Technical documentation for CropManager

Version December 2022

General description

CropManager is available online from the address https://www.cropmanager.eu. The tool is with a dynamic layout optimised for use on all devices, independent of screen resolutions. It uses the PWA (Progressive Web App) technology and can be installed as an individual app on all devices.

CropManager is for integrated nutrient management and all other relevant tasks for professional crop management. CropManager is intended for use by crop producers, who can share the access with other relevant persons that provide advice or shall execute planning or registrations. CropManager includes the following elements:

Enterprise level

- Livestock manure and other organic fertilisers: Nutrient accounting and budgeting, including nutrient accounting for own production, management of storages, accounting for purchases and sales of livestock manure and other organic fertilisers.
- Chemicals purchase registration: Electronic book for entering the purchase of chemicals, specified on plant protection chemicals and mineral fertilisers.
- Printing: Users can select among 14 printouts, including
    - a frontpage with detailed information about the *identity* of the enterprise etc.;
    - printouts with the main aim of *supporting crop management*, such as the fertiliser plans for individual fields, printouts to summarize the planned consumption of seeds, fertilisers and plant protection products for the purpose of contracting the procurement of these, and printouts to summarize the planned crop production economy; and
    - printouts to serve as *documentation to authorities*, such as a "Crop and fertiliser planning summary", a "Pesticide / chemicals journal" that makes accounts of storages of chemicals based on registered purchases and consumption via registration of actual spraying, and a "Production site registrations" that documents actual operations concerning for instance fertilisation, which in some cases is different from the planned operations.

  Several of the 14 printouts serves more of the three mentioned purposes.

  Printouts are made for specific calendar years, chosen by the user.

  All printouts are available in PDF formats, and a few also in EXCEL format.

Production site level

- Soil analyses: Soil analyses can be registered with various parameters, and they can be specified with respect to their geographical coordinates, which can be useful in case of practising precision farming.
- Production site planning: Comprises planning of crop rotation, use of seeds, irrigation, fertilisation, and crop protection. Registration of production sites includes geographical mapping and allow the use of official production site identities, like LPIS identification numbers and block numbers.
- Operations: The actual performed field operations, such as sowing, field spreading of fertilisers, harvesting etc. can be registered for use as documentation, for internal management and for making economic accounting after the crop production year.

Norms

- Crops: Crop standards includes specification of the crop as well as its primary and secondary yields harvested, the estimated residue crop, its nutrient need at standard yields, its chemical content, any legalised maximal fertilisation, expected value of the harvest, and more.
- Varieties: Specification of variety identity, standard seeding amount, and price for the seeds.
- Organic fertilisers: Specification of the type, including the animal type in case it is livestock manure, the physical form, the chemical content of solid and liquid fractions, the price, the expected nutrient availability for 1st, 2nd, and 3rd crop.
- Mineral fertilisers: Specification of the name, the type (solid, liquid, foliar), the origin (chemical, organic), the chemical content, the supplier, and the price.
- Plant protection products: Specification of name, category (herbicide, insecticide, etc.), producer, unit (litre, kg), and price.
- Operations: Specification of price for using a service provider, or/and specification of consumption of labour and fuel and their costs, costs for use of own machinery (depreciation, maintenance).

Normative standards to be used are managed by the user of CropManager. It is the user's responsibility to ensure that the used normative standards comply with the legislation. Users can see other users' normative standards in an anonymised form and copy these for own use, possibly after editing to make the specific standard relevant for the enterprise in question, for instance concerning the price. Users are, especially in the case of crop standards, encouraged to write an annotation about the source of information, for instance for the recommended nutrient demands at standard yields of the crop.

