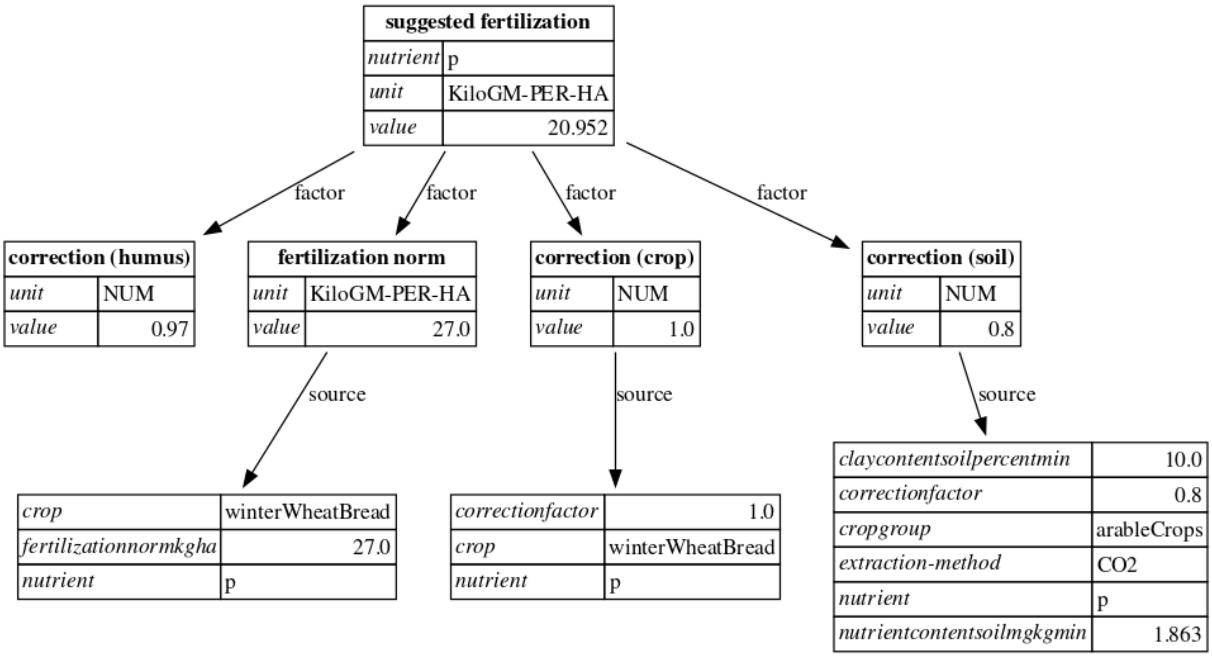
Technical Report / 2024



Providing the PRIF tables for digital applications

Technical report of the pilot project «WebGRUD»

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Summary

The "Principles of Fertilisation of Agricultural Crops in Switzerland" (PRIF) serve as the Swiss reference for all aspects of fertilisation and nutrition of agricultural crops. They contain around 150 interlinked tables, providing standard and correction values for crop- and site-specific fertilisation assessments. Currently, these tables are only available in paper and PDF format, limiting fertiliser requirement calculations to an analogue process. To support the digital transformation in agriculture and align with federal data strategies, the pilot project WebGRUD aimed to provide the content of selected PRIF tables in a machine-readable format. This project sought to facilitate access to these tables using standard programming languages, ensure consistent fertilisation recommendations across different users, and meet Open Government Data criteria.

A linked data service for storing and linking the PRIF tables and the development of a test application programming interface (API) for calculating and visualising fertilisation recommendations was considered the most suitable approach. For a proof of concept, we selected the PRIF tables for calculating nitrogen (method of the corrected norm), phosphorus, potassium, and magnesium fertilisation recommendations for arable crops. The Linked Data Service (LINDAS) of the Swiss Federal Archives was chosen for data storage and linking, as it utilizes the open W3C-standardised Resource Description Framework (RDF) technology and is accessible via the standard SPARQL query language. In preparation, the PRIF tables needed significant modification to convert them from wide format to normal form. The transformation from CSV to RDF, along with the augmentation and annotation of the RDF data cubes, was facilitated by the Cube Creator interface. Finally, the self-descriptive, hypermedia-driven test API webgrud-app was programmed to calculate fertilisation recommendations based on the conditional relationships between the PRIF tables. A simple web user interface enhanced human accessibility to the functionality of the test API.

The pilot project WebGRUD succeeded as a proof of concept, providing a selection of the most frequently used PRIF tables in machine-readable format and demonstrating the correct implementation of their conditional links in data models. However, it does not cover the full functionality of the PRIF or all crop groups included. Additionally, several constraints hindered the conversion of the PRIF tables to the required format for RDF transformation, such as purely descriptive or poorly defined information, essential data spread across table headers, footnotes, and main text, and inconsistencies within the PRIF contents. Suggestions for improvement and future work are provided.

1 Background, aims and scope

Author: Juliane Hirte

The Principles of Fertilisation of Agricultural Crops in Switzerland (PRIF) are the Swiss reference for all aspects of fertilisation and nutrition of agricultural crops for farmers, agricultural consulting services, researchers and personnel in administration and law enforcement dealing with aspects of crop nutrition and fertilization (Figure 1). They contain around 150 tables, most of which are linked to each other, with standard and correction values for crop- and site-specific fertilisation assessment. For example, the phosphorus fertiliser requirement of arable crops is calculated using (1) the nutrient removal of the plant based on the reference yield (module 8, table 9), (2) the nutrient and clay content of the soil (module 2, tables 10, 13, 16), (3) the humus content of the soil (module 2, table 9), (4) the crop (module 8, table 21), (5) the phosphorus balance of the previous year and (6) the harvest residues of the previous crop (module 8, table 9) (Figure 2).

These tables are currently only available in paper and PDF format, so that fertiliser requirements can only be calculated in analogue manner. In addition, various Excel-based calculation tools are used by consultants and cantonal authorities, some of which differ from each other and deviate from the current status of the PRIF. This considerably hampers the digital transformation in agriculture as well as work in science, consulting and law enforcement. In addition, federal data strategies call for the provision of tax-funded data in an open and non-proprietary form, such as the Digital Switzerland Strategy, Open Government Data (OGD) Strategy for Switzerland, Federal data science strategy, eCH E-Government Standards and Open Research Data strategy.

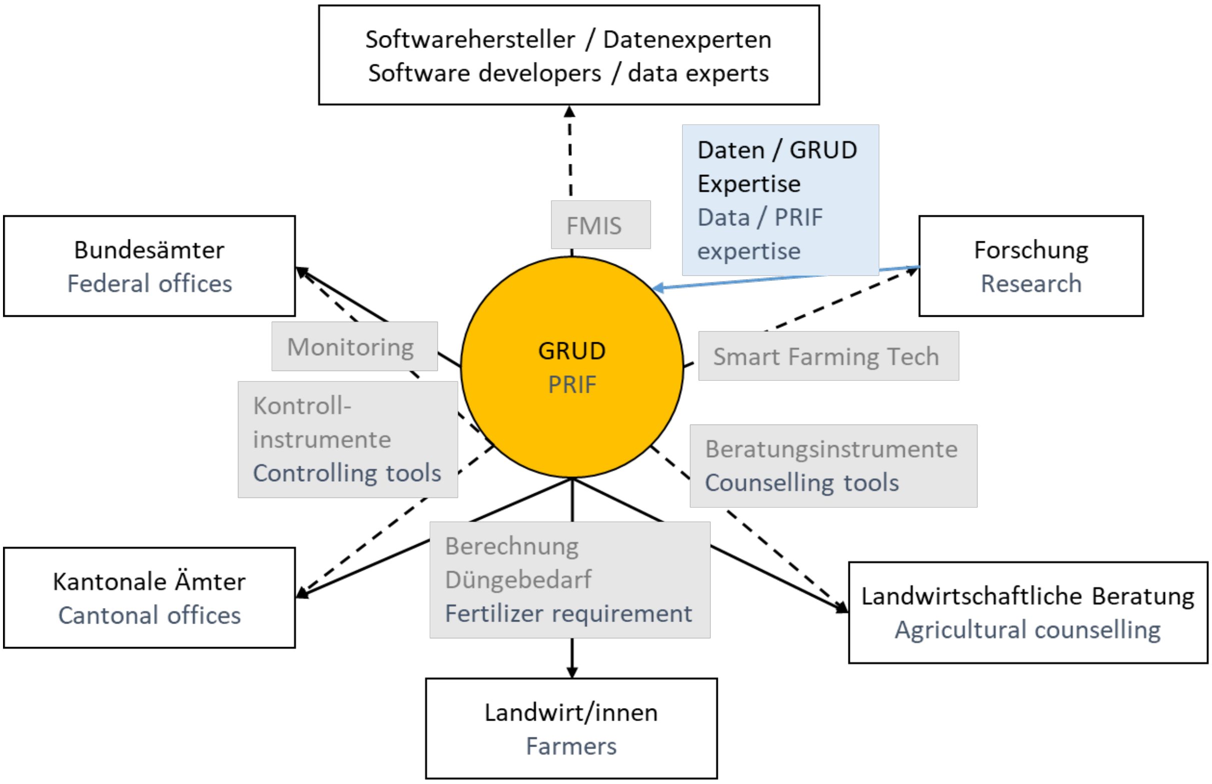

Figure 1: Context diagram of main user groups of the PRIF (framed boxes), information flows (arrows) and applications / tools (grey boxes). Solid / dashed lines depict well-established / prospective pathways.

The Federal Office for Agriculture (FOAG) has therefore asked for the digitisation of the PRIF tables for machine-readable purposes and up-to-date applicability within the Agroscope Work Programme 22-25. Among other things, the PRIF tables need to be available in machine-readable format by 2025 for the project "Digital Nutrient and Plant Protection Products Management" (digiFLUX). For this, the following requirements need to be fulfilled:

- freely accessible and standardised data storage of the PRIF tables and metadata with options for updating and version control
- standardised querying of table contents and metadata by data consumers
- mapping of conditional links between the tables
- user-friendly web interface for querying the table contents and outputting the calculated fertiliser requirements by data consumers

This pilot project aims to:

- provide the content of selected PRIF tables in machine-readable format
- facilitate access to the selected PRIF tables using standard programming languages
- enable individual updates of tables and links between tables, independent of the revision cycles of the modules
- document changes to the selected PRIF tables by version control
- guarantee identical results for fertilization recommendations by different users
- comply with Open Government Data (OGD) criteria
- use a tested and maintained platform with a service-level agreement (SLA) to be able to quantify and predict costs for maintenance and service

This pilot project does not intend to:

- cover the full functionality of the PRIF and all crop groups included
- guarantee completeness of the represented conditional links between the PRIF tables and of the overview of their inconsistencies
- make updates, additions, amendments or re-interpretations of the contents of the PRIF or solve inconsistencies in its interpretability
- provide a reference implementation or an excel-based calculation tool (or similar) to reproduce the conditional links between the PRIF tables (calculation steps)

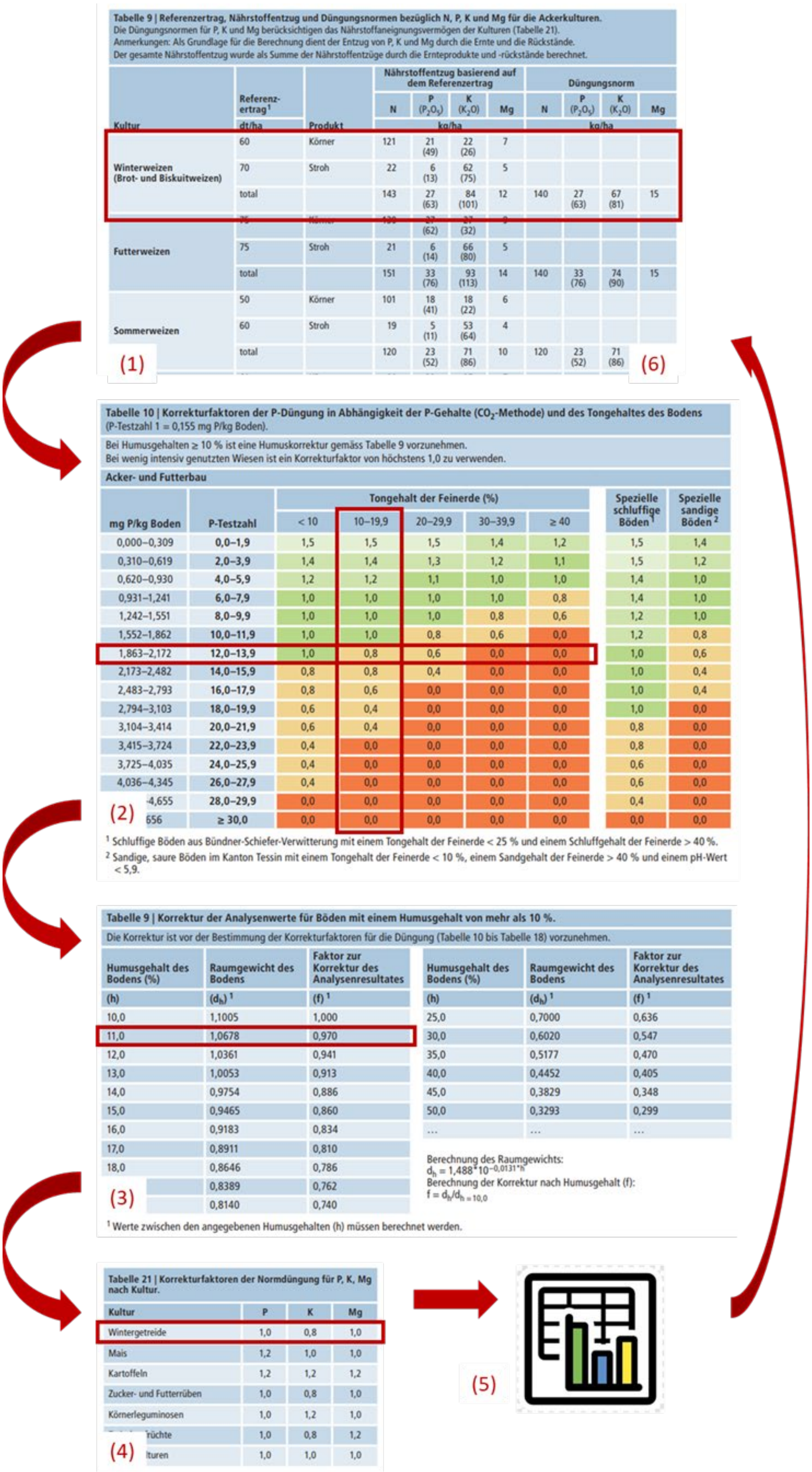

Tabelle 9 | Referenzertrag, Nährstoffentzug und Düngungsnormen bezüglich N, P, K und Mg für die Ackerkulturen.
Die Düngungsnormen für P, K und Mg berücksichtigen das Nährstoffaneignungsvermögen der Kulturen (Tabelle 21).
Anmerkungen: Als Grundlage für die Berechnung dient der Entzug von P, K und Mg durch die Ernte und die Rückstände.
Der gesamte Nährstoffentzug wurde als Summe der Nährstoffentzüge durch die Ernteprodukte und -rückstände berechnet.

Kultur	Referenzertrag[1]	Produkt	Nährstoffentzug basierend auf dem Referenzertrag				Düngungsnorm			
			N	P (P_2O_5)	K (K_2O)	Mg	N	P (P_2O_5)	K (K_2O)	Mg
	dt/ha		kg/ha				kg/ha			
Winterweizen (Brot- und Biskuitweizen)	60	Körner	121	21 (49)	22 (26)	7				
	70	Stroh	22	6 (13)	62 (75)	5				
	total		143	27 (63)	84 (101)	12	140	27 (63)	67 (81)	15
Futterweizen	[illegible]	[illegible]	[illegible]	[illegible] (62)	[illegible] (32)	[illegible]				
	75	Stroh	21	6 (14)	66 (80)	5				
	total		151	33 (76)	93 (113)	14	140	33 (76)	74 (90)	15
Sommerweizen	50	Körner	101	18 (41)	18 (22)	6				
	60	Stroh	19	5 (11)	53 (64)	4				
	total		120	23 (52)	71 (86)	10	120	23 (52)	71 (86)	

Tabelle 10 | Korrekturfaktoren der P-Düngung in Abhängigkeit der P-Gehalte (CO_2-Methode) und des Tongehaltes des Bodens (P-Testzahl 1 = 0,155 mg P/kg Boden).
Bei Humusgehalten ≥ 10 % ist eine Humuskorrektur gemäss Tabelle 9 vorzunehmen.
Bei wenig intensiv genutzten Wiesen ist ein Korrekturfaktor von höchstens 1,0 zu verwenden.
Acker- und Futterbau

mg P/kg Boden	P-Testzahl	Tongehalt der Feinerde (%)					Spezielle schluffige Böden[1]	Spezielle sandige Böden[2]
		< 10	10–19,9	20–29,9	30–39,9	≥ 40		
0,000–0,309	0,0–1,9	1,5	1,5	1,5	1,4	1,2	1,5	1,4
0,310–0,619	2,0–3,9	1,4	1,4	1,3	1,2	1,1	1,5	1,2
0,620–0,930	4,0–5,9	1,2	1,2	1,1	1,0	1,0	1,4	1,0
0,931–1,241	6,0–7,9	1,0	1,0	1,0	1,0	0,8	1,4	1,0
1,242–1,551	8,0–9,9	1,0	1,0	1,0	0,8	0,6	1,2	1,0
1,552–1,862	10,0–11,9	1,0	1,0	0,8	0,6	0,0	1,2	0,8
1,863–2,172	12,0–13,9	1,0	0,8	0,6	0,0	0,0	1,0	0,6
2,173–2,482	14,0–15,9	0,8	0,8	0,4	0,0	0,0	1,0	0,4
2,483–2,793	16,0–17,9	0,8	0,6	0,0	0,0	0,0	1,0	0,4
2,794–3,103	18,0–19,9	0,6	0,4	0,0	0,0	0,0	1,0	0,0
3,104–3,414	20,0–21,9	0,6	0,4	0,0	0,0	0,0	0,8	0,0
3,415–3,724	22,0–23,9	0,4	0,0	0,0	0,0	0,0	0,8	0,0
3,725–4,035	24,0–25,9	0,4	0,0	0,0	0,0	0,0	0,6	0,0
4,036–4,345	26,0–27,9	0,4	0,0	0,0	0,0	0,0	0,6	0,0
[illegible]-4,655	28,0–29,9	0,0	0,0	0,0	0,0	0,0	0,4	0,0
[illegible]656	≥ 30,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0

[1] Schluffige Böden aus Bündner-Schiefer-Verwitterung mit einem Tongehalt der Feinerde < 25 % und einem Schluffgehalt der Feinerde > 40 %.
[2] Sandige, saure Böden im Kanton Tessin mit einem Tongehalt der Feinerde < 10 %, einem Sandgehalt der Feinerde > 40 % und einem pH-Wert < 5,9.

Tabelle 9 | Korrektur der Analysenwerte für Böden mit einem Humusgehalt von mehr als 10 %.
Die Korrektur ist vor der Bestimmung der Korrekturfaktoren für die Düngung (Tabelle 10 bis Tabelle 18) vorzunehmen.

Humusgehalt des Bodens (%)	Raumgewicht des Bodens	Faktor zur Korrektur des Analysenresultates	Humusgehalt des Bodens (%)	Raumgewicht des Bodens	Faktor zur Korrektur des Analysenresultates
(h)	(d_h)[1]	(f)[1]	(h)	(d_h)[1]	(f)[1]
10,0	1,1005	1,000	25,0	0,7000	0,636
11,0	1,0678	0,970	30,0	0,6020	0,547
12,0	1,0361	0,941	35,0	0,5177	0,470
13,0	1,0053	0,913	40,0	0,4452	0,405
14,0	0,9754	0,886	45,0	0,3829	0,348
15,0	0,9465	0,860	50,0	0,3293	0,299
16,0	0,9183	0,834	…	…	…
17,0	0,8911	0,810			
18,0	0,8646	0,786			
[illegible]	0,8389	0,762			
[illegible]	0,8140	0,740			

Berechnung des Raumgewichts:
$d_h = 1{,}488 * 10^{-0{,}0131 * h}$
Berechnung der Korrektur nach Humusgehalt (f):
$f = d_h / d_{h=10,0}$

[1] Werte zwischen den angegebenen Humusgehalten (h) müssen berechnet werden.

Tabelle 21 | Korrekturfaktoren der Normdüngung für P, K, Mg nach Kultur.

Kultur	P	K	Mg
Wintergetreide	1,0	0,8	1,0
Mais	1,2	1,0	1,0
Kartoffeln	1,2	1,2	1,2
Zucker- und Futterrüben	1,0	0,8	1,0
Körnerleguminosen	1,0	1,2	1,0
[illegible]rüchte	1,0	0,8	1,2
[illegible]lturen	1,0	1,0	1,0

Figure 2: Calculation steps for the crop- and site-specific assessment of the phosphorus fertiliser requirement based on standard and correction values in the PRIF tables.

2 Methodological approach

Author: Juliane Hirte

We have identified the use of a linked data service for storage and linking of the PRIF tables and the programming of a test application programming interface (API) for outputting and visualising the table links as most suitable to achieve the above-mentioned aims. The data sources and tools are briefly described below.

2.1 Principles of Fertilisation of Agricultural Crops in Switzerland PRIF

The Principles of Fertilisation of Agricultural Crops in Switzerland (PRIF) are published by Agroscope and contain information on fertilisation and nutrition of agricultural crops under Swiss conditions. In 2017, fertilisation recommendations for all crops grown in Switzerland were published for the first time in a single basic document (PRIF 2017), with the option to update its chapters individually. Therefore, the PRIF could reflect the latest state of knowledge on fertilization recommendations if updated regularly.

