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Follow-up of a monitoring network of farms under Directive 2008/64/EG in order to assess the impact of derogation on the water quality

Final report 2011 – 2014

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Summary

The European Commission decided on June 29th 2011 to continue the possibility, with regard to the region of Flanders, to apply a higher amount of livestock manure in comparison with the general limitation of 170 kg N from livestock manure per hectare (derogation request). The selection of crops on which derogation could be requested remained and the selection of livestock manure which could be applied on derogation parcels also remained the same. This derogation decision held also conditions imposed on the competent authorities with regard to monitoring, controls and reporting. The objective of this investigation is the follow-up of a monitoring network of at least 150 farms in order to assess the impact of derogation on the nitrogen and phosphorus losses from the soil and on the water quality. In this research the first monitoring network is evaluated, re-established and followed-up.

The original set-up of the monitoring network of 188 farms and 227 parcels was evaluated. The aim was to retain as many farms and parcels of the former monitoring network as possible. This way, the data collected in the first research period (2009-2011) could be used as well. After screening, the monitoring network consists of 175 different farms in 2011. For 85 parcels (out of 217 selected parcels) derogation was requested in 2011. In 2012, 2013 and 2014 the monitoring network consisted of 216 parcels. Derogation was applied on 94, 111 and 80 parcels. Similar to 2011, grass was most frequently cultivated on derogation parcels followed by maize.

In order to compare derogation with no derogation parcels and to investigate the effect of derogation on the water quality, both soil and water samples are taken. Nitrate samples are taken from 0 to 90 cm in three layers (0-30, 30-60 and 60-90 cm) before and after winter. The amount of nitrate is determined in each soil layer. On a selection of parcels a second soil sample is taken before and after winter, the deep soil sample. A soil sample from 90 to 120 cm on which the amount of nitrate and phosphorus (in ammonium-lactate extract) is measured. In addition, on the deep soil samples the total amount of phosphorus and the different fractions (DIP and DOP) of phosphorus are determined. A standard soil sample is taken between January and March 2012 for standard soil analysis. Besides soil texture, pH and carbon, a variety of nutrients (phosphorus, magnesium, potassium, calcium and sodium) are determined.

Water samples are taken from MAP sampling points groundwater, monitoring wells, canals, ditches and drains. Each water sample is linked to one specific parcel in the monitoring network. In these samples the amount of nitrate and phosphorus (PO_4-P) is measured. In 50 % of the

water samples the total amount of phosphorus and the different fractions (DIP and DOP) of the phosphorus are measured.

In the beginning of 2012 a standard soil sample was taken on each parcel of the monitoring network. The results of the standard soil analysis showed that the long term application of derogation or no derogation has no consequence for the phosphorus content of the soil.

Since the composition of organic fertilisers can be highly variable, livestock manure used on parcels in the monitoring network, was sampled. The analyses are used to calculate the correct input of nutrients (N and P_2O_5) on individual parcel level, necessary to calculate the nutrient balances. On derogation parcels, grass and maize, consequently more organic nitrogen fertilisation is applied. However mineral nitrogen fertilisation on derogation parcels is not more restricted than on no derogation parcels. So not only organic fertilisation but also total nitrogen fertilisation is higher on derogation parcels. Discrepancy between derogation and no derogation parcels is most pronounced on grass parcels. This conclusion is very important since it makes the comparison of derogation (supposed and legitimate higher supply of organic N) legitimate.

The comparison of the nitrate residue on derogation and no derogation parcels is a start to investigate the effect of derogation on the quality of surface and groundwater, since the nitrate residue is the amount of nitrate-N which is susceptible to leaching during the winter. No statistical differences were detected between derogation and no derogation parcels in nitrate residue in the monitoring period 2011-2014. This was a confirmation of the lack of a statistical significant difference in nitrate residue of derogation and no derogation parcels in autumn 2009 and 2010. Also in the deep soil layer 90-120 cm in general no statistical significant differences were found between derogation and no derogation parcels.

Water samples related to the parcels of the monitoring network are essential. Water samples were taken twice a year, before and after winter. For surface water, samples are taken at drains and in canals and ditches. The water samples of drains, canals and ditches are used as an indication of the nitrate concentration in the surface water. The average values were almost always below the threshold value of 50 mg NO_3/l. However at each sampling moment also high nitrate concentrations were measured. More important and trustworthy are the measurements at the MAP sampling points groundwater and the self placed monitoring wells. In function of the travel time and the infiltration area the sampling point can be linked directly to an individual parcel. Comparison of the water quality in function of the application of derogation or no derogation is possible when the parcel characteristics are linked to the corresponding water analyses in function of the travel time. This comparison was complete for the parcel characteristics of 2009 and 2010. Nor for parcel characteristics of 2009 nor for those of 2010 the nitrate concentration in the groundwater was higher after the application of derogation. The highest average concentrations of orthophosphate-P were mostly measured in water samples originating from drains, canals and ditches. As for nitrate those water samples are used as an indication. The decreasing trend in phosphate concentration in the shallow groundwater noticed in the former monitoring network was continued at the MAP sampling points until spring 2013. At the monitoring wells this trend continued until autumn 2013, with exception of a sudden higher average value in autumn 2012.

In order to investigate the leaching of nitrate during winter, a soil sample is taken in autumn and spring. The Burns model is used to predict the movement of unabsorbed anions like nitrate. Calculations with the Burns model were done for the winters 2011-2012, 2012-2013 and 2013-2014. The Burns model results in a prediction of the amount of nitrate in the soil profile after winter. Those predicted values correlate significantly with the measured amounts of nitrate after winter. The estimated amount of leached nitrate did not differ between derogation and no derogation parcels, not for parcels cultivated with grass nor for parcels cultivated with maize. This agrees with the fact that there's no difference in the amount of nitrate in the soil profile before and after winter between derogation and no derogation parcels.

In order to explain the lack of differences in soil and water, in the nitrate residue and the nitrate concentration in groundwater, despite the higher input of total N on the derogation parcels, nutrient balances are calculated for the individual parcels. Two different approaches are used to calculate a nutrient balance: the input/output balance and a nitrogen-soil balance. Nor in 2012, 2013 or 2014 statistical significant differences were found between the Input-output balance results of derogation and no derogation parcels. Nor in 2012, 2013 or 2014 statistical significant differences were found between the nitrate-N soil balance results of derogation and no derogation parcels. Representing the nitrate-N soil balance in relative terms in function of the total input, shows clearly the impact of the mineralisation (f.i. in average 53 % of the total N-input on maize parcels in 2014) on the nitrate-N soil balance and the impact of the cover crop on derogation parcels. Yield sampling confirmed even on a limited number of parcels, the high variability in N-export, f.i. more than 100 kg N on maize parcels, 227 kg N/ha versus 104 kg N/ha.

The process factor was evaluated for the parcels of the network, when a monitoring well or a MAP sampling point was present. It is confirmed again that the process factor groundwater is highly variable without a clear spatial pattern.

Based on this extensive network of parcels and the variety of measurements on parcels and in the water, derogation in Flanders has no negative impact on the water quality.

Samenvatting

De Europese Commissie besloot op 29 juni 2011 toe te laten dat Vlaamse landbouwers ook gedurende de periode 2011-2014 onder strikte voorwaarden afwijken van de algemene bemestingsnorm van 170 kg stikstof per hectare per jaar uit dierlijke mest (derogatie). De teelten waarop derogatie kan worden toegepast en de dierlijke mest die binnen de derogatie mag worden toegepast, bleven ongewijzigd. Ook deze derogatiebeschikking omvatte voorwaarden naar de overheid toe. Voorwaarden omtrent monitoring, controle en rapportering. Het doel van dit onderzoek was het opvolgen van een monitoringnetwerk van minstens 150 bedrijven om de impact van derogatie op de stikstof- en fosforverliezen uit de bodem en de waterkwaliteit te bepalen. In dit onderzoek werd het eerder opgezette monitoringnetwerk in eerste instantie geëvalueerd en nadien verder opgevolgd.

De originele opzet van het monitoringnetwerk van 188 bedrijven en 227 percelen werd geëvalueerd. Het doel was om zo veel mogelijk bedrijven en percelen uit het eerder opgezette monitoringnetwerk te behouden. Op deze manier kunnen de data bekomen in de eerste onderzoeksperiode (2009-2011) verder aangevuld en gebruikt worden. Na screening in de eerste fase bestond het netwerk uit 175 bedrijven in 2011. In 2011 werd op 85 van de 217 geselecteerde percelen derogatie aangevraagd. In 2012, 2013 en 2014 werden 216 percelen opgevolgd. Net zoals in 2011 waren gras en maïs de meest voorkomende teelten. In 2012, 2013 en 2014 werd derogatie toegepast op 94, 111 en 80 percelen.

Om derogatie- en niet-derogatiepercelen te vergelijken en om het effect van derogatie op de waterkwaliteit te achterhalen, werden zowel bodem- als waterstalen genomen. Bodemstalen om de hoeveelheid nitraat te bepalen, werden voor en na de winter genomen tot 90 cm diepte, per bodemlaag van 30 cm (0-30, 30-60 and 60-90 cm). De hoeveelheid nitraat wordt bepaald per bodemlaag. Op een selectie van percelen wordt een tweede staal genomen voor en na de winter. Een diep bodemstaal in de laag van 90 tot 120 cm, waarop de hoeveelheid nitraatstikstof en het fosforgehalte (in ammoniumlactaat extract) bepaald wordt. Op de diepe bodemstalen wordt bijkomend de totale hoeveelheid fosfor en de verschillende fosforfracties (organische en minerale in oplossing) bepaald. Een standaardgrondstaal werd genomen tussen januari en maart 2012. Naast de bodemtextuur, de zuurtegraad en het organische koolstofgehalte wordt ook het P-, Mg-, K-, Ca- en Na-gehalte bepaald.

Waterstalen worden genomen aan MAP-meetpunten grondwater, aan zelfgeplaatste peilbuizen, aan drainages en in grachten en beken. Elk waterstaal wordt gekoppeld aan één specifiek perceel

van het derogatiemonitoringnetwerk. Op de waterstalen wordt het nitraat- en orthofosfaatgehalte bepaald. Op de helft van de waterstalen wordt het totale fosforgehalte bepaald alsook de verschillende fosforfracties.

Begin 2012 werd op elk perceel van het derogatiemonitoringnetwerk een standaardstaal genomen. De resultaten van de standaardgrondontleding toonden dat langdurige derogatie geen effect heeft op het fosforgehalte van de bodem.

Aangezien de samenstelling van organische mest sterk kan verschillen, werd alle dierlijke mest die op de percelen van het derogatiemonitoringnetwerk werd aangewend, bemonsterd. Deze analyseresultaten werden gebruikt om de nutriënteninput (N en P_2O_5) per perceel correct te begroten, wat nodig is om de nutriëntenbalansen te kunnen berekenen. Op de derogatiepercelen, zowel gras als maïs, wordt consequent meer organische stikstof aangewend. Desondanks wordt op de derogatiepercelen niet minder minerale stikstof toegepast. Bijgevolg wordt op de derogatiepercelen niet enkel meer organische stikstof maar ook meer totale stikstof aangewend. Dit onderscheid tussen derogatie en niet-derogatiepercelen is het meest uitgesproken op grasland. Dit besluit, dat op de derogatiepercelen wel degelijk meer organische (en totale) mest wordt toegepast, is zeer belangrijk. Het rechtvaardigt immers de vergelijking van derogatie- en niet-derogatiepraktijken.

De vergelijking van het nitraatresidu op derogatie- en niet-derogatiepercelen is bijgevolg een eerste stap in het bepalen van het effect van derogatie op de kwaliteit van het grond- en oppervlaktewater, aangezien het nitraatresidu de hoeveelheid nitraatstikstof is die gevoelig is aan uitspoeling tijdens de winter. Tijdens de monitoring in de periode 2011-2014 konden geen statistische verschillen worden aangetoond tussen het nitraatresidu op derogatie en niet-derogatiepercelen, net als in najaar 2009 en najaar 2010. Ook in de diepe bodemlaag 90-120 cm werd doorgaans geen statistisch significant verschil gevonden tussen derogatie- en niet-derogatiepercelen.

Waterstalen die kunnen gekoppeld worden aan de percelen van het derogatiemonitoringnetwerk zijn essentieel. De meetplaatsen voor water werden twee keer per jaar bemonsterd, voor en na de winter. Voor oppervlaktewater werden waterstalen genomen aan drainages en in beken en grachten. De waterstalen van drainages, beken en grachten geven eerder een indicatie van de nitraatconcentratie in het oppervlaktewater. De gemiddelde nitraatconcentratie lag nagenoeg steeds onder de drempelwaarde van 50 mg NO_3/l. Toch werden op elk moment van staalname ook hoge nitraatconcentraties gemeten. Van groter belang en meer betrouwbaar zijn de metingen en waterstalen aan MAP meetpunten van het MAP meetnet grondwater in Vlaanderen en aan de zelfgeplaatste peilbuizen. Rekening houdende met de reistijd en het intrekgebied kunnen deze meetpunten één op één gekoppeld worden aan een perceel van het derogatiemonitoringnetwerk. Vergelijking van de waterkwaliteit in functie van het al dan niet toepassen van derogatie is mogelijk wanneer de perceelskarakteristieken gekoppeld worden aan de corresponderende wateranalyses door rekening te houden met de reistijd. Dergelijke vergelijkingen zijn volledig voor de perceelsinvloeden van 2009 en 2010. Noch het toepassen van derogatie in 2009, noch het toepassen van derogatie in 2010 leidde tot hogere nitraatconcentraties in het grondwater. Derogatie heeft bijgevolg geen negatieve impact op het nitraatgehalte in het grondwater. De hoogste orthofosfaatwaarden werden doorgaans gemeten in waterstalen van drainages, beken en grachten. Deze waterstalen werden net zoals voor de nitraatconcentraties ook voor de fosfaatconcentraties aangewend als indicator, niet voor het vastleggen van statistische verschillen tussen derogatie en niet-derogatiepercelen. De dalende trend in fosfaatconcentratie in het oppervlakkige grondwater die in de vorige monitoringperiode werd opgemerkt, werd verdergezet in de MAP meetpunten grondwater tot voorjaar 2013. In de peilbuizen werd deze evolutie verder waargenomen tot najaar 2013, met uitzondering van een plotse hoge gemiddelde waarde in najaar 2012.

Om de uitspoeling tijdens de winter in te schatten worden bodemstalen genomen in het najaar en in het voorjaar. Het model van Burns wordt gebruikt om de beweging van vrije anionen, zoals $NO3^-$, te voorspellen. De berekeningen met het model van Burns werden uitgevoerd voor de winters 2011-2012, 2012-2013 and 2013-2014. Het resultaat van het model van Burns is een voorspelde nitraatreserve in het voorjaar. Deze voorspelde waarden correleerden significant met de gemeten nitraatvoorraden na de winter. De begrootte nitraatuitspoeling verschilde niet tussen derogatie en niet-derogatiepercelen, noch voor graspercelen, noch voor maïspercelen. Dit strookt met de vaststellingen dat noch de nitraatresidu's noch de voorjaarsreserves op derogatie- en niet-derogatiepercelen verschillen.

Om het uitblijven van verschillen in bodem en water, in nitraatresidu en nitraatgehalte in het grondwater te kunnen verklaren ondanks de aangetoonde hogere N-input op derogatiepercelen, worden op perceelsniveau nutriëntenbalansen opgesteld. De nutriëntenbalans werd op twee verschillende manieren benaderd: de input/output balans en de N-bodembalans. Noch in 2012, 2013 of 2014 werd een statistisch significant verschil vastgesteld tussen het input-outputbalansresultaat van derogatie- en niet-derogatiepercelen. Noch in 2012, 2013 of 2014 werd een statistisch significant verschil vastgesteld tussen het N-bodembalansresultaat van derogatie-en niet-derogatiepercelen. Wanneer de N-bodembalans relatief werd voorgesteld, namelijk door alle parameters van de balans af te wegen ten opzichte van de totale input, bleek duidelijk de impact van de mineralisatie (bv tot gemiddeld 53 % van de totale input op de maïspercelen in 2014) op de N-bodembalans. Maar ook het grotere belang van vanggewassen op derogatiepercelen dan op niet-derogatiepercelen bleek duidelijk. Proefoogsten toonden zelfs op een beperkt aantal percelen grote verschillen in N-export, bijvoorbeeld meer dan 100 kg N/ha op maïspercelen, 227 kg N/ha versus 104 kg N/ha.

De procesfactor grondwater werd geëvalueerd voor percelen, met gekoppeld MAP-meetpunt of peilbuis, uit het derogatiemonitoringnetwerk. Deze evaluatie bevestigde dat de procesfactor grondwater sterk varieert over Vlaanderen en dat er bijkomend geen duidelijk patroon in die spreiding kan gevonden worden.

Op basis van dit uitgebreide netwerk van percelen en de diversheid van bepalingen op perceelsniveau en op het niveau van het water, kan gesteld worden dat derogatie onder Vlaamse omstandigheden geen negatieve impact heeft op de waterkwaliteit.

Table of Contents

ABBREVIATIONS

AL	Ammonium-lactate
CF	Continuous Flow
DIP	Dissolved Inorganic Phosphorus
DOP	Dissolved Organic Phosphorus
EEC	European Economic Community
IC	Ion Chromatography
ICP	Inductive Coupled Plasma
KU Leuven	Katholieke Universiteit Leuven
MAP	Manure Action Program
PF	Process Factor
PSC	Phosphate Sorption Capacity
PSD	Phosphate Saturation Degree
SSB	Soil Service of Belgium
VLM	Flemish Land Agency
VMM	Flemish Environment Agency

1 Introduction

The objective of this research is the follow-up of a monitoring network of at least 150 farms (target of 180 farms and 225 parcels) in order to assess the impact of derogation on the nitrogen and phosphorus losses from the soil and on the water quality. If derogation would have a significant impact on the water quality, it is of great importance to identify the underlying causes and to determine the precise impact on the water quality.

The monitoring network provides data on fertilisation and farming practices on the parcels, nitrogen and phosphorus concentration in soil water, nitrogen in the soil profile, nitrogen and phosphorus losses through the root zone into the groundwater, nitrogen and phosphorus losses by surface and subsurface run-off. In this way, the impact on the water quality can be evaluated for parcels under derogation and no derogation conditions. The monitoring network should be representative for the different soil textures, crops and fertilisation practices commonly present in Flanders.

The existing MAP monitoring network for groundwater (MAP sampling points groundwater) was chosen as basis for the set-up of the monitoring network. The MAP monitoring network is a dense network of 2,107 measuring points distributed over Flanders. These MAP monitoring sites have small infiltration areas, so the water quality of one MAP monitoring site can be linked to an individual parcel. In Vandervelpen *et al.*, 2011, the infiltration area and the travel time of the water from the root zone to the MAP sampling point groundwater was calculated for every MAP sampling point groundwater.

However, the selection from the MAP sampling points groundwater did not result in a network of 225 parcels (as requested). Therefore, in the former monitoring project (Vandervelpen *et al.*, 2011) parcels were selected from candidate farmers. In order to measure the water quality on these parcels monitoring wells were placed. On parcels with a long travel time (>3 years), no monitoring well was placed. In these parcels the water quality is measured by sampling canals, ditches or drains.

More than half of the parcels in the network consist of sandy soils. Half of the parcels are cultivated with grass and approximately 30 % are cultivated with maize. This way the monitoring network is representative for the agricultural practices on derogation parcels in Flanders since derogation is mostly requested by dairy cow farms on sandy soils cultivated with grass or maize.

The first part of this report deals with the follow-up and evaluation of the existing monitoring network (Vandervelpen *et al.*, 2011). For 2011, 217 parcels and 175 farms were retained in the monitoring network. Table 1 shows the 217 parcels in the network for the different combinations of soil texture and cultivated crop. For 2012, 2013 and 2014, 216 parcels were retained in the monitoring network. Table 2 illustrates the time scale of the different measurements on the parcels. More details on the selection procedure and the different samples taken at parcel level are discussed in the report of the former monitoring project (Vandervelpen *et al.*, 2011).

The second part of this report will discuss the results of the field measurements. For each measured parameter it will be investigated whether there is a global difference between derogation and no derogation parcels in general (all crops, all soil textures). Next, more specific combinations of soil texture and cultivated crop will be analysed statistically. Nitrate and phosphorus are the two most important parameters in order to measure the effect of derogation on water quality, as such they will be discussed extensively in this report.

In order to compare derogation with no derogation parcels and to investigate the effect of derogation on the water quality, both soil and water samples are taken. First, a nitrate sample is taken from 0 to 90 cm in three layers (0-30, 30-60 and 60-90 cm) before and after winter. The amount of nitrate is determined in each soil layer. A second soil sample (the deep soil sample) is taken on a selection of parcels. On these parcels a soil sample is taken from 90 to 120 cm. Here the amount of nitrate and phosphorus (in ammonium-lactate extract) is measured. In addition, in 50 % of the deep soil samples the total amount of phosphorus and the different fractions (DIP and DOP) of phosphorus are determined. A third soil sample (standard soil sample) is taken between January and March for standard soil analysis. Besides soil texture, pH and carbon, a variety of nutrients (phosphorus, magnesium, potassium, calcium and sodium) are determined.

Besides the soil samples, water samples are taken from MAP sampling points groundwater, monitoring wells, canals, ditches and drains. Each water sample is linked to one specific parcel in the monitoring network. In these samples the amount of nitrate and phosphorus (PO_4-P) is measured. In 50 % of the water samples the total amount of phosphorus and the different fractions (DIP and DOP) of the phosphorus are measured.

In order to investigate the difference between derogation and no derogation parcels for different combinations of soil texture and cultivated crop, an ANOVA model was used with 0.05 significancy level (p-value). Since normality of the data and homogeneity of the variances are required, a logarithmic transformation of the data is carried out to fulfil these conditions.

Table 1: Overview of all the parcels in the monitoring network, Flanders, 2011, 2012, 2013 and 2014.

		Derogation				No derogation					
		Grass	Maize	Beets	Winter wheat	Grass	Maize	Beets	Winter wheat	Other	Total
2011	Sand	33	17	0	0	32	33	2	2	9	128
	Sandy loam	14	12	0	0	7	12	2	4	12	63
	Loam	0	0	0	0	1	5	0	0	2	8
	Clay	7	2	0	0	5	2	0	1	1	18
	Total	54	31	0	0	45	52	4	7	24	217
2012	Sand	36	25	1	0	25	29	0	4	7	127
	Sandy loam	16	8	0	0	6	22	0	2	9	63
	Loam	0	0	0	0	1	4	1	1	1	8
	Clay	7	1	0	0	3	4	0	3	0	18
	Total	59	34	1	0	35	59	1	10	17	216
2013	Sand	44	29	0	2	20	19	0	3	10	127
	Sandy loam	11	12	0	1	12	15	0	3	9	63
	Loam	0	1	0	0	1	5	0	1	0	8
	Clay	9	0	0	0	2	2	0	2	3	18
	Total	64	42	0	3	35	41	0	9	22	216
2014	Sand	37	18	0	0	22	38	2	4	6	127
	Sandy loam	10	4	1	1	12	21	2	2	10	63
	Loam	0	0	0	0	2	3	0	2	1	8
	Clay	8	1	0	0	4	2	0	1	2	18
	Total	55	23	1	1	40	64	4	9	19	216

Table 2: Time scale of measurements.

	Time scale													
Year	2011		2012-2013-2014											
Month	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Soil samples														
Standard soil sample														
Nitrate sample														
Deep soil sample														
Water samples														
MAP sample point														
Monitoring wells														
Drains														
Canals and ditches														
Water from deep soil sample														
Manure samples														
Yield samples grassland														
Yield samples maize														

2 Evaluation of 175 farms/217 parcels

The original set-up of a monitoring network of 188 farms and 227 parcels was evaluated. A detailed description of the set-up of the monitoring network can be consulted in the first intermediate report of 20th of January 2009: "Establishment and follow-up of a monitoring network of farms to assess the impact of derogation on the water quality, First intermediate report 20 January 2009" (Vandervelpen *et al.*, 2009). The aim is to retain as many farms and parcels of the existing monitoring network as possible. This way, the data collected in the first research period (2009-2011) can be used as well.

At first, the farmers were contacted to verify their willingness to continue to participate in the monitoring network for the period 2011-2014. A number of farmers were eliminated from the network since they were no longer the owner of the parcel. The new owners of those parcels were contacted but some of them were not interested to participate in the network.

In the existing monitoring network, farms and parcels were selected starting from MAP sampling points groundwater, the participation of candidate farms and the selection of additional parcels grassland. In the next tables and figures the features of the retained farms and parcels are discussed. The most important features are derogation, soil texture and cultivated crop. The geographical location of the parcels is also shown (Figure 1). Although a homogeneous geographical distribution was not required, the selected parcels of the monitoring network are well spread over the region of Flanders.

2.1 Farms

After screening, the monitoring network consists of 175 different farms in 2011. These 175 farms are almost equally divided in farms with derogation and farms without derogation in 2011 (Table 3). In 2012, one parcel, and as a consequence one farmer, was excluded from the monitoring network since no fertilisation nor any land management practices were executed on this parcel. In 2013 the monitoring network consists of 173 different farms. Farms that cultivated more than one parcel of the monitoring network stopped cultivating some parcels after winter 2013-2014. Because other farms cultivate these parcels in 2014, the network comprised 175 farms in 2014.

Table 3: Number of farms participating in the monitoring network, classified in derogation and no derogation farms in 2011, 2012, 2013 and 2014.

	Derogation	No derogation	Total
2011	72	103	175
2012	79	95	174
2013	85	88	173
2014	69	106	175

2.2 Parcels

The monitoring network consists of 217 parcels in 2011. Figure 1 shows the geographical location of the 217 parcels in the monitoring network. Distinction has been made between derogation (green) and no derogation (red) parcels for 2011. The parcels are located all over the region of Flanders, but most parcels are located in the Kempen, the Flemish sand region and Sandy loam region. Since derogation occurs mostly in these regions it is important to have the highest number of parcels there. Since derogation as well as no derogation parcels are located in all regions, a comparison will be possible on different soil textures.

Table 4 and Table 5 show the different combinations of soil textures and crops separately for the derogation and no derogation parcels. For 85 parcels (out of 217 selected parcels) derogation was requested in 2011. More than half of the parcels are cultivated on a sandy soil, followed by sandy loam. It needs to be noted that all soil textures used in this report are according to the Belgian classification. Grass is most frequently cultivated on derogation parcels followed by maize. Derogation parcels need to be cultivated with a derogation crop (grass, maize, beets, winter wheat), therefore the column “other” is empty. Since 2012 the monitoring network consists of 216 parcels. Grass and maize were each year the most important crops.

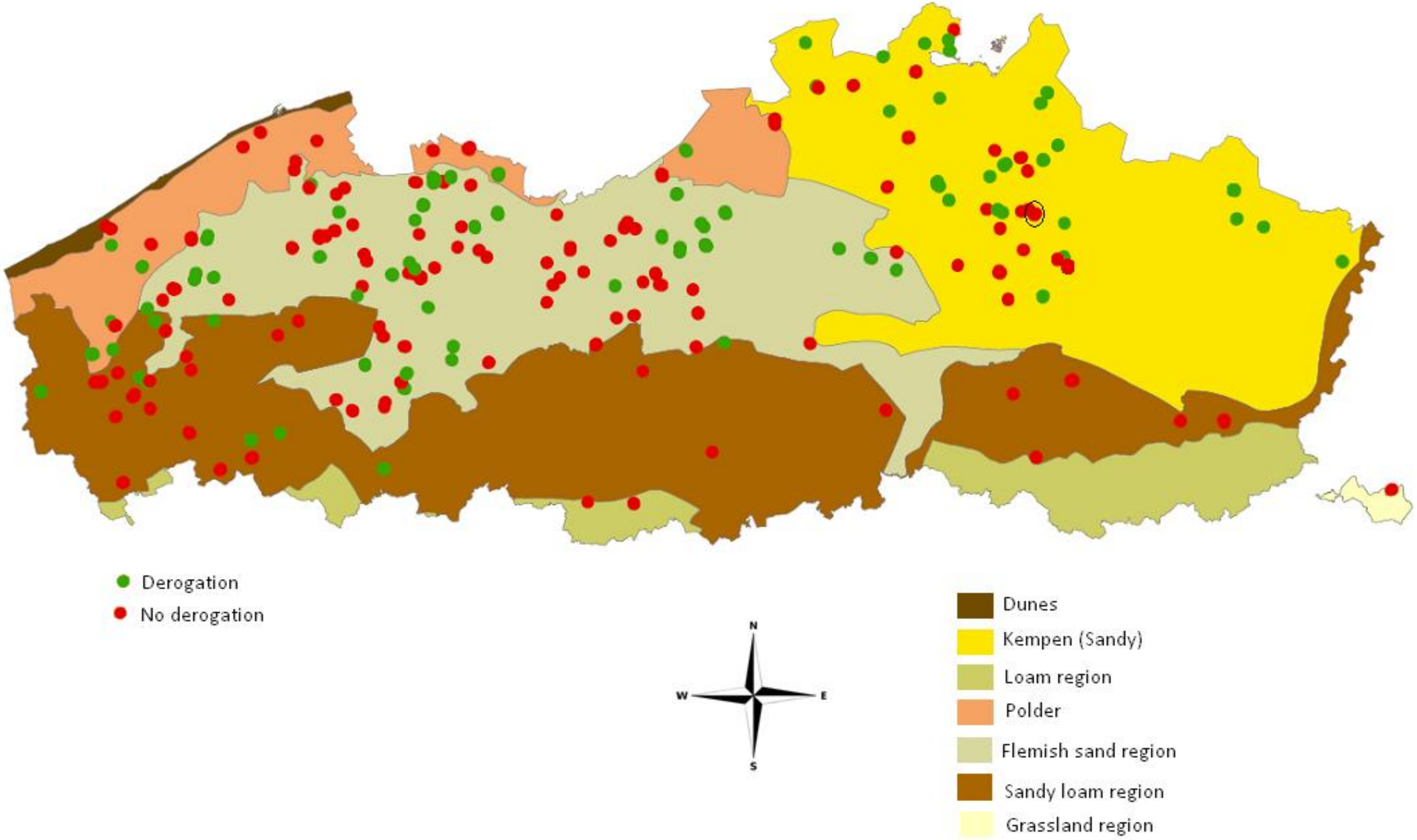


Figure 1: Location of the 217 parcels in the monitoring network on the agricultural regions of Flanders in 2011. The parcel marked with a black circle was discarded from the network since 2012.

Table 4: Number of derogation parcels for the different combinations of soil textures and crops in 2011, 2012, 2013 and 2014.

	Grassland	Maize	Beets	Winter wheat	Other	Total
2011						
Sand	33	17	0	0	0	50
Sandy loam	14	12	0	0	0	26
Loam	0	0	0	0	0	0
Clay	7	2	0	0	0	9
Total	54	31	0	0	0	85
2012						
Sand	36	25	1	0	0	62
Sandy loam	16	8	0	0	0	24
Loam	0	0	0	0	0	0
Clay	7	1	0	0	0	8
Total	59	34	1	0	0	94
2013						
Sand	44	31	2	0	0	77
Sandy loam	11	12	1	0	0	24
Loam	0	1	0	0	0	1
Clay	8	1	0	0	0	9
Total	63	45	3	0	0	111
2014						
Sand	37	18	0	0	0	55
Sandy loam	10	4	1	1	0	16
Loam	0	0	0	0	0	0
Clay	8	1	0	0	0	9
Total	55	23	1	1	0	80

In Table 5 the different combinations for the no derogation parcels are listed. The monitoring network comprised 132 no derogation parcels in 2011. On no derogation parcels also other crops than only derogation crops (vegetables, ...) are cultivated. Due to crop rotation it is possible that the next year a derogation crop will be cultivated on these parcels.

Table 5 shows that the combinations of sand and sandy loam soils with grassland and maize are the most important. This was also the case for the derogation parcels (Table 4). Comparison between derogation and no derogation parcels can be made especially for these combinations.

Table 5: Number of no derogation parcels for the different combinations of soil textures and crops in 2011, 2012, 2013 and 2014.

	Grassland	Maize	Beets	Winter wheat	Other	Total
2011						
Sand	32	33	2	2	9	78
Sandy loam	7	12	2	4	12	37
Loam	1	5	0	0	2	8
Clay	5	2	0	1	1	9
Total	45	52	4	7	24	132
2012						
Sand	25	29	0	4	7	65
Sandy loam	6	22	0	2	9	39
Loam	1	4	1	1	1	8
Clay	3	4	0	3	0	10
Total	35	59	1	10	17	122
2013						
Sand	20	20	3	0	7	50
Sandy loam	12	13	4	0	10	39
Loam	1	5	1	0	0	7
Clay	2	1	2	0	4	9
Total	35	39	10	0	21	105
2014						
Sand	22	38	2	4	6	72
Sandy loam	12	21	2	2	10	47
Loam	2	3	0	2	1	8
Clay	4	2	0	1	2	9
Total	40	64	4	9	19	136

3 Parcel characteristics based on the standard soil analysis

On each parcel of the monitoring network, a standard soil sample was taken only once, in the beginning of 2012. The analysis of a standard soil sample gives an insight into the soil fertility of the different parcels. The most important parameters of the standard soil sample are soil texture, pH-KCl, percentage organic carbon (%C) and amount of nutrients (P, K, Mg, Na and Ca). An optimal pH is necessary for the availability of nutrients in the soil and is thus important for crop growth. The percentage of organic carbon can be linked to the amount of organic matter in the soil (organic matter = percentage organic carbon multiplied with 1.72). This parameter is important in order to estimate mineralisation.

A standard soil sample in grassland is taken from 0 to 6 cm, since in this layer the root density is maximal. In arable land the standard soil sample is taken from 0 to 23 cm. Optimal conditions for crop growth are necessary in these soil layers.

A standard soil sample is obtained from a homogenous parcel with a maximum surface of 2 hectares. A representative sample consists of different subsamples taken at various locations in the parcel. For grassland one sample consists of 35 subsamples, for arable land 25 subsamples are sufficient.

After sampling, the standard soil sample is transported to the analytical laboratory. Here it is dried for 24 hours at a temperature of 70 °C. Next the sample is pulverized (only necessary for soils with a certain percentage of clay) and sieved (2 mm). The pH is measured in a KCl solution and organic carbon (%C) is determined with the adapted Walkley and Black method. For the different nutrients (P, K, Mg, Ca and Na) an extraction with ammonium lactate is used. K, Mg, Ca, Na and P are measured with ICP. Finally, the soil texture is determined manually by palpation.

3.1 The different soil fertility classes

Based on the standard soil analysis, the farmer receives a fertilisation and liming advice. This advice is based on field trial research combined with experience in the agricultural and the horticultural sector (Boon *et al.,* 2009; Maes *et al.*, 2012). For each parameter (%C, P, pH ...), seven soil fertility classes are established (ranging from very low (strongly acid for pH) to very high (peaty for %C)) depending on soil texture and organic carbon content of the soil. These soil fertility classes are distinct for grassland and arable land. The middle class is the optimal level. Within this level most plants show an optimal growth when rational fertilisation and liming is applied. When the measured value of a parameter is higher than the optimal level, the fertilisation can be reduced. When the measured value of a parameter is below the optimal level, the fertilisation needs to be increased in order to have an economically optimal yield. It needs to be noted that the soil fertility classes depend on soil texture and soil organic carbon. This means that the optimal level is unique for each parcel.

Table 6 illustrates the soil fertility classes for pH-KCl for arable land on different soil textures. The optimal level for pH-KCl is different for each soil texture and is lower on sandy soils than on soils containing loam and clay. The soil fertility classes for pH-KCl for grassland are shown in Table 7.

In Annex 1, the soil fertility classes for the different parameters are listed for both arable land and grassland.

Table 6: Soil fertility classes for pH-KCl for arable land, depending on the soil texture (only valid with normal carbon levels).

	pH-KCl			
Class	Sand	Sandy loam	Loam	Polder
Strongly acid	< 4.0	< 4.5	< 5.0	< 5.5
Low	4.0 - 4.5	4.5 - 5.5	5.0 - 6.0	5.5 - 6.4
Rather low	4.6 - 5.1	5.6 - 6.1	6.1 - 6.6	6.5 - 7.1
Optimal level	5.2 - 5.6	6.2 - 6.6	6.7 - 7.3	7.2 - 7.7
Rather high	5.7 - 6.2	6.7 - 6.9	7.4 - 7.7	7.8 - 7.9
High	6.3 - 6.8	7.0 - 7.4	7.8 - 8.0	8.0 - 8.1
Very high	> 6.8	> 7.4	> 8.0	> 8.1

Table 7: Soil fertility classes for pH-KCl for grassland, depending on the different soil textures (only valid with normal carbon levels).

	pH-KCl		
Class	Sand	Sandy loam - Loam	Polder
Strongly acid	< 4.4	< 4.6	< 4.9
Low	4.4 - 4.7	4.6 - 5.1	4.9 - 5.3
Rather low	4.8 - 5.0	5.2 - 5.6	5.4 - 5.6
Optimal level	5.1 - 5.6	5.7 - 6.2	5.7 - 6.4
Rather high	5.7 - 5.9	6.3 - 6.5	6.5 - 6.8
High	6.0 - 6.4	6.6 - 7.0	6.9 - 7.2
Very high	> 6.4	> 7.0	> 7.2

3.2 Fertilisation and liming advice

The fertilisation and liming advice, based on the standard soil analysis, is formulated for a rotation of 3 cultivated crops (or 3 growing seasons for perennial crops). In order to calculate the fertilisation and liming advice, a decision support expert system is developed by SSB, called BEMEX (BEMEstingsEXpertsysteem) (Geypens *et al.*, 1989; Vandendriessche *et al.*, 1996). The fertilisation and liming advice is highly dependent on the cultivated crop for the next 3 growing seasons. Fertilisation is necessary to reach economical optimal yields and to prevent nutrient depletion. The fertilisation advice does not depend on the fact if a parcel is under derogation or no derogation.

The liming advice, calculated by BEMEX, is based on the pH-KCl of the standard soil sample, soil texture, organic matter content and the sensitivity of the cultivated crop for liming. Depending on the cultivated crop, liming may be partitioned over 3 years. An accurate nitrogen fertilisation advice is formulated with the N-INDEX expert system, provided by SSB (Geypens *et al.*, 1994) (see chapter 4). It is important to note that the fertilisation advice provided by BEMEX is based on economical optimums, and that maximal fertilisation limits as defined by the government are not taken into account. Also, the fertilisation levels as advised by the standard soil analysis are based on effective nutrient levels. If organic fertilisers are used, only part of the organic fertiliser will be available to the cultivated crop during the first year after application.

Annex 2 shows an example of a report from a standard soil analysis of parcel 2 of the monitoring network. The first page shows the measured values for each parameter and the soil fertility class for each parameter measured on that specific parcel. The next pages give the fertilisation and liming advice for the different cultivated crops.

The result of the standard soil sample is determined by the history of the parcel. As such, no statistical analysis between derogation and no derogation parcels was conducted and only average, minimum and maximum are shown. In the next tables, only 186 of the 216 parcels are shown. Since some parcels were already fertilised when the soil sample was taken, these results were discarded.

3.2.1 Standard soil sample for grassland in spring 2012

In Table 8 the results of the standard soil sample for pH-KCl, %C and phosphorus (P-AL) in spring 2012 are shown. These are the average numbers for the different parcels of the monitoring network, cultivated with grass in 2012.

Table 8: Average pH-KCl, %C and P-AL measured in the standard soil sample (0-6 cm) for derogation and no derogation cultivated with grassland in 2012. The number of parcels is indicated by "n".

	Derogation	(min, max)	No derogation	(min, max)
n	42	-	38	-
pH-KCl	5.7	(4.2, 7.4)	5.7	(4.5, 7.6)
%C	2.8	(1.1, 6.5)	2.7	(1.0, 4.9)
P-AL (mg P/100 g dry soil)	32	(8, 68)	30	(6, 51)

Table 9 shows the percentage of parcels cultivated with grass in the different soil fertility classes. For the pH-KCl measured on the parcels cultivated with grassland, 50.0 % of the derogation parcels and 55.0 % of the no derogation parcels reach the optimal level.

For carbon 43.5 % of the parcels cultivated with grass on derogation parcels reach the optimal level. For no derogation parcels, this is only 37.5 %. 17.4 % of derogation parcels and 27.5 % of no derogation parcels are characterized by a low level of carbon. Parcels with a percentage carbon below optimum have a lower mineralisation and need more nutrient input.

Table 9: Percentage of parcels grassland in the different soil fertility classes for pH-KCl, %C and P-AL. Data are based on standard soil analysis in 2012.

	pH-KCl		%C		P-AL	
Class	Derogation	No derogation	Derogation	No derogation	Derogation	No derogation
Very low	2.2	0.0	8.7	12.5	0.0	2.5
Low	0.0	10.0	17.4	27.5	4.3	12.5
Rather low	15.2	10.0	10.9	10.0	4.3	2.5
Optimal level	50.0	55.0	43.5	37.5	21.7	7.5
Rather high	17.4	7.5	15.2	10.0	37.1	52.5
High	8.7	5.0	4.3	2.5	21.7	17.5
Very high	6.5	12.5	0.0	0.0	10.9	5.0

For phosphorus 21.7 % of the derogation parcels and 7.5 % of the no derogation parcels reach the optimal level. 69.7 % of derogation and 75.0 % of no derogation parcels have a phosphorus level above the optimal level. For these parcels it is possible to cultivate crops with a lower input for the parameter phosphorus. However, when the value of a parameter reaches the optimal level baseline fertilisation is still necessary (in order to prevent that levels of nutrients, pH and carbon drop below the optimal level). The average fertilisation advice for all grass parcels for the growing season 2012 is shown in Table 10.

Table 10: Average phosphorus (P_2O_5) fertilisation advice* for the growing season 2012, depending on the soil fertility class, for the parcels grassland in the monitoring network.

	P_2O_5 advice (kg/ha)	
Class	Derogation	No derogation
Very low	-	110
Low	108	88
Rather low	73	75
Optimal level	54	45
Rather high	33	27
High	0	0
Very high	0	0

*Fertilisation advice for grassland with grazing cattle. For grassland without grazing cattle higher phosphorus fertilisation advices are formulated, not comprised in the shown average phosphorus advices.

3.2.2 Standard soil sample for arable land in spring 2012

In Table 11 the results of the standard soil analysis for pH, %C and phosphorus (P-AL) in spring 2012 are shown. These are the average numbers for the different parcels arable land in Spring 2012. The level of carbon is lower for arable land than for grassland (Table 8, Table 11).

Table 11: Average pH-KCl, %C and P-AL measured in the standard soil sample (0-23 cm) for arable land in spring 2012. The number of parcels is indicated by "n".

	Derogation	(min, max)	No derogation	(min, max)
n	26	-	80	-
pH-KCl	5.6	(4.4, 7.0)	5.9	(4.2, 7.5)
%C	1.8	(0.8, 3.4)	1.4	(0.6, 3.2)
P-AL (mg P/100 g dry soil)	33	(12, 61)	35	(4, 65)

In 33.4 % of the derogation and 40.2 % of no derogation parcels the pH-KCl reaches the optimal level for crop growth (Table 12). This is a lower frequency than in grassland (Table 9). Of the derogation parcels 29.6 and 14.8 % is characterized by a pH value in the category rather low and rather high. Of the no derogation parcels 34.1 and 14.8 % is characterized by a pH-KCl value in the category rather low and rather high.

Table 12: Percentage of parcels arable land in the different soil fertility classes for pH-KCl, %C and P-AL. Data are based on standard soil analysis in spring 2012.

	pH-KCl		%C		P-AL	
Class	Derogation	No derogation	Derogation	No derogation	Derogation	No derogation
Very low	0.0	0.0	0.0	11.0	0.0	1.2
Low	14.8	8.5	11.1	26.8	0.0	0.0
Rather low	29.6	34.1	18.5	28.0	7.4	1.2
Optimal level	33.4	40.2	55.6	29.3	11.2	11.0
Rather high	14.8	14.8	14.8	4.9	29.6	22.0
High	7.4	1.2	0.0	0.0	48.1	52.4
Very high	0.0	1.2	0.0	0.0	3.7	12.2

For the parameter %C, more than half (55.6 %) of the parcels arable land reach the optimal level for derogation parcels. For no derogation parcels, this is only 29.3 %. 29.6 % of the derogation and 65.8 % of no derogation parcels have a %C below optimum. For phosphorus only 11.0 % of the parcels reach the optimal level. 81.4 % of the derogation parcels and 86.6 % of no derogation parcels have a value of phosphorus above the optimal level.

However, despite the high levels of phosphorus measured in the standard soil samples, an additional P-fertilisation is necessary. The average fertilisation advice for arable land for the growing season 2012 is shown in Table 13. The average advices in Table 13 do not take into account the P_2O_5 fertilisation limits of the Manure Decree, but are based on research data in order to optimise the soil fertility of a parcel.

Table 13: Average phosphorus (P_2O_5) fertilisation advice for the growing season 2012, depending on the soil fertility class, for the parcels arable land in the monitoring network.

	P_2O_5 advice (kg/ha)	
Class	Derogation	No derogation
Very low	-	220
Low	-	-
Rather low	160	110
Optimal level	130	108
Rather high	55	56
High	29	33
Very high	0	0

The differences in phosphorus advice between derogation and no derogation parcels arable land are caused by the fact that on derogation and no derogation parcels different crops are grown. Out of the 35 parcels arable land under derogation in 2012 (Table 4) only 1 parcel was meant to grow beets. On the arable land with no derogation also crops with a lower need of phosphorus than maize are grown.

Table 5 shows that of the 87 parcels arable land without derogation on 10 parcels winter wheat will be grown in 2012 and on 17 parcels “other” crops. The lower need of phosphorus of the winter wheat and the other crops on the no derogation parcels explains the lower average phosphorus advice for the no derogation parcels.

4 Parcel characteristics based on the N-INDEX

Nitrate in the soil profile may leach out during winter. In spring , a soil sample is taken on the parcels of the monitoring network in order to measure the amount of nitrate available to the crop after winter. Based on the nitrate and ammonia measured in the laboratory and additional information (cultivated crop, cultivar, organic matter in the soil layer, cultivated crop in the past season, organic fertiliser application ...) a nitrogen fertilisation advice is formulated for each parcel. This advice is calculated by means of the N-INDEX expert system, developed by SSB (Geypens *et al.*, 1994). N-INDEX calculates the amount of mineral nitrogen that is/will become available to the cultivated crop during the growing season. For this expert system, 3 input data are essential:

— the measured mineral N in the soil sample: a soil sample is taken in 3 layers of 30 cm. For crops with a deep root system a soil sample is taken from 0 to 90 cm in three layers (for example winter wheat). Other crops, like potatoes, have shallow roots and only the mineral N in the soil profile from 0 to 60 cm is important for the next growing season. In order to know the distribution of nitrate in the soil profile, all parcels in the monitoring network are sampled from 0 to 90 cm. One soil sample for each parcel consists of 15 subsamples. The mineral N is measured by continuous flow in a KCl-extract.

— the amount of nitrogen that will become available during the growing season: in order to calculate this factor with N-INDEX, some parcel characteristics are necessary (percentage carbon, pH, history of the parcel, organic fertilisation in the past, liming …).

— the amount of nitrogen that will be lost by leaching or suboptimal conditions.

After this input, a N-INDEX for that specific parcel is calculated. If the N-INDEX is high, a lot of nitrogen will be available to the crop during the next growing season and the corresponding nitrogen fertilisation advice will be low. The resulting nitrogen fertilisation advice is function of the N-INDEX and the nitrate required by the cultivated crop. This means additional information on the next growing season is necessary (crop, variety of the crop, agricultural practice …). A fertilisation advice by means of the N-INDEX expert system is always the effective amount of nitrogen.

4.1 N-INDEX for grassland in spring 2012

For grassland the average fertilisation advice by means of N-INDEX are shown in Table 14 for different soil textures. For each parcel grassland a fertilisation advice is formulated with grazing cattle and without grazing cattle (= only mowing). Since after each harvest a fertilisation will be necessary, the advices are presented for each grass cutting as well. When grassland is cultivated more intensively (for example on derogation parcels) with more than 3 grass cuttings, more than 3 fertilisations will be necessary. In this case higher total fertilisation is necessary in order to obtain sufficient crop growth. The first harvest of the season requires the highest fertilisation.

For grassland 34 % of the parcels were characterized by an N-INDEX lower than normal, 28 % normal and 38 % very low. So for grassland the average N-INDEX of the parcels was mostly lower than normal or very low, resulting in a high N fertilisation advice. Derogation parcels are characterized by a higher number of cuttings. When an extra cut of grass is harvested, an extra fertilisation was carried out.

Table 14: Average nitrogen (kg N/ha) fertilisation advice for grassland under derogation/no derogation on different soil textures for the growing season 2012. The advices are given for different harvests (cut 1, cut 2 and cut 3) and separately for grassland with or without grazing cattle. The number of parcels is indicated by "n".

		Derogation					No derogation				
		n	cut 1	cut 2	cut 3	sum	n	cut 1	cut 2	cut 3	sum
Grassland with grazing cattle	Sand	25	70	44	37	151	32	72	45	37	154
	Sandy loam	11	76	46	39	161	9	77	48	40	165
	Loam	-	-	-	-		-	-	-	-	-
	Clay	7	74	46	39	159	3	78	48	40	166
	All soils	-	72	45	38	155	-	73	45	38	156
Grassland without grazing cattle (= mowing)	Sand	25	90	65	55	210	32	91	65	55	211
	Sandy loam	11	95	67	56	218	9	97	68	57	222
	Loam	-	-	-	-		-	-	-	-	-
	Clay	7	94	66	56	216	3	97	68	57	222
	All soils	-	92	66	56	214	-	93	66	56	215

4.2 N-INDEX for arable land in spring 2012

In Table 15, the nitrogen advice is shown for parcels cultivated with maize in spring 2012. Sixty-one percent of the maize parcels have a normal N-INDEX and 33 % lower than normal. One percent of the maize parcels has a very low N-INDEX and 5 % have an N-INDEX higher than normal. For maize the nitrate fertilisation is mostly applied before sowing in one fraction for the mineral fertilisation and one fraction for the organic fertilisation. The average fertilisation advice for all parcels is 147 kg nitrate-N per hectare.

Table 15: Average nitrogen (kg N/ha) fertilisation advice for parcels cultivated with maize in spring 2012. Values are given separately for derogation and no derogation parcels for different soil textures. The number of parcels is indicated by "n".

	n	Derogation	(min, max)	n	No derogation	(min, max)
Sand	15	142	(87, 172)	32	150	(86, 183)
Sandy loam	9	134	(97, 159)	18	150	(101, 183)
Loam	-	-	-	4	152	(134, 170)
Clay	2	135	(110, 159)	4	150	(146, 164)
All soils	26	139	(87, 172)	58	150	(86, 183)

Table 16 shows the fertilisation advices for winter wheat, beets and potatoes. None of the parcels cultivated with these crops are under derogation. In winter wheat the fertilisation is mostly given in three fractions during the growing season. This way high yields are possible without quality losses. For potatoes fertilisation in 2 fractions is advised. The advices are always based on the potential yield a crop can obtain and does not take into account conditions like legal restrictions concerning the amount of organic and mineral fertilisation that can be applied on the parcel.

Table 16: Average nitrogen fertilisation (kg N/ha) advices for different crops for the growing season 2012. The total N-fertilisation advices as well as the different fractions are given. The number of parcels is indicated by "n".

	No derogation			
	n	Fraction 1	Fraction 2	Fraction 3
Winter wheat	9	77	57	62
Beets	1	139	-	-
Potatoes	7	154	47	-

4.3 N-INDEX for grassland in spring 2013

For grassland in 2013 the average fertilisation advice by means of N-INDEX is shown Table 17 for different soil textures. For each parcel grassland a fertilisation advice is formulated with grazing cattle and without grazing cattle (= only mowing). Since after each harvest a fertilisation will be necessary, the advices are presented for each grass cutting as well. When grassland is cultivated more intensively (for example on derogation parcels) with more than 3 grass cuttings, more than 3 fertilisations will be necessary. In this case higher total fertilisation is necessary in order to obtain sufficient crop growth. The first harvest of the season requires the highest fertilisation.

For grassland, 21 % of the parcels are characterized by a very low N-INDEX, 43 % have an N-INDEX lower than normal, 35 % have a normal N-INDEX and 1 % is characterized by an N-INDEX that was higher than normal. A low N-INDEX means there is little nitrogen in the soil for uptake by the cultivated crop, and the mineralisation is expected to be low. Therefore, a high nitrogen fertilisation advice is recommended.

Table 17: Average nitrogen (kg N/ha) fertilisation advice for grassland under derogation/no derogation on different soil textures for the growing season 2013. The advices are given for different harvests (cut 1, cut 2 and cut 3) and separately for grassland with with or without grazing cattle. The number of parcels is indicated by "n".

		Derogation				No derogation			
		n	cut 1	cut 2	cut 3	n	cut 1	cut 2	cut 3
Grassland with grazing cattle	Sand	34	71	43	37	20	72	45	38
	Sandy loam	13	70	46	39	9	74	47	39
	Loam	-	-	-	-	1	77	47	40
	Clay	7	76	47	40	2	74	46	38
	All soils	-	71	45	38	-	73	45	38
Grassland without grazing cattle (= mowing)	Sand	34	90	65	55	20	92	65	57
	Sandy loam	13	88	67	56	9	93	67	56
	Loam	-	-	-	-	1	96	67	57
	Clay	7	96	67	57	2	93	66	56
	All soils	-	90	66	55	-	91	66	56

4.4 N-INDEX for arable land in spring 2013

In Table 18, the nitrogen advice is shown for parcels cultivated with maize in spring 2013. More than half of the maize parcels (56 %) have a normal N-INDEX and 39 % lower than normal. Five percent of the maize parcels has a N-INDEX that is higher than normal. For maize the nitrate fertilisation is mostly applied before sowing in one fraction for the mineral fertilisation and one fraction for the organic fertilisation. The average fertilisation advice for all parcels is 150 kg nitrate-N per hectare.

Table 18: Average nitrogen (kg N/ha) fertilisation advice for parcels cultivated with maize in spring 2013. Values are given separately for derogation and no derogation parcels for different soil textures. The number of parcels is indicated by "n".

	n	Derogation	(min, max)	n	No derogation	(min, max)
Sand	19	150	(127, 174)	20	150	(105, 174)
Sandy loam	11	138	(63, 167)	14	156	(125, 173)
Loam	-	-	-	5	147	(130, 162)
Clay	1	175	175	1	157	157
All soils	31	147	(63, 175)	40	152	(105, 174)

Table 19 shows the fertilisation advices for winter wheat and potatoes. None of the parcels cultivated with these crops are under derogation. In winter wheat the fertilisation is mostly given in three fractions during the growing season. This way high yields are possible without quality losses. For potatoes fertilisation in 2 fractions is advised. The advices are always based on the potential yield of a crop and do not take into account conditions like legal restrictions concerning the amount of organic and mineral fertilisation that can be applied on the parcel.

Table 19: Average nitrogen fertilisation (kg N/ha) advices for different crops for the growing season 2013. The total N-fertilisation advices as well as the different fractions are given. The number of parcels is indicated by "n".

		No derogation		
	n	Fraction 1	Fraction 2	Fraction 3
Winter wheat	14	87	61	62
Potatoes	14	151	46	-

4.5 N-INDEX for grassland in spring 2014

For grassland in 2014 the average fertilisation advice by means of N-INDEX is shown in Table 20 for different soil textures. For each parcel grassland a fertilisation advice is formulated with grazing cattle and without grazing cattle (= only mowing). Since after each harvest a fertilisation will be necessary, the advices are presented for each grass cutting as well. When grassland is cultivated more intensively (for example on derogation parcels) with more than 3 grass cuttings, more than 3 fertilisations will be necessary. In this case higher total fertilisation is necessary in order to obtain sufficient crop growth. The first harvest of the season requires the highest fertilisation.

For grassland, 27 % of the parcels are characterized by a very low N-INDEX, 38 % have an N-INDEX lower than normal and 35% have a normal N-INDEX. A low N-INDEX means there is little nitrogen in the soil for uptake by the cultivated crop, and the mineralisation is expected to be low. Therefore, a high nitrogen fertilisation advice is recommended.

Table 20: Average nitrogen (kg N/ha) fertilisation advice for grassland under derogation/no derogation on different soil textures for the growing season 2014. The advices are given for different harvests (cut 1, cut 2 and cut 3) and separately for grassland with with or without grazing cattle. The number of parcels is indicated by "n".

		Derogation				No derogation			
		n	cut 1	cut 2	cut 3	n	cut 1	cut 2	cut 3
Grassland with grazing cattle	Sand	26	71	44	37	20	69	43	35
	Sandy loam	10	75	46	39	10	76	47	39
	Loam	-	-	-	-	2	77	47	40
	Clay	7	75	46	39	4	74	46	38
	All soils	43	72	44	38	36	72	44	37
Grassland without grazing cattle (= mowing)	Sand	26	90	65	55	20	89	63	52
	Sandy loam	10	94	67	56	10	95	67	56
	Loam	-	-	-	-	2	96	67	57
	Clay	7	94	66	56	4	94	66	56
	All soils	43	92	65	55	36	91	65	54

4.6 N-INDEX for arable land in spring 2014

The nitrogen advice for parcels cultivated with maize in 2014 is shown in Table 21. Only 1 % of the maize parcels has a very low N-index, 49 % have an N-INDEX lower than normal and 50 % have a normal N-INDEX. For maize the nitrate fertilisation is mostly applied before sowing in one fraction for the mineral fertilisation and one fraction for the organic fertilisation. The average fertilisation advice for all parcels is 157 kg nitrate-N per hectare.

Table 21: Average nitrogen (kg N/ha) fertilisation advice for parcels cultivated with maize in spring 2014. Values are given separately for derogation and no derogation parcels for different soil textures. The number of parcels is indicated by "n".

	n	Derogation	(min, max)	n	No derogation	(min, max)
Sand	12	153	(125, 164)	33	156	(90, 186)
Sandy loam	3	143	(138, 149)	17	157	(139, 182)
Loam	-	-	-	3	160	(137, 178)
Clay	1	178	-	3	171	(161, 183)
All soils	16	153	(125, 178)	56	158	(90, 183)

Table 22 shows the fertilisation advices for winter wheat, beets and potatoes. One parcel with winter wheat will be grown under derogation. In winter wheat the fertilisation is mostly given in three fractions during the growing season. This way high yields are possible without quality losses. For potatoes fertilisation in 2 fractions is advised. The advices are always based on the potential yield of a crop and do not take into account conditions like legal restrictions concerning the amount of organic and mineral fertilisation that can be applied on the parcel.

Table 22: Average nitrogen fertilisation (kg N/ha) advices for different crops for the growing season 2014. The total N-fertilisation advices as well as the different fractions are given. The number of parcels is indicated by "n".

	n	Fraction 1	Fraction 2	Fraction 3
Beets	4	168	-	-
Winter wheat - derogation	1	85	66	70
- no derogation	10	80	61	58
Potatoes	10	155	47	-

5 Fertilisation

5.1 Livestock manure

In order to determine the exact composition of nutrients present in the supplied manure, livestock manure is sampled. This way, the input of nutrients can be calculated on the parcels. The composition of livestock manure is highly variable (Coppens *et al.*, 2009) and depends on the type of animal and farm (differences in food, storage of the manure, farm characteristics …). Annually, for each parcel the farmer receives the laboratory results of the manure sample for the most important nutrients. In addition an advice concerning the fertilisation value of the manure is provided.

In Table 23, the number of samples taken in 2011, 2012, 2013 and 2014 are shown for the different types of livestock manure. The manure data of 2011 are obtained from the former monitoring project (Vandervelpen *et al.*, 2011). The analyses of 2011 were used for the fertilisation practices in 2011. Distinction is made between derogation and no derogation farms. A derogation farm has at least one parcel under derogation. On some farms of the monitoring network (mostly no derogation parcels) no manure was applied on parcels and thus no manure analysis was carried out. Since derogation is mostly requested by farmers having dairy cows, the majority of the analysed manure for derogation farms is cattle slurry. Some derogation farmers (having at least 1 derogation parcel in the monitoring network) applied no derogation manure on a no derogation parcel participating in the monitoring network.

Table 23: Number of livestock manure samples taken in the period from 2011-2014. Distinction is made between derogation and no derogation farms.

		Cattle slurry*	Cattle manure (solid)*	Pig slurry	Sows slurry	Other	Total
2011	Derogation	62	5	1	-	-	68
	No derogation	41	10	10	6	3	70
2012	Derogation	62	4	-	-	1	67
	No derogation	46	11	11	8	7	83
2013	Derogation	61	6	2	1	1	71
	No derogation	30	6	12	5	6	59
2014	Derogation	56	3	1	2	2	64
	No derogation	56	14	19	7	3	99

* Livestock manure that can be applied on derogation parcels.

In the Flemish derogation request, only livestock manure of cattle, horses, goats, sheep and, under specific conditions, the liquid fraction of pigs manure separated from other fractions by physical and mechanical separation may be used on derogation parcels. Table 23 shows that farms classified as a derogation farm also have analyses of no derogation manure. Since a derogation farm is defined as "a farm which has 1 or more parcels under derogation", these farms may have one or more parcels in the monitoring network which is under no derogation.

The average values of the most important nutrients are listed in Table 24, Table 26, Table 28 and Table 30. Because the majority of the samples are taken from cattle slurry, the average composition of cattle slurry is given separately for derogation and no derogation farms (Table 25, Table 27, Table 29, Table 31). Based on a one-way ANOVA ($p \leq 0.05$) on the log-transformed data, there is no significant difference in composition of cattle slurry between derogation and no derogation farms for none of the years. Average characteristics are compared with the data from the "Mestwegwijzer" (Coppens *et al.,* 2009).

There was a large standard deviation for each parameter and for all types of livestock manure.

Table 24: Average characteristics of different types of livestock manure to be used for fertilisation during the monitoring project in 2011. Values are given in kg/1000 kg manure. The number of samples is indicated by "n". Average numbers, based on manure analysis by the Soil Service of Belgium until 2007, are indicated as well (Coppens et *al.*, 2009)

Manure	n	Dry matter	Organic matter	N_{Tot}	N_{Min}	P_2O_5	K_2O	MgO	CaO	Na_2O	C/N
Cattle slurry	103	81.41	61.99	3.75	1.80	1.32	4.49	1.00	1.57	0.76	9.64
(Standard deviation)	-	(19.51)	(15.52)	(0.83)	(0.64)	(0.44)	(1.04)	(0.31)	(0.63)	(0.37)	(1.73)
(Average)	-	(85.7)	(63.7)	(5.2)	(2.9)	(1.5)	(4.8)	(1.0)	(1.5)	(0.7)	-
Cattle manure (solid)	15	218.67	168.92	5.16	0.72	2.53	6.96	1.40	3.53	0.86	19.69
(Standard deviation)	-	(40.61)	(29.13)	(1.55)	(0.70)	(0.78)	(2.78)	(0.48)	(1.76)	(0.51)	(3.11)
(Average)	-	(242.0)	(184.0)	(8.5)	(2.7)	(4.0)	(8.1)	(1.8)	(5.0)	(1.0)	-
Pigs slurry	11	83.00	57.78	6.13	3.55	3.88	4.48	2.09	4.39	1.49	5.57
(Standard deviation)	-	(20.19)	(14.84)	(1.81)	(1.08)	(1.13)	(1.47)	(0.54)	(2.16)	(0.49)	(1.14)
(Average)	-	(82.6)	(55.8)	(8.6)	(5.5)	(4.2)	(4.8)	(1.7)	(3.3)	(1.3)	-
Sows slurry	6	43.57	29.53	4.23	2.68	2.65	3.05	1.16	2.14	1.06	3.73
(Standard deviation)	-	(25.70)	(19.26)	(1.46)	(0.60)	(1.30)	(1.35)	(0.58)	(1.27)	(0.35)	(1.62)
(Average)	-	(51.8)	(34.3)	(5.0)	(3.2)	(3.2)	(2.8)	(1.2)	(2.6)	(0.9)	-
Other	3	79.43	52.65	2.53	1.30	0.99	4.88	0.57	1.58	0.86	12.05
(Standard deviation)	-	(100.16)	(73.70)	(1.34)	(1.27)	(0.74)	(2.93)	(0.29)	(1.75)	(0.64)	(12.65)

Table 25: Average characteristics together with standard deviation of cattle slurry to be used for fertilisation in 2011. Values are given in kg/1000 kg manure. The number of samples is indicated by "n".

	n	Dry matter	Organic matter	N_{Tot}	N_{Min}	P_2O_5	K_2O	MgO	CaO	Na_2O	C/N
Derogation	62	84.13	64.29	3.88	1.83	1.37	4.53	1.05	1.58	0.80	9.69
(Standard deviation)	-	(18.18)	(14.39)	(0.80)	(0.68)	(0.51)	(0.96)	(0.32)	(0.67)	(0.42)	(1.73)
No derogation	41	77.58	58.76	3.57	1.76	1.26	4.43	0.93	1.55	0.71	9.57
(Standard deviation)	-	(20.90)	(16.65)	(0.85)	(0.25)	(0.32)	(1.17)	(0.31)	(0.58)	(0.29)	(1.76)

Table 26: Average characteristics of different types of livestock manure to be used for fertilisation during the monitoring project in 2012. Values are given in kg/1000 kg manure. The number of samples is indicated by "n". Average numbers, based on manure analysis by the Soil Service of Belgium until 2007, are indicated as well (Coppens *et al.*, 2009).

Manure	n	Dry matter	Organic matter	N_{Tot}	N_{Min}	P_2O_5	K_2O	MgO	CaO	Na_2O	C/N
Cattle slurry	108	86.18	65.3	3.93	2.04	1.39	4.85	1.10	1.96	0.87	9.62
(Standard deviation)	-	(27.22)	(18.98)	(0.74)	(0.46)	(0.39)	(1.07)	(0.40)	(1.21)	(0.45)	(2.21)
(Average)	-	(85.7)	(63.7)	(5.2)	(2.9)	(1.5)	(4.8)	(1.0)	(1.5)	(0.7)	-
Cattle manure (solid)	15	242.60	178.47	4.96	0.53	3.06	7.54	1.88	4.11	1.02	21.32
(Standard deviation)	-	(68.76)	(16.13)	(1.20)	(0.28)	(1.05)	(2.00)	(0.77)	(2.15)	(0.43)	(4.32)
(Average)	-	(242.0)	(184.0)	(8.5)	(2.7)	(4.0)	(8.1)	(1.8)	(5.0)	(1.0)	-
Pigs slurry	11	72.61	51.53	6.44	4.39	3.65	5.46	1.89	3.30	1.57	4.83
(Standard deviation)	-	(15.35)	(12.53)	(1.85)	(1.31)	(1.49)	(1.87)	(0.65)	(1.09)	(0.53)	(1.27)
(Average)	-	(82.6)	(55.8)	(8.6)	(5.5)	(4.2)	(4.8)	(1.7)	(3.3)	(1.3)	-
Sows slurry	8	39.46	26.36	4.00	2.87	2.37	3.24	1.12	2.07	1.11	3.51
(Standard deviation)	-	(22.75)	(17.48)	(0.80)	(0.37)	(1.54)	(1.17)	(0.57)	(1.42)	(0.21)	(1.88)
(Average)	-	(51.8)	(34.3)	(5.0)	(3.2)	(3.2)	(2.8)	(1.2)	(2.6)	(0.9)	-
Other	8	68.03	46.57	3.54	2.26	1.44	5.62	1.03	3.09	1.64	6.06
(Standard deviation)	-	(102.56)	(84.15)	(2.87)	(1.29)	(1.65)	(4.16)	(1.25)	(4.82)	(2.14)	(5.40)

Table 27: Average characteristics together with standard deviation of cattle slurry to be used for fertilisation in 2012. Values are given in kg/1000 kg manure. The number of samples is indicated by "n". A one-way ANOVA was carried out on the log-transformed data ($p \leq 0.05$).

	n	Dry matter	Organic matter	N_{Tot}	N_{Min}	P_2O_5	K_2O	MgO	CaO	Na_2O	C/N
Derogation	62	89.50	67.71	3.93	2.01	1.41	4.99	1.12	1.89	0.86	9.98
(Standard deviation)	-	(30.82)	(20.42)	(0.71)	(0.47)	(0.33)	(1.08)	(0.33)	(1.32)	(0.44)	(2.60)
No derogation	46	81.72	62.30	3.93	2.09	1.36	4.67	1.07	2.05	0.88	9.12
(Standard deviation)	-	(20.94)	(16.54)	(0.78)	(0.45)	(0.47)	(1.05)	(0.47)	(1.04)	(0.46)	(1.40)
p-value	-	0.22	0.20	0.97	0.38	0.37	0.13	0.33	0.37	0.62	0.06

Table 28: Average characteristics of different types of livestock manure to be used for fertilisation during the monitoring project in 2013. Values are given in kg/1000 kg manure. The number of samples is indicated by "n". Average numbers, based on manure analysis by the Soil Service of Belgium until 2007, are indicated as well (Coppens *et al.*, 2009).

Manure	n	Dry matter	Organic matter	N_{Tot}	N_{Min}	P_2O_5	K_2O	MgO	CaO	Na_2O	C/N
Cattle slurry	91	82.50	62.76	3.64	1.85	1.27	4.16	0.91	1.55	0.69	10.18
Standard deviation	-	19.19	15.37	0.84	0.53	0.39	0.99	0.31	0.54	0.33	2.21
(Average)	-	(85.7)	(63.7)	(5.2)	(2.9)	(1.5)	(4.8)	(1.0)	(1.5)	(0.7)	-
Cattle manure (solid)	12	237.62	174.57	5.68	0.51	2.32	7.45	1.25	2.86	0.90	17.78
Standard deviation	-	76.27	59.08	1.24	0.21	0.65	2.58	0.43	1.09	0.38	4.16
(Average)	-	(242.0)	(184.0)	(8.5)	(2.7)	(4.0)	(8.1)	(1.8)	(5.0)	(1.0)	-
Pigs slurry	14	72.51	50.41	5.91	4.10	3.35	3.96	1.65	3.24	1.26	4.96
Standard deviation	-	25.58	19.58	1.61	1.28	1.66	1.60	0.77	1.85	0.52	1.83
(Average)	-	(82.6)	(55.8)	(8.6)	(5.5)	(4.2)	(4.8)	(1.7)	(3.3)	(1.3)	-
Sows slurry	6	37.37	24.76	3.66	2.78	2.22	2.60	0.96	1.73	1.19	3.48
Standard deviation	-	25.72	18.94	1.25	0.43	1.54	1.12	0.61	1.09	0.45	1.65
(Average)	-	(51.8)	(34.3)	(5.0)	(3.2)	(3.2)	(2.8)	(1.2)	(2.6)	(0.9)	-
Other	7	132.97	110.25	7.20	2.64	2.48	6.93	1.33	2.04	1.18	9.84
Standard deviation	-	210.19	186.18	11.49	1.93	4.02	7.25	2.15	3.39	1.04	17.84

Table 29: Average characteristics together with standard deviation of cattle slurry to be used for fertilisation in 2013. Values are given in kg/1000 kg manure. The number of samples is indicated by "n".

	n	Dry matter	Organic matter	N_{Tot}	N_{Min}	P_2O_5	K_2O	MgO	CaO	Na_2O	C/N
Derogation	61	84.14	64.23	3.79	1.94	1.32	4.25	0.97	1.64	0.75	9.92
(Standard deviation)	-	(16.96)	(14.14)	(0.65)	(0.43)	(0.31)	(0.71)	(0.30)	(0.54)	(0.32)	(1.94)
No derogation	30	78.64	59.43	3.32	1.67	1.18	3.96	0.78	1.36	0.56	10.66
(Standard deviation)	-	(23.34)	(17.69)	(1.11)	(0.66)	(0.51)	(1.41)	(0.29)	(0.49)	(0.30)	(2.63)

Table 30: Average characteristics of different types of livestock manure to be used for fertilisation during the monitoring project in 2014. Values are given in kg/1000 kg manure. The number of samples is indicated by "n". Average numbers, based on manure analysis by the Soil Service of Belgium until 2007, are indicated as well (Coppens *et al.*, 2009).

Manure	n	Dry matter	Organic matter	N_{Tot}	N_{Min}	P_2O_5	K_2O	MgO	CaO	Na_2O	C/N
Cattle slurry	112	84.06	61.84	3.69	2.01	1.30	3.95	0.93	1.91	0.72	9.95
Standard deviation	-	26.11	15.86	0.90	0.59	0.37	1.06	0.31	1.68	0.34	2.42
(Average)	-	(85.7)	(63.7)	(5.2)	(2.9)	(1.5)	(4.8)	(1.0)	(1.5)	(0.7)	-
Cattle manure (solid)	17	222.47	162.28	6.26	0.57	2.82	8.20	1.53	4.20	0.98	21.17
Standard deviation	-	53.52	32.84	1.47	0.37	0.81	3.15	0.50	2.55	0.79	5.34
(Average)	-	(242.0)	(184.0)	(8.5)	(2.7)	(4.0)	(8.1)	(1.8)	(5.0)	(1.0)	-
Pigs slurry	20	81.62	55.52	7.31	4.39	4.86	3.93	2.28	4.66	1.36	4.61
Standard deviation	-	33.59	23.04	3.78	2.43	3.07	1.58	1.23	3.29	0.64	1.60
(Average)	-	(82.6)	(55.8)	(8.6)	(5.5)	(4.2)	(4.8)	(1.7)	(3.3)	(1.3)	-
Sows slurry	9	64.59	45.11	4.58	2.66	3.50	2.83	1.54	2.91	0.86	5.22
Standard deviation	-	39.24	29.94	1.45	0.60	1.86	1.10	0.86	1.66	0.32	2.23
(Average)	-	(51.8)	(34.3)	(5.0)	(3.2)	(3.2)	(2.8)	(1.2)	(2.6)	(0.9)	-
Other	5	234.30	189.88	9.94	2.38	4.58	10.06	2.32	3.31	1.99	11.62
Standard deviation	-	216.75	195.13	11.46	1.63	5.74	6.86	2.83	2.48	1.39	7.49

Table 31: Average characteristics together with standard deviation of cattle slurry to be used for fertilisation in 2014. Values are given in kg/1000 kg manure. The number of samples is indicated by "n".

	n	Dry matter	Organic matter	N_{Tot}	N_{Min}	P_2O_5	K_2O	MgO	CaO	Na_2O	C/N
Derogation	56	88,24	63,96	3,94	2,14	1,40	4,18	1,05	2,14	0,77	9,57
(Standard deviation)	-	(30,11)	(15,36)	(0,83)	(0,69)	(0,40)	(0,97)	(0,30)	(1,85)	(0,33)	(2,11)
No derogation	56	79,87	59,73	3,44	1,88	1,19	3,72	0,82	1,67	0,66	10,32
(Standard deviation)	-	(20,82)	(16,20)	(0,89)	(0,44)	(0,31)	(1,10)	(0,28)	(1,47)	(0,35)	(2,67)

In order to illustrate the importance of manure sampling, the variation on the different cattle slurry samples is shown in Figure 2, Figure 3, Figure 4 and Figure 5. About 83 % of the manure samples had a total N between 3 and 5 kg/1000 kg cattle slurry in 2011. This number was 85 % in 2012 and 76 % in 2013 and 2014. If the N in the cattle slurry is higher as expected, farmers risk to fertilise too much, with increasing risks of high nitrate residues before a winter period. If the N in cattle slurry is lower as expected, farmers will fertilise too little, resulting in low yields.

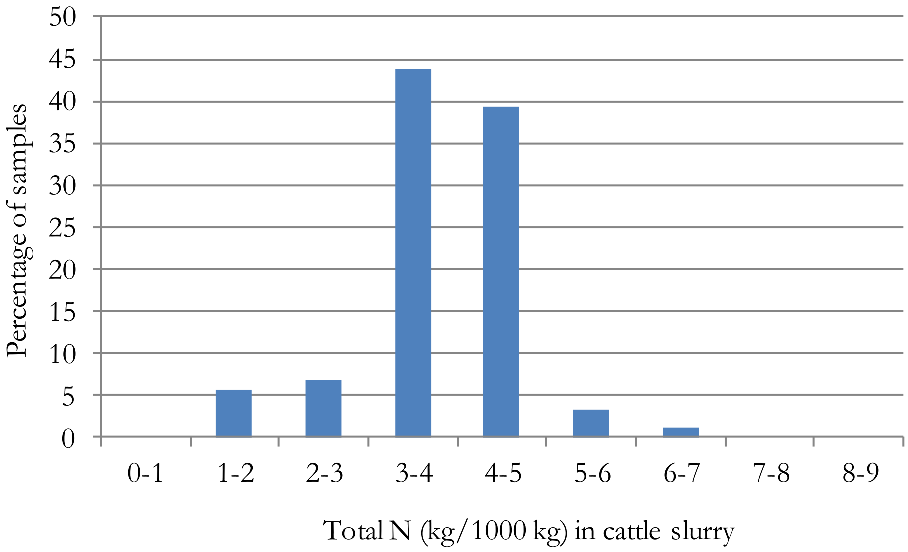


Figure 2: Histogram of the amount of total N (kg/1000 kg product) for the different samples taken from cattle slurry in 2011 in the monitoring network.

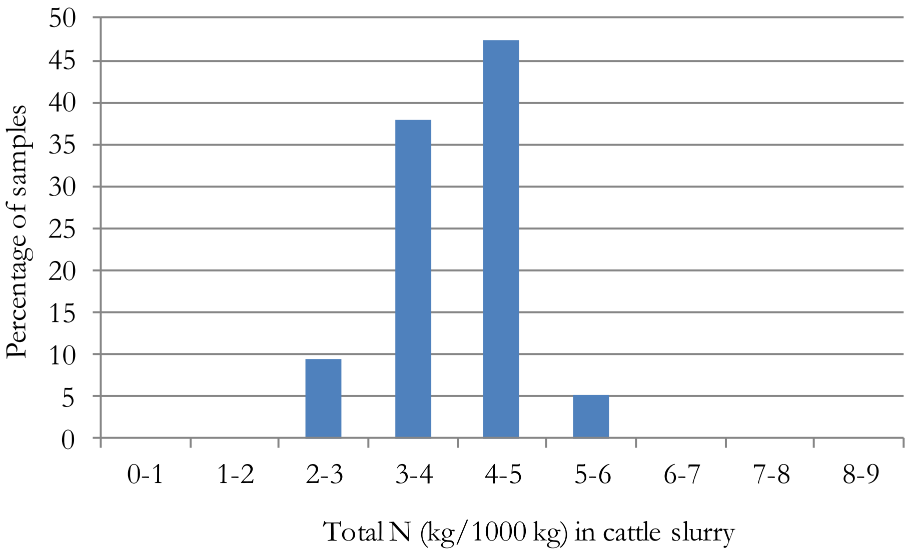


Figure 3: Histogram of the amount of total N (kg/1000 kg product) for the different samples taken from cattle slurry in 2012 in the monitoring network.

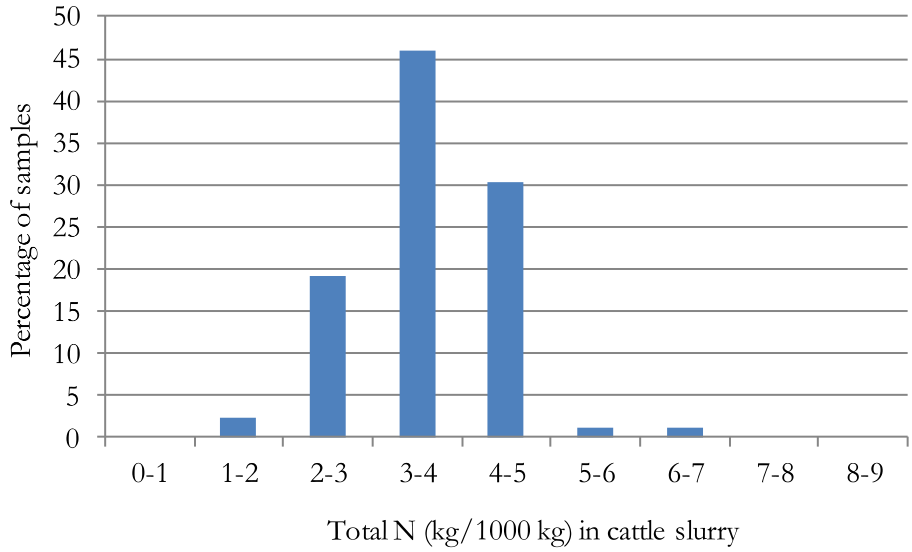


Figure 4: Histogram of the amount of total N (kg/1000 kg product) for the different samples taken from cattle slurry in 2013 in the monitoring network.

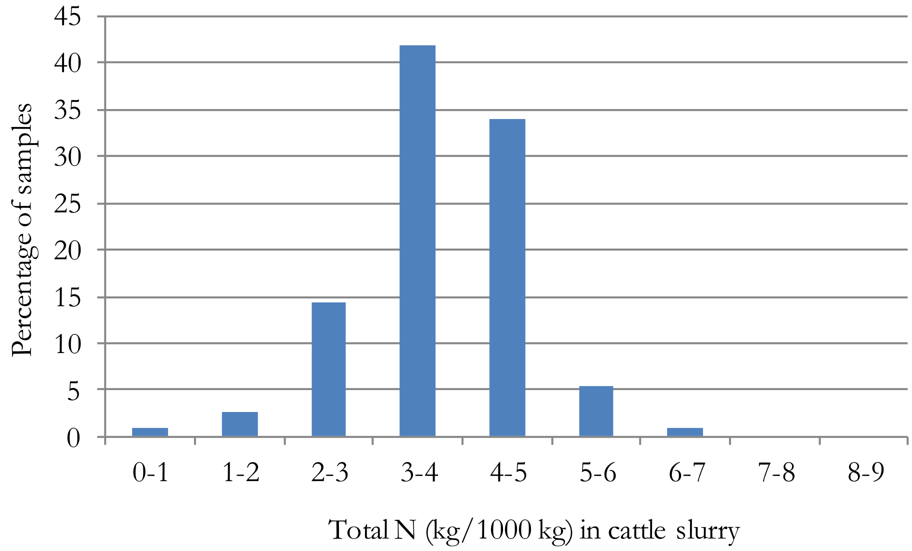


Figure 5: Histogram of the amount of total N (kg/1000 kg product) for the different samples taken from cattle slurry in 2014 in the monitoring network.

5.2 Amount of supplied nutrients

Nutrients are mostly applied on the parcels by means of fertilisation. Different types of fertilisation are possible: mineral fertilisation, application of organic fertilisers or organic input by grazing cattle.

The amounts of supplied nutrients shown are reduced with losses by emission of ammonia during the moment of fertilisation. This factor is only important for the organic fertilisation and is function of the fertiliser application. The used emission losses are shown in Table 32. The emission of grazing cattle is calculated by means of "Normen en richtwaarden 2011", available on www.vlm.be.

Table 32: Emission factors (NH_3-N) as % of the mineral N of the applied manure for arable land and grassland for different techniques and manure types.

	NH_3-N emission factor (% of $N_{mineral}$ applied)
Slurry	
Arable land	
Injection	10
Spreading + incorporation within 2 hours	21
Grassland	
Injection	20
Trailing hoses	35
Solid manure + incorporation within 24 hours	23

For grazing cattle, an emission factor of 8 % from the total manure-N production during grazing is used.

5.2.1 2011

The different nutrient inputs on the parcels of the monitoring network in 2011 are listed in Table 33. On most parcels phosphorus fertilisation was not applied by means of mineral fertilisers, which coincides with the governmental regulations and limitations. When comparing the mineral and total fertilisation on grassland and maize between derogation and no derogation parcels, the total N-fertilisation from organic manure is higher on derogation parcels. Since on derogation parcels more cuts of grass are harvested, more nutrients are removed from the parcels. For derogation parcels cultivated with maize an additional cut of grass is harvested. This additional cut requires nutrients as well.

Table 33: Average nutrient (total N and total P_2O_5 in kg/ha) input for derogation and no derogation parcels by fertilisation on the parcels in 2011. Values are given separately for the different cultivated crops. Distinction is made between total fertilisation, mineral fertilisation, organic fertilisation and organic fertilisation by grazing cattle. The emission losses during fertilisation are already subtracted.

Nutrient input	Mineral		Organic		Grazing cattle		Total organic		Total input	
	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
	Derogation parcels									
Grass, grazing cattle	139	2	119	73	83	35	202	108	341	110
Grass, only mowing	150	0	199	79	-	-	199	79	349	79
Maize and 1 grass cutting	48	4	173	67	-	-	173	67	221	71
Beets	-	-	-	-	-	-	-	-	-	-
Winter wheat	-	-	-	-	-	-	-	-	-	-
	No derogation parcels									
Grass	89	3	64	29	72	31	136	60	225	63
Maize	52	8	142	64	-	-	142	64	194	72
Beets	113	17	82	28	-	-	82	28	195	45
Winter wheat	184	4	28	23	-	-	28	23	212	27
Potatoes	109	9	81	40	-	-	81	40	190	49

5.2.2 2012

The average nutrient input for derogation and no derogation parcels by fertilisation, shown in Table 34, are the amounts of supplied nutrients reduced with losses by emission of ammonia during the moment of fertilisation.

On most parcels phosphorus fertilisation was not applied by means of mineral fertilisers, which coincides with the governmental regulations and limitations. On grass parcels more fertilisation, both mineral and organic, is applied on derogation parcels. On maize parcels, the difference in total N-input between derogation and no derogation parcels is more limited. The applied amount mineral N is about 50 kg N/ha at both types of parcels. The difference of organic N between derogation and no derogation parcels cultivated with maize was limited to 23 kg N/ha in 2012.

Table 34: Average nutrient (total N and total P_2O_5 in kg/ha) input for derogation and no derogation parcels by fertilisation on the parcels in 2012. Values are given separately for the different cultivated crops. Distinction is made between total fertilisation, organic fertilisation and organic fertilisation by grazing cattle. The emission losses during fertilisation are already subtracted.

Nutrient input	Mineral		Organic		Grazing cattle		Total organic		Total input	
	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
					Derogation parcels					
Grass, grazing cattle	123	0	95	44	96	40	191	84	313	84
Grass, only mowing	148	1	227	95	-	-	227	95	375	96
Maize and 1 grass cutting	50	2	176	82	-	-	176	82	226	84
Beets	100	0	229	123	-	-	229	123	329	123
Winter wheat	-	-	-	-	-	-	-	-	-	-
					No derogation parcels					
Grass	80	4	80	41	47	20	129	61	205	63
Maize	46	2	153	78	-	-	153	78	199	80
Beets	149	0	165	148	-	-	165	148	314	148
Winter wheat	167	0	79	50	-	-	79	50	246	50
Potatoes	74	0	156	81	-	-	156	81	230	81

5.2.3 2013

The average nutrient input for derogation and no derogation parcels by fertilisation, shown in Table 35, are the amounts of supplied nutrients reduced with losses by emission of ammonia during the moment of fertilisation. For grass parcels the conclusion can be the same as in 2011 and 2012. On derogation parcels clearly more fertilisation is applied, both mineral and organic. This coincides with the more intensive cultivation of these parcels. For maize parcels the difference in fertilisation between derogation and no derogation parcels were larger than in 2011 and 2012. On derogation parcels 254 kg total N/ha is applied while 189 kg total N/ha on no derogation parcels. The difference results from a higher input of organic manure (as meant by derogation). Both on derogation and no derogation parcels fertilisation limits are mostly respected.

Table 35: Average nutrient (total N and total P_2O_5 in kg/ha) input for derogation and no derogation parcels by fertilisation on the parcels in 2013. Values are given separately for the different cultivated crops. Distinction is made between total fertilisation, mineral fertilisation, organic fertilisation and organic fertilisation by grazing cattle. The emission losses during fertilisation are already subtracted.

Nutrient input	Mineral		Organic		Grazing cattle		Total organic		Total input	
	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
					Derogation parcels					
Grass, grazing cattle	158	0	108	43	93	35	202	78	360	78
Grass, only mowing	143	0	183	71	-	-	183	71	326	71
Maize and 1 grass cutting	58	2	196	122	-	-	196	79	254	81
Beets	-	-	-	-	-	-	-	-	-	-
Winter wheat	178	-	110	57	-	-	110	57	288	57
					No derogation parcels					
Grass	87	1	104	48	64	24	168	72	256	73
Maize	46	5	143	68	-	-	143	68	189	73
Beets	-	-	-	-	-	-	-	-	-	-
Winter wheat	199	0	80	39	-	-	80	39	279	39
Potatoes	110	0	143	61	-	-	143	61	253	61

5.2.4 2014

The average nutrient input for derogation and no derogation parcels by fertilisation, shown in Table 36, are the amounts of supplied nutrients reduced with losses by emission of ammonia during the moment of fertilisation. On derogation parcels clearly more fertilisation is applied, both mineral and organic. The difference is approximately 100 kg N/ha. This coincides often with the more intensive cultivation of these parcels. The difference in total nitrogen fertilisation between derogation and no derogation maize parcels was comparable to the difference in 2013. On derogation parcels 241 kg total N/ha is applied while 186 kg total N/ha on no derogation parcels. The difference results from a higher input of organic manure (as meant by derogation). Both on derogation and no derogation parcels fertilisation limits are mostly respected.

Table 36: Average nutrient (total N and total P_2O_5 in kg/ha) input for derogation and no derogation parcels by fertilisation on the parcels in 2014. Values are given separately for the different cultivated crops. Distinction is made between total fertilisation, mineral fertilisation, organic fertilisation and organic fertilisation by grazing cattle. The emission losses during fertilisation are already subtracted.

Nutrient input	Mineral		Organic		Grazing cattle		Total organic		Total input	
	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5	N	P_2O_5
					Derogation parcels					
Grass, grazing cattle	133	0	105	40	85	18	190	69	322	69
Grass, only mowing	187	0	185	79	0	0	185	79	372	79
Maize and 1 grass cutting	57	3	185	73	0	0	185	73	241	76
Beets	0	0	181	78	0	0	181	78	181	78
Winter wheat	134	18	0	0	0	0	0	0	134	18
					No derogation parcels					
Grass	125	2	81	36	43	9	124	53	249	55
Maize	41	4	145	73	0	0	145	73	186	77
Beets	79	10	188	75	0	0	188	75	267	85
Winter wheat	161	0	23	8	0	0	23	8	184	8
Potatoes	123	3	78	44	0	0	78	44	201	46

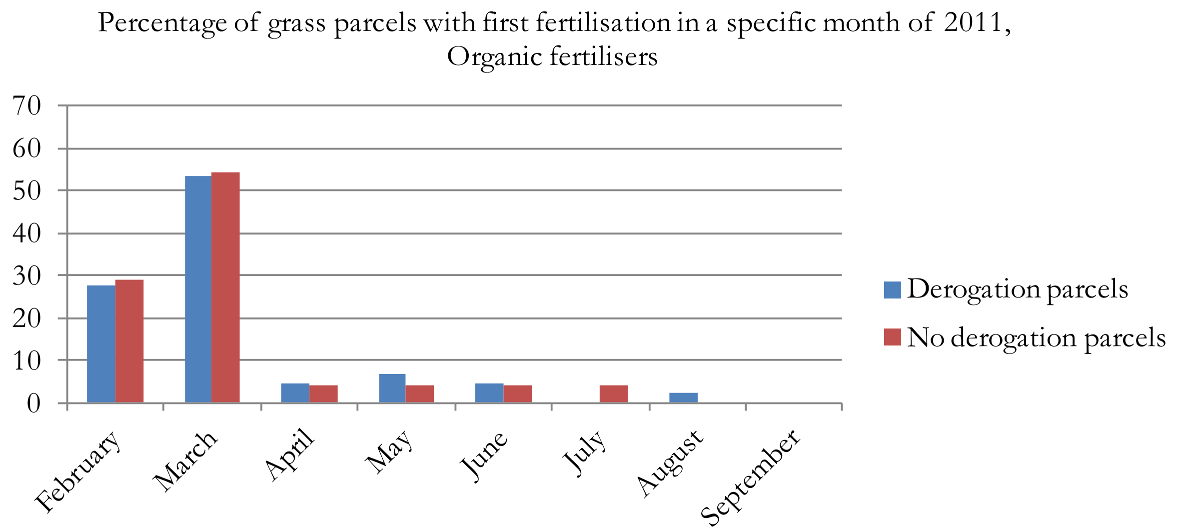
5.3 Fertilisation practices

It is also interesting to look at the different fertilisation practices between derogation and no derogation parcels. A parameter of interest is the date of fertilisation, especially the date of the first and the last fertilisation.

5.3.1 2011

Figure 6 to Figure 9 show the percentage of parcels fertilised the first and last time in a particular month in 2011, separately for grass, maize, derogation and no derogation parcels. Percentages are calculated separately for mineral and organic fertilisation by dividing the number of parcels with a first/last fertilisation in a specific month by the total number of parcels for a combination of derogation-crop. The organic fertilisation of grazing cattle (manure) is not taken into account. It needs to be noted that some maize parcels are only fertilised once, so that the date of first fertilisation equals the date of last fertilisation. In general, the results of 2011 are comparable to the results of 2009 and 2010 (Vandervelpen *et al.*, 2011).

Figure 6 shows the percentage of grass parcels fertilised the first time in a particular month. More than half of the derogation parcels (53 %) and no derogation parcels (54 %) are fertilised for the first time in March with organic fertilisers. When it comes to mineral fertilisation, about 63 % of the derogation parcels and 52 % of no derogation parcels are fertilised for the first time in March.



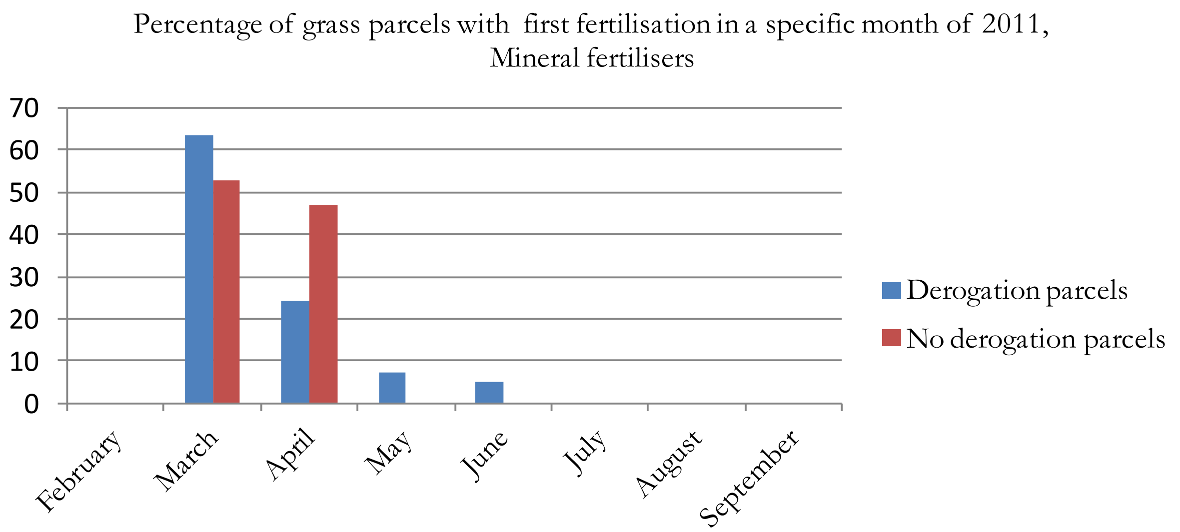
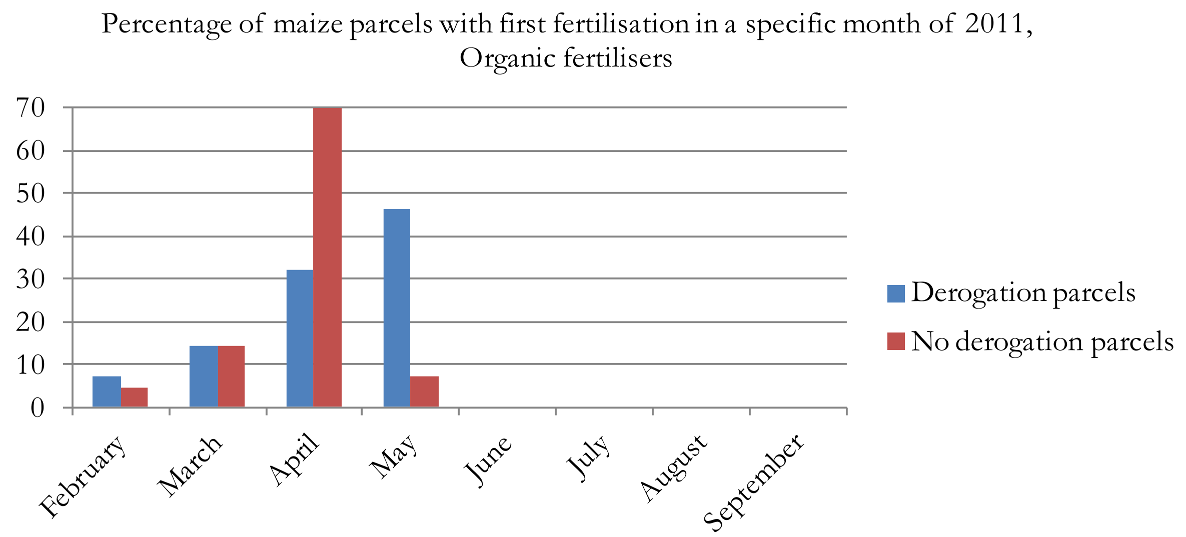


Figure 6: Percentage of grass parcels with first fertilisation with organic fertilisers (above) or mineral fertilisers (below) in a specific month of 2011, for derogation and no derogation parcels.

Figure 7 shows the percentage of maize parcels fertilised the first time in a particular month. A large majority of the no derogation parcels received organic fertilisers for the first time in April (74 %), whereas for derogation parcels the first organic fertilisation mainly occurs in May (46 %), followed by April (32 %).

However, when applying mineral fertilisers, 32 % of the maize derogation parcels are fertilised for the first time in March and 57 % in May. This early fertilisation on derogation parcels is destined for the grass present on these maize parcels, since grass before maize is a derogation condition. In April, 69 % of the no derogation parcels are fertilised for the first time with mineral fertilisers.



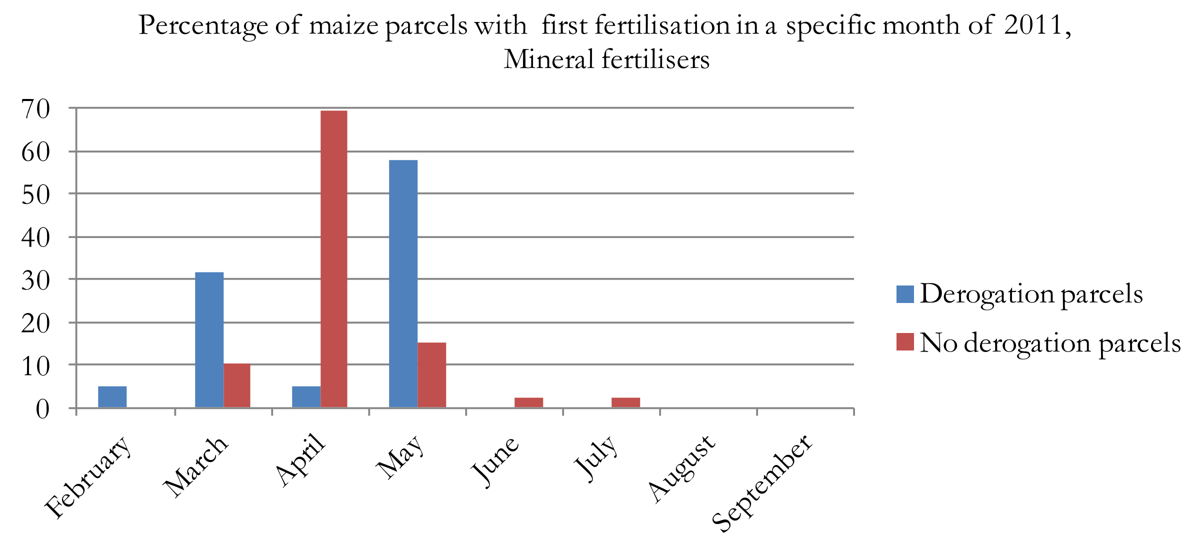
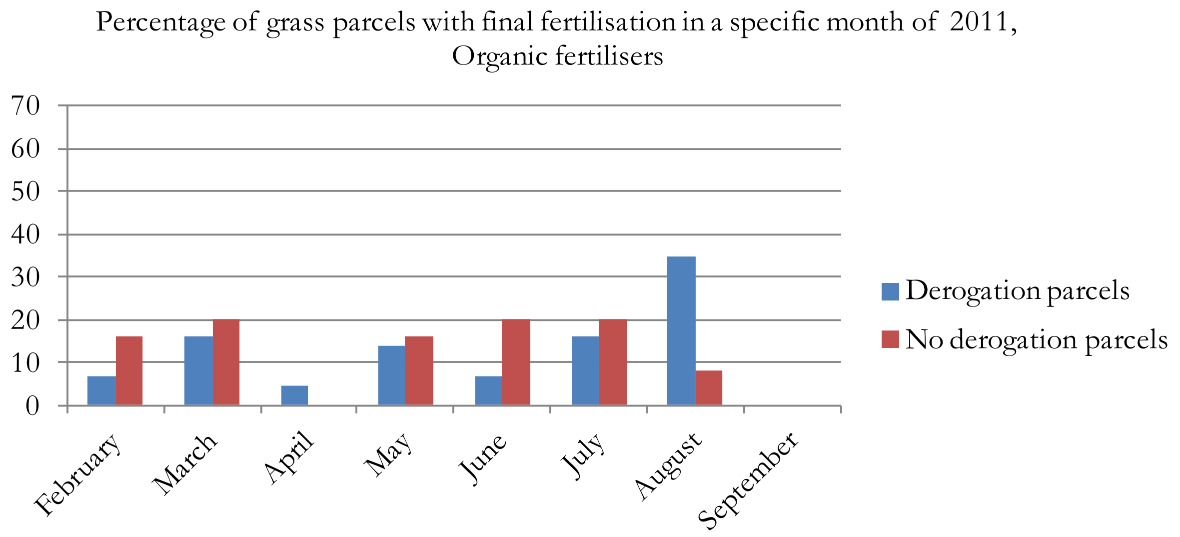


Figure 7: Percentage of maize parcels with first fertilisation with organic fertilisers (above) or mineral fertilisers (below) in a specific month of 2011, for derogation and no derogation parcels.

Figure 8 shows the percentage of grass parcels receiving a final organic or mineral fertilisation in a particular month. Thirty-five percent of the derogation parcels receive the final organic fertilisation in August. For no derogation parcels, in August only 8 % of the no derogation parcels receive a final organic fertilisation. Generally the final organic fertilisation on no derogation parcels occurs earlier (from February until July).

For derogation parcels cultivated with grass, final mineral fertilisation occurs on 33 % of the parcels in June and on 36 % of the parcels in July. On no derogation parcels, 48 % of the parcels are fertilised for the last time in July. On 19 % of derogation and 23 % of no derogation parcels, a final mineral fertilisation occurs in August.



