European Commission

FaST Navigator

Study for the development of a common framework for the quantitative advice of crop nutrient requirements and GHG emissions & removal assessment at farm level

· FaSTNavigator ·

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Context of study

New CAP strategic plan → FaST (Farm Sustainability Tool)

The FaST was defined as an electronic tool for on-farm decision support starting from minimum crop fertilization management functionalities and extendable to further sustainability objectives. The main objective of FaST is the wider adoption of nutrient management plans and takes advantage of the digital technologies to facilitate their computation.

Challenge of FaST implementation →availability of nutrient management algorithms: operational for different conditions

FaST Navigator (**N**utrient management **A**lgorithms, **V**alorisation of **I**nputs and **G**HG **A**ssessment – **T**ool for **O**ptimization of **R**esources)

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Objectives: Overall aim of study

1º to describe the methodological frameworks:
quantitative advice for fertilizer use and
GHG emissions/removal assessment;

2º to parameterize the frameworks in real systems…
…representing EU ag diversity

Main objectives (MO):

- MO1 – description of variables & timescales
- MO2 – calculation methodologies
- MO3 – optimize economic performance
- MO4 – estimate reliability of results
- M05 – implement in digital tool for farm/advisors

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FaST Navigator framework:

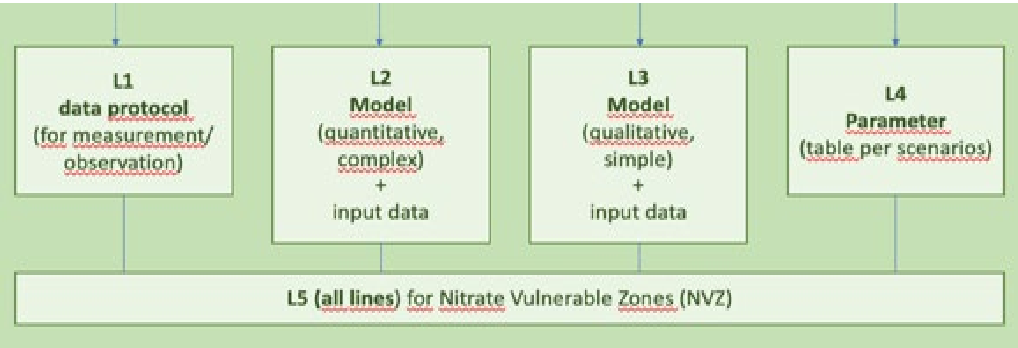
assessment of

→ **crop nutrient requirements at field scale,** **Nutrient balance NPK / best fertilizer**

→ **GHG emissions/removals at farm scale,** **Activity data * emission factors / CO_2, N_2O and CH_4**

→ **economic performance at farm scale.** **FADN-compatible**

Farm = crops, livestock, LULUCF / carbon, energy (direct/indirect)



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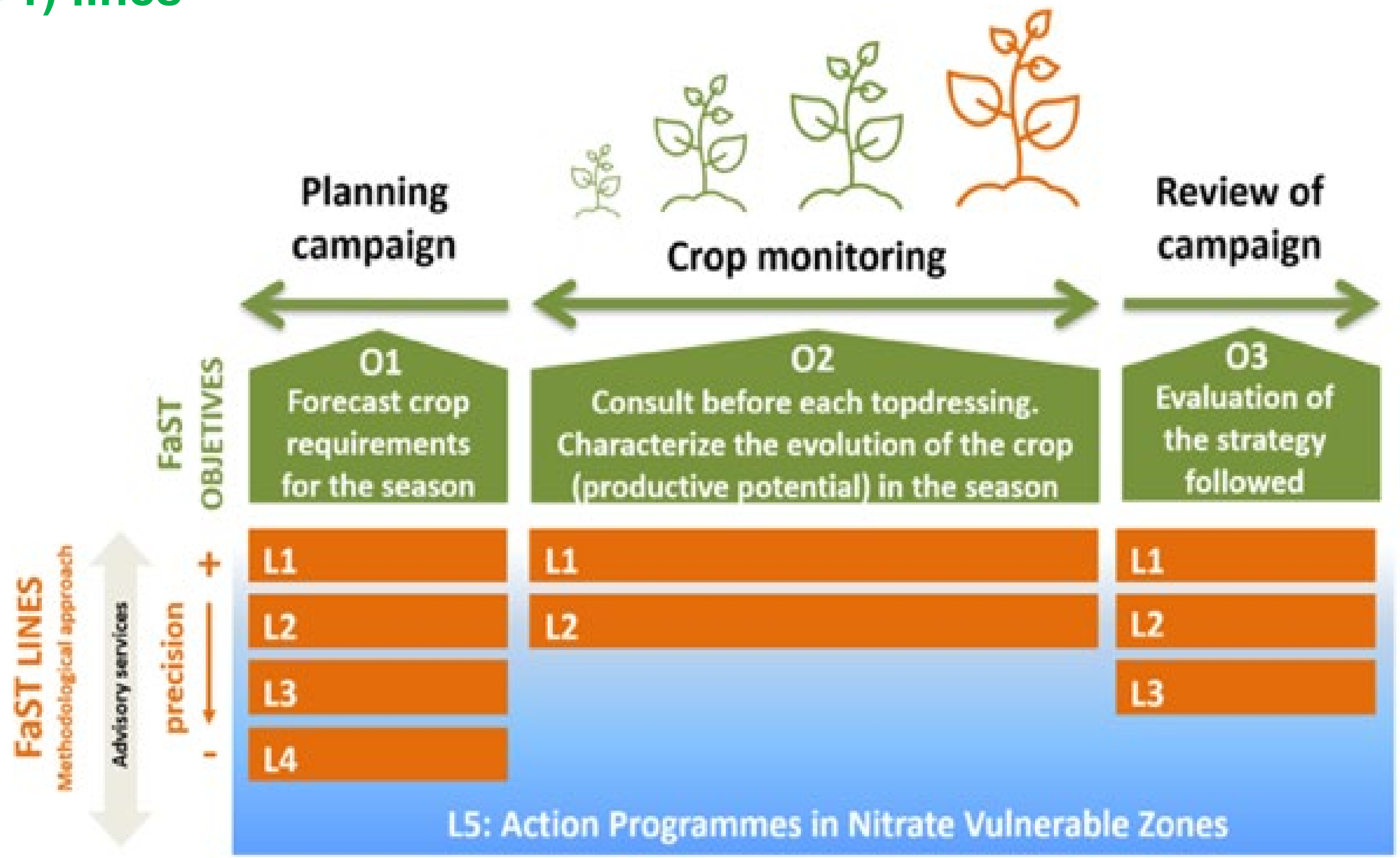
FaST Navigator framework for nutrients:

