parcel-level application guidance that can be directly implemented in the field. In doing so, EcoFerti supports the broader transition towards more efficient and sustainable nutrient management systems, in line with European policy objectives such as the reduction of nutrient losses by at least 50% under the European Commission Farm to Fork Strategy.

By embedding this transformation logic within a digital decision-support environment, EcoFerti ensures a **direct and functional linkage between knowledge generation (WP1–WP2) and knowledge application (WP3 and KEP deployment)**. This integration is essential for maximizing the impact of FERTITEC, as it enables stakeholders not only to access curated knowledge on alternative fertilisers, but also to **apply it in a structured, context-specific, and decision-oriented manner**, thereby enhancing uptake, improving nutrient use efficiency, and reducing environmental externalities.

The EcoFerti tool was developed and is hosted directly within the KEP (as described in D1.2), with its interface and layout built using Bubble.io, forming a dedicated and fully integrated page within the platform's architecture. The tool's computational functionalities are powered through API calls, ensuring that the agronomic calculations and recommendation logic operate seamlessly in the background while users interact with a clean and accessible front-end interface within the KEP environment.

3.1.3 Role in Supporting Decision-Making and Uptake

A central objective of FERTITEC is to accelerate the uptake of alternative fertilisers by reducing uncertainty, complexity, and perceived risk for end-users. In practice, adoption is often constrained not only by technical performance, but by a lack of decision-ready guidance that translates product

[10] Cassman, Kenneth & Dobermann, Achim & Walters, Daniel & Yang, Haishun. (2003). Meeting Cereal Demand While Protecting Natural Resources and Improving Environmental Quality. Annual Review of Environment and Resources. 28. 315-358. 10.1146/annurev.energy.28.040202.122858.

characteristics into field-level actions. EcoFerti directly addresses this barrier by providing a user-oriented decision support environment tailored to farmers and advisors during the fertilisation planning process. In its current implementation (M18), EcoFerti tool primarily supports users during the preparation of fertilisation plans by translating the technical characteristics of selected conventional and alternative fertilisers into crop-specific application recommendations. Based on crop requirements, soil conditions, and the fertilisers chosen by the user, the tool calculates recommended application amounts, nutrient coverage levels, and potential nutrient gaps, thereby enabling stakeholders to assess how alternative fertilising products can be integrated into practical fertilisation programmes. In this way, EcoFerti serves as a bridge between the information generated within FERTITEC and its application at farm level, supporting the adoption of alternative fertilisers through transparent and scientifically grounded nutrient planning. In the subsequent project phase (M36), the AI-enhanced version of EcoFerti will extend these capabilities by providing more advanced decision-support functionalities. In addition to calculating fertiliser application rates, the system will support the evaluation of fertiliser suitability under specific agronomic, environmental, and management conditions, taking into account historical data, contextual information, and knowledge generated throughout the project. This evolution will enable a more comprehensive assessment of alternative fertiliser options and provide users with increasingly tailored recommendations to support sustainable nutrient management decisions. By enabling users to evaluate different fertilisation options before implementation, EcoFerti facilitates the transition from generic recommendations to context-specific, data-driven fertilisation planning while progressively building towards more intelligent and adaptive decision-support capabilities.

At this stage of FERTITEC project (M18), EcoFerti operates as a **transparent, rule-based DSS** that embeds established agronomic principles into a structured workflow. The tool delivers **agronomically grounded recommendations** derived from crop requirements, local soil conditions, and user-defined management strategies, ensuring that fertilisation plans are both technically sound and practically applicable. It supports **nutrient balancing** by explicitly matching nitrogen N, P, and K requirements with the nutrient composition of selected fertilisers, thereby improving nutrient use efficiency and reducing the risk of losses to the environment. This is particularly relevant given that inefficient nutrient management remains a key driver of environmental impacts in agriculture, with significant proportions of applied nutrients not being taken up by crops.

In addition, EcoFerti enables users to **evaluate and compare different fertiliser options**, including alternative products derived from secondary raw materials, within a consistent analytical framework. By integrating these products into the same optimization logic as conventional fertilisers, the tool lowers the barrier to their adoption and supports more informed decision-making. At the same time, it enhances transparency by explicitly identifying remaining **nutrient gaps and potential over-application risks**, allowing users to understand trade-offs and adjust their choices accordingly. This functionality is aligned with broader European policy priorities aimed at improving nutrient use efficiency and reducing nutrient losses, such as the target to reduce nutrient losses by at least 50% under the European Commission Farm to Fork Strategy.

Through these capabilities, EcoFerti operationalizes a key ambition of FERTITEC: the transition from **static knowledge outputs,** such as reports, datasets, and case-study analyses—to **interactive, user-oriented decision support** that can be directly applied in real-world conditions. This shift is critical for ensuring that knowledge generated within the project leads to tangible impact, as decision-

support tools have been shown to play a central role in improving the adoption of sustainable agricultural practices by enhancing user understanding and reducing decision uncertainty.

Overall, EcoFerti contributes to equipping stakeholders with **practical, accessible, and scientifically robust tools** that facilitate the transition towards more sustainable fertilisation practices. By supporting informed decision-making at farm level, it strengthens the link between innovation and uptake, thereby reinforcing the effectiveness and long-term impact of the FERTITEC project.

3.1.4 Justification on Crop Selection

The crop types incorporated into the EcoFerti tool were selected to ensure that the system addresses a broad spectrum of agricultural systems, nutrient management challenges, and fertilisation practices relevant to European and Mediterranean agriculture. The selection reflects the objectives of FERTITEC to support sustainable fertilisation management across diverse production environments, while also enabling the practical evaluation and uptake of alternative fertilizing products under different agronomic conditions. The selected crops cover a wide range of:

- Agronomic systems (arable, horticultural, perennial, forage, and fallow systems)
- Nutrient demand profiles
- Fertilisation intensities
- Soil and climatic conditions
- Crop management practices

The selected crops cover a wide range of agronomic systems (arable, horticultural, perennial, forage, and fallow systems), nutrient demand profiles, fertilisation intensities, soil and climatic conditions, and crop management practices. The selection was designed to ensure that EcoFerti addresses the diversity of agricultural production systems encountered across Europe and the Mediterranean region. In particular, the inclusion of cereals (wheat, maize, barley, rice), oilseeds (sunflower), legumes (lentil, bean, chickpea), forage crops (alfalfa), vegetables (tomato, pepper, eggplant, potato, cabbage, lettuce), vineyards, olive groves, and fruit tree crops reflects the major crop categories reported in European agricultural production statistics and market observatories (Eurostat, 2024; European Commission, 2024).

The nutrient requirements shown in the application are average values from different sources compiled by Sadras et al.[11], Quemada et al.[12] and Delgado et al[13]. This diversity ensures that EcoFerti can support fertilisation planning under realistic and representative agricultural scenarios, increasing both the applicability and scalability of the tool across a broad range of European farming systems.

A major group included in the system consists of **cereal and arable crops**, such as wheat, maize (grain and silage), barley, rice, sunflower, and cotton. These crops represent some of the most widely cultivated and fertiliser-intensive production systems within Europe and Africa. Cereals in particular account for a substantial proportion of agricultural nitrogen and phosphorus consumption due to their

[11] Sadras, V. O., Villalobos, Francisco J., López-Bernal, Álvaro, Fereres Castiel, Elías, Villalobos, Francisco J., Radiation Interception, Radiation Use Efficiency, and Crop Productivity. 2024 [0000-0002-0990-2970]
[12] Quemada, M. & Delgado, Antonio & Mateos, Luciano & Villalobos, Francisco. (2016). Nitrogen Fertilization I: The Nitrogen Balance. 10.1007/978-3-319-46116-8_24.
[13] Delgado, Antonio & Quemada, M. & Mateos, Luciano & Villalobos, Francisco. (2024). Fertilization with Phosphorus, Potassium, and Other Nutrients. 10.1007/978-3-031-69150-8_28.

extensive cultivated area and high nutrient requirements. Including these crops therefore allows EcoFerti to address nutrient management challenges associated with large-scale field crop production, where improving nutrient use efficiency can generate significant environmental and economic benefits.

The inclusion of **grain legumes and forage crops**, including lentil, bean, chickpea, and alfalfa, is equally important due to their distinct role in sustainable agricultural systems. Leguminous crops contribute to biological nitrogen fixation and are increasingly recognized for their contribution to reducing dependency on synthetic nitrogen fertilisers and improving crop rotation sustainability. Their integration within EcoFerti enables the tool to account for different nitrogen dynamics and residual nutrient effects associated with legume-based systems, which are highly relevant within climate-smart and low-input agriculture approaches.

The tool also incorporates a wide range of **horticultural and vegetable crops**, including tomatoes, peppers, eggplants, potatoes, cabbage, and lettuce. These crops are characterized by relatively high nutrient demands, intensive management practices, and elevated fertilisation inputs, particularly under irrigated production systems. At the same time, horticultural systems are often associated with increased risks of nutrient losses due to frequent fertiliser applications and intensive cultivation practices. Including these crops therefore enables EcoFerti to support improved nutrient management in systems where optimization of fertiliser use is particularly critical for reducing environmental impacts while maintaining productivity and product quality.

A further important category includes **perennial and fruit tree crops**, such as grapevine, olive, apple, apricot, kiwi, orange, cherry, peach, and pear. These crops are highly representative of Mediterranean agriculture and are of major economic importance across Southern Europe. Perennial systems differ substantially from annual crops in terms of nutrient uptake dynamics, biomass allocation, and fertilisation strategies. Their inclusion within EcoFerti ensures that the tool can support long-term nutrient management planning in orchards and vineyards, where nutrient accumulation, soil fertility maintenance, and sustainable fertiliser use are particularly important considerations.

The inclusion of **olive and grapevine systems** is especially relevant within the Mediterranean context, where these crops dominate large agricultural areas and are strongly linked to regional agricultural economies and cultural landscapes. Similarly, high-value fruit crops such as kiwi, peach, cherry, and apple often require intensive fertilisation management to maintain yield and quality, making them particularly suitable for testing optimized nutrient management approaches and alternative fertilising products.

The EcoFerti crop list also includes **fallow land**, which serves as a reference condition within the system. The inclusion of fallow allows the tool to account for parcels without active nutrient extraction and supports crop rotation scenarios where nutrient dynamics differ significantly from productive systems. Overall, the selected crops were chosen to ensure:

- Broad representativeness across European and Mediterranean agricultural systems
- Coverage of contrasting nutrient management requirements
- Applicability across low-input and intensive systems
- Compatibility with both conventional and alternative fertilisation practices
- Relevance to the case studies and target user groups addressed within FERTITEC

By covering a diverse range of crop types and management conditions, EcoFerti is able to provide a flexible and scalable decision-support framework capable of supporting sustainable fertilisation planning across multiple agricultural sectors.