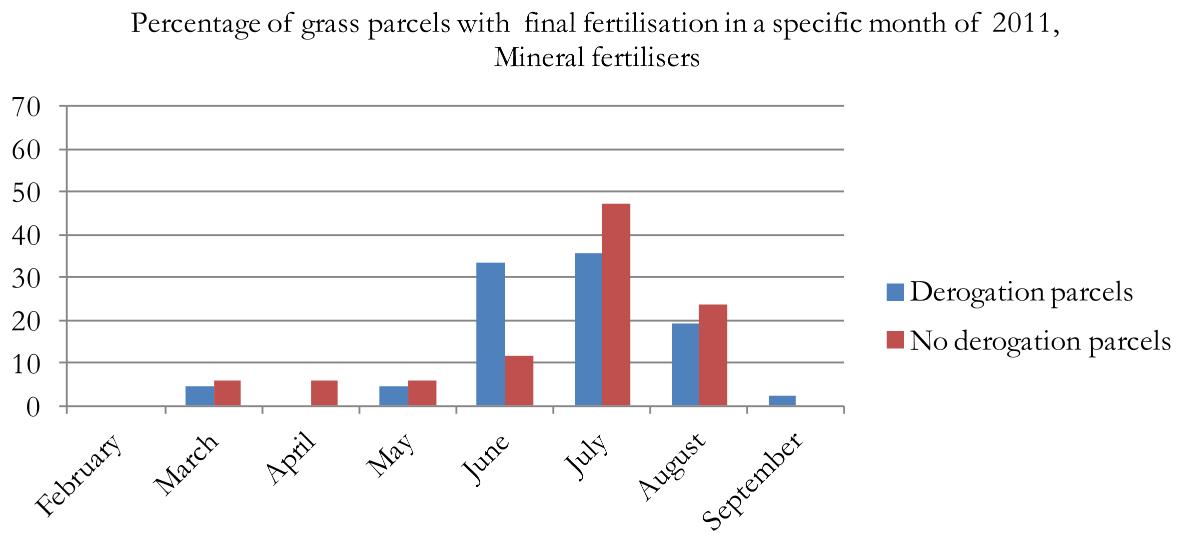
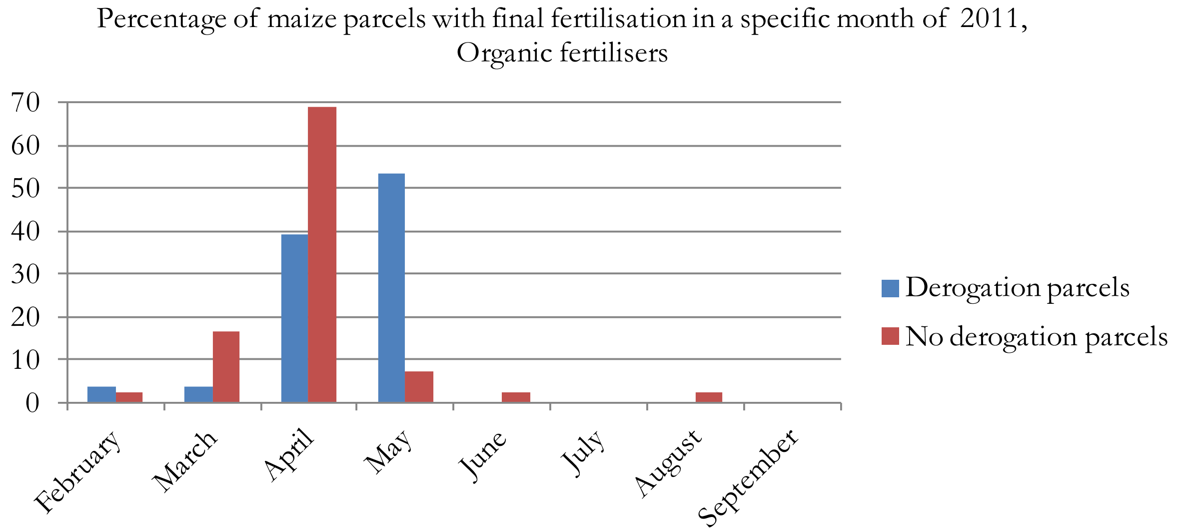


Figure 8: Percentage of grass parcels with final fertilisation with organic fertilisers (above) or mineral fertilisers (below) in a specific month of 2011, for derogation and no derogation parcels.

Figure 9 shows the percentage of maize parcels receiving a final fertilisation in a particular month. On no derogation parcels, the final application of organic fertilisers occurs earlier than on derogation parcels: 69 % of the no derogation parcels are fertilised for the last time in April, whereas 53 % of the derogation parcels are fertilised for the last time in May.



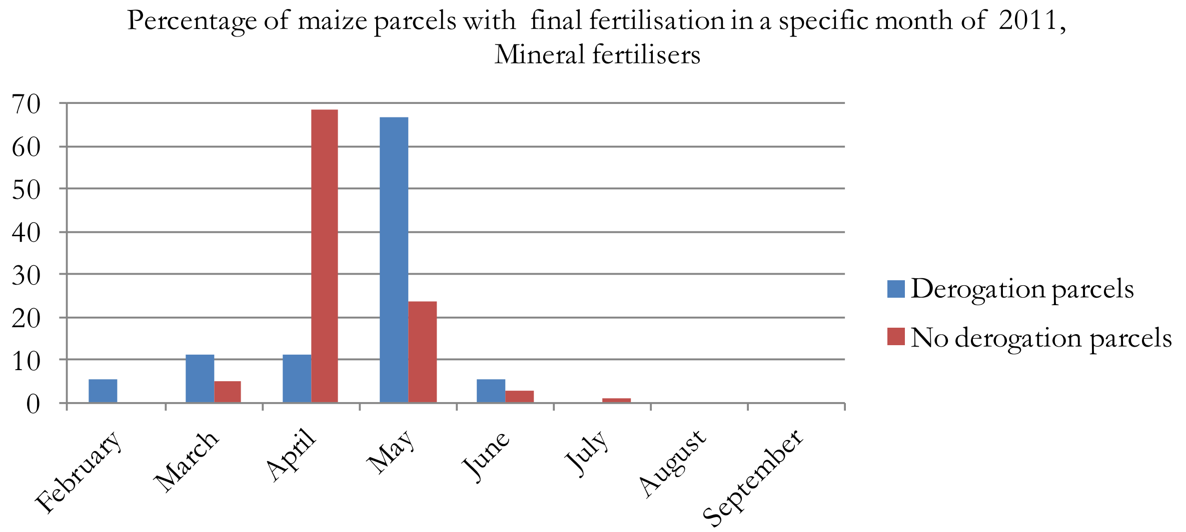


Figure 9: Percentage of maize parcels with final fertilisation with organic fertilisers (above) or mineral fertilisers (below) in a specific month of 2011, for derogation and no derogation parcels.

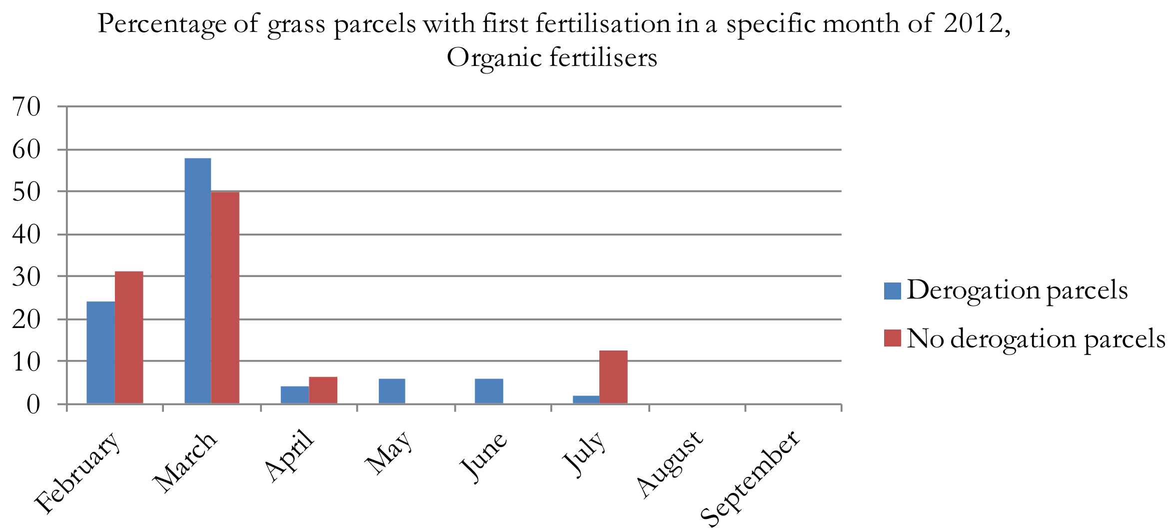
The same can be seen for the mineral fertilisation: 68 % of the no derogation parcels are fertilised for the last time in April, whereas 67 % of the derogation parcels are fertilised in May. Maize on derogation parcels is sown later than on no derogation parcels since one cut of grassland needs to be harvested on the derogation parcels before maize is sown. This cut of grassland is not present on no derogation parcels, therefore the fertilisation on no derogation parcels cultivated with maize is concentrated in April.

5.3.2 2012

Figure 10 to Figure 13 show the percentage of parcels fertilised the first and last time in a particular month in 2012, separately for parcels cultivated with grass or maize on derogation or no derogation parcels. The organic fertilisation of grazing cattle is not taken into account. On parcels which are only fertilised once, the date of the first and last fertilisation are equal. In general, the results are comparable to 2009, 2010 (Vandervelpen *et al.*, 2011) and 2011.

Figure 10 shows the percentage of grass parcels fertilised the first time in a particular month in 2012. Most of the derogation parcels (58 %) and no derogation parcels (50 %) are fertilised for the first time in March with organic fertilisers. When it comes to mineral fertilisation, about 70 % of the derogation parcels and 50 % of no derogation parcels are fertilised for the first time in March.

Figure 11 shows the percentage of maize parcels fertilised the first time in a particular month. Forty-six percent of no derogation parcels received organic fertilisers for the first time in April and 40 % in May, whereas for derogation parcels the first organic fertilisation mainly occurs in May (47 %), followed by March (27 %).



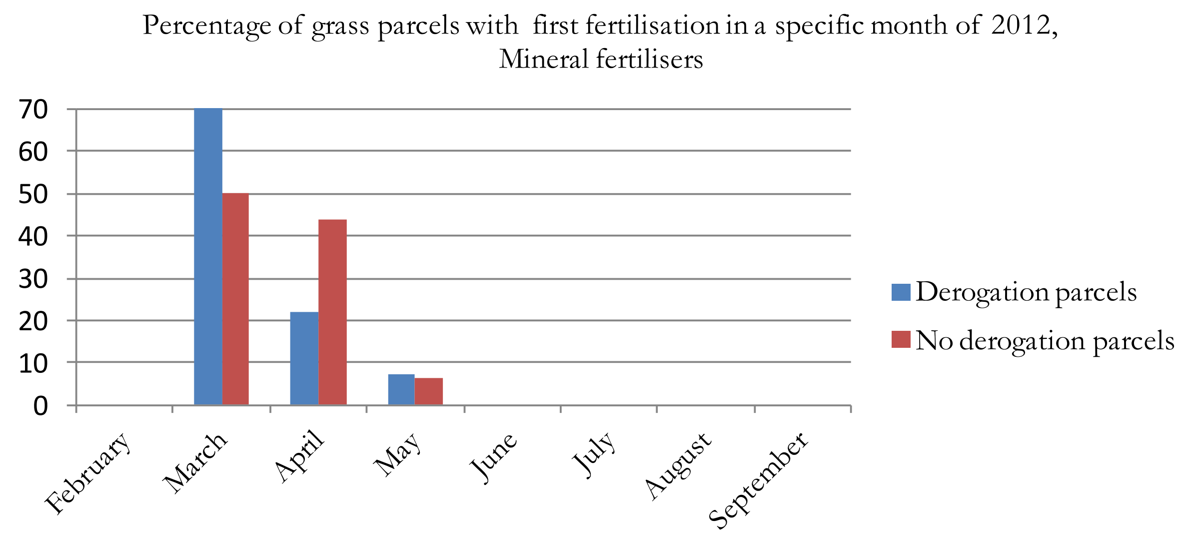
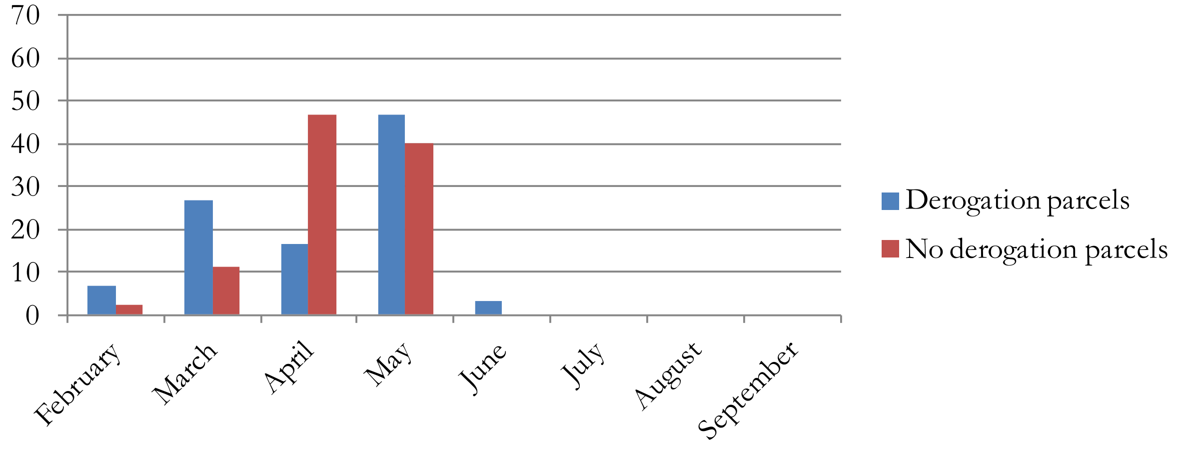


Figure 10: Percentage of grass parcels with first fertilisation with organic fertilisers (above) or mineral fertilisers (below) in a specific month of 2012, for derogation and no derogation parcels.

Percentage of maize parcels with first fertilisation in a specific month of 2012, Organic fertilisers



Percentage of maize parcels with first fertilisation in a specific month of 2012, Mineral fertilisers

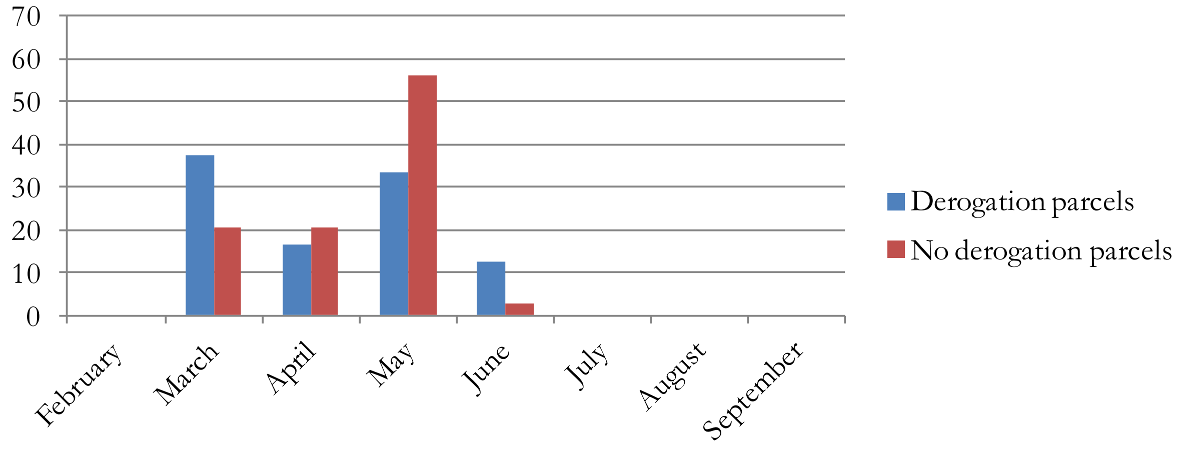
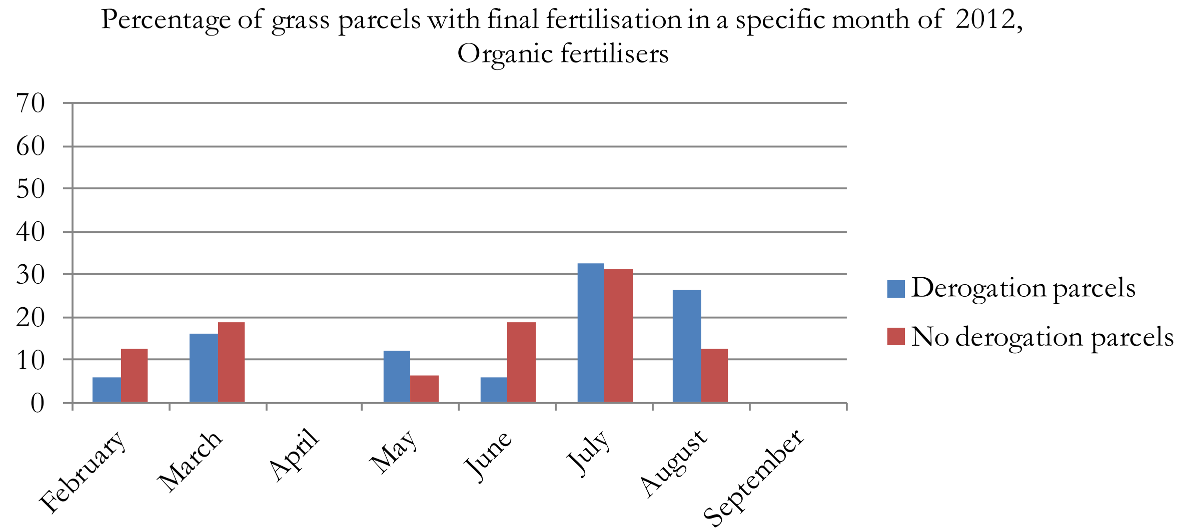


Figure 11: Percentage of maize parcels with first fertilisation with organic fertilisers (above) or mineral fertilisers (below) in a specific month of 2012, for derogation and no derogation parcels.

However, when applying mineral fertilisers, 37 % of the maize derogation parcels are fertilised for the first time in March and 33 % in May. This early fertilisation on derogation parcels is destined for the grass present on these maize parcels, since grass before maize is a derogation condition. In May, 56 % of the no derogation parcels are fertilised for the first time with mineral fertilisers.

Figure 12 shows the percentage of grass parcels receiving a final organic or mineral fertilisation in 2012 in a particular month. Thirty-three percent of the derogation parcels receive the final organic fertilisation in July and 27 % in August. For no derogation parcels, 31 % receive the final organic fertilisation in July and 13 % in August. For derogation parcels cultivated with grass, final mineral fertilisation occurs on 25 % of the parcels in July and 24 % of the parcels in June. On no derogation parcels, 26 % of the parcels have a final mineral fertilisation in April and 20 % in July and August.



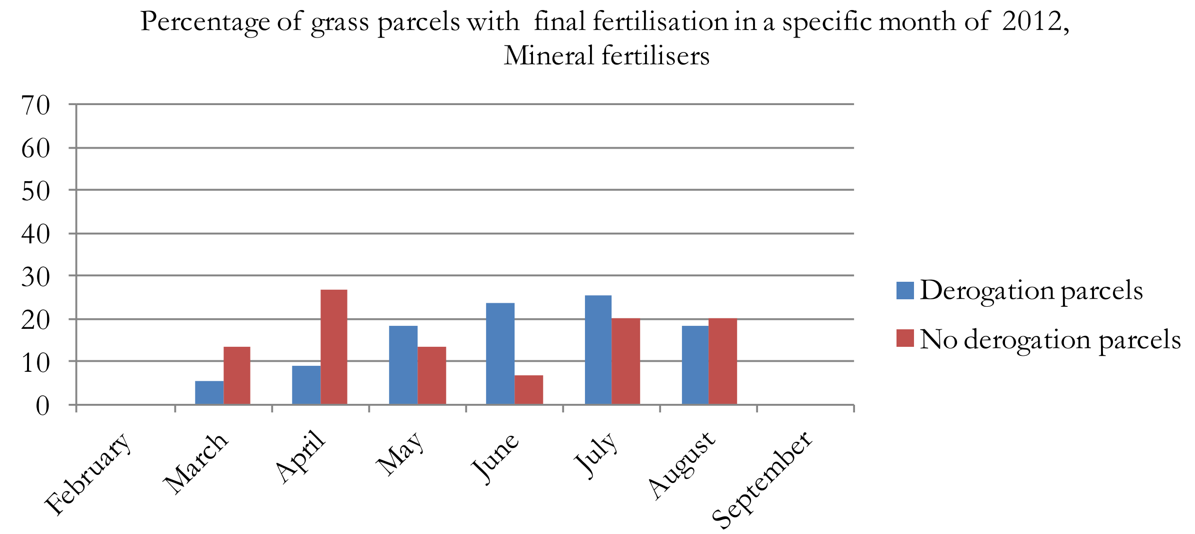
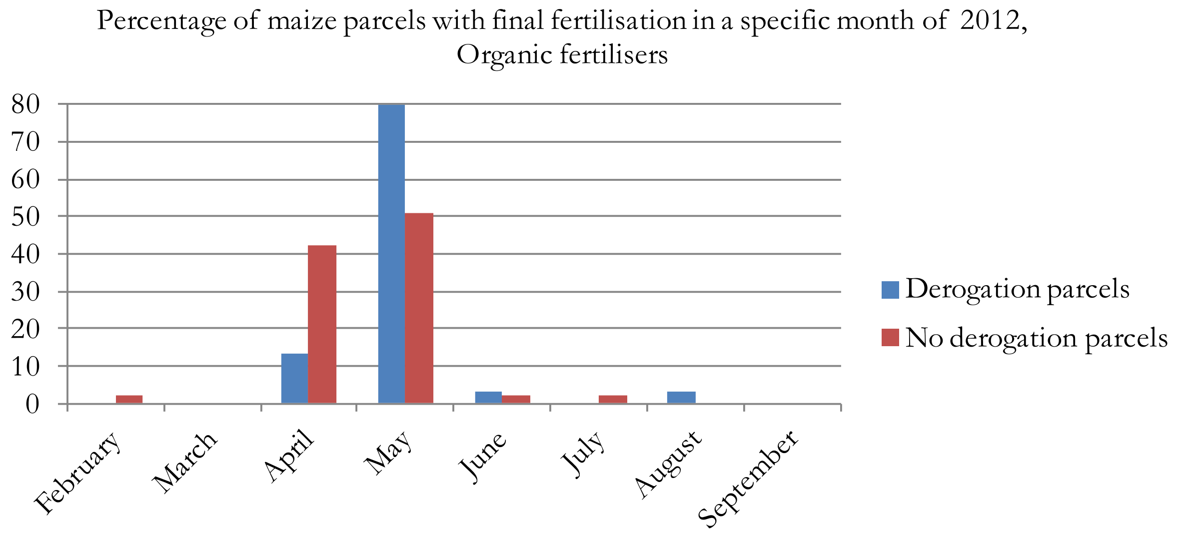


Figure 12: Percentage of grass parcels with final fertilisation with organic fertilisers (above) or mineral fertilisers (below) in a specific month of 2012, for derogation and no derogation parcels.

Figure 13 shows the percentage of maize parcels receiving a final fertilisation in a particular month. On no derogation parcels, the final application of organic fertilisers occurs earlier than on derogation parcels: 42 % of the no derogation parcels are fertilised for the last time in April and 51 % in May, whereas 80 % of the derogation parcels are fertilised for the last time in May.

Fifty percent of the derogation parcels and 58 % of the no derogation parcels are fertilised for the last time in May with mineral fertilisers.



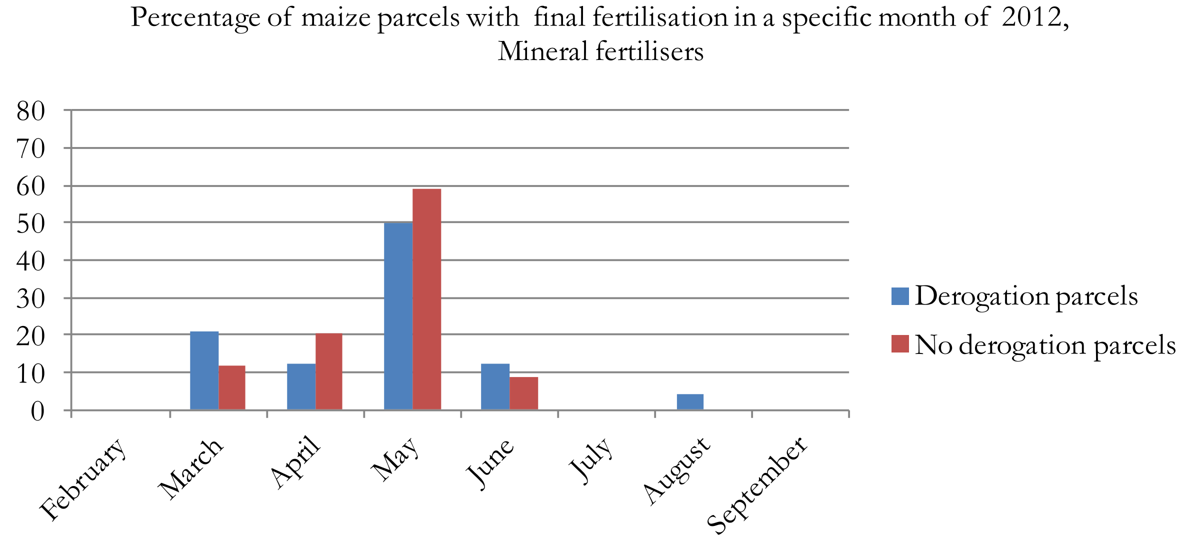


Figure 13: Percentage of maize parcels with final fertilisation with organic fertilisers (above) or mineral fertilisers (below) in a specific month of 2012, for derogation and no derogation parcels.

5.3.3 Comparison 2011-2012

Grass parcels, first fertilisation

The percentage of grass parcels with first fertilisation in a specific month of 2011 and 2012 is more or less the same: for organic fertilisers on derogation and no derogation parcels, most of the parcels are fertilised for the first time in March, followed by February, whereas for the mineral fertilizer application on derogation and no derogation parcels most of the parcels are fertilised for the first time in March, followed by May.

Grass parcels, final fertilisation

The percentage of grass parcels under derogation with final organic fertilisation in a specific month of 2011 and 2012 is more or less the same: for both years July and August. When looking at the final mineral fertilisation on grass parcels under derogation, most of the parcels in 2011 had a final mineral fertilisation in June to August, whether in 2012 it is spread more evenly over the different months.

The percentage of grass parcels under no derogation with final organic fertilisation is spread for the different months in 2011, whether for 2012 most of the no derogation parcels received this in July. When looking at the mineral fertilisation, most of the parcels are fertilised for the last time in 2011 in July, whether in 2012 it is spread over the different months, with slight peaks in April, July and August.

Maize parcels, first fertilisation

The percentage of maize parcels under derogation with first organic fertilisation in a specific month in 2011 is mostly situated in May, followed by April. In 2012, this takes a small shift, from May, followed by March. When looking at the mineral fertilisation, most of the derogation parcels are fertilised for the first time in May in 2011, where for 2012 they are mostly fertilised in March, followed by May and April. This means in 2011 there were some very specific fertilisation peaks, where in 2012 mineral fertilisation was more spread over different months.

The percentage of maize parcels under no derogation with first organic fertilisation in a specific month in 2011 is mainly situated in April. In 2012, this was more spread between April and May.

For the mineral fertilisation in 2011, most of the parcels are fertilised in April, where in 2012 it is executed in May.

Maize parcels, final fertilisation

For maize parcels under derogation, final organic fertilisation occurred mainly in May in 2011 (followed by April) whereas in 2012 80 % is fertilised in May. Final mineral fertilisation in 2011 and 2012 on derogation parcels occurred in May.

Maize parcels under no derogation were mainly fertilised with organic or mineral fertilisers in April in 2011, whereas in 2012 it was spread over May and April.

5.4 Fertilisation practices 2009-2014

It is interesting to verify if the last six years an evolution exists in fertilisation practices for parcels cultivated with grass or maize under derogation or no derogation.

In Table 37 the maximum fertilisation levels as defined by the government are shown. These levels are based on the system of total nitrogen. One of the most important changes from 2009-2010 to 2011-2014 is that since 2011 a distinction was made between grass parcels with only mowing and grass parcels with mowing and grazing. For maize parcels with no cut of grass (no derogation) the maximum input of mineral fertilisers on sandy soil changed from 150 to 35 kg N/ha/year in 2009-2010 and on no sandy soil from 150 to 50 kg N/ha/year in 2011-2014.

Table 37: Maximum fertilisation limits (kg N/ha/year) as defined by the government from 2009-2014 (source: www.vlm.be)

		2009-2010					2011-2014				
		Organic N	Mineral N		Total N		Organic N	Mineral N		Total N	
		All soils	Sand	No sand	Sand	No sand	All soils	Sand	No sand	Sand	No sand
Derogation	Grass, only mowing	250	250	250	350	350	250	200	210	370	380
	Grass, mowing + grazing						250	180	190	350	360
	Grass + Maize	250	150	150	260	275	250	100	130	270	300
No derogation	Grass, only mowing	170	250	250	350	350	170	200	210	370	380
	Grass, mowing + grazing						170	180	190	350	360
	Grass + Maize						170	100	130	270	300
	Maize	170	150	150	265	275	170	35	50	205	220

Figure 14 shows the average organic (no emission losses during fertilisation taken into account) and mineral N fertilisation for the parcels cultivated with grass under derogation. The average organic N fertilisation is rather stable last 4 years on derogation parcels cultivated with grass. The organic N fertilisation on derogation parcels with grass ranged in average between 219 and 232 kg N/ha in the period 2011-2014. The total N fertilisation ranged from 364 to 379 kg N/ha in the period 2011-2014.

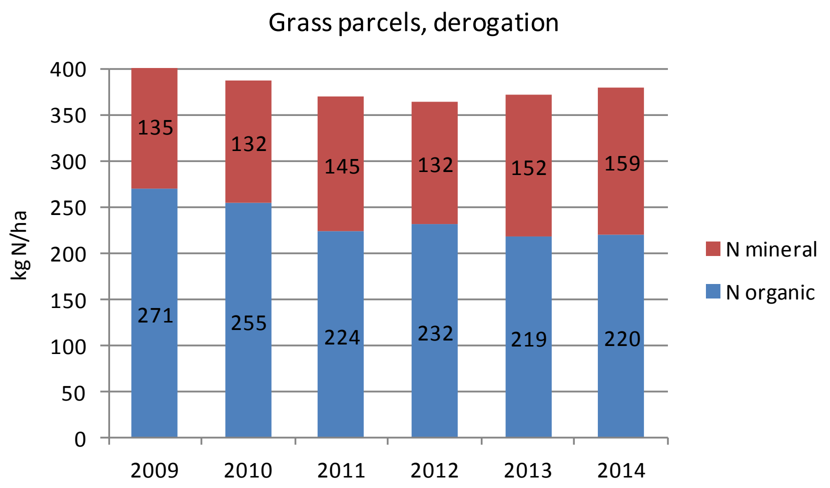


Figure 14: Average organic and mineral N fertilisation (kg/ha/year) for derogation parcels cultivated with grass in the monitoring network (2009-2014).

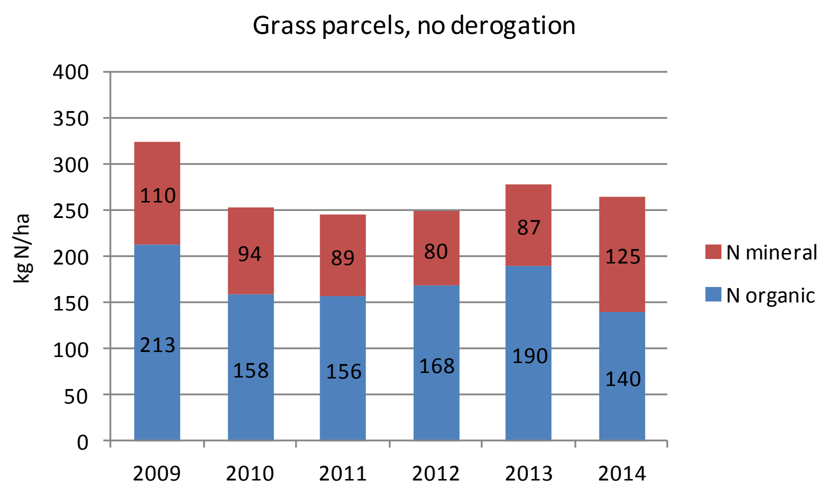


Figure 15: Average organic and mineral N fertilisation (kg/ha/year) for no derogation parcels cultivated with grass in the monitoring network (2009-2014).

On grass parcels without derogation (Figure 15) the average organic N fertilisation exceeded the maximal level (170 kg N/ha/year from organic manure) in 2009. In 2010, 2011 and 2012 the average organic N fertilization was near to the maximal organic N fertilisation limit. Mineral N fertilisation tended to decrease on derogation grass parcels in the period 2010-2012. In 2013 organic N fertilisation exceeded the maximum level while the mineral N fertilisation was at the same level as the years before. The average organic N fertilisation on no derogation parcels cultivated with grass in the period 2009-2014 was most limited in 2014. Only 140 kg N/ha was applied by organic manure. The mineral fertilisation in 2014 on the contrary, was the highest out of the last six years. Nevertheless the fertilisation standards were respected.

Figure 16 shows the average organic (no emission losses during fertilisation taken into account) and mineral N fertilisation for the parcels cultivated with maize under derogation. The organic N fertilisation on derogation parcels with maize increased in the period 2009-2011 with a maximum in 2011 near to the fertilisation limits as defined by the government (250 kg N/ha/year from organic manure). In the period 2012-2014 the average organic N fertilization is lower and ranges from 193 to 207 kg N/ha/year. The average amount of mineral N supplied varies between 48 and 62 kg N/ha/year.

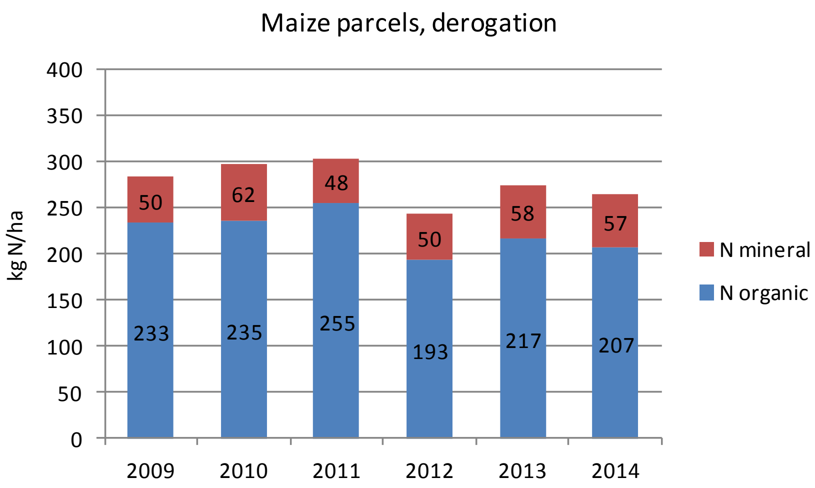


Figure 16: Average organic and mineral N fertilisation (kg/ha/year) for derogation parcels cultivated with maize in the monitoring network (2009-2014).

On the parcels cultivated with maize without derogation (Figure 17) the mineral N fertilisation is almost the same as on the derogation parcels. The average organic N fertilisation is since 2010 beneath the maximum fertilisation level of 170 kg N/ha/year from organic manure. In 2013 and

2014 only 160 kg organic N/ha was applied. The average total N fertilisation on the no derogation parcels with maize seemed to be reduced slightly since 2009.

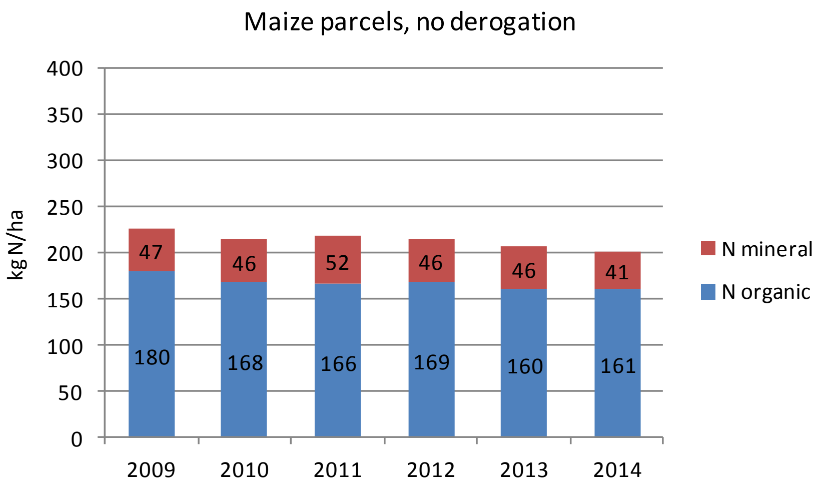


Figure 17: Average organic and mineral N fertilisation (kg/ha/year) for no derogation parcels cultivated with maize in the monitoring network (2009-2014).

5.5 Conclusion

The composition of animal manure is highly variable. So it is important to obtain a manure sample from all farms in the monitoring network. This large variance is also shown in Vandervelpen *et al.* (2011) for animal manure samples in 2010 and 2011.

More mineral and organic fertilisation is applied on derogation than on no derogation parcels. This is the most explicit on parcels cultivated with grass. On derogation parcels cultivated with grass, more grass cuts are removed, whereas on derogation parcels cultivated with maize a grass cut is harvested before the maize is sown (derogation condition).

Derogation parcels cultivated with maize receive mineral fertilisers earlier than no derogation parcels cultivated with maize. This fertilisation is for the grass present on the parcel. Since the maize is sown later than on no derogation parcels (because of the grass present before maize), maize on derogation parcels receives a final fertilisation later than no derogation parcels. Derogation parcels cultivated with grass receive both organic and mineral fertilisers later than no derogation parcels cultivated with grass.

6 Nitrate in the soil profile

A soil sample is taken in order to measure nitrate in the soil profile on all parcels of the monitoring network at two different moments during the year: between October 1st and November 15th and in February-April. As such, the evolution of the amount of nitrate and the distribution of nitrate in the soil profile can be monitored. Nitrate in the soil profile is affected by different soil processes. During winter little nitrate is taken up by crops and leaching may occur.

The data were log-transformed in order to require homogeneity of the data (a condition necessary to apply ANOVA, $p \leq 0.05$). The data are visually represented using box plots and bar graphs.

The box plots contain the mean, standard deviation and the standard error of the mean. The standard deviation is calculated as:

$s = [\sum(x_i - m)^2/(n-1)]^{1/2} = SD$

where

m is the sample mean

n is the sample size

The standard error of the mean is the theoretical standard deviation of all sample means of size "n" from a population.

$SE = s / \sqrt{m}$

where

s is the standard deviation

m is the sample mean

An overview of weather and climate conditions is given in Annex 3. These figures and values can explain evolutions of nitrate in the soil as seen at the different sampling moments.

6.1 Nitrate in autumn 2011

Between October 1st and November 15th soil samples were taken. In these soil samples the amount of nitrate in the soil profile from 0 to 30, 30 to 60 cm and 60 to 90 cm was measured, in order to determine the nitrate residue. During winter there is little nitrate uptake by crops and leaching may occur. It is thus very important to investigate possible differences in nitrate residue before winter between derogation and no derogation parcels.

In the next paragraphs, a box plot shows the variation of the groups (derogation and no derogation). The data were log-transformed in order to obtain normality of the dataset. All data are shown visually in bar graphs, which show the distribution of nitrate in the soil profile (0-30 cm, 30-60 cm, 60-90 cm). The results of homogeneous groups are analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data.

Four parcels with extreme nitrate levels (ranging from 341 to 504 kg N/ha) are considered statistical outliers and are excluded for further statistical analysis. Two out of the 3 statistical outliers were grassland in the past and were transformed into cropland. These statistical outliers are values that are common in practice, but were eliminated for the statistical analysis of the data. The 2 remaining parcels detected as outliers were cultivated with vegetables, cauliflower (408 kg N/ha) and spinach (374 kg N/ha). It is not uncommon that the nitrate residue is high on parcels cultivated with vegetables.

The average nitrate in the soil profile for each soil layer and for different combinations of crop, soil texture and derogation is shown in Table 38. The values in bold are average nitrate residues larger than 90 kg NO_3-N/ha. However, since 2011 the allowed maximum nitrate residue in the soil profile from 0-90 cm depends on the cultivated crop, soil type, focus or non-focus area[1]. Therefore, the values in bold in Table 38 (> 90 kg NO_3-N/ha) are indicative.

On the parcel cultivated with winter wheat on clay soil without derogation, no cover crop was sown after harvest, which resulted in a high nitrate residue of 140 kg N/ha. The parcel on clay soil cultivated with "other" crops, was cultivated with potatoes. Also on loam soil the "other" crops were potatoes, resulting in nitrate residues of 98 and 265 kg N/ha.

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[1] http://www.vlm.be/SiteCollectionDocuments/Mestbank/Algemeen/Drempelwaardeninfocusgebieden2011.pdf

Table 38: Average nitrate-N (kg/ha) in the soil profile (0-90 cm) and for each soil layer (0-30 cm, 30-60 cm, 60-90 cm) for the different combinations of crop, soil texture and derogation in autumn 2011. The number of parcels is indicated by "n". Numbers in bold have a nitrate-N (0-90 cm) larger than 90 kg N/ha.

	Soil	Crop 2011	n	Nitrate-N (kg/ha)			
				0-30 cm	30-60 cm	60-90 cm	0-90 cm
Derogation			85				
	Clay	Beets	-	-	-	-	-
		Grass	7	39	20	13	72
		Maize	1	22	15	8	45
		Winter wheat	-	-	-	-	-
	Loam	Beets	-	-	-	-	-
		Grass	-	-	-	-	-
		Maize	-	-	-	-	-
		Winter wheat	-	-	-	-	-
	Sand	Beets	-	-	-	-	-
		Grass	34	29	23	13	64
		Maize	18	54	32	23	**108**
		Winter wheat	-	-	-	-	-
	Sandy loam	Beets	-	-	-	-	-
		Grass	14	18	9	4	31
		Maize	11	53	32	20	**106**
		Winter wheat	-	-	-	-	-
No Derogation			132				
	Clay	Beets	-	-	-	-	-
		Grass	5	31	14	11	56
		Maize	3	99	55	25	**180**
		Winter wheat	1	68	46	26	**140**
		Other	1	82	36	21	**139**
	Loam	Beets	-	-	-	-	-
		Grass	2	6	3	1	9
		Maize	5	41	17	9	67
		Winter wheat	-	-	-	-	-
		Other	2	67	53	62	**182**
	Sand	Beets	2	29	13	8	50
		Grass	32	18	19	15	51
		Maize	31	51	39	22	**112**
		Winter wheat	2	18	22	20	59
		Other	9	38	49	36	**123**
	Sandy loam	Beets	2	7	5	4	15
		Grass	8	23	9	8	40
		Maize	13	49	30	15	**94**
		Winter wheat	4	18	22	15	55
		Other	10	51	29	19	**99**

Table 39 shows the average nitrate-N in the soil profile and for each soil layer for grass with 1-3 cuttings or 4-7 cuttings and for silage and grain maize.

Table 39: Average nitrate-N (kg/ha) in the soil profile (0-90 cm) and for each soil layer (0-30 cm, 30-60 cm, 60-90 cm) for grass and maize in autumn 2011. The number of parcels is indicated by "n".

			Nitrate-N (kg/ha)			
		n	0-30 cm	30-60 cm	60-90 cm	0-90 cm
Grass, 1-3 grass cuttings	Derogation	17	31	19	8	58
	No derogation	16	15	13	10	37
Grass, 4-7 grass cuttings	Derogation	20	27	13	9	49
	No derogation	7	18	19	17	54
Silage maize	Derogation	30	52	31	22	105
	No derogation	32	59	36	20	115
Grain maize	Derogation	0	-	-	-	-
	No derogation	20	43	36	18	97

6.1.1 All crops on all soil textures

First, the comparison is made between derogation and no derogation parcels for all crops on all soil textures. For both derogation and no derogation parcels, a large variation in nitrate measurements is observed (Figure 18), ranging from 5 to 269 kg N/ha in derogation parcels and from 5 to 265 kg N/ha in no derogation parcels.

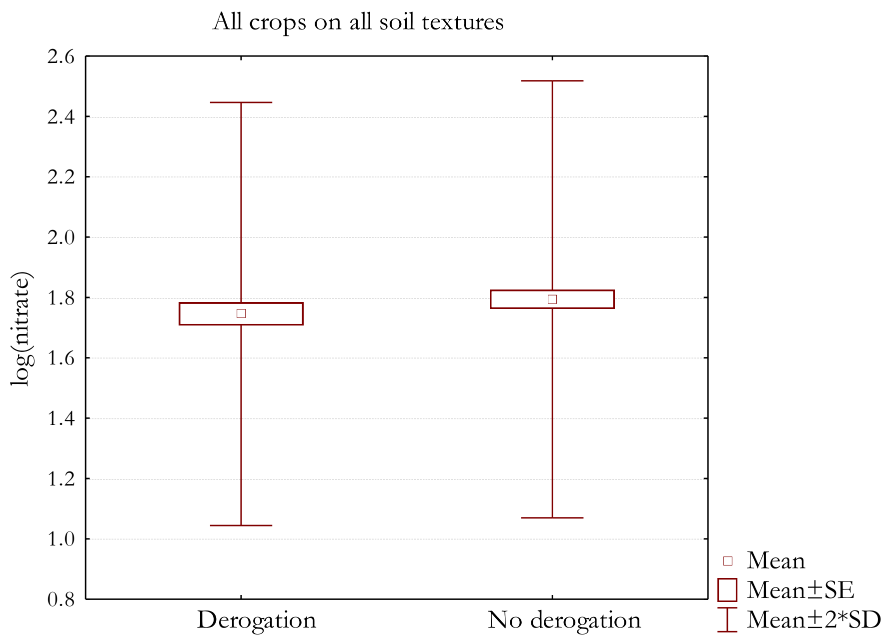


Figure 18: Box plot of log(nitrate-N) for derogation and no derogation parcels for all crops on all soil textures in autumn 2011. SE: standard error of the mean. SD: standard deviation.

The average nitrate-N is 74 (± 54) kg N/ha for derogation parcels and 84 (± 62) kg N/ha for no derogation parcels (Figure 19). Most of the nitrate can be found in the upper soil layer (0-30 cm). Since no derogation crops (vegetables, ...) are present in this dataset, the compared groups are not homogeneous and no statistical analysis was conducted between derogation and no derogation parcels. The little rainfall in autumn 2011 was also responsible for the lower amounts of nitrate in the soil layer 60-90 cm (Figure 244).

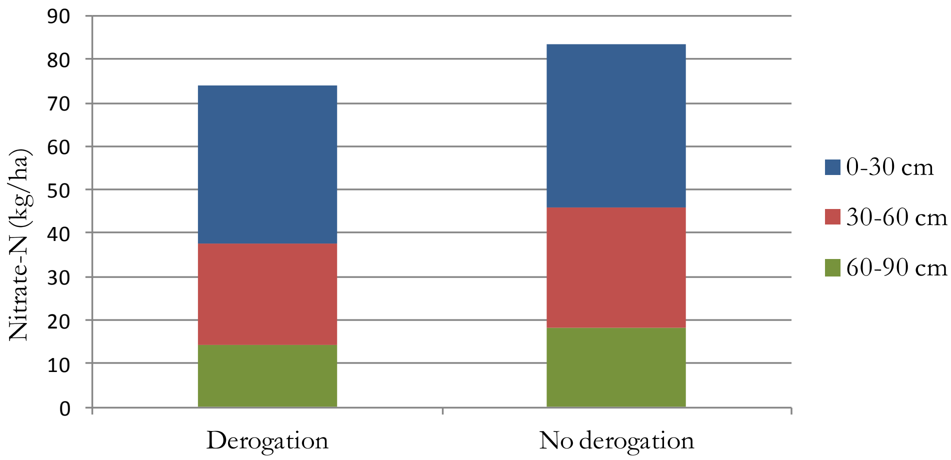


Figure 19: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2011 for all crops on all soil textures.

6.1.2 Derogation crops on all soil textures

The further analysis is limited to parcels with derogation crops (maize, grass, beets and winter wheat) only. There is a large variance for derogation and no derogation parcels (Figure 20) and no statistically significant difference ($p = 0.80$) can be found between derogation (74 ± 54 kg N/ha) and no derogation parcels (76 ± 57 kg N/ha) (Figure 21).

Nitrate in the first (0-30 cm) soil layer can leach out to the next layer but is still available to the cultivated crop. Nitrate in the 60-90 cm soil layer is not completely available for the plants, so it may leach out to the groundwater during winter. Therefore, with respect to the water quality, higher nitrate levels in the upper layers are more favourable than high levels in the deeper soil layers. Figure 21 demonstrates that about 80 % of the nitrate residue is present in the upper soil layers (from 0-30 cm and 30-60 cm) in both derogation and no derogation parcels cultivated with derogation crops and on all soil textures.

Figure 20: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on all soil textures in autumn 2011. SE: standard error of the mean. SD: standard deviation.

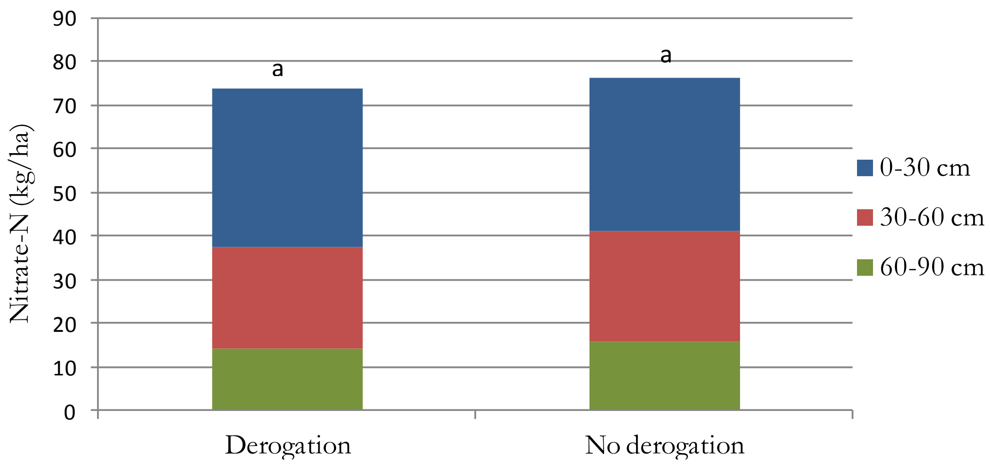


Figure 21: Average nitrate-N (kg/ha) on derogation and no derogation parcels for derogation crops on all soil textures in autumn 2011. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

No statistically significant differences in nitrate residue in autumn 2011 are found between derogation and no derogation parcels. Since nitrate residue is influenced by the soil texture, the nitrate residue between derogation and no derogation parcels will be analysed for specific soil textures. Since derogation is mostly requested on sandy and sandy loam soil textures, these soil textures are discussed in detail in the following paragraphs. For the other soil textures, the data are listed in Table 38.

6.1.3 Derogation crops on sandy soils

Derogation is mostly requested on sandy soils. There is still a large variance for the different parcels within one group (Figure 22). No statistically significant difference can be found ($p = 0.99$) between derogation (80 ± 59 kg N/ha) and no derogation parcels (79 ± 60 kg N/ha). Because of the specific characteristics of a sandy soil (low water retention capacity), the available nutrients are very sensitive to leaching. Therefore it is important to determine in which soil layer the largest amount of nitrate residue is present. Most of the nitrate can be found in the upper soil layer (0-30 cm), with 38 ± 32 kg N/ha in this layer for derogation parcels and 33 ± 28 kg N/ha for no derogation parcels (Figure 23).

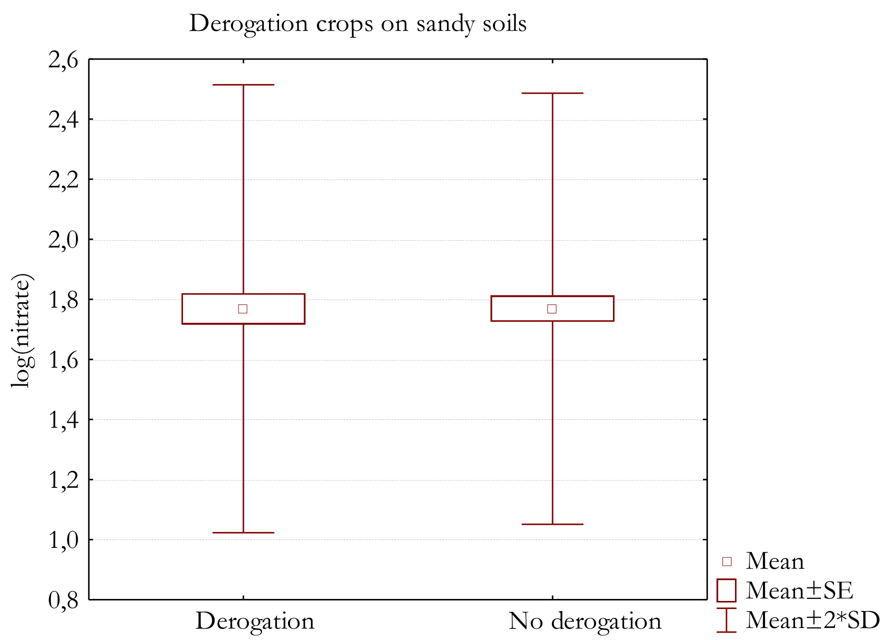


Figure 22: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on sandy soils in autumn 2011. SE: standard error of the mean. SD: standard deviation.

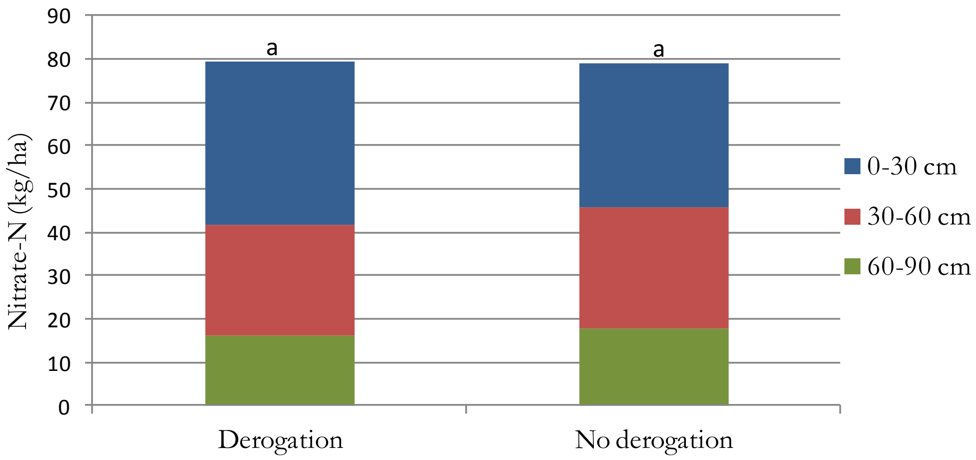


Figure 23: Average nitrate-N (kg/ha) on derogation and no derogation parcels for derogation crops on sandy soils in autumn 2011. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.1.3.1 Grass and maize on sandy soils

Except for the soil texture, the nitrate residue is mainly related to the cultivated crop. It is thus interesting to verify if a statistically significant effect exists between derogation and no derogation parcels for specific combinations of soil texture and cultivated crop.

Table 38 shows that the majority of derogation parcels consists of sandy soil, cultivated with grass or maize. The average nitrate residue levels are shown in Figure 24. However both grass and maize parcels are shown on this bar graph, the statistical analysis was conducted separately for parcels cultivated with grass or maize. No significant difference exists between derogation and no derogation parcels cultivated with grass ($p = 0.31$) or maize ($p = 0.82$) on sandy soils.

For parcels cultivated with grass on sandy soils, the derogation parcels have a nitrate residue of 64 ± 52 kg N/ha for derogation, while the no derogation parcels have a nitrate residue of 51 ± 51 kg N/ha. The derogation parcels cultivated with maize have an average nitrate residue of 108 ± 61 kg N/ha versus 112 ± 58 kg N/ha for no derogation parcels cultivated with maize.

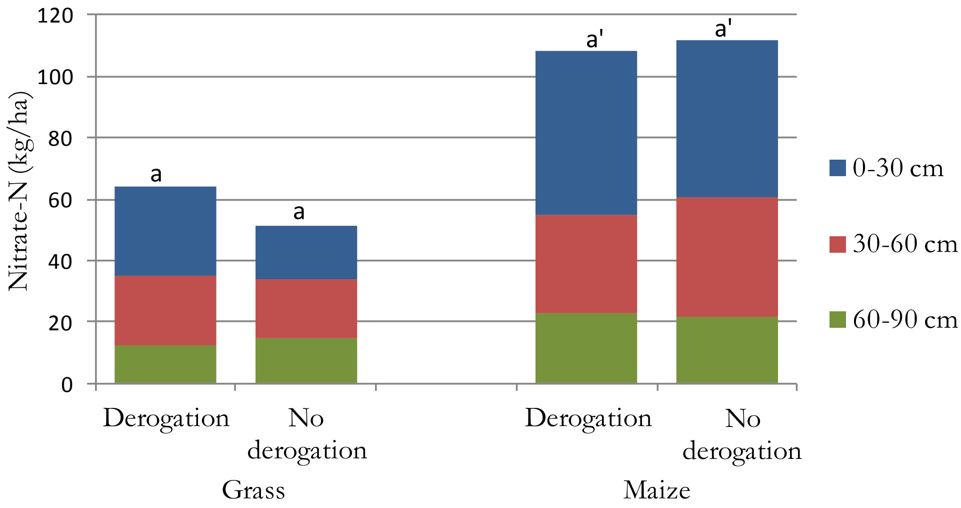


Figure 24: Average nitrate-N (kg/ha) on derogation and no derogation parcels with grass or maize on sandy soils in autumn 2011. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

6.1.4 Derogation crops on sandy loam soils

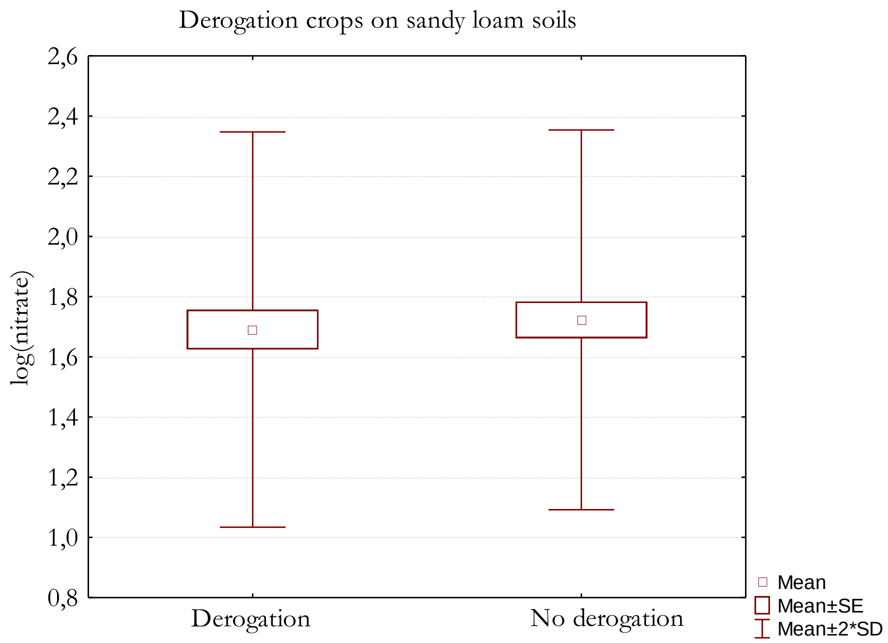


Figure 25: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on sandy loam soils in autumn 2011. SE: standard error of the mean. SD: standard deviation.

Derogation is common on sandy loam soils as well. The average nitrate residues for derogation crops on derogation and no derogation parcels on sandy loam soils are shown in Figure 26. There are no significant differences between derogation (64 ± 46 kg/ha) and no derogation (66 ± 45 kg/ha) parcels ($p = 0.72$). Like on sandy soils the upper soil layer (0-30 cm) contains most of the nitrate. More than 50 % of the nitrate residue on sandy loam soils in autumn 2011 was situated in the soil layer 0-30 cm. The variation in the nitrate levels is high (Figure 25).

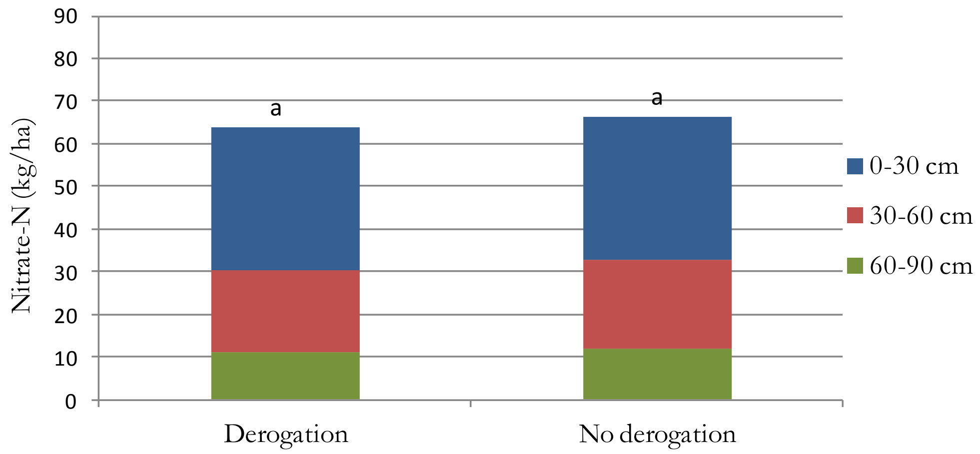


Figure 26: Average nitrate-N (kg/ha) in derogation and no derogation parcels for derogation crops on sandy loam soils in autumn 2011. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.1.4.1 Grass and maize on sandy loam soils

Since grass and maize on sandy loam soils are common in the monitoring network, a separate statistical analysis is carried out for these crops (Table 38). The average values for grass and maize with and without derogation for a sandy loam soil are shown in Figure 27. The average level of nitrate-N for derogation parcels cultivated with grass is 31 ± 14 kg/ha versus 40 ± 18 kg/ha for no derogation parcels. There is no statistical difference in nitrate-N level for derogation and no derogation parcels ($p = 0.23$).

For parcels cultivated with maize there is no statistically significant difference between derogation (106 ± 38 kg nitrate-N/ha) and no derogation (94 ± 56 kg nitrate-N/ha) parcels ($p = 0.43$).

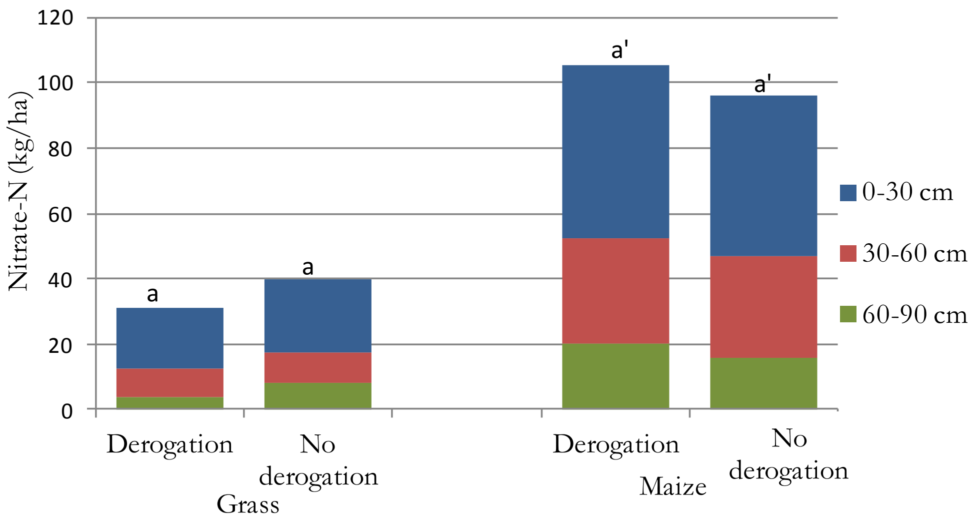


Figure 27: Average nitrate-N (kg/ha) on derogation and no derogation parcels with grass or maize on sandy loam soils in autumn 2011. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

6.2 Nitrate in autumn 2011, parcels which were continuously under derogation/no derogation during 2009-2011

In order to verify the long-term impact of derogation on the nitrate residue in the soil, only the parcels which were continuously under derogation/no derogation during 2009-2011 were retained for statistical analysis.

In the next paragraphs, a box plot shows the variation of the groups (derogation and no derogation). The data were log-transformed in order to obtain normality of the dataset. All data are shown visually in bar graphs, which show the distribution of nitrate in the soil profile (0-30 cm, 30-60 cm, 60-90 cm). The results of homogeneous groups are analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data.

In Table 40 the average nitrate-N (kg/ha) in the soil profile in autumn 2011 for parcels continuously under derogation/no derogation during 2009-2011 is shown. The values in bold are average nitrate residues larger than 90 kg NO_3-N/ha. However, since 2011 the allowed maximum nitrate residue in the soil profile from 0-90 cm depends on the cultivated crop, soil type, focus or non-focus area. Therefore, the values in bold (> 90 kg NO_3-N/ha) are indicative.

Table 40: Average nitrate-N (kg/ha) in the soil profile for parcels continuously under derogation/no derogation during 2009-2011, in autumn 2011. The nitrate-N is given for the different combinations of soil texture, cultivated crop and derogation. For each combination the total amount of nitrate is given as well as for each soil layer (layer 1: 0-30 cm, layer 2: 30-60 cm and layer 3: 60-90 cm). The number of parcels is indicated by "n".

	Soil	Crop 2011	n	Nitrate-N (kg/ha)			
				0-30 cm	30-60 cm	60-90 cm	0-90 cm
Derogation			60				
	Clay	Beets	-	-	-	-	-
		Grass	6	42	21	13	76
		Maize	-	-	-	-	-
		Winter wheat	-	-	-	-	-
	Loam	Beets	-	-	-	-	-
		Grass	-	-	-	-	-
		Maize	-	-	-	-	-
		Winter wheat	-	-	-	-	-
	Sand	Beets	-	-	-	-	-
		Grass	23	34	23	13	70
		Maize	12	59	33	22	**114**
		Winter wheat	-	-	-	-	-
	Sandy loam	Beets	-	-	-	-	-
		Grass	13	23	10	6	39
		Maize	6	52	31	23	**105**
		Winter wheat	-	-	-	-	-
No derogation			89				
	Clay	Beets	-	-	-	-	-
		Grass	4	33	14	10	56
		Maize	2	71	63	30	**164**
		Winter wheat	-	-	-	-	-
		Other	2	75	41	24	**140**
	Loam	Beets	-	-	-	-	-
		Grass	1	3	1	1	5
		Maize	4	42	15	8	65
		Winter wheat	-	-	-	-	-
		Other	1	116	94	55	**265**
	Sand	Beets	1	43	16	8	67
		Grass	20	21	21	15	57
		Maize	21	51	40	22	**113**
		Winter wheat	2	18	22	20	59
		Other	6	37	48	35	**119**
	Sandy loam	Beets	1	6	5	5	16
		Grass	6	23	10	10	43
		Maize	9	53	36	17	**99**
		Winter wheat	2	28	24	18	69
		Other	8	46	25	18	88

6.2.1 All crops on all soil textures

From all parcels, two no derogation parcels were considered statistical outliers (408 and 504 kg N/ha). One parcel was cultivated with grass and converted into maize (504 kg N/ha), the other parcel was cultivated with cauliflower. Figure 28 shows a large variation in nitrate residue for derogation and no derogation parcels.

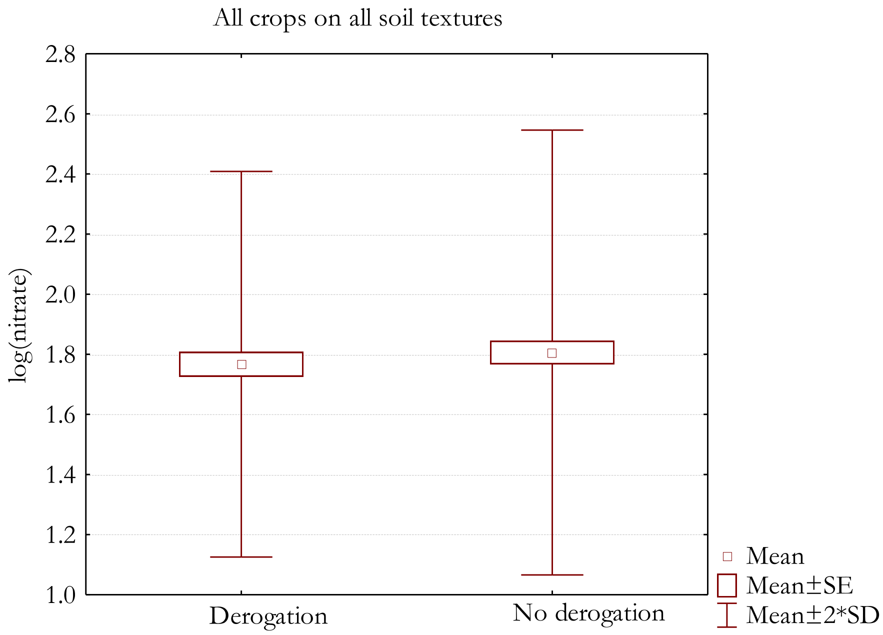


Figure 28: Box plot of log(nitrate-N) for derogation and no derogation parcels in autumn 2011, for all crops on all soil textures including only parcels which were continuously under derogation/no derogation during 2009-2011. SE: standard error of the mean. SD: standard deviation.

The average nitrate-N in derogation parcels is 76 ± 56 kg N/ha and in no derogation parcels 87 ± 64 kg N/ha (Figure 29). Most of the nitrate is located in the upper soil layer (0-30 cm). Since no derogation crops (vegetables, ...) are present in this dataset, the compared groups are not homogeneous and no statistical analysis was conducted between derogation and no derogation parcels.

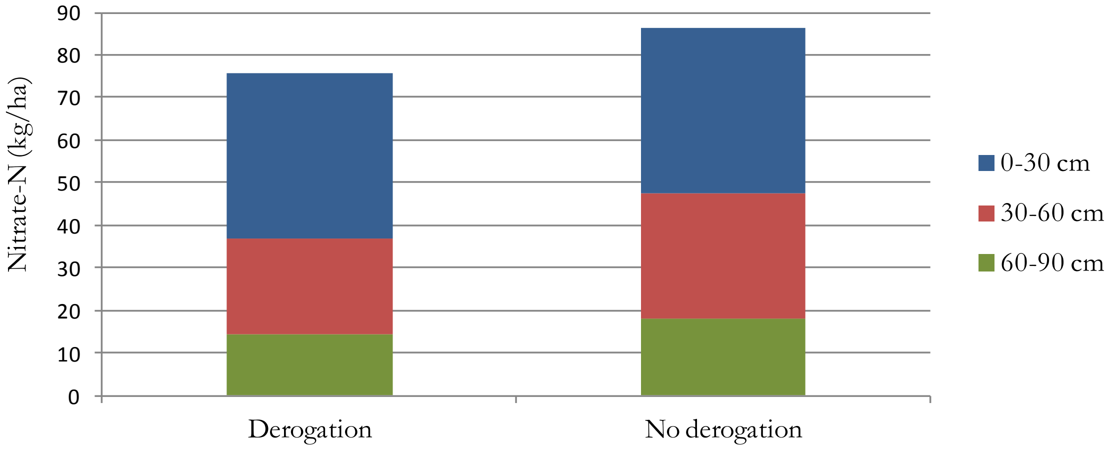


Figure 29: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2011 for all crops on all soil textures, including only parcels which were continuously under derogation/no derogation during 2009-2011.

6.2.2 Derogation crops on all soil textures

Figure 30 shows a large variation in nitrate residue for derogation and no derogation parcels.

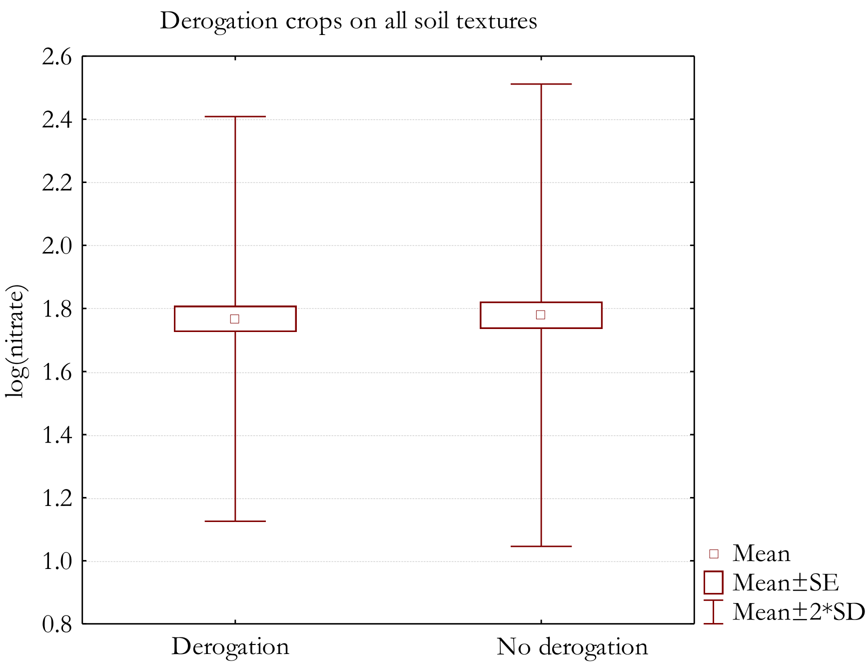


Figure 30: Box plot of log(nitrate-N) for derogation and no derogation parcels in autumn 2011, for derogation crops on all soil textures, including only parcels which were continuously under derogation/no derogation during 2009-2011. SE: standard error of the mean. SD: standard deviation.

There is no significant (p = 0.85) difference between the nitrate residue in derogation parcels (76 ± 56 kg N/ha) and in no derogation parcels (80 ± 60 kg N/ha) (Figure 31). Again, most of the nitrate is located in the upper soil layer (0-30 cm).

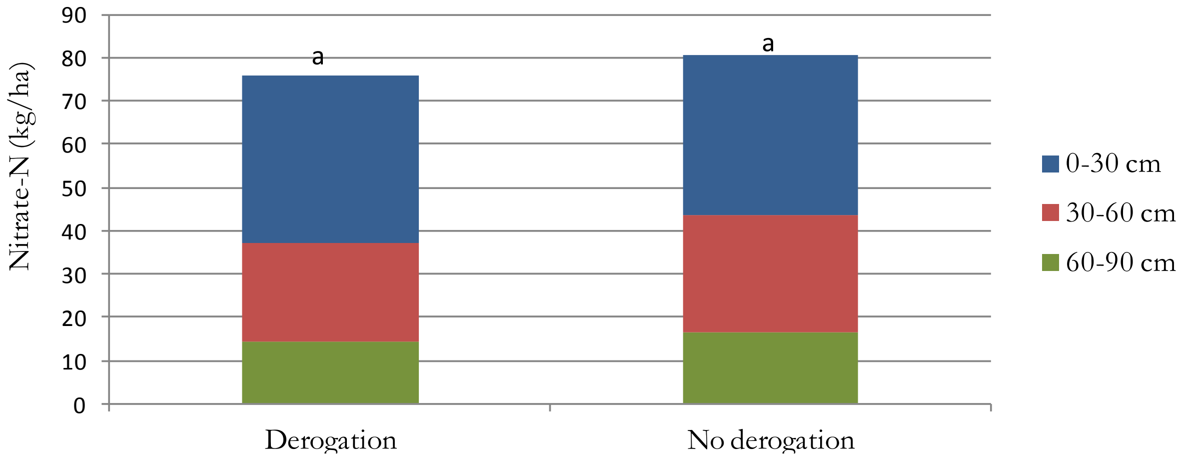


Figure 31: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2011 for derogation crops on all soil textures, including only parcels which were continuously under derogation/no derogation during 2009-2011. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.2.3 Derogation crops on sandy soils

Figure 32 shows a large variation in nitrate residue for derogation and no derogation parcels on sandy soil.

The nitrate-N between derogation parcels (85 ± 61 kg/ha) and no derogation parcels (84 ± 66 kg/ha) is not significantly different (p = 0.64) (Figure 33). Most of the nitrate is located in the upper soil layer (0-30 cm).

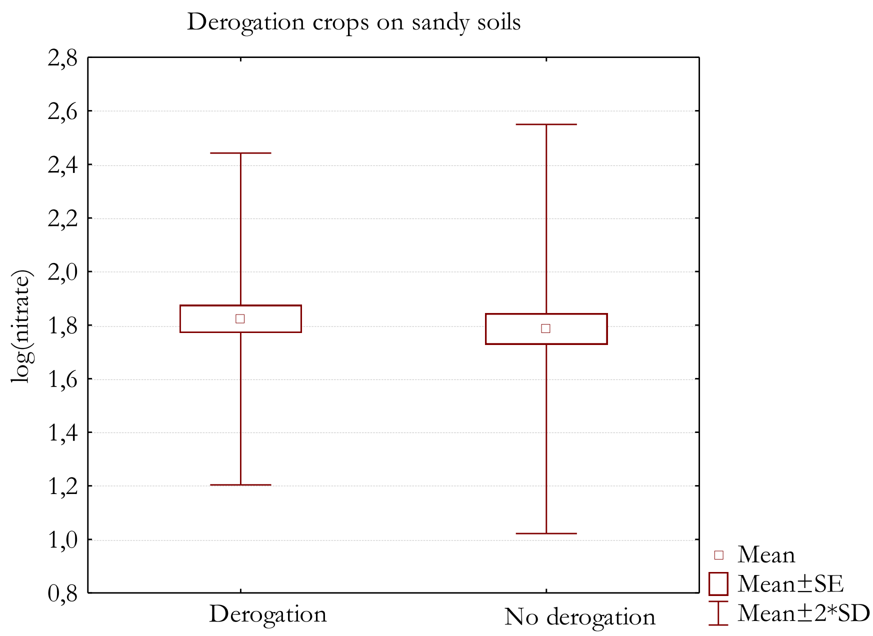


Figure 32: Box plot of log(nitrate-N) for derogation and no derogation parcels in autumn 2011, for derogation crops on sandy soils, including only parcels which were continuously under derogation/no derogation during 2009-2011. SE: standard error of the mean. SD: standard deviation.

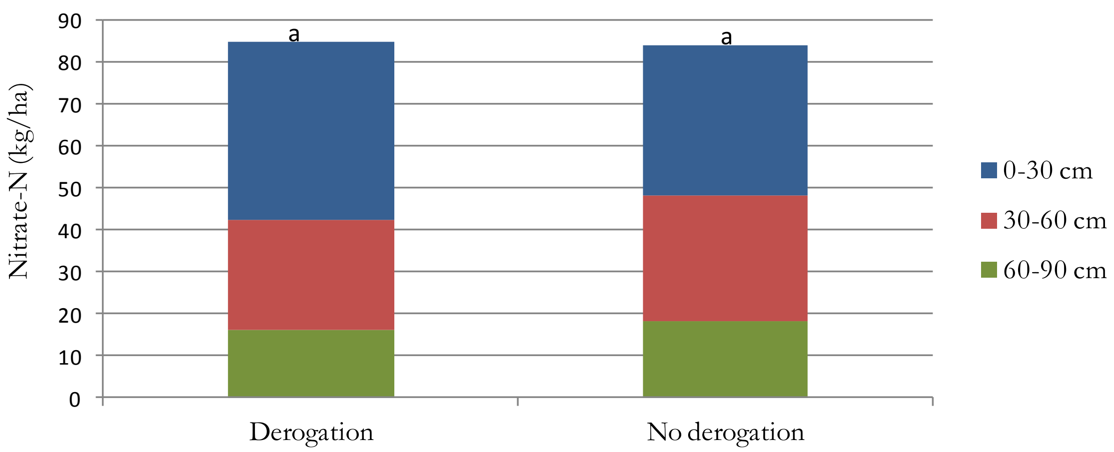


Figure 33: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2011 for derogation crops on sandy soils, including only parcels which were continuously under derogation/no derogation during 2009-2011. The results were analysed statistically by means of a one-way ANOVA (p ≤ 0.05) on the log-transformed data. Identical letters indicate no statistical difference.

6.2.3.1 Grass and maize on sandy soils

The average nitrate-N on grass parcels under derogation is 70 ± 50 kg N/ha and 57 ± 56 kg N/ha on no derogation parcels (Figure 34). For maize, the average nitrate-N under derogation is 114 ± 62 kg N/ha and 113 ± 68 kg N/ha on no derogation parcels. For both crops on sandy soil, derogation has no significant effect on the nitrate residue ($p = 0.15$ for grass parcels and $p = 0.94$ for maize parcels).

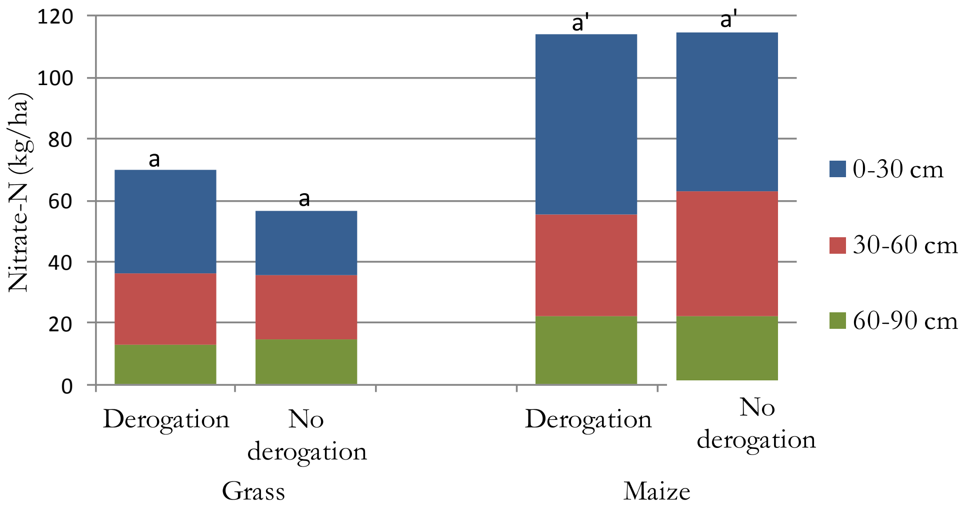


Figure 34: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2011 for grass and maize on sandy soils, including only parcels which were continuously under derogation/no derogation during 2009-2011. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

6.2.4 Sandy loam soils

Figure 35 shows a large variation in nitrate residue for derogation and no derogation parcels on sandy loam soils. The average nitrate is 60 ± 47 kg N/ha on derogation parcels and 73 ± 49 kg N/ha on no derogation parcels. There is no significant effect of derogation on the nitrate residue ($p = 0.29$) (Figure 36). Most of the nitrate is located in the upper soil layer (0-30 cm).

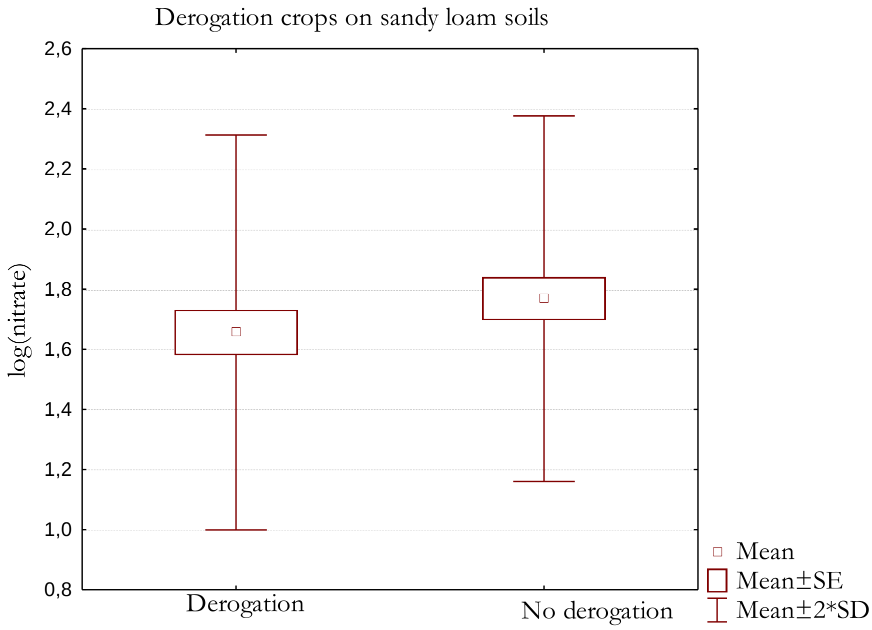


Figure 35: Box plot of log(nitrate-N) for derogation and no derogation parcels in autumn 2011, for derogation crops on sandy loam, including only parcels which were continuously under derogation/no derogation during 2009-2011. SE: standard error of the mean. SD: standard deviation.

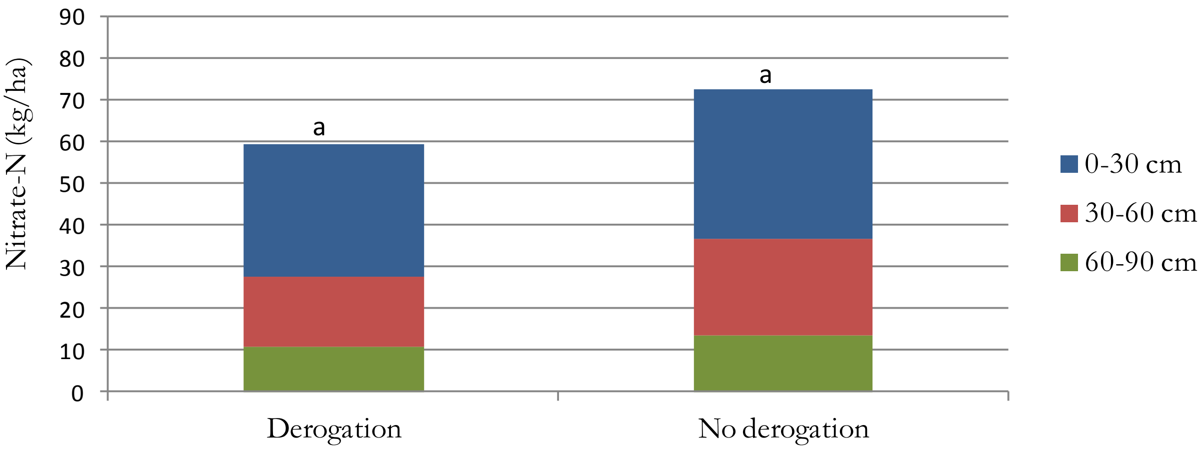


Figure 36: : Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2011 for derogation crops and on sandy loam soils, including only parcels which were continuously under derogation/no derogation during 2009-2011. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.2.4.1 Grass and maize on sandy loam soils

The average nitrate-N in grass parcels under derogation is 39 ± 28 kg N/ha, in no derogation parcels this is 43 ± 20 kg N/ha (Figure 37). The average nitrate-N in maize parcels under derogation is 105 ± 50 kg N/ha, in no derogation parcels 99 ± 53 kg N/ha. Most of the nitrate is located in the upper soil layer (0-30 cm). There is no significant difference between derogation and no derogation crops cultivated with grass or maize ($p = 0.56$ for grass parcels and $p = 0.83$ for maize parcels).

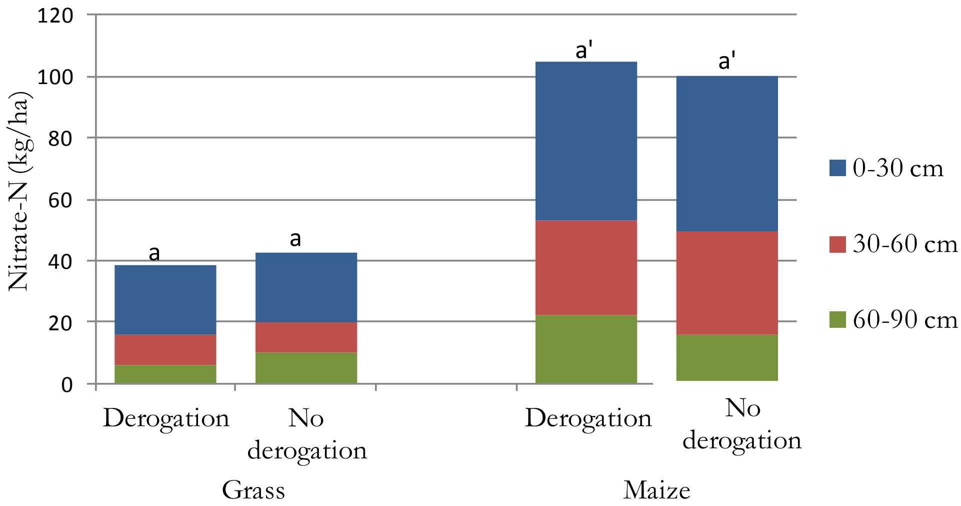


Figure 37: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2011 for grass and maize and on sandy loam soils, including only parcels which were continuously under derogation/no derogation during 2009-2011. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

6.3 Nitrate in autumn 2011 in the deeper soil layer

For 40 parcels an additional soil sample was taken from 90 to 120 cm (the "deep soil sample"). In this soil layer the amount of nitrate is measured. Three statistical outliers were removed (106.2 kg N/ha under derogation, 86.7 and 120.9 kg N/ha under no derogation). Data were considered statistical outliers when exceeding the average plus 2 times the standard deviation.

A significantly ($p \leq 0.05$) positive correlation exists between the amount of nitrate present in the soil profile from 0-90 cm and the nitrate present in the soil profile from 90-120 cm. This means that when the nitrate residue in the 0-90 cm layer is high, a high nitrate content in the 90-120 cm soil layer is expected.

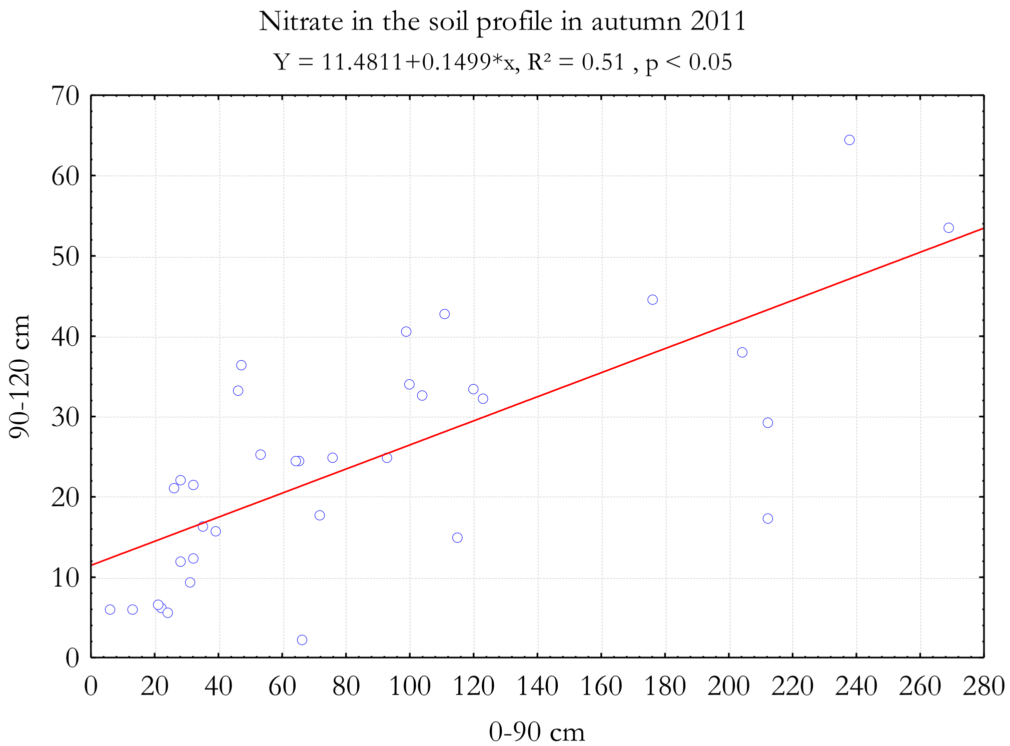


Figure 38: Scatterplot of the nitrate-N (kg/ha) in the soil profile from 0-90 cm versus the nitrate-N (kg/ha) in the soil profile from 90-120 cm in autumn 2011.

Since the deep soil samples are taken on a selection of parcels it is not possible to carry out a statistical analysis for all combinations of derogation, soil texture and cultivated crop. The comparison was limited to grass and maize on all soil textures. The statistical analyses was conducted on the log-transformed data for grass and maize separately.

There is an average of 30 ± 10 kg nitrate-N/ha and 17 ± 12 kg nitrate-N/ha present in the soil layer from 90-120 cm in parcels cultivated with maize and grass respectively. There is no statistical difference between derogation and no derogation parcels cultivated with grass for the soil layer from 0 to 120 cm ($p = 0.49$) nor for parcels cultivated with maize ($p = 0.58$). This is illustrated in Figure 39.

The decreasing amount of nitrate-N regarding to the deeper soil layers, was explained by the little amount of precipitation in autumn 2011 (Figure 244).

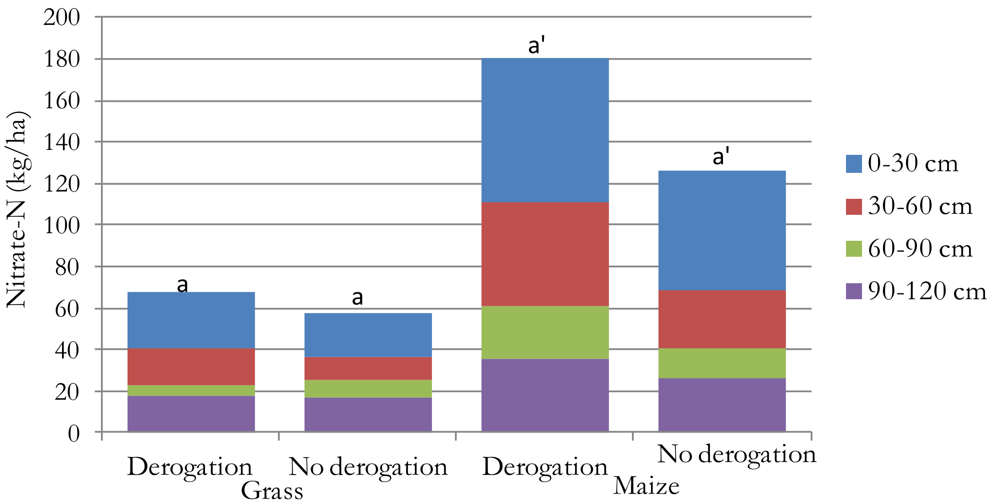


Figure 39: Average nitrate-N (kg/ha) in the 4 soil layers on derogation and no derogation parcels on all soil textures cultivated with grass or maize in autumn 2011. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

6.4 Nitrate in spring 2012

In each parcel of the monitoring network a nitrate sample has been taken from February to April 2012. This nitrate sample consists of three soil layers (0-30 cm, 30-60 cm and 60-90 cm) and provides information on the amount of nitrate in the soil profile after winter and the amount available to the cultivated crop for the next growing season. Every farmer receives a nitrate fertilisation advice, based on the N-INDEX expert system (Geypens *et al.*, 1994). This advice is function of the amount of nitrate in the soil profile, the crop (different crops needs different amounts of nutrients and crops with deeper roots can take up nitrate from deeper layers) and soil characteristics (pH, carbon ...). The soil characteristics are of great importance to estimate the amount of nitrate released by mineralisation. The distribution of nitrate in the soil profile is important: more nitrate in the top layer is desirable for a good water quality, since only few crops are able to take up the nitrate from the layer 60-90 cm. By comparing with the nitrate in autumn 2011, the nitrate sample in spring 2012 is an indication for the amount of nitrate that leached out during winter.

In the next paragraphs, a box plot shows the variation of the groups (derogation and no derogation). The data were log-transformed in order to obtain normality of the dataset. All data are shown visually in bar graphs, which show the distribution of nitrate in the soil profile (0-30 cm, 30-60 cm, 60-90 cm). The results of homogeneous groups are analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data.

The average level of nitrate-N measured in the soil samples in autumn 2011 and spring 2012 is shown in Table 41. The amount of nitrate is given for the combinations of derogation, soil texture and cultivated crop for the total soil profile (0-90 cm) and for each soil layer of 30 cm. Only 189 parcels are listed in this table (instead of 217). Twenty parcels were already fertilised when the soil samples were taken. Moreover, only the parcels are shown where there was no statistical outlier present for autumn 2011, nor for spring 2012. Therefore, values in this Table 41 are not identical for autumn 2011 as shown in Table 38.

The values in bold in Table 41 have high levels of nitrate (> 90 kg N/ha) in autumn 2011. However, since 2011 the allowed maximum nitrate residue in the soil profile from 0-90 cm depends on the cultivated crop, soil type, focus or non-focus area. Therefore, the values in bold (> 90 kg NO_3-N/ha) are indicative. All these combinations with a high nitrate in the soil profile in autumn 2011 had also high levels of nitrate in the soil during spring 2012.

The relation between nitrate-N in the soil profile from 0-90 cm in autumn 2011 and spring 2012 is shown in a scatterplot (Figure 40). A significant correlation ($p \leq 0.05$) exists between nitrate in autumn 2011 and spring 2012. The model explained 31 % of the variance.

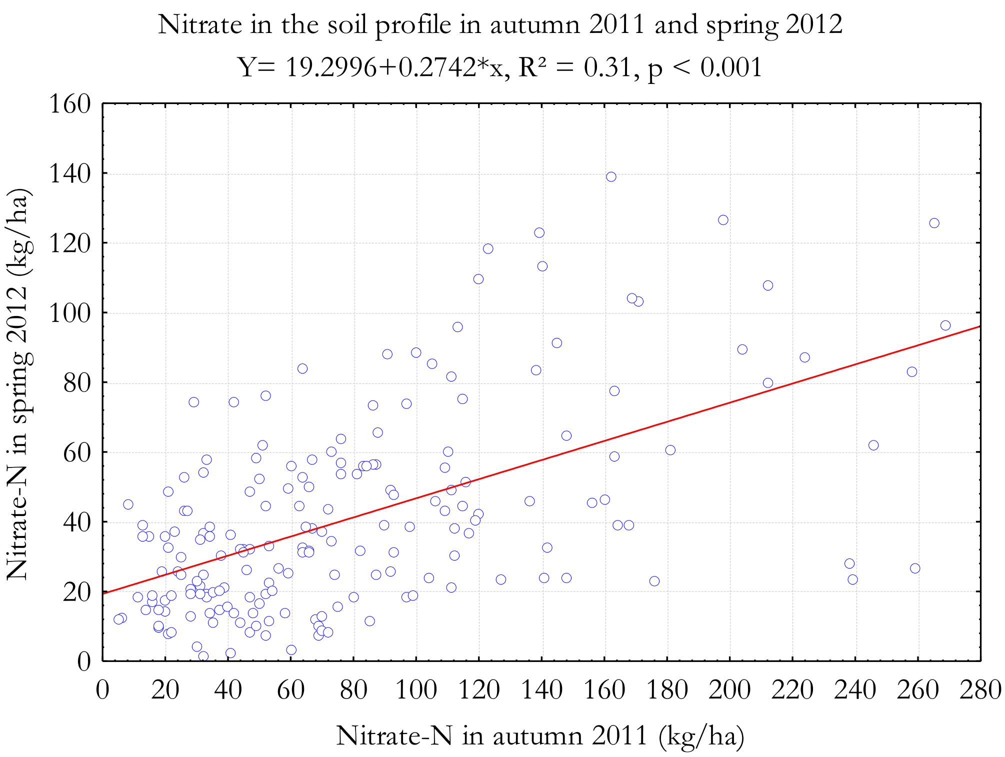


Figure 40: Scatterplot of the nitrate-N (kg/ha) in the soil profile from 0-90 cm in autumn 2011 versus the nitrate-N (kg/ha) in the soil profile from 0-90 cm in spring 2012.

Table 41: Average nitrate-N (kg/ha) in the soil profile in autumn 2011 and spring 2012. The nitrate-N is given for the different combinations of soil texture, cultivated crop and derogation in 2011. For each combination the total amount of nitrate is given as well as for each soil layer (layer 1: 0-30 cm, layer 2: 30-60 cm and layer 3: 60-90 cm). The number of parcels is indicated by "n".

	Soil	Crop 2011	n	Autumn 2011	Nitrate-N (kg/ha) in spring 2012			
				0-90 cm	0-30cm	30-60cm	60-90cm	0-90cm
Derogation			72					
	Clay	Beets	-	-	-	-	-	-
		Grass	7	72	24	21	22	67
		Maize	2	**129**	8	15	33	56
		Winter wheat	-	-	-	-	-	-
	Loam	Beets	-	-	-	-	-	-
		Grass	-	-	-	-	-	-
		Maize	-	-	-	-	-	-
		Winter wheat	-	-	-	-	-	-
	Sand	Beets	-	-	-	-	-	-
		Grass	27	64	12	10	9	31
		Maize	14	**112**	8	16	21	45
		Winter wheat	-	-	-	-	-	-
	Sandy loam	Beets	-	-	-	-	-	-
		Grass	12	33	11	8	6	25
		Maize	10	**104**	9	22	24	55
		Winter wheat	-	-	-	-	-	-
No derogation			117					
	Clay	Beets	-	-	-	-	-	-
		Grass	4	56	13	13	14	40
		Maize	2	**164**	20	36	36	92
		Winter wheat	1	**140**	39	39	35	**113**
		Other	1	**139**	29	54	41	**124**
	Loam	Beets	-	-	-	-	-	-
		Grass	-	-	-	-	-	-
		Maize	5	67	13	16	21	50
		Winter wheat	-	-	-	-	-	-
		Other	2	**182**	16	30	36	82
	Sand	Beets	2	50	25	13	10	48
		Grass	29	52	10	9	12	31
		Maize	29	**107**	10	12	19	41
		Winter wheat	2	59	4	2	2	8
		Other	7	59	4	2	2	8
	Sandy loam	Beets	2	15	11	11	8	30
		Grass	7	41	12	9	6	27
		Maize	11	**90**	14	18	24	56
		Winter wheat	4	55	9	8	8	25
		Other	9	**97**	9	16	23	48

6.4.1 All crops on all soil textures

In the first part of the analysis, the total amount of nitrate in spring 2012 is compared between derogation and no derogation parcels for all crops on all soil textures. On both derogation and no derogation parcels, the nitrate measurements show a large variation (Figure 41).

The average nitrate-N is 44 ± 36 kg/ha for derogation parcels and 47 ± 39 kg/ha for no derogation parcels. The nitrate in the upper soil layer (0-30 cm) is small compared to the other soil layers (Figure 42). Since no derogation crops (vegetables, ...) are present in this dataset, the compared groups are not homogeneous and no statistical analysis was conducted between derogation and no derogation parcels.

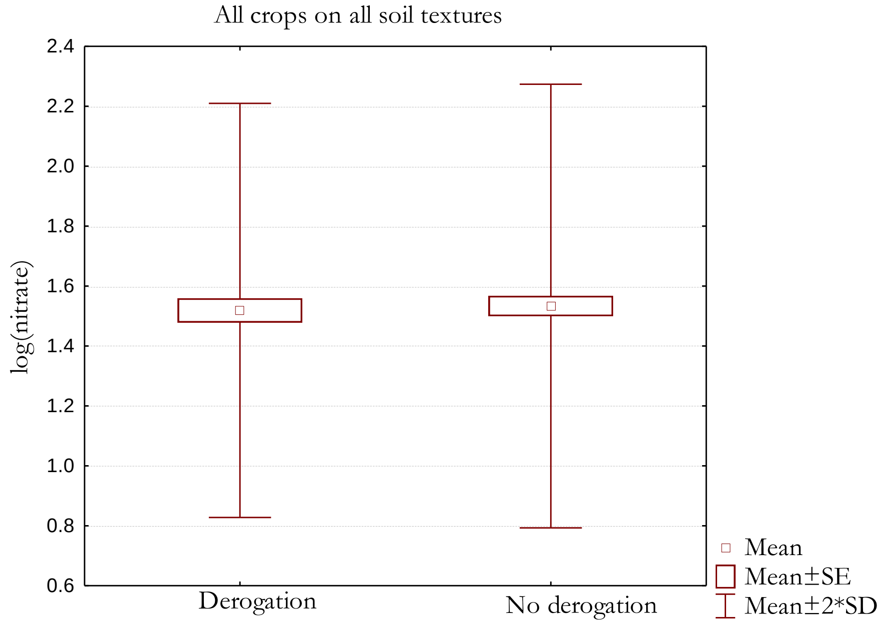


Figure 41: Box plot of log(nitrate-N) for derogation and no derogation parcels with all crops on all soil textures in spring 2012. SE: standard error of the mean. SD: standard deviation.

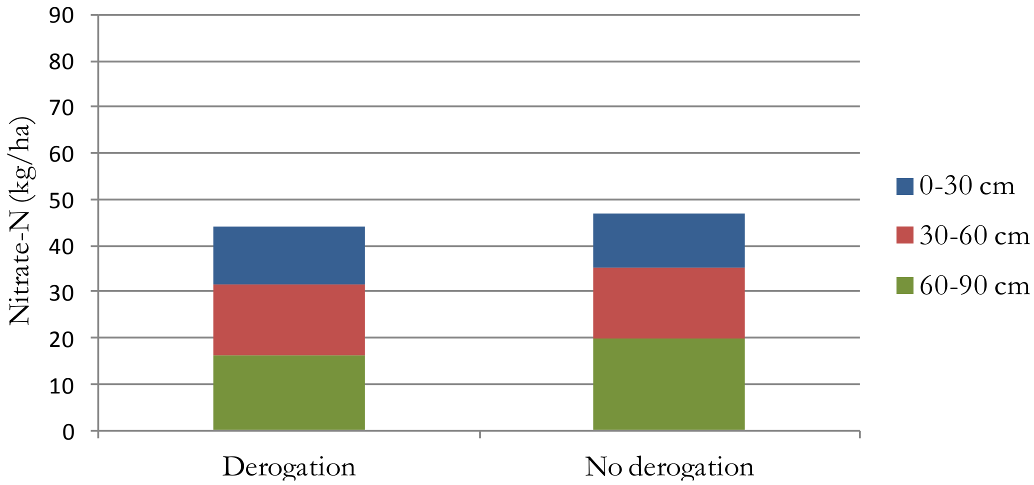


Figure 42: Average nitrate-N (kg/ha) on derogation and no derogation parcels with all crops on all soil textures in spring 2012.