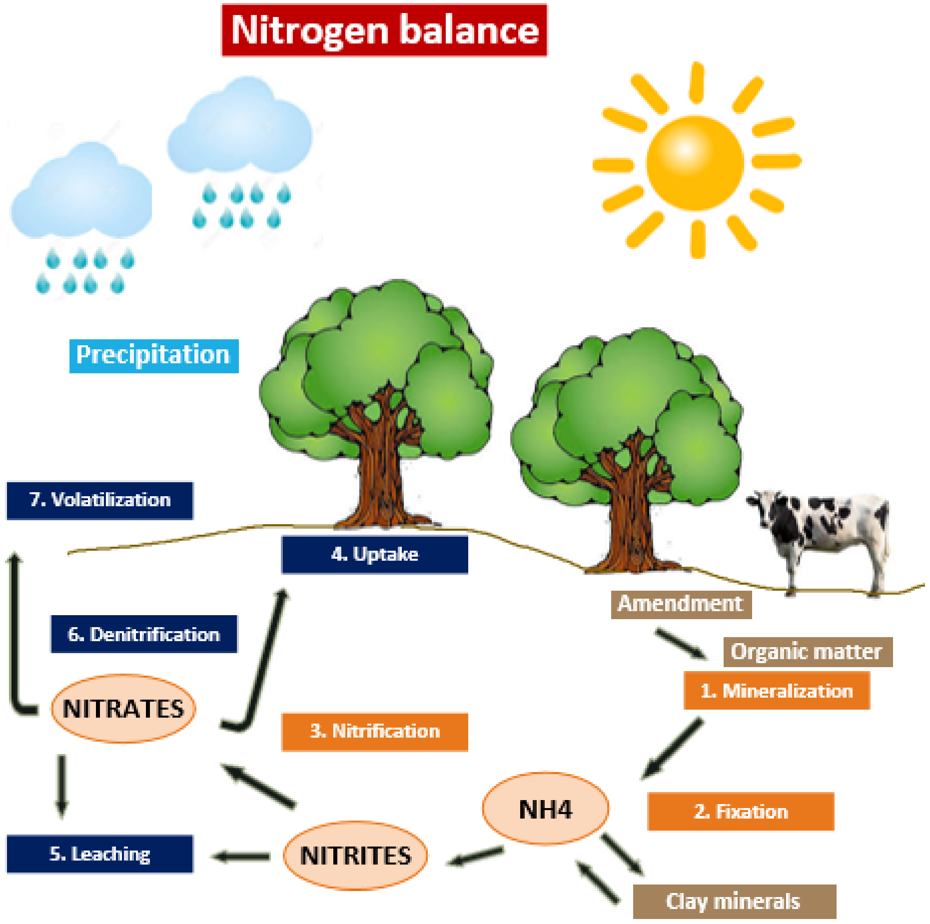
Framework

→ 3 objectives

→ 4 (+1) lines



Nutrient requirements based on nutrient balance



Mineralization
Is the process by which chemicals present in organic matter are descomposed into easily available forms to plants.

Fixation
Nitrogen fixation means the combination of molecular nitrogen with oxygen or hydrogen to obtain oxides or ammonium that can be incorporated into the biosphere.

Uptake
Uptake is a process in which the plants absorbs nitrates from the soil.

Leaching
Nitrate leaching is a naturally process, it occurs when nitrate leaves the soil in drainage water.

Denitrification
Process where nitrate is reduced and produces molecular nitrogen.

Volatilization
Is the transfer of the chemical as a gas through the soil-air interface under environmental conditions.

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Introduction on nutrients balance

Nitrogen balance

INPUTS OF BALANCE (+)

- Mineralization
- Fixation

OUTPUTS OF BALANCE (−)

- Leaching
- Uptake
- Denitrification
- Volatilization

+ Contributions

− Losses

Balance equation

(N leached + N uptake + N denitrication + N volatilized)

−

(N mineralized + N fixation)

=

Nitrogen recomendation

Outputs terms − Inputs terms = Recomendation

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Nutrient framework: lines

F1
- Daily nutrient balance
- Water balance
- Best fertilization
- NDVI

F2
- Daily nutrient balance
- Water balance
- Best fertilization

F3
- Seasonal nutrient balance
- Best fertilization

F4
- Seasonal nutrient balance
- Best fertilization

Implement

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NPK framework (example N)

Methodologies in each N balance process implemented in the tool

<table>
<tr><th></th><th colspan="4">Outputs in the N balance</th><th colspan="2">Inputs in the N balance</th><th></th></tr>
<tr><th></th><th>Uptake</th><th>Volatilization</th><th>Denitrification</th><th>Leaching</th><th>Fixation</th><th>Mineralization</th><th>Nitrification</th></tr>
<tr><td>F1</td><td rowspan="2">AA</td><td rowspan="4">FAO</td><td rowspan="4">M-A</td><td rowspan="2">AA</td><td rowspan="4">PAS</td><td rowspan="2">AA</td><td rowspan="2">FATIMA</td></tr>
<tr><td>F2</td></tr>
<tr><td>F3</td><td rowspan="2">PAS</td><td rowspan="2">PAS</td><td rowspan="2">NC</td><td rowspan="2"></td></tr>
<tr><td>F4</td></tr>
</table>

Legend	
NC	Nitrogen calculator (DSS).
AA	Agroasesor (DSS).
FAO	Food and Agricultural Organization (model).
PAS	Principles of Agronomy for Sustainable Agriculture (bibliographic reference). Fertilicalc model included.
FATIMA	FArming Tools for external nutrient Inputs and water MAnagement (DSS).
M-A	Meta-analysis model.

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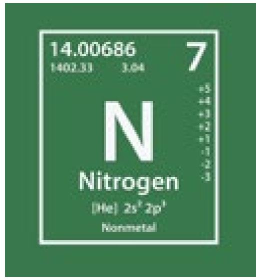
Methodology implemented in N balance: key components for recommendation

N BALANCE OUTPUT PROCESSES

F3 -F4

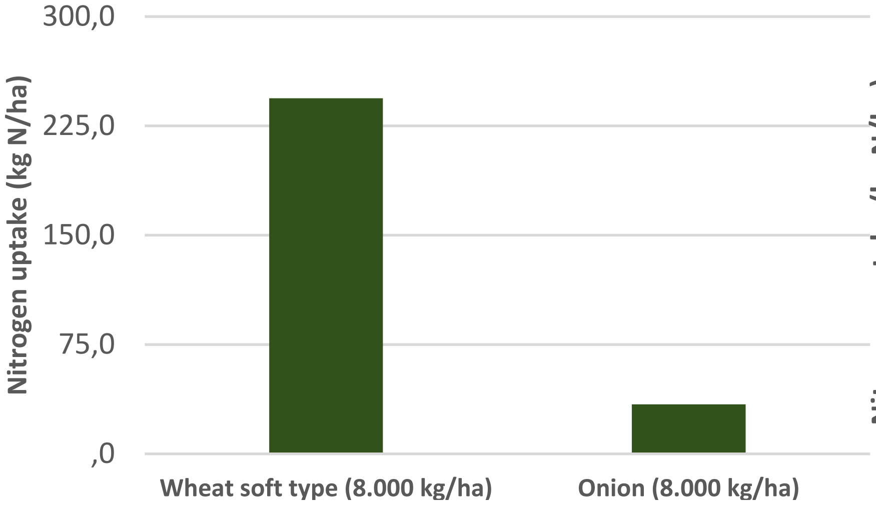


1) UPTAKE

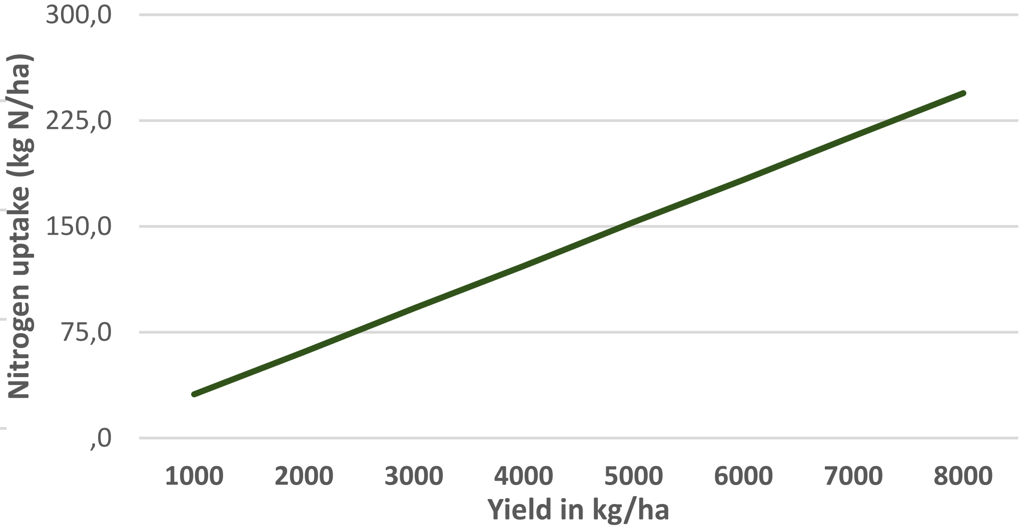
Principles of Agronomy for Sustainable Agriculture

Methodology based on the Principles of Agronomy for Sustainable Agriculture:
https://link.springer.com/book/10.1007/978-3-319-46116-8

Calculation of N uptake for different crops.



Calculation of N uptake for different yields in wheat soft type.



Quemada, M., Delgado, A., Mateos, L., Villalobos, F.J., 2016a. Nitrogen fertilization II: Fertilizer Requirements. in: Villalobos, F.J, Fereres, E. (Eds.), Principles of Agronomy for Sustainable Agriculture. Springer, Cham, Switzerland, pp. 371-375.

