Effective organic matter input seems to have no strong influence on nitrate leaching and maize yield.

Martijn van Overveld

MSc thesis PPS

December 2015

Wageningen UR
For quality of life

Effective organic matter input seems to have no strong influence on nitrate leaching and maize yield.

Student
Martijn van Overveld

Registration number
921211638100

Contact
martijn.vanoverveld@wur.nl

Study
MSc Plant Science

Course Code
PPS- 80436
MSc Thesis Plant Production Systems

Supervisors

MSc .R.Hijbeek (WUR)

ir. J.J de Haan (WUR-PPO)

Ing. H.A.G Verstegen (WUR-PPO)

Examinator:

dr. ir. G.W.J van de Ven (WUR)

Date
22 December 2015

Front page picture: Slurry application in the neighbourhood of Tiel, the Netherlands. Picture by J. Saarloos, spring 2015

Acknowledgements

I would like to thank the following persons: prof dr. ir. Martin van Ittersum and ing. Bert Rijk for supervising my thesis in early stages, Msc. Renske Hijbeek , ir. Janjo de Haan and ing. Harry Verstegen for supervising the major part of the thesis, for their time and constructive support. Dr.ir Wim van den Berg for his support on the statistical analyses . Dr. Ir. Jaap Schröder, Ing. Bert Rijk, and dr. Ir. Bert Janssen for supporting the construction of the balance sheets. Leontine van der Wielen for support in making the lay-out of the report. I would also like to thank my parents René and Jenny van Overveld, who made it possible for me to study at Wageningen UR.

Table of contents

Summary

One of the effects of agriculture on the environment is nitrate leaching from the agricultural system to ground water. In this study, it was hypothesized that soil organic matter (SOM) may reduce the amount of nitrate leaching due to its binding capacity, its function as carbon source for denitrification bacteria and a positive contribution to crop yield, leading to a larger nitrogen uptake by the harvested crops.

To test this hypothesis, data was analysed from a long-term experiment on an experimental farm called Vredepeel. Three organic matter supply treatments were compared with each other: 1. Conventional high effective organic matter (EOM*) input (2200 kg EOM ha^{-1} y^{-1}) 2. Conventional low EOM input (1450 kg EOM ha^{-1} y^{-1}) 3. organic (3200 kg EOM ha^{-1} y^{-1}). Descriptive figures with trends, nitrogen balance sheets and statistical analyses were done. The statistical analyses were done to assess which factors and variates give the best fit for explaining variance in leaching and maize yield. Due to time constraints the data from 2011 till 2014 were analysed.

The results show that the nitrate concentration in the upper meter of the ground water was significantly higher in the conventional treatments than in the organic treatments and there was no significant difference between the conventional treatment with high EOM input and the conventional treatment with low EOM input. Overall, there is no significant difference in maize yield. No evidence of strong effects of EOM input and nitrogen supply on leaching was found in this study. Plot, treatment and green manure show the strongest significant explanation of variance of nitrate leaching. So there was no strong influence of EOM input on nitrate leaching and yield.

**EOM : effective organic matter, the part of the applied organic matter a year after application and which will present in soil for a long term .*

Key words: *nitrate leaching, effective organic matter (EOM) , model selection, N fertilization, N balance sheet.*

Glossary:

Term	Explanation
SOM	Soil organic matter: components of the soil which exist of organic residues such as plants, yeasts and bacteria. Part of these components decomposes and nutrients are released.
EOM	Effective organic matter: The amount of organic matter which is still present one year after supply or application.
N total fertilization	Total fertilization of nitrogen. Main sources of nitrogen fertilization are slurry, manure and synthetic fertilizer.
N effective fertilization	Part of the total nitrogen content in manure or slurry, applied just before or during the cropping season which becomes available for plants within the growing season,.
N surplus	Nitrogen fertilization plus deposition plus fixing minus the nitrogen uptake by harvested products: the nitrogen which is left in the soil after crop harvest.
Nitrate leaching	Nitrate which leaves an agricultural system transported by rain into the ground water.
N pure leaching	Nitrogen leaches as nitrate. Nitrate consists of nitrogen and oxygen, N pure is the nitrogen the nitrate -> 4.43 grams of nitrate contains 1 gram N.
Leaching fraction	Percentage N leached of the N surplus
EU nitrate norm	EU-directive: a maximum of 50 mg nitrate in the ground water is allowed in the entire European Union.
Model selection	Statistical analyses which create a model for explaining variance in a dataset. Factors and (co)variates are selected which are included in the best fitting model for explaining variance of data.
LSD	Least significant difference: statistical tests where means were compared with each other. When the mean difference is bigger than the LSD than the difference is significant and vice versa.

1. Introduction

1.1 Agriculture in the Netherlands

In 2013, the total agricultural land area of the Netherlands was about 1,85 million ha (about 60% of the total land area). 3% of this total agricultural area was cultivated as organic agriculture, while conventional agriculture is practiced on the remaining 97% Berkhout et al., (2014)**.**

Conventional agriculture uses external inputs such as high yielding cultivars, fertilizers and crop protection agents. Agriculture may have negative effects on the environment. Soil erosion, decrease of SOM, ground and surface water polluted with residues of crop protection agents and fertilizers, development of resistances against crop protection agents and emission of greenhouse gasses are examples of these negative effects Edwards, (1989) and Aneja et al., (2009). This study focuses on nitrogen fertilization and nitrate leaching.

Nitrogen

Nitrogen (N) enters an agricultural system by inputs such as fertilizer, animal manures, atmospheric deposition, biological fixation and run on of soil. Agricultural systems also have N outputs such as N in harvested products, volatilization, denitrification, run off and N leaching in the form of nitrate (Figure 1.1). Figure 1.1 describes the N fluxes in an agricultural system in the Netherlands based on Schröder et al., (2003) and Mosier et al., (2013). Run on and run off were not taken in account in figure 1.1 because soil erosion hardly occurs in the Netherlands.

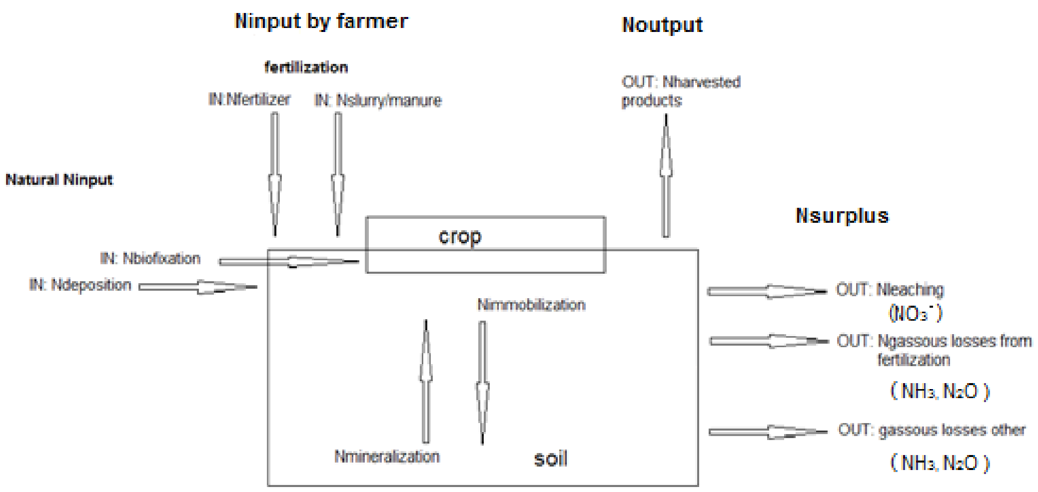


Figure 1.1: Schematic overview of N fluxes in an agricultural system based on Schröder et al., (2003) and Mosier et al., (2013).

Ninput minus Noutput is the N surplus and can cause leaching, ammonia volatilization and other gaseous losses of N_2 and N_2O which are caused by denitrification. (equation (1.1)).

$$N\ surplus = N\ fertilization\ (kg * ha^{-1}) + deposition\ (kg * ha^{-1}) + fixation(kg * ha^{-1}) - N\ uptake\ by\ harvested\ products\ (kg * ha^{-1}) \quad (1.1)$$

Figure 1.2 shows the N fertilization, N offtake by harvested products and N surplus in kg per ha in the Netherlands during 1970, 1980, 1986, 1990, 2000, 2005, 2010, 2011 and 2012. Highest levels of N had been supplied during 1980 and 1986, in these years the N surplus was higher than the N offtake by harvested products. After 1998 the N fertilization levels per hectare decreased due to legislation of N fertilization through MINAS: mineral accounting system, Withagen and Betsema, (2005) followed by the legislation with crop specific N application standards in 2006. Van Dijk and Schröder, (2007) This resulted in lower N offtake by harvested products and lower N surpluses from 2000 onwards.

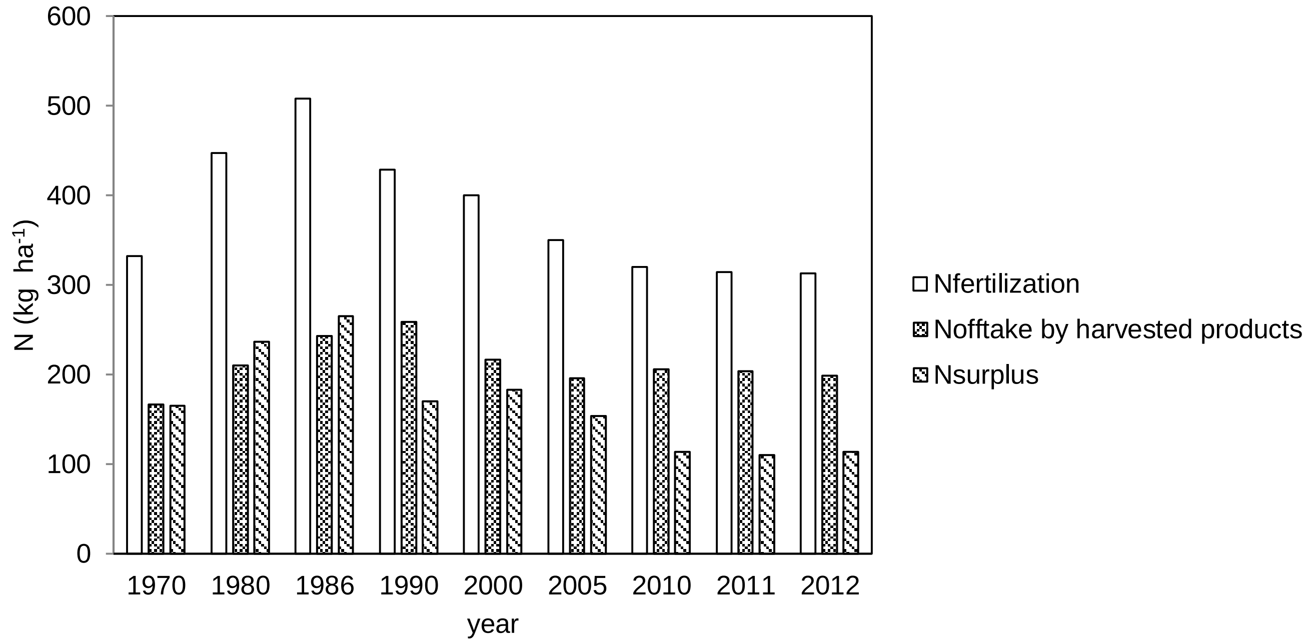


Figure 1.2: N fertilization N offtake by harvested products and N surplus in kg per ha in the Netherlands during 1970, 1980, 1986, 1990, 2000, 2005, 2010, 2011 and 2012 Berkhout et al., (2014) .

Part of the N surplus leaves the agricultural system by leaching; nitrate in upper soil layers is transported to the groundwater by percolating water from rainfall or irrigation. The leaching fraction of N differs per soil type and on N fertilization, and crop uptake RIVM, (2007). The leaching fraction is the amount of the N surplus which leaches into the ground water (equation 1.2)

$$Leaching\ fraction = \frac{N\ leaching\ (kg\ ha^{-1})}{N(mineral\ form)\ surplus(kg\ ha^{-1})} \qquad (1.2)$$

1.2 Effects of nitrate in surface water

When more N is supplied than the uptake of the crops, nitrate can leach to the ground water. An excess of nitrate in ground water may lead to eutrophication of surface water. Eutrophication of surface water may lead to excessive growth of algae and macrophytes and oxygen shortage in surface water. Eutrophication has negative or even toxic effects on fish, cattle and human beings. Another effect of eutrophication is an algae bloom in estuaries.

Drinking water with increasing concentrations of nitrate increases the risk for human health. It is considered that drinking water with higher concentrations of nitrate than 50 mg/l affects red blood cells and may result into a reduced oxygen absorption capacity of human blood. Mosier et al., (2013) . However, the assumption that blood absorption is affected by nitrate concentration in drinking water is disputable. Fan and Steinberg, (1996)

1.3 Legislation of nitrate concentration in ground water.
Consequences of increasing nitrate concentration in ground water and surface water have resulted in policies to protect ground and surface water against contamination with nitrate. The EU-directive has introduced legislation on the maximum nitrate concentration to make sure nitrate in ground and surface waters does not exceed tolerable concentrations. Fan and Steinberg, (1996).

Standards for maximum concentrations of nitrate in ground water are based on a report of the American Public Health Association APHA, (1950). This resulted in a recommended maximum concentration of 50 mg nitrate l^{-1} (50 mg nitrate corresponds with 11,3 mg N) in ground water in the EU and 44 mg/ nitrate (10 mg N-nitrate/l) in ground water the USA. These values agree with the WHO recommendations of 1970 and are reviewed and reconfirmed by the WHO in 2004 Powlson et al., (2008).

1.4 Nitrate concentration in the Netherlands
N leaches from the agricultural system in the form of nitrate and the nitrate concentration in ground water is an indicator for the amount N leaching.

Within The Netherlands, nitrate concentrations in ground water differ per soil type and per farming sector (figure 1.3) RIVM, (2012). Nitrate concentration was highest in the upper meter of ground water of sandy soils and lowest in upper meter of ground water peat soils between 1992 and 2003 (figure 1.3a). The nitrate concentration in upper meter of ground water declines over time for all soils except for peat soils (figure 1.3a) RIVM, (2012).

For sandy soils, nitrate concentrations were averaged for specific farm types such as dairy farms, arable farms, meat production farms and other farm types (figure 1.3b). From 2004 onwards, nitrate concentration in the upper meter ground water of dairy farms are around the EU nitrate norm. Between 1992 and 2011, on arable farms on sandy soils the nitrate concentration in upper meter ground water hardly meets the EU norm and the upper meter ground water on meat production farms contains the highest concentration of nitrate more than 200 % of the EU norm during 2006. From 2004 onwards, other farm types follow the same trend as arable farms.

Figure 1.4 shows a map of average nitrate concentrations in upper meter of ground water in different soils of the Netherlands from 2007 till 2010 RIVM, (2012). This figure shows that high concentrations of nitrate mainly occurs in the east and south-east part of the Netherlands. These regions have sandy soils (figure 1,5) and the south east part of the Netherlands has the highest slurry production. Staalduinen et al., (2002)

The Dutch government currently tries to reach the maximum nitrate concentration of 50 mg l^{-1} in the upper meter ground water by using legislation limiting N fertilization by farmers RIVM, (2007). The limit on total N fertilization at farm level depends on crops cultivated on the farm, soil texture of fields of the farm, crop area of the farm and the region where the farm is located. Ground water levels also affect nitrate leaching. Denitrification increases when the soil oxygen content decreases. This is caused by anaerobic denitrification bacteria which convert nitrate to nitrite. Hiscock et al., (1991). In the section results of this report the effect of ground water level is further described.

Each crop has a maximum allowed level of nitrogen fertilization per hectare and this may differ per soil texture per region. Models e.g. WOG-WOD were used to calculate these maximum levels of N fertilization, starting from a nitrate concentration of 50 mg/l in the upper meter of ground water Groenendijk et al. (2014). Equation 1.3 shows how a farmer can calculate the maximum N fertilization at farm level, but the farmer is free to distribute the fertilizer over the crops on the fields. In equation 1.3 area (ha) indicates the areal of a certain crop of a certain soil texture on a farm in a certain region and N max (kg ha^{-1}) is the limit of N fertilization on a certain crop, certain soil texture in a certain region within the Netherlands.

$$Maximum\ N\ fertilization\ at\ farm\ level = \sum_{c,t,r}(area\ c,t,r * Nmax\ c,t,r) \qquad (1.3)$$

c=crop, t= soil texture, r= region

There is also legislation for manure application: a farmer is limited to apply 170 kg N ha^{-1} from manure and during winter slurry application is not allowed in the Netherlands.

However, there are more strategies to reduce nitrate leaching from agricultural soils, than only reduced nitrogen fertilization. These strategies are described in the following section called 'strategies to reduce nitrate leaching'.

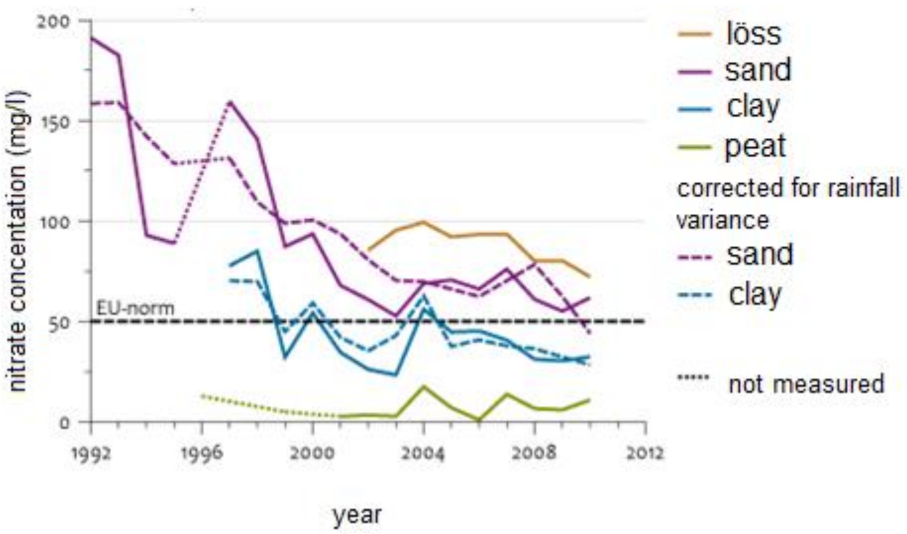


Figure 1.3a: Trend of nitrate concentration in upper meter ground water of different soil textures of the Netherlands from 1992 till 2010, RIVM, (2012). Interrupted lines indicate the nitrate concentration in upper meter of ground water corrected for the variance in rainfall. Dotted lines indicates a inter/extrapolation of nitrate concentration in upper meter of ground water, however RIVM did not explain this extrapolation in their report.

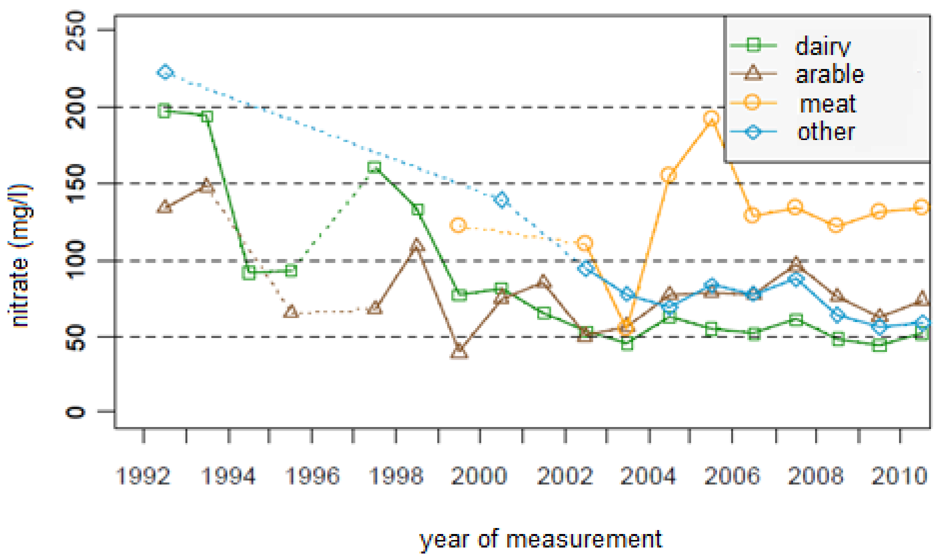


Figure 1.3b: Trend of nitrate concentration in upper meter ground water for main farming sectors (dairy, arable, meat production and other sectors) on sandy soils of the Netherlands from 1992 till 2011. Meat production represents the production of pigs, poultry and beef. Dotted lines indicates an inter/extrapolation of nitrate, however RIVM did not explain this inter/extrapolation in their report. RIVM, (2012)

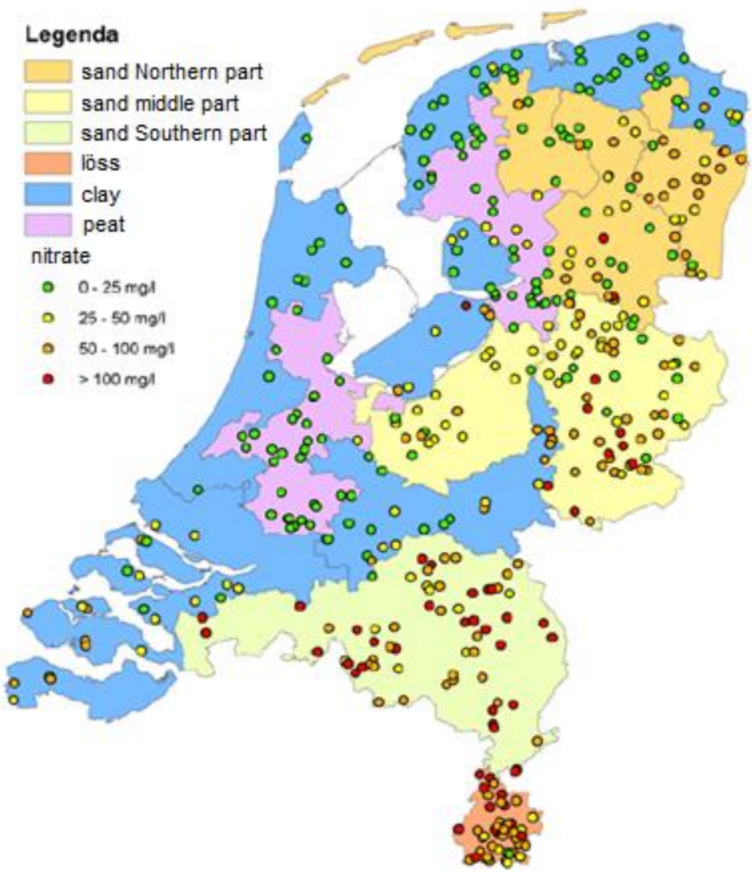


Figure 1.4: The average nitrate concentration in the upper meter of the ground water in the Netherlands of the period 2007-2010. RIVM, (2012).

1.5 Strategies to reduce nitrate leaching

1.5.1 improve nitrogen use efficiency

Strategies for farmers to reduce nitrate leaching can be placed into two broad categories: applying lower N fertilization or- and increase the Nitrogen Use Efficiency (NUE). In this section the treatment to reduce nitrate leaching by increasing NUE is described. NUE is defined here as the supplied nitrogen by fertilization (kg/ha) divided by crop dry yield (kg/ha), (equation 1.4).

$$NUE = \frac{crop\ dry\ yield\ (kg\ ha^{-1})}{nitrogen\ fertilization(kg\ ha^{-1})} \qquad (1.4)$$

NUE is affected by crop characteristics, environmental factors and crop management Mosier et al., (2013). Examples of crop characteristics are: harvest index, annual or perennial crops and root or cereal crops. Perennial (e.g. apple) and cereal (e.g. barley) crops have higher NUE than annual root crops (e.g. sugar beet).This is caused by differences in rooting depth and length of the growing season. Resistance of cultivars against pathogens also affect NUE, because the influence of yield reducing factors are lower and yield is higher at a similar N fertilization level Mosier et al., (2013).

Examples of environmental effects are: crop growth determining or crop growth limiting factors. Some of these have influence on processes in the N cycle e.g. rainfall affects nitrate leaching. The order of importance of environmental factors on nitrate leaching mentioned by Mosier et al., (2013) is as follows: rainfall>temperature>irradiance.

Farmers have little influence on environmental effects and crop characteristics, therefore the best option for a farmer to influence NUE is by changing the farm management. The effects of different farm management practices on NUE are described by Mosier et al., (2013). These practices are: applying crop rotation, cover crops and weed and pest management: these practices have indirect effects on NUE. In addition, cover crops may have a better root system than cash crops and can recover nitrogen which was not taken up by cash crops. Diseases, pests and weeds reduce crop yield if they are not controlled. When crop yield is reduced and the same amount of N has been applied, NUE is reduced. Mosier et al., (2013) assumed the crop rotation and cover crops both improve soil physical conditions and build up soil organic matter (SOM).

1.5.2 Role of soil organic matter

SOM has an essential role in soil; it affects soil physical, chemical and biological properties. SOM is found in plant and animal manure residues that are decomposing and in soil fauna (yeasts and microorganisms and their residues) Rice et al., (2007). Table 1.1 shows an overview of the effects of SOM on soil chemical, physical and biological properties described by Rice et al., (2007).

