PlantyOrganic

Design and results 2012

Geert-Jan van der Burgt
Michiel Bus

LOUIS BOLK INSTITUUT
de natuurlijke kennisbron

PlantyOrganic; Design and results 2012
G.J. van der Burgt, M. Bus, 37 p.
Keywords: soil fertility, nitrogen, cut-and-carry fertilizers, green manures, nutrient cycling.
Publication number 2012-048 LbP.
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Preface

This report deals about developing a farming system without external input of minerals or nitrogen. This development takes place in the project “PlantyOrganic”, an initiative from the organic farmers association of the wadden area “Biowad” and is located at the SPNA experimental farm “Kollumerwaard”. The project is funded by Province Groningen, Province Friesland, Rabobank, Biowad en Ministry of EL&I.

This project is a next step in optimizing the nitrogen dynamics in organic arable farming. Related projects deal with the optimization of cut-and-carry fertilizers and its effect on long-term soil fertility (at the Van Strien farm) and with the long-term effects of different types of manure on soil fertility, nitrogen dynamics and yield (MAC-trial).

We acknowledge the members of Biowad for their input, Michiel Bus (Avestura) for organizing the project and the team of the SPNA experimental farm Kollumerwaard for their contribution in realizing this challenging experiment. We also acknowledge the institutions funding this project.

Content

Summary

Increasingly strict legislation about fertilizer inputs and developing organic regulations are a strong stimulation to optimize the internal nutrient dynamics of organic arable farms. In the project “PlantyOrganic” , initialized by Biowad and realized at SPNA location Kollumerwaard, a challenging arable system is developed and tested: 100% internal nitrogen supply without input of nutrients from outside. In this report the design of the rotation and fertilizer scheme is presented and discussed, and the starting conditions in spring 2012 are documented. The NDICEA nitrogen model is used to explore the nitrogen dynamics. It is concluded that a 100% farm-own nitrogen supply can be achieved with good production levels. The 2012 results gave no reason to reconsider the rotation and fertilizer design, but since this was the first year of this experiment none of the crops had the pre-crop as foreseen in the design and the fertilizer used was only partly cut-and-carry fertilizer.

Samenvatting

Vanwege aanscherpingen in de mestwetgeving en de biologische regelgeving is er grote behoefte om de interne mineralenhuishouding van biologische akkerbouwbedrijven verregaand te optimaliseren. In het project PlantyOrganic, een initiatief van Biowad en uitgevoerd op SPNA locatie Kollumerwaard, wordt een uitdagend bedrijfssysteem ontwikkeld en beproefd: 100% eigen stikstofvoorziening zonder aanvoer van mineralen van buiten het bedrijf. In dit rapport wordt het ontwerp van vruchtwisseling en bemesting gepresenteerd en besproken en wordt de uitgangssituatie van dit in het voorjaar van 2012 gestarte experiment gedocumenteerd. Het NDICEA stikstof model is gebruikt om de verwachte stikstofdynamiek in beeld te brengen. Er wordt geconcludeerd dat 100% eigen stikstofvoorziening mogelijk is met geode opbrengstniveaus. De bevindingen van 2012 geven geen aanleiding het bedrijfsontwerp te herzien, maar dit was het eerste jaar van dit experiment en geen van de gewassen had de voorvrucht die in het ontwerp is voorzien, en niet alle bemestingen zijn uitgevoerd met maaimeststoffen.

Part 1: design

1 Introduction and background

Organic farming in Holland is confronted with big challenges. Due to legal restrictions in the amount of phosphate input, purchase of manure and compost is limited in arable farming and gardening. This results in a general decline in nitrogen input. On top of this is the organic sector in a transition towards (almost) zero use of conventional manure. These things combined implicate that on-farm nitrogen fixation by leguminous crops and reductions of nitrogen losses (leaching, denitrification, volatilization) are of utmost importance.
These two themes are since long under investigation at the Louis Bolk Instituut. A recent innovation is the introduction of cut-and-carry fertilizers (Van der Burgt et al, 2011; Van der Burgt en Rietberg, 2012).
The association of organic farmers in the Wadden area 'BioWad' added a dimension to this nitrogen question, aiming at optimizing the farm-internal nutrient and organic matter cycles and stocks. A 100% farm-internal nitrogen supply is combined with non-inversion soil tillage and, for the time being, no input at all from nutrients. This idea has resulted in the project "PlantyOrganic". During at least six years, a farming system will be developed and monitored based on 100% farm-own nitrogen and without any input of external manures or composts. Internal cut-and-carry fertilizers are part of the approach, as is the non-inversion soil tillage. By not replacing the nutrients which are discharged from the field, the large nutrient stocks in the soil are to be mobilized. This is preferred above depleting the mines, and meanwhile civil society can organize the recycling of urban wastes to be directed back to agriculture. Mobilizing the soil stock requires an optimal soil structure, rooting capacity and soil life, and non-inversion soil tillage can contribute to that.

For the design and development of the farming system the following items are considered.

- Nitrogen will be brought into the farm by means of leguminous crops. Nitrogen cycling is organized partly via redistribution of above-ground leguminous biomass (cut-and-carry fertilizers) and partly via soil-bound transfer (in situ incorporation of leguminous biomass). Basic crop nutrient supply comes from mineralization of soil organic matter.
- There is a large stock of phosphate, potassium and other nutrients in this soil. This will be explored by means of a maximum amount of catch crops in the rotation, mobilizing nutrients both out of topsoil and subsoil.
- The nitrogen moving through this agro ecological system will as much as possible be organically bound. Losses of inorganic nitrogen due to leaching and denitrification will strongly be reduced by minimizing the periods of bare soil and by avoiding peaks of soil mineral nitrogen.
- Soil tillage in this system has the aim to disturb soil life as least as possible. Non-inversion soil tillage maintains soil stratification, keeping intact the soil life and functionality of it.

In this report the design of the farming system will be presented and discussed, as will the results from 2012. Chapter two describes the objectives for the design. In chapter three the resulting farm system is described. In chapter four the results of the farm system design are presented, and this is discussed in chapter five. Chapter six deals with the findings in the first year of running this farm system.