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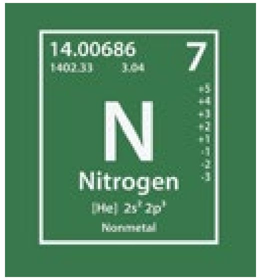
Methodology implemented in N balance: key components for recommendation

N BALANCE OUTPUT PROCESSES

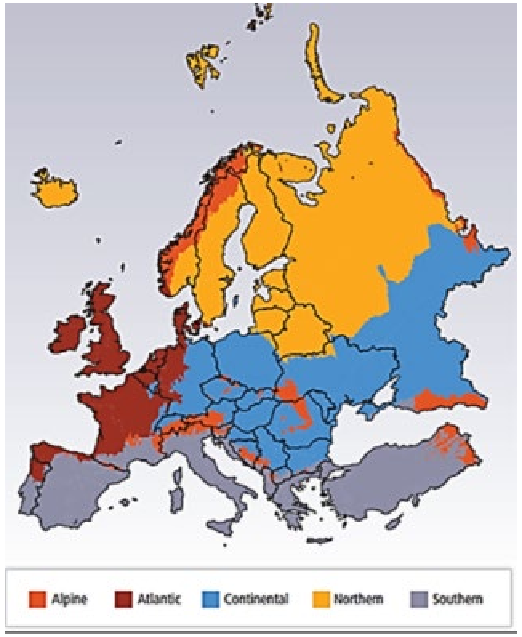
F3 -F4

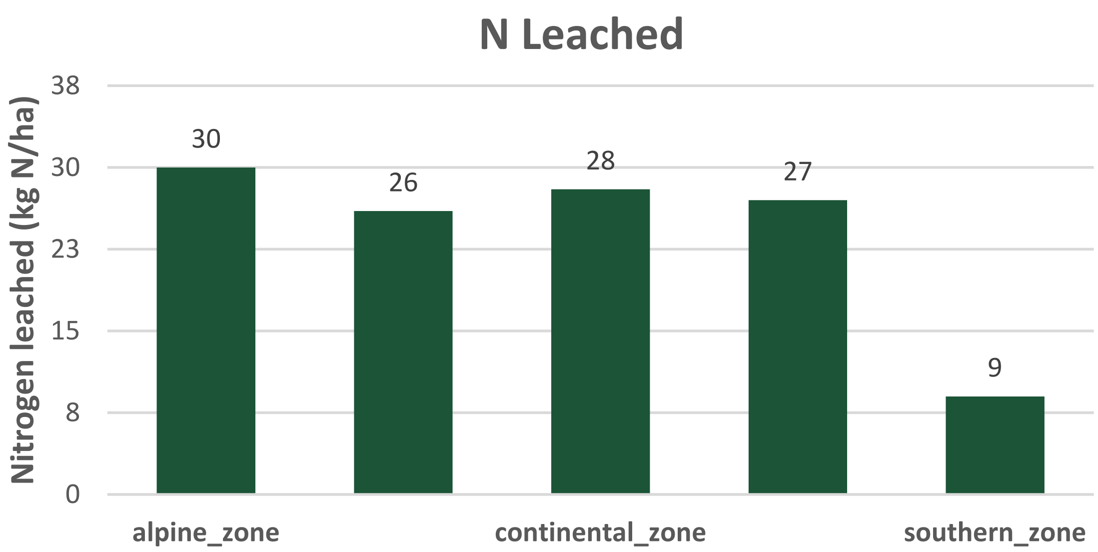


2) LEACHING

Principles of Agronomy for Sustainable Agriculture

Methodology based on the Principles of Agronomy for Sustainable Agriculture:
https://link.springer.com/book/10.1007/978-3-319-46116-8





Quemada, M., Delgado, A., Mateos, L., Villalobos, F.J., 2016a. Nitrogen fertilization II: Fertilizer Requirements. in: Villalobos, F.J, Fereres, E. (Eds.), Principles of Agronomy for Sustainable Agriculture. Springer, Cham, Switzerland, pp. 371-375.

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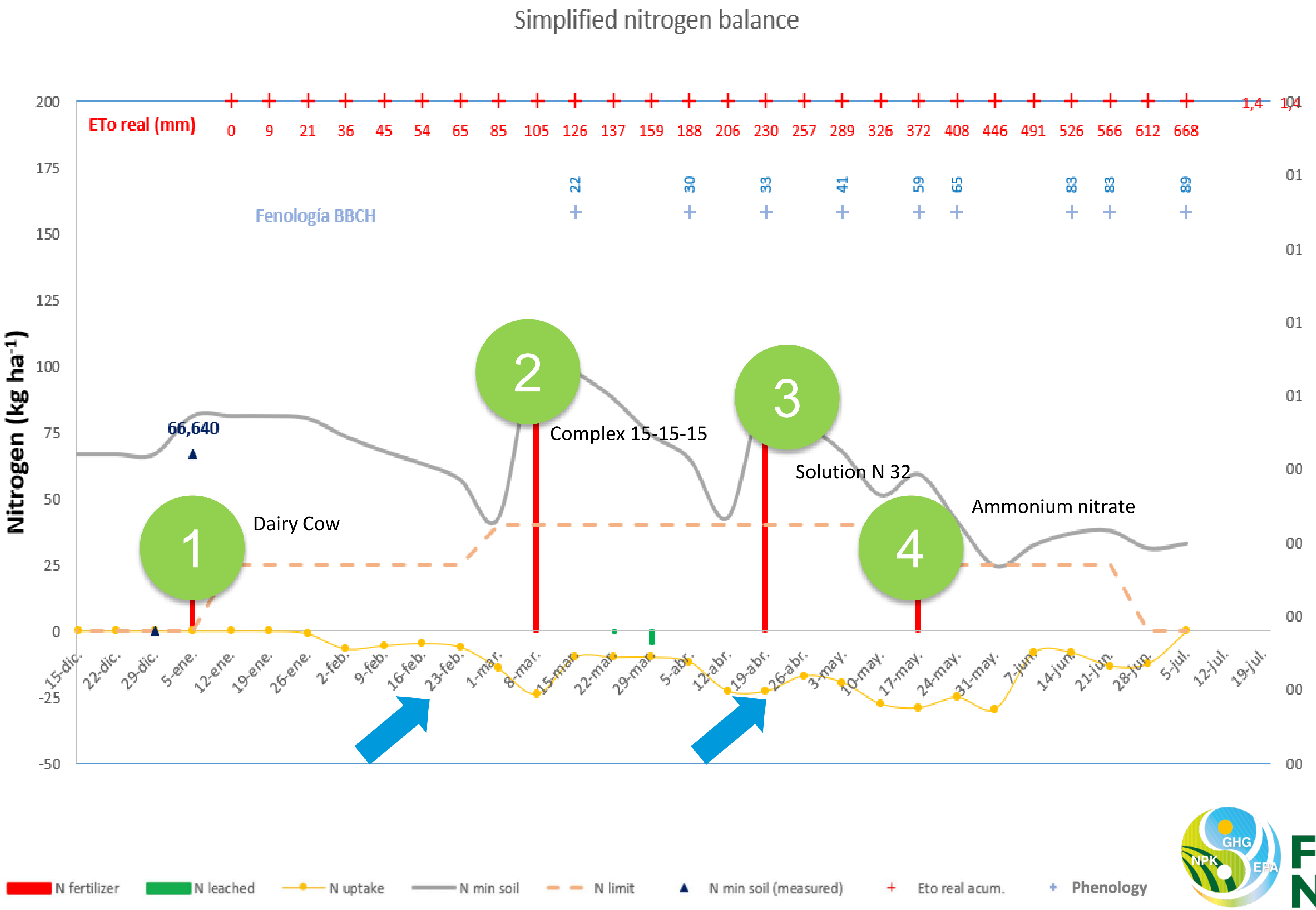
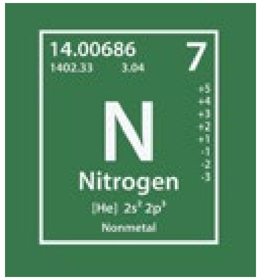
Methodology implemented in N balance

