Louis Bolk Instituut

An SPNA project

Evaluation Planty Organic 2012-2020

Plant-based fertilizer: nitrogen and organic matter

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Search terms: Planty Organic, nitrogen, organic matter, Cut&Carry fertilizer, Ndicea

Publication number 2021-012 LbP

55 pages

This publication can be found at
www.louisbolk.nl/publicaties en via www.stikstoftelen.nl

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Louis Bolk Instituut:
Research and advice to advance sustainable agriculture, nutrition and health.

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Research station for arable farming on the Dutch northern Clay region

Preface

The research themes soil quality and sustainable arable farming request a long time span. It is impressing that SPNA and the involved stakeholders have been able to run a nine-year project on organic arable farming base on 100% own nitrogen supply by leguminous plants, developing and documenting the system. This report evaluates these nine years and shows insight in the potency of this system with Cut&Carry fertilizer as essential but not one and only component of the success.

After nine years there are still questions left, but the most important questions about nitrogen and soil organic matter are largely answered.

The next step could be the transformation into a regional circular demonstration farm by introducing the input of regional residual organic supplies like compost and bokashi. In that way, the other plant nutrients beside nitrogen are brought into a more circular system.

There is another argument to maintain this Planty Organic experimental field. It is one of the few places in the Netherlands where production is realised on pure plant-based fertilizer applications. A market for these products is hardly there, but considering the developments in society a market could come into life as a 'plus' on organic produce. In that case there is already a well-documented farm able and willing to share knowledge and experience, beside other initiatives with pure plant-based fertilizers in the Netherlands.

At the moment of publishing this report, it is unknown whether the experiment can be continued or not. So therefor: offer your assistance to maintain this unique experimental field!

Hero Havenga

Chairman Biowerk Foundation, initiator of Planty Organic.

This report is a deliverable from the POP3-project 'Stikstof Telen', financed by the EU, Brancheorganisatie Akkerbouw and Friesland province via SNN.

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Summary

Methodology

Situated on the SPNA experimental farm Kollumerwaard, from 2012 up to 2020 the Planty Organic experiment was run: and organic arable farming system based on 100% nitrogen input by means of leguminous plants. Soil, crops, green manures and Cut&Carry fertilizers were measured. In 2019 and 2020 six more fields were monitored from the Kollumerwaard organic business unit, the Kollumerwaard Conventional business unit and a nearby situated organic farm, thus enabling system comparisons.
All data were used to create in total 12 field scenarios in the Ndicea App. In case of Planty Organic, KW Organic and KW Conventional the model scenarios were good enough to be transformed into Ndicea scenarios on rotation level. These three scenarios are used to compare results such as input-output, nitrogen losses, nitrogen use efficiency, organic matter dynamics and field-internal dynamics.

Results

Planty Organic has a high score in N-efficiency and environmental and biodiversity indicators. Productivity is substantially lower than in KW Conventional. The soil organic matter and the soil organic nitrogen levels are stable in the Planty Organic system. This is a remarkable result, considering the zero external input in this system.
KW Organic has a middle position. The productivity is in the same order as in Planty Organic, but beside the arable products grassclover is taken out and manure is brought in. This can be considered as a partly internal flow, enabling animal production elsewhere. The nitrogen losses (leaching, denitrification, volatilization) are comparable to KW Conventional. KW Organic is the system in which a small but clear increase in soil organic matter is realized, mainly due to the use of solid goat manure.

Fllow-up plans

It is proposed to continue the trial field, using regional residual streams as inputs to compensate for nutrient runoff with products, with P balance as a guideline. Strips will remain unfertilized to create sharp contrasts in soil P to enable research on P availability under low or no P supply.

Nederlands

Dit rapport is ook in het Nederlands beschikbaar, te downloaden van www.spna.nl of www.louisbolk.nl

Deutsch

Dieser Bericht ist auch auf Deutsch verfügbar, zu downloaden von www.spna.nl oder www.louisbolk.nl

1 Introduction

1.1 Background, targets and conditions

Within the farmers' association Biowad, in 2010 the question rose how to reduce the input of conventional manure in the organic farming practice. The idea came to life to create on one of the organic maintained fields of the SPNA experimental farm Kollumerwaard a separate rotation based on biologically fixed nitrogen only. This was prepared in 2011 and in 2012 the project 'Planty Organic started. After the spring manure application in 2011 no external input has been brought in.

> *The overall question was to explore the potential of such a system. Is it executable, will soil fertility stay stable, what will be the production level, does it perform better on environmental parameters and biodiversity, what about the economics of this system?*

The following assumptions are used (Van der Burgt 2012):

> Cut&Carry fertilizers
> A Cut&Carry fertilizer is a mixture of leguminous species or grassclover mixture harvested as if it were fodder but used as 'green fertilizer' without passing through an animal. From the perspective of NUE Nitrogen Use Efficiency this has several advantages.

- Nitrogen will be added to the system by means of leguminous plants. The internal nitrogen flows imply partly an above-ground redistribution by means of Cut&Carry fertilizer (see text right side) and partly a soil-bound handover by the rootmass of the Cut&Carry fertilizer crop and the use of leguminous catch crops. The basic process nevertheless is the mineralisation of the present and continuously supplemented soil organic matter.
- Phosphate, potassium and other plant nutrients are abundant in this type of soil, both in topsoil and second layer. This supply is mobilised. Deep-rooting crops and green manures can mobilise nutrients in topsoil and second soil layer and bring them in circulation.
- The nitrogen present in the system will be as much as possible be bound in organic matter to prevent losses due to leaching and denitrification from inorganic nitrogen. To realise this target, fertilization is done with a green herbal fertilizer with almost no mineral nitrogen content (the farm-internal Cut&Carry fertilizer). The aim is a maximum presence in time of growing plants and a green cover in winter.
- Soi tillage will hinder the functions of the soil life as little as possible. Reduced and non-inversion tillage enables to maintain the different soil layer, thus keeping intact the functionality. GPS-based fixed traffic lanes promote the development of a good soil structure.

The farming system want to fulfil the next targets:

- 100% own nitrogen supply by means of clover, alfalfa and green manures.
- No input of manure or compost.
- Enough plant available nitrogen to realise a good yield and quality of sold crops.
- A sustainable crop rotation, related to soil quality and nitrogen supply.
- At least maintain the soil organic matter and soil organic nitrogen.
- A crop rotation and crop choice representative for organic arable farming in the region.
- As much as possible winter-green fields.
- Alternation of more and less demanding crops as starting point for a multifunctional crop rotation (Vereijken, 1997. Wijnands, 2000).

1.2 Crop sequence and fertilization

The crop sequence has been in general the same during these nine years. Since 2015 no changes have occurred and the fertilizer strategy is stabilized. This is shown in Figure1.

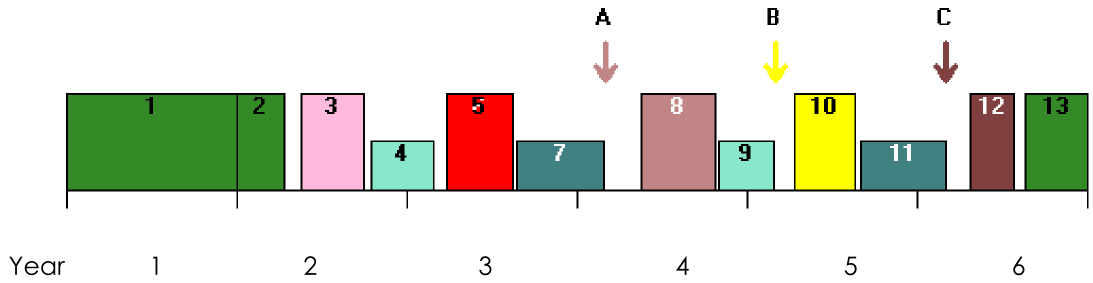


Figure1. Crop sequence and fertilization

1,2,13: Leguminous crop mixture ; 3: Pumpkin ; 5/6: Wheat/Field bean ; 8: Winter carrot ; 10: Oats ; 12: Seed potato .

4,9: Green manure without leguminous plants ; 7,11: Green manure mixture with leguminous plants.

A: Cut&Carry fertilizer, about 20% of last years' stock . B:the same, about 30% ; C: the same, about 50%.

1.3 Measurement scheme and method

To obtain insight in the dynamics of soil organic matter and soil nitrogen a measurement protocol has been set up.

- All years, all (6) plots, November: general soil fertility measurement: sampling and analysis by Eurofins Agro, bundle "bemestingswijzer compleet".
- All years, all plots: crop yield (by SPNA), analysis nutrient content (by Eurofins Agro)
- All years: yield Cut&Carry fertilizer (by SPNA) en analysis N-P-K (sampling and analysis by Eurofins Agro)

- All years, all plots: Mineral nitrogen (N-min) in 0-30 cm, number depending on crop / plot / year. Sampling by SPNA, analysis in moist or dried soil by EurofinsAgro, SPNA or Louis Bolk Instituut.
- 2019-2020: yield crop residues (SPNA) and analysis of N-P-K (Eurofins Agro)
- 2019-2020: yield green manures (SPNA) and analysis of N-P-K (Eurofins Agro)
- 2019-2020: nitrate analysis in drainwater, about every two weeks if drains were running. Sampling by SPNA, analysis by Groen Agro Control.
- October 2019: sampling for soil life analysis by Bioclear Earth.

In 2019-2020 this research was part of the POP3-project "Stikstof Telen" (Growing Nitrogen). Beside the Planty Organic plots measurements were done, though less intensive, on two organic (KW Org) and two conventional (KW Conv) cultivated fields of Kollumerwaard, and two fields of the adjacent farm Bakker Bio, project partner. This extension enables to a certain extend a system comparison between Planty Organic, KW Org and KW Conv.
Together with statistical analysis of soil and crop measurements the App Ndicea (Van der Burgt et al, 2006) was used to require insight in the organic matter and nitrogen dynamics. From the six Planty Organic and the six added 2019-2020 fields. Ndicea field scenarios are created, serving two targets. First, building a quantitative overview of the organic matter and nitrogen dynamics and check the reliability by means of mineral N and organic matter measured data. Second, create, based on the field scenarios, a general crop rotation scenario in Ndicea with average input data from the field scenarios. The Planty Organic crop rotation scenario is the instrument for system evaluation and comparison with those from the KW Org and KW Conv system.

1.4 Readers' instruction

- In chapter 2 the six Planty Organic field scenarios are presented and quantitatively assessed. After that the other six field scenarios are presented. These are based on much less measurements and for these the assessment is merely qualitative. In the assessment the mineral N and the organic matter measurements play a central role.
- In chapter 3 the development of the soil is shown and related to a possible relation with the nutrient content of the crops.
- In chapter 4 the crop rotation scenarios from Planty Organic, KW Org and KW Conv are described. Also a hypothetical future-oriented scenario is introduced in which the Planty Organic system is modified by addition of compost base on P-equilibrium.
- Chapter 5 is about the comparison of the three systems based on criteria such as input/output, nitrogen use efficiency NUE and field internal processes. Out of this follows a hypothetical explanation of the high NUE of the Planty Organic system.
- In chapter 6 the consequences on the farm economics of a choice for a 100% farm-own nitrogen input by means of Cut&Carry fertilizer, green manures and leguminous

crops is briefly described. This analysis is based on the Planty Organic system including compost input as a mimicry for regional nutrient cycling

- Chapter 7 finishes this report with conclusions and recommendations.

2 Ndicea field scenarios

2.1 General remarks

We used the Ndicea version 6 as it can be downloaded from www.ndicea.nl . All the model default parameter values were used except for two. The first adaptation is the parameter determining the relation between soil mineral N level and the amount of N-fixation by leguminous crops, in Ndicea named 'N-fixation barrier'. It has brought down from 15 to 5 based on experiences in much other scenarios ((expert judgement G.J. van der Burgt, G. Oomen). By doing this, the preference for soil-N uptake compared to fixation is increased. The second deviation from the default parameter values is the choice for 'no tillage' instead of 'reduced tillage'. Already after a few years in this project this seemed to deliver better model results. This is discussed in chapter 4.

The initial values of the three model soil organic matter pools are, in case of the Planty Organic field scenarios, based on the results of a short Ndicea scenario of the previous years. For the other field scenarios he Ndicea default values are used. These field scenarios start in 2011 (KW Organic) and in 2016 or 2017 (KW Conventional and Bakker Bio). So, in these scenarios there are at least two years preceding the measurements in 2019-2020. This reduces the influences of uncertainties in the initial values of soil organic matter in the results of 2019-2020.

All measured data from crops and Cut&Carry fertilization are used. If absent, the Ndicea default values are used. Measurements of crops and fertilizer can be found in Appendix 1; those of the soil in Appendix 2.

Local precipitation data are used. For temperature and evapotranspiration data from the nearby weather station 'Lauwersoog' are used.

Topsoil is set at 0-30 cm, and so are the mineral N measurements. Second soil layer is set at 30-60 cm, which is elsewhere discussed.

2.2 Conditions for judgement

For the judgement of the model performance several criteria are used:

- The degree of similarity between measured and simulated values of mineral nitrogen 0-30 cm. For this the RMSE (Wallach and Goffinet, 1989) has been used.
- The degree of overestimate or underestimate of simulated mineral nitrogen compared to measured values.
- The number of crops or green manures with a simulated nitrogen shortage.
- The degree of similarity between simulated and measured values for soil organic nitrogen and soil organic matter.
- The degree of similarity between a measured increase or decrease of mineral nitrogen 0-30 cm and the simulated changes in mineral nitrogen. This is a qualitative judgement.
- The degree of similarity between simulated and measured changes in soil organic matter and soil organic nitrogen.

Preceding the final judgement three model explorations are done on the six Planty Organic field scenarios. The first was an increase of maximum rooting depth from 60 cm to 90 cm. This resulted in marginal changes, and not always with better results. The second was the calibration of a set of soil parameters based on the difference between simulated and measured mineral nitrogen and soil organic matter (measured once every year). This resulted in substantial changes in model outcome. Related to RMSE of mineral nitrogen the differences were small. Related to the change in soil organic matter a big discrepancy showed up; see next paragraph. The third was the difference between the tillage choice 'reduced' or 'no tillage'. For the RMSE of mineral nitrogen the changes were variable and not big. For the RMSE of measured and simulated level of soil organic matter the choice for 'no tillage' compared to 'reduced tillage' resulted in four out of six scenarios in a better outcome and in one a less good result. The choice for 'reduced' compared to 'none' also resulted in a stronger decrease of soil organic matter than what is shown by the measurements.
As a result of these explorations the judgement has been done with the scenarios 0-60 cm maximum rooting depth, without calibration and with 'no soil tillage' as choice for tillage effect although the tillage was best characterized as 'reduced'. This needs further attention and maybe model adaptation.

2.3 Judgement of Planty Organic scenarios

2.3.1 Based on soil organic matter and total N

If the objective is to show that an arable system based on 100% nitrogen fixation as input is feasible, the soil organic matter and soil N-total may not decrease. Considering the margin of errors in the analysis, a long-year sequence is needed. In Planty Organic this is realized: nine years with six plots being pseudo-repetitions. Because of the importance of this, the organic matter an nitrogen are separately shown and discussed here below, Table 1 and Table 2. Other soil parameters are discussed further down.

Table 1. Soil organic matter (%)

		A	B	C	D	E	F	Average
2012	March							* 1,8
2012	November	1,6	1,6	1,8	1,8	1,8	1,8	1,7
2013	November	1,8	1,9	2,1	1,9	1,9	2,1	2,0
2014	November	2,4	1,9	2,0	2,0	1,8	2,0	2,0
2015	November	1,8	1,9	2,0	2,0	2,2	2,2	2,0
2016	November	1,7	1,9	2,0	1,9	1,8	1,6	1,8
2017	November	2,1	1,9	1,9	1,9	2,2	2,1	2,0
2018	November	2,0	2,0	2,0	2,4	2,1	2,3	2,1
2019	November	1,6	1,8	1,6	2,0	1,6	1,7	1,7
2020	November	1,9	2,1	1,1	1,1	1,6	1,0	1,5
2021	January**	1,8	2,0	2,2	2,0	2,0	2,0	2,0
* One sample from A - F								
** New sampling and analysis, loss on ignition instead of NIRS								

Table 2. Soil total-N (mg/kg)

		A	B	C	D	E	F	**Average**
2012	March							* 710
2012	November	1200	1250	1260	1270	1300	1250	1255
2013	November	990	930	1030	890	1040	1070	992
2014	November	1180	1030	1040	1120	970	1110	1075
2015	November	920	910	1100	960	1170	1170	1038
2016	November	1010	1240	1190	850	960	860	1018
2017	November	970	880	1100	910	1010	1070	990
2018	November	1020	1090	1290	1070	1200	1080	1125
2019	November	1140	850	910	1030	1240	830	1000
2020	November	1140	970	660	670	910	650	833
2021	January**	1010	1070	1140	1060	1050	1090	1070
* One sample from A - F together								
** New sampling and analysis								

Printed in red the values which are questionable with actual knowledge as reference.