General

- App settings includes several possibilities for the user to select their preference:
    - Country: The user can select a country affiliation of normative standards. It is recommended never to switch among countries after a first selection, as this would damage all existing data for the enterprise. Users attempts to switch country is therefore given a warning.
    - Area unit: In many cases the used area unit is hectares, whereas enterprises based on greenhouse production might prefer sqm, etc. The chosen area unit can be changed on-the-fly. The chosen area unit takes effect in all parts of CropManager, except at printouts, which in all cases are based on hectares.
    - Fertilisation strategy: A maintenance strategy means balancing the supply via fertilisers against the nutrient needs of the crop, much related to the removal with the crop harvest. A sufficiency strategy means that P, K and Mg alone is fertilised in case soil analyses shows values below threshold values, generally meaning below values considered as average. The chosen fertilisation strategy can be changed on-the-fly.

In general, CropManager works with “admin users”, to which member businesses are registered. An admin user can register an unlimited number of enterprises, and they can invite an unlimited number of “normal” users to access their data in CropManager. A crop producer can for example invite a crop adviser for assisting with crop management and planning, etc., or employees for registration of operations, etc. There is no limit for the number of production sites per enterprise.

In specific, CropManager is prepared for users’ ability to import data from public registers, such as Integrated Administration and Control System (IACS) data, including data from the Land Parcel Identification System (LPIS) and the Herd and Animal Register, in order for CropManager to work on the basis of this information and be compliant with FaST (Farm Sustainability Tool) principles, and use the same data as basis as is used by the official control bodies. Member States shall according to Regulation EU/2021/2115 (European Commission, 2021), article 15.4.g, ensure “sustainable management of nutrients, including at the latest as from 2024 the use of a Farm Sustainability Tool for Nutrients, which is any digital application that provides at least:

(i) a balance of the main nutrients at field-scale;

(ii) the legal requirements on nutrients;

(iii) soil data, based on available information and analyses;

(iv) data from the integrated administration and control system (IACS) relevant for nutrient management;”

Apart from aiming at serving the role as a FaST tool in accordance with Regulation EU/2021/2115, CropManager is further developed on basis of inputs from an EIP-AGRI Focus Group on Digital tools for sustainable nutrient management (DG-AGRI, 2022).

Data privacy

CropManager is based on a privacy policy[1] that determines that no data or information about the users and their crop production are shared with third parties, neither can it be published by Organe Institute. Exceptions from this is where the CropManager user has given an explicit permission for data sharing.

Calculation of crops' nutrient demand in CropManager

While CropManager aims at being transparent and self-explanatory, and many places providing information icons - (i) - under which the user is given additional clarification, some details of the calculation of crops' nutrient demand are explained and exemplified in the following.

A production site planned for growing winter wheat is used for the exemplification. A soil analysis for the production site shows the following results:

Table 1: Soil analysis results from a production site, used in the following for exemplifying CropManager's calculation of crops nutrient needs.

Analysis date	25/08/2022
Organic matter, %	3.2 - Normal
Soil texture class	Clay loam
Soil acidity, pH	7.2 - Neutral
N_{MIN} level, mg N per kg (i)	67.0 - Very high
P level (plant available), mg/Kg	27.0 - Optimal
K level (plant available), mg/Kg	122.0 - Optimal
Mg level (plant available), mg/Kg	187.0 - Low

It is noted that the soil analysis is made on 22 August 2022, which in this case means after harvest of the previous crop. Therefore, any nitrogen effect of the preceding crop or of the use

[1] https://www.cropmanager.eu/docs/Privacy_policy.pdf

of organic fertilisers for the previous two crops is neglected because the N_{MIN} (mineralised nitrogen) analysis result would comprise such effects.

Aspects considered

Under planning, the fertilisation planning part (see above) consists of three fertilisation planning sub-parts:

- Nutrient needs
- Organic fertilisation
- Optimise fertilisation

Nutrient needs

Under ‘Nutrient needs’, the user is presented with the calculated nutrient needs of the crop, expressed in kg nutrient per chosen area unit. It can for instance be presented like the specific example in Table 1, where the chosen fertilisation strategy is “Maintenance”, the selected crop is wheat, sown 25 November 2022 and planned for being harvested 1 June 2023. The calculated nutrient needs are based on the soil analysis results shown in Table 1.