The individual chapters can be accessed via the website www.grud.ch / www.prif.ch and are referred to as modules. The relevant modules for the project WebGRUD are:

- 2/ Soil Characteristics and Soil Analyses
- 4/ Properties and Use of Fertilisers
- 8/ Fertilisation of Arable Crops
- 10/ Fertilisation in Vegetable Production

2.2 Linked Data Service LINDAS

The Linked Data Service (LINDAS; Figure 3) of the Swiss Federal Archives (SFA) offers data for public use that can be automatically linked to each other. LINDAS utilises the Resource Description Framework (RDF) technology, which is based on the formulation of logical statements about content. These information elements are stored as triples and can be retrieved via a web-based interface using the standard SPARQL query language. By using open W3C-standardised technology, LINDAS guarantees very high technical quality and the possibility of linking data with applications that can offer additional solutions based on the LINDAS service. The visualisation tool "visualize" provided by the Federal Office for the Environment (FOEN) enables data to be retrieved and displayed in LINDAS without specific knowledge of the triple-store infrastructure. Access to LINDAS can be requested at support.lindas@bar.admin.ch.

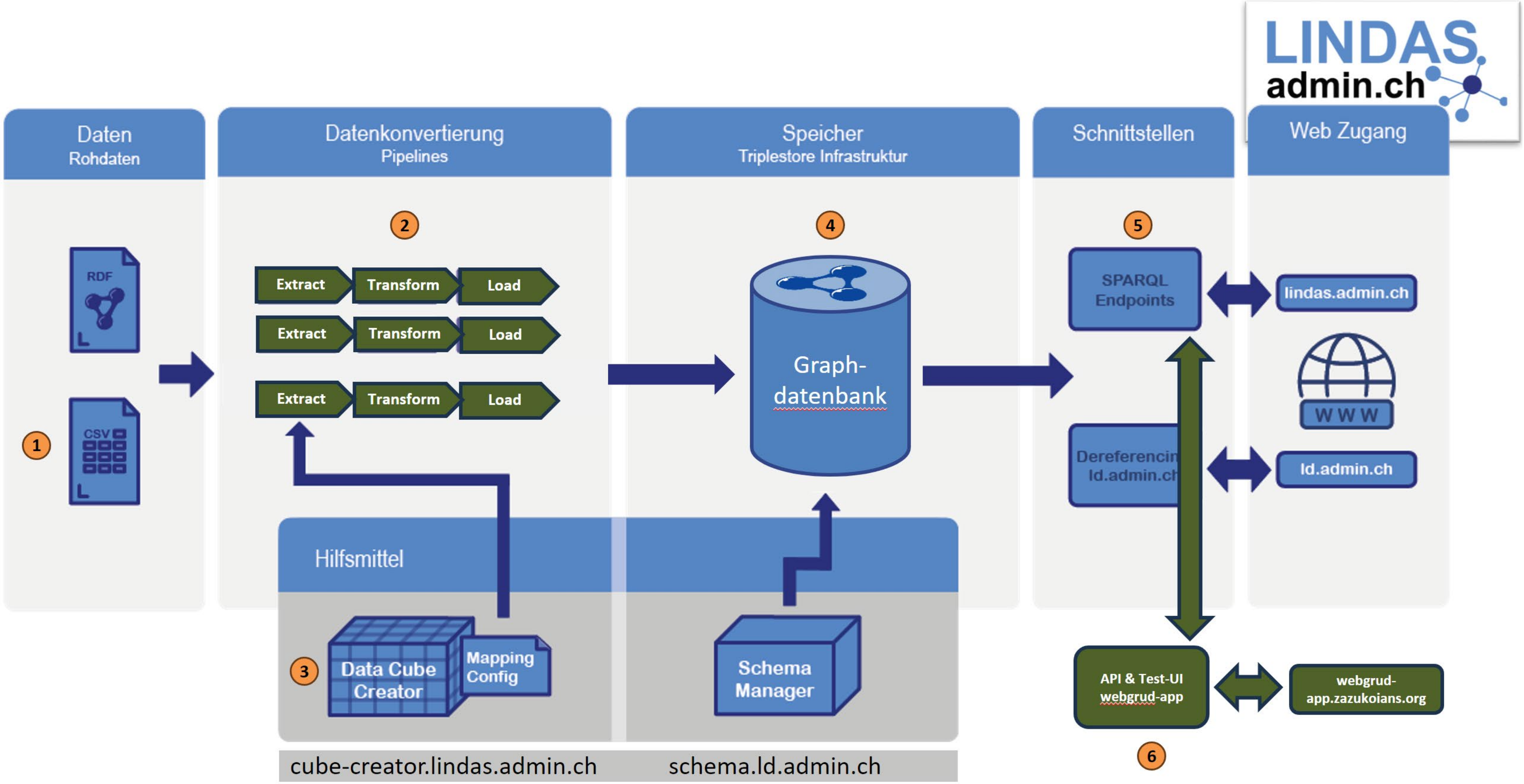

Figure 3: Overview of the LINDAS platform. Components of the LINDAS platform are shown in blue color. Components that are WebGRUD specific are shown in green color.

2.3 Cube Creator

Cube Creator is an API developed by Zazuko and hosted by the SFA to facilitate the data transformation from CSV-format to RDF. It requires tables in normal form, i.e. each table must contain only one measure dimension and each data entry (combination of key and measures dimensions) must be unique. Cube Creator supports the augmentation and annotation of the input data in form of cubes, which can be used to visualize the data with further tools. Access to Cube Creator is granted by the SFA via a CH-LOGIN (https://www.eiam.swiss/) and can be requested at support.lindas@bar.admin.ch.

2.4 Test API webgrud-app

The test API webgrud-app developed by Zazuko enables the examination and visualization of the data models used to link the WebGRUD cubes by conditions defined in the PRIF. A github account and access to Zazuko's organizational account is needed to view the detailed calculation steps and results of performing a calculation.

3 PRIF tables: selection, conversion and transformation

Author: Juliane Hirte

All PRIF tables are currently available as unstructured data in PDF format in three languages (DE, FR, IT), while some tables are also available as word- or excel-files. The tables need to be copied to CSV or excel using a conversion software (e.g. Tabular, free open source) and the decimal separator needs to be changed from , (comma) to . (point). For this project, we have also translated the table contents and meta-information to English in compliance with scientific standards.

3.1 Overview of selected PRIF tables for this pilot project

The PRIF comprise approx. 150 tables; 85 of which contain norm, reference or correction values required for the calculation of fertilization recommendations (Table 1). This pilot project focuses on arable crops and the nutrients phosphorus, potassium, magnesium, and nitrogen. Hence, most of the relevant PRIF tables that are needed for those calculations are included (Table 2), with few exceptions: For the calculation of nitrogen fertilization recommendations, only the method of the corrected norm is considered, however, not to full extent (Figure 4). In addition, the list of vegetable crops is provided (Table 2) but currently not used for any calculations.

Table 1: Overview of all PRIF tables, their type of contents and relevance for the calculation of fertilization recommendations. Special crops comprise vegetable crops, viticulture, fruit crops, berry crops, medicinal plants and ornamentals.

Type of content	#	Relevance for calculation
Information / description	50	No
Classification	15	potentially
Norm and reference values for arable crops and grassland	30	Yes
Correction values for arable crops and grassland	20	Yes
Norm and reference values for special crops	30	Yes
Correction values for special crops	5	Yes

Table 2: Overview of the selected PRIF tables. Module 8, tables 16, 17, 19 and 20 are currently not included in the project, but would be necessary for the full functionality of calculating nitrogen fertilization recommendations.

Module #	Modul name	Table #
2	Soil Characteristics and Soil Analyses	9, 10, 11, 12, 13, 14, 15, 16, 17, 18
4	Properties and Use of Fertilisers	6
8	Fertilisation of Arable Crops	9, 11, 12, 13, 14, 15, 21
10	Fertilisation in Vegetable Production	1

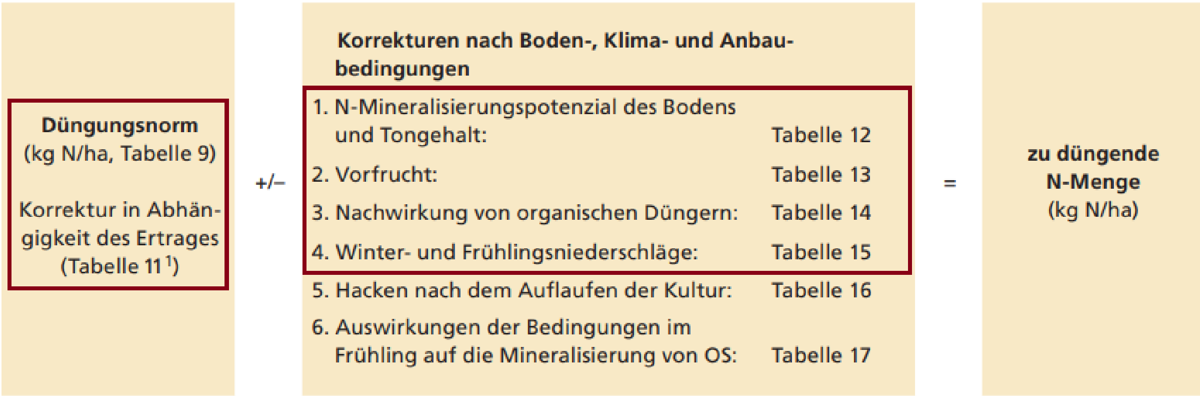

Figure 4: Schematic representation of the method of the corrected norm for nitrogen fertilization recommendations (PRIF 8/24). Parts included in this project are framed.

3.2 Converting wide format to normal form

3.2.1 Requirements and constraints

As the tables in the printed version of the PRIF are meant to be human-readable, they are mostly organised in wide format, i.e. the same measure variable (e.g. module 2, table 10: correction factor) is spread over multiple columns with different levels of a key variable (e.g. module 2, table 10: soil clay content) as column headers. The normal form requires a long format, i.e. the measure variable is arranged in one column and the levels of the key variable are arranged as identifiers in a separate column. Hence, most of the PRIF tables need to be rearranged to fulfil the requirement for transformation to RDF. Transforming a table from wide to long format can be done with several functions in R, e.g. gather() from package tidyr or melt() from package reshape2: http://www.cookbook-r.com/Manipulating_data/Converting_data_between_wide_and_long_format/.

In addition, a variety of constraints need to be solved before the PRIF tables can be converted to the required format for transformation to RDF (Table 3; Figure 5).

Table 3: Constraints for converting the PRIF tables to the required format for transformation to RDF with examples.

Constraint	Example
Multiple measure variables in one table	module 8, table 9: reference yield, nutrient removal, fertilization norm
Same sets of variables in multiple tables (redundant)	module 2, tables 10-18: soil nutrient content, soil clay content, correction factor
Different units of measure variable (implies different measure variables)	module 4, table 6: kg m^{-3} and kg t^{-1}
Purely descriptive information in key variable (not clearly defined)	module 8, table 20: “low to medium yield potential of the site”
Numerical ranges or functions as measure variables (not distinct)	module 8, table 20: 0-30 kg N ha^{-1} fertilization recommendation
Key variables as conditions or comments in measure variables (not retrievable)	module 8, table 20: “at planting”
Meta-information for correct use of the data in the table caption or footnote	module 2, tables 13, 16, 18: table can only be applied for soils with certain pH-values
Meta-information for correct use of the data in the main text or additional tables / figures	module 8, figure 7: meta-information for module 8, table 11

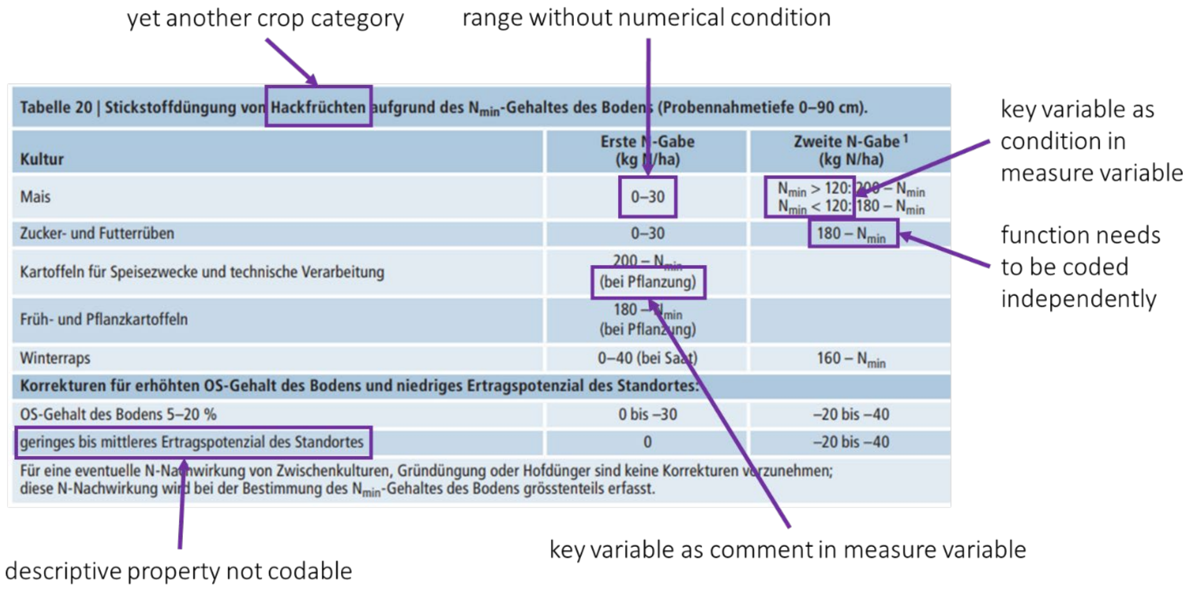

Tabelle 20 | Stickstoffdüngung von Hackfrüchten aufgrund des N_{min}-Gehaltes des Bodens (Probennahmetiefe 0–90 cm).

Kultur	Erste N-Gabe (kg N/ha)	Zweite N-Gabe [1] (kg N/ha)
Mais	0–30	N_{min} > 120: 200 – N_{min} N_{min} < 120: 180 – N_{min}
Zucker- und Futterrüben	0–30	180 – N_{min}
Kartoffeln für Speisezwecke und technische Verarbeitung	200 – N_{min} (bei Pflanzung)	
Früh- und Pflanzkartoffeln	180 – N_{min} (bei Pflanzung)	
Winterraps	0–40 (bei Saat)	160 – N_{min}
Korrekturen für erhöhten OS-Gehalt des Bodens und niedriges Ertragspotenzial des Standortes:		
OS-Gehalt des Bodens 5–20 %	0 bis –30	–20 bis –40
geringes bis mittleres Ertragspotenzial des Standortes	0	–20 bis –40

Für eine eventuelle N-Nachwirkung von Zwischenkulturen, Gründüngung oder Hofdünger sind keine Korrekturen vorzunehmen; diese N-Nachwirkung wird bei der Bestimmung des N_{min}-Gehaltes des Bodens grösstenteils erfasst.

Figure 5: Constraints for converting the PRIF tables to the required format for transformation to RDF illustrated on module 8, table 20.

3.2.2 Changes to the PRIF tables to solve the constraints

Consequently, most of the PRIF tables included in this pilot project are split, reduced, extended, and/or otherwise changed, to solve those constraints (Table 4).

For example, columns containing ranges instead of discrete values need to be split into two columns containing the minimum and maximum value of the range, which can be efficiently executed in R (base R functions and dplyr operations):

```
new_table <- old_table %>%
  mutate(nutrient_min = ifelse(grepl("<", nutrient_range), 0, sub("-.*|.*>=|.*>", "", nutrient_range)),
         nutrient_max = ifelse(grepl(">=|>", nutrient_range), 1000, sub(".*<|.*-", "", nutrient_range)),
         clay_min = ifelse(grepl("<", clay_range), 0, sub("-.*|.*>=|.*>", "", clay_range)),
         clay_max = ifelse(grepl(">=|>", clay_range), 100, sub(".*<|.*-", "", clay_range))) %>%
  as.data.frame()
```

Several changes result in some loss of information and flexibility as the table contents get to be clearly defined and room for interpretation gets eliminated. An example of a PRIF table in wide format is given in Figure 6 and an example for a table in normal form is given in Table 5. The full list of included PRIF tables is given in Table 6. The prepared CSV files are stored together with this report and can also be directly downloaded from Cube Creator.

Table 4: Changes to the selected PRIF tables in order to solve the constraints for converting the tables to the required format for transformation to RDF.

Module / table	Type of change	Explanation
2/9	Extension	OM content 1-9 added with correction factor = 1
2/10	Split	silty and sandy soils as separate tables
2/10-18	Merge	tables 10 to 18 as one table
2/10-18	Extension	extraction method and nutrient as additional identifiers
2/10-18	Adjustment	minimum values of nutrient and clay contents instead of ranges
4/6	Elimination	dry matter and organic matter not included
4/6	Split	solid and liquid fertilizers as separate tables
8/9	Split	nutrient removal and fertilization norm as separate tables
8/11	Extension	remaining arable crops added with maximum target yield = reference yield and correction value = 0
8/12	Adjustment	minimum values of clay and OM contents instead of ranges
8/12	Adjustment	mean values of correction values instead of ranges
8/13	Reduction	pre-crop reduced to unique identifier (crop or crop group)
8/13	Extension	season of sowing of main crop and specifications as additional identifiers
8/13	Adjustment	mean values of correction values instead of ranges
8/13	Extension	remaining arable crops added with correction value = 0
8/13	Reduction	no additive correction considered
8/15	Extension	average intensity of precipitation added with correction value = 0
8/15	Reduction	no additive correction considered
8/21	Extension	remaining arable crops added with correction value = 0

Tabelle 15 | Korrektur der Stickstoff-Normdüngung in Abhängigkeit der Winter- und Frühjahrsniederschläge.

	Korrektur der N-Düngung (kg N/ha)			
	Niederschlagsperiode und -intensität			
	Winterruhe (November–Januar)		Vegetationsbeginn/Saat (März–Mai)	
Kultur	gering (< 60 mm/Monat)	hoch (> 90 mm/Monat)	gering (< 60 mm/Monat)	hoch (> 90 mm/Monat)
Winterraps	–10	+10	0	0
Wintergetreide	–20	+20	0	0
Sommergetreide	–20	0	–10	+10
Frühkartoffeln	–20	+10	–10	+30
Rüben, Mais, Kartoffeln (Pflanzkartoffeln, Kartoffeln für Speisezwecke und technische Verarbeitung)	0	+10	–10	+30

Figure 6: Example of a PRIF table (module 8, table 15) in wide format.

Table 5: Example of a PRIF table (module 8, table 15) in normal form. Crops are filtered to three examples but comprise all crops of the shared dimension Arable crops in the original CSV file.

Crop	Period of precipitation	Intensity ID	Intensity of precipitation	Niederschlagsintensität	Intensité de précipitations	Intensità delle precipitazioni	Correction value
springOat	winter	low	low (< 60 mm)	niedrig (< 60 mm)	faible (< 60 mm)	basso (< 60 mm)	-20
grainMaize	winter	low	low (< 60 mm)	niedrig (< 60 mm)	faible (< 60 mm)	basso (< 60 mm)	0
sugarbeet	winter	low	low (< 60 mm)	niedrig (< 60 mm)	faible (< 60 mm)	basso (< 60 mm)	0
springOat	winter	high	high (> 90 mm)	hoch (> 90 mm)	élevé (> 90 mm)	elevato (> 90 mm)	0
grainMaize	winter	high	high (> 90 mm)	hoch (> 90 mm)	élevé (> 90 mm)	elevato (> 90 mm)	10
sugarbeet	winter	high	high (> 90 mm)	hoch (> 90 mm)	élevé (> 90 mm)	elevato (> 90 mm)	10
springOat	spring	low	low (< 60 mm)	niedrig (< 60 mm)	faible (< 60 mm)	basso (< 60 mm)	-10
grainMaize	spring	low	low (< 60 mm)	niedrig (< 60 mm)	faible (< 60 mm)	basso (< 60 mm)	-10
sugarbeet	spring	low	low (< 60 mm)	niedrig (< 60 mm)	faible (< 60 mm)	basso (< 60 mm)	-10
springOat	spring	high	high (> 90 mm)	hoch (> 90 mm)	élevé (> 90 mm)	elevato (> 90 mm)	10
grainMaize	spring	high	high (> 90 mm)	hoch (> 90 mm)	élevé (> 90 mm)	elevato (> 90 mm)	30
sugarbeet	spring	high	high (> 90 mm)	hoch (> 90 mm)	élevé (> 90 mm)	elevato (> 90 mm)	30
springOat	winter	average	average (60 - 90 mm)	durchschnittlich (60 - 90 mm)	moyenne (60 - 90 mm)	media (60 - 90 mm)	0
grainMaize	winter	average	average (60 - 90 mm)	durchschnittlich (60 - 90 mm)	moyenne (60 - 90 mm)	media (60 - 90 mm)	0
sugarbeet	winter	average	average (60 - 90 mm)	durchschnittlich (60 - 90 mm)	moyenne (60 - 90 mm)	media (60 - 90 mm)	0
springOat	spring	average	average (60 - 90 mm)	durchschnittlich (60 - 90 mm)	moyenne (60 - 90 mm)	media (60 - 90 mm)	0
grainMaize	spring	average	average (60 - 90 mm)	durchschnittlich (60 - 90 mm)	moyenne (60 - 90 mm)	media (60 - 90 mm)	0
sugarbeet	spring	average	average (60 - 90 mm)	durchschnittlich (60 - 90 mm)	moyenne (60 - 90 mm)	media (60 - 90 mm)	0

3.3 Shared dimensions, concept tables and cube tables

The prepared CSV files can be readily transformed to RDF using the Cube Creator interface. For this, two categories of CSV files are published: shared dimensions and cube projects containing concept tables and cube tables (Table 6).