2 Objectives

The farming system will be developed on one of the fields of the SPNA experimental farm "Kollumerwaard". In Spring 2012 the selected field is subdivided in six subfields. From these subfields soil samples are taken for general soil fertility analysis. The average data are given in Table 1. Annex 1 contains all data.

Table 1: Soil chemical analysis data; average of six fields.

Parameter		
N-total	1255	Mg kg^{-1}
N-delivering capacity	75	kg N ha^{-1} $year^{-1}$
C	9,7	g kg^{-1}
C/N	8	
Pw	25	mg P_2O_5 L^{-1}
P-AL	38	mg P_2O_5 $100g^{-1}$
P-PAE	1,6	mg P kg^{-1}
K-HCl	19	mg K_2O $100g^{-1}$
K-number	25	-
Potassium	64	mg K kg^{-1}
Magnesium	42	mg Mg kg^{-1}
Sodium	42	mg Na kg^{-1}
pH-KCl	7,6	-
Organic matter	1,7	%
$CaCO_3$	4,4	%
"Afslibbaarheid"	17	%
Clay content	12	%
CEC	95	mmol kg^{-1}

The farm design should fulfill the following objectives.

- Complete farm-own nitrogen supply by means of clover-grass, alfalfa or leguminous green manures and catch crops.
- No purchase of manure or compost
- Enough available nitrogen for a good yield and acceptable quality
- A sustainable rotation considering soil quality and nitrogen supply
- Maintenance or increase of soil organic matter content
- A for this region representative crop choice.
- During winter as much green land as possible
- Alternation of crops which are harvested above-ground (cereals, clover-grass, …) and harvested out of the soil (potatoes, carrots, ...)

During the design phase the nitrogen and organic matter model NDICEA (www.ndicea.nl) was used to gain insight in the central theme of the system: the nitrogen dynamics. In exchange with the engaged BioWad farmers and the involved SPNA associates the crop rotation and the fertilizer scheme is designed. Some items are still open for discussion, but the baseline is set.

3 Farm design

The farm design which resulted out of the design process is presented in Figure 1 and in Table 2. The calculations are made for fields of 1 hectare, with a six-year rotation resulting in a six hectare farm.

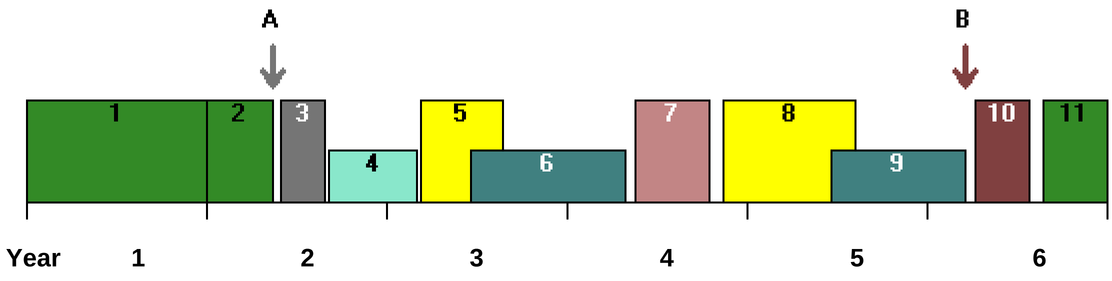


Figure 1: Crop sequence and fertilizer scheme

Table 2: Clarification of crops and fertilizers

	Crop		Fertilizer type	Amount
1	Clover-grass			
2	Clover-grass			
3	Cauliflower		Clover-grass incorporated	3,0 tonne dm ha^{-1}
		A	Clover-grass c&c fertilizer	3,5 tonne dm ha^{-1}
4	Fodder radish			
5	Spring wheat			
6	Clover + ..			
7	Carrots			
8	Winter rye			
9	Clover + ..			
10	Potatoes	B	Clover-grass c&c fertilizer	6,5 tonne dm ha^{-1}
11	Clover-grass			

The green manures 6 and 9 are not chosen yet. For the clover grass and the green manures the following productions are assumed (Table 3):

Table 3: Production and N-content of clover-grass and clover green manures above-ground biomass

		Production kg dm ha^{-1}	N-content kg $tonne^{-1}$ dm	N-yield kg ha^{-1}
1	Clover-grass	10000	28	280
2	Clover-grass	3000	26	78
11	Clover-grass	1500	26	39
6	Clover + ..	3000	32	96
9	Clover + ..	3500	32	112
	Total			605

The clover-grass preceding the cauliflower will be incorporated on location (3 tonnes dm with 26 kg N per tonne dm, total 78 kg N). Additionally there will be applied cut-and-carry fertilizer, 3,5 tonne dm with 28 kg N per tonne dm, total 98 kg N. The rest of the available cut-and-carry fertilizer, 6,5 ton with 28 kg N per ton dm, total 182 kg N ha^{-1} , will be applied to the potatoes.

Considering the cauliflower, the first cut of the preceding clover grass (crop number 2) will be incorporated in the soil as will be the first cut (cut-and-carry fertilizer) of the full-year clover grass field (crop number 1). The next cuts of the full-year clover grass, 6,5 tonne dm per hectare, will be silaged and saved for next-year potato fertilization. The autumn production of clover grass after potatoes (crop number 11) is estimated to be 1500 kg ha^{-1}; this production and nitrogen fixation is not involved in these calculations.

Table 4 reveals the nutrient content and nutrient discharge of the crops.