3.2 EcoFerti Overview and User Workflow

The EcoFerti tool is designed as a structured decision-support system that transforms user-provided agronomic data into clear, actionable fertilisation recommendations. Its architecture follows a stepwise workflow, ensuring transparency, traceability, and ease of use, while maintaining a strong scientific foundation. Within the FERTITEC framework, this workflow is not only a technical implementation, but also a practical interface through which stakeholders interact with project knowledge, enabling the application of fertilisation strategies aligned with both crop needs and sustainability objectives. The tool was developed and is hosted directly within the KEP, built using Bubble.io, and is accessible to users as a dedicated page within the KEP, in the same environment as the datasheets and the other platform resources.

3.2.1 Conceptual Workflow Overview

EcoFerti operates through a three-layer process: i) the **Data Input Layer**, a collection of user and contextual data; ii) the **Processing Layer** which estimates nutrient requirements and optimizes fertiliser allocation; and iii) the **Output Layer** that generates recommendations and advisory messages. This structured pipeline ensures that each recommendation is:

a) Based on **explicit inputs and assumptions**

b) Derived through **transparent computational steps**

c) Delivered in a **user-friendly format**

The workflow reflects the project's emphasis on **traceable and explainable decision support**, ensuring that users can both apply and understand the results.

3.2.2 User Inputs

The EcoFerti workflow begins with a set of **standardized inputs** required by the user, which define the agronomic context of the parcel under analysis. These inputs are essential to ensure that recommendations are **site-specific and management-relevant**. The required inputs include:

1. **Crop information:** current crop type and target yield (kg/ha)
2. **Cropping history:** previous crop and yield (kg/ha).
3. **Soil characteristics:** including texture, organic matter, pH, nutrient levels, cation exchange capacity, P and K concentration

***Note**: If P concentration is not determined using the Olsen method, the user can select from a list of alternative methods. The EcoFerti tool will then automatically convert the value to an Olsen equivalent*

using the established conversion coefficients developed by Neyrood and Lischer [14]. The list of coefficients is provided in Table 1 and calculated with the following equation.

$$STLOlsen = k \times STLm$$

Where STL_{Olsen} represents the Olsen-equivalent soil P level, where k is the conversion factor and STL_m refers to the soil P level determined using a specific method listed in Table 2.

Table 4 Conversion coefficient values of soil phosphorus test methods into an Olsen equivalent[15]

Method	Coefficient k
Ammonium lactate	0.25
Mehlich III	0.36
Bray	0.47
Ammonium acetate + EDTA	0.48
Calcium lactate	0.49
Calcium lactate acetate	0.52
Paper strip	1.5
Acid ammonium acetate	1.6
H_2O	3.8
Saturated water	15
$CaCl_2$	25
Olsen	1

Table 5 Soil Texture Classification Based on Sand, Silt, and Clay Percentages (USDA Soil Texture Triangle)

Soil texture class	Sand%	Silt%	Clay%
Sand	**85-100**	0-15	0-10
Loamy sand	**70-85**	0-30	0-15
Sandy Loam	**43-85**	0-50	0-20
Loam	**23-52**	**28-50**	**7-27**
Silty Loam	0-50	**50-88**	**12-27**
Silt	0-20	**88-100**	**0-12**
Sandy Clay Loam	**45-80**	0-28	**20-35**
Clay Loam	**20-45**	**15-53**	**27-40**
Silty Clay Loam	0-20	**40-73**	**27-40**
Sandy Clay	**45-65**	0-20	**35-55**
Silty Clay	0-20	**40-60**	**40-60**
Clay	0-45	0-40	**40-100**

[14] Neyroud, J.-A. and Lischer, P. (2003), Do different methods used to estimate soil phosphorus availability across Europe give comparable results?. Z. Pflanzenernähr. Bodenk., 166: 422-431. https://doi.org/10.1002/jpln.200321152

[15] Kristin Steinfurth, Juliane Hirte, Christian Morel, Uwe Buczko, Conversion equations between Olsen-P and other methods used to assess plant available soil phosphorus in Europe – A review, Geoderma, Volume 401, 2021, 115339, ISSN 0016-7061, https://doi.org/10.1016/j.geoderma.2021.115339.

4. **Geolocation (Lat, Long):** Alternative input pathway: when soil analysis data are not available, the system can estimate soil parameters using geolocation-based soil information retrieved from the integrated backup soil database (Lucas Topsoil database and SoilGrids). While this functionality enables broader accessibility and usability of the tool, the resulting recommendations may exhibit lower precision compared to recommendations derived from direct laboratory soil analyses
5. **Fertilisation strategy selection**: sufficiency, buildup, maintenance, or maximum yield. EcoFerti allows users to select among four fertilisation strategies, reflecting different nutrient management objectives and soil fertility conditions. The selected strategy influences the calculation of nutrient requirements and the resulting fertiliser recommendations

a. Sufficiency Strategy

The sufficiency strategy aims to supply nutrients only when soil nutrient availability is expected to limit crop growth. Under this approach, phosphorus (P) and potassium (K) fertilisers are recommended only when soil test levels fall below predefined threshold values associated with crop response to fertilisation. The objective is to provide sufficient nutrients to achieve the target yield while avoiding unnecessary fertiliser inputs and nutrient accumulation in the soil. This strategy is generally appropriate for fields with adequate soil fertility levels and where the primary objective is to optimise nutrient use efficiency while minimising fertiliser costs and environmental impacts.

b. Buildup Strategy

The buildup strategy is intended for situations where soil nutrient reserves are below desirable levels. In addition to compensating nutrients removed through crop harvest, the strategy gradually increases soil fertility by applying additional phosphorus and potassium beyond immediate crop requirements. The objective is to progressively raise soil nutrient levels towards target fertility thresholds, thereby improving long-term soil productivity and reducing the risk of future nutrient deficiencies.

c. Maintenance Strategy

The maintenance strategy focuses on preserving existing soil fertility levels. Fertiliser applications are calculated to replace nutrients removed by the harvested crop, thereby maintaining a near-neutral nutrient balance over time. This approach is suitable for fields where soil fertility is already considered adequate, and the objective is to sustain productivity without either depleting or excessively increasing soil nutrient reserves.

d. Maximum Yield Strategy

The maximum yield strategy prioritises crop productivity by ensuring that nutrient availability does not become a limiting factor. Compared to the sufficiency and maintenance approaches, this strategy adopts more conservative assumptions regarding nutrient supply and seeks to minimise the risk of nutrient deficiencies that could reduce yield potential. As a result, fertiliser recommendations may be higher than those generated under other strategies, reflecting a management approach focused on maximising production rather than minimising fertiliser inputs.

Strategy Selection Considerations

The choice of fertilisation strategy depends on the user's production objectives, soil fertility status, economic considerations, and environmental concerns. While sufficiency and maintenance approaches generally promote higher nutrient use efficiency and reduced nutrient surpluses, buildup and maximum yield strategies may be more appropriate where soil fertility restoration or yield maximisation are primary goals.

6. **Fertiliser selection**: 1-3 products (conventional or alternative, selected on Task 2.1), including allocation preferences. The optimisation workflow supports the simultaneous evaluation and recommendation of up to three fertiliser products within a single fertilisation plan. This design choice was adopted to balance agronomic flexibility, computational

efficiency, and operational usability within the decision-support framework. The selected configuration enables the representation of the majority of fertilisation strategies addressed within the FERTITEC case studies, including combinations of conventional and alternative fertilisers, base and complementary applications, and mixed nutrient supply schemes. At the same time, limiting the optimization space to three products reduces excessive solution complexity and improves transparency and interpretability of the generated recommendations for end-users. It is recognised that certain agricultural systems may involve more complex fertilisation programmes incorporating additional products, such as organic amendments, foliar applications, fertigation inputs, or staged nutrient applications. However, the current EcoFerti implementation focuses on the primary fertilisation planning layer required for parcel-level nutrient balancing and optimisation.

This input structure allows the system to capture: i) Crop demand, ii) Soil nutrient supply and iii) Management objectives, ensuring that the subsequent calculations are **context-aware and agronomically consistent**.

3.2.3 Technical Implementation

The EcoFerti tool was developed by the engineering team using **PHP version 8.2**, following modern software engineering practices to ensure reliability, maintainability, and scalability. Code quality and robustness were further supported through the adoption of static analysis procedures, with the **PHPStan validation level set to 6**. This level enables relatively strict code verification, including checks for undefined variables, type inconsistencies, invalid method calls, incorrect parameter usage, and return type validation, thereby improving code reliability and consistency across the application.

To facilitate integration within the broader FERTITEC digital ecosystem, the tool was implemented within a **Laravel 12.0 framework**, exposing its functionalities through a structured **Application Programming Interface (API)** architecture. This approach enables seamless communication between the EcoFerti backend and KEP, allowing users to interact with the system through a user-friendly web interface while maintaining modularity and extensibility at the system level. The API-based implementation also supports future interoperability with additional digital services and decision-support components foreseen in later project stages.

The EcoFerti API is hosted on a dedicated Virtual Private Server (VPS) infrastructure and deployed within a Docker containerized environment, ensuring portability, reproducibility, and controlled service management. System exposure is handled through a Nginx HTTP web server, configured to minimise the attack surface and expose only the strictly necessary services required for operation.

Additional security measures include controlled API access, request validation procedures, and rate-limiting mechanisms to prevent misuse and reduce the risk of unauthorized or excessive requests. Furthermore, only encrypted HTTPS connections are permitted, while unnecessary ports and services remain disabled at the server level.

To ensure secure communication and data protection, all API calls are protected through SSL/TLS encryption certificates, ensuring that user-submitted data remain encrypted during transmission and aligned with current cybersecurity best practices. This architecture supports secure interaction between the EcoFerti backend services, the KEP, and the end-user interface while maintaining system integrity and operational reliability.

3.2.4 Backup Soil Database

A critical component of the EcoFerti infrastructure is the integration of a **backup soil data system**, designed to support fertilisation planning in cases where users do not possess detailed soil analysis data. Since the availability of soil laboratory analyses remains a major limitation for many agricultural stakeholders, especially in large-scale or low-input farming systems, EcoFerti incorporates an automated soil estimation mechanism that enables the generation of approximate soil parameters based on parcel location.