3.3.1 Shared dimensions

Shared dimensions contain general information that is relevant for multiple cubes. They are arranged as lists with a unique identifier for each list level and the corresponding names in four languages (EN, DE, FR, IT) (Figure 7). Hence, data published as shared dimension is uniquely defined (e.g. seasons) or a widely accepted standard among data consumers (e.g. crops according to the PRIF).

The shared dimensions published for this pilot project comprise the lists of:

- Crop groups (according to the individual modules of the PRIF)
- Arable crops (module 8, table 9)
- Vegetable crops (module 10, table 1)
- Main products of agricultural crops, currently for arable crops only (module 8, table 9)
- By-products of agricultural crops, currently for arable crops only (module 8, table 9)
- Organic fertilizers (module 4, table 6 and module 8, table 14)
- Seasons (module 8, tables 13 and 15)

3.3.2 Cube projects with concept tables and cube tables

Cube projects contain specific information on a measure variable and its dependence on one or several key variable(s). Key variables can be either directly linked to shared dimensions by a unique identifier or mapped as concept tables that contain, similar to shared dimensions, a unique identifier for each list level and the corresponding names in four languages (EN, DE, FR, IT). Hence, information linked to a shared dimension is included as unique identifier while information mapped as concept table is fully integrated in the CSV file (one column each for the unique identifier and corresponding names in multiple languages) that is deployed as a cube project (Figure 8).

The concept tables included in this pilot project comprise the lists of:

- extraction method, currently method abbreviation only (not multilingual) (module 2, tables 10-18)
- nutrient form (module 4, table 6)
- mineralisation potential of organic matter (module 8, table 12)
- specifications of pre-crops (module 8, table 13)
- precipitation intensity (module 8, table 15)

*Table 6: Overview of PRIF tables, their splitting and/or merging to cube projects or shared dimensions with corresponding names, included output tables with corresponding names, and variables with data types and units. * IDs need to be updated for the sake of consistency.*

Module	Table	Project / shared dimension ID	Project / shared dimension name	Output table	Table name	Variable name	Data type	Unit
-	-	CropGroup *	Crop groups	Shared			nominal	
8	9	agroscopeCrops *	Arable crops	Shared			nominal	
8	9	mainProduct	Main products of agricultural crops	Shared			nominal	
8	9	byProduct	By-products of agricultural crops	Shared			nominal	
4, 8	6, 14	organicFertilizer	Organic fertilizers	Shared			nominal	
8	13, 15	season	Seasons	Shared			nominal	
10	1	vegtables *	Vegetable Crops	Shared			nominal	
2	9	PRIFm2t9	PRIF Module 2 Table 9	Cube	Correction factor OM	Organic matter content	ratio	%
2	9	PRIFm2t9	PRIF Module 2 Table 9	Cube	Correction factor OM	Soil bulk density	ratio	g per cm3
2	9	PRIFm2t9	PRIF Module 2 Table 9	Cube	Correction factor OM	Correction factor	ratio	number
2	10	PRIFm2t10a	PRIF Module 2 Table 10a	Cube	Correction factor silt	Crop group	nominal	
2	10	PRIFm2t10a	PRIF Module 2 Table 10a	Cube	Correction factor silt	Soil P content, minimum	ratio	mg per kg
2	10	PRIFm2t10a	PRIF Module 2 Table 10a	Cube	Correction factor silt	Correction factor	ratio	number
2	10	PRIFm2t10b	PRIF Module 2 Table 10b	Cube	Correction factor sand	Crop group	nominal	
2	10	PRIFm2t10b	PRIF Module 2 Table 10b	Cube	Correction factor sand	Soil P content, minimum	ratio	mg per kg
2	10	PRIFm2t10b	PRIF Module 2 Table 10b	Cube	Correction factor sand	Correction factor	ratio	number
2	10-18	PRIFm2t10t18	PRIF Module 2 Tables 10 to 18	Cube	Correction factor	Crop group	nominal	
2	10-18	PRIFm2t10t18	PRIF Module 2 Tables 10 to 18	Cube	Correction factor	Nutrient	nominal	
2	10-18	PRIFm2t10t18	PRIF Module 2 Tables 10 to 18	Concept	Extraction method	Extraction method	nominal	

Module	Table	Project / shared dimension ID	Project / shared dimension name	Output table	Table name	Variable name	Data type	Unit
2	10-18	PRIFm2t10t18	PRIF Module 2 Tables 10 to 18	Cube	Correction factor	Soil nutrient content, minimum	ratio	mg per kg
2	10-18	PRIFm2t10t18	PRIF Module 2 Tables 10 to 18	Cube	Correction factor	Soil clay content, minimum	ratio	%
2	10-18	PRIFm2t10t18	PRIF Module 2 Tables 10 to 18	Cube	Correction factor	Correction factor	ratio	number
4	6	PRIFm4t6m	PRIF Module 4 Table 6m	Cube	Nutrient content organic fertilizer	Organic fertilizer	nominal	
4	6	PRIFm4t6m	PRIF Module 4 Table 6m	Cube	Nutrient content organic fertilizer	Nutrient	nominal	
4	6	PRIFm4t6m	PRIF Module 4 Table 6m	Concept	Nutrient form	Nutrient form	nominal	
4	6	PRIFm4t6m	PRIF Module 4 Table 6m	Cube	Nutrient content organic fertilizer	Nutrient content	ratio	kg per t
4	6	PRIFm4t6s	PRIF Module 4 Table 6s	Cube	Nutrient content organic fertilizer	Organic fertilizer	nominal	
4	6	PRIFm4t6s	PRIF Module 4 Table 6s	Cube	Nutrient content organic fertilizer	Nutrient	nominal	
4	6	PRIFm4t6s	PRIF Module 4 Table 6s	Concept	Nutrient form	Nutrient form	nominal	
4	6	PRIFm4t6s	PRIF Module 4 Table 6s	Cube	Nutrient content organic fertilizer	Nutrient content	ratio	kg per m3
8	9	PRIFm8t9a	PRIF Module 8 Table 9a	Cube	Reference yield	Crop	nominal	
8	9	PRIFm8t9a	PRIF Module 8 Table 9a	Cube	Product type	Product type	nominal	
8	9	PRIFm8t9a	PRIF Module 8 Table 9a	Cube	Reference yield	Reference yield	ratio	dt per ha
8	9	PRIFm8t9b	PRIF Module 8 Table 9b	Cube	Nutrient removal	Crop	nominal	
8	9	PRIFm8t9b	PRIF Module 8 Table 9b	Cube	Nutrient removal	Nutrient	nominal	
8	9	PRIFm8t9b	PRIF Module 8 Table 9b	Cube	Product type	Product type	nominal	
8	9	PRIFm8t9b	PRIF Module 8 Table 9b	Cube	Nutrient removal	Nutrient removal	ratio	kg per ha

Module	Table	Project / shared dimension ID	Project / shared dimension name	Output table	Table name	Variable name	Data type	Unit
8	9	PRIFm8t9c	PRIF Module 8 Table 9c	Cube	Fertilization norm	Crop	nominal	
8	9	PRIFm8t9c	PRIF Module 8 Table 9c	Cube	Fertilization norm	Nutrient	nominal	
8	9	PRIFm8t9c	PRIF Module 8 Table 9c	Cube	Fertilization norm	Fertilization norm	ratio	kg per ha
8	11	PRIFm8t11	PRIF Module 8 Table 11	Cube	Correction target yield	Crop	nominal	
8	11	PRIFm8t11	PRIF Module 8 Table 11	Cube	Correction target yield	Maximum target yield	ratio	dt per ha
8	11	PRIFm8t11	PRIF Module 8 Table 11	Cube	Correction target yield	Correction value	ratio	kg per dt
8	12	PRIFm8t12	PRIF Module 8 Table 12	Concept	Mineralisation potential OM	Mineralization potential of OM	nominal	
8	12	PRIFm8t12	PRIF Module 8 Table 12	Cube	Correction mineralisation potential OM	Clay content, minimum	ratio	%
8	12	PRIFm8t12	PRIF Module 8 Table 12	Cube	Correction mineralisation potential OM	Organic matter content, minimum	ratio	%
8	12	PRIFm8t12	PRIF Module 8 Table 12	Cube	Correction mineralisation potential OM	Correction value	ratio	kg per ha
8	13	PRIFm8t13	PRIF Module 8 Table 13	Cube	Correction pre-crop	Pre-crop	nominal	
8	13	PRIFm8t13	PRIF Module 8 Table 13	Cube	Correction pre-crop	Season of mulching / incorporation	nominal	
8	13	PRIFm8t13	PRIF Module 8 Table 13	Cube	Correction pre-crop	Season of sowing (main crop)	nominal	
8	13	PRIFm8t13	PRIF Module 8 Table 13	Concept	Specifications	Specification	nominal	
8	13	PRIFm8t13	PRIF Module 8 Table 13	Cube	Correction pre-crop	Correction value	ratio	kg per ha
8	14	PRIFm8t14	PRIF Module 8 Table 14	Cube	Correction organic fertilizer N	Organic fertilizer	nominal	
8	14	PRIFm8t14	PRIF Module 8 Table 14	Cube	Correction organic fertilizer N	Percentage of applied total N	ratio	%
8	15	PRIFm8t15	PRIF Module 8 Table 15	Cube	Correction precipitation	Crop	nominal	

Module	Table	Project / shared dimension ID	Project / shared dimension name	Output table	Table name	Variable name	Data type	Unit
8	15	PRIFm8t15	PRIF Module 8 Table 15	Cube	Correction precipitation	Period of precipitation	nominal	
8	15	PRIFm8t15	PRIF Module 8 Table 15	Concept	Precipitation intensity	Intensity of precipitation	ratio	mm
8	15	PRIFm8t15	PRIF Module 8 Table 15	Cube	Correction precipitation	Correction value	ratio	kg per ha
8	21	PRIFm8t21	PRIF Module 8 Table 21	Cube	Correction factor crop	Crop	nominal	
8	21	PRIFm8t21	PRIF Module 8 Table 21	Cube	Correction factor crop	Nutrient	nominal	
8	21	PRIFm8t21	PRIF Module 8 Table 21	Cube	Correction factor crop	Correction factor	ratio	number

Seasons

Name	Identifiers
primavera@it spring@en Frühling@de printemps@fr	spring
autumn@en Herbst@de automne@fr autunno@it	autumn
summer@en Sommer@de été@fr estate@it	summer
Winter@de winter@en hiver@fr inverno@it	winter

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Figure 7: Example of a table published as shared dimension.

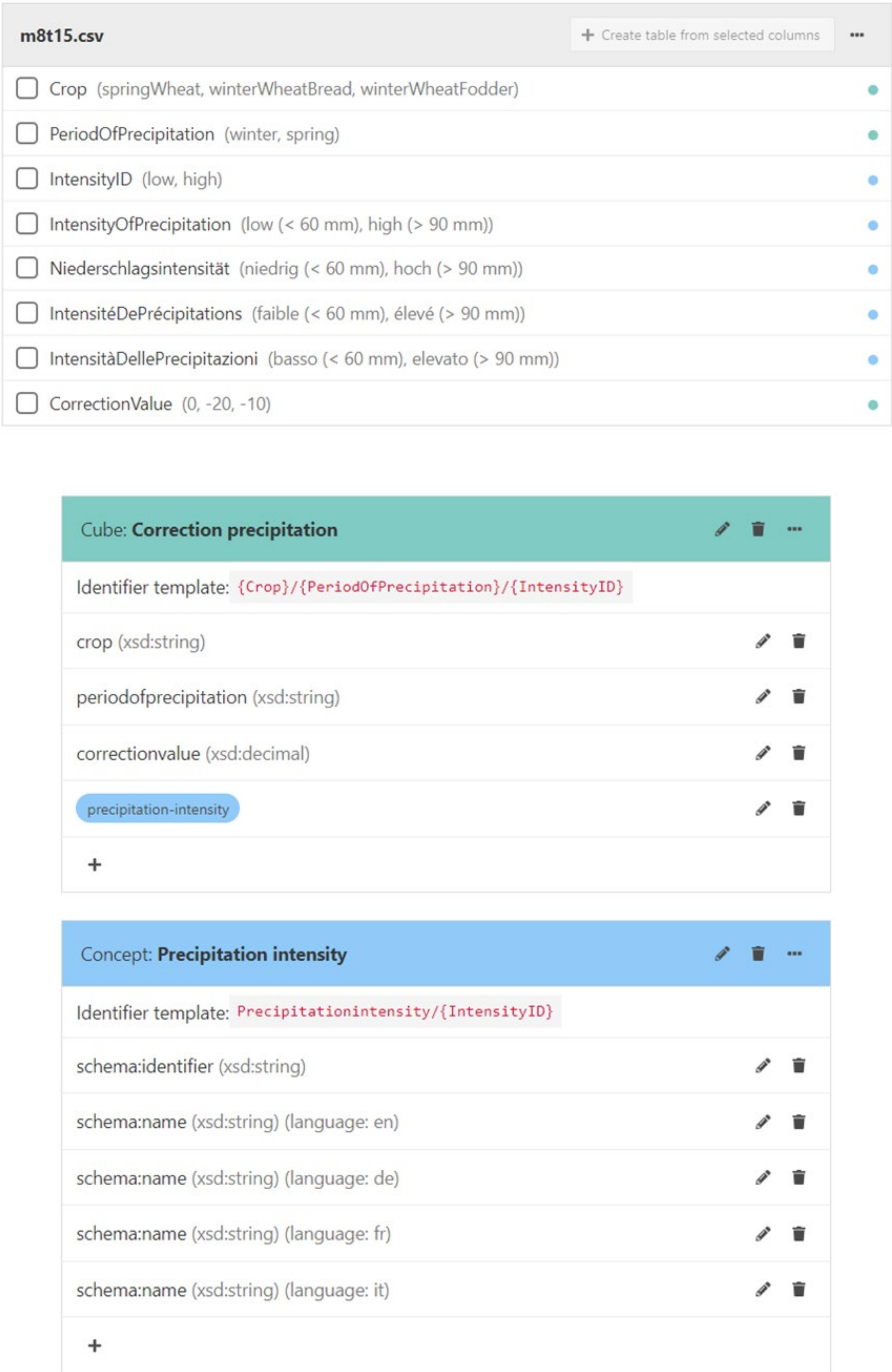

Figure 8: Example of a table deployed as cube project. The variables (top: table columns showing up to three levels per variable) are mapped as cube (middle: crop, period of precipitation, correction value) or concept table (bottom: precipitation intensity). Crop is linked to the shared dimension arable crops, period of precipitation is linked to the shared dimension season.

3.4 Transformation of CSV to RDF using Cube Creator

A general user documentation for Cube Creator is provided by Zazuko on github and will not be reproduced here. Shared dimensions are manually generated, while cubes are configured from uploaded CSV files. The specific steps for the PRIF tables are shown in Appendix I.

3.5 Conditional relationships between PRIF tables

To calculate fertilization recommendations, the respective PRIF tables need to be linked to one another and further conditions need to be met. In case of inconsistencies (e.g. module 8, table 11 column header: correction of the nitrogen fertilization depending on the yield (unit: kg N dt-1 additional grain yield) vs. main text: “The factor fyield estimates the correction of the nitrogen demand when a higher or lower yield compared to the reference yield is targeted.”), we have opted for one possibility of interpretation (here: main text). The individual steps for the calculations are represented in Table 7, Figure 9 and Figure 10. As some information in the PRIF is missing, the respective calculations cannot be performed and no result will be returned:

- Phosphorus: extraction method H2O10 AND pH < 5.0, extraction method H2O10 AND pH >7.8, extraction method AAE10 AND pH ≥ 6.8
- Magnesium: extraction method AAE10 AND pH ≥ 6.8
- Nitrogen: no value of N content in organic fertilizer provided by user AND organic fertilizer = Ricokalk, compost, manure compost OR composted manure

Table 7: Explanation of symbols used in Figure 9 and Figure 10.

Symbol	Explanation
crop	input information needed for filtering cube table, key dimension
N in organic fertilizer kg ha-1	input information needed for calculation, independent of tables
PRIF m8t12	cube
Fertiliz. norm kg ha-1	output from cube table, measure dimension, value needed for calculation
Correction target yield kg ha-1	intermediate result or end result
	operator
nutrient	decision knot for calculation
	stop calculation and return NA

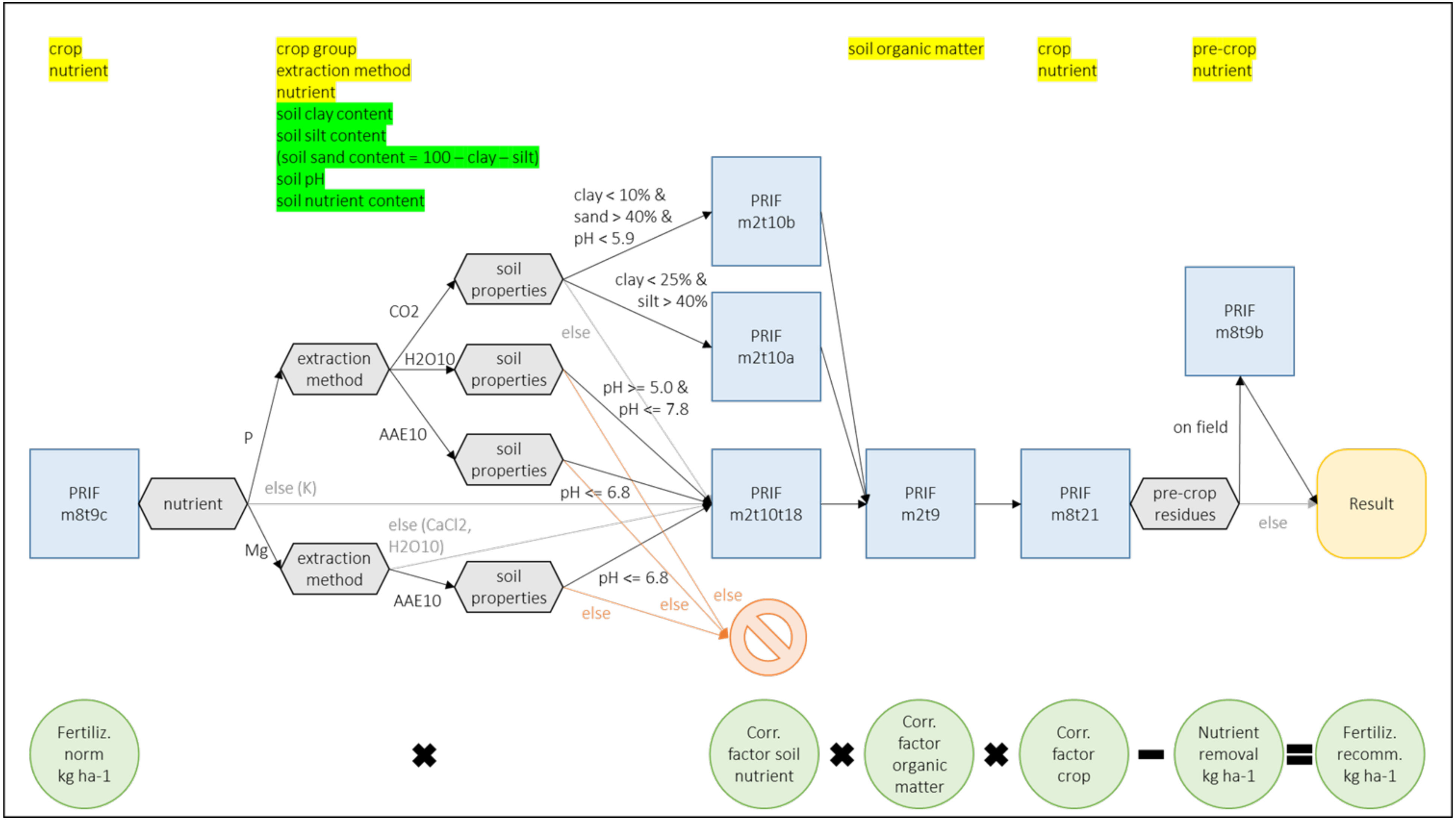

Figure 9: Conceptual overview of the cube links for calculating phosphorus, potassium and magnesium fertilization recommendations for arable crops (PRIF module 8 tables 9 and 21, module 2 tables 9-18).