6.4.2 Derogation crops on all soil textures

In a next step derogation and no derogation parcels cultivated with only derogation crops (grass, maize, beets, winter wheat) are compared. The measured nitrate values are highly variable (Figure 43).

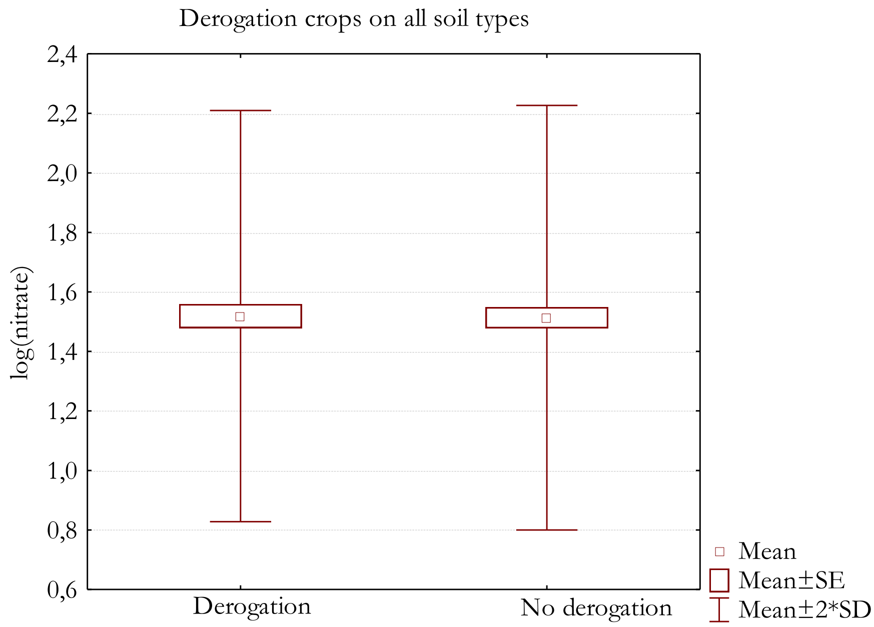


Figure 43: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on all soil textures in spring 2012. SE: standard error of the mean. SD: standard deviation.

No statistically significant difference was found between nitrate measured on derogation (44 ± 36 kg N/ha) and no derogation (44 ± 36 kg N/ha) parcels (Figure 44, p = 0.92). The first soil layer of derogation parcels contains 29 % of the nitrate from 0-90 cm, the second layer 34 % and the third layer 37 %. The first soil layer for no derogation parcels contains 27 % of the nitrate-N from 0-90 cm, the second layer 32 % and the third layer 41 %.

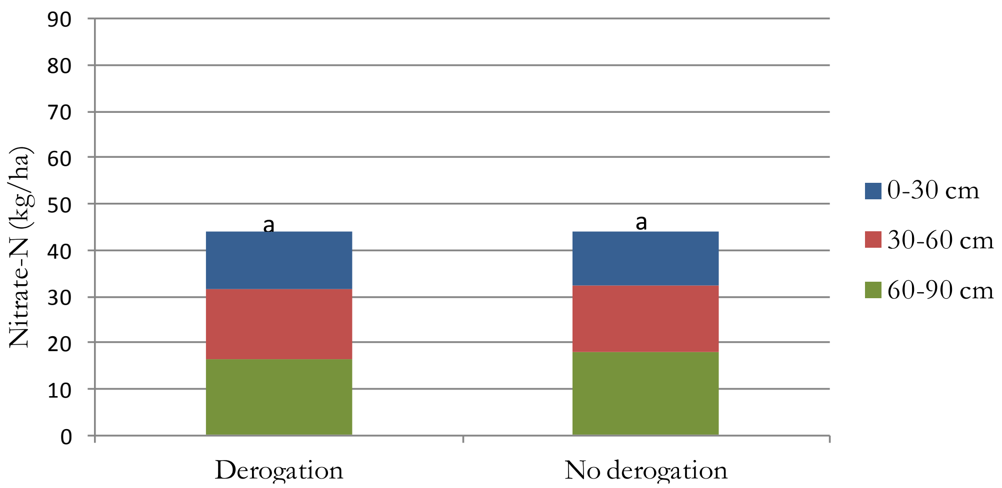


Figure 44: Average nitrate-N (kg/ha) on derogation and no derogation parcels for derogation crops on all soil textures in spring 2012. The results were analysed statistically by means of a one-way ANOVA (p ≤ 0.05) on the log-transformed data. Identical letters indicate no statistical difference.

6.4.3 Derogation crops on sandy soils

In the next step, differences between derogation and no derogation parcels for the most important soil textures and derogation crops are explored. Table 41 shows that the most dominant soil texture in the monitoring network is sand.

The average value of nitrate-N for derogation crops on sandy soils is 43 ± 42 kg/ha for derogation parcels and 42 ± 37 kg/ha for no derogation parcels. The variation within one group is large (Figure 45). The nitrate measured in sandy soils in derogation parcels from 0-90 cm does not differ significantly from the nitrate measured in no derogation parcels (Figure 46, p = 0.77). For the different soil layers separately no significant effect of derogation was found. In all parcels the largest amount of nitrate is present in the soil layer from 60 to 90 cm. The first soil layer of derogation parcels contains 29 % of the nitrate from 0-90 cm, the second layer 34 % and the third layer 37 %. The first soil layer of no derogation parcels contains 26 % of the nitrate-N from 0-90 cm, the second layer 31 % and the third layer 43 %.

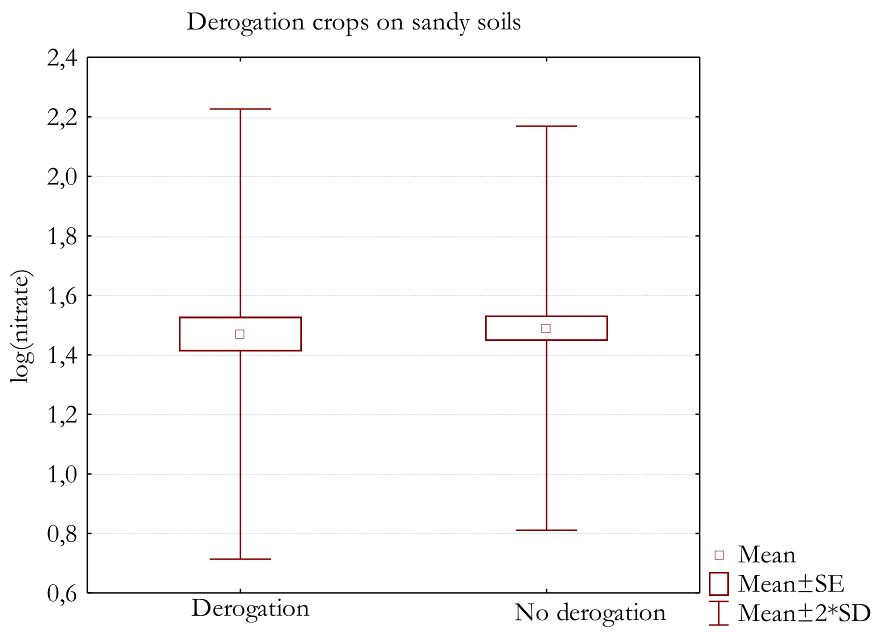


Figure 45: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on sandy soils in spring 2012. SE: standard error of the mean. SD: standard deviation.

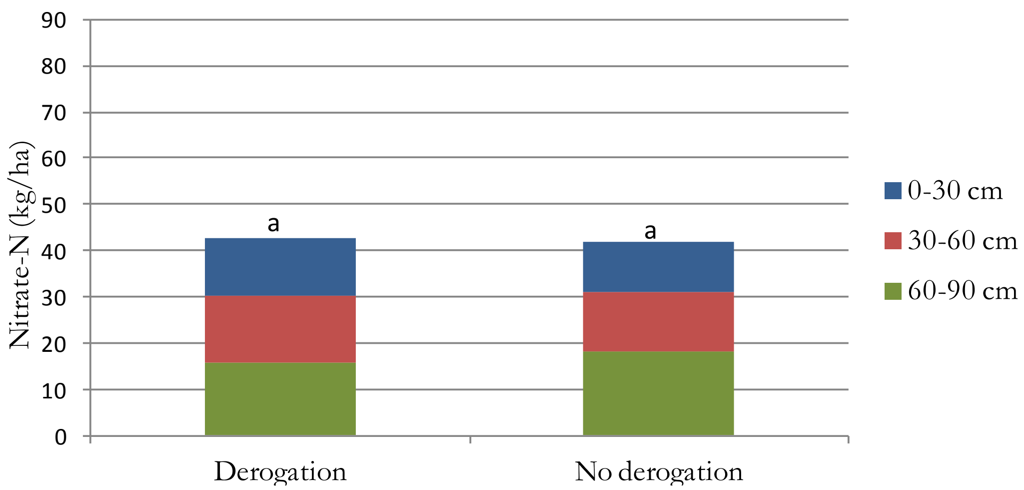


Figure 46: Average nitrate-N (kg/ha) on derogation and no derogation parcels for derogation crops on sandy soils in spring 2012. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.4.3.1 Grass and maize on sandy soils

So far no significant differences were found between derogation and no derogation parcels for derogation crops on sandy soils. Since grass and maize are mostly cultivated on sandy soils, these combinations are compared statistically (Figure 47).

For grass the nitrate-N was 31 ± 34 kg/ha in derogation parcels and 36 ± 33 kg/ha in no derogation parcels. There is no significant difference for nitrate-N in the soil profile between derogation and no derogation parcels cultivated with grass ($p = 0.95$).

For maize the nitrate-N was 59 ± 52 kg/ha in derogation parcels and 49 ± 41 kg/ha in no derogation parcels. There is no significant difference for nitrate-N in the soil profile between derogation and no derogation parcels cultivated with maize ($p = 0.89$).

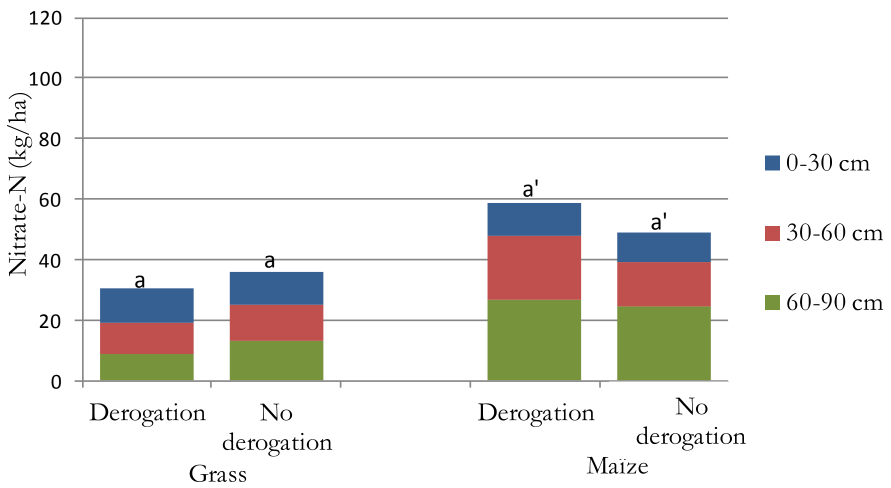


Figure 47: Average nitrate-N (kg/ha) on derogation and no derogation parcels with grass or maize on sandy soils in spring 2012. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

6.4.4 Derogation crops on sandy loam soils

Besides on sandy soils, most of the parcels in the monitoring network are characterized by sandy loam soils (Table 41). In Figure 48 and Figure 49 the analysis is carried out for parcels with derogation crops.

On no derogation parcels on sandy loam soil, a larger variation was observed than on derogation parcels (Figure 48). No significant difference was found between derogation (39 ± 24 kg N/ha) and no derogation parcels (43 ± 36 kg N/ha) on sandy loam soils (Figure 49, $p = 0.80$). Also, for the individual layers, the measured nitrate did not differ between derogation and no derogation parcels for the sandy loam soils, with only derogation crops.

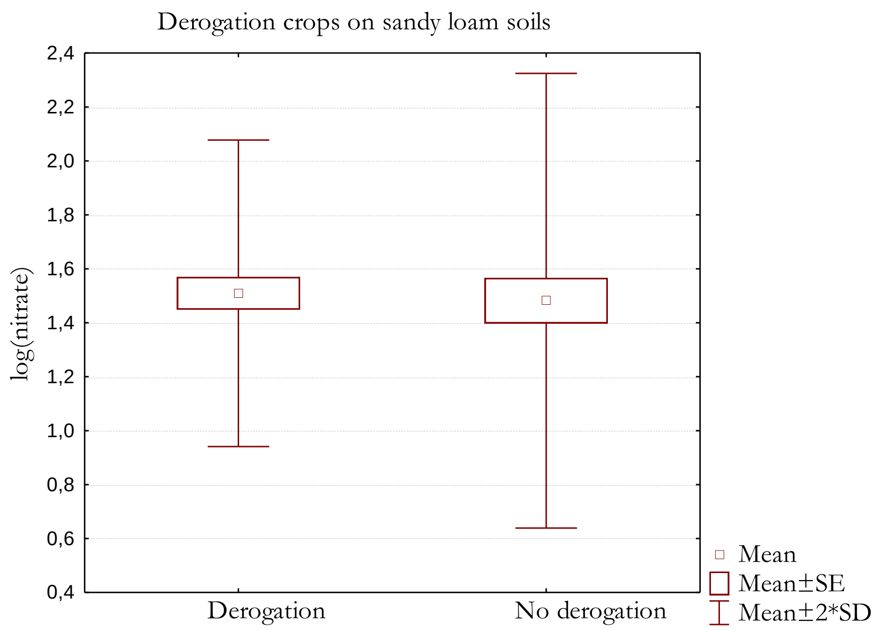


Figure 48: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on sandy loam soils in spring 2012. SE: standard error of the mean. SD: standard deviation.

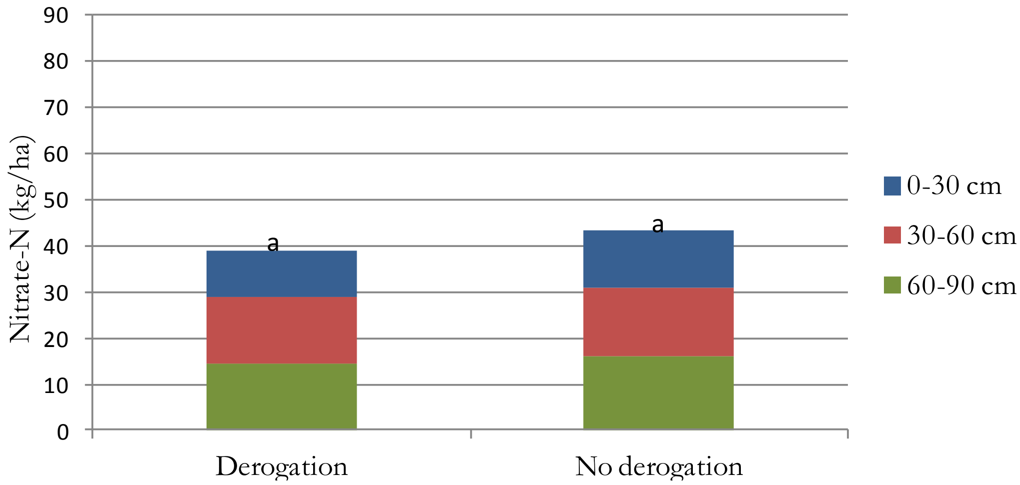


Figure 49: Average nitrate-N (kg/ha) on derogation and no derogation parcels for derogation crops on sandy loam soil in spring 2012. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.4.4.1 Grass and maize on sandy loam soils

Figure 50 shows the average values of nitrate-N in the total soil profile and the different soil layers for grass and maize on sandy loam soils. For grass the average nitrate-N was 25 ± 13 kg/ha in derogation parcels and 27 ± 20 kg/ha in no derogation parcels.

The largest amount of nitrate is present in the upper soil layer 0-30 cm (45 % of the nitrate) for parcels cultivated with grass. There is no significant difference between derogation and no derogation parcels cultivated with grass ($p = 0.57$).

For maize the average nitrate level was 55 ± 22 kg N/ha on derogation parcels and 61 ± 42 kg N/ha on no derogation parcels (Figure 50). There is no significant difference between derogation and no derogation parcels cultivated with maize ($p = 0.88$).

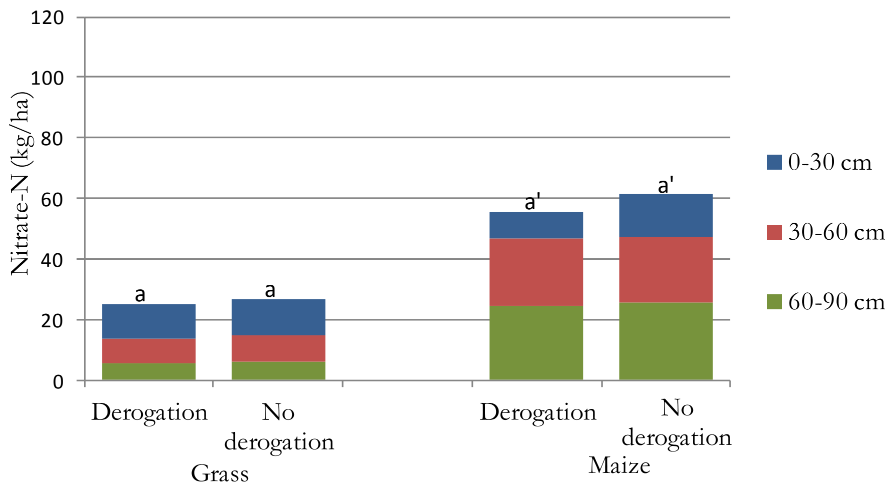


Figure 50: Average nitrate-N (kg/ha) on derogation and no derogation parcels with grass or maize on sandy loam soils in spring 2012. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

6.5 Nitrate in spring 2012, parcels which were continuously under derogation/no derogation during 2009-2012

6.5.1 All crops on all soil textures

In order to verify the long-term impact of derogation on the nitrate in the soil spring 2012, only the parcels which were continuously under derogation/no derogation during 2009-2012 were retained for statistical analysis.

In the next paragraphs, a box plot shows the variation of the groups (derogation and no derogation). The data were log-transformed in order to obtain normality of the dataset. All data are shown visually in bar graphs, which show the distribution of nitrate in the soil profile (0-30 cm, 30-60 cm, 60-90 cm). The results of homogeneous groups are analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data.

The values in bold in Table 42 have high levels of nitrate in autumn 2011 (> 90 kg N/ha). However, since 2011 the allowed maximum nitrate residue in the soil profile from 0-90 cm depends on the cultivated crop, soil type, focus or non-focus area. Therefore, the values in bold (> 90 kg NO_3-N/ha) are indicative.

Table 42: Average nitrate-N (kg/ha) in the soil profile in autumn 2011 and spring 2012 for parcels continuously under derogation/no derogation during 2009-2012. The nitrate-N is given for the different combinations of soil texture, cultivated crop and derogation. For each combination the total amount of nitrate is given as well as for each soil layer. The number of parcels is indicated by "n".

	Soil	Crop 2011	n	Autumn 2011	Nitrate-N (kg/ha) spring 2012			
				0-90 cm	0-30cm	30-60cm	60-90cm	0-90cm
Derogation			52					
	Clay	Beets	-	-	-	-	-	-
		Grass	6	76	23	21	22	66
		Maize	1	-	10	23	47	80
		Winter wheat	-	-	-	-	-	-
	Loam	Beets	-	-	-	-	-	-
		Grass	-	-	-	-	-	-
		Maize	-	-	-	-	-	-
		Winter wheat	-	-	-	-	-	-
	Sand	Beets	-	-	-	-	-	-
		Grass	20	70	15	13	10	38
		Maize	10	**114**	11	23	29	63
		Winter wheat	-	-	-	-	-	-
	Sandy loam	Beets	-	-	-	-	-	-
		Grass	10	39	12	8	6	26
		Maize	5	**105**	9	19	18	46
		Winter wheat	-	-	-	-	-	-
No derogation			71					
	Clay	Beets	-	-	-	-	-	-
		Grass	3	56	11	12	13	35
		Maize	1	**164**	16	26	34	75
		Winter wheat	1	**140**	39	39	35	**113**
		Other	-		-	-	-	-
	Loam	Beets	-	-	-	-	-	-
		Grass	-	5	-	-	-	-
		Maize	4	65	11	16	21	48
		Winter wheat	-	-	-	-	-	-
		Other	-	265	-	-	-	-
	Sand	Beets	2	67	25	13	10	48
		Grass	18	57	11	15	16	42
		Maize	19	**113**	10	13	27	49
		Winter wheat	1	59	4	3	4	10
		Other	1	**119**	4	3	3	10
	Sandy loam	Beets	1	16	8	6	5	19
		Grass	7	43	12	9	6	27
		Maize	9	**99**	17	26	30	72
		Winter wheat	2	69	12	11	13	36
		Other	2	88	4	7	15	26

On both derogation and no derogation parcels, a large variation in nitrate in spring 2012 can be noticed (Figure 51). Since no derogation crops (vegetables, ...) are present in this dataset, the compared groups are not homogeneous and no statistical analysis was conducted between derogation and no derogation parcels.

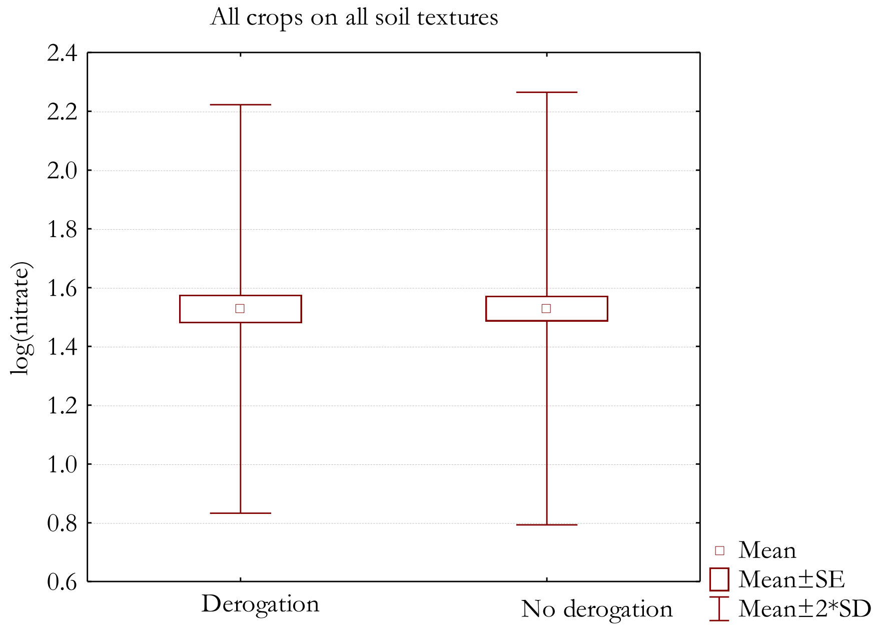


Figure 51: Box plot of log(nitrate-N) for derogation and no derogation parcels on all soil textures in spring 2012, including only parcels which were continuously under derogation/no derogation during 2009-2012. SE: standard error of the mean. SD: standard deviation.

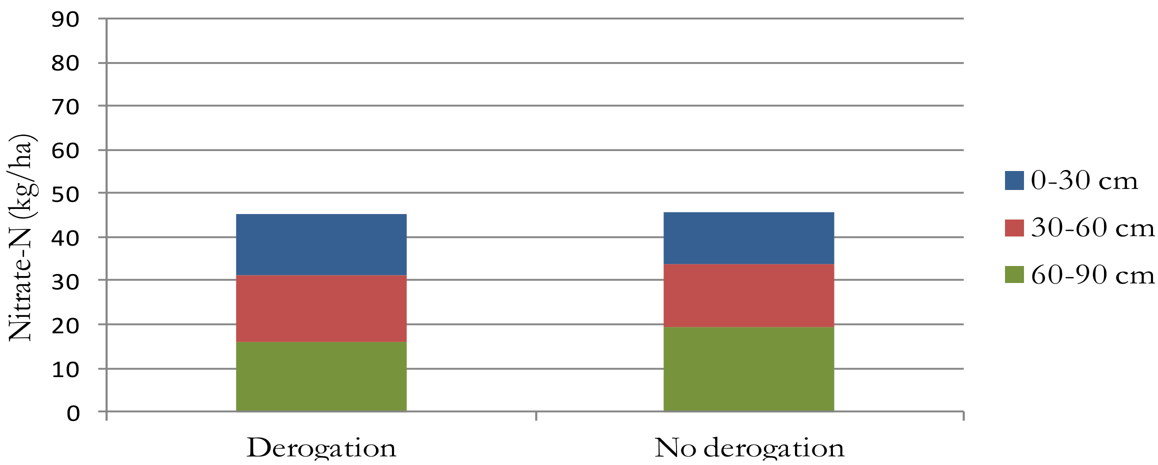


Figure 52: Average nitrate-N (kg/ha) on derogation and no derogation parcels in spring 2012 for all crops on all soil textures, including only parcels which were continuously under derogation/no derogation during 2009-2012.

The average nitrate-N is 45 ± 38 kg/ha on derogation parcels and 46 ± 37 kg/ha on no derogation parcels (Figure 52). Due to leaching after winter, most of the nitrate is located in the soil layer from 60-90 cm.

6.5.2 Derogation crops on all soil textures

Figure 53 shows a large variation in nitrate in both derogation and no derogation parcels cultivated with derogation crops. The average nitrate-N is 45 ± 38 kg/ha in derogation parcels and 47 ± 37 kg/ha in no derogation parcels. There is no significant difference between derogation and no derogation parcels (Figure 54, $p = 0.83$). Most of the nitrate is located in the soil layer from 60-90 cm.

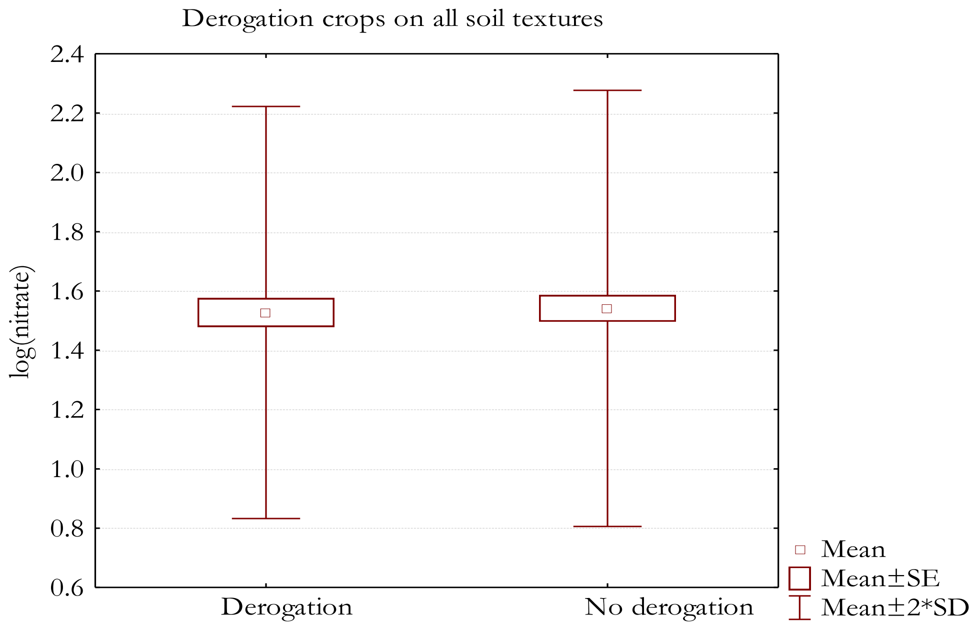


Figure 53: Box plot of log(nitrate-N) for derogation and no derogation parcels in spring 2012, for derogation crops on all soil textures, including only parcels which were continuously under derogation/no derogation during 2009-2012. SE: standard error of the mean. SD: standard deviation.

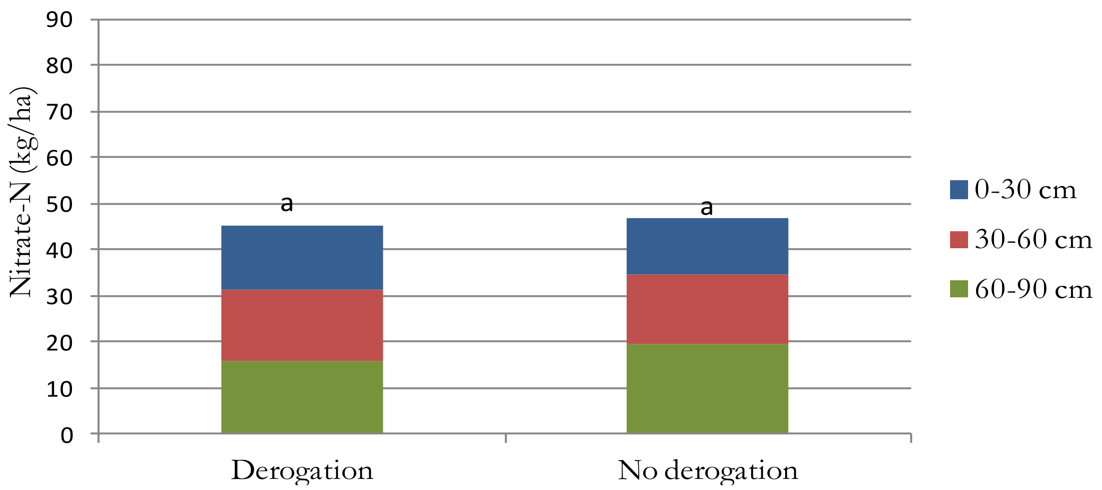


Figure 54: Average nitrate-N (kg/ha) on derogation and no derogation parcels in spring 2012 for derogation crops on all soil textures, including only parcels which were continuously under derogation/no derogation during 2009-2012. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.5.3 Derogation crops on sandy soils

On both derogation and no derogation parcels cultivated with derogation crops on sandy soils, a large variation in nitrate in spring 2012 can be noticed (Figure 55).

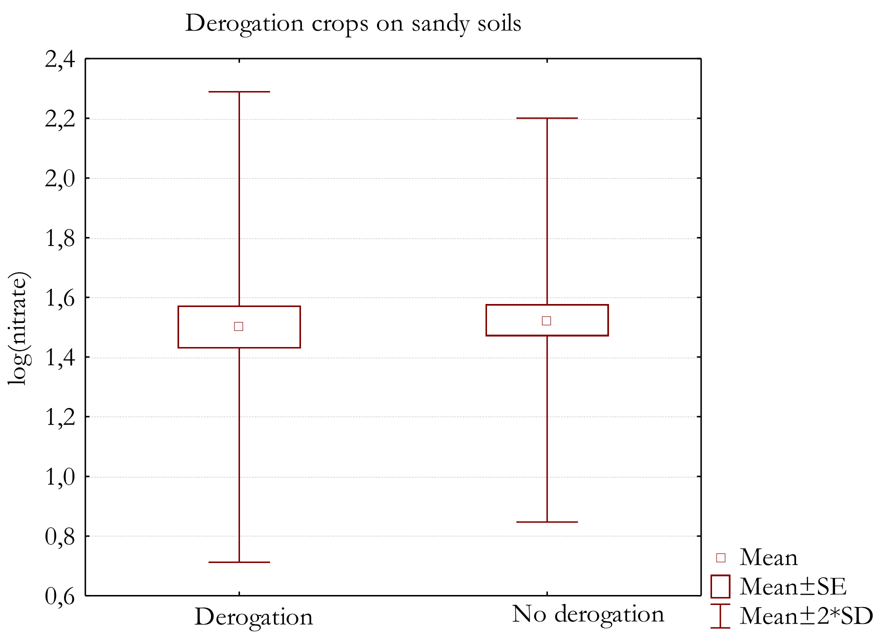


Figure 55: Box plot of log(nitrate-N) for derogation and no derogation parcels in spring 2012, for derogation crops on sandy soils, including only parcels which were continuously under derogation/no derogation during 2009-2012. SE: standard error of the mean. SD: standard deviation.

The average nitrate-N is 46 ± 46 kg/ha on derogation parcels and 44 ± 38 kg/ha on no derogation parcels. There is no significant effect of derogation on nitrate in the soil (0-90 cm) in spring 2012 (Figure 56, p = 0.79). Most of the nitrate is located in the soil layer from 60-90 cm.

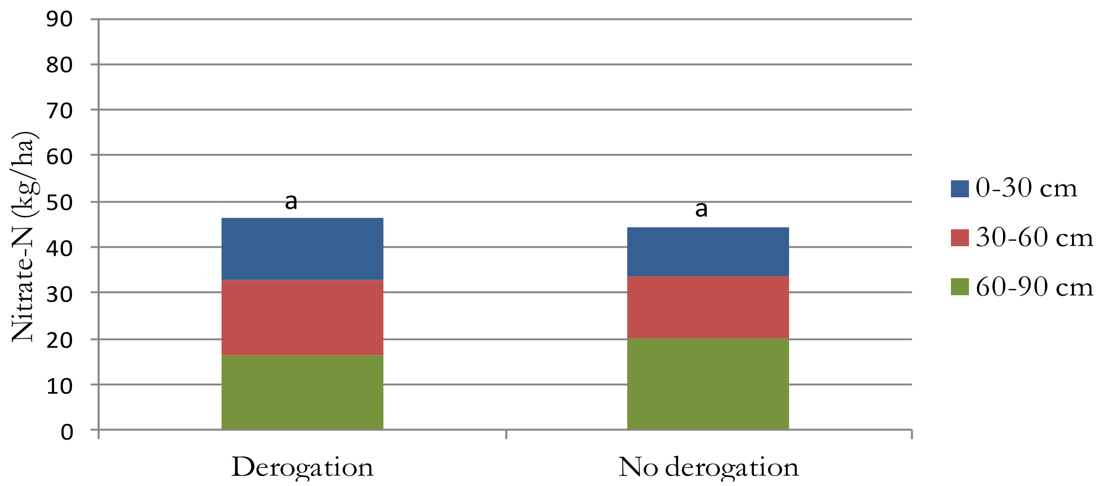


Figure 56: Average nitrate-N (kg/ha) on derogation and no derogation parcels in spring 2012 for derogation crops on sandy soils, including only parcels which were continuously under derogation/no derogation during 2009-2012. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.5.3.1 Grass and maize on sandy soils

On sandy soils cultivated with grass, the average nitrate-N is 38 ± 38 kg/ha on derogation parcels and 42 ± 39 kg/ha on no derogation parcels. There is no significant effect of derogation on the parcels cultivated with grass (p = 0.86).

For maize, the average nitrate-N is 63 ± 57 kg N/ha on derogation parcels and 49 ± 40 kg N/ha on no derogation parcels. (Figure 57). There is no significant effect of derogation on the parcels cultivated with maize (p = 0.87).

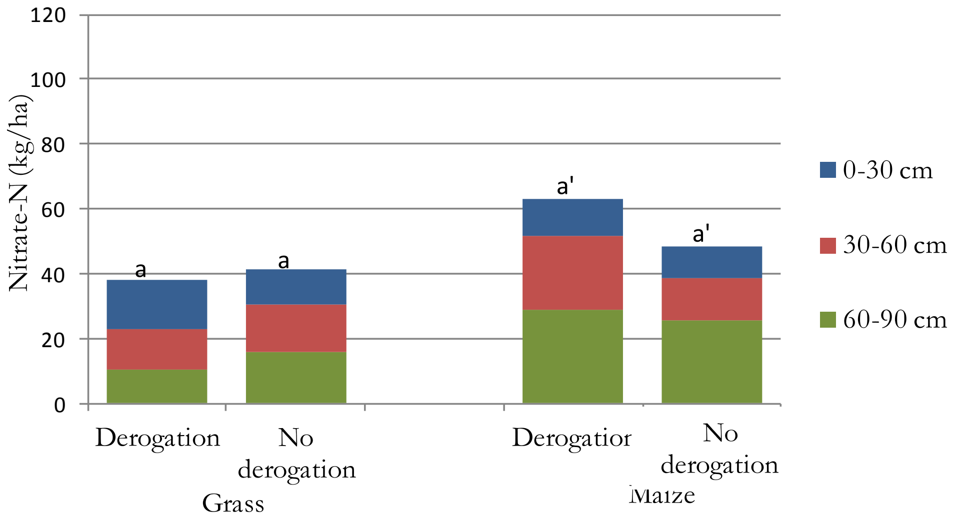


Figure 57: Average nitrate-N (kg/ha) on derogation and no derogation parcels in spring 2012 for grass and maize and on sandy soils, including only parcels which were continuously under derogation/no derogation during 2009-2012. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

6.5.4 Derogation crops on sandy loam soils

On sandy loam soils the variation on no derogation parcels cultivated with derogation crops is larger (Figure 58).

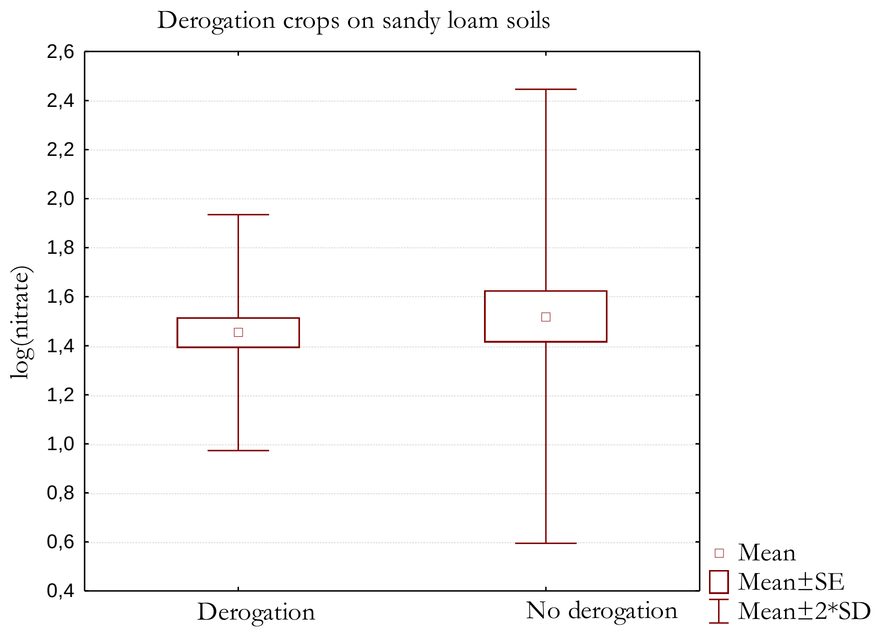


Figure 58: Box plot of log(nitrate-N) for derogation and no derogation parcels in spring 2012, for derogation crops on sandy loam soils, including only parcels which were continuously under derogation/no derogation during 2009-2011. SE: standard error of the mean. SD: standard deviation.

There is no significant ($p = 0.62$) difference in average nitrate-N between derogation (32 ± 17 kg/ha) and no derogation parcels (49 ± 39 kg/ha) (Figure 59).

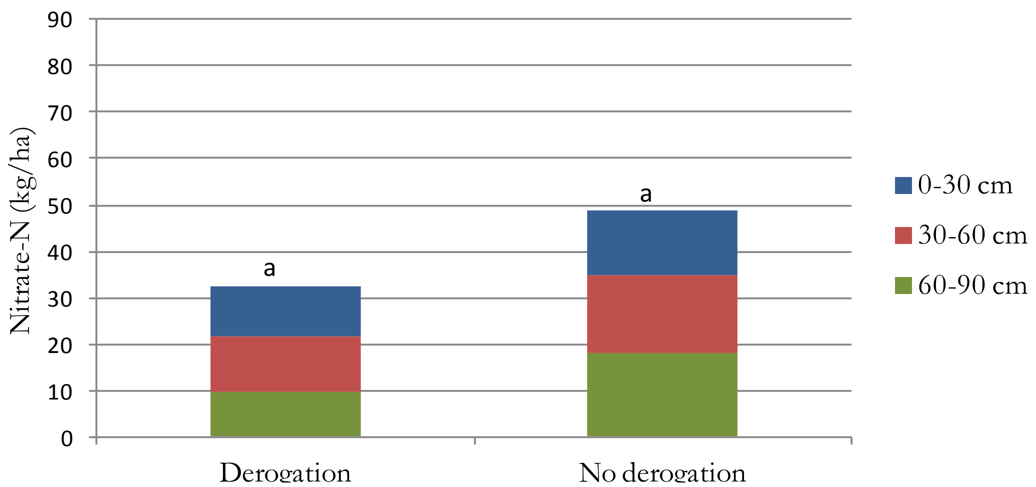


Figure 59: Average nitrate-N (kg/ha) on derogation and no derogation parcels in spring 2012 for derogation crops on sandy loam soils, including only parcels which were continuously under derogation/no derogation during 2009-2012. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.5.4.1 Grass and maize on sandy loam soils

On sandy loam soils there are only 10 parcels cultivated with grass under derogation, 7 parcels cultivated with grass under no derogation, 5 parcels cultivated with maize under derogation and 9 parcels cultivated with maize under no derogation. Due to the small sample size, no statistical analysis is done.

6.6 Nitrate in spring 2012 in the deeper soil layer

In spring 2012, 33 parcels were also sampled from 90 to 120 cm ("deep soil sample"). The objective was to have 40 deep soil samples, however 7 parcels were already fertilised at the moment of sampling. In this deep soil layer the amount of nitrate-N is measured. These deep soil samples are taken simultaneously with the nitrate sample (from 0 to 90 cm) after winter. Data were considered as statistical outlier when exceeding the average plus 2 times the standard deviation. Three statistical outliers were removed: 186 kg N/ha for a derogation parcel cultivated with maize, 161 kg N/ha for a no derogation parcel cultivated with maize and 151 kg N/ha for a no derogation parcel cultivated with grass. These parcels with a statistical outlier of the deeper soil layer in spring 2012 were no statistical outliers in autumn 2011.

The average nitrate-N of the soil layer from 90-120 cm for grass parcels under derogation is 16 ± 14 kg/ha and for parcels with no derogation 31 ± 24 kg/ha. The effect of derogation is not significant ($p = 0.19$). The average nitrate-N of the soil layer from 90-120 cm for maize parcels under derogation is 52 ± 25 kg/ha and 36 ± 15 kg/ha without derogation. There is no significant effect of derogation on the average nitrate-N of the soil layer from 90-120 cm for maize parcels ($p = 0.24$) (Figure 60). Despite the lack of statistical significant differences between derogation and no derogation parcels, it seems for grass parcels that the soil layer 90-120 cm contains less nitrate-N on derogation parcels than on no derogation parcels, whilst on maize parcels the opposite is observed.

Most of the nitrate in the soil profile in spring 2012 is located in the soil layer from 90-120 cm. For grass parcels under derogation, 40 % of the nitrate in the layer 0-120 cm is located in the soil layer from 90-120 cm. For grass parcels with no derogation 51 % of the nitrate in the layer 0-120 cm is located in the soil layer from 90-120 cm. For maize parcels under derogation, 53 % of the nitrate in the layer 0-120 cm is located in the soil layer from 90-120 cm and for maize parcels with no derogation 45 %. During winter nitrate moved down (leached) and deeper soil layers were enriched regarding the situation in autumn 2011. December 2011 was a month with more rainfall as normal (Figure 244).

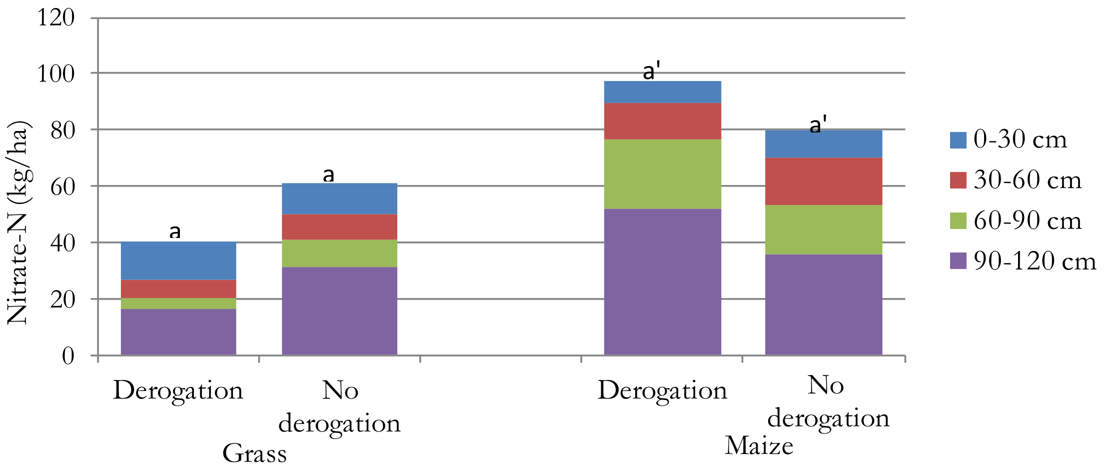


Figure 60: Average nitrate-N (kg/ha) in the 4 soil layers on derogation and no derogation parcels on all soil textures cultivated with grass or maize in spring 2012. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

6.7 Nitrate in autumn 2012

Between 1st of October and 15th of November, soil samples were taken in order to determine the amount of nitrate in the soil profile from 0 to 30, 30 to 60 and 60 to 90 cm. In the next paragraphs, a box plot shows the variation of the groups (derogation and no derogation). The data were log-transformed in order to obtain normality of the dataset. All data are shown visually in bar graphs, which show the distribution of nitrate in the soil profile (0-30 cm, 30-60 cm, 60-90 cm). The results of homogeneous groups are analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data.

Ten parcels with a nitrate level exceeding the average plus 2 times the standard deviation are considered statistical outliers and are excluded for further statistical analysis. These numbers range from 166 to 303 kg N/ha and include 5 derogation and 5 no derogation parcels. Three parcels were converted grass parcels, conversion in spring 2012 and cultivation of maize (303 kg N/ha, 240 kg N/ha and 226 kg N/ha). One parcel was cultivated with grass and turned into a maize parcel in spring 2011 (296 kg N/ha). For 2 parcels cultivated with maize (both 166 kg N/ha) a lower yield was mentioned by the farmers. On one parcel sugar beets were cultivated (235 kg N/ha) but the yield was not good, only 60 ton/ha. Winter wheat was sown after harvest. Time between harvest and sampling of nitrate residue was 1 month. The minor harvest, the labour of the soil, the remaining crop residues (leaves) and the application of chicken manure (with a rather slow release) in spring can be responsible for the high nitrate residue. Another parcel was fertilised (organic and mineral) in august, before planting the leek, resulting in a high residue of 261 kg N/ha.

The average nitrate in the soil profile for each soil layer and for different combinations of crop, soil texture and derogation is shown in Table 43. The values in bold are average nitrate residues larger than 90 kg NO_3-N/ha. However, since 2011 the allowed maximum nitrate residue in the soil profile from 0-90 cm depends on the cultivated crop, soil type, focus or non-focus area. Therefore, the values in bold in Table 43 (> 90 kg NO_3-N/ha) are indicative.

For some parcels cultivated with winter wheat the nitrate residue was high although winter wheat is a crop with a lower average nitrate residue. The nitrate residue on the parcel cultivated with winter wheat on loam soil was 137 kg N/ha. The winter wheat was harvested mid August and a cover crop (Italian rye-grass) was sown mid September, but in August solid animal manure was applied (50 ton/ha).

Table 43: Average nitrate-N (kg/ha) in the soil profile in autumn 2012 for parcels under derogation/no derogation in 2012. The nitrate-N is given for the different combinations of soil texture, cultivated crop and derogation. For each combination the total amount of nitrate is given as well as for each soil layer. The number of parcels is indicated by "n".

	Soil	Crop 2012	n	Nitrate-N (kg/ha) in autumn 2012			
				0-30cm	30-60cm	60-90cm	0-90cm
Derogation			87				
	Clay	Beets	-	-	-	-	-
		Grass	7	22	14	11	48
		Maize	1	7	13	11	31
		Winter wheat	-	-	-	-	-
	Loam	Beets	-	-	-	-	-
		Grass	-	-	-	-	-
		Maize	-	-	-	-	-
		Winter wheat	-	-	-	-	-
	Sand	Beets	1	26	16	25	67
		Grass	34	13	15	12	41
		Maize	20	24	24	20	68
		Winter wheat	-	-	-	-	-
	Sandy loam	Beets	-	-	-	-	-
		Grass	16	11	6	5	23
		Maize	8	29	28	24	80
		Winter wheat	-	-	-	-	-
No derogation			116				
	Clay	Beets	-	-	-	-	-
		Grass	3	19	7	9	36
		Maize	3	18	19	22	59
		Winter wheat	3	16	22	20	58
		Other	-	-	-	-	-
	Loam	Beets	-	-	-	-	-
		Grass	1	6	3	3	12
		Maize	4	25	11	5	41
		Winter wheat	1	27	68	42	**137**
		Other	1	19	27	27	73
	Sand	Beets	-	-	-	-	-
		Grass	27	11	11	10	32
		Maize	25	18	20	19	57
		Winter wheat	4	35	43	30	**108**
		Other	6	11	16	28	55
	Sandy loam	Beets	-	-	-	-	-
		Grass	7	17	10	11	38
		Maize	20	17	21	17	54
		Winter wheat	2	6	7	3	16
		Other	9	11	17	17	45

On sandy soil, 4 parcels were cultivated with winter wheat. On one parcel no cover crop was sown (93 kg N/ha). On 2 parcels a cover crop was sown and no fertilisation was applied after harvest (98 and 130 kg N/ha). On the 4th parcel (109 kg N/ha) white mustard was sown as cover crop shortly after harvest, but in autumn winter wheat was sown again. So at time of sampling the nitrate residue (November 2nd), mineralisation of white mustard could be measured.

6.7.1 All crops on all soil textures

For derogation and no derogation parcels, a large variation in nitrate in the soil profile (0-90 cm) is observed (Figure 61), ranging from 5 to 151 kg N/ha for derogation parcels and 6 to 153 kg N/ha for no derogation parcels.

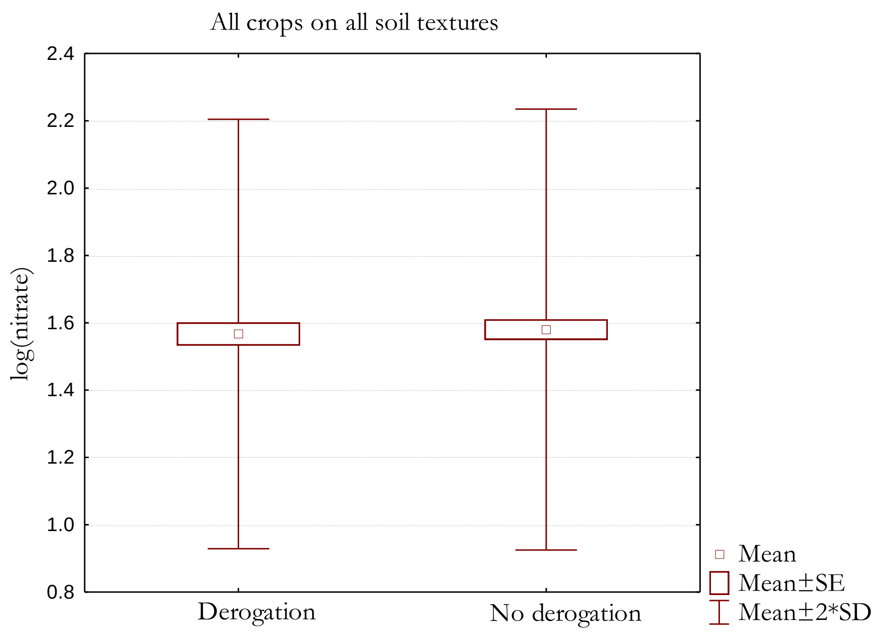


Figure 61: Box plot of log(nitrate-N) for derogation and no derogation parcels for all crops on all soil textures in autumn 2012. SE: standard error of the mean. SD: standard deviation.

The average nitrate-N is 48 (± 37) kg N/ha for derogation parcels and 49 (± 34) kg N/ha for no derogation parcels (Figure 62). The amount of nitrate in each soil layer is approximately equal. Since no derogation crops (vegetables, ...) are present in this dataset, the compared groups are not homogeneous and no statistical analysis was conducted between derogation and no derogation parcels.

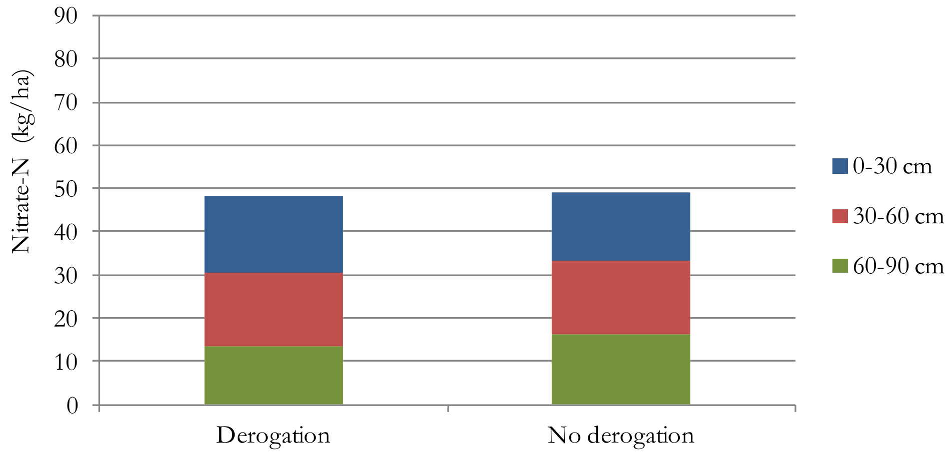


Figure 62: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2012 for all crops on all soil textures.

6.7.2 Derogation crops on all soil textures

The further analysis is limited to parcels with derogation crops (maize, grass, beets and winter wheat) only.

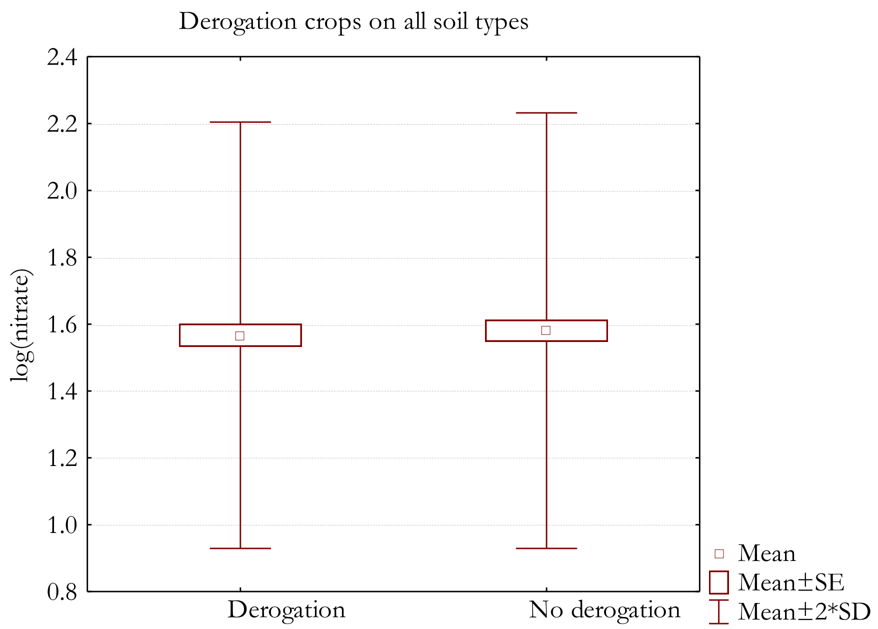


Figure 63: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on all soil textures in autumn 2012. SE: standard error of the mean. SD: standard deviation.

There is a large variance in nitrate in the soil (0-90 cm) for derogation and no derogation parcels (Figure 63) and no statistically significant difference ($p = 0.91$) can be found between derogation (48 ± 37 kg N/ha) and no derogation parcels (49 ± 33 kg N/ha) (Figure 64).

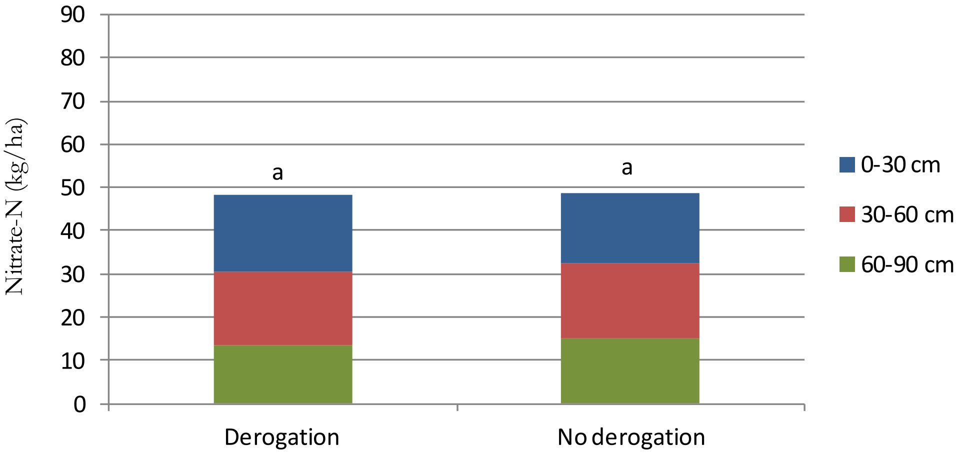


Figure 64: Average nitrate-N (kg/ha) on derogation and no derogation parcels for derogation crops on all soil textures in autumn 2012. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

The nitrate residue between derogation and no derogation parcels will be statistically analysed for specific soil textures. Since derogation is mostly requested on sandy and sandy loam soil textures, these soil textures are discussed in the following paragraphs. For the other soil textures, the data are listed in Table 43.

6.7.3 Derogation crops on sandy soils

Derogation is mostly requested on sandy soils (Table 43). There is a large variance for the different parcels for derogation and no derogation parcels (Figure 65).

No statistically significant difference is found ($p = 0.70$) between derogation (51 ± 38 kg N/ha) and no derogation parcels (49 ± 36 kg N/ha) (Figure 66). The nitrate-N was more or less equally distributed over the 3 soil layers.

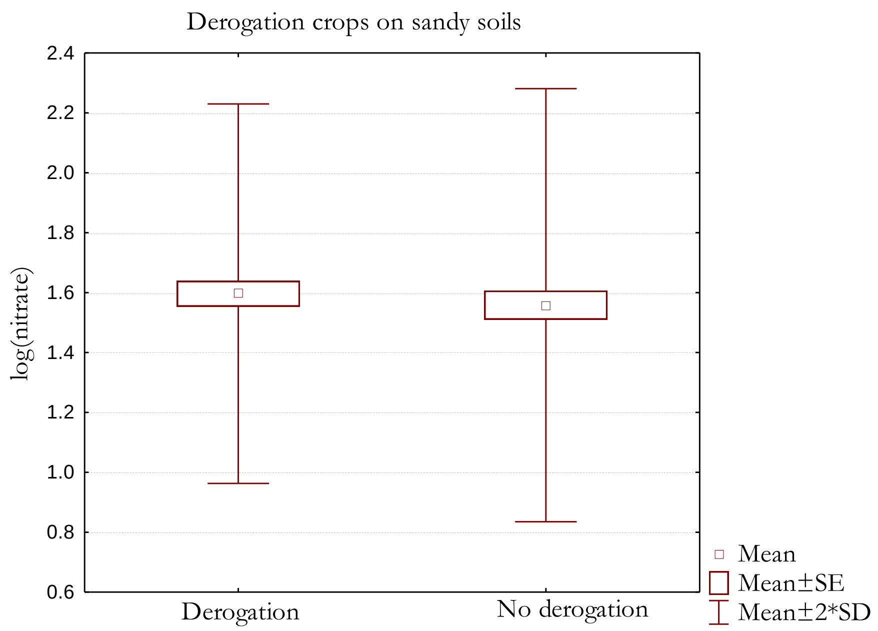


Figure 65: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on sandy soils in autumn 2012. SE: standard error of the mean. SD: standard deviation.

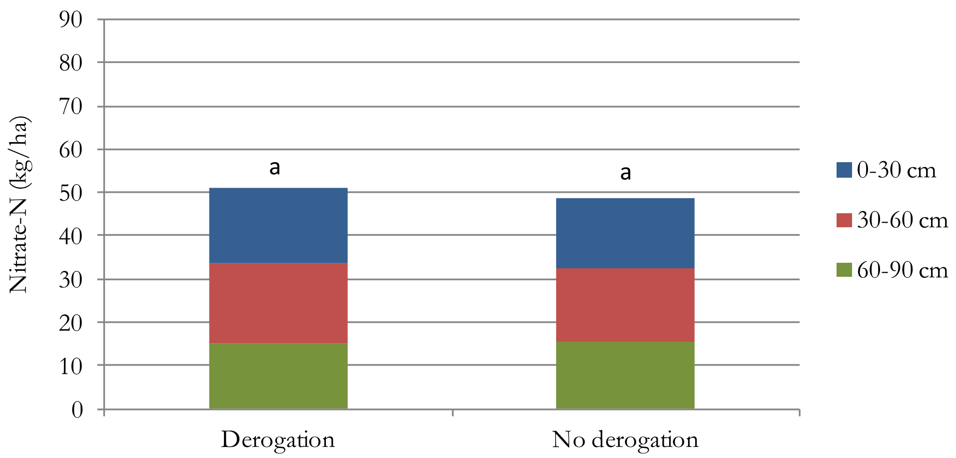


Figure 66: Average nitrate-N (kg/ha) on derogation and no derogation parcels for derogation crops on sandy soils in autumn 2012. The results were analysed statistically by means of a one-way ANOVA (p ≤ 0.05) on the log-transformed data. Identical letters indicate no statistical difference.

6.7.3.1 Grass and maize on sandy soils

Table 43 shows that the majority of derogation parcels have a sandy soil and are cultivated with grass or maize. The average nitrate residue levels are shown in Figure 67.

A statistical analysis was carried out for grass and maize separately. No significant differences exist between derogation and no derogation parcels cultivated with grass ($p = 0.23$) or maize ($p = 0.36$).

For parcels cultivated with grass on sandy soils, the derogation parcels have a nitrate residue of 41 ± 33 kg N/ha for derogation, while the no derogation parcels have a nitrate residue of 32 ± 23 kg N/ha. The derogation parcels cultivated with maize have an average nitrate residue of 68 ± 42 kg N/ha versus 57 ± 36 kg N/ha for no derogation parcels cultivated with maize.

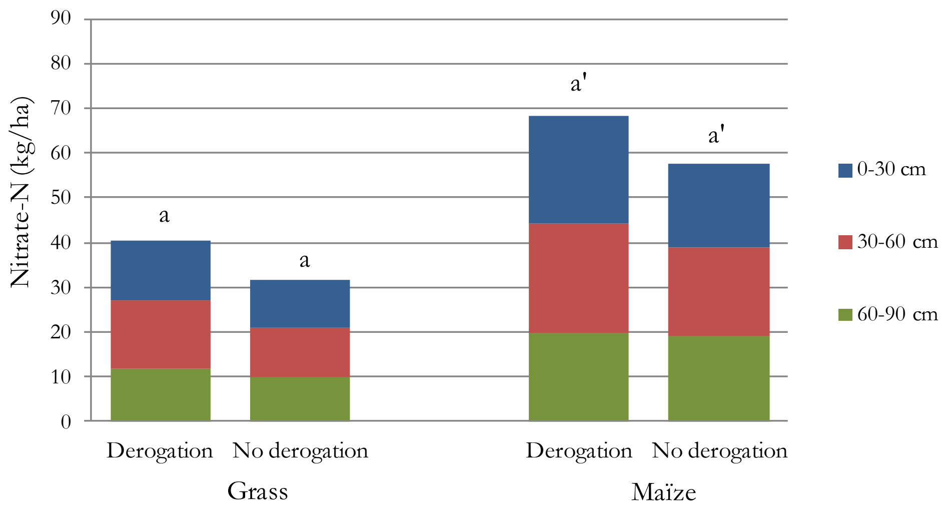


Figure 67: Average nitrate-N (kg/ha) on derogation and no derogation parcels cultivated with grass or maize on sandy soils in autumn 2012. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

6.7.4 Derogation crops on sandy loam soils

Derogation is common on sandy loam soils as well. The nitrate residue for derogation crops on sandy loam soils is shown in Figure 69.

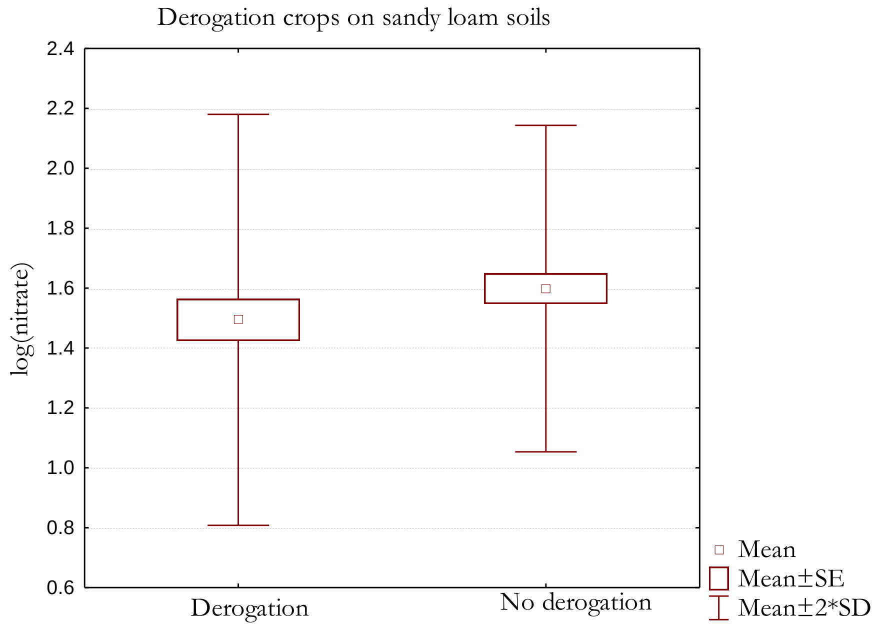


Figure 68: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on sandy loam soils in autumn 2012. SE: standard error of the mean. SD: standard deviation.

There is no significant difference between derogation (42 ± 35 kg/ha) and no derogation (48 ± 29 kg/ha) parcels (p = 0.53). The variation in the nitrate levels is high (Figure 68).

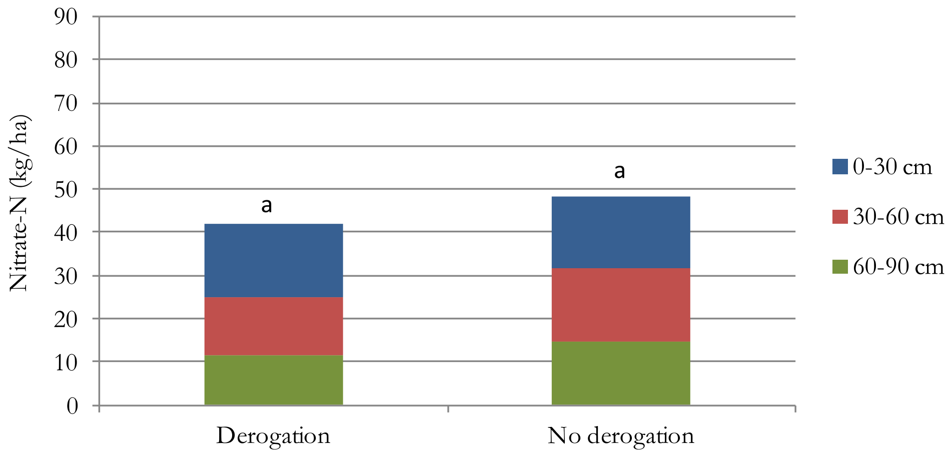


Figure 69: Average nitrate-N (kg/ha) on derogation and no derogation parcels for derogation crops on sandy loam soils in autumn 2012. The results were analysed statistically by means of a one-way ANOVA (p ≤ 0.05) on the log-transformed data. Identical letters indicate no statistical difference.

6.7.4.1 Grass and maize on sandy loam soils

Since grass and maize on sandy loam soils are common combinations in the monitoring network, a separate statistical analysis is carried out. The average values for grass and maize with and without derogation on a sandy loam soil are shown in Figure 70. A statistical analysis was carried out for grass and maize separately. There is no significant difference between derogation and no derogation parcels cultivated with grass ($p = 0.05$) or maize ($p = 0.06$). The average level of nitrate-N for derogation parcels cultivated with grass is 24 ± 10 kg/ha versus 38 ± 22 kg/ha for no derogation parcels. The average level of nitrate-N for derogation parcels cultivated with maize is 80 ± 36 kg/ha versus 54 ± 30 kg/ha for no derogation parcels.

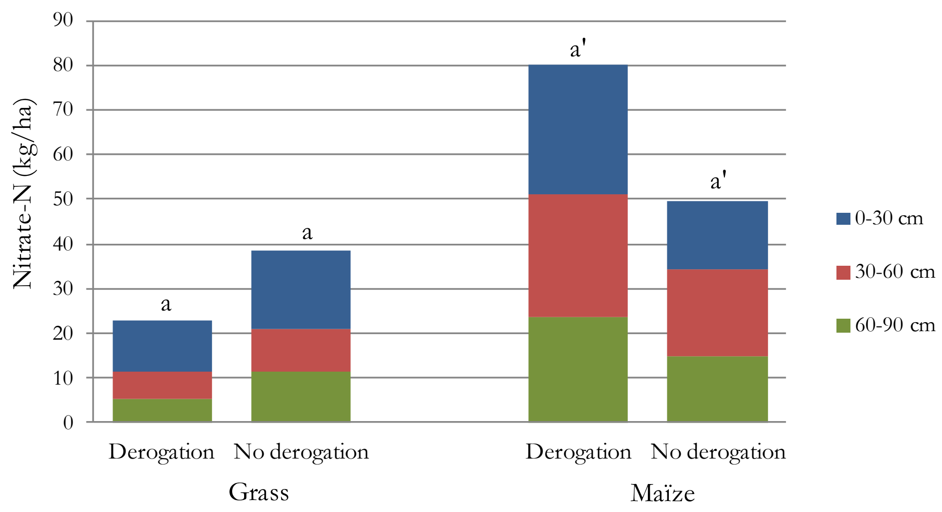


Figure 70: Average nitrate-N (kg/ha) on derogation and no derogation parcels cultivated with grass or maize on sandy loam soils in autumn 2012. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

6.8 Nitrate in autumn 2012, parcels which were continuously under derogation/no derogation during 2009-2012

In order to verify the long-term impact of derogation on the nitrate residue in the soil, only the parcels which were continuously under derogation/no derogation during 2009-2012 were retained for statistical analysis.

In the next paragraphs, a box plot shows the variation of the groups (derogation and no derogation). The data were log-transformed in order to obtain normality of the dataset. All data are shown visually in bar graphs, which show the distribution of nitrate in the soil profile (0-30 cm, 30-60 cm, 60-90 cm). The results of homogeneous groups are analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data.

In Table 44, the average nitrate-N (kg/ha) in the soil profile for parcels continuously under derogation/no derogation is shown. The values in bold are average nitrate residues larger than 90 kg NO_3-N/ha. However, since 2011 the allowed maximum nitrate residue in the soil profile from 0-90 cm depends on the cultivated crop, soil type, focus or non-focus area. Therefore, the values in bold in the table (> 90 kg NO_3-N/ha) are indicative.

Table 44: Average nitrate-N (kg/ha) in the soil profile for parcels continuously under derogation/no derogation during 2009-2012, in autumn 2012. The nitrate-N is given for the different combinations of soil texture, cultivated crop and derogation. For each combination the total amount of nitrate is given as well as for each soil layer (layer 1: 0-30 cm, layer 2: 30-60 cm and layer 3: 60-90 cm). The number of parcels is indicated by "n".

	Soil	Crop 2012	n	Nitrate-N (kg/ha)			
				0-30 cm	30-60 cm	60-90 cm	0-90 cm
Derogation			55				
	Clay	Beets	-	-	-	-	-
		Grass	6	18	9	7	34
		Maize	-	-	-	-	-
		Winter wheat	-	-	-	-	-
	Loam	Beets	-	-	-	-	-
		Grass	-	-	-	-	-
		Maize	-	-	-	-	-
		Winter wheat	-	-	-	-	-
	Sand	Beets	-	-	-	-	-
		Grass	23	12	15	13	40
		Maize	11	28	29	25	83
		Winter wheat	-	-	-	-	-
	Sandy loam	Beets	-	-	-	-	-
		Grass	11	13	6	4	23
		Maize	4	31	26	22	79
		Winter wheat	-	-	-	-	-
No derogation			86				
	Clay	Beets	-	-	-	-	-
		Grass	3	19	7	9	36
		Maize	3	18	19	22	59
		Winter wheat	2	14	18	20	51
		Other	-	-	-	-	-
	Loam	Beets	-	-	-	-	-
		Grass	1	6	3	3	12
		Maize	3	29	7	3	39
		Winter wheat	-	-	-	-	-
		Other	1	19	27	27	73
	Sand	Beets	-	-	-	-	-
		Grass	20	12	13	11	35
		Maize	19	15	19	19	53
		Winter wheat	4	35	43	30	**108**
		Other	3	31	38	16	84
	Sandy loam	Beets	-	-	-	-	-
		Grass	6	16	10	12	38
		Maize	14	19	23	16	57
		Winter wheat	1	4	7	5	16
		Other	6	16	19	16	51

6.8.1 All crops on all soil textures

Figure 71 shows a large variation in nitrate residue for long-term derogation and no derogation parcels.

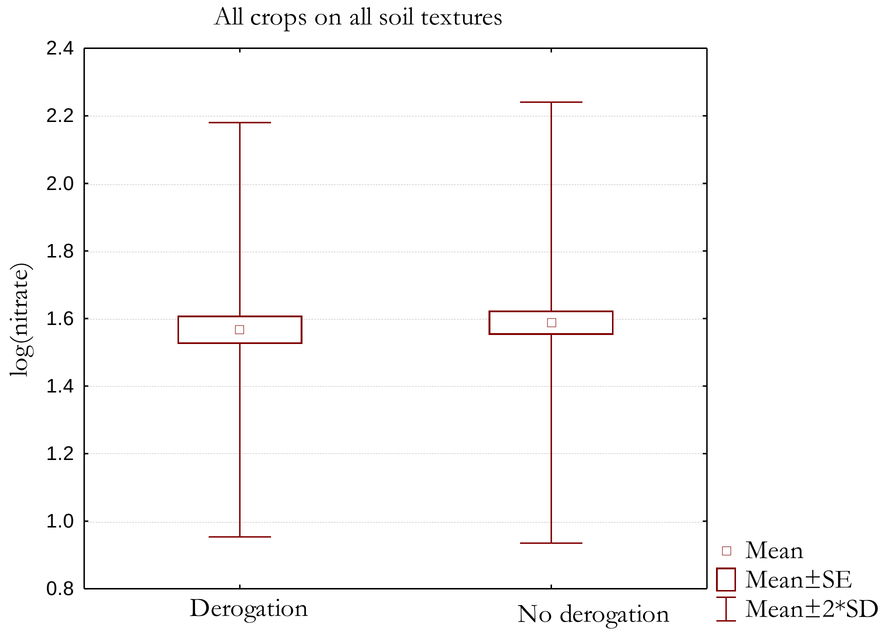


Figure 71: Box plot of log(nitrate-N) for derogation and no derogation parcels in autumn 2012, for all crops on all soil textures including only parcels which were continuously under derogation/no derogation during 2009-2012. SE: standard error of the mean. SD: standard deviation.

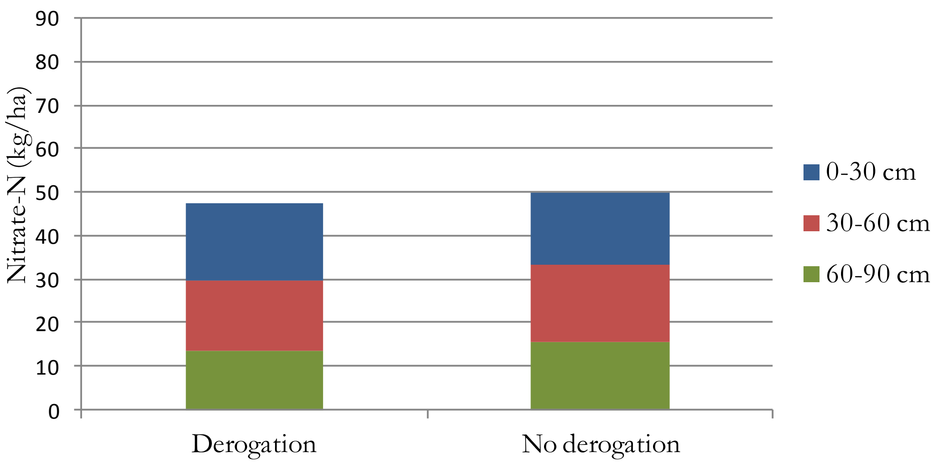


Figure 72: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2012 for all crops on all soil textures, including only parcels which were continuously under derogation/no derogation during 2009-2012.

The average nitrate-N on derogation parcels is 47 ± 35 kg/ha and on no derogation parcels 50 ± 34 kg N/ha (Figure 72).

Since no derogation crops (vegetables, ...) are present in this dataset, the compared groups are not homogeneous and no statistical analysis was conducted between derogation and no derogation parcels.

6.8.2 Derogation crops on all soil textures

Figure 73 shows a large variation in nitrate residue for derogation and no derogation parcels. There is no significant ($p = 0.72$) difference between the nitrate residue on derogation parcels (47 ± 35 kg N/ha) and no derogation parcels (49 ± 32 kg N/ha) (Figure 74).

Figure 73: Box plot of log(nitrate-N) for derogation and no derogation parcels in autumn 2012, for derogation crops on all soil textures, including only parcels which were continuously under derogation/no derogation during 2009-2012. SE: standard error of the mean. SD: standard deviation.

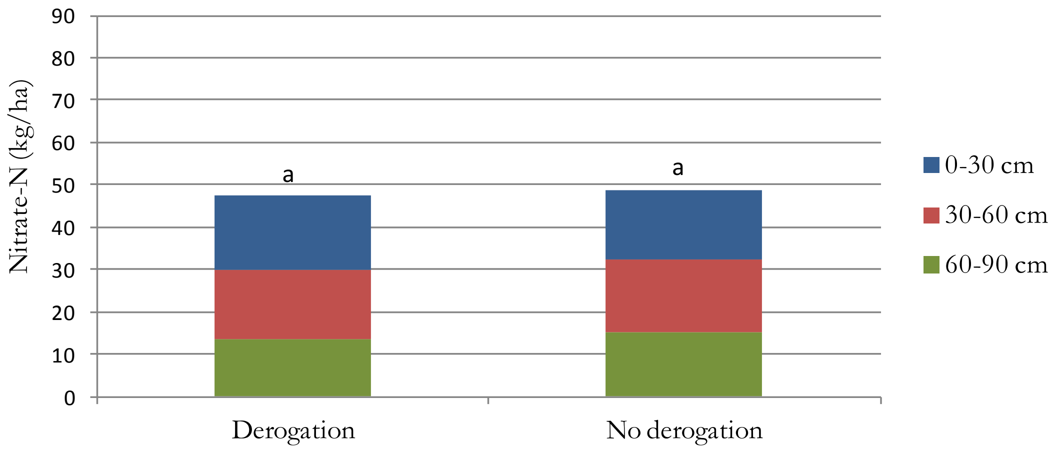


Figure 74: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2012 for derogation crops and soil textures, including only parcels which were continuously under derogation/no derogation during 2009-2012. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.8.3 Derogation crops on sandy soils

Figure 75 shows a large variation in nitrate residue for derogation and no derogation parcels on sandy soil. The nitrate-N between derogation parcels (54 ± 38 kg/ha) and no derogation parcels (50 ± 35 kg/ha) is not significantly different ($p = 0.57$) (Figure 76).

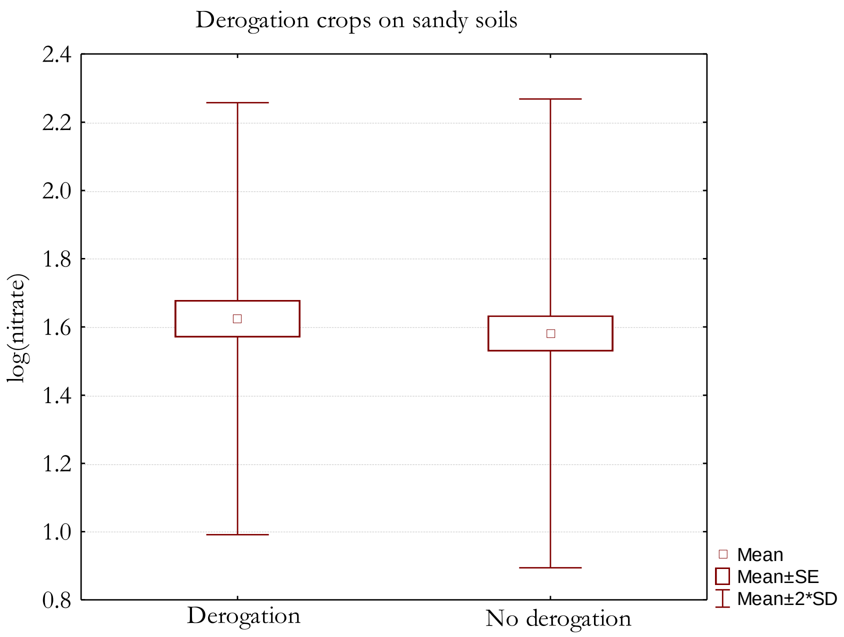


Figure 75: Box plot of log(nitrate-N) for derogation and no derogation parcels in autumn 2012, for derogation crops on sandy soils, including only parcels which were continuously under derogation/no derogation during 2009-2012. SE: standard error of the mean. SD: standard deviation.

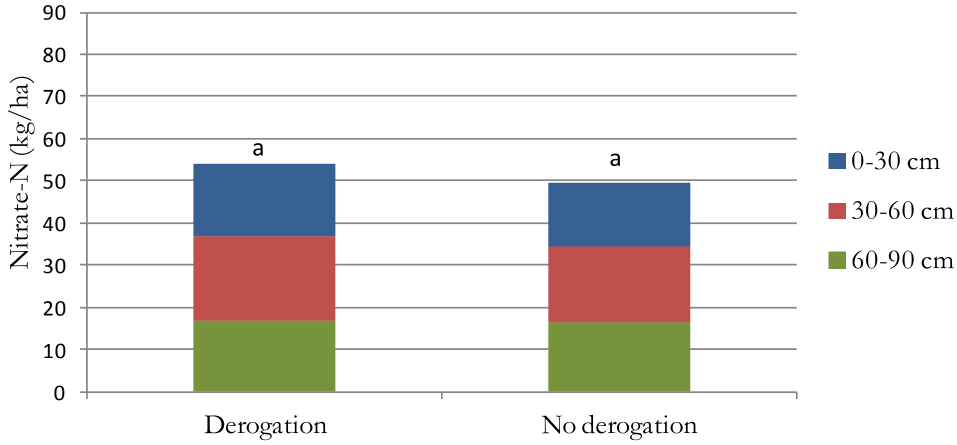


Figure 76: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2012 for derogation crops and on sandy soils, including only parcels which were continuously under derogation/no derogation during 2009-2012. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.8.3.1 Grass and maize on sandy soils

The average nitrate on grass parcels under derogation is 40 ± 26 kg N/ha and 35 ± 9 kg N/ha on no derogation parcels (Figure 77). For maize, the average nitrate-N under derogation is 83 ± 42 kg/ha and 53 ± 34 kg/ha on no derogation parcels. There is no significant difference between derogation and no derogation parcels cultivated with grass ($p = 0.42$) or maize ($p = 0.07$).

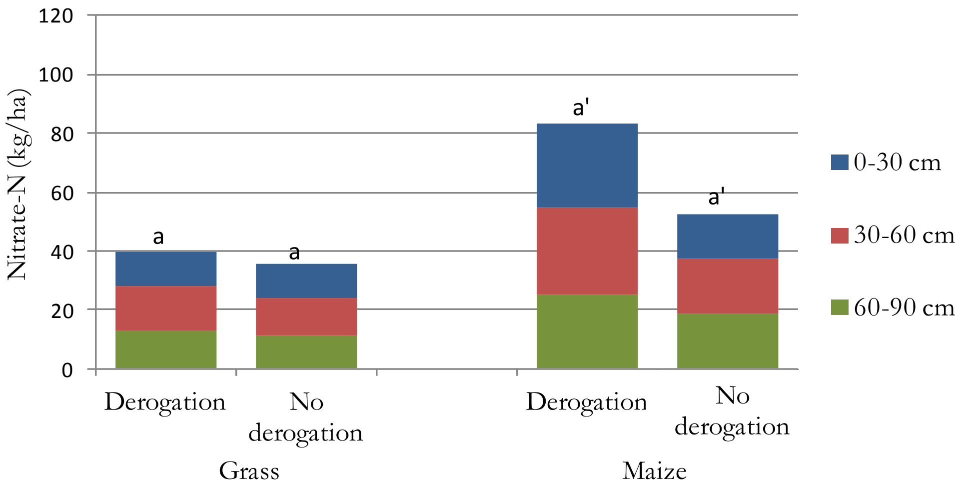


Figure 77: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2012 for grass and maize on sandy soils, including only parcels which were continuously under derogation/no derogation during 2009-2012. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

6.8.4 Derogation crops on sandy loam soils

Figure 78 shows a large variation in nitrate residue for derogation crops on sandy loam soils. The average nitrate is 38 ± 34 kg N/ha on derogation parcels and 49 ± 31 kg/ha on no derogation parcels (Figure 79). There is no significant effect of derogation on the nitrate residue ($p = 0.15$)

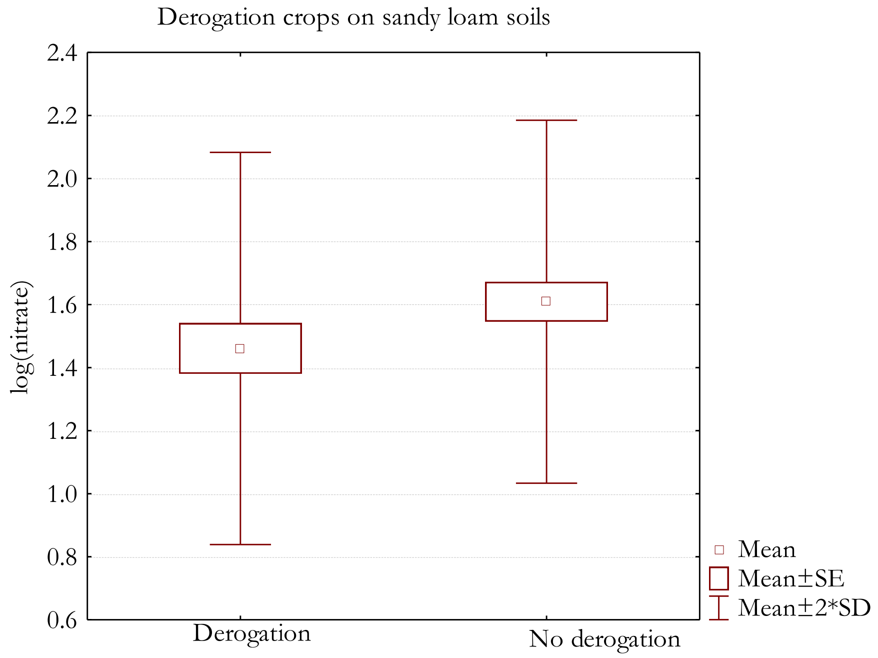


Figure 78: Box plot of log(nitrate-N) for derogation and no derogation parcels in autumn 2012, for derogation crops on sandy loam, including only parcels which were continuously under derogation/no derogation during 2009-2012. SE: standard error of the mean. SD: standard deviation.

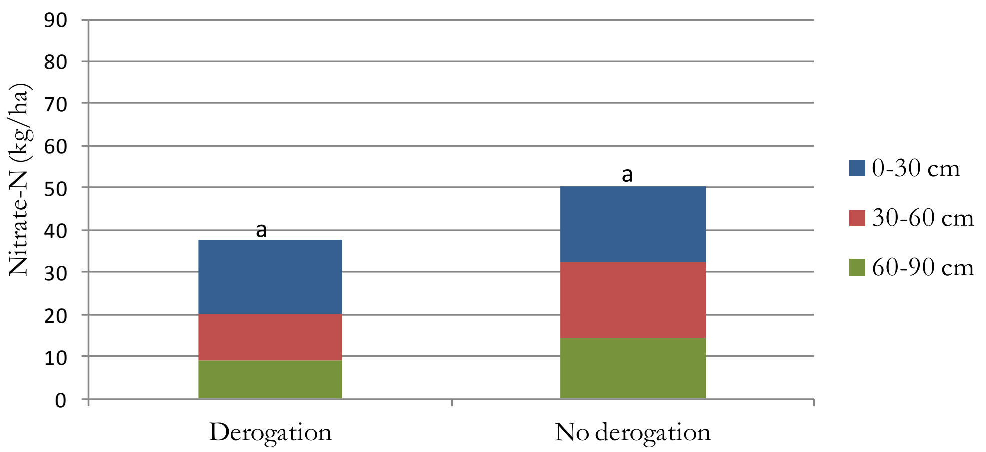


Figure 79: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2012 for derogation crops and on sandy loam soils, including only parcels which were continuously under derogation/no derogation during 2009-2012. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.8.4.1 Grass and maize on sandy loam soils

On sandy loam soils, there is no significant difference in nitrate residue between derogation and no derogation parcels cultivated with grass (p = 0.09) or maize parcels (p = 0.31). The average nitrate-N on grass parcels under derogation is 23 ± 9 kg/ha, on no derogation parcels this is 38 ± 24 kg/ha (Figure 80). The average nitrate-N on maize parcels under derogation is 79 ± 45 kg/ha, on no derogation parcels 57 ± 32 kg/ha. Most of the nitrate is located in the upper soil layer (0-30 cm).

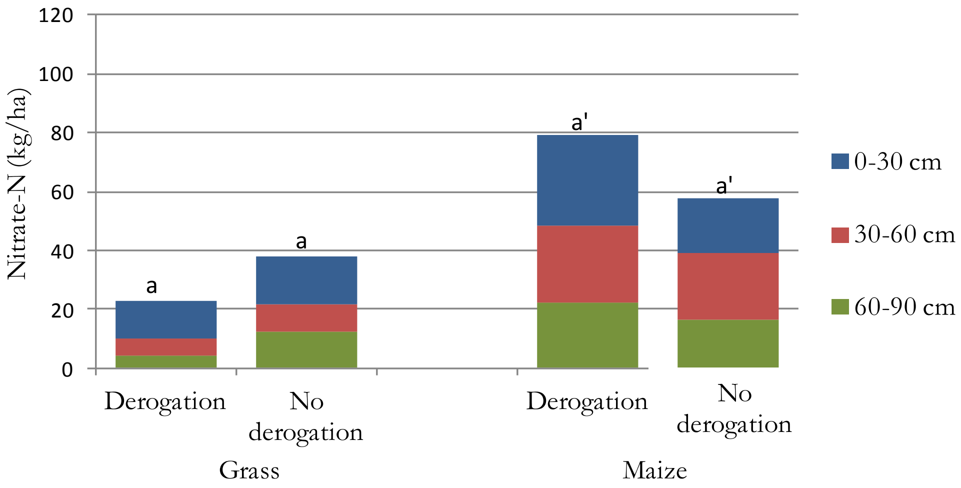


Figure 80: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2012 for grass and maize and on sandy loam soils, including only parcels which were continuously under derogation/no derogation during 2009-2012. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

6.9 Nitrate in autumn 2012 in the deeper soil layer

For 40 parcels an additional soil sample was taken from 90 to 120 cm (the "deep soil sample"). In this soil layer the amount of nitrate is measured. Data were considered statistical outliers when exceeding the average plus 2 times the standard deviation. Two statistical outliers were removed (486 kg N/ha and 448 kg N/ha for 0-120 cm, both no derogation parcels). For one parcel the amount of nitrate-N in the deeper soil layer (90-120 cm) (152 kg N/ha) and the nitrate residue in the soil layer from 0 to 90 cm in autumn 2012 (296 kg N/ha) was detected as a statistical outlier. This parcel was converted from grass parcel into arable parcel in spring 2011. On the other parcel (352 kg N/ha; 90-120 cm) potatoes were grown and harvested early in July. Potatoes are a crop with often a high nitrate residue but especially because of the early date of harvest a larger amount of nitrate-N in the soil profile was possible since there was a long time of mineralisation without nutrient uptake.

After removing the statistical outliers the dataset still contained some high nitrate values (Figure 81) and no significant correlation ($p = 0.43$) is found between the amount of nitrate present in the soil profile from 0-90 cm and the nitrate present in the soil profile from 90-120 cm. The large nitrate values present in the graph are no statistical outliers but the graph shows that they influence strongly the relation between the amount of nitrate present in the soil profile from 0-90 cm and the nitrate present in the soil profile from 90-120 cm. When removing the 3 parcels with high nitrate values in the soil layer 0-90 cm or 90-120 cm (filled dots on the graph), the amount of nitrate present in the soil profile from 0-90 cm and the nitrate present in the soil profile from 90-120 cm were significantly correlated ($p \leq 0.05$) (Figure 81).

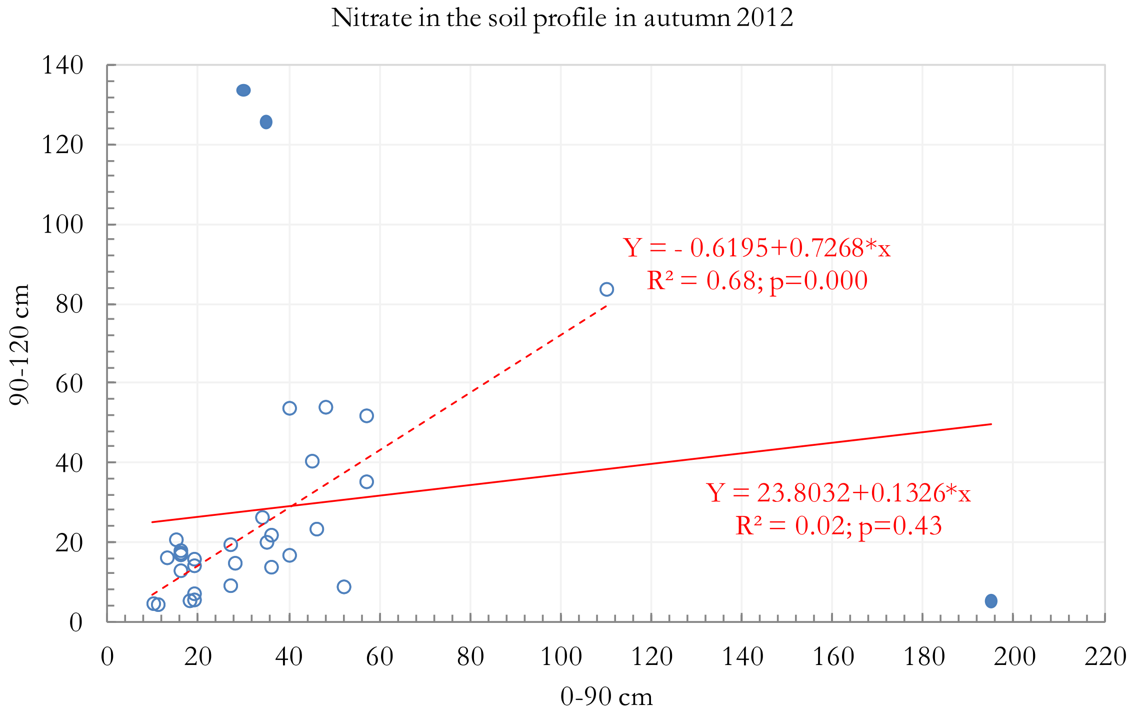


Figure 81: Scatterplot of the nitrate-N (kg/ha) in the soil profile from 0-90 cm versus the nitrate-N (kg/ha) in the soil profile from 90-120 cm in autumn 2012. Solid line=relation based on all measurements; dashed line= trendline based on the dataset of not filled dots.

The filled dots with high amount of nitrate-N in the soil layer 90-120 cm were a parcel cultivated with spinach followed by leek and a grass parcel which was mowed begin October but grass was left on the parcel.

The deep soil samples are taken on a selection of parcels. Therefore it is not possible to carry out a statistical analysis for all combinations of derogation, soil texture and cultivated crop. The comparison was limited to grass and maize on all soil textures. The statistical analysis was conducted for grass and maize separately. No significant difference was found between derogation and no derogation parcels in the soil layer from 90 to 120 cm for grass ($p = 0.23$) or maize ($p = 0.76$). There is also no significant difference between derogation and no derogation parcels in the soil layer from 0-120 cm for grass ($p = 0.43$) or maize ($p = 0.29$). The average level of nitrate-N in parcels cultivated with grass for the soil layer 0-120 cm under derogation is 60 ± 43 kg/ha and under no derogation 44 ± 32 kg/ha. The average level of nitrate-N in parcels cultivated with maize for the soil layer 0-120 cm under derogation is 92 ± 79 kg/ha and 59 ± 24 under no derogation.

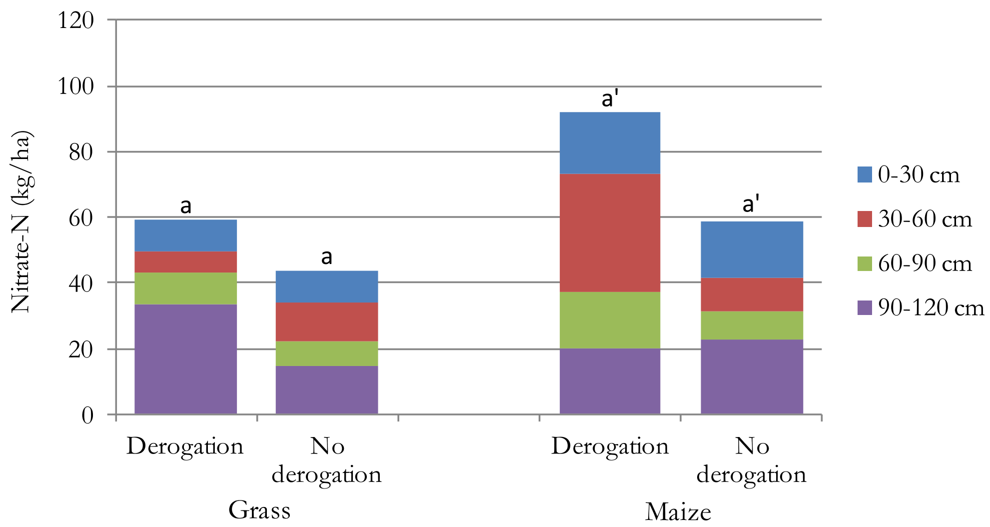


Figure 82: Average nitrate-N (kg/ha) in the 4 soil layers on derogation and no derogation parcels on all soil textures cultivated with grass or maize, autumn 2012. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

6.10 Nitrate in spring 2013

As in spring 2012, at each parcel of the monitoring network a nitrate sample has been taken from February to April 2013. This nitrate sample consists of three soil layers (0-30 cm, 30-60 cm and 60-90 cm) and provides information on the amount of nitrate in the soil profile after winter and the amount available to the cultivated crop for the next growing season. Every farmer receives a nitrate fertilisation advice, based on the N-INDEX expert system (Geypens *et al.*, 1994). Comparison of the nitrate in autumn 2012 and the nitrate sample in spring 2013, gives an indication of the amount of nitrate that leached out during winter.

In the next paragraphs, a box plot shows the variation of the groups (derogation and no derogation). The data were log-transformed in order to obtain normality of the dataset. All data are shown visually in bar graphs, which show the distribution of nitrate in the soil profile (0-30 cm, 30-60 cm, 60-90 cm). The results of homogeneous groups are analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data.

The average level of nitrate-N measured in the soil samples in autumn 2012 and spring 2013 is shown in Table 45. The amount of nitrate is given for the combinations of derogation, soil texture and cultivated crop for the total soil profile (0-90 cm) and for each soil layer of 30 cm.

The values in bold in Table 45 have high levels of nitrate (> 90 kg N/ha) in autumn 2012. However, since 2011 the allowed maximum nitrate residue in the soil profile from 0-90 cm depends on the cultivated crop, soil type, and focus or non-focus area. Therefore, the values in bold (> 90 kg NO_3-N/ha) are indicative.

Since only the average of parcels, which were no outlier in autumn 2012 and no outlier in spring 2013, are shown, the values for autumn 2012 in Table 45 are not identical as values shown in Table 43.

Table 45: Average nitrate-N (kg/ha) in the soil profile in autumn 2012 and spring 2013. The nitrate-N is given for the different combinations of soil texture, cultivated crop and derogation in 2012. For each combination the total amount of nitrate is given as well as for each soil layer (layer 1: 0-30 cm, layer 2: 30-60 cm and layer 3: 60-90 cm). The number of parcels is indicated by "n".

	Soil	Crop 2012	n	Autumn 2012	Nitrate-N (kg/ha) in spring 2013			
				0-90 cm	0-30cm	30-60cm	60-90cm	0-90cm
Derogation			75					
	Clay	Beets	-	-	-	-	-	-
		Grass	7	48	24	21	22	67
		Maize	1	31	5	7	18	30
		Winter wheat	-	-	-	-	-	-
	Loam	Beets	-	-	-	-	-	-
		Grass	-	-	-	-	-	-
		Maize	-	-	-	-	-	-
		Winter wheat	-	-	-	-	-	-
	Sand	Beets	1	67	13	18	31	62
		Grass	29	41	12	10	10	32
		Maize	16	71	9	14	16	39
		Winter wheat	-	-	-	-	-	-
	Sandy loam	Beets	-	-	-	-	-	-
		Grass	14	24	9	11	12	32
		Maize	7	72	6	18	21	45
		Winter wheat	-	-	-	-	-	-
No derogation			106					
	Clay	Beets	-	-	-	-	-	-
		Grass	2	28	11	12	14	37
		Maize	3	59	22	29	38	89
		Winter wheat	3	58	20	35	28	83
		Other	-	-	-	-	-	-
	Loam	Beets	-	-	-	-	-	-
		Grass	-	-	-	-	-	-
		Maize	4	41	14	15	17	46
		Winter wheat	1	**137**	6	11	22	39
		Other	1	73	10	22	33	65
	Sand	Beets	-	-	-	-	-	-
		Grass	24	33	9	9	13	31
		Maize	22	59	8	12	18	38
		Winter wheat	4	**108**	7	8	21	36
		Other	6	55	15	15	21	51
	Sandy loam	Beets	-	-	-	-	-	-
		Grass	7	38	16	11	7	34
		Maize	20	54	12	16	20	48
		Winter wheat	2	16	9	25	33	67
		Other	7	50	11	18	20	49

The relation between nitrate in the soil profile from 0-90 cm in autumn 2012 and spring 2013 is shown in a scatterplot (Figure 83). A significant correlation ($p \leq 0.05$) exists. The regression model explained 10 % of the variance.