Table 4: Expected yield, nutrient content and nutrient discharge

	Yield tonne ha^{-1}	**dm %** %	**N in dm** %	**P_2O_5 n dm** %	**K_2O in dm** %	**N discharge** kg ha^{-1}	**P_2O_5 discharge** kg ha^{-1}	**K_2O discharge** kg ha^{-1}
Cauliflower	15	6,6	4,21	1,42	5,89	42	14	58
Spring wheat	5,5	85	2,00	1,00	0,60	94	47	28
Carrots	50	10,4	1,27	0,69	4,18	66	36	217
Winter rye	4,5	85	1,65	0,84	0,71	63	32	27
Potatoes	40	21	1,57	0,59	2,72	132	50	228
Total						396	178	559
Discharge per hectare						66	30	93

4 Expected results from the designed system

In Figure 2 the crop rotation is shown again

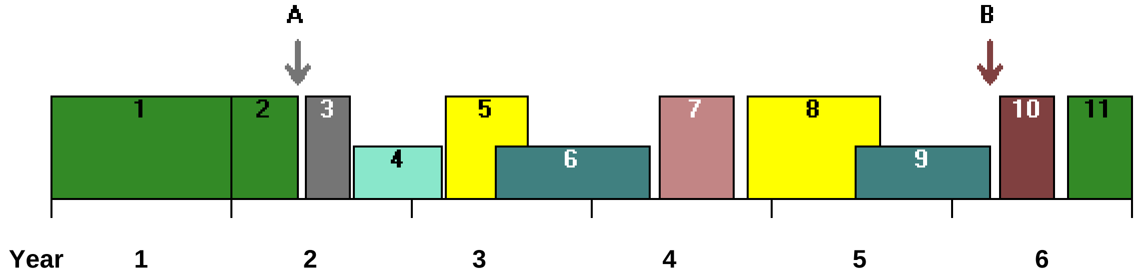


Figure 2: Crop sequence and fertilizer scheme

This crop rotation with accessory fertilizer scheme is used as input for the NDICEA model. The calculated composition of the soil organic matter *after* six years is transferred to the *beginning* of the six year simulation time lapse, and the scenario is recalculated. In this way the results of the *second* rotation are shown. Doing so, uncertainties in the default soil organic matter composition are reduced because default values (especially the proportion of fast and slow decaying soil organic matter) are replaced by system-generated values.

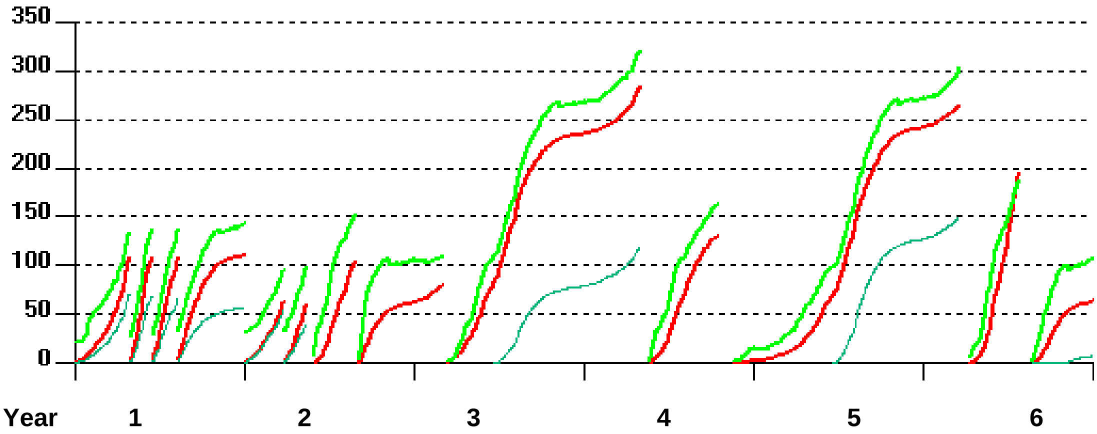


Figure 3: Cumulative nitrogen availability (green line), crop uptake (red line) and nitrogen fixation (turquoise). Y-axis: kg N ha^{-1}

Figure 3 shows that for all crops nitrogen availability is sufficient to realize the expected yield. Nitrogen availability takes into account the rooting depth of the crops. The very high crop uptake in year 3 - 4 and in year 5 – 6 is due to the continuous N-uptake from crop and undersown green manure. The potatoes (crop 10) with an expected yield of 40 tonne ha^{-1} would use all available nitrogen (Figure 3, year 6, green line touches the red line), so this is in the design a critical point in the rotation.

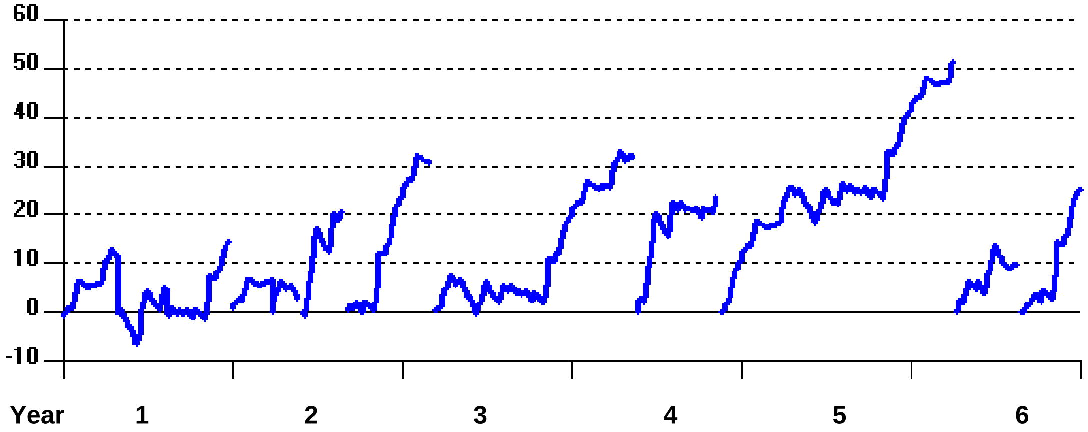


Figure 4: Cumulative leaching of nitrate below the rooting zone. With the start of a new crop the graph is reset at zero. Decreasing leaching is equivalent to nitrogen input by capillary rise of groundwater. Y-axis: kg N ha^{-1}

The losses due to leaching are shown in Figure 4. Leaching is low or very low during every year of the rotation, despite a water surplus of about 300 mm year^{-1}. The year 5 - 6 seems to be an exception, but it is not. The blue line is reset at zero when a new crop is sown, with exception of an undersown green manure. In year 5 clover is undersown in rye, resulting in a cumulative leaching line representing almost one and a half year. See also Table 5.