- The measured values of N-total in 2012 are remarkable higher than in all following years while the organic matter content is in line with the other years. This results in a very low C/N in 2012 (8 on average). In 2013 it is 10 on average and comparable with the following years. In 2019 a new analysis was done on the 2012 samples. This resulted in much lower values of N-total (on average 900 compared to 1255 in the original analysis) and comparable values for organic matter (on average 1.6 compared to 1.7 in the original analysis
- In 2019 and 2020 a number of measurements from both organic matter and N-total are below or far below what could be normally expected, even when taking the margin of error into account. Because of this, new samples have been gathered and analysed in January 2021, both by Eurofins. Organic matter has been analysed by Loss On Ignition instead of NIRS, and N has been analysed according Dumas. In these results both organic matter and nitrogen are for all six fields in the same range, as expected in pseudo-repetitions, and in line with the years before.

The organic matter and nitrogen data are analysed statistically in Genstat 19.1, regression analysis. For nitrogen the 2012 data were excluded. For nitrogen and organic matter, the November 2020 data are excluded and the January 2021 data included, Table 3.

Table 3. Results of regression analysis Total-N (mg/kg) and Organic matter (%)

Parameter	**Total N**	**OM**
p-value	0.502	0.336
Intercept	-8684.	-18.2
Slope	4.82	0.0100
Result	NS	NS
NS = not significant		

Taking into account the remarks about the measurements and the results of the statistical approach we conclude that the level of organic matter and total-N is stable. This is used as input for the Ndicea modelling and the interpretation of the results, shown in the next paragraph.

2.3.2 Based on mineral N measurements

The graphical representation of the model results of the six plots is shown in Appendix 3. Table 4 summarizes the assessment of the six plots.

Table 4. Judgement of model results

	1	2	3	4	5	6	7	8
Field	n	RMSE	# Sim>=Obs	# Sim<Obs	# deficiency	Delta N	Delta OM	Pattern
A	34	17	12	22	1/14	-1	-88	
B	36	22	14	22	1/19	4	33	
C	35	27	15	20	0/16	-5	-291	
D	34	20	13	21	3/17	-9	-234	
E	30	23	13	17	1/14	-7	-371	
F	34	29	17	17	0/15	-1	-87	
sum	203		84	119				
%			41%	59%				
average		23				-3	-173	

Explanation:

Column 1: number measurements mineral N 0-30 cm

Column 2: RMSE of simulated and observed values mineral 0-30 cm (kg/ha)

Column 3: Number of measurements in which the simulated value is equal to or higher than the measured value

Column 4: Number of measurements in which the simulated value is lower than the measured value

Column 5: Number of crops with simulated N-shortage / total crop number

Column 6: Calculated decrease in soil-N, kg jaar^{-1}

Column 7: Calculated decrease in soil organic matter, kg jaar^{-1}

Column 8: Qualitative judgement of the pattern of increase or decrease of soil mineral nitrogen: does the simulation follow the changes in measured values?. Green = satisfactory, orange = mediocre.

In two out of six fields the RMSE (Column 2) is <= 20 , which is proposed as maximum value for acceptable model result (van der Burgt et al., 2006).

The model has a tendency to underestimate the available nitrogen (column 3 and 4).

The number of crops with a simulated nitrogen shortage (Column 5) is low. In most cases this shortage is not much bigger than the supposed model margin of error (20 kg).

The as good as stable simulated soil organic matter (column 6) resembles the results of the statistical analysis of total-N, paragraph 2.3.1.

The simulated small decrease of soil organic matter resembles the results of the statistical analysis of soil organic matter, paragraph 2.3.1. Two things are remarkable. The decrease in organic matter (carbon) is bigger than the decrease in total-N, resulting in a small decrease of C/N (too small to be measurable). Also remarkable is the difference between field B with a small calculated increase and field E with a decrease. All fields are pseudo repetitions, but apparently small differences in applied organic matter (Cut&Carry fertilizer, crop residue, root mass, green manures) are substantial enough to result in such a difference.

Our overall conclusion is: the simulation resembles the observations well enough to justify the use of the simulation as base for system comparison.

2.3.3 The other fields on Kollumerwaard

In Table 5 the measured values of soil organic matter in three other Kollumerwaard fields are shown.

Table 5. Soil organic matter in %

	2013	2017	2018	2019	2020
Org P2	2,2	2,1	2,7	2,3	1,9
Org P7	2,2	2,5		2,2	1,5
Conv P4		3,5		2,5	2,3

Similar to the measurements of the Planty Organic fields there are changes over the years and differences between KW Org P2 and P7 which cannot be explained by agronomic arguments. If a margin of error is assumed from +/- 10% it could be said that the organic matter content in Bio P2 and Bio P7 is about 2.3%. The 2020 measurements are questionable, as discussed before.

2.4 Judgement of the other Ndicea scenarios

The measurements on the other six fields were much less intensive, so no quantitative judgement can be made. The graphic presentation can be found in appendix 3. A qualitative judgement is given below.

KW Org

The simulated levels of mineral N correspond sufficiently with the observed values. For none of the crops a nitrogen deficit is calculated. The observed pattern of increase and decrease of mineral N of well followed by the simulation. There is no structural overestimate or underestimate of available N in the topsoil. Soil organic matter is stable or slightly increasing in the simulation.

> *Conclusion: when accepting the margin of error in the observed soil organic matter content the organic matter quantity stays at the same level, and a crop rotation scenario in Ndicea cab be based on these field scenario's.*

Bakker Bio

The simulated values of mineral N do not correspond well with the measurements. There is no crop with a simulated N-shortage. There is a tendency towards a underestimation of available N. There are no measured values of soil organic matter. However, the changes in simulated soil organic matter appear logic on fields with a comparable crop rotation and fertilizer management: in the field with a relative low organic matter content the level doesn't change while on the field with a higher content the simulation shows a small decrease.

Conclusion: it doesn't seem reasonable to create a general crop rotation scenario in Ndicea.

KW Conv

The simulated levels of mineral N do correspond well with the observed values. None of the crops shows a simulated N-shortage. The observed pattern of increase and decrease of mineral N of well followed by the simulation. There is no structural overestimate or underestimate of available N in the topsoil. Soil organic matter is stable or slightly decreasing in the simulation. A rough organic matter balance calculation according to the Dutch system of 'Effective Organic Matter' confirms this situation. The observed levels of soil organic matter on field 4 suggest a sharp decrease of 3.5% to 2.3%% within three years, which cannot be explained by actual knowledge of soil organic matter dynamic.

Conclusion: neglecting the unlikely decrease in measured soil organic matter content a Ndicea general crop rotation scenario can be constructed based on the field scenarios.

3 Planty Organic: changes in soil and crop mineral content

3.1 Soil

The changes in soil organic matter and soil total N are presented in the previous chapter because that functions as input for the model judgement. Here the other nutrients are discussed.

Keep in mind that in this experiment the main question was about nitrogen and organic matter, and that because of that the decision was made that no other input would take place. Decrease in soil parameters could be expected, but could also be prevented by realising external input is future.

In appendix 2 the complete chemical analysis data are shown. Here (Table 6) we look at P-PAE (Plant Available), P-Al , P-w , C/N , K-number, K-PAE en pH. The data on Calcium show some very unlikely values and are not discussed here, also because the soil is very rich in Ca. Several micro-nutrients have a presence below detection level in several of the nine years, so statistical analysis is not possible. The data on soil life are part of the total analysis bundle since only the last few years and are discussed neither.

Table 6. Data from regression analysis other soil parameters

Parameter	P-PAE	P-Al	Pw	C/N	K-number	K-PAE	pH
p-value	0.105	0.837	0.014	0.002	<.001	<.001	0.323
intercept	46.2	112.	1081.	-378.	2548.	7501.	26.9
slope	-0.0222	-0.036	-0.522	0.1922	-1.256	-3.692	-0.00972
conclusion	NS	NS	decrease	increase	decrease	decrease	NS
NS = not significant							

The phosphorus stock is huge (P-PAE ; P-Al) and this is in itself an explanation that a decrease cannot yet be measured. With regard to phosphorus, only the P-w shows a decease, being the P-parameter with a fast response on changes.

The C/N is increasing, also when the unreliable low levels of 2012 are not taken into account. This is an unquestionable change. There might be a certain relationship with N-efficiency.

The availability of Potassium is decreasing. This is a point of concern because Potassium is known to be important for leguminous crops, so for nitrogen fixation. The pH is not changing, despite the slightly acid character of the Cut@Carry fertilizer. This is not surprising, because it is a soil rich in Calcium.

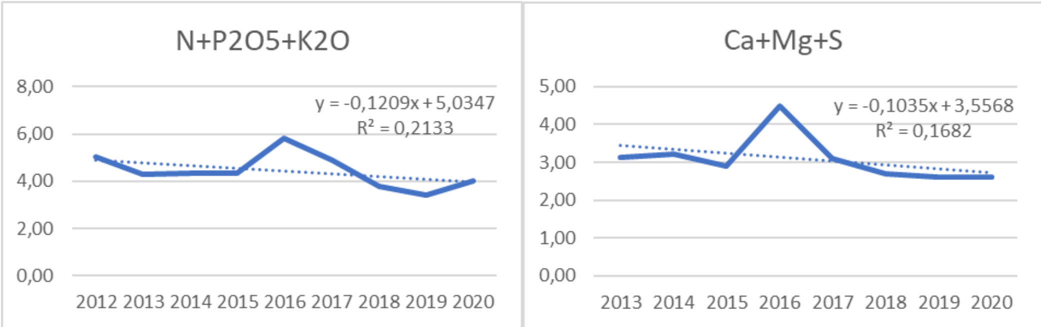
3.2 Crop

The nutrient content of the crops is analysed to get an impression of the relation between changes in soil and changes in plant nutrient content. This is not the central question of the study, but nevertheless interesting. Contrary to the soil there are no replicated measurements, so any result will not be more than an indication. In appendix 4 the graphs of the nutrient content of potato, carrot, oats, pumpkin and the wheat/ bean mixed crop are given together with the trend line. These are the crops which were continuously present since

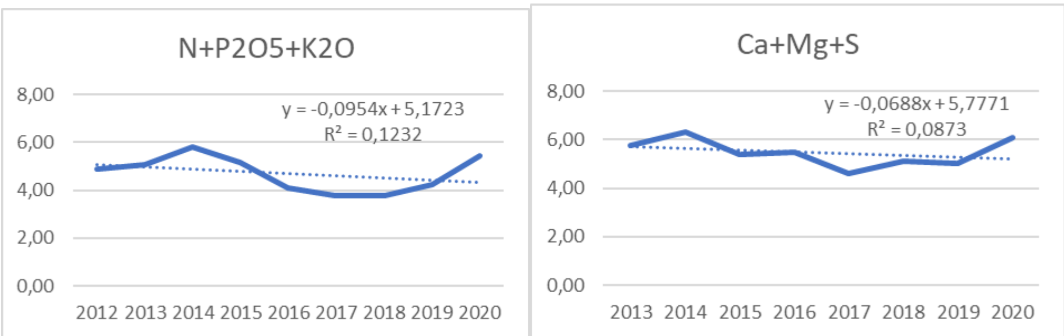
2015. Both measurements and trend lines show a wide diversity, and if a conclusion could be made it will be that there is no structural increase or decrease in nutrient content of the crops. Year effects and variety choice play also a role here.

In an attempt to summarize the results visually, in Figure 2 the data and trend lines are given of N-P2O5-K2O taken together and Ca-Mg-S taken together, for the five crops mentioned above. There might be a very small decrease overall, but there is visually no corresponding pattern in the graphs.

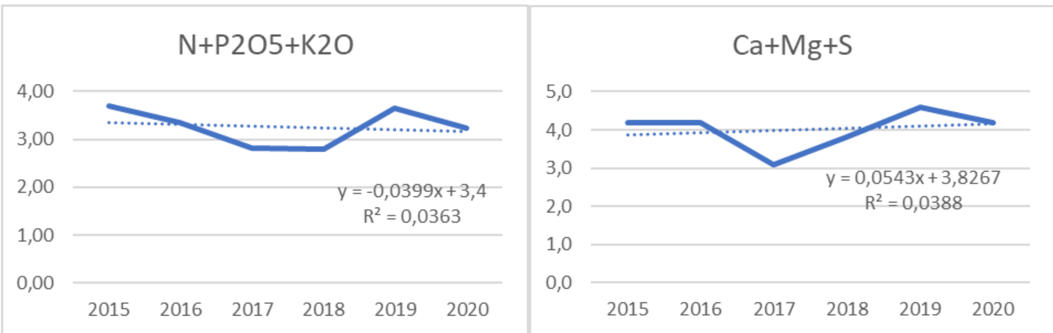
Seed potato (N+P2O5+K2O: % of d.m. ; Ca+Mg+S: g/kg d.m.)



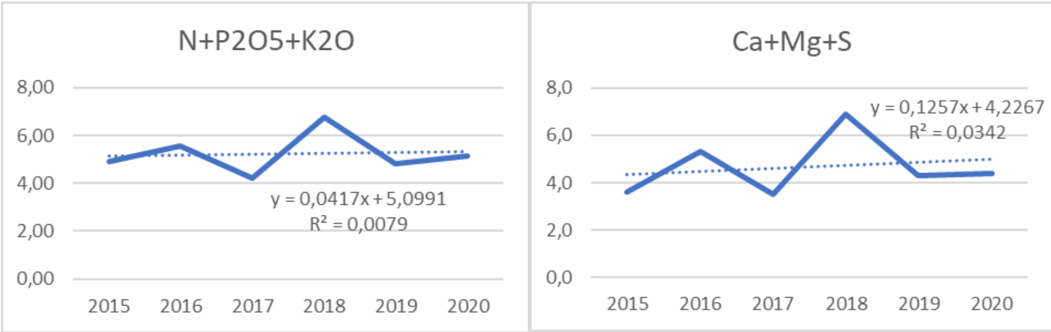
Carrots



Oats



Pumpkin



Wheat/fieldbean

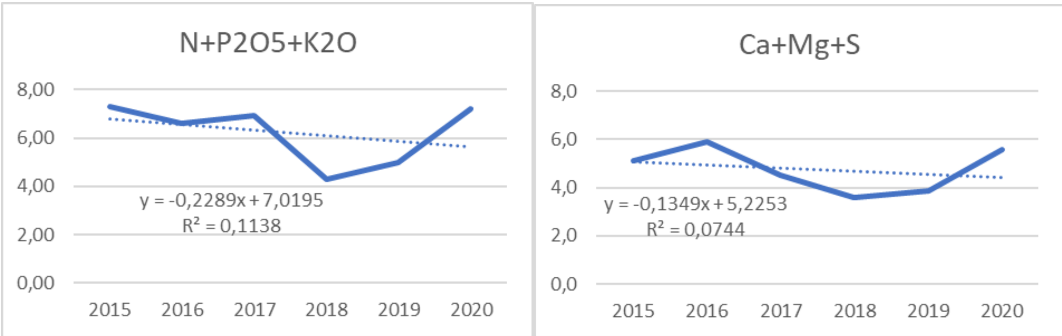


Figure 2. Nutrient content crops, summarized

4 System scenarios

4.1 Planty Organic

The soil parameters as used for the field scenarios are copied into the system scenarios. Weather data for all six years are Ndicea default data for the North of Holland. The initial values for the three pools of soil organic matter are slightly adapted to the average % soil organic matter in 2012: 1.73%. The distribution of the Cut&Carry fertilizer over carrots, oats and seed potato is done just as it was practice the last years. Average yield over the whole project period is used, but there were differences in the number of years in which a crop was grown (Table 7). Crop N-content in the system scenarios is the average of the nine years. Measurements of the last two years are used to determine the N-content of the crop residue and the ratio product/residue. Data of the green manure crops in the last two years (dry matter yield and N-content) are used, but this is a very limited amount of data.

Table 7. Yield

	# year	2012	2013	2014	2015	2016	2017	2018	2019	2020	Average
Cut&Carry fertilizer (in d.s.)	9	8799	9024	11434	8836	10008	10429	4511	9019	10939	9222
Pumpkin	7			16000	14400	27181	24697	19300	22583	20495	20665
Wheat/fieldbean (85% d.s.)	6				2980	2545	4776	4486	4339	8308	4572
Carrots	9	77477	80000	59725	82800	61000	59688	46566	71680	70313	67694
Oats	7		7836		3600	5188	5428	5827	4411	7164	5636
Seed potatoes	9	29229	34879	38000	35900	27550	39198	29367	42381	42213	35413

In Figure 3 crops and fertilizer application are put in a time line.