Table 1.1: Effects of SOM on soil chemical, physical and biological properties according to Rice et al., (2007).

Chemical	**physical**	**biological**
Part of C, N, P, S cycle.	Key role in formation and stabilization of soil aggregates.	Source of energy and carbon for many microorganisms.
Sink-source of C,N, P,S.	Improves soil structure	Improves formation of SOM by microorganisms
Important source of N and S.	Improve soil aggregation; make soil less prone to crusting and compaction.	Is part of food web for organisms that mix the soil.
Store other nutrients in soil due to CEC *	Enhance water holding capacity	Drives microorganisms that are responsible to mineralization and immobilization of nutrients

*cation exchange capacity

Long-term experiment Vredepeel

In literature no experiments were found where the assumptions that SOM decrease nitrate leaching and improves yield were scientifically tested with quantitative analyses. In this study, the effects of SOM on nitrate leaching were tested by analyzing date from an experimental farm. This was an experimental farm in Vredepeel, in the South-East of the Netherlands. On this experimental farm a long term (2001-onwards) experiment about the effects of organic matter supply take place. The experimental farm and the set-up of the long term experiment in Vredepeel are explained in the section 'Vredepeel' on the next page.

1.6 Vredepeel experiment

Near by the village Vredepeel is an experimental farm of applied plant research (PPO), PPO is a part of Wageningen UR. Vredepeel is located in the South East part of the Netherlands (figure 1.6). This experimental farm consist of 110 ha drought sensitive sandy soil. The soil texture consist of 93,3 % sand, 4,5% silt and 2,2 % clay. The soil has a high to very high phosphorus content (+/- 2,2 mg kg^{-1}) Schrama et al., (2013). The climate in Vredepeel is a sea climate with an average temperature of 3.5 °C during January and 18°C during July. KNMI , (2015)

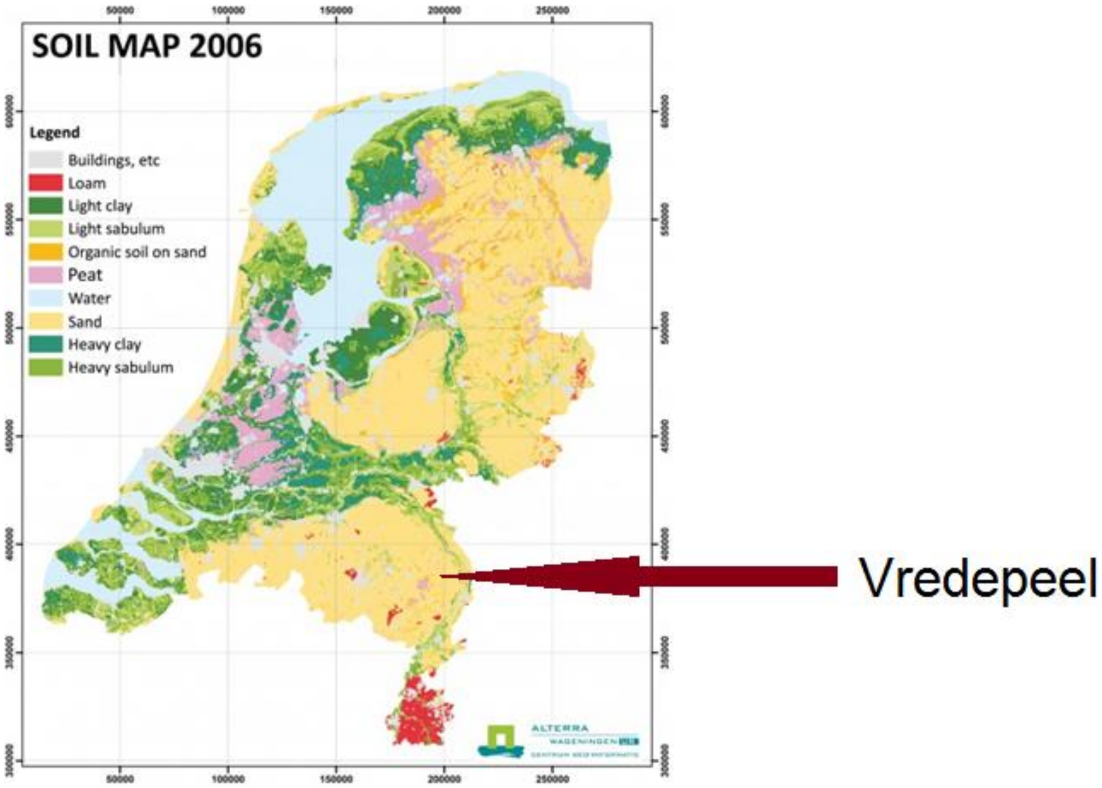


Figure 1.5: Location of Vredepeel (N 51° 32' 36", E 5° 51' 13") in the Netherlands soil map Alterra (2006).

On the Vredepeel experimental farm a long-term (2001-2015) experiment is performed to assess effects of effective organic matter (EOM) input. EOM is the part of the applied organic matter which is still present one year after application. The main objective of this long-term experiment is to compare agricultural systems, such as conventional or organic on a number of indicators. In addition, hopefully insights can be gained into the relation between the input of effective organic matter (EOM) on the one hand and on the other hand the crop yield, nitrate leaching, soil properties such as SOM content, water holding capacity etc. and financial result for farmers in the long term. The main target audiences of this experiment are the farmers who cultivate vegetables and governmental/agricultural organizations.

From the Vredepeel experiment only the data of 2011 till 2014 was analyzed in this study. The Vredepeel farm management organized the data for these years clearest. Due to time constraints there was no possibility to analyze the data for all years. Moreover, it was expected that the differences between the treatments were strongest after several years. These treatments are described below.

Treatments

The long term experiment has three treatments and each treatment has a different level of EOM input. Figure 1.6 shows the set-up of the treatments on the fields of the Vredepeel experimental farm. These treatments are as follows:

1.Conventional high EOM input : This is a treatment with an conventional agricultural system with an average EOM input of <u>2190</u> kg ha^{-1} y^{-1} during 2011-2014. This treatment consists of 6 plots with a length of 200 m and a width of 33m. On these plots a 6 year sequence of the crops: 1. of *Solanum tuberosum L.* (potato), 2. *Pisum sativum L. (*peas), 3. *Allium porrum L.* (leek), 4. *Hordeum vulgare L*. (barley),5. *Beta vulgaris L.* (sugar beet) and 6. *Zea mays L.* (maize) are cultivated. Each year all crops are grown. In this treatment artificial fertilizers and crop protection agents were used.

Cattle slurry, crop residues and green manure are sources of EOM in this treatment (table 1.2). The green manure was only considered a source of EOM when the green manure crop was well established. The cultivated green manures in this treatment are *Raphanus sativus L*. (fodder radish*), Hordueum vulgare L*. (barley), *Lolium perenne* (rye grass), *Tagetes L*. (Marigold) and *(Avena sativa L.)* oat.

2. Conventional Low EOM input: This is a treatment with a conventional agricultural system with an average EOM input of <u>1447</u> kg ha^{-1} y^{-1} during 2011-2014. This treatment consists also of 6 plots and these plots have a length of 200 m and a width of 36 m. The same crop sequence is cultivated as in the conventional high EOM input treatment and all crops are grown each year. In this treatment also artificial fertilizer and crop protection agents are used.

Cattle slurry, crop residues and green manure are sources of EOM in this treatment (table 1.2) The green manure was only considered a source of EOM in the years that the green manure crop was well established The cultivated green manures in this treatments *Raphanus sativus L*. (fodder radish), Hordueum vulgare L. (barley) and *Lolium perenne* (rye grass) and *(Avena sativa L.)* oat.

***3. Organic*:** This is a treatment with an organic cultivation system. Artificial fertilizers and crop protection agents were <u>not</u> used. This treatment had an average EOM input of 3219 kg ha^{-1} y^{-1} during 2011-2014. This treatment also consists of 6 plots with a length of 190 m and a width of 33 or 36 meters. The following crop sequence is cultivated in the organic treatments: 1. of *Solanum tuberosum L.* (potato), 2. *Pisum sativum L. (*peas), 3. *Allium porrum L.* (leek), 4. *Hordeum vulgare L*. (barley),5. *Daucus carota L.(carrot)* and 6. *Zea mays L.* (maize). The only difference in crop sequence between the conventional and organic treatments is the cultivation of carrots instead of sugar beets in the organic treatments. Carrots are included into the organic treatment because there is no market for selling organic sugar beets in The Netherlands. The Vredepeel experimental farm management considered that carrots are the best alternative for sugar beets in this experiment.

Cattle slurry, farm yard manure, crop residues and green manure are sources of EOM in this treatment. The green manure was only considered a source of EOM in the years that the green manure crop was well established (table1.3) The cultivated green manures in this treatments are (*Lolium perenne L. + Trifolium L.)* grass clover , (*Raphanus sativus L*.) fodder radish, (*Lolium perenne*) rye grass, and (Hordeum vulgare L.) Barley and *(Avena sativa L.)* oat

The sources of EOM differs per crop, each crops has an own combination of EOM sources. These combinations EOM sources are summarized by table 1.2. The size of each EOM source for are shown by table 1.3 for all treatments. The average EOM input (kg ha^{-1} y^{-1}), its standard deviation, minimum and maximum value are shown for each EOM source during 2011 till 2014.

Table 1.2: EOM sources for each crop in the conventional treatments and in the organic treatment In the conventional treatments amounts are smaller in the low EOM input version. Green manures were only considered an EOM source if it was well established (substantial crop growth to produce biomass, as determined by the field managers). NA means Not Applicable: The crop is not present in the rotation of the specific treatment.

Treatment	Potato	Peas	Leek	Barley	Sugar beet	Maize	Carrot
Conventional high and low EOM input	– crop residues – slurry – green manure	– crop residues – slurry – green manure	– crop residues – slurry – green manure	– crop residues	– crop residues – slurry	– crop residues – slurry	NA
Organic	– crop residues – slurry – farm yard manure	– crop residues – slurry – green manure	– crop residues – slurry – green manure	– crop residues – slurry	– NA	– crop residues – slurry – farm yard manure	– crop residues – slurry

Table 1.3: The EOM input sources for each treatment from 2011-till 2014. The values of average, st. deviation, minimum and maximum of the EOM sources are expressed in kg ha^{-1} y^{-1}.

treatment	EOM source	average	st. deviation	minimum	maximum
conventionall high EOM input	total	2190	840	794	3804
	slurry	735	860	73	2625
	crop residues	1023	327	615	1382
	green manure	1016	136	800	1123
conventional low EOM input	total	1447	751	375	2505
	slurry	48	27	8	99
	crop residues	816	415	310	1382
	green manure	1005	138	800	1123
organic	total	3219	1407	1360	5805
	slurry	984	414	221	1715
	farm yard manure	2197	320	1523	2555
	crop residues	893	481	310	2175
	green manure	929	182	518	1123

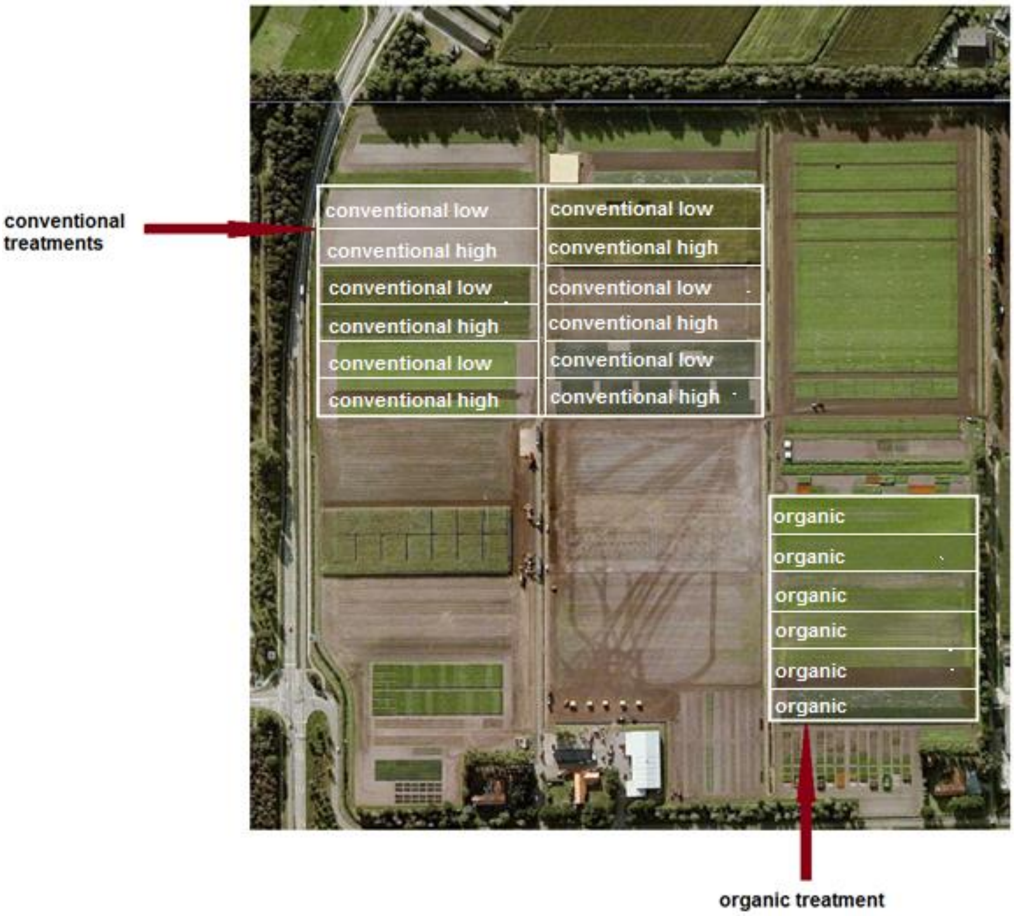


Figure 1.6: Aerial picture of the Vredepeel experimental farm with the orientation of the treatments (Google, 2015) The treatments are described in the plots.

To assess the effects of organic matter on nitrate leaching and maize yield with this experiment, a research question and hypotheses were formulated. These are described in the next section.

2. Main question and hypothesis

The aim of this study was to compare the effects of three organic matter input treatments on N-leaching and crop yield. The research question and hypotheses were as follows:

Main question: *What are the effects of different treatments of organic matter supply on the N cycle in a rotation of arable, vegetable and feed crops at farm level on sandy soils in the south east of the Netherlands?*

Hypotheses

1. High input of EOM with similar N inputs (total and effective) through organic and mineral fertilizers gives a lower level of nitrate leaching.
2. High input of EOM with similar N inputs (total and effective) through organic and mineral fertilizers gives a higher maize yield and N offtake by harvested products.

Schematic overview of the hypotheses

EOM input ↑ **:** N nitrate leaching ↓

EOM input ↑ **:** maize yield + N offtake by harvested product ↑

To test these hypotheses, nutrient balance sheets were constructed and significance of effective organic matter input on nitrate leaching was tested.

3. Methodology

To test the two hypotheses that higher inputs of effective organic matter give higher crop yield, higher N uptake and lower nitrate leaching, two approaches were followed: 1) construction of a nitrogen balance for each treatment. 2) statistical analyses to determine the significance of the effects of EOM and other factors on nitrate leaching and maize yield.
First, yield data, nitrate leaching data, and data of potential influencing factors such fertilization, weather data, sowing and harvest date etc. were organized in a data file. From this data file trends and correlations were visualized. Secondly a nutrient balance for total N was created to provide more insight in the differences in N fluxes between the EOM input treatments; these were focused on N input by fertilization, biological fixation and deposition. Finally a statistical analyses was done to find the most influencing factors for maize yield and nitrate leaching.

3.1 methods

From Vredepeel experimental farm the following data were available:

a. Nitrate concentration in upper meter of ground water
b. Yield
c. N mineral in soil after crop harvest and in November
d. N Input with fertilizer slurry and manure.
e. EOM input
f. Weather data :precipitation, temperature and radiation
g. OM content

The data file was divided into, factors, (co)variates for nitrate leaching and (co)variates for maize yield. Details for each group are described in the sections ‘factors’, ‘(co)variates for nitrate leaching’ and ‘(co)variates for maize yield’. In these sections it is also explained why these factors and (co)variates were included.

Initially trends of the measured (co)variates were investigated with graphical plots. The graphical plots provided an insight which analyses should be applied to the data. Software packages GenStat and Microsoft Excel were used to create graphs which show the relation between maize yield and nitrate leaching to a (co)variate. Maize yield and nitrate leaching are on the y-axis and the (co)variates on the x-axis within these plots.

Due to time constraints only maize yield was analyzed. Moreover for maize the same cultivar was used in each treatment of the Vredepeel experiment, this makes maize better comparable than other crops were different cultivars were used.

3.2 dataset 2011-2014

3.2.1 Factors included in the statistical analysis

Plot

The factor plot was included in the dataset to represent the location of a plot within the trial field (Appendix 9.1). The code of the plot also indicates tillage and treatment. The data management of the Vredepeel experimental farm indicated the plots with a plot code. Plot codes were included in all measurements of the Vredepeel experiment in each data file. On this way one big data set could be created. There were 36 plots included in the experiment (table 3.1).

Treatment

The factor treatment represents the different EOM input treatments. 1: conventional high input of EOM treatment (2190 kg EOM ha^{-1} y^{-1}) 2. Conventional low input of EOM treatment 1447 (kg EOM ha^{-1} y^{-1}) 3.organic EOM treatment (3219 kg EOM ha^{-1} y^{-1}). When visualizing trends, data was divided in these three groups.

Crop

Crop type may have a strong effect on the results of the measurements due to the cropping calendar and other crop characteristics; therefore crop type was also included as a factor in the statistical analysis. In the organic treatment no sugar beet was cultivated, because the experimental farm wants to resemble real farms and in the Netherlands there is no market for organic sugar.

Green manure

The presence of green manure is taken as factor because it influences input of EOM and it can affect the size of nitrate leaching Wyland et al., (1996). Green manure used in the Vredepeel experiment are: (*Lolium perenne L.+ Trifolium L.)* grass clover , (*Raphanus sativus L.)* fodder radish, *(Avena sativa L.)* Oat *(Lolium perenne L.)* rye grass and (Tagetes L.) Marigold

Year

Crops are rotated over the plots annually, crop yield and weather circumstances vary over years. For these reasons year is included as factor. In the Vredepeel experiment crops are rotated over the plots and all crops are present each year.

3.2.2 (co)variates influencing leaching

To analyze the effect of EOM input on nitrate leaching, different variables were included in the dataset, which could be classified into the following groups: nitrate concentration in the upper meter ground water N measurement in soil, OM N, PK and weather data. Table 3.1 shows a summary of (co)variates which are included into the dataset.

Nitrate concentration in upper meter ground water (response variate).

Measurements of nitrate concentration in upper meter of ground water (mg l^{-1}). Nitrate concentration is an indicator of N leaching. Legislation on nitrogen in agriculture is based on a maximum nitrate concentration in ground water. Measurements were done during November, December, January and February. The measurements of January and February were allocated to the previous year.

N-measurement soil (variates)

Measurements of soil N at different depths provide an indication of the amount of nitrogen which is present in the soil and may be prone for nitrate leaching. Soil N measurement indicates the amount of mineral N in the soil (NH_3, NO_3^-) and is expressed in N (kg ha^{-1}). A soil sample was taken by mineral form of N was measured after harvest of crops and November in each plot. The measurements took place in a range of 3 depths: 0-30 cm, 30-60 cm and 60-90 cm into soil. The measurements of 0-30 cm and 30-60 cm are applied in all plots and the measurements of 0-90 cm are not applied in all plots. N-soil measured after harvest is an indication of N surplus from the cultivation of a crop. N soil measurement in November gives an indication of nitrogen which may be prone for nitrate leaching.

In this study only nitrate leaching on ploughed plots during the period 2012-2014 was analyzed, because no nitrate concentration measurements were done in the non-ploughed plots and during 2011 no nitrate measurements were done in all plots.

OM (variate)

EOM (kg ha^{-1}) input represents the amount of effective organic matter supply which is supplied to the field within the cultivation of a crop or a green manure and both (EOM total) SOM content is the organic matter content in the soil and is expressed as a percentage.

N (variate)

In each system there were different sources and levels of N input which were taken into account in the data set and may differ among the treatments. N was supplied by slurry, fertilizer and farm yard manure. N which leaves the system by harvested products is the N offtake. In the dataset the N suplus is indicated as follows: N surplus is the total N input to crop/green manure minus the N output by harvested products. N input, N offtake, N surplus and N effective are expressed in (kg ha^{-1}). The variates of N were specified for each crop and green manure, these covariates were summed, (e.g. $N_{\text{supply total}} = N_{\text{supply crop}} + N_{\text{supply green manure}}$) + deposition.

P and K

P and K has the same inputs and outputs as N as described above.

Weather (covariate)

Weather circumstances such as rainfall and temperature also affect the nitrogen which leaves the system by nitrate leaching. Temperature affects the rate of mineralization during the winter, winters with relative high temperatures will result in a higher mineralization rate of N than relative cold winter.

Nitrate leaching is also strongly affected by rainfall; nitrate is transported to the ground water by water from rainfall during winter. Temperature is expresses as the temperature sum of a certain period (°C) and rainfall is expresses as the sum of rainfall of a certain period (mm).

Table .3.1: Overview of (co)variates and their units which are incorporated into the dataset nitrate leaching.

	variate	unit	variate	unit	variate	unit	variate	unit
N measurment soil	ground water		soil		soil			
ground water	NO_3^- concentration November	mg/l	N mineral after harvest 0-30 cm	kg/ha	N mineral after harvest 60-90 cm	kg/ha	N mineral after harvest 0-90cm	kg/ha
	NO_3^- concentration December	mg/l	N mineral Novemer 0-30 cm	kg/ha	N mineral Novemer 60-90 cm	kg/ha	N mineral Novemer 0-90 cm	kg/ha
	NO_3^- concentration January	mg/l	N mineral after harvest 30-60 cm	kg/ha	N mineral after harvest 0-60 cm	kg/ha		
	NO_3^- concentration February	mg/l	N mineral Novemer 30-60 cm	kg/ha	N mineral Novemer 0-60 cm	kg/ha		
OM								
	Effective oranic matter supply for crop	kg/ha						
	Effective oranic matter supply for green manure	kg/ha						
	Effective oranic matter supply crop + green manure	kg/ha						
	Organic matter content	%						
N								
	N supply slurry for crop	kg/ha	total N supply for crop	kg/ha	N offtake for green manure	kg/ha	N surplus total	kg/ha
	N supply slurry for green manure	kg/ha	total N supply for green manure	kg/ha	N offtake total	kg/ha	N effective crop	kg/ha
	N supply fertilizer for crop	kg/ha	total N supply crop + green manure	kg/ha	N surplus crop	kg/ha	N effective green manure	kg/ha
	N supply fertilizer for green manure	kg/ha	N offtake for crop	kg/ha	N surplus gm	kg/ha	N effective total	kg/ha
P								
	P supply slurry for crop	kg/ha	total P supply for crop	kg/ha	P offtake for green manure	kg/ha		
	P supply slurry for green manure	kg/ha	total P supply for green manure	kg/ha	P offtake total	kg/ha		
	P supply fertilizer for crop	kg/ha	total P supply crop + green manure	kg/ha	P surplus crop	kg/ha		
	P supply fertilizer for green manure	kg/ha	P offtake for crop	kg/ha	P surplus gm	kg/ha		
K								
	K supply slurry for crop	kg/ha	total K supply for crop	kg/ha	K offtake for green manure	kg/ha		
	K supply slurry for green manure	kg/ha	total K supply for green manure	kg/ha	K offtake total	kg/ha		
	K supply fertilizer for crop	kg/ha	total K supply crop + green manure	kg/ha	K surplus crop	kg/ha		
	K supply fertilizer for green manure	kg/ha	K offtake for crop	kg/ha	K surplus gm	kg/ha		
weather								
	Sum of rainfall April year x - April year (x+1)	mm	Sum of temperature April year x - April year (x+1)	°C				
	Sum of rainfall September - April	mm	Sum of rainfall temperature September - April	°C				
	Sum of rainfall September - January	mm	Sum of temperature September - January	°C				
	Sum of rainfall January - April	mm	Sum of temperature January - April	°C				

3.2.3 (co)variates influencing maize yield

To test the influence of EOM input on yield levels of maize, a number of statistical analyses including a number of (co)variates including EOM input were done on yield data. The (co)variate which could partly be placed into the following groups: N measurements in soil, weather data, EOM input, nutrient (N,P,K). Table 3.3 shows an overview of co-variates which are included in the dataset for yield.

Crop yield (response variate)

Maize yield was analyzed from 2011 till 2014 for all plots. Other crops were not taken in account because of the bad comparability of different cultivars and the limit of time of this study. For maize the same cultivar was used in all treatments.

Growing season (covariate)

Sowing date and harvest date define the period and the length of the growth season. Sowing and harvest date are expressed as Julian date (0-366).

Weather (variate)

Weather circumstances such as radiation, temperature and rainfall are crop growth determining factors. Radiation, temperature and rainfall are summed over the growing season and expressed as (W/m^2), °C and mm.