When direct soil analysis data are not provided by the user, EcoFerti queries a dedicated **soil analysis API**, hosted independently on a separate VPS infrastructure. This API accesses a spatially structured soil database covering both **European and African Union territories**, enabling broad geographical applicability of the tool and supporting the international scope of FERTITEC activities.

The backup soil database was developed through the integration and harmonisation of two major soil information sources:

- The **LUCAS (Land Use and Coverage Area frame Survey)** Topsoil database of the European Commission European Soil Data Centre (ESDAC), which provides harmonised topsoil survey data across Europe

Note: *The current implementation primarily relies on the LUCAS 2018 dataset. The LUCAS soil database constitutes one of the largest harmonised soil survey initiatives in Europe. Since LUCAS surveys are periodically updated through subsequent survey campaigns, the EcoFerti soil database infrastructure has been designed to support future updates and integration of newer releases as they become available, thereby ensuring the long-term relevance and continuous improvement of the system.*

- **SoilGrids**, developed by ISRIC World Soil Information, providing global gridded (250m) soil information through machine-learning-based spatial prediction models[16].

The LUCAS soil database constitutes one of the largest harmonised soil survey initiatives in Europe, providing measured information on key soil properties such as:

- Soil texture
- Organic carbon content
- pH
- Cation exchange capacity
- Nutrient-related indicators

To complement and extend this coverage beyond Europe, SoilGrids provides continuous global soil property maps at multiple depths using spatial prediction techniques and environmental covariates. This enables EcoFerti to obtain estimated soil parameters even in regions where direct survey data may be sparse or unavailable.

The combined use of LUCAS and SoilGrids enables EcoFerti to generate fallback soil estimates with improved spatial coverage and consistency. When users provide parcel coordinates or select field locations through the interface, the soil API retrieves the corresponding soil information and

[16] Poggio, L., De Sousa, L. M., Batjes, N. H., Heuvelink, G. B. M., Kempen, B., Ribeiro, E., & Rossiter, D. (2021). SoilGrids 2.0: Producing soil information for the globe with quantified spatial uncertainty. *SOIL*, *7*(1), 217-240. https://doi.org/10.5194/soil-7-217-2021

transforms it into the parameters required by the optimisation engine. These estimated values are then used as proxy inputs for nutrient requirement calculations and fertiliser optimisation.

It is important to note that this functionality does not replace laboratory soil analysis. Instead, it serves as a **decision-support fallback mechanism**, ensuring that users can still access meaningful fertilisation recommendations in the absence of measured soil data. Consequently, recommendations generated using estimated soil parameters should be interpreted as approximate and may exhibit lower precision compared to recommendations derived from direct soil analyses.

The integration of this soil infrastructure significantly enhances the operational usability and accessibility of EcoFerti by:

- Reducing dependency on laboratory analyses
- Supporting wider geographical deployment
- Enabling rapid parcel-level estimations
- Improving accessibility for stakeholders with limited soil data availability
- Providing a scalable data infrastructure capable of incorporating higher-resolution soil datasets and updated soil information products as they become available

Furthermore, the modular architecture of the soil database infrastructure allows future integration of updated LUCAS releases, enhanced SoilGrids products, and other regional or national soil datasets. This ensures that EcoFerti tool can continuously improve the spatial resolution, accuracy, and relevance of its soil estimations as new soil information becomes available.

3.2.5 Calculation methods

Once the user completes all necessary inputs, the EcoFerti tool will calculate the actual nutrient requirements for the crop. The following chapters provide detailed reports on the parameters, equations and adjustments required to calculate the actual requirements for each macronutrient.

3.3.3.1 Estimation of the crop's N requirements for arable crops

Nitrogen requirement calculation will be independent of the fertilisation strategy that the user is going to apply. Methodology is based on Quemada et al., 2024[17]. The calculation of N requirements for arable crops is made through the equation:

$$Nrate = \frac{Nend + (1 + fNR) * (Nyield + Nres) - KimFresNres" - fNR(Nyield' + Nres') - Nother}{1 - n}$$

Where:

- ***Nend*** *is the final soil inorganic N (residual N). In the current implementation, a value of 25 kg N/ha is used as a representative residual nitrogen pool, consistent with values commonly adopted in nutrient balance approaches and fertilisation recommendation systems. This value reflects the fact that soils typically retain a certain quantity of mineral nitrogen following crop harvest and therefore should not be assumed to be completely depleted of available nitrogen (Weil & Brady, 2017[18])*

[17] Quemada, M., Delgado, A., Mateos, L., Villalobos, F.J. (2024). Nitrogen Fertilization II: Fertilizer Requirements. In: Villalobos, F.J., Fereres, E. (eds) Principles of Agronomy for Sustainable Agriculture. Springer, Cham. https://doi.org/10.1007/978-3-031-69150-8_27
[18] Weil, Raymond & Brady, Nyle. (2017). The Nature and Properties of Soils. 15th edition.

- ***fNR*** *is the ratio between nitrogen contained in root biomass and nitrogen contained in aboveground biomass. A value of 0.2 was adopted, indicating that root nitrogen is assumed to represent approximately 20% of shoot nitrogen. This coefficient falls within the range commonly reported for agricultural crops and is widely used as a representative value in nutrient balance and crop nutrient uptake calculations where crop-specific root nitrogen measurements are unavailable (Marschner, 2012[19]).*
- ***Nyield and Nres*** *is the N accumulated in the harvest organ and residues of the present crop and are calculated as a percentage of dry matter for the average crop yield (Table 4 for each crop) as follows:*

$$Nyield = yield\left(\frac{kg}{ha}\right) * \mathrm{DM\%(yield)} * \mathrm{N} - \mathrm{CON\%yield}$$

$$Nres = yield\left(\frac{kg}{ha}\right) * \mathrm{DM\%(yield)} * \mathrm{N} - \mathrm{CON\%residues}$$

Nyield', Nres' is the N accumulated in the harvest organ and residues of the crop cultivated in the ***previous year***. The parameters Nyield' and Nres' are calculated as percentage of dry matter for the average crop yield, as follows:

$$Nyield' = yield\left(\frac{kg}{ha}\right) * DM\%(Yield) * N - CON\%yield$$

$$Nres' = yield\left(\frac{kg}{ha}\right) * DM\%(yield) * DM\%(Residues) * N - CON\%residues$$

- **Yield (kg/ha)** = expected crop yield expressed on a fresh weight basis.
- **DM%Yield** = dry matter content of the harvested product (%), representing the proportion of the harvested yield that consists of dry biomass.
- **DM%Residues** = residue-to-yield dry matter ratio (%), representing the amount of crop residues produced relative to the harvested yield.
- **N-CON%Yield** = nitrogen concentration of the harvested product (% of dry matter).
- **N-CON%Residues** = nitrogen concentration of crop residues (% of dry matter).
- **Nyield'** = nitrogen accumulated in the harvested portion of the crop cultivated during the previous season (kg N/ha).
- **Nres'** = nitrogen accumulated in the crop residues of the previous crop (kg N/ha).

3.3.3.2 Estimation of the crop's N requirements for tree-perennial crops

The calculation of N requirements in this case is made through the equation (*Quemada et al., 2024*):

$$Nc = Y * \left(Cnfruit + Bpl * \frac{1 - HI}{HI}\right) * CNpl$$

where ***Y*** is the crop yield and is calculated by the following equation:

[19] Horst Marschner, Preface to Second Edition, Editor(s): Petra Marschner, Marschner's Mineral Nutrition of Higher Plants (Third Edition), Academic Press, 2012, Page ix, ISBN 9780123849052, https://doi.org/10.1016/B978-0-12-384905-2.00026-1.

$$Y = yield\left(\frac{kg}{ha}\right) * DM\%yield$$

Cnfruit is the N concentration of each crop in fruits % and is calculated by the following equation:

$$Cnfruit = N - CON\%yield$$

- For the coefficient ***kim***, a fixed value of 0.70 is used.
- ***Fres*** is the fraction of residues that are left at the field and has a fixed value of 1.
- ***Nother*** is the total N received by atmospheric deposition, symbiotic fixation and irrigation water, and has a fixed value of 5 kg/ha.
- The ***1-n*** in the equation represents the fraction of applied N that is lost through (leaching, volatilization, denitrification) and is attributed with the value of 0.85. The N rate is calculated in kg/ha.

Note: The coefficients ***kim***, ***Fres***, ***Nother***, and ***1-n*** represent standard agronomic parameters used within the EcoFerti nitrogen balance calculations. Their purpose is to account for nitrogen mineralisation from crop residues, residue management practices, background nitrogen inputs, and nitrogen use efficiency, respectively. The mineralisation coefficient (***kim***=0.70) assumes that approximately 70% of the nitrogen contained in crop residues becomes potentially available through mineralisation processes. The residue retention coefficient (***Fres***=1) reflects the assumption that crop residues remain in the field after harvest. The parameter ***Nother***=5 kg N/ha accounts for background nitrogen inputs from atmospheric deposition, irrigation water, and biological processes, while the nitrogen efficiency coefficient (1-n=0.85) assumes that approximately 15% of applied nitrogen may be lost through leaching, volatilisation, denitrification, and other pathways. These coefficients are values commonly adopted in nutrient balance approaches and fertilisation recommendation systems and were selected to provide consistent parcel-level estimations within the operational framework of EcoFerti (Delgado et al., 2024; Havlin et al., 2014[20])

Table 6 Nitrogen concentration and dry matter content in yield and residues for different crops.

Crop type	Avg yield (kg/ha)	Type	DM% yield	N-CON % yield	Straw or Residues	DM % Residues	N-CON % Residues
Wheat	2800	Grain	85	2	Straw	95	0.40
Maize (grain)	13500	Grain	86	1.35	Straw	87	0.90
Maize (silage)	50000	Sillage	30	1.10		0	0
Cotton	4500	Seed	91	2.32	-	92.5	0.90
Sunflower	2800	Seed	91.5	2.80	Residues	87	0.40
Barley	3000	Grain	86.5	2.20	Residues	90	0.90
Alfalfa	12000	-	85	2.5	-	-	-
Lentil	1600	Grain	90	4.20	Straw	91	1.10
Bean	2000	Seed	89	3.50	Straw	89	1.10
Chickpea	1400	Seed	90	3.50	Straw	89	0.85
Grapevine	25000	Fruit	20	0.70	-	-	-

[20] Havlin, J. L., Tisdale, S. L., Nelson, W. L., & Beaton, J. D. (2014). Soil Fertility and Fertilization: An Introduction to Nutrient Management (8th ed., p. 516). Pearson Prentice Hall.