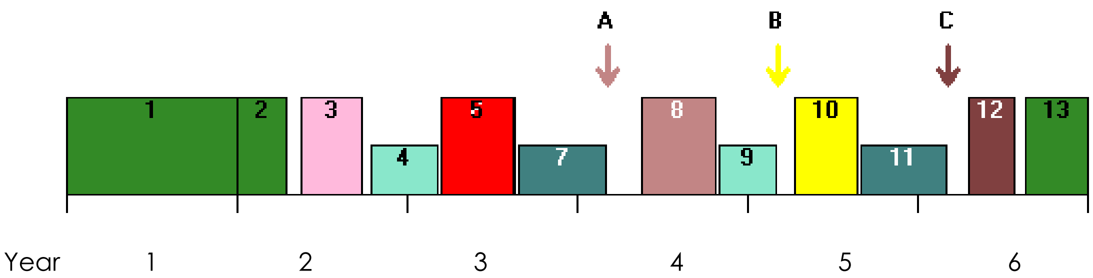
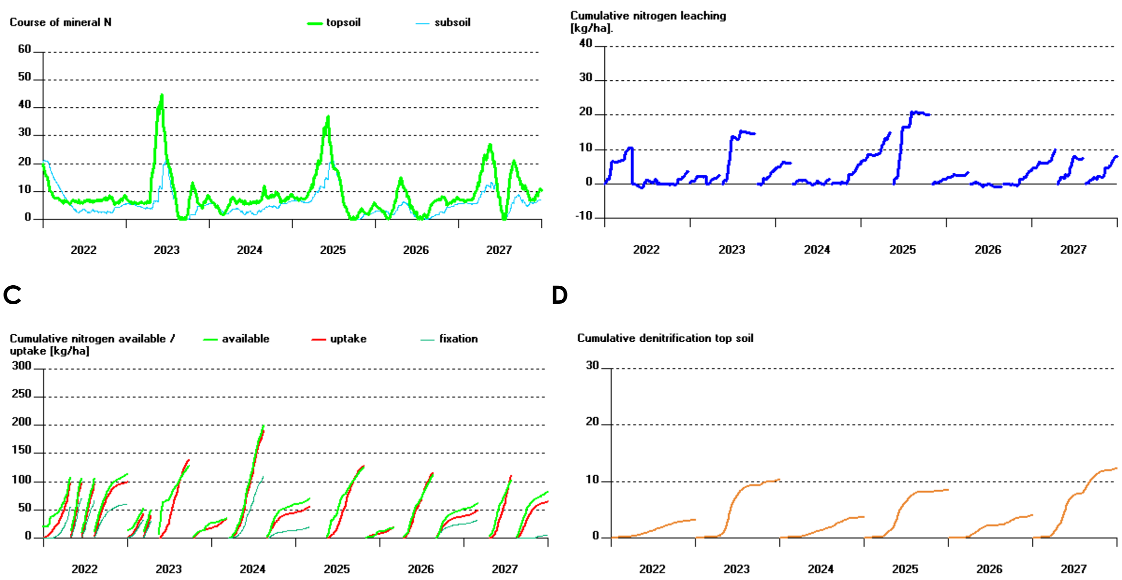


Figure 3. Overview crop sequence and fertilizer applications

1,2,13: Leguminous crop mixture ; 3: Pumpkin ; 5/6: Wheat/Field bean ; 8: Winter carrot ; 10: Oats ; 12: Seed potato .

4,9: Green manure without leguminous plants ; 7,11: Green manure mixture with leguminous plants.

A: Cut&Carry fertilizer, about 20% of last years' stock . B:the same, about 30% ; C: the same, about 50%.



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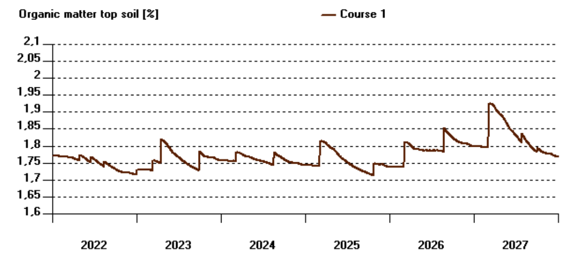


	N kg/h
Fertilizer suplied	0
Nitrogen fixation	80
Deposition	21
Total supply	101
Product removal	77
Calculated remainder	24
Volatilization	0
Denitrification	7
Leaching / Denitrification subsoil	17
Increase soil N	-1

Figure 4. Result graphs Planty Organic

For the judgement of this system the Ndicea calculation is repeated once, which means that he results of the second 6-year crop sequence are shown (Figure 4). By doing so, the uncertainty of the initial values of the soil organic matter are substantially reduced. Graph A and C show that available nitrogen is closely followed by requested nitrogen (Graph C, green line respectively red line). Calculated nitrogen shortage (green line crossing the red line) are limited in number and the amount of nitrogen shortage stays within the uncertainty of the model. This results in very low levels of soil available mineral nitrogen (Graph A). It also illustrates that the system is dominantly nitrogen-limited.

Leaching is very low (Graph B). After pumpkin and carrots the leaching is relatively high but still at a low level. The pumpkin profits from the nitrogen which becomes available after the clover-alfalfa sward. This nitrogen is not completely taken up by crop and green manure (sown late, if sown). With some assumptions the leaching water contains 3 mg Nitrate-N l^{-1} where the EU maximum allowed level is 11 mg Nitrate-N l^{-1}. Denitrification is very low (Graph D), mainly caused by the overall very low level of nitrate in the topsoil (Graph A). The soil organic matter level is stable (Graph E).

The mineral balance shows that nitrogen fixation by Cut&Carry fertilizer, field bean and green manures together is 80 kg N ha^{-1} $year^{-1}$. This is the input for the system, together with 21 kg deposition resulting in 101 kg N-input ha^{-1} $year^{-1}$. N-turnover in Cut&Carry fertilizer is 48 kg, so more than half of the fixed nitrogen. This is internal nitrogen, so it is not visible as fertilizer input in the balance, but it is of course an essential shackle in the chain. From the yearly input, 77 kg N is sold in products, resulting in a surplus of 24 kg ha^{-1} $year^{-1}$.
Volatilization in this system is zero because no manure or artificial fertilizer is used. The denitrification is 7 kg ha^{-1} $year^{-1}$ and could be reduced only by reducing the N-mineral level in the cultivation of pumpkin and potatoes. This is out of economic viewpoint no option.
The leaching is 17 kg N ha^{-1} $year^{-1}$. Best option for reducing this is a better growth of the green manures. This means a very short time interval between harvest of the main crop and sowing of the green manure. In case of oats and maybe wheat/bean undersowing of the green manure might be considered.
Soil organic matter is stable, as is the soil total N. On average 87% of the time there is a growing crop covering the soil surface. 51% of the time a leguminous crop is growing: a 100% leguminous mixture (Cut&Carry fertilizer) or mixtures with not-leguminous components (wheat/bean; green manure)

4.2 KW Org

The Ndicea KW Org system scenario is based on nine field scenarios 2011-2020. Two fields were part of the 'Stikstof Telen" project 2019-2020 (KW Org P2 and P7) and were monitored parallel to the Planty Organic fields. The Ndicea simulations proved to be acceptable to use as input for the system scenario.
The nine-year crop rotation has only minor variations from year to year. Together with the farmer an 'average' rotation was composed with appurtenant fertilizer applications and yields. The nutrient content of the applied fertilizers was deducted from laboratory measurements. The nutrient content of products and crop residues were taken from the Ndicea crop database. The soil parameters are the same as those used in the Planty Organic Scenario with one exception: soil rooting depth was set at 90 cm. Here the results of the second calculated crop rotation are presented.

In Figure 5 crop sequence and fertilizer applications are shown. In Table 8 the yields of this organic arable system are given. Figure 6 shows the Ndicea results.

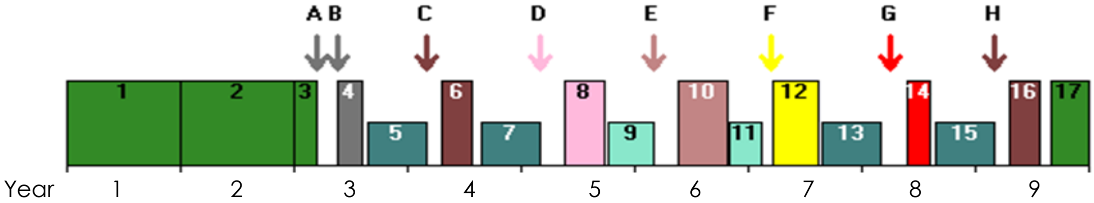


Figure 5. Overview crop sequence and fertilizer applications

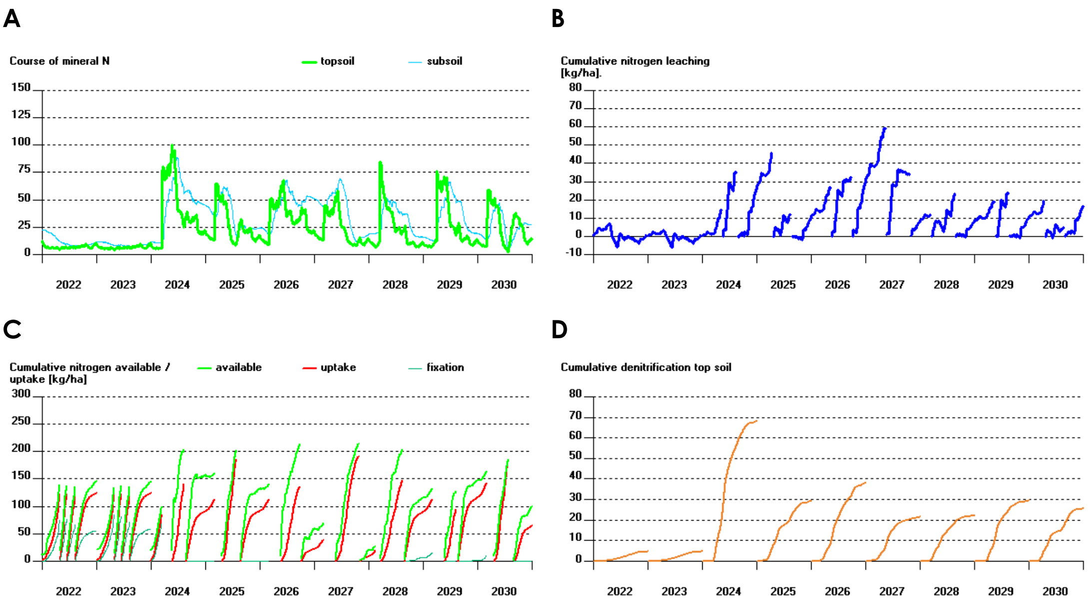
1,2,3,17: Grassclover ; 4: Cauliflower ; 6: Seed potatoes ; 8: Pumpkin ; 10: Wintercarrot ; 12:Spring wheat ; 14: Green beans ; 16: Seed potatoes .

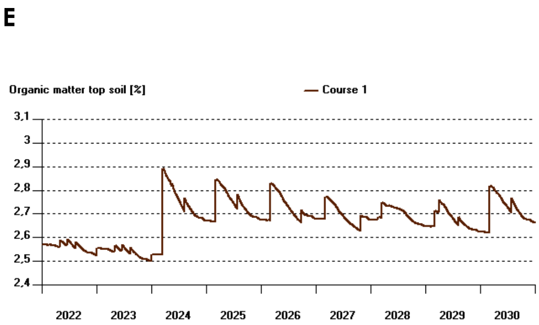
5, 7, 13, 15: Green manure mixture with leguminous species ; 9,11: Green manure without leguminous specious.

A: Goat manure 35 ton/ha ; C: GM 25 ton ; D: GM 20 ton ; E GM 15 ton ; H: GM 25 ton ; B: organic pellets 25 kg N ; F: Cattle slurry 40 ton ; G: Cattle slurry 35 ton

Table 8. Yields (Grassclover: in dry matter)

	ton/ha
Grassclover	11,5
Cauliflower	20
Seed potatoes	40
Pumpkin	22
Winter carrot	70
Spring Wheat	5,8
Green beans	12





	N kg/h
Fertilizer application	148
Nitrogen fixation	76
Deposition	21
Total supply	245
Product removal	138
Calculated remainder	107
Volatilization	5
Denitrification	27
Leaching / Denitrification subsoil	44
Increase soil N	25

Figure 6. Result graphs KW org

Looking at Seed potatoes, Winter carrot and Pumpkin, the crops which are part of both crop rotations, the yield of KW Org are at a higher level, but not substantially higher.
KW Org has clearly a higher level of nitrogen availability (Graph A and C) than Planty Organic. The nitrogen fixation is comparable, but here manure is added to the system. Nitrogen removal is twice that of Planty Organic, including the two years of grass clover which is sold. Taking into account the produce for human consumption, it is 70 kg ha^{-1} yr^{-1}, so a bit lower than in Planty Organic. The level of mineral nitrogen in 0-30 cm (Graph A, green line) is in general higher than in Planty Organic and the gap in Graph C between availability (green) and demand (red) is bigger. Only in case of the seed potatoes availability and demand stay close together.
Leaching and denitrification (Graph B and D) are twice that of Planty Organic. Denitrification (Graph D) is higher due to the higher mineral N level (Graph A). There is some volatilisation due to the application of manure. The calculated remainder is not lost completely: 25 kg ha^{-1} yr^{-1} is added to the soil as increase in organic matter bound nitrogen.
On average 83% of the time the soil is covered with a growing crop. 53% of the time the growing crop has a leguminous component: grass clover, green beans, green manures. This is about the same as in Planty Organic.

4.3 KW Conv

The Ndicea system scenario KW conv is based on six field scenarios 2016-2020 from which two fields (KW Conv P1 and P4) were monitored in 2019 and 2020 parallel to the Planty Organic fields. The field model results were sufficient accurate to be the base for the system scenario.
The crop rotation is relatively stable, but a seed potato cultivation 1:4 within a six-field farm set-up implicates some irregularities in the crop sequence. Together with the farm manager a best look-alike crop rotation was defined together with corresponding fertilizer scheme and yields. Due to this, two crops which are a more or less regular part of the crop rotation are not present in the scenario: winter barley and onion. Mineral content of the organic fertilizers are taken from measurements. Nutrient content of products and crop residues are taken from the Ndicea default database. The soil parameters are the same as those used in the Planty organic and KW org scenarios. Maximum rooting depth of the soil is set at 90 cm, the same as for the organic system. The starting value of soil organic matter is 2.8% in 0-30 cm. Soil cultivation is regularly done by ploughing, so in Ndicea the 'conventional soil cultivation' is selected.
Here the results are shown from the second crop cycle. Figure 7 shows crop sequence and fertilizer applications. In Table 9 average yields are listed. In Figure 8 the results of this system scenario are presented.

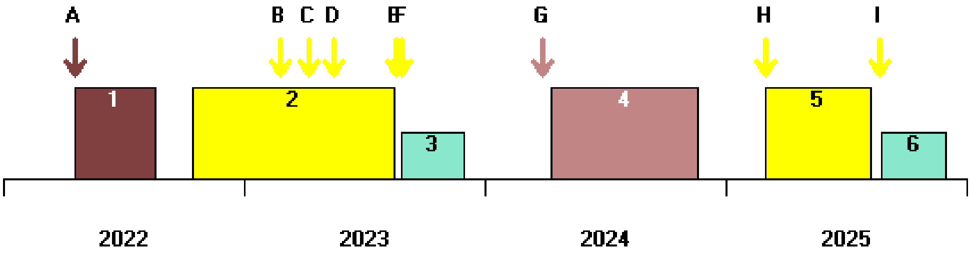
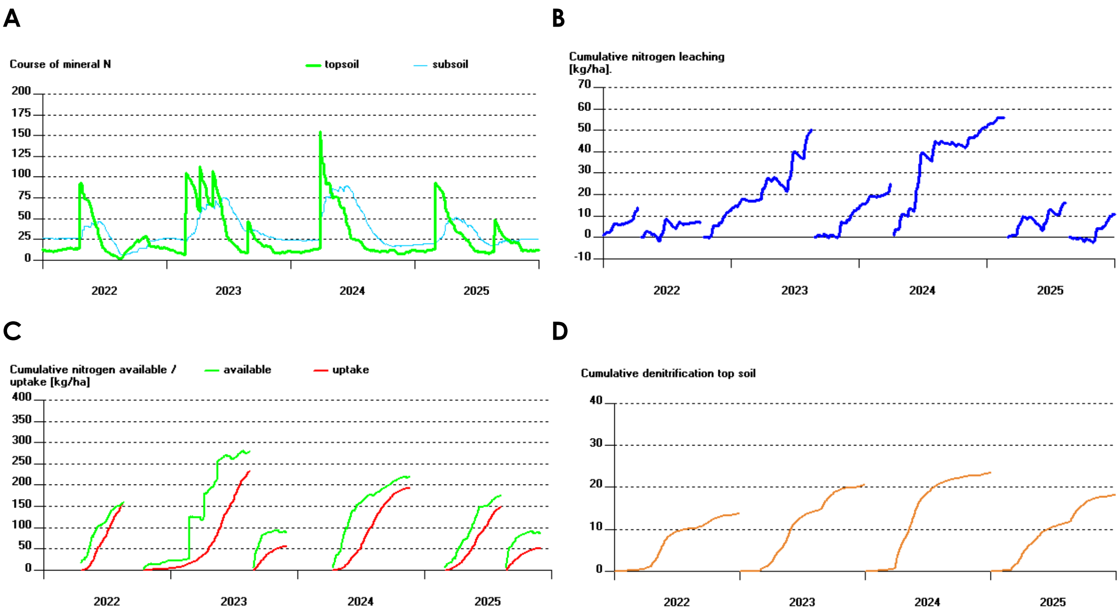


Figure 7. Overview crop sequence and fertilizer applications
1: Seed potato ; 2: Winter wheat ; 4: Sugar beet ; 5: Spring barley
3,6: Green manure mixture without leguminous component
A: Artificial Fertilizer 80 kg N ha⁻¹ ; B: AF 100 kg ha⁻¹ ; C: Dairy slurry 25 ton ha⁻¹ ; D: AF 50 kg N ha⁻¹ ; E: Compost 25 ton ha⁻¹ ; F: AF 40 kg N ha⁻¹ ; G: AF 140 kg N ha⁻¹ ; H: AF 80 kg N ha⁻¹ ; I: AF 40 kg N ha⁻¹.