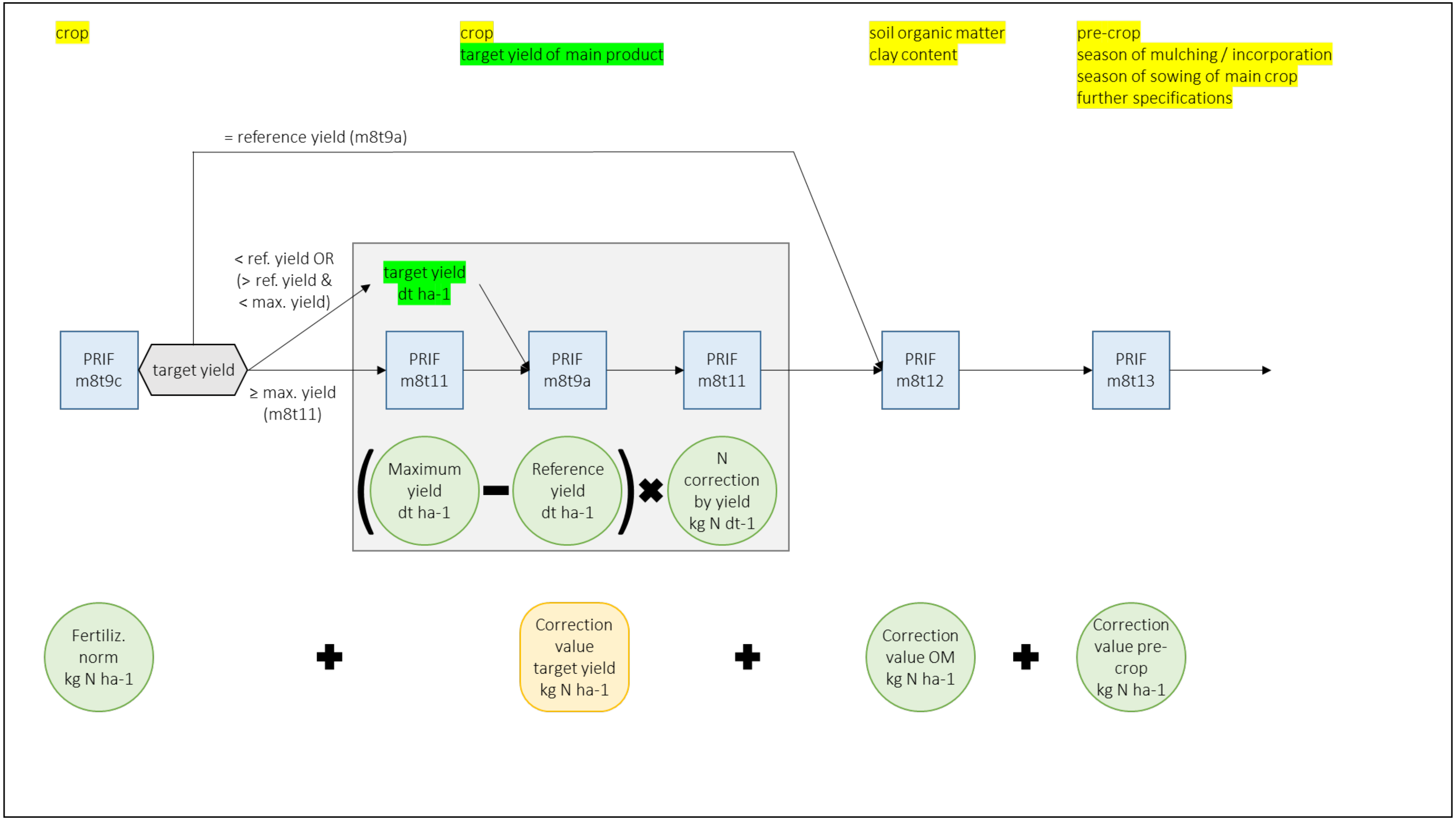

Figure 10: Conceptual overview of the cube links for calculating nitrogen fertilization recommendations for arable crops (PRIF module 8 tables 9, 11, 12, 13).

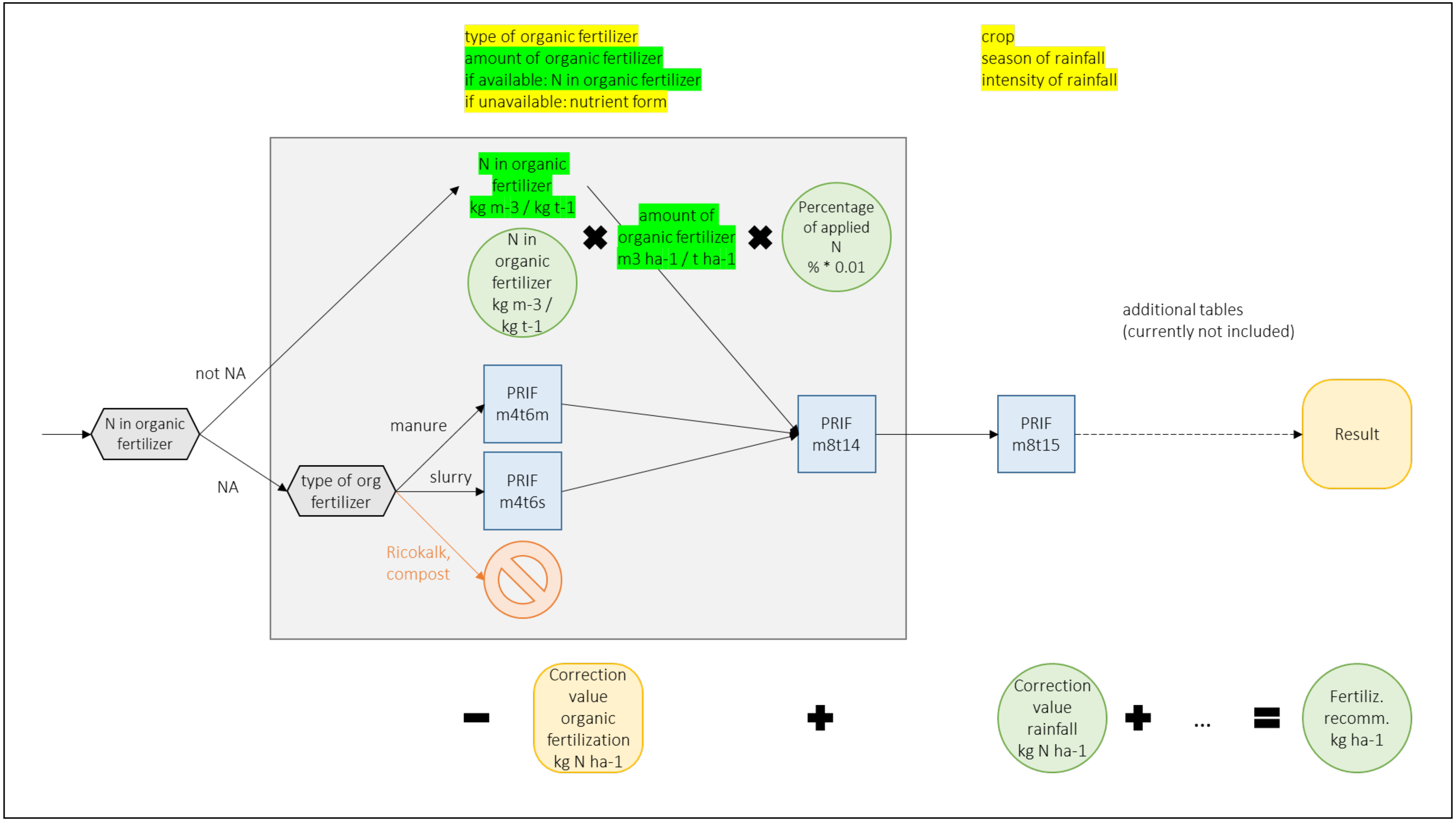

Figure 10 (continued): Conceptual overview of the cube links for calculating nitrogen fertilization recommendations for arable crops (PRIF module 4 table 6, module 8 tables 14 and 15).

4 System documentation

Author: Michael Rauch

4.1 Architectural overview

This section shows an overview of the components that make up the WebGRUD system and the interactions between the components. The WebGRUD system is built on the LINDAS platform, re-using a lot of the functionality this platform provides. LINDAS consists at its core of a triplestore (RDF graph database) to which a set of tools for data conversion and integration as well as a query interface for data retrieval is added (Figure 3).

4.1.1 Data sources

- PRIF tables and shared dimensions
- EPPO codes (computer codes developed for plants and pests (including pathogens) which are important in agriculture and plant protection)
- Chemical elements and compounds (all chemical elements and a selection of relevant chemical compounds fetched from Wikidata)

4.1.2 ETL pipelines

Two ETL pipelines implement explicit data transformations to RDF.

EPPO codes

EPPO codes are downloaded from https://data.eppo.int/files/xmlfull.zip and then converted from XML to RDF using a Barnard59 ETL pipeline with XRM mappings leveraging the CARML service to transform the data. The result is a defined term set which, once stored in the named graph https://lindas.admin.ch/agroscope/eppo of LINDAS, is available as a shared dimension EPPO codes in Cube Creator.

Pipeline definition: https://gitlab.ldbar.ch/pipelines/agroscope-webgrud/-/blob/develop/pipelines/eppocodes.ttl

Chemical elements and compounds

All chemical elements and a selection of relevant compounds are loaded with a Barnard59 ETL pipeline which gets the data with a SPARQL query from Wikidata and produces two defined term sets - one for the chemical elements and another one for the chemical compounds. Both term sets are published in the LINDAS named graph https://lindas.admin.ch/agroscope/chemicals. Both term sets are available as shared dimensions in Cube Creator: chemical elements and chemical compounds.

Pipeline definition: https://gitlab.ldbar.ch/pipelines/agroscope-webgrud/-/blob/develop/pipelines/chemicals.ttl

4.1.3 Data cubes

Cube Creator is a tool to create RDF cubes from CSV files, including metadata curation and management of shared dimensions (dimensions shared among multiple data cubes). Based on the specific mapping configuration of a cube, the Cube Creator runs an ETL pipeline to transform the data to RDF. Consider loading the crops using a pipeline since many more crops will be added in the future (at the moment we only have those in the arable and vegetable crops categories) and there are technical issues in creating links to EPPO codes using Cube Creator.

4.1.4 Graph database (triplestore)

The RDF graph database (Stardog) is the core of the LINDAS platform.

4.1.5 SPARQL endpoint

The SPARQL endpoint is the generic query interface used for data retrieval from the graph database. All data from the PRIF tables and the shared dimensions can be queried using this interface, by writing a specific SPARQL query.

4.2 Data model

This section shows the data/information perspective of WebGRUD, the main entities in the graph and how they are connected.

4.2.1 PRIF tables

PRIF tables are represented as RDF data cubes. A data cube contains observations and metadata. Observations can be classified along key dimensions. For details, have a look at the https://cube.link/ schema. Currently, there are 15 cubes representing PRIF tables (Table 8). To easily explore cubes without Cube Creator, go to https://cube-viewer.zazuko.com/ (click on Endpoint config) and set the following settings:

- SPARQL endpoint URL: https://int.lindas.admin.ch/query for
- Source graph: https://lindas.admin.ch/agroscope/cube

Table 8: Overview of RDF data cubes based on the PRIF tables with links to cube-viewer.

Identifier (linked to cube-viewer)	Title
PRIFm2t9	Correction factor for soil nutrient status by soil organic matter content
PRIFm2t10a	Correction factor for P fertilization norm by soil P for silty soils
PRIFm2t10b	Correction factor for P fertilization norm by soil P for sandy soils
PRIFm2t10t18	Correction factor for P, K, Mg fertilization norm
PRIFm4t6m	Standard values for the nutrient content of solid organic fertilizers (manure) of different types of livestock (stable housing)
PRIFm4t6s	Standard values for the nutrient content of liquid organic fertilizers (slurry) of different types of livestock (stable housing)
PRIFm8t9a	Reference yield of arable crops
PRIFm8t9b	Nutrient removal by arable crops
PRIFm8t9c	N, P, K, Mg fertilization norm for arable crops
PRIFm8t11	Correction of N fertilisation for a target yield that deviates from the average yield (reference yield)
PRIFm8t12	Correction of N fertilisation depending on the mineralisation potential of the organic matter (OM)
PRIFm8t13	Correction of nitrogen fertilization depending on pre-crop
PRIFm8t14	Correction of N fertilization norm due to the legacy effect of organic fertilizers
PRIFm8t15	Correction of N fertilization norm by winter and spring precipitation
PRIFm8t21	Correction factor for P, K, Mg fertilization norm by crop

When you click Fetch cubes, you will get only the Agroscope cubes in the drop-down list (ignore the first six entries, they were test cubes). When you select one cube, you can find its link in the address bar of the browser, so you can easily share it.

Several key dimensions are defined as shared dimensions and are used (or at least could be used) by multiple cubes. They are manually curated in Cube Creator.

- Arable crops
- Crop groups
- Main products of agricultural crops
- By-products of agricultural crops
- Organic fertilizers
- Seasons
- Vegetable crops

There are also key dimensions that are currently not shared (but could be potentially shared in the future, when more tables are represented). Those tables are currently defined as concept tables. SPARQL queries are useful to explore and understand the data model further (examples: PRIF cubes, PRIF classes). The links between different tables are showcased in Figure 11 and Figure 12.

4.2.2 Fertilization calculations

Fertilization calculations can be realized via the webgrud-app and visualized via a basic web user interface. Details are given in chapter 5 Test API webgrud-app.

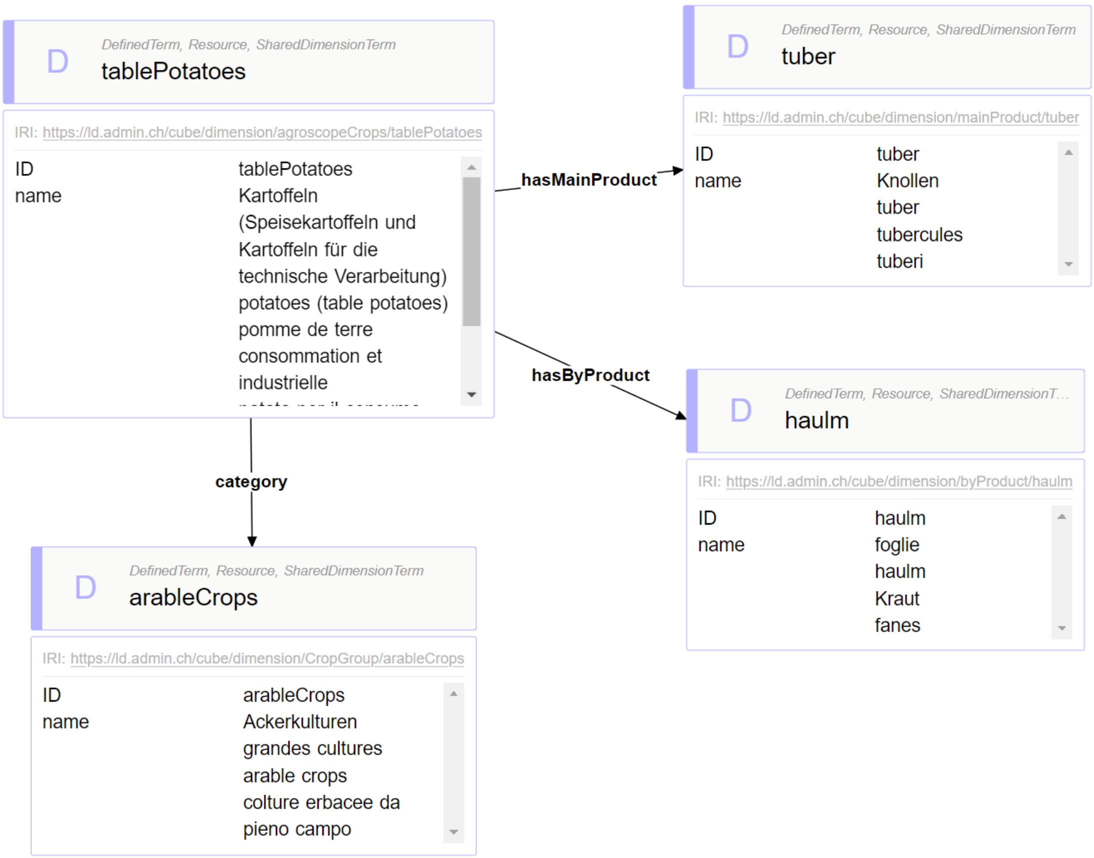

Figure 11: Illustration of the link of the crop "table potatoes" to the crop group "arable crops", main-product "tuber" and by-product "haulm".

Figure 12: Illustration of the link of the crop "table potatoes" and the nutrient "nitrogen" from entries in two different tables (PRIFm8t9b on the left, PRIFm8t9c on the right). The chemical element "nitrogen" is further linked to its entry in Wikidata.

5 Test API webgrud-app

Author: Giacomo Citi

The webgrud-app offers the calculation of fertilization recommendations as a service to other applications and is based on the conditional relationships between the PRIF tables. Its functionality is specific to WebGRUD (it is not part of LINDAS). It also offers a domain-specific access tailored to the WebGRUD data, enabling data retrieval for software clients without requiring them to construct SPARQL queries themselves. The API itself is self-describing as a graph. Also the dependencies of the fertilization calculations are defined declaratively in a graph (Figure 13). Hence it is possible for the system to also answer questions such as “Which calculations depend on data from table PRIFm8t9c?”. This kind of introspection capability on the logic of the system itself will be very useful to self-document and validate dependencies and will become more valuable when the scope of data and logic of the system grows in the future. Further details - for example the detailed calculation steps carried out and leading up to the calculated result for a given input - are also produced as a result of performing a calculation (see https://github.com/zazuko/webgrud-app/tree/master).

The API is implemented as hypermedia-driven web API. Hypermedia roughly means that the API is self-describing using a standard vocabulary and lets client applications understand and follow URLs in the same vein as users following links in regular web pages. Additionally to the API, a very basic and raw web user interface is provided. It is using the API and is intended to make the scope and functionality of the API more tangible for human users of this prototype.

Tables and calculations are publicly available at https://webgrud-app.zazukoians.org. The API description is available here (it is meant to be machine-readable, not easily readable by humans). It uses RDF for input and output data. RDF can be expressed in many different formats. JSON-LD is the default (but others like text/turtle can be requested in the Accept header). The home page provides a sort of index. You can recognize the URL of other resources like https://webgrud-app.zazukoians.org/tables, which you can copy in the browser's address bar to get the list of available tables (e.g. Microsoft edge, Firefox or Google Chrome with the pretty-print option).

There are different categories of resources besides tables and calculations: dimensions, queries, rules and other ones may be easily added in the future (e.g. shapes). We describe all of them briefly.

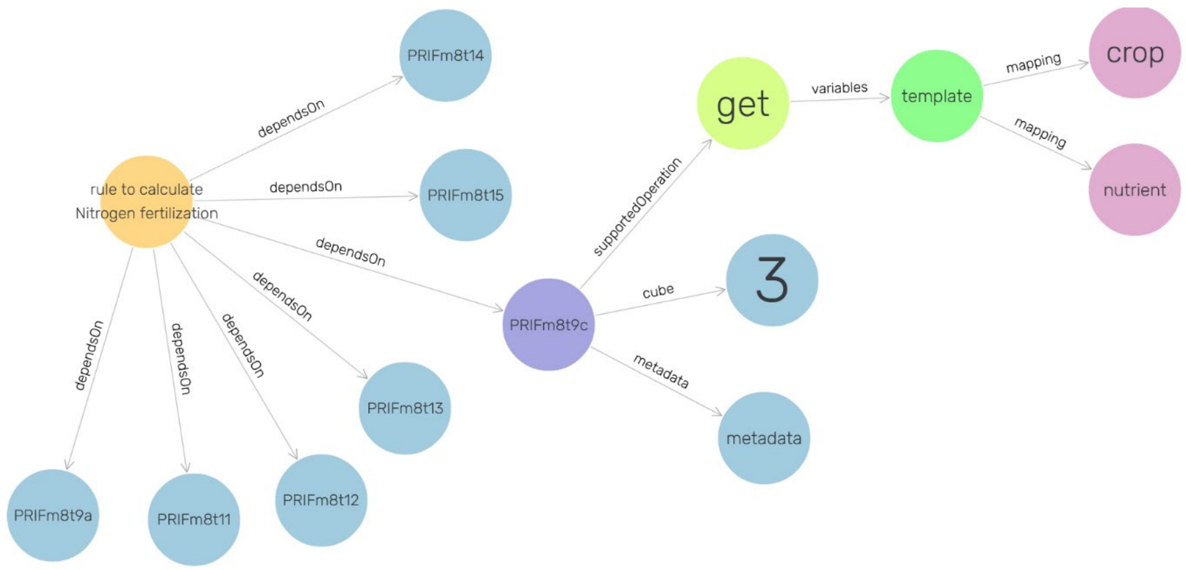

Figure 13: Fragment of the graph that is driving the functionality of the webgrud-app. It shows which tables the “Nitrogen fertilization” calculation is based on and also shows that slices from the PRIFm8t9c table can be fetched from the API using the parameters “crop” and “nutrient”.

5.1 Tables

Tables correspond to cubes in LINDAS. From the list of tables, you can choose one and get its contents, for example:

https://webgrud-app.zazukoians.org/table/PRIFm2t10a.

You can also filter a subset of rows adding a filter in the query string:

https://webgrud-app.zazukoians.org/table/PRIFm2t10a?cropgroup=https://ld.admin.ch/cube/dimension/CropGroup/arableCrops

Another filter available for this table is on the nutrient contents of the soil:

https://webgrud-app.zazukoians.org/table/PRIFm2t10a?cropgroup=https://ld.admin.ch/cube/dimension/CropGroup/arableCrops&nutrientcontentsoilmgkgmin=2.3

Notice how the result contains a single row (observation) with a value of 2.173 for the nutrient field. This is because, for this field, the value in the table represents the beginning of a range of values to which the observation applies. Decreasing the input from 2.3 to 2.1 will give you a different observation.

5.2 Table metadata

Each table has a rich set of metadata that is available appending */metadata* to the table URL. For example https://webgrud-app.zazukoians.org/table/PRIFm2t10a/metadata. Metadata include name and description of each field in multiple languages, as well as units of measure and, depending on the kind of dimension, the list or range of possible values

5.3 Shared dimensions

Shared dimensions are sets of terms referenced by tables. Their list is available here. Some dimensions are not exposed either because too big (EPPO codes) or not needed yet (like vegetable crops) but they can be easily added in the future.