OM (variate)

Described in section 3.2.2

N (variate)

Described in section 3.2.2

P and K

Described in section 3.2.2

Other

Irrigation during the growth season of a crop is expressed in (mm)

Table 3.2: Overview of (co)variates and their units which are incorporated into the dataset yield.

	variate	unit	variate	unit	variate	unit	variate	unit
growth season	sowing day of year							
	harvest day of year							
	length of growth season							
weather								
	Sum of rainfall during growing season	mm						
	Sum of rainfall temperature during growing season	°C						
	sum of radiation during growing season	MJ*550						
OM								
	Effective oranic matter supply for crop	kg/ha						
	Effective oranic matter supply for green manure	kg/ha						
	Effective oranic matter supply crop + green manure	kg/ha						
	Organic matter content	%						
N								
	Nsupply slurry for crop	kg/ha	total N supply for crop	kg/ha	N offtake for greenmanure	kg/ha	Nsurplus total	kg/ha
	Nsupply slurry for green manure	kg/ha	total N supply for green manure	kg/ha	N offtake total	kg/ha	N effective crop	kg/ha
	Nsupply fertilizer for crop	kg/ha	total N supply crop + green manure	kg/ha	N surplus crop	kg/ha	N effective green manure	kg/ha
	Nsupply fertilizer for green manure	kg/ha	N offtake for crop	kg/ha	N surplus gm	kg/ha	N effective total	kg/ha
P								
	Psupply slurry for crop	kg/ha	total P supply for crop	kg/ha	P offtake for greenmanure	kg/ha		
	Psupply slurry for green manure	kg/ha	total P supply for green manure	kg/ha	P offtake total	kg/ha		
	Psupply fertilizer for crop	kg/ha	total P supply crop + green manure	kg/ha	P surplus crop	kg/ha		
	Psupply fertilizer for green manure	kg/ha	P offtake for crop	kg/ha	P surplus gm	kg/ha		
K								
	Ksupply slurry for crop	kg/ha	total K supply for crop	kg/ha	K offtake for greenmanure	kg/ha		
	Ksupply slurry for green manure	kg/ha	total K supply for green manure	kg/ha	K offtake total	kg/ha		
	Ksupply fertilizer for crop	kg/ha	total K supply crop + green manure	kg/ha	K surplus crop	kg/ha		
	Ksupply fertilizer for green manure	kg/ha	K offtake for crop	kg/ha	K surplus gm	kg/ha		
other								
	irrigation during growth season	mm						

3.3 N balance sheets

N balance sheets were created for each EOM input treatment from 2012 to 2014 to provide more insight in N fluxes coming into and going out of the agricultural system. Figure 3.1 shows a schematic overview of the N fluxes coming in, going out and circulating within the agricultural system based on Schröder et al., (2003) and Mosier et al., (2013). In the N-balance sheets the entire crop sequence was assessed.

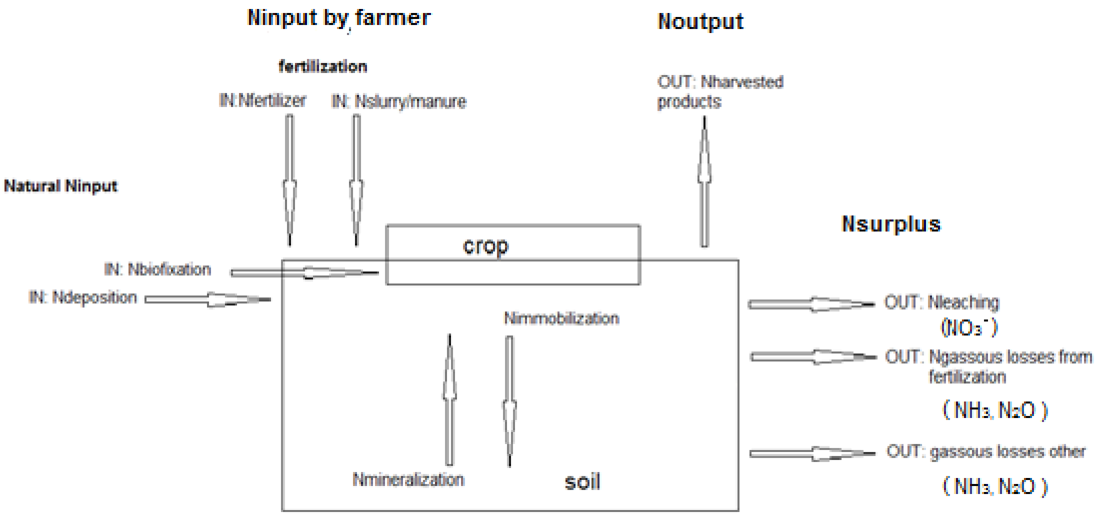


Figure 3.1: Schematic overview of N fluxes in the Vredepeel experiment: There are human N inputs, natural inputs, human outputs, natural outputs and internal fluxes. Schröder et al., (2003) Mosier et al., (2013)

3.3.1 Inputs

Data of external human N inputs by slurry, manure and fertilizer are used from the created dataset of the Vredepeel experiment. Atmospheric deposition and biological fixation were estimated as follows:

Atmospheric deposition was calculated from Velders et al., (2013). In this report the deposition in Vredepeel was estimated between 3000 and 3500 moles N per ha. 1 mole of N weights 14.01 grams so the average deposition of nitrogen is 3250 moles*14.01)/1000= 45,5 kg/ha.

Biological fixation of nitrogen by peas was estimated for 50 kg/N ha Smil, (1999). Clover result in a fixation of about 100 kg/ha in case of full crop Mueller and Thorup-Kristensen, (2001), in the Vredepeel experiment a mixture of grass clover was used and is estimated that this result into a biological fixation of 50 kg/ha.

Plant material

Only seed potatoes are taken in account from data of the Vredepeel farm, this input was estimated as 9 kg N per ha. Other inputs by seeds were neglected.

Output

Data of N offtake by harvested products was used from the data set from the Vredepeel experiment.

Natural outputs such as N leaching, denitrification gaseous losses by supplying N and other gaseous losses were calculated as follows:

N Leaching and denitrification were calculated using two different methods: **1.** N leaching kg N ha $^{-1}$ can be derived from a rain surplus. **2.** N leaching can be derived from nitrate concentration measurements in upper meter of ground water (mg nitrate l^{-1}) during November till February.

1. N leaching calculated from surplus

At first N surplus was calculated by subtracting N offtake by harvested crops from N fertilization in mineral form, deposition and biological fixation. The fraction of the mineral nitrogen surplus which leaves the system by leaching is the leaching fraction, (equation 3.1). For Vredepeel approximately 60% of this nitrogen surplus (mineral form) will leave the system by leaching; the other 40 % will leave the system by denitrification at ground water level VI RIVM, (2007).

$$Leaching\ fraction\ for\ balance\ sheet = \frac{N\ leaching\ (kg\ ha^{-1})}{N\ mineral\ surplus\ (kg\ ha^{-1})} \qquad (3.1)$$

2. N leaching calculated from nitrate measurements

For calculating N leaching from nitrate measurements the average nitrate concentration of the measurements from December till February was taken in account. Based on figure 4.3 the measurement during November deviates from the other measurements, so November was not taken in account.

The average concentration was multiplied by the rain surplus to convert a concentration to a weight unit. After that the product of nitrate concentration and rain surplus was divided by 100 to convert mg nitrate per m^2 to kg nitrate per ha. The final step was converting (kg nitrate ha^{-1}) to (kg N ha^{-1}) for this: kg nitrate was divided by 4.43. The precipitation at the Vredepeel the Netherlands is around 300 mm Huijsmans et al., (2008).

Gaseous losses by applying slurry/manure:

Slurry: Slurry contains about 60% Total Ammonia Nitrogen (TAN) and 2% will volatize by injection slurry into the soil. Total N slurry *0.6*0.02=0.012 -> 1.2 % gaseous loss by supplying. (Huijsmans *et al.*, 2008)

Manure: cattle manure contains about 20% TAN and 22 % will volatize by spreading followed by working in. Total N manure*0.2*0.22=0.044 -> 4.4% gaseous losses by supplying slurry. (Huijsmans *et al.*, 2008)

Other gaseous losses and internal fluxes

Other gaseous losses and internal fluxes were not calculated in this study. The other gassous losses were products of denitrification which leaves the agricultural system in the form of gass. Internal fluxes were not calculated because a steady state of was assumed (mineralization= immoblilization). In the discussion estimates of these losses will be made by taking this as outcome of the calculations.

3.4 Statistical analyses (model selections)

Model selection procedures within GenStat were used to assess if there is an effect of a factor/(co)variate and its effect on nitrate leaching and maize yield. In case of a significant effect, this effect can be quantified by GenStat. The fraction of total variance of a response variate which is explained by a certain factor/(co)variate and corrected for the amount of variates within a regression model is expressed as R^2 adjusted. GenStat also calculated the significance of R^2 adjusted. An example of such a regression model is shown below. The statistical analysis was applied on all crops.

In the statistical analysis two approaches have been applied. At first, plot, treatment, crop and the presence of green manure were used as fixed effects and average of 2012-2014 of each measurement of nitrate concentration in upper meter ground water was analyzed separately. In the second approach, plots were included as random effects instead of fixed effects and the averages of nitrate concentration in upper meter ground water measurements for each year were used as a variate.

Plot as fixed effect

Initially model selections were done in which plot was taken as a fixed factor (equation 3.2).

$$Y_{py} = PLOT_p + YEAR_y + \sum_{i=1}^{n} \beta_i x_i + \sum_{i=1}^{n} \gamma_i c_i + \varepsilon_{ij} \quad (3.2)$$

Nitrate leaching depends on PLOT and YEAR effects and soil (co)variates (x) and weather (co)variates and an error term. β represents the parameter estimate for the variates, γ respresents the parameter estimate for the covariates and ε represents the random part of equation 4.1. In eq , 4,1 $_i$ and $_j$ are indicators for the specific (co)variates, i indicates a variate and could be e.g. N total fertilization or EOM input and j indicates a covariate and could be e.g. P fertilization or K fertilization.

Taking plot as fixed factor, averages of each measurements from 2012 till 2014 were analysed. So there is output of analyses of nitrate concentration of November (2012-2014), December (2012-2014), January (2012-2014) and February (2012-2014). Parameter estimations of the plot effects on nitrate concentration are also given and the plot effects are spatially shown in a map of the Vredepeel experiment .

Plot as random effect

Plots may differ in properties such as: soil texture, ground water level, distance to the nearest ditch c.q. canal, pH etc. which may affect nitrate leaching. These properties were not known or taken into account in this study. To handle these plot effects a new approach of statistical analysis was done: the factor plot was taken in account as a random factor instead of a fixed factor.(Equation 3.3)

$$Y_{py} = YEAR_y + \sum_{i=1}^{n} \beta_i x_i + \sum_{i=1}^{n} \gamma_i c_i + \varepsilon_{ij} + \varepsilon_{plot} \quad (3.3)$$

Nitrate leaching depends on YEAR effects and soil (co)variates (x) and weather (co)variates and an error term. Plot is part of the error term in this analyses. β represents the parameter estimate for the variates, γ respresents the parameter estimate for the covariates and ε represents the random part of equation 3.1. In eq , 3,1 $_i$ and $_j$ are indicators for the specific (co)variates, i could be N total fertilization, EOM input and j could be P fertilization and K fertilization.

Taking plot as random effect was based on new insights for analyses of the Vredepeel experiment. With this new insights it was assumed that taking averages of measurements for each year and all years would be more representative for taking conclusions about the effects of EOM input on leaching. So there are analyses of : 1. Averages of the measurements November till February for 2012, 2013, 2014 and all years. 2. Averages of the measurements December till February for 2012, 2013, 2014 and all years. 3. Averages of January and February for 2012, 2013, 2014 and all years.

Comparing the three treatments

Initially, model selections were done comparing all treatments with each other.

Comparing only the conventional treatment

Other factors than EOM input which may affect nitrate leaching may differ between the organic and the conventional treatments. To provide a more comparable result the comparison of only the two conventional treatments were done, more over there is also no significant difference in N fertilization between the two conventional treatments.

The factors and (co)variates were ranked on their value of R^2 -adjusted, R^2 adjusted is a measure for representativeness of the regression model through the data points related to the specific (factor/ (co)variate) separately. In fact R^2-adjusted is the variance explained by the (factor and (co)variate) divided by the total variance factor and (co)variates + 'random' variance) corrected for the number of factors and (co)variates) which were included in the analyses. Single effects and multiple effects of the factors/(co)variates were tested, plots were taken into account as fixed factor or as random factor and all treatments or only the conventional treatments were compared with each other. For nitrate leaching, the average nitrate concentration of December, January and February were taken as a response variate. Figure 3.2 Shows an overview of different statistical analyses which had been applied to the data set.

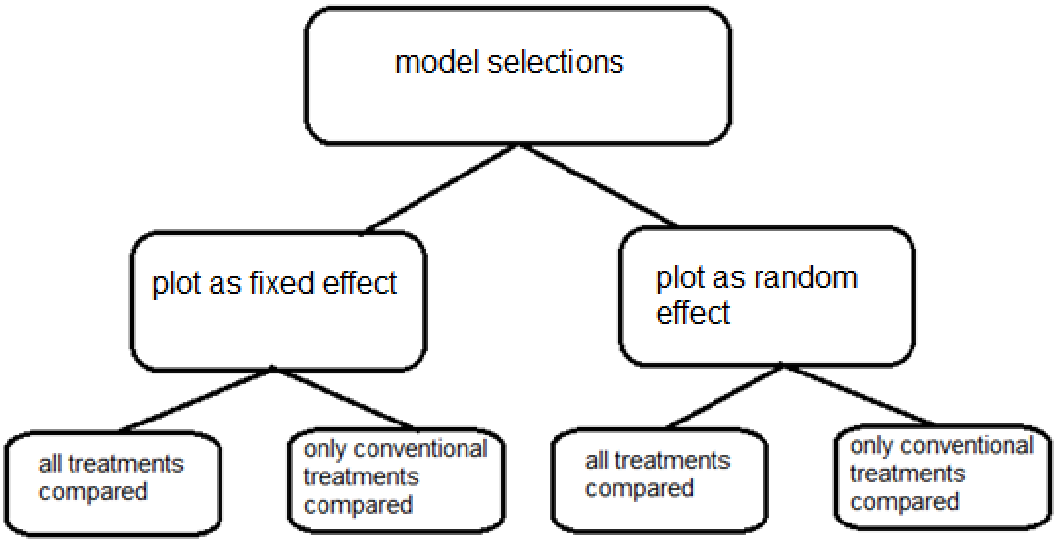


Figure 3.2: Overview of model selections for leaching which had been applied to the data set.

4. Results

To answer the research question and hypotheses several analyses were done such as creating descriptive figures, creating N balance sheets and statistical analyses.

Descriptive figures are shown in section 4.1, N balance sheet are shown in section 4.2, results of the statistical analyses for nitrate leaching are given in section 4.3, a spatial overview of parameter estimates for plot is shown in section 4.4 and results of the statistical analyses for maize yield are given in section 4.5. As the factor plot has a strong influence, in the last section also parameter estimates of selected models for plot are shown, combined with ground water levels of the Vredepeel experimental farm.

4.1 Descriptive general figures

At first descriptive figures of soil organic matter content in and annual patterns of rainfall surplus are shown. Secondly figures of nitrate concentration in upper meter ground water, N fertilization, (N total and N effective), N surplus and relations between nitrogen fertilization are shown. These figures provide more insight in differences between the three treatments, trends and relations of nitrate concentration between N fertilization and nitrate concentration in upper meter groundwater.

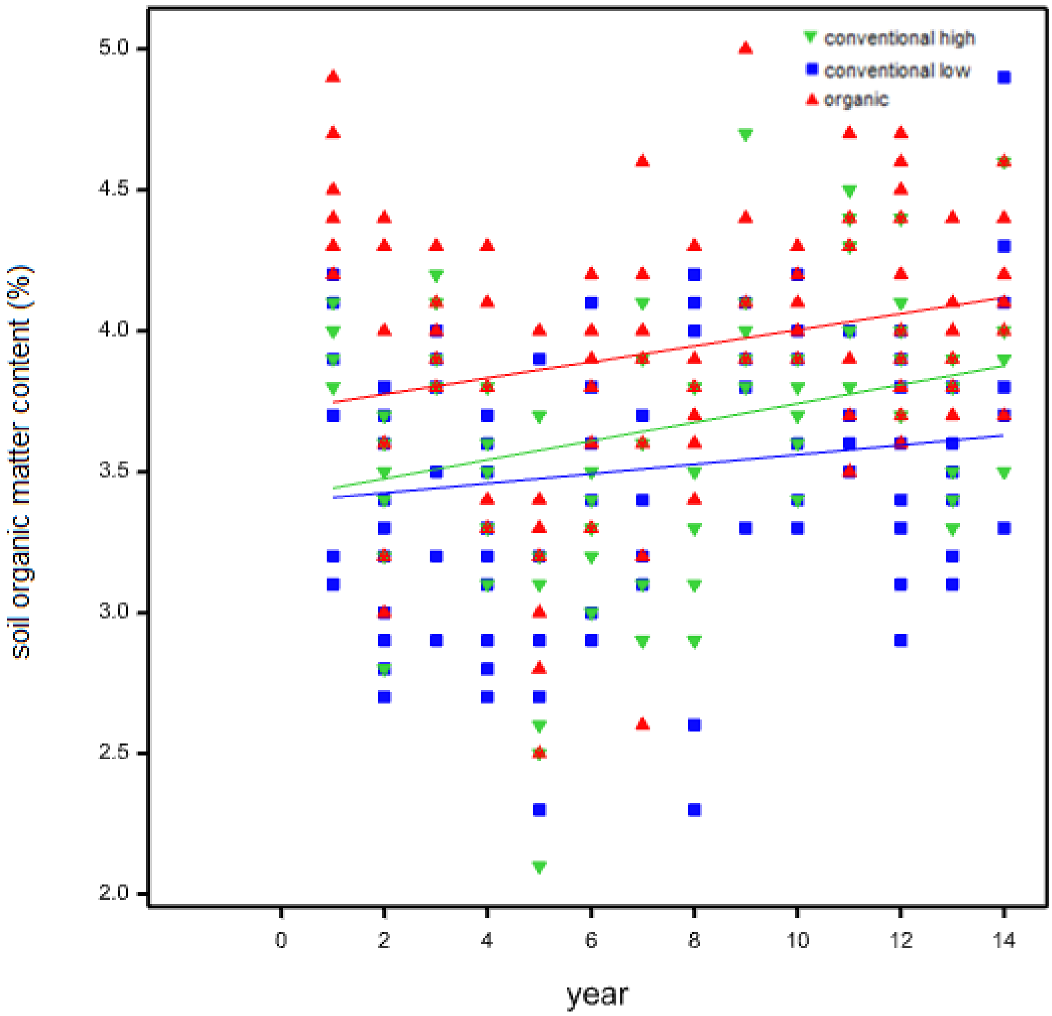


Figure 4.1: SOM content (%) for each plot form 2001 till 2014 of the Vredepeel experiment.

Trends in SOM from 2001 till 2014 and monthly rainfall from 2011 till 2014 are shown by figures 4.1 and 4.2. Table 4.1 shows the estimates and p-values of the intercept with the y-axis and the slope for SOM as function of years. Table 4.2 shows the significance of differences in SOM content from 2011 till 2014.

Table 4.1: Parameter estimates of the trends of SOM content (%) as function of time (year 1-14) per treatment.

Treatment	R^2	Intercept y-axis	p-value intercept y-axis	slope	p-value slope
conventional high	0.07	3.40	0.001	0.033	0.010
conventional low	0.019	3.39	0.001	0.0169	0.068
organic	0.041	3.71	0.001	0.0286	0.013

Table 4.2: Comparison of means of average SOM content from 2011- till 2014 using least significant difference (95 % confidence).

Treatment comparison	Difference of means	LSD	significant
organic versus conventional high EOM input	0.17	0.187	no
organic versus conventional low EOM input	0.51	0.187	yes
conventional high EOM input versus conventional low EOM input	0.34	0.187	yes

SOM content (weight%) of plots differ between treatments: highest SOM content was observed in the plots of the organic treatment all years. SOM content was lowest in the conventional low EOM input treatment (figure 4.1). From 2011 till 2014 the plots of the conventional low EOM input treatments had significant lower SOM content than the plots of the organic and conventional high EOM input treatment. There was no significant difference between SOM content of the plots of the organic and conventional high treatments (table 4.2).

Figure 4.1 shows that SOM is increasing over time in all treatments. There is a significant trend (p=0.014 and 0.013) of increasing SOM content in the conventional high EOM input and organic treatments. In the conventional low EOM input treatment no significant trend of increasing SOM content was observed (table 4.1).

Figure 4.2 shows the pattern of rain surplus c.q. shortage over the year, the x-axis represent months and the y-axis represent the rain surplus c.q. shortage over the year (mm) (rainfall-evapotranspiration of grassland). The rainfall surplus was calculated from data of rainfall surplus during January rainfall (mm) is positive (mm) (EPV24) in all years. From March till June there is less rainfall (mm) than evapotranspiration (mm). Except for 2013, there is a rain surplus during July and August and during September there is less precipitation than evaporation. During December there is more rain than evaporation in all years. Rainfall surplus during February and October differs over years. Water available in the soil profile and capillary rise are not taken into account in this approach.

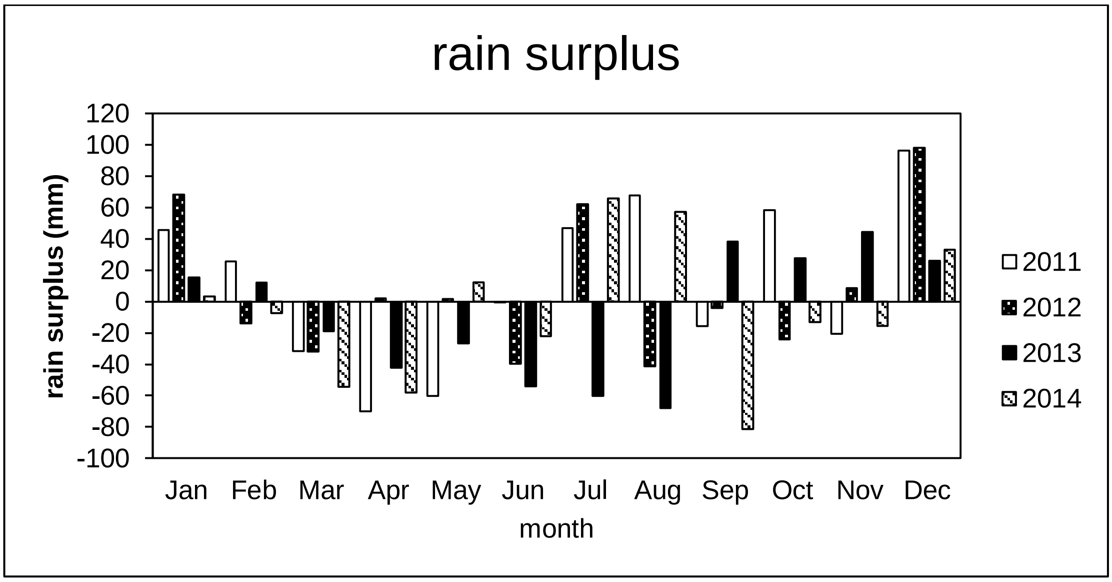


Figure 4.2: Monthly rain surplus c.q. shortage (mm) minus evapotranspiration grassland. The bars indicate the monthly surplus of rainfall (mm) during the years 2011, 2012, 2013 and 2014. A positive value indicates a rainfall surplus and a negative value indicates a rainfall shortage.

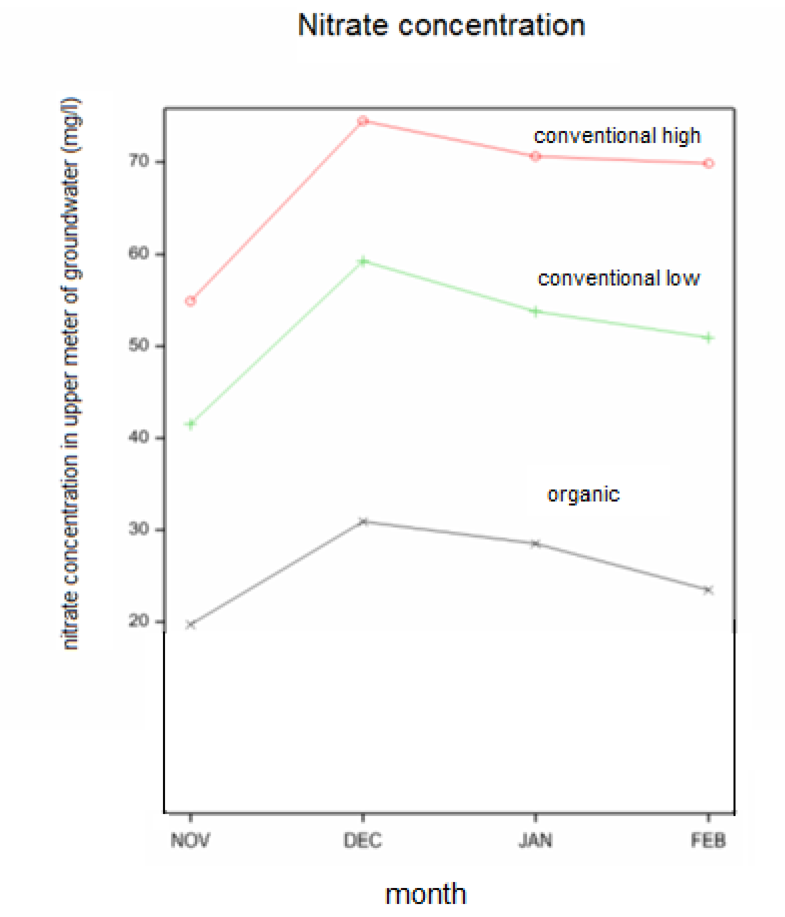


Figure 4.3: Nitrate concentration (mg/l) upper meter ground water during November till February (average of 2012-2014).