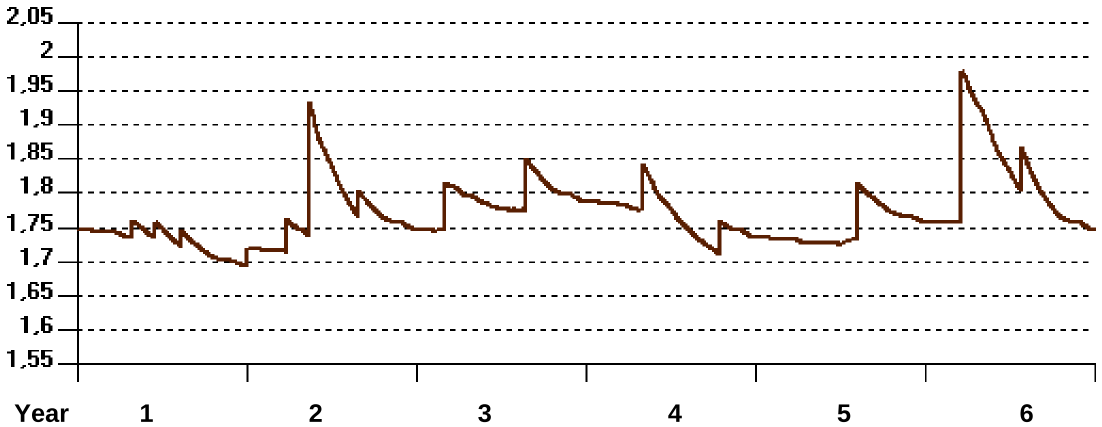


Figure 5: Course of soil organic matter in the topsoil, 0-30 cm. Y-axis: % organic matter.

The organic matter content of the soil stays stable (Figure 5). To reach this without input from outside the farm, all clover-grass biomass is used, partly directly incorporated in the soil, partly used as cut-and-carry fertilizer. Besides this, two green manures and the straw of two cereal crops are put in the ground.

The mineral balance at farm level is given in Table 5.The data from N-fixation, denitrification, leaching and increase soil-N result from NDICEA model calculations.

Table 5: Mineral balance, average per hectare per year, in kg

		N	P_2O_5	K_2O
Supply	N-fixation	107		
	Deposition	28	3	8
	Total	135	3	8
Discharge	Crops	66	30	93
Remaining		69	-27	-85
Remaining:	Denitrification	21		
	Leaching	41		
	Increase in soil organic matter	-4		

The nitrogen balance is nearly closed. Phosphate and Potassium show a strong negative result, as expected. This quantity must be provided by mobilizing the soil stock. The question whether this is possible yes or no is part of the experiment.

5 Discussion on the design

The rotation and fertilizer scheme as presented fulfills the objectives as presented in chapter 2. Two remarks on this:

- The minimum requirement for soil organic matter is met: the maintenance of the actual situation. An increase is not foreseen. A remark on this is necessary. The NDICEA model calculation is based on ‘normal’ soil tillage activities, which means: once a year ploughing. In case of this PlantyOrganic project, the plough is not used. It is expected that this will lead to a change in mineralization of soil organic matter. Possibly the speed of decay will become temporarily or continually lower, resulting in an increase in soil organic matter and a (temporarily) decrease in nitrogen mineralization. This mechanism is not yet incorporated in the model. At this moment there are projects running, related to reduced soil tillage including NDICEA assessments (BASIS, at the Broekemahoeve in Lelystad, Netherlands; Bodemkwaliteit Zand at experimental farm Vredepeel, Netherlands; EU-project Tilman-org (www.tilman-org.net)). The description of the requested adaptation of NDICEA to reduced tillage is foreseen as outcome of these projects.
- The potatoes need all available nitrogen, according to the model approach, when 40 ton production is assumed. Field monitoring will show whether this production level is realistic or not, and model validation will show whether this nitrogen dynamics calculation is realistic or not.

Besides the objectives there are more items which ask for attention coming years. Some of them are discussed here

- Experience with the non-inversion soil tillage has to be build up at this experimental farm. Incorporating the clover-grass sward without ploughing is mentioned as a critical point.
- An increase of weed pressure is expected: ploughing reduces weed pressure compared to non-ploughing systems.
- So far, the soil on this farm was ploughed in fall. From now on the main soil cultivation will take place in spring. Effects on soil structure can be expected.
- The timing of the cultivation of cauliflower is critical. The pre-crop clover-grass needs time in spring to fix the nitrogen needed for the cauliflower. After finishing the clover grass sward, time is needed to start decomposition of the freshly soil-incorporated organic matter. Both points of interest delay the start of the cauliflower cultivation. At the other end of the cultivation period, the cauliflower should be harvested early enough to enable the cultivation of a catch crop. Will this all be possible in practice or will weather and soil conditions disturb this scheme?
- What will be the most adequate green manures and catch crops? We want the crop to fixate nitrogen and to survive a normal Dutch winter. On the other hand it must be relatively easy to incorporate in the soil and it may not result in regrowth of the green manure. To finish with, nitrogen release out of the green manure must be fast enough.
- Almost 50% of the time a leguminous crop is on the fields. Is that possible or will it create soil health problems, for example related to nematodes?
- Soil supply of phosphate and other nutrients is high, but will it be possible to mobilize it in a sufficient quantity to feed the crops?

Part 2: first year,2012

6 Results 2012

2012 was the first year of the system development. Results from this first year must be interpreted with care for several reasons:

- All (sub)plots had the same pre-crop, so none of the crops was growing after the crop according to the design.
- The requested cut-and-carry fertilizer stock was not yet build up. Instead of this, organic fertilizer pellets have been used in the potatoes, the cauliflower and the spring wheat.
- Experience has to be build up in the practice of non-inversion soil tillage.