N BALANCE OUTPUT PROCESSES

F1 -F2





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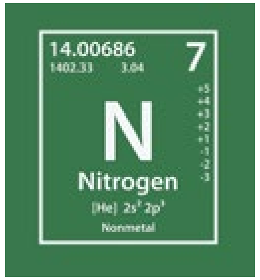
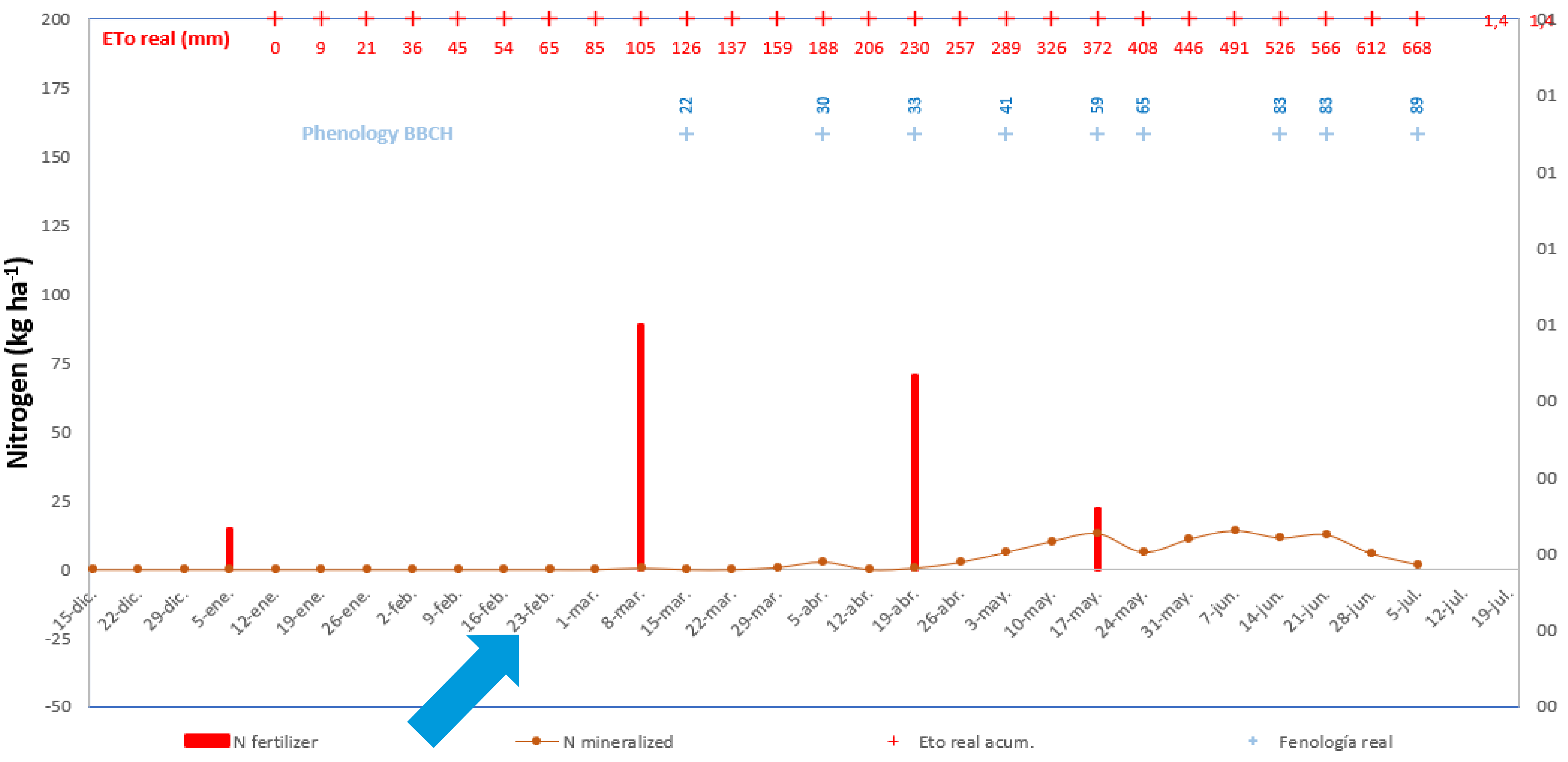
Methodology implemented in N balance

Mineralization of the soil

N BALANCE INPUTS PROCESSES

F1 -F2





Mary, B., Beaudoin, N., Justes, E., Machet, J. M. 1999. Calculation of nitrogen mineralization and leaching in fallow soil using a simple dynamic model. Eur. J. Soil Sci., 50: 549-566.

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Methodology implemented for P & K

F1

F2

F3

F4

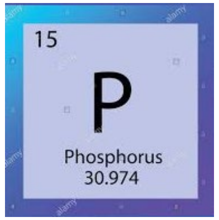
Methodology implemented

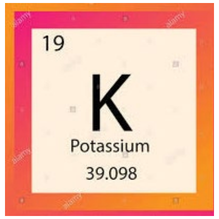
Principles of Agronomy for Sustainable Agriculture

Methodology based on the Principles of Agronomy for Sustainable Agriculture:

https://link.springer.com/book/10.1007/978-3-319-46116-8

A. Delgado et al.,2016a. Fertilization with Phosphorus, Potassium and Other Nutrients. Villalobos, F.J, Fereres, E. (Eds.), Principles of Agronomy for Sustainable Agriculture. Springer, Cham, Switzerland, pp. 381-405.





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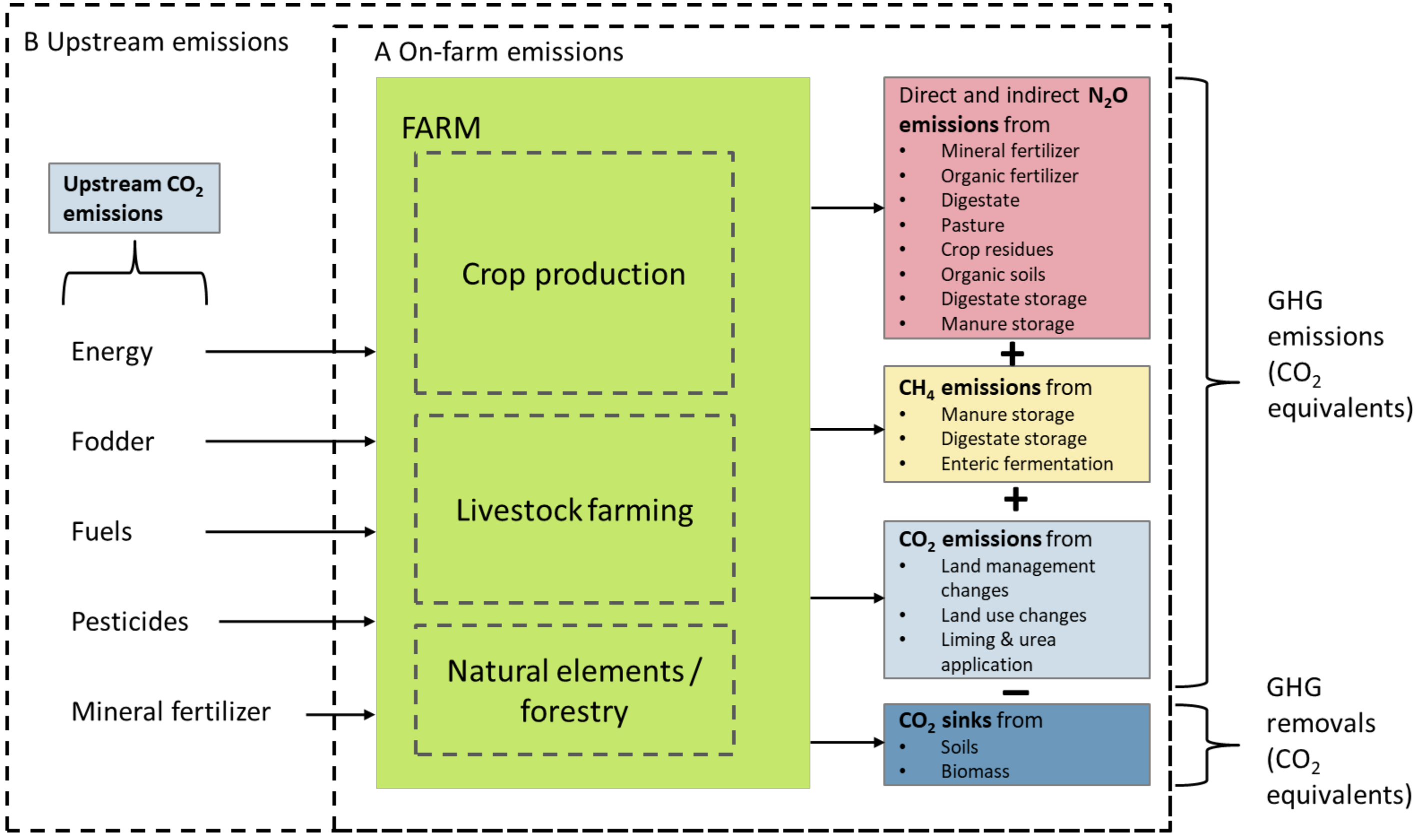
GHG framework