The three treatments differed in nitrate concentration in upper meter ground water. Lowest nitrate concentration in the upper meter ground water was observed in the organic treatment and highest nitrate concentration in the upper meter ground water was observed in conventional high input of EOM treatment. Conventional low EOM input treatment was in between the two mentioned ones.

In all treatments the nitrate concentration in the upper meter ground water was highest during December. The measurments during November showed the lowest nitrate concentration in the upper meter ground water in all treatments. The nitrate concentration in upper meter ground water was decreasing during January and February in all treatments. The EU norm of 50 mg nitrate /l was exceeded in the conventional high EOM input treatment, partly exceeded in the conventional low EOM input treatment and not exceeded in the organic treatment.

For treatment comparison, mean nitrate concentrations in the upper meter ground water were calculated from the measurements during December, January and February for each treatment and year. Figure 4.4 shows the mean nitrate concentrations in the upper meter ground water of each treatment.

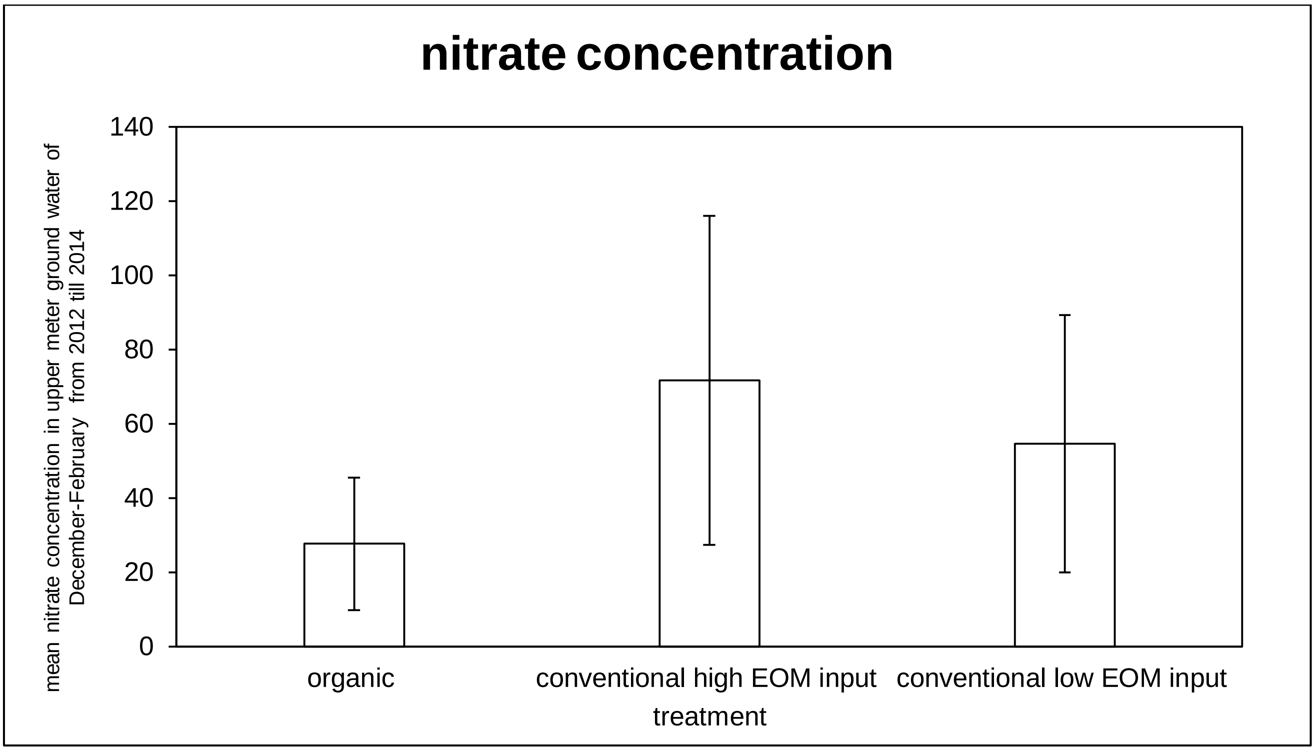


Figure 4.4: Mean nitrate concentration in upper meter ground water from December till February (mg/l) per treatment from 2012 till 2014 for all crops.The error bars indicate the 95% confidence interval.

Nitrate concentration of the upper meter of ground water differed between the treatments; the organic treatment showed the lowest average nitrate concentration. Conventional high EOM input resulted in the highest mean nitrate concentration in upper meter of ground water. Conventional low EOM input treatment resulted in moderate mean nitrate concentration in upper meter ground water. However there were no significant differences in mean nitrate concentration in the upper meter ground water between the treatments. In the conventional treatments the mean nitrate concentration upper meter ground water exceeds the EU-norm of 50 mg/l. The EU-norm is not exceeded in the organic treatment. Based on the 95 confidence interval is remarkable that there is a strong deviation in the average nitrate concentration, especially for the conventional high EOM input treatment.

For treatment comparison, annual mean N total and N effective fertilization (kg ha^{-1}) (figure 4.5) were calculated of 2011, 2012, 2013 and 2014. Figure 4.5 shows the mean N total and N effective fertilization with the 95% confidence interval. In the confidence interval only the variance between years was included. At first the average N fertilization for all crops were calculated for each treatment for 2011, 2012, 2013 and 2014. Than the average over the years was calculated. On this way large deviation caused by different N inputs on crops are not included in the 95% confidence interval for a treatment comparison.

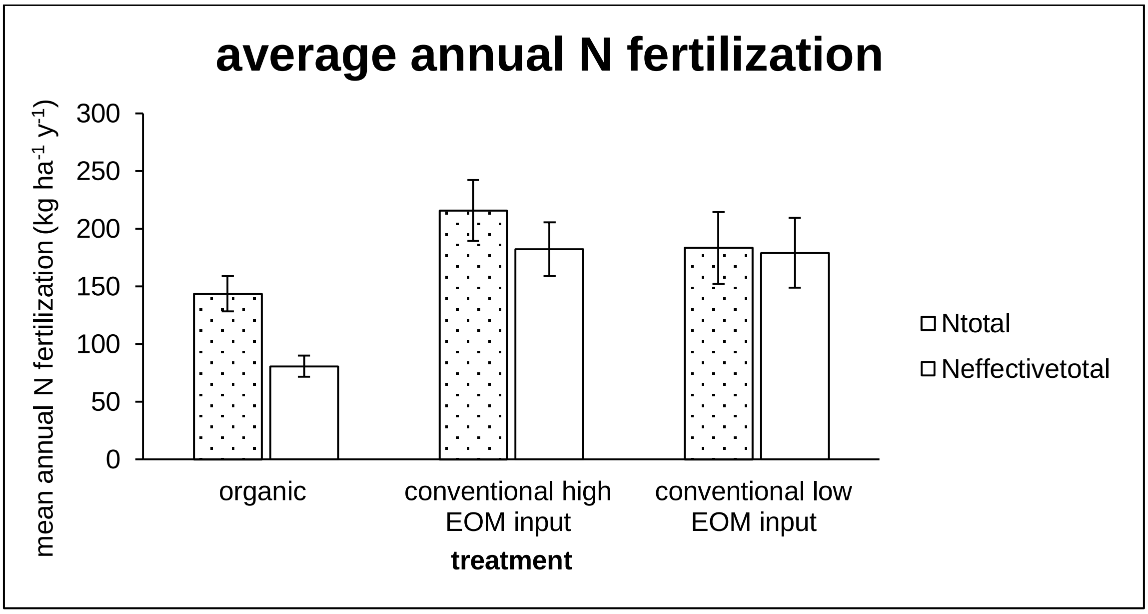


Figure 4.5: Mean annual N fertilization (total N and effective N) from 2011 till 2014 per treatment for all crops. The error bars indicates the 95% confidence interval which is based on the variance between years.

Figure 4.5 shows the mean total N and total effective fertilization in kg ha^{-1} y^{-1} per treatment of 2011 till 2014. The order of treatment mean N total fertilization from high to low was: conventional high EOM input (215 kg ha^{-1} y^{-1}) → conventional low EOM input (183 kg ha^{-1} y^{-1}) → organic (143 kg ha^{-1} y^{-1}). The conventional high EOM input treatment had a significant higher mean N total fertilization than the organic treatment during 2011-2014. There was no significant difference in N total fertilization between the conventional treatments and the organic and conventional LOW EOM input treatment during 2011-2014 (figure 4.5).

The mean N effective fertilization during 2011-2014 were in the conventional high EOM input treatments significant higher than in the organic treatment. There was no significant difference in mean N effective fertilization during 2011-2014 between the conventional low and organic treatments (Figure 4.5) The treatment order of mean N effective fertilization (kg ha^{-1} y^{-1}) from high to low was: conventional high EOM input (182 kg ha^{-1} y^{-1}) → conventional low EOM input (179 ha^{-1} y^{-1}) → organic (80 kg ha^{-1} y^{-1}).

Based on the results shown in figures 4.4 and 4.5 there might be a relation between N total or N effective fertilization and nitrate concentration in upper meter ground water. Therefore, simple regression analyses of N total, N effective and N surplus and nitrate concentration in the upper meter ground water were applied to show and test this relation. Figure 4.6 and table 4.3 shows the relation between N total fertilization and mean nitrate concentration in upper meter ground water from December till February of the years 2012-2014. Raw data of N fertilization was included in these simple regressions, so the N fertilization was not averaged beforehand as in figure 4.5.

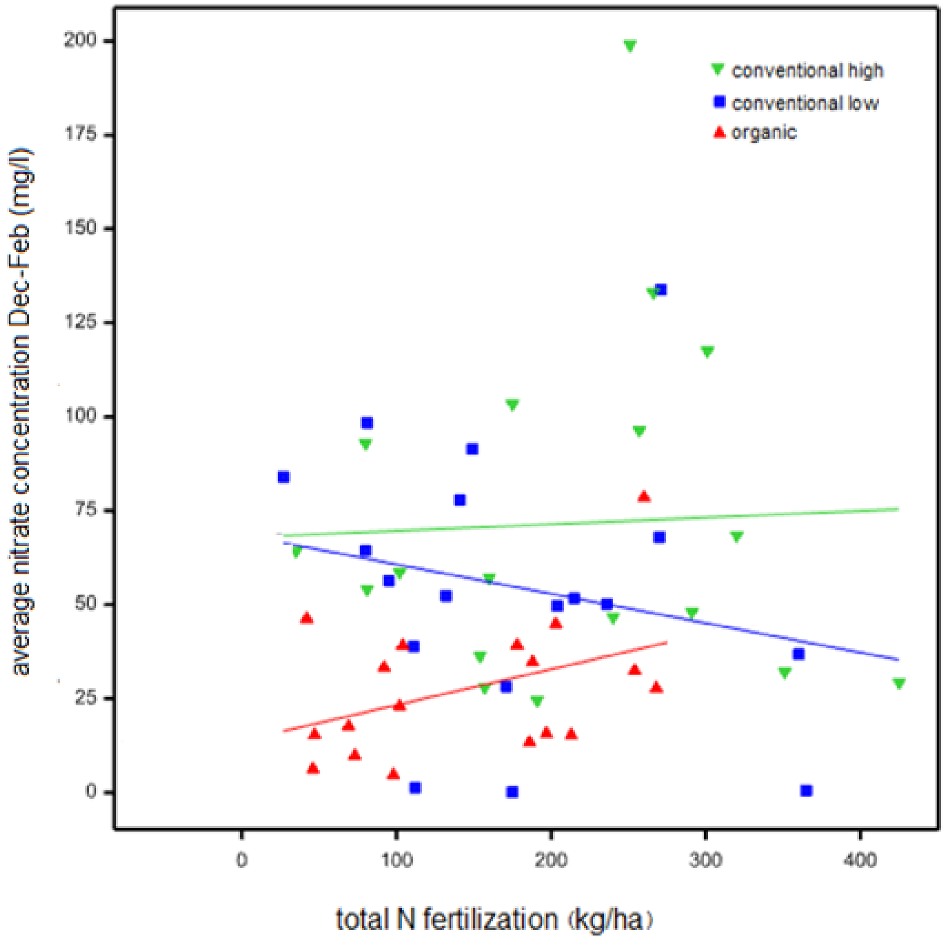


Figure 4.6: Nitrate concentration as function of total N fertilization 2012 till 2014 at the Vredepeel experiment.

Figure 4.6 shows that nitrate concentration in the upper meter ground water increased when N total fertilization increased for the treatments conventional high EOM input and organic. For conventional low EOM input treatment the nitrate concentration in the upper meter ground water decreased when N total fertilization increased. However, table 4.3 shows that the slopes in figure 4.6 (which represent the relations between N total fertilization and nitrate concentration in upper meter ground water) were not significant.

Table 4.3: Output of simple regression analyses of the nitrate concentration as function of N total fertilization) from 2012 till 2014 – is an indication that the residual variance exceeded the variance of the response variate, Genstat was not able to show a result in these cases.

treatment	R^2	intercept	p-value intercept	Slope	p-value slope
Conventional high	-	67.9	0.017	0.108	0.872
Conventional low	-	68.6	0.002	-0.0782	0.404
Organic	0.115	13.80	0.133	0.0951	0.092

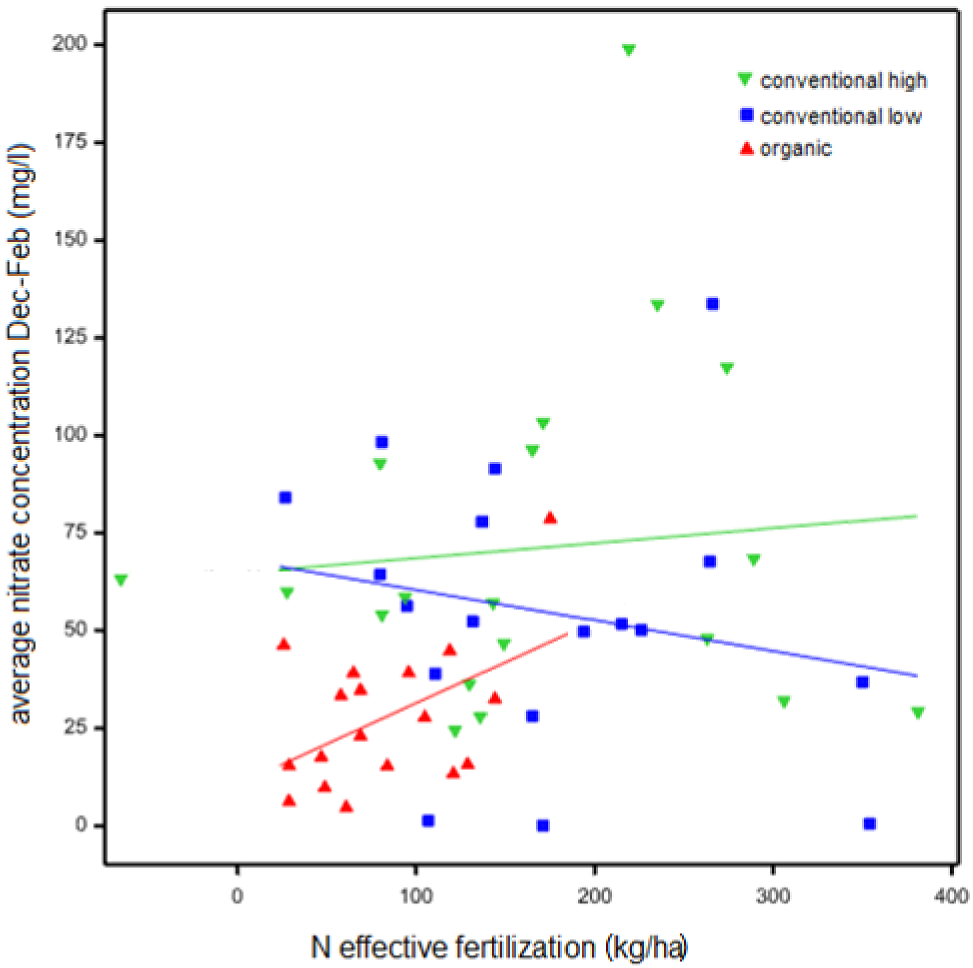


Figure 4.7: Nitrate concentration as function of N effective fertilization from 2012 till 2014 at the Vredepeel experiment for all crops.

Figure 4.7 shows that nitrate concentration in upper meter ground water increased when effective N fertilization increased for the treatments conventional high EOM input and organic. For conventional low EOM input treatment the nitrate concentration in upper meter decreased when N effective fertilization increased. However the slopes (which represent the relation between N effective fertilization and nitrate concentration in upper meter ground water) were not significant for the treatments conventional high and conventional low (table 4.4). The slope between N effective fertilization and nitrate concentration in upper meter ground water was significant for the organic treatment (figure 4.7 and table 4.4).

Table 4.4: Output of simple regression analyses of the nitrate concentration as function of N effective fertilization from 2012 till 2014. – is an indication that the residual variance exceeded the variance of the response variate, Genstat was not able to show a result in these cases.

treatment	R^2	intercept	p-value intercept	Slope	p-value slope
Conventional high	-	64.7	0.018	0.038	0.755
Conventional low	-	68.2	0.002	-0.0783	0.420
Organic	*0.192*	*10.49*	*0.0238*	*0.2092*	*0.039*

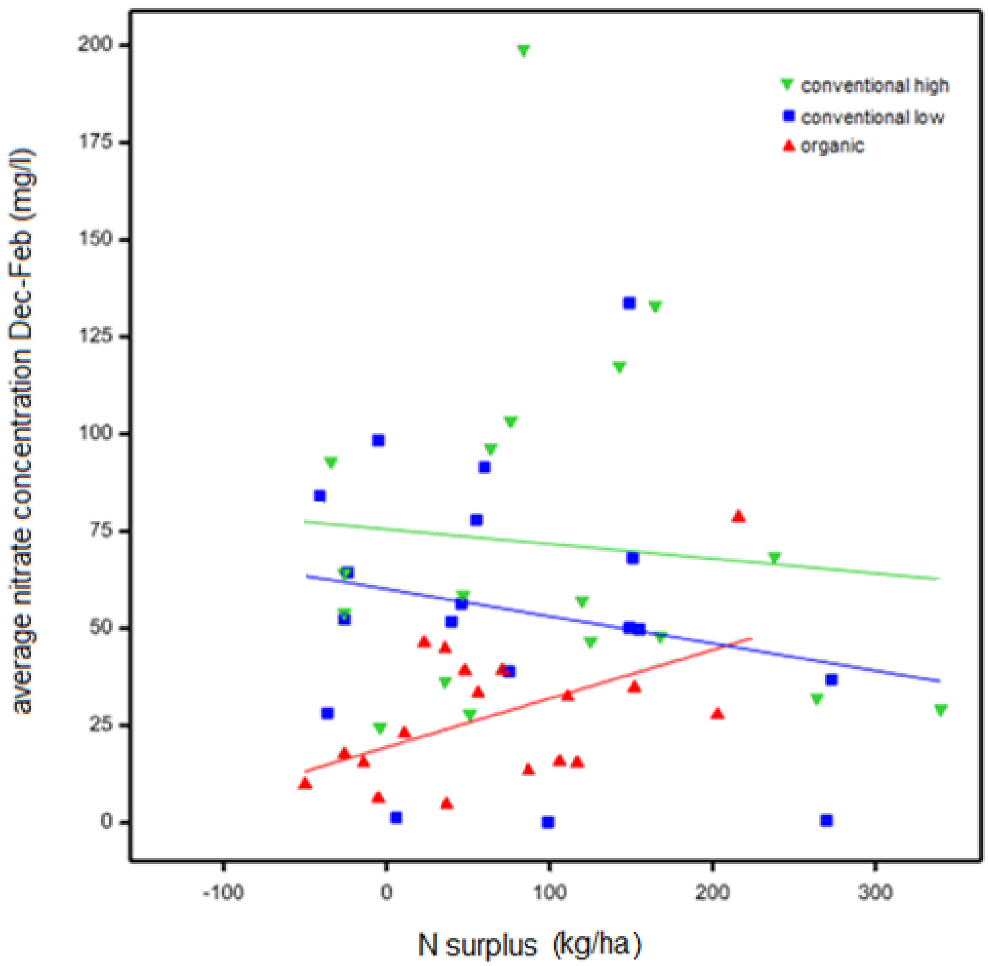


Figure 4.8: Nitrate concentration of N surplus from 2012 till 2014 at the Vredepeel experiment for all crops.

Figure 4.8 shows that nitrate concentration in the upper meter ground water decreased when N surplus increased for the treatments conventional high EOM input and conventional low EOM input. For the organic treatment the nitrate concentration in upper meter increased when N surplus increased. However table 4.5 shows that the slopes (which represent the relation between N total and nitrate concentration in upper meter ground water) were not significant for the treatments conventional high and conventional low. For the organic treatment the slope was significant (table 4.5)

Table 4.5: Output of simple regression analyses of the nitrate concentration as function of N surplus from 2012 till 2014 – is an indication that the residual variance exceeded the variance of the response variate. Genstat was not able to show a result in these cases.

treatment	**R^2**	**intercept**	**p-value intercept**	**Slope**	**p-value slope**
Conventional high	-	75.5	0.001	-0.038	0.730
Conventional low	-	60.1	0.001	-0.07	0.445
Organic	*0.217*	*19.45*	*0.002*	*0.125*	*0.029*

4.2 N balances

For 2012, 2013 and 2014 for each treatment, N balances were constructed to provide insight into the differences in N fluxes between the EOM input treatments. Figures about N input from different sources and N ouput and parts of the N surplus were created for all crops. From the nitrogen balances, the leaching fraction was calculated. Leaching fractions were calculated using the N surplus and the rainfall and nitrate concentration in the upper meter ground water measurements. In this section the results for 2012 are shown. The balanace sheets for 2012, 2013, 2014 and figures of the years 2013 and 2014 are shown by appendix 9.2.

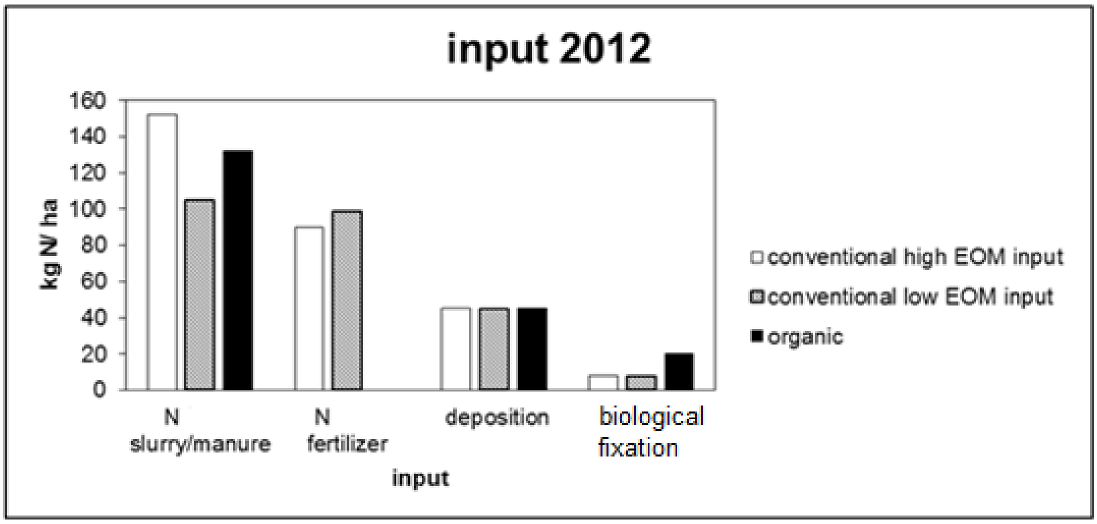


Figure 4.9: Average of total N inputs of each EOM input treatment for the year 2012. The N input of slurry and manure is the total N in the slurry and manure.

Figure 4.9 shows the average N inputs of the EOM treatments at for all crops in kg N ha^{-1} in 2012. N fertilization from slurry and manure was highest for the conventional high EOM input treatment and lowest for the conventional low EOM input treatment. N fertilization from slurry and manure in the organic EOM input treatment was in between the two conventional treatments. N input by fertilizer was highest in the conventional low EOM input treatment, lower in the conventional high EOM treatment and the organic treatment had no N input by fertilizer. N depostion is equal in al treatments. Biological fixation is equal in both conventional EOM input treatments and higher in the organic treatment because grass clover was used as green manure for the organic treatment and not for the conventional treatments.