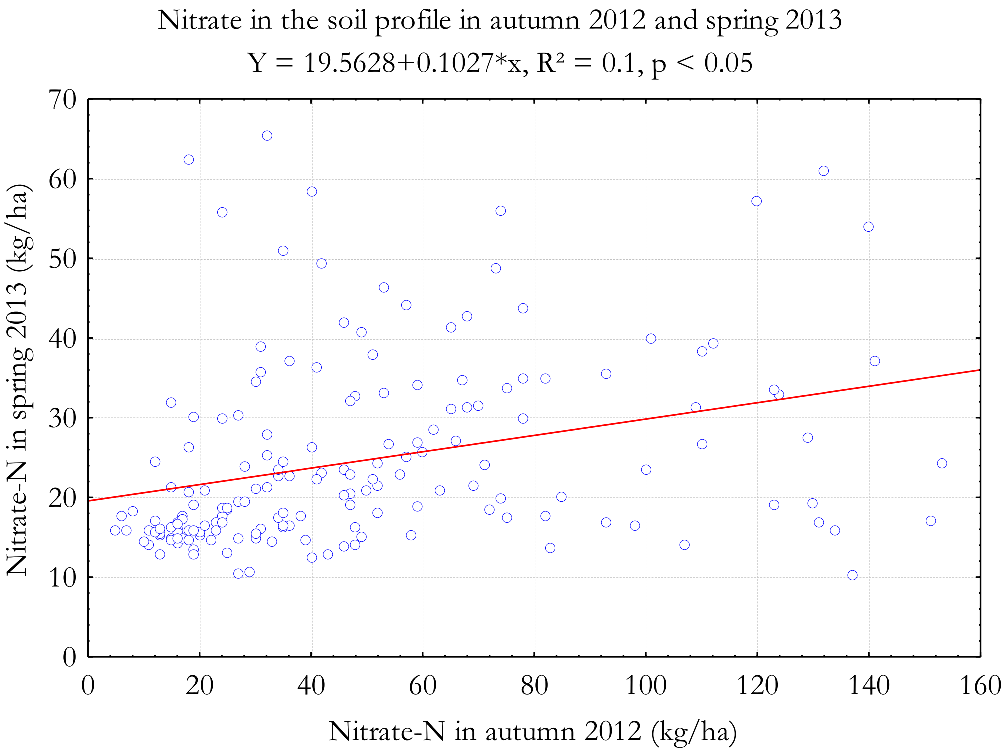


Figure 83: Scatterplot of the nitrate-N (kg/ha) in the soil profile from 0-90 cm in autumn 2012 versus the nitrate-N (kg/ha) in the soil profile from 0-90 cm in spring 2013.

6.10.1 All crops on all soil textures

In the first part of the statistical analysis, the total amount of nitrate-N in spring 2013 is compared for all crops on all soil textures between derogation and no derogation parcels. In both derogation and no derogation parcels, the nitrate measurement shows a large variation (Figure 84). Since no derogation crops (vegetables, ...) are present in this dataset, the compared groups are not homogeneous and no statistical analysis was conducted between derogation and no derogation parcels.

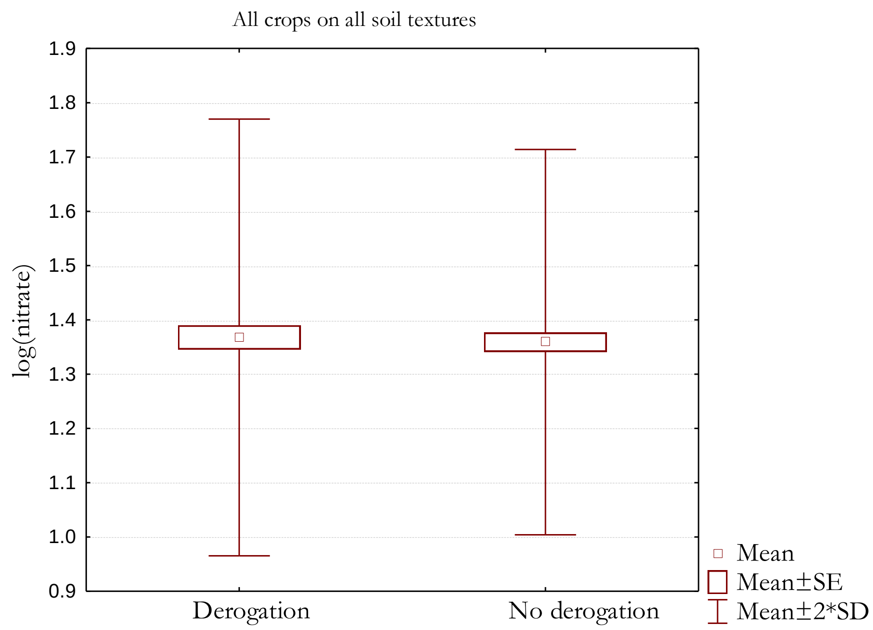


Figure 84: Box plot of log(nitrate-N) for derogation and no derogation parcels with all crops on all soil textures in spring 2013. SE: standard error of the mean. SD: standard deviation.

The average amount of nitrate-N is 26 ± 14 kg/ha on derogation parcels and 25 ± 11 kg/ha on no derogation parcels (Figure 85). The amount of nitrate is more or less equally distributed over all three soil layers.

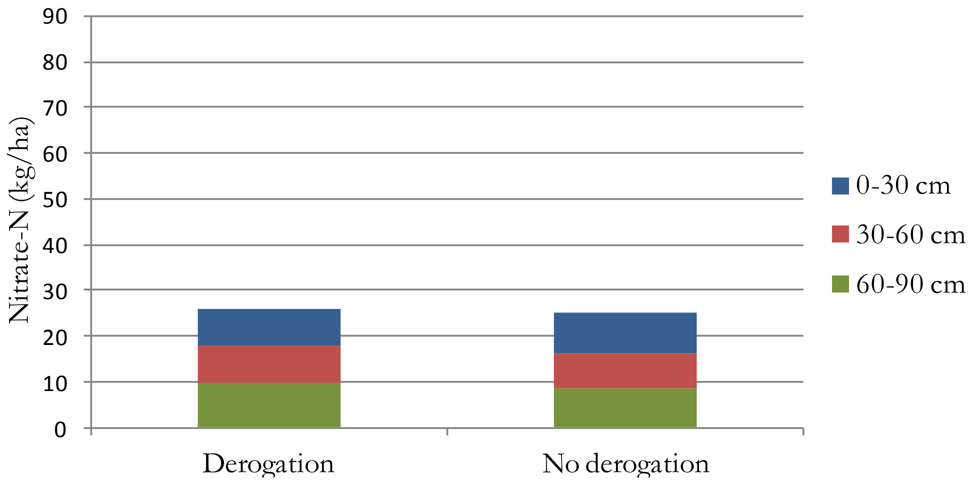


Figure 85: Average nitrate-N (kg/ha) on derogation and no derogation parcels with all crops on all soil textures in spring 2013.

6.10.2 Derogation crops on all soil textures

In a next step derogation and no derogation parcels cultivated with only derogation crops (grass, maize, beets, winter wheat) are compared. The measured nitrate values are highly variable (Figure 86).

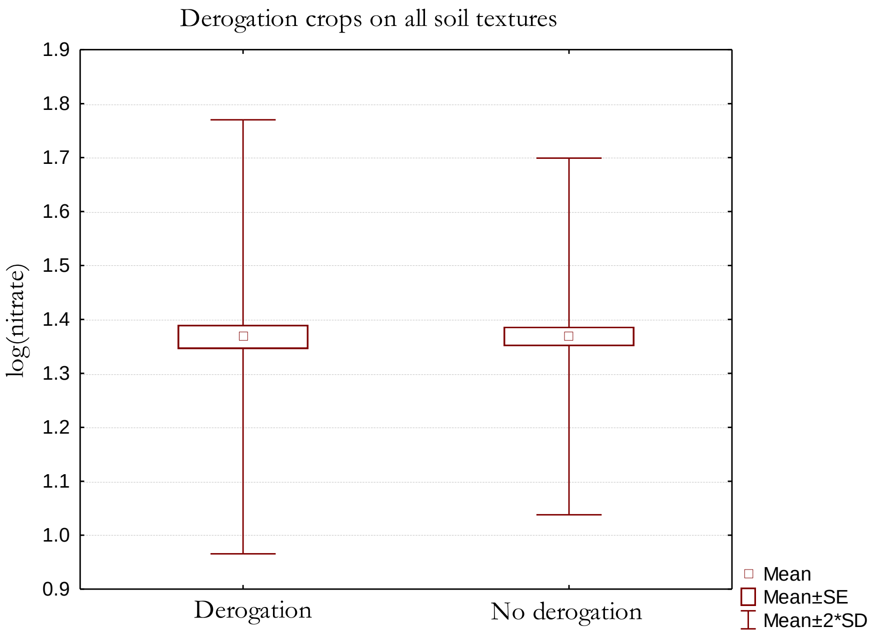


Figure 86: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on all soil textures in spring 2013. SE: standard error of the mean. SD: standard deviation.

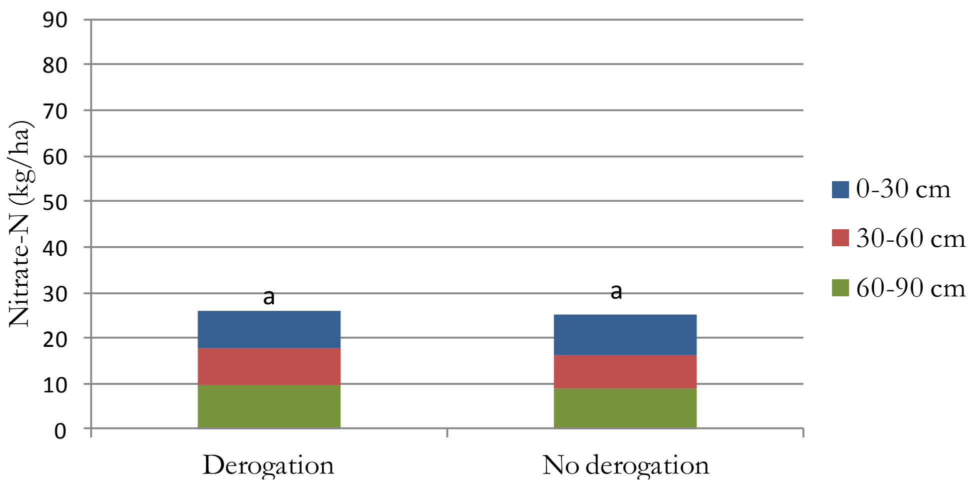


Figure 87: Average nitrate-N (kg/ha) on derogation and no derogation parcels for derogation crops on all soil textures in spring 2013. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

No statistically significant difference was found between nitrate-N measured on derogation (26 ± 14 kg N/ha) and no derogation (25 ± 10 kg N/ha) parcels (Figure 87, $p = 0.98$). The amount of nitrate is more or less equally distributed over all three soil layers.

6.10.3 Derogation crops on sandy soils

In the next step, significant differences between derogation and no derogation parcels for the most important soil textures and derogation crops are explored. There is a large variation within one group (both on derogation or no derogation) (Figure 88).

Figure 88: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on sandy soils in spring 2013. SE: standard error of the mean. SD: standard deviation.

The average value of nitrate-N for derogation crops on sandy soils is 24 ± 13 kg/ha for derogation parcels and 27 ± 18 kg/ha for no derogation parcels. The amount of nitrate-N measured in sandy soils on derogation parcels from 0-90 cm does not differ significantly from the amount of nitrate-N measured on no derogation parcels (Figure 89, $p = 0.66$).

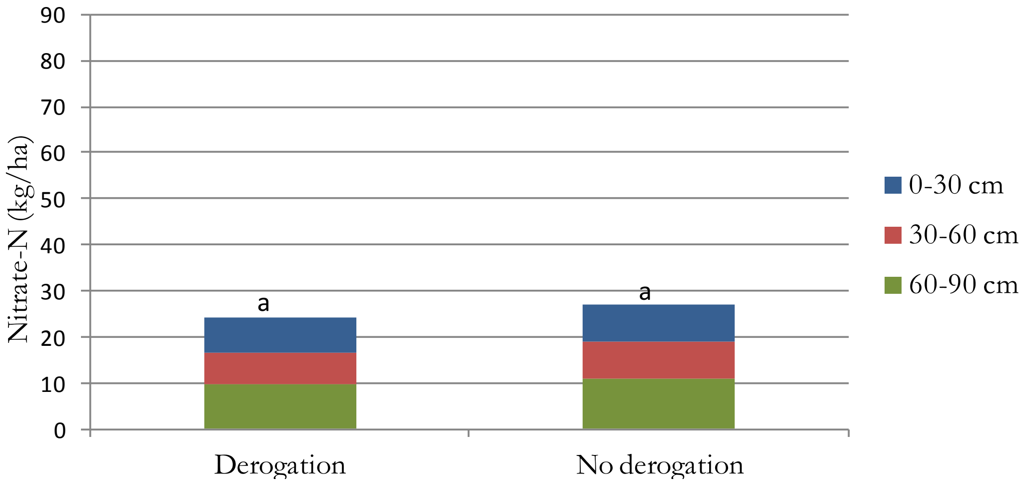


Figure 89: Average nitrate-N (kg/ha) on derogation and no derogation parcels for derogation crops on sandy soils in spring 2013. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.10.3.1 Grass and maize on sandy soils

So far no significant differences were found between derogation and no derogation parcels for all crops and soil textures and for derogation crops on sandy soils. Since grass and maize are mostly cultivated on sandy soils, these combinations are compared separately for grass and maize by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data (Figure 90).

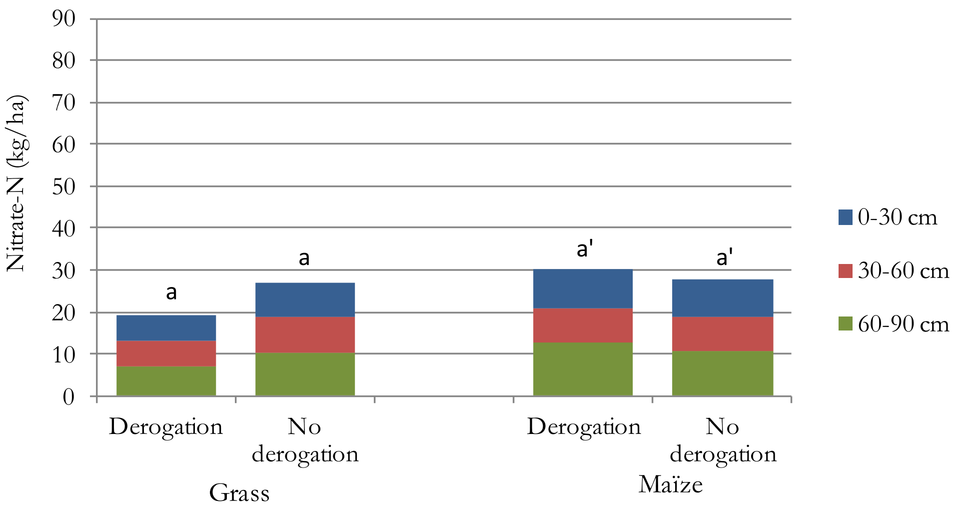


Figure 90: Average nitrate-N (kg/ha) on derogation and no derogation parcels with grass or maize on sandy soils in spring 2013. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

For grass the nitrate-N was 19 ± 8 kg/ha on derogation parcels and 27 ± 24 kg/ha on no derogation parcels. For maize the nitrate-N was 30 ± 16 kg/ha on derogation parcels and 28 ± 15 kg/ha on no derogation parcels. There is no significant difference between derogation and no derogation parcels cultivated with grass ($p = 0.81$) or with maize ($p = 0.70$).

6.10.4 Derogation crops on sandy loam soils

Next, derogation and no derogation parcels cultivated with derogation crops on sandy loam soils were investigated. On both derogation and no derogation parcels on sandy loam soil, a large variation is observed (Figure 91). No significant difference was found between derogation (34 ± 25 kg N/ha) and no derogation parcels (30 ± 23 kg N/ha) on sandy loam soils (Figure 92, $p = 0.65$) by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data.

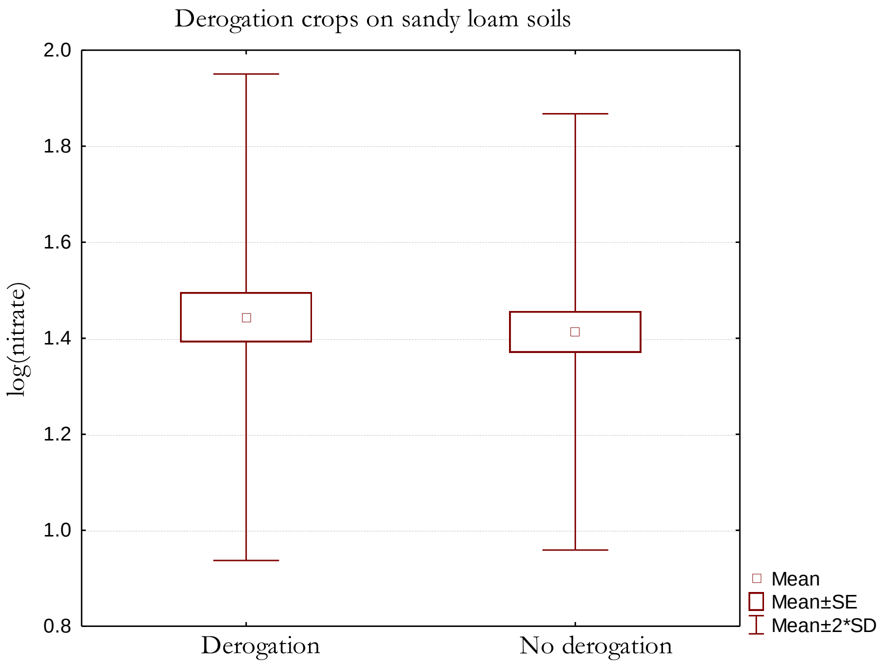


Figure 91: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on sandy loam soils in spring 2013. SE: standard error of the mean. SD: standard deviation.

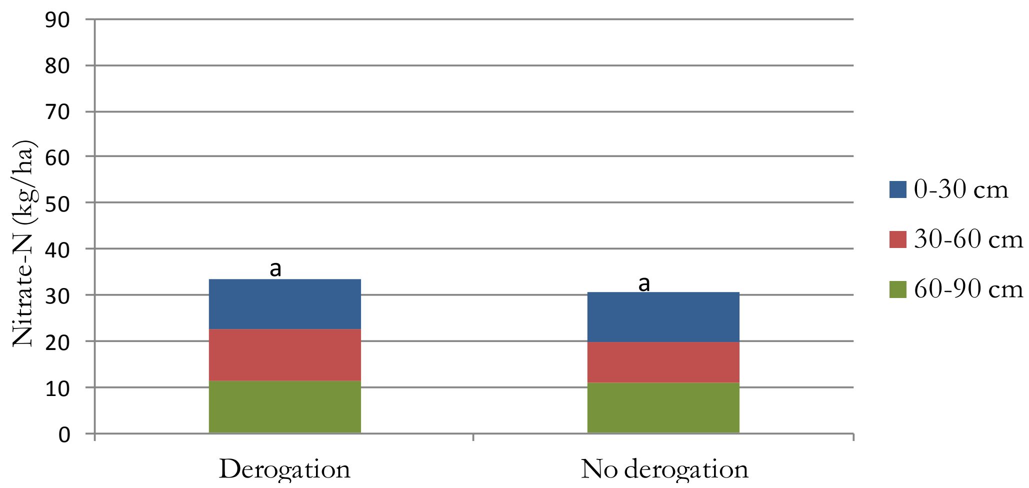


Figure 92: Average nitrate-N (kg/ha) on derogation and no derogation parcels for derogation crops on sandy loam soil in spring 2013. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.10.4.1 Grass and maize on sandy loam soils

Figure 93 shows the average values of nitrate-N in the total soil profile and the different soil layers for grass and maize on sandy loam soils.

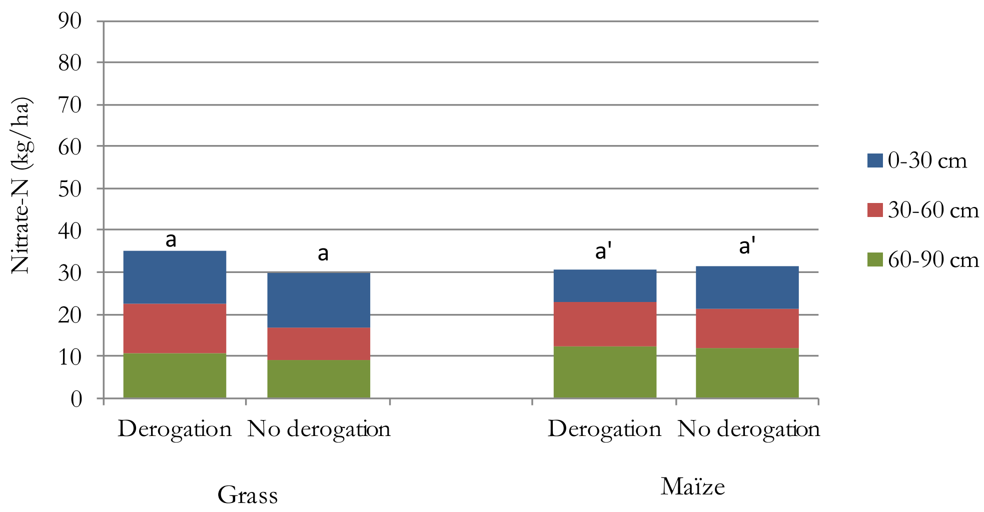


Figure 93: Average nitrate-N (kg/ha) on derogation and no derogation parcels with grass or maize on sandy loam soils in spring 2013. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

For grass the average nitrate-N was 35 ± 31 kg/ha on derogation parcels and 30 ± 28 kg /ha on no derogation parcels. For maize the average nitrate level was 31 ± 13 kg N/ha on derogation parcels and 31 ± 22 kg N/ha on no derogation parcels (Figure 93). A statistical analysis between derogation and no derogation parcels was conducted separately for grass and maize by means of a one-way ANOVA ($p \leq 0.05$) of the log-transformed data. There is no statistical significant difference between derogation and no derogation parcels cultivated with grass ($p = 0.62$) or with maize ($p = 0.87$).

6.11 Nitrate in spring 2013 in the deeper soil layer

For 30 parcels an additional soil sample was taken from 90 to 120 cm (the "deep soil sample"). In this soil layer the amount of nitrate is measured.

No significant correlation ($p = 0.08$) exists between the amount of nitrate present in the soil profile from 0-90 cm and the nitrate present in the soil profile from 90-120 cm. The amount of nitrate in the soil layer 90-120 cm is low.

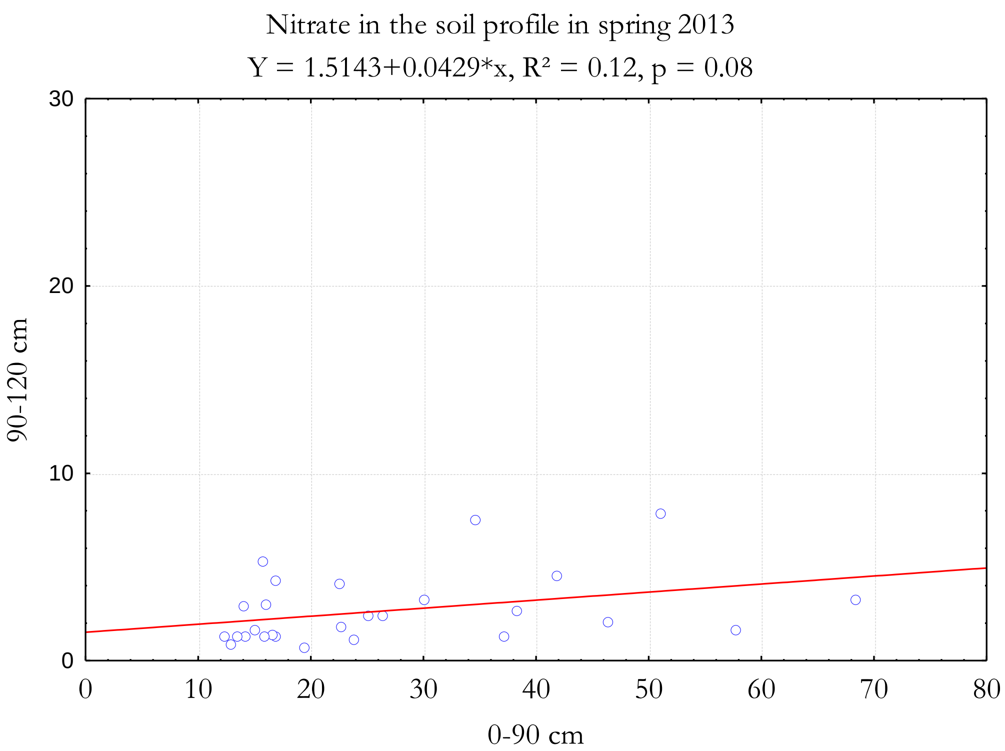


Figure 94: Scatterplot of the nitrate-N (kg/ha) in the soil profile from 0-90 cm versus the nitrate-N (kg/ha) in the soil profile from 90-120 cm in spring 2013.

The deep soil samples are taken on a selection of parcels. Therefore it is not possible to carry out a statistical analysis for all combinations of derogation, soil texture and cultivated crop. The comparison was limited to grass and maize on all soil textures. The statistical analysis was conducted for grass and maize separately. No significant difference was found between derogation and no derogation parcels in the soil layer from 90 to 120 cm for grass ($p = 0.08$) or maize ($p = 0.23$). There is also no significant difference between derogation and no derogation parcels in the soil layer from 0-120 cm for grass ($p = 0.20$) or maize ($p = 0.35$). The average level of nitrate-N in the soil layer 0-120 cm on parcels cultivated with grass under derogation is 27 ± 25 kg/ha and 15 ± 2 kg/ha without derogation. The average level of nitrate-N in the soil layer 0-120 cm on parcels cultivated with maize under derogation is 29 ± 21 kg/ha and 40 ± 17 kg/ha without derogation.

The deep soil layer contained almost no nitrate-N in spring 2013. In autumn 2012 this soil layer contained in relative terms more nitrate than in autumn 2011 and abundant rainfall in December 2012 (Figure 247) resulted in an "empty" soil layer 90-120 cm in spring 2013.

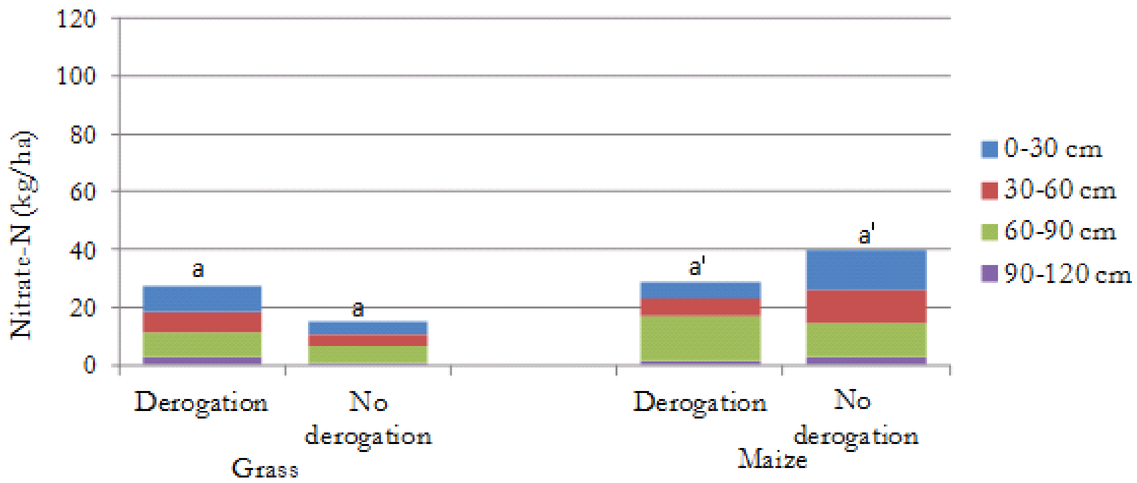


Figure 95: Average nitrate-N (kg/ha) in the 4 soil layers on derogation and no derogation parcels on all soil textures cultivated with grass or maize, spring 2013. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

6.12 Nitrate in autumn 2013

Between October 1st and November 15th, soil samples were taken in order to determine the amount of nitrate in the soil profile from 0 to 30, 30 to 60 and 60 to 90 cm. In the next paragraphs, box plots show the variation of the groups (derogation and no derogation). The data were log-transformed in order to obtain normality of the dataset. All data are shown visually in bar graphs, which show the distribution of nitrate in the soil profile (0-30 cm, 30-60 cm, 60-90 cm). The results of homogeneous groups are analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data.

One parcel was detected as a statistical outlier. The log of the nitrate content in the soil profile 0-90 cm on the parcel exceeded the average plus 2 times the standard deviation. It was a maize parcel without derogation on sandy soil with a nitrate residue of 261 kg NO_3-N/ha. No exuberant fertilisation was applied and harvest was good.

The average nitrate in the soil profile for each soil layer and for different combinations of crop, soil texture and derogation is shown in Table 46. The values in bold are average nitrate residues larger than 90 kg NO_3-N/ha. However, since 2011 the allowed maximum nitrate residue in the soil profile from 0-90 cm depends on the cultivated crop, soil type, focus or non-focus area. Therefore, the values in bold in the table (> 90 kg NO_3-N/ha) are indicative.

Although winter wheat is a crop with a low average nitrate residue, high nitrate residues are measured on parcels of the monitoring network cultivated with winter wheat. On the derogation parcels on sand and sandy loam soil cultivated with winter wheat, cover crops were sown but animal manure was applied in August after harvest. On clay soil the three parcels with no derogation crops were cultivated with potatoes. Nitrate residues of 162, 174 and 189 kg N/ha were measured. Potatoes are often a crop with a higher nitrate residue.

Table 46: Average nitrate-N (kg/ha) in the soil profile in autumn 2013. The nitrate-N is given for the different combinations of soil texture, cultivated crop and derogation in 2013. For each combination the total amount of nitrate is given as well as for each soil layer (layer 1 : 0-30 cm, layer 2: 30-60 cm and layer 3: 60-90 cm). The number of parcels is indicated with "n".

	Soil	Crop 2013	n	Nitrate-N (kg/ha)			
				0-30 cm	30-60 cm	60-90 cm	0-90 cm
Derogation			106				
	Clay	Beets	-	-	-	-	-
		Grass	9	33	16	11	60
		Maize	-	-	-	-	-
		Winter wheat	-	-	-	-	-
	Loam	Beets	-	-	-	-	-
		Grass	-	-	-	-	-
		Maize	1	37	31	23	91
		Winter wheat	-	-	-	-	-
	Sand	Beets	-	-	-	-	-
		Grass	41	21	17	14	52
		Maize	29	28	25	17	70
		Winter wheat	2	35	58	53	**146**
	Sandy loam	Beets	-	-	-	-	-
		Grass	11	17	14	12	43
		Maize	12	28	21	15	64
		Winter wheat	1	30	38	32	**100**
No derogation			99				
	Clay	Beets	-	-	-	-	-
		Grass	2	25	11	10	46
		Maize	2	31	28	28	87
		Winter wheat	2	45	24	8	77
		Other	3	32	90	53	**175**
	Loam	Beets	-	-	-	-	-
		Grass	1	3	3	3	9
		Maize	5	24	19	15	58
		Winter wheat	1	29	29	7	65
		Other	-	-	-	-	-
	Sand	Beets	-	-	-	-	-
		Grass	20	20	22	12	54
		Maize	14	29	36	24	89
		Winter wheat	3	43	60	34	**137**
		Other	10	34	38	24	**96**
	Sandy loam	Beets	-	-	-	-	-
		Grass	10	15	12	7	34
		Maize	15	27	20	18	65
		Winter wheat	3	12	22	17	51
		Other	8	22	30	21	73

6.12.1 All crops on all soil textures

For both derogation and no derogation parcels, a large variation in amount of nitrate in the soil profile (0-90 cm) is observed (Figure 96). On derogation parcels the amount of nitrate-N ranged from 8 to 242 kg. For parcels without derogation the range was 6 to 261 kg N/ha.

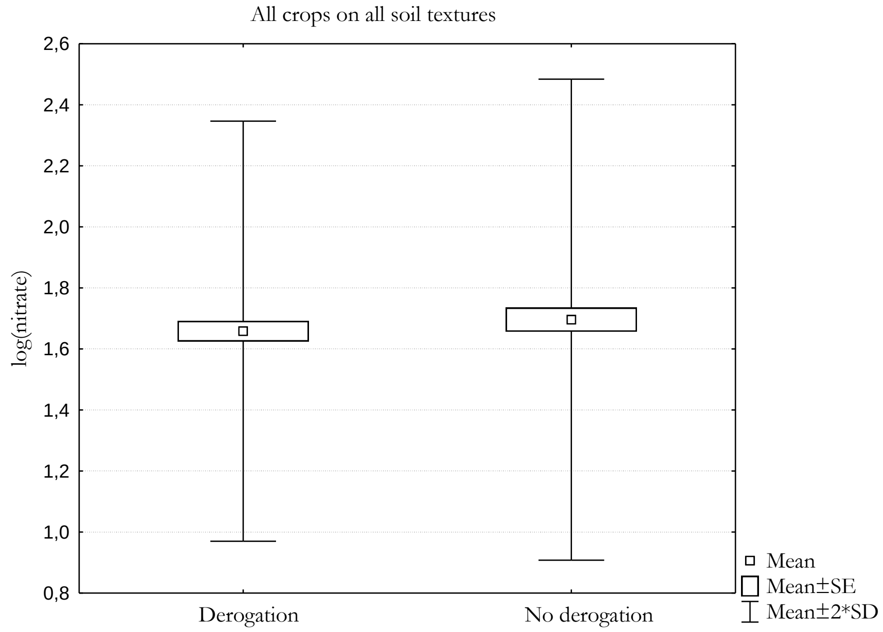


Figure 96: Box plot of log(nitrate-N) for derogation and no derogation parcels in autumn 2013, for all crops on all soil textures. SE: standard error of the mean. SD: standard deviation.

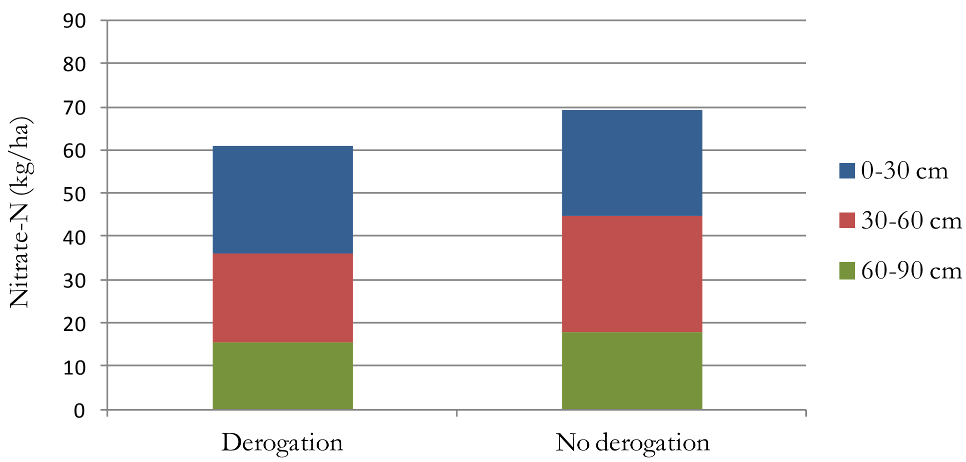


Figure 97: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2013 for all crops on all soil textures.

The average nitrate-N in the soil profile (0-90 cm) is 61 (± 47) kg N/ha for derogation parcels and 69 (± 53) kg N/ha for no derogation parcels (Figure 97). The first two layers contain the most nitrate-N while the layer 60-90 contains less than the layers above. This is the most pronounced for the no derogation parcels. Since all crops (vegetables, potatoes, ...) are included in this dataset, the groups of derogation and no derogation parcels are no homogeneous groups. These groups cannot be statistically compared.

6.12.2 Derogation crops on all soil textures

To conduct a statistical analysis the further comparisons are limited to parcels cultivated with a derogation crop (grass, maize, winter wheat and beets). There is a large variance in nitrate in the soil (0-90 cm) on derogation and no derogation parcels (Figure 98). The amount of nitrate-N on derogation parcels (61 ± 47 kg N/ha) was not significantly different from the amount on no derogation parcels (61 ± 46 kg N/ha) ($p = 0.90$) (Figure 99).

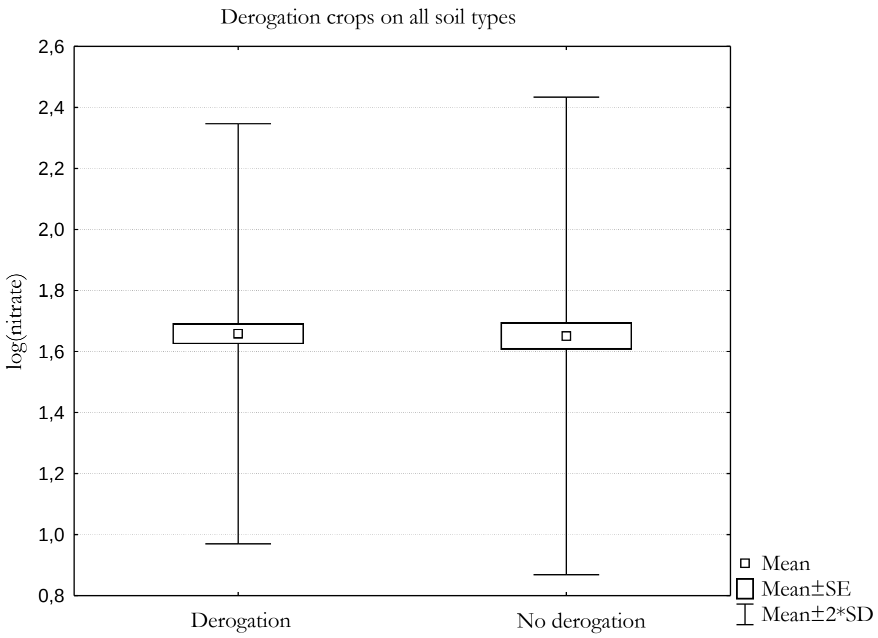


Figure 98: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on all soil textures in autumn 2013. SE: standard error of the mean. SD: standard deviation.

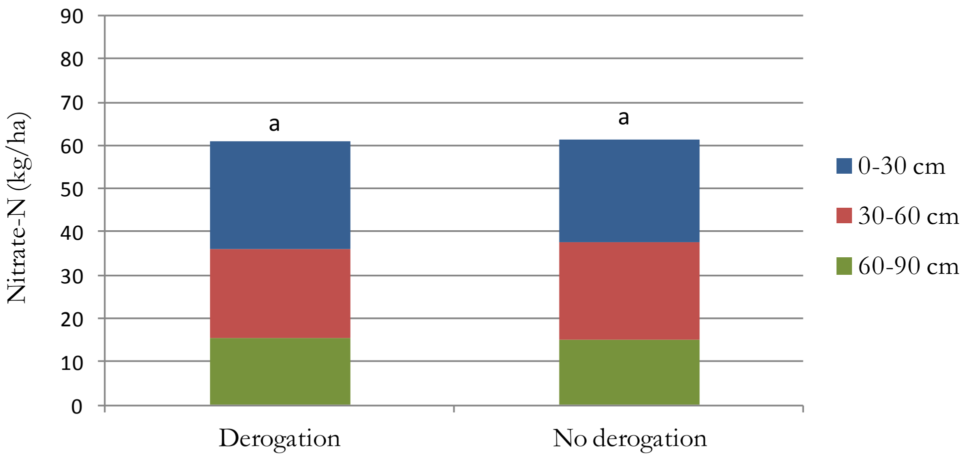


Figure 99: Average nitrate-N (kg N/ha) on derogation and no derogation parcels for derogation crops on all soil textures in autumn 2013. These results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

The nitrate residue will be statistically compared between derogation and no derogation parcels for specific soil textures. Since sandy and sandy loam soils are the soil textures on which derogation is mostly requested, the effect of derogation on the nitrate residue will be discussed in more detail in the following paragraphs for these soil textures. The data for the other soil textures are listed in Table 46.

6.12.3 Derogation crops on sandy soils

Like shown for all soils, on sandy soils there is a large variance for both groups of parcels (Figure 100). Derogation and no derogation parcels on sandy soils cultivated with derogation crops did not differ significantly ($p = 0.80$). On the derogation parcels the average amount of nitrate-N was 62 (± 48) kg N/ha and on no derogation parcels 68 (± 59) kg N/ha (Figure 101).

Figure 100: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on sandy soils in autumn 2013. SE: standard error of the mean. SD: standard deviation.

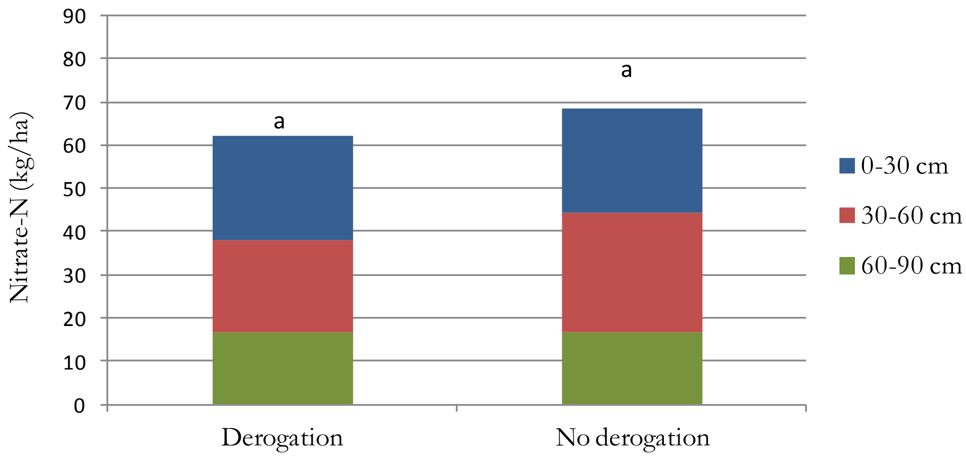


Figure 101: Average nitrate-N (kg N/ha) on derogation and no derogation parcels for derogation crops on sandy soils in autumn 2013. These results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.12.3.1 Grass and maize on sandy soils

The derogation crops grown on sandy soils are mostly grass and maize. Comparison of derogation and no derogation parcels on sandy soil with grass ($p = 0.37$) or maize ($p = 0.65$) showed no statistical differences. Derogation parcels with grass on sandy soils have a nitrate residue of 52 ± 45 kg N/ha and the no derogation parcels with grass 54 ± 58 kg N/ha. For maize parcels the derogation parcels had a nitrate residue of 71 ± 46 kg N/ha in the soil profile and the no derogation parcels 74 ± 41 kg N/ha. Although there is no statistically significant difference, the no derogation parcels grown with maize tend to have a higher amount of nitrate-N in the soil profile in autumn 2013 on sandy soils.

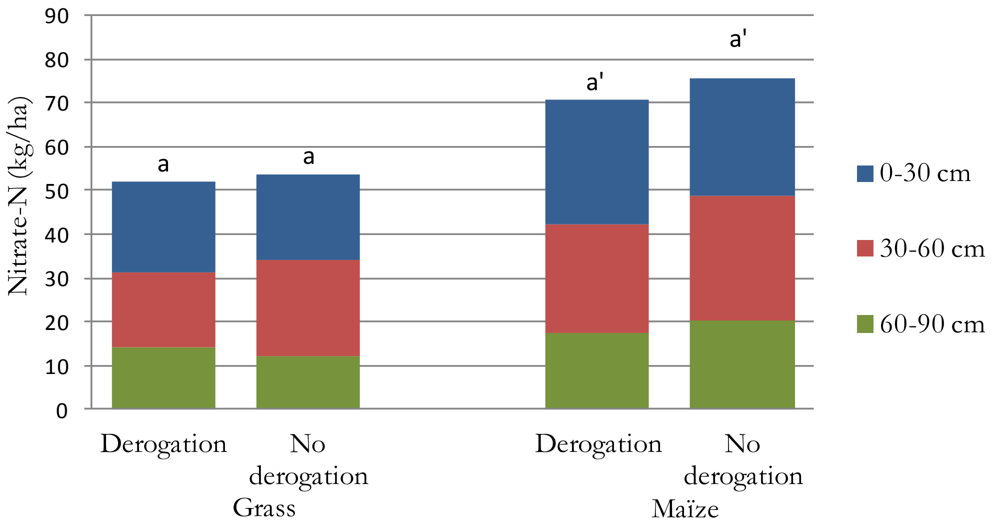


Figure 102: Average nitrate-N (kg N/ha) on derogation and no derogation parcels cultivated with grass or maize on sandy soils in autumn 2013. The results for grass and maize were analysed separately. These results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.12.4 Derogation crops on sandy loam soils

The second soil type on which derogation is frequently requested, is sandy loam. The variance in nitrate residue is for both derogation and no derogation parcels large (Figure 103). On the no derogation parcels with derogation crops on sandy loams soils the variance was smaller than on the derogation parcels, just like in autumn 2012. The derogation parcels on sandy loam showed an average nitrate residue of 56 ± 51 kg N/ha and the no derogation parcels almost the same (53 ± 32 kg N/ha) (Figure 104).

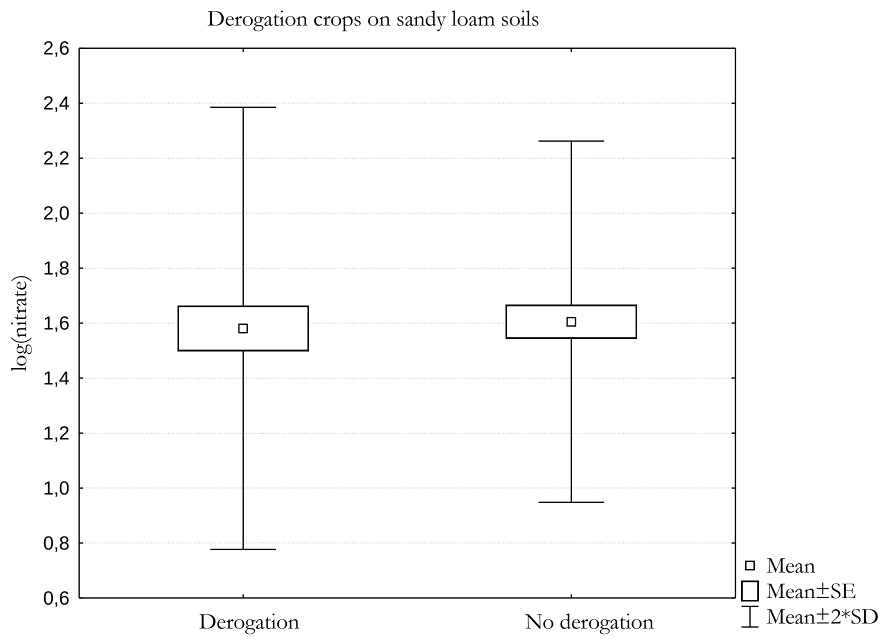


Figure 103: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on sandy loam soils in autumn 2013. SE: standard error of the mean. SD: standard deviation.

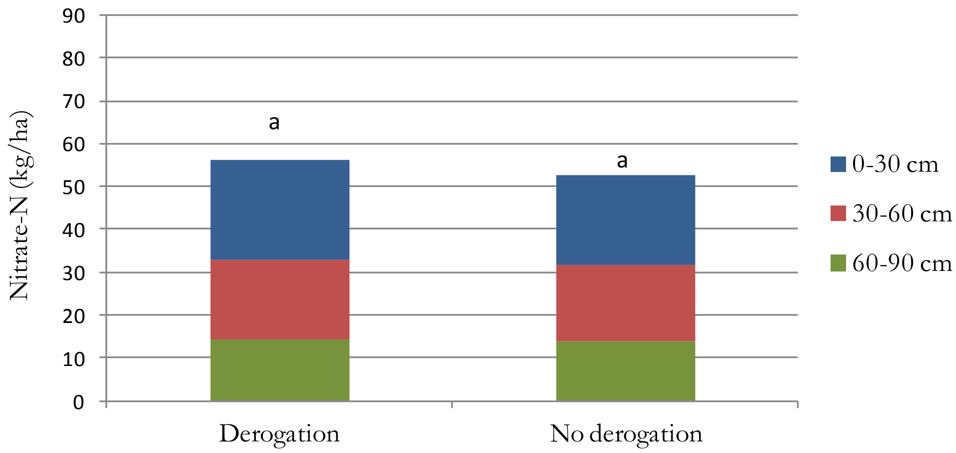


Figure 104: Average nitrate-N (kg N/ha) on derogation and no derogation parcels for derogation crops on sandy loam soils in autumn 2013. These results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.12.4.1 Grass and maize on sandy loam soils

Grass and maize are the most commonly grown derogation crops on sandy loams soils. For these crops a separate statistical analysis is conducted. Nor for grass ($p = 0.95$) nor for maize ($p = 0.56$) there was a statistical significant difference between derogation and no derogation parcels (Figure

105). The average amount of nitrate-N on derogation parcels with grass is 43 ± 45 kg N/ha on sandy loam soils. On the no derogation parcels with grass this was 34 ± 23 kg N/ha. On the maize parcels with and without derogation the average nitrate residue was 65 ± 56 kg N/ha and 66 ± 33 kg N/ha.

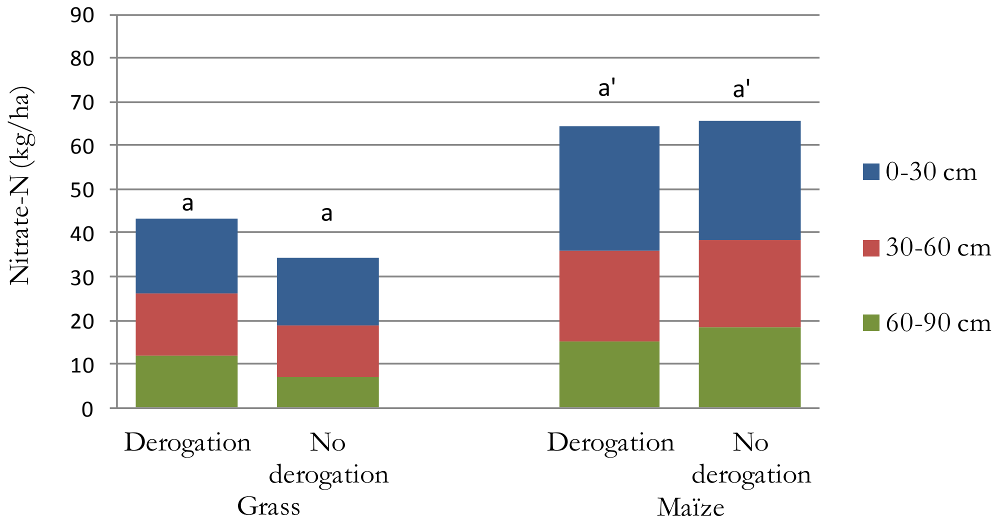


Figure 105: Average nitrate-N (kg N/ha) on derogation and no derogation parcels cultivated with grass or maize on sandy loam soils in autumn 2013. The results for grass and maize were analysed separately. These results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.13 Nitrate in autumn 2013, parcels which were continuously under derogation/no derogation during 2009-2013

In order to verify the long-term impact of derogation on the nitrate residue, only the parcels which were continuously under derogation/no derogation during 2009-2013 were retained for statistical analysis.

In the next paragraphs, box plots show the variation of the groups (derogation and no derogation). The data were log-transformed in order to obtain normality of the dataset. All data are shown visually in bar graphs, which show the distribution of nitrate in the soil profile (0-30 cm, 30-60 cm, 60-90 cm).

On both derogation and no derogation parcels, a large variation in nitrate residue in autumn 2013 is noticed. The average nitrate-N on derogation parcels is 60 ± 48 kg/ha and on no derogation parcels 61 ± 49 kg/ha. Since no limitation to derogation crops, no statistical analysis is carried out.

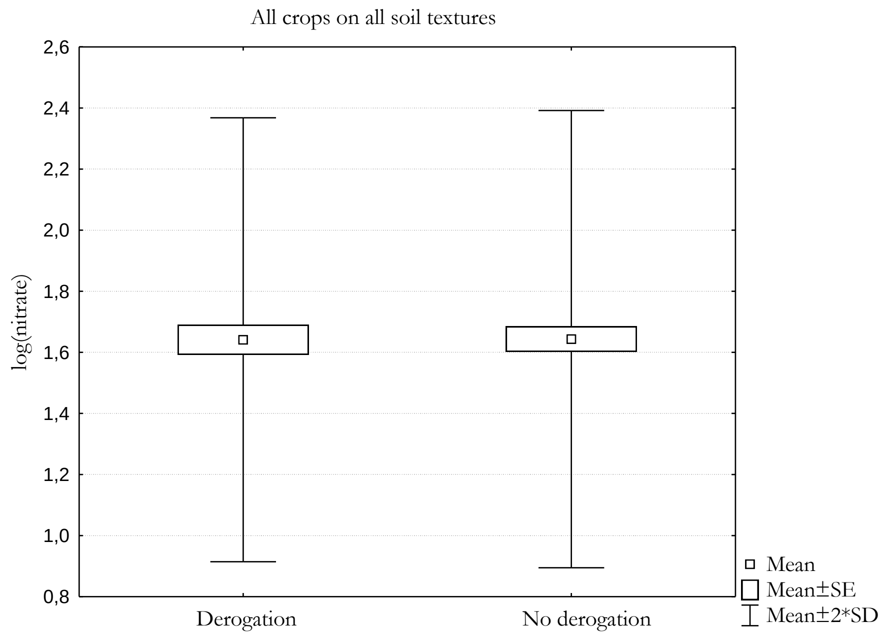


Figure 106: Box plot of log(nitrate-N) for derogation and no derogation parcels on all soil textures in autumn 2013, including only parcels which were continuously under derogation/no derogation during 2009-2013; SE: standard error of the mean. SD: standard deviation.

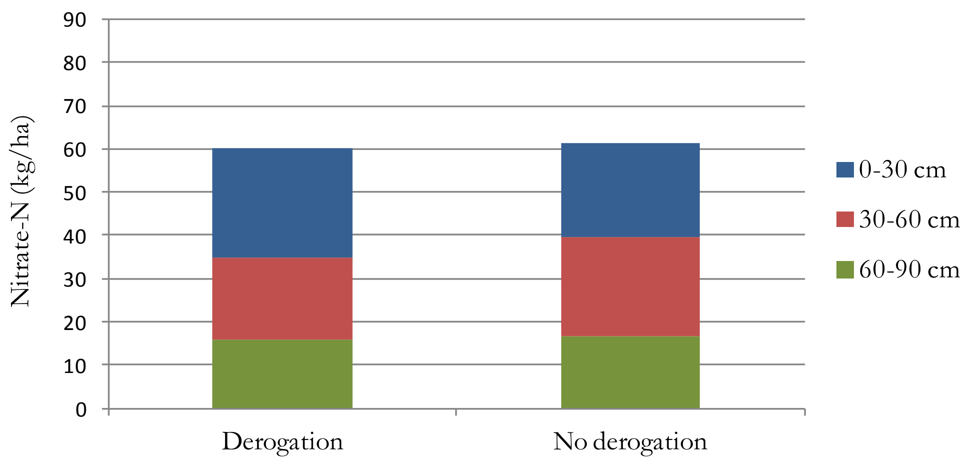


Figure 107: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2013 on all soil textures, including only parcels which were continuously under derogation/no derogation during 2009-2013.

Since sand and sandy loam are the soil textures on which derogation is most frequently requested, the long-term impact of derogation/no derogation is shown separately for these soil textures. Figure 108 shows a large variation in nitrate residue for long-term derogation and no derogation parcels on sandy soils. The average nitrate residue on derogation parcels is 63 ± 43 kg/ha and 64 ± 56 kg/ha on no derogation parcels (Figure 109).

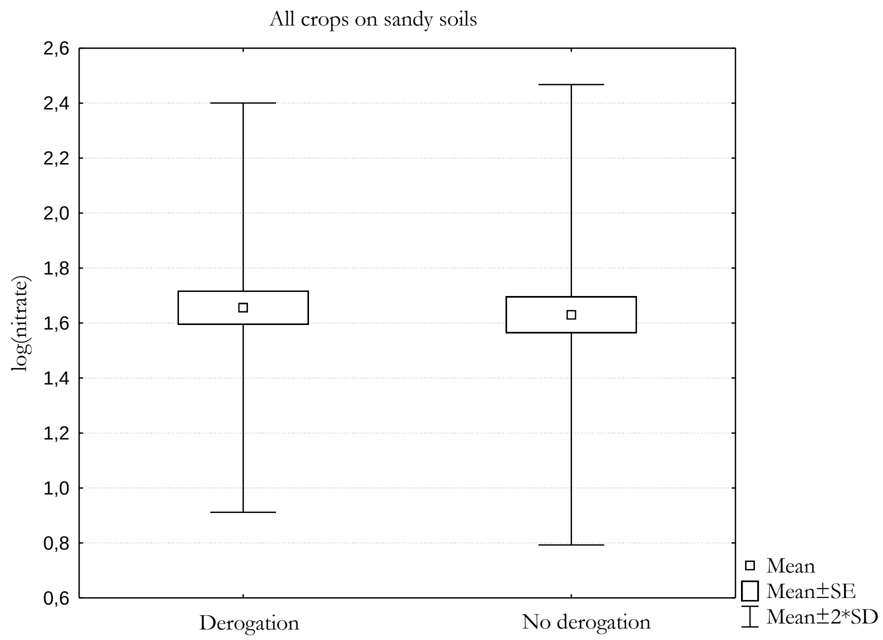


Figure 108: Box plot of log(nitrate-N) for derogation and no derogation parcels on sandy soils in autumn 2013, including only parcels which were continuously under derogation/no derogation during 2009-2013; SE: standard error of the mean. SD: standard deviation.

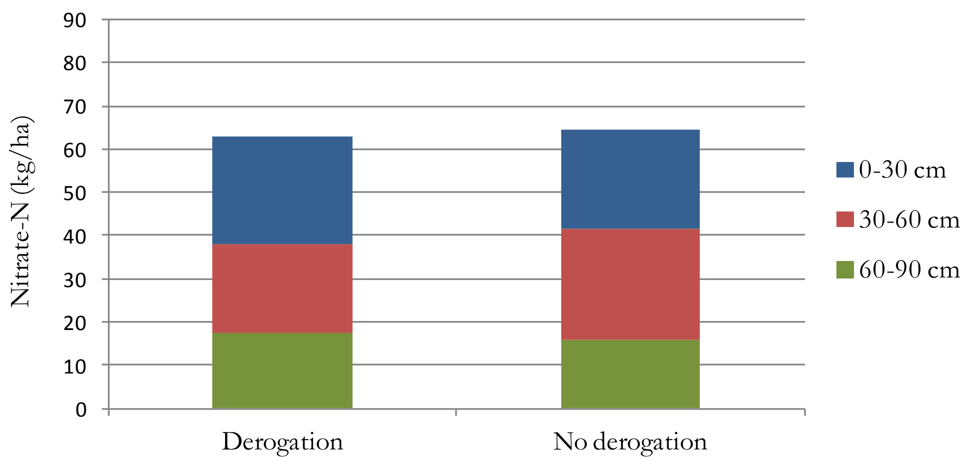


Figure 109: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2013 on sandy soils, including only parcels which were continuously under derogation/no derogation during 2009-2013.

The variation in nitrate residue for long-term derogation and no derogation parcels on sandy loam soils is shown in Figure 110. The variation on the parcels without derogation is obviously smaller than on the derogation parcels. The average nitrate residue on derogation parcels is 54 ± 47 kg/ha and 52 ± 33 kg/ha on no derogation parcels (Figure 111).

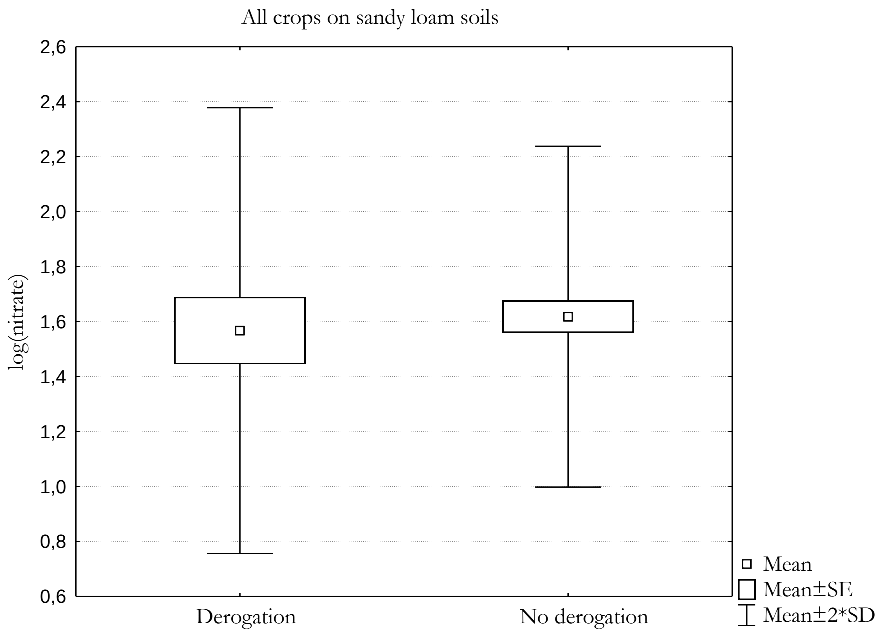


Figure 110: Box plot of log(nitrate-N) for derogation and no derogation parcels on sandy loam soils in autumn 2013, including only parcels which were continuously under derogation/no derogation during 2009-2013; SE: standard error of the mean. SD: standard deviation.

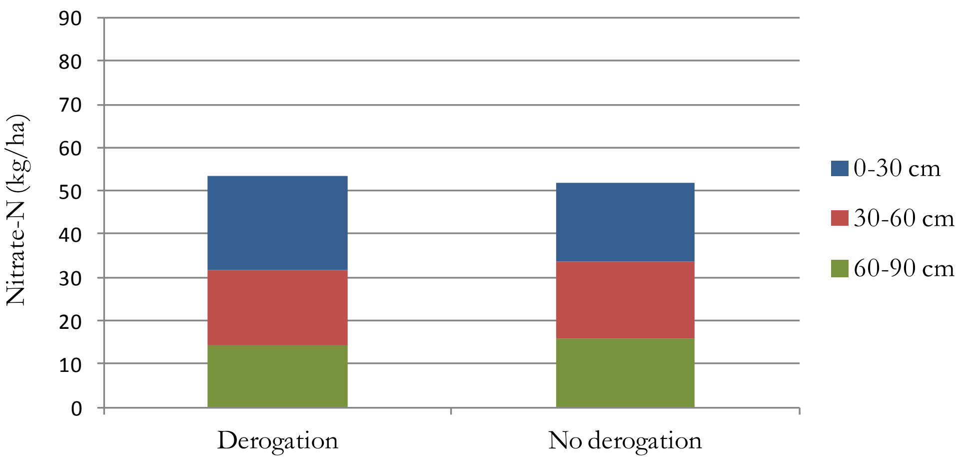


Figure 111: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2013 on sandy loam soils, including only parcels which were continuously under derogation/no derogation during 2009-2013.

On the parcels continuously grown with grass in the period 2009-2013 the variation of the nitrate residues on both types of parcels was high and no statistical difference between derogation and no derogation parcels is detected (p = 0.44) (Figure 112).

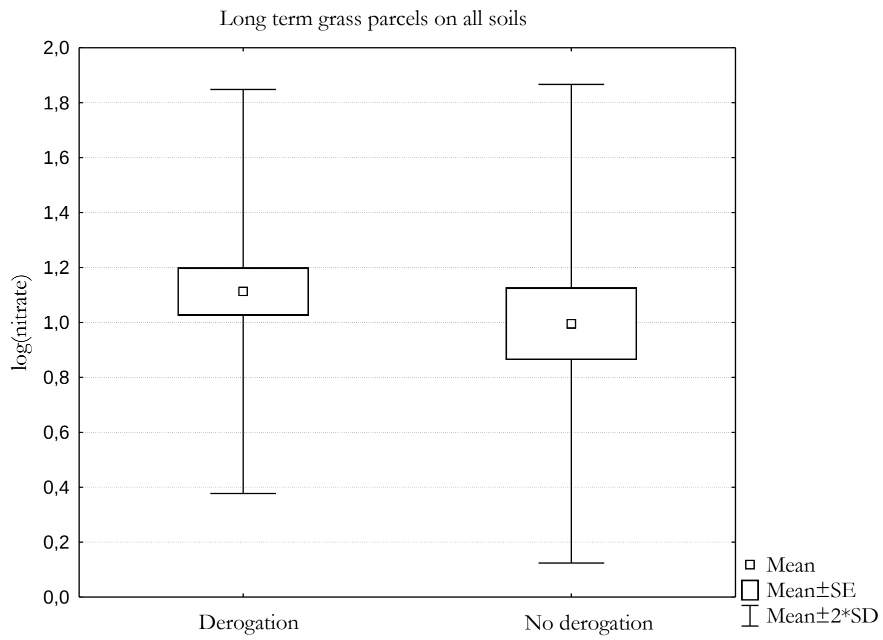


Figure 112: Box plot of log(nitrate-N) for derogation and no derogation parcels on all soils in autumn 2013, including only parcels which were continuously under derogation/no derogation during 2009-2013 and grown with grass; SE: standard error of the mean. SD: standard deviation.

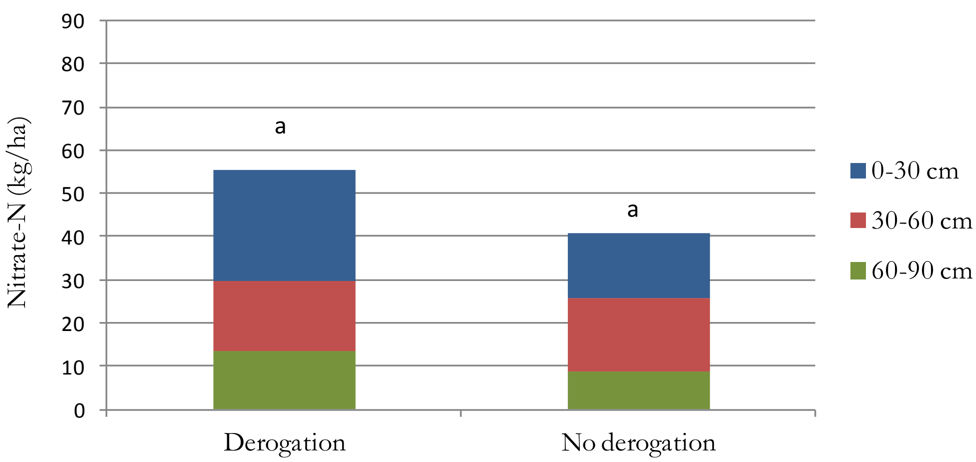


Figure 113: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2013 on all soils, including only parcels which were continuously under derogation/no derogation during 2009-2013 and grown with grass. The results were analysed statistically by means of a one-way ANOVA (p≤0.05) on the log-transformed data. Identical letters indicate no statistical difference.

On the parcels continuously under derogation in the period 2009-2013 and continuously grown with grass the nitrate residue was 56 ± 42 kg N/ha in autumn 2013 and 41 ± 42 kg N/ha on no derogation parcels (Figure 113).

Since not enough long-term maize parcels were available, no statistical analysis is carried out. But Figure 114 shows that the average nitrate residues were close. On parcels continuously under derogation in the period 2009-2013 and grown with maize every year, the nitrate residue was 55 ± 25 kg N/ha in autumn 2013. On parcels continuously without derogation in the period 2009-2013 and grown with maize every year, the nitrate residue was 57 ± 32 kg N/ha.

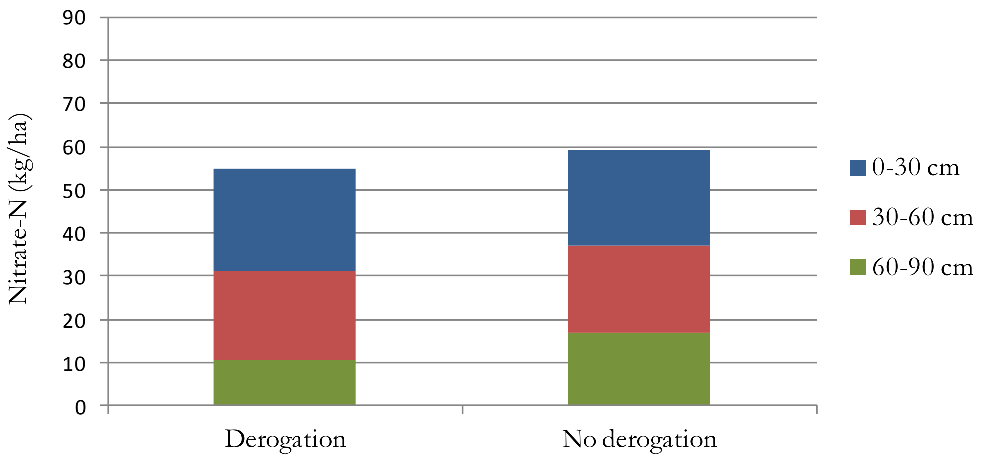


Figure 114: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2013 on all soils, including only parcels which were continuously under derogation/no derogation during 2009-2013 and grown with maize.

6.14 Nitrate in autumn 2013 in the deeper soil layer

In autumn 2013 for 36 parcels an additional soil sample was taken from 90 to 120 cm (the "deep soil sample"). In this soil layer the amount of nitrate is measured. Data are considered statistical outliers when exceeding the average plus 2 times the standard deviation. One outlier is removed. A derogation parcel on a sandy soil cultivated with grass, with 128 kg N/ha in the soil layer 90-120. On this parcel the soil layers above contained 144 kg N/ha (27 kg N/ha in the soil layer 0-30 cm, 48 kg N/ha in the soil layer 30-60 cm and 69 kg N/ha in the soil layer 60-90 cm). After mowing, the parcel was grazed until November.

In autumn 2013 a significant correlation (p = 0.00) exists between the amount of nitrate in the soil profile from 0-90 cm and the amount of nitrate in the soil layer from 90-120 cm (Figure 115).

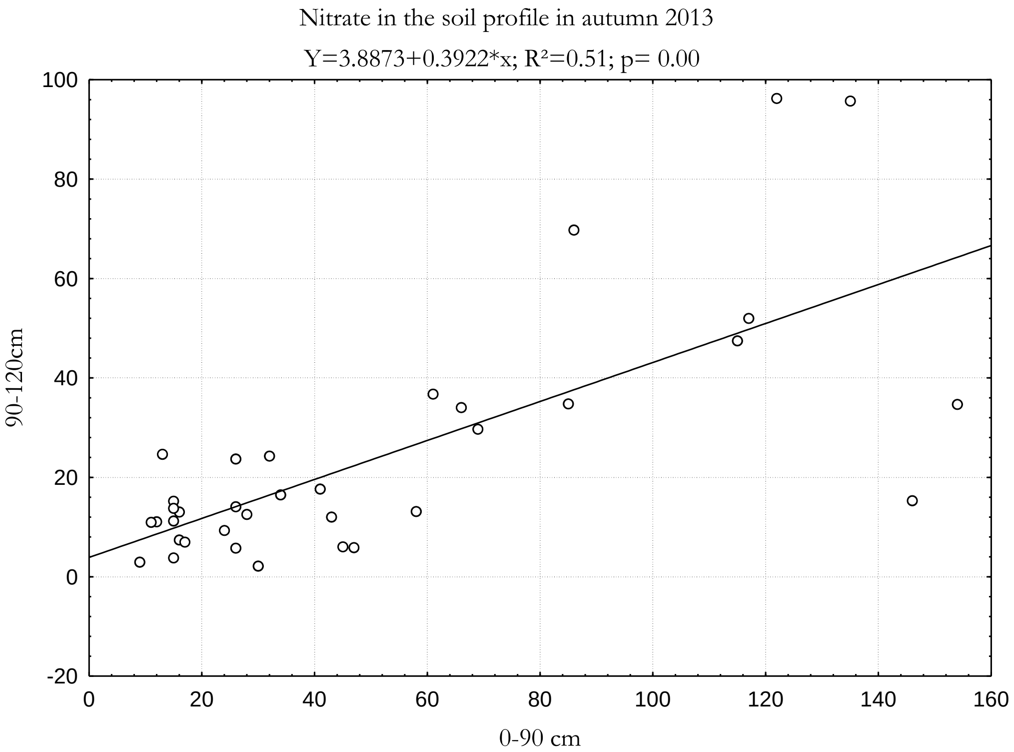


Figure 115: Scatterplot of the nitrate-N (kg/ha) in the soil profile from 0-90 cm versus the nitrate-N (kg/ha) in the soil profile from 90-120 cm in autumn 2013.

Since the deep soil samples are taken on a selection of parcels, it is not possible to carry out a statistical analysis for all combinations of derogation, soil texture and cultivated crop. A comparison is made of derogation and no derogation parcels with grass or maize on all soil textures.

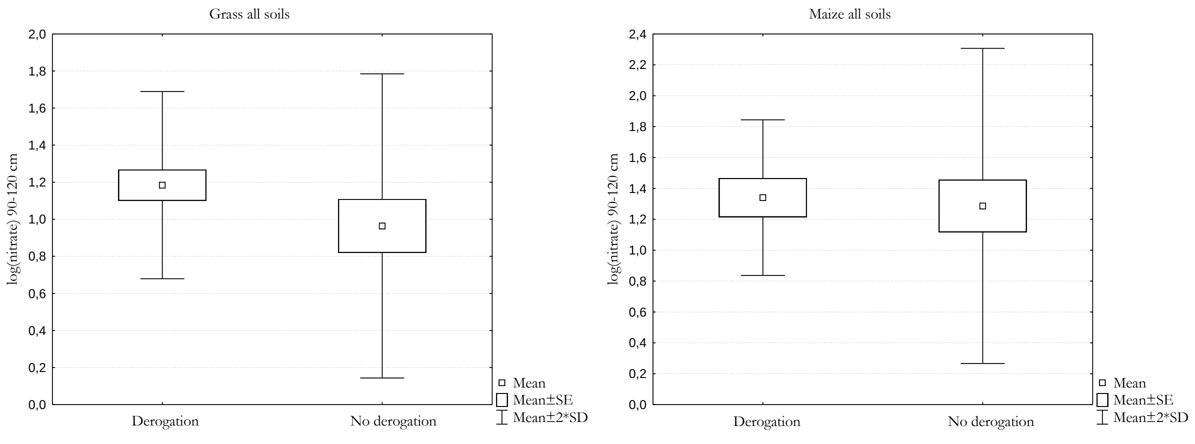


Figure 116: Box plot of log(nitrate-N, 90-120 cm) for derogation and no derogation parcels in autumn 2013, for grass (left) and maize (right) on all soil textures. SE: standard error of the mean. SD: standard deviation.

The average nitrate-N content in the soil layer 90-120 cm on derogation parcels with grass in autumn 2013 is 18 ± 11 kg/ha and 13 ± 11 kg/ha on no derogation parcels. For maize parcels the nitrate content in the soil layer 90-120 cm in autumn 2013 is 25 ± 18 kg/ha on derogation parcels and 34 ± 37 kg/ha on no derogation parcels.

The average level of nitrate-N in the soil profile till 120 cm on parcels cultivated with grass under derogation is 51 ± 35 kg/ha and 69 ± 67 kg/ha under no derogation. The average level of nitrate-N in the soil profile till 120 cm on parcels cultivated with maize under derogation is 77 ± 62 kg/ha and 93 ± 80 kg/ha under no derogation (Figure 118).

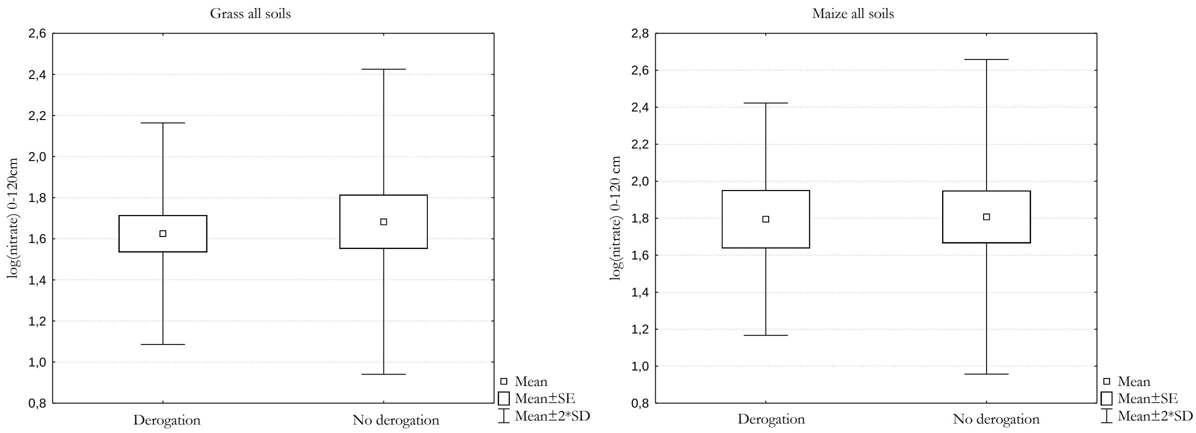


Figure 117: Box plot of log(nitrate-N, 0-120 cm) for derogation and no derogation parcels in autumn 2013, for grass (left) and maize (right) on all soil textures. SE: standard error of the mean. SD: standard deviation.

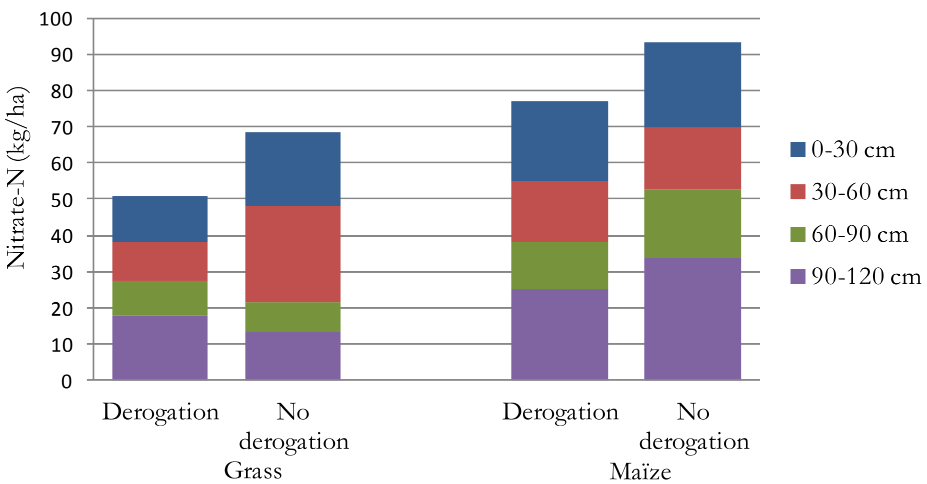


Figure 118: Average nitrate-N (kg/ha) in the 4 soil layers on derogation and no derogation parcels on all soil textures cultivated with grass or maize, autumn 2013.

In average 33 to 36 % of the nitrate-N in the soil profile 0-120 cm is situated in the soil layer 90-120 cm in autumn 2013 on derogation parcels cultivated with grass and derogation and no derogation parcels cultivated with maize. On the no derogation parcels cultivated with grass, only 19 % of the nitrate-N content was situated in the deepest soil layer.

6.15 Nitrate in spring 2014

On the parcels of the monitoring network a nitrate sample has been taken in spring 2014. This nitrate sample consists of three soil layers (0-30 cm, 30-60 cm and 60-90 cm) and provides information on the amount of nitrate in the soil profile after winter and the amount available to the cultivated crop for the next growing season. Every farmer receives a nitrate fertilisation advice, based on the N-INDEX expert system (Geypens *et al.*, 1994).

The average level of nitrate measured in the soil samples in autumn 2013 and spring 2014 is shown in Table 47. The amount of nitrate is given for the combinations of derogation, soil texture and cultivated crop for the total soil profile (0-90 cm) and for each soil layer of 30 cm in spring. The values in bold in Table 47 have high levels of nitrate (> 90 kg N/ha) in autumn 2013. However, since 2011 the allowed maximum nitrate residue in the soil profile from 0-90 cm depends on the cultivated crop, soil type, focus or non-focus area. Therefore, the values in bold are indicative.

Not all parcels are covered by the shown average values, since some parcels were already fertilised in spring 2014 while other parcels were detected as statistical outlier in autumn 2013 or spring 2014. Therefore values in Table 47 for autumn 2013 are not identical to those shown in Table 46. In spring 2014, two parcels were detected as statistical outlier. One parcel was also detected as statistical outlier in autumn 2013. It was cultivated with maize in 2013 without derogation on sandy soil with a nitrate residue of 261 kg NO_3-N/ha. No exuberant fertilisation was applied and harvest had been good. The amount of nitrate-N at February 1st was 167 kg N/ha. On the second parcel detected as outlier in spring 2014, the amount of nitrate-N was 107 kg N/ha at January 28th. No fertilisation had already been applied at that moment but the parcel was grazed in autumn 2013.

Table 47: Average nitrate-N (kg/ha) in the soil profile in autumn 2013 and spring 2014. The nitrate-N is given for the different combinations of soil texture, cultivated crop and derogation in 2013. For each combination the total amount of nitrate is given as well as for each soil layer (layer 1: 0-30 cm, layer 2: 30-60 cm and layer 3: 60-90 cm). The number of parcels is indicated by "n".

	Soil	Crop 2013	n	Autumn 2013	Nitrate-N (kg/ha) in spring 2014			
				0-90 cm	0-30cm	30-60cm	60-90cm	0-90cm
Derogation			86					
	Clay	Beets	-	-	-	-	-	-
		Grass	9	60	12	13	6	31
		Maize	-	-	-	-	-	-
		Winter wheat	-	-	-	-	-	-
	Loam	Beets	-	-	-	-	-	-
		Grass	-	-	-	-	-	-
		Maize	1	**91**	17	21	21	59
		Winter wheat	-	-	-	-	-	-
	Sand	Beets	-	-	-	-	-	-
		Grass	30	52	6	6	5	17
		Maize	23	79	8	8	12	28
		Winter wheat	2	**146**	4	2	5	11
	Sandy loam	Beets	-	-	-	-	-	-
		Grass	10	37	8	9	7	24
		Maize	10	54	6	9	10	25
		Winter wheat	1	**100**	3	2	1	6
No derogation			85					
	Clay	Beets	-	-	-	-	-	-
		Grass	2	46	9	8	7	24
		Maize	2	87	5	8	10	23
		Winter wheat	2	77	14	19	21	54
		Other	3	**175**	2	2	7	11
	Loam	Beets	-	-	-	-	-	-
		Grass	1	9	1	0	0	1
		Maize	5	57	9	9	11	29
		Winter wheat	1	65	8	13	40	61
		Other	-	-	-	-	-	-
	Sand	Beets	-	-	-	-	-	-
		Grass	15	64	7	9	6	22
		Maize	11	83	11	8	12	31
		Winter wheat	3	**137**	3	3	5	11
		Other	9	**96**	5	4	7	16
	Sandy loam	Beets	-	-	-	-	-	-
		Grass	9	33	9	5	4	18
		Maize	14	65	9	10	14	33
		Winter wheat	3	51	3	2	4	9
		Other	5	73	10	10	11	31

The relation between nitrate in the soil profile from 0-90 cm in autumn 2013 and spring 2014 is shown in a scatterplot (Figure 119). A significant correlation ($p \leq 0.05$) exists. Three percent of the variance is explained by the model.

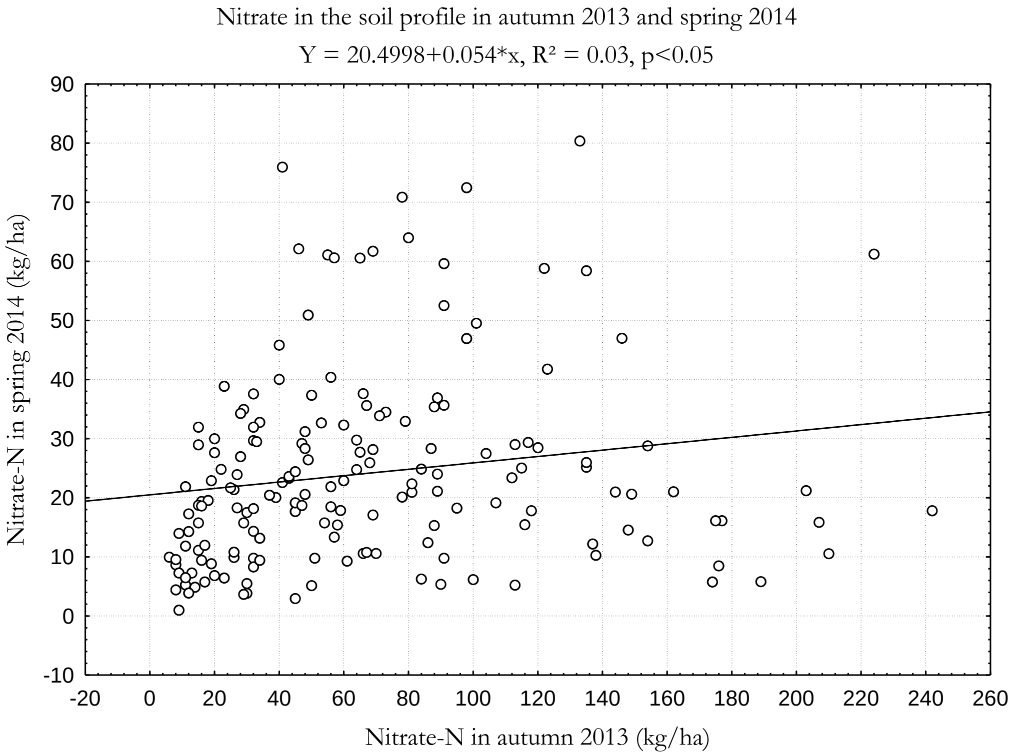


Figure 119: Scatterplot of the nitrate-N (kg/ha) in the soil profile from 0-90 cm in autumn 2013 versus the nitrate-N (kg/ha) in the soil profile from 0-90 cm in spring 2014.

6.15.1 All crops on all soil textures

In the first part of the statistical analysis, the total amount of nitrate in spring 2014 between derogation and no derogation parcels is compared for all crops on all soil textures. On both derogation and no derogation parcels, the nitrate measurements show a large variation (Figure 120). Since no derogation crops (vegetables, ...) are present in this dataset, the compared groups are not homogeneous and no statistical analysis was conducted between derogation and no derogation parcels.

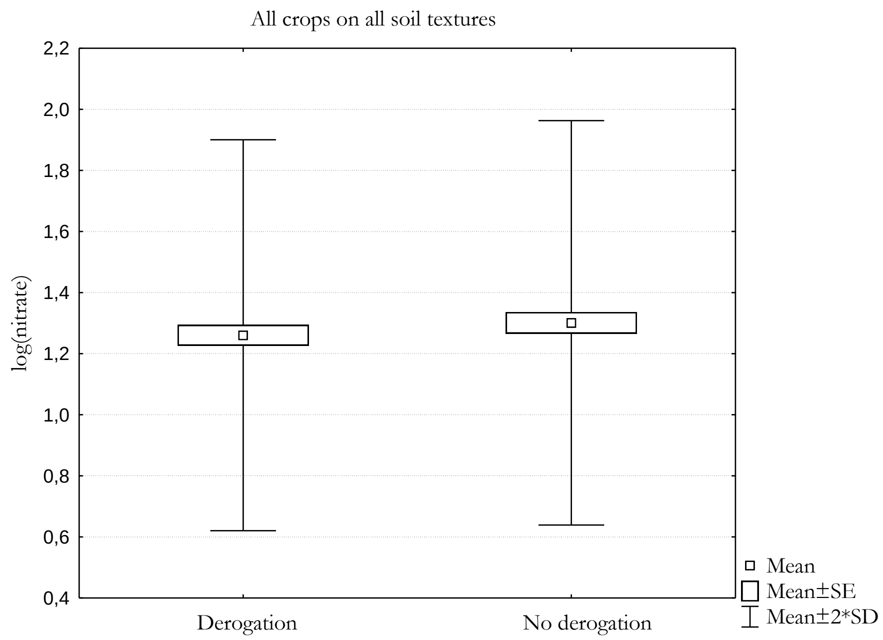


Figure 120: Box plot of log(nitrate-N) for derogation and no derogation parcels with all crops on all soil textures in spring 2014. SE: standard error of the mean. SD: standard deviation.

The average amount of nitrate-N is 23 ± 16 kg/ha for derogation parcels and 26 ± 18 kg/ha for no derogation parcels (Figure 121). The amount of nitrate is more or less equally distributed over all three soil layers.

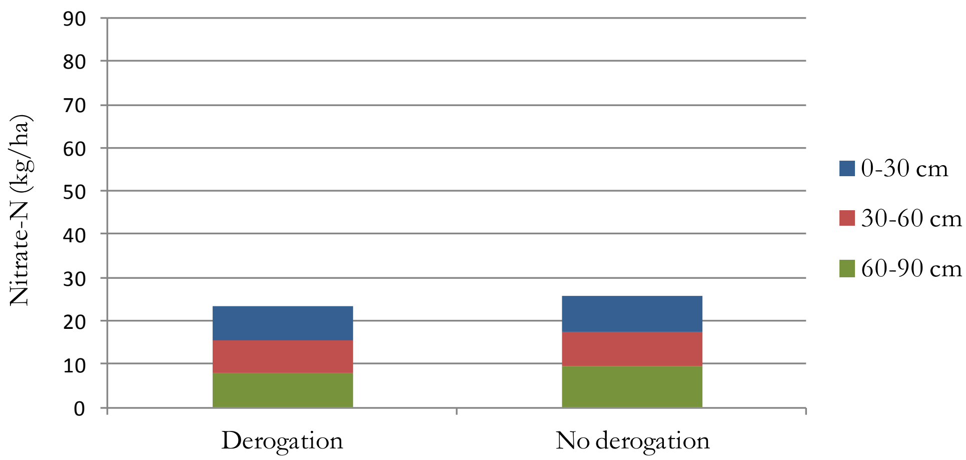


Figure 121: Average nitrate-N (kg/ha) on derogation and no derogation parcels with all crops on all soil textures in spring 2014.

6.15.2 Derogation crops on all soil textures

In a next step derogation and no derogation parcels cultivated with only derogation crops (grass, maize, beets, winter wheat) are compared. The measured nitrate values are highly variable (Figure 122).

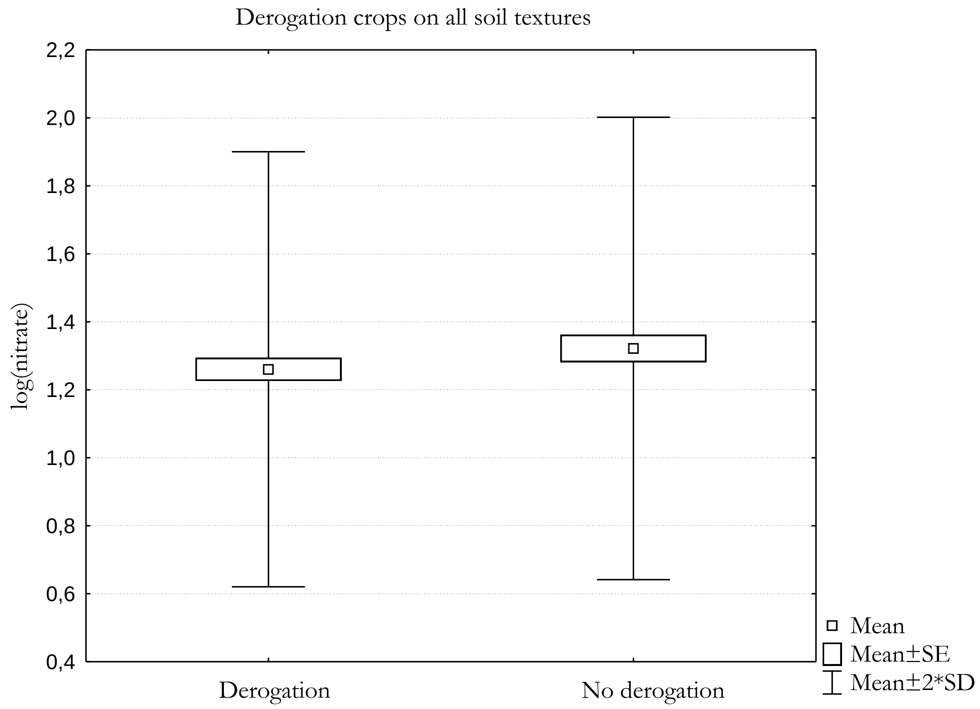


Figure 122: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on all soil textures in spring 2014. SE: standard error of the mean. SD: standard deviation.

No statistically significant difference was found between nitrate-N measured on derogation (23 ± 16 kg N/ha) and no derogation (27 ± 18 kg N/ha) parcels (Figure 123, $p = 0.24$). The amount of nitrate is more or less equally distributed over all three soil layers.

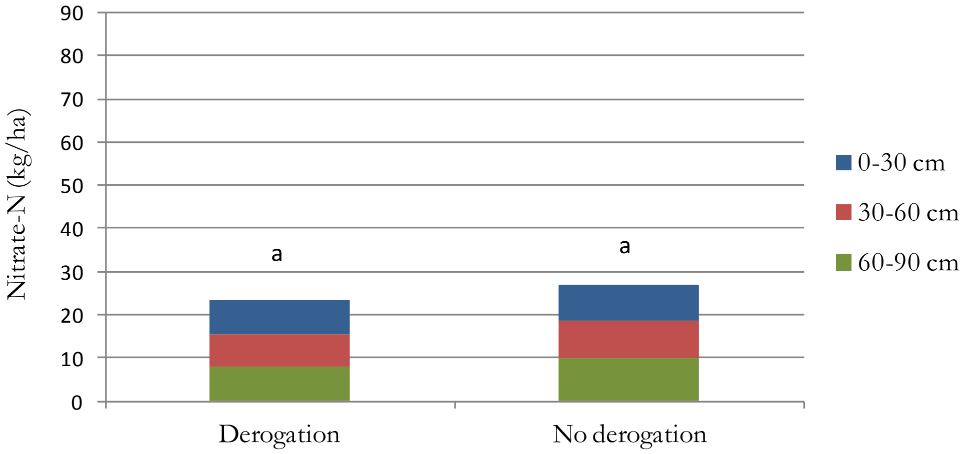


Figure 123: Average nitrate-N (kg/ha) on derogation and no derogation parcels for derogation crops on all soil textures in spring 2014. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.15.3 Derogation crops on sandy soils

In the next step, significant differences between derogation and no derogation parcels for the most important soil textures and derogation crops are explored.

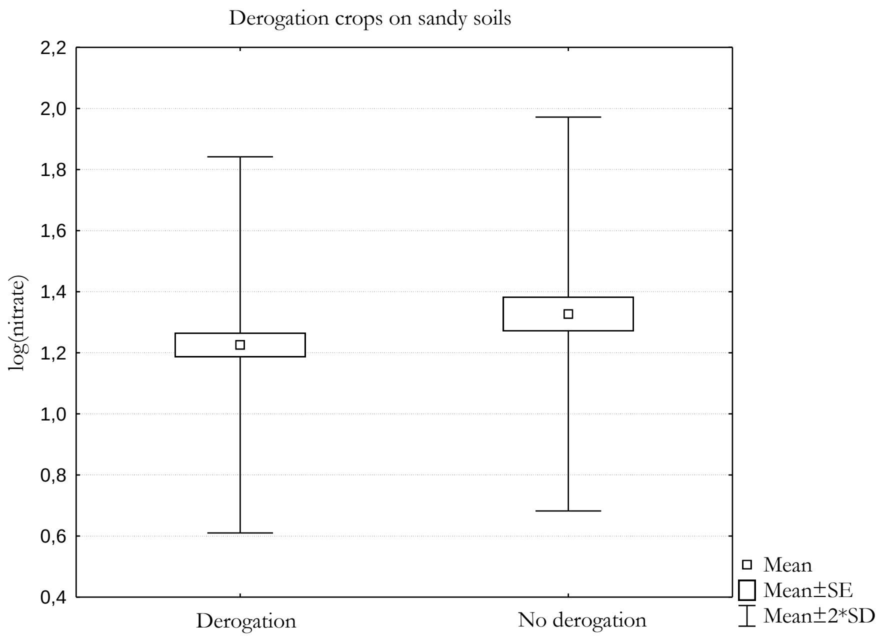


Figure 124: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on sandy soils in spring 2014. SE: standard error of the mean. SD: standard deviation.

The average value of nitrate-N for derogation crops on sandy soils is 21 ± 15 kg/ha for derogation parcels and 27 ± 19 kg/ha for no derogation parcels. There is a large variation within each group (Figure 124). The nitrate-N measured on sandy soils on derogation parcels from 0-90 cm does not differ significantly from the nitrate measured on no derogation parcels (Figure 125, $p = 0.15$).

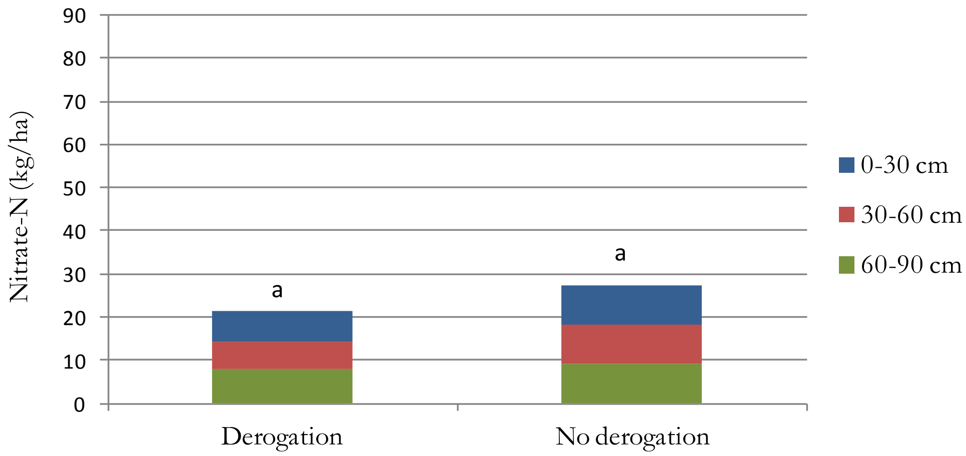


Figure 125: Average nitrate-N (kg/ha) on derogation and no derogation parcels for derogation crops on sandy soils in spring 2014. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.15.3.1 Grass and maize on sandy soils

So far no significant differences were found between derogation and no derogation for derogation crops on sandy soils. Since grass and maize are mostly cultivated on sandy soils, these combinations are compared separately for grass and maize by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data (Figure 126).

For grass the nitrate-N was 17 ± 11 kg /ha in derogation parcels and 22 ± 14 kg/ha in no derogation parcels. For maize the nitrate-N was 28 ± 18 kg/ha on derogation parcels and 36 ± 22 kg/ha on no derogation parcels. There is no significant difference between derogation and no derogation parcels cultivated with grass ($p = 0.22$) or with maize ($p = 0.24$).

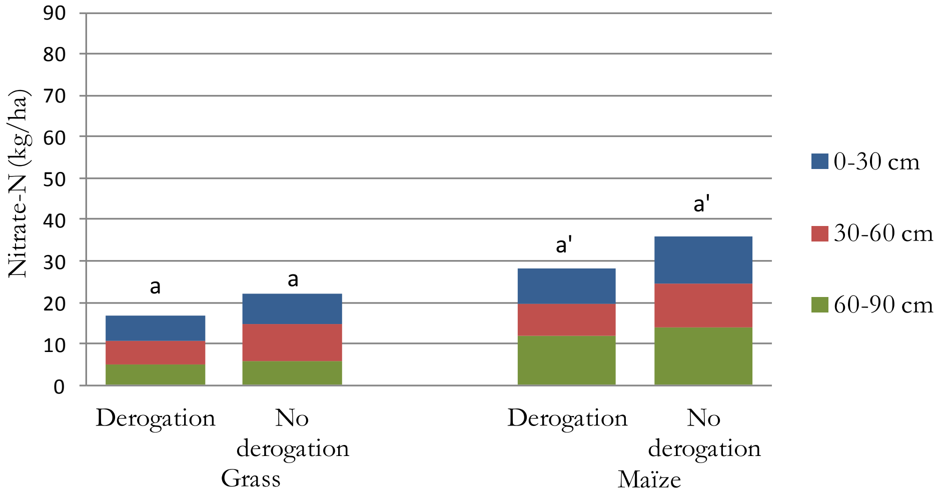


Figure 126: Average nitrate-N (kg/ha) on derogation and no derogation parcels with grass or maize on sandy soils in spring 2014. The results for grass and maize were analysed separately. A one-way ANOVA ($p \leq 0.05$) was conducted on the log-transformed data. Identical letters indicate no statistical difference.

6.15.4 Derogation crops on sandy loam soils

Next, derogation and no derogation parcels cultivated with derogation crops on sandy loam soils were compared.

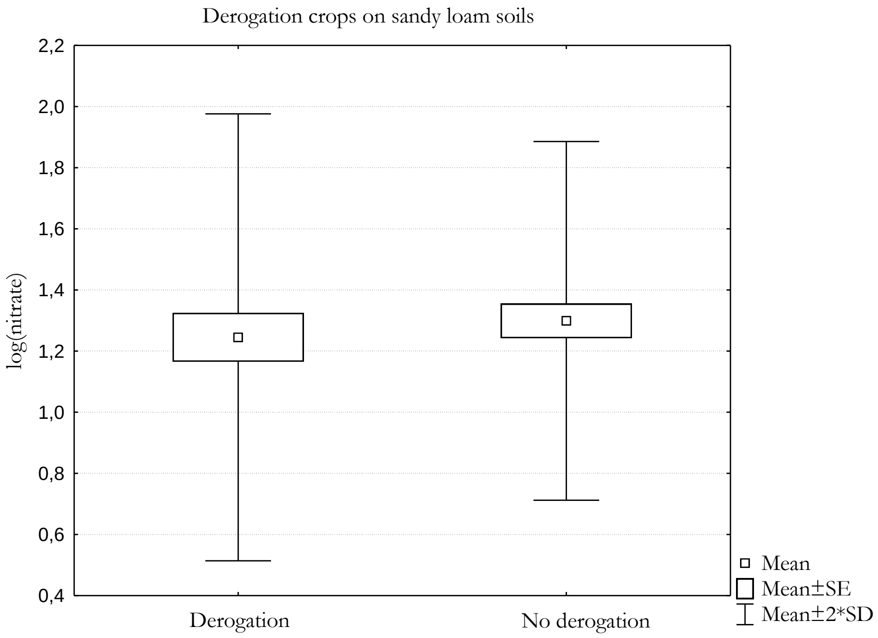


Figure 127: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on sandy loam soils in spring 2014. SE: standard error of the mean. SD: standard deviation.

On both derogation and no derogation parcels on sandy loam soil, a large variation is observed in the amount of nitrate-N (Figure 127). No significant difference was found between derogation (24 ± 18 kg N/ha) and no derogation parcels (25 ± 17 kg N/ha) on sandy loam soils (Figure 128, p = 0.57) by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data.

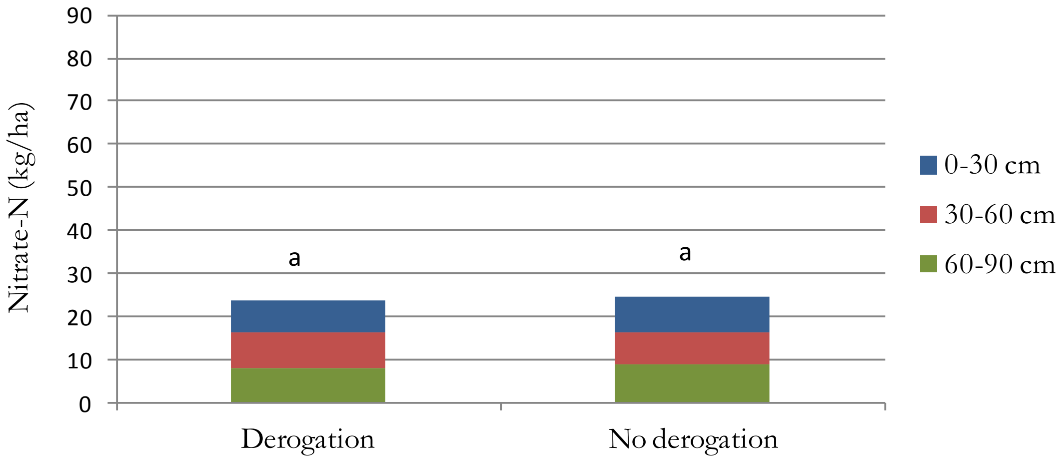


Figure 128: Average nitrate-N (kg/ha) on derogation and no derogation parcels for derogation crops on sandy loam soil in spring 2014. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.15.4.1 Grass and maize on sandy loam soils

Figure 129 shows the average values of nitrate-N in the total soil profile and the different soil layers for grass and maize on sandy loam soils. For grass the average nitrate-N is 24 ± 22 kg/ha on derogation parcels and 18 ± 6 kg /ha on no derogation parcels. For maize the average nitrate level was 25 ± 14 kg N/ha on derogation parcels and 33 ± 20 kg N/ha on no derogation parcels (Figure 129). A statistical analysis between derogation and no derogation parcels was conducted separately for grass and maize by means of a one-way ANOVA ($p \leq 0.05$) of the log-transformed data. There is no significant difference between derogation and no derogation parcels cultivated with grass (p=0.91) or with maize (p=0.31).