Table 2: Example of CropManager’s presentation of the crops nutrient need under planning.

	Crop code: name, harvest year Nutrient needs in Kg/ha					View details
	407: Wheat, 2023 145.4 N	54.1 P	98.5 K	1.8 Mg	15.0 S	

It is in Table 2 noted, that the user can click on a magnifying glass to view the details, which in that case shows Table 3.

Table 3: Details of calculation of crops nutrient needs for the given example.

(Expected yield of primary crop: 6.00 T/ha)	N	P_2O_5	K_2O	Mg	S
Norm requirement	150.0	100.0	100.0	18.0	15.0
Corrections					
Yield	20.1	19.9	25.7	1.8	2.0
Soil texture	-7.5	4.0	-7.0	-1.8	
Organic matter	-10.5				
pH					
Soil analysis	-6.7			3.6	
Previous crop after effect					
2nd crop effect of organic fertilisers					
3rd crop effect of organic fertilisers					
Irrigation water					
User adjustments					
Adjustment to legal maximum					
Adjustment for strategy					
Calculated nutrient need	145.4	123.9	118.7	21.6	15.0
Total need, recalculated into pure nutrients	**145.4**	**54.1**	**98.5**	**21.6**	**15.0**

In the following is explained each element in the calculation of the resulting nutrient need:

- Norm requirement. This comes from the crop standard (explained above) and is valid for the expected standard yield. For example, in the case of Malta, this can be based on the standard nutrient requirement for N, P_2O_5 and K_2O that are recommended in Schedule I of the Nitrate Action Programme (S.L.549.66).

  As in this case, many other recommendations for nutrient demands of crops do alone mention the nutrients N, P and K, whereas Mg and S are increasingly recognised as important macro-nutrients.

  Recommendations for crops' demand for Mg can in such cases be sought from other sources. The example is using a standard crop need for Mg of 18 kg per ha.

  Requirements for sulphur (S) is calculated as a function of the crop requirement for nitrogen (N), according to the following formula:

  *S need = N need * SN constant + S constant*

  For most crops, the need for S is 10% of the need for N, which would cater for the building of amino acids holding sulphur to become part of the protein content of the crop. Hence, a SN constant of 0.1 and a S constant of 0 is relevant for many crops. Some crops contain protein with a high share of S-containing amino acids, such as rape seed / canola, where a SN constant of 0.2 is relevant. In case of nitrogen fixating crops, such as beans or alfalfa, the need for S cannot be set in relation to the need for N, because this is 0, and it is in that case relevant with a S constant, for instance in the case of peas could be 25 kg, dependent on the yield level.

Table 4 shows the nutrient requirements at standard yield of 5 tonnes of primary product (grain) harvested per ha for the used example.

Table 4: Nutrient requirements at standard yield of 5 tonnes of primary product (grain) harvested per ha for the used example.

	N	P_2O_5	K_2O	Mg	S
Nutrient requirement at standard yield, Kg/ha	150	100	100	18	15.0

- Yield (corrections): In case the user expects a harvested yield level of the primary crop that differs from the standard yield, CropManager will calculate the reduced nutrient need in case of lower expectations to the yield, or higher nutrient need in case a higher productivity is expected. For the given example, the standard yield is 5 tonnes per ha, but the concrete expectation is 6 tonnes per ha, and there will therefore be a yield correction of the nutrient need. The yield correction is based on information in the specific crop standard under Norms - see table 5.

Table 5: Yield correction of nutrient requirements (N, P_2O_5, K_2O and Mg) used for the given example. It is noted that CropManager shows guiding yield corrections based on the chemical content of the primary and secondary harvested crop, recalculated from pure nutrients for chemical content in case of P and K.

Nutrient requirement yield correction, Kg/T	20.1	19.9	25.7	1.8
Guiding yield correction, kg/T	*20.1*	*19.9*	*25.7*	

Typically, yield corrections are determined in relation to the chemical content of the harvested crop, considering the yield expectation to the primary crop and as well a possible secondary crop and crop residues, considering that a harvested secondary crop in some cases can contain a considerable amount of plant nutrients, for example in the case of haulm of bean or pea. In some cases, the yield corrections are set slightly lower than the chemical content of the crop, in the anticipation that the higher or lower expected productivity is much influenced by the crop management quality, not alone the nutrient supply.