Table 9. Yield KW org

	ton/ha
Seed potatoes	44
Winterwheat	9,5
Sugarbeet	85
Spring barley	7



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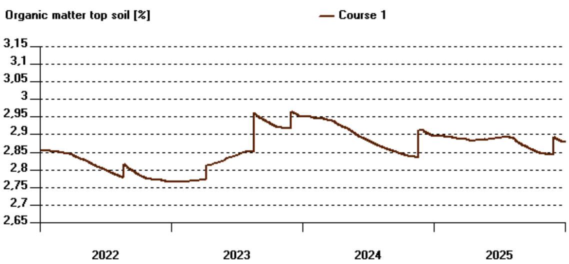


	N kg/h
Fertilizer suplied	189
Nitrogen fixation	0
Deposition	21
Total supply	210
Product removal	135
Calculated remainder	76
Volatilization	6
Denitrification	19
Leaching / Denitrification subsoil	47
Increase soil N	6

Figure 8. Result graphs KW org

The seed potato yield is only a bit higher than in KW org, which is in its turn a bit higher than Planty Organic. The other three crops are not part of the KW organic or Planty Organic system; the yield level is comparable to that of the region.

In case of the seed potato growth, the nitrogen availability is closely related to nitrogen uptake. When harvested, the soil profile contains only a small amount of residual nitrogen (graph A and C). All other crops have a higher level of residual nitrogen at harvest time. Due to the fertilizer regime there are high but short-during peaks in soil mineral nitrogen 0-30 cm (graph C). Nitrogen leaching occurs mainly after winter wheat and sugar beet (graph B) but is in general comparable with KW org.

The denitrification (graph D) is closely related to the soil mineral N level 0-30 cm. Soil organic matter content is almost stable, maybe increasing a bit (graph E). The contribution of the compost application after winter wheat is decisive.

Nitrogen amount sold as product is twice the amount as it is in KW org and Planty Organic. On average 68% of the time the soil is covered with a growing crop. Leguminous crops are not present, although a leguminous component in the green manures is considered now.

5 Comparison of the system scenarios

This chapter compares characteristic properties of the three arable systems at Kollumerwaard. In outline, these are input - throughput - output properties. In the case of Planty Organic and KW Conv, this is limited to field level; in the case of KW Organic, a small further step is made because of the sale of grass clover and the purchase of manure. The parameter of focus is nitrogen, with a small excursion into organic matter. 'Production' is defined here as 'Nitrogen in product sold'.

5.1 Input – output

Table 10 gives an overview of the three systems in terms of input and output. In addition, it shows what happens to the nitrogen surplus. All numbers in kg per hectare per year.

Table 10. Input – output, N in kg/ha

	N-input					N-output	
	Fixation	**Manure**	**Art. Fertiliser**	**Deposition**	**Total in**	**Product**	**GrassClover**
Planty Organic	80	0	0	21	101	76	
KW Org	76	148	0	21	245	73	68
KW Conv	0	57	132	21	210	125	
	Volatilisation	**Denitrification**	**Leaching**	**Increase in o.m.**	**Total loss**		
Planty Organic	0	7	17	-1	24		
KW Org	5	27	44	25	76		
KW Conv	6	19	47	6	72		

N-fixation

N-fixation is similar at Planty Organic and KW Org. That's N input virtually without further environmental impact such as CO_2 emissions for fertilizer production.

Fertilizer use

KW Org and KW Conv make use of organic manure and compost, which can be seen as recycled products. In case of animal manure, land use 'elsewhere' comes into the picture, and so 'supply of animal feed from elsewhere', but such an overall analysis is far beyond the scope of this study. In the case of KW Conv, N-fertilizer is supplied with the accompanying CO_2 burden. This is also beyond the scope of this report but is mentioned.

Production

The production of Planty Organic and KW Org is comparable. The sold grass clover at KW Org (average 68 kg/ha) could be offset against part of the organic manure supplied. However, with that transaction a return of 50% of the amount of nitrogen (Fuchs, 2020) can be expected because the rest is transformed into milk and meat (20%) and is lost in the manure pathway (30%). With this assumption, the supply of organic manure at KW Bio could thus be mathematically reduced by 34 kg and end up with 114 kg of external supply.

The production of KW Conv is twice as high as for Planty Organic and KW Org. However, of the 135 kg mentioned, 10 kg is removal in the form of straw, so not for human consumption.

Cut&Carry fertilizers versus feed -> manure

A characteristic difference between the use of (grass) clover as a Cut&Carry fertilizer or as a livestock feed with manure as a return product is around 30% loss of nitrogen at production level and 50% loss of nitrogen viewed from a farm that makes the choice between utilizing Cut&Carry fertilizer itself or selling it as livestock feed and applying manure.

Losses

Planty Organic is distinguished by very low volatilization, denitrification and leaching. KW Org and KW Conv are a bit similar in that respect, but the denitrification is higher in KW Org. This is largely explained by the high peak in cauliflower cultivation. The rest of the difference can be explained by a combination of overall higher N-mineral level and a higher level of conversion of organic matter (soil life activity).

Soil organic matter and organic N

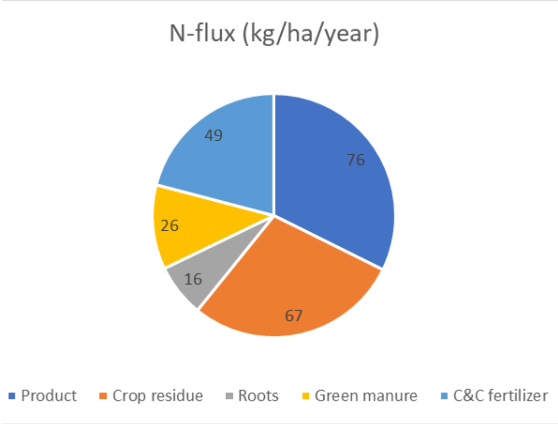
Planty Organic is able to maintain soil nitrogen and organic matter levels without external inputs. At KW Org the level of soil organic N rises slightly, with the supply of external fertilizer as the most important explanatory factor. Of course, grass clover also plays a role in this. The conventional system is almost stable in soil nitrogen and soil organic matter. Compost supply and two of four years of cereal cultivation (with a substantial root mass) are the explanatory factors.

5.2 Throughput

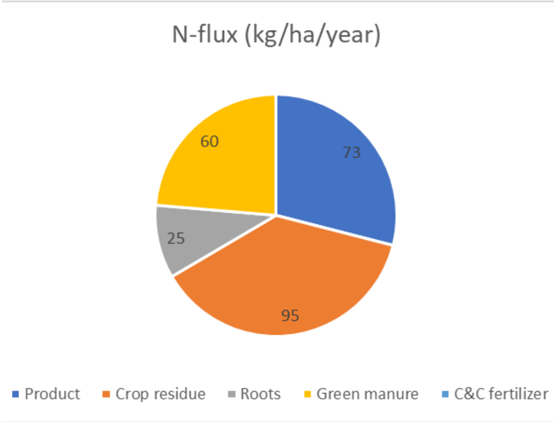
This section discusses the internal flows of nitrogen. Fertilization is only one of the sources of nitrogen for crop growth in the ongoing season. A significant part of the nitrogen supply is delivered by the soil: mineralization of all organic amendments from previous years. This can be taken into account when preparing a fertilization plan.

The N-flux towards crop growth, split up into product, crop residue and root residue, has been examined. In addition, the Cut&Carry fertilizer (Planty Organic), grass clover (KW Org) and straw sold (KW Org and Conv) are portrayed. Figure 9 is the graphical representation, Table 11 gives the values in kg/ha/y and in % for the three systems.

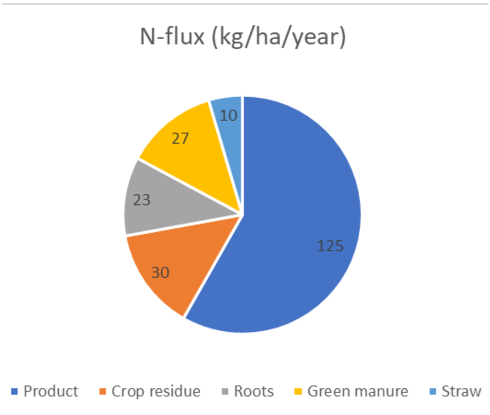
Planty Organic. Average yearly N-flux 235 kg/ha



KW Org. Average yearly N-flux 324 kg/ha



KW Conv. Average yearly N-flux 215 kg/ha



	Planty Organic		KW Org		KW Conv	
	kg/ha	%	kg/ha	%	kg/ha	%
Product	76	32	73	23	125	58
Crop residue	67	29	95	29	30	14
Roots	16	7	25	8	23	11
Green manure	26	11	60	18	27	13
C&C fertilizer	49	21				
Grass clover			69	21		
Straw			2	1	10	5
Total	235		324		215	

Figure 9. Destination of N-uptake, in kg average per year and per hectare.

Table 11. Destination of N-uptake, in kg average per year and per hectare

The following observations can be made on this.

- The N-flux, i.e. the total nitrogen taken up by plants on average per hectare per year, is highest for KW Org. Planty Organic is considerably lower and KW conventional is in the same order of magnitude as Planty Organic.
- The N sold in products (excluding straw and grass-clover) is 66% higher for KW Conv than for Planty Organic and KW Org.
- Crop residues show large differences. KW Conv is low because two out of four years is grain cultivation with straw removed. KW Org is high because the crop residues from grass clover cultivation are significant. Perhaps there is an overestimation because the default values of Ndicea were used. There are too few measurements to say more about this.

- The root residues are especially high on KW Org because of the biennial grass clover. At KW Conv the amount is similar but the main source here is two out of four years of cereal cultivation.
- KW Org is higher than the other two systems in terms of green manures. There are relatively more years with green manures, and also relatively many years where the green manure can be sown early resulting in a higher production.
- Planty Organic's Cut&Carry fertilizer contains less nitrogen per hectare on average than KW Org grass clover because it is only 1:6 in the crop rotation and the grass clover 2:9. The N-content itself is higher in the Cut&Carry fertilizer.

5.3 Interpretation

Most strikingly is the difference in production compared to 'internal'. In KW Conv more than half of the N flux is converted into marketable product, and only 90 kg/ha remains internal. For Planty Organic, 32% ends up in marketable products and 159 kg is in internal circulation. For KW Organic, those numbers are 23% production and 251 internal where the grass clover is virtually exchanged for animal manure. However, the large internal N flow at Planty Organic does not lead to low nitrogen efficiency. This can be seen in Table 12, where 21 kg of deposition is included as input and straw (KW Conv) is not included as output. KW Org is not shown because there the grass clover is partly converted to manure with in between animal production and N-loss, which makes the calculation of N-efficiency considerably more complex. That is outside the scope of this study.

Table 12. N-efficiency

	In *	Out	N-efficiency
Planty Organic	101	76	75
KW Conv	210	125	60
* inclusive deposition, 21 kg/ha/jr			

The N-input next to deposition within the Planty Organic system does require land area but in addition little external energy (tractor and seed) while with KW Conv, with a substantial amount of N-fertilizer, this involves a hefty energy and therefore CO_2 cost.
The 'output' next to the production concerns loss costs (Table 10) and these are three times higher at KW Conv than at Planty Organic. KW Org is in terms of losses comparable to KW Conv.

In the Planty Organic system, by far the largest part of plant nutrition goes through the soil and not directly from (green) manure to plant. A system geared to this process must be designed for it as a whole. This is the case with Planty Organic:

- Hardly ever an N-mineral content in the top soil is higher than 40 kg N ha^{-1} because no artificial fertilizer or animal manure is used. This results in relatively low denitrification and potentially low leaching.

- No volatilization of nitrogen from fertilizer or animal manure.
- N-input entirely plant-based, see previous point. This is characterized by relatively slow nitrogen availability which can be seen as an advantage in this context.
- Maximum coverage of the soil with a growing crop. This is particularly important in the autumn and winter in connection with an excess of precipitation. This also plays a role in protecting the soil structure and in nurturing soil life year-round.
- Maximum use of green manures, see previous point
- Optimal soil structure through non-inversion tillage and GPS controlled traffic farming. This provides maximum opportunity for roots to absorb nutrients.
- Non-inversion tillage to maintain the stratification of the soil layers in the top soil.
- Sophisticated crop rotation with a view to nitrogen utilization, but also to alternating above-soil products (Leguminous crops, cereals) and in-soil products (Carrots, potatoes), weed control and hygiene with regard to diseases and pests.
- Biodiversity above ground and below ground through extensive crop rotation, clover/ alfalfa mixture, wheat/field bean mixed culture and green manure mixtures.

6 Farm economics

This report is not the place to compare the economic potential of conventional arable farming with that of organic arable farming. For that, one can look at the CBS figures and the professional literature. In summary it can be said that many organic arable farms are certainly not doing worse than conventional arable farms.
A comparison between Planty Organic and KW Org is possible, but the crops grown are partly different and that has an impact. A comparison between Planty Organic and a similar rotation with exchange (sale - purchase) of grass clover (instead of clover/ alfalfa) and manure is also possible.

6.1 Comparison Planty Organic and KW ORG

Table 13 provides an outline comparison of these two systems. Data per hectare.

Table 13. Comparison Planty Organic and KW Org

		Yield/ha			
	Product price	**Planty Organic**		**KW Org**	
	Euro/ton	**ton**	**€**	**ton**	**€**
Clover/Alfalfa mixture					
Pumpkin	€ 380	20,7	€ 7.853	22,0	€ 8.360
Wheat/Fieldbean	€ 400	4,6	€ 1.829		
Carrot	€ 180	67,7	€ 12.185	70,0	€ 12.600
Oats	€ 500	5,6	€ 2.818	5,8	€ 3.150
Seed potatoes	€ 700	35,4	€ 24.789	40,0	€ 28.000
Seed potatoes	€ 700			40,0	€ 28.000
Green beans	€ 400			12,0	€ 4.800
Cauliflower					€ 1.800
GrassClover 1st yearr	€ 110			11,5	€ 1.265
GrassClover second year	€ 110			11,5	€ 1.265
Total revenu			€ 49.474		€ 89.240
Hectare number			6		9
Revenueper ha (including nil Clover/Alfalfa)			€ 8.246		€ 9.916
Costs per ha (including purchase of compost)			€ 2.756		€ 2.115
Results			€ 5.490		€ 7.801
Loss per hectare			€ 2.311		

Revenue

- Planty Organic's physical yields are on average 6% below those of KW Organic but the seed potato with the highest kilogram price is 11% below it.
- At Planty Organic, the clover/alfalfa does not yield any revenue, only a savings on fertilizer costs (see below). KW Org grass clover does result in revenue.
- KW Org has relatively more seed potato in the rotation (2:9) than Planty Organic (1:6) having a high revenue.
- KW Org has another relatively high-yielding crop: green beans.

Costs

- The grass clover in KW Bio requires only one tillage and sowing activity for two years of production. The rest of the work is done by the buying party. Planty Organic incurs higher costs (more expensive seed) for only one year of production.
- The leased land for cauliflower cultivation in KW Bio does not incur any costs.
- In Planty Organic, no manure was supplied until now, so zero costs. For this calculation, the plans for continuation were assumed: an average of 15 tons of high-quality compost per hectare per year. That is more expensive than the current manure supply at KW Org.