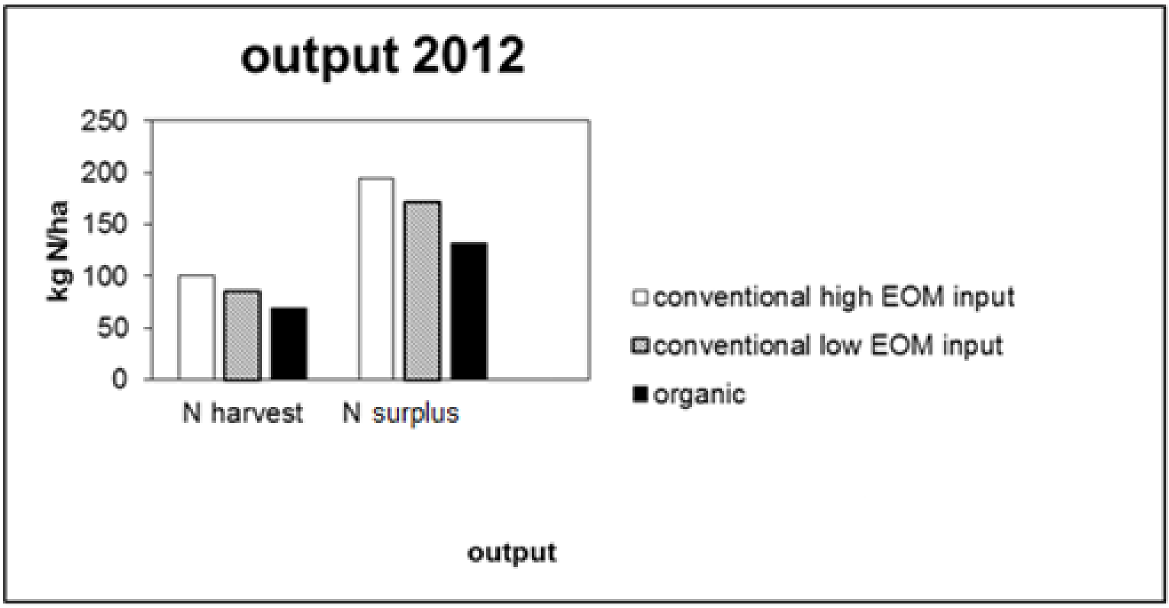


Figure 4.10: Average of N output and surplus of each EOM input treatment for all crops.

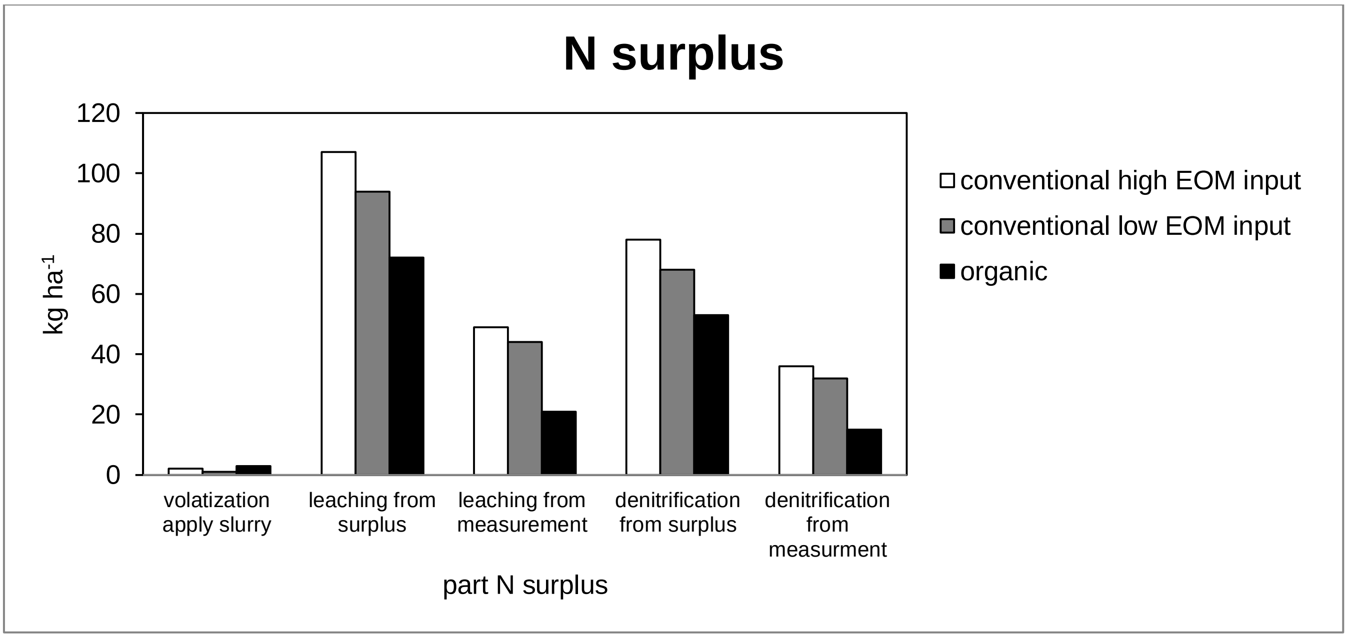


Figure 4.11: Averages of parts of the nitrogen surplus per treatment for 2012-2014 for all crops.

Figure 4.11 shows the different parts of nitrogen surplus, the leaching calculated from N surplus seems to be higher than the leaching calculated from the nitrate measurements on the Vredepeel experiment. N volatization by applying slurry seems to be marginal. N denitrification and leaching has the order of conventional high EOM input -> conventional low EOM input -> organic, the way of calculating leaching didn't make sense for this order while these were calculated independently of each other.

Figure 4.10 shows the average N outputs and N surplus of the EOM treatments at the rotation level for all crops were all three ranked as follows: Conventional high input -> conventional low input -> organic. N output by leaching was calculated by:

$$Nleaching = \frac{Nitrate\ concentration * rainsuplus}{4.43}$$

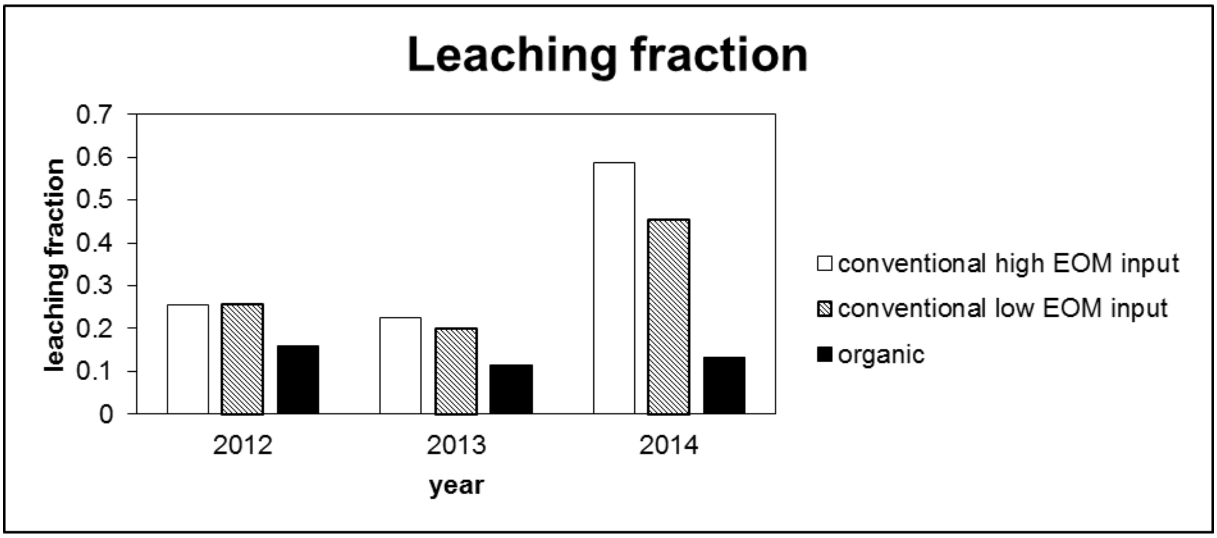


Figure 4.12: Leaching fraction of each EOM input treatment during 2012,. bar colors/patterns are indications of treatments.

The leaching fraction was calculated as follows :

$$Leaching\ fraction = \frac{Nleaching\ calculated\ by\ nitrate\ measurement}{Nsurplus\ for\ balance\ sheet}$$

Figure 14.11 shows that the organic treatments had a lower leaching fraction than the conventional treatments in all years. In 2014 the leaching fractions of the conventional treatments were higher than the leaching fractions of the conventional treatments in 2012 and 2013.

4.3 Statistical model selection for nitrate leaching

4.3.1 Model selections with the effects of single factors/(co)variates on nitrate concentration in upper meter ground water when plot was taken as fixed effect.

Single effects of factors/(co)variates may differ when all treatments were compared or when only the conventional treatments were compared.

Table 4.6 shows the output of model selections for the nitrate concentration in the upper meter ground water of November, December, January and February of 2012-2014. In these analyses plot was taken as fixed effect and all treatments were compared with each other.

Table 4.7 shows the output of model selections for the nitrate concentration in the upper meter ground water of November, December, January and February of 2012-2014. In these analyses plot was taken as fixed effect and only the conventional treatments were compared with each other.

Table 4.6: Overview of the size of the effect of single significant factor and (co)variates which were significant 2012-2014 for all treatments comparison.

All treatments comparison			
Measurement nitrate concentration	*Value $R^2_{adjusted}$*	*Significant plot/(co)variate*	*p-value*
nitrate concentration during November	0.4582	plot	0.001
	0.1475	treatment	0.006
nitrate concentration during December	0.4823	plot	0.000
	0.1916	treatment	0.002
nitrate concentration during January	0.4126	plot	0.002
	0.1346	treatment	0.009
nitrate concentration during February	0.6326	plot	0.000
	0.1724	treatment	0.003
	0.865	Neffective fertilization	0.018

Table 4.7: Overview of significant variables of the size of the effect of single factor/variate 2012-2014 for only the conventional treatments comparison.

Only conventional treatments comparison			
Measurement nitrate concentration	*Value $R^2_{adjusted}$*	*Significant plot/(co)variate*	*p-value*
nitrate concentration during November	0.4079	plot	0.008
nitrate concentration during December	0.4251	plot	0.006
nitrate concentration during January	0.3685	plot	0.015
nitrate concentration during February	0.6223	plot	0

Table 4.8 shows that the factors plot and treatment significantly explained the variance of nitrate concentration in upper meter ground water (2012-2014) strongest when all treatments were compared. Variance in nitrate concentration in the upper meter ground water during December was also significantly explained by N effective fertilization. Comparing the effects on nitrate concentration in the upper meter ground water the variate plot explained the existing variance much stronger than the variate treatment.

In case of only the conventional treatments comparison with each other only the factor plot explained the variance significantly.

4.3.2 Model selections with the effects of single factors/(co)variates on nitrate concentration in upper meter ground water when plot was taken as random effect.
Based on the results of the statistical analyses in which plot was taken as fixed effect, the factor plot was the strongest factor to explain variance in nitrate concentration in upper meter ground water. Therefore, an alternative set up of model selection was tested in which the factor plot was taken as random effect.

Table 4.8: Significant factors/(co)variates including plot as random effect for all treatments comparison.

period	**R^2 adjusted**	**significant factor/(co)variate**	**p-values**
November till February			
2012-2014	0.2127	Treatment	0.001
2012	0.2942	total EOM input	0.012
2013	0.2935	Treatment	0.029
2014	0.2574	green manure	0.022
December till February			
2012-2014	0.1902	treatment	0.002
2012	0.2979	total EOM input	0.011
2013	0.2649	treatment	0.039
2014	0.3467	green manure	0.008
January and February			
2012-2014	0.1531	treatment	0.006
2012	0.233	treatment	0.024
2013	0.2491	treatment	0.046
2014	0.3983	green manure	0.004

Table 4.10 shows the factors/(co)variates which explain the variance of average nitrate concentration in the upper meter ground water from November-February, December February and January February significantly. In these model selections, plot was taken as a random effect and all treatments were compared with each other.

Variance of the average nitrate concentration from November till February was significantly explained by the variate total EOM input during 2012 and the factor treatment during 2013. GenStat also showed the parameter estimations of factors and variates which were included into the regression equations (3.2 and 3.3) The parameter estimation of the variate EOM input during 2012 was: -0.01353 so 1 additional kg of EOM results into 0.01353 less mg l^{-1} nitrate in groundwater.

Variance of the average nitrate concentration from December till February was significantly explained by the variate total EOM input during 2012 , the factor treatment during 2013 the factor green manure during 2014, and by the factor treatment for all years. The parameter estimation of the variate EOM input during 2012 was : -0.01909 so 1 extra kg of EOM results into 0.01909 less mg l^{-1} nitrate in groundwater.

Variance of the average nitrate concentration from January and February was significantly explained by the factor treatment during 2012, the factor treatment during 2013 the factor green manure during 2014, and by the factor treatment for all years.

Table 4.9: Significant factors/(co)variates including plot as random effect only conventional treatments comparison. No all analyses gave significant results, this is indicated by: - .

period	R^2 adjusted	significant factor/(co)variate	p-values
November till February			
2012-2014	-	-	-
2012	0.2808	total EOM input	0.044
2013	-	-	-
2014	0.4291	green manure	0.017
December till February			
2012-2014	-	-	-
2012	0.2979	total EOM input	0.043
2013	-	-	-
2014	0.5095	green manure	0.008
January and February			
2012-2014	-	-	-
2012	-	-	-
2013	-	-	-
2014	0.5613	green manure	0.005

Table 4.9 shows the factors/(co)variates which explains variance of average nitrate concentration in upper meter ground water from November-February, December- February and January February significantly. In these model selections plot was taken as random effect and only the conventional treatments were compared.

Variance of the average nitrate concentration from November till February is significantly explained by the variate total EOM input during 2012 and by the factor green manure during 2014. The parameter estimation for EOM input was not given by Genstat for this analysis.

Variance of the average nitrate concentration from December till February was significantly explained by the variate total EOM input during 2012 and by the factor green manure during 2014. GenStat also showed the parameter estimations of factors and variates which were included into the regression equations (3.2 and 3.3) The parameter estimation of the variate EOM input during was **:** 0.0231

Variance of the average nitrate concentration from January and February was significantly explained by the factor green manure during 2014.

4.3.3 Model selection for multiple factors/(co)variates all treatments comparison

Variance in nitrate concentration in the upper meter ground water may be better explained by a model which includes multiple factors/(co)variates instead of a model with a single factor/ variate. This assumption was tested and in this sub section the output of the model selections with multiple variates is presented.

In the model selections with the effects of multiple (co)variates, the average of the nitrate concentration measurements during December till February was taken as response variate. It was assumed that this response variate give the best representation of nitrate concentration in ground water. The measurements during November deviated from the other measurements (figure 4.3). In this subsection all treatments were compared and the plot factor was taken as random effect.

For comparison the treatments with multiple factors and (co)variates included in an multiple regression model plot was taken as fixed effect and the average of December-February (2012-2014) was analyses, Plot was also taken as random effect, the average of December-February (2012, 2013, 2014 and 2012-2014 was analysed. Table 4.11 shows the R^2- adjusted and the factors/(covariates) with p-value which were included in the best explaining model when all treatments are compared with each other.

Plot was taken as fixed effect for 2012-2014 and plot was taken as random factor for 2012-2014, 2012, 2013 and 2014.

Table 4.10: Factors and (co) variates of best selected model combining variates and all treatments comparison.

	R^2- adjusted	**relevant factor/co-variate**	**p-values**
plot as fixed effect			
2012-2014	0.7012	K fertilization	0.055
		year	0.102
		crop	0.039
		plot	0
plot as random effect			
2012-2014	0.2217	treatment	0.02
		year	0.266
2012	0.5522	EOM input	0.023
		N mineral in soil (0-60 cm)	0.151
		crop	0.089
2013	0.2701	N mineral in soil (0-60 cm)	0.311
		treatment	0.05
2014	0.4006	EOM input	0.091
		N mineral in soil (0-60 cm)	0.089
		treatment	0.053
		crop	0.211

For 2012-2014 variance of nitrate concentration in the upper meter ground water from December-to February was best explained by the combination of K fertilization, year crop and plot when plot was taken as fixed effect. The factors plot and crop were significant and this model had a R^2- adjusted of 70.12. Plots year and crop had negative or positive effects and K fertilization had a positive effect (appendix 9.3)

For 2012-2014 variance of nitrate concentration in upper meter ground water of December-February was best explained by the combination of treatment and year when plot was taken as random effect. The factor treatment was significant and this model had a R^2- adjusted of 22.17.

For 2012 variance of nitrate concentration in upper meter ground water of December-February was best explained by the combination of EOM input, N mineral in soil 0-60 and crop when plot was taken as random effect. The variate EOM input was significant and this model had a R^2- adjusted of 55.22.

For 2013 variance of nitrate concentration in upper meter ground water of December-February was best explained by the combination of N mineral in soil 0-60 and treatment when plot was taken as random effect. The factor treatment supply was significant and this model had a R^2- adjusted of 27.01.

For 2014 variance of nitrate concentration in upper meter ground water of December-February was best explained by the combination of N mineral in soil 0-60, treatment and crop when plot was taken as random effect. No factors/variates were significant and this model had a R^2- adjusted of 40.06.

4.3.4 Model selection for multiple factors/(co)variates for only conventional treatments comparison.

Table 4.11 shows the R^2- adjusted and the factors/(covariates) with p-value which were included in the best explaining model when only the conventional treatments are compared with each other. Plot was taken as fixed effect for 2012-2014 and plot was taken as random effect for 2012-2014, 2012, 2013 and 2014.

Table 4.11: Variates of best explaining model selection for only conventional treatments comparison.

	R^2- adjusted	**relevant factor/co-variate**	**p-values**
plot as fixed effect			
2012-2014	0.6213	EOM input	0.059
		N mineral in soil (0-60cm)	0.019
		Year	0.035
		plot	0.000
plot as random effect			
2012-2014	0.0047	K fertilization	0.289
2012	0.3996	EOM input	0.017
		P fertilization	0.176
		Treatment	0.249
2013	-	-	-
	-	-	-
2014	0.5288	N effective fertilization	0.229
		K fertilization	0.170
		Green manure	0.009

For 2012-2014 variance of nitrate concentration in upper meter ground water of December-February was best explained by the combination of EOM input, N mineral in soil (0-60cm), year and plot when plot was taken as fixed effect. The Factors N mineral in soil year and plot were significant and this model had a R^2- adjusted of 62.13.

During 2012-2014 variance of nitrate concentration in upper meter ground water of December-February the variance was strongest explained by the covariate K fertilization. K fertilization was not significant and this model had a R^2- adjusted of 0.47.

During 2012 variance of nitrate concentration in upper meter ground water of December-February the variance was strongest explained by the combination of EOM input, treatment and P fertilization when plot was taken as random effect. The variate EOM input was significant and this model had a R^2- adjusted of 39.96.

During 2013 there was no model which had a R^2- adjusted higher than 0.000. There were no results to present in table 4.12

During 2014 variance of nitrate concentration in upper meter ground water of December-February the variance was best explained by the combination of N effective fertilization, K fertilization and green manure in soil when plot was taken as random effect. The factor green manure was significant and this model had a R^2- adjusted of 52.88.

4.4 Map of estimated plot influence

Plot effects showed in Map of the Vredepeel Experiment

The factor plot showed the strongest explanation of variance in nitrate in the upper meter ground water. GenStat also calculated the parameter estimates which were included in the regression equations (3.2 and 3.3). Based on the results of the statistical analyses in which plot was taken as fixed effect and all treatments were compared from 2012 till 2014 (table 4.10), the parameter estimates for nitrate concentration for each plot with standard errors are shown in figure 4.13 and 4.14. It seems that parameter estimates were lower in the organic plots, this might partly be explained by ground water level. Therefore a map of ground water level is also shown in figure 4.15.

Comparing the three treatments and distance from the Peel canal it can be concluded that the parameter estimates in the organic treatment are lower than the parameter estimates in the conventional treatments. Contrary to what may be expected beforehand, there is no indication that the distance to the Peel canal affects the nitrate concentration in upper meter ground water. It seems that within the conventional treatments the plot south of the ditch has a lower parameter estimate for nitrate concentration in the upper meter of ground water. In general it can be concluded that the organic plots have lower parameter estimates and there was heterogeneity in parameter estimates between the plots. This heterogeneity in parameter estimates was stronger within the conventional treatments.

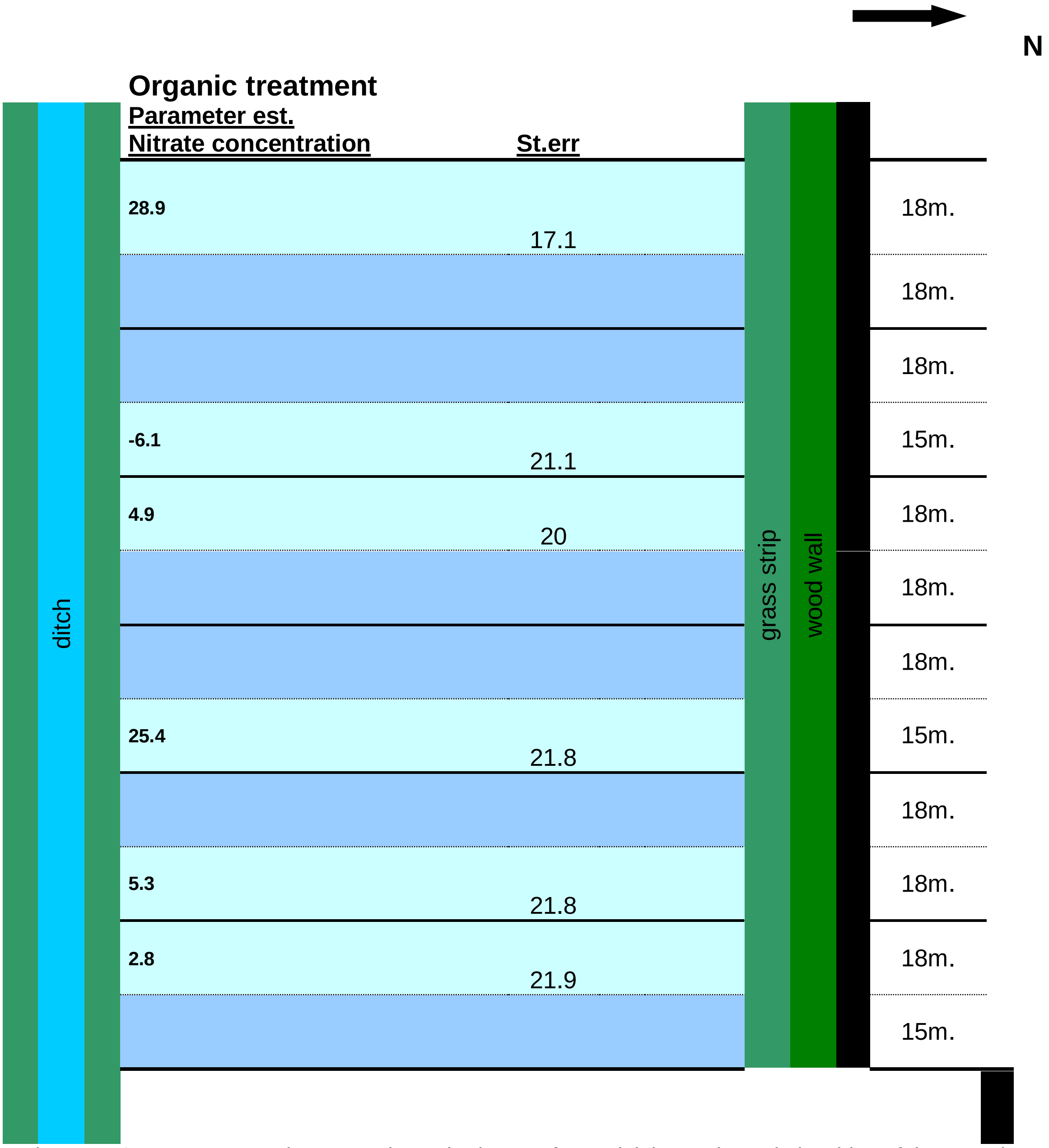


Figure 4.13: Parameter estimates and standard errors for explaining variance in leaching of the organic treatments for each plot. This figure represents the parameter estimations which were included of the analyses for the years 2012-2014 and plot was taken as fixed effect. Par est indicated the parameter estimation and st. err indicates the standard error of the parameter estimation.

Figure 4.14: Parameter estimates and standard error of the plots of the conventional treatments. This figure represents the parameter estimations which were included of the analyses for the years 2012-2014 and plot was taken as fixed effect. Par est indicated the parameter estimation and st. err indicates the standard error of the parameter estimation.