Olive	6000	Fruit	70	2	-	-	-
Tomato	67000	Fruit	6	2.30	Residues	20	1.80
Rice	8500	Grain	85	1.05	Residues	90	0.50
Apple	42000	Fruit	18	0.45	-	-	-
Apricot	25000	Fruit	14	1.70	-	-	-
Kiwi	32000	Fruit	18	0.90	-	-	-
Orange	33000	Fruit	18	1.40	-	-	-
Cherry	13000	Fruit	19	1.20	-	-	-
Peach	40000	Fruit	12	1.50	-	-	-
Pear	25000	Fruit	18	0.55	-	-	-
Eggplant	35000	Fruit	7	2.40	-	-	-
Potato	30000	Bulb	24	1.20	Residues	51	2.0
Cabbage	30000	Fruit	9	3.0	-	-	-
Lettuce	15000	Leaves	6	4.0	-	-	-
Pepper	30000	Fruit	10	2.10	-	-	-
Fallow	0	-	-	-	0	-	-

Table 7 The harvest index and percentage of residues for each crop in the EcoFerti tool.

Crop type	Harvest Index	Residues (%)
Arable crops		
Wheat	0.4	70
Maize (grain)	0.45	70
Maize (sillage)	0.9	70
Cotton	0.35	70
Sunflower	0.35	70
Barley	0.4	70
Alfalfa	0.9	70
Lentil	0.35	70
Bean	0.35	70
Chickpea	0.35	70
Rice	0.4	70
Trees, vineyards & vegetables		
Grapevine	0.6	70
Olive	0.6	70
Tomato	0.6	70
Apple	0.6	70
Apricot	0.6	70
Kiwi	0.6	70
Orange	0.6	70
Cherry	0.6	70
Peach	0.6	70
Pear	0.6	70

Eggplant	0.6	70
Potato	0.7	70
Cabbage	0.8	70
Lettuce	0.9	70
Pepper	0.6	70
Fallow	0	0

Note on Table 6: The current implementation of EcoFerti adopts a harmonised parameterisation framework for several agronomic coefficients used in nutrient requirement calculations, including harvest index values, crop residue proportions, and nutrient recycling parameters. While these coefficients may vary across cultivars, environmental conditions, management practices, and production systems, representative parameter values were selected to ensure consistency, robustness, and interoperability within the operational decision-support framework. Such harmonised parameterisation approaches are commonly adopted in crop modelling and agricultural decision-support systems, in order to support broad applicability across heterogeneous agricultural systems while limiting excessive calibration complexity and data requirements (Jones et al., 2003[21]; Manschadi et al., 2020[22]).

3.3.3.3 Adjustment of P and K based on management practices

The methodology for P and K fertilisation is based on Delgado et al., 2016b[23]. The P and K fertilisation plan is structured based on soil nutrient content and the fertilisation strategy selected in User Input 5. The sufficiency approach prioritizes minimizing the risk of over-fertilisation by applying only the necessary nutrients, though this may lead to potential yield losses. The buildup approach focuses on long-term soil fertility, aiming to maximize returns and reduce yield loss risks by preserving optimal nutrient levels. The maintenance strategy does not account for soil nutrient content in its calculations; instead, it simply aims to replace the nutrients removed through harvest to sustain productivity. The steps of P and K requirement calculation that the EcoFerti tool follows are: i) Chooses the calculation path based on fertilisation strategy and soil nutrient levels (table 7); ii) Calculates the requirements of P and K; iii) Compares and adjusts (if necessary) with the upper allowable thresholds; and iv) Provides the final P and K requirements. The four fertilisation approaches are described below.

Sufficiency approach: If the initial soil test level (STL) is below the threshold value (STLt) value, this strategy begins with buildup applications, which may be spread over several years, similar to the buildup approach. Once STL exceeds the threshold, annual testing is conducted and fertiliser is applied only when nutrient levels fall below the threshold. The sufficiency approach aims to mitigate environmental issues associated with excessive phosphorus accumulation, which can lead to high phosphorus concentrations in water bodies and trigger eutrophication. Additionally, this strategy encourages greater utilization of residual phosphorus and potassium in the soil as the gradual depletion can enhance the transformation of non-available forms into plant-available ones, improving

[21] https://abe.ufl.edu/Faculty/jjones/ABE_5646/Week%207/The%20DSSAT%20Cropping%20System%20Model.pdf

[22] Manschadi, A.M., Eitzinger, J., Breisch, M. *et al.* Full Parameterisation Matters for the Best Performance of Crop Models: Inter-comparison of a Simple and a Detailed Maize Model. *Int. J. Plant Prod.* **15**, 61–78 (2021). https://doi.org/10.1007/s42106-020-00116-2

[23] Delgado, Antonio & Quemada, M. & Villalobos, Francisco & Mateos, Luciano. (2016). Fertilization with Phosphorus, Potassium and Other Nutrients. 10.1007/978-3-319-46116-8_26.

nutrient uptake. However, over time, this depletion may necessitate higher fertiliser application rates to maintain soil fertility (Delgado et al., 2016b).

Buildup Approach: In this approach, if the soil test level STL is below the STLt, the soil nutrient content must be corrected to bring it a bit higher than STLt value for P and K. This increase usually requires several years, being much slower when soils have a high fixating capacity. When STL levels exceed the threshold value, the buildup strategy is adjusted as mentioned in table 7 (Delgado et al., 2016b).

Maximum yield approach: This approach closely follows the buildup strategy but is optimized for maximum yield, ensuring that nutrient deficiencies are entirely avoided. However, this comes at the expense of higher fertiliser inputs and increased environmental risks. In this case, the threshold values applied are 25 ppm (Olsen) for P and 280 ppm for K, maintaining maximum soil nutrient levels to support peak crop performance.

Maintenance approach: This approach is used in case the system is unable to acquire STL values from soil test analysis or the LUCAS topsoil database. In such cases, phosphorus (P) and potassium (K) requirements are determined solely based on the amount of nutrients exported through harvest.

Estimations for P

$$Prate = ExportedP + \frac{10 * Pb * z}{Nyear} * (STLt - STL) * 10$$

If the soil test level is below the threshold value (STLt>STL), the P or K requirement is calculated as the sum of the nutrient exported through harvest and an additional buildup component required to progressively increase soil nutrient levels towards the threshold. When the soil test level is equal to or above the threshold (STLt≤STL), no additional P or K requirement is generated under this strategy, as the soil nutrient status is considered sufficient to support crop demand:

$$ExportedP = Yield\left(\frac{kg}{ha}\right) * DM(\%)yield * P - CON(\%)$$

- **DM_{yield}** and **P-CON** values are provided on table 8.
- ***Pb*** is the soil bulk density (gr/cm^3) that is acquired from LUCAS 2018.
- ***Z*** (m) is the soil depth, using the fixed value of 0.15.
- ***Nyear*** equals 1.5.
- ***STLt*** is the soil P level threshold provided in Table 6, adjusted according to the soil texture classes.
- ***STL*** is the concentration of phosphorus in the soil, acquired from soil analysis or the LUCAS topsoil database with resolution analysis of 250x250m.

Table 8 STLt P values per soil texture class.

Soil texture	*Threshold P levels in mg/kg soil (ppm)*
Sand, Loamy sand, Sandy loam	*16*
Loam, Silt, Silt Loam, Sandy Clay Loam	*12*

Clay Loam, Silty Clay Loam, Silty Clay, Clay, Sandy Clay	*10*

Note: Different time horizons are applied for phosphorus and potassium buildup to reflect their distinct behaviour and retention dynamics in soils. Phosphorus availability is strongly influenced by fixation processes and tends to exhibit more immediate agronomic response following application, leading to shorter buildup adjustment periods. In contrast, potassium is generally more mobile within the soil exchange complex and its buildup or depletion occurs over longer timeframes, particularly in medium- to high-clay soils where cation exchange processes play an important role. Consequently, EcoFerti applies differentiate N_{year} coefficients (1.5 years for phosphorus and 6 years for potassium) to better represent the typical temporal dynamics associated with nutrient accumulation and soil fertility correction (Brady & Weil, 2008[24]).

Estimations for K

$$\text{Krate} = Exported\ K + \frac{10 * Pb * z}{Nyear} * (STLt - STL) * 10$$

If $\mathbf{STL_t > STL}$ K rate is calculated by the previous equation, if $\mathbf{STL_t \leq STL}$ the K rate is equal to the exported K value. $\mathbf{STL_t}$ values are found in table 7 and are based on exchangeable potassium measurements, typically determined using neutral ammonium acetate extraction methods.

Exported K is calculated for each crops harvested parts with the following formula:

$$Exported\ K = Yield\left(\frac{kg}{ha}\right) * DM(\%)yield * K - CON(\%)$$

- $\mathbf{DM_{yield}}$ and **K-CON** values are provided on table 8.
- ***Pb*** is the soil bulk density (gr/cm^3) that is acquired from LUCAS 2018.
- ***Z*** (m) is the soil depth, using the fixed value of 0.15.
- ***Nyear*** in this case equals 6.
- ***STLt*** is the soil potassium level threshold provided in Table 7, adjusted according to the soil texture classes. ***STL*** is the concentration of potassium in the soil (soil analysis or LUCAS).

Table 9 STLt K values per different CEC value ranges.

Cation exchange capacity (CEC) $mmol_c/kg$	*Threshold K levels in mg/kg soil (ppm)*
<100	*150*
100-199	*150*
200-299	*180*
300-399	*210*
>400	*240*

Table 10 Average P and K concentrations (% in dry weight) in harvested parts for the different crop types included in the EcoFerti tool (Delgado et al., 2016a).