Net result difference

All in all, the Cut&Carry fertilizer system at Kollumerwaard results in a disadvantage of € 2,311 per hectare compared to KW Org. In summary, this is due to differences in crop rotation and choice of crops, differences in fertilization costs, differences in yield of grass-clover versus cut-yield fertilizer and relatively small differences in physical yield in which seed potatoes count heavily. A Cut&Carry fertilizer system with 2:9 seed potato cultivation would look more favourable.

6.2 Comparison Planty Organic and variant manure

Quantitative comparison

In this calculation (Table 14) the clover alfalfa Cut&Carry fertilizer is replaced by grass clover which is sold, and animal manure is applied as it is done usually on KW Org. Yields are equalized at the level of KW Org. So here all is equalized except for clover/ alfalfa versus grass/clover, and use of Cut&Carry fertilizer versus sale of grass clover and purchase of manure.

Table 14. Comparison Cut&Carry fertilizer system and exchange grass clover - manure

	Cut&Carry fertilizer	Grassclover sold, manure purchased
Crop revenu	€ 8.246	€ 9.744
Costs	€ 2.756	€ 2.162
Result	€ 5.490	€ 7.582
Loss per hactare	€ 2.093	

In the Cut&Carry fertilizer system, a compost price of €15 per ton was calculated. That is an expensive compost. In the case of the manure, the calculation was made at € 15 per ton. In both cases, applying it to the land costs € 4 per ton.

- The crop yield goes up (assumption) to the current level KW Organic plus the selling price of the grass/clover.

- The costs decrease mainly because fewer tons of manure are delivered than compost.
- A small factor is the lower cost of grass clover compared to clover alfalfa Cut&Carry fertilizer.

The loss per hectare is still considerable.

Reflection: regional cycling.

The Planty Organic Cut&Carry fertilizer system can, in principle, realize a regional cycle for the plant nutrients besides nitrogen with supply of regional residual flows. A P_2O_5 return flow of 30 kg/ha could be maintained, which amounts to equilibrium with nutrient outflow. If a clean natural compost with 2.5% P2O5 is chosen, this amounts to 12 tons per hectare per year. In case of the sale of grass clover and the purchase of animal manure in the quantities shown in the above example, there is a net phosphate supply to the farm. The removal compared with Cut&Carry fertilizer increases by 15 kg P_2O_5 per hectare (sale of grass clover) to 45 kg, and the supply amounts to 53 kg P_2O_5 per hectare.

Reflection: manure and market

With a different choice of compost (€10 per tonne) and a 50% increase in the price of organic solid manure, the loss in the Planty Organic system is only €200 compared to the feed-manure system. If the allowed use of conventional manure is reduced from the current 30% to 0%, it is inevitable that a strong upward effect on prices will occur. Growers will then respond by adjusting not only their fertilization practices, but also their cultivation planning and crop rotation. The latter will be accompanied by elements from the Cut&Carry fertilizer system without the need to copy it completely.

Reflection: another example

Dutch organic arable farmer van Strien switched completely to a Cut&Carry fertilizer system in 2020 after years of building up experience. This is a 90-hectare arable farm with 20 hectares for the production of Cut&Carry fertilizer, so 2:9 Cut&Carry fertilizer. He assumes unchanged yields, and calculates €100 per hectare as additional costs for fertilization. The latter is partly because he has been able to supply regional compost cheaply. He is willing to pay the extra costs to exclude the risk of introducing residues of crop protection residues in (conventional) straw in organic manure.

7 Conclusions and recommendations

7.1 Conclusions

The six Planty Organic fields were monitored and modelled in Ndicea for a period of nine years. The field scenarios proved sufficiently reliable to serve as a basis for a general crop rotation scenario. This was also true for the plots of KW Org and KW Conv added in 2019; unfortunately not for the two scenarios of Bakker Bio which was therefore not included in the system comparison.
Based on the crop rotation scenarios and all other information and experiences, we came to the following conclusions:

Agronomic:

- The Cut&Carry fertilizer system has proven to be feasible in practice.
- There is a hefty list of sub-measures that all, coordinated together, make the system run and robust.
- The soil quality measured in terms of organic matter and nitrogen remains stable in Planty Organic, without any input from outside. This is a remarkable conclusion. Non-inversion reduced tillage plays probably a significant role in this. The KW Conv system has a modelled modest growth of soil organic matter and nitrogen. In efficiency terms that seems like "loss" but we consider it as "investment in future soil fertility".
- Yields per hectare in Planty Organic are slightly lower than those of an organic arable system based on animal manure and significantly lower than the KW Conv system. However, this Cut&Carry fertilizer system requires one unit of land area to keep the other five units productive. This unit does not directly generate income.
- A different crops choice and crop rotation can significantly reduce the financial gap (this is interpretation, no direct result of this experiment).
- There is an extremely high degree of nitrogen utilization in which the nitrogen is obtained exclusively through the natural process of biological nitrogen fixation. The other two systems score less well.
- The high degree of nitrogen use efficiency goes hand in hand with a high degree of field-internal flows of organic matter and nitrogen. This counter-intuitive observation may well be a key point in the process: there is a high degree of efficiency and stability because there are large internal flows, but this requires further research.
- The nitrogen losses through volatilization, denitrification and leaching are very low. This results in a calculated groundwater load of 3 mg NO3 l-1 (the maximum standard is 11 mg l-1). The other two systems have higher losses though below the maximum.
- There are no significant problems with diseases and pests in Planty Organic with the exception of Phytophthora, as is common in organic farming.
- In nine year there is a tendency towards an increased weed pressure. This might lead to small adaptations in the system.

- The only externalization of resources is seed, diesel and equipment. Other than that, it runs on its own merits and virtually without passing on negative effects.

Farm economics (Comparison only Planty Organic and KW Org)

- The Planty Organic Cut&Carry fertilizer system is associated with only slightly lower yields per hectare but has one of the six plots with no direct yield. KW Organic does have income from the two years of grass/clover and has relatively more seed potatoes in its cropping plan which have a high revenue. The total sales value per hectare for Planty Organic is therefore lower than for KW Org.
- The costs are higher. Although savings are made on the purchase of manure, compost or another regional residual flows are brought to keep the other nutrients in balance. The costs connected to Cut&Carry fertilizer are also slightly higher than for grass/clover and cannot be spread over two years. In the KW Org system Cauliflower cultivation takes place on leased land which generates income but does not incur costs.
- In a hypothetical comparison of Planty Organic with the variant 'itself' (so no more differences in cropping plan) but with grass clover sales and manure purchase, the system with manure purchase still appears to be financially better. This is mainly due to an assumed higher crop yield, similar to that of KW Organic in recent years.
- With cheaper compost and a higher price for organic manure due to the gradual phasing out of the use of conventional manure in organic farming, the difference between the two systems will become smaller. This possible change in the price of organic manure is in the first place policy dependent, and second on how the organic sector will react and adapt itself to this new situation.

7.2 Recommendations

- Now that the nitrogen question has been largely answered, the findings can be enriched by continuing the Cut&Cary fertilizer system and supplementing it into a regional recycling example farm. This could include supplying regional residual streams with absolute P balance as a starting point. Given the yields and P contents, that comes down to the purchase of 30 kg P2O5 per hectare per year, equivalent to 12-15 tons of nature compost.
- The trial field can again take up an advanced position by leaving strips unfertilized (no compost, no other input), thus creating an interesting field research situation with a contrast in phosphate application. Also, in experiments with P-fertilization steps in the unfertilized strips, various questions can be investigated around P-availability with decreasing P-supply.
- The agronomy within the Cut&Carry fertilizer system can be further optimized. For example, underseeding of green manures in oat cultivation, the direct use of the first cut of mowing fertilizer instead of silage (a relatively expensive link in the chain), smart

sowing technique to be able to sow rye green manure after a late carrot harvest, etc. This might even be supplemented by taking out the Cut&Carry fertilizer completely and replace it by, for example, green manure – green peas production – green manure. This saves cost (Cut&Carry fertilizer production), generates income (peas) while maintaining the high N-fixation during this year in the rotation.

- The question whether and how a large field-internal nitrogen and organic matter flow contributes to or is essential for efficiency, stability and resilience of the system could be further investigated.
- Make sure that this knowledge and experience reaches the organic arable farmers and gardeners. Even without them integrally adopting the system, there is a long list of partial actions that can contribute to a reduced need for external nitrogen.

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Dutch:

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Appendix 1: Crop measurements

2012		Potato	Carrot		Summer wheat	Cauliflower
N	%	1,38	0,94		1,73	3,48
P2O5	%	0,6	0,53			1,35
K2O	%	3,05	3,40			5,09

2013		Potato	Carrot	Oats	Summer wheat	Cauliflower
N	%	1,32	0,83	1,70	1,68	2,59
P2O5	%	0,44	1,11	2,64	1,91	2,49
K2O	%	2,52	3,15	0,67	0,47	5,38
Ca	g/kg d.m.	1,15	3,59	1,35	0,53	3,02
Mg	g/kg d.m.	0,93	1,11	1,43	1,21	1,00
S	g/kg d.m.	1,04	1,04	1,53	1,07	
Cu	mg/kg d.m.	4,4	5,3	3,7	3,60	
FE	mg/kg d.m.	87,2	69,1	63,9	29,20	
Mn	mg/kg d.m.	4,7	6,6	16,8	10,60	
Zn	mg/kg d.m.	19,10	22,00	40,70	32,90	

2014		Potato	Carrot	Summer wheat	Pumpkin	Rye
N	%	1,01	1,36	1,55	1,58	1,32
P2O5	%	0,60	0,71	0,80	0,62	0,94
K2O	%	2,71	3,72	0,56	3,01	0,66
Ca	g/kg d.m.	0,71	3,20	0,33	1,10	0,47
Mg	g/kg d.m.	1,1	1,2	1,0	1,1	1,0
S	g/kg d.m.	1,4	1,9	1,3	1,5	1,2
Cu	mg/kg d.m.	6,9	7,6	4,2	4,5	4,6
FE	mg/kg d.m.	56,7	36,2	27,3	39,8	29,9
Mn	mg/kg d.m.	2,6	2,9	5,4	1,8	11,8
Zn	mg/kg d.m.	19,7	34,5	39,9	28,0	40,0

						Field Bean/
2015		Potato	Carrot	Oats	Pumpkin	Summer wheat
N	%	1,16	1,26	1,92	1,70	4,41
P2O5	%	0,48	0,60	1,10	0,76	1,40
K2O	%	2,72	3,32	0,67	2,47	1,50
Ca	g/kg d.m.	0,6	3,4	0,9	0,9	1,7
Mg	g/kg d.m.	1,0	0,9	1,5	1,2	1,5
S	g/kg d.m.	1,3	1,1	1,8	1,5	1,9
Cu	mg/kg d.m.	4,3	5,0	4,0	5,7	14,9
FE	mg/kg d.m.	90	61	106	83	57
Mn	mg/kg d.m.	6	5	18	5	15
Zn	mg/kg d.m.	15	21	34	26	47

						Field Bean/
2016		**Potato**	**Carrot**	**Oats**	**Pumpkin**	**Summer wheat**
N	%	1,53	1,10	1,67	1,28	3,49
P2O5	%	0,85	0,69	0,98	1,03	1,63
K2O	%	3,42	2,32	0,71	3,26	1,48
Ca	g/kg d.m.	1,3	3,5	1,0	1,5	1,7
Mg	g/kg d.m.	1,3	1,0	1,3	1,2	1,8
S	g/kg d.m.	1,9	1,0	1,9	2,6	2,4
Cu	mg/kg d.m.	7,07	6,86	3,05	8,09	12,3
FE	mg/kg d.m.	284	149	76	337	88
Mn	mg/kg d.m.	12	7	23	6	13
Zn	mg/kg d.m.	17	16	26	24	46

						Field Bean/
2017		**Potato**	**Carrot**	**Oats**	**Pumpkin**	**Summer wheat**
N	%	1,28	1,04	1,47	1,49	4,13
P2O5	%	0,62	0,66	0,80	0,55	1,35
K2O	%	2,99	2,06	0,56	2,17	1,44
Ca	g/kg d.m.	0,70	2,90	0,80	1,10	1,30
Mg	g/kg d.m.	1,00	0,80	1,00	1,00	1,30
S	g/kg d.m.	1,40	0,90	1,30	1,40	1,90
Cu	mg/kg d.m.	5,28	4,40	3,30	4,65	12,84
FE	mg/kg d.m.	145	290	77	162,43	113
Mn	mg/kg d.m.	6,22	5,90	12,39	2,76	14,00
Zn	mg/kg d.m.	16,44	29,55	23,49	16,86	41,10

						Field Bean/
2018		**Potato**	**Carrot**	**Oats**	**Pumpkin**	**Summer wheat**
N	%	1,07	1,44	1,26	2,79	2,63
P2O5	%	0,48	0,62	0,85	0,82	0,87
K2O	%	2,21	1,73	0,68	3,17	0,80
Ca	g/kg d.m.	0,40	3,10	1,00	2,90	0,70
Mg	g/kg d.m.	1,00	0,90	1,40	1,80	1,20
S	g/kg d.m.	1,30	1,10	1,40	2,20	1,70
Cu	mg/kg d.m.	4,80	7,70	3,90	7,40	6,70
FE	mg/kg d.m.	60	48	110	170	43
Mn	mg/kg d.m.	4,00	5,00	12,00	9	9,00
Zn	mg/kg d.m.	12,00	23,00	26,00	29	36,00

2019		Potato	Carrot	Oats	Pumpkin	Field Bean/ Summer wheat
N	%	0,89	1,53	1,8	1,71	3,1
P2O5	%	0,458	0,55	1	0,57	0,94
K2O	%	2,0812	2,15	0,7139	2,55	0,93
Ca	g/kg d.m.	0,7	3,1	1,2	1,3	0,94
Mg	g/kg d.m.	0,8	1	1,7	1,3	1,36
S	g/kg d.m.	1,1	0,9	1,7	1,7	1,56
Cu	mg/kg d.m.	3,6	6,6	4,8	6	8,1
FE	mg/kg d.m.	260	110	76	95	43,76
Mn	mg/kg d.m.	7	6	15	6	12,3
Zn	mg/kg d.m.	10	19	35	20	40,2

2020		Potato	Carrot	Oats	Pumpkin	Field Bean/ Summer wheat
N	%	0,94	1,52	1,55	2,03	4,36
P2O5	%	0,53	0,8	1	0,76	1,3
K2O	%	2,53	3,12	0,77	2,36	1,55
Ca	g/kg d.m.	0,6	3,6	1,2	1,3	2,03
Mg	g/kg d.m.	1	1	1,4	1,3	1,7
S	g/kg d.m.	1	1,5	1,6	1,8	1,83
Cu	mg/kg d.m.	4,1	5,7	4,2	6,2	12,58
FE	mg/kg d.m.	67	198	65	66	59,06
Mn	mg/kg d.m.	4	8	12	5	16,65
Zn	mg/kg d.m.	12	22	27	27	46,4

Appendix 2: Soil Measurements

2012		A	B	C	D	E	F	Avg. A-F
N-Total	mg N/kg	1200	1250	1260	1270	1300	1250	1255
C/N		8	7	8	8	8	8	8
N supply capacity	kg N/jaar	73	75	76	76	77	75	75
P plant available	mg P/kg	1,20	1,70	1,80	1,70	1,30	1,70	1,57
P-AL	!O5/100 gr	35	36	40	40	36	40	38
Pw	ng P2O5/l	22	23	27	27	24	26	25
K pant abailable	mg K/kg	63	68	64	76	55	59	64
K-number		29	29	22	27	22	21	25
Mg plant available	mg Mg/kg	34	41	45	44	44	46	42
Na plant avaiable	mg Na/kg	30	38	86	55	11	30	42
pH		7,6	7,6	7,6	7,6	7,6	7,5	7,6
Organic matter	%	1,6	1,6	1,8	1,8	1,8	1,8	1,7
C-inorganic	%	0,9	0,9	1,0	1,0	1,0	1,0	1,0
CaCO3	%	4,1	4,3	4,3	4,5	4,6	4,4	4,4
Lutum	%	11	11	11	12	12	12	12