6.1 Crop and soil measurements

In Table 6 the crop data for 2012 are given, as are the NDICEA default data used in the system design phase.

Table 6: Measured crop data, NDCIEA default crop data and expected yield

		Yield	**dm**	**N-total**	**P_2O_5**	**K_2O**
		kg ha-1	**%**	**% in dm**	**% in dm**	**% in dm**
Measured	Potato	29224	17,7	1,38	0,60	3,05
	Carrot	77477	11,8	0,94	0,53	3,40
	Cauliflower	19408	8,5	3,48	1,35	5,09
	Wheat	3134	81,15	1,73	n.m.	n.m.
Default or	Potato	40000	21,0	1,57	0,59	2,72
expected	Carrot	50000	10,4	1,27	0,69	4,18
	Cauliflower	15000	6,6	4,21	1,42	5,89
	Wheat	5500	85,0	2,00	1,00	0,60

n.m. = not measured

In Table 7Table 7 all soil mineral N measurements are presented. A up to F represent the six fields of the experiment. In 2012 the crops were grown as follows: A Potato ; B Carrots ; C Cauliflower ; D Summer wheat ; E and F Clover-grass.

Table 7: Mineral nitrogen in kg ha^{-1}

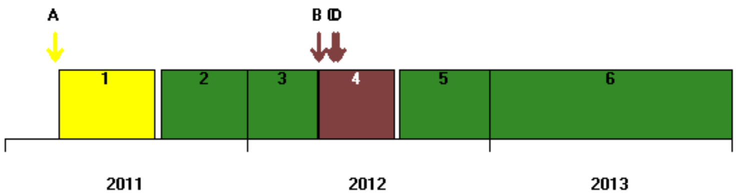
Date	**A**	**B**	**C**	**D**	**E**	**F**
16 May	23	10	5	14	5	5
9 August	20	18	80			
21 August			95	1		
21 September			18			
15 October		5				

6.2 Agronomy and NDICEA calculations

A Potato

The crop was growing sufficient and looked good, but due to potato blight the growth had to be stopped. The applied fertilizers were not those out of the system design. The yield of the potato crop is lower than expected. This disappointing yield cannot be seen as a proof that 40 tonnes is unrealistic.
The nitrogen content of the tubers is lower than the default value, phosphate content is the same, and potassium content is higher than default.

Figure 6 shows the NDICEA results. The upper part reveals the crop sequence and fertilizer applications; the lower part shows the course of soil mineral N as simulated and measured. The simulation has a very good match with the measurements.



1 = Oats ; 2,3,5,6 = Clover-grass ; 4 = Potatoes.

A = Dairy slurry, 25 tons ha^{-1} ; B = Organic pellets, 500 kg ha^{-1}, 25 kg N ha^{-1} ; C = Organic pellets, 680 kg ha^{-1}, 35 kg N ha^{-1} ; D = Cut-and-carry fertilizer, 4.4 tons dm ha^{-1}, 122 kg N-total ha^{-1} .

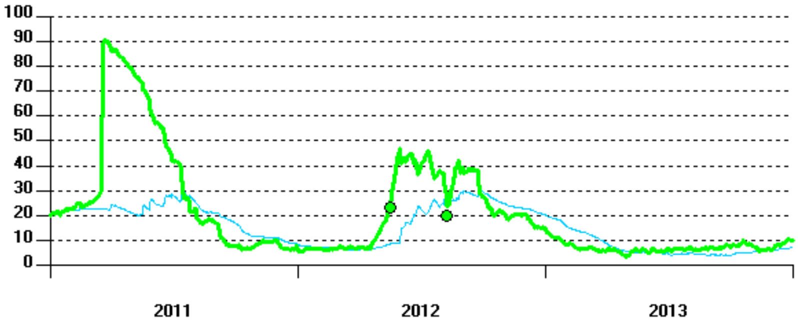
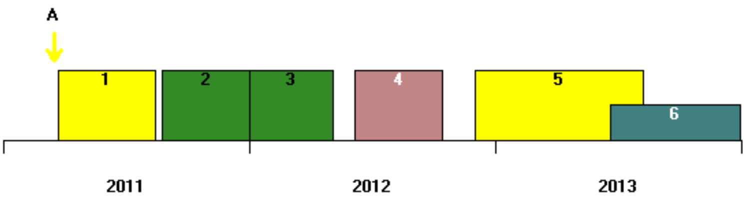


Figure 6: Course of soil mineral N. Green line is topsoil, 0-30 cm. Blue line is subsoil, 30-60 cm. Green dots are measurements in topsoil. Y-axis: kg mineral N ha^{-1}

B Carrot

2012 showed a good crop growth and there were no specific problems. The yield was much higher than expected and the quality was good. The nitrogen content of the carrots was lower than expected. It took (too) much hand labor to control weed growth, but the work done was successful.

Figure 7 shows the NDICEA results. Although the modeled level of soil available nitrogen is close to the three measurements, the modeling is not satisfying because available nitrogen goes down to zero. Figure 8 reveals the modeled shortage of nitrogen for this crop, which is about 20 kg ha^{-1} (2012, the green line crosses the red line). This is not satisfying but observed in more NDICEA scenarios with carrots. The crop parameters for the carrots may need revision.



1 = Oats ; 2,3 = Clover-grass ; 4 = carrots ; 5 = winter rye (planned, not realized) ; 6 = clover green manure (planned).