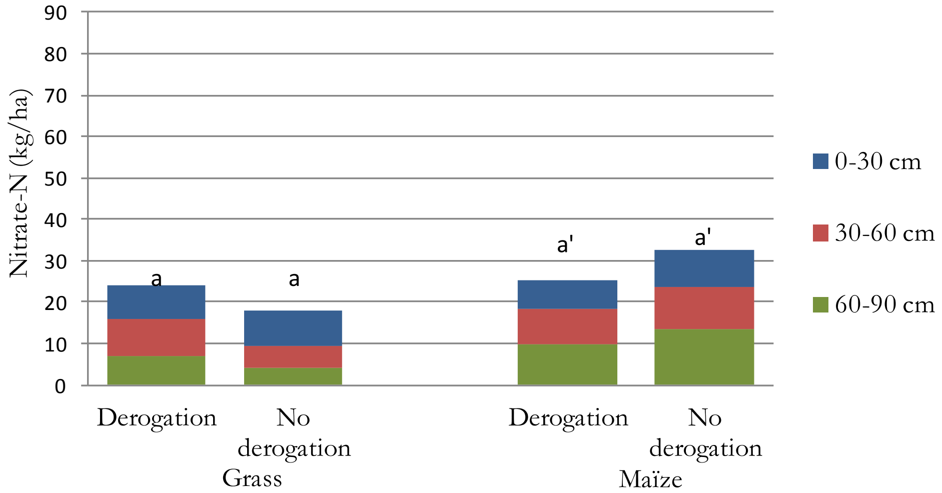


Figure 129: Average nitrate-N (kg/ha) on derogation and no derogation parcels with grass or maize on sandy loam soils in spring 2014. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.16 Nitrate in spring 2014, parcels which were continuously under derogation/no derogation during 2009-2013

In order to verify the long-term impact of derogation on the nitrate in the soil in spring 2014, only the parcels which were continuously under derogation/no derogation during 2009-2013 were compared.

In this paragraph box plots show the variation of the groups (derogation and no derogation). The data were log-transformed in order to obtain normality of the dataset. All data are shown visually in bar graphs, which show the distribution of nitrate in the soil profile (0-30 cm, 30-60 cm, 60-90 cm).

On both derogation and no derogation parcels the variation in amount of nitrate-N in the soil profile 0-90 cm in spring 2014 is rather large as shown in Figure 130. In spring 2014 the average nitrate-N on derogation parcels is 23 ± 15 kg/ha and 26 ± 18 kg/ha on no derogation parcels (Figure 131). The nitrate-N is on both types of parcels, derogation or no derogation, equally distributed in the layers 0-30 cm, 30-60 cm and 60-90 cm.

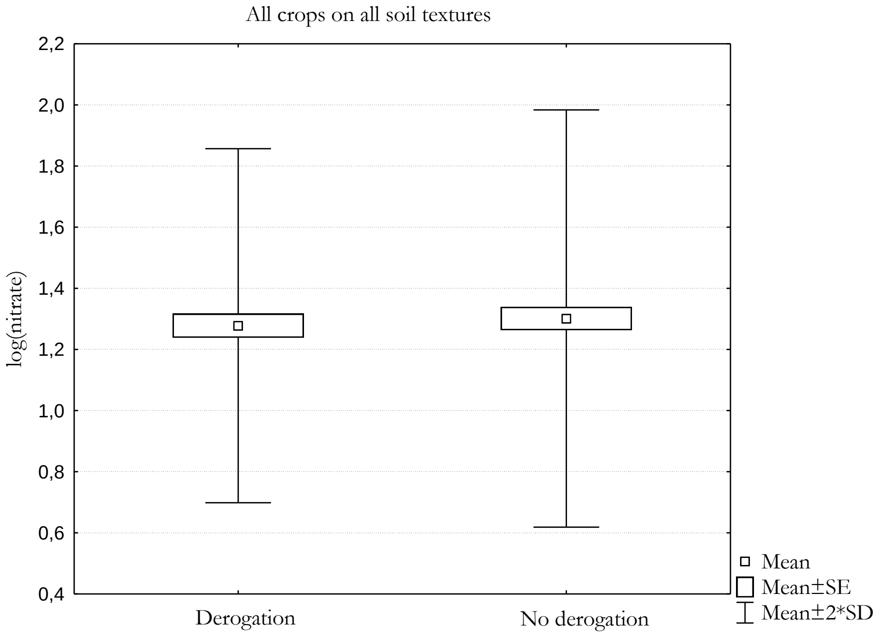


Figure 130: Box plot of log(nitrate-N) for derogation and no derogation parcels on all soil textures in spring 2014, including only parcels which were continuously under derogation/no derogation during 2009-2013; SE: standard error of the mean. SD: standard deviation.

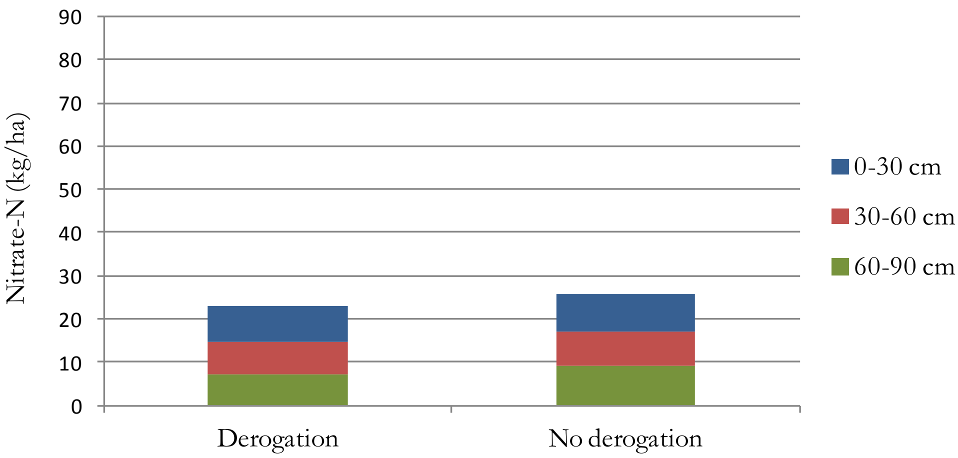


Figure 131: Average nitrate-N (kg/ha) on derogation and no derogation parcels in spring 2014 on all soil textures, including only parcels which were continuously under derogation/no derogation during 2009-2013.

For the most important soil textures for derogation, sand and sandy loam, the comparison between derogation and no derogation parcels is made separately. Since on the no derogation parcels also no derogation crops are grown no statistical analysis is carried out.

On sandy soils the average nitrate-N in the soil profile of long-term derogation parcels is 21 ± 15 kg/ha in spring 2014 and 24 ± 17 kg/ha on no derogation parcels (Figure 133).

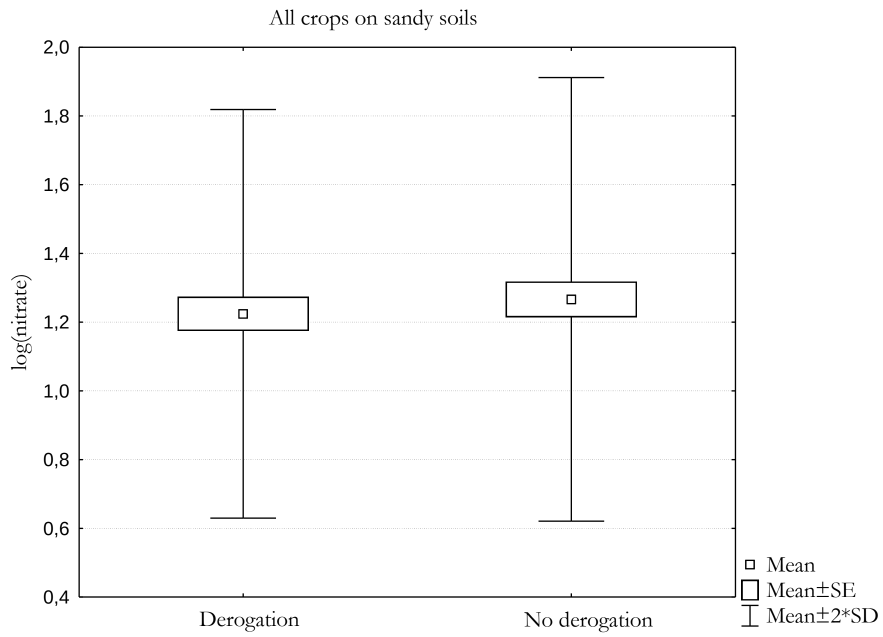


Figure 132: Box plot of log(nitrate-N) for derogation and no derogation parcels on sandy soils in spring 2014, including only parcels which were continuously under derogation/no derogation during 2009-2013; SE: standard error of the mean. SD: standard deviation.

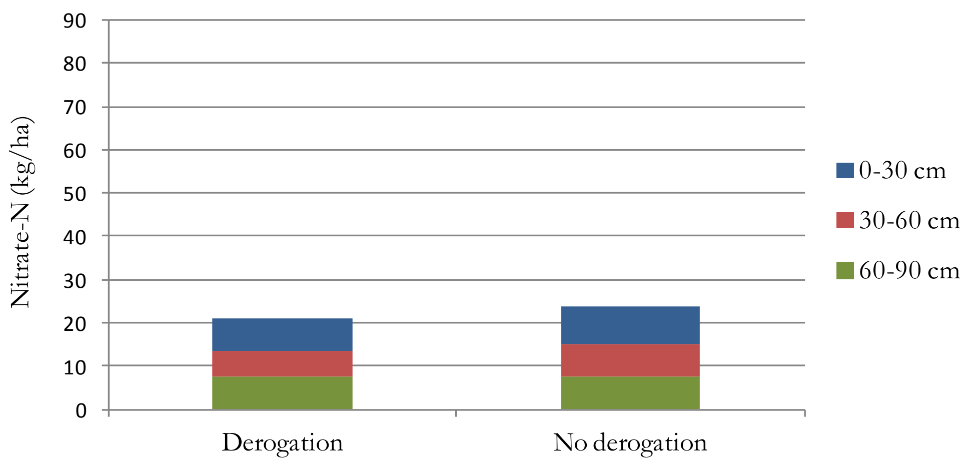


Figure 133: Average nitrate-N (kg/ha) on derogation and no derogation parcels in spring 2014 on sandy soils, including only parcels which were continuously under derogation/no derogation during 2009-2013.

In spring 2014 the variation in nitrate-N on no derogation parcels was almost the same as the variation on derogation parcels on sandy loam soils (Figure 134). The average nitrate-N is 24 ± 11 kg/ha on derogation parcels and 27 ± 18 kg/ha on no derogation parcels (Figure 135).

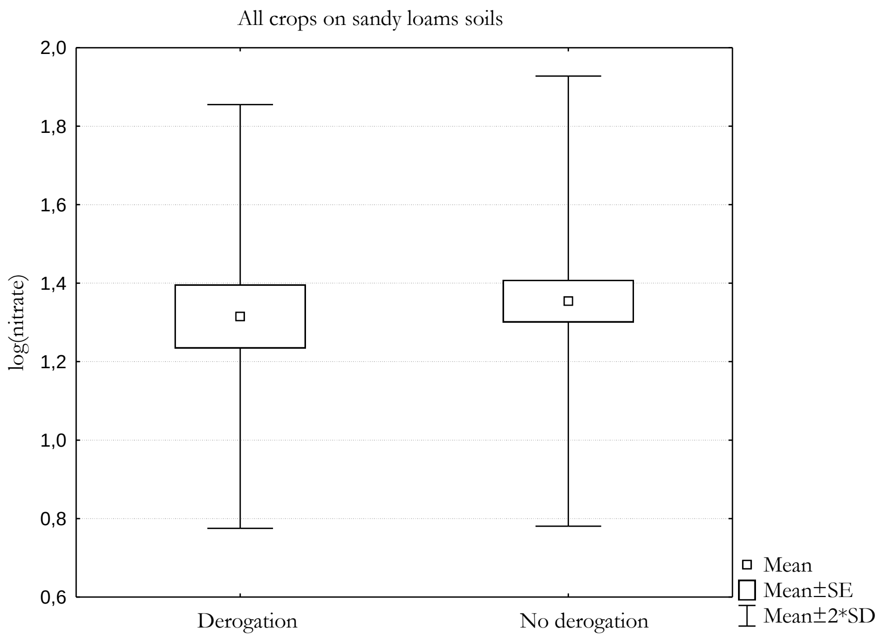


Figure 134: Box plot of log(nitrate-N) for derogation and no derogation parcels on sandy loam soils in spring 2014, including only parcels which were continuously under derogation/no derogation during 2009-2013; SE: standard error of the mean. SD: standard deviation.

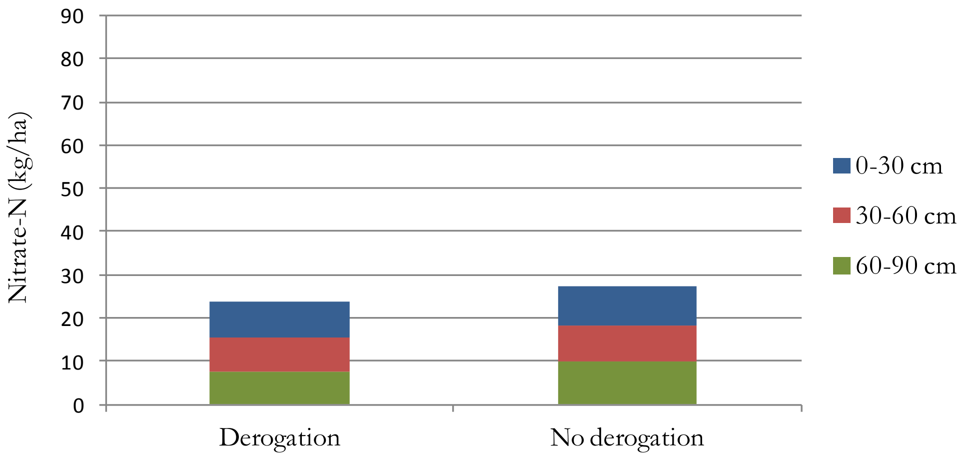


Figure 135: Average nitrate-N (kg/ha) on derogation and no derogation parcels in spring 2014 on sandy loam soils, including only parcels which were continuously under derogation/no derogation during 2009-2013.

On the parcels continuously under derogation in the period 2009-2013 and continuously grown with grass the amount of nitrate-N was 24 ± 21 kg N/ha in spring 2014 and 27 ± 29 kg N/ha on no derogation parcels (Figure 137). Figure 136 shows that the variation in amount of nitrate-N on both types of parcels was high and no statistical difference between derogation and no derogation parcels is detected (p = 0.77).

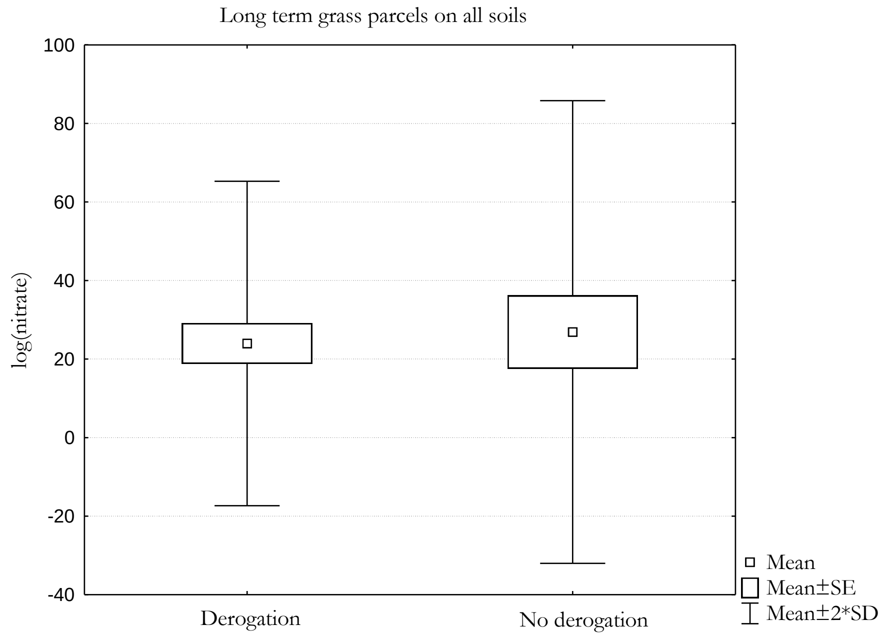


Figure 136: Box plot of log(nitrate-N) for derogation and no derogation parcels on all soils in spring 2014, including only parcels which were continuously under derogation/no derogation during 2009-2013 and grown with grass; SE: standard error of the mean. SD: standard deviation

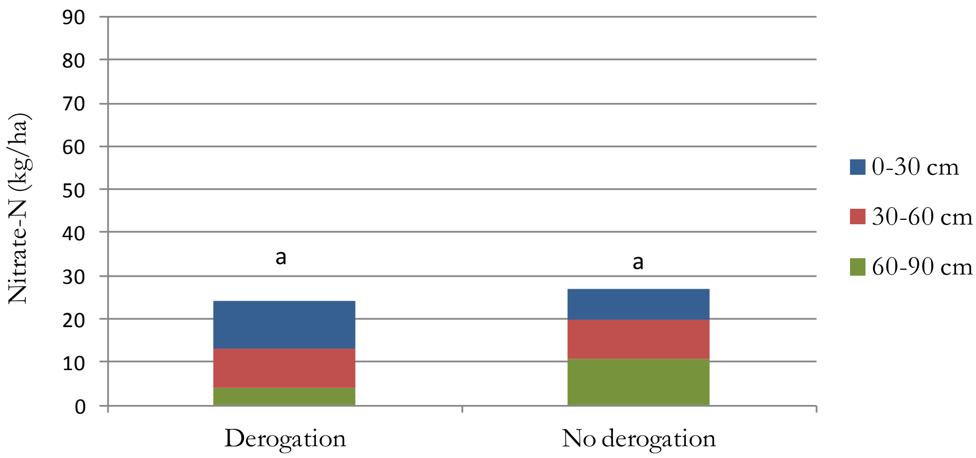


Figure 137: Average nitrate-N (kg/ha) on derogation and no derogation parcels in spring 2014 on all soils, including only parcels which were continuously under derogation/no derogation during 2009-2013 and grown with grass. The results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

On the parcels continuously under derogation in the period 2009-2013 and grown every year with maize the amount of nitrate-N was 32 ± 8 kg N/ha in spring 2014 and 37 ± 22 kg N/ha on no derogation parcels (Figure 138).

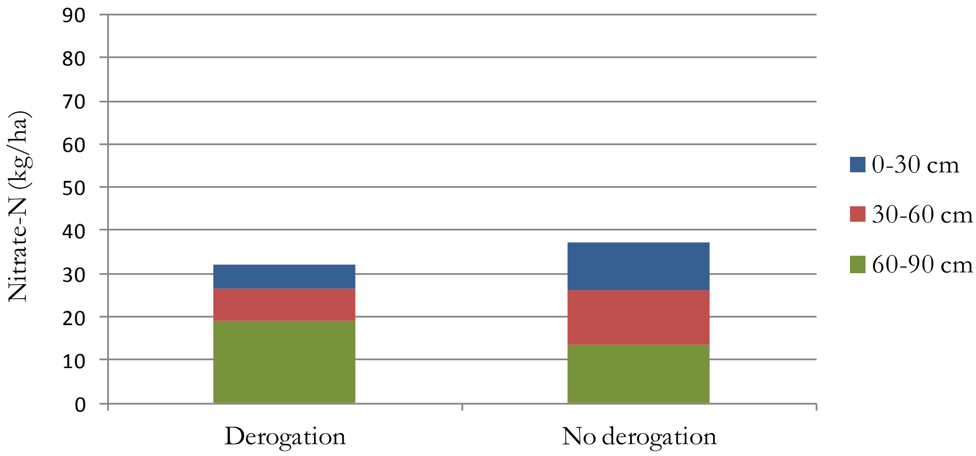


Figure 138: Average nitrate-N (kg/ha) on derogation and no derogation parcels in spring 2014 on all soils, including only parcels which were continuously under derogation/no derogation during 2009-2013 and grown with maize.

6.17 Nitrate in spring 2014 in the deeper soil layer

For a selection of parcels an additional soil sample was taken from 90 to 120 cm (the "deep soil sample"). In this soil layer the amount of nitrate is measured. No statistical outliers were detected in spring 2014.

No significant correlation ($p = 0.12$) is found between the amount of nitrate-N present in the soil profile from 0-90 cm and the amount of nitrate-N present in the soil profile from 90-120 cm (Figure 139).

The deep soil samples are taken on a selection of parcels. Therefore it is not possible to carry out a statistical analysis for all combinations of derogation, soil texture and cultivated crop. The comparison was limited to grass and maize on all soil textures (Figure 140 and Figure 141).

The average level of nitrate-N on parcels cultivated with grass for the soil layer 90-120 cm under derogation is 21 ± 23 kg/ha and under no derogation 22 ± 18 kg/ha. The average level of nitrate-N on parcels cultivated with maize for the soil layer 90-120 cm under derogation is 15 ± 9 kg/ha and 34 ± 30 kg/ha under no derogation.

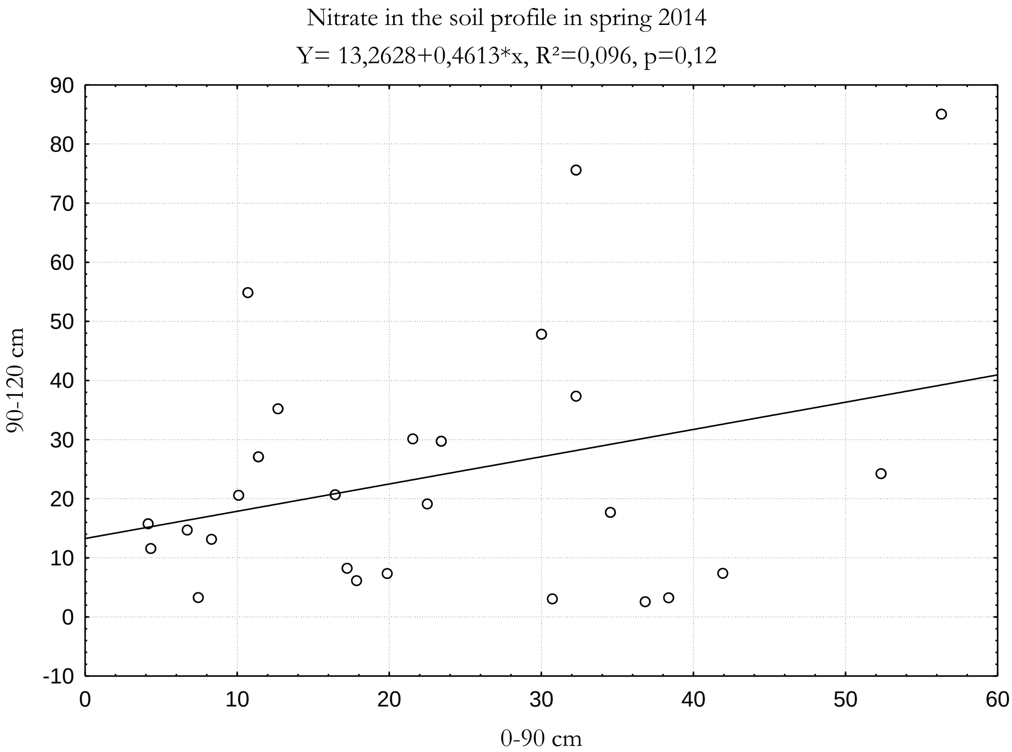


Figure 139: Scatterplot of the nitrate-N (kg/ha) in the soil profile from 0-90 cm versus the nitrate-N (kg/ha) in the soil profile from 90-120 cm in spring 2014.

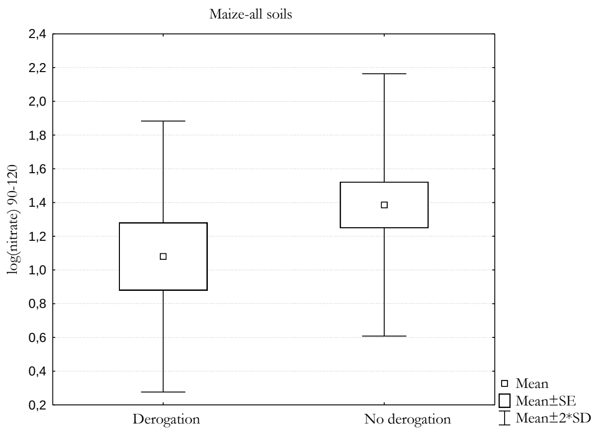


Figure 140: Box plot of log(nitrate-N, 90-120 cm) for derogation and no derogation parcels in spring 2014, for grass (left) and maize (right) on all soil textures. SE: standard error of the mean. SD: standard deviation.

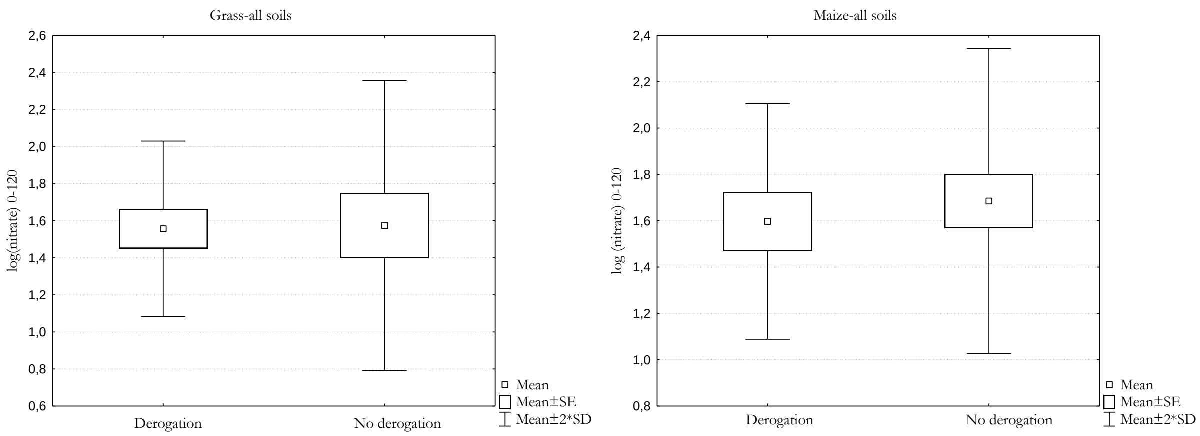


Figure 141: Box plot of log(nitrate-N, 0-120 cm) for derogation and no derogation parcels in spring 2014, for grass (left) and maize (right) on all soil textures. SE: standard error of the mean. SD: standard deviation.

The soil layer 90-120 cm contained the largest amount of nitrate-N (Figure 142). On derogation parcels cultivated with grass 51 % of the nitrate-N in the layer 0-120 cm was situated in the soil layer 90-120 cm. On no derogation parcels with grass or maize the soil layer 90-120 cm contained 44 % and 54 % of the nitrate-N in the soil layer 0-120 cm. On no derogation parcels with grass the fraction of nitrate-N in the soils layer 90-120 cm was limited to 34 %.

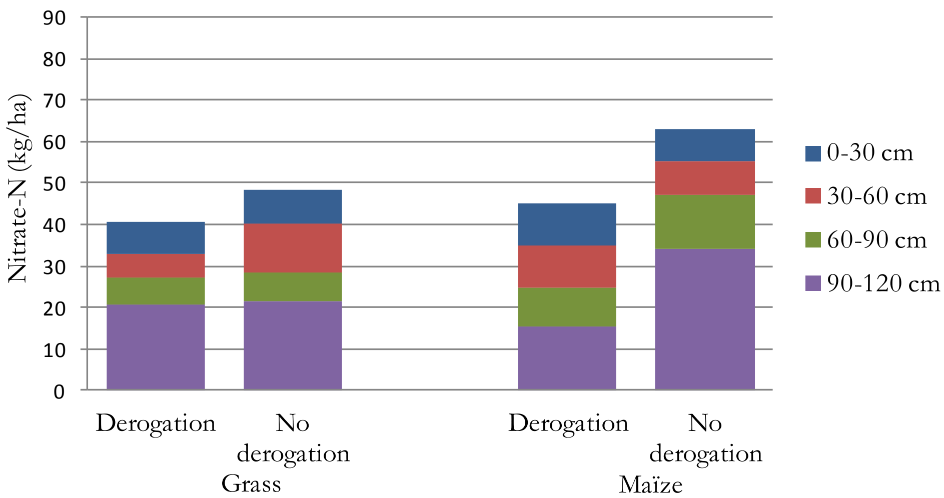


Figure 142: Average nitrate-N (kg/ha) in the 4 soil layers on derogation and no derogation parcels on all soil textures cultivated with grass or maize, spring 2014.

The average level of nitrate-N in the soil layer 0-120 cm on parcels cultivated with grass is 41 ± 23 kg/ha under derogation and 49 ± 32 kg/ha without derogation. The average level of nitrate-N in the soil layer 0-120 cm on parcels cultivated with maize under derogation is 45 ± 28 kg/ha and 63 ± 50 kg/ha without derogation.

6.18 Nitrate in autumn 2014

Between October 1st and November 15th, soil samples were taken in order to determine the amount of nitrate in the soil profile from 0 to 30, 30 to 60 and 60 to 90 cm. In the next paragraphs, box plots show the variation of the groups (derogation and no derogation). The data were log-transformed in order to obtain normality of the dataset. All data are shown visually in bar graphs, which show the distribution of nitrate in the soil profile (0-30 cm, 30-60 cm, 60-90 cm). The results of homogeneous groups are analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data.

One parcel was detected as a statistical outlier. The logarithm of the nitrate content in the soil profile 0-90 cm on the parcel exceeded the average plus 2 times the standard deviation. It was a maize parcel on sandy soil with a nitrate residue of 381 kg NO_3-N/ha. The sod of grass (sown in 2007) was terminated in autumn 2013 by a herbicide treatment, and converted into maize in 2014.

The average nitrate in the soil profile for each soil layer and for different combinations of crop, soil texture and derogation is shown in Table 48. The values in bold are average nitrate residues larger than 90 kg NO_3-N/ha. However, since 2011 the allowed maximum nitrate residue in the soil profile from 0-90 cm depends on the cultivated crop, soil type, and focus or non-focus area. Therefore, the values in bold in the table (> 90 kg NO_3-N/ha) are indicative.

The highest average nitrate residues were measured on parcels cultivated with "other" crops. The "other" crops on clay and loam soil were potatoes, after which higher nitrate residues are measured. On sandy loam soils "other" crops comprised in 2014 besides potatoes also vegetables like leek, cauliflower, spinach and beans. On sandy loam parcels cultivated with potatoes the nitrate residue ranged between 41 and 180 kg N/ha. The nitrate residue on these parcels was mostly around 90 kg N/ha. The nitrate residue on the parcels on sandy loam soil cultivated with vegetables ranged between 169 and 256 kg N/ha. On clay soil the nitrate residue of grass parcels without derogation ranged between 24 and 227 kg N/ha. The parcels with a nitrate residue of 227 kg N/ha was grazed until autumn 2014.

Table 48: Average nitrate-N (kg/ha) in the soil profile in autumn 2014. The nitrate-N is given for the different combinations of soil texture, cultivated crop and derogation in 2014. For each combination the total amount of nitrate is given as well as for each soil layer (layer 1 : 0-30 cm, layer 2: 30-60 cm and layer 3: 60-90 cm). The number of parcels is indicated with "n".

	Soil	Crop 2014	n	Nitrate-N (kg/ha) in autumn 2014			
				0-30cm	30-60cm	60-90cm	0-90cm
Derogation			80				
	Clay	Beets	-	-	-	-	-
		Grass	8	35	19	14	68
		Maize	1	22	9	5	36
		Winter wheat	-	-	-	-	-
	Loam	Beets	-	-	-	-	-
		Grass	-	-	-	-	-
		Maize	-	-	-	-	-
		Winter wheat	-	-	-	-	-
	Sand	Beets	-	-	-	-	-
		Grass	37	22	22	16	60
		Maize	18	32	19	19	70
		Winter wheat	-	-	-	-	-
	Sandy loam	Beets	1	15	13	11	39
		Grass	10	24	15	6	45
		Maize	4	43	22	15	80
		Winter wheat	1	20	32	23	75
No derogation			135				
	Clay	Beets	-	-	-	-	-
		Grass	4	61	23	13	**97**
		Maize	2	31	18	11	60
		Winter wheat	1	37	27	14	78
		Other	2	71	41	34	**146**
	Loam	Beets	-	-	-	-	-
		Grass	2	6	3	3	12
		Maize	3	24	16	11	51
		Winter wheat	2	9	11	12	32
		Other	1	36	39	31	**106**
	Sand	Beets	2	11	13	15	39
		Grass	22	23	17	14	54
		Maize	37	27	26	22	75
		Winter wheat	4	25	22	20	67
		Other	6	27	29	23	79
	Sandy loam	Beets	2	11	8	5	24
		Grass	12	27	12	7	46
		Maize	21	38	27	23	88
		Winter wheat	2	34	19	10	63
		Other	10	60	46	26	**132**

6.18.1 All Crops on all soil textures

Like every year in autumn for both derogation and no derogation parcels, a large variation in amount of nitrate-N in the soil profile (0-90 cm) is observed in autumn 2014 (Figure 143). On derogation parcels the amount of nitrate-N ranged from 11 to 215 kg/ha. On no derogation parcels the amount of nitrate-N in the soil profile (0-90 cm) ranged from 8 to 256 kg/ha.

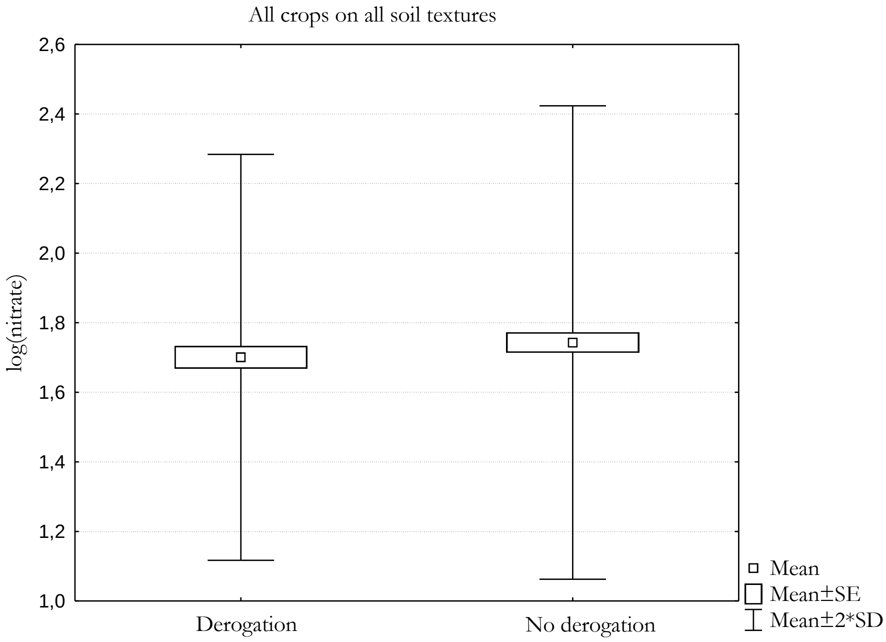


Figure 143: Box plot of log(nitrate-N) for derogation and no derogation parcels in autumn 2014, for all crops on all soil textures. SE: standard error of the mean. SD: standard deviation

The average nitrate-N in the soil profile (0-90 cm) is 62 (± 41) kg N/ha for derogation parcels and 73 (± 55) kg N/ha for no derogation parcels (Figure 144). In the upper layer of 0-30 cm approximately 42 % of the amount of nitrate-N in the soil profile until 90 cm is found. In the layers 30-60 cm and 60-90 cm about 33 % and 25 % is measured.

Since all crops (vegetables, potatoes, ...) are included in this dataset, the groups of derogation and no derogation parcels are no homogeneous groups. These groups cannot be statistically compared. Further comparisons are limited to parcels cultivated with derogation crops (grass, maize, winter wheat and beets) to make a statistical analysis possible.

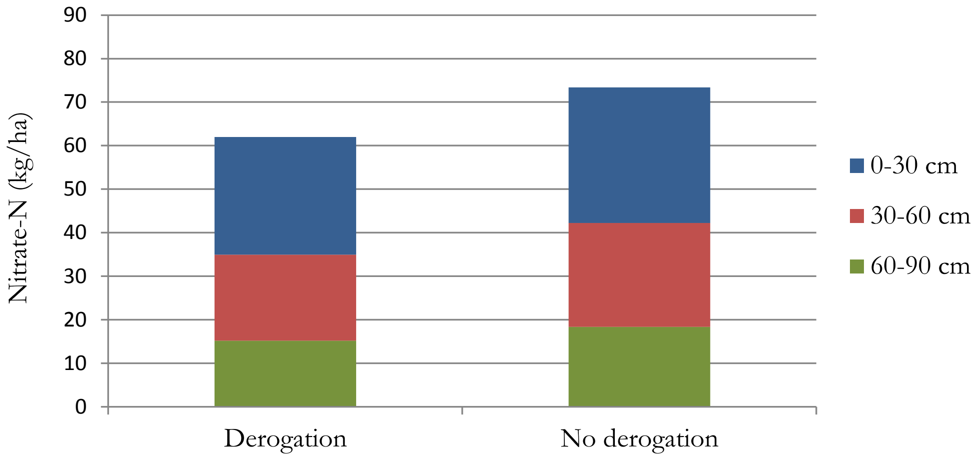


Figure 144: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2014 for all crops on all soil textures.

6.18.2 Derogation crops on all soil textures

Also for derogation crops there's a large variance in nitrate-N in the soil profile (0-90 cm) on derogation and no derogation parcels (Figure 145).

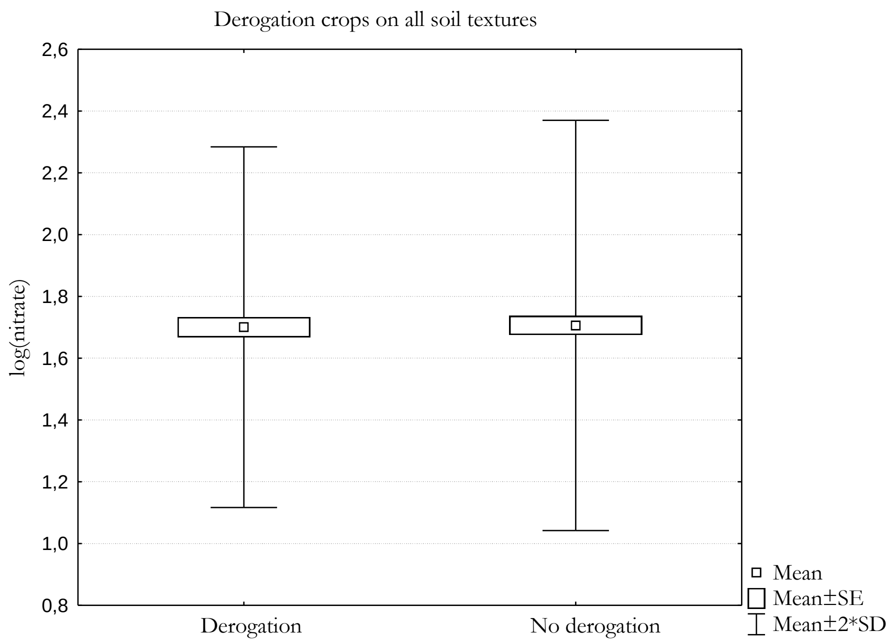


Figure 145: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on all soil textures in autumn 2014. SE: standard error of the mean. SD: standard deviation.

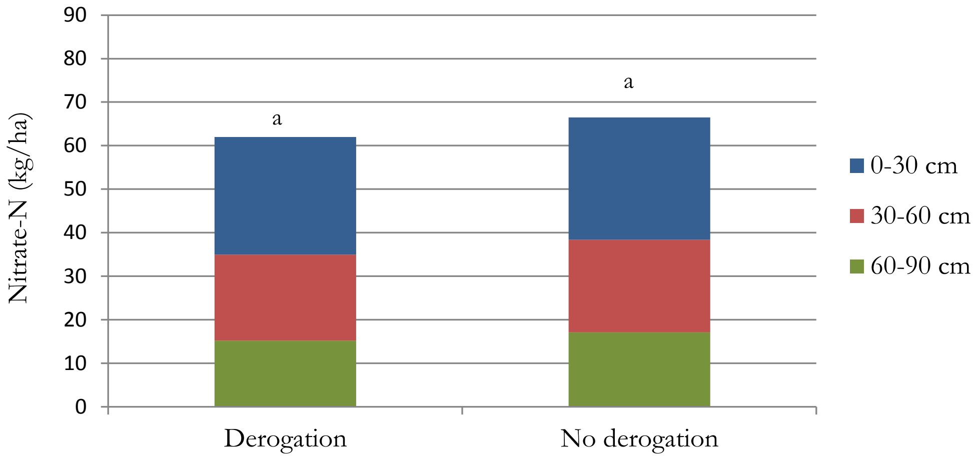


Figure 146: Average nitrate-N (kg/ha) on derogation and no derogation parcels for derogation crops on all soil textures in autumn 2014. These results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

The amount of nitrate-N on derogation parcels (62 ± 41 kg N/ha) was not significantly different from the amount of nitrate-N on no derogation parcels (67 ± 49 kg N/ha) ($p = 0.91$) (Figure 146).

In further analysis the nitrate residue on derogation and no derogation parcels will be statistically compared for specific soil textures. Since sandy and sandy loam soils are the soils on which derogation is mostly requested, the effect of derogation on the nitrate residue will be discussed in more detail in the following paragraphs for these soil textures. The data for the other soil textures are listed in Table 48.

6.18.3 Derogation crops on sandy soils

On both derogation and no derogation parcels on sandy soils the variance in nitrate-N in the soil profile (0-90 cm) is large (Figure 147). On sandy soils the amount of nitrate-N in the soil profile on derogation parcels grown with derogation crops ranged from 11 to 215 kg N/ha. On no derogation parcels grown with derogation crops on sandy soils the amount of nitrate-N was situated between 8 and 226 kg N/ha. The nitrate-N residue on these derogation and no derogation parcels did not differ significantly ($p = 0.80$).

The average nitrate residue on derogation and no derogation parcels with derogation crops on sandy soils was respectively 64 (± 43) kg N/ha and 66 (± 46) kg N/ha (Figure 148).

Figure 147: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on sandy soils in autumn 2014. SE: standard error of the mean. SD: standard deviation.

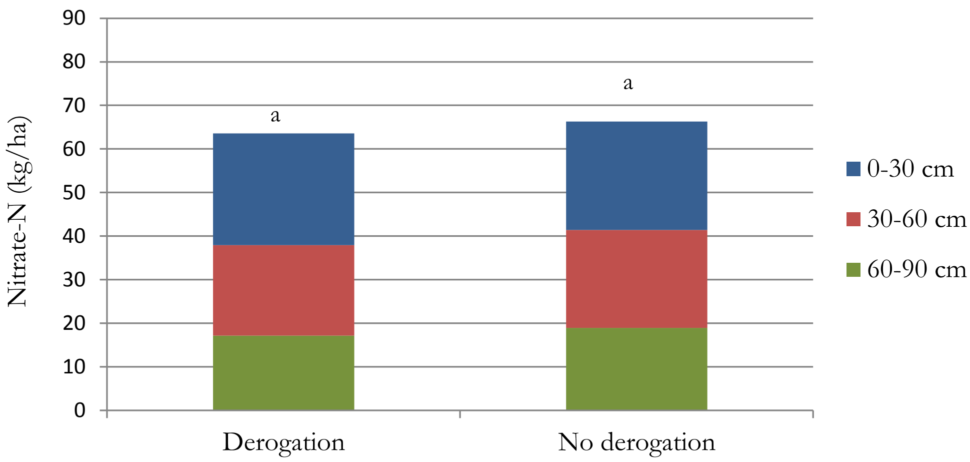


Figure 148: Average nitrate-N (kg/ha) on derogation and no derogation parcels for derogation crops on sandy soils in autumn 2014. These results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.18.3.1 Grass and maize on sandy soils

The most frequently grown derogation crops on sandy soils are grass and maize. Comparison of derogation and no derogation parcels on sandy soil with grass ($p = 0.31$) or maize ($p = 0.52$) showed no statistical differences. Derogation parcels with grass on sandy soils have a nitrate residue of 60 ± 42 kg N/ha and the parcels without derogation cultivated with grass 54 ± 45 kg N/ha. For maize parcels the derogation parcels had an amount of 70 ± 48 kg NO_3-N/ha in the soil profile and the no derogation parcels 75 ± 45 kg NO_3-N/ha.

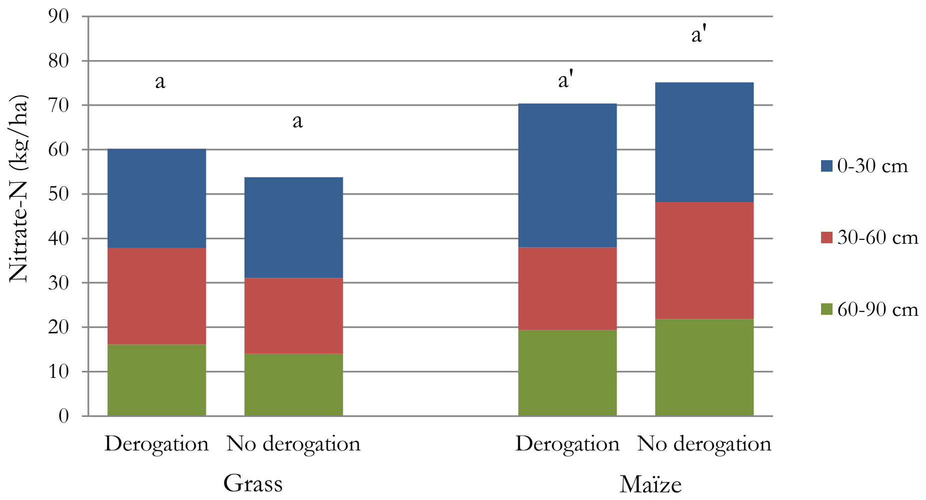


Figure 149: Average nitrate-N (kg/ha) on derogation and no derogation parcels cultivated with grass or maize on sandy soils in autumn 2014. The results for grass and maize were analysed separately. These results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.18.4 Derogation crops on sandy loam soils

Besides sandy soils, sandy loam soils are a soil type on which derogation is frequently requested. As for sandy soils the variance in nitrate residue is large for both derogation and no derogation parcels on sandy loam soils.

On derogation parcels the average nitrate residue was 55 ± 35 kg NO_3-N/ha and 70 ± 53 kg NO_3-N/ha on no derogation parcels. Due to the large range of nitrate residue on both types of parcels the difference between the average nitrate residue was not statistically significant ($p = 0.54$).

Figure 150: Box plot of log(nitrate-N) for derogation and no derogation parcels for derogation crops on sandy loam soils in autumn 2014. SE: standard error of the mean. SD: standard deviation.

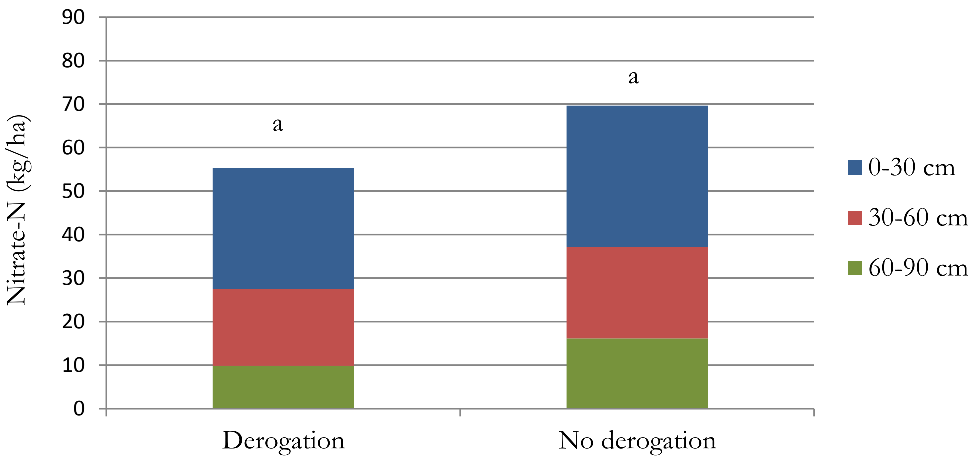


Figure 151: Average nitrate-N (kg/ha) on derogation and no derogation parcels for derogation crops on sandy loam soils in autumn 2014. These results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.18.4.1 Grass and maize on sandy loam soils

Grass and maize are the most commonly grown derogation crops on sandy loam soils. For these crops a separate statistical comparison is made of derogation and no derogation parcels. For grass (p = 0.90), nor for maize (p = 0.84) the nitrate residue of derogation and no derogation parcels was significantly different (Figure 152). The average amount of nitrate-N on derogation parcels with grass on sandy loam soils is 45 ± 36 kg NO_3-N/ha in autumn 2014. On the parcels without derogation cultivated with grass it is 46 ± 40 kg NO_3-N/ha. On the maize parcels with and without derogation the average nitrate residue was respectively 80 ± 28 kg NO_3-N/ha and 88 ± 57 kg NO_3-Nha.

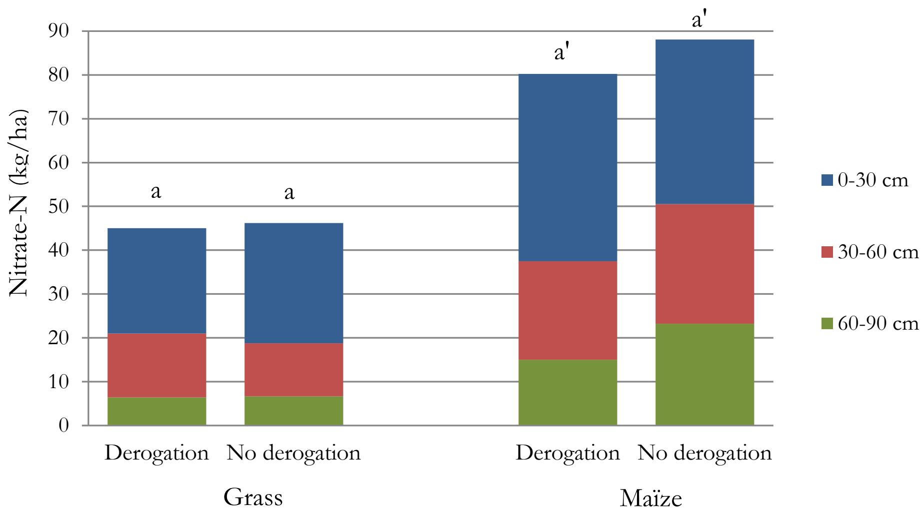


Figure 152: Average nitrate-N (kg/ha) on derogation and no derogation parcels cultivated with grass or maize on sandy loam soils in autumn 2014. The results for grass and maize were analysed separately. These results were analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.19 Nitrate in autumn 2014, parcels which were continuously under derogation/no derogation during 2009-2014.

In order to verify the long-term impact of derogation on the nitrate residue, only the parcels which were continuously under derogation/no derogation during 2009-2014 were retained for statistical analysis.

The following box plots show the variation of the nitrate residue within the groups (derogation and no derogation). The data are log-transformed in order to obtain normality of the dataset. All data are shown visually in bar graphs, which show the distribution of nitrate in the soil profile (0-30 cm, 30-60 cm, 60-90 cm).

On both derogation and no derogation parcels, a large variation in nitrate residue in autumn 2014 is noticed (Figure 153). The average amount of nitrate-N on parcels continuously under derogation since 2009 is 60 ± 36 kg/ha. On parcels continuously without derogation it is 73 ± 57 kg/ha (Figure 154). Since no limitation to derogation crops, no statistical analysis is carried out.

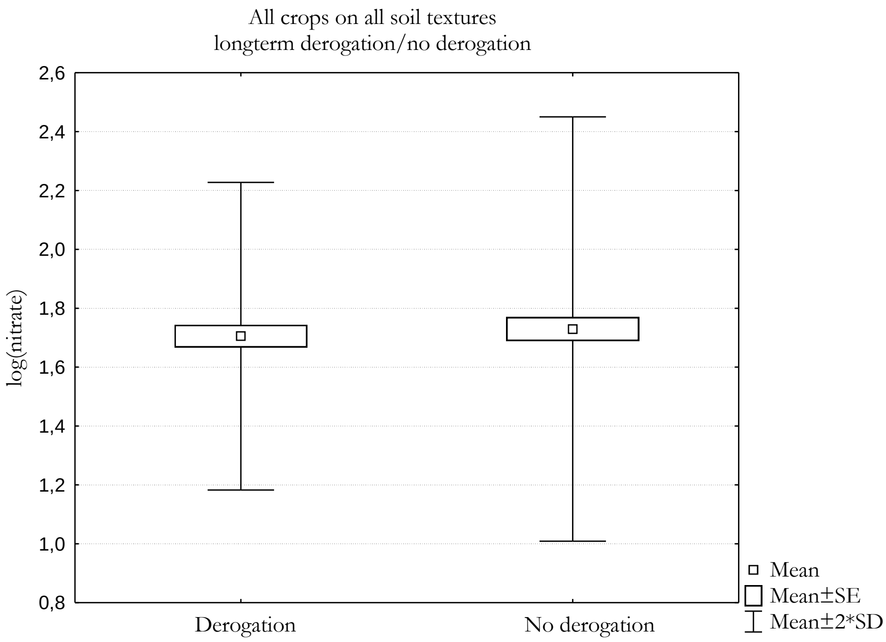


Figure 153: Box plot of log(nitrate-N) for derogation and no derogation parcels on all soil textures in autumn 2014, including only parcels which were continuously under derogation/no derogation during 2009-2014. SE: standard error of the mean. SD: standard deviation.

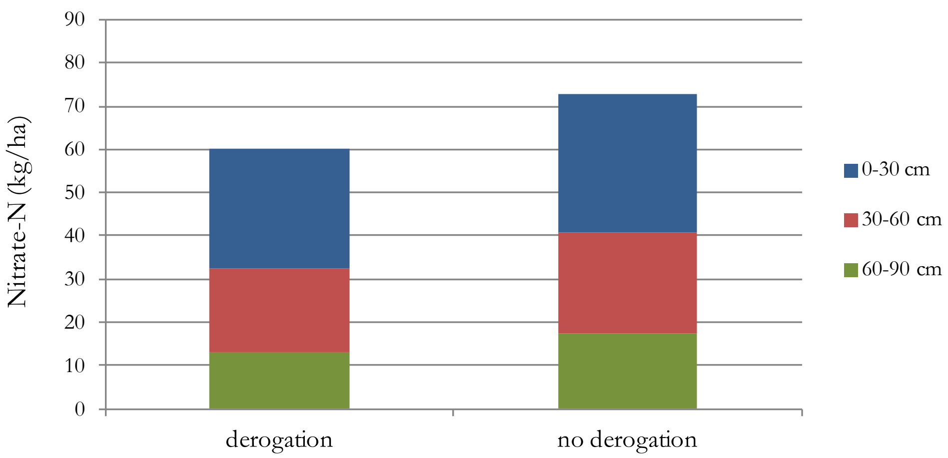
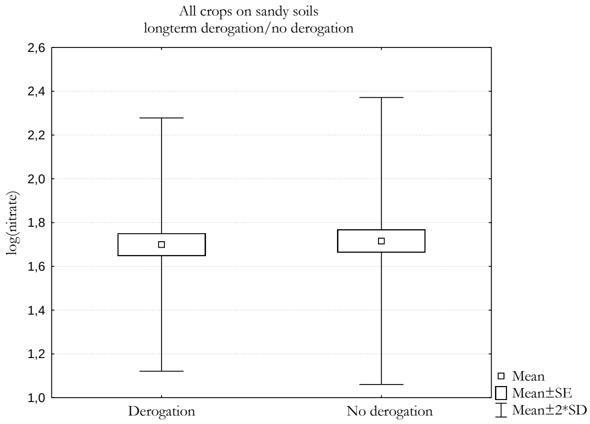


Figure 154: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2014 on all soil textures, including only parcels which were continuously under derogation/no derogation during 2009-2014.

Parcels continuously cultivated with or without derogation conditions were compared separately for sandy and sandy loam soils, since on these soil types derogation is most frequently requested. Since on the parcels without derogation also no derogation crops are grown in the period 2009-2014, no statistical analysis is carried out.



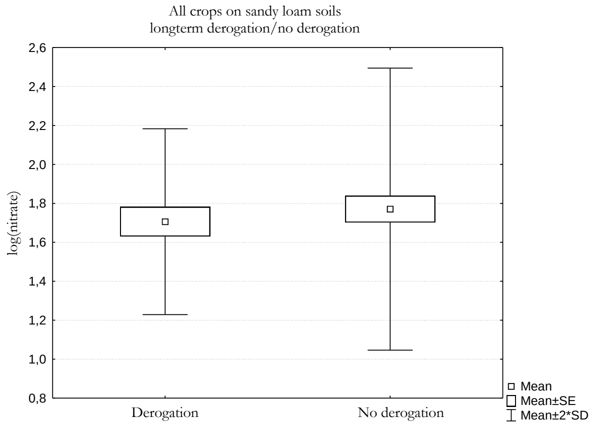


Figure 155: Box plot of log(nitrate-N) for derogation and no derogation parcels on sandy soils (left) and sandy loam soils (right) in autumn 2014, including only parcels which were continuously under derogation/no derogation during 2009-2014. SE: standard error of the mean. SD: standard deviation.

On sandy soils cultivated under derogation conditions in the period 2009-2014, the average nitrate residue in autumn 2014 is 61 ± 39 kg N/ha. On parcels cultivated without derogation in this period the nitrate residue is 67 ± 49 kg N/ha in autumn 2014 (Figure 156).

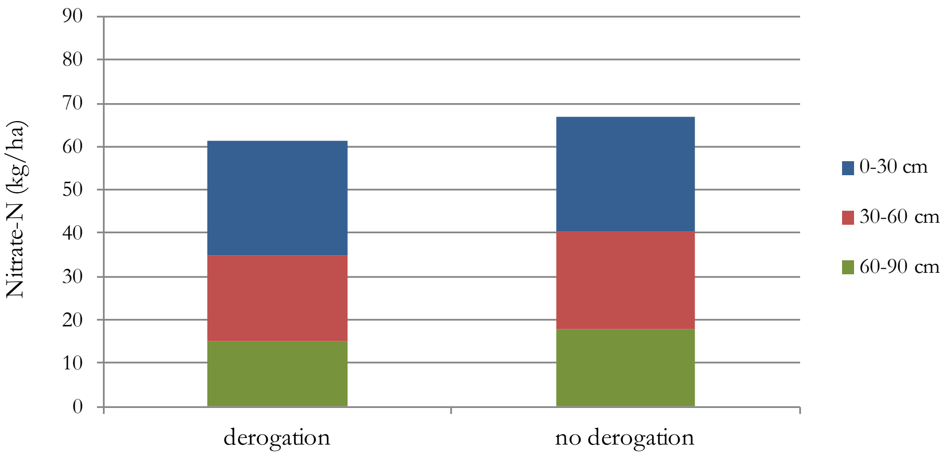


Figure 156: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2014 on sandy soils, including only parcels which were continuously under derogation/no derogation during 2009-2014.

On sandy loam soils cultivated under derogation conditions in the period 2009-2014, the average nitrate residue in autumn 2014 is 59 ± 35 kg N/ha. On parcels cultivated without derogation in this period the nitrate residue is 81 ± 65 kg N/ha in autumn 2014 (Figure 157).

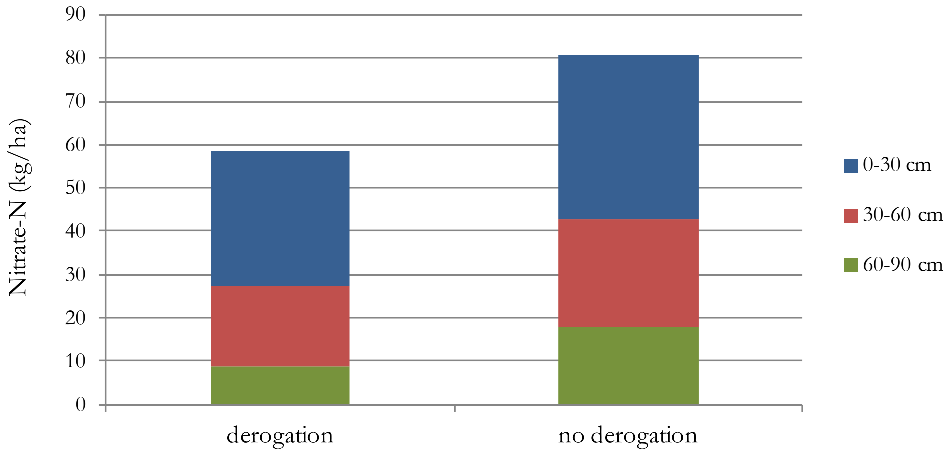


Figure 157: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2014 on sandy loam soils, including only parcels which were continuously under derogation/no derogation during 2009-2014.

Limiting to derogation crops cultivated in the period 2009-2014 makes a statistical comparison of derogation and no derogation parcels possible.

On long-term derogation parcels cultivated with derogation crops the average nitrate residue in autumn 2014 is 60 ± 36 kg N/ha. On parcels cultivated with derogation crops without derogation in the period 2009-2014 the nitrate residue is 58 ± 43 kg N/ha in autumn 2014. The nitrate residue did not differ significantly ($p = 0.30$) (Figure 159).

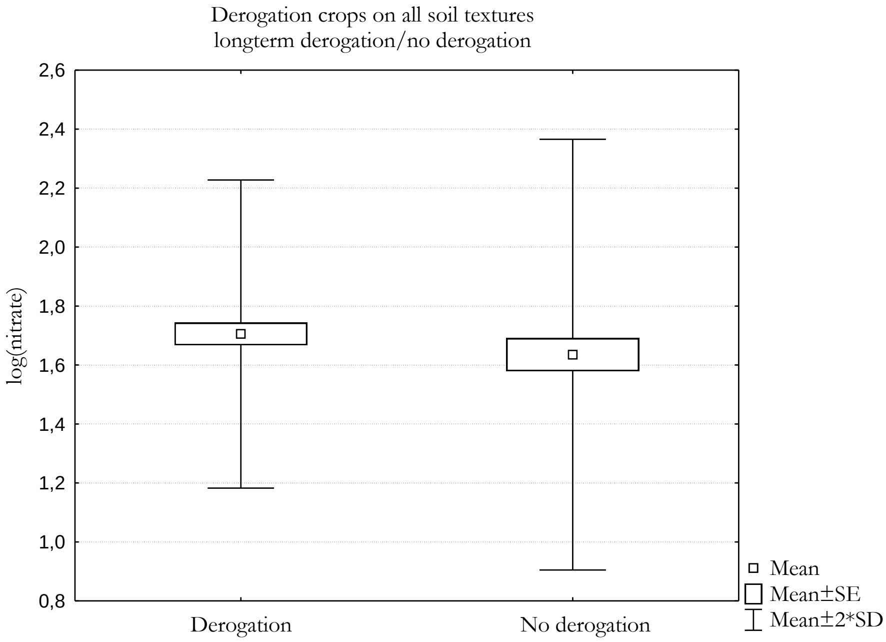


Figure 158: Box plot of log(nitrate-N) in autumn 2014 for derogation and no derogation parcels cultivated with derogation crops on all soil textures, including only parcels which were continuously under derogation/no derogation during 2009-2014. SE: standard error of the mean. SD: standard deviation.

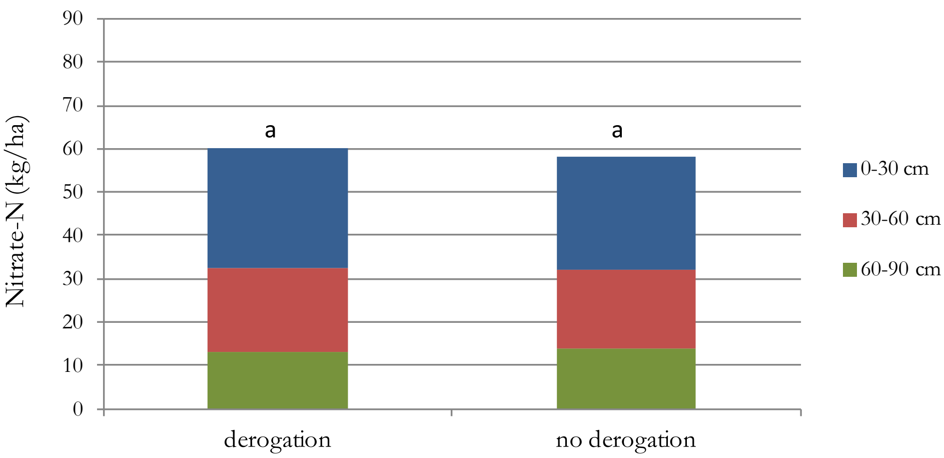


Figure 159: Average nitrate-N (kg/ha) in autumn 2014 on derogation and no derogation parcels cultivated with derogation crops on all soils, including only parcels which were continuously under derogation/no derogation during 2009-2014. The results were analysed statistically by means of a one-way ANOVA (p≤ 0.05) on the log-transformed data. Identical letters indicate no statistical difference.

Since sandy and sandy loam soils are the soil textures on which derogation is most frequently requested, a comparison of continuous derogation and no derogation parcels grown with derogation crops, is made separately for sandy and sandy loam soils.

On sandy soils cultivated with derogation crops under derogation conditions in the period 2009-2014, the average nitrate residue in autumn 2014 is 61 ± 39 kg N/ha. On parcels cultivated without derogation in this period the nitrate residue is 60 ± 35 kg N/ha in autumn 2014. Derogation and no derogation parcels did not differ significantly (p = 0.82) (Figure 161).

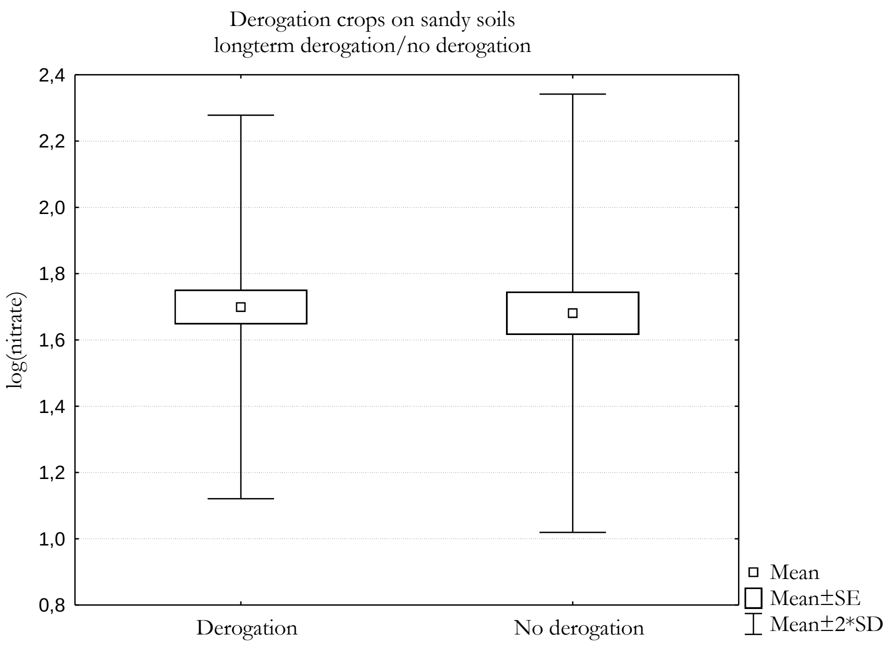


Figure 160: Box plot of log(nitrate-N) in autumn 2014 for derogation and no derogation parcels cultivated with derogation crops on sandy soils, including only parcels which were continuously under derogation/no derogation during 2009-2014. SE: standard error of the mean. SD: standard deviation.

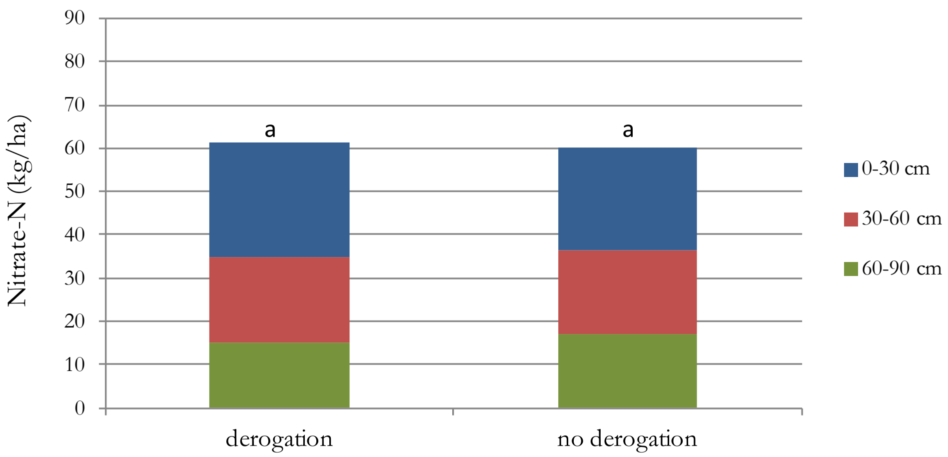


Figure 161: Average nitrate-N (kg/ha) in autumn 2014 on derogation and no derogation parcels cultivated with derogation crops on sandy soils, including only parcels which were continuously under derogation/no derogation during 2009-2014. The results were analysed statistically by means of a one-way ANOVA (p≤ 0.05) on the log-transformed data. Identical letters indicate no statistical difference.

On sandy loam soils cultivated with derogation crops under derogation conditions in the period 2009-2014, the average nitrate residue in autumn 2014 is 59 ± 35 kg N/ha. On parcels cultivated without derogation in this period the nitrate residue is 57 ± 34 kg N/ha in autumn 2014. Derogation and no derogation parcels did not differ significantly (p = 0.70) (Figure 163).

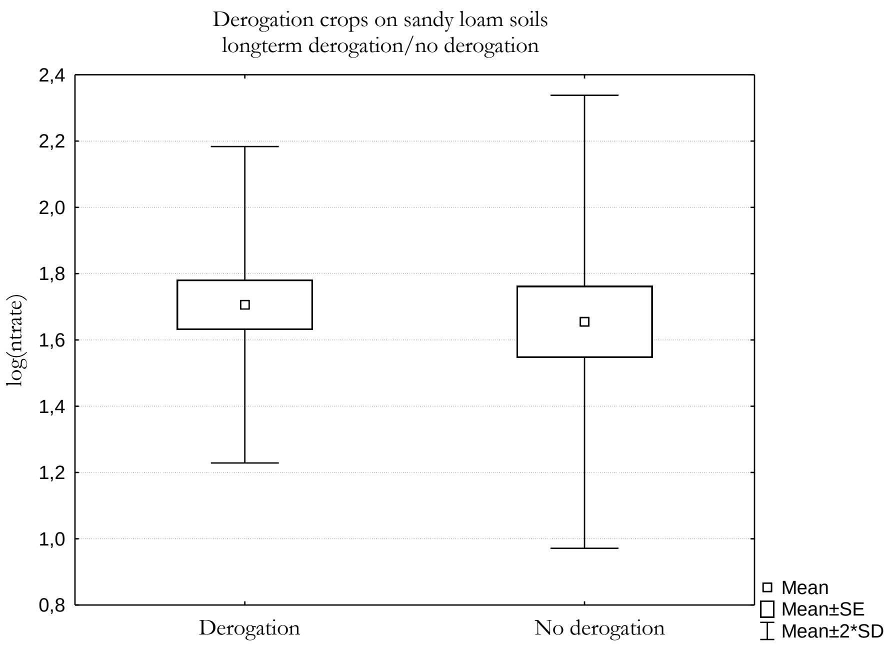


Figure 162: Box plot of log(nitrate-N) in autumn 2014 for derogation and no derogation parcels cultivated with derogation crops on sandy loam soils, including only parcels which were continuously under derogation/no derogation during 2009-2014. SE: standard error of the mean. SD: standard deviation.

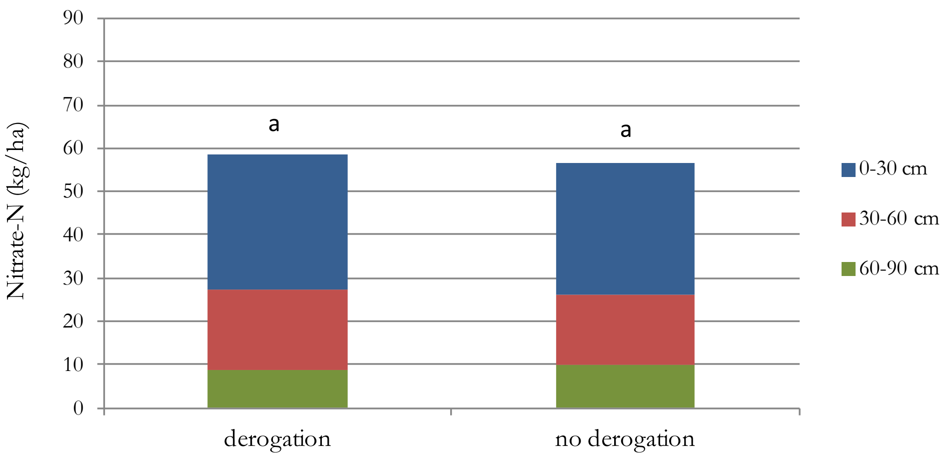


Figure 163: Average nitrate-N (kg/ha) in autumn 2014 on derogation and no derogation parcels cultivated with derogation crops on sandy loam soils, including only parcels which were continuously under derogation/no derogation during 2009-2014. The results were analysed statistically by means of a one-way ANOVA (p≤ 0.05) on the log-transformed data. Identical letters indicate no statistical difference.

Since grass is one of the most important derogation crops, a statistical comparison is made for parcels continuously grown with grass or maize in the period 2009-2014, irrespective the soil texture. On parcels continuously grown with grass and continuously under derogation conditions the nitrate residue in autumn 2014 is 54 ± 32 kg N/ha (Figure 165). When cultivated without derogation the nitrate residue on the parcels continuously cultivated with grass since 2009, is 57 ± 56 kg N/ha in autumn 2014. Figure 164 shows that the variation in nitrate residue was larger on parcels without derogation. No statistical difference between long term derogation and no derogation grass parcels is detected (p = 0.37).

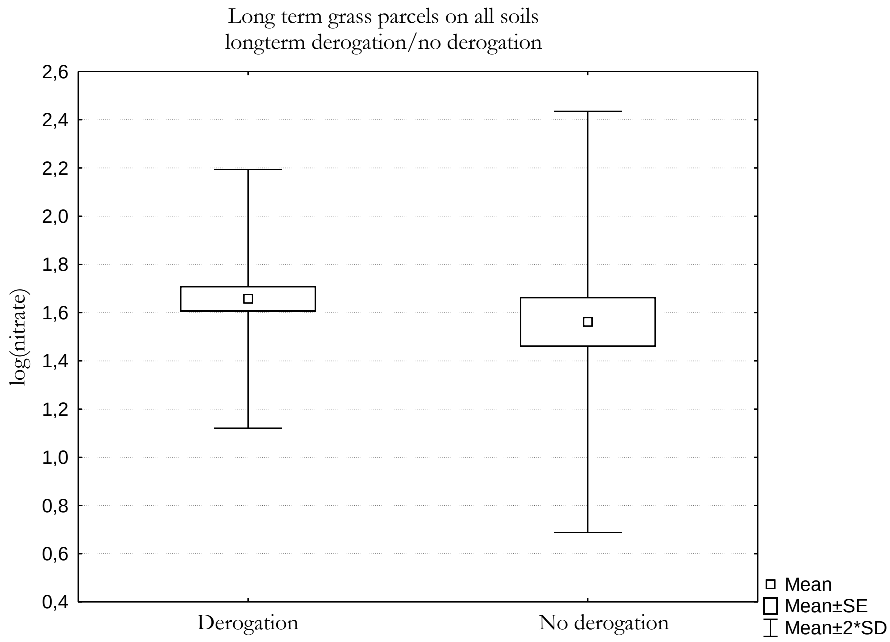


Figure 164: Box plot of log(nitrate-N) in autumn 2014 for derogation and no derogation parcels on all soil textures cultivated with grass, including only parcels which were continuously under derogation/no derogation during 2009-2014 and grown with grass. SE: standard error of the mean. SD: standard deviation.

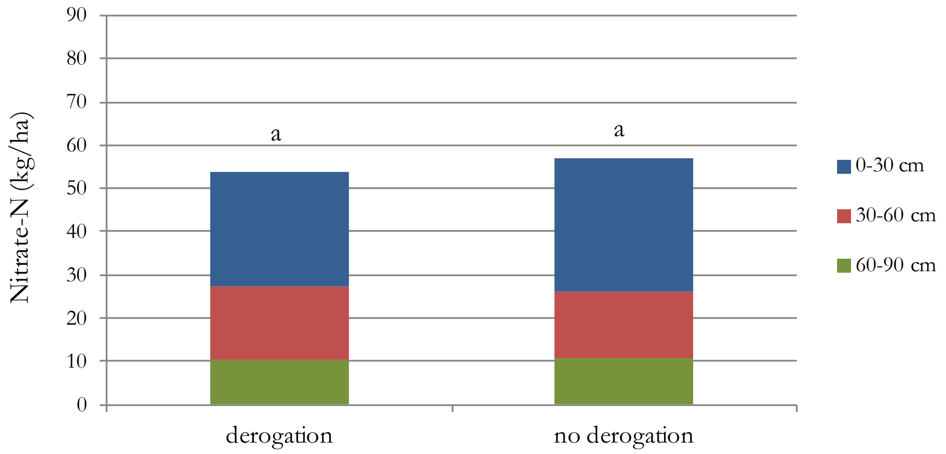


Figure 165: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2014 on all soils, including only parcels which were continuously under derogation/no derogation during 2009-2014 and grown with grass. The results are analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

Since the number of parcels on which maize is cultivated every year is too limited, no statistical comparison is done, but variation is large on both types of parcels (Figure 166).

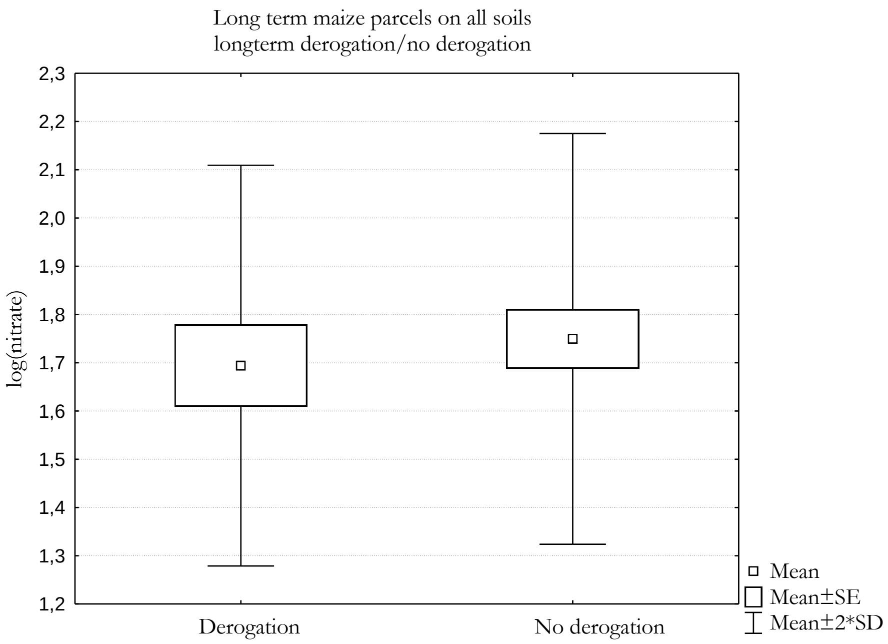


Figure 166: Box plot of log(nitrate-N) in autumn 2014 for derogation and no derogation parcels cultivated with maize every year on all soil textures, including only parcels which were continuously under derogation/no derogation during 2009-2014. SE: standard error of the mean. SD: standard deviation.

On parcels every year grown with maize and continuously under derogation conditions the nitrate residue in autumn 2014 is 54 ± 25 kg N/ha. When cultivated without derogation the nitrate residue on the parcels yearly cultivated with maize since 2009 is 62 ± 28 kg N/ha in autumn 2014 (Figure 167).

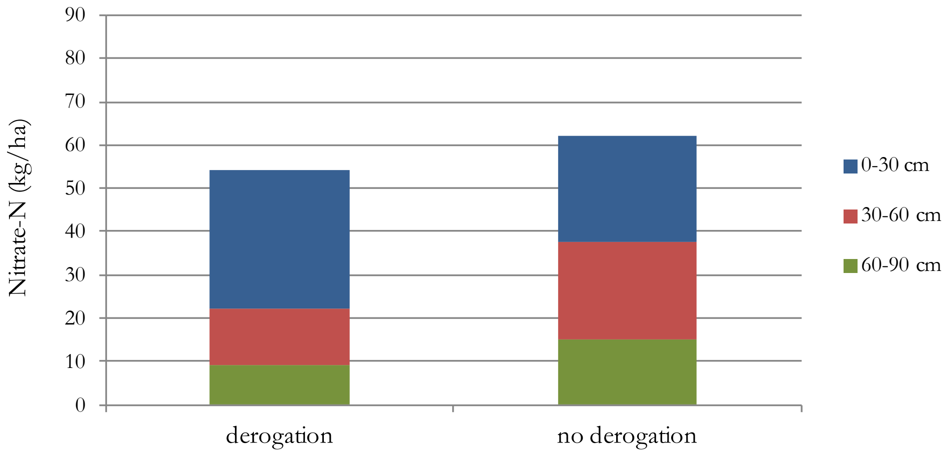


Figure 167: Average nitrate-N (kg/ha) on derogation and no derogation parcels in autumn 2014 on all soils, including only parcels which were continuously under derogation/no derogation during 2009-2014 and grown with maize. The results are analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.20 Nitrate in autumn 2014 in the deeper soil layer

For a selection of parcels an additional soil sample is taken from 90 to 120 cm (the "deep soil sample"). In this soil layer the amount of nitrate is measured. In autumn 2014 on 37 parcels a deep soil sample was taken. Data are considered statistical outliers when exceeding the average plus 2 times the standard deviation. One outlier is removed, a parcel on sandy soil cultivated with maize without derogation. The amount of nitrate-N in the soil layer 90-120 cm is 165 kg N/ha. The soil profile from 0-90 cm contained only 30 kg N/ha on this parcel. No exuberant fertilisation was applied and yield was good. A cover crop was sown at October 1st, 25 days before sampling of the nitrate residue.

Like in autumn 2013 a significant correlation ($p=0.00$) is found between the amount of nitrate in the soil profile from 0-90 cm and the amount of nitrate in the soil profile from 90-120 cm (Figure 168).

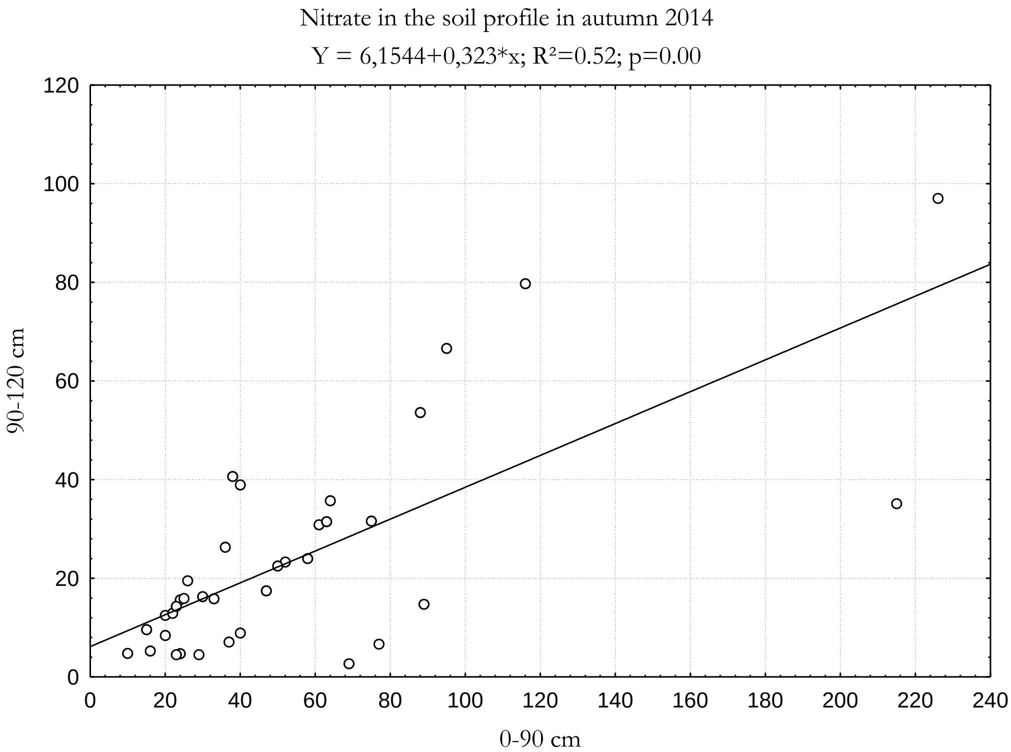


Figure 168: Scatterplot of the nitrate-N (kg/ha) in the soil profile from 0-90 cm versus the nitrate-N (kg/ha) in the soil profile from 90-120 cm in autumn 2014.

Since the deep soil samples are taken on a selection of parcels, it is not possible to carry out a statistical analysis for all combinations of derogation, soil texture and cultivated crop. The comparison is limited to grass and maize on all soil textures, based on a box plot of the log-transformed data (Figure 169 and Figure 170).

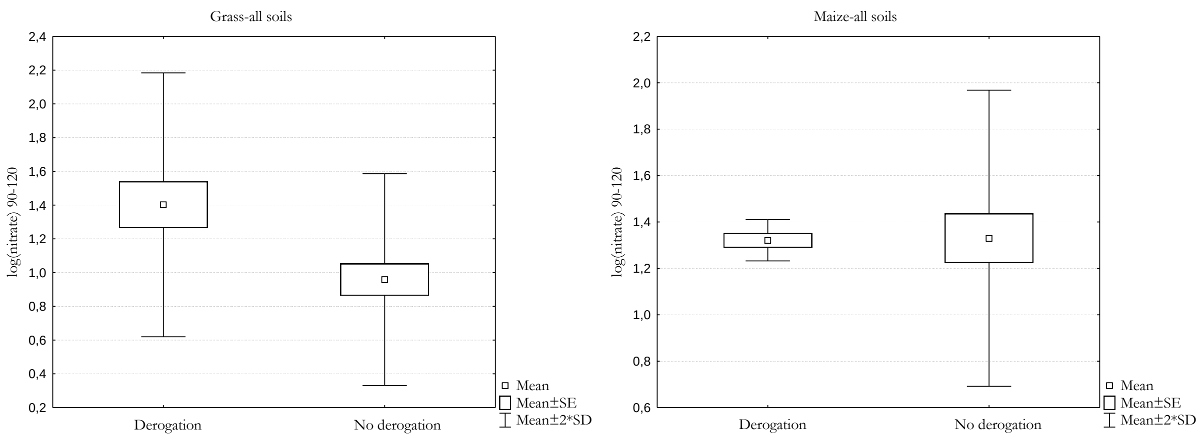


Figure 169: Box plot of log(nitrate-N, 90-120 cm) for derogation and no derogation parcels in autumn 2014, for grass (left) and maize (right) on all soil textures. SE: standard error of the mean. SD: standard deviation.

The average level of nitrate-N in the soil layer 90-120 cm on parcels cultivated with grass under derogation is 34 ± 24 kg/ha and 11 ± 8 kg/ha without derogation. The average level of nitrate-N in the soil layer 90-120 cm on parcels cultivated with maize under derogation is 21 ± 2 kg/ha and 27 ± 27 without derogation.

In the soil profile till 120 cm, the average level of nitrate-N is 89 ± 57 kg/ha on derogation parcels and 44 ± 24 kg/ha on no derogation parcels. On parcels cultivated with maize the amount of nitrate-N in the soil profile 0-120 cm is 59 ± 19 kg/ha with derogation and 79 ± 38 kg/ha without derogation.

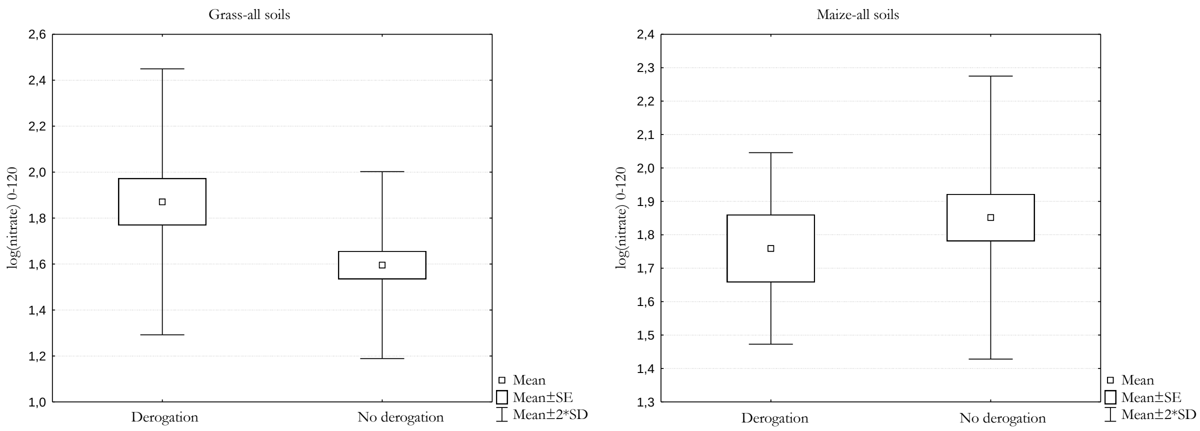


Figure 170: Box plot of log(nitrate-N, 90-120 cm) for derogation and no derogation parcels in autumn 2014, for grass (left) and maize (right) on all soil textures. SE: standard error of the mean. SD: standard deviation.

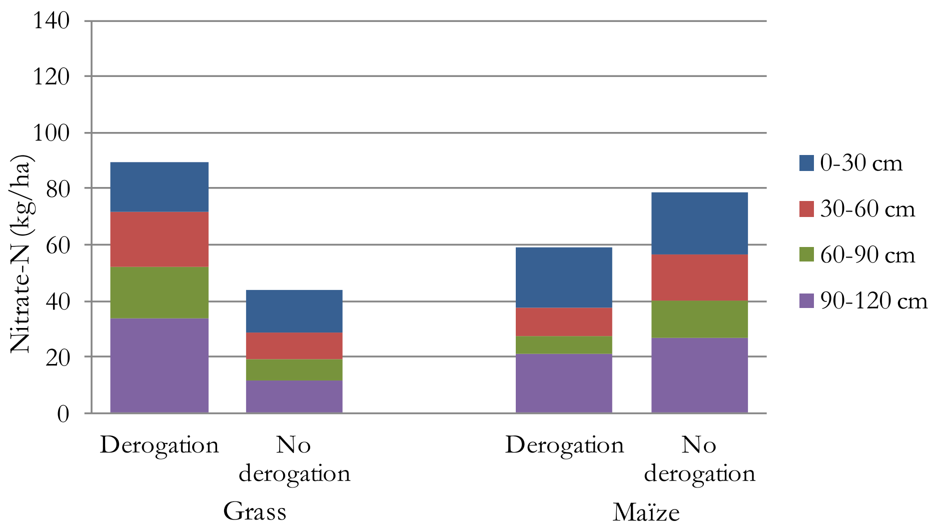


Figure 171: Average nitrate-N (kg/ha) in the 4 soil layers on derogation and no derogation parcels on all soil textures cultivated with grass or maize, autumn 2014.

6.21 Nitrate in the deeper soil layer 2011-2014

Since the deep soil sample is taken on a selection of parcels, a rather limited number of data is available at each sampling moment. Therefore a statistical analysis is performed on all data of all sampling moments. For this analysis outliers were detected in the whole group, not as an outlier per sampling moment. As such 5 values were detected as statistical outlier. The first outlier was detected in spring 2012, the amount of nitrate-N in the soil layer 90-120 cm was 186 kg N/ha. The amount of nitrate-N in the profile 0-90 cm was 96 kg/ha (14, 27 and 55 kg N/ha in the soil layers 0-30 cm, 30-60 cm and 60-90 cm). The parcel was cultivated with maize in 2011 and had a high nitrate residue in autumn 2011, 269 kg N/ha (166, 70 and 33 kg N/ha in the soil layers 0-30 cm, 30-60 cm and 60-90 cm). The large amount of nitrate-N in the deep soil layer was clearly the result of nitrate leaching out the soil profile 0-90 cm during winter 2011-2012. Three outliers were measurements of autumn 2012. One parcel was cultivated with potatoes in 2012. In the soil layer 90-120 the amount of nitrate-N was 352 kg/ha. In the soil profile above 134 kg N/ha (12-29-93) was measured. Another parcel was cultivated with spinach and leek, which had no high nitrate residue in the soil layer 0-90 cm (30 kg N/ha) but 134 kg N/ha in the soil layer 90-120 cm. The third parcel was converted from grass land into arable land (maize) in spring 2011. Nitrate was distributed in the soil profile till 120 cm per soil layer of 30 cm as follows: 41-150-105-152 kg N/ha. The fifth value detected as outlier was a sample of autumn 2014. A maize parcel with a normal nitrate residue (30 kg N/ha, 0-90 cm), good yield and no exuberant fertilisation but a high amount of nitrate-N in the soil layer 90-120 cm: 165 kg N/ha.

As done at each sampling moment, the correlation between the nitrate-N content in the soil layers 0-90 cm and 90-120 cm is shown. The correlation between the amount of nitrate in the soil profile from 0-90 cm and the amount of nitrate in the soil layer 90-120 cm is significant ($p = 0.00$), but the regression explains only 27 % of the variance. Both for derogation ($p = 0.00$) and no derogation parcels ($p = 0.00$) separately, the correlation is statistically significant. Even though the models explains only 16 % (derogation parcels) and 35 % (no derogation parcels) of the variance (Figure 172).

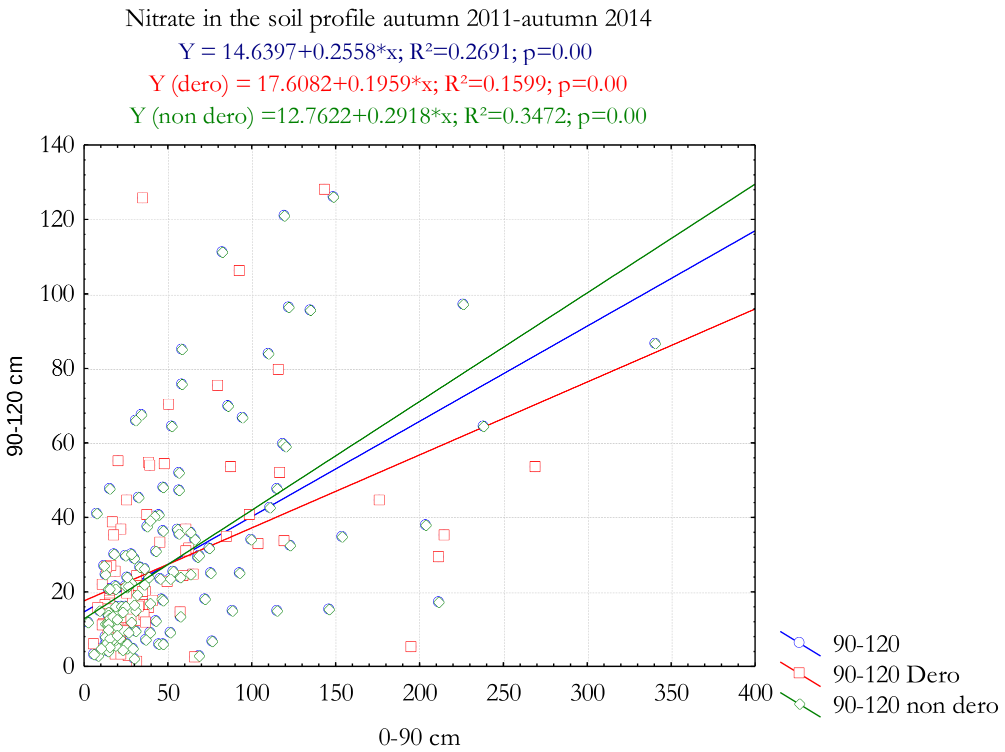


Figure 172: Scatterplot of the nitrate-N (kg/ha) in the soil profile from 0-90 cm versus the nitrate-N (kg/ha) in the soil profile from 90-120 cm-2011-2014, for all parcels (blue), derogation parcels (red) and no derogation parcels (green).

On parcels cultivated with derogation crops, no statistical significant difference exists between the amount of nitrate-N in the soil layer 90-120 cm of derogation and no derogation parcels (p=0.58) (Figure 173). In the soil layer 90-120 cm the amount of nitrate-N is 27 ± 25 kg/ha on derogation parcels and 26 ± 24 kg/ha on no derogation parcels.

On grass parcels cultivated under derogation conditions the level of nitrate-N in the soil layer 90-120 cm was 26 ± 26 kg/ha. On grass parcels cultivated without derogation this amount was 18 ± 16 kg/ha. Due to variation there was no statistical significant difference between derogation and no derogation grass parcels (p = 0.07) (Figure 174).

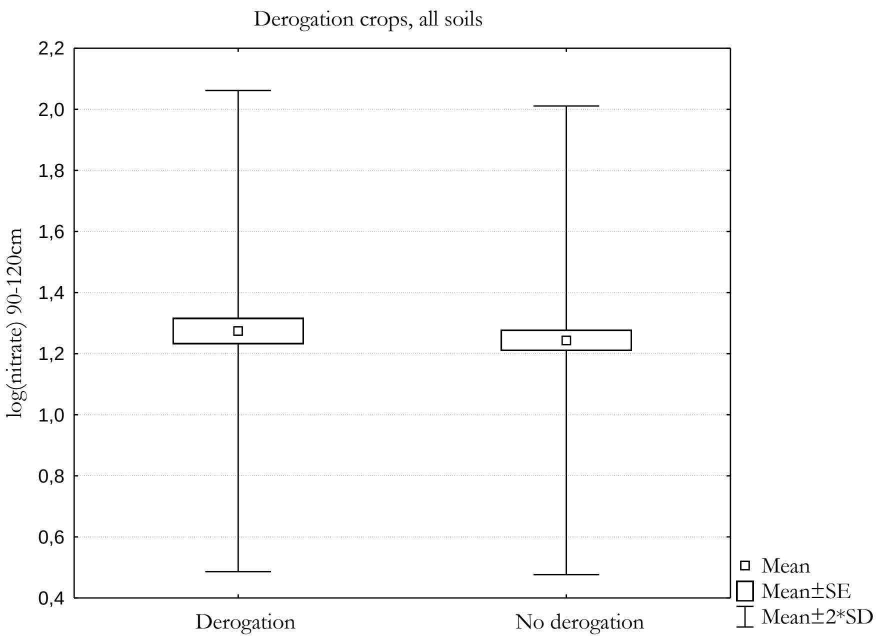


Figure 173: Box plot of log(nitrate-N, 90-120 cm, 2011-2014) for derogation and no derogation parcels cultivated with derogation crops on all soil textures. SE: standard error of the mean. SD: standard deviation.

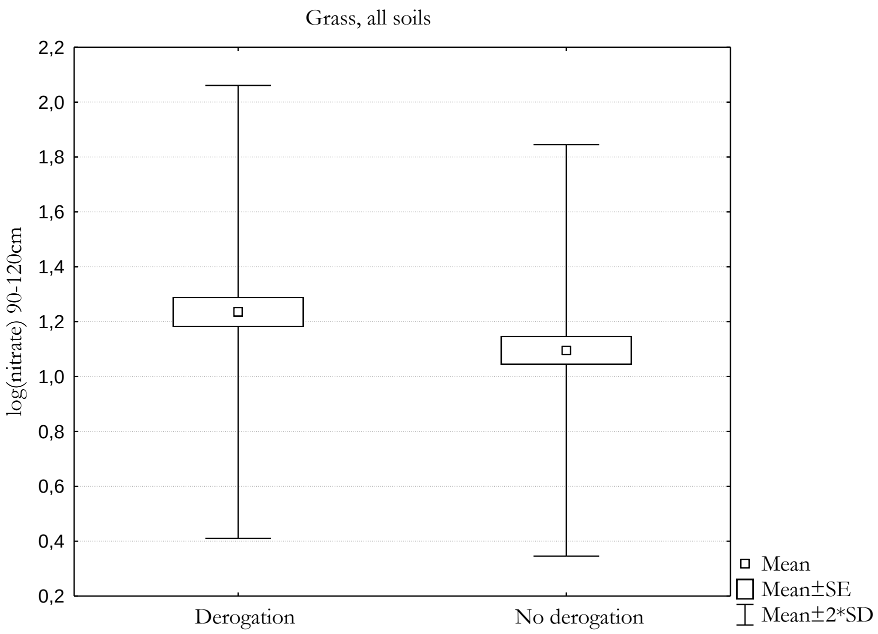


Figure 174: Box plot of log(nitrate-N, 90-120 cm, 2011-2014) for derogation and no derogation parcels cultivated with derogation crops on all soil textures. SE: standard error of the mean. SD: standard deviation.

On maize parcels the amount of nitrate-N in the soil layer 90-120 was 30 ± 23 kg/ha on derogation parcels and 34 ± 28 kg/ha on no derogation parcels. As for grass no statistical difference in nitrate-N in the soil layer 90-120 cm is found on maize parcels (p = 0.45) (Figure 175).

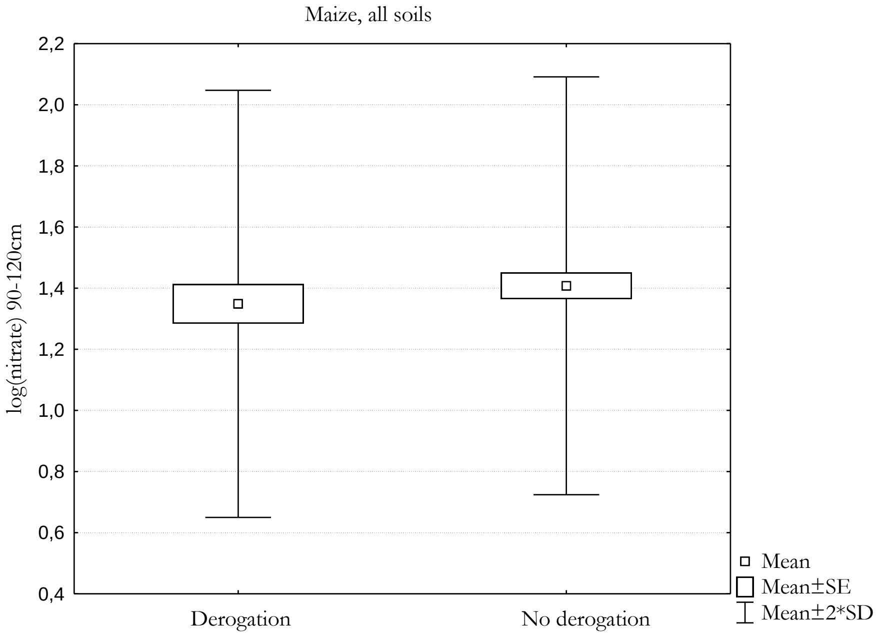


Figure 175: Box plot of log(nitrate-N, 90-120 cm, 2011-2014) for derogation and no derogation parcels cultivated with derogation crops on all soil textures. SE: standard error of the mean. SD: standard deviation.

The lack of statistical significant differences in the amount of nitrate-N in the soil layer 90-120 cm between derogation and no derogation parcels cultivated with grass was also revealed on sandy (p = 0.09) and sandy loam (p = 0.17) soils (Figure 176). The same was done for parcels cultivated with maize on sandy (p = 0.14) and sandy loam (p = 0.60) soils (Figure 177).