2013		A	B	C	D	E	F	Avg. A-F
N-Total	mg N/kg	990	930	1030	890	1040	1070	992
C/N		9	10	10	11	9	10	10
N supply capacity	kg N/jaar	59	53	60	47	64	60	57
S-total	mg S/kg	520	600	570	380	440	350	477
C/S		17	16	19	25	22	30	22
S Supply capacity	kg S/jaar	40	44	42	27	32	24	35
P plant available	mg P/kg	1,1	1,8	1,4	1,9	1,3	1,4	1,5
P-AL	!O5/100 gr	37	39	45	43	38	40	40
Pw	ng P2O5/l	31	37	37	39	33	35	35
K pant abailable	mg K/kg	54	69	93	86	57	113	79
K stock	mmol+/kg	2,6	2,3	3,1	2,9	2,7	3,0	2,8
K-number		14	17	22	22	16	28	20
Ca plant available	kg Ca/ha	177	278	226	328	177	326	252
Ca stock	kg Ca/ha	4745	5035	5300	5020	5305	5165	5095
Mg plant available	mg Mg/kg	37	48	51	48	42	48	46
Na plant available	mg Na/kg	7	9	8	10	9	14	10
Si plant available	µ Si/kg	26660	31730	28350	34090	28940	28570	29723
Fe plant available	µ Fe/kg	< 3020	7860	<3020	4800	< 3020	<3020	
Zn plant available	µ Zn/kg	< 100	< 100	< 100	< 100	< 100	< 100	
Mn plant available	µ Mn/kg	< 250	<250	< 250	820	<250	3610	
Cu plant available	µ Cu/kg	<20	<20	20	20	22	21	
Co plant available	µ Co/kg	<2,5	<2,5	<2,5	3,6	< 2,5	6,6	
B plant available	µ B/kg	186	262	244	225	206	218	224
Mo plant available	µ Mo/kg	5	8	8	10	8	16	9
Se plant available	µ Se/kg	2,7	3,9	2,3	3,4	2,7	2,8	3,0
pH		7,1	7,1	7,1	7,2	7,3	7,4	7,2
C-org	%	0,9	0,9	1,1	1	1	1,1	1,0
Organic matter	%	1,8	1,9	2,1	1,9	1,9	2,1	2,0
C-inorganic	%	0,72	0,69	0,71	0,7	0,75	0,61	0,7
CaCO3	%	5,3	5	5,2	5,1	5,5	4,4	5,1

2014		A	B	C	D	E	F	Avg. A-F
N-total	mg N/kg	1180	1030	1040	1120	970	1110	1075
C/N		10	9	10	9	9	9	9
N supply capacity	kg N/jaar	67	63	56	69	61	67	64
S-total	mg S/kg	570	500	450	490	350	380	457
C/S		21	19	22	21	26	27	23
S supply capacity	kg S/jaar	41	37	33	36	25	26	33
P plant available	mg P/kg	1,3	1,4	1,4	1,3	1,0	1,8	1,4
P-AL	!O5/100 gr	39	42	42	41	34	41	40
Pw	ng P2O5/l	33	36	36	34	29	38	34
K plant available	mg K/kg	76	77	76	82	46	107	77
K stock	mmol+/kg	3,6	3,4	3,1	3,5	3,0	3,4	3,3
K-number		20	20	20	20	14	25	20
Ca plant available	kg Ca/ha	25	50	26	26	177	327	105
Ca stock	kg Ca/ha	6020	5550	5225	6070	4795	5650	5552
Mg plant available	mg Mg/kg	49	48	49	51	45	48	48
Na plant available	mg Na/kg	13	11	10	13	11	12	12
SI plant available	µ Si/kg	43840	37080	34090	42730	42270	37780	39632
Fe plant available	µ Fe/kg	<2010	<2010	<2010	<2010	2320	<2010	
Zn plant available	µ Zn/kg	<100	<100	<100	<100	<100	<100	
Mn plant available	µ Mn/kg	<250	<250	260	<250	<250	<250	
Cu plant available	µ Cu/kg	36	49	36	43	42	46	42
Co plant available	µ Co/kg	<2,5	<2,5	<2,5	<2,5	<2,5	<2,5	
B plant available	µ B/kg	312	247	260	334	238	235	271
Mo plant available	µ Mo/kg	6	12	12	11	9	12	10
Se plant available	µ Se/kg	3,6	3,7	3,5	3,7	3,4	3,4	4
pH		7,4	7,4	7,4	7,1	7,2	7,2	7,3
C-organic	%	1,2	1,0	1,0	1,1	0,9	1,0	1,0
Organic matter	%	2,4	1,9	2,0	2,0	1,8	2,0	2,0
C-inorganic	%	0,92	0,87	0,67	0,91	0,7	0,83	0,82
CaCO3	%	6,9	6,5	4,9	6,8	5,1	6,1	6,1
Lutum	%	13	10	10	12	10	11	11
Silt	%	33	29	14	30	19	24	25
Sand	%	45	53	69	49	64	57	56
CEC	mmol+/kg	107	96	91	106	83	98	97
CEC-occupation	%	100	100	100	100	100	100	100
Soil life	mg N/kg	33	28	39	40	29	27	33

2015		A	B	C	D	E	F	Avg. A-F
N-total	mg N/kg	920	910	1100	960	1170	1170	1038
C/N		10	10	9	10	9	9	10
N supply capacity	kg N/jaar	52	53	67	56	71	71	62
S-total	mg S/kg	680	640	430	350	460	620	530
C/S		13	15	24	28	24	17	20
S supply capacity	kg S/jaar	45	45	30	24	32	45	37
P plant available	mg P/kg	1,0	1,0	1,6	1,8	1,1	1,4	1,3
P-AL	!O5/100 gr	32	35	43	42	36	38	38
Pw	ng P2O5/l	23	26	30	31	25	27	27
K plant available	mg K/kg	50	60	81	63	41	73	61
K stock	mmol+/kg	2,8	2,7	2,9	3,0	2,4	2,8	2,8
K-number		15	16	20	17	12	18	16
Ca plant available	kg Ca/ha	25	202	377	151	100	250	184
Ca stock	kg Ca/ha	5165	5255	5980	5535	6065	5910	5652
Mg plant available	mg Mg/kg	35	39	43	42	41	54	42
Na plant available	mg Na/kg	10	9	9	9	10	11	10
SI plant available	µ Si/kg	32710	31930	33440	37050	30450	33940	33253
Fe plant available	µ Fe/kg	<2020	<2020	<2020	<2020	<2020	<2020	
Zn plant available	µ Zn/kg	<100	<100	<100	<100	<100	110	
Mn plant available	µ Mn/kg	<250	<250	<250	<250	<250	440	
Cu plant available	µ Cu/kg	<20	<20	<20	<20	<20	<20	
Co plant available	µ Co/kg	<2,5	<2,5	<2,5	<2,5	<2,5	<2,5	
B plant available	µ B/kg	93	203	227	210	200	238	195
Mo plant available	µ Mo/kg	11	12	13	8	9	4	10
Se plant available	µ Se/kg	3,6	3,8	3,6	3,1	3,9	3,2	3,5
pH		7,1	7,1	7,3	7,3	7,4	7,1	7,2
C-organic	%	0,9	0,9	1,0	1,0	1,1	1,1	1,0
Organic matter	%	1,8	1,9	2,0	2,0	2,2	2,2	2,0
C-inorganic	%	0,73	0,74	0,78	0,81	0,77	0,69	0,75
CaCO3	%	5,3	5,4	5,7	6,0	5,7	5,0	5,5
Lutum	%	11	11	12	9	11	11	11
Silt	%	27	26	25	26	23	29	26
Sand	%	55	56	55	57	58	53	56
CEC	mmol+/kg	88	90	103	96	104	102	97
CEC-occupation	%	100	100	100	100	100	100	100
Soil life	mg N/kg	36	35	34	29	40	41	36

2016		A	B	C	D	E	F	Avg. A-F
N-total	mg N/kg	1010	1240	1190	850	960	860	1018
C/N		8	8	8	11	10	10	9
N supply capacity	kg N/jaar	66	73	77	46	52	47	60
S-total	mg S/kg	530	540	500	420	540	450	497
C/S		16	17	20	22	17	18	18
S supply capacity	kg S/jaar	40	42	36	31	41	34	37
P plant available	mg P/kg	1,4	1,8	1,9	1,8	1,6	1,5	1,7
P-AL	2O5/100 gr	33	37	43	40	34	38	38
Pw	ng P2O5/l	25	29	31	30	27	28	28
K plant available	mg K/kg	34	41	80	38	37	62	49
K stock	mmol+/kg	2,4	2,8	3,3	3,1	2,5	3,1	2,9
K-number		11	12	19	12	12	17	14
Ca plant available	kg Ca/ha	254	278	302	177	228	178	236
Ca stock	kg Ca/ha	5040	5615	5800	5850	5665	5425	5566
Mg plant available	mg Mg/kg	23	30	39	32	33	34	32
Na plant available	mg Na/kg	<6	7	8	7	7	7	7
SI plant available	µ Si/kg	32770	48350	35340	36650	48760	34470	39390
Fe plant available	µ Fe/kg	<2020	2460	<2020	<2020	3360	<2020	
Zn plant available	µ Zn/kg	<100	<100	<100	<100	110	<100	
Mn plant available	µ Mn/kg	<250	<250	<250	<250	<250	<250	
Cu plant available	µ Cu/kg	53	58	61	42	48	53	53
Co plant available	µ Co/kg	<2,6	2,7	<2,6	<2,6	3,1	<2,6	
B plant available	µ B/kg	137	175	229	173	189	216	187
Mo plant available	µ Mo/kg	23	22	22	8	14	24	19
Se plant available	µ Se/kg	4,4	5,2	6,3	5,5	5	5,3	5,3
pH		7,5	7,5	7,3	7,6	7,5	7,3	7,5
C-organic	%	0,8	0,9	1,0	0,9	0,9	0,8	0,9
Organic matter	%	1,7	1,9	2,0	1,9	1,8	1,6	1,8
C-inorganic	%	0,73	0,71	0,69	0,82	0,75	0,78	0,75
CaCO3	%	5,3	5,2	5	6,1	5,5	5,7	5,5
Lutum	%	9	11	11	10	10	9	10
Silt	%	22	26	24	26	22	16	23
Sand	%	62	56	58	56	61	68	60
CEC	mmol+/kg	85	96	101	100	96	93	95
CEC-occupation	%	100	100	100	100	100	100	100
Soil life	mg N/kg	55	51	52	45	44	49	49

2017		A	B	C	D	E	F	Avg. A-F
N-total	mg N/kg	970	880	1100	910	1010	1070	990
C/N		12	10	10	12	11	10	11
N supply capacity	kg N/jaar	60	65	80	55	65	70	66
S-total	mg S/kg	485	425	270	350	435	505	412
C/S		24	22	42	31	25	20	27
S supply capacity	kg S/jaar	41	36	20	29	36	45	35
P plant available	mg P/kg	1,3	1,4	1,7	1,4	1,3	1,4	1,4
P-AL	!O5/100 gr	40	40	39	42	37	48	41
Pw	ng P2O5/l	27	28	29	28	26	30	28
K plant available	mg K/kg	66	44	48	36	46	70	52
K stock	mmol+/kg	2,6	3,1	2,7	2,6	2,6	2,9	2,8
K-number		17	12	14	11	14	18	14
Ca plant available	kg Ca/ha	150	240	275	335	270	510	297
Ca stock	kg Ca/ha	6695	6435	7190	6740	7350	7750	7027
Mg plant available	mg Mg/kg	39	39	39	39	38	47	40
Na plant available	mg Na/kg	11	11	10	10	16	10	11
SI plant available	µ Si/kg	32930	49890	48730	28770	34800	45160	40047
Fe plant available	µ Fe/kg	< 2020	9310	7730	< 2010	< 2010	< 2020	8520
Zn plant available	µ Zn/kg	< 100	110	110	<100	< 100	< 100	
Mn plant available	µ Mn/kg	< 250	370	370	< 250	390	320	
Cu plant available	µ Cu/kg	25	30	28	21	28	27	27
Co plant available	µ Co/kg	< 2,6	3,5	3,4	< 2,6	< 2,6	3,2	
B plant available	µ B/kg	212	232	219	169	178	223	206
Mo plant available	µ Mo/kg	11	10	12	12	10	15	12
Se plant available	µ Se/kg	3,2	3,1	3,1	2,8	2,8	3,0	3
pH		7,1	7	7,3	7,2	7,3	7,4	7,2
C-organic	%	1,2	0,9	1,1	1,1	1,1	1,0	1,1
Organic matter	%	2,1	1,9	1,9	1,9	2,2	2,1	2,0
CaCO3	%	6,2	5,8	6,1	6,6	6,3	5,8	6,1
Lutum	%	11	10	13	10	10	12	11
Silt	%	23	14	19	21	23	24	21
Sand	%	58	68	60	61	59	56	60
CEC	mmol+/kg	99	95	104	97	107	112	102
CEC-occupation	%	100	100	100	100	100	100	100
Soil life	mg N/kg	28	34	26	26	43	41	33

2018		A	B	C	D	E	F	Avg. A-F
N-total	mg N/kg	1020	1090	1290	1070	1200	1080	1125
C/N		10	9	8	10	9	11	10
N supply capacity	kg N/jaar	70	80	95	70	80	70	78
S-total	mg S/kg	405	445	345	375	535	565	445
C/S		26	23	30	27	19	21	24
S supply capacity	kg S/jaar	34	38	28	31	45	45	37
P plant available	mg P/kg	1,2	1,5	1,5	1,4	0,9	1,5	1,3
P-AL	2O5/100 gr	37	36	39	36	35	37	37
Pw	mg P2O5/l	26	27	28	26	23	27	26
K plant available	mg K/kg	53	62	44	36	41	59	49
K stock	mmol+/kg	2,7	3	2,8	2,3	2,5	3	2,7
K-number		15	17	13	11	12	16	14
Ca plant available	kg Ca/ha	30	150	180	30	180	270	140
Ca stock	kg Ca/ha	7170	6945	7395	7010	7150	7255	7154
Mg plant available	mg Mg/kg	39	47	43	43	41	43	43
Na plant available	mg Na/kg	12	14	11	11	14	10	12
SI plant available	µ Si/kg	29770	35140	37290	31930	33620	42250	35000
Fe plant available	µ Fe/kg	< 2020	< 2020	3230	< 2020	< 2021	< 2022	
Zn plant available	µ Zn/kg	< 100	< 101	100	< 100	< 101	160	
Mn plant available	µ Mn/kg	380	280	320	580	290	340	365
Cu plant available	µ Cu/kg	34	34	33	30	38	37	34
Co plant available	µ Co/kg	< 2,6	< 2,6	< 2,6	< 2,6	< 2,6	< 2,6	
B plant available	µ B/kg	183	223	205	192	211	211	204
Mo plant available	µ Mo/kg	14	12	14	9	13	13	13
Se plant available	µ Se/kg	3,7	3,9	4,3	4	3,6	4,9	4,1
pH		7,2	7,4	7,1	7	7,3	7,1	7,2
C-organic	%	1,1	1,0	1,0	1,0	1,0	1,2	1,1
Organic matter	%	2,0	2,0	2,0	2,4	2,1	2,3	2,1
CaCO3	%	6,2	5,8	6,1	6,6	6,3	5,8	6,1
Lutum	%	10	12	13	10	11	10	11
Silt	%	30	20	17	15	23	24	22
Sand	%	53	61	63	68	59	58	60
CEC	mmol+/kg	102	100	106	101	102	106	103
CEC-occupation	%	100	100	100	100	100	100	100
Soil life	mg N/kg	41	50	49	29	50	37	43
microbial biomass	mg C/kg	5	9	7	7	5	1	6
bacterial biomass	mg C/kg	53	83	84	72	47	11	58
Ffungal biomass	mg C/kg	48	54	61	65	52	7	48
fung/bact		0,9	0,7	0,7	0,9	1,1	0,6	0,8