A = Dairy slurry, 25 tons ha^{-1}

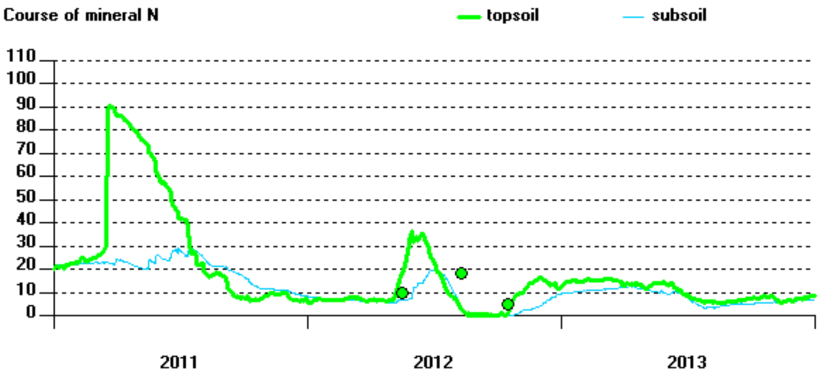


Figure 7: Course of soil mineral N. Green line is topsoil, 0-30 cm. Blue line is subsoil, 30-60 cm. Green dots are measurements in topsoil. Y-axis: kg mineral N ha^{-1}

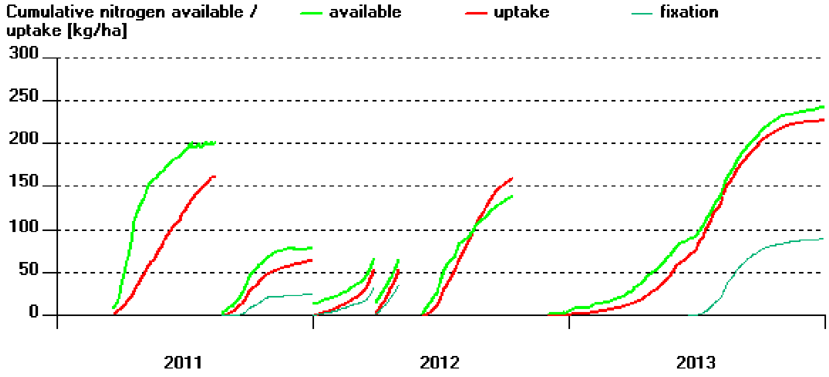
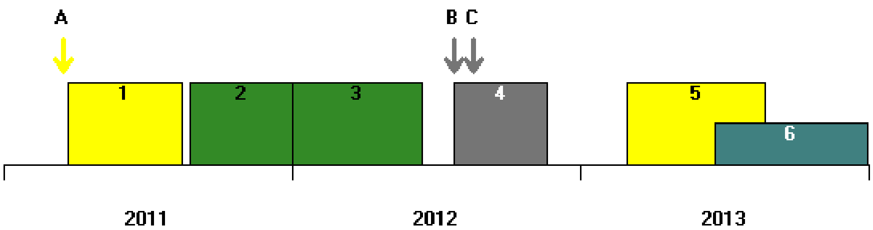


Figure 8: Cumulative nitrogen availability (green line), crop uptake (red line) and nitrogen fixation (turquoise). Y-axis: kg N ha^{-1}

C Cauliflower

The crop was planted later than planned. Incorporation of the clover-grass was successful. Additional fertilizer was done by organic herbal pellets because of lack of stored cut-and-carry fertilizer in this first year. At the end of the growing season the crop showed nitrogen shortage, and part of the product was not harvested because of the size: too small. Total production was 19408 kg ha^{-1} of which 16510 kg could be harvested and sold. This is according to expectation. It was too late in the season and soil conditions were unfavorable for sowing a catch crop.

The NDICEA model simulates a N-mineral level which is during crop growth much lower than measured (Figure 9). The simulation of the mineral N level before planting and after harvest is in accordance with the measurements. So far we can not explain this aberration.



1 = Oats ; 2,3 = Clover-grass ; 4 = cauliflower ; 5 = Spring wheat ; 6 = clover

A = Dairy slurry, 25 tons ha^{-1} ; B = Organic pellets, 500 kg ha^{-1}, 25 kg N ha^{-1} ; C = Organic pellets, 900 kg ha^{-1}, 45 kg N ha^{-1}

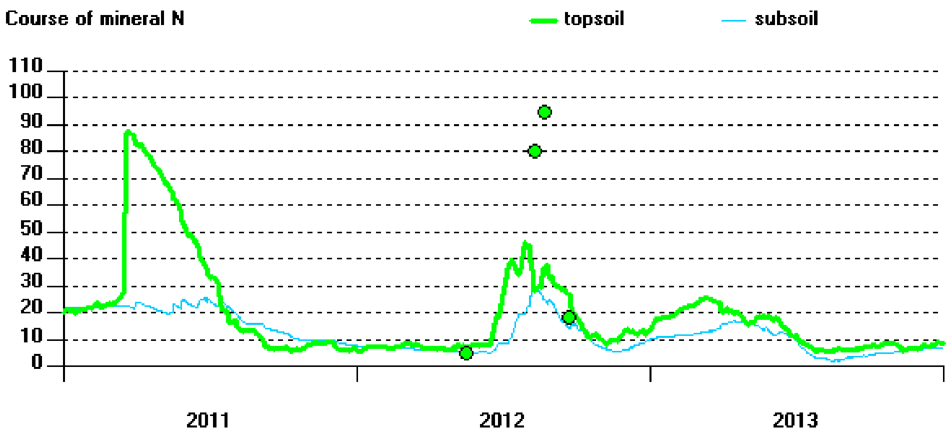
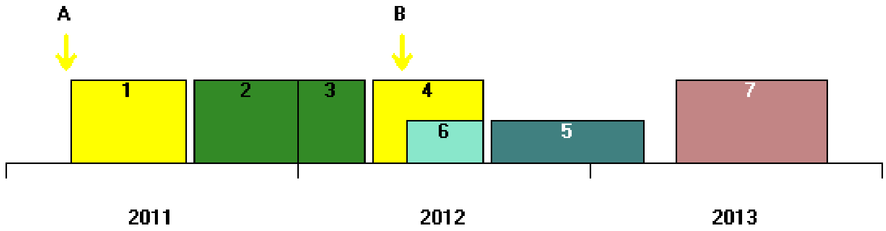


Figure 9: Course of soil mineral N. Green line is topsoil, 0-30 cm. Blue line is subsoil, 30-60 cm. Green dots are measurements in topsoil. Y-axis: kg mineral N ha^{-1}

D Spring wheat

The destruction of the clover-grass sward was nut successful, resulting in a substantial regrowth of grasses and other weeds. This has reduced the yield, which was far below expectation.