[24] https://www.redwoods.edu/resources/syllabi/Agriculture/2017-2018/Spring/2018S-AG17-E3665-Houghton.pdf

Crop type	Average yield (kg/ha)	Dry matter DM% Yield	P-CON %	K-CON %
Wheat	2800	85	0.42	0.5
Maize (grain)	13500	86	0.32	0.34
Maize (silage)	50000	30	0.2	1.0
Cotton	4500	91	0.41	0.49
Sunflower	2800	91.5	0.63	0.72
Barley	3000	86.5	0.35	0.49
Alfalfa	12000	85	0.26	2.10
Lentil	1600	90	0.43	0.86
Bean	2000	89	0.54	2.7
Chickpea	1400	90	0.4	1.2
Grapevines	25000	20	0.05	1.02
Olive	6000	70	0.14	1.25
Tomato	67000	6	0.47	4.28
Rice	8500	85	0.3	0.45
Apple	42000	18	0.05	0.75
Apricot	25000	14	0.14	2.17
Kiwi	32000	18	0.18	1.43
Orange	33000	18	0.14	1.35
Cherry	13000	19	0.01	1.16
Peach	40000	12	0.12	1.55
Pear	25000	18	0.07	0.77
Eggplant	35000	7	0.31	0.30
Potato	30000	24	0.25	2
Cabbage	30000	9	0.35	2.73
Lettuce	15000	6	0.75	6.67
Pepper	30000	10	0.35	2
Fallow	0	-	-	-

Soil nutrient levels	*Estimation of P and K Requirements per fertilisation approach*
	Sufficiency Approach
STL< STL$_t$	$Prate = ExportedP + \frac{10 * Pb * z}{Nyear} * (STLt - STL) * 10$ $\text{Krate} = Exported\ K + \frac{10 * Pb * z}{Nyear} * (STLt - STL) * 10$
STL ≥ STL$_t$	*Not any P and K requirements*
	Buildup Approach
STL < STL$_t$	$Prate = ExportedP + \frac{10 * Pb * z}{Nyear} * (STLt - STL) * 10$ $\text{Krate} = Exported\ K + \frac{10 * Pb * z}{Nyear} * (STLt - STL) * 10$
STL$_t$≤ STL≤ 2STL$_t$	$Prate = Exported\ P * 1.15$

	$Krate = Exported\ K$
STL > 2STL$_t$	$Prate = Exported\ P * 0.5$ $Krate = Exported\ K$*0.5
Maximum yield Approach	
Irrelevant	$Prate = ExportedP + \frac{10 * Pb * z}{Nyear} * (25 - STL) * 10$ $\text{Krate} = Exported\ K + \frac{10 * Pb * z}{Nyear} * (280 - STL) * 10$
Maintenance Approach	
Irrelevant	$Prate = Exported\ P$ $Krate = Exported\ K$

3.3.3.4 Comparison against environmental thresholds

At the final stage, the dose of N-P-K that will occur from the process briefly described in table 8 will be compared to upper allowable thresholds for each element individually (table 10). If the recommendation calculated previously is higher than the threshold values, the dose will be equal to the upper threshold. On the other hand, if the recommendation is less than or equal to the threshold values, then it will be accepted as the final recommendation.

Table 11 Upper allowable thresholds of NPK requirements for each crop type (kg/ha) (Villalobos et al., 2016).

Crop type	N- Threshold (kg/ha)	P-Threshold (kg/ha)	K-Threshold (kg/ha)
Wheat	180	50	65
Maize (grain)	285	80	235
Maize (sillage)	285	80	160
Cotton	180	80	110
Sunflower	170	90	180
Barley	160	40	40
Alfalfa	40	60	95
Lentil	60	30	40
Bean	150	90	165
Chickpea	70	40	40
Grapevines	200	43	185
Olive	250	100	350
Tomato	450	105	580
Rice	140	120	230
Apple	230	100	250
Apricot	180	90	150
Kiwi	230	90	210
Orange	220	100	200
Cherry	120	60	120
Peach	200	150	200
Pear	120	100	200
Eggplant	350	150	330
Potato	250	140	300
Cabbage	160	100	120
Lettuce	100	40	150
Pepper	400	150	705
Fallow	-	-	-

***Note on Regulatory Considerations*:** The fertilisation thresholds presented in Table 11 are intended to provide a harmonised operational framework for nutrient management within the current implementation of EcoFerti. These values were selected to support representative agronomic recommendations and environmental safeguards across a broad range of agricultural systems and use cases. It is recognised, however, that fertilisation limits and nutrient application restrictions may vary significantly between countries and regions due to differences in the implementation of the EU European Commission Nitrates Directive, national legislation, agri-environmental schemes, vulnerable zone designations, and crop-specific regulatory requirements. Consequently, the threshold values integrated within EcoFerti should not be interpreted as universally applicable regulatory limits. Users are therefore advised to verify compliance with applicable national, regional, and local regulations before implementing fertilisation plans generated by the tool, particularly in areas subject to specific nutrient management restrictions or environmental protection measures. Future versions of EcoFerti may incorporate region-specific regulatory parameterisation and localisation functionalities to further improve regulatory alignment and operational applicability across different jurisdictions.

3.3.3.5 Fertiliser Allocation and Optimisation

Once EcoFerti has calculated the crop's final nitrogen (N), phosphorus (P) and potassium (K) requirements, the next step is to determine how these needs should be met using the fertilisers selected by the user. This chapter explains how the system transforms nutrient requirements into specific fertiliser amounts, using a transparent, rule-based algorithm. The goal is to:

- Minimize over-application and avoid imbalanced fertilisation
- Provide a step-by-step, traceable recommendation

To achieve this, EcoFerti uses a sequence of equations and decision rules. Below, each equation is introduced with a high-quality explanation of what it does and why it is needed.

Determining the Portion of Nutrients to Be Covered by the Basic Fertiliser

Farmers often designate a primary or "basic" fertiliser as their main input. The EcoFerti tool allows the user to specify what percentage of total nutrient requirements will be covered by this fertiliser (Step 5). Before optimization begins, the system allocates the corresponding fraction (percentage selected in Step 5) of N, P and K requirements to the basic fertiliser.

$$Nrb = Nr * Pc, \qquad Prb = Pr * Pc, \qquad Krb = Kr * Pc$$

Where:

- **Nr, Pr, Kr** are the total nutrient requirements
- **Pc** is the percentage of needs covered by the basic fertiliser
- **Nrb, Prb, Krb** are the nutrient requirements assigned to the basic fertiliser

The amount of basic fertiliser is calculated by the following equation:

$$(Equation\ 1)\ Basic\ FA = \frac{Pcon * Prb + Kcon * Krb + Ncon * Nrb}{Pcon_2 + Kcon_2 + Ncon_2}$$

Ncon, Pconc and ***Kcon*** are the concentrations of N-P-K in the selected fertiliser and are calculated by the following equations:

$$Ncon = \frac{Ntype}{100}, Pcon = Ptype * \frac{0{,}436}{100}, Kcon = Ktype * \frac{0{,}83}{100}$$

Where: N_{type}, P_{type} and K_{type} are the numbers shown in fertiliser composition (e.g. 22-15-17 ⇒ N_{type}=22, P_{type}= 15, K_{type}=17).

Checking for Excessive Nutrient Application

Nitrogen use efficiency is highly variable under field conditions, with significant losses occurring through leaching, volatilisation, and denitrification. Global nitrogen use efficiency commonly ranges between 30–60%, depending on crop type, soil conditions, and management practices, indicating that moderate variability in nitrogen allocation is agronomically unavoidable (Ali et al., 2025[25]). In contrast, phosphorus presents substantially higher long-term environmental risk due to accumulation in soils and transport to aquatic systems, where even relatively small surpluses can contribute to eutrophication. Consequently, phosphorus management generally requires stricter control of over-application compared to nitrogen and potassium (Meng-ze et al., 2023[26]).

Complex fertilisers rarely match crop needs perfectly. Sometimes, the amount required to meet P or K ends up providing too much of another nutrient. To prevent environmentally excessive fertilisation while maintaining agronomic flexibility, EcoFerti applies tolerance thresholds during the optimization process. Specifically, recalculation is triggered when nutrient over-application exceeds **15% for nitrogen (N) and potassium (K)** and **10% for phosphorus (P)**. These thresholds were selected to reflect both the inherent uncertainty associated with nutrient use efficiency and the differing environmental sensitivities of the major macronutrients.

Within this context, the thresholds implemented in the EcoFerti tool represent a conservative compromise between optimization flexibility and environmental protection, ensuring that fertilisation recommendations remain agronomically realistic while minimising nutrient surplus risks.

$$Unit(excess) = \frac{Xun - Xrb}{Xrb} * 100$$

Where Xun is the applied amount of nutrient (N-P-K) and Xrb is the corresponding requirement. If Unitexcess is >15% for N, K or >10% for P equation 1 is adjusted to the specific nutrient(s) to avoid this. For example, in a case that P exceeds by 10% equation 1 is adjusted to

$$Basic\ FA = \frac{Pcon * Prb}{Pcon_2}$$

[25] Ali A, Jabeen N, Farruhbek R, Chachar Z, Laghari AA, Chachar S, Ahmed N, Ahmed S and Yang Z (2025) Enhancing nitrogen use efficiency in agriculture by integrating agronomic practices and genetic advances. Front. Plant Sci. 16:1543714. doi: 10.3389/fpls.2025.1543714

[26] Meng-ze XU, Yu-hong WANG, Cai-e NIE, Gui-pei SONG, Su-ning XIN, Yan-li LU, You-lu BAI, Yin-jie ZHANG, Lei WANG, Identifying the critical phosphorus balance for optimizing phosphorus input and regulating soil phosphorus effectiveness in a typical winter wheat–summer maize rotation system in North China, Journal of Integrative Agriculture, Volume 22, Issue 12, 2023, Pages 3769-3782, ISSN 2095-3119, https://doi.org/10.1016/j.jia.2023.05.030.

Once the amount of fertiliser has been finalised (either initial or adjusted), the tool calculates how many kilograms (units) of N, P, and K this fertiliser actually contributes. These values must then be subtracted from the crop's remaining requirements. For each nutrient the units are calculated as follows:

- Nun_{basic}= Basic FA x Ncon
- Pun_{basic}= Basic FA x Pcon (2)
- Kun_{basic}= Basic FA x Kcon

Updating Remaining Nutrient Requirements: After applying the basic fertiliser, some nutrient requirements may be fully satisfied while others remain partially unmet. EcoFerti computes the remaining requirements and prepares for the next fertiliser (if any). Nutrients that fall below **1 kg/ha** are considered negligible and treated as fully satisfied.

Remaining nutrient requirements for each are calculated:

- Nr_{rem}= Nrb-Nun_{basic}
- Pr_{rem}= Prb-Pun_{basic} (3)
- Kr_{rem}= Krb-Kun_{basic}

These updated values serve as the new targets in the next iteration.

Applying Secondary Fertilisers (Iterative Algorithm): If the user has selected additional fertilisers, EcoFerti repeats the previous steps. This iterative approach continues until:

- all selected fertilisers have been used, or
- all remaining requirements are < 1 kg/ha

Each secondary fertiliser is optimized using the same equations, but based only on the remaining nutrient requirements.