Ground water levels

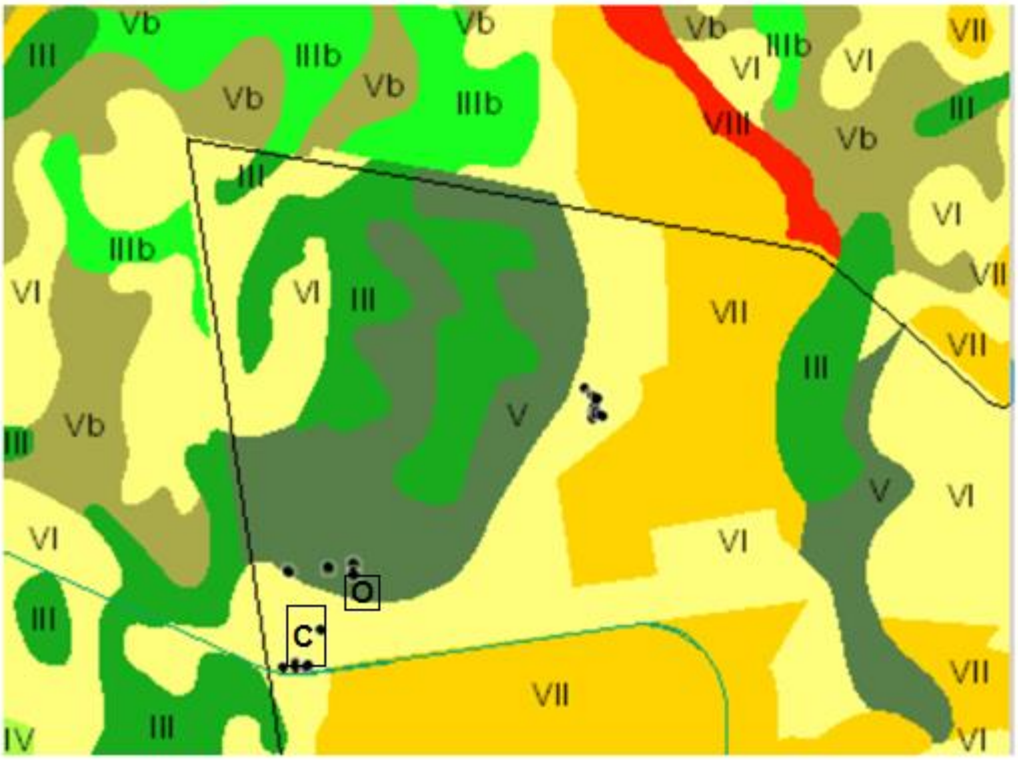


Figure 4.15: Map of ground water level of the Vredepeel experimental farm. The location of the conventional treatments is indicated with C and the location of the organic treatment is indicated with O. BIS Nederland, (2015)

Figure 4.15 shows that the plots of the organic treatment are located in the fields with a different ground water level compared to the plots of the conventional treatments. Based on table 4.12 it seems that the ground water level resulted in a leaching fraction of 0.58 in the conventional plots and 0.45 in the organic plots. This might be an additional explanation of variance in nitrate concentration in upper meter ground water. In next studies the ground water level should to be taken in account.

Table 4.12: Leaching fraction per ground water level of sandy soils RIVM, (2007).

	I/II/II*	III	III*	IV	V	V*	VI	VII	VIII
arable land	0,04	0,07	0,28	0,38	0,45	0,43	0,58	0,74	0,89
grassland	0,02	0,04	0,14	0,20	0,23	0,22	0,30	0,38	0,46

4.5 Descriptive figures to show relations for yield.

Maize yield

To assess the size of the effect of the factors and (co)variates on maize yield, a descriptive figure was created and model selections were done. The variates which were included are shown by table 4.14.

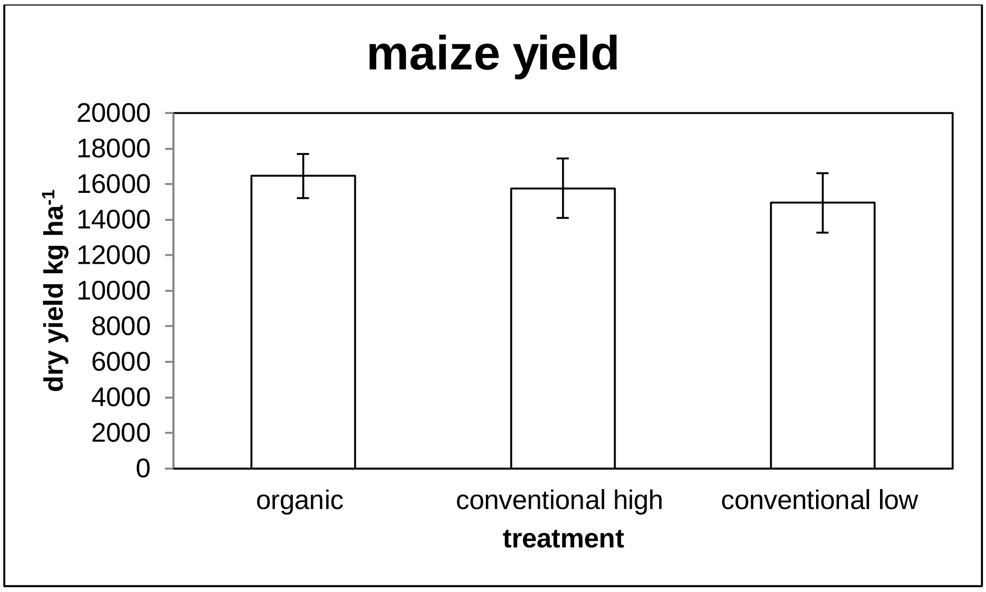


Figure 4.16: Average maize yield 2011-2014 of the 3 treatments. The error bars indicate the 95% confidence interval for each treatment.

Figure 4.16 shows that there were no significant differences in yield between the three treatments.

Table 2.13: Output of model selection of maize yield.

Factor/variate	R^2 adjusted	P-value
Irrigation	14.16	0.039
Sum of radiation during growing season	13.32	0.045
Treatment	8.59	0.15
Sum of temperature during growing season	3.37	0.193
Total K fertilization on crop	1.94	0.24
Total P fertilzation on crop	1.13	0.273
Total N fertilization on crop	0.12	0.322
Tillage	0.000	0.55

A model selection was also applied on maize yield to assess which variate shows the best fits for explaining variance in maize yield within the treatments. Only a model selection with single variates and taken plot as fixed factor were done. Table 4.13 shows the result of the analyses of the size of the effects of the different factors/(co)variates) on maize yield. The variates irrigation (R^2_{adj} =14.16 p= 0.039) and sum of radiation during growing season R^2_{adj} =13.32 p= 0.045) has a significant contribution to explain variance of maize yield.

5. Discussion

trend SOM content

The conventional high EOM input treatment showed the highest increase in SOM content, however this increase is 0.033 % per year so over 14 years the increase was 0.44% so errors in measurement may have a stronger impact. Figure 4.1 shows there is a lot of variation in measurements of SOM content. When this deviation is caused by errors in measurements, the average SOM content is sensitive for measurement errors.

Plots of the organic treatment had the highest SOM content from 2001 onwards. Conclusions of the effects of EOM input in the organic treatment may be biased with the higher SOM content instead of the EOM input in the Vredepeel experiment. In this study conclusions were based on the EOM input and not on the SOM content. Errors in measurements of SOM contents has a high effect on taking conclusions when a difference of 0.44 has a great impact. Errors of EOM input has less impact for taking conclusions. An error of 0.44 in 2000 kg would not make a big difference .On the other hand a higher SOM content gives a higher decomposition and is would be harder to increase SOM content in soil an organic matter balance could more insight on this aspect and allows correcting for SOM. However the Vredepeel experimental farm was interested in differences EOM input treatments on nitrate leaching. The treatments were based on EOM input and not on SOM content. For next studies it might be useful to take SOM content in account and make a comparison with the results of this study.

The organic treatment has a higher annual EOM input than the conventional high treatment, 2190 kg EOM/ha/y versus 3219 kg EOM ha/).The increase in SOM content was higher in the high conventional EOM input treatment than in the organic treatment but the EOM input in the conventional high EOM input treatment was lower than the EOM input in the organic treatment. This seems to contradict, this can be explained by more mineralisation in the organic treatment due to a higher SOM content. Another explanation could be that the conventional high EOM input treatment has higher crop yields and SOM is increased by a higher quantity of crop residues which are not included in the estimation of EOM input.

nitrate concentration

Nitrate concentration showed a pattern during the year. In all treatments the nitrate concentration in the upper meter of ground water was ranked from high to low: December -> January -> February -> November. November showed the lowest nitrate concentration in all treatments. An explanation could be that in November there may still be mineralisation or nitrate is still in upper soil layer and will be transported to the upper meter ground water by rainfall later on.

Mean nitrate concentrations for the balance sheets and for part of the statistical analyses were calculated from the measurements in December, January and February. It was assumed that mineralisation still takes place in November or nitrate is still in upper soil layer, and therefore the measurements in November were not included to calculate the mean.

The nitrate concentration in the organic treatment was significantly not significantly different from the conventional treatments. There was no significant difference between the conventional treatments (figure 4.4). It is also remarkable that there was a large deviation in nitrate concentration, this could be caused by outliers or that all plots crops and years were included for this calculation. Despite there were no significant differences the figure is still useful because it agrees with the statistical analyses and the Dutch legislation for nitrogen fertilization to reach the EU norm is based on the average nitrate concentration.

Based on figure 4.5 it seems that nitrate concentration is partly dependent on the nitrogen fertilization. However, figures 4.7, and 4.8 and tables 4,4 and 4,5 show that only for the organic treatment nitrate concentration in soil significantly increased if N total fertilization and N effective fertilization increased.

N balance sheets
Except for the organic EOM input treatment in 2014 the order of N supply, N offtake by harvested products, N surplus and N leaching from measurements and leaching fraction was as follows -> conventional high EOM input -> conventional low EOM input -> organic. From the balance sheets it cannot be concluded that an increase of EOM input increases N offtake by harvested products. The differences of leaching fractions are described in the paragraph on organic versus conventional and the conventional treatments had a lower leaching fraction than the conventional treatments.
There isn't an explanation of the discrepancy between the calculated and measured N-concentration in the ground water.

model selections
In all analyses where plot was taken as fixed effect, which gave the best explanation of the variance in average nitrate concentration in the upper meter of ground water. The effects of the plot factor were not affected by the moment of the measurements, nor when measurements were averaged (see Tables 4.6, 4.7, 4.10 and 4.11).

Taking plot as a random effect for the single effects; treatment, EOM input and green manure explained significantly best variance when comparing all treatments so EOM input partly plays a role in explaining variance of nitrate concentration. Taking plot as a random effect the single effects EOM input and green manure explained significantly best variance when comparing only the conventional treatments (see Tables 4.7, 4.9 and 4.11).
When combinations of variates were allowed to explain the variance for nitrate concentration and plot was taken as a random effect and all treatments were compared with each other the following variates were included in the best fitting model: the factors crop, year, treatment, the variates EOM input and N mineral in soil (0-60 cm) (table 4.10). Crop year and treatment had negative or positive effects, the variate EOM input had a negative effect and one year a (parameter estimation: (0.01246) effect and the variate N mineral in soil had in positive effect. Within these models the factor treatment and the variate EOM input were significant in some analyses. So overall, EOM supply has a small negative effect on nitrate concentration.

Taking plot as random effect and only conventional treatment comparison, the best fitted model included the factors: treatment, green manure and the factors EOM input, P fertilization, K fertilization and N effective fertilization (table 4.11). Green manure and EOM input had negative effects the other factors/variates had positive effects. Within these models the factor green manure and the variates EOM input were significant in some analyses.

In the model selection of best fitting models with multiple variates, not all variates were significant. However, GenStat selected these models based on the highest value of R^2-adjusted. Selection of best models based on R^2-adjusted and the alternative method to select models based on significant variates can be discussed. In this survey the selection based on R^2-adjusted was preferred because it gives the best fit in explaining variance.

In some analyses EOM input was a significant factor in explaining variance. The parameter estimates for EOM input vary between: -0,019 and -0,013. This means that increasing EOM input would decrease nitrate concentration in upper meter ground water. However EOM input was only significant during 2012 and in other analyses EOM input was not a variate which strongly explained variance in nitrate concentration in upper meter ground water, so more factors than EOM input are involved for explaining variance in nitrate leaching.

Summarizing all model selection, the factor plot shows the strongest explanation of variance in nitrate concentration in upper meter ground water of the Vredepeel experiment.

organic versus conventional.
The treatments differed in EOM supply, one treatment differs also in two another aspects This treatment was organic while the other two were conventional. This organic treatment has the highest level of EOM input and the fields are located separately from the conventional treatments. Below the comparison of organic and conventional will be discussed.
The SOM content was higher in the plots of the organic treatment than in the conventional treatments. The SOM content was significantly lower in the conventional treatments than the organic treatment

during 2011-2011. From 2001 the SOM content of the organic plots was higher than the conventional plots.

There was a significant difference in nitrate concentration in the upper meter of ground water between the organic EOM input treatment and the conventional EOM input treatments during 2011-2014. The nitrate concentration in the upper meter of ground water of the organic EOM input treatment was less than a half of the in nitrate concentration in the upper meter of ground water of the conventional EOM input treatments. By Kramer et al., (2006), the annual nitrate leaching in high conventional plots was even 4.4-5.6 times higher than in organic plots.
The organic treatment had not only higher EOM input, but also a lower nitrogen and effective nitrogen input than the conventional EOM input treatments. Therefore it was difficult to assess the specific contribution of EOM input to nitrate leaching. The average N effective supply in the organic EOM input treatment was significantly lower than the conventional EOM input treatment (figure 4.1) .
N supply within treatments can differ between years and crops.

Leaching fraction (the ratio between N leaching and N surplus) is lower in the organic treatment than in the conventional EOM input treatment in all year's. The difference in the leaching fraction may be explained by the N source (fertilizer/ slurry/manure) and the amount of supply, because in 2012 the N surplus was lower in the organic EOM input treatments than in the conventional treatments.
Another explanation of differences in leaching fraction could be that there is no steady state in immobilization and mineralisation. With a low leaching fraction there could be a higher immobilization than mineralization.

The difference in nitrate concentration in the upper meter of ground water between organic and conventional could also be explained by the level of ground water. Figure 4.15 shows that the organic treatment is located in an area with a ground water level which has a leaching fraction of 0.45 whereas the conventional plots had a lower ground water level with a corresponding leaching fraction of 0.58.

In fact without correcting nitrate concentration of the ground water level the organic and conventional treatments cannot be compared with each other. Next studies should include a correction for ground water level on nitrate concentration for comparing the organic and conventional treatments. A new set up of the experiment where all treatments are in the same ground water level could also improve the reliability. Calculating a fictive nitrate concentration in ground water could also be an option, but this method will be sensitive errors of measurements of nitrogen fertilization by slurry, N deposition, N uptake by harvested product and errors in estimations of N biological fixation. Errors in these measurements/estimations may lead to an over or under estimation of the fictive nitrate concentration.

plot size effect
The analyses show that there were strong random effects of the plot location in the Vredepeel experiment for explaining variance in nitrate measurements. Factors such as the ground water level, phosphate, pH soil texture, soil structure, SOM content are related to plot and may explain differences in leaching.
The assumption that more factors than EOM and nitrogen fertilization explain differences of nitrate leaching is supported by Dinnes et al., (2002). In this article it is considered that the amount of nitrate leaching is caused by a combination of factors such as tillage, drainage, crop selection, SOM, hydrology and temperature and rainfall patterns.
.
For this reason plot was taken in account as random effect in the new analyses. This resulted in significant explanation of variance of nitrate measurements by total EOM input, treatment and the presence green manure. In this analyses it was assumed that the properties of the plots has director and indirect effect on nitrate leaching. Next studies may provide more knowledge of the size of the direct and indirect effect of plot related properties.

The maps of the parameter estimated of the plot factor showed that: Comparing the three treatments and distance from the Peel canal it can be concluded that the parameter estimates in the organic treatment are lower than the parameter estimates in the conventional treatments. Contrary to what was expected beforehand, there is no indication that the distance to the Peel canal affects the nitrate concentration in upper meter ground water. It seems that within the conventional treatments the plot south of the ditch has a lower parameter estimate for nitrate concentration in the upper meter of ground water. In general it can be concluded that the organic plots have lower parameter estimates and there was a heterogeneity in parameter estimates between the plots. This heterogeneity in parameter estimates was stronger within the conventional treatments

green manure

When including plot as a random effect, in some years the variance of nitrate concentration in upper meter ground water was significantly explained by the presence of green manure. This supports findings by Wyland et al., (1996). They found a nitrate leaching reduction of 65-70 % with presence of a green manure. However in this study the nitrate reducing effect of green manures was not as large as the nitrate reducing effect considered by Wyland et al., (1996). Based on the parameters of appendix 9.3 estimates the reduction of nitrate in ground water by green manure was about 55 %.

yield and irrigation

Variance in yield is significantly explained by irrigation, however irrigation was connected to weather conditions as irrigation only occurs in dry periods. The finding that irrigation decreases maize crop yield is probably an indication of water limitations and maybe soil structure problems caused by irrigation.

EOM input and the hypotheses

To test the hypothesis that with equal levels of N fertilization an increase of EOM input will result in a lower concentration in nitrate in upper meter ground water, the Vredepeel experimental set-up was not adequate. The EOM input treatments did not have the same nitrogen fertilization level and there was no significant difference in nitrate leaching between the conventional treatments. The organic plots had also a lower leaching fraction caused by a higher ground water level and a lower N fertilization.

When plot was taken as a random effect, an increase in EOM input resulted in a decrease of nitrate concentration when all treatments were compared. When plot factor was taken as a fixed factor, in all analyses plot was significant, but R^2-adjusted was generally higher than when plot was taken as random factor. When plot was taken as a random factor, green manure sometimes gave the strongest explanation in variance compared with other factors and (co)variates.

For testing the hypothesis that high input of EOM with similar N inputs also through organic and mineral fertilizers gives a higher yield and N offtake, the Vredepeel experiment was not adequate. There was not any significant difference in maize yield between the EOM input treatments. According to figure 4.10,4.11 and (appendix9.2) the assumption that N offtake by the harvested product was dependent on the N supply is stronger than the assumption that N offtake by harvested product was dependent on the EOM input and there was no indication that the N fertilization was sub optimal.

The finding from this study that nitrate leaching was not directly ascribed to nitrogen fertilization and EOM input is supported by Dinnes et al., (2002). More factors related to the allocation of the plots may affect nitrogen leaching. To investigate the effects of the EOM input treatments, more focus has to be put on plot properties.

The fact that there was no significant difference in yield disagrees with the result of Johnston et al., 2009). Johnston et al considered that crop yield increases in long term supply of higher levels of EOM. It could be that only comparing the crop maize is not sufficient to draw clear conclusions about the effects of EOM input on crop yield. Comparing crop rotations may provide more insight into the effect of EOM input on crop yield.
For investigating yield the entire rotation should be taken in account, from one crop no clear conclusions can be drawn for the rotation level.

The Vredepeel experiment is a long-term experiment from 2001, but only data between 2011-2014 were analysed, because it was assumed that in the most recent years the effects of long term EOM input were stabilized. An analyses from 2001 till 2014 could provide more insight. Alternatively, it could also be that 15 years is a too short to find significant effects of EOM input.

6. Conclusions

Based on the results of this study several conclusions can be made and are described in this section. The Vredepeel experimental set-up was not sufficient for testing the hypothesis that an increase of annual EOM input decreases nitrate leaching by equal nitrogen fertilization, because the nitrogen fertilization rate differs between treatments. Nitrate concentration of ground water in a plot in the Vredepeel experiment is strongly dependent on the location of the plot. The plot effect may be explained by ground water level, and heterogeneity of soil properties within in the trial fields. The effect of the factor plot had a stronger effect in explaining variance than the factor treatment. No strong effects of EOM input on decreasing leaching were found.

According to the nitrogen balance sheet, a higher N supply seems to lead to a higher N offtake, N surplus and N-leaching ranking from high to low as follows: conventional high EOM input → conventional low EOM input→ organic. However, when comparing leaching as function of N supply, higher N input does not automatically lead to a higher nitrate concentration in the conventional treatments. According to the balance sheets the leaching fraction in the organic treatment is lower than in the conventional treatments each year. This may be caused by a lower N fertilization and/or a different ground water level.

For maize yield there is not any significant difference in yield and variance in maize yield is only significantly explained by the variate irrigation.

7. Recommendations

The Vredepeel experiment gives interesting insights comparing organic and conventional treatments. However, when looking at the specific effect of EOM input , it was not possible to look at this independently from nitrogen supply. In a next survey it might be useful to design an experiment where EOM input and nitrogen supply are independent of each other. The Vredepeel experiment also shows that there might be specific properties for each plot which affect nitrate concentrations. It might therefore be useful to focus on plot properties such as soil texture ground water level and horizontal ground water fluxes related to leaching in next studies. This study mainly focused on nitrate leaching, it would be interesting to focus on the difference in crop yield on rotation level between the treatments. Nitrate concentration in upper meter ground water in the organic treatment should be corrected for comparison with the conventional treatments, because the ground water level differs. If it is practically possible, the organic treatment should be on fields with the same ground water level. Collecting data and creating a dataset required a lot of time for this study and this data set might be useful for next analyses.

8. References

Alterra soil map, 2006 :http://www.urbangreenbluegrids.com/water/

Aneja, V.P., W.H. Schlesinger and J.W. Erisman, 2009. Effects of agriculture upon the air quality and climate: Research, policy, and regulations. Environmental science & technology, 43(12): 4234-4240.

Berkhout, P., H. Silvis and I. Terluin, 2014. Landbouw-economisch bericht 2014. LEI WUR.

Bis Nederlands2015, Alterra Wageningen UR: http://maps.bodemdata.nl/bodemdatanl/index.jsp

Dinnes, D.L., D.L. Karlen, D.B. Jaynes, T.C. Kaspar, J.L. Hatfield, T.S. Colvin and C.A. Cambardella, 2002. Nitrogen management strategies to reduce nitrate leaching in tile-drained midwestern soils. Agronomy journal, 94(1): 153-171.

Edwards, C.A., 1989. The importance of integration in sustainable agricultural systems. Agriculture, ecosystems & environment, 27(1): 25-35.

Fan, A.M. and V.E. Steinberg, 1996. Health implications of nitrate and nitrite in drinking water: An update on methemoglobinemia occurrence and reproductive and developmental toxicity. Regulatory toxicology and pharmacology, 23(1): 35-43.

RIVM, 2007. De uitspoeling van het stikstofoverschot naar grond-en oppervlaktewater op landbouwbedrijven.

Groenendijk, P., L. Renaud, O. Schoumans and J. Schröder, 2014 Vergelijking van het wog-wod model en het mambo-stone model.

Google 2015, Google Earth 2015 Aerodata International Surveys

Hiscock, K., J. Lloyd and D. Lerner, 1991. Review of natural and artificial denitrification of groundwater. Water Research, 25(9): 1099-1111.

RIVM, 2012. Waterkwaliteit op landbouwbedrijven: Evaluatie meststoffenwet 2012: Deelrapport ex post. RIVM rapport 680123001.

Huijsmans, J.F.M., J. Schröder, G. Vermeulen, d.R. Goede, D. Kleijn and W. Teunissen, 2008. Emissiearme mesttoediening: Ammoniakemissie, mestbenutting en nevenaspecten.

Johnston, A.E., P.R. Poulton and K. Coleman, 2009. Soil organic matter: Its importance in sustainable agriculture and carbon dioxide fluxes. Advances in agronomy, 101: 1-57.

KNMI, 2015 KLimaat atlas 19-12-2015 http://www.klimaatatlas.nl/klimaatatlas.php

Kramer, S.B., J.P. Reganold, J.D. Glover, B.J. Bohannan and H.A. Mooney, 2006. Reduced nitrate leaching and enhanced denitrifier activity and efficiency in organically fertilized soils. Proceedings of the National Academy of Sciences of the United States of America, 103(12): 4522-4527.

Mosier, A., J.K. Syers and J.R. Freney, 2013. Agriculture and the nitrogen cycle: Assessing the impacts of fertilizer use on food production and the environment. Island Press.

Mueller, T. and K. Thorup-Kristensen, 2001. N-fixation of selected green manure plants in an organic crop rotation. Biological agriculture & horticulture, 18(4): 345-363.

Powlson, D.S., T.M. Addiscott, N. Benjamin, K.G. Cassman, T.M. de Kok, H. van Grinsven, J.-L. L'hirondel, A.A. Avery and C. Van Kessel, 2008. When does nitrate become a risk for humans? Journal of environmental quality, 37(2): 291-295.

Rice, C.W., K. Fabrizzi, P. White, J. Kimble, D. Reed, S. Mooney, R. Follett and R. Lal, 2007. Benefits of soil organic carbon to physical, chemical, and biological properties of soil. Soil Carbon Management: Economic, Environmental and Societal Benefits. JM Kimble, CW Rice, D. Reed, S. Mooney, RF Follett, and R. Lal (eds.). CRC Press, Boca Raton, FL: 155-162.

RIVM, 2007. De uitspoeling van het stikstofoverschot naar grond-en oppervlaktewater op landbouwbedrijven.

Schrama M, De Haan J.J, Carvalo S, Kroonen M, Verstegen H,Van Der Putten, 2013, Spatial and temporal stability in organic versus conventional farming systems, PPO WUR

Schröder, J., H. Aarts, H. Ten Berge, H. Van Keulen and J. Neeteson, 2003. An evaluation of whole-farm nitrogen balances and related indices for efficient nitrogen use. European Journal of Agronomy, 20(1): 33-44.

Smil, V., 1999. Nitrogen in crop production: An account of global flows. Global biogeochemical cycles, 13(2): 647-662.

Staalduinen, L.v., M. Hoogeveen, H. Luesink, G. Gotteleer, H. Van Zeijts, P. Dekker and C. De Bont, 2002. Actualisering landelijk mestoverschot 2003. LEI.

Van Dijk, W. and J. Schröder, 2007. Adviezen voor stikstofgebruiksnormen voor akker en tuinbouwgewassen op zand en lössgrond bij verschillende uitgangspunten. Rapport.