The NDICEA model simulates a continuously low level of available nitrogen, which is in accordance with the two measurements. This is also reflected in the nitrogen content of the grains (1.73%), lower than expected.



1 = Oats ; 2,3 = Clover-grass ; 4 = Spring wheat ; 5 = Vetch ; 6 = Weeds; 7 = Carrots

A = Dairy slurry, 25 tons ha^{-1} ; B = Organic pellets, 1080 kg ha^{-1}, 54 kg N ha^{-1}

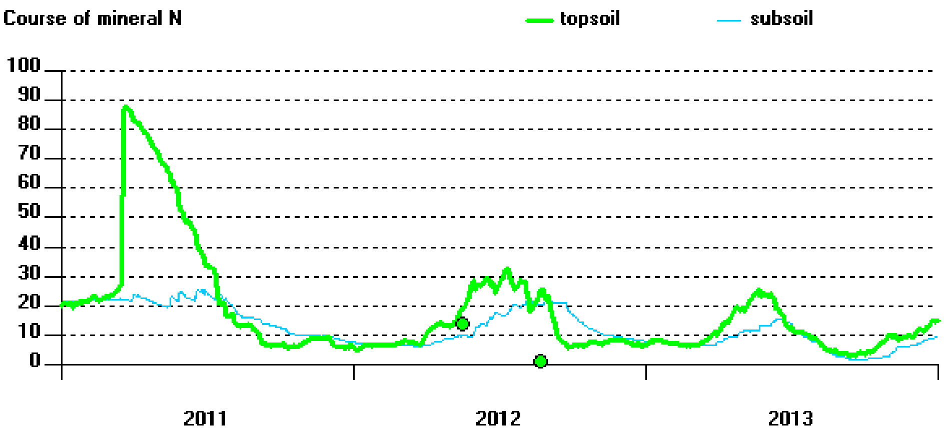
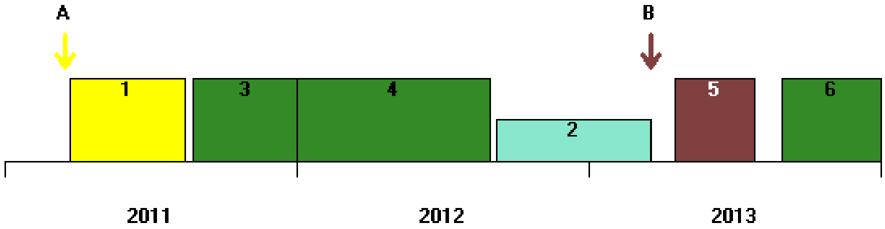


Figure 10: Course of soil mineral N. Green line is topsoil, 0-30 cm. Blue line is subsoil, 30-60 cm. Green dots are measurements in topsoil. Y-axis: kg mineral N ha^{-1}

E Clover-grass

The clover-grass sward was incorporated in the soil at the end of august and fodder radish was sown as catch crop. This was done to simulate as much as possible the pre-crop for the 2013 potato crop according to the system design. The NDICEA simulation showed a slightly too high level of nitrogen availability. Since this depends on one single model parameter, this parameter was adjusted to fit the simulated level to the (one time only) measured level. So the perfect match as shown in Figure 11 is the result of calibration and not the original model result.

For 2013 a nitrogen shortage is foreseen in the potato crop, expecting a production level of 40 tonnes per hectare. It still has to be decided what to do with this knowledge.



1 = Oats ; 3,4 = Clover-grass ; 2 = Fodder radish ;; 5 = Potato ; 6 = Clover-grass

A = Dairy slurry, 25 tons ha^{-1} ; B = Cut-and-carry fertilizer, 6.5 tonnes dry matter, 182 kg N ha^{-1}

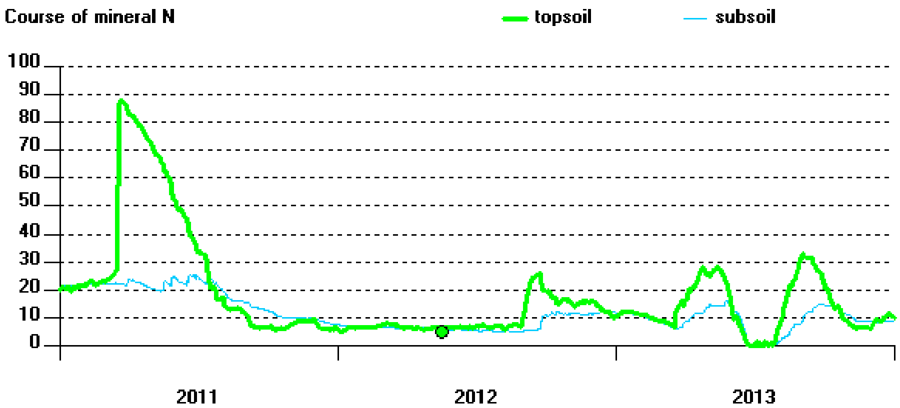
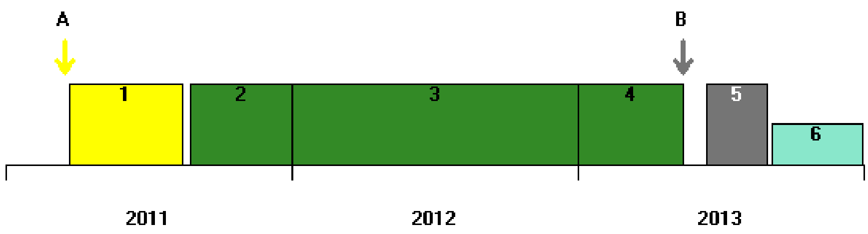


Figure 11: Course of soil mineral N. Green line is topsoil, 0-30 cm. Blue line is subsoil, 30-60 cm. Green dots are measurements in topsoil. Y-axis: kg mineral N ha^{-1}

F Clover-grass

This field of clover-grass is kept intact, contrary to the adjacent field E. This results in the foreseen pre-crop for the cauliflower in 2013.