The chemical content of the primary and secondary harvested crop for the given example is shown in Table 6.

Table 6: Chemical content of the primary and secondary harvested crop for the given example.

	N	P	K	C
Chemical content in primary yield, Kg/T	15.6	6.9	5.9	340.0
Chemical content in secondary yield, Kg/T	4.5	1.8	15.4	340.0

- Soil texture (corrections): For the given example, the soil texture class is 'Clay loam'. The soil texture correction factors are shown in Table 7. If there are no available soil analysis, the correction factor is 1.00, meaning that no correction takes place. Otherwise, the correction factor is multiplied with the nutrient need. The influence of the soil texture on the nutrient need is much related with the water binding capacity of the soils, hence its geology, hydrology and chemistry etc., therefore universal, and Table 3 is established after inspiration from Mičurova and Skudra (2008) and Osann (2022).

Table 7: Correction factors for soil texture class.

#	Soil texture name	Correction factor for			
		N	P_2O_5	K_2O	Mg
1	Not analysed	1.00	1.00	1.00	1.00
2	Sand	1.00	0.95	0.85	1.10
3	Loamy sand	0.99	0.97	0.86	1.00
4	Sandy loam	0.98	0.98	0.88	0.95
5	Loam	0.97	1.00	0.89	0.95
6	Silty loam	0.96	1.01	0.90	0.90
7	Silt	0.96	1.03	0.92	0.90
8	Clay loam	0.95	1.04	0.93	0.90
9	Sandy clay loam	0.94	1.06	0.95	0.90
10	Silty clay loam	0.93	1.07	0.96	0.90
11	Sandy clay	0.92	1.08	0.97	0.90
12	Silty clay	0.91	1.09	0.99	0.90
13	Clay	0.90	1.10	1.00	0.90
14	Peat	0.60	1.20	1.40	0.80

- Organic matter (corrections): The soil organic matter analysis result is in CropManager associated with one of five levels – see Table 8, which determines an organic matter correction factor. Corrections are alone made for the crop need for nitrogen. The correction factors reflect the availability of the fertilised nitrogen for the crop, or vice-versa, the risk for the nitrogen to be lost via leaching etc. before crop uptake. The influence of the soil organic matter on the nitrogen need is much based on soil geology, hydrology and chemistry etc., therefore universal, and Table 4 is established after inspiration from Mičurova and Skudra (2008).

Table 8: Correction factors for soil organic matter.

#	Min. analysis result	Max. Analysis result	Text	Correction factor for N
1	-	-	Not analysed	1.00
2	0.1	1.5	Very low	1.10
3	1.6	2.5	Low	1.02
4	2.6	5.0	Normal	0.93
5	5.1	10.0	High	0.85
6	10.1	100.0	Very high	0.80

- Soil acidity (corrections): The pH analysis result is in CropManager associated with one of seven pH levels – see Table 9, which determines a soil acidity correction factor. Correction factors for soil acidity are based on the nutrient availability for the crop at different pH levels. Of the 5 macro nutrients CropManager works with, the availability of phosphorus is most sensitive to soil pH. The relation between pH and nutrient availability is based on chemical reactions, therefore universal and described by many, for instance Binkley & Vitousek (1989). The used correction factors are shown in Table 9.

Table 9: Correction factors for soil acidity.