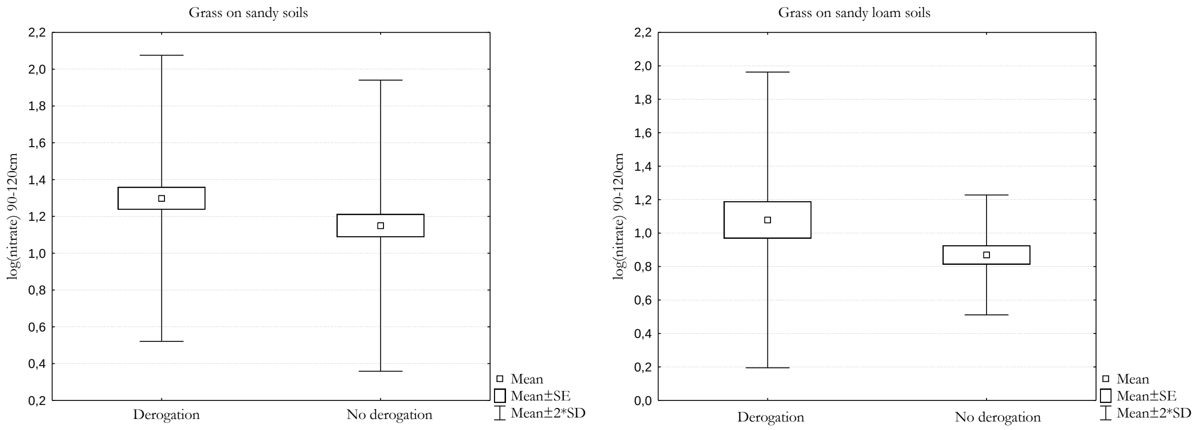


Figure 176: Box plot of log(nitrate-N, 90-120 cm, 2011-2014) for derogation and no derogation parcels cultivated with grass on sandy soils (left) and sandy loam soils (right). SE: standard error of the mean. SD: standard deviation.

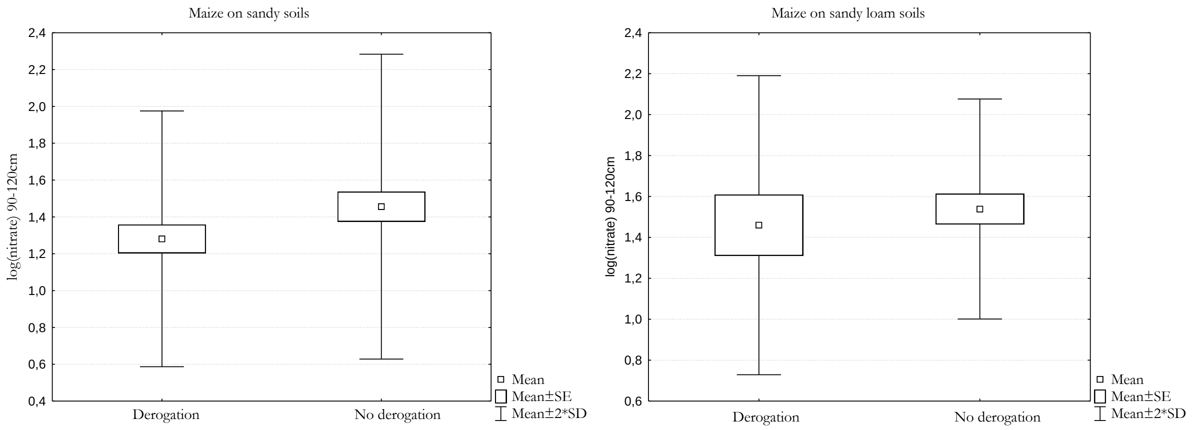


Figure 177: Box plot of log(nitrate-N, 90-120 cm, 2011-2014) for derogation and no derogation parcels cultivated with maize on sandy soils (left) and sandy loam soils (right). SE: standard error of the mean. SD: standard deviation.

Since no statistical significant differences are found between derogation and no derogation parcels for the amount of nitrate-N in the soil layers 0-90 cm and 90-120 no statistical differences are expected for the soil profile 0-120 cm. Comparison of the amount of nitrate-N in the soil profile 0-120 cm, based on all sampling data in the period 2001-2014, shows on derogation and no derogation parcels cultivated with derogation crops a similar variation (Figure 178). On parcels cultivated with derogation crops the amount of nitrate-N in the soil profile 0-120 cm is 76 ± 65 kg/ha on derogation parcels and 74 ± 66 kg/ha on no derogation parcels (Figure 179). This difference is not statistical significant (p = 0.74).

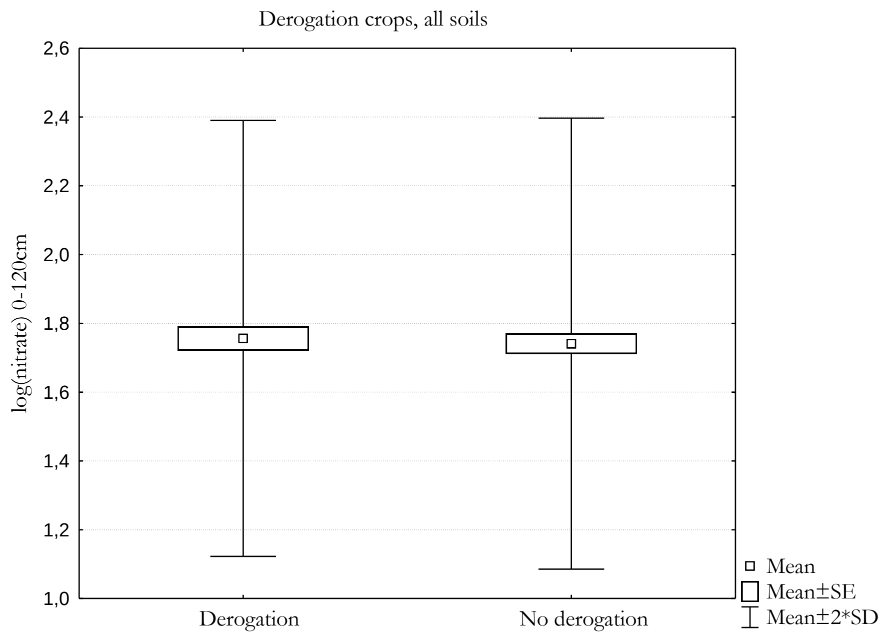


Figure 178: Box plot of log(nitrate-N, 0-120 cm, 2011-2014) for derogation and no derogation parcels cultivated with derogation crops on all soil textures. SE: standard error of the mean. SD: standard deviation.

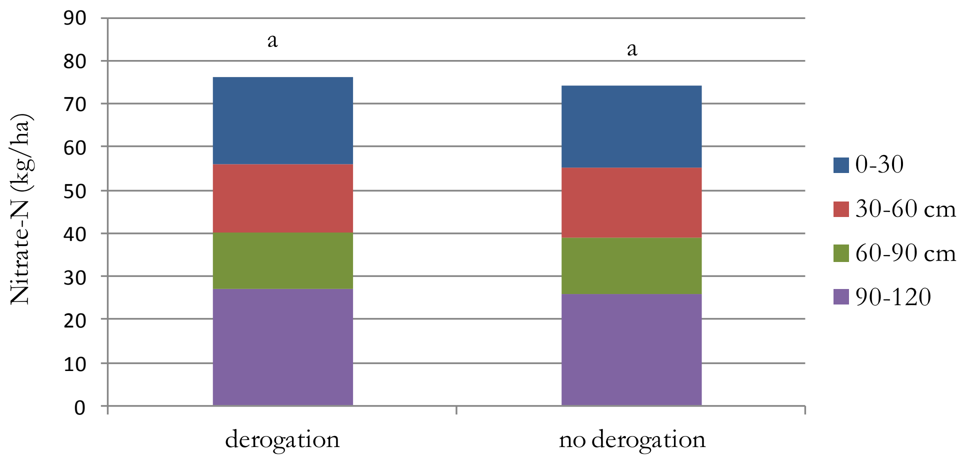


Figure 179: Average nitrate-N (kg/ha) (2011-2014) in the 4 soil layers on derogation and no derogation parcels cultivated with derogation crops on all soil textures. The results are analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

Focus on the most important derogation crops and soil textures on which derogation is most requested, results in the same conclusion.

On grass parcels on sandy soils the soil layer 0-120 cm contains in average 66 ± 58 kg N/ha when cultivated under derogation and 60 ± 46 kg N/ha when cultivated without derogation (p = 0.62) (Figure 180 and Figure 181). On grass parcels on sandy loam soils the soil layer 0-120 cm contains in average 53 ± 29 kg N/ha when cultivated under derogation and 35 ± 10 kg N/ha when cultivated without derogation (p = 0.07) (Figure 180 and Figure 183).

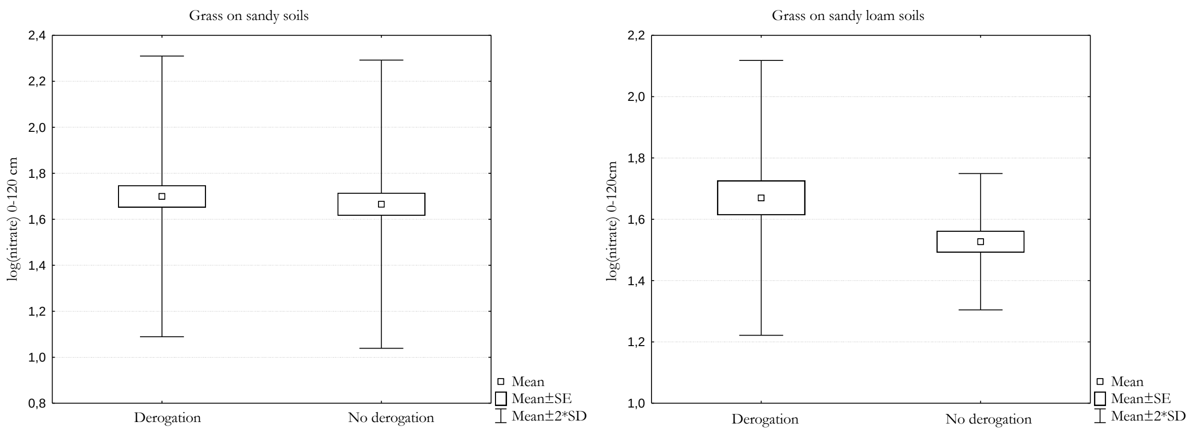


Figure 180: Box plot of log(nitrate-N, 0-120 cm, 2011-2014) for derogation and no derogation parcels cultivated with grass on sandy soils (left) and sandy loam soils (right). SE: standard error of the mean. SD: standard deviation.

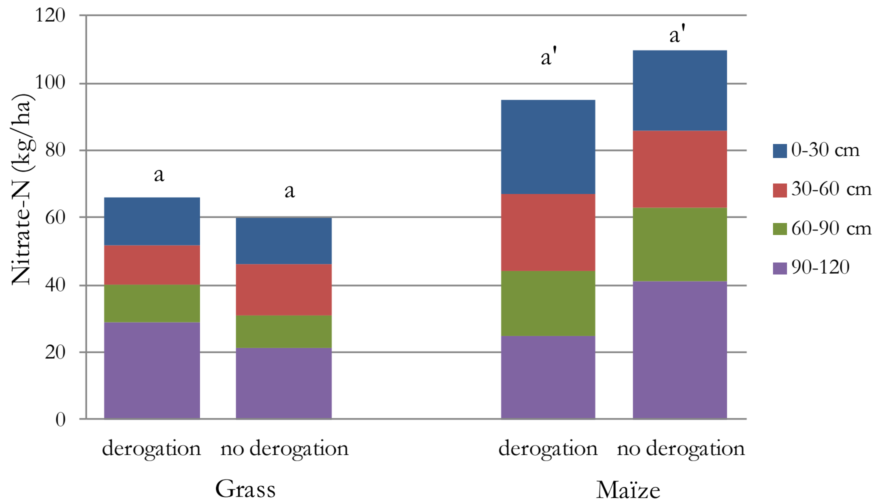


Figure 181: Average nitrate-N (kg/ha) (2011-2014) in the 4 soil layers on derogation and no derogation parcels cultivated with grass or maize on sandy soils. The results are analysed statistically by means of a one-way ANOVA (p≤0.05) on the log-transformed data. Identical letters indicate no statistical difference.

On maize parcels on sandy soils the soil layer 0-120 cm contains in average 95 ± 81 kg N/ha when cultivated under derogation and 110 ± 102 kg N/ha when cultivated without derogation (p = 0.75) (Figure 181 and Figure 182). On maize parcels on sandy loam soils the soil layer 0-120 cm contains in average 100 ± 78 kg N/ha when cultivated under derogation and 109 ± 59 kg N/ha when cultivated without derogation (p = 0.42) (Figure 182 and Figure 183).

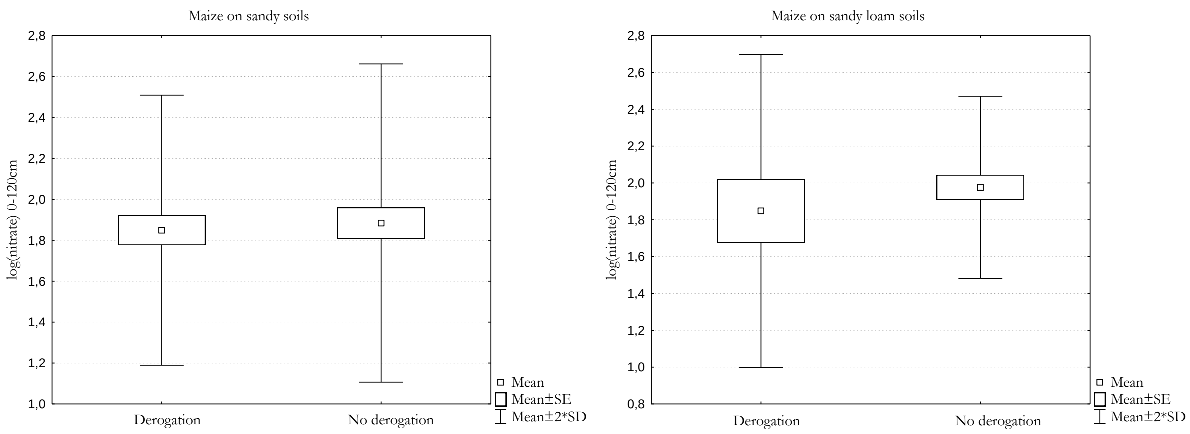


Figure 182: Box plot of log(nitrate-N, 0-120cm, 2011-2014) for derogation and no derogation parcels cultivated with maize on sandy soils (left) and sandy loam soils (right). SE: standard error of the mean. SD: standard deviation.

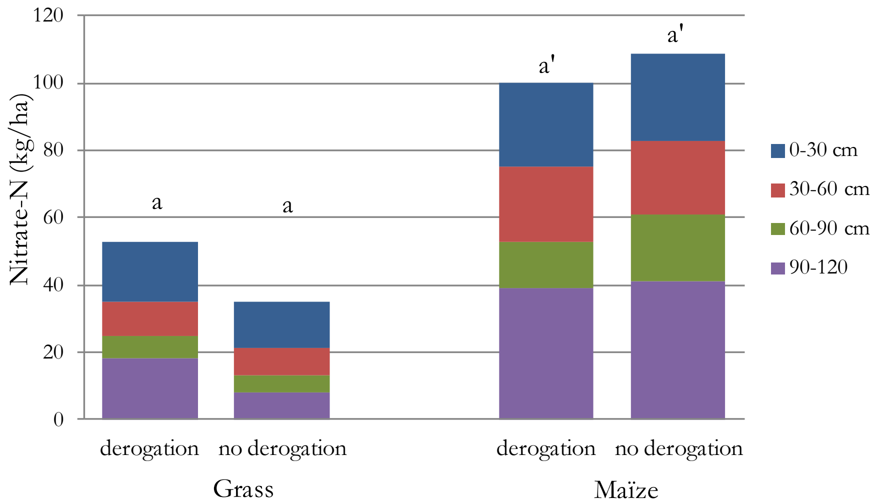


Figure 183: Average nitrate-N (kg/ha) (2011-2014) in the 4 soil layers on derogation and no derogation parcels cultivated with grass or maize on sandy loam soils. The results are analysed statistically by means of a one-way ANOVA ($p \leq 0.05$) on the log-transformed data. Identical letters indicate no statistical difference.

6.22 Conclusion

There is no significant difference for nitrate-N (kg/ha) in the soil profile (0-90 cm) between derogation and no derogation parcels cultivated with derogation crops (on all soil textures, sandy soils or sandy loam soils), cultivated with grass (on sandy soils or sandy loam soils) and parcels cultivated with maize (on sandy soils or sandy loam soils) at the sampling moments in the period autumn 2011-autumn 2014. At any of the sampling moments statistical significant differences in the amount of nitrate-N between derogation and derogation parcels are measured.

Even for parcels continuously under derogation/no derogation in the period 2009-2014, there is no significant difference for nitrate-N (kg/ha) in the soil profile (0-90 cm).

The nitrate in the soil profile (0-90 cm) and the nitrate in the deep soil layer (90-120 cm) are often significantly correlated. Derogation has no effect on the amount of nitrate-N in the deeper soil layer of 90-120 cm. No statistical difference is shown between derogation and no derogation parcels for the nitrate-N in the deeper soil layer.

7 Nitrate in the surface and groundwater

The purpose of this study is to determine if derogation has a possible effect on water quality. Therefore different water samples related to the parcels of the monitoring network are taken and different parameters are measured. In the water samples nitrate is one of the most important parameters to determine if derogation parcels have a negative impact on the water quality in comparison with no derogation parcels.

7.1 Canals, ditches and drains

Some parcels of the network are linked to a canal or a ditch, or are drained. An overview of the number of parcels of which a water sample is taken from a canal, ditch or drain is shown in Table 49. In autumn 2011 and spring 2012 for 24 and 25 parcels respectively, a water sample is taken from a canal, ditch or drain, compared with 37 parcels in autumn 2012. The low number of measurements in autumn 2011 and spring 2012 is the result of dry canals, drains or ditches. Therefore on these sites no water sample was obtained.

Table 49: Overview of the number of parcels for which a water sample is taken from a canal, ditch or drain.

	Number of parcels
Autumn 2011	24
Spring 2012	25
Autumn 2012	37
Spring 2013	37
Autumn 2013	36
Spring 2014	36
Autumn 2014	33

These samples could give an indication of the surface water quality. However, the link between the sampling point for the surface water and a particular parcel of the monitoring network is not always very clear. Especially canals and ditches may be influenced by more than one parcel or by other non-agricultural practices. Moreover, the concentrations of nitrate in the water samples of drains, canals and ditches are influenced by the moment of sampling (recent rainfall) with variability in the results as consequence. Therefore the concentrations of nitrate in the water samples of drains, canals and ditches are rather indicative.

The average amount of nitrate measured in the water samples is shown in Table 50. Because of the drought in autumn 2011, many drains were dry. Low concentrations of nitrate were measured in drains, canals and ditches in autumn 2011. Because of the drought, little nitrogen had leached out into the water. It needs to be noted that in autumn 2011, 11 of the 24 water samples had a nitrate content below the detection limit.

The nitrate concentration was lower in autumn 2011 (before winter) than in spring 2012 (after winter). This means that after winter, possibly a part of the nitrate from the soil has leached out into drains, canals and ditches. However, since only few parcels are measured, no ANOVA analysis was carried out.

In autumn 2012, two parcels had a very high nitrate concentration (one in a drain, one in a canal or ditch). The parcel linked to a canal or ditch with a high nitrate concentration in autumn 2012, also had a high nitrate concentration in spring 2012 (150 mg NO_3/l). In autumn 2011, this parcel had a nitrate concentration of 0.22 mg NO_3/l. Since more parcels may influence one canal or ditch, it is not easy to link the fertilisation- and management practices to one parcel.

Table 50: Average values of nitrate (mg NO_3/l) measured in water samples taken from the surface water linked to specific parcels of the monitoring network. Distinction is made between derogation and no derogation parcels. The number of parcels is indicated by "n".

		n	Nitrate (mg/l)	(min-max)
Autumn 2011				
Drains	Derogation	0	-	-
	No derogation	2	dl	(dl, dl)
Canals and ditches	Derogation	14	1	(dl, 4)
	No derogation	8	1	(dl, 3)
Spring 2012				
Drains	Derogation	3	15	(dl, 27)
	No derogation	1	dl	dl
Canals and ditches	Derogation	11	13	(dl, 150)
	No derogation	10	9	(dl, 33)
Autumn 2012				
Drains	Derogation	6	61	(dl, 196)
	No derogation	6	22	(0.9, 84)
Canals and ditches	Derogation	16	15	(dl, 151)
	No derogation	9	3	(dl, 13)
Spring 2013				
Drains	Derogation	6	26	(dl, 80)
	No derogation	6	37	(9, 105)
Canals and ditches	Derogation	16	16	(dl, 75)
	No derogation	9	2	(dl, 4)
Autumn 2013				
Drains	Derogation	3	74	(dl, 137)
	No derogation	2	22	(9, 43)
Canals and ditches	Derogation	18	27	(dl, 157)
	No derogation	13	15	(dl, 84)
Spring 2014				
Drains	Derogation	3	36	(0.41-64)
	No derogation	5	30	(4.6-70)
Canals and ditches	Derogation	18	25	(dl-145)
	No derogation	10	27	(dl-172)
Autumn 2014				
Drains	Derogation	0	-	-
	No derogation	2	4	(1.5-7)
Canals and ditches	Derogation	16	7	(dl-55)
	No derogation	16	10	(dl-44)

The derogation parcel with a very high nitrate concentration in autumn 2012 in a drain (196 mg NO_3/l) was cultivated with maize and had a low nitrate concentration in autumn 2012 in the soil (27 kg NO_3-N/ha).

In spring 2013, one parcel had a very high nitrate concentration in a drain of 105 mg NO_3/l. In autumn 2012, the nitrate concentration in this drain was 84 mg NO_3/l. In spring 2012 and autumn 2011 however, the drain had a nitrate concentration below detection limit.

In autumn 2013 two parcels with a high nitrate concentration in the surface water were detected. At a drain 137 mg NO_3/l was measured and 157 mg NO_3/l was measured in a ditch.

In spring 2014 a high nitrate concentration of 145 mg NO_3/l was measured in the ditch with high nitrate concentration in autumn 2013.

In autumn 2014 no high levels of nitrate is surface water are measured. In canals and ditches the average concentration is 7 mg NO_3/l for derogation parcels and 10 mg NO_3/l for no derogation parcels. These average values are with the lowest average values measured since autumn 2011. Only in autumn 2011 these values were smaller. Of the water samples taken at a drain, the nitrate concentration of 1 sample was below detection limit. Of the water samples taken in a ditch or canal, at derogation and no derogation parcels, in 4 and 5 samples, nitrate concentration was below detection limit.

The quality threshold of nitrate in the groundwater is 50 mg NO_3/l. The average values shown in Table 50 are all below this value, except for drains in autumn 2012, where the average nitrate was 61 mg NO_3/l, and drains in autumn 2013, where the average concentration was 74 mg NO_3/l. When looking more in detail to the minimum and maximum values, some drains, canals and ditches regularly exceed the limit of 50 mg NO_3/l.

Due to the low number of samples (especially for drains) it is not desirable to compare derogation and no derogation parcels statistically. Moreover, the measurements of the different samples are often highly variable, as can be seen from the minimum and maximum values in Table 50. Variability of the measurements at each moment of sampling and for both derogation and no derogation parcels is shown in Figure 184. Figure 185 shows also the variability of the measurement but even demonstrates by the position of the median that a large number of measurements is situated near detection limit.

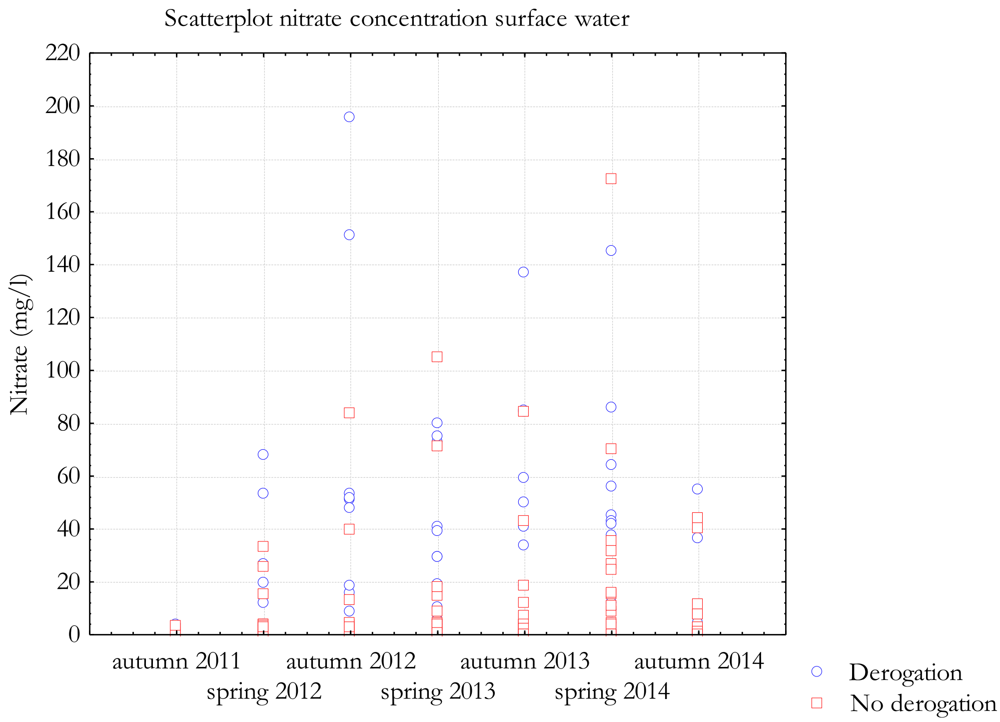


Figure 184: Scatterplot of the nitrate concentration (mg NO_3/l) in the surface water at drains, canals and ditches at derogation and no derogation parcels for each moment of sampling.

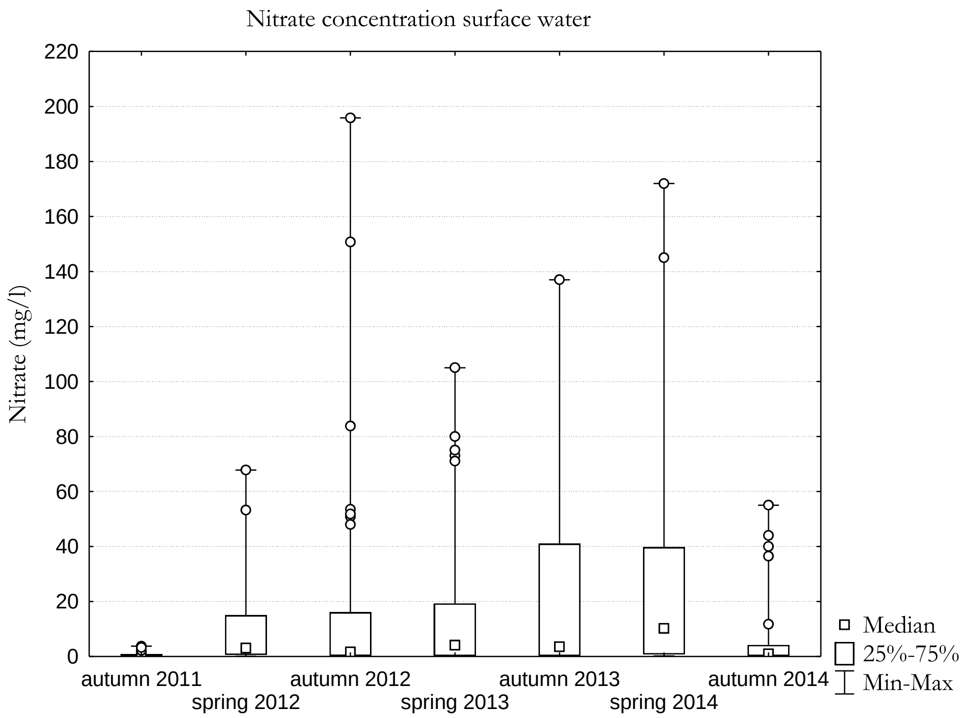


Figure 185: Boxplot of the nitrate concentration (mg NO_3/l) in the surface water at drains, canals and ditches for each moment of sampling.

7.2 Shallow groundwater (MAP sampling points groundwater and monitoring wells)

Another parameter to measure the possible impact of derogation on the water quality is the nitrate concentration in MAP sampling points groundwater and monitoring wells (shallow groundwater). The water quality measured in these sampling points is mainly influenced by a single agricultural parcel and could therefore be linked to the characteristics (fertilisation practices and cultivated crop) of this parcel. The data of nitrate in the monitoring wells for 2009_autumn, 2010_spring, 2010_autum and 2011_spring were obtained from the report "Establishment and follow-up of a monitoring network of farmers to assess the impact of derogation on the water quality" (Vandervelpen *et al.*, 2011).

Table 51: Average nitrate concentration (mg NO_3/l) in the MAP (M) sampling points and monitoring wells (W) linked to a parcel of the monitoring network for different years. For each year the number of parcels is indicated by "n".

	Nitrate (mg/l)					
	n	M	(min, max)	n	W	(min, max)
2009_autumn	84	25	(dl, 260)	42	25	(dl, 320)
2010_spring	104	28	(dl, 220)	49	35	(dl, 202)
2010_ autumn	102	27	(dl, 180)	42	25	(dl, 224)
2011_ spring	101	24	(dl, 210)	43	27	(dl, 159)
2011_ autumn	93	19	(dl, 216)	47	18	(dl, 195)
2012_ spring	102	24	(dl, 167)	46	19	(dl, 125)
2012_ autumn	92	25	(dl, 180)	48	21	(dl, 192)
2013_ spring	100	29	(dl, 220)	48	21	(dl, 132)
2013_ autumn	90	27	(dl, 237)	48	23	(dl, 147)
2014_ spring	-	-	-	48	19	(dl, 141)
2014_autumn	-	-	-	32	19	(dl, 139)

dl: detection limit (0.2 mg/l nitrate for groundwater). For the samples below detection limit, half of the detection limit (0.1 mg nitrate/l) is used for calculations.

The average nitrate concentrations at both monitoring wells and MAP sampling points are rather stable since autumn 2009. The average values are at each moment of sampling below the quality threshold of 50 mg NO_3/l in the groundwater. As the minima and maxima show, the variability in nitrate concentration at both MAP sampling points and monitoring wells was large. The nitrate concentration was often below detection limit but other monitoring wells or MAP sampling points regularly exceeded the quality threshold.

In the next paragraphs, the estimated travel time of water from a specific parcel to the sampling point or monitoring well was used to link parcel characteristics (derogation and cultivated crop) to water measurements in the MAP sampling point or monitoring well of a specific year. For example, for the parcel characteristics of 2009, if water of one parcel had a travel time of 1 year, the water measurements in the sampling point of monitoring well of 2010 was used. This way, the impact of derogation on nitrate in shallow groundwater can be determined.

7.2.1 Parcel characteristics of 2009

Based on the travel time, water samples from autumn and spring of 2009, 2010, 2011 or 2012 were linked to the parcel characteristics of 2009. For example, if the travel time is 1.13 years, the water sample of spring 2010 is linked to the parcel characteristics of 2009. A one-way ANOVA ($p \leq 0.05$) test was carried out on the log-transformed data in order to verify significant differences between derogation and no derogation parcels. There is no significant effect of derogation in 2009 on the nitrate in the monitoring points (Table 52).

Table 52: Average nitrate (mg/l) of monitoring points linked (based on the travel time) to the parcel characteristics of 2009. The number of parcels is indicated by "n", the number of parcels with a nitrate value below detection limit is indicated by "< dl". A one-way ANOVA test ($p \leq 0.05$) was carried out on the log-transformed data.

	Nitrate (mg/l)								
	Derogation				No derogation				
	n	average	(min, max)	<dl	n	average	(min, max)	<dl	p-value
All crops	63	26	(dl, 210)	16	78	24	(dl, 180)	20	
Derogation crops	63	26	(dl, 210)	16	60	24	(dl, 150)	15	0.53
Grass	34	12	(dl, 140)	9	18	21	(dl, 92)	5	0.16
Maize	27	39	(dl, 210)	5	31	23	(dl, 150)	5	0.43

dl: detection limit (0.2 mg/l nitrate for groundwater). For the samples below detection limit, half of the detection limit (0.1 mg nitrate/l) is used for calculations.

The percentages of sampling points in a specific range of nitrate concentration are given for derogation and no derogation parcels separately in Figure 186 to Figure 189. For parcels cultivated with all crops and on all soil textures, 86 % of sampling points linked to derogation parcels have a nitrate concentration below 50 mg/l while 81 % of sampling points linked to no derogation parcels have a nitrate concentration below 50 mg/l (Figure 186). For parcels cultivated with derogation crops on all soil textures, 86 % of sampling points linked to derogation parcels have a nitrate concentration below 50 mg/l while 80 % of sampling points linked to no derogation parcels have a nitrate concentration below 50 mg/l (Figure 187).

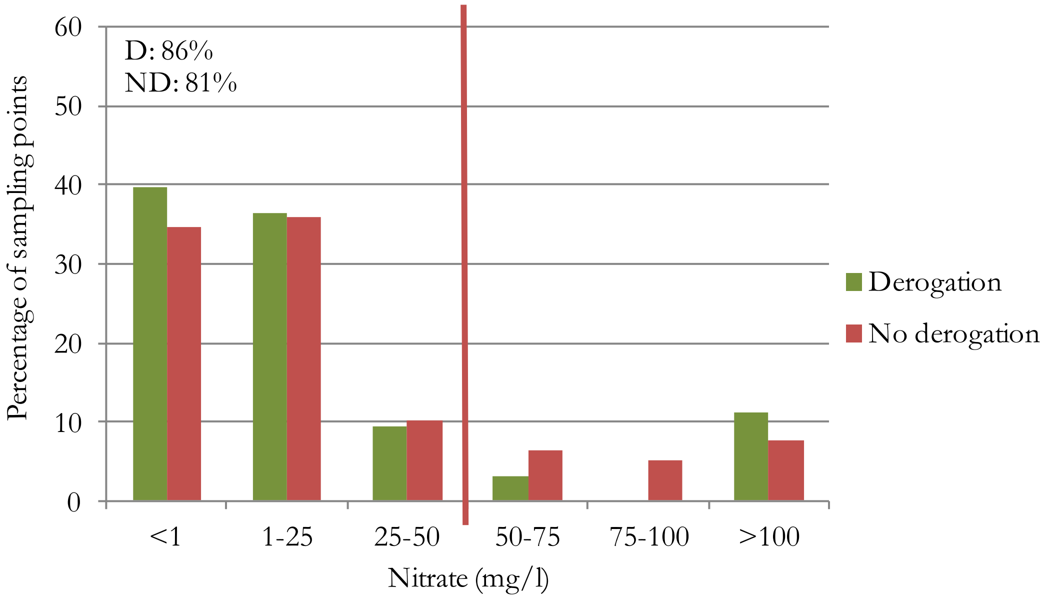


Figure 186: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcel characteristics of 2009 for all crops, based on the travel time. The red vertical line indicates the quality threshold of 50 mg/l.

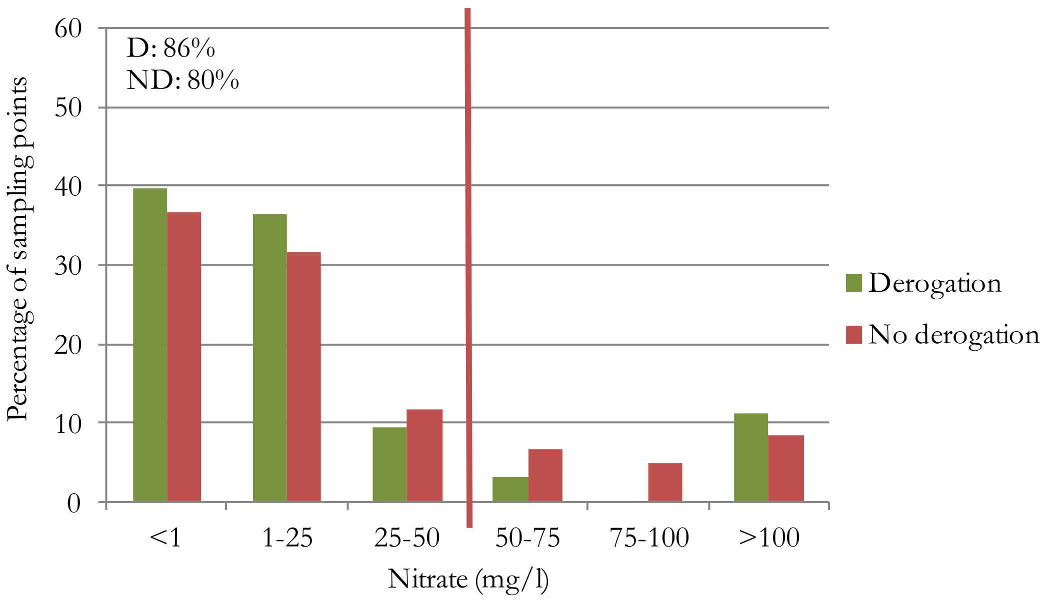


Figure 187: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcel characteristics of 2009 cultivated with derogation crops, based on the travel time. The red vertical line indicates the quality threshold of 50 mg/l.

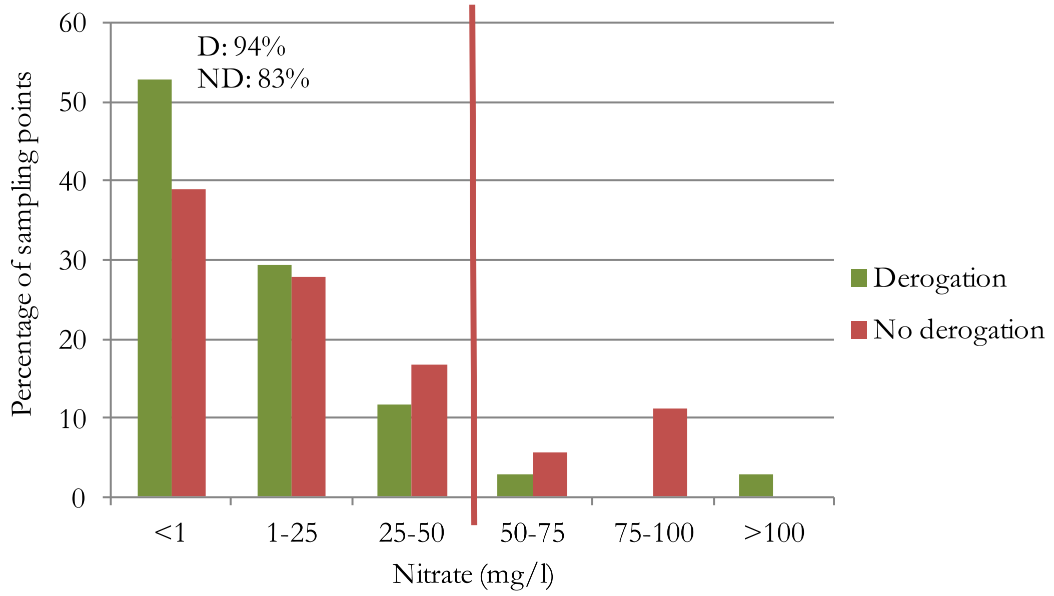


Figure 188: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcel characteristics of 2009 cultivated with grass, based on the travel time. The red vertical line indicates the quality threshold of 50 mg/l.

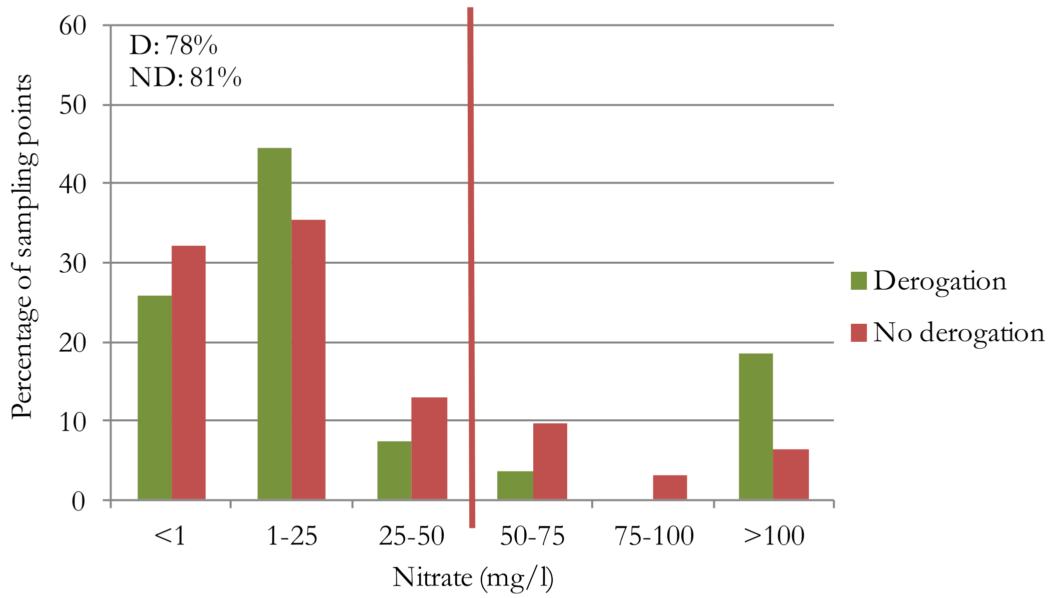


Figure 189: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcel characteristics of 2009 cultivated with maize, based on the travel time. The red vertical line indicates the quality threshold of 50 mg/l.

For parcels cultivated with grass on all soil textures, 94 % of sampling points linked to derogation parcels have a nitrate concentration below 50 mg/l while 83 % of sampling points linked to no derogation parcels have a nitrate concentration below 50 mg/l (Figure 188).

For parcels cultivated with maize on all soil textures, 78 % of sampling points linked to derogation parcels have a nitrate concentration below 50 mg/l while 81 % of sampling points linked to no derogation parcels have a nitrate concentration below 50 mg/l (Figure 189). A large variation exists between the sampling points and in some of the sampling points (linked to both derogation and no derogation parcels) very high concentrations (> 100 mg/l) are measured.

Table 53 shows the nitrate residue in 2009 and the nitrate concentration in groundwater linked to the parcel characteristics of 2009 based on the travel time. It is very important to notice that the nitrate concentration in the groundwater is not only influenced by the nitrate residue. Other parameters that influence the effect of the nitrate residue on the nitrate concentration in the groundwater are the concentration of nitrate in the profile at -90 cm and the process factor as discussed in paragraph 14.

Table 53: Average nitrate residue in 2009 (kg N/ha) and average nitrate concentration in groundwater (mg NO_3/l) of monitoring points linked (based on the travel time) to the parcel characteristics of 2009.

	Derogation				No derogation			
	Nitrate residue (kg N/ha)		Nitrate (mg/l)		Nitrate residue (kg N/ha)		Nitrate (mg/l)	
	average	(min, max)	average	(min, max)	average	(min, max)	average	(min, max)
All crops	82	(11, 283)	26	(dl, 210)	102	(14, 464)	24	(dl, 180)
Derogation crops	82	(11, 283)	26	(dl, 210)	78	(14, 195)	24	(dl, 150)
Grass	69	(11, 283)	12	(dl, 140)	59	(14, 141)	21	(dl, 92)
Maize	97	(32, 216)	39	(dl, 210)	83	(27, 161)	23	(dl, 150)

For derogation crops and more specifically for grass and maize no significant differences between derogation and no derogation parcels were found, not in nitrate residue (see Vandervelpen et al., 2011) nor in nitrate measured in the water (Table 52).

7.2.2 Parcel characteristics of 2010

Based on the travel time, water samples from autumn of 2010, autumn and spring of 2011, 2012 or 2013 were linked to the parcel characteristics of 2010. A statistical analysis was conducted by means of a one-way ANOVA ($p \leq 0.05$) of the log-transformed data. No statistical analysis was conducted for "all crops", since no derogation crops are present in this dataset and therefore the compared groups are not homogeneous.

Table 54: Average nitrate (mg/l) of monitoring points linked (based on the travel time) to the parcel characteristics of 2010. The number of parcels is indicated by "n". A one-way ANOVA ($p \leq 0.05$) was carried out between derogation and no derogation parcels based on the log-transformed data.

	Nitrate (mg/l)								
	Derogation				No derogation				
	n	average	(min, max)	<dl	n	average	(min, max)	<dl	p-value
All crops	66	17	(dl, 156)	28	74	28	(dl, 216)	15	-
Derogation crops	66	17	(dl, 156)	28	61	27	(dl, 216)	5	0.02
Grass	40	17	(dl, 156)	18	18	26	(dl, 216)	5	0.23
Maize	24	14	(dl, 87)	10	36	28	(dl, 155)	9	0.05

dl: detection limit (0.2 mg/l nitrate for groundwater). For the samples below detection limit, half of the detection limit (0.1 mg nitrate/l) is used for calculations.

There is a significant effect of derogation on nitrate in the monitoring points for derogation crops and maize on all soils (Table 54) based on a one-way ANOVA ($p \leq 0.05$) of the log-transformed data. From Table 54 can be seen that a large number of water samples have a nitrate concentration below the detection limit.

The percentages of sampling points in a specific range of nitrate concentration are given for derogation and no derogation parcels separately in Figure 190 to Figure 193. For parcels cultivated with all crops and on all soil textures, 86 % of sampling points linked to derogation parcels have a nitrate concentration below 50 mg/l while 82 % of sampling points linked to no derogation parcels have a nitrate concentration below 50 mg/l (Figure 190). For parcels cultivated with derogation crops on all soil textures, 86 % of sampling points linked to derogation parcels have a nitrate concentration below 50 mg/l while 82 % of sampling points linked to no derogation parcels have a nitrate concentration below 50 mg/l (Figure 191). For parcels cultivated with grass on all soil textures, 88 % of sampling points linked to derogation parcels have a nitrate concentration below 50 mg/l while 89 % of sampling points linked to no derogation parcels have a nitrate concentration below 50 mg/l (Figure 192).

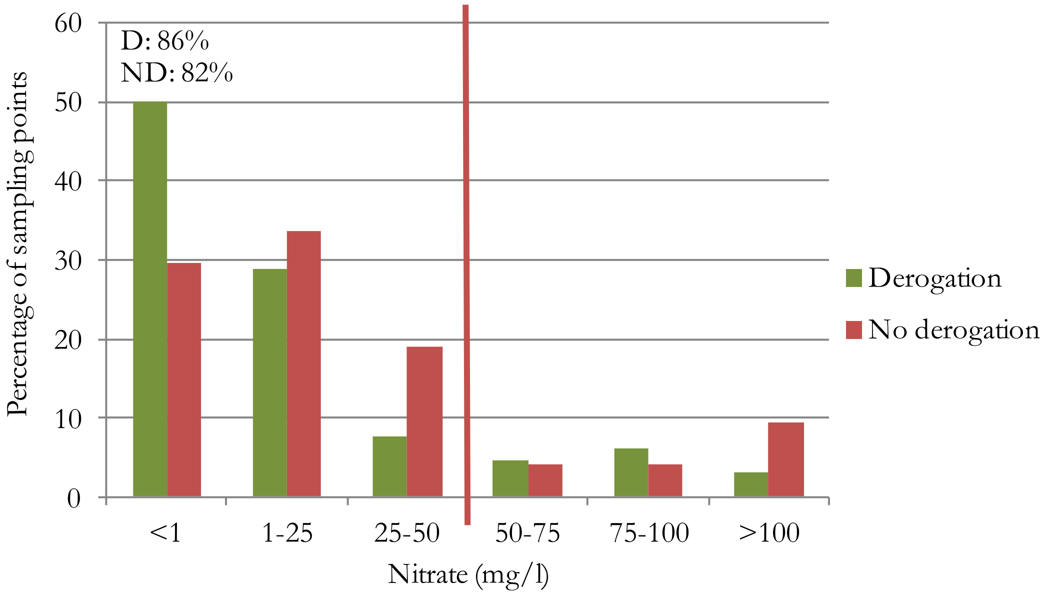


Figure 190: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcels of 2010 for all crops, based on the travel time. The red vertical line indicates the quality threshold of 50 mg/l.

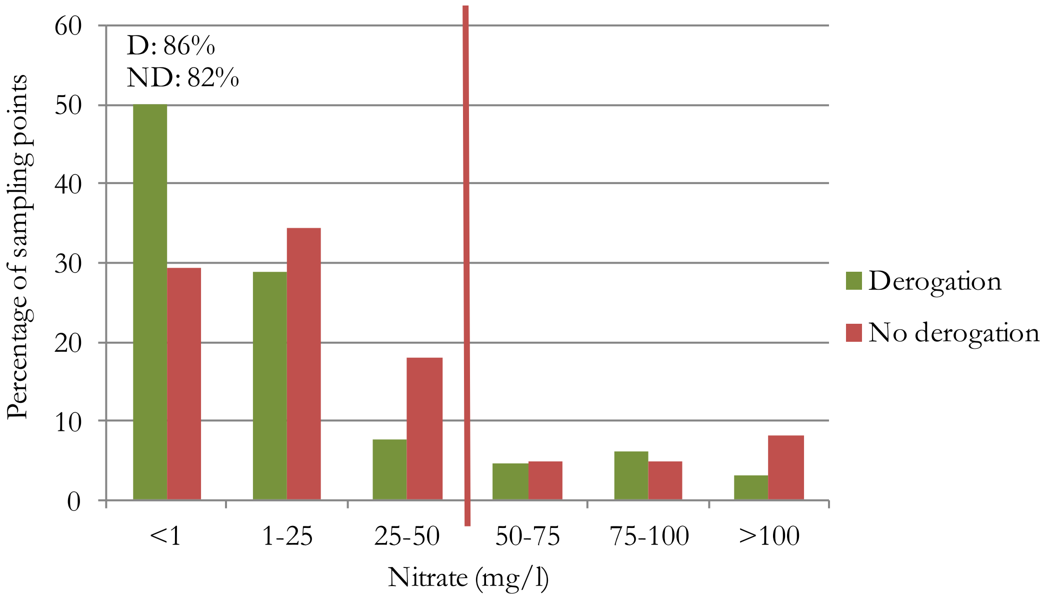


Figure 191: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcels of 2010 cultivated with derogation crops, based on the travel time. The red vertical line indicates the quality threshold of 50 mg/l.

For parcels cultivated with maize on all soil textures, 88 % of sampling points linked to derogation parcels have a nitrate concentration below 50 mg/l while 81 % of sampling points linked to no derogation parcels have a nitrate concentration below 50 mg/l (Figure 193). A large variation exists between the sampling points and in some of the sampling points (linked to both derogation and no derogation parcels) very high concentrations (> 100 mg/l) are measured.

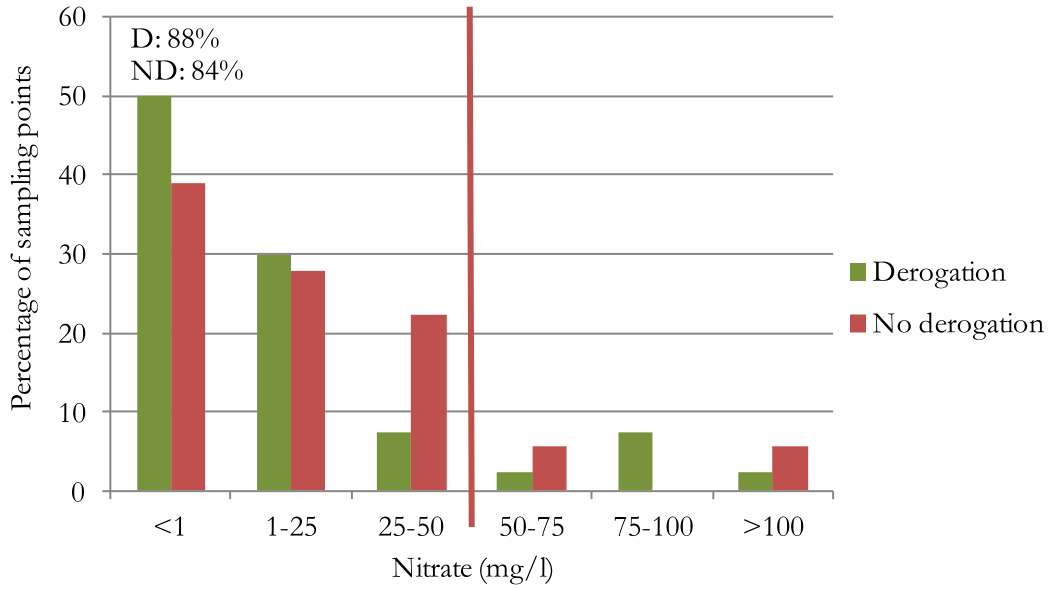


Figure 192: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcels of 2010 cultivated with grass, based on the travel time. The red vertical line indicates the quality threshold of 50 mg/l.

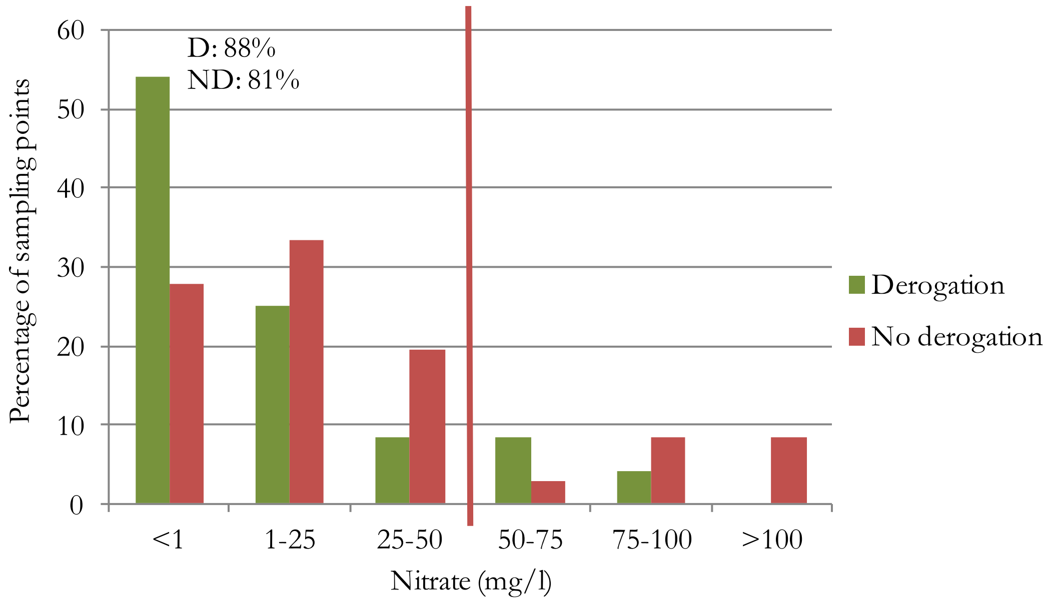


Figure 193: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcels of 2010 cultivated with maize, based on the travel time. The red vertical line indicates the quality threshold of 50 mg/l.

Table 55 shows the nitrate residue in 2010 and the nitrate concentration in groundwater linked to the parcel characteristics of 2010 based on the travel time. It is very important to notice that the nitrate concentration in the groundwater is not only influenced by the nitrate residue. Other parameters that influence the effect of the nitrate residue on the nitrate concentration in the groundwater are the concentration of nitrate in the profile at -90 cm and the process factor as discussed in paragraph 14.

Table 55: Average nitrate residue in 2010 (kg N/ha) and average nitrate concentration in groundwater (mg NO_3/l) of monitoring points linked (based on the travel time) to the parcel characteristics of 2010.

	Derogation				No derogation			
	Nitrate residue (kg N/ha)		Nitrate (mg/l)		Nitrate residue (kg N/ha)		Nitrate (mg/l)	
	average	(min, max)	average	(min, max)	average	(min, max)	average	(min, max)
All crops	59	(8, 185)	17	(dl, 156)	64	(8, 319)	28	(dl, 216)
Derogation crops	59	(8, 185)	17	(dl, 156)	63	(8, 319)	27	(dl, 216)
Grass	47	(8, 163)	17	(dl, 156)	39	(8, 126)	26	(dl, 216)
Maize	82	(9, 185)	14	(dl, 87)	80	(9, 319)	28	(dl, 155)

7.2.3 Parcel characteristics of 2011

Based on the travel time, water samples from autumn of 2011, autumn and spring of 2012 and 2013 or spring 2014 were linked to the parcel characteristics of 2011. This comparison cannot be finished since water samples until spring 2014 are therefore needed. For the MAP sampling points only the measurements until autumn 2013 are published and measurements of spring 2014 are not available yet.

Table 56: Average nitrate (mg/l) of monitoring points linked (based on the travel time) to the parcel characteristics of 2011. The number of parcels is indicated by "n". A one-way ANOVA ($p \leq 0.05$) was carried out between derogation and no derogation parcels based on the log-transformed data.

	Nitrate (mg/l)								
	Derogation				No derogation				
	n	average	(min, max)	<dl	n	average	(min, max)	<dl	p-value
All crops	57	26	(dl, 180)	18	81	22	(dl, 190)	19	-
Derogation crops	57	26	(dl, 180)	18	67	20	(dl, 190)	18	0.99
Grass	34	18	(dl, 131)	14	23	10	(dl, 69)	7	0.80
Maize	23	38	(dl, 180)	4	37	27	(dl, 190)	7	0.88

dl: detection limit (0.2 mg/l nitrate for groundwater). For the samples below detection limit, half of the detection limit (0.1 mg nitrate/l) is used for calculations.

A statistical analysis was conducted by means of an ANOVA ($p \leq 0.05$) of the log-transformed data. No statistical analysis was conducted for "all crops", since no derogation crops are present in this dataset and therefore the compared groups are not homogeneous.

There is no significant effect of derogation on nitrate in the monitoring points (Table 56). From Table 56 can be seen that a large number of water samples have a nitrate concentration below the detection limit.

The percentages of sampling points in a specific range of nitrate concentration are given for derogation and no derogation parcels separately in Figure 194 to Figure 197. For parcels cultivated with all crops and on all soil textures, 82 % of sampling points linked to derogation parcels and 77 % of sampling points linked to no derogation parcels have a nitrate concentration below 50 mg/l (Figure 194).

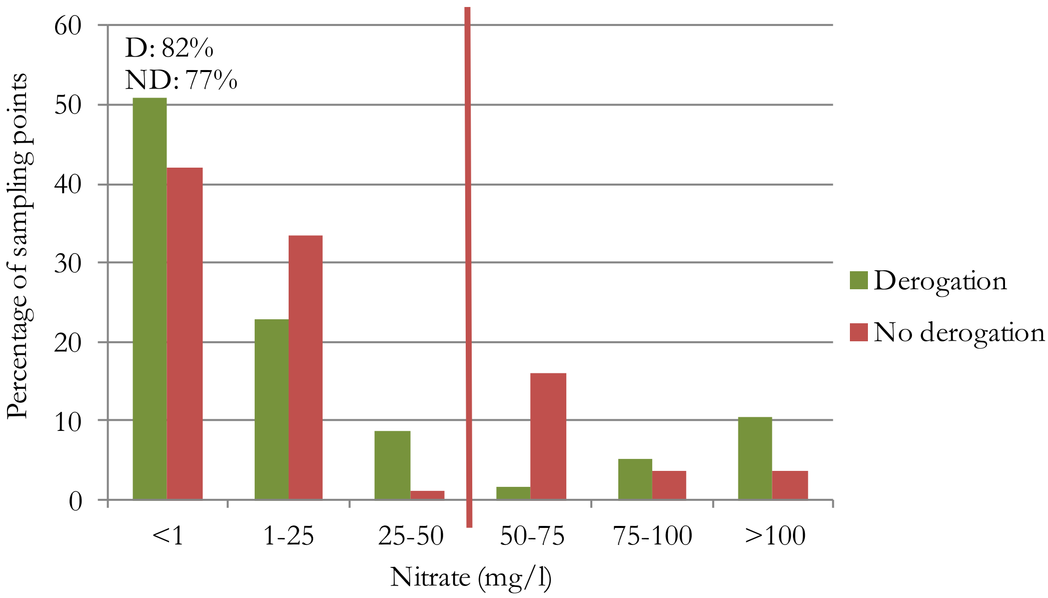


Figure 194: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcels of 2011 for all crops, based on the travel time. The red vertical line indicates the quality threshold of 50 mg/l.

For parcels cultivated with derogation crops on all soil textures, 82 % of sampling points linked to derogation parcels have a nitrate concentration below 50 mg/l while 78 % of sampling points linked to no derogation parcels have a nitrate concentration below 50 mg/l (Figure 195).

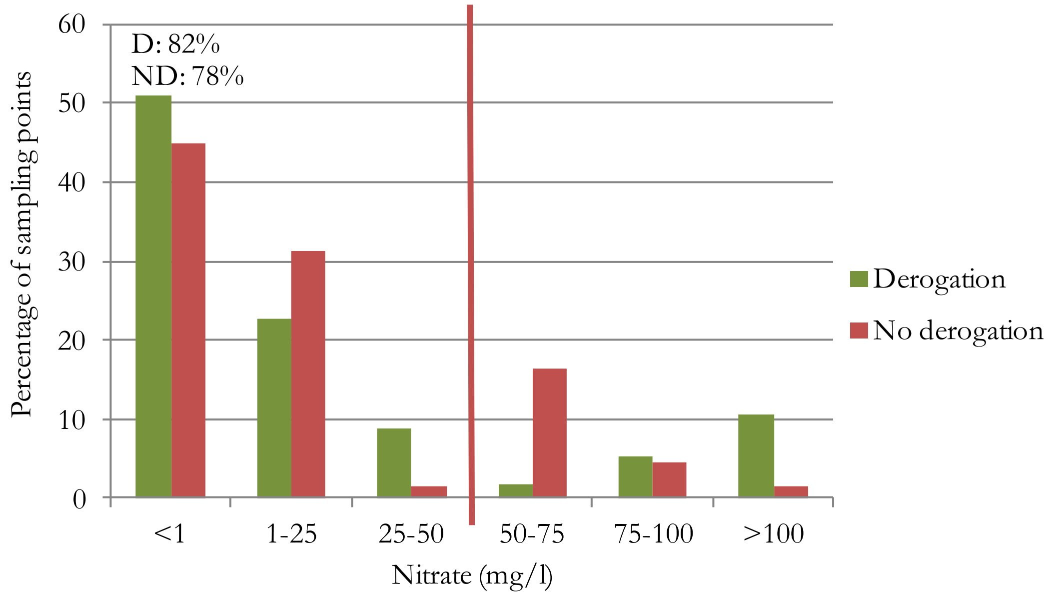


Figure 195: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcels of 2011 for derogation crops, based on the travel time. The red vertical line indicates the quality threshold of 50 mg/l.

For derogation and no derogation parcels cultivated with grass on all soil textures, respectively 88 and 87 % of sampling points linked to the parcels have a nitrate concentration below 50 mg/l (Figure 196). For parcels cultivated with maize on all soil textures, 74 % of sampling points linked to derogation parcels have a nitrate concentration below 50 mg/l and 70 % of sampling points linked to no derogation parcels have a nitrate concentration below 50 mg/l (Figure 197). A large variation exists between the sampling points and in some of the sampling points (linked to both derogation and no derogation parcels) very high concentrations (> 100 mg/l) are measured.

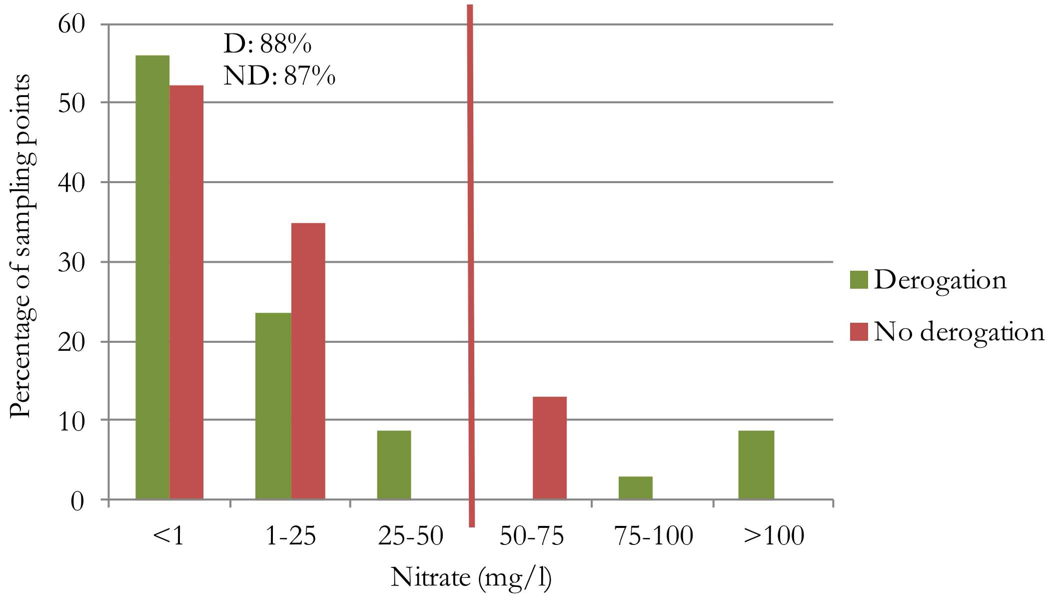


Figure 196: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcels of 2011 cultivated with grass, based on the travel time. The red vertical line indicates the quality threshold of 50 mg/l.

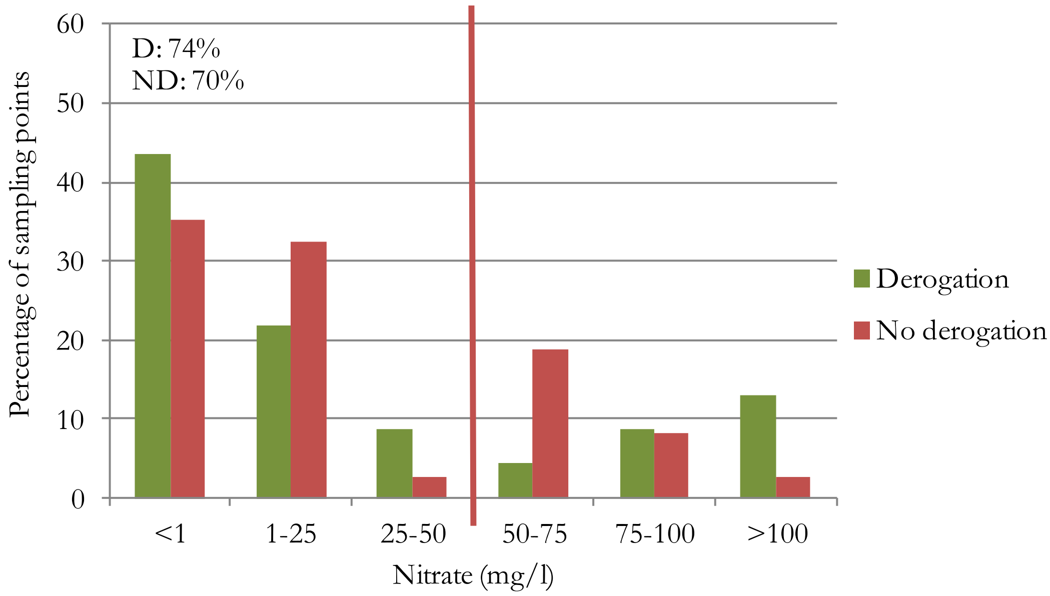


Figure 197: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcels of 2011 cultivated with maize, based on the travel time. The red vertical line indicates the quality threshold of 50 mg/l.

Table 57 shows the nitrate residue in 2011 and the nitrate concentration in groundwater linked to the parcel characteristics of 2011 based on the travel time. As mentioned before it is very important to notice that the nitrate concentration in the groundwater is not only influenced by the nitrate residue. Other parameters that influence the effect of the nitrate residue on the nitrate concentration in the groundwater are the concentration of nitrate in the profile at -90 cm and the process factor as discussed in paragraph 14.

Table 57: Average nitrate residue in 2011 (kg N/ha) and average nitrate concentration in groundwater (mg NO_3/l) of monitoring points linked (based on the travel time) to the parcel characteristics of 2011.

	Derogation				No derogation			
	Nitrate residue (kg N/ha)		Nitrate (mg/l)		Nitrate residue (kg N/ha)		Nitrate (mg/l)	
	average	(min, max)	average	(min, max)	average	(min, max)	average	(min, max)
All crops	87	(5, 504)	26	(dl, 180)	100	(8, 408)	22	(dl, 190)
Derogation crops	87	(5, 504)	26	(dl, 180)	86	(8, 341)	20	(dl, 190)
Grass	63	(5, 176)	18	(dl, 131)	48	(8, 112)	10	(dl, 69)
Maize	123	(21, 504)	38	(dl, 180)	114	(15, 341)	27	(dl, 190)

For derogation crops, and more specifically for grass and maize, no significant difference between derogation and no derogation were found, neither in nitrate residue (see paragraph 6.1) nor in nitrate measured in the water (Table 56).

7.2.4 Parcel characteristics of 2012

Based on the travel time, water samples from autumn of 2012, autumn and spring of 2013 and 2014 were linked to the parcel characteristics of 2012. This comparison is not complete for several reasons. To complete this dataset water samples should be taken until spring 2015 regarding the travel time. At the monitoring wells no water samples will be taken in spring 2015. For the MAP sampling points only the measurements until autumn 2013 are published and measurements of spring and autumn 2014 are not available yet.

A statistical analysis was conducted by means of an ANOVA ($p \leq 0.05$) of the log-transformed data. No statistical analysis was conducted for “all crops”, since no derogation crops are present in this dataset and therefore the compared groups are not homogeneous.

Table 58: Average nitrate (mg/l) of monitoring points linked (based on the travel time) to the parcel characteristics of 2012. The number of parcels is indicated by "n". A one-way ANOVA (p ≤ 0.05) was carried out between derogation and no derogation parcels based on the log-transformed data.

	Nitrate (mg/l)								
	Derogation				No derogation				
	n	average	(min, max)	<dl	n	average	(min, max)	<dl	p-value
All crops	42	19	(dl, 139)	19	35	24	(dl, 237)	10	-
Derogation crops	42	19	(dl, 139)	19	30	15	(dl, 124)	10	0.36
Grass	26	12	(dl, 132)	13	9	16	(dl, 93)	5	0.66
Maize	16	29	(dl, 139)	6	18	10	(dl, 79)	4	0.81

dl: detection limit (0.2 mg/l nitrate for groundwater). For the samples below detection limit, half of the detection limit (0.1 mg nitrate/l) is used for calculations.

There is no significant effect of derogation in 2012 on nitrate in the monitoring points (Table 58), nor when grass (p = 0.66) nor when maize (p = 0.81) was cultivated.

The percentages of sampling points in a specific range of nitrate concentration are given for derogation and no derogation parcels separately in Figure 198 to Figure 201. For parcels cultivated with all crops and on all soil textures, 83 % of sampling points linked to derogation parcels and 86 % of sampling points linked to no derogation parcels have a nitrate concentration below 50 mg/l (Figure 198).

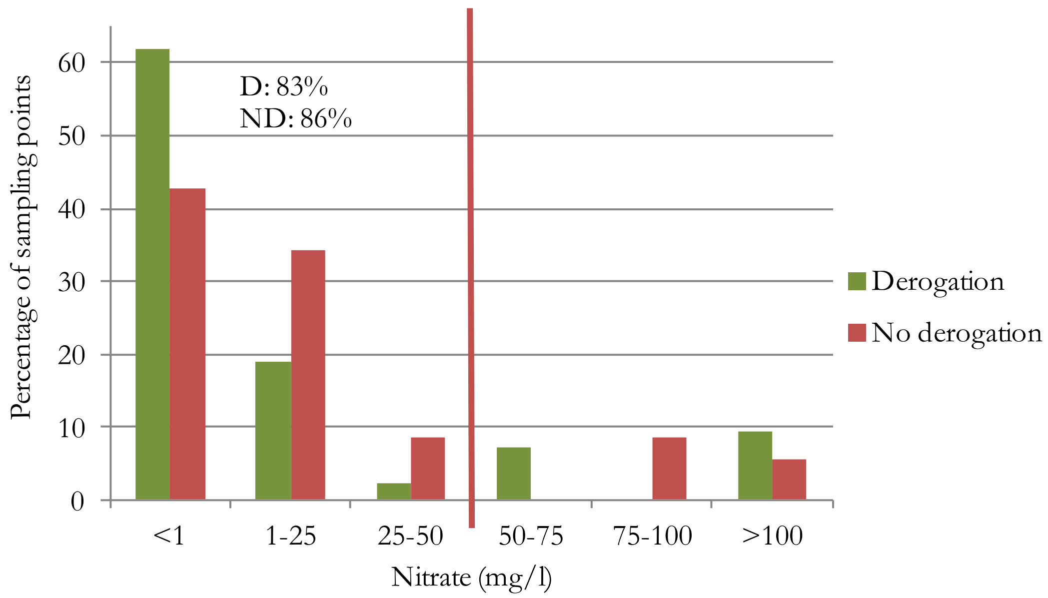


Figure 198: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcels of 2012 for all crops, based on the travel time. The red vertical line indicates the quality threshold of 50 mg/l.

For parcels cultivated with derogation crops on all soil textures, 83 % of sampling points linked to derogation parcels have a nitrate concentration below 50 mg/l and 90 % of sampling points linked to no derogation parcels have a nitrate concentration below 50 mg/l (Figure 199).

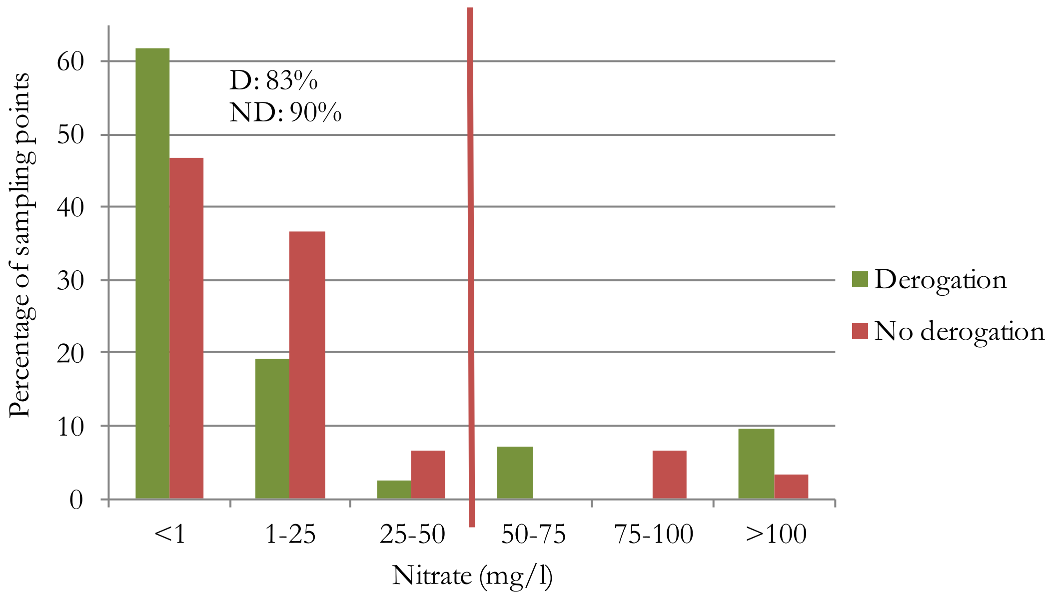


Figure 199: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcels of 2012 for derogation crops, based on the travel time. The red vertical line indicates the quality threshold of 50 mg/l.

For derogation and no derogation parcels cultivated with grass on all soil textures, respectively 88 and 89 % of sampling points linked to the parcels have a nitrate concentration below 50 mg/l (Figure 200). For parcels cultivated with maize on all soil textures, 75 % of sampling points linked to derogation parcels have a nitrate concentration below 50 mg/l and 94 % of sampling points linked to no derogation parcels have a nitrate concentration below 50 mg/l (Figure 201). A large variation exists between the sampling points and in some of the sampling points (linked to both derogation and no derogation parcels) very high concentrations (> 100 mg/l) are measured.

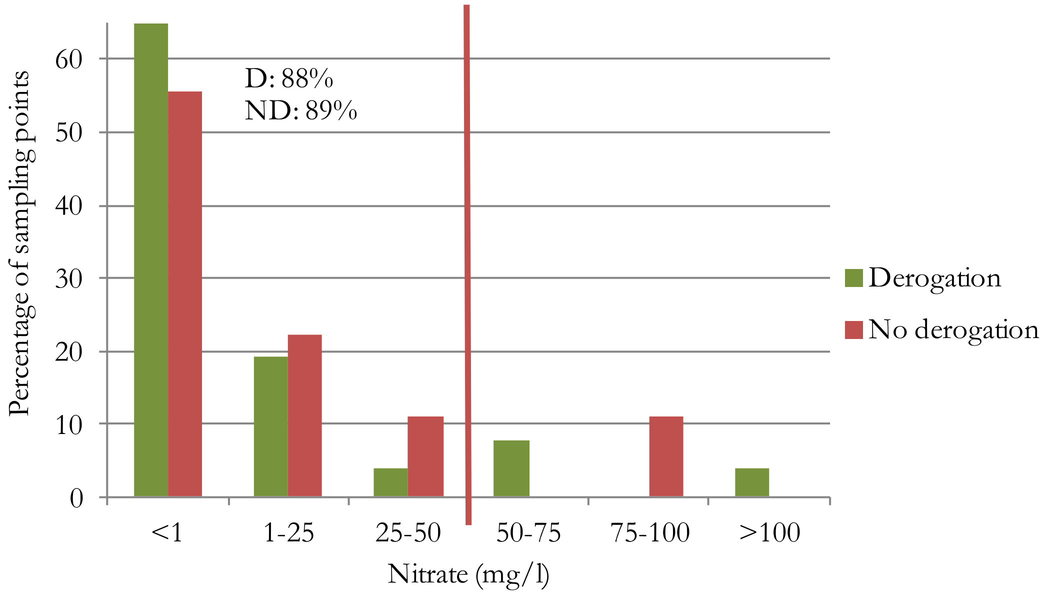


Figure 200: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcels of 2012 cultivated with grass, based on the travel time. The red vertical line indicates the quality threshold of 50 mg/l.

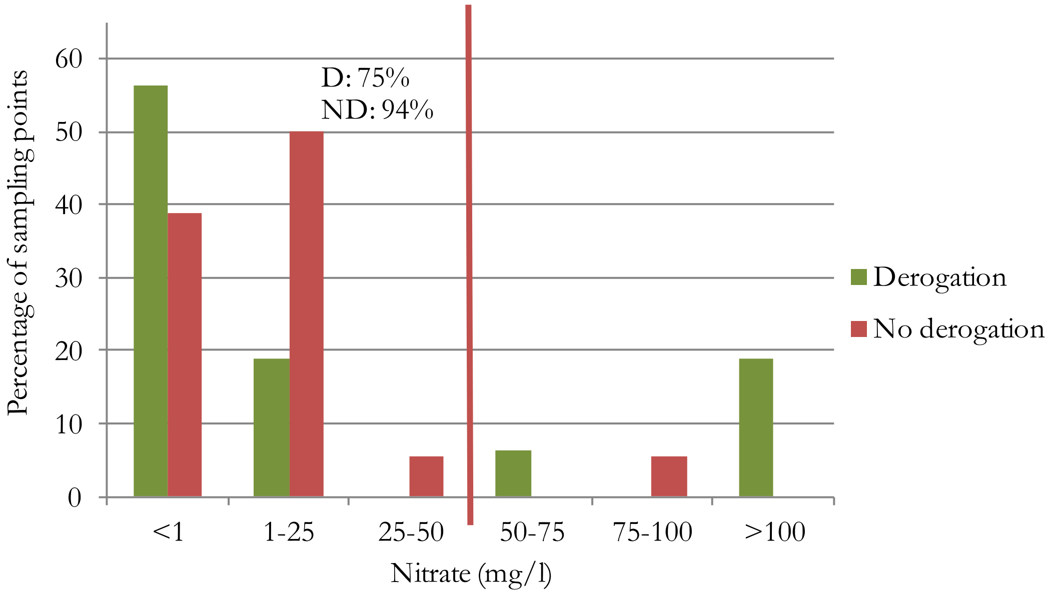


Figure 201: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcels of 2012 cultivated with maize, based on the travel time. The red vertical line indicates the quality threshold of 50 mg/l.

7.2.5 Parcel characteristics of 2013

Based on the travel time, water samples from autumn of 2013, autumn and spring of 2014 were linked to the parcel characteristics of 2013.

Table 59: Average nitrate (mg/l) of monitoring points linked (based on the travel time) to the parcel characteristics of 2013. The number of parcels is indicated by "n".

	Nitrate (mg/l)								
	Derogation				No derogation				
	n	average	(min, max)	<dl	n	average	(min, max)	<dl	p-value
All crops	18	19	(dl, 141)	3	3	46	(dl, 111)	0	-
Derogation crops	18	19	(dl, 141)	3	3	46	(dl, 111)	0	-
Grass	9	13	(dl, 59)	1	2	70	(dl, 111)	0	-
Maize	9	26	(dl, 141)	2	1	0.34	-	0	-

dl: detection limit (0.2 mg/l nitrate for groundwater). For the samples below detection limit, half of the detection limit (0.1 mg nitrate/l) is used for calculations.

Comparison of derogation and no derogation practices in 2013 is at end 2014 possible for only 21 parcels. For some parcels the necessary measurements of MAP sampling points are not available yet and other parcels have a longer travel time. Since the parcels are selected in such a way that travel time is limited, evaluation of the effect of derogation and no derogation practices in 2013 on the nitrate content in shallow groundwater, can be finished when measurements until spring 2016 will be finished and available.

Since the comparison in function of the parcel characteristics of 2013 is based on a small number of parcels, no graphs are made and no statistical analysis is conducted.

7.3 Nitrate in the soil water

On selected parcels a soil sample from 90 to 120 cm is taken in spring and autumn. Most of these parcels have a low groundwater level. As a consequence the water samples from MAP sampling points groundwater or monitoring wells linked to these parcels have long travel times. The nitrate measured in the deeper soil layers is an indication of the amount of nitrate in the water of that specific parcel. By taking into account the moisture content of the soil, the amount of nitrate measured in the soil profile is recalculated to a nitrate concentration in the water.

In Table 60, the average value for the nitrate (mg/l) concentration in the soil water is shown. A statistical analysis was conducted by means of an ANOVA ($p \leq 0.05$) of the log-transformed data. No statistical analysis was conducted for "all crops", since no derogation crops are present in this dataset and therefore the compared groups are not homogeneous.

In autumn 2011, there is no significant difference in nitrate concentration between derogation and no derogation parcels cultivated with derogation crops and grass. However, maize parcels under derogation have a statistically higher nitrate concentration than no derogation parcels. Since spring 2012 until spring 2014 there is no significant difference in nitrate concentration between derogation and no derogation parcels not for derogation crops, nor for parcels cultivated with grass or maize.

Table 60: Average value for the nitrate (mg/l) concentration measured and recalculated in the deep soil layer (90-120 cm) for the different moments of sampling. Distinction is made between derogation and no derogation parcels. The number of parcels is indicated by "n". A one-way ANOVA (p ≤ 0.05) was carried out between derogation and no derogation parcels based on the log-transformed data.

Date		Nitrate (mg/l) in the soil water						
		n	Derogation	(min, max)	n	No derogation	(min, max)	p-value
Autumn 2011								
	All crops	15	97	(3, 302)	24	82	(9, 343)	-
	Derogation crops	15	97	(3, 304)	20	68	(9, 224)	0.71
	Grass	9	52	(3, 122)	9	47	(9, 87)	0.83
	Maize	6	166	(60, 303)	11	85	(38, 224)	0.03
Spring 2012								
	All crops	10	61	(1, 240)	22	107	(9, 281)	-
	Derogation crops	10	61	(1, 240)	18	112	(9, 281)	0.52
	Grass	7	34	(1, 115)	10	88	(9, 281)	0.07
	Maize	3	123	(62, 240)	8	142	(39, 240)	0.90
Autumn 2012								
	All crops	13	84	(6, 395)	19	65	(12, 282)	-
	Derogation crops	13	84	(6, 395)	17	45	(12, 148)	0.33
	Grass	9	90	(31, 395)	7	42	(12, 148)	0.10
	Maize	4	71	(6, 210)	8	52	(13, 69)	0.57
Spring 2013								
	All crops	12	51	(13, 147)	17	83	(13, 368)	-
	Derogation crops	12	51	(13, 147)	13	63	(13, 215)	0.57
	Grass	8	58	(13, 147)	4	46	(13, 126)	0.48
	Maize	4	36	(23, 68)	8	76	(32, 215)	0.09
Autumn 2013								
	All crops	13	54	(12, 118)	20	50	(5, 198)	-
	Derogation crops	13	54	(12, 118)	17	48	(5, 198)	0.16
	Grass	9	51	(12, 83)	8	36	(5, 108)	0.15
	Maize	4	60	(29, 118)	8	64	(6, 198)	0.62
Spring 2014								
	All crops	9	38	(6, 119)	16	50	(7, 154)	-
	Derogation crops	9	38	(6, 119)	13	50	(7, 154)	0.31
	Grass	5	44	(6, 119)	5	50	(7, 116)	0.68
	Maize	4	32	(7, 51)	7	54	(14, 154)	0.34
Autumn 2014								
	All crops	11	112	(9, 318)	26	64	(7, 328)	-
	Derogation crops	11	112	(9, 318)	25	64	(7, 328)	0.05
	Grass	8	121	(9, 318)	11	27	(7, 52)	0.01
	Maize	3	86	(46, 162)	11	113	(14, 328)	0.92

In autumn 2014 a statistical significant difference is found between derogation and no derogation parcels for derogation crops and for grass parcels. However the range of nitrate concentration in soil water was for both derogation and no derogation parcels large (Figure 202 and Figure 203), as experienced at earlier sampling moments. However the results of autumn 2014 need to be approached with the necessary precautions since the nitrate concentration in the soil water was clearly influenced by the moisture content of the soil. This was not experienced at earlier sampling moments (Figure 204).

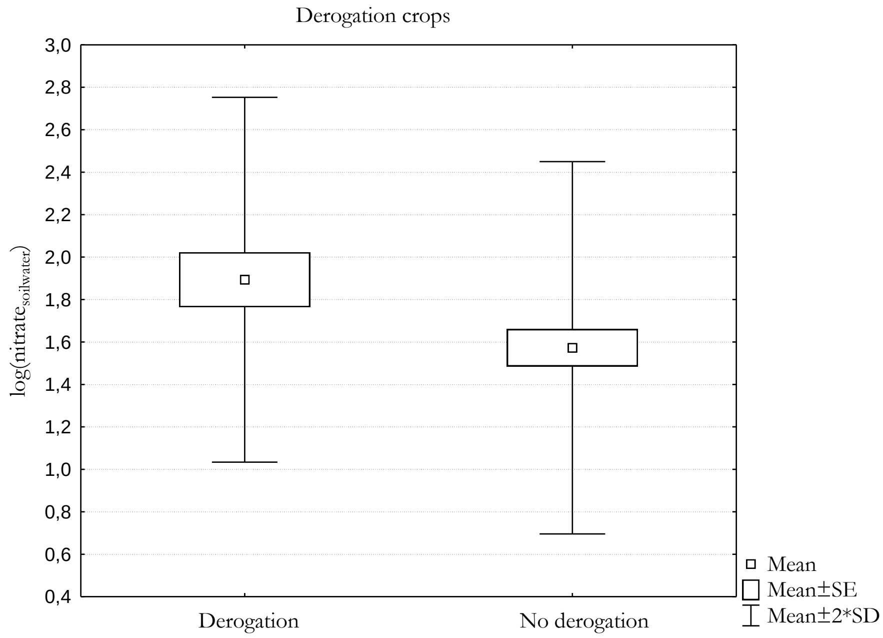


Figure 202: Box plot of log(nitrate soil water) for derogation and no derogation parcels cultivated with derogation crops on all soil textures in autumn 2014. SE: standard error of the mean. SD: standard deviation.

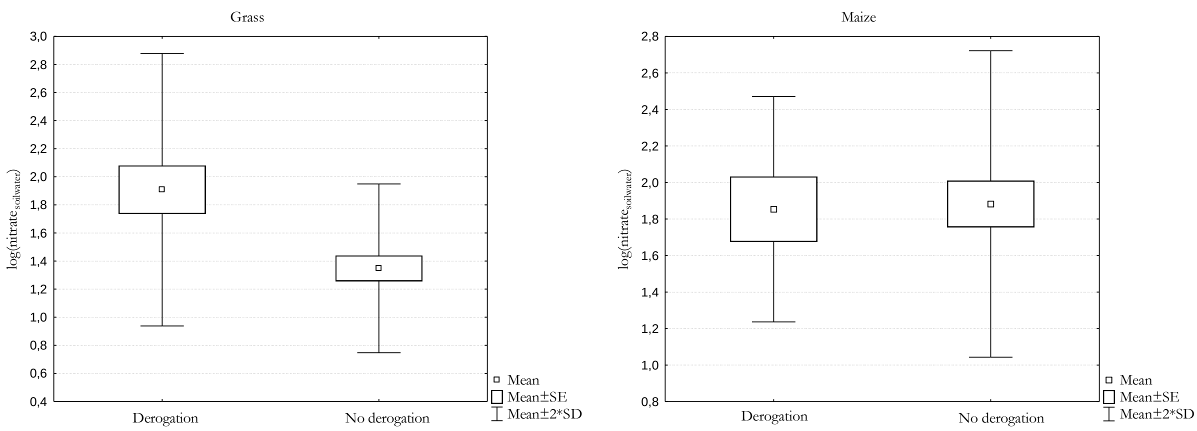


Figure 203: Box plot of log(nitrate soil water) for derogation and no derogation parcels cultivated with grass (left) and maize (right) on all soil textures in autumn 2014. SE: standard error of the mean. SD: standard deviation.

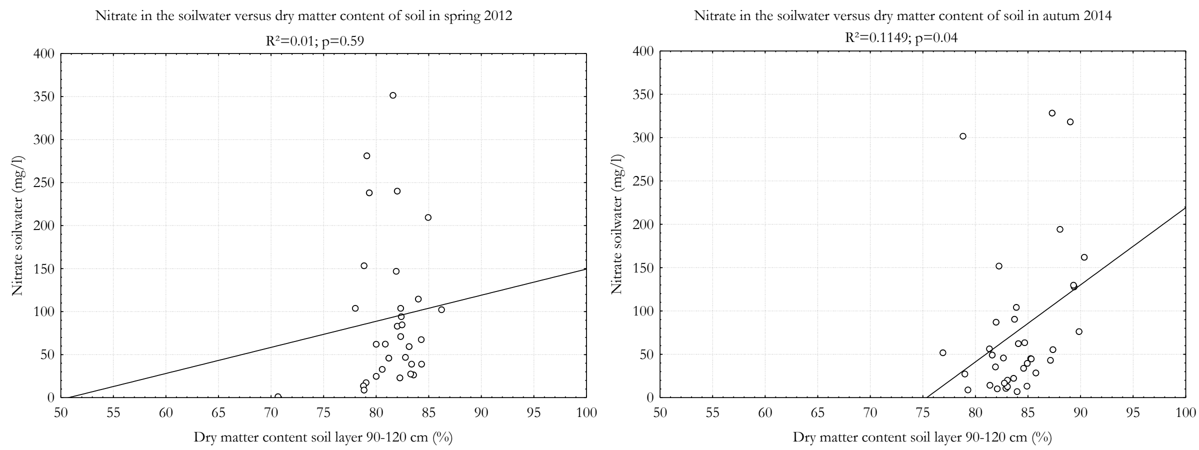


Figure 204: Scatterplot of the nitrate concentration in the soilwater (mg/l) versus the dry matter content (%) of the soil layer 90-120 cm in spring 2012 (left) and autumn 2014 (right).

7.4 Case studies 2009-2014

For statistical analysis outliers are removed as indicated before. Some outliers, however, can be explained and are the logical consequence of an event. These outliers provide a lot of useful information.

Table 61 shows an overview of 4 parcel conversions of grass in 2011. On parcel 1 in March 2011, before the maize was sown, the amount of nitrate in the soil (0-90 cm) was 54 kg NO_3-N/ha. When the grassland was ploughed, the grass started to mineralize. This results in a high nitrate residue in October 2011 (504 kg NO_3-N/ha). Since this parcel has a travel time of nitrate from the parcel soil to the monitoring well of almost 2 years, the results of this crop change can be measured in soil water in autumn 2012. The concentration of nitrate in the soil water was 1.7 mg NO_3/l, slightly higher as at the sampling moments before. But at the same level as in autumn 2009 and the concentration in the soil water diminished at later sampling moments. In 2011, less fertiliser was applied due to the conversion from grassland into maize.

The same can be seen for parcels 2 and 3: in 2011 the grassland is converted into maize and in October the nitrate residue is high (parcel 2: 232 kg NO_3-N/ha; parcel 3: 341 kg NO_3-N/ha). Fertilisation in 2011 was lower for maize than for grass the years before. The high nitrate residue in autumn 2011 was a clear signal for the farmers to reduce fertilisation again. On both parcels less than 100 kg N/ha was applied. The effect of grass conversion in spring 2011 can be measured in soil water in autumn 2012 for parcel 2 and in autumn 2013 for parcel 3. For parcel 2 no increase of nitrate concentration in the groundwater, related to travel time, is seen after conversion of grass. For parcel 3 the conversion of grass in spring 2011 resulted in a higher nitrate concentration in the groundwater in autumn 2013. The nitrate concentration reached 58 mg NO_3/l. At former sampling moments the nitrate concentration ranged between 21 and 39 mg NO_3/l.

For parcel 4 travel time is shorter. As on the previous parcels, the nitrate residue in autumn 2011 is high due to conversion of grassland. The nitrate concentration in the groundwater linked to the agricultural practices of 2011 and 2012 increased. The nitrate concentration reached 82 mg NO_3/l in spring 2012 and was even higher in autumn 2012. The nitrate concentration at this monitoring well stays at a higher level until autumn 2014.

Conversion of grassland into cropland can cause a risk for water quality. For some parcels there's no impact or a rather small impact on nitrate concentration in groundwater.

Table 61: Overview of 4 parcels with a conversion of grass in 2011. The cultivated crop, fertilisation, NO_3 in the ground water linked to the parcel according to travel time, NO_3 in the ground water not based on the travel time and NO_3-N in the soil (0-90 cm) is shown for October 2009 to 2014. (n.a.= not available)

Parcel 1 (sandy soil)	Oct	Spring	Oct 2010	Spring	Oct 2011	Spring	Oct 2012	Spring	Oct 2013	Spring	Oct 2014
Derogation (Yes/No)	Y	Y		Y		Y		Y		Y	
Crop	Grass	Grass		Maize + grass		Maize + grass		Maize + grass		Maize + grass	
Fertilisation (kg N/ha)	299	292		134		208		135		n.a.	
NO_3-N (kg/ha) soil	119	56	93	54	504	206	140		90	5	25
NO_3 (mg/l) not linked	1.3	0.1	0.1	1.3	0.2	0.3	1.7	1.4	0.68	n.a.*	n.a.
NO_3 (mg/l) linked	0.1	0.2		1.7		0.68					
Parcel 2 (sandy soil)	Oct	Spring	Oct 2010	Spring	Oct 2011	Spring	Oct 2012	Spring	Oct 2013	Spring	Oct 2014
Derogation (Yes/No)	N	N		N		N		N		N	
Crop	Grass	Grass		Maize		Maize		Potatoes		Maize	
Fertilisation (kg N/ha)	479	271		127		90		n.a.		69	
NO_3-N (kg/ha) soil	30	23	21	26	232	190	52	18	210	11	51
NO_3 (mg/l) not linked	31	53	43	33	25	1.3	0.38	27	0.94	n.a.	n.a.
NO_3 (mg/l) linked	43	25		0.38		0.94					
Parcel 3 (sandy soil)	Oct	Spring	Oct 2010	Spring	Oct 2011	Spring	Oct 2012	Spring	Oct 2013	Spring	Oct 2014
Derogation (Yes/No)	Y	Y		N		N		N		N	
Crop	Grass	Grass		Maize		Maize		Maize		Maize	
Fertilisation (kg N/ha)		270		188		81		165		n.a.	
NO_3-N (kg/ha) soil	36	43	14	31	341	149	296	82	122	59	166
NO_3 (mg/l) not linked	39	39	34	32	32	31	21	48	58	n.a.	n.a.
NO_3 (mg/l) linked	32	21		58		-					
Parcel 4 (sandy soil)	Oct	Spring	Oct 2010	Spring	Oct 2011	Spring	Oct 2012	Spring	Oct 2013	Spring	Oct 2014
Derogation (Yes/No)	Y	Y		Y		Y		Y		N	
Crop	Grass	Grass		Maize + grass		Maize + grass		Maize + grass		Maize + grass	
Fertilisation (kg N/ha)	277	277		201		120		105		n.a.	
NO_3-N (kg/ha) soil	69	30	49	35	224	87	124	11	65	28	23
NO_3 (mg/l) not linked	27	70	8	21	51	82	191	132	147	141	139
NO_3 (mg/l) linked	70	21		82		132		141			

7.5 Conclusion

The nitrate concentration in drains linked to derogation parcels was in spring 2013 and 2014 lower than in autumn 2012 and 2013, while the nitrate concentration in drains linked to no derogation parcels was higher in spring 2013 and 2014 than in autumn 2012 and 2013.

No statistical analysis was conducted since only a small number of drains are available and the measurement of canals and ditches may be influenced by other parameters.

MAP sampling points groundwater and monitoring wells were linked to a single agricultural parcel based on the travel time and infiltration area and the parcel characteristics of 2009, 2010, 2011 and 2012. There is mostly no statistically significant difference ($p \leq 0.05$) in nitrate concentration in MAP monitoring points groundwater and monitoring wells of derogation and no derogation parcels with derogation crops, grass or maize. Only in 2010 derogation crops and maize on no derogation parcels resulted in higher nitrate concentrations in the groundwater.

The nitrate content in the deeper soil layer (90-120) cm was calculated to a nitrate concentration in the soil water. There is no statistical difference in autumn 2011, 2012 and 2013, and spring 2012, 2013 and 2014, between derogation and no derogation parcels with derogation crops for nitrate in the soil water. However, for parcels cultivated with maize in autumn 2011, derogation parcels have a statistically higher nitrate concentration in the soil water than no derogation parcels. There is no statistical difference in spring 2012, autumn 2012, spring 2013, autumn 2013 and spring 2014 between derogation and no derogation parcels for nitrate in the soil water for parcels cultivated with derogation crops and grass. In autumn 2014 derogation parcels have a statistically higher nitrate concentration in the soil water than no derogation parcels when cultivated with grass.

8 Phosphorus in the soil profile

8.1 P-AL in the standard soil sample

On all parcels of the derogation monitoring network a standard soil sample was taken. On this standard soil sample different parameters were analysed (soil texture, pH, C, P, K, Mg, Ca, Na). Based on the standard soil sample a fertilisation advice was formulated for each parcel for the next 3 years. In Table 62 only 186 of the 217 parcels are shown. This is due to the fact that some parcels were already fertilized when the soil sample was taken and statistical outliers were removed. Eight statistical outliers were removed: 4 from derogation parcels (68 mg P/100 g dry soil, 66 mg P/100 g dry soil, 61 mg P/100 g dry soil and 61 mg P/100 g dry soil) and 4 from no derogation parcels (58 mg P/100 g dry soil, 6 mg P/100 g dry soil, 6 mg P/100 g dry soil and 4 mg P/100 g dry soil).

From the high statistical outliers (68, 66, 61, 61 and 58 mg P/100g dry soil) 4 parcels exceeded the maximal limits of fertilized P_2O_5. On these parcels, 150, 135, 131 and 100 kg P_2O_5/ha/year was applied in 2011. Two parcels were cultivated with grass and were grazed; one parcel was cultivated with maize and one with spinach.

Since a standard soil sample is taken from 0 to 6 cm for grassland and from 0 to 23 cm for maize and other crops, a statistical analysis was only carried out for these crops separately. Phosphorus on the standard soil sample is measured in an ammonium-lactate (AL) extract.

Table 62: Average phosphorus (mg/100 g dry soil, in ammonium-lactate extract) measured in the soil layer from 0-6 cm for grass and 0-23 cm for other crops in spring 2012. Distinction is made between derogation and no derogation parcels. The number of parcels is indicated by "n". A one-way ANOVA ($p \leq 0.05$) was carried out between derogation and no derogation parcels based on the log-transformed data.

	P-AL (mg/100g dry soil)						
	n	Derogation	(min, max)	n	No derogation	(min, max)	p-value
All crops	68	31	(8, 52)	118	33	(8, 56)	-
Derogation crops	68	31	(8, 52)	106	33	(8, 51)	-
Grass	42	30	(8, 52)	38	31	(8, 51)	0.36
Maize	24	30	(12, 47)	55	34	(13, 55)	0.16

Based on the soil fertility classes, as established by SSB (Maes et al., 2012), the plant available phosphorus on the parcels of the derogation monitoring network is relatively high for grass parcels (30 mg P/100 g dry soil), whereas for arable land it is considered high (30-34 mg P/100 g dry soil). However, it is not uncommon in Belgium to have a high P-AL in the soil: 77 % of the parcels with arable land and 56% of the grass parcels in Belgium have a P-AL above the optimal level (Maes et al., 2012).

Comparison of the average P-AL in the soil profile in 2009 (Vandervelpen et al., 2011) and the average P-AL for grass and maize parcels in 2012 shows that P-AL was rather the same at both moments. The amount of phosphorus was still in the same order of magnitude.

In Figure 205 the percentage of derogation and no derogation parcels is shown for different P-AL soil fertility classes for both derogation and no derogation parcels. Most of the derogation and no derogation parcels are classified as "rather high" for the parameter P-AL.

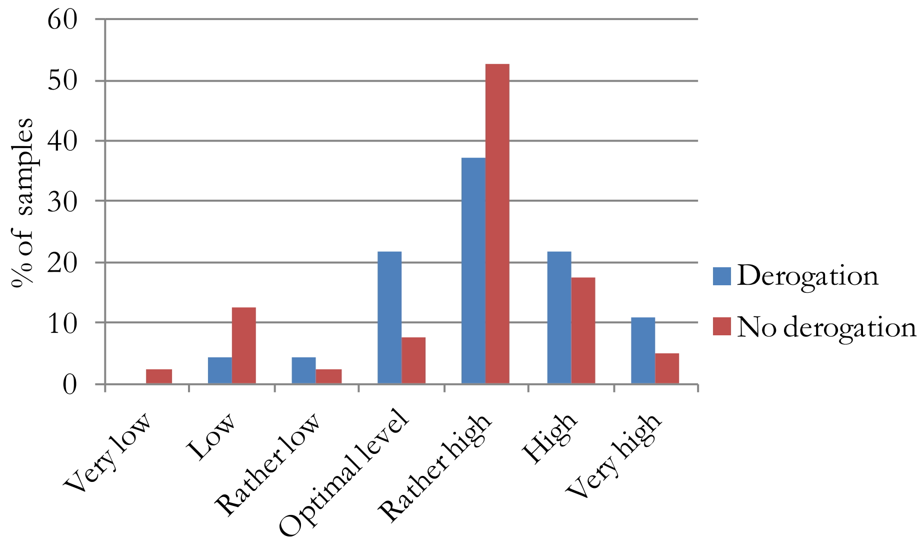


Figure 205: Percentage of derogation and no derogation samples in different soil fertility classes for the parameter P-AL (mg/100g dry soil) in spring 2012.

8.2 P-AL in the standard soil sample, parcels which were continuously under derogation/no derogation during 2009-2011

In order to verify the long-term impact of derogation on the P-AL in the soil, only parcels that were continuously under derogation/no derogation during 2009-2011 were retained. Table 63 shows the average values for the soil phosphorus of derogation and no derogation parcels and for different crops in spring 2012. For all soil fertility parameters, seven soil fertility classes (ranging from very low to very high) are established depending on soil texture and organic matter content of the soil (Maes et al., 2012). These soil fertility classes are different for grassland and arable land. The middle class is the optimal level. Within this level most plants show an optimal growth if rational fertilisation and liming are applied. For grass parcels, 27 and 30 mg P/100 g dry soil is relatively high, whereas for arable land 34 and 37 mg P/100 g dry soil is high. Since a standard soil sample is taken from 0 to 6 cm for grassland and from 0 to 23 cm for maize and other crops, a statistical analysis was only carried out for these crops separately.

Table 63: Average phosphorus (mg/100 g dry soil, in ammonium-lactate extract) measured in the soil layer from 0-6 cm for grass and 0-23 cm for other crops in spring 2012, only for parcels which were under derogation/no derogation during 2009-2011. Distinction is made between derogation and no derogation parcels. The number of parcels is indicated by "n". A one-way ANOVA (p ≤ 0.05) was carried out between derogation and no derogation parcels based on the log-transformed data.

	P-AL (mg/100g dry soil)						
	n	Derogation	(min, max)	n	No derogation	(min, max)	p-value
All crops	48	29	(8, 52)	78	34	(8, 56)	-
Derogation crops	48	29	(8, 52)	65	34	(8, 55)	-
Grass	35	27	(8, 51)	28	30	(8, 51)	0.65
Maize	14	34	(12, 52)	33	37	(11, 55)	0.35

8.3 P-AL in the deep soil samples (90-120 cm)

In all deep soil samples (from 90 to 120 cm) the amount of phosphorus is also measured in an ammonium-lactate extract. Year after year a relative high number of samples had an amount of phosphorus below detection limit, ranging from 47 % in autumn 2012 to 67 % in autumn 2013.