- **System boundary: farm**
- **GHGs covered: N2O, CH4, CO2**
  - **Transferred into CO2 equivalents based on 2007 IPCC GWPs (CH4: 25; N2O: 298)**
- **Methodologies**
  - **LCA / PEF (cradle – to – gate including upstream emissions)**
  - **2006 IPCC Tier 1 – 2 (plus 2019 refinement, 2013 supplement)**
- **Emissions covered**
  - **A: Direct emissions ocurring at the farm**
  - **B: Upstream emissions from the production of materials and energy**

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Crop production (fertilizers)

N_2O emissions

G4-G3

- Direct emissions on mineral soils: defaults based on Stehfest & Bouwman 2002
- Other emissions: IPCC Tier 1
- Link to nutrient module for N2O going into volatilisation and leaching

G1-G2

- Direct emissions on mineral soils: Fertilizer Induced Emissions (FIE) based on Stehfest & Bouwman 2006
- Other emissions: IPCC Tier 1
- Link to nutrient module for N2O going into volatilisation and leaching

Direct N_2O emissions from fertilizer application on mineral soils $N_2O_{(dir,F)}$ [kg N_2O-N ha^{-1}]:

$$\exp(c + 0.0038 * (F_{SN} + F_{ON}) + ev_{soc} + ev_{ph} + ev_{tex} + ev_{clim} + ev_{veg} + ev_{expl}) - \exp(c + ev_{soc} + ev_{ph} + ev_{tex} + ev_{clim} + ev_{veg} + ev_{expl})$$

Value type		Value
Constant value c		-1,516
Fertilizer input		0.0038 x kg N input
Soil organic carbon content	<1%	0
	1-3%	0.0526
	>3%	0.6334
pH	<5,5%	0
	5,5-7,3%	-0.0693
	>7,3%	-0.4836
Soil texture (tex)	Coarse	0
	Medium	-0.1528
	Fine	0.4312
Climate (clim)	temperate continental	0
Vegetation (veg)	Cereal	0
	grass	-0.3502
	legume	0.3783
	rice	-0.885
	other	0.442
Length (expl)	1 yr	1.991

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CH_4 emissions

Livestock

G2-G4

1) Enteric fermentation

- Livestock categories: IPCC Tier 2
- Milk yield and weight: default values (line 2: own values)
- CH4 emissions: 2006 IPCC simplified Tier 2 (2019 refinement)

2) Manure management

Livestock categories: as enteric fermentation
N excretion: IPCC Tier 1 default values
Emissions: direct and indirect; 2006 IPCC default values (2019 refinement, disaggregated into manure management systems)

3) Manure management

Livestock categories: as enteric fermentation
Manure management system (MMS): IPCC Tier 2
Emissions: taking into account maximum methane producing capacity, methane conversion factors, temperature, MMS

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CH_4 emissions

Livestock

G1

1) Enteric fermentation (CH_4)

- Livestock categories: as line 2-4; own data on weight an milk yield
- CH4 emissions: IPCC simplified Tier 2 (2019 refinement), dry matter intake (DMI) based on feed module
- Feed module: forage (19), single feed (e.g. wheat; 20); concentrate (per animal category)

2) Manure management (CH_4)

- Livestock categories: see enteric fermentation
- Manure management system (MMS): as line G4-G2
- Emissions: own data for volatile solid (VS) excretion and methane yield (M_Y)

3) Manure management (N_2O)

- Livestock categories: as line 4-2
- N excretion rates: own data

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CO_2 emissions

Carbon (soil)

G1-G2

1) Mineral soils

- SOC content: default (based on 2006 IPCC classification)
- SOC change: 2006 IPCC Tier 1 stock change factors; delta with worst case; reflect tillage, crop residue management, organic carbon input, cover crops
    - SOC content: default (based on IPCC classification)
    - SOC change: type and time duration of improvements; calculation of annual and accumulated changes
        - conventional tillage to no till
        - Cover cropping
        - Compost
        - Manure additions
        - Residue incorporation

2) Organic soils

- SOC content: default (based on IPCC 2013 wetland supplement)
- Rewetting: Emission (savings) based on IPCC 2013 supplement

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CO_2 emissions

3. Carbon (biomass)

G1

G4-G2

1) Natural infrastructure

G1: Own data on current C stock and annual increment

- annual crops and grassland: no net accumulation of biomass carbon stock
- perennial crops and woody elements: default values for stocks and growth rates for above ground biomass

2) Forest

G1: Own data on current C stock and annual increment

- annual change in carbon stock: sum of the annual increase due to biomass growth and the decrease due to losses from harvest and disturbances (e.g. pests, fire)
- 2006 IPCC Tier 1 (2019 refinement) default values

3) Land use change

- Carbon stock changes (soils & biomass) due to changes between cropland, grassland, forests
- 2006 IPCC Tier 1 default data (line G4 – G1)

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4. Upstream emissions

CO_2 equ. emissions

G4-G1

GHG emissions from farms

A Direct emissions

Crop
- N_2O emissions (direct, indirect) from fertilizers (mineral and organic), crop residues, managed organic soils
- CO_2 emissions from lime & urea
- CH_4 emissions from managed organic soils

Livestock
- CH_4 emissions from enteric fermentation
- CH_4, N_2O emissions from manure management
- N_2O emissions from pastures

Carbon cycle
- Carbon storage in biomass (perennial crops, woody elements, forests)
- Carbon storage in soil (organic, mineral)
- Carbon stock changes from management changes
- Carbon stock changes from land use changes

Energy use
- Electricity (grid, photovoltaic, wood)
- Fossil energy carriers (e.g. heating oil gas)
- Transport fuels (e.g. diesel, biofuel)
- Biomass (e.g. wood chips, wood pellets)

B Indirect emissions / upstream emissions

- Crop: Manufacturing of fertilizers, pesticides, seeds
- Livestock: External production of feedstock
- Energy use: Production of energy / energy carriers