In red: very unlikely data

2019		A	B	C	D	E	F	Avg. A-F
N-total	mg N/kg	1140	850	910	1030	1240	830	1000
C/N		9	12	11	11	8	12	11
N supply capacity	kg N/jaar	80	50	60	65	90	50	66
S-total	mg S/kg	515	505	455	525	455	455	485
C/S		19	20	22	21	21	22	21
S supply capacity	kg S/jaar	45	44	39	45	40	40	42
P plant available	mg P/kg	1,1	1,3	1,5	1,7	1,2	1,5	1,4
P-AL	2O5/100 gr	35	37	45	37	39	44	40
Pw	mg P2O5/l	24	26	30	28	26	30	27
K plant available	mg K/kg	40	49	46	37	40	65	46
K stock	mmol+/kg	2,8	3	2	3,2	2,6	2,7	2,7
K-number		12	15	13	12	12	17	14
Ca plant available	kg Ca/ha	185	30	490	210	365	30	1250
Ca stock	kg Ca/ha	6265	6685	6725	7470	6495	6780	6737
Mg plant available	mg Mg/kg	40	38	41	44	38	44	41
Na plant available	mg Na/kg	13	12	10	11	9	7	10
SI plant available	µ Si/kg	47880	38040	45380	39250	34470	34640	39943
Fe plant available	µ Fe/kg	3810	< 2020	3800	2420	< 2020	< 2010	
Zn plant available	µ Zn/kg	140	230	130	120	110	< 100	
Mn plant available	µ Mn/kg	410	< 250	370	330	< 250	< 250	
Cu plant available	µ Cu/kg	30	31	27	24	24	21	26
Co plant available	µ Co/kg	2,6	2,6	2,8	< 2,6	< 2,6	< 2,6	
B plant available	µ B/kg	223	214	230	227	228	235	226
Mo plant available	µ Mo/kg	11	9	10	8	11	14	11
Se plant available	µ Se/kg	3,4	3,8	3,5	3,2	3,1	3,1	3,4
pH		7,3	7,3	7,4	7,4	7,1	7	7,3
C-organic	%	1,0	1,0	1,0	1,1	1,0	1,0	1,0
Organic matter	%	1,6	1,8	1,6	2	1,6	1,7	1,7
CaCO3	%	5,4	5,7	5,6	6	5,7	4,7	5,5
Lutum	%	11	11	12	11	10	11	11
Silt	%	28	32	17	21	33	28	27
Sand	%	54	50	64	60	50	55	56
CEC	mmol+/kg	88	95	94	107	91	96	95
CEC-occupation	%	100	100	100	100	99	100	100
Soil life	mg N/kg	44	30	12	52	44	46	38
microbial biomass	mg C/kg	98	173	190	179	130	257	171
bacterial biomass	mg C/kg	47	66	89	65	53	102	70
Ffungal biomass	mg C/kg	31	71	54	43	48	91	56
fung/bact		0,7	1,1	0,6	0,7	0,9	0,9	0,8

In red: very unlikely data

2020		A	B	C	D	E	F	Avg. A-F
N-total	mg N/kg	1140	970	660	670	910	650	833
C/N		9	12	11	9	9	10	10
N supply capacity	kg N/jaar	85	60	45	50	65	45	58
S-total	mg S/kg	635	425	410	655	555	430	518
C/S		17	28	17	9	15	15	17
S supply capacity	kg S/jaar	45	34	39	45	45	41	42
P plant available	mg P/kg	1,2	1,4	1,7	1,1	1,0	1,4	1,3
P-AL	!O5/100 gr	37	40	41	40	36	38	39
Pw	ng P2O5/l	26	28	30	26	24	27	27
K plant available	mg K/kg	52	59	43	46	37	61	50
K stock	mmol+/kg	3,3	2,8	2,3	1,9	2,3	1,8	2,4
K-number		15	16	13	14	12	16	14
Ca plant available	kg Ca/ha	210	360	95	805	30	250	292
Ca stock	kg Ca/ha	7570	7450	5275	5820	5960	4825	6150
Mg plant available	mg Mg/kg	43	43	44	43	38	42	42
Na plant available	mg Na/kg	10	9	11	15	11	9	11
SI plant available	µg Si/kg	47380	42690	52450	47020	57370	52580	49915
Fe plant available	µg Fe/kg	3590	< 2020	3760	2480	6550	3860	
Zn plant available	µg Zn/kg	<100	< 100	120	< 100	110	< 100	
Mn plant available	µg Mn/kg	<250	< 250	250	260	280	820	
Cu plant available	µg Cu/kg	43	41	38	33	41	35	39
Co plant available	µg Co/kg	<2,6	< 2,6	2,6	< 2,6	3,3	4,6	
B plant available	µg B/kg	197	226	211	241	217	211	217
Mo plant available	µg Mo/kg	14	12	12	11	9	12	12
Se plant available	µg Se/kg	4,3	3,7	3,9	4,1	3,6	3,9	3,9
pH		7,6	7,6	7,2	7,5	7,5	7,3	7,5
C-organic	%	1,1	1,2	0,7	0,6	0,8	0,7	0,9
Organic matter	%	1,9	2,1	1,1	1,1	1,6	1	1,5
CaCO3	%	6,2	5,9	4,6	4,2	4,5	3,7	4,9
Lutum	%	12	11	8	7	8	7	9
Silt	%	34	25	10	12	14	16	19
Sand	%	46	56	76	76	72	72	66
CEC	mmol+/kg	108	106	73	80	83	67	86
CEC-occupation	%	100	100	100	100	100	100	100
Soil life	mg N/kg	48	29	36	36	79	31	43
microbial biomass	mg C/kg	169	178	194	164	289	192	198
bacterial biomass	mg C/kg	54	77	93	36	69	55	64
Ffungal biomass	mg C/kg	38	67	53	38	62	36	49
fung/bact		0,7	0,9	0,6	1,1	0,9	0,7	0,8

In red: very unlikely data

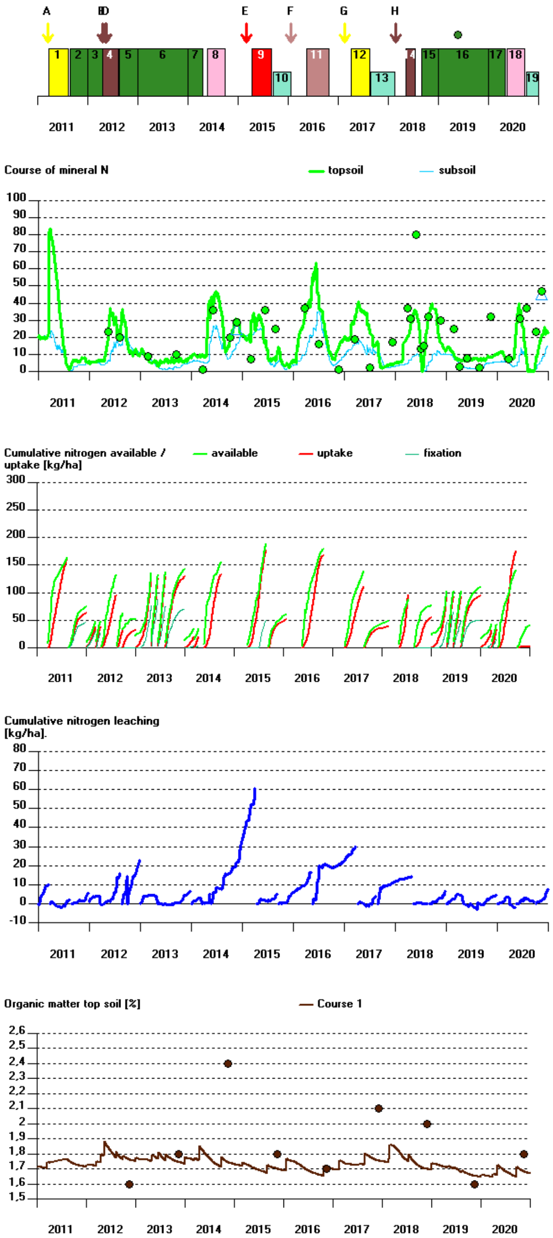
Appendix 3: Ndicea grafic output

Planty Organic

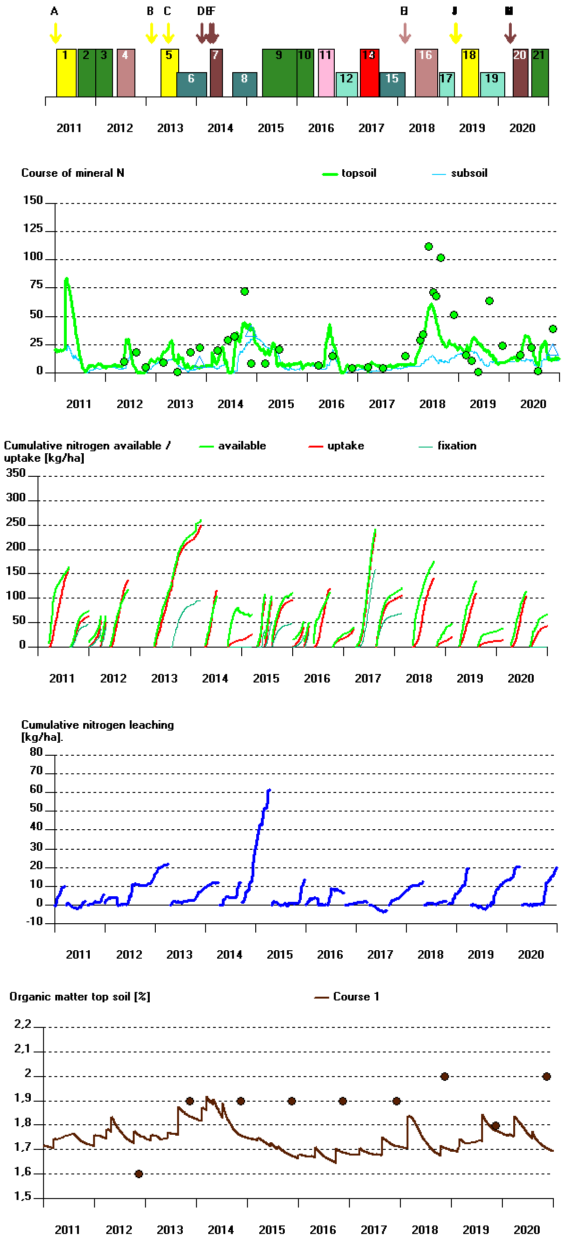
Green = Mixture of leguminous species for Cut&Carry fertilizer ; Yellow = cereals (last six years: oats ; Dark brown = seed potatoes ; Rose = pumpkin ; Red = field bean/wheat ; Light brown = winter carrot, Grey = cauliflower ; Grey-blue = green manure mixture with leguminous species ; Light blue = green manure without leguminous component.

Note that the Y-axes may have different scale layouts. Maximum rooting depth 60 cm.