Handling Remaining Gaps and Overapplication Conflicts: In some cases, the remaining requirement for one nutrient cannot be met with the available fertilisers **without overapplying** others. EcoFerti detects this situation automatically.

If meeting P, for example, would cause large excess N or K, the system:

1. **Warns the user**
2. Offers the option to:
    - accept the excess, **or**
    - choose another fertiliser

This ensures transparency and prevents unintended nutrient imbalances.

Output Conversion for Liquid fertilisers (kg/ha to L/ha): While all internal calculations are performed in kg/ha, the final recommended application rate for liquid fertilisers is expressed in L/ha to align with practical field application units. The conversion is performed as follows:

$$F(L/ha) = \frac{F\left(\frac{kg}{ha}\right)}{\rho}$$

Where:

- $\mathbf{F_{L/ha}}$ → Final recommended application rate in L/ha
- $\mathbf{F_{kg/ha}}$ → Optimized fertiliser amount calculated by the model
- $\boldsymbol{\rho_{(kg/L)}}$ → Fertiliser density, the value that will be used is: 1.2

This ensures that recommendations remain both **computationally consistent** and **operationally applicable**, allowing users to directly implement the suggested fertilisation plan under real field conditions.

2.3.3.6 Outputs

The final stage of the EcoFerti workflow consists of generating **structured, user-oriented outputs** designed to support fertilisation planning and decision-making at parcel level. The outputs are presented in a transparent and interpretable format, enabling users to understand both the calculated nutrient requirements and the extent to which the selected fertilisers satisfy these needs.
The EcoFerti tool provides the following outputs:

Crop Nutrient Requirements

Based on the selected crop type, target yield, soil characteristics, previous crop, and fertilisation strategy, EcoFerti calculates the estimated crop nutrient requirements expressed in:

- N-P-K (kg/ha)

These values represent the total nutrient demand required to achieve the expected yield while maintaining soil fertility under the selected management approach. The calculated requirements form the baseline for the subsequent fertiliser optimization process.

Recommended Fertiliser Amounts

EcoFerti provides fertiliser recommendations based on the products selected by the user during Step 5 of the workflow. The system supports optimization using up to three fertilisers, including both conventional and alternative fertilising products. For each fertiliser, the tool provides:

- Fertiliser name/type
- Recommended application amount
- Unit of application:
    - kg/ha for solid fertilisers
    - L/ha for liquid fertilisers

The recommendations are generated through the optimization algorithm described in Section 4, ensuring that the selected fertiliser combination covers crop nutrient requirements as efficiently as possible while minimizing excessive nutrient application. Depending on the number of fertilisers selected by the user, the outputs may include:

- Primary fertiliser recommendation
- Secondary fertiliser recommendation
- Additional fertiliser recommendation

Nutrient Coverage (%)

For each nutrient (N, P, and K), EcoFerti calculates the percentage of crop requirements covered by the selected fertiliser combination. The tool therefore provides:

- Nitrogen coverage (%)
- Phosphorus coverage (%)
- Potassium coverage (%)

This functionality allows users to directly evaluate the effectiveness of the selected fertilisation strategy and understand how closely the recommendations match the estimated crop needs.

Unmet Nutrient Requirements

In cases where the selected fertiliser combination cannot fully satisfy crop nutrient demands without causing excessive nutrient application, EcoFerti calculates and displays the remaining unmet requirements for:

- Nitrogen – kg/ha
- Phosphorus – kg/ha
- Potassium – kg/ha

These values indicate the nutrient quantities that remain uncovered after completion of the optimization process. Nutrient gaps may occur when:

- Fertiliser nutrient compositions are not fully compatible with crop requirements
- Covering one nutrient would lead to excessive application of another nutrient
- User-selected fertilisers provide limited flexibility for balancing N-P-K ratios

Comments and Advisory Messages

To support interpretation of the results, EcoFerti provides contextual comments explaining the origin of unmet nutrient requirements or optimization constraints. Typical advisory messages include examples like:

- Nitrogen requirements cannot be fully covered without exceeding phosphorus or potassium thresholds
- Additional fertiliser application would result in overfertilisation
- Alternative fertiliser combinations may provide a more balanced nutrient supply

These comments are intended to improve transparency and support informed decision-making by helping users understand the trade-offs associated with different fertilisation strategies and fertiliser combinations.

Through this output structure, EcoFerti transforms complex agronomic calculations into practical, interpretable, and decision-oriented information, enabling users to optimize fertiliser management while minimizing environmental risks and improving nutrient use efficiency.

3.3 User guidelines and practical use

The EcoFerti tool is designed to support users in performing **structured, step-by-step fertilisation planning**, translating agronomic data into clear recommendations. The following guidelines provide practical instructions for using the tool effectively, ensuring reliable outputs and proper interpretation of results within real farming conditions.

Figure 13 EcoFerti Tool Header overview

To begin using EcoFerti, the user should first ensure that all required information is available or can be reasonably estimated. The tool operates based on a sequence of inputs, and the quality of these inputs directly influences the accuracy of the recommendations. The user is first prompted to define the **crop type and target yield**, which form the basis for all subsequent calculations. It is important to provide realistic yield targets, as overestimation may lead to unnecessarily high fertilisation recommendations, while underestimation may result in nutrient deficiencies.

The next step requires the user to enter information regarding the **previous crop and its yield**. This is a critical component, as EcoFerti accounts for residual nutrient effects from crop rotation. Users should therefore input accurate historical data whenever possible. Following this, the tool requires **soil-related information**, including parameters such as soil texture, organic matter, pH, cation exchange capacity, and nutrient levels (P and K). If a complete soil analysis is not available, the tool allows the user to define the parcel location via coordinates, enabling the system to acquire soil properties from established soil databases. However, users should be aware that such estimations reduce the precision of the results compared to laboratory soil data.

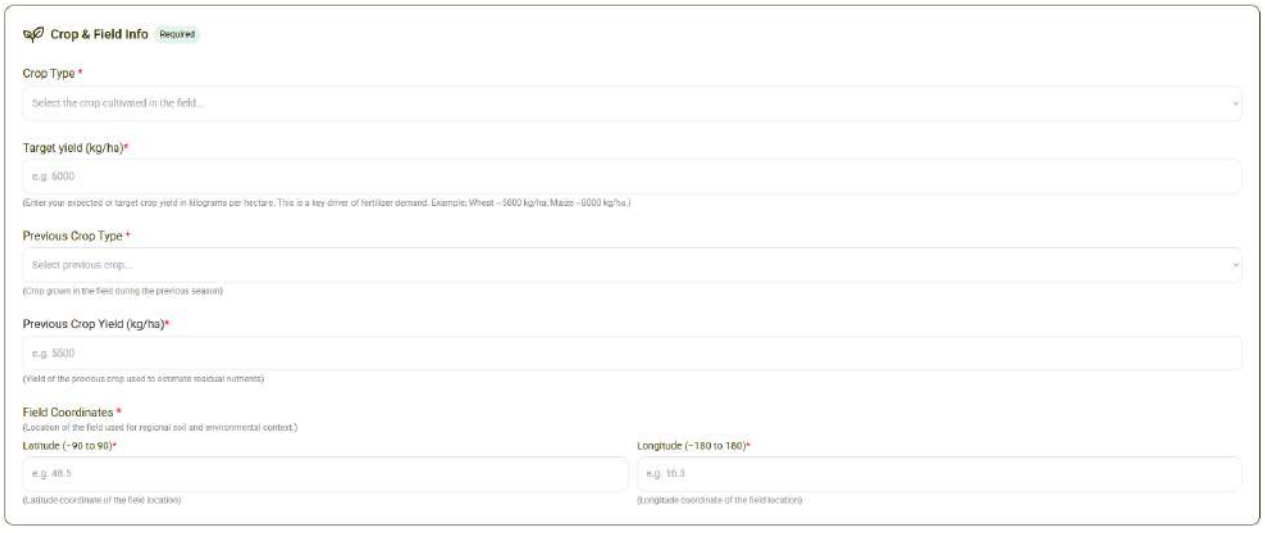

Figure 14 User inputs related to parcel information.

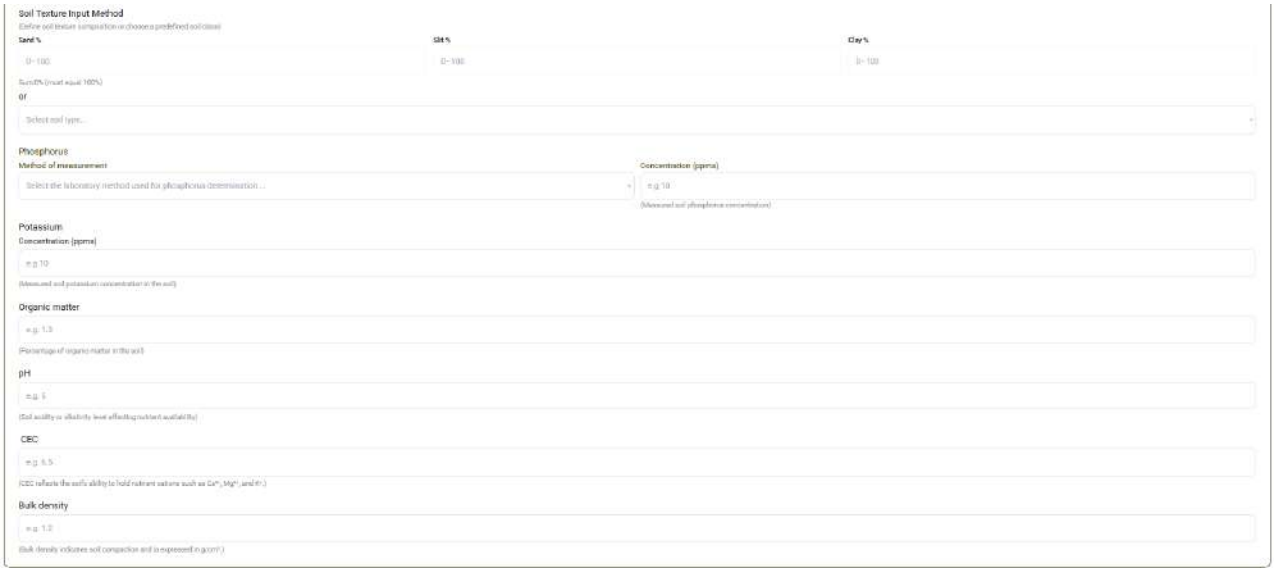

Figure 15 User inputs related to soil properties.