5.4 Queries

Under this category, we have parametric SPARQL queries to address specific needs. The cropGroup query is useful during calculations to retrieve the category of a crop. The eppo query allows to get EPPO codes associated with a crop. There's no use case for it yet, it was added as an example.

5.5 Rules

We use a formalism called Notation-3 (n3) to express rules allowing to choose the appropriate calculations to be performed and the relevant tables. Most rules are not difficult to read, ensuring the implementation adheres to the requirements as expressed by domain experts.

5.6 Calculations

The API provides two calculations (https://webgrud-app.zazukoians.org/calculation/fertilization and https://webgrud-app.zazukoians.org/calculation/fertilizationN) to suggest the right amount of fertilization. The first one applies to phosphorus, potassium and magnesium; the other one to nitrogen. Opening the link we get the definition of the calculation (you can see the tables and rules involved). To actually perform the calculation, we need to POST a request to that URL with an input payload. To help testing calculations, there are temporary pages with a basic user interface to POST calculation requests. The pages use the turtle format (instead of JSON-LD) which is a bit more human-readable:

- https://webgrud-app.zazukoians.org/test: includes a few example inputs which can be edited to experiment
- https://webgrud-app.zazukoians.org/ui/fertilization: includes fields for manual inputs of required data for calculating P, K, or Mg fertilization recommendations
- https://webgrud-app.zazukoians.org/ui/fertilizationN: includes fields for manual inputs of required data for calculating N fertilization recommendations

The response includes details explaining the calculation performed. To help understanding and debugging the calculation, we provide a simplified visualization of the response (Figure 14). For this, the following steps need to be performed:

- make the appropriate entries at https://webgrud-app.zazukoians.org/ui/fertilization or https://webgrud-app.zazukoians.org/ui/fertilizationN, submit and copy the calculation response (lower text field)
- paste into a Text Editor file and save as .ttl file (select file type "All files" and replace .txt with .ttl)
- upload the .ttl file to the visualisation app https://giacomociti.github.io/rdf2dot/
- also upload the .n3 file (see Appendix II) to this app via costum rules (needs to be done only once per session)
- press show to visualize and check the calculation path

The suggested fertilization result is the "root" of a tree structure reflecting the calculation steps. The "leafs" of the tree are usually data from the relevant tables. Notice that this structure is not fixed. Depending on input data, different tables may be consulted (for example in case the rules determine that the soil is sandy or silty) and different operations may apply.

5.7 How to explore a table

A client can leverage metadata to explore a table. A specific example using the table *PRIFm2t10* is given in Appendix III.

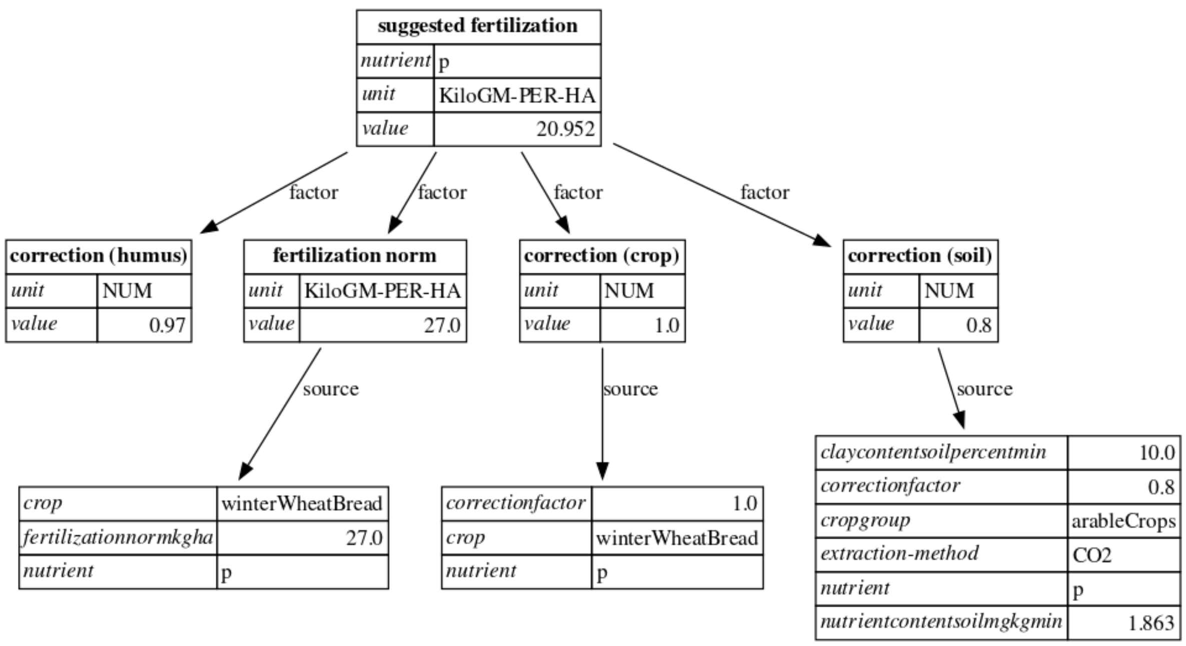

Figure 14: Visualization of the calculation path (response).

6 Additional sources for RDF visualisation

Author: Yannic L. Meyer

Visualizations can help to better understand API requests and responses. Visualizations are also particularly helpful for understanding the JSON-LD RDF tables of the WebGRUD API:

WebGRUD API Entrypoint:

- /Calculations, /Tables, /Dimensions, /Api, /shape/fertilizationN-inputShape are the subdomains that are the most important (Example: webgrud-app.zazukoians.org/dimensions).
- /Metadata can be attached to table domains to learn more about them (Example: webgrud-app.zazukoians.org/table/PRIFm8t13/metadata).

JSON-LD Playground:

- Can show JSON-LD (from API) in table format and transform to N-Quads.

Visualization tool for RDF 1:

- Raw representation of the data as graph.
- Check the box "Send form as HTTP POST (needed for large RDF data)" for big files / most transformed JSON-LD data from API.

Visualization tool for RDF 2:

- Very useful for understanding API tables. From JSON-LD with Playground to N-Quads, from N-Quads with this tool to graph.
- Custom rules visualization.n3 for reduction of displayed information.

Test UI for N fertilization from Zazuko, webgrud-app.zazukoians.org/ui/fertilizationN:

- UI to generate request
- Request and response can be displayed graphically using the visualization tools mentioned above.

General examples from Zazuko, https://webgrud-app.zazukoians.org/test

First website based on the API, https://agroscope-webgrud.netlify.app/

Probably the most important point for understanding the API: API-tables, requests and responses can be visualized by the visualization tools for RDF (latest after transformation with the Playground).

7 Limitations and suggestions for continuing work

Author: Juliane Hirte

This pilot project was meant as a proof-of-concept to provide a selection of the most frequently used PRIF tables in machine-readable format and showcase the correct implementation of their conditional links in data models. Hence, the project does not cover the full functionality of the PRIF and all crop groups included. The major limitations are listed below:

- The project focused on arable crops and the calculation of fertilization recommendations for the nutrients phosphorus, potassium, magnesium, and nitrogen. Hence, most of the relevant PRIF tables that are needed for those calculations were included, but not all of them.
- The original PRIF tables were considerably altered in their structure in order to provide them in the required format for transformation to RDF. With this, some information is lost (e.g. purely descriptive information in key variables, which is not clearly defined and, hence, not interpretable by a machine).
- Inconsistencies in the contents of the PRIF (e.g. module 8, table 11 column header: correction of the nitrogen fertilization depending on the yield (unit: kg N dt^{-1} *additional* grain yield) vs. main text: “The factor f_{yield} estimates the correction of the nitrogen demand when a higher *or lower* yield compared to the reference yield is targeted.”) are not reflected in the data models and links provided in this project. We have solved those instances to our best knowledge but cannot guarantee accuracy of content.
- As the test API webgrud-app is meant to illustrate the functionality of the cubes and links, it is currently limited to single uses of the individual tables for correcting fertilization recommendations (i.e. no additive corrections from one table). It does not provide a user-friendly frontend, which are part of a side project and continuing work within this project.
- The detailed calculation steps used in the test API webgrud-app are currently not easily accessible for non-developers as it is written in the Notation-3 language. This could hamper the correct use of the tables and links in external applications.
- External applications might be sensitive to changes to the cubes when e.g. links to concept tables are hardcoded. This calls for publication of lists as shared dimensions instead of concept tables.

Some suggestions for improvement and continuing work are given in Table 9.

Table 9: Suggestions for continuing work in the WebGRUD project on different levels of activities.

Level	Suggestion for continuing work
PRIF	Remove inconsistencies in nitrogen fertilization recommendation
PRIF	Translate descriptive information in key variables to machine-interpretable data
PRIF	Remove ranges from measure variables and define key variables for the correct use of minimum, mean, maximum, … values of the ranges
PRIF	Integrate meta-information given in table headers, footers, cell comments, main text, etc. for the correct use of the tables as key variables in the tables
PRIF	Eliminate further constraints for providing the PRIF tables in the required format for transformation to RDF
Cubes	Extend the set of available cubes to cover the full functionality of calculating the nitrogen fertilization recommendation for arable crops, i.e. module 8, tables 16 and 17 (method of the corrected norm) and module 8, tables 19 and 20 (method of the mineral nitrogen content of the soil)
Cubes	Add the lists of further crop groups as shared dimension (grassland, viticulture, fruits, berries, etc.)
Cubes	Extend the set of available cubes to cover the fertilization norm of further crop groups
Cubes	Deploy available cubes in PROD so that cubes are publicly shown in LINDAS
Cubes	Provide concept tables as shared dimensions
Documentation	Provide user-related manuals for Agroscope staff responsible for the PRIF (data providers) and API developers (data consumers)
Documentation	Provide the description of the calculation steps in a common human language (e.g. EN) and a reference implementation in a widely used programming language (e.g. JavaScript)
API	Develop and maintain a fully functional API for calculating and visualizing fertilization recommendations (including additive corrections from one table, e.g. module 8, tables 13 and 15) and test intensively
Interface	Develop and maintain an interface to e.g. digiFLUX, a website and/or a farm management information system and test intensively

Glossary

Term	Explanation	Reference
API	Application programming interface	https://en.wikipedia.org/wiki/API
Barnard59	An intuitive and flexible RDF pipeline solution designed to simplify and automate ETL processes for efficient data management	https://github.com/zazuko/barnard59
Carml-service	Service to convert non-RDF data to RDF via an http API	https://github.com/zazuko/carml-service
Concept	Dimension with some additional (meta) data added to all the possible values of this dimension	https://github.com/zazuko/cube-creator/wiki/Glossary
Concept table	side table of a cube project to provide multilingual labels and additional information (for grouping or external identifiers) for concepts	https://github.com/zazuko/cube-creator/wiki/1.-CSV-Mapping#concept-table-1
Confluence	Web-based corporate wiki, team workspace for collaboration and knowledge exchange	https://www.atlassian.com/software/confluence
Cube	Form of data storage, contains augmented and annotated data	https://cube.link/
Cube Creator	API to transform data in CSV format to RDF	https://github.com/zazuko/cube-creator/wiki
Cube table	main table of a cube project to represent the observations, with their multiple dimensions	https://github.com/zazuko/cube-creator/wiki/1.-CSV-Mapping#cube-table
digiFLUX	Web application to register trade and application of plant protection products and nutrients, launched by FOAG	https://digiflux.info/de/
Dimension	Column in input CSV file for transformation in RDF	https://github.com/zazuko/cube-creator/wiki/Glossary
EPPO	European and Mediterranean Plant Protection Organization	https://www.eppo.int/
ETL	Extract, transform, load	https://en.wikipedia.org/wiki/Extract,_transform,_load
FOAG, BLW	Federal Office for Agriculture, Bundesamt für Landwirtschaft	https://www.blw.admin.ch/blw/en/home.html
FOEN, BAFU	Federal Office for the Environment, Bundesamt für Umwelt	https://www.bafu.admin.ch/bafu/en/home.html
GitHub	Developer platform to host open source software	https://en.wikipedia.org/wiki/GitHub
HERMES	Handbuch der Elektronischen Rechenzentren des Bundes, eine Methode zur Entwicklung von Systemen, offener Standard zur Führung und Abwicklung von IT-Projekten	https://www.hermes.admin.ch/
Hydra CG	Hydra W3C Community Group	https://www.hydra-cg.com/
Hypermedia	Nonlinear medium of information that includes graphics, audio, video, plain text and hyperlinks	https://en.wikipedia.org/wiki/Hypermedia
Jira	Project management software	https://www.atlassian.com/software/jira
JSON-LD	JavaScript Object Notation for Linked Data	https://en.wikipedia.org/wiki/JSON-LD
LINDAS	Linked Data Service, technology that allows data to be easily related to each other	https://lindas.admin.ch/

Term	Explanation	Reference
N3	Shorthand for non-XML serialization of RDF models	https://en.wikipedia.org/wiki/Notation3
Normal form	Form of a table that meets defined criteria	https://en.wikipedia.org/wiki/Database_normalization
N-Quads	Extension of N-Triples with an optional context value at the fourth position	https://en.wikipedia.org/wiki/N-Triples#N-Quads
N-Triples	Format for storing and transmitting data. Line-based, plain text serialisation format for RDF graphs, subset of the Turtle format	https://en.wikipedia.org/wiki/N-Triples
OGD	Open Government Data	https://www.bfs.admin.ch/bfs/en/home/services/ogd.html
PRIF, GRUD	Principles of fertilisation of agricultural crops in Switzerland, Grundlagen für die Düngung landwirtschaftlicher Kulturen in der Schweiz	www.grud.ch, www.prif.ch
RDF	Resource Description Framework, W3C standard designed as a data model for metadata	https://en.wikipedia.org/wiki/Resource_Description_Framework
SFA, BAR	Swiss Federal Archives, Schweizerisches Bundesarchiv	https://www.bar.admin.ch/bar/en/home.html
Shared dimension	concept (not only a dimension) that is reused throughout different datasets	https://github.com/zazuko/cube-creator/wiki/Glossary
SLA	Service-level agreement	https://en.wikipedia.org/wiki/Service-level_agreement
SPARQL	SPARQL Protocol and RDF Query Language	https://en.wikipedia.org/wiki/SPARQL
SPARQL endpoint	SPARQL interface of LINDAS allowing to write SPARQL queries directly in the web browser in a slightly assisted way	https://schema.ld.admin.ch/sparql/
Stardog	Company with specialization in graph data virtualization and high-performance graph database	https://www.stardog.com/platform/
Triplestore	purpose-built database for the storage and retrieval of triples through semantic queries	https://en.wikipedia.org/wiki/Triplestore
Turtle	Terse RDF Triple Language. Syntax and file format for expressing data in the RDF data model	https://en.wikipedia.org/wiki/Turtle_(syntax)
W3C	World Wide Web Consortium	https://en.wikipedia.org/wiki/World_Wide_Web_Consortium
WebGRUD	Project with the aim to provide the PRIF tables in machine-readable format	
XRM	Expressive RDF Mapper	https://github.com/zazuko/expressive-rdf-mapper
YASGUI	Technical product used for SPARQL endpoint	https://docs.triply.cc/yasgui-api/
Zazuko	Company with specialization in data-centric applications and knowledge graphs	https://zazuko.com/

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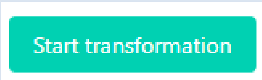
Appendix

Appendix I: Step-by-step guide to transform CSV to RDF using Cube Creator

Author: Juliane Hirte

Supplementary table 1: Overview of common icons in Cube Creator with respective explanations.

Icon	Name	Explanation
	Button	Execute a process
	Checkbox	Check an option
	Pencil	Edit an item
	Bin	Delete an item
	Chain link	Link to a shared dimension

Appendix Ia: Shared dimensions

(0) Creating a shared dimension

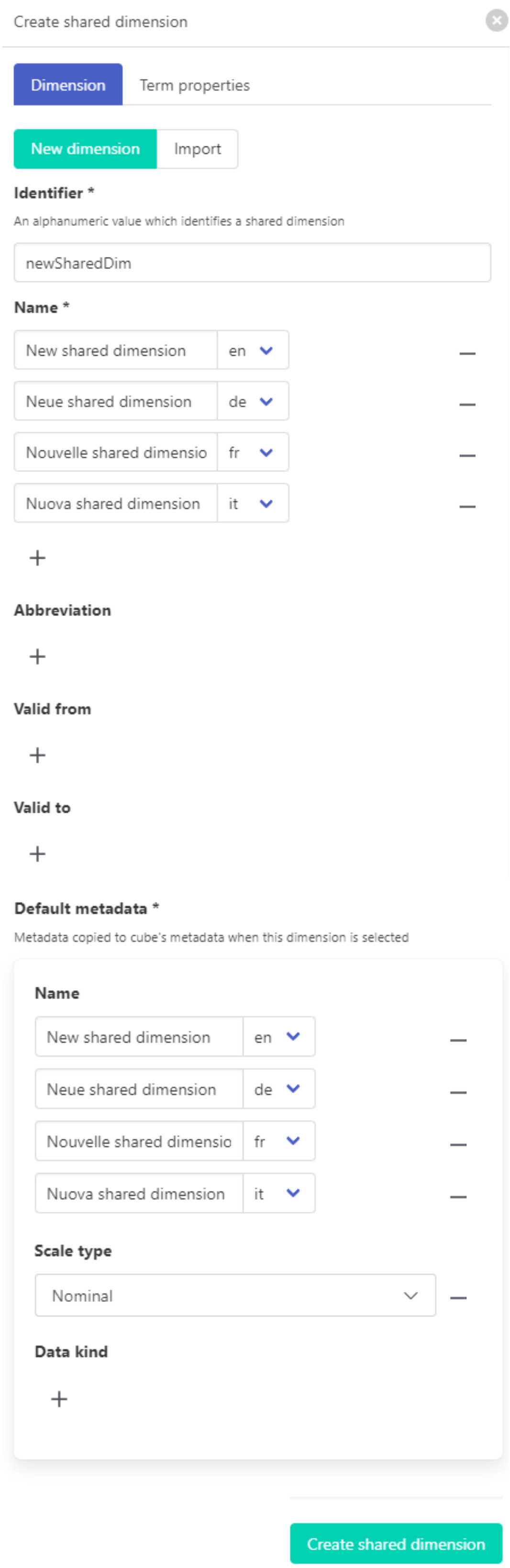
Tab: Shared dimensions
Press button + Create shared dimension.
This opens a mask for dimension specifications (Supplementary figure 1).

Tab: Dimension, New dimension

- Identifier * → define identifier
- Name * → define names in four languages
- Abbreviation → leave empty
- Valid from → leave empty
- Valid to → leave empty
- Default metadata *
  - Name → define names in four languages (same as above)
  - Scale type → select scale type
  - Data kind → leave empty

Press button Create shared dimension.

Tab: Term properties
Additional properties can be added to a shared dimension, e.g. EPPO codes, a crop group or product types. To use this feature, consult the [user documentation for Cube Creator].



Supplementary figure 1: Mask for dimension specifications.

(1) Adding terms

Add terms to the shared dimension
This needs to be done for each term individually.
Press button + Add term.
This opens a mask for adding a term (Supplementary figure 2).

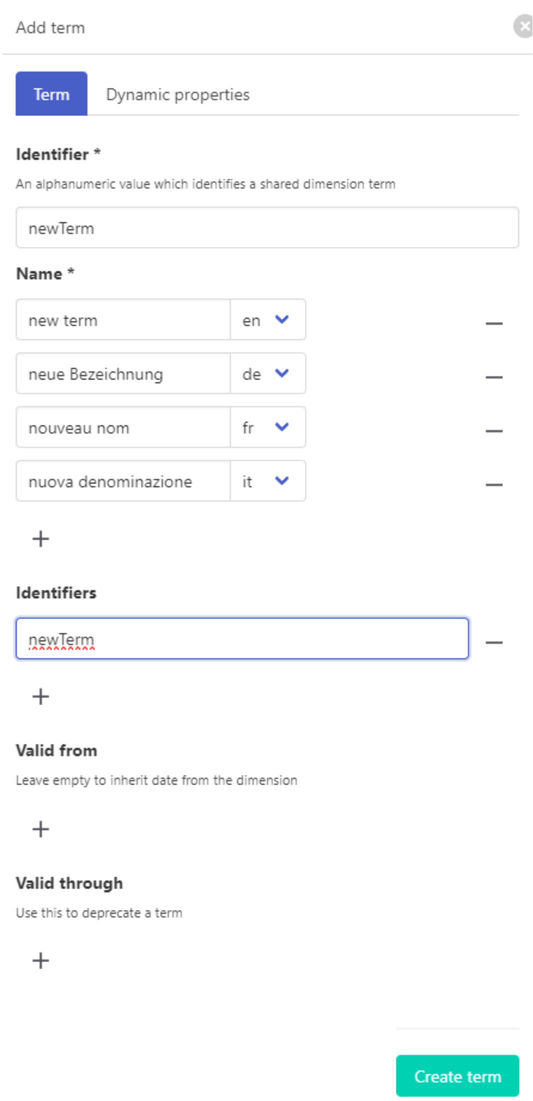
Tab: Term

- Identifier * → define identifier
- Name * → define names in four languages
- Identifiers → define identifier (same as above)
- Valid from → leave empty
- Valid through → leave empty

Press button Create term.

Terms cannot be deleted. If you want to deprecate a term, edit the term (pencil icon) and set a Valid through date.

Tab: Dynamic properties
Additional properties assigned to the shared dimension will appear here.



Supplementary figure 2: Mask for adding a term to a shared dimension.