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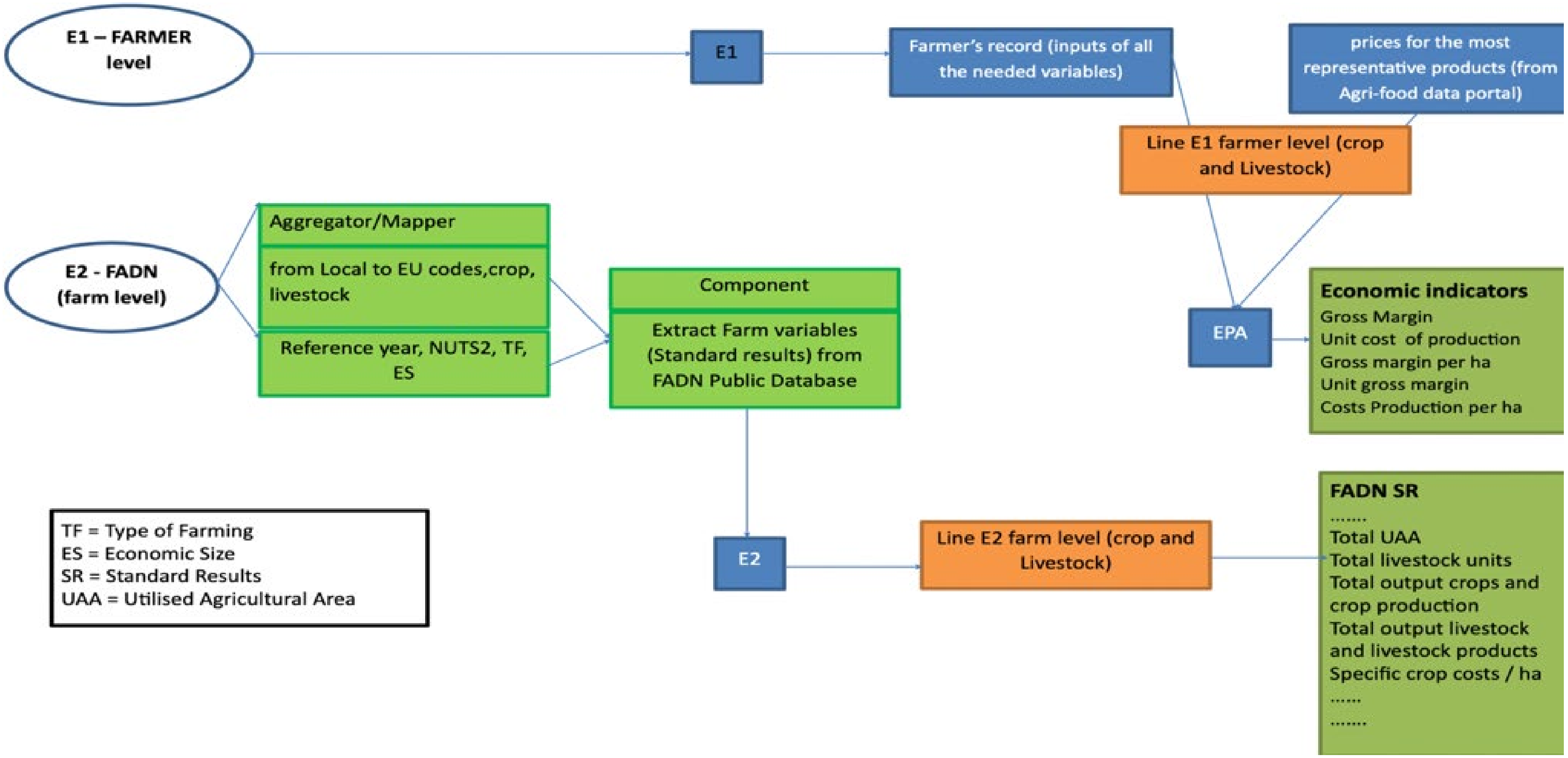
Economic performance assessment (EPA) framework



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EPA Lines and Scenarios

2 Lines (E1 and E2)

—> same variables and indicators (coming from FADN survey)

E1 is most detailed, input data provided by the farmer.

- shows the effective costs and incomes of farmers, according to their management strategy;
- different decisions taken by the farmers will lead to different outcomes

E2: data coming only from FADN and allow a benchmark activity with farms of same typological classification —> shows the current level of efficiency of the farm respect to others.

2 Scenarios (FARM and FADN)

- **Synergies with the modules: EPA data consistent with both GHG and the NPK**
  - EPA module run with data coming as an output of other modules of the Navigator tool.
  - Variables reported in physical units in NPK and GHG module will be expressed in EPA in terms of associated costs, benefits and incomes.
- **Policy: EPA can consider the CAP subsidies**
  - highlight the **policy contribution** to good economic farm performance
- **Play with the tool: end-users can simulate various management strategies**

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FADN Reference Model

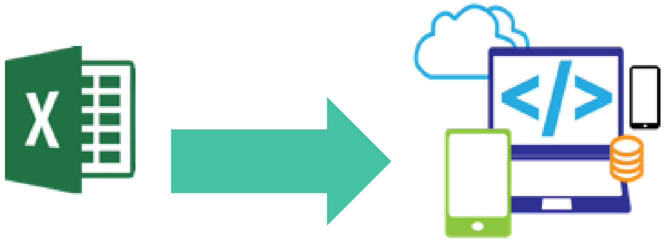
- **FADN typological classification**

TF8 Grouping	Principal type of farming
1. Fieldcrops	11. Specialist cereals
	12. General field cropping
	60. Mixed cropping
2. Horticulture	20. Specialist horticulture
3. Wine	31. Specialist vineyards
4. Other permanent crops	32. Specialist fruit and citrus fruit
	33. Specialist olives
	34. Various permanent crops combined
5. Milk	41. Specialist dairying
6. Other grazing livestock	42.Specialist cattle-rearing and fattening
	43.Cattle-dairying, rearing and fattening combined
	44. Sheep, goats and other grazing livestock
7. Granivores	50. Specialist granivores
8. Mixed	71. Mixed livestock, mainly grazing livestock
	72. Mixed livestock, mainly granivores
	81. Field crops-grazing livestock combined
	82. Various crops and livestock combined

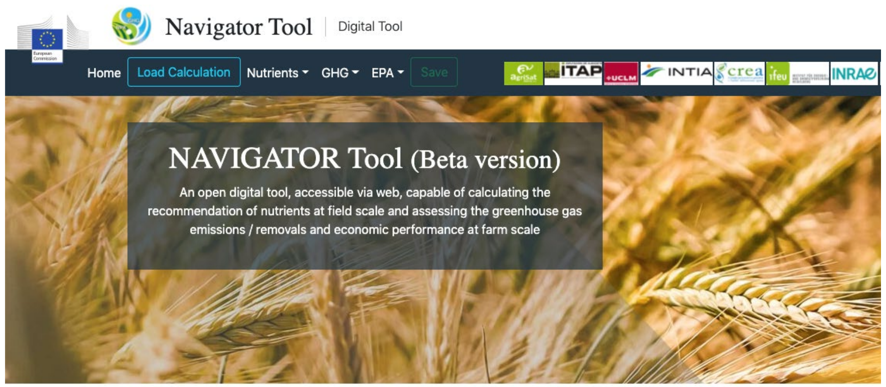
https://tool.fastnavigator.eu

Navigator Tool

- **Core Engine**
  - The code for computing via web the NPK requirements, GHG emissions and EPA, at L1-L4 scales, comes from state-of-art developments by the partners' teams in charge of it.
  - It was required to translate the original model, generally made in the form of a spreadsheet, onto a computer language. The procedure used is flexible enough to easily incorporate new updates/versions.



- **Interface, as simple as possible, but enough for**
  - Performing benchmarking exercise,
  - User´s access, either a single crop and plot or farm.
  - Results from a first calculation can be stored into the user´s device to be reutilized for a new computation
  - Able to print the results in pdf
- **Privacy,**
  - no login required,
    no info is stored into the tool once the session ends.