Velders, G., J. Aben, G. Geilenkirchen, H. den Hollander, B. Jimmink, E. van der Swaluw, W. de Vries, J. Wesseling and M. van Zanten, 2013. Grootschalige concentratie-en depositiekaarten nederland: Rapportage 2013. RIVM rapport 680362003.

Withagen, C. and M. Betsema, 2005. Profijt van het mestbeleid?

Wyland, L., L. Jackson, W. Chaney, K. Klonsky, S. Koike and B. Kimple, 1996. Winter cover crops in a vegetable cropping system: Impacts on nitrate leaching, soil water, crop yield, pests and management costs. Agriculture, Ecosystems & Environment, 59(1): 1-17.

9. Appendices

9.1 Maps of Vredepeel experiment – set up of the Vredepeel experiment

9.1.1 map of conventional EOM input treatments

Conventional treatments 2014

N →

canal

grass strip | grass strip

				ditch					18 m.
									18 m.
									18 m.
Crop	treatment	Area	Plot #		Crop	treatment	Area	Plot #	15 m.
sugar beet	low	0,3446 ha	18.2 b		potato	low	0,3492 ha	28.2 b	18 m.
sugar beet	low	0,3446 ha	18.2 a		potato	low	0,3492 ha	28.2 a	18 m.
sugar beet	high	0,3491 ha	18.1 b		potato	high	0,3492 ha	28.1 b	18 m.
sugar beet	high	0,2910 ha	18.1 a		potato	high	0,2910 ha	28.1 a	15 m.
silage maize	low	0,3546 ha	17.2 b		barley	low	0,3492 ha	27.2 b	18 m.
silage maize	low	0,3546 ha	17.2 a		barley	low	0,3492 ha	27.2 a	18 m.
silage maize	high	0,3546 ha	17.1 b		barley	high	0,3492 ha	27.1 b	18 m.
silage maize	high	0,2955 ha	17.1 a		barley	high	0,2910 ha	27.1 a	15 m.
peas	low	0,3546 ha	16.2 b		gm ray grass+ leek	low	0,3492 ha	26.2 b	18 m.
peas	low	0,3546 ha	16.2 a		gm ray grass+ leek	low	0,3492 ha	26.2 a	18 m.
peas	high	0,3546 ha	16.1 b		gm ray grass+ leek	high	0,3492 ha	26.1 b	18 m.
peas	high	0,2955 ha	16.1 a		gm ray grass+ leek	high	0,2910 ha	26.1 a	15 m.
		4,0479 ha		path			4,0158 ha		
	200m.					200m.			

9.1.2 map of organic EOM input treatment

N

Organic treatment 2014

ditch

grass strip

Crop	area	Plot	
barley	0,3258 ha	34.2 b	18m.
baley	0,3258 ha	34.2 a	18m.
carrot	0,3258 ha	34.1 b	18m.
carrot	0,2715 ha	34.1 a	15m.
peas	0,3258 ha	33.2 b	18m.
peas	0,3258 ha	33.2 a	18m.
gm grass clover	0,3258 ha	33.1 b	18m.
gm grass clover	0,2715 ha	33.1 a	15m.
potato	0,3258 ha	32.2 b	18m.
potato	0,3258 ha	32.2 a	18m.
silage maize	0,3258 ha	32.1 b	18m.
silage	0,2715 ha	32.1 a	15m.
	3,7467 ha		

grass strip

wood wall

9.2: Nutrient balances

9.2.1 nutrient balance sheets conventional high EOM input treatment

Balance sheet Nitrogen Vredepeel experiment conventional High EOM input 2012

input	potato	peas	leek	barley	sugar beet	silage maize	rotation (SUM)	rotation (avg)
Slurry							0	0
crop	136	90	158	0	136	208	728	121
green manure			116		69		185	31
fertilizer								
crop	165	0	151	81	41	32	470	78
green manure		70					70	12
deposition								
crop	23	11	23	23	26	23	128	21
green manure /bare soil	23	34	23	23	19	23	143	24
fixatie								
crop		50					50	8
green manure								
N plant material	9						9	2
total	355	255	470	126	291	285	1782	297

output	potato	peas	leek	barley	sugar beet	silage maize	rotation (SUM)	rotation (avg)
harvested product	158	40	85	107	100	114	604	101
soil surplus	*195*	*214*	*382*	*19*	*189*	*169*	1167	195
soil surplus (from NO3 measurement)	*137*	*67*	*34*	*63*	*156*	*55*	512	85
volitization supply slurry	2	1	3	0	2	2	11	2
							0	0
leaching calculated from surplus	107	118	210	10	104	93	642	107
leaching calculated from measurement	80	39	20	37	90	32	296	49
							0	0
denitrification calculated from surplus	78	86	153	8	75	67	467	78
denitrifacation calculated from measurment	58	28	14	27	66	23	216	36
							0	0
calculated NO3- concentration	159	174	310	15	153	137	948	158
measured NO3 concentration	118	57	29	54	133	47	438	73

Balance sheet Nitrogen Vredepeel experiment conventional low EOM input 2012

input	potato	peas	leek	barley	sugar beet	silage maize	rotation	rotation (avg)
Slurry							0	0
gewas	106		98		116	106	426	71
groenbemester			116		89		205	34
kunstmest								0
gewas	165	41	151	81	41	43	522	87
groenbemester		70					70	12
Depositie								0
gewas	23	11	23	23	26	23	128	21
groenbemester	23	34	23	23	19	23	143	24
fixatie								0
gewas		50					50	8
groenbemester								0
								0
pootgoed	9							0
total	325	206	410	126	291	194	1552	258.6666667

output	potato	peas	leek	barley	sugar bee	silage maiz	rotation	rotation (avg)
harvested product	123	36	95	86	88	89	517	86
soil surplus	201	170	312	40	201	104	1027	171
soil surplus (from NO3 measurement)	134	47	1	115	53	107	456	76
volitization supply slurry	1	0	3	0	2	1	8	1
							0	0
leaching calculated from surplus	110	94	172	22	110	57	565	94
leaching calculated from measurement	78	27	0	67	30	62	264	44
							0	0
denitrification calculated from surplus	80	68	125	16	80	41	411	68
denitrification calculated from measurment	57	20	0	48	22	45	192	32
							0	0
calculated NO3 concentration	163	138	254	32	163	84	834	139
measured NO3 concentration	115	40	0	98	45	92	390	65
								0
								0

Balance sheet Nitrogen Vredepeel experiment organic 2012

input	potato	peas	leek	barley	carrot	silage maize	rotation	rotation (avg)
Slurry								
gewas	33		197	104	73	170	577	96
groenbemester								
manure								
groenbemester	68	42				104	214	36
Depositie								
gewas	23	11	23	23	26	23	128	21
groenbemester	23	34	23	23	19	23	143	24
fixatie								
gewas		50					50	8
green manure		50	50					
plant material	9							
groenbemester								
total	155.3	187	292	149	118	319.2	1220.5	203.4166667

output	potato	peas	leek	barley	carrot	silage maiz	rotation	rotation (avg)
harvested product	36	19	91	56	123	91	416	69
soil surplus	116	166	199	92	-6	222	788	131
soil surplus (from NO3 measurment)	41	54	18	46	11	46	216	36
volitization supply slurry	3	2	2	1	1	7	16	3
							0	0
leaching calculated from surplus	64	91	109	50	-3	122	433	72
leaching calculated from measurement	24	31	11	26	7	27	125	21
							0	0
denitrification calculated from surplus	46	66	79	37	-2	89	315	53
denitrification from measurment	17	23	8	19	5	19	91	15
							0	0
							0	0
measured NO3 concentration	35	46	16	39	10	39	185	31
calculated NO3 concentration	94	135	161	75	-5	180	640	107

9.2.2 nutrient balance sheets conventional low EOM input treatment

Balance sheet Nitrogen Vredepeel experiment conventional high EOM input 2013

input	aardappel	erwt	prei	gerst	suikerbieten/peen	mais	rotation		output	aardappel	erwt	prei	gerst	suikerbiet	mais	rotation	rotation (avg)
slurry							0	0	**harvested product**	124	55	87	99	106	92	563	94
crop	167	48	161	0	143	202	721	120	*soil surplus*	221	88	309	175	96	210	1099	183
greemmanure			82	94			176	29	*soil surplus (from NO3 measurment)*	56	69	38	121	33	113	429	71
fertilizer							0	0	**volitization supply slurry**	2	1	3	1	2	2	11	2
crop	124	0	108	81	14	55	382	64								0	0
greem manure				54			54	9	**leaching calculated from surplus**	133	53	185	105	58	126	659	110
deposition							0	0	**leaching calculated from measurement**	32	40	22	70	19	65	248	41
crop	22.5	11.3	22.5	22.5	26.25	22.5	128	21								0	0
green manure	22.5	33.8	22.5	22.5	18.75	22.5	143	24	**denitrification calculated from surplus**	88	35	124	70	38	84	440	73
fixation							0	0	**denitrification from measurment**	24	29	16	51	14	47	180	30
crop		50					50	8								0	0
greem manure							0	0								0	0
							0	0	**measured NO3 concentration**	48	59	32	103	28	96	366	61
plant material	9						9	2	**calculated NO3 concentration**	196	78	274	155	85	186	974	162
total	345	143	396	274	202	302	1662	277									

Balance sheet Nitrogen Vredepeel experiment conventional low EOM input 2013

input	aardappel	erwt	prei	gerst	suikerbieten/peen	mais	rotation	rotation (avg)	output	aardappel	erwt	prei	gerst	suikerbiet	mais	rotation	rotation (avg)
slurry							0	0	**harvested product**	119.0	49.0	87.0	76.0	86.0	207.0	624.0	104.0
crop	116		121		95	116	448	75	*soil surplus*	196.0	141.0	318.0	144.0	100.0	9.0	908.0	151.3
green manure			82	94			176	29	*soil surplus (from NO3 measurment)*	76.8	63.5	41.6	0.1	87.9	31.7	301.6	50.3
fertilizer							0	0	**volitization supply slurry**	1.4	0.0	2.4	1.1	1.1	1.4	7.5	1.2
crop	154	41	157	81	46	55	534	89								0.0	0.0
green manure		54					54	9	**Leaching calculated from surplus**	117.6	84.6	190.8	86.4	60.0	5.4	544.8	90.8
deposition							0	0	**leaching calculated from measurement**	46.1	38.1	25.0	0.1	52.7	19.0	181.0	30.2
crop	22.5	11.3	22.5	22.5	26.25	22.5	127.5	21								0.0	0.0
green manure	22.5	33.8	22.5	22.5	18.75	22.5	142.5	24	**denitrification calculated from surplus**	78.4	56.4	127.2	57.6	40.0	3.6	363.2	60.5
fixation							0	0	**denitrification from measurment**	30.7	25.4	16.6	0.0	35.2	12.7	120.7	20.1
crop		50					50	8								0.0	0.0
green manure							0	0								0.0	0.0
								0								0.0	0.0
plant material	9							0								0.0	0.0
total	315	190	405	220	186	216	1532	255	**measured NO3 concentration**	68.0	56.3	36.9	0.1	77.9	28.1	267.3	44.5
									calculated NO3 concentration	173.7	124.9	281.7	127.6	88.6	8.0	804.5	134.1

Balance sheet Nitrogen Vredepeel experiment organic 2013

input	aardappel	erwt	prei	gerst	suikerbieten/peen	mais	rotation	rotation (avg)	output	aardappel	erwt	prei	gerst	suikerbiet	mais	rotation	rotation (avg)
slurry							0	0	**harvested product**	96	61	99	61	95	167	579	97
crop	78.4	47	186	98	69	54.24	532.64	88.77333333	soil surplus	171	131	182	82	19	67	652	109
green manure							0	0	*soil surplus (from NO3 measurment)*	10	10	9	3	12	30	75	13
manure							0	0	**volitization supply slurry**	7	1	2	1	1	7	18	3
crop	134.5					134.5	269	44.83333333								0	0
green manure							0	0	**Leaching calculated from surplus**	103	79	109	49	11	40	391	65
deposition							0	0	**leaching calculated from measurement**	10	10	9	3	12	30	75	13
crop	22.5	11.3	22.5	22.5	26.25	22.5	127.5	21.25								0	0
green manure	22.5	33.8	22.5	22.5	18.75	22.5	142.5	23.75	**denitrification calculated from surplus**	68	52	73	33	8	27	261	43
fixation							0	0	**denitrification from measurment**	7	7	6	2	8	20	50	8
crop		50					50	8.333333333								0	0
green manure		50	50				100	16.66666667								0	0
plant material	9						9	1.5	**measured NO3 concentration**	15	15	13	5	18	45	111	19
	266.9	192	281	143	114	233.74	1230.64	205.1066667	**calculated NO3 concentration**	151.4174	116.066	161.252	72.652	16.834	59.13164	577.35304	96.22550667

9.2.2 nutrient balance sheets organic treatment

Balance sheet Nitrogen Vredepeel experiment conventional high EOM input 2014

input	aardappel	erwt	prei	gerst	suikerbieten/peen	mais	rotation	rotation (avg)	output	aardappel	erwt	prei	gerst	suikerbiet	mais	rotation	rotation (avg)
slurry							0	0	**harvested product**	167	61	81	114	117	195	735	123
crop	141	35	107	0	124	164	571	95	soil surplus	138	69	193	11	82	44	537	90
green manure							0	0	*soil surplus (from NO3 measurment)*	223	73	56	105	41	28	526	88
fertilzer							0	0	**volitization supply slurry**	2	0	1	0	1	2	7	1
crop	110	0	122	80	30	30	372	62								0	0
manure							0	0	**Leaching calculated from surplus**	83	41	116	7	49	26	322	54
deposition							0	0	**leaching calculated from measurement**	134	44	34	63	25	17	315	53
crop	22.5	11.3	22.5	22.5	26.25	22.5	127.5	21								0	0
green manure	22.5	33.8	22.5	22.5	18.75	22.5	142.5	24	**denitrification calculated from surplus**	55	28	77	4	33	18	215	36
fixation							0	0	**denitrification from measurment**	89	29	22	42	16	11	210	35
crop		50					50	8								0	0
green manure							0	0								0	0
plant material	9						9	2	**measured NO3 concentration**	198	64	50	93	36	25	466	78
	305	130	274	125	199	239	1272	212	**calculated NO3 concentration**	122	61	171	10	73	39	476	79

Balance sheet Nitrogen Vredepeel experiment conventional low EOM input 2014

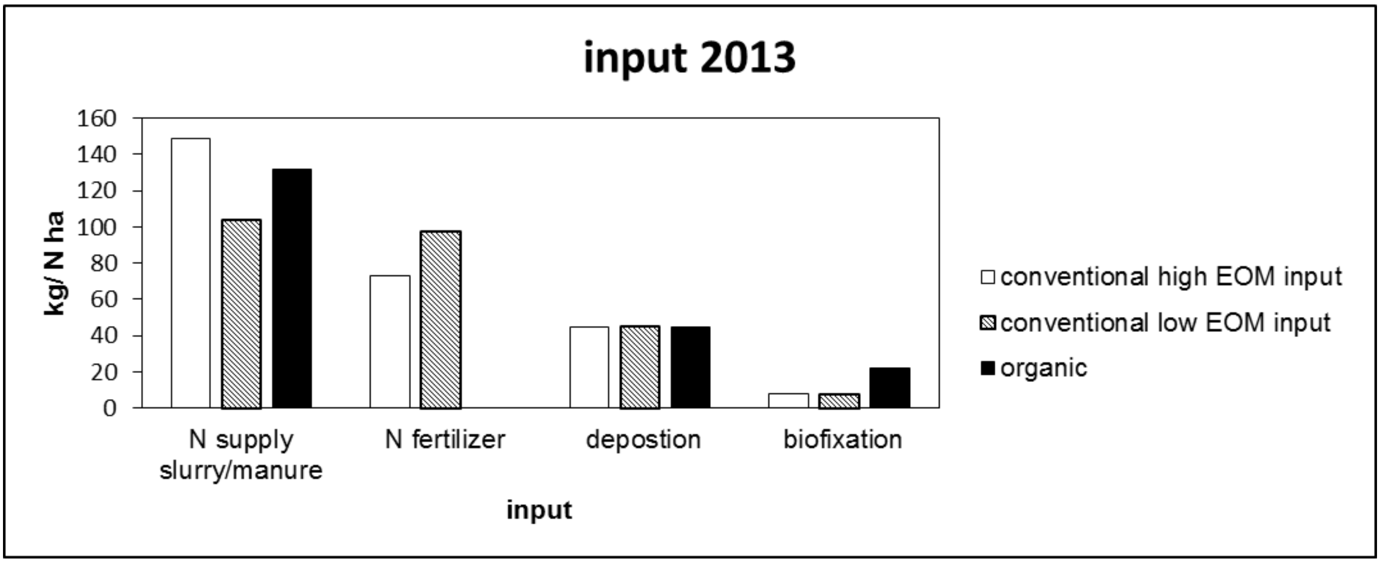
input	aardappel	erwt	prei	gerst	suikerbieten/peen	mais	rotation	rotation (avg)	output	aardappel	erwt	prei	gerst	suikerbiet	mais	rotation	rotation (avg)
slurry							0	0	**harvested product**	175	27	49	104	106	158	619	103
crop	105		113		98	105	421	70	soil surplus	94	95	200	21	51	19	480	80
green manure			91				91	15	*soil surplus (from NO3 measurment)*	58	95	77	73	1	59	364	61
fertilizer							0	0	**volitization supply slurry**	1	0	2	0	1	1	6	1
crop	110	27	0	80	14	27	258	43								0	0
green manure							0	0	**Leaching calculated from surplus**	56	57	120	13	31	11	288	48
depostion							0	0	**leaching calculated from measurement**	35	57	46	44	1	35	218	36
crop	22.5	11.3	22.5	22.5	26.25	22.5	127.5	21								0	0
green manure	22.5	33.8	22.5	22.5	18.75	22.5	142.5	24	**denitrification calculated from surplus**	38	38	80	8	20	8	192	32
fixation							0	0	**denitrification from measurment**	23	38	31	29	1	24	145	24
crop		50					50	8								0	0
green manure							0	0								0	0
plant material	9						9		**measured NO3 concentration**	52	84	68	64	1	52	322	54
total	269	122	249	125	157	177	1099	1.5	**calculated NO3 concentration**	83	84	177	19	45	17	425	71

Balance sheet Nitrogen Vredepeel experiment organic 2014

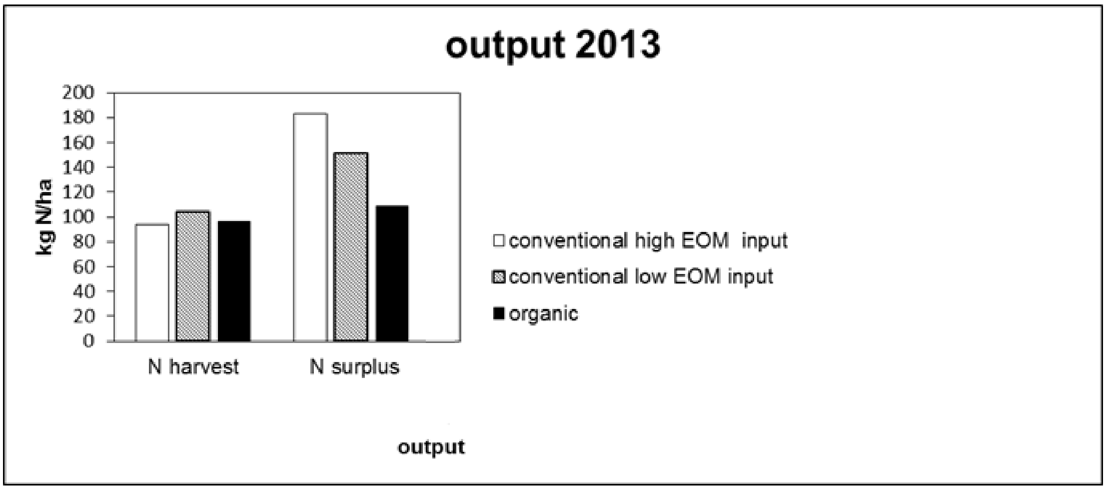
input	aardappel	erwt	prei	gerst	suikerbieten/peen	mais	rotation	rotation (avg)	Afvoer	aardappel	erwt	prei	gerst	suikerbiet	mais	rotation	rotation (avg)
slurry							0	0	**harvested product**	64	51	44	36	90	143	428	71
crop	115.25	46	260	92	102	101.5	716.75	119	soil surplus	258	140	311	101	57	156	1023	170
green manure							0	0	*soil surplus (from NO3 measurment)*							0	0
manure							0	0	**volitization supply slurry**	32	1	3	1	1	32	71	12
crop	152.5					152.5	305	51								0	0
green manure							0	0	**Leaching calculated from surplus**	155	84	187	61	34	94	614	102
deposition							0	0	**leaching calculated from measurement**	19	4	53	23	16	22	136	23
crop	22.5	11.3	22.5	22.5	26.25	22.5	127.5	21								0	0
green manure	22.5	33.8	22.5	22.5	18.75	22.5	142.5	24	**denitrification calculated from surplus**	103	56	124	40	23	62	409	68
fixation							0	0	**denitrification from measurment**	13	3	35	15	10	15	91	15
crop		50					50	8								0	0
green manure		50	50				100	17								0	0
plant material	9						9	2	**measured NO3 concentration**	28	6	79	33	23	32	201	34
total	321.75	191	355	137	147	299	1450.75	241.7916667	**calculated NO3 concentration**	228	124	276	89	51	138	906	151

9.2.2 summary of in and outputs of N balance for each year

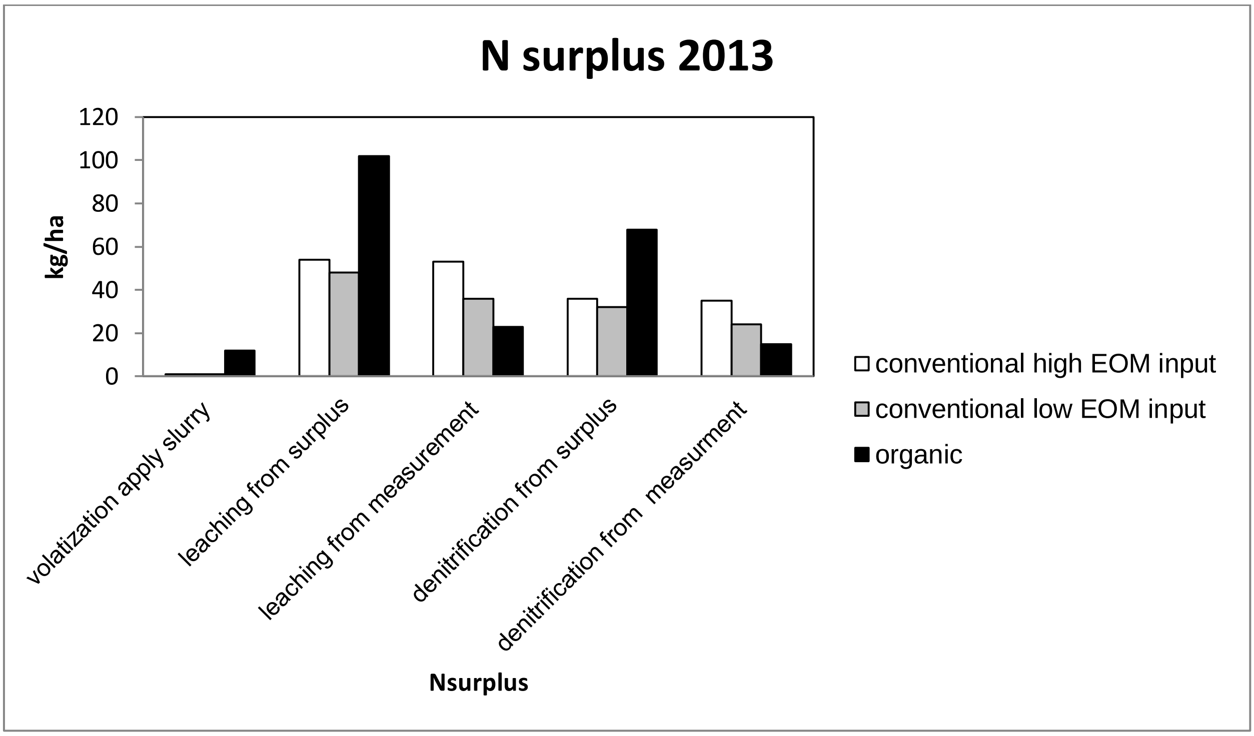
Average of N inputs of each EOM input treatment during 2013, left blanc bars indicate the conventional high EOM input treatment, middle bars with dioganal pattern indicate the conventional low EOM treatment and right black bars indicates the organic treatment.