Appendix Ib: Cube projects

(0) Creating a cube project

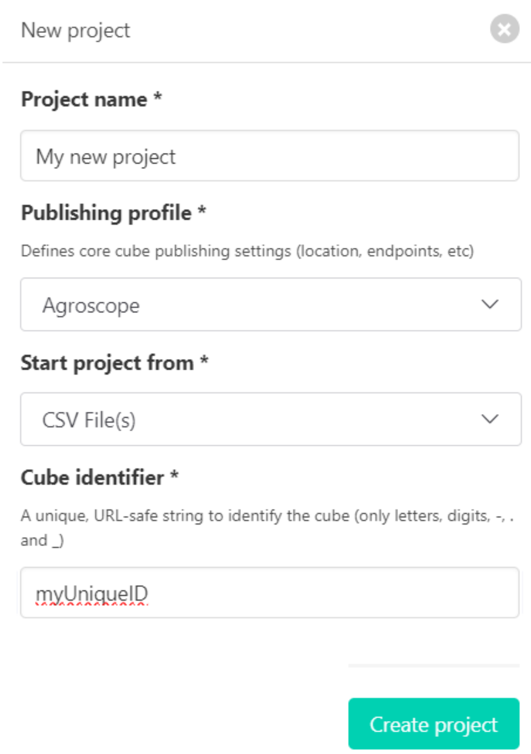
Tab: Cube Projects

Press button + New project.

This opens a mask for project specifications (Supplementary figure 3).

- Project name * → define name
- Publishing profile * → select Agroscope
- Start project from * → select CSV File(s)
- Cube identifier * → define identifier

Press button Create project.



Supplementary figure 3: Mask for project specifications.

(0) CSV mapping

Input CSVs

Press button + (Upload CSV file).

This opens a mask with drag-and-drop option for the selected CSV file (Supplementary figure 4).

The CSV needs to be UTF-8 encoded.

Press button Upload 1 file.

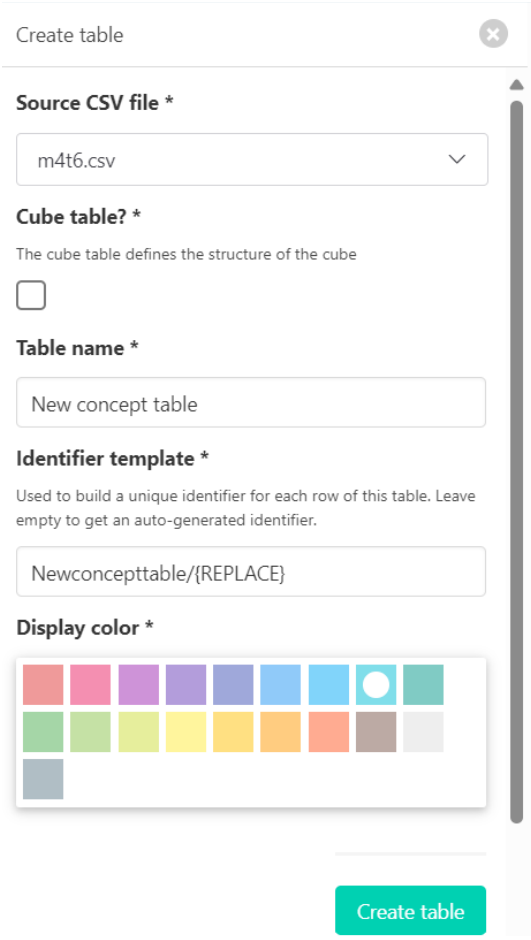
Supplementary figure 4: Mask for CSV file upload.

Does the CSV file contain variables that need to be mapped as a concept table? If yes, continue below. If no, continue at Create the cube table.

Create the concept table:
Check the checkboxes of the columns for the concept table (unique identifier and corresponding names in four languages).
Press button + Create table from selected columns.
This opens a mask for the table specifications (Supplementary figure 5).

- Source CSV file * → leave pre-filled
- Cube table? * → leave unchecked
- Table name * → define name
- Identifier template * → leave empty (will be created automatically)

Press button Create table.
The concept table is created and can be edited and deleted using the pencil and bin icons next to the table name.



Supplementary figure 5: Mask for editing the table specifications.

Specify the metadata of the columns of the concept table:
This needs to be done for each column individually.
Press the pencil icon (Edit column mapping) next to the column name.
This opens a mask for the column specifications (Supplementary figure 6).

Column with identifier:

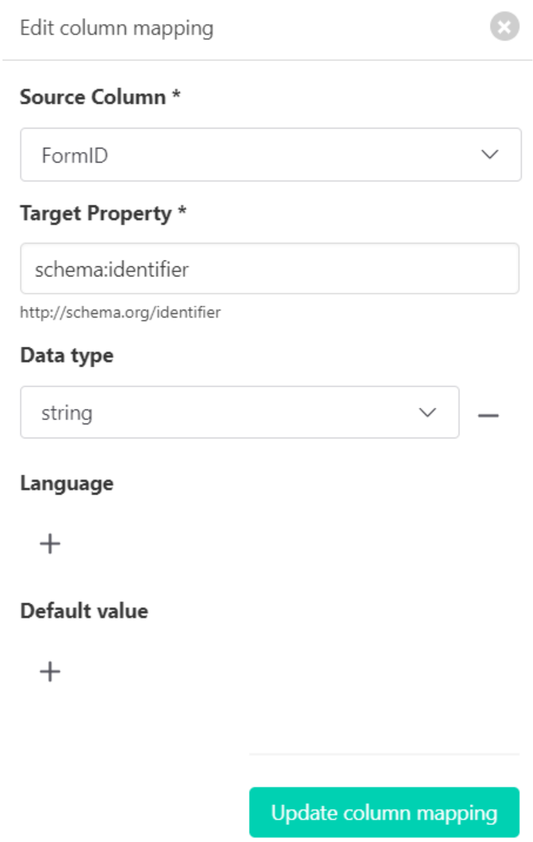
- Source Column * → leave current choice
- Target Property * → enter schema:identifier
- Data type → select string
- Language → leave empty
- Default value → leave empty

Press button Update column mapping.

Columns with names in different languages:

- Source Column * → leave current choice
- Target Property * → enter schema:name
- Data type → select string
- Language → choose respective language
- Default value → leave empty

Press button Update column mapping.

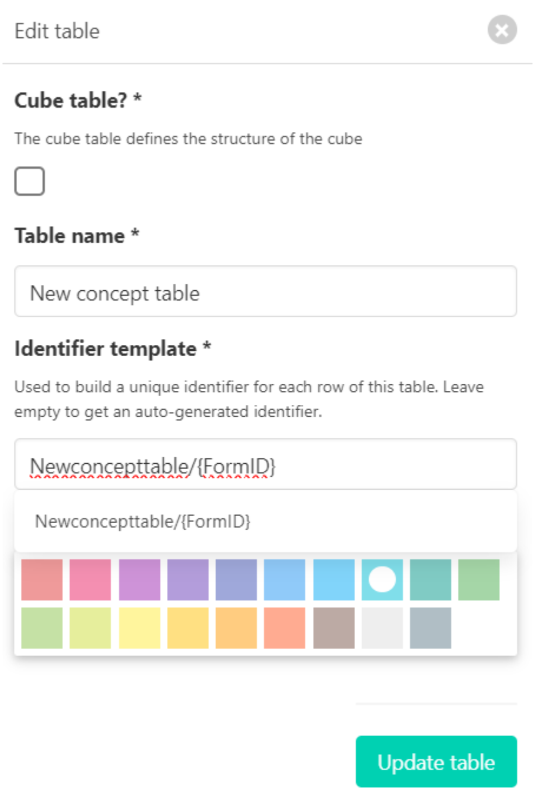


Supplementary figure 6: Mask for editing the column mapping.

Edit the concept table to update the correct identifier:
Press the pencil icon (Edit table) next to the table name.
This opens again the mask for the table specifications (Supplementary figure 7).

- Identifier template * → enter correct identifier

Press button Update table.



Supplementary figure 7: Mask for editing the table specifications (Update of the Identifier template).

Create the cube table:
Check the checkboxes of the remaining columns for the cube table.
Press button + Create table from selected columns.
This opens a mask for the table specifications (same as Supplementary figure 5).

- Source CSV file * → leave pre-filled
- Cube table? * → check
- Table name * → define name
- Identifier template * → leave empty (will be created automatically)

Press button Create table.
The cube table is created and can be edited and deleted using the pencil and bin icons next to the table name.

Specify the metadata of the columns of the cube table:
#This needs to be done for each column individually.
Press the pencil icon (Edit column mapping) next to the column name.
This opens a mask for the column specifications (same as Supplementary figure 6).

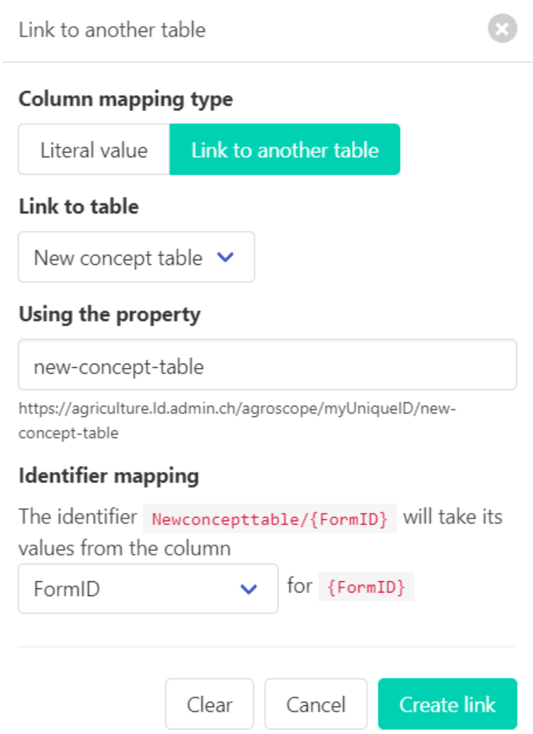
- Source Column * → leave current choice
- Target Property * → use name (pre-filled)
- Data type → select respective data type
- Language → leave empty
- Default value → leave empty

Press button Update column mapping.

Link the concept table to the cube table:
Press button + (Map column) below the column names of the cube table.
This opens a mask for the column mapping type (Supplementary figure 8).
Choose tab Link to another table.

- Link to table → select respective name of concept table
- Using the property → leave pre-filled
- Identifier mapping → select identifier

Press button Create link.
The link is created and appears as additional column in the cube table.



Supplementary figure 8: Mask for column mapping.

Edit the cube table to update the correct identifier:
Press the pencil icon (Edit table) next to the table name.
This opens again the mask for the table specifications (Supplementary figure 7).

- Identifier template * → enter correct identifier (including identifier of linked concept table), e.g. {OrganicFertilizer}/{Nutrient}/{FormID}

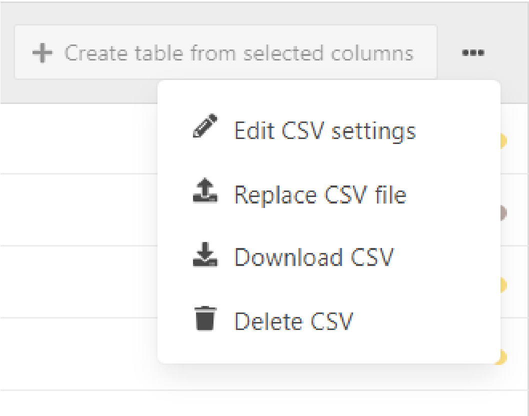
Press button Update table.

Change the CSV file:

The uploaded CSV file can be replaced, downloaded or deleted using.

Press the … icon next to + Create table from selected columns.

This opens a mask for changing to the CSV file (Supplementary figure 9).



Supplementary figure 9: Mask for changes to the CSV file.

(2) Transformation

Press button Start transformation.

Depending on the size of the table, this step might take a couple of minutes.

(3) Cube designer

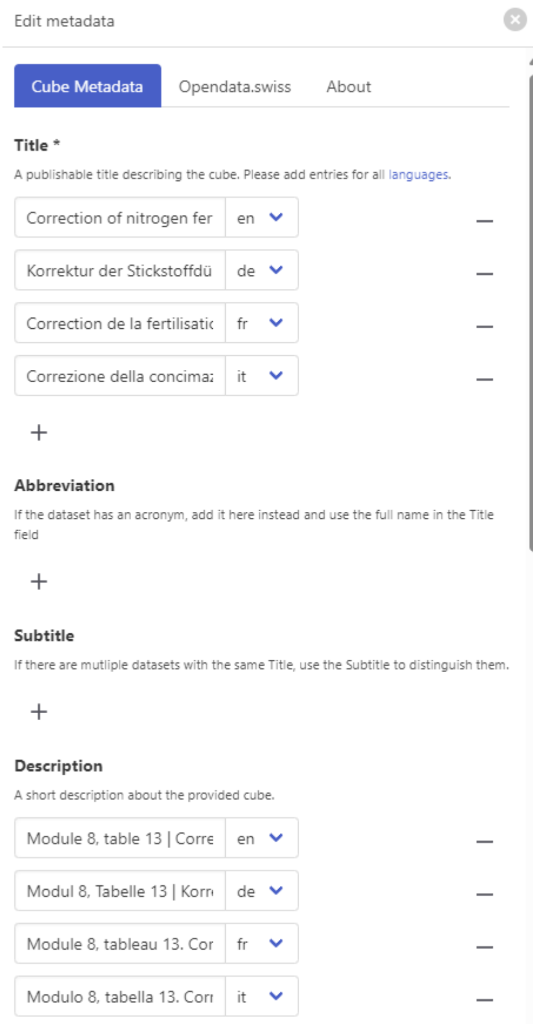
Edit the cube metadata:

Press the pencil icon next to the cube name.

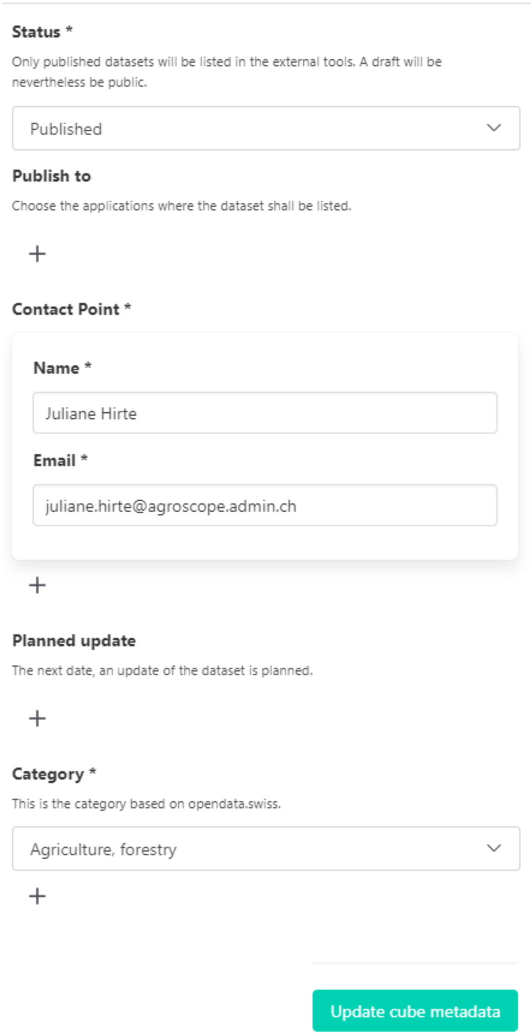
This opens a mask for editing the cube metadata (Supplementary figure 10).

- Title * → enter table title (as in PRIF) in four languages and specify language
- Abbreviation → leave empty
- Subtitle → if required, enter subtitles in four languages and specify language
- Description → if required, enter description in four languages and specify language (e.g. to describe the correct usage of the table)
- Status * → leave as Draft and change to Published once everything is finished, before the publication step
- Publish to → leave empty
- Contact point * → enter Name and E-Mail
- Planned update → leave empty
- Category * → select Agriculture, forestry

Press button Update cube metadata.



Supplementary figure 10: Mask for editing the cube metadata.



Supplementary figure 10 (continued): Mask for editing the cube metadata.

Edit the dimension metadata:

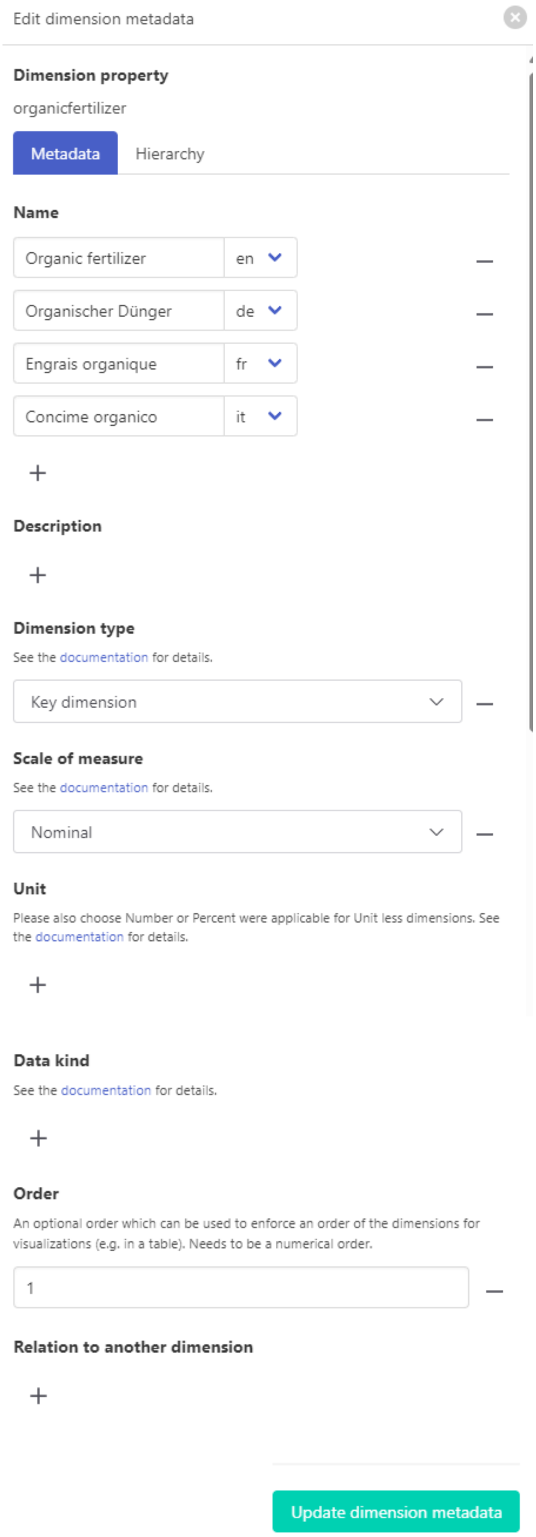
Press the pencil icon next to the dimension name.

This opens a mask for editing the dimension metadata (Supplementary figure 11).

- Name → enter variable name (as in PRIF) in four languages and specify language; if column is linked to a shared dimension, take care of consistency in naming
- Description → if required, enter description in four languages and specify language (e.g. to specify the correct usage of the table)
- Dimension type → key dimension for x, measure dimension for y
- Scale of measure → nominal, interval (when numbers do not refer to a scale that has a proportional meaning, e.g. degrees C), ratio (when numbers refer to a scale that has a proportional meaning, e.g. % or kg per ha), ordinal (when levels refer to an intensity, e.g. low-high)
- Unit → select from drop-down (don't copy-paste or use pre-filled -> will not be saved)
- Data kind → leave empty
- Order → enter 1...n for the position of the column in the table
- Relation to another dimension → leave empty

Press button Update dimension metadata.

As soon as the dimension metadata has been edited, a chain link icon appears next to the pencil icon and dimension name.

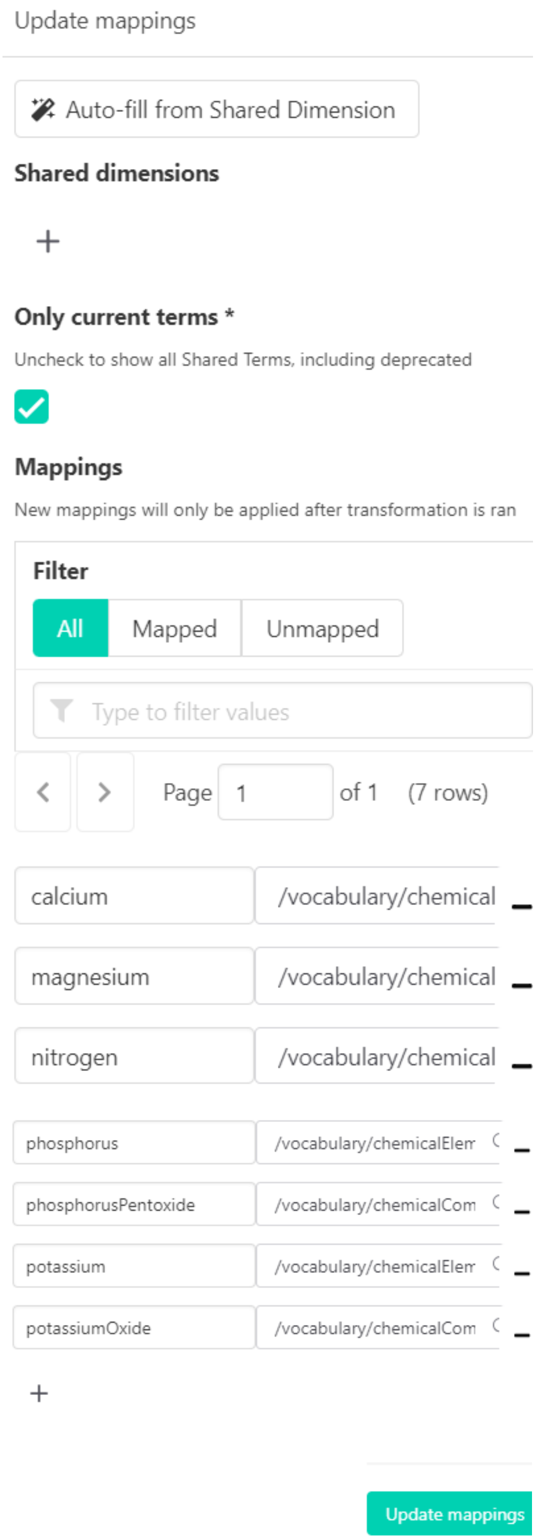


Supplementary figure 11: Mask for editing the dimension metadata.