#	Min. pH	Max. pH	pH level name	*Correction factor for*			
				N	*P*	*K*	*Mg*
1	-	-	Not analysed	1.00	1.00	1.00	1.00
2	0.1	5.4	Strongly acidic	1.15	1.30	1.10	1.10
3	5.5	6.0	Acidic	1.10	1.10	1.05	1.10
4	6.1	6.7	Slightly acidic	1.00	1.05	1.00	1.00
5	6.8	7.3	Average	1.00	1.00	1.00	1.00
6	7.4	8.1	Slightly alkaline	1.00	1.05	0.95	1.00
7	8.2	8.6	Alkaline	1.10	1.10	0.95	0.95
8	8.7	13.0	Strongly alkaline	1.15	1.15	1.00	0.95

- Soil analysis (corrections): Analysis results for the soil content of Mineralised N (N_{MIN}), P, K and Mg are considered in CropManager in the following way:
  - N_{MIN} is in general the soil content of N on nitrate (NO_3^-) and ammonium (NH_4^+) form, expressed as mg N per kg soil in the root depth of the crop. In CropManager, the N_{MIN} analysis result is used for correction of the crop need for N in the following way: Corrections are calculated as the N_{MIN} level above average (determined as 40 mg N/kg soil), multiplied with a utilisation coefficient (0.1 in case of 40-50 mg N/kg soil and 0.2 for higher levels), and multiplied with a coefficient for organic matter content of soils (1 in case of > 2.5% organic matter, else = % organic matter / 2.5). The calculation method is inspired by Osann (2022).

Table 10: Utilisation coefficient for the N_{MIN} (mineralised nitrogen) content of soils.

#	Min. analysis result (Mg/kg)	Max. Analysis result (Mg/kg)	Interpretation	Utilisation coefficient
1	-	-	Not analysed	0
2	0.1	10.0	Very low	0
3	10.1	20.0	Low	0
4	20.1	40.0	Optimal	0
5	40.1	50.0	High	0.10
6	50.1	∞	Very high	0.20

- The P soil analysis result is in CropManager associated with one of 5 levels that determines the used correction factor for the crop need for P – see table 11. The minimum and maximum analysis results in Table 11, that determines the level, and thereby the used correction factor, depends on the used analysis method. Table 6 is assuming soil P is analysed using the Olsen extraction method. The availability of P for the crop, dependent on the soil analysis result, is related to soil geology, hydrology and chemistry etc., therefore universal, and Table 11 is established after inspiration Passari & Ingenito (2012).

Table 11: Correction factors for the phosphorus soil analysis result.

#	Min. analysis result Mg/kg	Max. Analysis result	Interpretation	Correction factor for P
1	-	-	Not analysed	1.00
2	0.1	12.4	Very low	1.60
3	12.5	24.9	Low	1.30
4	25.0	49.9	Optimal	1.00
5	50.0	100.0	High	0.40
6	100.1	∞	Very high	0.20

- The K soil analysis result is in CropManager associated with one of 5 levels that determines the used correction factor for the crop need for K – see table 12. The minimum and maximum analysis results in Table 12, that determines the level, and thereby the used correction factor, depends on the used analysis method. The availability of K for the crop, dependent on the soil analysis result, is related to soil geology, hydrology and chemistry etc., therefore universal, and Table 12 is established after inspiration from Mičurova and Skudra (2008).

Table 12: Correction factors for the potassium soil analysis result.

#	Min. analysis result	Max. Analysis result	Interpretation	Correction factor for K
	Mg/kg			
1	-	-	Not analysed	1.00
2	0.1	40.0	Very low	1.40
3	40.1	90.0	Low	1.20
4	90.1	125.0	Optimal	1.00
5	125.1	175.0	High	0.80
6	175.1	∞	Very high	0.40

- The Mg soil analysis result is in CropManager associated with one of 5 levels that determines the used correction factor for the crop need for Mg – see table 13.

The minimum and maximum analysis results in Table 13, that determines the level, and thereby the used correction factor, depends on the used analysis method. The availability of Mg for the crop, dependent on the soil analysis result, is related to soil geology, hydrology and chemistry etc., therefore universal.

Table 13: Correction factors for the magnesium soil analysis result.