Once the agronomic context has been defined, the user must select a **fertilisation strategy**. This choice significantly influences the output and should reflect the user's objectives. The sufficiency strategy is recommended when the aim is to minimize input use and environmental impact, applying nutrients only when needed. The buildup strategy is more suitable for improving soil fertility over time, especially in nutrient-deficient soils. The maintenance strategy is appropriate when the goal is to replace nutrients removed through harvest without modifying soil nutrient levels. The maximum yield strategy should be used when achieving the highest possible production is the priority, although it may lead to higher input use. Users are advised to select the strategy carefully, as it determines how nutrient requirements are calculated and interpreted.

In the next step, the user selects one or more **fertilisers** to be used. EcoFerti supports both conventional and alternative fertilizing products, allowing users to define combinations based on availability and preference. The user may also specify what proportion of the nutrient requirements should be covered by a primary fertiliser. When selecting fertilisers, it is recommended to consider their nutrient composition (N-P-K ratios), as this directly affects the optimization process. Using a combination of fertilisers often leads to more balanced nutrient supply and better alignment with crop needs.

Figure 16 Nutrient strategy and fertiliser selection.

After all inputs have been provided, the tool generates the outputs. The user is first presented with the **crop nutrient requirements**, expressed in kg/ha for nitrogen, phosphorus, and potassium. These values represent the total nutrient demand required to achieve the defined yield under the selected

conditions. The user should review these values carefully, as they provide the baseline for understanding the fertilisation plan.

The tool then provides **fertiliser application recommendations**, specifying the required amount for each selected product. Solid fertilisers are expressed in kg/ha, while liquid fertilisers are automatically converted and presented in L/ha to match practical application units. The user should ensure that the recommended doses are feasible within their operational context and compatible with available equipment.

In cases where the selected fertilisers cannot fully satisfy the nutrient requirements without causing imbalances, EcoFerti will display the **remaining nutrient requirements**. These values indicate nutrient gaps that remain after applying the recommended fertilisers. Users should interpret these gaps as an indication that the current fertiliser combination is not fully optimal. In such cases, the tool provides **advisory messages**, suggesting actions such as selecting an alternative fertiliser with a more suitable nutrient composition or accepting a minor imbalance depending on practical constraints. To support further exploration, a dedicated Datasheets button is displayed, allowing users to navigate directly to the Datasheets page of the KEP where they can browse the full catalogue of alternative fertilising products and techniques to identify a more suitable option.

Figure 17 Results on crop nutrient requirements.

Users should pay particular attention to warnings related to **over-application of nutrients**. Due to the fixed composition of fertilisers, it is sometimes not possible to meet all nutrient requirements without exceeding one of them. The tool identifies such situations and adjusts recommendations where possible. However, the final decision remains with the user, who must consider agronomic, environmental, and economic factors.

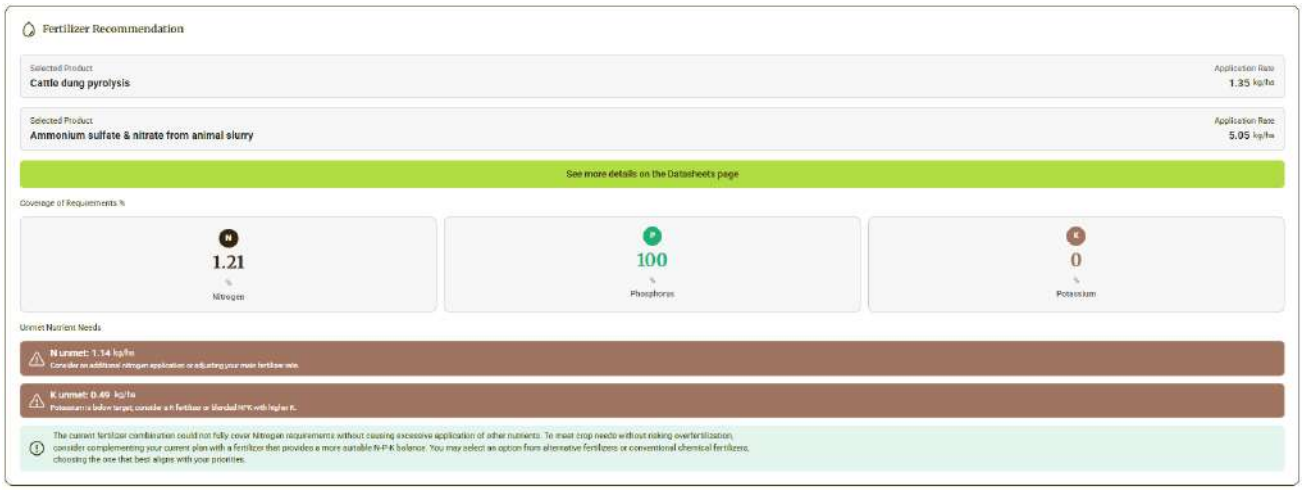

Figure 18 Results on amounts of fertilisers suggested, nutrient requirement coverage, and comments on unmet requirements

For optimal use of EcoFerti, it is recommended that users:

1. Use accurate and up-to-date soil data whenever available

2. Avoid unrealistic yield targets
3. Combine fertilisers to improve nutrient balance
4. Review advisory messages before finalizing decisions
5. Consider local conditions such as weather, irrigation, and management practices

It is important to emphasize that EcoFerti is a decision-support tool and not a fully automated prescription system. While it provides scientifically grounded fertilisation recommendations, users are expected to apply their own expertise and adapt the outputs to the specific agronomic, environmental, and operational conditions of each production system. In particular, factors such as timing of nutrient application, split fertilisation strategies, field variability, irrigation management, weather conditions, and operational constraints are not fully captured within the current implementation of the tool and should therefore be considered externally during decision-making. This is especially relevant for nitrogen management, where application timing and dose splitting can substantially influence nitrogen use efficiency, crop uptake, and the risk of environmental losses through leaching, volatilisation, or runoff. Consequently, EcoFerti outputs should be interpreted as decision-support recommendations intended to complement, rather than replace, local agronomic expertise and advisory services. Users are encouraged to integrate the generated recommendations with local technical guidance, regional best management practices, and applicable regulatory requirements in order to optimize both agronomic performance and environmental sustainability.

At the stage of D2.3, EcoFerti operates as a **rule-based system with fully transparent logic**, ensuring that all recommendations can be understood and validated. This makes it particularly suitable for initial deployment, testing, and stakeholder engagement within the FERTITEC project. Future versions will introduce more advanced functionalities, including AI-based enhancements, but the current version prioritizes clarity, reliability, and ease of use.

By following these guidelines, users can effectively utilize EcoFerti to improve fertilisation planning, optimize nutrient use, and support more sustainable agricultural practices in line with the objectives of the project.

4. Sustainability, Data Protection and Impact

4.1 GDPR and Cookie Management

The Datasheets page and the EcoFerti tool have been designed with full respect for user privacy and in compliance with the GDPR. Neither page collects or retains personal data. The data entered by users within the EcoFerti tool, such as crop type, soil parameters, and yield targets, are entirely anonymous, contain no personally identifiable information, and are not stored by the platform in any form.

Each user interaction with the EcoFerti tool constitutes an independent session: inputs submitted through the KEP interface are transmitted to the EcoFerti API solely for the purpose of performing the requested calculations, and no data — including parcel coordinates provided for soil estimation purposes — are stored, logged, or retained on the server following the completion of the API call. Intermediate calculation results are processed transiently in memory and discarded immediately after the response is returned to the user. No user profiles, session histories, or location data are retained at any point.

To ensure compliance with GDPR and applicable data protection standards, a validated Cookie Consent plugin provided by Bubble.io has been installed on the platform. This plugin allows both registered and unregistered users to manage their cookie preferences transparently. A Privacy Policy has been developed in accordance with the project's DMP. Further details on cookie management, data protection, and the platform's privacy framework are provided in D1.2.

4.2 KPIs and Promotion

The development and deployment of the Datasheets and the EcoFerti tool contribute directly to the achievement of the project's KPIs. O3 encompasses a set of achievement indicators related to the technical, environmental and socioeconomic assessment of case studies, including the number of assessments conducted and techniques evaluated. The indicators related to the technical and environmental assessments and the socioeconomic analyses are reported in D2.1 and D2.2 respectively. Within the scope of this deliverable, the production of 30 datasheets fulfils the datasheet-specific target set under O3, which has been successfully achieved at this stage.

A further key target is KPI-4, which aims for 1.000+ unique visitors to the EcoFerti tool, representing farmers, agricultural advisors, farmers' associations, and cooperatives interested in adopting sustainable fertilisation solutions. To work towards this target, the consortium is actively promoting both tools through social media channels and the project website, in close coordination with all partners and Q-Plan (Communication and Dissemination Manager). Promotional activities are already underway and will be further intensified in the coming project period. Progress towards this target will be reported in subsequent deliverables in coordination with the dissemination activities of WP4 and WP5.

4.3 Long-term Availability and Platform Sustainability

The Datasheets page and the EcoFerti tool are designed to remain fully operational and publicly accessible for four years following the completion of the project, ensuring continued availability of the knowledge and decision-support resources generated within the project. The technical maintenance and hosting of the platform during this post-project period will be undertaken by AgAp, covering server monitoring, security updates, and GDPR compliance.

During the post-project period, no cookies will be collected by the platform. All existing resources, including the Datasheets and the EcoFerti tool, will remain freely accessible to all users without the need for registration.

With regard to the soil data infrastructure underpinning the EcoFerti tool, AgAp will monitor the availability of updated soil datasets, including future releases of the LUCAS topsoil database and SoilGrids, and will assess the feasibility of incorporating updated data sources during the post-project maintenance period. This ensures that the soil estimation functionality of the tool remains as accurate and relevant as possible over time. The approach to soil data updates will be further reviewed and addressed in the context of the AI-enhanced version of the EcoFerti tool to be delivered in D3.3 at M36. Further details on the sustainability framework of the KEP and its components are provided in D1.2.

5. Next Steps

T2.3 is completed at M18, with the delivery of the 30 Datasheets and the EcoFerti tool as presented in this deliverable. Following the completion of this task, the Datasheets page will continue to be maintained and improved under T3.3 (M19–M36), with functional enhancements and refinements implemented based on user feedback collected during the operational period.