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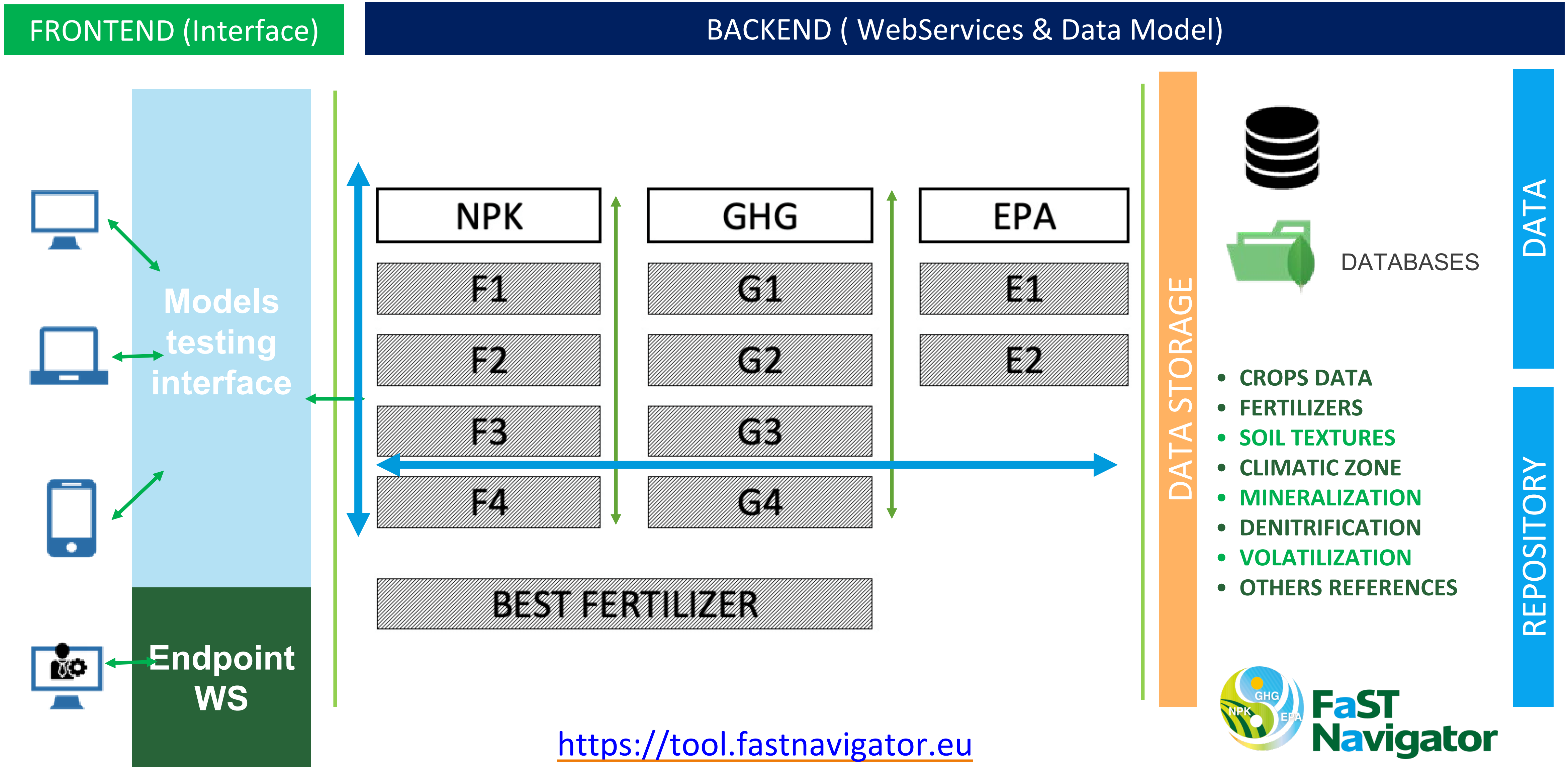
Conceptual Overview of components in Navigator Tool



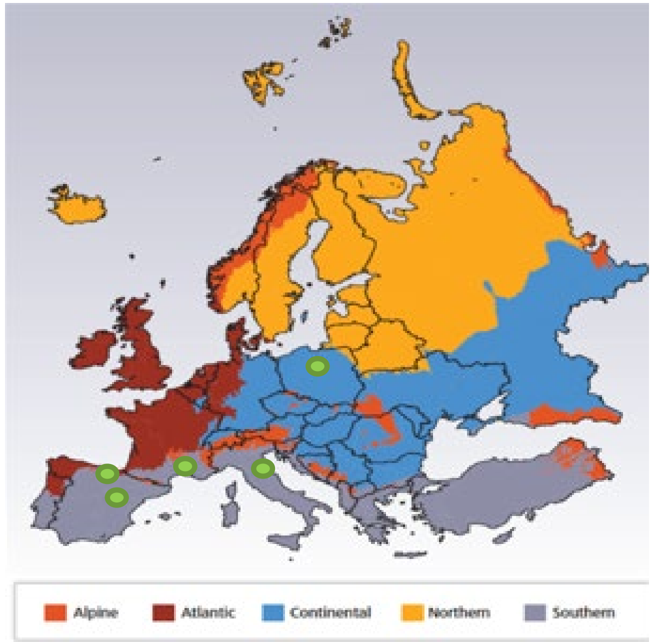
https://tool.fastnavigator.eu

Benchmarking

objective

Defined the accuracy of the Lines included on the Navigator tool in relation to the NPK fertilisation recommendation (N_{rate}, P_{rate} and K_{rate}) and to establish the basis for the quality indicators (traffic lights) definition.

NPK fertilisation recommendation that **enables the achievement of the foreseen target yield**.



$$\varepsilon_{Line} = \varepsilon_{Line} + \varepsilon_{inputs} + \varepsilon_{context}$$

- ε_{line}: the line error itself due to their formulation.
- ε_{inputs}: the inputs accuracy that could impact the outputs.
- $\varepsilon_{context}$: the farming context (climate-year)

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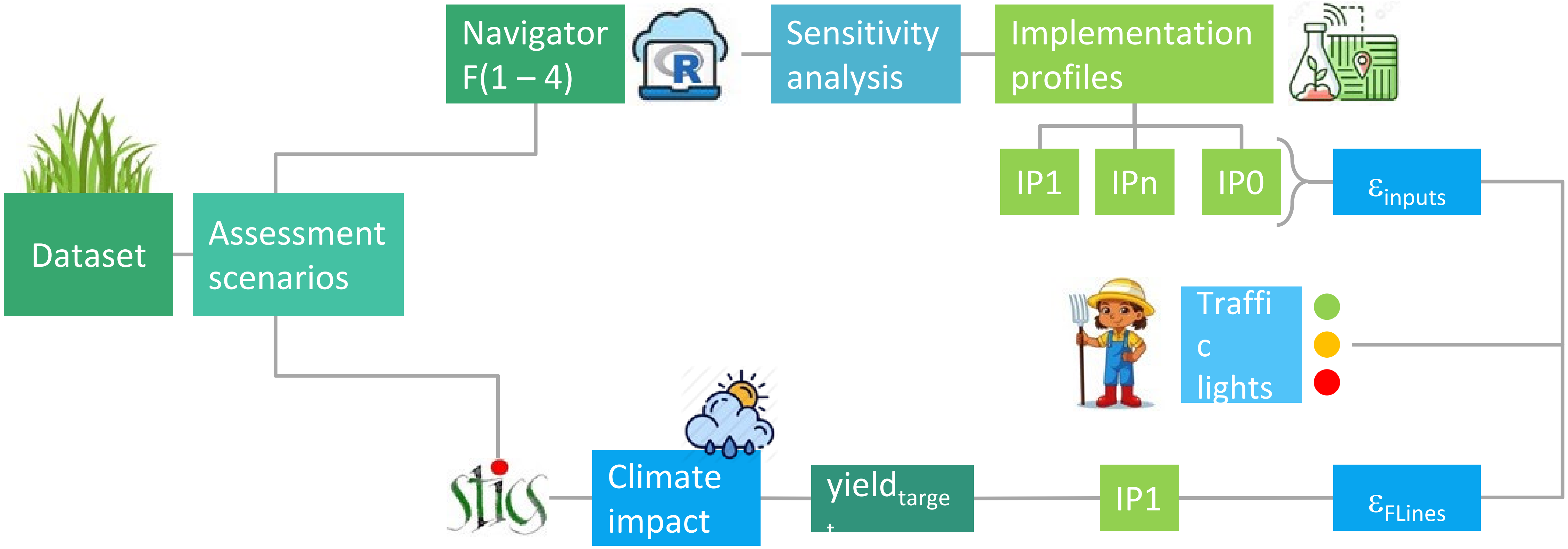
Benchmarking



Workflow of the benchmarking approach for the definition of the F lines included on the Navigator tool in relation to NPK fertilisation recommendation and to establish the basis for the quality indicators (traffic lights) definition.