#	Min. analysis result	Max. Analysis result	Text	Correction factor for Mg
1	-	-	Not analysed	1.00
2	0.1	25.0	Very low	1.30
3	25.1	250.0	Low	1.20
4	250.1	600.0	Normal	1.00
5	600.1	1500.0	High	0.70
6	1500.1	∞	Very high	0.50

- Previous crop after effect (corrections): Some crops are known to leave the soils with a higher level of plant available nitrogen than other crops. This is in specific nitrogen fixating crops like clover, alfalfa and beans, as well as crops like rape seed, potatoes, beets, and other. In some cases, the nitrogen after effect is related to the used practice for disposal of the secondary crop, and the after effect of beets is for example much related to an often-used practice of leaving the top leaves on the field, whereby its containing nutrients becomes available for the succeeding crop. The nitrogen after effect is based on an agronomic expert assessment and is typically set between 0 and 20 kg N per ha. The effect is in case registered in the specific crop standard under 'Norms' in CropManager. In CropManager, the nitrogen after effect is disregarded in case there exists a soil analysis result for N_{MIN} that is newer than the latest harvest date.

- Organic fertilisers' 2nd and 3rd crop N effect: Organic fertilisers are characterised by containing organic matter, which binds a part of the nutrients, especially nitrogen, in organic compounds. The organic compounds are degraded over time, often via microbial activity, and the contained nitrogen is thus slowly released along with this degradation and further microbial decay. Thus, nitrogen in organic fertilisers have an immediate effect, related to their content of mineralised nitrogen, mainly ammonium (NH_4^+), as well as an effect on the succeeding crop as well as a small effect on the crop after the succeeding crop. Although the situation is comparable for other plant nutrients, CropManager is alone considering nitrogen and the reason being that nitrogen fertiliser is readily taken up by the crop whereas other nutrients merely go into the turnover in the soil pool, thus normally having an indirect and longer-term effect on crop uptake. The

2nd crop N effect and 3rd crop N effect of organic fertilisers is based on an agronomic expert assessment and is typically set between 40 and 80% for the present/first crop, 5 - 35% for the succeeding crop, and 0 – 25% for the crop after the succeeding crop. Liquid organic fertilisers have due to a typically higher share of NH_4^+-N of N_{TOTAL} normally a higher first crop effect and lower effects later than solid organic fertilisers, and vice versa. The nitrogen effects can be lowered by bad organic fertiliser management practices, including practices for storage and field-spreading, and they can be raised, especially the first-year effect, by use of good organic fertiliser management practices as well as use of certain processing technology like anaerobic digestion or acidification. The expected effect is in case registered in the specific organic fertiliser standard under 'Norms' in CropManager. In CropManager, these 2nd and 3rd crop N effect of organic fertilisers are disregarded in case there exists a soil analysis result for N_{MIN} that is newer than the latest, respectively the second latest harvest date.

Table 14 shows an example of an assessed nitrogen effect of the present crop, succeeding crop and crop after the succeeding crop for an organic fertiliser (cow slurry separation solids). For the given example, it is this assessed that alone 50% / half of the nitrogen content in the organic fertiliser will be actually be taken up by crops, meaning 30% + 15% + 5%.

Table 14: Example of an assessed nitrogen effect of the present crop, succeeding crop and crop after the succeeding crop for an organic fertiliser.

	Nitrogen field effect, %	
	Liquid	***Solid***
Present / first crop		30
Succeeding crop		15
Crop after succeeding crop		5

- <u>Irrigation water (corrections):</u> In some countries, the use of irrigation is a normal crop production practice. It is in such cases relevant to consider the irrigation water as a nutrient source for the crop. In CropManager, the irrigation is planned with respect to the water consumption and the nitrate content of the irrigation water. The nitrogen supply of the crop with the irrigation water is thus calculated after a simple formula:

  *Kg N per area unit = cbm. water per area unit * mg NO_3^-/litre * 7/31 mg N/Mg NO_3^-*