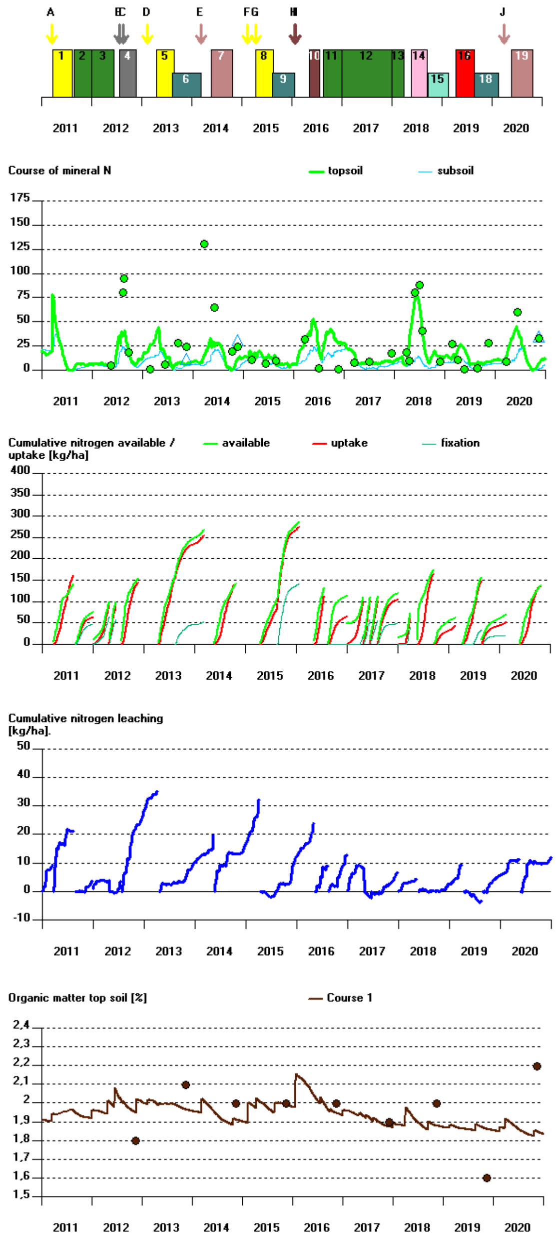
Planty Organic plot A



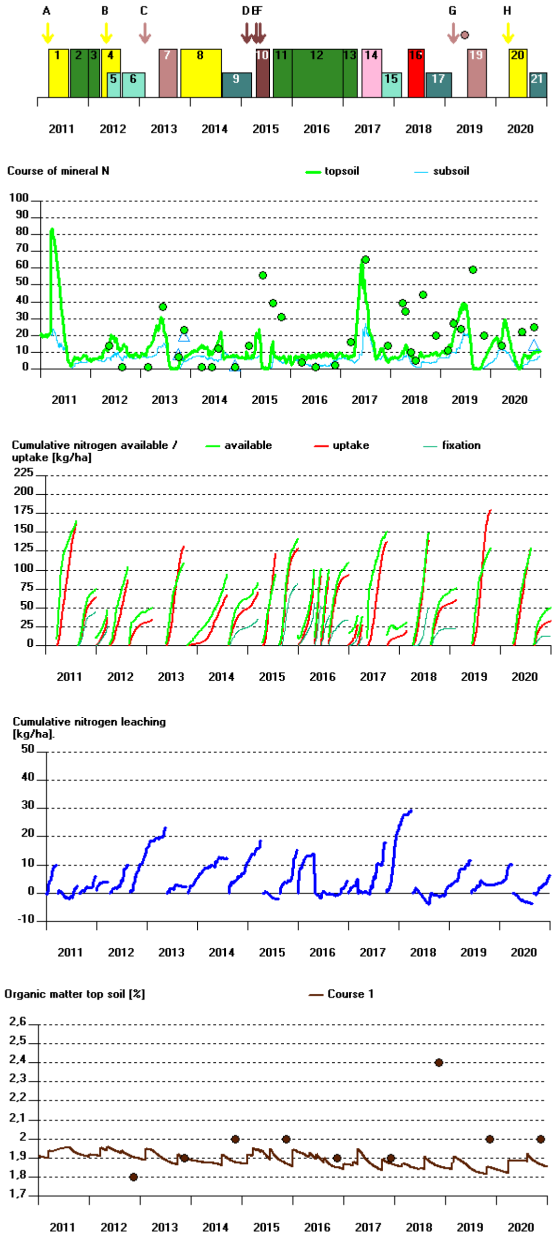
Planty Organic plot B



Planty organic plot C

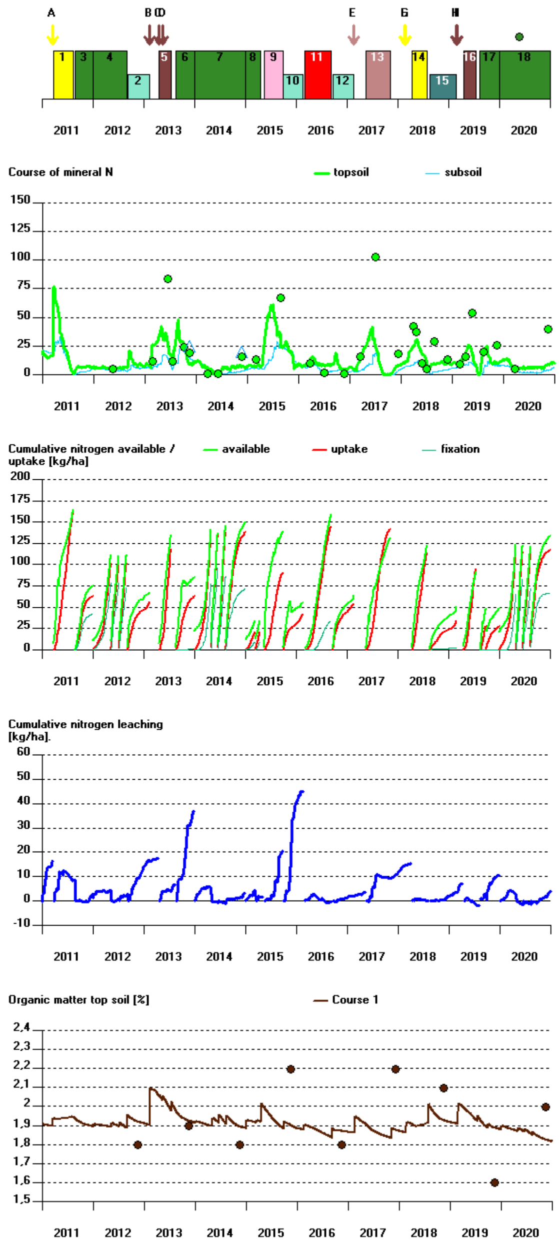


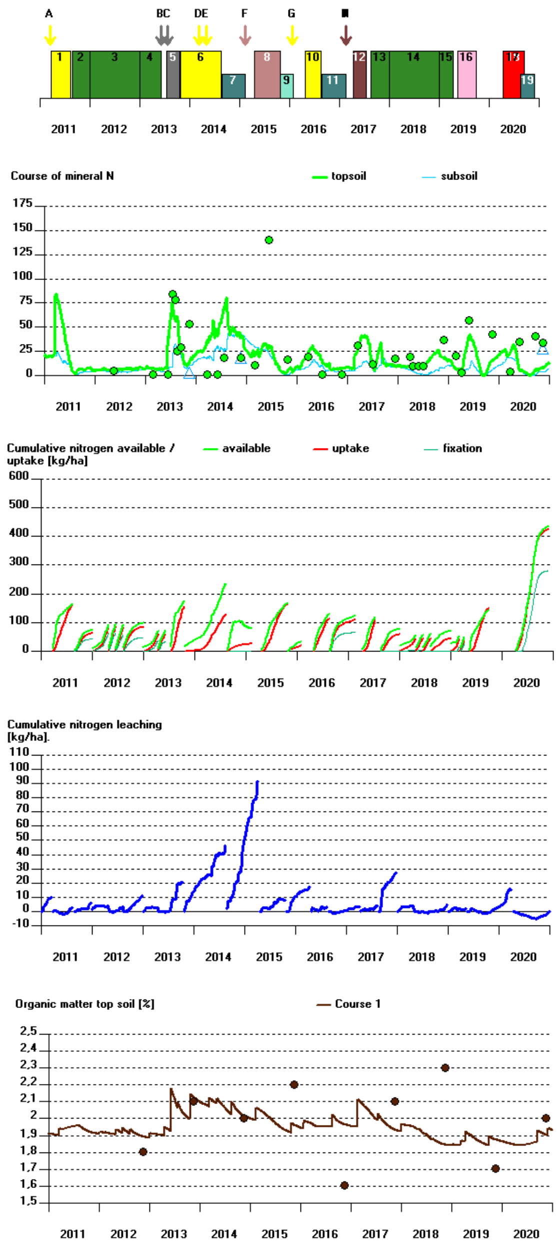
Planty Organic plot D



Note that the Y-axes may have different scale layouts

Planty organic plot E **Planty Organic plot F**





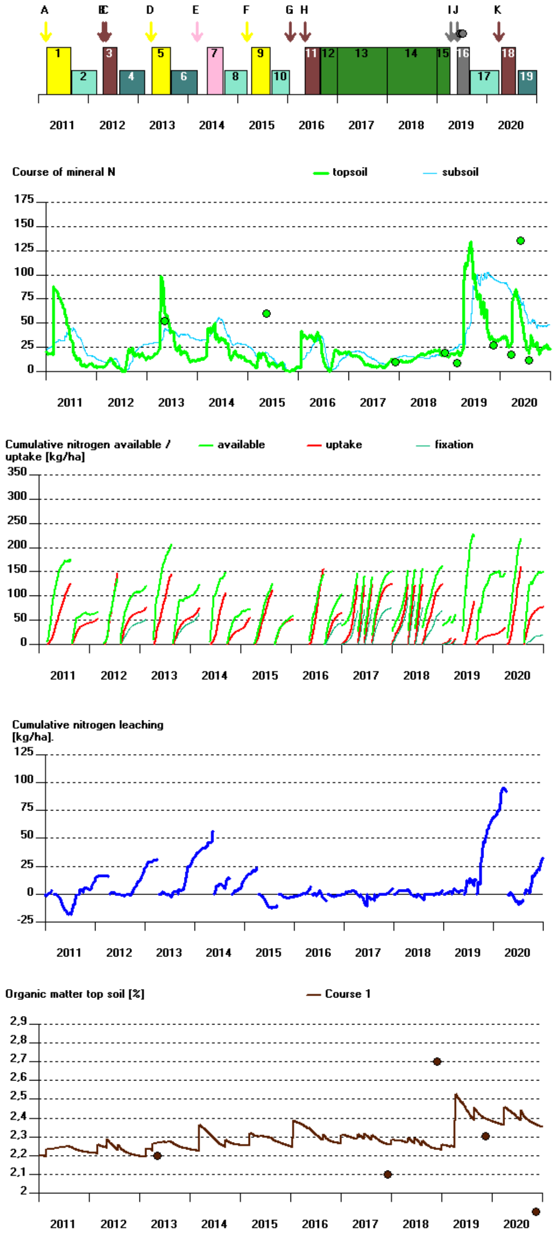
Note that the Y-axes may have different scale layouts

KW Org

Yellow = cereal ; Dark brown = seed potatoe ; Rose = pumpkin ; Green = grassclover, Grey = Cauliflower ; Light brown = winter carrot ; Light blue = green manure mixture without leguminous component ; Grey blue = green manure mixture with leguminous component

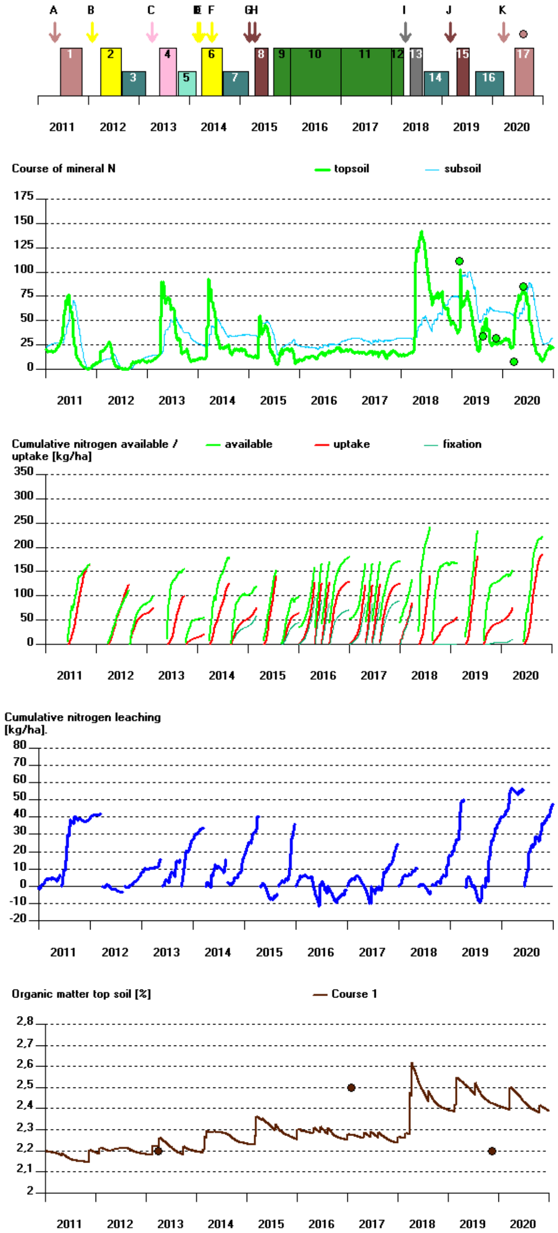
Note that the Y-axes may have different scale layouts. Maximum rooting depth 90 cm.

KW Org P2



Measurement organic matter 2020: 1,9 %, wrong

KW Org P7



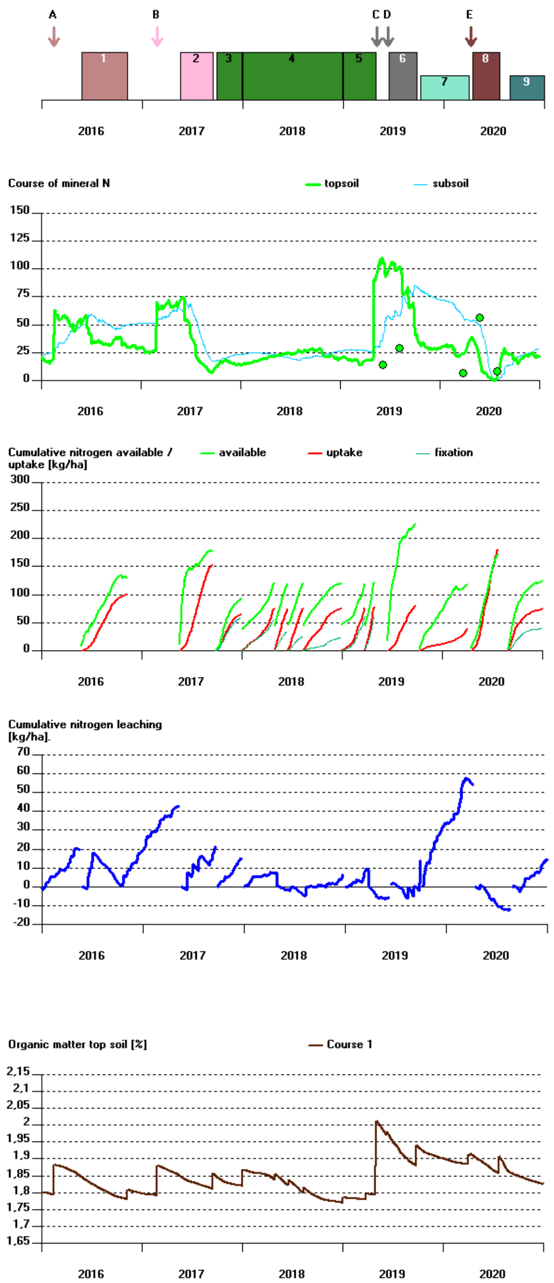
Measurement organic matter 2020: 1,5 %, wrong

Bakker Bio

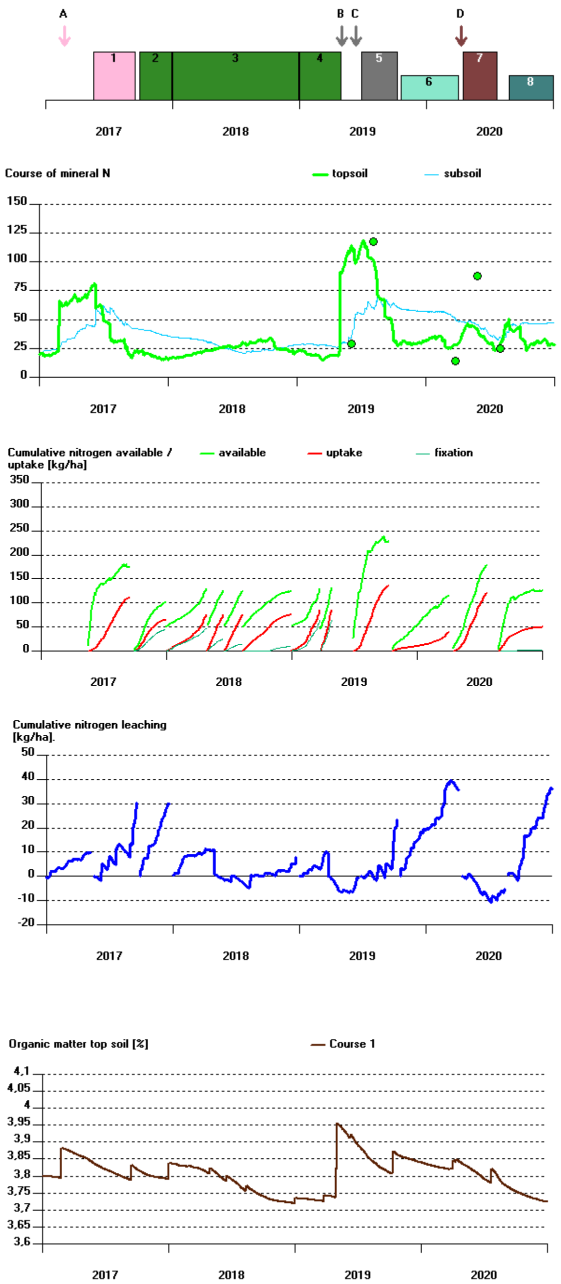
Light brown = eleriac ; Rose = pumpkin ; Green = grassclover ; Grey =Cauliflower ; Light blue = japanese oats green manure ; Dark brown = seed potatoes ; Grey-bluw = gtreen manure mixture with leguminous component

Note that the Y-axes may have different scale layouts. Maximum rooting depth 80 cm.

Bakker Bio field Nitt



Bakker Bio field Oldb

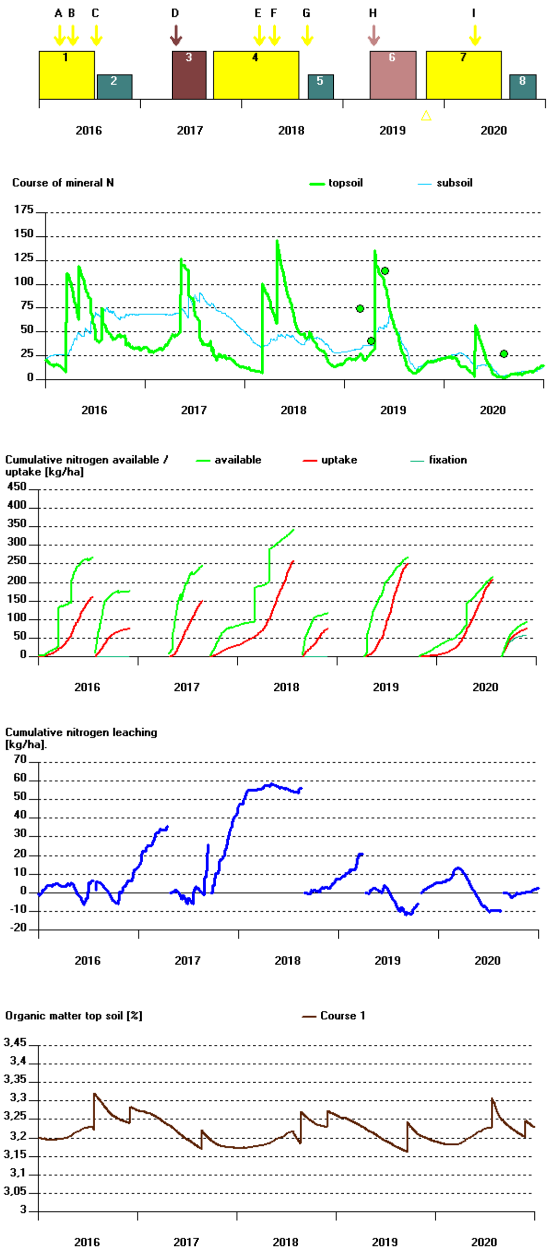


KW Conv

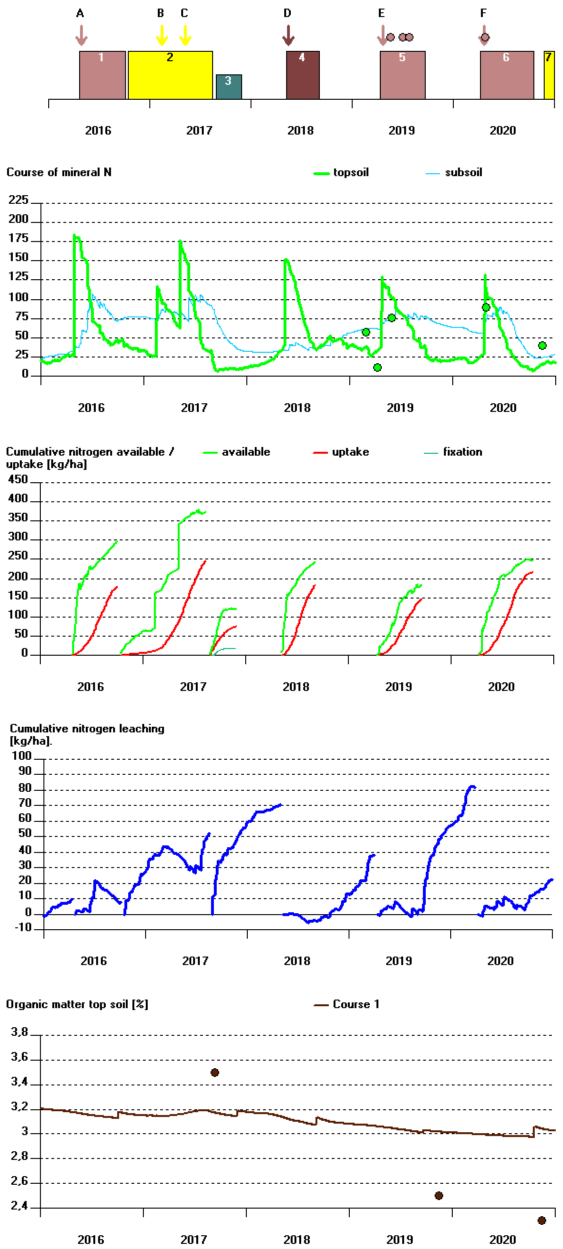
Yellow = cereal ; Light brown = seed onion or sugar beet ; Dark brown = seed potatoes ; Grey- blue = green manure mixture with leguminous component

Note that the Y-axes may have different scale layouts. Maximum rooting depth 90 cm.

KW Conv P1



KW Conv P4



Measurement organic matter in 2020: 2,3 %, wrong

Appendix 4: Nutrient content crops.

Seed potatoes | Carrot | Oats | Pumpkin | Wheat/Bean