Link a cube dimension to a shared dimension:
This needs to be done for all respective dimensions individually.
Press the chain link icon (Link to shared dimension) next to the dimension name.
This opens a mask for editing the dimension metadata (Supplementary figure 12).
Press button Auto-fill from shared dimension.

- Shared dimension * → select shared dimension name from drop-down
- Identifier property * → enter schema:identifier (for most shared dimensions) or schema:name (for e.g. chemical elements)
  # Some dimensions need to be linked manually (e.g. chemical compounds)
- Only current terms * → check relevant answer

Press button Map terms from shared dimension.
Check Mapped and Unmapped under Filter if the mapping has been successful.
Repeat Auto-fill from shared dimension when the column needs to be linked to more than one shared dimension (e.g. chemical elements and chemical compounds).
Press button Update mappings.



Supplementary figure 12: Mask for updating mappings.

Update all links between tables and dimensions:
Repeat the **(2) Transformation** step after linking all shared dimensions.

(4) Publication

Make sure that the Status of the cube metadata is
set to Published (Supplementary figure 10).
Press button Start publication.
The cube and its links to shared dimensions are now
published on LINDAS.

Appendix Ic: Cube descriptions (metadata)

Module 2, table 9

Module 2, table 9 | Correction of analytical values for soils with a humus content of more than 10 %. The correction is to be done before determining the correction factors for fertilization (Table 10 to Table 18).

Modul 2, Tabelle 9 | Korrektur der Analysenwerte für Böden mit einem Humusgehalt von mehr als 10 %. Die Korrektur ist vor der Bestimmung der Korrekturfaktoren für die Düngung (Tabelle 10 bis Tabelle 18) vorzunehmen.

Module 2, tableau 9. Correction des valeurs analysées pour les sols contenant plus de 10% d'humus. Cette correction est à faire avant la correction de la fertilisation (tableaux 10 à 18).

Modulo 2, tabella 9. Correzione da applicare al risultato dell'analisi di suoli con tenori in humus superiori al 10 %. Questa correzione si applica al risultato dell'analisi del suolo prima di utilizzarlo per determinare il fattore di correzione che verrà, infine, moltiplicato con la norma di concimazione della coltura (tabelle 10–18).

Module 2, tables 10 to 18

Module 2, tables 10 to 18 | Correction factors for P, K and Mg fertilization depending on the P, K and Mg contents (CO2, CaCl2, H2O10 and AAE10 methods) and the clay content of the soil. For humus contents ≥ 10 %, a humus correction must be done according to Table 9. For extensive meadows, a correction factor of 1.0 or less is to be applied. Tables 11 and 17 (correction factors for K fertilization, CO2 and AAE10 methods): For intensive and medium-intensive pastures, correction factors greater than 1.2 are strongly discouraged without analysis of forage K contents. For forage K contents above 25 g K/kg dry matter, a maximum correction factor of 1.0 is to be applied. Table 13 (correction factors for P fertilization, H2O10 method): Applies to soils with pH ≥ 5.0 and ≤ 7.8. Tables 16 and 18 (correction factors for P and Mg fertilization, AAE10 method): For calcareous soils (lime pre-test positive or pH ≥ 6.8 or AAE10-Ca ≥ 4000 mg Ca/kg soil), the correction factors for P and Mg fertilization are not valid.

Modul 2, Tabellen 10 bis 18 | Korrekturfaktoren der P-, K- und Mg-Düngung in Abhängigkeit der P-, K- und Mg-Gehalte (CO2-, CaCl2-, H2O10- und AAE10-Methode) und des Tongehaltes des Bodens. Bei Humusgehalten ≥ 10 % ist eine Humuskorrektur gemäss Tabelle 9 vorzunehmen. Bei wenig intensiv genutzten Wiesen ist ein Korrekturfaktor von höchstens 1.0 zu verwenden. Tabellen 11 und 17 (Korrekturfaktoren der K-Düngung, CO2- und AAE10-Methode): Für intensive und mittelintensive Wiesen wird von Korrekturfaktoren von mehr als 1.2 ohne Analyse der K-Gehalte im Futter dringend abgeraten. Bei K-Gehalten des Futters über 25 g K/kg Trockensubstanz ist ein maximaler Korrekturfaktor von 1.0 zu verwenden. Tabelle 13 (Korrekturfaktoren der P-Düngung, H2O10-Methode): Gilt für Böden mit einem pH-Wert von ≥ 5.0 und ≤ 7.8. Tabellen 16 und 18 (Korrekturfaktoren der P- und Mg-Düngung, AAE10-Methode): Für kalkhaltige Böden (Kalkvorprobe positiv oder pH ≥ 6.8 oder AAE10-Ca ≥ 4000 mg Ca/kg Boden) sind die Korrekturfaktoren für die Bemessung der P- und Mg-Düngung nicht gültig.

Module 2, tableaux 10 à 18. Facteurs de correction de la fertilisation P, K et Mg selon des teneurs en P, K et Mg (méthodes CO2, CaCl2, H2O10 et AAE10) et en argile du sol. Pour les teneurs en humus ≥ 10 %, il faut procéder à la correction selon le tableau 9. Pour les prairies peu intensives, le facteur de correction ne doit pas dépasser 1,0. Tableaux 11 et 17 (Facteurs de correction de la fertilisation K, méthode CO2 et AAE10): Pour les prairies intensives et mi-intensives, il est déconseillé d'utiliser un facteur de correction > 1,2 sans analyse préalable du K dans les fourrages. Si la teneur est supérieure à 25 g K/kg de MS, le facteur de correction ne doit pas être > 1,0. Tableau 13 (Facteurs de correction de la fertilisation P, méthode H2O10): Valable pour les sols au pH situé entre 5,0% et 7,8%. Tableaux 16 et 18 (Facteurs de correction de la fertilisation P et Mg, méthode AAE10): Pour les sols carbonatés (test CaCO3 positif, ou le pH ≥ 6,8 ou le Ca-AAE10 ≥ 4000 mg Ca/kg) ces corrections ne sont pas valables pour la fertilisation P et Mg.

Modulo 2, tabelle 10 a 18. Fattori di correzione della concimazione P, K e Mg in funzione del tenore in P, K e Mg (metodo CO2, CaCl2, H2O10 e AAE10) e in argilla della terra fine. Per i suoli con un tenore in humus ≥ 10 %, bisogna correggere il risultato dell'analisi secondo la tabella 9. Per le superfici prative «poco intensive», non si devono applicare fattori di correzione > 1,0. Tabelle 11 et 17 (Fattori di correzione della concimazione K, metodo CO2 e AAE10): Per le superfici prative «intensive» e «mediamente intensive», si raccomanda di non applicare un fattore di correzione > 1,2 senza prima analizzare il tenore in K nel foraggio. Se nel foraggio si rilevano più di 25 g K/kg di SS, non si devono applicare fattori di correzione > 1,0. Tabella 13 (Fattori di correzione della concimazione P, metodo H2O10): Questo metodo dà risultati validi solo in suoli con pH ≥ 5,0 e ≤ 7,8. Tabelle 16 e 18 (Fattori di correzione della concimazione P e Mg, metodo AAE10): Per suoli calcarei (test CaCO3 positivo o pH ≥6,8 o Ca-AAE10 ≥4'000 mg Ca/kg di terra fine) i fattori di correzione di questa tabella non sono validi per determinare il tenore in P e Mg.

Module 2, tables 10a and 10b

Module 2, table 10a | Correction factors for P fertilization depending on the P contents (CO2 method) and clay content of the soil for silty soils from Bündner-Schiefer weathering with a clay content of the fine soil < 25 % and a silt content of the fine soil > 40 %. For humus contents ≥ 10 %, a humus correction must be done according to Table 9. For extensive meadows, a correction factor of 1.0 or less is to be applied.

Module 2, table 10b | Correction factors for P fertilization as a depending on the P contents (CO2 method) and clay content of the soil for sandy, acidic soils in the canton of Ticino with a clay content of the fine soil < 10 %, a sand content of the fine soil > 40 % and a pH value < 5.9. For humus contents ≥ 10 %, a humus correction must be done according to Table 9. For extensive meadows, a correction factor of 1.0 or less is to be applied.

Modul 2, Tabelle 10a | Korrekturfaktoren der P-Düngung in Abhängigkeit der P-Gehalte (CO2-Methode) und des Tongehaltes des Bodens für schluffige Böden aus Bündner-Schiefer-Verwitterung mit einem Tongehalt der Feinerde < 25 % und einem Schluffgehalt der Feinerde > 40 %. Bei Humusgehalten ≥ 10 % ist eine Humuskorrektur gemäss Tabelle 9 vorzunehmen. Bei wenig intensiv genutzten Wiesen ist ein Korrekturfaktor von höchstens 1.0 zu verwenden.

Modul 2, Tabelle 10b | Korrekturfaktoren der P-Düngung in Abhängigkeit der P-Gehalte (CO2-Methode) und des Tongehaltes des Bodens für sandige, saure Böden im Kanton Tessin mit einem Tongehalt der Feinerde < 10 %, einem Sandgehalt der Feinerde > 40 % und einem pH-Wert < 5,9. Bei Humusgehalten ≥ 10 % ist eine Humuskorrektur gemäss Tabelle 9 vorzunehmen. Bei wenig intensiv genutzten Wiesen ist ein Korrekturfaktor von höchstens 1.0 zu verwenden.

Module 2, tableau 10a. Facteurs de correction de la fertilisation P selon des teneurs en P (méthode CO2) et en argile du sol pour les sols silteux issus de l'altération des schistes des Grisons ayant une teneur en argile 40 %. Pour les teneurs en humus ≥ 10 %, il faut procéder à la correction selon le tableau 9. Pour les prairies peu intensives, le facteur de correction ne doit pas dépasser 1,0.

Module 2, tableau 10b. Facteurs de correction de la fertilisation P selon des teneurs en P (méthode CO2) et en argile du sol pour les sols sableux et acides du Tessin ayant une teneur en argile 40 % et un pH <5,9. Pour les teneurs en humus ≥ 10 %, il faut procéder à la correction selon le tableau 9. Pour les prairies peu intensives, le facteur de correction ne doit pas dépasser 1,0.

Modulo 2, tabella 10a. Fattori di correzione della concimazione P in funzione del tenore in P (metodo CO2) e in argilla della terra fine per suoli siltosi derivati dalla disgregazione dei calcescisti grigionesi con un tenore in argilla < 25% e in silt > 40% espressi sulla terra fine. Per i suoli con un tenore in humus ≥ 10 %, bisogna correggere il risultato dell'analisi secondo la tabella 9. Per le superfici prative «poco intensive», non si devono applicare fattori di correzione > 1,0.

Modulo 2, tabella 10b. Fattori di correzione della concimazione P in funzione del tenore in P (metodo CO2) e in argilla della terra fine per sabbiosi e acidi del Cantone Ticino con un tenore in argilla < 10% e in sabbia > 40% espressi sulla terra fine, nonché un pH < 5,9. Per i suoli con un tenore in humus ≥ 10 %, bisogna correggere il risultato dell'analisi secondo la tabella 9. Per le superfici prative «poco intensive», non si devono applicare fattori di correzione > 1,0.

Module 4, tables 6m and 6s

Module 4, table 6m | Standard values for the nutrient content of solid organic fertilizers (manure) of different types of livestock (stable housing). For information on N forms and losses, see section 2.3. Unless otherwise stated, the values refer to average manure decomposition (see Appendix 1). Poultry manure: Applies regardless of the fattening period for the most common systems.

Module 4, table 6s | Standard values for the nutrient content of liquid organic fertilizers (slurry) of different types of livestock (stable housing). For information on N forms and losses, see section 2.3. The slurry contents refer to undiluted slurry. The dilution resulting from the addition of waste water must be determined using Table 5. Example for dilution 1 : 1.5 (parts slurry : parts water): Content undiluted / (1+1.5). Pig slurry (mast): For more detailed information, see footnote 4 in Table 3. Pig slurry (breeding): For more detailed information, see footnote 5 in Table 3.

Modul 4, Tabelle 6m| Richtwerte der Gehalte an Nährstoffen von festen Hofdüngern (Mist) verschiedener Nutztierarten bei Stallhaltung. Für Angaben zu N-Formen und -Verlusten vgl. Kapitel 2.3. Wo nicht anders angegeben beziehen sich die Werte auf eine mittlere Mistverrottung (vgl. Anhang 1). Pouletmist: Gilt unabhängig von der Mastdauer für die gebräuchlichsten Systeme.

Modul 4, Tabelle 6s| Richtwerte der Gehalte an Nährstoffen von flüssigen Hofdüngern (Gülle) verschiedener Nutztierarten bei Stallhaltung. Für Angaben zu N-Formen und -Verlusten vgl. Kapitel 2.3. Die Güllegehalte beziehen sich auf unverdünnte Gülle. Die durch die Zufuhr von Abwasser entstehende Verdünnung muss anhand von Tabelle 5 bestimmt werden. Beispiel bei Verdünnung 1 : 1,5 (Teile Gülle : Teile Wasser): Gehalt unverdünnt / (1+1,5). Schweinegülle Mast: Für detailliertere Angaben vgl. Fussnote 4 in Tabelle 3. Schweinegülle Zucht: Für detailliertere Angaben vgl. Fussnote 5 in Tabelle 3.

Module 4, tableau 6m. Teneurs indicatives en éléments nutritifs des engrais de ferme solides (fumier) pour différentes espèces d'animaux de rente en stabulation. Pour les données sur les formes et les pertes de N, voir chapitre 2.3. Sauf indication contraire, les valeurs se rapportent à du fumier moyennement décomposé (annexe 1). Fumier de poulet: Valable indépendamment de la durée d'engraissement dans les systèmes les plus courants.

Module 4, tableau 6s. Teneurs indicatives en éléments nutritifs des engrais de ferme liquides (lisier) pour différentes espèces d'animaux de rente en stabulation. Pour les données sur les formes et les pertes de N, voir chapitre 2.3. Les teneurs du lisier/purin se rapportent à du lisier/purin non dilué. Les dilutions provenant de l'apport d'eaux usées doivent être prises en compte selon le tableau 5. Exemple avec une dilution 1:1,5 (part de lisier/purin:part d'eau): teneur du lisier/purin non dilué / (1 + 1,5). Lisier de porc, engrais: Des détails à propos de la note 4 se trouvent dans le tableau 3. Lisier de porc d'élevage Des détails à propos de la note 5 se trouvent dans le tableau 3.

Modulo 4, tabella 6m. Tenori di riferimento in elementi nutritivi dei concimi solidi aziendali (letame) prodotti da diverse specie di animali da reddito stabulate. Il capitolo 2.3 riporta informazioni dettagliate sulle forme e sulle perdite di N dei concimi aziendali. Se non specificato altrimenti, i valori si riferiscono a letame mediamente maturo (allegato 1). Pollina di pollo da ingrasso: Dati validi indipendentemente dalla durata del periodo d'ingrasso negli usuali sistemi di produzione.

Modulo 4, tabella 6s. Tenori di riferimento in elementi nutritivi dei concimi liquido aziendali (liquame) prodotti da diverse specie di animali da reddito stabulate. Il capitolo 2.3 riporta informazioni dettagliate sulle forme e sulle perdite di N dei concimi aziendali. I tenori in elementi nutritivi dei liquami si riferiscono a liquami non diluiti. Per calcolare i tenori effettivi dei liquami diluiti bisogna tenere conto della quantità d'acqua esausta aggiunta nella fossa, secondo quanto riportato nella tabella 5 (tenore dei liquami diluiti = tenore dei liquami non diluiti / (parti di liquami non diluiti + parti d'acqua). Per esempio, per una diluizione di 1:1,5 (1 parte di liquami:1,5 parti d'acqua) i tenori dei liquami non diluiti vanno divisi per 2,5. Liquame suino da ingrasso: La tabella 3 riporta informazioni dettagliate a proposito della nota 4. Liquame suino da rimonta: La tabella 3 riporta informazioni dettagliate a proposito della nota 5.

Module 8, tables 9a, 9b and 9c

Module 8, table 9a | Reference yield for arable crops with a common moisture content at harvest.

Module 8, table 9b | Nutrient removal of N, P, K and Mg for arable crops. Notes: Total nutrient removal was calculated as the sum of nutrient removal by crop products and residues.

Module 8, table 9c | Fertilization norms for N, P, K, and Mg for arable crops. Fertilization norms for P, K, and Mg take the nutrient appropriation capacity of the crops into account (Table 21). Notes: The basis for the calculation is the removal of P, K, and Mg by the crop and residues.

Modul 8, Tabelle 9a | Referenzertrag für die Ackerkulturen mit einem bei der Ernte üblichen Wassergehalt.

Modul 8, Tabelle 9b | Nährstoffentzug bezüglich N, P, K und Mg für die Ackerkulturen. Anmerkungen: Der gesamte Nährstoffentzug wurde als Summe der Nährstoffentzüge durch die Ernteprodukte und -rückstände berechnet.

Modul 8, Tabelle 9c | Düngungsnormen bezüglich N, P, K und Mg für die Ackerkulturen. Die Düngungsnormen für P, K und Mg berücksichtigen das Nährstoffaneignungsvermögen der Kulturen (Tabelle 21). Anmerkungen: Als Grundlage für die Berechnung dient der Entzug von P, K und Mg durch die Ernte und die Rückstände.

Module 8, tableau 9a. Rendements de référence avec une teneur en eau moyenne à la récolte.

Module 8, tableau 9b. Prélèvements en N, P, K, Mg pour les grandes cultures. Explications: Le prélèvement total est la somme des prélèvements des produits récoltés et des résidus de récolte.

Module 8, tableau 9c. Normes de fertilisation en N, P, K, Mg pour les grandes cultures. Les normes de fertilisation en P, K et Mg tiennent compte de la capacité d'absorption des cultures (tableau 21). Explications: Les données de bases servant au calcul sont le prélèvement par la récolte et les résidus en P, K et Mg.

Modulo 8, tabella 9a. Rese di riferimento per le diverse colture erbacee da pieno campo con un tenore in acqua medio alla raccolta.

Modulo 8, tabella 9b. Prelievi N, P, K e Mg per le diverse colture erbacee da pieno campo. Spiegazioni: Il prelievo totale equivale alla somma dei prelievi dei prodotti raccolti e dei residui colturali.

Modulo 8, tabella 9c. Norme di concimazione N, P, K e Mg per le diverse colture erbacee da pieno campo. (le norme di concimazione P, K e Mg tengono conto della capacità d'assorbimento delle colture [tabella 21]). Spiegazioni: i calcoli si basano sui prelievi di P, K e Mg dei prodotti raccolti (prodotti principali) e dei residui colturali (sottoprodotti).

Module 8, table 11

Module 8, table 11 | Correction of N fertilisation for a target yield that deviates from the average yield (reference yield). Example: For an expected yield of 75 dt/ha winter wheat (bread grain), i.e. 15 dt/ha additional yield compared to the reference yield, 15 kg/ha N it to be added to the fertilisation norm. The fertilisation norm is only corrected for winter cereals and winter rape based on the yield, for all other crops the correction value is 0.

Modul 8, Tabelle 11 | Korrektur der N-Düngung bei einem Zielertrag, der vom Durchschnittsertrag (Referenzertrag) abweicht. Beispiel: Für einen erwarteten Ertrag von 75 dt/ha Winterweizen (Brotgetreide), d. h. 15 dt/ha Mehrertrag im Vergleich zum Referenzertrag, müssen zusätzlich zur Düngungsnorm 15 kg/ha N addiert werden. Die Düngungsnorm wird nur für Wintergetreide und Winterraps in Abhängigkeit des Ertrags korrigiert, für alle weiteren Kulturen ist der Korrekturwert 0.

Module 8, tableau 11. Correction de la fertilisation N lorsque le rendement cible diffère du rendement moyen de référence. Exemple: pour un rendement attendu de 75 dt/ha de blé panifiable d'automne, soit 15 dt/ha supérieur au rendement moyen de référence, ajouter 15 kg/ha N à la norme de fertilisation). La norme de fertilisation est corrigée en fonction du rendement uniquement pour les céréales d'hiver et colza d'hiver, pour toutes les autres cultures, la valeur de correction est 0.

Modulo 8, tabella 11. Correzione della concimazione N qualora l'obiettivo di resa differisca dalla resa di riferimento. Esempio: per una resa attesa di 75 q/ha di frumento autunnale panificabile (di 15 q/ha superiore alla resa di riferimento), aggiungere 15 kg N alla norma di concimazione. La norma di concimazione si corregge secondo la resa solo per i cereali invernali e la colza invernale, per tutte le altre colture il valore di correzione è 0.

Module 8, table 12

Module 8, table 12 | Correction of N fertilisation depending on the mineralisation potential of the organic matter (OM). low to medium: 0 to +40 kg N/ha, medium: 0 kg N/ha, medium to high: 0 to -40 kg N/ha, high to very high: -40 to -80 kg N/ha, very high: -80 to -120 kg N/ha.