- <u>User adjustments (corrections):</u> CropManager gives the possibility for the user to correct the calculated nutrient requirement of the crop in case there are certain conditions that justifies this. An example of a relevant justification is in case the previous crop was given more of a certain nutrient, for instance phosphorus, than needed. This often happens because most fertilisers contain more nutrients, for instance both N, P and K, and it is alone with single fertiliser possible to spread the exact needed amount of nutrients. If, for example, the previous crop was given 15 kg more phosphorus (P) than the crop actually needed, then there is reason to believe that at least a part of this surplus is available for the succeeding crop. Another reason for a user adjustment is in case the previous harvest was larger or smaller than expected when the fertilisation of that previous crop happened, and therefore have removed larger or smaller amounts of nutrients from the field than expected. In CropManager, the user adjustments of the otherwise calculated nutrient demand for the crop can be both negative and positive values. The adjustments happen during the planning of the fertilisation by clicking the edit button shown to the left in Table 2. The user can write an annotation to the made adjustment, for instance the justification for it.

- Adjustment to legal maximum (corrections): Several countries have regulated crop-specific legal maximum for nitrogen fertilisation, connected to expected yield levels. Such legal maximums can be registered in CropManager under the specific crop standards under Norms. There can be registered up to 3 maximums related to expected crop yields, as well as an absolute maximum. In case the other nutrient needs, including corrections, exceeds the regulated maximums, CropManager will automatically reduce the resulting nutrient need to the legal maximum to ensure the fertiliser plan is legal. The user is in such case made aware of this adjustment by displaying an asterisk (*) besides the nutrient need for N.

- Adjustment for strategy (corrections): Finally, the last correction happens for the chosen fertilisation strategy, explained above under App settings. In the used example, there is no adjustments (see Table 3) because the used strategy is “Maintenance”. If instead the strategy is “Sufficiency”, then the adjustment for strategy for the given example would result in no need for P and K because soil analyses for these minerals show optimal levels – see Table 15.

Table 15: Adjustment for strategy and the resulting calculated nutrient ned for the given example in case the fertilisation strategy is changed to "Sufficiency".

(Expected yield of primary crop: 6.00 T/ha)	N	P_2O_5	K_2O	Mg	S
Norm requirement	150.0	100.0	100.0	18.0	15.0
Corrections					
Yield	20.1	19.9	25.7	1.8	2.0
Soil texture	-7.5	4.0	-7.0	-1.8	
Organic matter	-10.5				
pH					
Soil analysis	-6.7			3.6	
Previous crop after effect					
2nd crop effect of organic fertilisers					
3rd crop effect of organic fertilisers					
Irrigation water					
User adjustments					
Adjustment to legal maximum					
Adjustment for strategy		-123.9	-118.7		
Calculated nutrient need	145.4	0.0	0.0	21.6	15.0
Total need, recalculated into pure nutrients	**145.4**	**0.0**	**0.0**	**21.6**	**15.0**

Summing up, CropManager uses an additive method for taking into consideration all relevant factors for crop nutrient needs. It shall, in this connection, be kept in mind that fertiliser planning is a strategic and tactical planning that often happens several months before the crop is actually sown/planted, as it has the purpose to serve as a management tool on which basis for instance the procurement of seeds, fertilisers and pesticides can happen.

In connection with the execution, meaning the actual field spreading, the fertiliser plans can be further adjusted on basis of more detailed information at the time of fertilisation. For instance, the dose of nitrogen fertiliser can be adjusted according to actual weather conditions, including temperature, which according Osaan (2022) influence the availability of the mineralised nutrients in the soil. Another example is in case the fertilisation is split, and the second dose is given to the growing crop, this can be dosed according to the crop development, including leaf analyses. It shall thus be understood that fertiliser planning in CropManager is for tactical/strategical purposes, and for example not for adjusting field spreading equipment during execution of the fertilisation.

Organic fertilisation

For a crop producer an informed nutrient demand of a crop is not immediately useful. The nutrient demand must be interpreted in terms of amounts and qualities of fertilisers, taking into account the availability and prices of fertiliser types.