The EcoFerti tool will continue to be developed throughout the remaining project period. In accordance with the project's GA, the tool will be enhanced with AI-powered optimisation capabilities under T3.3, in collaboration with RISE, and will be delivered in its final form by M36 (D3.3). This enhancement will further improve the precision and personalisation of the fertilisation recommendations provided to users, strengthening the tool's contribution to the adoption of alternative fertilising products across the EU and beyond.

6. Conclusion

The outputs delivered through D2.3 mark a concrete step in the FERTITEC project's transition from knowledge generation to practical application. By making 30 structured datasheets and a fully operational decision-support tool freely accessible through the KEP, the consortium has created a tangible resource for farmers, advisors, industries and policymakers seeking to navigate the shift towards alternative fertilising products.

The value of these outputs lies not only in the information they contain, but in the way they have been designed: the datasheets provide comparable, evidence-based insights across diverse technologies and regions, while the EcoFerti tool translates this knowledge into actionable, parcel-level recommendations. Together, they lower the barrier to adoption and support more informed decision-making at farm level.

As the project moves into its second period, these foundations will be built upon, through continued stakeholder engagement, the integration of user feedback, and the planned AI enhancement of the EcoFerti tool. The work presented in this deliverable thus represents not an endpoint, but a platform for the broader impact that FERTITEC aims to achieve.

7. Annex

Appendix I Preliminary Mockups & Designs

The initial design mockups of the Datasheets and EcoFerti Tool were developed using UX Pilot and shared with consortium partners for review and feedback during March and April 2025.

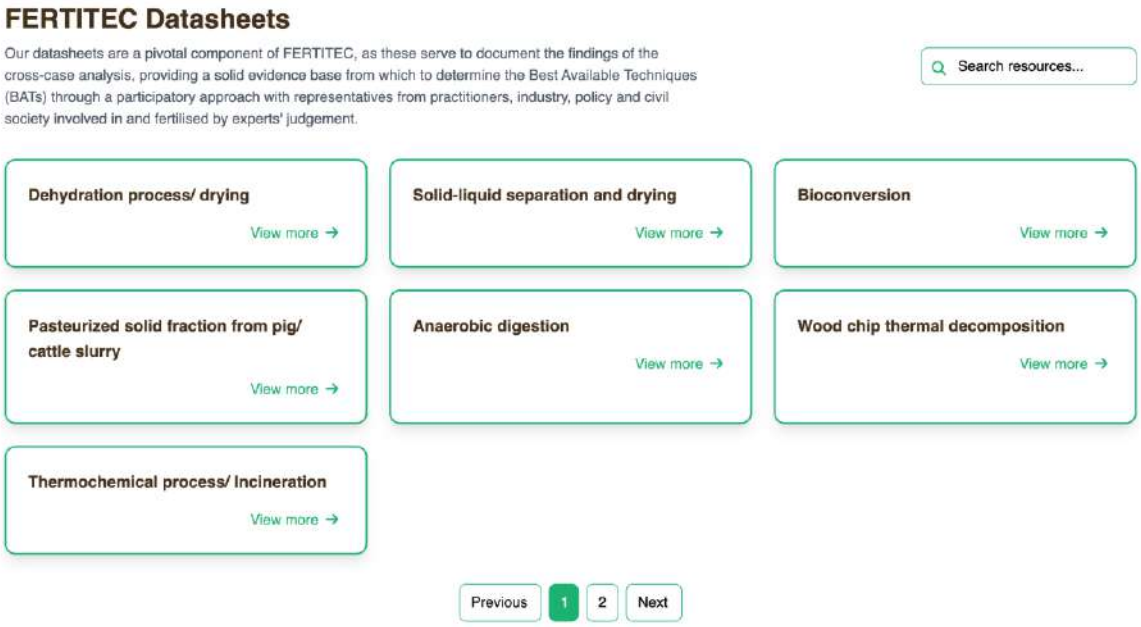

Figure 19 Initial Design of Datasheets page

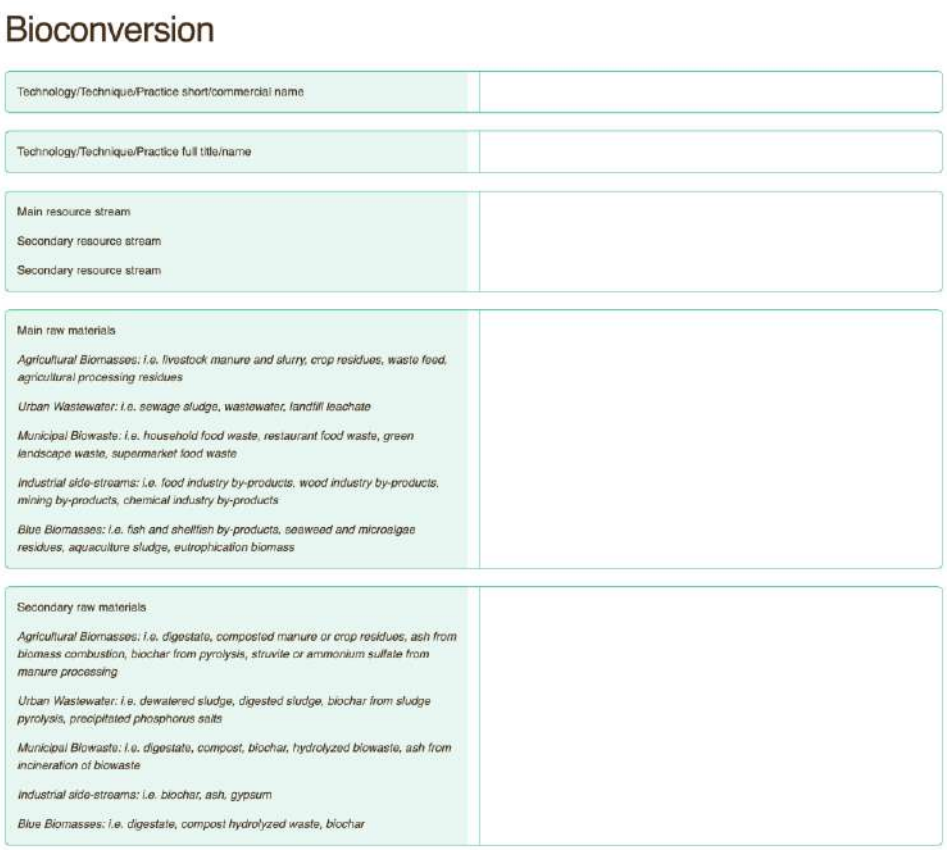

Figure 20 Initial Design of Datasheets individual page

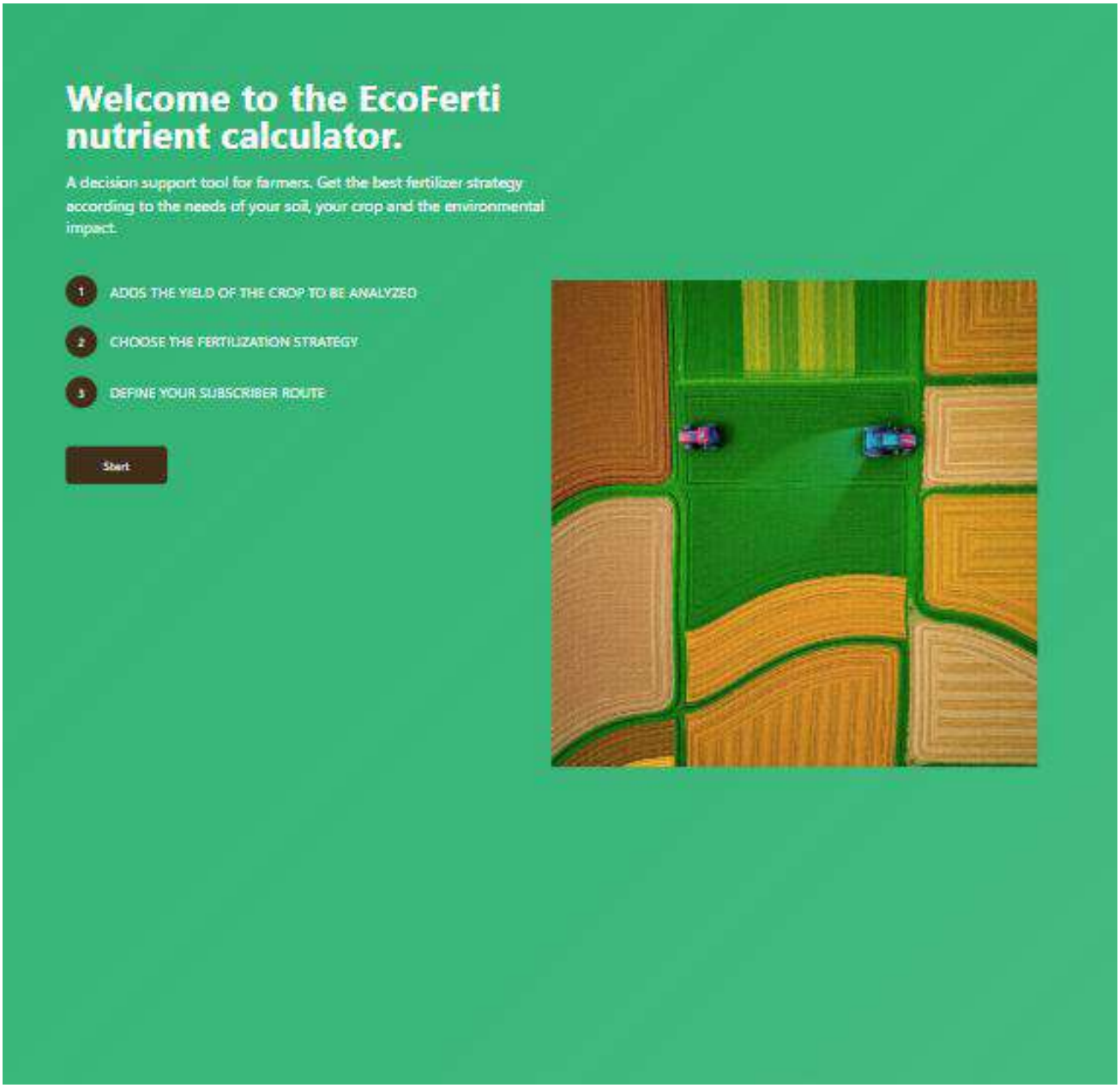

Figure 21 Initial Design of EcoFerti Tool

FERTITEC

INNOVATIVE RECOVERY TECHNIQUES
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