Module 8, Tabelle 12 | Korrektur der Stickstoffdüngung in Abhängigkeit des Mineralisierungspotenzials der organischen Substanz (OS). schwach bis mittel (low to medium): 0 to +40 kg N/ha, mittel (medium): 0 kg N/ha, mittel bis hoch (medium to high): 0 to -40 kg N/ha, hoch bis sehr hoch (high to very high): -40 to -80 kg N/ha, sehr hoch (very high): -80 to -120 kg N/ha.

Module 8, tableau 12. Correction de la fertilisation N en fonction du potentiel de minéralisation de la matière organique (MO). Faible à moyen (low to medium): 0 to +40 kg N/ha, Moyen (medium): 0 kg N/ha, Moyen à élevé (medium to high): 0 to -40 kg N/ha, Elevé à très élevé (high to very high): -40 to -80 kg N/ha, Très élevé (very high): -80 to -120 kg N/ha.

Modulo 8, tabella 12. Correzione della concimazione N in funzione del potenziale di mineralizzazione della sostanza organica (SO). Da scarso a medio (low to medium): 0 to +40 kg N/ha, Medio (medium): 0 kg N/ha, Da medio a elevato (medium to high): 0 to -40 kg N/ha, Da elevato a molto elevato (high to very high): -40 to -80 kg N/ha, Molto elevato (very high): -80 to -120 kg N/ha.

Module 8, table 13

Module 8, table 13 | Correction of nitrogen fertilization depending on pre-crop. Correction for grain legumes: mean value.

Modul 8, Tabelle 13 | Korrektur der Stickstoffdüngung in Abhängigkeit der Vorkultur. Korrektur für Körnerleguminosen: Mittelwerte.

Module 8, tableau 13. Correction de la fertilisation N en fonction du précédent cultural. Correction pour les légumineuses à graines : valeurs moyennes.

Modulo 8, tabella 13. Correzione della concimazione N in funzione del precedente colturale. Correzione per le leguminose da granella: valori medi.

Module 8, table 14

Module 8, table 14 | Correction of N fertilization norm due to the legacy effect of organic fertilizers in the second year after application. The N effect of farmyard manures in the year of application is included in Table 7 of Module 4/ Properties and Application of Fertilizers.

Modul 8, Tabelle 14 | Korrektur der N-Normdüngung infolge Nachwirkung organischer Dünger im zweiten Jahr nach der Anwendung. Die N-Wirkung der Hofdünger im Anwendungsjahr ist in Tabelle 7 von Modul 4/ Eigenschaften und Anwendung von Düngern enthalten.

Module 8, tableau 14. Correction de la fertilisation N en fonction des arrière-effets des apports d'engrais organiques au cours de la deuxième année suivant l'application. L'efficacité du N des engrais de ferme, l'année de leur application, est donnée dans le tableau 7 du module 4.

Modulo 8, tabella 14. Correzione della concimazione N in funzione dell'effetto residuo degli apporti di concimi organici nel secondo anno dall'applicazione. La tabella 7 del modulo 4 illustra l'efficacia dell'N contenuto nei concimi aziendali già durante l'anno di distribuzione.

Module 8, table 15

Module 8, table 15 | Correction of fertilisation norm for nitrogen depending on winter and spring precipitation. Rainfall period and intensity: winter dormancy (winter: November-January), vegetation start/seeding (spring: March-May), low (< 60 mm/month), high (> 90 mm/month).

Modul 8, Tabelle 15 | Korrektur der Stickstoff-Normdüngung in Abhängigkeit der Winter- und Frühjahrsniederschläge. Niederschlagsperiode und -intensität: Winterruhe (winter: November–Januar), Vegetationsbeginn/Saat (spring: März–Mai), gering (low: < 60 mm/Monat), hoch (high: > 90 mm/Monat).

Module 8, tableau 15. Correction de la fertilisation N en fonction des pluies d'hiver et de printemps. Période de précipitations et intensité: Repos hivernal (winter: novembre–janvier), Reprise de la végétation et semis (spring: mars–mai), faible (low: < 60 mm/mois), forte (high: > 90 mm/mois).

Modulo 8, tabella 15. Correzione della concimazione N in funzione delle precipitazioni invernali e primaverili. Periodo e intensità delle precipitazioni. Riposo vegetativo (winter: novembre–gennaio), Risveglio vegetativo e semina (spring: marzo–maggio), deboli (low: < 60 mm/mese), forti (high: > 90 mm/mese).

Module 8, table 21

Module 8, table 21 | Correction factors of standard fertilization for P, K, Mg by crop.

Modul 8, Tabelle 21 | Korrekturfaktoren der Normdüngung für P, K, Mg nach Kultur.

Module 8, tableau 21. Coefficients de correction de la norme P, K, Mg selon la culture.

Modulo 8, tabella 21. Fattori di correzione della norma di concimazione P, K e Mg a seconda della coltura.

Appendix II: Code for the .n3 file needed to visualize the calculation response

Author: Giacomo Citi

Copy-paste the code below (between ### Start ### and ### Finish ###) into a Text Editor file and save it as an n3 file (select file type "All files" and replace .txt with .n3).

```
### Start ###

# custom rules to visualize calculation results with https://giacomociti.github.io/rdf2dot/

@prefix xsd: <http://www.w3.org/2001/XMLSchema#> .
@prefix rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#> .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
# eye built-ins
@prefix log: <http://www.w3.org/2000/10/swap/log#> .
@prefix list: <http://www.w3.org/2000/10/swap/list#> .
@prefix math: <http://www.w3.org/2000/10/swap/math#> .
@prefix string: <http://www.w3.org/2000/10/swap/string#> .
# vocabulary of calculation results
@prefix : <https://agriculture.ld.admin.ch/prif/> .
@prefix calc: <https://agriculture.ld.admin.ch/prif/calc#> .
@prefix qudt: <http://qudt.org/schema/qudt/> .
@prefix dcterms: <http://purl.org/dc/terms/> .
# visualization vocabulary
@prefix v: <http://view/> .
@prefix attr: <http://view/dot/attribute/> .
# local auxiliary terms
@prefix aux: <http://aux/org/> .

@prefix cube: <https://cube.link/> .
@prefix schema: <http://schema.org/> .


# specific configuration

calc:factor aux:mapLink "factor"  .
calc:summand aux:mapLink "+"  .
calc:minuend aux:mapLink "+" .
calc:subtrahend aux:mapLink "-"  .
calc:source aux:mapLink "source"  .

rdf:value aux:mapField "value" .
qudt:unit aux:mapField "unit" .
:nutrient aux:mapField "nutrient" .

cube:Observation a aux:Entity .

# uncomment to see also input
# :Request a aux:Entity .
# :fertilization aux:mapLink "fertilization" .
```

```
{ ?s calc:note [ aux:escape ?tooltip ] } => { ?s attr:tooltip ?tooltip } .

{
   [] a [ a aux:Entity ] ; ?p [] .

   ?p log:notEqualTo aux:field , attr:shape , attr:label , attr:tooltip, attr:color , rdf:type , cube:observedBy , :fertilization
.
   ?p log:localName ?fieldName .
}
=>
{
   ?p aux:mapField ?fieldName .
}
.



{
   ?s ?p [ qudt:unit ?unit ; rdf:value ?value ] .
   ?p aux:mapField ?fieldName .
   ?unit log:localName ?unitName .
   ("%s (%s)" ?value ?unitName) string:format ?fieldValue .
    ('<TR><TD   ALIGN="LEFT"><I>%s</I></TD><TD   ALIGN="LEFT">%s</TD></TR>'   ?fieldName   ?fieldValue)
string:format ?field
}
=>
{
  ?s aux:field ?field
}.



{
   ?s calc:label ?label .
   ('<TR><TD ALIGN="CENTER" COLSPAN="2"><B>%s</B></TD></TR>' ?label) string:format ?field .
}
=>
{
   ?s aux:field ?field
} .

{
   v:digraph v:hasNode ?s .
   ?s calc:error ?error .
}
=>
{
   ?s attr:label "error" .
   ?s attr:color "red" .
   ?s attr:tooltip ?error .
} .

xsd:string aux:align "LEFT" .
xsd:double aux:align "RIGHT" .
```

```
xsd:integer aux:align "RIGHT" .
xsd:decimal aux:align "RIGHT" .

{
   v:digraph v:hasNode ?s .
   ?p aux:mapField ?fieldName .
   ?s ?p ?o .
   (?fieldValue ?dataType) log:dtlit ?o . # when is literal
   ?dataType aux:align ?align .
   ?fieldValue aux:escape ?escapedValue .
   ('<TR><TD ALIGN="LEFT"><I>%s</I></TD><TD ALIGN="%s">%s</TD></TR>' ?fieldName ?align
?escapedValue) string:format ?field
}
=>
{
   ?s aux:field ?field .
} .

{
   v:digraph v:hasNode ?s .
   ?p aux:mapField ?fieldName .
   ?s ?p ?o .
   ?o log:rawType log:Other .
   ?o log:localName ?fieldValue . # when is not literal
   ?fieldValue aux:escape ?escapedValue .
   ('<TR><TD ALIGN="LEFT"><I>%s</I></TD><TD ALIGN="LEFT">%s</TD></TR>' ?fieldName ?escapedValue)
string:format ?field
}
=>
{
   ?s aux:field ?field .
} .


# if a node has fields, its label is a table with the fields as rows
{
   v:digraph v:hasNode ?s .
   ( ?f { ?s aux:field ?f } ?fs ) log:collectAllIn [] .
   ?fs log:notEqualTo () .
   ?fs list:sort ?sorted .
   (?sorted "\n") string:join ?joined .
   ( '< <TABLE BORDER="0" CELLBORDER="1" CELLSPACING="0">\n%s\n</TABLE> >' ?joined) string:format
?label
}
=>
{
   ?s attr:shape "plaintext" ; attr:label ?label
}
.

{
   ?s ?p ?o .
```

```
    ?p aux:mapLink ?label .
    ?p log:uri ?tooltip .
    ?o log:uri ?u . # ensure is not literal
}
=>
{
    v:digraph v:hasNode ?s , ?o .
    v:digraph v:hasEdge [
        v:source ?s ;
        v:target ?o ;
        attr:label ?label ;
        attr:tooltip ?tooltip
    ]
} .

{
    [] calc:source ?obs .
    ?cube cube:observationSet [ cube:observation ?obs ] .
    ?cube schema:name ?cubeName .
    (?tooltip 'en') log:langlit ?cubeName .
}
=>
{
    ?obs attr:tooltip ?tooltip .
}
.


{ ?text aux:escape ?escaped } <= {
     (?text
        ("&" "<" ">" '"')
        ("&amp;" "&lt;" "&gt;" "&quot;")
    ) string:replaceAll ?escaped .
} .


### Finish ###
```

Appendix III: How to explore a table using the example of PRIFm2t10

Author: Giacomo Citi

The JSON-LD payload retuned by the metadata API includes (among many other things):

a cube:


```
{
	"@id": "https://agriculture.ld.admin.ch/agroscope/PRIFm2t10a/3",
	"@type": "https://cube.link/Cube"
},
```


constrained by a shape:


```
{
	"@id": "https://agriculture.ld.admin.ch/agroscope/PRIFm2t10a/3",
	"https://cube.link/observationConstraint": {
	"@id": "https://agriculture.ld.admin.ch/agroscope/PRIFm2t10a/3/shape/"
	}
},
```

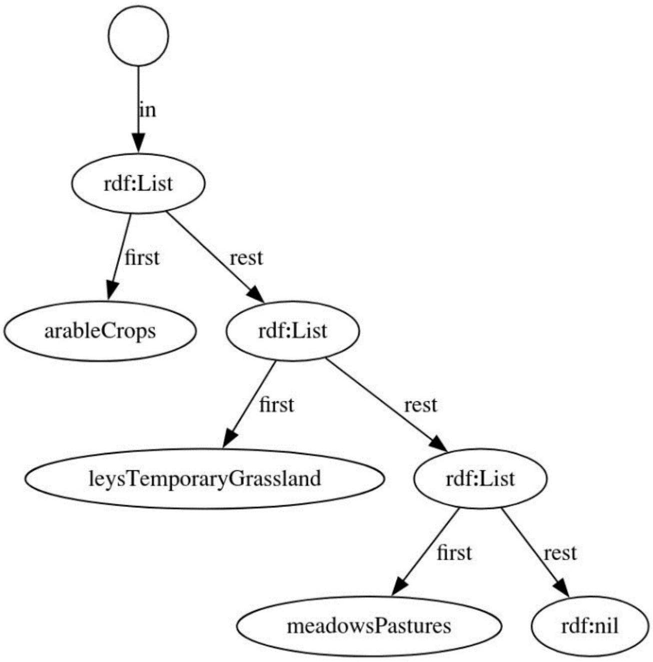

having a few properties:


```
{
	"@id": "https://agriculture.ld.admin.ch/agroscope/PRIFm2t10a/3/shape/",
	"http://www.w3.org/ns/shacl#property": {
	"@id":
"_:b260627_genid2d8f024f370de94eb18726dae5668253392dABBD679220969EFA5FEE45AAEACE7BD2"
	}
},
{
	"@id": "https://agriculture.ld.admin.ch/agroscope/PRIFm2t10a/3/shape/",
	"http://www.w3.org/ns/shacl#property": {
	"@id":
"_:b260627_genid2d8f024f370de94eb18726dae5668253392dD7CF66146F4E6E01C3BE865BAC2D5E53"
	}
},
```

like, for example, the crop group property which is a key dimension:


```
{
        "@id":
"_:b260627_genid2d8f024f370de94eb18726dae5668253392dABBD679220969EFA5FEE45AAEACE7BD2",
        "@type": "https://cube.link/KeyDimension"
        },
{
        "@id":
"_:b260627_genid2d8f024f370de94eb18726dae5668253392dABBD679220969EFA5FEE45AAEACE7BD2",
        "http://www.w3.org/ns/shacl#path": {
        "@id": "https://agriculture.ld.admin.ch/agroscope/PRIFm2t10a/cropgroup"
        }
},
{
        "@id":
"_:b260627_genid2d8f024f370de94eb18726dae5668253392dABBD679220969EFA5FEE45AAEACE7BD2",
        "http://schema.org/name": {
        "@language": "en",
        "@value": "Crop group"
        }
},
{
        "@id":
"_:b260627_genid2d8f024f370de94eb18726dae5668253392dABBD679220969EFA5FEE45AAEACE7BD2",
        "http://schema.org/name": {
        "@language": "de",
        "@value": "Kulturgruppe"
        }
},
```


You can even know the possible values for *cropgroup*, available as a list (RDF lists are quite verbose and hard to read since they are represented as linked lists with elements connected by blank nodes, but they should be easily converted to regular javascript arrays). The visual representation of the list should clarify its structure (Supplementary figure 13).



Supplementary figure 13: Visual representation of a list.


```
{
    "@id":
"_:b260627_genid2d8f024f370de94eb18726dae5668253392dABBD679220969EFA5FEE45AAEACE7BD2",
    "http://www.w3.org/ns/shacl#in": {
    "@id":
"_:b260627_genid2d8f024f370de94eb18726dae5668253392dE660077FBDDAC2858D9425373A0F3892"
    }
},
{
    "@id":
"_:b260627_genid2d8f024f370de94eb18726dae5668253392dE660077FBDDAC2858D9425373A0F3892",
    "http://www.w3.org/1999/02/22-rdf-syntax-ns#first": {
    "@id": "https://ld.admin.ch/cube/dimension/CropGroup/arableCrops"
    }
},
{
    "@id":
"_:b260627_genid2d8f024f370de94eb18726dae5668253392dE660077FBDDAC2858D9425373A0F3892",
    "http://www.w3.org/1999/02/22-rdf-syntax-ns#rest": {
    "@id":
"_:b260627_genid2d8f024f370de94eb18726dae5668253392d32A39C0C385CFF5C9653532B61045012"
    }
},
```

```
{
        "@id":
"_:b260627_genid2d8f024f370de94eb18726dae5668253392d32A39C0C385CFF5C9653532B61045012",
        "http://www.w3.org/1999/02/22-rdf-syntax-ns#first": {
        "@id": "https://ld.admin.ch/cube/dimension/CropGroup/leysTemporaryGrassland"
        }
},
{
        "@id":
"_:b260627_genid2d8f024f370de94eb18726dae5668253392d32A39C0C385CFF5C9653532B61045012",
        "http://www.w3.org/1999/02/22-rdf-syntax-ns#rest": {
        "@id":
"_:b260627_genid2d8f024f370de94eb18726dae5668253392d32ED73FDDD0EE1788C8A36BA60C8064E"
        }
},
{
        "@id":
"_:b260627_genid2d8f024f370de94eb18726dae5668253392d32ED73FDDD0EE1788C8A36BA60C8064E",
        "http://www.w3.org/1999/02/22-rdf-syntax-ns#first": {
        "@id": "https://ld.admin.ch/cube/dimension/CropGroup/meadowsPastures"
        }
},
{
        "@id":
"_:b260627_genid2d8f024f370de94eb18726dae5668253392d32ED73FDDD0EE1788C8A36BA60C8064E",
        "http://www.w3.org/1999/02/22-rdf-syntax-ns#rest": {
        "@id": "http://www.w3.org/1999/02/22-rdf-syntax-ns#nil"
        }
},
```


Once we know about the key dimension with path

https://agriculture.ld.admin.ch/agroscope/PRIFm2t10a/cropgroup

and possible values

https://ld.admin.ch/cube/dimension/CropGroup/arableCrops

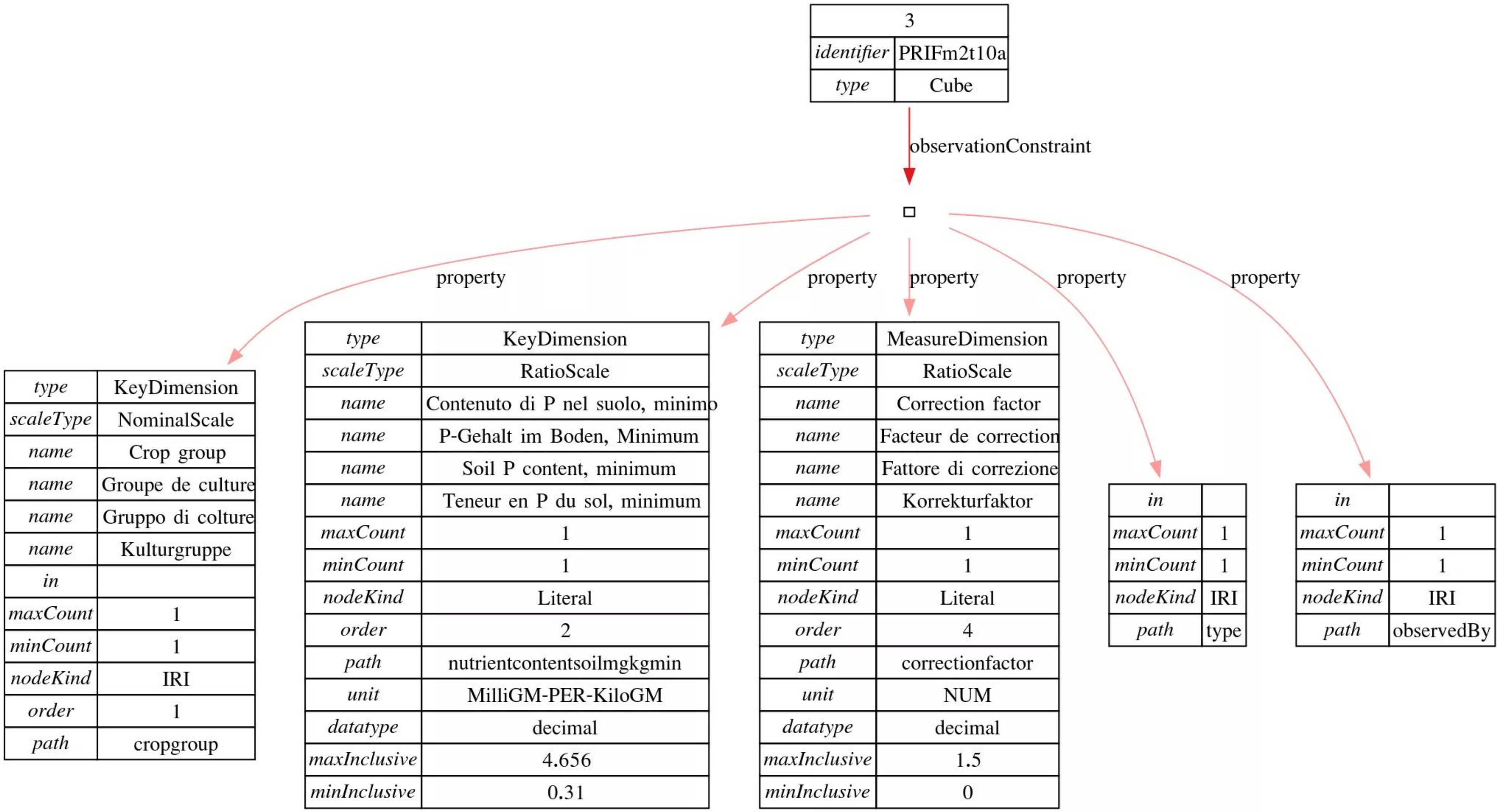
https://ld.admin.ch/cube/dimension/CropGroup/leysTemporaryGrassland

https://ld.admin.ch/cube/dimension/CropGroup/meadowsPastures

we can call the table API with a filter to get only the rows with a given crop group:

https://webgrud-app.zazukoians.org/table/PRIFm2t10a?cropgroup=https://ld.admin.ch/cube/dimension/CropGroup/leysTemporaryGrassland

Notice how we use only *cropgroup* (the last part of the value of *path*). A visual overview of the shapes is given in Supplementary figure 14.



Supplementary figure 14: Visual overview of the shapes.