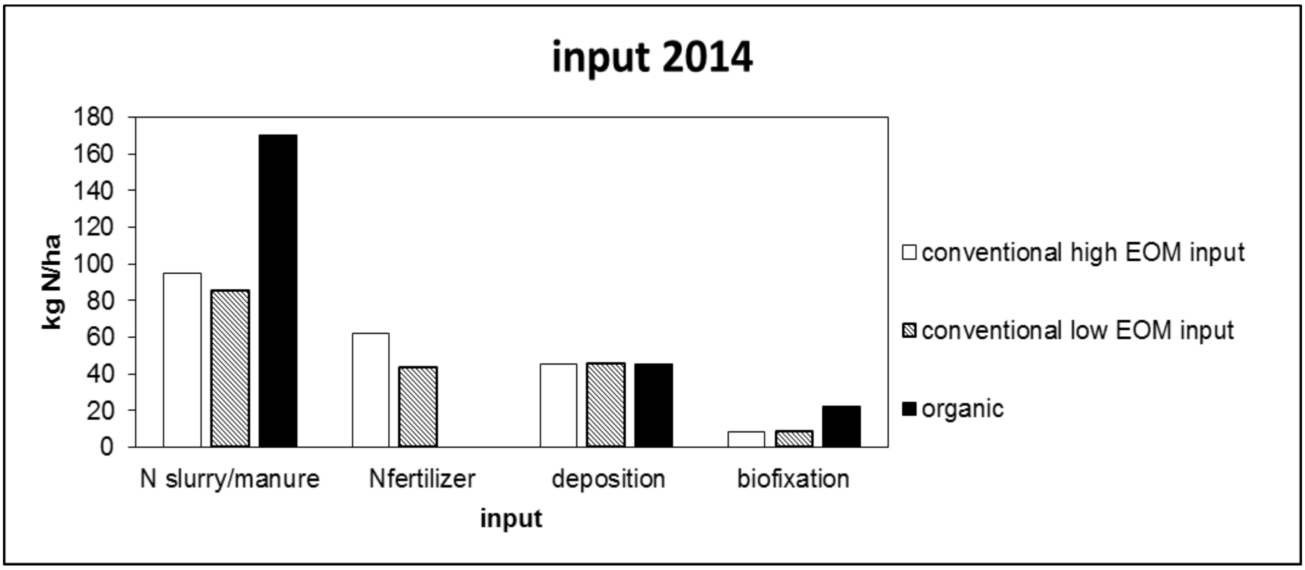


Average of N inputs of each EOM input treatment during 2013, left blanc bars indicate the conventional high EOM input treatment, middle bars with dioganal pattern indicate the conventional low EOM input treatment and right black bars indicates the organic treatment.

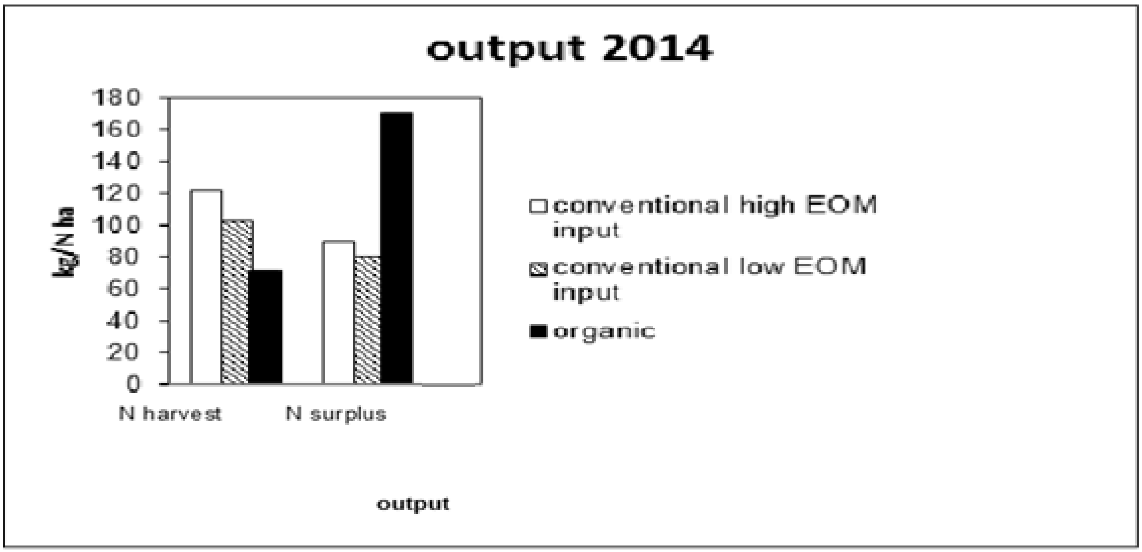


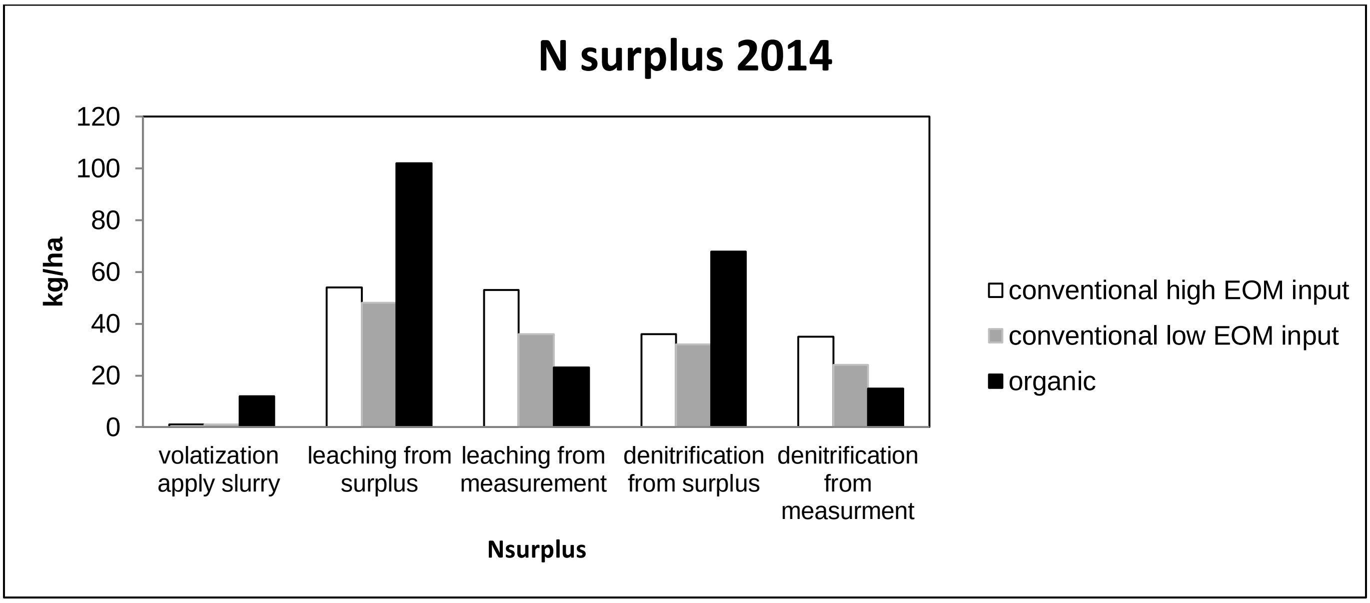
Average of N inputs of each EOM input treatment during 2013, left blanc bars indicate the conventional high EOM input treatment, middle bars with dioganal pattern indicate the conventional low EOM input treatments and right black bars indicates the organic treatment.





Average of N inputs of each EOM input treatments during 2014, left blanc bars indicate the conventional high EOM input treatments, middle bars with dioganal pattern indicate the conventional low EOM input treatments and right black bars indicates the organic treatment.





Average of N inputs of each EOM input treatment during 2014, left blanc bars indicate the conventional high EOM input treatments, middle bars with dioganal pattern indicate the conventional low EOM input treatments and right black bars indicates the organic treatments.

Appendix 9.3 output analyses on leaching

Output of statistical analyses of NITRATE measurement during November, in this analyses the factor plot was taken as fixed factor and all treatments or only the conventional treatments were compared with each other

NITRATE concentration during November, plot: fixed factor, all treatments comparison		
	R^2 Adjusted	***p-value***
plot	*45,82*	*0,001*
treatment	*14,75*	*0,006*
total supply of N Effective	*2,54*	*0,129*
sum of rainfall from September till April	*1,09*	*0,214*
sum of rainfall from September till January	*0,91*	*0,228*
green manure	*0,68*	*0,248*
total supply of N	*0,2*	*0,297*
total EOM input	*<0.00*	*0,471*

output of statistical analyses of NITRATE measurement during November, in this analyses the factor plotwas included and only the two conventional treatments were included in this analyses.

NITRATE concentration during November, plot: fixed factor, conventional treatments comparison		
	R^2 Adjusted	***p-value***
plot	*40,79*	*0,008*
treatment	*0,5*	*0,286*
sum of rainfall from September till January	*<0.00*	*0,387*
sum of rainfall from September till April	*<0.00*	*0,404*
N-mineral after harvest (0-60)	*<0.00*	*0,41*
green manure	*<0.00*	*0,437*
total EOM input	*<0.00*	*0,634*
total N surplus	*<0.00*	*0,778*

Output of model selection nitrate February

NITRATE concentration during December plot: fixed factor, all treatments comparison		
	R^2 Adjusted	***p-value***
PLOT	48.23	0
TREATMENT	19.16	0.002
EOMTOT	4.09	0.077
GREENMANURE	2.76	0.12
RAINSUM_SEP_APR	2.25	0.142
RAINSUMSEP_JAN	0.88	0.231
NEFFECTIVE_TOTAL	0.48	0.268
NTOTAL	<0.00	0.723

NITRATE concentration during December, plot: fixed factor, conventional treatments comparison		
	R^2 Adjusted	***p-value***
PLOT	42.51	0.006
GREENMANURE	3.2	0.151
NMINH0_60	2.13	0.193
RAINSUM_SEP_APR	0.87	0.261
TREATMENT	0.82	0.264
RAINSUMSEP_JAN	<0.00	0.349
NSURPLUSTOTAL	<0.00	0.351
NEFFECTIVE_TOTAL	<0.00	0.521

Output of model selection nitrate January

NITRATE concentration during January plot: fixed factor, all treatments comparison		
	R^2 Adjusted	***p-value***
PLOT	41.26	0.002
TREATMENT	13.46	0.009
EOMTOT	4.33	0.071
NEFFECTIVE_TOTAL	3.9	0.082
NTOTAL	0.61	0.255
RAINSUM_SEP_APR	0.26	0.291
RAINSUMSEP_JAN	<0.00	0.352
GREENMANURE	<0.00	0.374

NITRATE concentration during January plot: fixed factor, only conventional treatments comparison		
	R^2 Adjusted	***p-value***
PLOT	36.85	0.015
TREATMENT	0.56	0.282
RAINSUM_SEP_APR	<0.00	0.334
GREENMANURE	<0.00	0.466
EOMTOT	<0.00	0.479
NSURPLUSTOTAL	<0.00	0.53
RAINSUMSEP_JAN	<0.00	0.571
NMINH0_60	<0.00	0.573

Output of model selection nitrate February

NITRATE concentration during February plot: fixed factor, all treatments comparison		
	R^2 Adjusted	***p-value***
PLOT	63.26	0
TREATMENT	17.24	0.003
NEFFECTIVE_TOTAL	8.65	0.018
NTOTAL	4.16	0.075
EOMTOT	1.22	0.204
NSURPLUSTOTAL	0.54	0.262
RAINSUM_SEP_APR	<0.00	0.538
RAINSUMSEP_JAN	<0.00	0.591

NITRATE concentration during February plot: fixed factor, only conventional treatments comparison		
	R^2 Adjusted	***p-value***
PLOT	62.23	0
TREATMENT	1.7	0.214
NTOTAL	<0.00	0.571
NEFFECTIVE_TOTAL	<0.00	0.617
RAINSUM_SEP_APR	<0.00	0.629
RAINSUMSEP_JAN	<0.00	0.708
NMINH0_60	<0.00	0.769
NSURPLUSTOTAL	<0.00	0.826

Parameter estimated of the model selections

Parameter estimates with standard errors of the best selected model for explaining variance of the average nitrate concentration in upper meter ground water from December, February during 2012 till 2014. Plot were taken in account as fixed factor and all treatments were compared with each other.

All treatment comparison 2012-2014 with plot was fixed factor.

Parameter	estimate	s.e.
PLOT 16.1b	33.4	21.2
PLOT 16.2a	68.3	19.3
PLOT 17.1a	13.6	17.3
PLOT 17.2b	56.5	16.6
PLOT 18.1a	32.3	19.2
PLOT 18.2b	-23.4	19.2
PLOT 26.1a	65.5	21.4
PLOT 26.2b	61.3	22.2
PLOT 27.1b	41.7	20.9
PLOT 27.2a	28.2	20.7
PLOT 28.1a	90.1	21.8
PLOT 28.2b	19.5	19.3
PLOT 32.1b	2.8	21.9
PLOT 32.2a	5.3	21.8
PLOT 33.1a	25.4	21.8
PLOT 33.2b	4.9	20.0
PLOT 34.1a	-6.1	21.1
PLOT 34.2b	28.9	17.1
CROP barley	15.4	12.0
CROP carrot	-3.7	17.9
CROP leek	-43.5	19.0
CROP peas	-7.3	14.1
CROP potato	-7.0	14.4
CROP silage_maize	-11.7	12.3
CROP sugar_beet	0	*
YEAR 2012	11.47	7.27
YEAR 2013	-2.77	7.63
YEAR 2014	0	*
total K fertilization	0.1101	0.0548

Parameter estimates with standard errors of the best selected model for explaining variance of the average nitrate concentration in upper meter ground water from December, February during 2012 till 2014. Plots were taken in account as random factor and all treatments were compared with each other.

Parameter	estimate	s.e.
ORGANIC	26.29	9.10
CONVENTIONAL HIGH	62.73	9.48
CONVENTIONAL LOW	53.32	9.10
YEAR 2012	10.1	10.0
YEAR 2013	-6.1	10.0
YEAR 2014	0	*

.

Estimates PLOT : random factor, comparison of all treatments for 2012

Parameter estimates with standard errors of the best selected model for explaining variance of the average nitrate concentration in upper meter ground water from December, February during 2012. Plots were taken in account as random factor and all treatments were compared.

Parameter	estimate	s.e.
CROP barley	91.6	19.9
CROP carrot	41.7	31.2
CROP leek	23.0	36.8
CROP peas	89.7	23.1
CROP potato	111.2	20.9
CROP silage maize	102.1	25.5
CROP sugar_beet	114.0	26.7
Nmineral in soil (0-60 cm)	0.740	0.472
Total EOM input	-0.01909	0.00701

Estimates PLOT : random factor, comparison of all treatments for 2013

Parameter estimates with standard errors of the best selected model for explaining variance of the average nitrate concentration in upper meter ground water from December, February during 2013. Plots were taken in account as random factor and all treatments were compared with each other.

Parameter	estimate	s.e.
Nmineral soil 0-60cm	0.678	0.645
ORGANIC	10.3	13.2
CONVENTIONAL HIGH	50.9	14.3
CONVENTIONAL LOW	36.6	13.0

Estimates PLOT : random factor, comparison of all treatments for 2014

Parameter estimates with standard errors of the best selected model for explaining variance of the average nitrate concentration in upper meter ground water from December, February during 2014. Plot were taken in account as random factor and all treatments were compared with each other.

Parameter	estimate	s.e.
ORGANIC	-75.4	35.6
CONVENTIONAL HIGH	-20.3	24.6
CONVENTIONAL LOW	-13.1	20.6
CROP barley	57.7	20.0
CROP carrot	54.4	29.9
CROP leek	21.4	24.3
CROP peas	49.3	20.3
CROP potato	20.9	23.4
CROP silage_maize	15.0	20.4
CROP sugar_beet	0	*
Nmineral soil 0-60	0.824	0.405
total EOM input	0.01246	0.00619

Model selection comparing only conventional treatments with plot as a random factor

Estimates Plot fixed factors and conventional treatment comparison

Parameter estimates with standard errors of the best selected model for explaining variance of the average nitrate concentration in upper meter ground water from December, February during 2012 till 2014. Plot were taken in account as fixed factor and conventional treatments were compared with each other.

Parameter	estimate	s.e.
PLOT 16.1b	87.0	18.5
PLOT 16.2a	103.9	15.6
PLOT 17.1a	68.7	17.6
PLOT 17.2b	97.8	15.2
PLOT 18.1a	115.0	23.0
PLOT 18.2b	29.9	16.6
PLOT 26.1a	124.1	19.9
PLOT 26.2b	113.5	17.3
PLOT 27.1b	94.6	19.3
PLOT 27.2a	76.3	18.2
PLOT 28.1a	170.7	25.1
PLOT 28.2b	83.3	18.7
YEAR 2012	10.89	8.90
YEAR 2013	-14.70	9.38
YEAR 2014	0	*
Nmineral soil 0-60 cm	-0.773	0.301
Total EOM input	-0.01031	0.00514

Parameter estimate with standard error of the best selected model for explaining variance of the average nitrate concentration in upper meter ground water from December, February during 2012 till 2014. Plots were taken in account as random factor and the conventional treatments were compared with each other.

Parameter	estimate	s.e.
Total K fertilization	0.1899	0.0297

Estimates PLOT: random factor, comparison of conventional treatments for 2012.

Parameter estimates with standard errors of the best selected model for explaining variance of the average nitrate concentration in upper meter ground water from December, February during 2012. Plot ware taken in account as random factor and the conventional treatments were compared with each other.

Parameter	estimate	s.e.
CONVENTIONAL HIGH	126.3	32.8
CONVENTIONAL LOW	100.3	26.4
Total P fertilization	0.493	0.332
Total EOM input	-0.0355	0.0118

Estimates PLOT : random factor, comparison of conventional treatments for 2014.

Parameter estimates with standard errors of the best selected model for explaining variance of the average nitrate concentration in upper meter ground water from December, February during 2014. Plots were taken in account as random factor and the conventional treatments were compared with each other.

Parameter	estimate	s.e.
no green manure	34.6	13.0
green manure	84.0	13.6
Total K fertilzation	-0.1466	0.0959
TotalNeffectivefertizatio	0.230	0.175

Conventional treatments

N

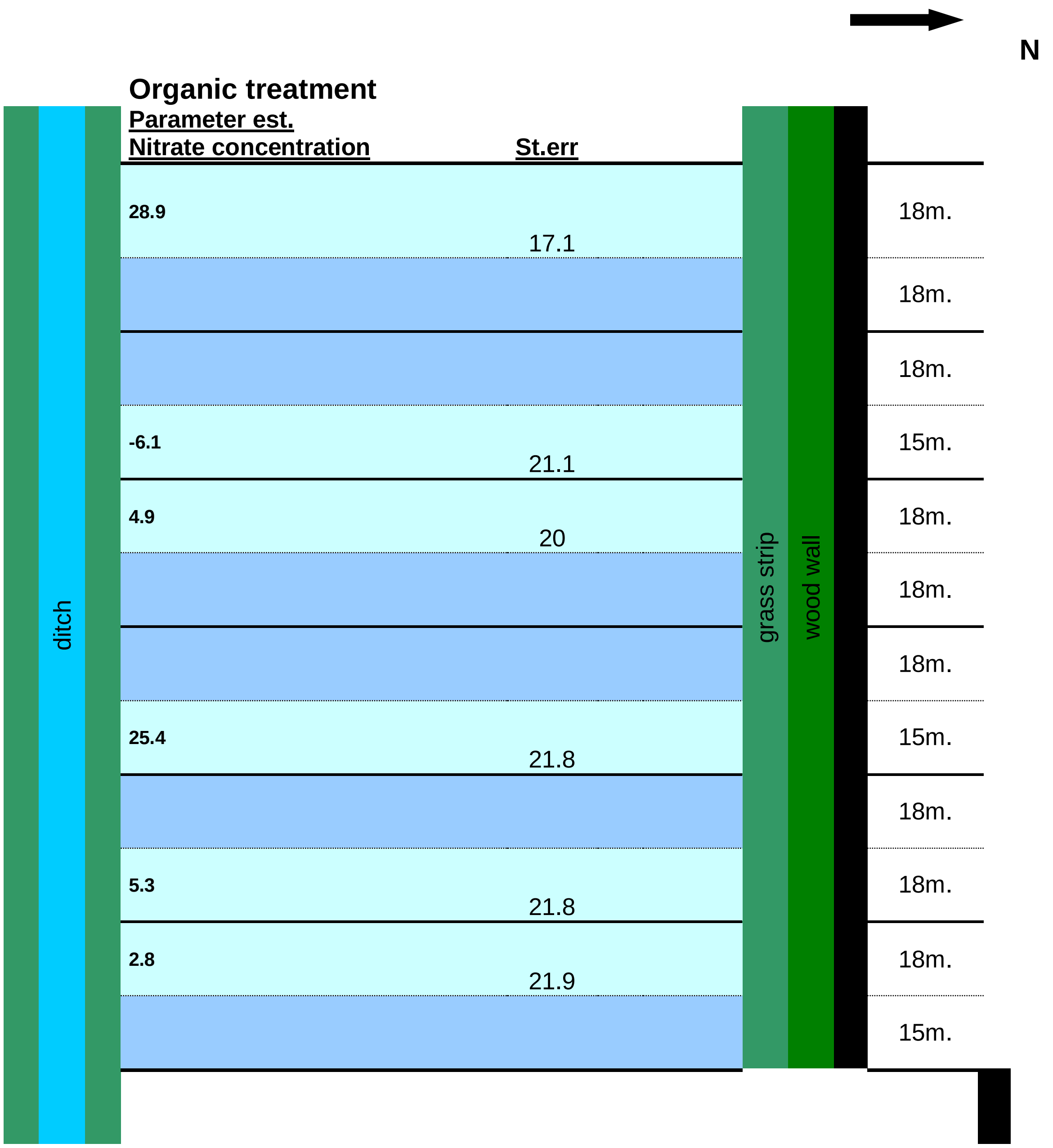


Figure 4.12 Parameter estimates and standard errors of the plots of the organic treatments.

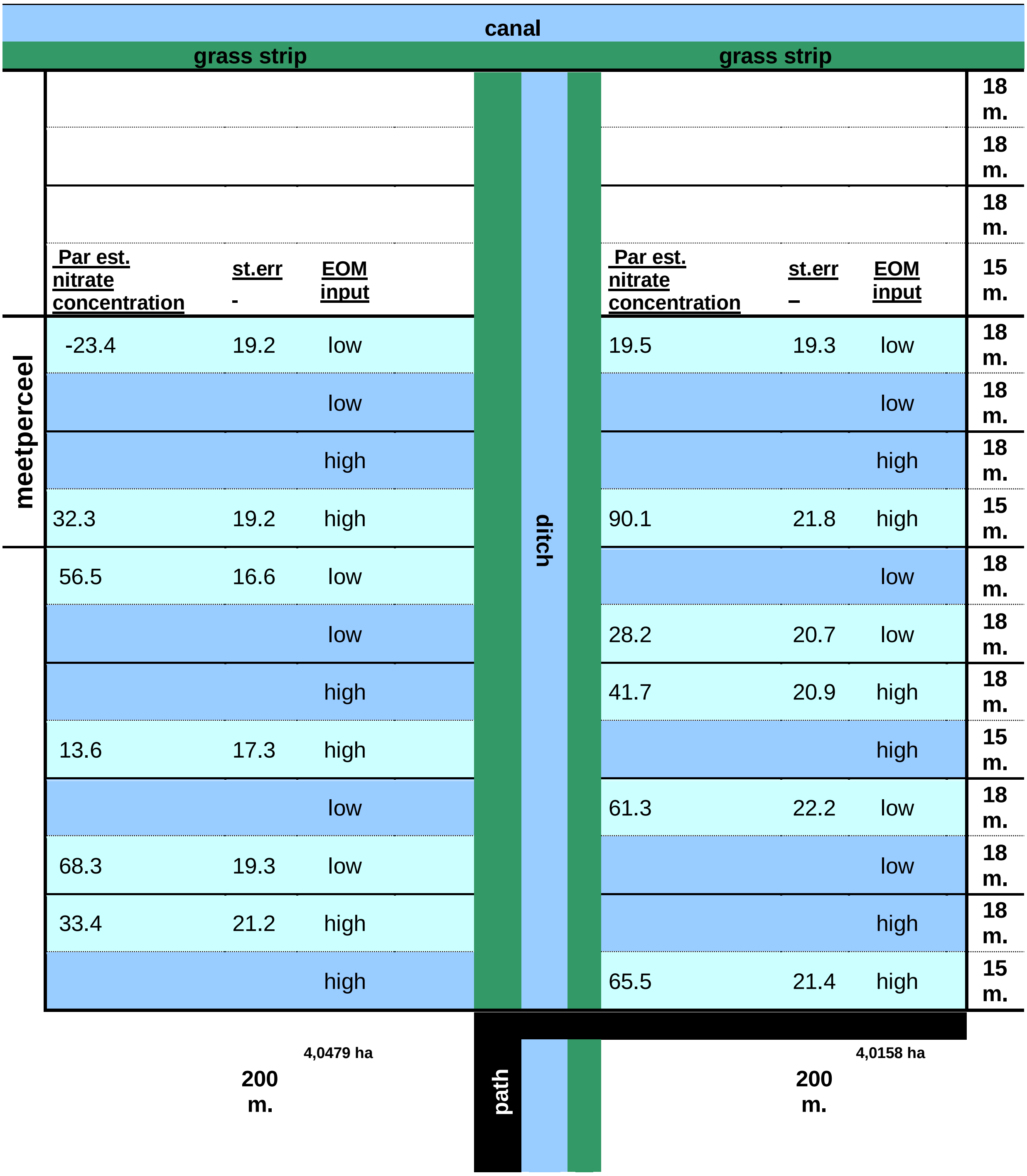


Figure 4.13: Parameter estimates and standard error of the plots of the conventional treatments.