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Implementation profiles (IP) & inputs accuracy: F3-N_{rate}

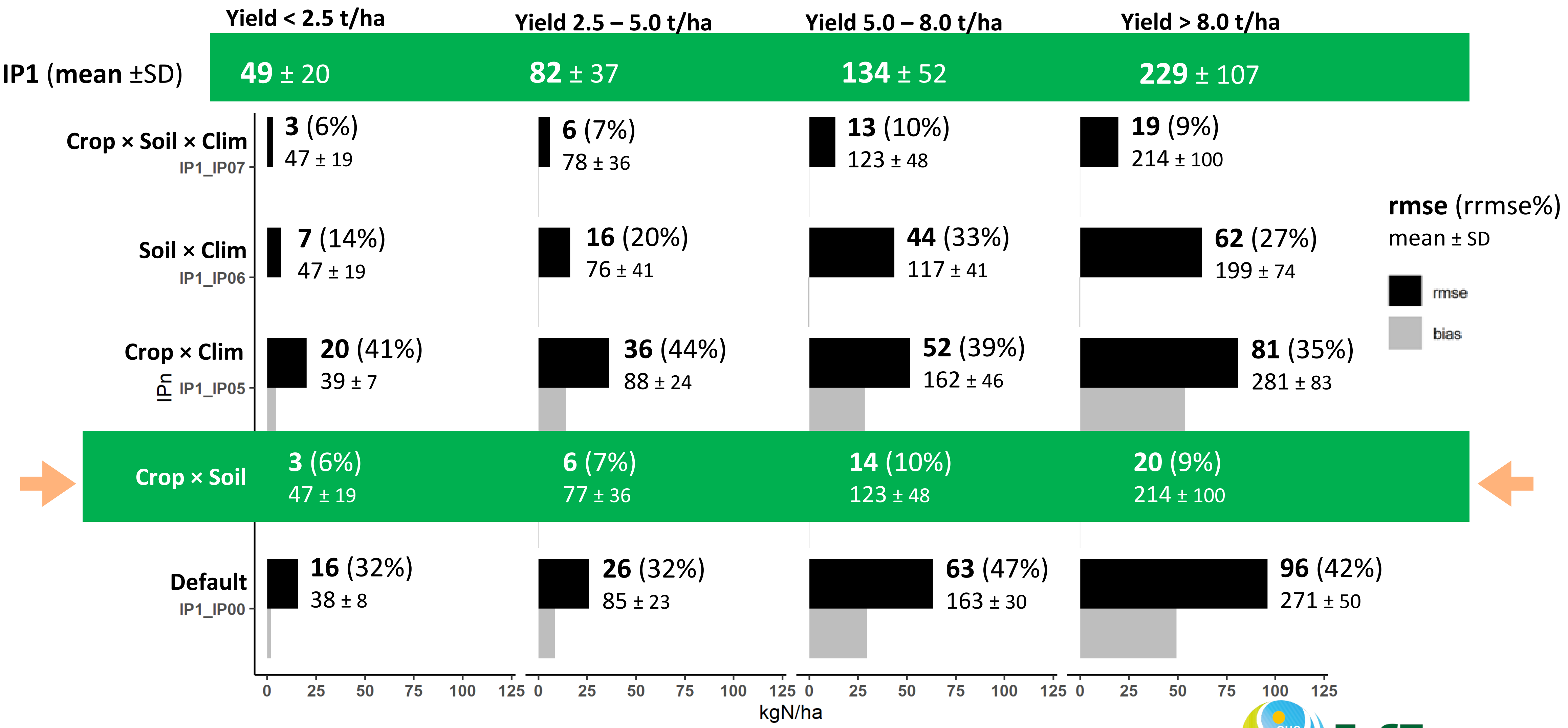

Figure. Root mean squares error (rmse) computed between the Nrate obtained form the Implementation profiles described in the Table 1 (IPn) and the reference (IP1, with all inputs as measurements).

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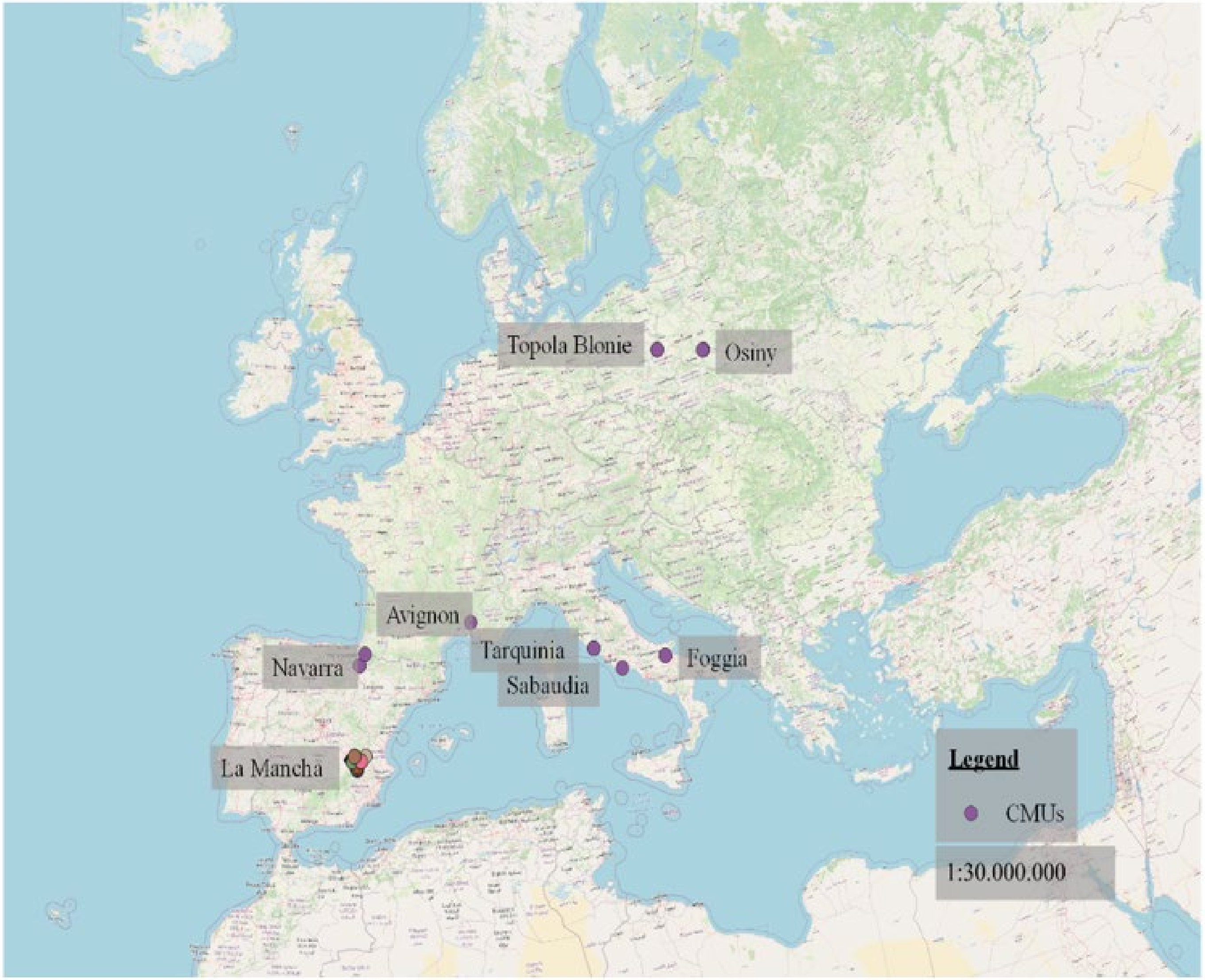
Parameterisation for real cases

Database geographic coverage



study
ntries with detailed datasets: d)
ultry, beef, dairy, sheep); stry; crop, livestock, forestry)
ennial, grassland, fruit
nple, compound, complex;

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Parameterisation

Real cases – input data: example F3

Crop data:

- crop type
- target yield;
- PK strategy

Soil data:

- texture
- SOM;
- N content initial;
- P content;
- P content method;
- K content

Parcel data:

- irrigated / rainfed
- irrigation system;
- irrigation rate;
- climate zone

Real cases – input data G3: long list

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Conclusions

FaST Navigator framework (available as monograph):

Nutrients + GHG emissions/removals + economic performance (field & farm scale)

Farm = crops, livestock, LULUCF/carbon, energy.

4 lines of complexity/accuracy

Implemented in Navigator Tool (open source)

Traffic light code indicates accuracy of results (derived from benchmarking analysis)

Parameterization **valid for cereals, maize, legumes, industrial, grassland, major EU climate zones, intensive monocultures & rotations.**

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Thank you

Köszönöm aitäh
Dziękuję Ci Grazzi Ačiū Paldies
mulțumesc tack dank u
σας ευχαριστώ gracias
Grazie **Kiitos** **merci**
Благодаря ти. danke Děkuju
tak skal du have
Ďakujem Hvala vam
go raibh maith agat