Although a large proportion of the phosphorus measurements were below detection limit, parcels with very high amounts of phosphorus were observed at every time of sampling. Further interpretation of these data when considered as outliers, is given below.

In autumn 2011 the measured phosphorus is high in 6 parcels (>10 mg P/100 g dry soil). In spring 2012, the measured phosphorus is higher than 10 mg P/100 g dry soil in 7 parcels. Among these parcels with a high phosphorus in the soil layer from 90-120 cm, there are both derogation and no derogation parcels present (Table 64). For spring 2012, two statistical outliers were removed: 47 mg P/100 g dry soil for a derogation parcel cultivated with grass and 39 mg P/100 g dry soil for a no derogation parcel cultivated with spinach. For autumn 2012, two statistical outliers were removed (31 and 29 mg P/100 g dry soil for one derogation and one no derogation parcel). For spring 2013, 2 statistical outliers were removed, parcels cultivated with maize with derogation (18 mg P/100 g dry soil) and without derogation (15 mg P/100 g dry soil). For autumn 2013, three statistical outliers were removed (16, 14 and 13 mg P/100 g dry soil) for a maize parcel without derogation on clay soil and parcels without derogation on sandy soil cultivated with winter wheat and grass. However the amount of phosphorus in the soil layer 90-120 cm was below detection limit in 61 % of deep soil samples. In spring 2014 in 46 % of the samples the amount of phosphorus is below the detection limit of 4 mg P/100 g dry soil. Three outliers were detected. Two parcels with derogation on sandy soil with grass (17 mg P/100 g dry soil) and maize (15 mg P/100 g dry soil). One parcel on sandy loam soil cultivated with cabbage in 2013. In autumn 2014 1 outlier was detected for the amount of phosphorus in the soil layer from 90 to 120 cm. The grass parcel on sandy soil cultivated without derogation showed had an amount of 14 mg P/100 g dry soil in the deep soil layer.

The amount of phosphorus in the deep soil layer (90-120 cm) is mostly influenced by fertilisation history and long term culture practices. Therefore an explanation of the outliers is not always possible. However some parcels are detected as statistical outlier at several sampling moments. Even though it needs to be noticed that the values detected as statistical outlier diminished. High values of 47 and 39 mg P/100 g dry soil are no longer noticed since spring 2013.

The average phosphorus level in the deep soil layer was similar on derogation and no derogation parcels. Only in autumn 2011, autumn 2012 and spring 2013 some larger difference (> 1 mg P/ 100 g dry soil) was seen. However, because of the large number of samples below detection limit, no statistical analysis is conducted.

Table 64: Average phosphorus (mg/100 g dry soil, in ammonium-lactate extract) for the soil layer 90-120 cm for derogation and no derogation parcels. The number of parcels is indicated by "n".

	Derogation				No derogation			
	n	average	(min, max)	<dl	n	average	(min, max)	<dl
Autumn 2011	17	6.52	(dl, 27)	10	22	4.18	(dl, 15)	15
Spring 2012	12	5.73	(dl, 15)	7	18	5.47	(dl, 15)	8
Autumn 2012	12	6.67	(dl, 20)	4	20	5.15	(dl, 19)	11
Spring 2013	12	3.33	(dl, 8)	9	17	5.88	(dl, 13)	6
Autumn 2013	14	4.00	(dl, 11)	9	19	3.68	(dl, 18)	13
Spring 2014	13	5.23	(dl, 11)	6	19	4.74	(dl, 13)	10
Autumn 2014	11	4.27	(dl, 9)	5	26	4.48	(dl,10)	13

For the samples below the detection limit (4 mg/100 g dm), half of the detection limit (2 mg/100 g dm) is used for the calculations.

8.4 Phosphate saturation degree

High concentrations of phosphorus in the surface- and groundwater are not desirable, since it may result in eutrophication. The general eutrophication limit of orthophosphate is 0.1 mg P/l (Schouwmans, 2004). Soils have a certain sorption capacity: when phosphorus is added to the soil, (a part of) the total phosphate sorption capacity is occupied. In this way, the phosphate sorption capacity decreases and eventually phosphorus will leach out. The amount of phosphate leaching out is function of the total phosphorus in the soil, the soil binding capacity and the hydrological characteristics of the soil. A good management of phosphorus in the soil is necessary in order to prevent risks of phosphorus leaching.

Van der Zee et al. (1990 a, b) developed a protocol for acid sandy soils to test whether a soil is phosphate saturated. In acid sandy soils, phosphate is mostly absorbed by iron and aluminium oxides and hydroxides. When soils are calcareous, phosphorus will form insoluble complexes with calcium. In that case not only the amount of iron and aluminium is of importance to calculate the phosphate sorption capacity (PSC). By an ammonium oxalate extraction the phosphorus absorbed on aluminium and iron oxides and hydroxides is measured and the PSC can be calculated. Besides iron and aluminium also the oxalate extractable P is measured. Van der Zee quantified the relation between PSC and Pox (oxalate extractable phosphorus) as the Phosphate Saturation Degree (PSD).

The phosphate saturation degree (PSD) can be expressed as:

$$PSD = (100 * P_{ox})/PSC$$

With PSC: Phosphate sorption capacity: $0.5 * (Al_{ox} + Fe_{ox})$

Table 65 shows the results of the phosphate saturation degree measured in 30 parcels of the monitoring network. All parcels are characterized by a sandy soil type and are mostly acid, so that the model of Van der Zee can be used in order to calculate the phosphate saturation degree. More than half of the tested parcels are phosphate saturated (PSD > 35 %, as declared in Flemish legislation). This means that on these parcels phosphate may leach out of the soil profile to the surface- and groundwater. The phosphate saturated parcels are both derogation and no derogation parcels and are both cultivated with grass and maize. Due to the low number of tested parcels, no statistical comparison was made between derogation and no derogation parcels.

Table 65: Phosphate saturation degree measured on a selection of 30 parcels on sandy soils of the monitoring network at the end of 2012. The results for oxalate extractable phosphorus (Pox), oxalate extractable aluminium (Al_{ox}), oxalate extractable iron (Fe_{ox}), Phosphate Sorption Capacity (PSC), Phosphate Saturation Degree (PSD) and the number of phosphate saturated parcels conform Flemish legislation are shown.

Crop 2012	n	P_{ox} (mmol/kg)	Al_{ox} (mmol/kg)	Fe_{ox} (mmol/kg)	PSC (mmol P/kg)	PSD (%)	Nr P-saturated parcels-conform Flemish legislation
			Derogation				
Grass	6	16.3	32.6	45.0	38.8	42.6	4
Maize	9	15.8	41.5	50.0	45.8	37.9	5
			No derogation				
Grass	6	17.6	48.2	63.2	55.7	29.9	3
Maize	9	17.5	40.9	43.5	42.3	41.3	6

8.5 Conclusion

The average P-AL (mg/100g dry soil) is 31 and 33 mg P/100g dry soil in derogation parcels and no derogation parcels respectively. There is no significant difference in P-AL in grass parcels under derogation or no derogation. There is also no significant difference in P-AL in maize parcels under derogation or no derogation.

For parcels continuously under derogation or no derogation during 2009-2011, the average P-AL of derogation or no derogation parcels did not differ statistically, nor for grass parcels nor for maize parcels.

In the deeper soil layer (90-120 cm), variable concentrations of P-AL are found at all moments of sampling, from autumn 2011 till autumn 2014. A large part of the data for the deep soil sample is under detection limit. Therefore no statistical analysis is conducted.

More than half of the selected grass and maize parcels cultivated on sandy soils are phosphate saturated according to the Flemish legislation where phosphate saturated parcels are defined as parcels with a PSD higher than 35 %. Since no protocol exists yet to calculate the phosphate saturation degree on other soil types, it is not possible to investigate this parameter in detail.

9 Phosphorus in the surface and groundwater

9.1 Drains, canals, ditches and sampling points

In all water samples (from canals, ditches, drains, MAP sampling points groundwater and monitoring wells) of the monitoring network the amount of phosphorus is measured by using a continuous flow system. The results are summarized in Table 66 and Table 67. Since data for MAP sampling points for spring and autumn 2014 are not available yet, these data are not represented in the table.

These samples could give an indication of the water quality. However, the link between the sampling point for the surface water and a particular parcel of the monitoring network is not always very clear. Therefore the concentrations of phosphorus in the water samples of drains, canals and ditches are rather indicative.

During the different years, the highest concentration of phosphorus is measured in drains, canals and ditches. The lowest concentrations are measured in the monitoring wells, representing shallow groundwater. However no decreasing trend was observed for 2011-2014.

For canals and ditches in November 2011, two statistical outliers (9.17 and 4.07 mg P/l) were removed. The first parcel is a long term grass parcel for which the amount of P-AL in the soil layer 0-6 cm was 31 mg P-AL/100 g dry soil in spring 2012. On the second parcel also deep soil samples were taken. In the soil layer 90-120 cm in autumn 2011 the amount of P-AL measured was 27 mg P-AL/ 100 g dry soil, the highest value measured in the deep soil samples at that moment. For the monitoring wells, one statistical outlier is removed (3.87 mg P/l) and for the MAP sampling points groundwater, two statistical outliers were removed as well (3.0 and 3.0 mg P/l). For February 2012, one statistical outlier (3.41 mg P/l) was removed for the monitoring wells.

For canals and ditches in November 2012, three statistical outliers were removed (2.73, 2.78 and 3.51 mg P/l; grass parcels with and without derogation). For the drains, one statistical outlier was removed (7.04 mg P/l; grass parcel without derogation). For the monitoring wells, one statistical outlier was removed (3.44 mg P/l; grass parcel with derogation). For the MAP sampling points one statistical outlier was removed (3.01 mg P/l). In spring 2013, two statistical outliers were removed: 8.5 (drain), 3.4 (monitoring well) mg P/l. For the MAP sampling points groundwater, three statistical outliers were removed (1.23, 1.35 and 1.97 mg P/l). On 62 out of the 97 sampled

MAP sampling points groundwater the orthophosphate-P concentration was below detection limit.

In autumn 2013 one outlier was removed for canals and ditches (6.48 mg P/l) and one outlier for drains (7.82 mg P/l). Also for the monitoring wells two statistical outliers were removed (4.30 and 1.78 mg P/l). The drain and monitoring well which were outliers in autumn 2013, were also outliers in spring 2014 (drain: 11.72 mg P/l; monitoring well: 4.00 mg P/l). For the MAP sampling points 2 outliers were removed (1.90 and 1.30 mg P/l) in autumn 2013. These MAP sampling points were also detected as outliers in spring 2013. For 37 of the 90 sampled MAP sampling points groundwater in autumn 2013, the orthophosphate-P concentration was below detection limit.

Table 66: Average values for orthophosphate-P (mg P/l) measured in the different water samples. Difference is made between derogation and no derogation parcels.

	PO_4-P mg/l					
	Derogation			No derogation		
	n	average	(min, max)	n	average	(min, max)
Autumn 2011						
Drains	0	-	-	2	1.63	(1.62, 2.00)
Canals, ditches	12	0.98	(dl, 2.92)	8	1.04	(dl, 2.10)
Spring 2012						
Drains	3	0.40	(0.09, 0.99)	1	1.49	-
Canals, ditches	11	0.22	(dl, 0.57)	10	0.56	(dl, 2.50)
Autumn 2012						
Drains	6	0.42	(0.07, 1.00)	5	0.40	(dl, 0.88)
Canals, ditches	15	0.20	(dl, 0.7)	7	0.64	(dl, 1.43)
Spring 2013						
Drains	6	0.29	(dl, 1.07)	5	0.16	(dl, 0.40)
Canals, ditches	16	0.21	(dl, 0.68)	9	0.63	(dl, 1.33)
Autumn 2013						
Drains	3	0.30	(0.07, 0.75)	1	dl	-
Canals, ditches	17	0.53	(dl, 2.21)	13	0.29	(dl, 1.60)
Spring 2014						
Drains	3	0.30	(0.10, 0.46)	4	0.09	(dl, 0.24)
Canals, ditches	18	0.46	(dl, 3.25)	10	0.38	(dl, 1.56)
Autumn 2014						
Drains	0	-	-	2	0.60	(dl, 1.17)
Canals, ditches	15	0.58	(dl, 2.05)	13	0.46	(dl, 1.66)

For the samples below the detection limit (0.04 mg/l orthophosphate-P), half of the detection limit (0.02 mg/l orthophosphate-P) is used for the calculations.

In autumn 2014 4 outliers were detected at canals and ditches, all at grass parcels. Three parcels were cultivated without derogation (2.70, 2.83 and 4.89 mg P/l). The parcel at which 4.89 mg P/l was measured at the ditch, showed also a higher P-values in the deep soil layer 90-120 cm in autumn 2014. This soil layer contained 14 mg P-AL/100 g dry soil, detected as the only statistical outlier in autumn 2014. The fourth parcel detected as outlier at canals and ditches, was cultivated without derogation (3.03 mg P/l). For the monitoring wells 2 outliers were detected: 2.01 and 2.28 mg P/l.

For some parcels the amounts of orthophosphate-P in the water samples are regularly detected as statistical outliers. This concerns however both derogation and no derogation parcels. For one parcel with a monitoring well, the amount of orthophosphate-P in the groundwater was detected as statistical outlier at every moment of sampling. This parcel was a long term grass parcel on clay soil. The input-output balance for P was negative (output higher than input).

Table 67: Average orthophosphate-P concentration (mg P/l) in the MAP sampling points (M) and monitoring wells (W) linked to a parcel of the monitoring network for different years. For each year the number of parcels is indicated by "n".

	PO_4-P (mg/l)					
	n	M	(min, max)	n	W	(min, max)
2011_ autumn	91	0.15	(dl, 1.08)	47	0.23	(dl, 1.84)
2012_ spring	98	0.18	(dl, 1.75)	46	0.19	(dl, 1.05)
2012_ autumn	91	0.10	(dl, 1.32)	47	0.26	(dl, 1.48)
2013_ spring	97	0.05	(dl-0.45)	47	0.14	(dl, 1.30)
2013_ autumn	88	0.08	(dl-0.62)	46	0.13	(dl, 1.03)
2014_ spring	-	-	-	47	0.17	(dl, 1.22)
2014_autumn	-	-	-	30	0.26	(dl, 1.27)

For the samples below the detection limit (0.04 mg/l orthophosphate-P), half of the detection limit (0.02 mg/l orthophosphate-P) is used for the calculations.

9.2 DIP, DOP and total P

In 50 % of all water samples of the derogation monitoring network the total amount of phosphorus is measured by ICP (Inductive Coupled Plasma). The fraction of DIP (dissolved inorganic phosphorus) and DOP (dissolved organic phosphorus) are determined by measuring the amount of DIP with IC (Ion Chromatography). The amount of DIP is subtracted from the total phosphorus, which results in the amount of DOP. By determining the fractions of DIP and

DOP from the total phosphorus amount, it is possible to identify the most important fraction (DIP or DOP). The results of the measurements are shown in Table 68.

For both derogation and no derogation parcels, the concentration of total phosphorus in drains is higher than in canals, ditches, monitoring wells or centrifuged soil water (except in Autumn 2012 and spring 2013 for derogation parcels). The concentration of total phosphorus in monitoring wells and soil water is the lowest. In monitoring wells, approximately 60 % of the measured total phosphorus is below detection limit. However, some of the monitoring wells have very high values of total phosphorus. In spring 2013 the amount of DIP was in almost all water samples below detection limit, as seen in Table 68.

In spring 2013 all water samples were analysed for total amount of phosphorus and the amount of dissolved inorganic phosphorus (Table 69). These results confirm the fact that the concentration of total phosphorus in drains is often higher than in canals, ditches, monitoring wells or soil water. Like in spring and autumn 2012 and on the selection of parcels in spring 2013, the concentration of total phosphorus in drains was higher on parcels without derogation.

Table 68: Average amount of total phosphorus (TP, mg P/l), DIP (dissolved inorganic phosphorus, mg P/l)) and DOP (dissolved organic phosphorus, mg P/l) for the different water samples. For each combination the number (n) of samples is given as well as the number of samples with a DIP measurement below detection limit (<dl).

		Derogation							No derogation						
		n	TP	DIP	DOP	% DIP	% DOP	< dl	n	TP	DIP	DOP	% DIP	% DOP	<dl
Autumn 2011	Drains	1	3.31	2.78	0.52	84.0	16.0	0	1	2.71	1.46	1.25	53.9	46.1	0
	Canals and ditches	9	2.67	2.38	0.38	89.1	10.9	0	5	0.74	0.59	0.15	79.7	20.3	0
	Monitoring wells	13	0.26	0.21	0.04	80.8	19.2	6	11	0.31	0.21	0.09	67.7	32.3	9
	Soil water (90-120 cm)	16	0.13	0.12	0.05	92.3	7.7	15	20	0.16	0.01	0.18	6.3	93.8	19
Spring 2012	Drains	3	0.63	0.15	0.47	23.8	76.2	0	1	1.46	1.21	0.26	82.9	17.1	0
	Canals and ditches	6	0.25	0.06	0.19	24.0	76.0	2	5	0.37	0.22	0.15	59.5	40.5	2
	Monitoring wells	13	0.13	0.06	0.07	46.2	53.8	9	12	0.18	0.07	0.11	38.9	61.1	8
	Soil water (90-120 cm)	10	0.25	0.13	0.14	52.0	48.0	2	22	0.21	0.08	0.13	38.1	61.9	3
Autumn 2012	Drains	3	0.42	0.16	0.26	38.1	61.9	1	1	9.02	8.35	0.67	62.6	7.4	0
	Canals and ditches	5	0.48	0.20	0.28	46.7	58.3	4	5	1.16	0.60	0.56	51.7	48.3	1
	Monitoring wells	16	0.17	0.05	0.12	29.4	70.46	14	10	0.02	0.01	0.01	50.0	50.0	10
	Soil water (90-120 cm)	12	0.30	0.09	0.21	30.0	70.0	9	17	0.22	0.05	0.17	22.7	77.3	13
Spring 2013	Drains	3	0.24	0.01	0.24	2.1	97.9	3	1	8.36	0.02	8.34	0.2	99.8	0
	Canals and ditches	6	0.27	0.01	0.27	1.9	98.1	6	5	0.63	0.01	0.63	0.8	99.2	3
	Monitoring wells	16	0.22	0.01	0.22	2.2	97.8	16	8	0.09	0.01	0.09	5.4	94.6	8
	Soil water (90-120 cm)	11	0.22	0.01	0.22	2.3	97.7	11	17	0.41	0.01	0.41	1.2	98.8	17

for the calculation of values below detection limit, half of the detection limit is used.

Table 69: Average amount of total phosphorus (TP, mg P/l), DIP (dissolved inorganic phosphorus, mg P/l)) and DOP (dissolved organic phosphorus, mg P/l) for the different water samples of spring 2013. For each combination the number (n) of samples is given as well as the number of samples with a DIP measurement below detection limit (<dl).

		Derogation							No derogation						
		n	TP	DIP	DOP	% DIP	% DOP	< dl	n	TP	DIP	DOP	% DIP	% DOP	<dl
Spring 2013	Drains	6	0.33	0.01	0.33	1.5	98.5	5	6	1.58	0.01	1.57	0.5	99.5	5
	Canals and ditches	16	0.24	0.01	0.23	2.1	97.9	16	9	0.60	0.01	0.60	0.8	99.2	6
	Monitoring wells	33	0.27	0.01	0.27	1.9	98.1	31	15	0.10	0.01	0.10	4.9	95.1	15

for the calculation of values below detection limit, half of the detection limit is used.

In general, the total phosphorus is lower in spring 2012 compared to autumn 2011. This is due to the fact that the amount of DIP decreases, while the concentration of DOP remains constant over time. The total phosphorus concentration in autumn 2012 is comparable to the total phosphorus in spring 2012.

The total P measured in the water samples is highly variable both under derogation and no derogation conditions. This is illustrated in a box plot in Figure 206 for the measurements in the monitoring wells in Autumn 2011. Same variation is observed for other measurements (drains, canals, ditches and soil water).

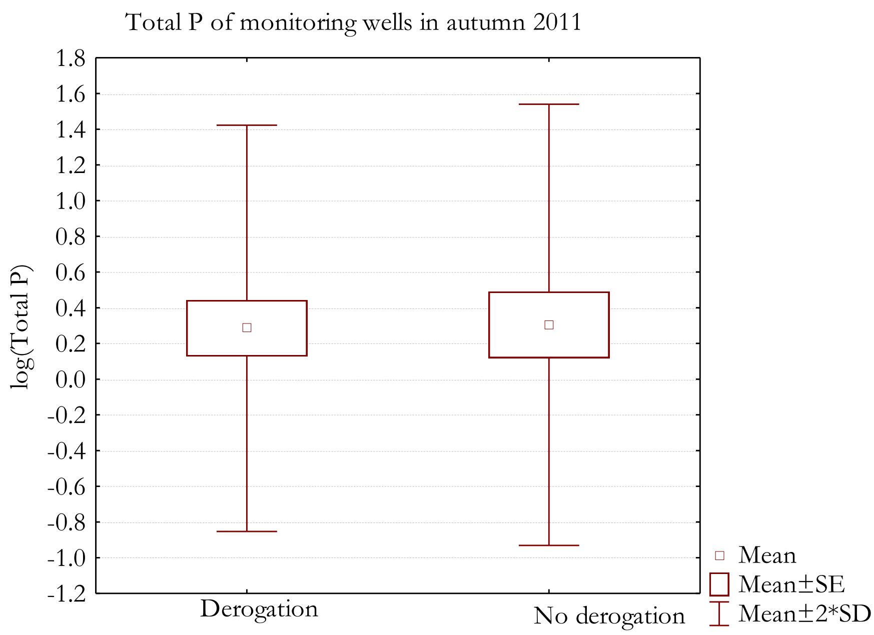


Figure 206: Box plot of log(total phosphorus (mg P/l)) measured with CF for the monitoring wells in autumn 2011. SE: standard error of the mean. SD: standard deviation.

In chapter 9.1 the amount of phosphorus is measured with the continuous flow (CF) system. CF gives an indication of the amount of DIP in the water samples. CF is based on a colour reaction with the inorganic phosphorus fraction, but also a part of the organic fraction of phosphorus. Theoretically, phosphorus measurements with CF should be slightly higher than DIP measurements with IC (Table 70). As seen in the table, the phosphorus measurements with CF are higher than DIP measurements with IC, except for canals and ditches in autumn 2011 and 2012. Since in spring 2013 the amount of DIP was in almost all of the samples below detection limit, the average values of DIP are very low.

Table 70: Average value of DIP (mg P/l) and PO_4-P (mg P/l) for parcels where DIP was measured.

		n	DIP (IC)	PO_4-P (CF)
Autumn 2011	Drains	3	2.08	2.22
	Canals and ditches	14	1.94	1.78
	Monitoring wells	24	0.21	0.32
Spring 2012	Drains	4	0.42	0.67
	Canals and ditches	11	0.13	0.39
	Monitoring wells	25	0.07	0.22
Autumn 2012	Drains	4	2.21	2.21
	Canals and ditches	10	0.40	1.13
	Monitoring wells	26	0.03	0.26
Spring 2013	Drains	12	0.01	0.92
	Canals and ditches	25	0.01	0.36
	Monitoring wells	48	0.01	0.20

9.3 Conclusion

There was a high concentration of orthophosphate-P in drains compared to the orthophosphate-P in canals and ditches until spring 2013. For the monitoring wells, a decrease in orthophosphate-P can be seen from autumn 2011 to autumn 2013, with the exception of autumn 2012 where the average P increased. Total P is also lower in spring 2012 in comparison with autumn 2011. This is due to the fact that the concentration of DIP in the water samples and soil water is lower in spring 2012 compared to autumn 2011, while the concentration of DOP is more or less constant in time. In spring 2013 in almost all of the samples the amount of DIP was below detection limit.

10 Organic carbon in the soil profile

On all parcels of the derogation monitoring network a standard soil sample was taken in spring 2012. On this standard soil sample different parameters were analysed (soil texture, pH, C, P, K, Mg, Ca, Na). Based on the standard soil sample a fertilisation advice was formulated for each parcel for the next 3 years. The %C measured in the standard soil sample is shown in Table 71. Since a standard soil sample is taken from 0 to 6 cm for grassland and from 0 to 23 cm for maize and other crops, the results are given separately for both crops.

Table 71: Average value for %C measured in the soil layer from 0-6 cm for grass and 0-23 cm for other crops in spring 2012. Distinction is made between derogation and no derogation parcels. The number of parcels is indicated by "n".

	%C					
	n	Derogation	(min, max)	n	No derogation	(min, max)
All crops	72	2.37	(0.78, 6.48)	122	1.80	(0.6, 4.87)
Derogation crops	72	2.37	(0.78, 6.48)	108	1.92	(0.6, 4.87)
Grass	45	2.80	(1.08, 6.48)	40	2.70	(0.96, 4.87)
Maize	26	1.82	(0.78, 3.37)	47	1.44	(0.6, 3.17)

In Figure 207 the percentage of derogation and no derogation parcels is shown for different %C soil fertility classes. Most of the derogation and no derogation parcels are classified as "optimal".

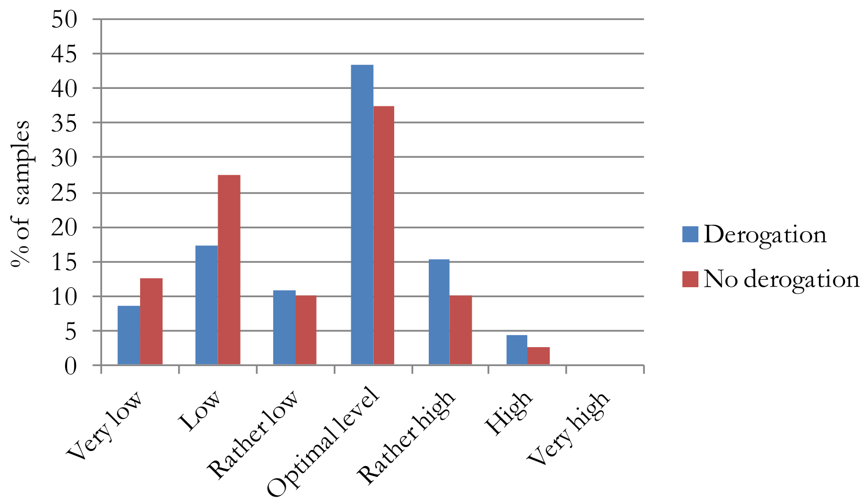


Figure 207: Percentage of derogation and no derogation samples in different soil fertility classes for the parameter %C in spring 2012.

10.1 Organic carbon in the standard soil sample, parcels which were continuously under derogation/no derogation during 2009-2011

In order to verify the long-term impact of derogation on the organic carbon in the soil, only parcels that were continuously under derogation/no derogation during 2009-2011 were retained. Table 72 shows the average values for the percentage of organic carbon of derogation and no derogation parcels and for different crops.

Table 72: Average %C measured in the soil layer from 0-6 cm for grass and 0-23 cm for other crops in spring 2012, only for parcels which were under derogation/no derogation during 2009-2011. Distinction is made between derogation and no derogation parcels. The number of parcels is indicated by "n".

	%C					
	n	Derogation	(min, max)	n	No derogation	(min, max)
All crops	50	2.63	(0.82, 6.48)	81	1.81	(0.60, 4.87)
Derogation crops	50	2.63	(0.82, 6.48)	68	1.94	(0.96, 4.87)
Grass	35	2.93	(1.20, 6.48)	28	2.85	(0.96, 4.87)
Maize	14	2.09	(1.14, 3.37)	33	1.35	(0.60, 1.74)

10.2 Conclusion

The mean organic carbon in the soil profile in 2012 (Table 71) is higher for all crops under derogation (2.37 %) than for all crops under no derogation (1.80 %). However, when looking more in detail to the cultivated crops, for parcels cultivated with grass the %C is almost equal for derogation and no derogation parcels. For parcels cultivated with maize derogation parcels have a slightly higher %C in comparison to no derogation parcels.

The mean organic carbon in the soil profile in 2012, for parcels continuously under derogation/no derogation (2009-2011) cultivated with all crops is 2.63 % for parcels under derogation and 1.81 % for parcels under no derogation.

11 Burns model

During winter there is little nutrient uptake by the cultivated crops. In this period, one of the most important soil processes is leaching. This soil process may be influenced by different factors and starts when the soil profile has reached field capacity.

In order to investigate the leaching of nitrate during winter, a soil sample is taken in autumn and spring. These nitrate soil samples are discussed in the previous paragraphs. Often when studying leaching, the Burns model (Burns, 1974) is used to predict the movement of unabsorbed anions, such as nitrate, in freely drained soils. The nitrate transfer is calculated from the amount of water movement through the soil profile on a proportional basis. Nitrate is dissolved in water and the transport through the soil is identically to the transport of water due to the specific characteristics of nitrate (no absorption).

11.1 Input parameters

For the Burns model, different parameters are required as input. For each parcel of the monitoring network, the combination of these parameters is unique. The most important and necessary parameters are:

- rainfall and evaporation (water balance);
- nitrate in the soil profile;
- thickness of the different soil layers;
- field capacity (depending on soil texture and important for water retention capacity);
- sampling date.

Based on these parameters, the amount of nitrogen leaching out is calculated over a specific period. Since leaching occurs when the soil profile is above field capacity, it is important to know the moisture content of the soil samples at the moment of sampling. Since the Burns model is not suited for clay soils, the leaching on parcels with clay texture is not reported.

On each parcel in the monitoring network a nitrate sample was taken in the different soil layers of 30 cm (layer 1: 0-30 cm, layer 2: 30-60 cm and layer 3: 60-90 cm) from October 1st to March 15th. So the thickness of the different soil layers used in the model is 30 cm. Results of these nitrate residue measurements are discussed earlier in this report.

Since nitrate only leaches out if water is supplied to the soil, rainfall is a very important parameter. For each weather station it is important that the observed data are complete. Only the weather stations where 95 % or more of the rainfall data were available from October to March, were retained. For the dates where no rainfall data were available from these stations, the mean of rainfall of the region of Flanders was used for that specific date. Another important factor for the water balance is evapotranspiration. Calculations for ETo are available from different stations. However, stations without data of ETo, or if one date is missing, are replaced in this analysis by the mean ETo of the region of Flanders for a specific date.

An overview of the different stations with observations for rainfall and evapotranspiration are listed in Table 73.

Table 73: Overview of the selected stations for the weather observations for rainfall and evapotranspiration (ETo).

Rainfall	ETo	Winter
Beauvechain	Beauvechain	2011-2012; 2012-2013; 2013-2014
Beitem	Mean of Flanders	2011-2012; 2013-2014
Bierset	Bierset	2011-2012; 2012-2013; 2013-2014
Deurne	Deurne	2011-2012; 2012-2013; 2013-2014
Gorsem	Mean of Flanders	2012-2013; 2013-2014
Herent	Mean of Flanders	2011-2012; 2012-2013; 2013-2014
Kleine Brogel	Kleine Brogel	2011-2012; 2012-2013; 2013-2014
Koksijde	Koksijde	2011-2012; 2012-2013; 2013-2014
Kruishoutem	Mean of Flanders	2011-2012; 2013-2014
Melsbroek	Melsbroek	2011-2012; 2012-2013; 2013-2014
Middelkerke	Middelkerke	2011-2012; 2012-2013; 2013-2014
Passendale	Mean of Flanders	2011-2012; 2012-2013; 2013-2014
Semmerzake	Semmerzake	2011-2012; 2012-2013; 2013-2014
Sint-Katelijne-Waver	Mean of Flanders	2011-2012; 2012-2013; 2013-2014
Stabroek	Mean of Flanders	2011-2012; 2013-2014
Tienen	Mean of Flanders	2011-2012; 2012-2013;
Ukkel	Ukkel	2011-2012; 2012-2013; 2013-2014

By using the rainfall and ETo data, a water balance (rainfall - evapotranspiration) is calculated for each retained weather station for a specific month. The water balance for each weather station is summarized in Table 74 for winter 2011-2012, in Table 75 for winter 2012-2013 and in Table 76 for winter 2013-2014 for the most important months during winter. Mostly the water balance is positive for the months October, November, December, January and February.

Table 74: Water balance (rainfall – evapotranspiration, L/m²) for the different weather stations for different months-winter 2011-2012.

	Oct/11	Nov/11	Dec/11	Jan/12	Feb/12	March/12
Beauvechain	-8.4	-3.1	94.0	61.4	5.4	-22.1
Beitem	11.8	-2.3	153.6	48.1	9.2	34.4
Bierset	-9.5	-13.1	96.2	64.5	12.2	-30.3
Deurne	15.3	-3.4	179.0	57.2	10.2	-13.1
Herent	2.1	-3.3	121.5	68.9	8.7	-12.6
Kleine Brogel	29.0	0.0	153.0	66.9	17.8	-15.5
Koksijde	0.5	1.6	138.6	18.2	1.1	29.7
Kruishoutem	9.6	2.1	177.4	60.0	6.3	5.8
Melsbroek	9.0	-7.3	105.5	61.8	2.5	-15.8
Middelkerke	9.8	-4.7	129.7	23.9	1.5	31.1
Passendale	14.8	2.2	137.4	38.4	2.1	30.9
Semmerzake	9.8	2.1	155.2	60.7	5.4	2.8
Sint-Katelijne-Waver	2.8	-7.1	136.4	54.2	11.7	-10.4
Stabroek	29.7	-3.6	192.4	82.6	24.9	-8.6
Tienen	-7.0	-4.1	104.1	48.9	6.6	-24.1
Ukkel	11.2	-5.1	135.0	69.0	14.1	-4.3

The negative water balance for November in autumn 2011 is explained by weather conditions mentioned in Annex 3-Climate 2011(Figure 244, Figure 245, Figure 246).

Table 75: Water balance (rainfall – evapotranspiration, L/m²) for the different weather stations for different months-winter 2012-2013.

	Oct/12	Nov/12	Dec/12	Jan/13	Feb/13	March/13
Beauvechain	65.3	8.3	100.7	16.3	17.0	-13.1
Bierset	74.2	28.8	115.5	32.2	36.3	-3.0
Deurne	56.7	18.0	169.0	38.6	20.2	-6.3
Gorsem	73.3	14.7	122.1	4	17.1	-5.0
Herent	61.2	20.8	135.6	33.5	21.5	6.8
Kleine Brogel	38.3	19.9	130.7	31.7	29.9	-4.0
Koksijde	127.6	94.8	108.2	32.2	18.9	27.1
Melsbroek	59.8	22.9	113.0	28.9	16.02	-2.5
Middelkerke	116.2	70.3	117.3	30.1	20.07	25.7
Passendale	109.1	55.2	119.1	38.6	26.7	30.7
Semmerzake	59.2	20.9	137.1	27.9	21.7	6.8
Sint-Katelijne-Waver	57.3	23.8	162.8	30.9	19.9	-1.9
Tienen	68.4	5.4	88.2	20.3	21.9	-8.3
Ukkel	89.3	29.5	159.2	42.4	37.9	26.3

Table 76: Water balance (rainfall – evapotranspiration, L/m²) for the different weather stations for different months-winter 2013-2014.

	Oct/13	Nov/13	Dec/13	Jan/14	Feb/14	March/14
Beauvechain	32.4	95.1	54.9	30.6	9.9	-26.9
Beitem	106.1	96.5	33.2	62.2	41.0	-17.2
Bierset	30.8	82.5	31.5	10.4	0.3	-36.6
Deurne	67.7	85.1	39.1	50.3	37.7	-32.7
Gorsem	30.4	78.3	40.5	21.5	11.9	-31.7
Herent	28.7	81.7	47.4	35.1	19.5	-27.5
Kleine Brogel	51.6	110.1	74.9	26.8	39.9	-29.2
Koksijde	119.6	122.2	29.5	41.5	63.6	-11.2
Kruishoutem	57.7	115.1	47.3	82.8	54.7	-13.3
Melsbroek	39.1	80.7	40.3	26.5	21.0	-35.4
Middelkerke	86.6	96.7	26.6	55.7	53.2	-17.3
Passendale	95.0	98.5	28.1	61.4	55.3	-13.1
Semmerzake	56.3	124.6	45.9	58.5	40.6	-23.6
Sint-Katelijne-Waver	69.3	80.6	46.0	54.1	32.0	-25.9
Stabroek	111.5	113.2	37.7	62.3	58.5	-11.5
Tienen	28.1	89.4	37.6	34.6	10.9	-32.9
Ukkel	42.6	88.2	60.3	50.8	37.7	-28.4

11.2 Winter 2011-2012

Each parcel of the network is linked to a combination of the 3 closest weather stations which were retained and the data are the result of a weighed average of the observations at the 3 weather stations.

The Burns model results in an amount of nitrate-N leaching out, for each soil layer of 30 cm. For nitrate after leaching calculated with Burns (autumn 2011 to spring 2012), rainfall data are used until the parcels were sampled in spring 2012. Since autumn was very dry, soils where not at field capacity in autumn 2012. Therefore the amount of rainfall needed in order to reach field capacity was calculated for each soil texture. This amount of necessary rainfall was deducted from the amount of rainfall on each parcel in December. After winter, the lowest levels are present in sandy soils and highest in loam soils.

Since all soils have a certain mineralisation capacity, the soil will release nitrogen from the organic matter during winter. Therefore, in Table 77 the estimated values of nitrate-N with Burns are shown with and without a correction for mineralisation.

Table 77: Average amount of nitrate-N (kg N/ha) estimated with the Burns model for different soil textures, with or without mineralisation. The end date of leaching with Burns is the date of the measured nitrate soil sample spring 2012. The average amounts of nitrate-N (kg N/ha) measured in spring 2012 are also shown.

Without mineralisation	Nitrate-N (kg/ha) after leaching out (Burns)			
	0-30 cm	30-60 cm	60-90 cm	0-90 cm
Sand	3.2	4.9	6.1	14.2
Sandy loam	6.7	10.5	12.4	29.6
Loam	9.6	14.7	17.9	42.2

With mineralisation	Nitrate-N (kg/ha) after leaching out (Burns)			
	0-30 cm	30-60 cm	60-90 cm	0-90 cm
Sand	7.7	7.8	8.2	23.7
Sandy loam	11.7	13.5	14.2	39.4
Loam	15.0	18.0	19.9	52.8

Measured	Nitrate-N (kg/ha) in spring 2012			
	0-30 cm	30-60 cm	60-90 cm	0-90 cm
Sand	11.0	13.2	17.2	41.5
Sandy loam	11.3	16.3	18.9	46.5
Loam	13.7	20.0	25.1	58.8

When we compare these results with the values measured in spring 2012, values calculated with the Burns model are lower. This difference is largest for sandy soils. The calculations with the Burns model are an underestimation of the effective measured nitrate in the soil profile after winter, certainly in sandy soils.

During leaching, nitrate-N migrates from the upper soil layers to the deeper soil layers. As a consequence, after winter the soil layer from 0 to 30 cm has very low levels of nitrate-N. The result of the Burns model is an amount of nitrate leaving the upper soil layer and moving to the lower soil layers. This process is identical for each soil layer. Finally this results in an amount of nitrate-N leaving the soil profile at 90 cm and an amount of nitrate-N still present in every soil layer. Results of the estimated nitrate present in the soil after winter calculated with Burns (both with and without mineralisation) and the measured values after winter for each parcel and for different soil types and derogation/no derogation are summarized in Table 78.

Table 78: Results of the calculations by the Burns model in comparison with measured amount of nitrate-N (kg/ha) in the soil profile (0-90 cm), spring 2012. The end date of leaching with Burns is the date of the measured nitrate soil sample in spring 2012.

		Calculated with Burns (nitrate-N kg/ha)		Measured
		without mineralisation	with mineralisation	after winter
Sand	Derogation	13.0	22.8	40.8
Sand	No derogation	14.5	23.8	42.5
Sandy loam	Derogation	20.5	29.9	38.8
Sandy loam	No derogation	33.4	45.8	51.2
Loam	Derogation	-	-	-
Loam	No derogation	42.2	52.8	58.8

Figure 208 illustrates the relation between the measured and the estimated amount of nitrate-N (kg/ha) with the Burns model, spring 2012 with corrections for mineralisation taken into account. When we compare these results, for most of the parcels the Burns model makes an overestimation of the leaching of nitrate-N and the estimated nitrate-N after winter is lower than the measured values.

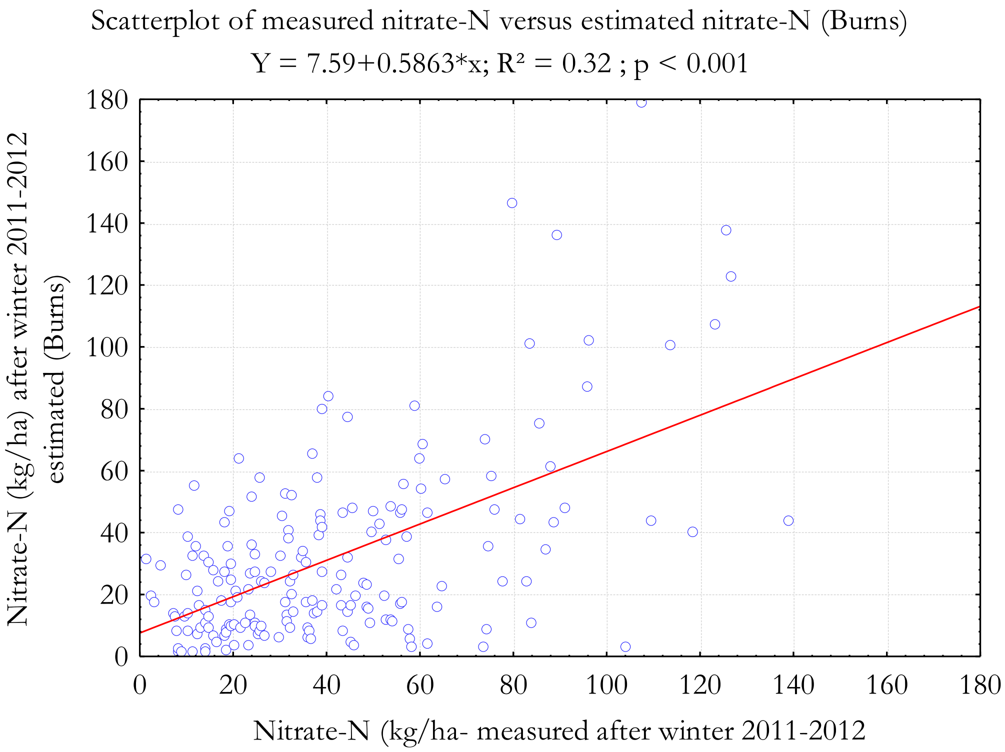


Figure 208: Scatterplot of nitrate-N (kg/ha) measured in spring 2012 versus the nitrate-N (kg/ha) estimated by the Burns model until the date of the nitrate soil sample in spring 2012, with corrections for mineralisation.

Figure 209 shows a scatterplot of the amount of nitrate-N in autumn 2011 minus spring 2012, versus the amount of nitrate that leached out according to Burns. Since some parcels were sampled in March, there was already mineralisation on the parcels, resulting in negative values for nitrate in autumn 2011 minus spring 2012.

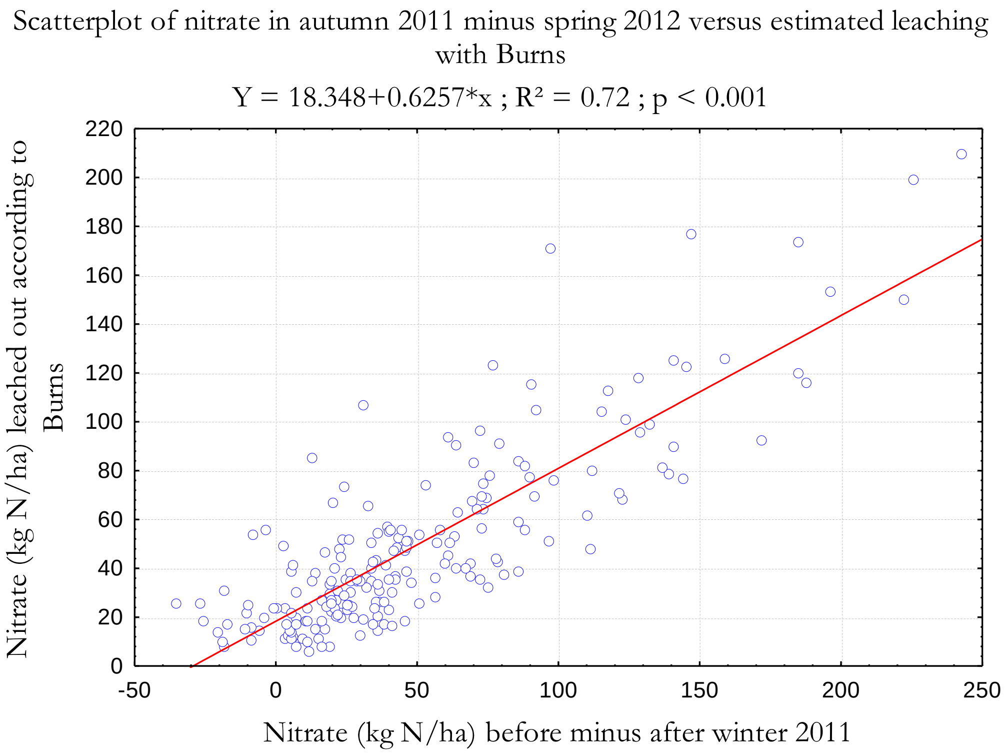


Figure 209: Scatterplot of nitrate-N (kg/ha) measured in autumn 2011 minus spring 2012 versus the nitrate-N (kg/ha) estimated by the Burns model including mineralisation.

Next, we will investigate if there are any statistical differences in nitrate leaching out of the soil profile calculated with Burns, between derogation and no derogation parcels cultivated with grass or maize. The leaching on maize parcels is larger than on grass parcels (Table 79). There is no significant difference in leaching of nitrate estimated by Burns between derogation and no derogation parcels cultivated with grass or maize.

Table 79: Results of the estimated leaching by the Burns model in winter 2011-2012 for grass and maize parcels. A one-way ANOVA ($p \leq 0.05$) on the log-transformed data was carried out for grass and maize separately.

	Calculated with Burns (nitrate-N kg/ha)				
	Derogation	(min,max)	No derogation	(min,max)	p-value
Grass	44.5	(3.8; 163.5)	44.1	(0.4; 245.1)	0.42
Maize	70.7	(17.3; 199.5)	71.8	(4.3; 243.8)	0.29

11.3 Winter 2012-2013

Each parcel of the network is linked to a combination of the 3 closest stations which were retained and the data are the result of a weighed average of the observations between the 3 stations.

The Burns model results in an amount of nitrate-N leaching out, for each soil layer of 30 cm. For nitrate after leaching calculated with Burns, rainfall data are used until the parcels were sampled in spring 2013. In Table 80, the estimated values of nitrate-N with Burns are shown with and without a correction for mineralisation taken into account.

Table 80: Average amount of nitrate-N (kg N/ha) estimated with the Burns model for different soil textures, with or without mineralisation. The end date of leaching with Burns is the date of the measured nitrate soil sample in spring 2013. The average amount of nitrate-N (kg N/ha) measured in spring 2013 is also given.

Without mineralisation	Nitrate-N (kg/ha) after leaching out (Burns)			
	0-30 cm	30-60 cm	60-90 cm	0-90 cm
Sand	0.4	1.1	2.2	3.7
Sandy loam	1.6	3.6	5.9	11.1
Loam	3.9	8.3	10.7	22.9

With mineralisation	Nitrate-N (kg/ha) after leaching out (Burns)			
	0-30 cm	30-60 cm	60-90 cm	0-90 cm
Sand	4.4	2.4	3.3	10.1
Sandy loam	10.0	6.4	7.8	24.3
Loam	18.0	12.6	14.0	44.6

Measured	Nitrate-N (kg/ha) spring 2013			
	0-30 cm	30-60 cm	60-90 cm	0-90 cm
Sand	7.4	6.9	8.3	22.6
Sandy loam	8.8	8.0	9.0	25.8
Loam	11.7	11.1	10.7	33.5

The calculations with Burns including mineralisation are a good estimation of the amount of nitrate in the soil profile after winter for sandy loam soils, an underestimation for sandy soils and an overestimation for loam.

During leaching, nitrate-N migrates from the upper soil layers to the deeper soil layers. As a consequence, after winter the soil layer from 0 to 30 cm has very low levels of nitrate-N. The result of the Burns model is an amount of nitrate leaving the upper soil layer and moving to the lower soil layers. This process is identical for each soil layer. Finally this results in an amount of nitrate-N leaving the soil profile at 90 cm and an amount of nitrate-N still present in every soil layer.

Figure 210 illustrates the relation between the measured and the estimated amount of nitrate-N (kg/ha) in spring with the Burns model, with corrections for mineralisation taken into account. A significant correlation exists between the nitrate-N in spring 2013 measured and estimated with Burns. The regression model explained 83 % of the variance.

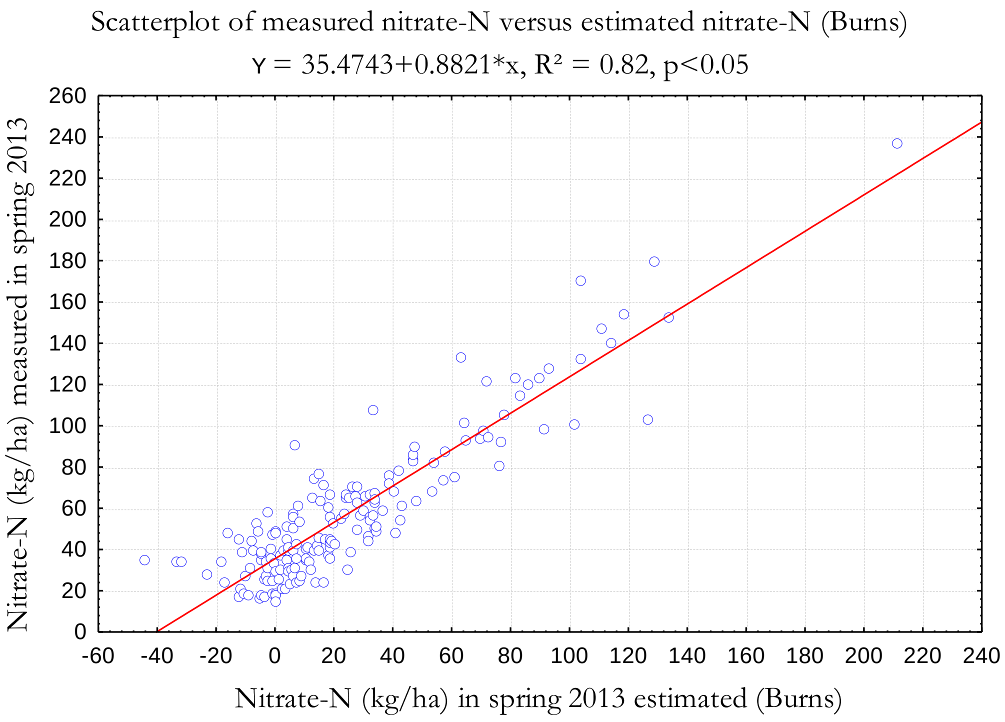


Figure 210: Scatterplot of nitrate-N (kg/ha) measured in spring 2013 versus the nitrate-N (kg/ha) estimated by the Burns model until the date of the nitrate soil sample in spring 2013, including mineralisation.

Next, we will investigate if there are any statistical differences in nitrate leaching out of the soil profile calculated with Burns, between derogation and no derogation parcels cultivated with grass or maize. Therefore, an ANOVA ($p \leq 0.05$) analysis was carried out on the log-transformed data.

The leaching on maize parcels is larger than on grass parcels (Table 81). There is no significant difference in leaching of nitrate estimated by Burns between derogation and no derogation parcels cultivated with grass or maize.

Table 81: Results of the estimated leaching by the Burns model in winter 2012-2013 for grass and maize parcels. A one-way ANOVA ($p \leq 0.05$) on the log-transformed data was carried out for grass and maize separately.

	Calculated with Burns (nitrate-N kg/ha)				
	Derogation	(min,max)	No derogation	(min,max)	p-value
Grass	35.6	(7.7; 111.3)	30.9	(9.2; 61.2)	0.22
Maize	54.6	(21.4; 118.8)	44.9	(13.5; 141.9)	0.07

11.4 Winter 2013-2014

Each parcel of the network is linked to a combination of the 3 closest stations which were retained and the data are the result of a weighed average of the observations between the 3 stations.

The Burns model results in an amount of nitrate-N leaching out, for each soil layer of 30 cm. For nitrate after leaching calculated with Burns, rainfall data are used until the parcels were sampled in spring 2014.

In Table 82, the estimated values of nitrate-N with Burns are shown with and without a correction for mineralisation taken into account. For winter 2013-2014 the calculations with Burns without mineralisation were a good estimation of the amount of nitrate in the soil profile after winter for sandy loam and loam soils. For sandy soils the calculation with Burns without mineralisation resulted in an underestimation of the amount of nitrate-N in the soil profile after winter. The amount of nitrate-N in the soil profile after winter on sandy soils was best estimated with Burns taken mineralisation into account.

Table 82: Average amount of nitrate-N (kg N/ha) estimated with the Burns model for different soil textures, with or without mineralisation. The end date of leaching with Burns is the date of the measured nitrate soil sample in spring 2014. The average amount of nitrate-N (kg N/ha) measured in spring 2014 is also given.

Without mineralisation	Nitrate-N (kg/ha) after leaching out (Burns)			
	0-30 cm	30-60 cm	60-90 cm	0-90 cm
Sand	1.1	3.1	5.1	9.3
Sandy loam	3.1	8.4	10.9	22.4
Loam	6.2	14.4	15.2	35.8
With mineralisation	Nitrate-N (kg/ha) after leaching out (Burns)			
	0-30 cm	30-60 cm	60-90 cm	0-90 cm
Sand	9.3	9.1	10.1	28.5
Sandy loam	16.9	18.6	18.0	53.5
Loam	21.2	24.7	20.8	66.7

Measured	Nitrate-N (kg/ha) spring 2014			
	0-30 cm	30-60 cm	60-90 cm	0-90 cm
Sand	7.5	7.5	9.4	24.4
Sandy loam	8.1	8.0	8.9	25.0
Loam	8.8	10.2	14.4	33.4

During leaching, nitrate-N migrates from the upper soil layers to the deeper soil layers. As a consequence, after winter the soil layer from 0 to 30 cm has very low levels of nitrate-N. The result of the Burns model is an amount of nitrate leaving the upper soil layer and moving to the lower soil layers. This process is identical for each soil layer. Finally this results in an amount of nitrate-N leaving the soil profile at 90 cm and an amount of nitrate-N still present in every soil layer.

Figure 211 illustrates the relation between the measured and the estimated amount of nitrate-N (kg/ha) in spring 2014 with the Burns model, with corrections for mineralisation taken into account. The correlation between the nitrate-N measured in spring 2014 and the nitrate-N estimated with Burns was statistically significant but only 9 % of the variance is explained by the model. When mineralisation was not taken into account in the calculation with Burns, the correlation between the measured and estimated nitrate-N (Figure 212) was also statistically significant and the model explained only 11 %.

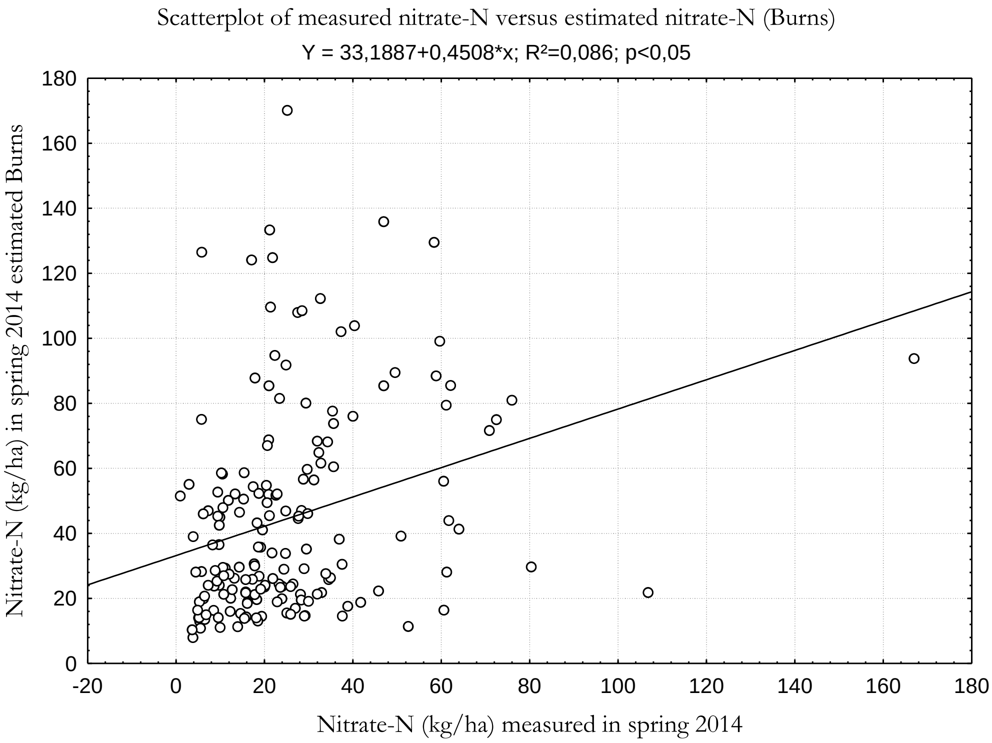


Figure 211: Scatterplot of nitrate-N (kg/ha) measured in spring 2014 versus the nitrate-N (kg/ha) estimated by the Burns model until the date of the nitrate soil sample in spring 2014, including mineralisation.

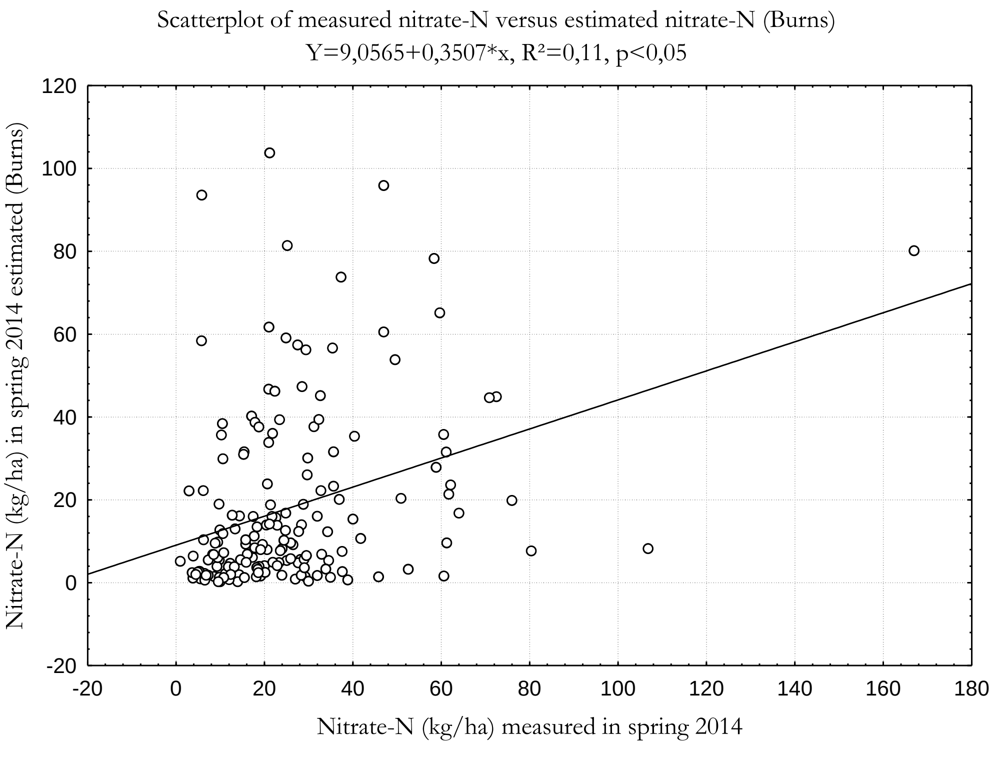


Figure 212: Scatterplot of nitrate-N (kg/ha) measured in spring 2014 versus the nitrate-N (kg/ha) estimated by the Burns model until the date of the nitrate soil sample in spring 2014, mineralisation not taken into account.

Next, we will investigate if there are any statistical differences in nitrate leaching out of the soil profile calculated with Burns, between derogation and no derogation parcels cultivated with grass or maize. Therefore, an ANOVA ($p \leq 0.05$) analysis was carried out on the log-transformed data.

The leaching on maize parcels is larger than on grass parcels (Table 83). There is no significant difference in leaching of nitrate estimated by Burns between derogation and no derogation parcels cultivated with grass or maize.

Table 83: Results of the estimated leaching by the Burns model in winter 2013-2014 for grass and maize parcels. A one-way ANOVA ($p \leq 0.05$) on the log-transformed data was carried out for grass and maize separately.

	Calculated with Burns (nitrate-N kg/ha)				
	Derogation	(min,max)	No derogation	(min,max)	p-value
Grass	66.4	(7.0; 292.8)	57.4	(13.0; 200.0)	0.38
Maize	80.0	(13.7; 252)	66.6	(11.8; 178.6)	0.16

11.5 Conclusion

The Burns model estimates the amount of nitrate leaching out of the soil profile. For individual parcels, large differences between calculated and measured nitrate levels are sometimes present.

Correlations were found between the nitrate-N measured in spring and the nitrate-N calculated with Burns for spring 2012, spring 2013 and spring 2014.

There is no significant difference in nitrate-N leaching out during winter calculated with Burns between derogation and no derogation parcels, neither for parcels cultivated with maize nor for parcels cultivated with grass on all soil types. This lack of statistical significant difference was found in winter 2011-2012, winter 2012-2013 and winter 2013-2014.

12 Nutrient balance

For each parcel in the monitoring network a nutrient balance is calculated. A nutrient balance tries to explain nitrate residue levels on the parcels and nitrate concentrations in water samples. Moreover, differences in nutrient balances for derogation and no derogation parcels will be explored more in detail. Two different approaches are used to calculate a nutrient balance: the input/output balance and a nitrogen-soil balance.

12.1 Input/output balance

The first approach for calculating a nutrient balance is the difference between the effective input and output of nutrients on parcel level. The input comprises organic and mineral fertiliser application, as well as atmospheric deposition. Nutrients are exported by means of the harvested crop and emission losses during organic fertiliser application (Table 84). The result of this balance is an indicator for the enrichment or impoverishment of nutrients in the soil profile.

Table 84: Schematic presentation of the input/output nutrient balance.

Input	**Output**
Organic fertilisers	Harvested crop
Mineral fertilisers	Emission during fertilisation
Atmospheric deposition	
Balance = input – output	

12.1.1 Input of organic and mineral fertilisers

Detailed information on the input of organic and mineral fertilisers for the different years is given in paragraph 5.2. The total amounts of supplied nutrients (N and P) as well as the different fractions (mineral, organic and organic by grazing cattle) are given separately for derogation and no derogation parcels and for each cultivated crop.

12.1.2 Input of atmospheric deposition

For all the parcels in the monitoring network atmospheric deposition occurs during the season. This atmospheric deposition is the same for all parcels in the monitoring network and is estimated at 30 kg N/ha each year.

12.1.3 Output of emission losses

During application of organic manure some emission losses will occur. The method of fertilisation application is the most determining parameter. These emission losses are shown in Table 32.

12.1.4 Output of the harvested crop

Harvest of the cultivated crop is the most important nutrient export factor. So yield data are the most important data. Yield data are reported by the participating farmers. Based on the dry matter, nitrogen and phosphorus content, the amount of exported nutrients can be calculated. The effective nutrient content is not known; therefore the figures shown in Table 85 and Table 86 are used.

Table 85: Amount of nitrogen and phosphorus for each ton dry matter and fresh weight (moisture content of the harvested crop is given). Levels are separately given for different crops. Source: "Ontwerp actieprogramma nitraatrichtlijn 2011-2014[2]".

		Dry matter (DM)		Yield		
		kg N /ton DM	kg P_2O_5 /ton DM	kg N /ton yield	kg P_2O_5 /ton yield	Moisture (%)
Potatoes	Tubers	17	2.1	3.74	1.05	
Winter wheat	Grain	22.0	3.8	18.9	7.4	14
Winter barley	Grain	19.0	3.8	16.3	7.4	14
Sugar beets	Beets	8.0	1.6	1.8	0.84	
Fodder beets	Beets	12.8	1.3	2.56	0.6	
Corn maize	Corn	15.1	3.3	13	6.5	14

Table 86: Amount of nitrogen and phosphorus exported by the harvest of silage maize (above-ground) for different classes of yield.

Yield (above-ground)	Dry matter (ton/ha)	N (kg/ha)	P (kg P_2O_5/ha)
Very poor	16.7	200	82
Poor	18.3	220	90
Good	20	240	98
Very good	21.7	260	106

For winter wheat, sugar beets, potatoes and corn maize the yield was mostly communicated as an amount of kilogramme for each parcel. By using Table 85 the amount of nitrogen and phosphorus (kg/ha) exported by the cultivated crops can be calculated for each parcel. For silage maize the exact yield (kg/ha) for each parcel is not always available. The silage maize is harvested and stored together for many parcels. In some cases an exact yield is known but for the other parcels it is an estimation and yield classes are used to estimate the yield of the different parcels. Therefore the numbers in Table 86 are used.

Another difficult crop to estimate the yield is grass. For parcels cultivated with grass different possibilities are present: cutting, cutting and grazing cattle or only grazing cattle. The required information is given by the farmers. When cutting the grass, the yield for each cutting has to be estimated, almost none of the farmers has an exact weight of the grass after harvest. Therefore the numbers in the next table (Table 87) are used.

Table 87: Amount of nitrogen and phosphorus exported by the grassland (above-ground) for each cutting with a specific level of yield.

Yield (above-ground)	Dry matter (ton/ha)	N (kg/ha)	P (kg P_2O_5/ha)
Very poor	2.0	60	17.4
Poor	2.5	75	21.8
Good	3.0	90	26.1
Very good	3.5	105	30.5

Besides the cultivated crop, nutrient export is also possible by the catch crop sown after harvest. To estimate the nutrient uptake by the catch crop Table 88 is used.

Table 88: Export of nitrogen (kg N/ha) for different stages of development and for different types of catch crop sown after harvest of the cultivated crop.

	Development of catch crop		
	little	good	very good
Catch crop, leaf	30 – 50	50 – 70	70 – 90
Catch crop, grass	20 – 40	40 – 60	60 – 80
Catch crop, N fixation	30 – 50	50 – 75	75 – 100

(Source: praktijkgids bemesting bij suikerbieten)

12.1.5 Balance result 2012

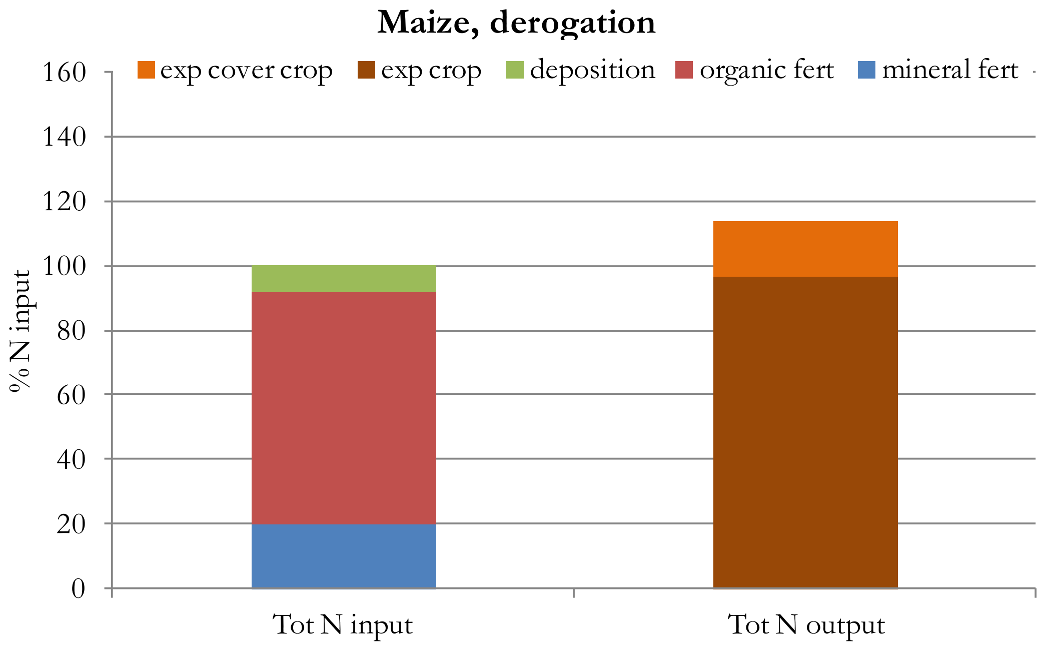
The result of the input-output balance 2012 is shown in Table 89. Balance results are very variable at parcel level: some parcels have positive values for the balance where others have negative. An ANOVA analysis was made in order to notify statistical differences for derogation and no derogation parcels cultivated with different crops. For parcels cultivated with maize, no statistical difference is found between derogation and no derogation parcels, not for N ($p = 0.47$), nor for P_2O_5 ($p = 0.79$). For parcels cultivated with grass, a statistical difference is found between derogation and no derogation parcels, both for N and P_2O_5 ($p < 0.05$). For beets, no statistical analysis was made since only 1 beet parcel is present.

Table 89: N-balance (input-output), P-balance (input-output) and nitrate residue for derogation and no derogation parcels-year 2012.

	N (input-output)	P_2O_5 (input-output)	Nitrate residue
		Derogation	
Maize	-24	-23	71
Grassland	3	-25	37
Beets	-15	58	67
Winter wheat	-	-	-
		No derogation	
Maize	-39	-21	60
Grassland	-115	-47	33
Beets	-	-	-
Winter wheat	27	-30	77
Potatoes	-42	24	70

Graphs were made in order to estimate the percentage of each factor of the nutrient balance (organic fertilisers, mineral fertilisers, atmospheric deposition, harvested crop and emission during fertilisation) in function of the total input. Figure 213 shows this for maize under derogation and under no derogation. For both groups, input by organic fertilisation is the most important input. Both on derogation and no derogation parcels the output exceeds the total input. On no derogation parcels even the export by only the maize is 10 % higher than the total input while for derogation parcels the export by the crop is 97 % of the total input.

Figure 214 shows the percentage of each factor in function of the total input in the input/output balance for grass under derogation and under no derogation. On derogation parcels 44 % of the total input is of organic fertilisation. On grass parcels without derogation organic fertilisation is 35 % of the total input. Export of the grass on no derogation parcels exceeds the total input with 48 %.



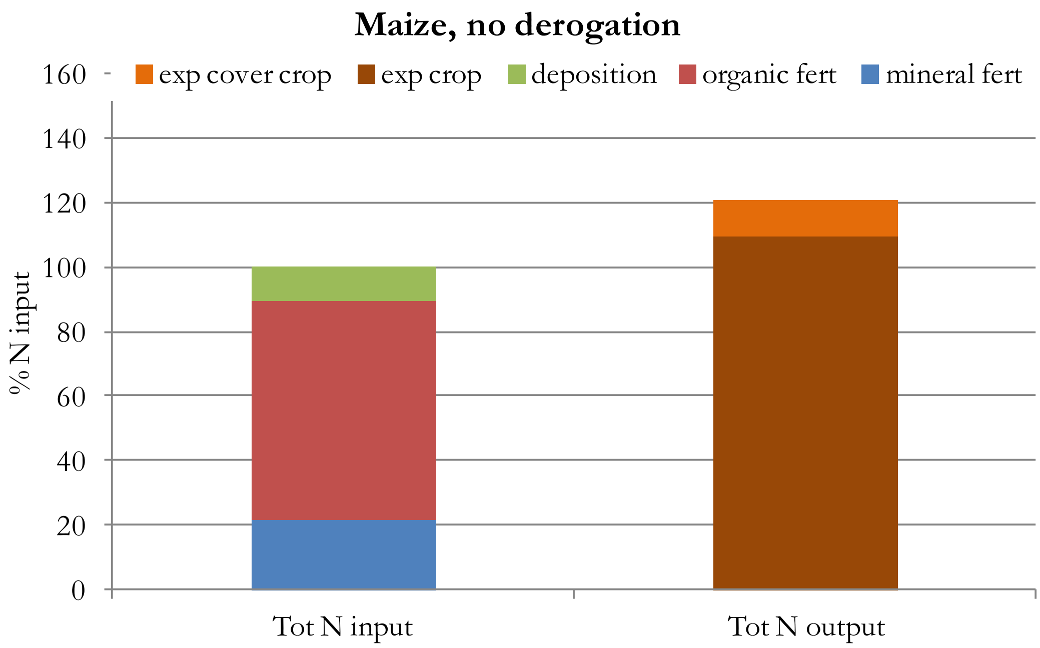
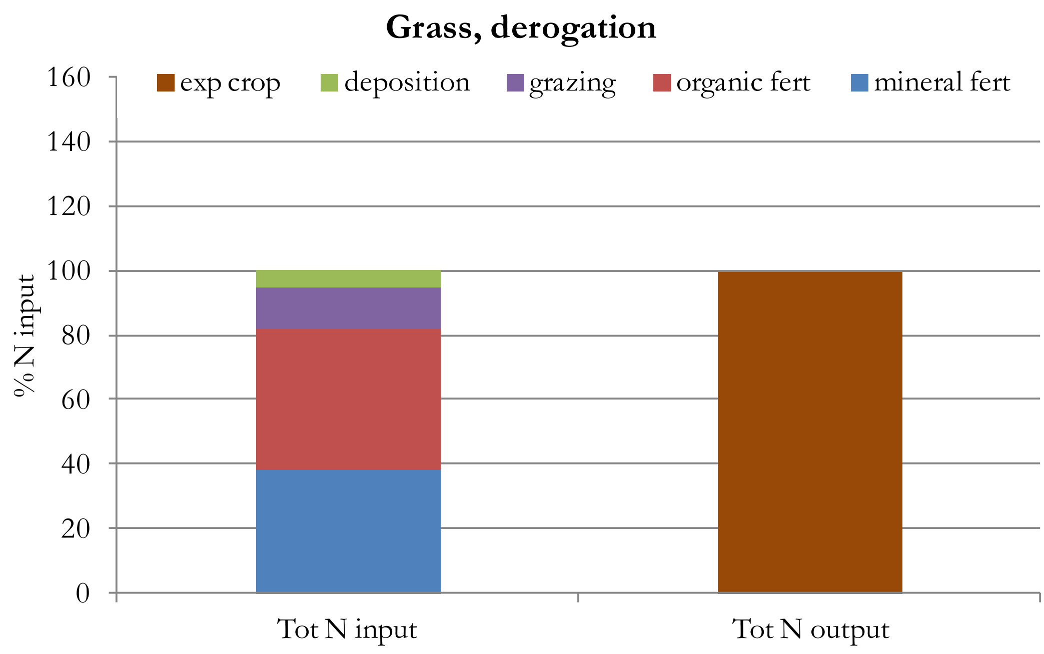


Figure 213: Percentage of each factor in relation to the total input in the input/output balance for parcels cultivated with maize under derogation and no derogation-year 2012.



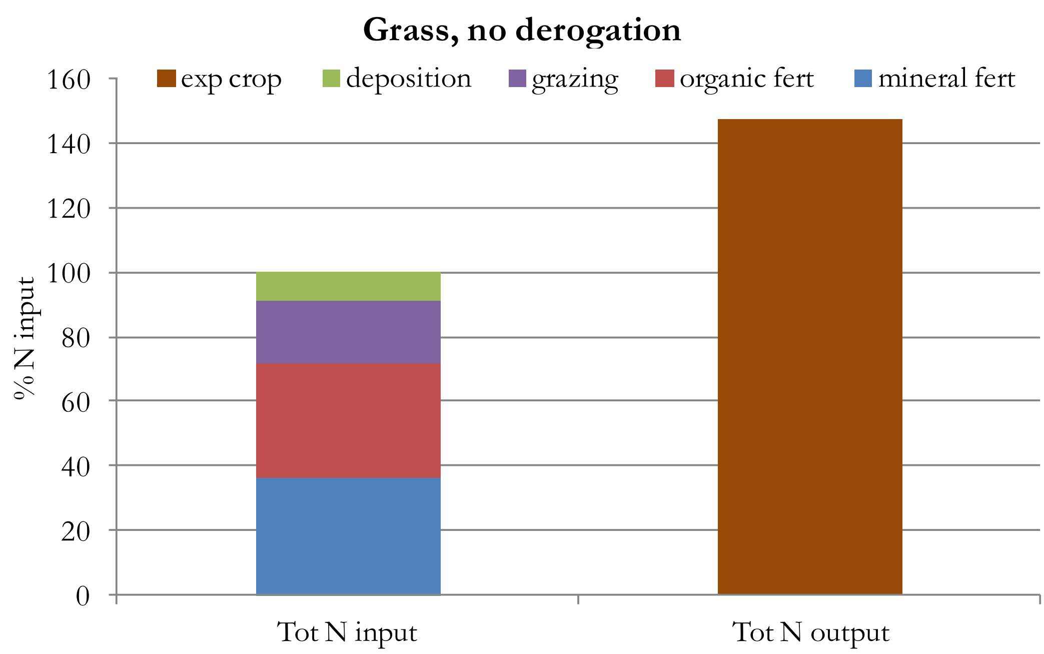


Figure 214: Percentage of each factor in relation to the total input in the nutrient balance for parcels cultivated with grass under derogation and no derogation-year 2012.

Next, the correlation between the balance result (input-output) for nitrogen and the nitrate residue is shown in Figure 215. The correlation between the input-output balance and the nitrate residue for the growing season 2012 is not strong. Some important soil processes are not taken into account in this balance model in order to link the nitrate residue to fertilisation and nutrient uptake by the crops. By means of a nitrogen-soil balance (see next paragraph), these soil processes are discussed.

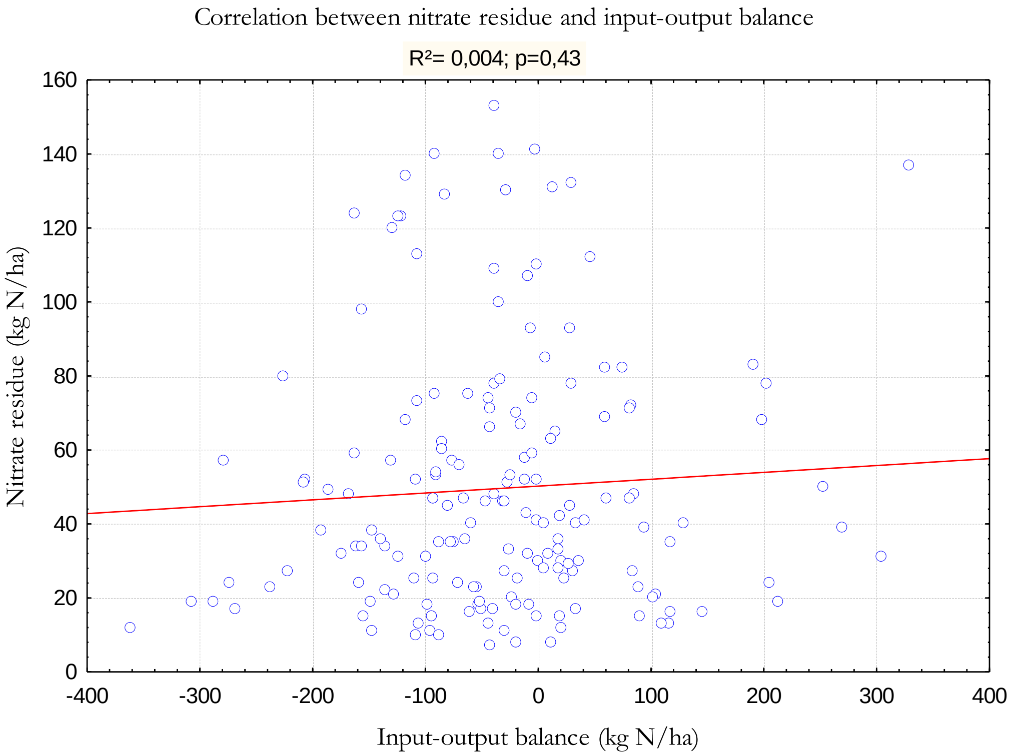


Figure 215: Nitrate residue versus Input-output balance for the growing season of 2012 for all parcels.

12.1.6 Balance result 2013

The result of the input-output balance 2013 is shown in Table 90. The variability of balance results between parcels was still high. On grass parcels a large difference was found between the mean balance result of parcels with mowing and grazing and grass parcels with only mowing. These differences are shown in Table 91.

An ANOVA analysis was made in order to notify statistical differences between derogation and no derogation parcels in function of the cultivated crop. For parcels cultivated with maize no statistical difference was found between derogation and no derogation, nor for N ($p = 0.63$), nor for P_2O_5 ($p = 0.15$). For parcels cultivated with grass a statistical significant difference was detected between derogation and no derogation parcels for P_2O_5 ($p < 0.05$) but not for N ($p = 0.23$).

Table 90: N-balance (input-output), P-balance (input-output) and nitrate residue for derogation and no derogation parcels-year 2013.

	N (input-output)	P_2O_5 (input-output)	Nitrate residue
		Derogation	
Maize	-14	-35	54
Grassland	59	-110	55
Beets	-	-	-
Winter wheat	129	-17	108
		No derogation	
Maize	-6	-22	75
Grassland	25	-76	42
Beets	-	-	-
Winter wheat	135	-29	101
Potatoes	100	10	110

Table 91: N-balance (input-output), P-balance (input-output) and nitrate residue for derogation and no derogation parcels cultivated with grass with grazing and mowing or only mowing-year 2013.

	N (input-output)	P_2O_5 (input-output)	Nitrate residue
		Derogation	
Grass-grazing & mowing	96	-93	64
Grass-mowing	3	-137	40
		No derogation	
Grass-grazing & mowing	47	-67	41
Grass-mowing	-34	-99	44

Graphs were made in order to visualize the share of each factor of the nutrient balance (organic fertilisers, mineral fertilisers, atmospheric deposition, harvested crop and emission during fertilisation) in function of the total input. Figure 216 shows this for maize under derogation and under no derogation. For both groups, input by organic fertilisation is the most important input. On derogation and no derogation parcels the output exceeds the total input with respectively 5 and 3 %. On no derogation parcels the export by only the maize is higher than the total input, like was noticed for the input/output balance in 2012. For derogation parcels the export by the main crop is 84 % of the total input.

Figure 217 shows the percentage of each factor in function of the total input in the input/output balance for grass under derogation and under no derogation. On derogation parcels 37 % of the total input is of organic fertilisation and 15 % input by grazing. On grass parcels without derogation organic fertilisation is 29 % of the total input. Export of the grass on both derogation parcels and no derogation parcels was smaller than the total input.

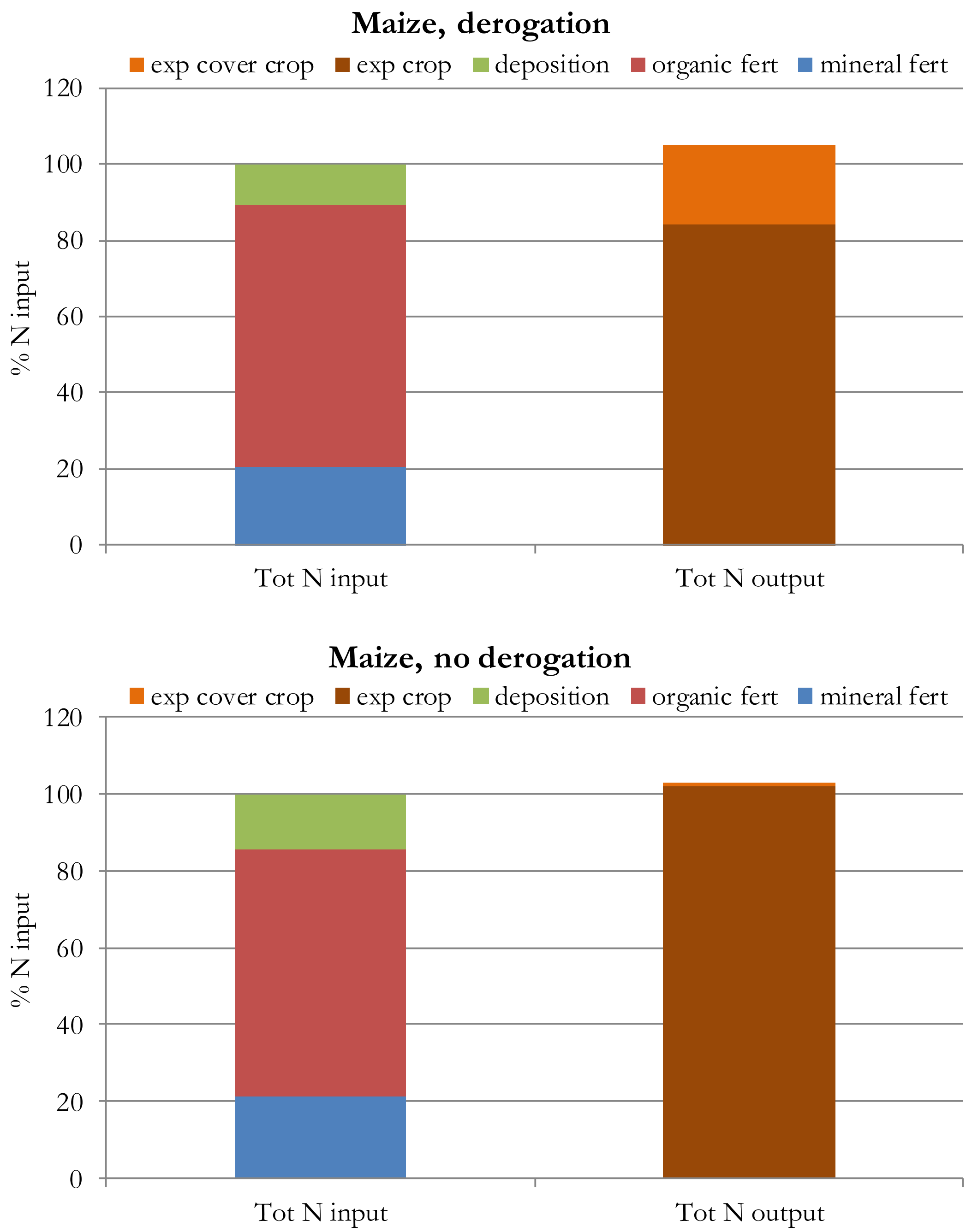


Figure 216: Percentage of each factor in relation to the total input in the input/output balance for parcels cultivated with maize under derogation and no derogation-year 2013.

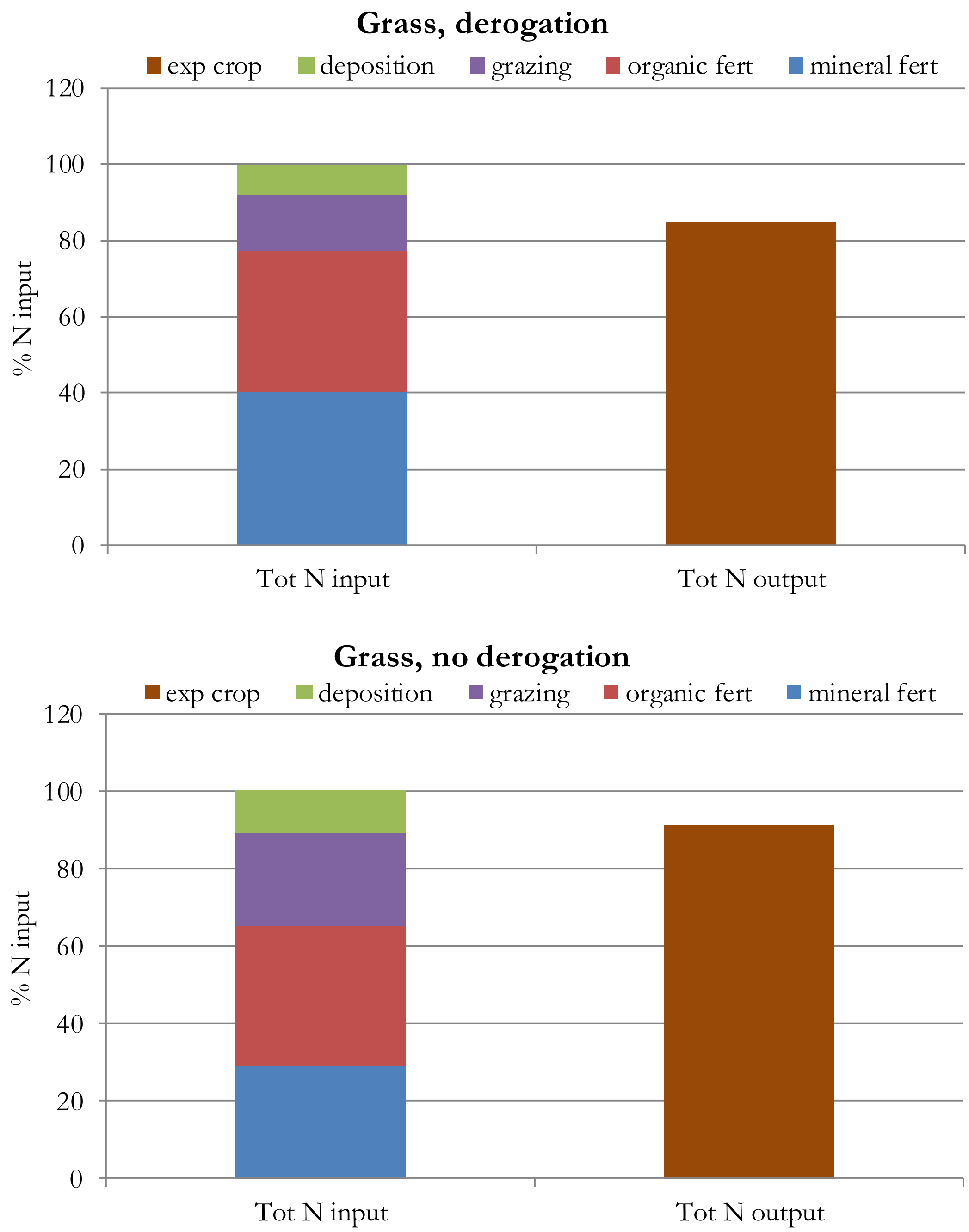


Figure 217: Percentage of each factor in relation to the total input in the nutrient balance for parcels cultivated with grass under derogation and no derogation-year 2013.

In contrast to the results of 2012, the correlation between the nitrate residue and the result of the input-output balance was statistically significant. However the regression explains only 3 % of the variability (Figure 218).

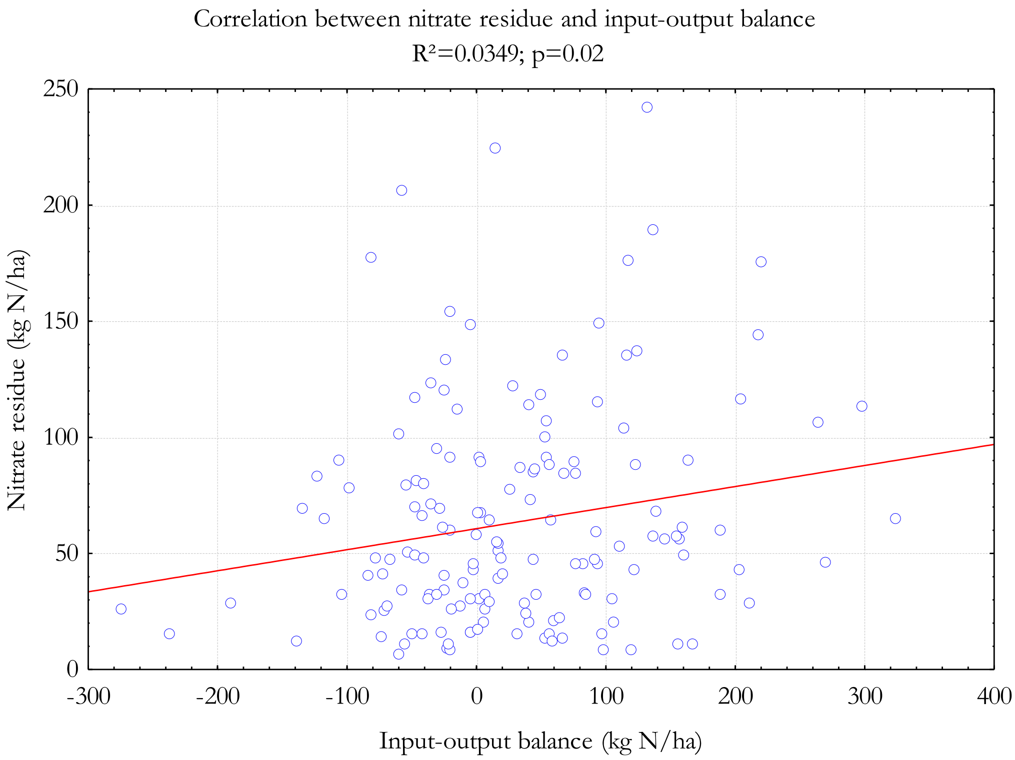


Figure 218: Nitrate residue versus Input-output balance for the growing season of 2013 for all parcels.

12.1.7 Balance result 2014

The result of the input-output balance 2014 is shown in Table 92. The variability of balance results between parcels was high. On grass parcels a large difference was found between the mean balance result of parcels with mowing and grazing and grass parcels with only mowing. These differences are shown in Table 93.

An ANOVA analysis was conducted in order to notify statistical differences in balance result between derogation and no derogation parcels in function of the cultivated crop. For parcels cultivated with grass no statistical difference was found between derogation and no derogation, nor for N ($p = 0.93$), nor for P_2O_5 ($p = 0.51$). For parcels cultivated with maize a statistical significant difference was detected between derogation and no derogation parcels for P_2O_5 ($p < 0.05$) but not for N ($p = 0.12$). For beets and winter wheat no statistical comparison is made between derogation and no derogation parcels since the number of parcels was too limited.

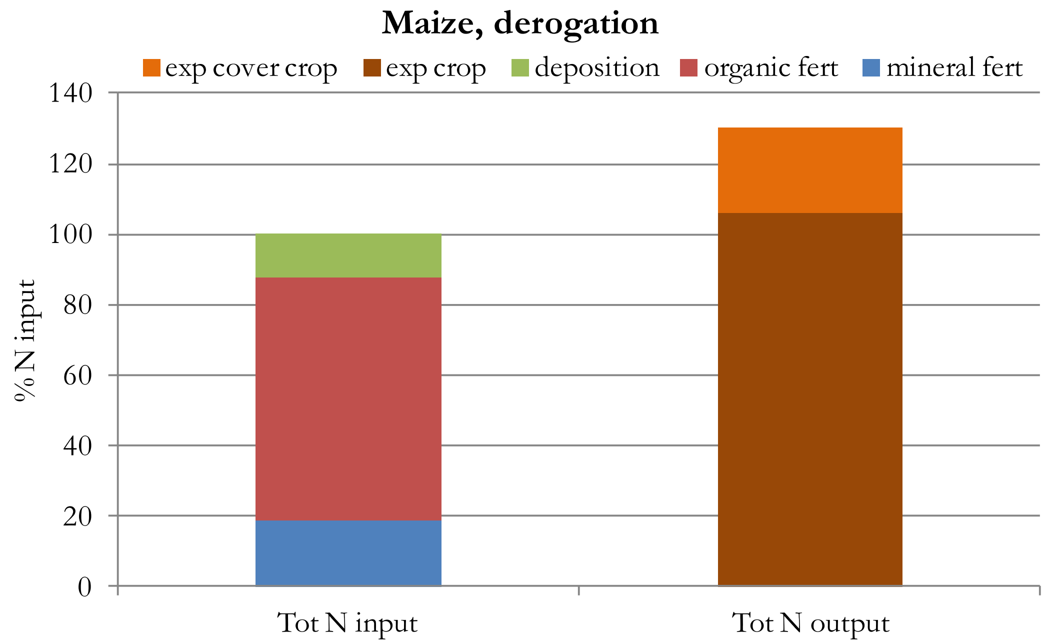
Table 92: N-balance (input-output), P-balance (input-output) and nitrate residue for derogation and no derogation parcels-year 2014.

	N (input-output)	P_2O_5 (input-output)	Nitrate residue
		Derogation	
Maize	-59	-48	83
Grassland	23	-28	57
Beets	79	17	39
Winter wheat	-27	-57	75
		No derogation	
Maize	-23	-25	85
Grassland	20	-21	47
Beets	142	14	44
Winter wheat	18	-68	64
Potatoes	63	-2	124

Table 93: N-balance (input-output), P-balance (input-output) and nitrate residue for derogation and no derogation parcels cultivated with grass with grazing and mowing or only mowing-year 2014.

	N (input-output)	P_2O_5 (input-output)	Nitrate residue
		Derogation	
Grass-grazing & mowing	50	-19	46
Grass-mowing	-7	-38	68
		No derogation	
Grass-grazing & mowing	34	-19	56
Grass-mowing	-10	-25	28

Graphs were made in order to visualize the share of each factor of the nutrient balance (organic fertilisers, mineral fertilisers, atmospheric deposition, harvested crop and emission during fertilisation) in function of the total input. Figure 219 shows this for maize under derogation and under no derogation. For both groups, input by organic fertilisation is the most important input. On derogation and no derogation parcels the output exceeds the total input with respectively 30 and 25 %. On both types of parcels the export by only the maize is higher than the total input. On no derogation parcels the export by the maize accounted for 123 % of the total input. On derogation parcels the export by the main crop is 106 % of the total input. The export by the cover crop was 24 % of the total input on derogation parcels compared to 3 % on no derogation parcels.



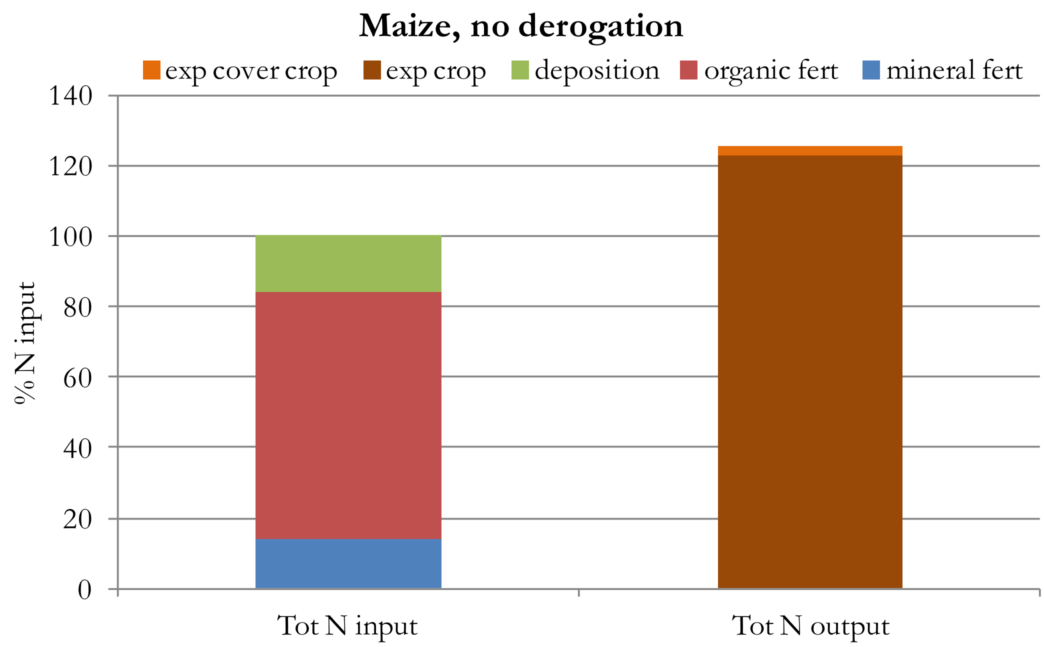
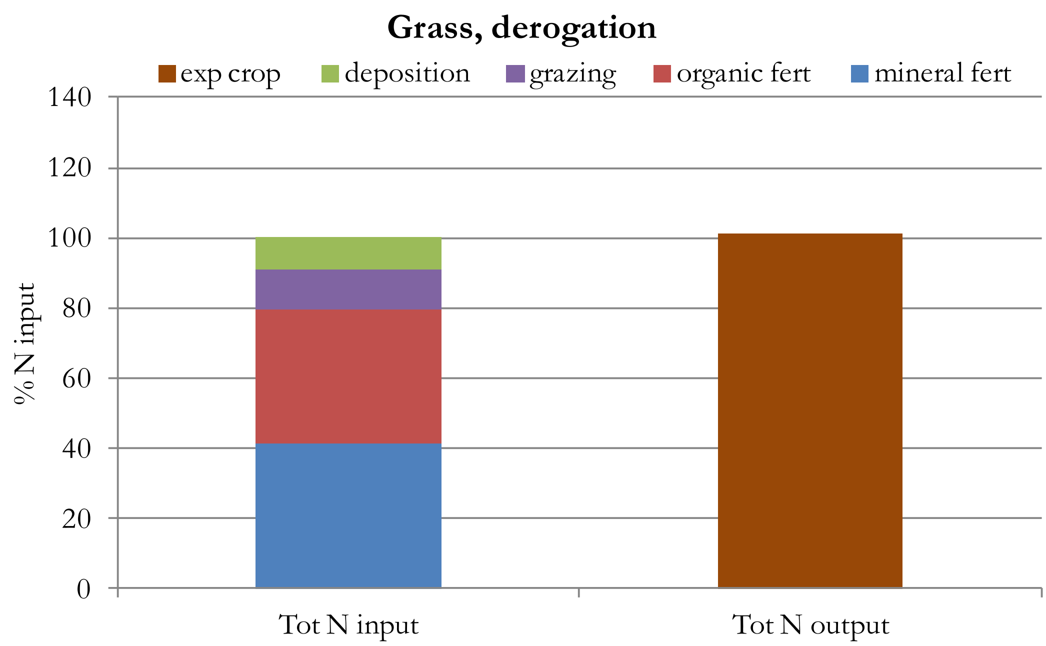


Figure 219: Percentage of each factor in relation to the total input in the input/output balance for parcels cultivated with maize under derogation and no derogation-year 2014.

Figure 220 shows the percentage of each factor in function of the total input in the input/output balance for grass under derogation and under no derogation. On derogation parcels 38 % of the total input is of organic fertilisation and 11 % input by grazing. On grass parcels without derogation organic fertilisation is 30 % of the total input. Export of the grass on both derogation parcels and no derogation parcels was near to the total input. On derogation parcels the export was 101 % of the total input, 74 % by cuttings and 27 % by grazing. On no derogation parcels the export of the grass was 106 % of the total input, 61 % by cutting the grass and 45 % by grazing cattle.



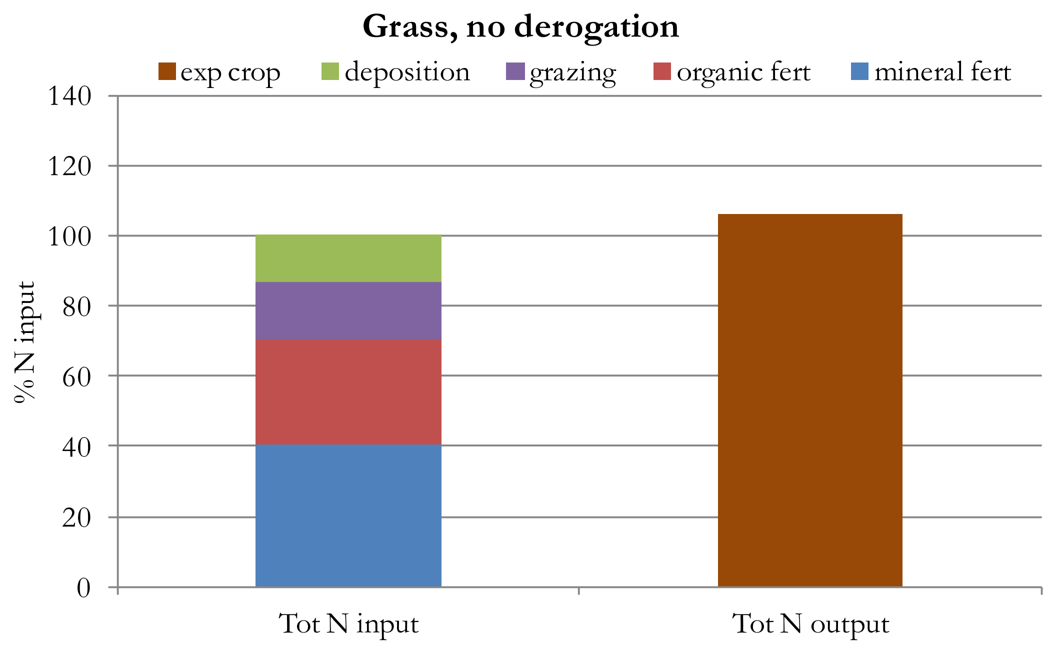


Figure 220: Percentage of each factor in relation to the total input in the nutrient balance for parcels cultivated with grass under derogation and no derogation-year 2014.