1 = Oats ; 2,3,4 = Clover-grass ; 5 = Cauliflower ; 6 = Fodder radish

A = Dairy slurry, 25 tons ha^{-1} ; B = Cut-and-carry fertilizer, 3.5 tonnes dry matter, 98 kg N ha^{-1}

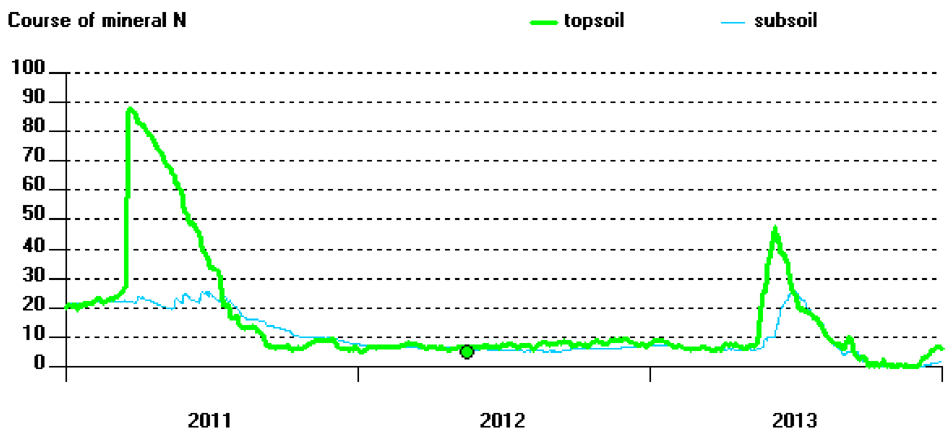


Figure 12: Course of soil mineral N. Green line is topsoil, 0-30 cm. Blue line is subsoil, 30-60 cm. Green dots are measurements in topsoil. Y-axis: kg mineral N ha^{-1}

7 Discussion 2012

As said, 2012 was the first year of this long-term field experiment. None of the crops had the pre-crop as foreseen in the designed crop rotation, and the fertilizer used was predominantly organic pellets and not farm-produced cut-and-carry fertilizer.

Overall yield in 2012 was acceptable, with the carrot yield being excellent, potato and cauliflower yield at an acceptable level, and spring wheat disappointing. It is thought that nitrogen was not limiting in carrots and potatoes. In the spring wheat nitrogen may have been limiting production, but weed is seen as major cause of the low yield. In case of the cauliflower, a nitrogen shortage was visually observed in the second half of the growing season, resulting in a less green color and in an insufficient size of the product.

This first year without ploughing did not cause serious problems. The clover-grass green manure prior to the wheat was not adequately incorporated and resulted in a strong regrowth of grass and weeds. For the other three crops the termination of the clover-grass was successful. Weed control was very labor-demanding in the carrots only.

The timing is a critical moment in the cauliflower and the carrot cultivation. The cauliflower cannot be planted (photo) early because a sufficient amount of the preceding clover-grass green mass is needed as fertilizer. Some weeks space between incorporation of the clover grass and planting of the cauliflower is likely to be necessary.

At the end of the season, there must remain enough time to grow an acceptable catch crop. This year this time was insufficient and no catch crop was sown. For carrots, the autumn might be a problem. There is a need for relatively early harvest to enable the sowing of the winter rye. This year, the combination of a late carrot harvest and unfavorable weather conditions hindered the sowing of the winter cereal.

Overall the experiences in 2012 were valuable. Some straits are identified but there is no need for a review of the design.

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Annex 1: Soil analysis, May 2012

Parameter	Unit	A	B	C	D	E	F	Average
N-total	Mg kg^{-1}	1200	1250	1260	1270	1300	1250	1255
N-delivering capacity	kg N ha^{-1} year^{-1}	73	75	76	76	77	75	75
C	g kg^{-1}	9	9	10	10	10	10	9,7
C/N		7,8	7,4	8,3	8,2	8,1	8,4	8
Pw	mg P2O5 L^{-1}	22	23	27	27	24	26	25
P-AL	mg P2O5 100g^{-1}	35	36	40	40	36	40	38
P-PAE	mg P kg^{-1}	1,2	1,7	1,8	1,7	1,3	1,7	1,6
K-HCl	mg K2O 100g^{-1}	19	19	18	22	18	17	19
K-number	-	29	29	22	27	22	21	25
Potassium	mg K kg^{-1}	63	68	64	76	55	59	64
Magnesium	mg Mg kg^{-1}	34	41	45	44	44	46	42
Sodium	mg Na kg^{-1}	30	38	86	55	11	30	42
pH-KCl	-	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
CaCO3	%	4,1	4,3	4,3	4,5	4,6	4,4	4,4
“Afslibbaarheid”	%	16	16	17	18	18	18	17
Clay content	%	11	11	11	12	12	12	12
CEC	mmol kg^{-1}	88	88	95	99	99	99	95

Annex 2: Clover-grass analysis

			1	2	Pellet	
	16 May	14 June	4 July	4 July	27 Sept	
DM	15,7	13,9	28,2	30,3	90,6	% fresh
N	27,7	18,7	23,5	23	36,2	g/kg dm
N-org	26,1	18,4	20,5	20,4	35,4	g/kg dm
NH4-N	1,6	0,3	3	2,5	0,5	g/kg dm
NO3-N	0,1	<0,1	<0,1	<0,1	0,2	g/kg dm
P2O5	4,1	6,4	8	7,3	7,6	g/kg dm
K2O	32,5	31,6	34,3	32,5	31,4	g/kg dm
MgO	1,7	1,8	2,4	2,3	2,2	g/kg dm
CaO	25,7	12,4	17,2	16,3	11,6	g/kg dm
Na2O	5,8	0,4	0,5	0,4	2,2	g/kg dm
OS	80,2	86,5	86,9	86,1	86,7	% dm