After determination of the nutrient needs of the crop according to the above, the user will first consider the use of organic fertilisers, such as processed products of livestock manures. The reasons for this are that

- such nutrient supplies are typically cheaper than that of mineral fertilisers; and
- in case of own livestock production, there is an ongoing livestock manure production that must be disposed of considering storage capacity limitations.

The user is under 'Organic fertilisation' having the possibility to add organic fertilisers, under the condition that storages are established under 'Enterprises' and 'Manure accounting' according to the above. In case this condition is met, the user will be presented with Table 16 after clicking the button 'Add organic fertilisation' to the production site. The table informs the nutrient need of the crop before any organic fertiliser is distributed to the production site, as well as the remaining nutrient need after the suggested amount and quality of organic fertiliser is entered. At the same time, the user can follow the remaining amount in the chosen storage, in order to ensure the planned use of organic fertiliser complies with the availability.

It should be noted that the remining nutrient needs are calculated according to the present / first crop field effect of nitrogen, originating from the specific types and amounts of organic fertilisers that are kept in the specific manure storage. Please refer to the above explanation of the so-called field effect of nitrogen for the present/first crop, the succeeding crop and the crop after the succeeding crop, which is registered for organic fertilisers under 'Norms'.

It is noted in Table 16, that the year is switched to 2023, since we wish to spread liquid manure on the growing wheat in March 2023.

Table 16: Screen for distribution of organic fertilisers in CropManager.

Edit manure fertilisation 2023

Crop, area and expected planting date	Wheat, 0.52 ha, 25/11/2022
Manure type	14: Tank for liquids

	N	P	K	Mg	S
Nutrient needs, kg/ha	145.4	54.1	98.5	21.6	15.0
Manure nutrients, kg/ha	114.4	43.4	62.0	0.0	0.0

	Ton available	- use, ton/ha	= rest
January	123	0.0	129
February	128	0.0	134
March	134	15	132
April	131	0.0	137
May	137	0.0	143

Optimise fertilisation

In CropManager, the second step in converting the nutrient needs into a fertiliser plan is the determination of the cheapest option of how the remaining nutrient needs (after distribution of organic fertilisers), can be fulfilled by selecting the ideal mix of commercially available fertilisers, based on their nutrient content and price.

The user can under 'Optimise fertilisation' make a manual selection among the 'Mineral fertilisers' under 'Norms' that is connected to the user's enterprise and see the consequent balance after selection of given fertiliser types and quantities. See Table 17 for the result of an optimisation for the given example.

It is noted for Table 17 that after balancing, the need for Mg is not covered. The reason for this is simply that the offered commercial fertilisers for the balancing does not comprise any with a content of Mg.

All figures are per ha or per the preferred area unit. The planned consumption of fertilisers for the production site in question, in this case 0.52 ha, will appear from the fertiliser plan, meaning the printout "Fertiliser plans and nutrient balances", found under "Enterprises" and "Printing".

Table 17: Result of balancing remaining nutrient needs (initial balance) with commercial fertilisers via a linear regression optimisation ('Optimise rest need') that find the cheapest combination that fulfils the remaining needs among the available fertilisers with a known price.

Crop code: Crop name, expected planting date				Kg/ha N	P	K	Mg	S
3: Wheat, 25-11-22 - Initial balance				**-31**	**-11**	**-37**	**-22**	**-15**
2796: (2500.00 € /Ton) Potassium ch	november 2022	61	Kg/ha			37		
2795: (1750.00 € /Ton) Triple super p	november 2022	23	Kg/ha		11			
2779: (2000.00 € /Ton) Ammonia Nit	november 2022	52	Kg/ha	18				
2774: (720.00 € /Ton) Ammonia sulp	februar 2023	63	Kg/ha	13				15
Balance after application of commercial fertilisers				***0***	***0***	***0***	***-22***	***0***
Add commercial fertiliser	Optimise rest need							

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Terminology used

Enterprise:	An enterprise is a business that is engaged in crop production, such as a farm, a horticulture, a plantation, a vineyard and alike.
Production site:	A production site is a subdivision of an enterprise, such as a field or a greenhouse.