The correlation between the nitrate residue and the result of the input-output balance was not statistically significant (p = 0.097) as shown in Figure 221. However there is one parcel with a high nitrate residue (381 kg N/ha) while the balance result was rather low (-61 kg N/ha). This parcel was a maize parcel which was converted after 7 years being grassland. Since the input-output balance does not comprise mineralisation the balance result will not show the effect of an enhanced mineralisation after converting the grass. The nitrate residue on the contrary, shows the effect of the enhanced mineralisation. Leaving this parcel out of the dataset in order to reveal a possible correlation, resulted in a statistically significant correlation between the nitrate residue and the result of the input-output balance (Figure 222). However like in 2013 the regression explains only 3 % of the variability.

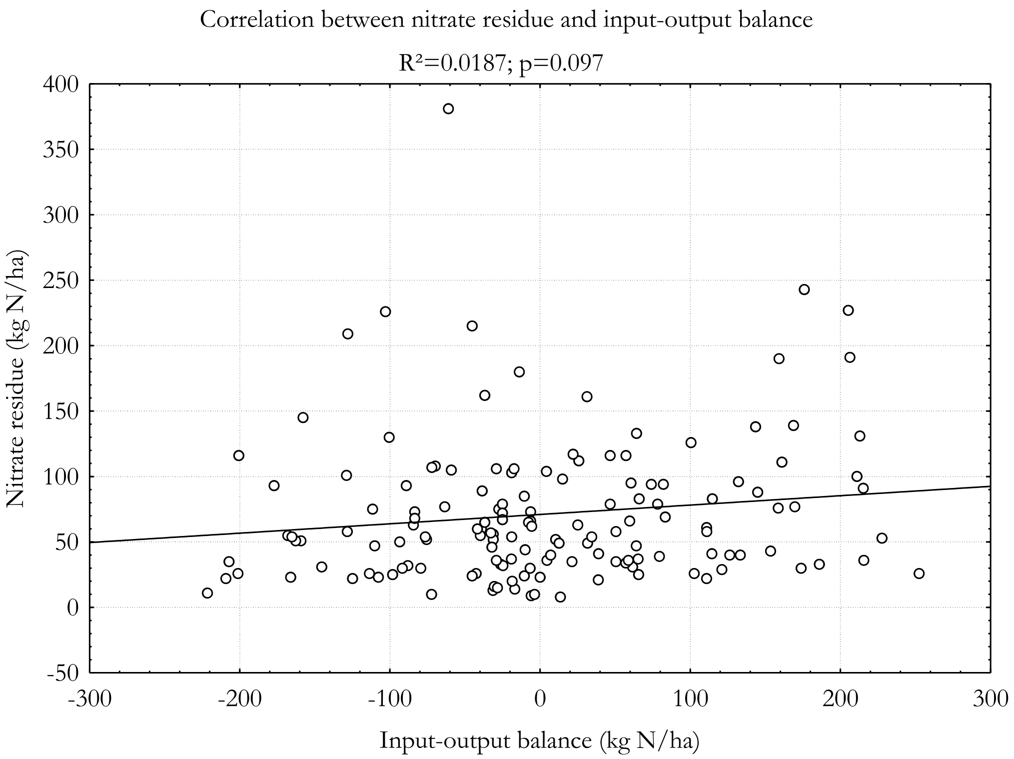


Figure 221: Nitrate residue versus Input-output balance for the growing season of 2014 for all parcels.

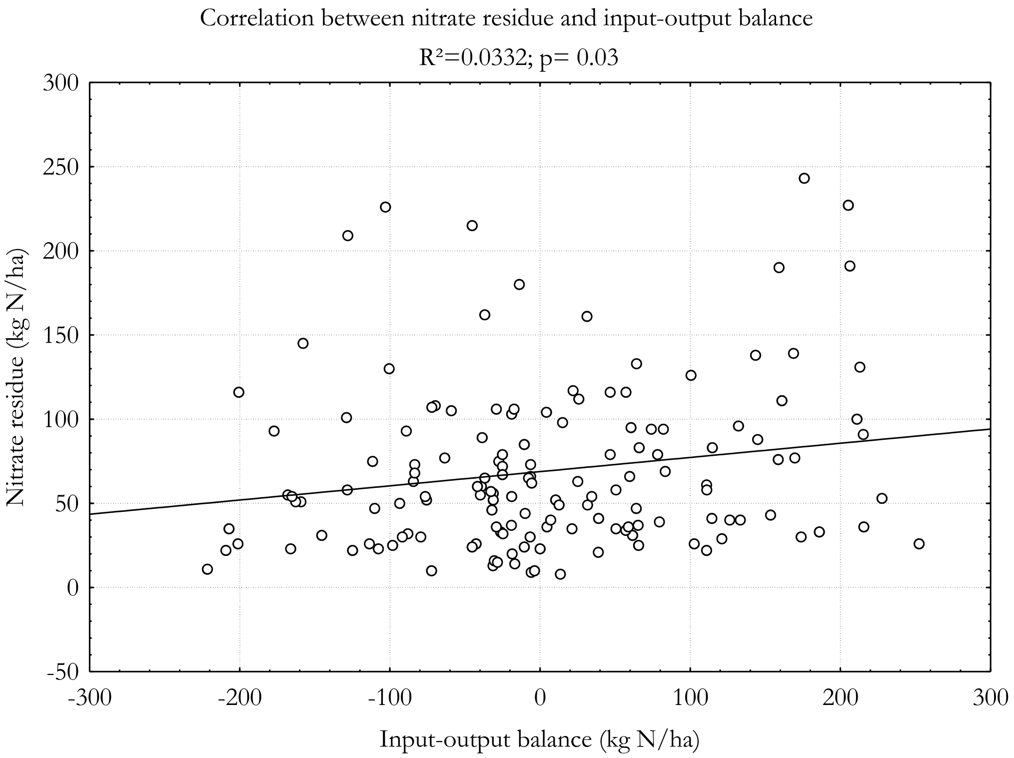


Figure 222: Nitrate residue versus Input-output balance for the growing season of 2014, converted grass parcel excluded.

12.2 Nitrate-N soil balance

The second approach is the nitrate-N soil balance, where the nitrate-N in the soil profile is monitored during the growing season. This balance starts with the amount of nitrate at the beginning of the season and ends with the nitrate residue at the end of the season. This is schematically represented in Table 94.

Table 94: Schematic overview of the different factors influencing the evolution of nitrate-N in the soil profile during the growing season.

Input	Output
N in soil profile, begin of season	N uptake by cultivated crop
N from mineral fertiliser	Leaching out of N
N from organic fertiliser	N in soil profile, end season (nitrate residue)
N from atmospheric deposition	
Mineralisation (from organic matter)	
Balance = input – output	

12.2.1 Nitrate in the soil profile before the growing season

The nitrate in the soil profile before the growing season is the starting point for calculating the nitrate balance. Nitrate is measured on all parcels of the monitoring network at the beginning of the growing season. The samples are taken from 0 to 90 cm in three layers. This nitrate sample gives information about the amount of nitrogen in the soil profile available for the cultivated crop, since mostly at this point no fertilisers are applied yet. The amount of nitrate in the soil profile before the growing season can be seen in paragraph 6.

12.2.2 Fertilisation (organic and mineral)

The amount of nitrogen that will be available during the growing season originating from organic fertilisation (organic fertilisers and grazing cattle) and mineral fertilisation is an important factor for calculating the nutrient balance. In the first approach (input/output balance) the total amount of nitrogen supplied on the parcels was taken into account. For this second approach, the nitrogen which is available for the plant during the growing season (= the effective amount of nitrogen) is of great importance. For organic fertilisers, information on the effective nitrogen is present in the analysis report of the manure samples (taken by SSB for the different types of organic manure). In general a coefficient of 60 % is used to calculate the plant available nitrogen from animal manure or other organic fertilisers. For solid manure, this coefficient is 30 %. For excretion by grazing cattle, the coefficient is 20 % and for mineral fertilisers a coefficient of 100 % is used.

12.2.3 Mineralisation

An important amount of nitrogen will become available during the growing season due to mineralisation.

<u>Organic fertilisation</u>

Some of the nitrogen present in organic fertilisers is only plant available after mineralisation has occurred. This amount is calculated by the working coefficients of the organic manure and results in an amount of effective nitrogen (12.2.2). The amount of effective nitrogen consists of the mineral fraction (directly plant available), and the fraction which will be available during the growing season due to mineralisation. For solid manure, an important fraction of the nitrogen present in the organic manure becomes available by mineralisation during the second year after application.

Soil organic matter

The most important source of mineralisation originates from the soil organic matter. The amount of nitrogen released during the growing season is influenced by different parameters, from which the two most important ones are soil texture and the percentage of carbon. By using data from the N-(eco)² project (Herelixka et al., 2002; Table 95) it is possible to estimate the amount of N released from the soil organic matter in function of soil texture, percentage carbon and sampling date. The highest levels of mineralisation are found in the clay soils and sandy soils; the lowest levels in sandy loam and loam soils.

Table 95: Estimated monthly N mineralisation (kg N/ha) of soil organic matter in function of percentage carbon and soil texture on arable land (source: N-(eco)²). Levels are presented for optimal conditions of soil humidity and temperature.

Soil texture	%C	Jan	Feb	March	April	May	June	July	Aug	Sept	Okt	Nov	Dec	Sum
Sand														
	2.3	11.5	11.5	16.6	19.7	26.9	33.5	36.6	36.0	31.4	20.9	15.8	12.5	272.9
	1.8	9.1	9.1	13.1	15.6	21.3	26.4	28.9	28.4	24.8	16.5	12.5	9.8	215.5
	1.3	6.9	6.9	9.9	11.8	16.1	20.0	21.9	21.5	18.8	12.5	9.4	7.4	163.1
Sandy loam														
	1.3	7.4	7.4	10.6	14	19.4	24.3	26.8	26.4	21.4	15.0	10.1	8.0	190.8
	1.1	6.4	6.4	9.2	12.2	16.8	21.0	23.2	22.8	18.5	13.0	8.8	6.9	165.2
	0.7	3.9	3.9	5.7	7.5	10.3	13.0	14.3	14.1	11.4	8.0	5.4	4.3	101.8
Loam														
	1.4	6.5	6.5	9.4	12.4	17.2	21.5	23.7	23.3	18.9	13.3	9.0	7.1	168.8
	1.2	5.9	5.9	8.5	11.2	15.5	19.4	21.4	21.1	17.1	12.0	8.1	6.4	152.5
	0.9	4.4	4.4	6.3	8.3	11.5	14.4	15.9	15.6	12.7	8.9	6.0	4.7	113.1
Clay														
	2.8	16.6	16.6	23.8	31.6	43.6	54.6	60.2	59.2	48.1	33.8	22.7	17.9	428.7
	1.2	5.5	5.5	7.9	10.5	14.5	18.1	20.0	19.7	16.0	11.2	7.5	6.0	142.4
	0.9	4.0	4.0	5.8	7.7	10.6	13.3	14.6	14.4	11.7	8.2	5.5	4.4	104.2

Based on Table 95, nitrate from mineralisation of soil organic matter is calculated for each parcel. For each parcel the percentage carbon and soil texture are known. The mineralisation of soil organic matter is calculated for the period between the nitrate sample at the beginning of the season (spring year x) and the nitrate residue sample at the end of the growing season (autumn year x). This way the mineralisation of soil organic matter in year x is calculated.

Catch crop

Mineralisation of the catch crop sown after the cultivated crop in year x-1 is another source of mineralised nitrogen.

For cultivating maize with derogation the presence of a catch crop is a requirement. Since the requirement of harvesting one cut of the catch crop, mineralisation of the catch crop will be rather small. On parcels cultivated with maize without derogation a catch crop is not always present. If grass is cultivated before maize without derogation there's no requirement of harvesting the catch crop. Mineralisation of the catch crop can be important if not harvested. Amounts of nitrogen originating from mineralisation of the catch crop are based on Table 96.

Table 96: N-release (kg N/ha) by different catch crops (source: Wageningen UR, 2005).

Type catch crop	Length (cm)	Efficient N (kg/ha) released for	different moment of incorporation
		Before winter	After winter
Rye-grass	15	10	20
	30	15	35
	45	25	50
Cruciferea	40	10	15
	60	15	30
	90	25	45
Leguminous	20	15	30
	40	30	60
	60	45	90

Crop residues

Other organic material that will be mineralised are crop residues. Mineralisation of crop residues will be only important for some crops and depends on the time period between the harvest of the cultivated crop and the moment of sampling after winter. Especially for beets, cauliflower, sprouts, peas and beans mineralisation of crop residues will be important. The carbon-nitrogen ratio of these crop residues is low, which means that mineralisation will be fast.

If harvest is more than two months before the moment of sampling the parcel, a part of the nitrogen will be mineralised and will be measured in the profile at the beginning of the growing season. In this case the expected mineralisation for these crops ranges between 20 and 30 kg nitrate-N/ha. If less than two months between sampling the profile and harvest, the expected mineralisation will be higher.

12.2.4 Uptake by the cultivated crop

In this approach, both the amount of nitrogen exported by the harvest and the amount of nitrogen taken up by the parts of the cultivated crops that are not harvested are taken into account for the calculation of the nutrient balance.

For grassland and maize, these are mostly the roots. For some other crops it can be the leaves (sugar beet). Especially for beets the amounts of nitrogen extracted from the soil profile by not harvested parts (leaves) is considerable.

Table 97: Amount of nitrogen (kg N/ha) and phosphorous (kg P_2O_5/ha) uptake by the roots and leaves of different cultivated crops. The levels are based on average yields. Source: "Ontwerp actieprogramma nitraatrichtlijn 2011-2014".

		Average yield	
		N-uptake	P_2O_5-uptake
Potatoes	Leaves	41	
Potatoes	Roots	10	
Winter wheat	Straw	33	13
Winter wheat	Roots	30	
Winter barley	Straw	23	10
Winter barley	Roots	30	
Sugar beets	Leaves	150	
Sugar beets	Roots	10	
Fodder beets	Leaves	134	24
Fodder beets	Roots	10	
Corn maize	Straw	48	
Corn maize	Roots	25	
Silage maize	Roots	25	
1 cut of grass	Roots	20	
Grass (mowing)	Roots	45	
Grass (mowing + grazing)	Roots	40	

12.2.5 Leaching and atmospheric deposition

During the growing season the process of leaching is less important in comparison with the winter period. From the date of sampling at the beginning of the year till the moment of active nutrient take up by the cultivated crops, leaching is still possible, especially for arable land. The process of leaching is also important after harvest or when crop growth is stopped. Leaching during the growing season is related to the cultivated crop and will be a complex calculation. More information is necessary to calculate leaching during the growing season. Most important is the moisture content of the soil during the growing season. Another factor is atmospheric deposition. This is almost the same on all parcels in the monitoring network.

To calculate the nitrogen/soil balance the effect of leaching during the growing season (nitrate output) and the effect of atmospheric deposition (nitrate input) are not taken into account.

12.2.6 Nitrate residue

The nitrate residue in the soil profile at the end of the season is the last parameter which is taken into account at the output side. The nitrate residue is measured on all parcels between October 1st and November 15th.

12.2.7 Nitrate-N soil balance results 2012

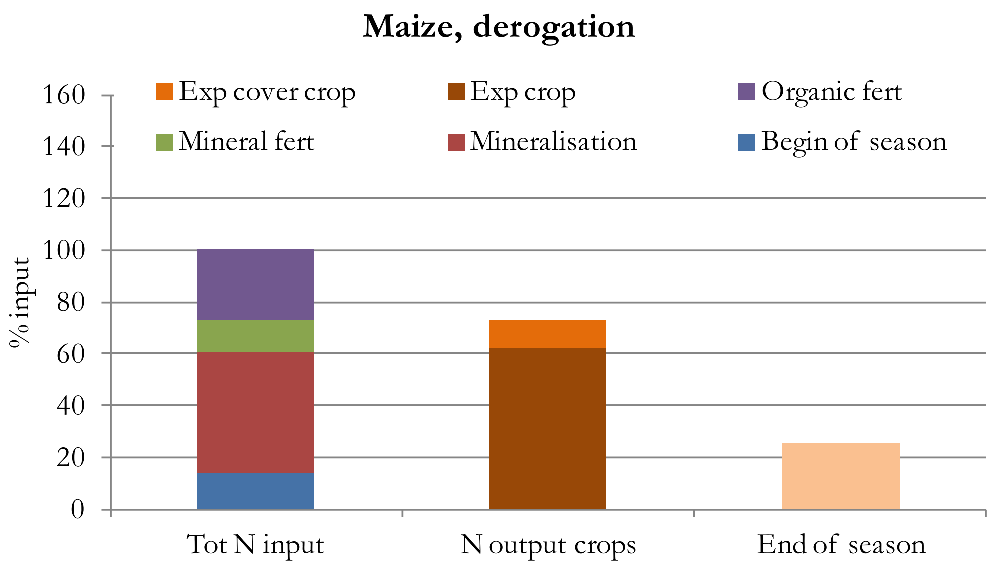
For the parcels in the monitoring network, a nutrient balance was calculated. Results of the calculations are shown in Table 98.

Table 98: Nitrate-N soil balance result of 2012 for the most important derogation and no derogation crops.

	Balance result
Derogation	
Maize	20
Grassland	36
Beets	-85
Winter wheat	-
No derogation	
Maize	3
Grassland	-86
Beets	-
Winter wheat	72
Potatoes	-31

For maize, the nitrate soil balance almost equals 0, both for derogation and no derogation parcels. However when looking at individual parcels, the nutrient balance for maize parcels ranges from 230 to -185 kg N/ha. There is no significant difference in nitrate soil balance result for maize parcels under derogation and no derogation (p = 0.67). There is a significant difference in nitrate-N soil balance between derogation and no derogation parcels cultivated with grass.

Graphs were also made in order to estimate the percentage of each factor of the nutrient balance (Nitrate in the beginning of the season, nitrate from soil mineralisation, mineral fertilisation, organic fertilisation, grazing, export by cultivated crop, export by cover crop and nitrate in the end of the season) in function of the total input. Figure 223 shows this for maize under derogation and under no derogation. For both groups the input by soil mineralisation is the most important input factor, followed by the organic fertilisation. Export by the cultivated crop recovers 62 % of the total input on maize parcels with derogation. On maize parcels without derogation 74 % of the total input is recovered by the cultivated crop.



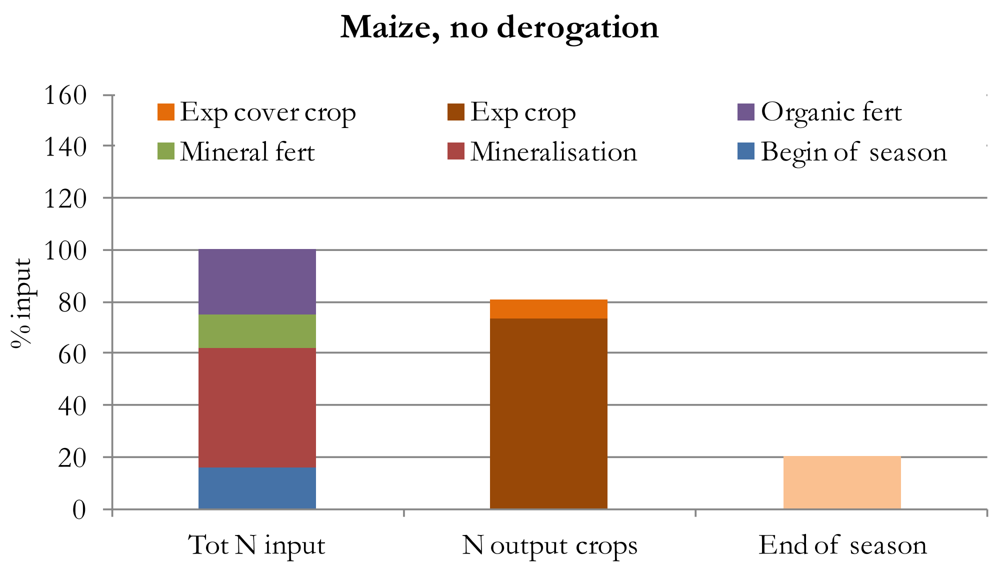
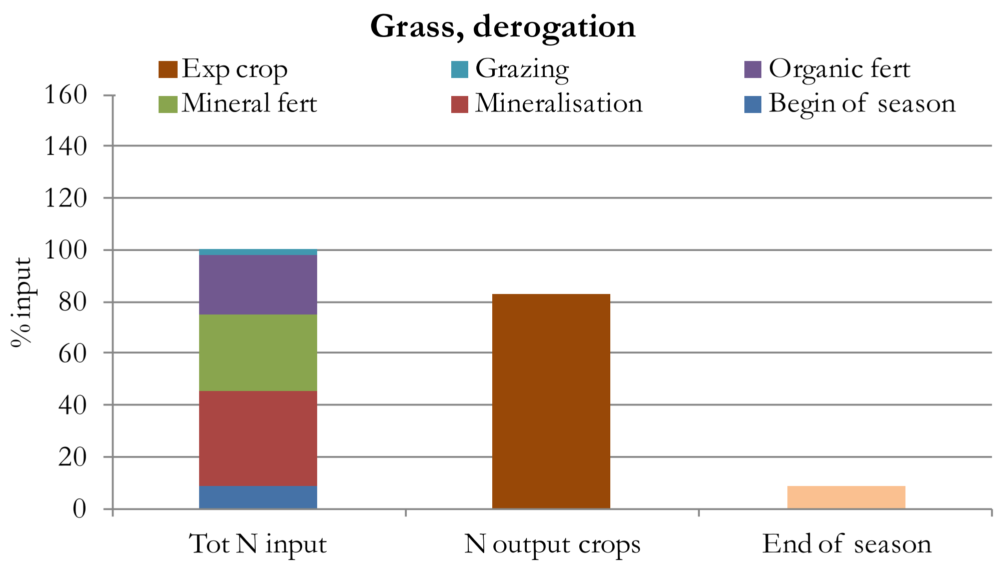


Figure 223: Percentage of each factor in the nitrate-N/soil balance for parcels cultivated with maize under derogation and no derogation-year 2012.

Figure 224 shows the percentage of each factor of the nitrate-N soil balance in function of the total N input for grass under derogation and under no derogation. For both groups, the input by soil mineralisation is the highest input. On derogation parcels cultivated with grass, 83 % of the total N input was recovered by the cultivated crop. On grass parcels without derogation the N-output by the cultivated crop exceeded the total N-input with 17 %.



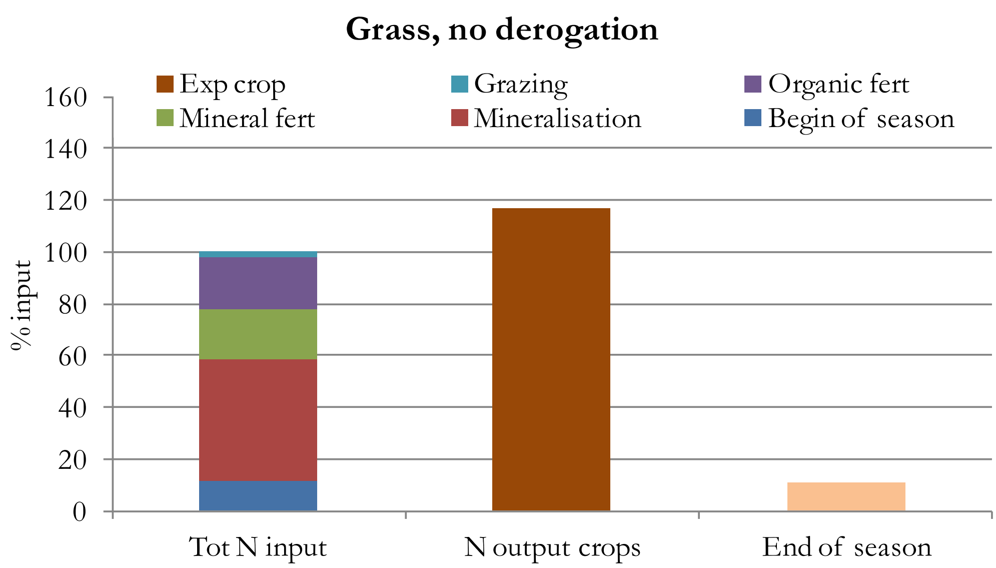


Figure 224: Percentage of each factor in the nitrate-N/soil balance for parcels cultivated with grass under derogation and no derogation-year 2012.

12.2.8 Nitrate-N soil balance results 2013

For the parcels in the monitoring network, also the nitrate-N balance of 2013 is calculated. Results of the calculations are shown in Table 98. When looking at individual parcels, the nutrient balance for maize parcels ranges from -207 to 140 kg N/ha.

There is no significant difference in nitrate soil balance result for maize parcels under derogation and no derogation ($p = 0.10$) in 2013. Also for parcels cultivated with grass there is no statistical significant difference between parcels with or without derogation ($p = 0.72$).

Table 99: Nitrate-N soil balance result of 2013 for the most important derogation and no derogation crops.

	Balance result
Derogation	
Maize	21
Grassland	18
Beets	-
Winter wheat	58
No derogation	
Maize	-5
Grassland	10
Beets	-
Winter wheat	78
Potatoes	43

The parcel which showed a result of -207 for the nitrate-N soil balance was a parcel cultivated with silage maize without derogation on a sandy soil (Table 100).

Table 100: Nitrate-N soil balance 2013 no derogation parcel cultivated with maize on sandy soil, converted of grassland into cropland in spring 2012.

Maize, no derogation, sandy soil					
Nitrate in soil	8/2/2013	39	Uptake maize	harvest-export	260
				roots	25
Fertilisation	organic	53			
	mineral	81	Catch crop	spring 2013	-
				autumn 2013	0
Mineralisation	Soil organic matter	129			
	Solid manure 2012	-	Residue	9/10/2013	224
	Catch crop 2012	-			
	Crop residue 2012	-			
		302			509
Result nitrate-N soil balance					**-207**

The good harvest resulted in an export of 260 kg N/ha. Despite the high N-export a high nitrate residue was found at 9 October 2013. The balance result supposes an underestimation of the N-input. The history of the parcel can explain the high nitrate residue and the underestimation of the mineralisation of soil organic matter. The parcel was converted of grassland into cropland in spring 2012.

Graphs were made in order to visualize the share of each factor of the nutrient soil balance (nitrate in the beginning of the season, nitrate from mineralisation, mineral fertilisation, organic fertilisation, grazing, uptake by cultivated crop, uptake by cover crop and nitrate in the end of the season) in function of the total input. Figure 225 shows this for maize under derogation and under no derogation. For both groups the input by soil mineralisation is confirmed to be the most important input factor. Organic fertilisation is 30 and 28 % of total input on maize parcels with and without derogation respectively. On maize parcels under derogation in 2013, 66 % of the total N-input is recovered by the maize and 16 % by the catch crop. On parcels cultivated with maize without derogation 79 % of the total N-input is recovered by the maize but only 2 % by a catch crop.

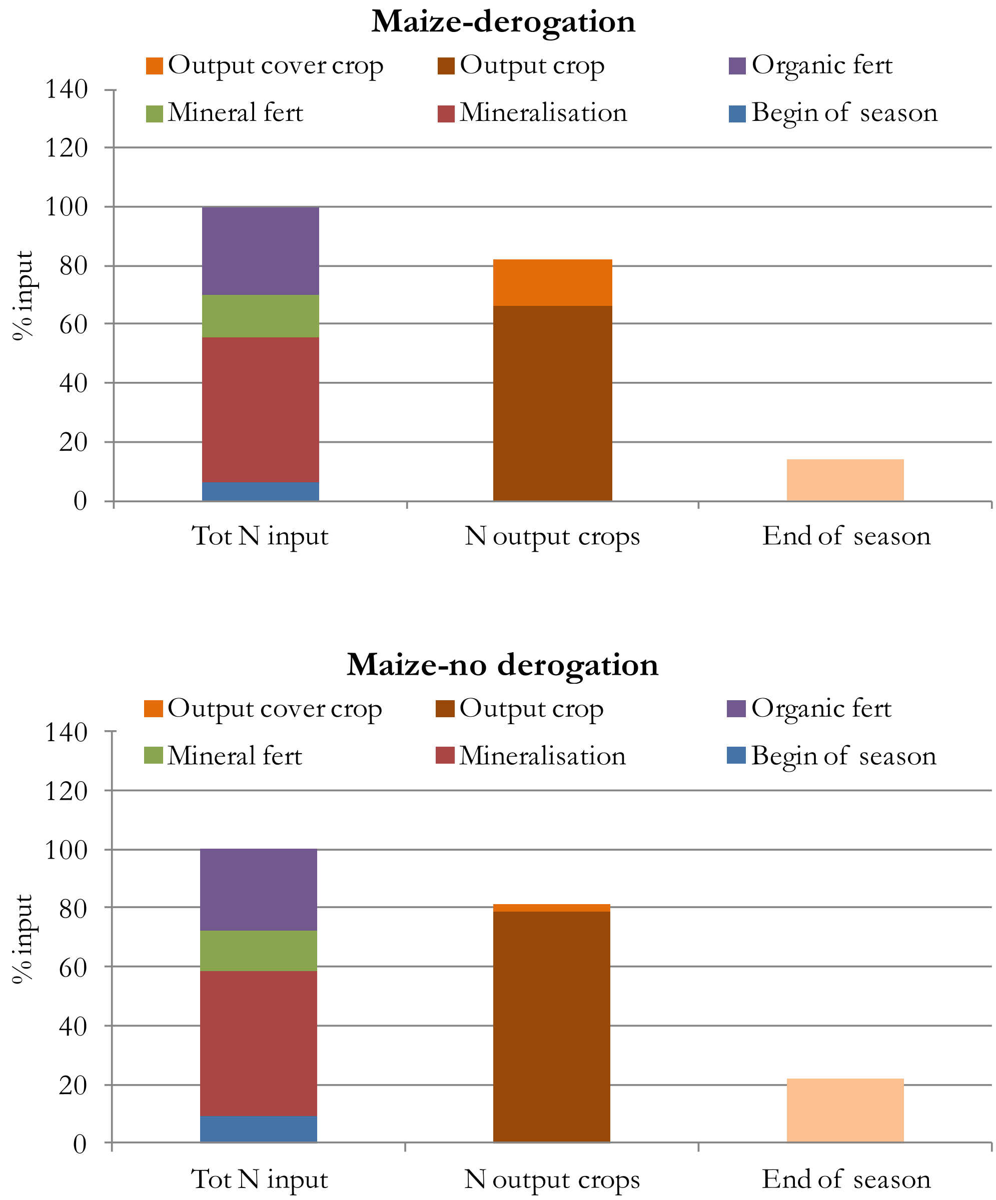
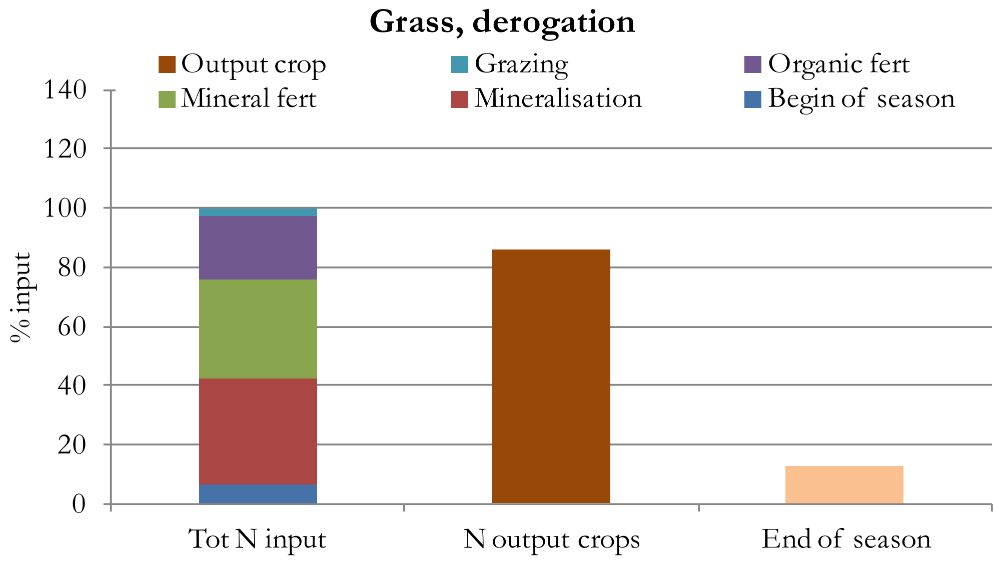


Figure 225: Percentage of each factor in the nitrate-N soil balance for parcels cultivated with maize under derogation and no derogation-year 2013.

Figure 226 shows the percentage of each factor of the nitrate-N soil balance in function of the total N input for grass under derogation and not under derogation. Like for maize parcels also for both groups of parcels cultivated with grass, input by soil mineralisation is the highest input. Organic fertilisation is about 21 % of total N-input on both derogation and no derogation parcels. On both derogation and no derogation parcels cultivated with grass, 86 % of the total N-input was recovered by N-uptake of the grass.



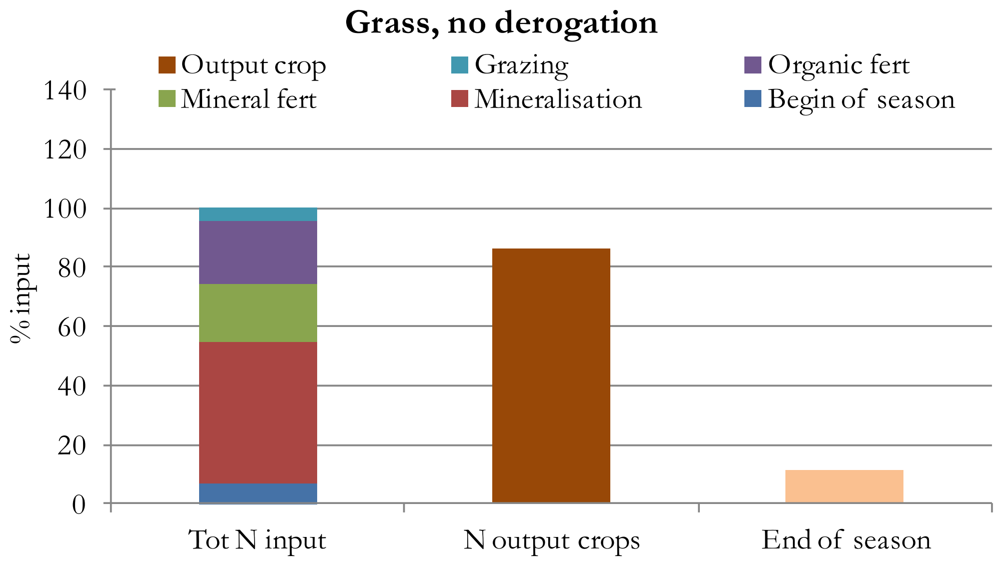


Figure 226: Percentage of each factor in the nitrate-N soil balance for parcels cultivated with grass under derogation and no derogation-year 2013.

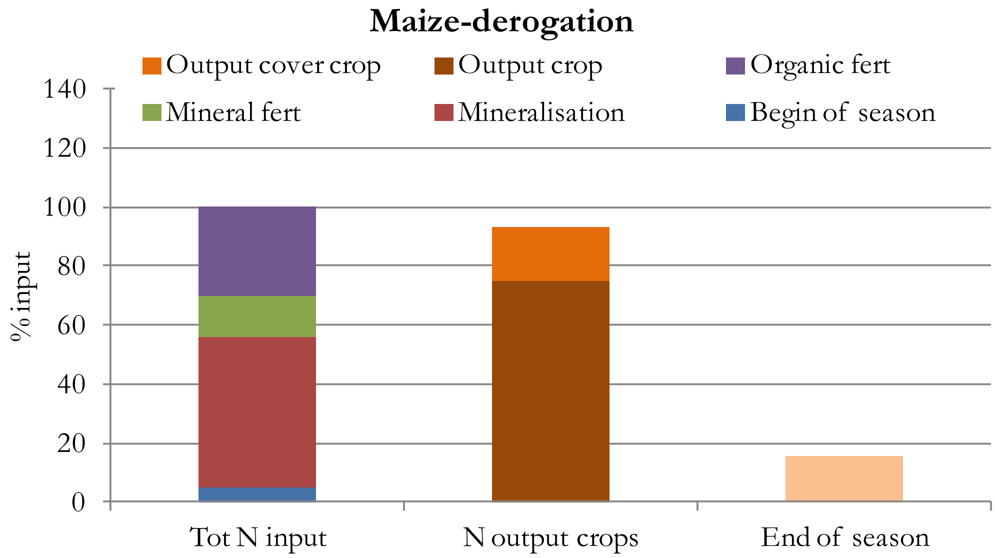
12.2.9 Nitrate-N soil balance results 2014

Like in 2012 and 2013 the nitrate-N soil balance of 2014 is calculated for the parcels in the monitoring network. Results of the calculations are shown in Table 101. There is no significant difference in nitrate-N soil balance result for maize parcels under derogation and no derogation (p = 0.77) in 2014. Also for parcels cultivated with grass there is no statistical significant difference between parcels with or without derogation (p = 0.92).

Table 101: Nitrate-N soil balance result of 2014 for the most important derogation and no derogation crops.

	Balance result
Derogation	
Maize	-24
Grassland	5
Beets	0
Winter wheat	-14
No derogation	
Maize	-17
Grassland	8
Beets	-70
Winter wheat	15
Potatoes	55

Graphs were made in order to visualize the share of each factor of the nutrient soil balance (nitrate in the beginning of the season, nitrate from mineralisation, mineral fertilisation, organic fertilisation, grazing, uptake by cultivated crop, uptake by cover crop and nitrate in the end of the season) in function of the total input. Figure 227 shows this for maize under derogation and under no derogation. For both groups the input by soil mineralisation is the most important input factor as shown earlier. Organic fertilisation is 30 and 26 % of total input on maize parcels with and without derogation respectively. On maize parcels under derogation in 2014, 75 % of the total N-input is recovered by the maize and 18 % by the catch crop. On parcels cultivated with maize without derogation 83 % of the total N-input is recovered by the maize but only 3 % by a catch crop.



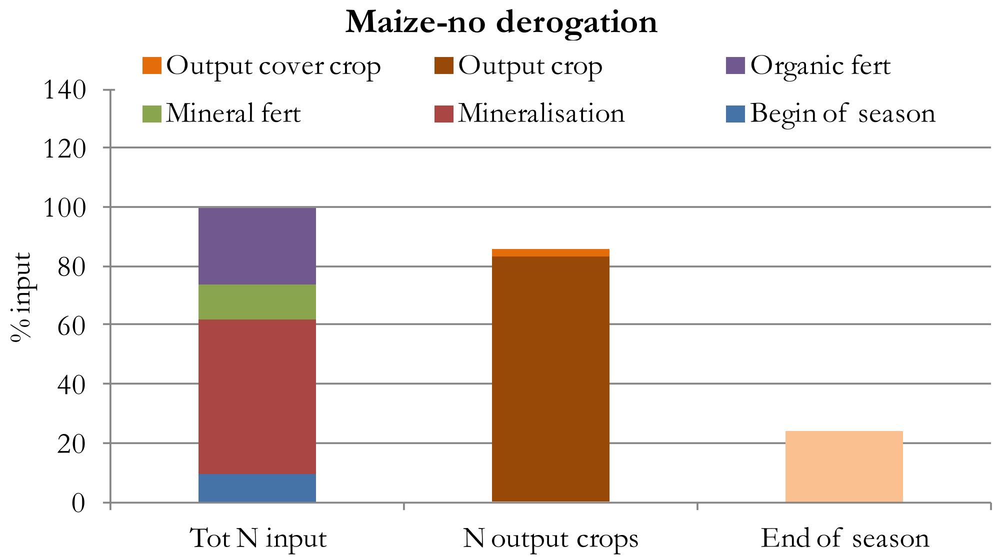


Figure 227: Percentage of each factor in the nitrate-N/soil balance for parcels cultivated with maize under derogation and no derogation-year 2014.

Figure 228 shows the percentage of each factor of the nitrate-N soil balance in function of the total N input for grass under derogation and not under derogation. Like for maize parcels also for both groups of parcels cultivated with grass, the input by soil mineralisation is the highest input. Organic fertilisation is 16 and 21 % of total N-input on no derogation and derogation parcels respectively. On both derogation and no derogation parcels cultivated with grass, about 90 % of the total N- input was recovered by N-uptake of the grass.

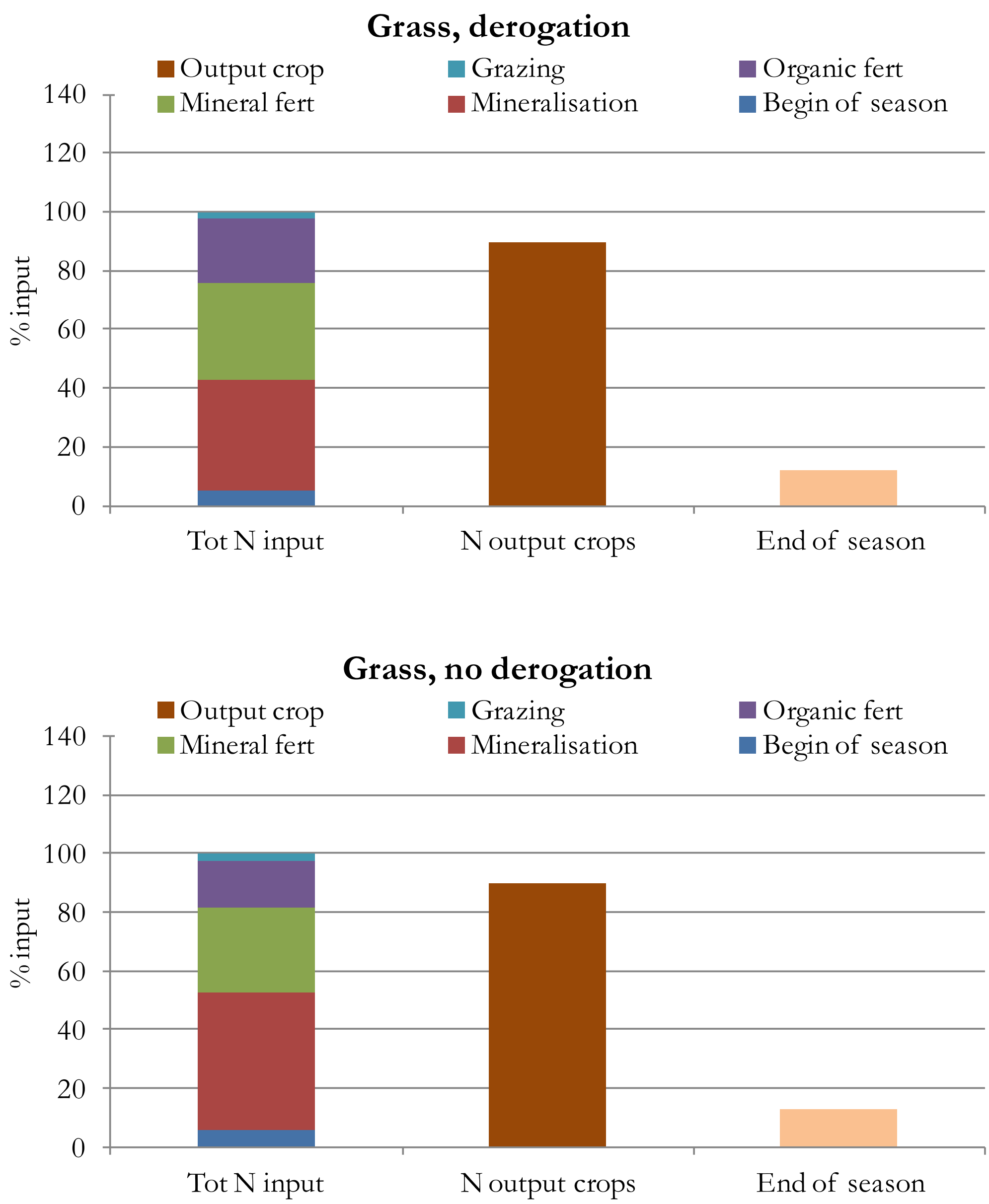


Figure 228: Percentage of each factor in the nitrate-N soil balance for parcels cultivated with grass under derogation and no derogation-year 2014.

12.3 Yield sampling

In Vandervelpen *et al.* (2011) as well as in the current monitoring study it is shown that huge deviations can occur for individual parcels. Since nutrient uptake by the cultivated crop is a determining factor, as shown for the different nutrient balances, a less accurate estimation of the yield is one possible reason for aberrations in the nutrient balances.

Therefore a more accurate estimation of yield and nutrient export is aimed by yield sampling at grass and maize parcels and determination of the dry matter content and the N- and P-content of the crop. Ten parcels with grassland and 10 maize parcels were selected.

12.3.1.1 Grassland-2013

For the grass parcels it was meant to harvest the first two cuttings. Fresh yield, dry matter content and N and P content are determined to reach a better insight in N and P-export per ha per year for grassland.

In 2013 10 grass parcels were selected. On all parcels the first cut was sampled. At 4 randomly selected sites in the parcels the crop was harvested on 5-10 m². The crop samples were analysed for dry matter content, N and P content. Harvesting the second cut wasn't always possible. Because weather conditions are determining crop growth and the moment of harvest, some parcels were already harvested before sampling was possible while other parcels were no longer meant to mow but for grazing.

The results of the yield sampling at the first cut show dry matter yields of 2.3-6.7 ton/ha representing a N-export of 58.7-167.6 kg N/ha and a P_2O_5-export of 11.5-31.0 kg P_2O_5/ha.

Table 102: Results of yield sampling of the 2 first cuttings on 10 grass parcels of the monitoring network in 2013, dry matter yield (ton/ha) and the amount of nutrients exported by the crop (kg N/ha, kg P_2O_5/ha).

	Cut 1			Cut2		
	Dry matter (ton/ha)	N crop (kg N/ha)	P_2O_5 crop (kg P_2O_5/ha)	Dry matter (ton/ha)	N crop (kg N/ha)	P_2O_5 crop (kg P_2O_5/ha)
			Derogation			
	3.79	70.51	18.40	2.73	56.90	20.32
a	3.20	60.08	16.54			
b	3.15	58.50	19.37			
c	2.30	61.97	16.50			
d	2.47	58.67	12.59	2.39	83.74	15.72
e	2.69	60.79	12.92	4.50	132.75	38.33
f	4.08	134.23	11.49			
g	4.37	67.28	19.21	1.32	46.60	9.73
			No derogation			
	6.73	167.63	30.99			

For the second cut, yield sampling was done on only 4 parcels. These results also confirm the large differences in yield between parcels. Dry matter yield ranged from 1.3 to 4.5 ton/ha. The range for N and P-export was 46.6-132.8 kg N/ ha and 15.7-38.3 kg P_2O_5/ha.

The nitrate-N soil balances in Figure 229 take the yield sampling on the grass parcels into account. For some parcels the balance result was near to zero. On parcels “b” and “d” the result of the nitrate-N soil balance was very good. For these parcels the information of the yield communicated by the farmers was detailed and the result of the balance based on these figures was already near to zero. Parcels “a” and “c” were also grazed, which creates uncertainty about the export by grazing. On parcel “c” animals were on the parcel until 6 days before the parcel was sampled in autumn. This could explain the high nitrate residue.

The organic N-input amounted for 13 to 33 % of the total N-input. The N-output by the crop amounted 84 to 107 % of the total N-input. For parcel “c” the output by the crop was limited to only 54 %.

For two parcels the nitrate-N soil balance could not be made because of incomplete information.

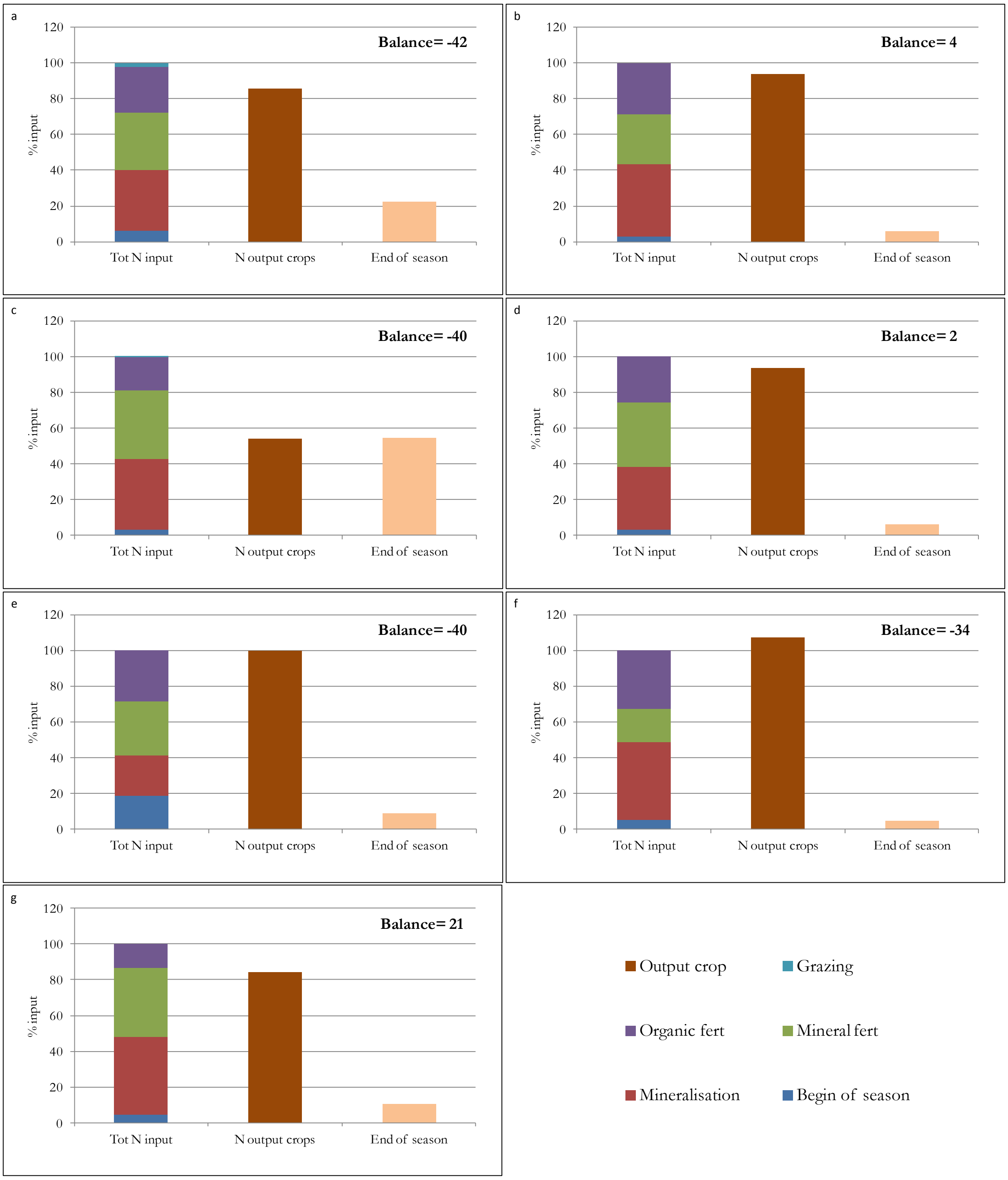


Figure 229: Nitrate-N soil balances for parcels with yield sampling of grass, percentage of each factor relative to total input-year 2013.

12.3.1.2 Maize parcels-2013

Ten maize parcels of the monitoring network were selected and on each parcel 2 rows of 4 m at 5 randomly chosen sites in the parcel were harvested. The results showed a large variability between the parcels. The largest dry matter yield was 20.5 ton/ha while the smallest harvest was only 11.7 ton dry matter/ha (Table 103). The variability in dry matter content and N content resulted in N export by the crop of 104.5 kg N/ha to 226.6 kg N/ha. For phosphorus an export range of 43.7-90.2 kg P_2O_5 was measured.

Table 103: Results of yield sampling on maize parcels in 2013, dry matter yield (ton/ha) and the amount of nutrients exported by the crop (kg N/ha, kg P_2O_5/ha).

	Dry matter (ton/ha)	N crop (kg N/ha)	P_2O_5 crop (kg P_2O_5/ha)
		Derogation	
a	18.16	179.77	81.09
b	14.36	152.25	43.74
c	12.59	104.48	76.10
	14.38	161.09	76.42
	14.99	182.83	73.10
d	20.51	203.07	90.19
e	16.41	164.09	77.79
f	18.27	226.55	
g	14.36	215.37	67.73
		No derogation	
h	11.68	189.15	59.36

Figure 230 shows the nitrate-N soil balance of the parcels on which yield samples are taken. These nitrate-N soil balances take the results of the yield sampling into account. A more accurate estimation of the nutrient export resulted in better balance results. The balance results were near to zero. Parcel "c" showed despite the yield sampling, a balance result of 146. On this parcel the N-export was only 105 kg N/ha, far below the average, caused by low yield and low N-content of the crop.

For two parcels nitrate-N soil balance could not be made because incomplete information.

The organic N-input amounted for 14-37 % of the total N-input. The N-export by the maize amounted for 25-74 % of the total N-input.

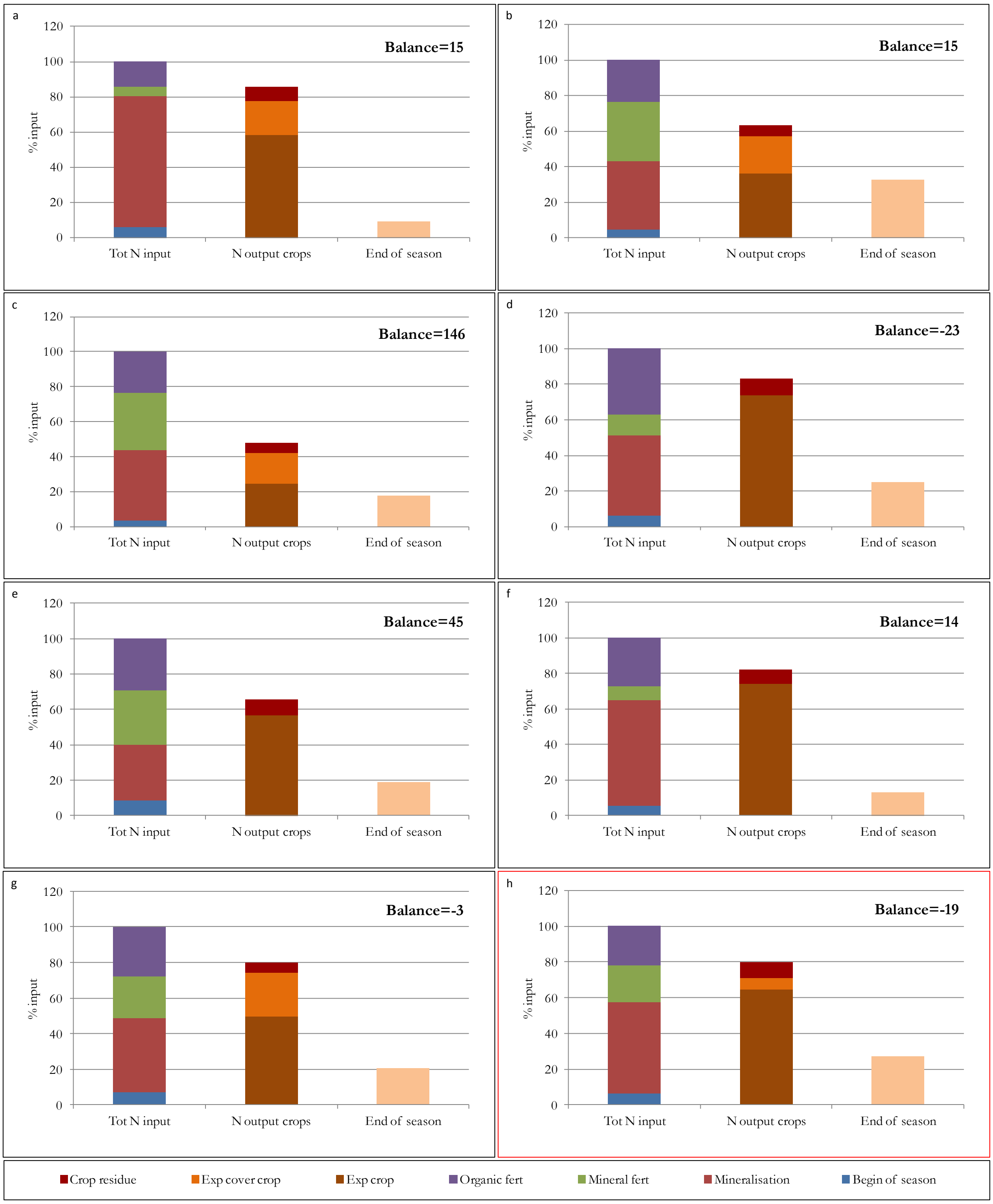


Figure 230: Nitrate-N soil balances for parcels with yield sampling of maize, percentage of each factor relative to total input-year 2013.

12.3.1.3 Grassland-2014

For the yield sampling on parcels cultivated with grass, 10 parcels were selected. Farmers were contacted and it was agreed to sample the two first cuttings of the grass. However harvesting grass is often an urgent decision in a period with a lot of work on the field and high time pressure. On some parcels only one cut could be sampled and on other parcels even the third cut was sampled. The crop samples were analysed for dry matter content, N and P content.

The results of the yield sampling at the first cut show an average dry matter yield of 3.06 ton/ha. Dry matter yields ranged from only 0.61 ton/ha to 4.85 ton/ha (Table 104). Differences in dry matter yield and N-content resulted in a range of N-export of 23.87 to 131.92 kg N/ha at the first cut. P_2O_5-export at the first cut was situated between 7.57 and 34.76 kg P_2O_5/ha. For the second cut, yield sampling was done on only 4 parcels.

Table 104: Results of yield sampling on 10 grass parcels of the monitoring network in 2014, dry matter yield (ton/ha) and the mount of nutrients exported by the crop (kg N/ha, kg P_2O_5/ha).

	Cut 1			Cut 2			Cut 3		
	Dry matter (ton/ha)	N crop (kg N/ha)	P_2O_5 crop (kg P_2O_5/ha)	Dry matter (ton/ha)	N crop (kg N/ha)	P_2O_5 crop (kg P_2O_5/ha)	Dry matter (ton/ha)	N crop (kg N/ha)	P_2O_5 crop (kg P_2O_5/ha)
Derogation									
a	3.42	105.01	21.23	2.17	84.81	16.63			
b							3.41	139.72	34.34
c	1.88	65.13	16.73						
d	0.61	23.87	7.57						
e	4.85	131.92	34.76	3.13	91.51	25.91	2.66	90.54	21.89
f	4.54	131.11	31.69						
g	2.19	43.66	16.78	2.73	87.67	26.27			
No derogation									
h	3.29	128.22	34.63						
i	3.72	104.90	23.51	5.44	145.19	39.60			

These results confirm the large differences in yield between parcels. Dry matter yield at the second cut ranged from 2.17 to 5.44 ton/ha. The range for N and P-export was respectively 84.81-145.19 kg N/ ha and 16.63-39.60 kg P_2O_5/ha. At the third cut, sampled on two parcels, in average 3.03 ton of dry matter is harvested, and 115.13 kg N and 28.11 kg P_2O_5/ha are exported.

The nitrate-N soil balances made up regarding to the yield sampling (Figure 231 and Table 105), were negative (output higher than input) for 4 parcels out of 6. Parcels 'b', 'e' and 'f' show a high input combined with a high output and a rather low nitrate residue. On parcels 'g' and 'h' the lower input resulted in a clearly lower output. Parcel 'h' was grazed. The N-export by grazing is lower than in a mowing system.

For three parcels the nitrate-N soil balance could not be made because of incomplete information.

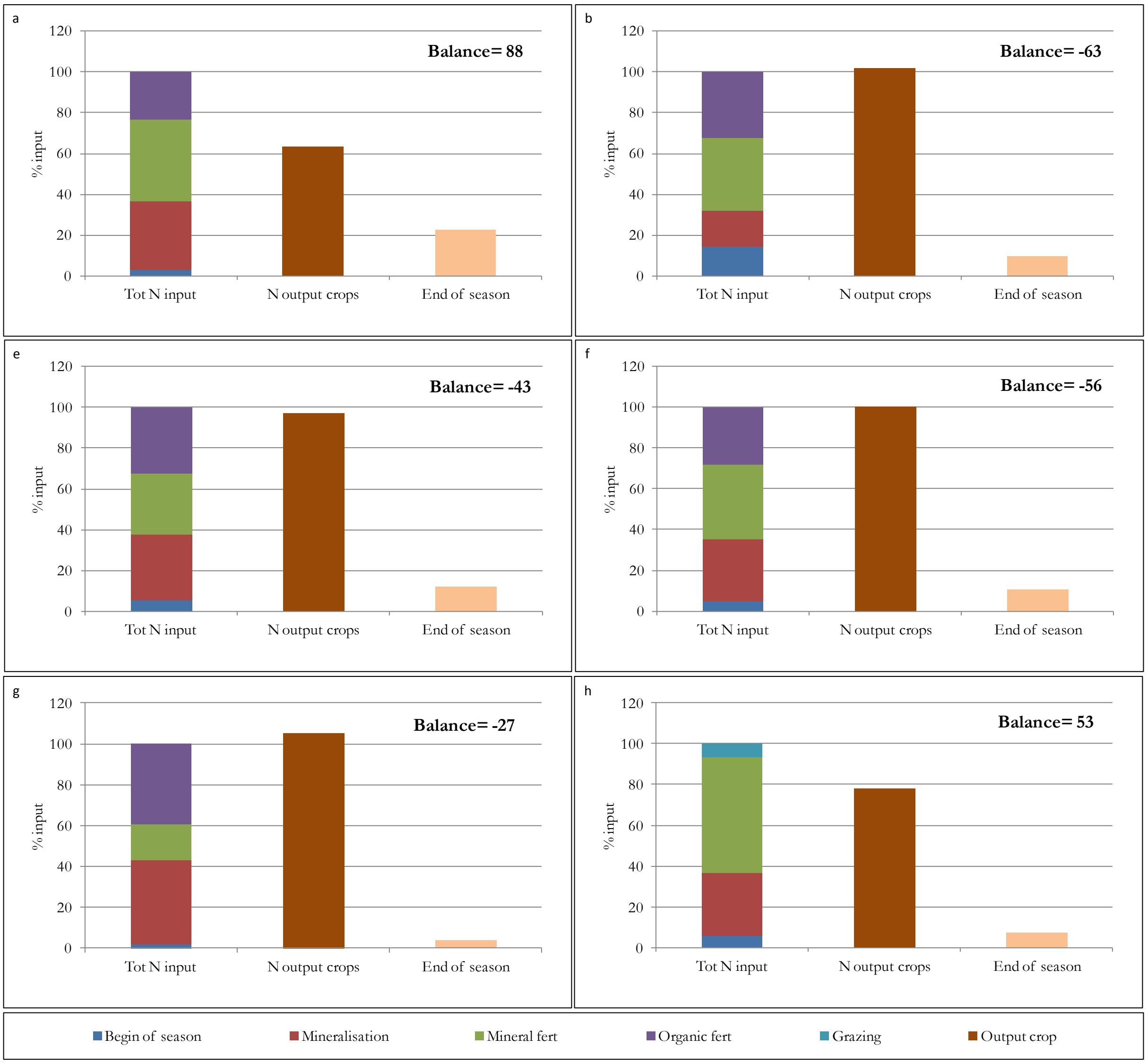


Figure 231: Nitrate-N soil balances for parcels with yield sampling of grass, percentage of each factor relative to total input-year 2014.

Table 105: Nitrate-N soil balances for parcels with yield sampling of grass, amount of nitrate-N by factor of input/output, year 2014.

a-Grass-only mowing, derogation, sandy soil

Nitrate in soil	28/03/2014	19	Uptake grass	harvest-export	343
				roots	45
Fertilisation	organic	144	Catch crop	spring 2014	0
	mineral	243		autumn 2014	0
	grazing	0			
Mineralisation	soil organic matter	208			
	Solid manure 2013	-			
	catch crop 2013	-			
	crop residue 2013	-			
			Residue	2/10/2014	138
		614			526
Result nitrate-N soil balance		88			

b-Grass-only mowing, derogation, sandy loam soil

Nitrate in soil	15/02/2014	76	Uptake grass	harvest-export	500
				roots	45
Fertilisation	organic	173	Catch crop	spring 2014	0
	mineral	191		autumn 2014	0
	grazing	0			
Mineralisation	soil organic matter	95			
	Solid manure 2013	-			
	catch crop 2013	-			
	crop residue 2013	-			
			Residue	8/10/2014	52
		534			597
Result nitrate-N soil balance		-63			

e-Grass-only mowing, derogation, clay soil

Nitrate in soil	30/01/2014	25	Uptake grass	harvest-export	407
				roots	45
Fertilisation	organic	151	Catch crop	spring 2014	0
	mineral	139		autumn 2014	0
	grazing	0			
Mineralisation	soil organic matter	150			
	Solid manure 2013	-			
	catch crop 2013	-			
	crop residue 2013	-			
			Residue	21/10/2014	56
		465			508
Result nitrate-N soil balance		-43			

f-Grass-only mowing, derogation, sandy soil

Nitrate in soil	20/03/2014	24	Uptake grass	harvest-export	470
				roots	45
Fertilisation	organic	145	Catch crop	spring 2014	0
	mineral	189		autumn 2014	0
	grazing	0			
Mineralisation	soil organic matter	156			
	Solid manure 2013	-			
	catch crop 2013	-			
	crop residue 2013	-			
			Residue	1/10/2014	55
		514			570
Result nitrate-N soil balance		-56			

g-Grass-only mowing, derogation, sandy soil

Nitrate in soil	31/01/2014	5	Uptake grass	harvest-export	281
				roots	45
Fertilisation	organic	122	Catch crop	spring 2014	0
	mineral	54		autumn 2014	0
	grazing	0			
Mineralisation	soil organic matter	129			
	Solid manure 2013	-			
	catch crop 2013	-			
	crop residue 2013	-			
			Residue	20/10/2014	11
		310			337
Result nitrate-N soil balance		-27			

h-Grass-grazing, no derogation, sandy loam soil

Nitrate in soil	19/02/2014	21	Uptake grass	harvest-export	240
				roots	40
Fertilisation	organic	0	Catch crop	spring 2014	0
	mineral	203		autumn 2014	0
	grazing	24			
Mineralisation	soil organic matter	112			
	Solid manure 2013	-			
	catch crop 2013	-			
	crop residue 2013	-			
			Residue	1/10/2014	26
		359			306
Result nitrate-N soil balance		53			

12.3.1.4 Maize parcels-2014

Ten maize parcels of the monitoring network were selected and on each parcel maize is harvested. Fresh weight was measured at the field and dry matter, N and P content were measured at the laboratory. At two parcels, ‘a’ and ‘h’, yield sampling resulted in aberrant values. For those two parcels the results and the nitrate-N soil balance is not shown.

The average yield of dry matter on the sampled maize parcels in autumn 2014 was 18.0 ton/ha, compared to 15.6 ton in autumn 2013. This confirms the overall expectation of a high yield of maize before the harvest season and the overall experience of the farmers in the maize season. Nevertheless an important variability between the parcels is still noticed. The largest dry matter yield was 22.0 ton/ha while smaller harvests of only 14.5 ton dry matter/ha were measured (Table 106). The variability in dry matter content and N content resulted in N export by the crop of 169 kg N/ha to 255 kg N/ha. For phosphorus an export range of 37-78 kg P_2O_5 was measured.

Table 106: Results of yield sampling on maize parcels in 2014, dry matter yield (ton/ha) and the amount of nutrients exported by the crop (kg N/ha, kg P_2O_5/ha).

	Dry matter (ton/ha)	N crop (kg N/ha)	P_2O_5 crop (kg P_2O_5/ha)
		Derogation	
a		aberrrant values	
b	19.4	217	78
c	14.5	169	37
d	19.8	190	53
e	15.5	189	40
		No derogation	
f	17.9	255	72
g	17.9	211	54
h		aberrrant values	
i	22.0	233	56
j	17.6	212	68

For parcels 'd' and 'j' information was incomplete and the nitrate-N soil balance could not be made.

The result of the nitrate-N soil balance was positive (input higher than output) for all parcels on which the yield of the maize was monitored. On parcels 'b', 'c' and 'e', derogation parcels, the uptake of the catch crop is obviously important. On the no derogation parcels ('f', 'g', 'i') in average 63 % of the total N input was recovered by the maize. On the derogation parcels ('b', 'c', 'e') in average 50 % of the total N input was recovered by the maize. However on these parcels the cover crop recovered 22 % of the total N input. On the no derogation parcels the cover crop recovered only 6 % of the total N input.

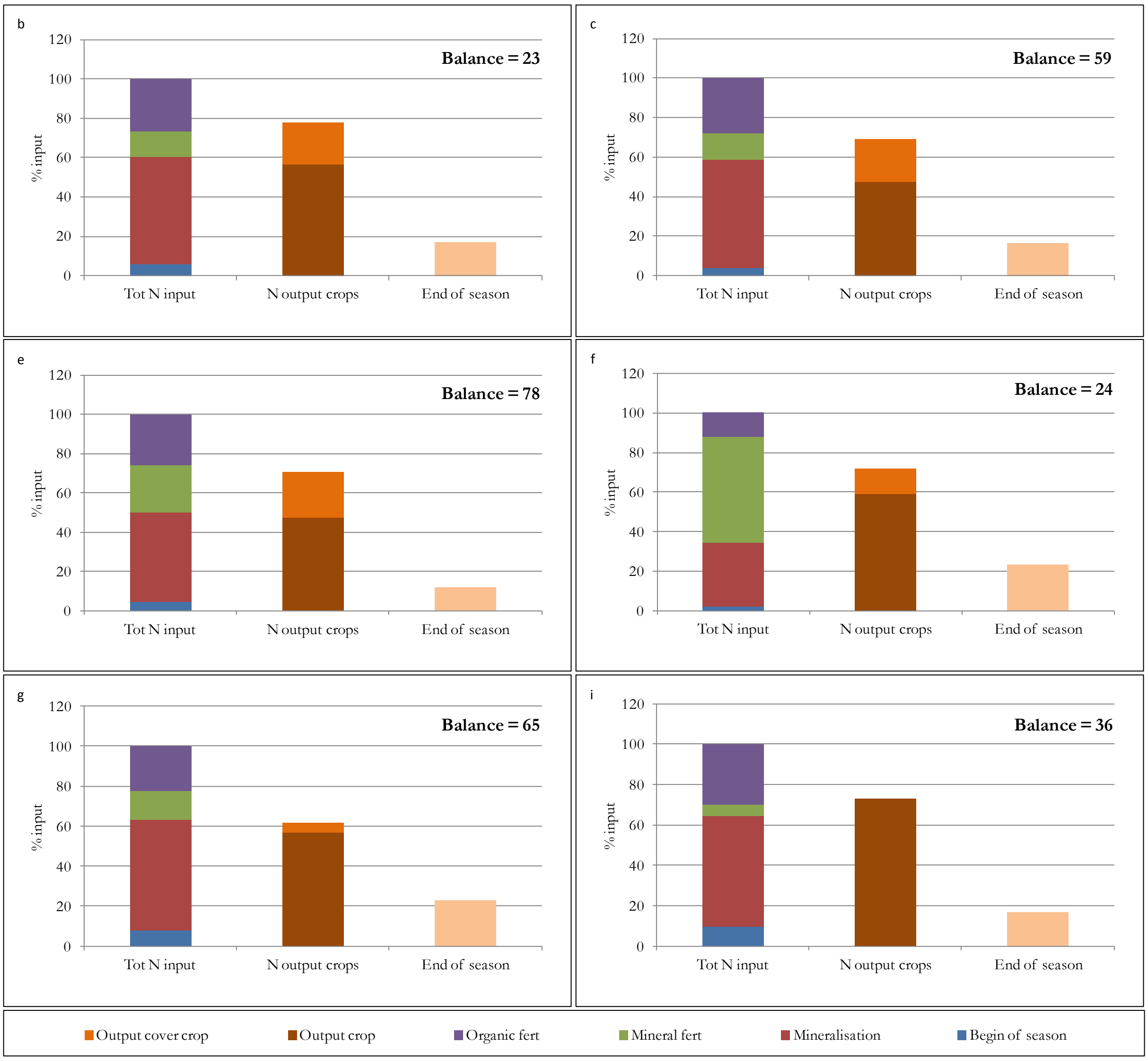


Figure 232: Nitrate-N soil balances for parcels with yield sampling of maize, percentage of each factor relative to total input-year 2014.

Table 107: Nitrate-N soil balances for parcels with yield sampling of maize, amount of nitrate-N by factor of input/output-year 2014.

b-Maize, derogation, sandy soil					
Nitrate in soil	28/01/14	24	Uptake maize	harvest-export	217
				roots	25
Fertilisation	organic	115	Catch crop	spring 2014	90
	mineral	54		autumn 2014	0
Mineralisatior	soil organic matter	215			
	Solid manure 2013	-			
	catch crop 2013	20			
	crop residue 2013	-			
			Residue	2/10/14	73
		428			405
Result nitrate-N soil balance		23			

c-Maize, derogation, sandy soil					
Nitrate in soil	29/01/14	16	Uptake maize	harvest-export	169
				roots	25
Fertilisation	organic	115	Catch crop	spring 2014	90
	mineral	54		autumn 2014	0
Mineralisatior	soil organic matter	206			
	Solid manure 2013	-			
	catch crop 2013	20			
	crop residue 2013	-			
			Residue	2/10/14	68
		411			352
Result nitrate-N soil balance		59			

e-Maize, derogation, sandy loam soil					
Nitrate in soil	10/02/14	20	Uptake maize	harvest-export	189
				roots	25
Fertilisation	organic	117	Catch crop	spring 2014	90
	mineral	108		autumn 2014	15
Mineralisatior	soil organic matter	186			
	Solid manure 2013	-			
	catch crop 2013	20			
	crop residue 2013	-			
			Residue	6/10/14	54
		451			373
Result nitrate-N soil balance		78			

f-Maize, no derogation, sandy loam soil					
Nitrate in soil	11/02/14	10	Uptake maize	harvest-export	255
				roots	25
Fertilisation	organic	57	Catch crop	spring 2014	60
	mineral	255		autumn 2014	0
Mineralisatior	soil organic matter	134			
	Solid manure 2013	-			
	catch crop 2013	20			
	crop residue 2013	-			
			Residue	14/10/14	111
		475			451
Result nitrate-N soil balance		24			

g-Maize, no derogation, sandy soil					
Nitrate in soil	26/02/14	33	Uptake maize	harvest-export	211
				roots	25
Fertilisation	organic	94	Catch crop	spring 2014	20
	mineral	60		autumn 2014	0
Mineralisatior	soil organic matter	194			
	Solid manure 2013	-			
	catch crop 2013	35			
	crop residue 2013	-			
			Residue	30/10/14	95
		416			351
Result nitrate-N soil balance		65			

i-Maize, no derogation, sandy soil					
Nitrate in soil	10/03/14	34	Uptake maize	harvest-export	233
				roots	25
Fertilisation	organic	106	Catch crop	spring 2014	0
	mineral	20		autumn 2014	0
Mineralisatior	soil organic matter	194			
	Solid manure 2013	-			
	catch crop 2013	0			
	crop residue 2013	-			
			Residue	23/10/14	60
		353			318
Result nitrate-N soil balance		36			

12.4 Nitrate-N/soil balance of 2010 and nitrate in monitoring wells, based on the travel time

In Vandervelpen *et al.* (2011), the nutrient balance was calculated for the growing season of 2010. Based on the travel time of nitrate from the parcels to the groundwater, it could be expected that a positive nutrient balance would result in more leaching and thus a higher nitrate concentration in the groundwater. Therefore, a correlation was made between the result of the nutrient balance for the growing season of 2010 and nitrate in the groundwater based on the travel time. The result is shown in Figure 233.

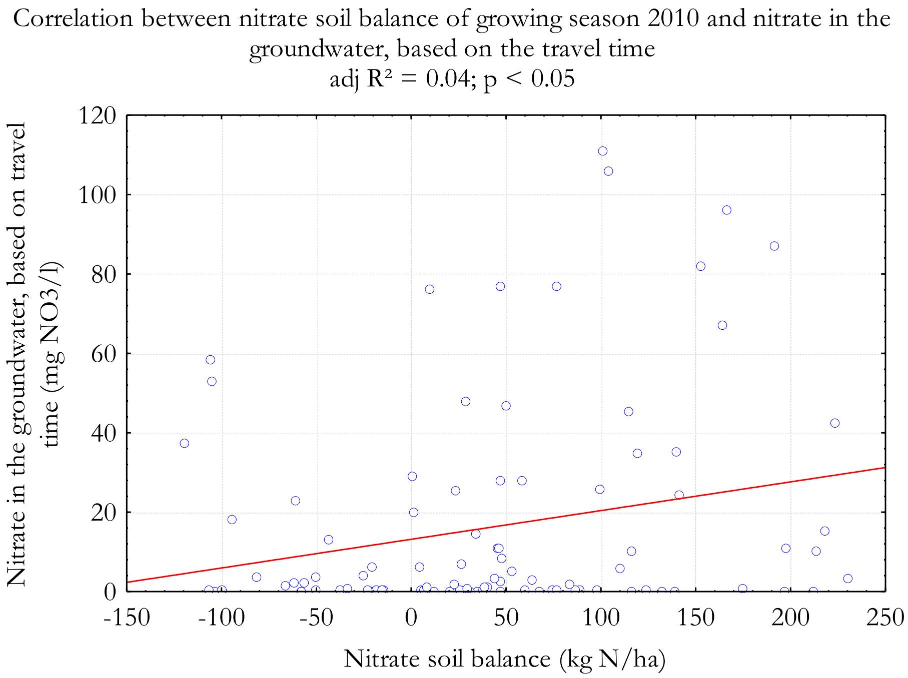


Figure 233: Scatterplot of calculated nitrate soil balance (kg N/ha) versus nitrate in the groundwater, based on the travel time (mg NO3/l).

There is a positive correlation between the result of the nitrate soil balance and the nitrate in the groundwater, based on the travel time. Only 4 % of the variance is explained by the model. This is probably due to the fact that almost all nitrate concentrations in the groundwater are below the detection limit.

12.5 Conclusion

The input/output balance evaluates roughly the input and the output. In 2012 the output was in average higher than the input. No correlation was found between the result of the input/output balance in 2012. In 2013 and 2014 the correlation between the nitrate residue and the result of the input/output balance was statistical significant. Higher balance results (input higher than output) correlated with higher nitrate residues. In 2013 the result of the input/output balance was often positive (input higher than output).

The results of the nitrate-N soil balance for derogation and no derogation parcels do not differ significantly.

The yield sampling confirmed even on a limited number of parcels, the high variability in N-export. Not only dry matter yield but also the nitrogen content can differ greatly which can result in a highly different N-export. More accurate figures of yield and N-export by yield sampling often help to realise a more accurate nutrient soil balance of the individual parcel. However even when N-export is measured the result of the nitrogen soil balance will not always reach zero. The yield sampling is an advantage for the individual parcel, but the aberrations realised in the nitrate-N soil balances based on average figures, will not be avoided by yield sampling.

Furthermore it needs to be mentioned that a result of zero for the nitrate-N soil balance does not mean that all factors of the balance are interpreted correctly. When different factors are interpreted wrong, and one is overestimated while the other one is underestimated, the result will still reach zero while the result could be negative or positive. Although it's sometimes difficult to interpret, the nitrate-N soil balance can be a useful instrument for declaring the input and output in more detail.

13 Simulation of the effect of derogation on the level of Flanders

Besides the monitoring of the possible effect of derogation on water quality which can at this moment already be measured, it's also opportune to look ahead and estimate the possible long term implications of the possibility of derogation on water quality. This way it will be possible to act not only curative but also pro-active.

13.1 ArcNEMO in general

The effect of derogation on water quality in Flanders can be estimated with ArcNEMO (Van Opstal et al., 2014). In this model, in a first step, the effect on fertilisation on parcel level is estimated with the Fertiliser Allocation Model (BemestingsAllocatieModel, BAM), which was developed for ArcNEMO. For this study, BAM was run for the years 2010, 2011 and 2012.

13.2 General procedure of BAM

BAM calculates the total amount of fertiliser used per farm and per year and assigns it to the agricultural parcels of each farm, taking into account the fertiliser type, the crop and the corresponding fertilisation limit.

In a first step, all parcels are fertilised consecutively per crop type, maximally up to the fertilisation limit (or until all fertilisers of the farm have been assigned). The following order is used: first the maize parcels, then grass, potatoes, sugar beets, vegetables, fruit, other crops, cereals, legumes.

For the farms where not all of the used fertiliser can be assigned in this way, a surplus fertilisation of maximum 150 % of the fertilisation limit is assigned to the maize, grass, cereal and legume parcels consecutively (second step).

Finally, the allocated fertilisation dosages on all the parcels are corrected per farm either according to its total fertiliser allocation capacity (i.e. sum of parcel areas multiplied by corresponding fertilisation limits) or according to its total amount of fertiliser used (the most limiting of both criteria). This correction guaranties that the total amount of fertiliser used by each farm is maximally assigned to its parcels, without exceeding its total fertiliser allocation capacity. In other words, the farm fertilisation balance (fertiliser allocation capacity – assigned fertiliser) will never be negative. As a consequence, if a scenario has an impact on the fertiliser allocation capacity, this impact will also be visible in the calculated fertilisation on parcel level.

13.3 The no derogation scenario (scenario 2)

For the evaluation of the effect of derogation on the fertilisation at parcel level in Flanders, the results of a scenario without derogation (scenario 2) are compared to the results of a reference scenario (scenario 0).

The reference scenario (scenario 0) is based on the real farm and parcel data (manure production, fertiliser use, crops, management agreement, granted derogation,…) of 2010, 2011 and 2012. For the determination of the fertilisation limits for each parcel, the stricter phosphorus limits applicable from 2018 were used:

- Grassland (mowing): 90 kg $P_2O_5.ha^{-1}.year^{-1}$ (instead of 95)
- Grassland (mowing & grazing): 90 kg $P_2O_5.ha^{-1}.year^{-1}$
- 1 grass cutting + maize: 90 kg $P_2O_5.ha^{-1}.year^{-1}$ (instead of 95)
- Maize: 70 kg $P_2O_5.ha^{-1}.year^{-1}$ (instead of 80)
- Winter wheat and triticale: 70 kg $P_2O_5.ha^{-1}.year^{-1}$ (instead of 75)
- Winter barley and other cereals: 70 kg $P_2O_5.ha^{-1}.year^{-1}$
- Other crops: 55 kg $P_2O_5.ha^{-1}.year^{-1}$ (instead of 65)

For the P-limits no distinction is made between sandy and non-sandy soils.

For P-saturated soils a general limit of 40 kg $P_2O_5.ha^{-1}.year^{-1}$ is applicable for all the crops. For P-saturated soils with low P-binding capacity the above mentioned P-limits minus 10 kg $P_2O_5.ha^{-1}.year^{-1}$ are applicable.

The no-derogation scenario (scenario 2) was calculated with the same farm and parcel data, but for the derogation parcels, fertilisation limits of no derogation parcels were applied.

13.4 Results scenario 2

Scenario 2 has a clear effect on the total fertiliser allocation capacity in Flanders. Without derogation the total fertiliser allocation capacity is lower for N from animal manure, but higher for P_2O_5 from mineral fertilizers (Figure 234).

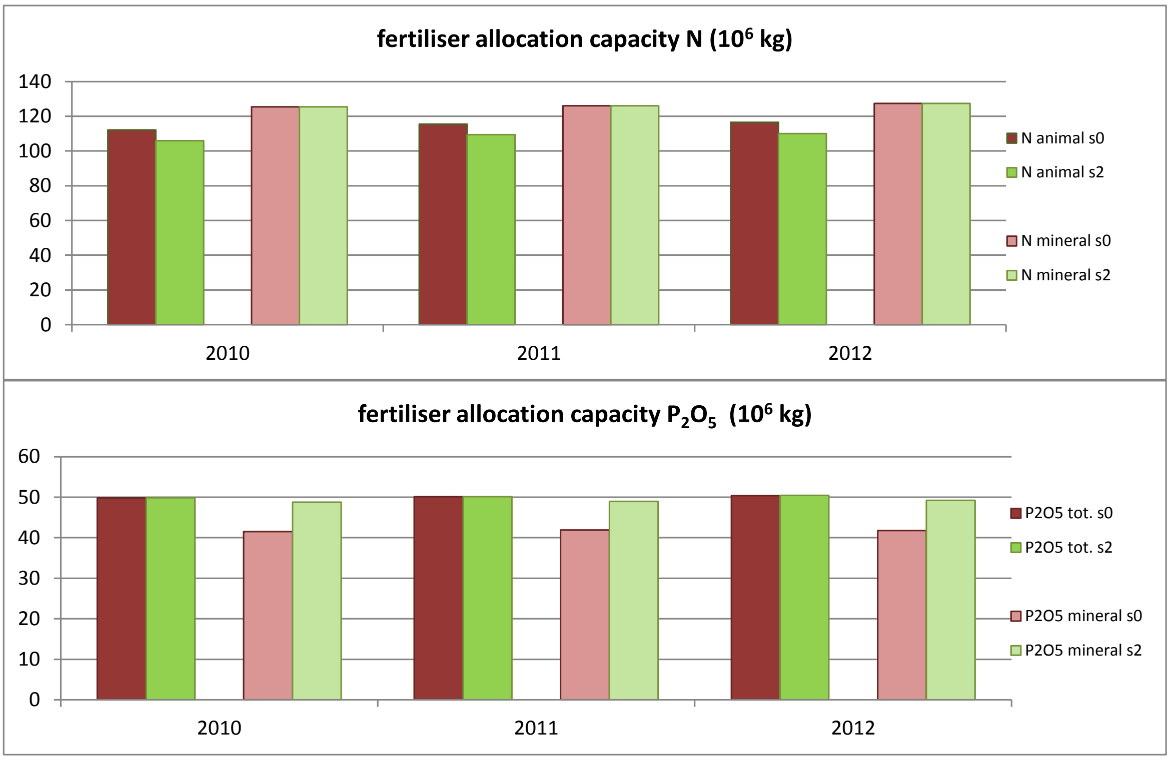


Figure 234: Total fertiliser allocation capacity in Flanders for N and P_2O_5 from animal manure and from mineral fertilisers.

As a consequence, BAM assigns less animal manure to agricultural parcels in scenario 2 than in the reference scenario (scenario 0). As for N, this effect is partially compensated by a slightly higher fertilisation with mineral fertilisers. As for P, fertilisation with mineral fertilisers is significantly higher in scenario 2 than in the reference scenario, due to the larger fertiliser allocation capacity of P from mineral fertilisers (Figure 235).

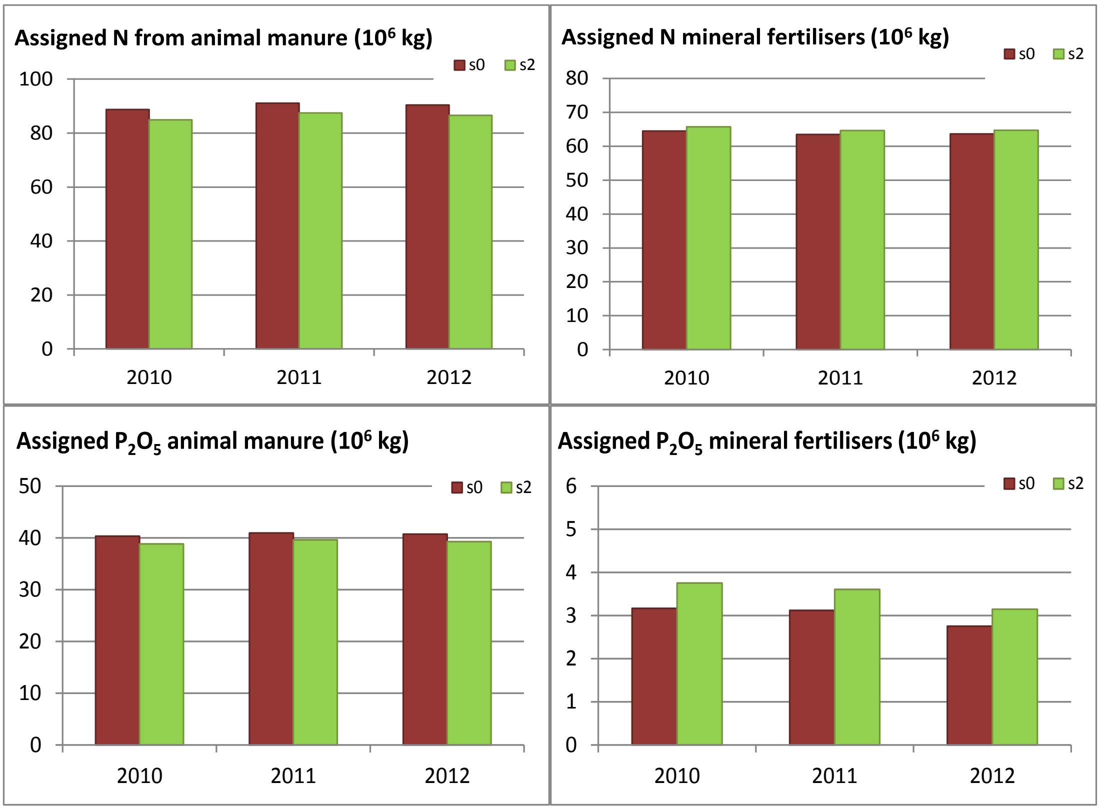


Figure 235: Total assignment of N and P_2O_5 from animal manure and from mineral fertilisers to agricultural parcels in Flanders, according to scenario 0 (red) and scenario 2 (green).

The lower assignment of animal manure in scenario 2 occurs mainly on the maize and grassland parcels. Therefore, because in derogation farms less manure can be assigned to maize and grassland parcels, in some cases more manure is available for the other crops, resulting in a sometimes slightly higher fertilisation dosage for these other crops.

The effects of scenario 2 on the calculated (animal and mineral) fertiliser dosages per crop is similar in the three years (2010, 2011 and 2012). In the next figure the results per crop are shown for N and P_2O_5 in 2012 (Figure 236).

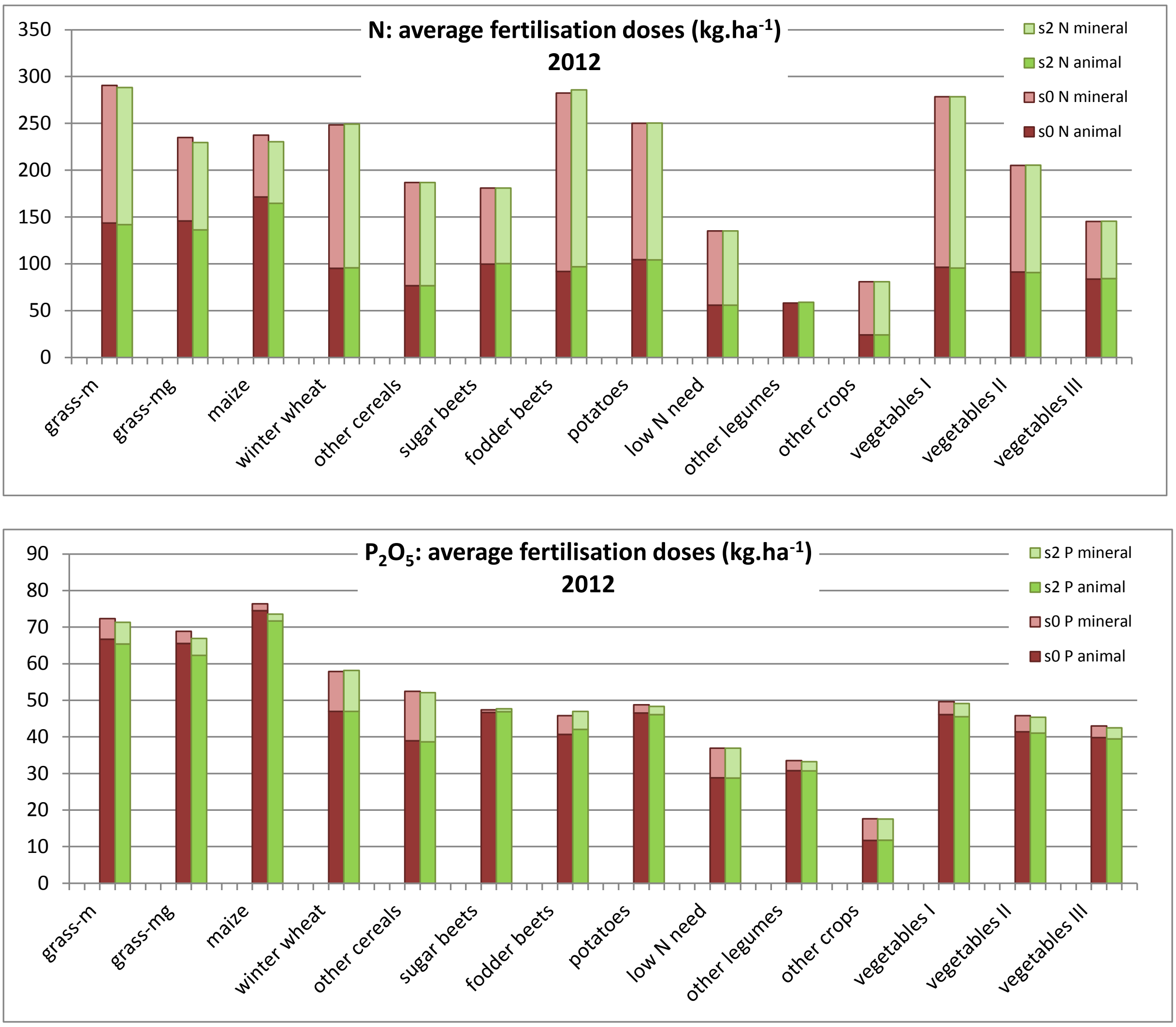


Figure 236: Average calculated N and P_2O_5 doses from animal manure and from mineral fertilisers per crop in 2012, according to scenario 0 (red) and scenario 2 (green).

13.5 Conclusion

Animal manure: In scenario 2 almost 4.10^6 kg or 4,2 % less N from animal manure is applied to parcels than in scenario 0, on the level of Flanders. For P_2O_5 from animal manure the difference is smaller: ± 3,6 % or $1,5.10^6$ kg.

Effective N: the lower amount of applied N from animal manure is partially compensated by a slightly higher application of mineral N. The difference in application of total effective N is on average $0,8.10^6$ kg or 0,8 % lower in scenario 2 than in scenario 0.

Total P_2O_5: In scenario 2 more P_2O_5 from mineral fertilisers is applied (+15 % or $+0,5.10^6$ kg). The total amount of applied P_2O_5 is only 2,3 % lower in scenario 2 than in scenario 0.

The results of the BAM simulations indicate that, on the level of Flanders, derogation has a limited impact on the application of animal manure (+4 % with derogation) and mineral fertilisers (-1,6 % for N and -15,2 % for P_2O_5 with derogation). This impact will probably be more pronounced in regions with relatively more derogation parcels, f.i. the regions of "Brugse Polders" , "Gentse Kanalen", "Maasbekken" and "Netebekken". Therefore, simulations with the ArcNEMO model for the estimation of the effect on water quality, will focus on these regions.

14 Process factors for groundwater

This section focuses on the calculation and analysis of process factors for groundwater for each of the monitored field plots for which both residual nitrate contents and nitrate concentrations in the shallow groundwater were determined. The process factor for groundwater is an empirical dimensionless factor that quantifies the degree of dilution and denitrification occurring from the moment that the nitrate leaches out of the root zone at 90 cm below the surface until the moment that it reaches the groundwater (where it is being measured with an observation well) (Van Overtveld et al., 2011). Low process factors (≈ 1) mean that the nitrate leached out of the root zone will be found in an almost equal concentration in the groundwater, whereas high process factors mean that the nitrate is diluted and/or denitrified and thus that a lower concentration will be measured in groundwater.

In Figure 237, the groundwater flow through a hypothetical cross section is shown. The process factor for groundwater is the ratio between the average nitrate concentration in the soil water at -90 cm over the winter period and the average nitrate concentration measured in a monitoring well of the phreatic groundwater that receives the water from the area where the nitrate concentration at the bottom of the root zone is determined. Similarly, a process factor for surface water can be defined as the ratio between the average nitrate concentration below the root zone at -90 cm and the mean nitrate concentration in the surface water recipient. In this study we only focussed on the process factor for groundwater.

The EU Nitrates Directive (91/676/EEC) states that the nitrate concentration in surface water or groundwater should not exceed 50 mg NO_3^- per litre of water. Process factors for ground water are therefore a useful mean to determine the maximum nitrate concentration below the root zone of a parcel, in order not to exceed this limit of 50 mg/l in the groundwater.

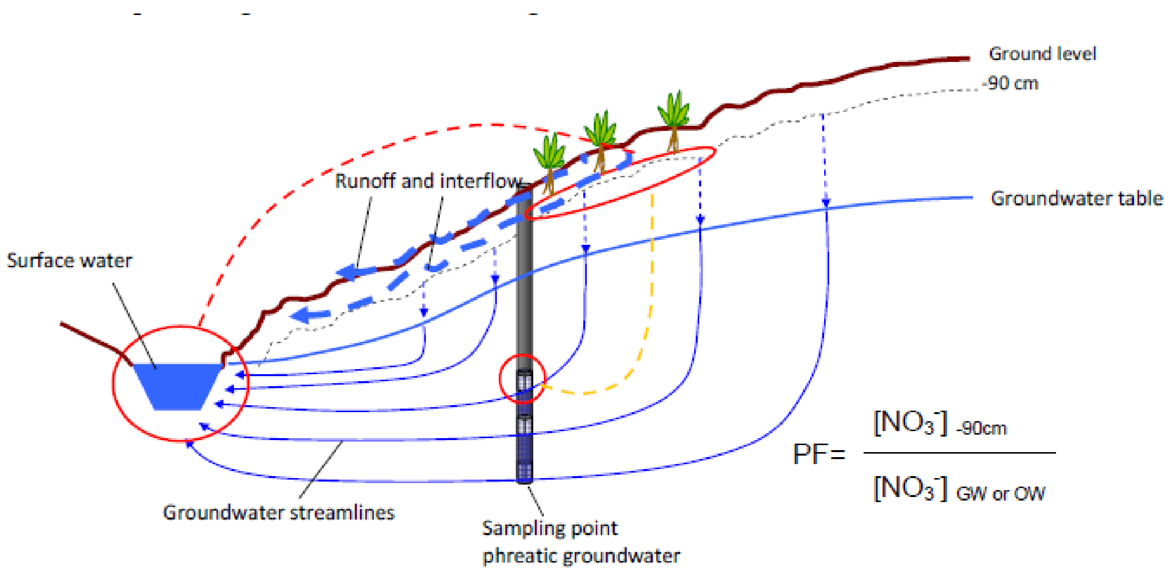


Figure 237: Schematic representation of groundwater flow and process factors related to surface water and groundwater. The process factor for groundwater (GW) is defined as the ratio between the average nitrate concentration below the root zone over the winter period and the average concentration in the groundwater monitoring well (yellow dotted line). A similar process factor for surface water (OW) is defined as the ratio the average nitrate concentration below the root zone and the concentration in the surface water (red dotted line) (from Van Overtveld et al., 2011).

14.1 Calculation of the process factor for groundwater.

14.1.1 Determination of the recharge zone of monitoring wells and of travel times from soil to well

For each monitoring well, the contributing recharge area was determined as an elliptical region, upstream of the sampling point, from which the water measured in the sampling point originates with 75 % certainty (Figure 238). For each sampling point, the travel time through the unsaturated and saturated zone was also calculated.

This was achieved by calculating (i.e. back-tracking) the flow line from the middle of the well to the water divide based on a groundwater map for Flanders. That map was derived in 2009 by kriging the available groundwater head observations and using predictions from a simple groundwater model that was constrained on water levels in the surface water network. The map was obtained by combining both sources of information using Bayasian Data Fusion (Peeters et al., 2010; Van Overtveld et al., 2011). Once the flow line through the well was determined, the most likely position of the recharge point of the monitoring well filter on the flow line (upstream from the well) was determined from the vertical position of the filter relative to the phreatic surface and the base of the aquifer. Spatial variability in transmissivities implies that flow lines and hence the recharge point is subject to uncertainty. This consideration and literature information on typical spatial variation of transmissivities led to the definition of an elliptical region situated around the calculated recharge point, from which the water measured in the sampling point originates with 75 % certainty.

The travel time in the saturated zone (from the moment the soil water reaches the water table till the moment it reaches the filter of the monitoring well) was calculated from flow velocities and the horizontally travelled distance along the flow line. The travel time in the unsaturated zone (from soil surface to phreatic surface) was estimated as well by using the integral form of the Darcy equation (see section 14.1.2) (Jury and Horton, 2004, eq. 3.42). All calculations were performed in Matlab R2013a (The MathWorks Inc., Natick, MA, USA). The full details of the procedures and theoretical background is given by Van Overtveld et al. (2011).

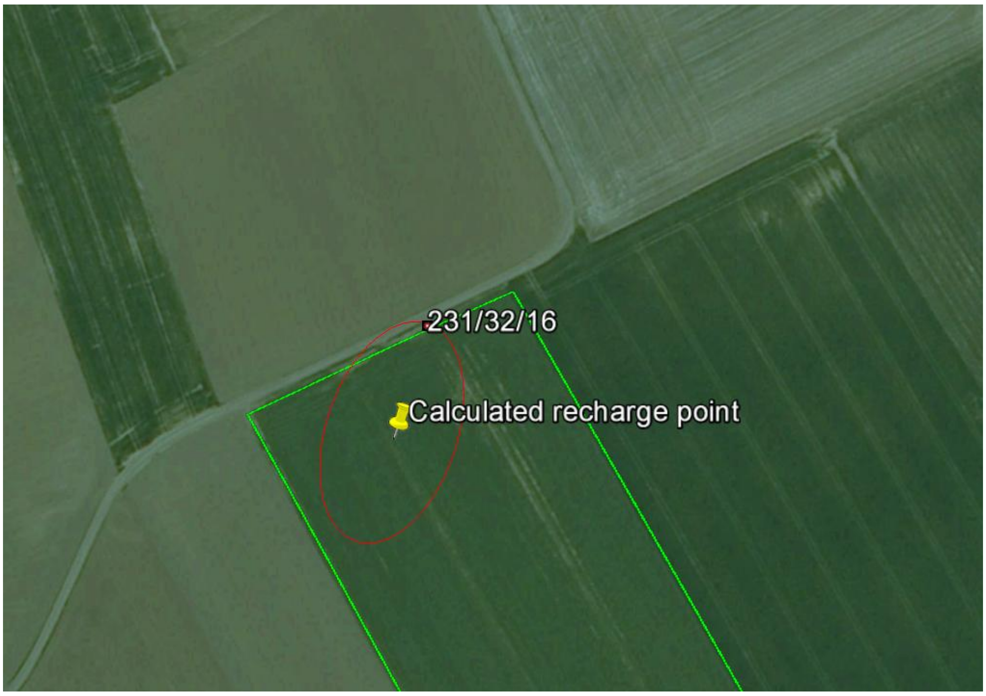


Figure 238: Aerial photograph (Google Earth, Image from Aerodata International Surveys) showing position of a monitoring well (labeled 231/231/16) and the calculated recharge point of the filter of the well (yellow placeholder). An ellipse around the calculated recharge point delineates the zone from which the water measured in the monitoring well originates with 75 % certainty.

14.1.2 Calculation of the average nitrate concentration at the bottom of the root zone (-90 cm)

Between October 1st and November 15th soil samples were taken in the monitored farmers' fields. In these soil samples the amount of nitrate in the soil profile from 0 to 30, 30 to 60 cm and 60 to 90 cm was measured, in order to determine the residual nitrate content. During winter there is little nitrate uptake by crops and most of the residual nitrate leaches out of the soil profile due to the precipitation excess (precipitation – evapotranspiration) over the winter period. The average nitrate concentration at -90 cm over the winter period for the fields that contained the recharge zone (75 % confidence ellipse) was calculated from the measured residual nitrate from 0 to 30, 30 to 60 cm and 60 to 90 cm using an analytical leaching model (an analytical solution of the convection-dispersion equation; Van Overtveld et al., 2011).

The higher the residual nitrate, the higher is the predicted concentration, but other factors that influence the average nitrate concentration at -90 cm over the winter period are (1) the precipitation excess over that winter (precipitation- reference evapotranspiration from ET0 from November 1st till March 31st was given as input to the model, (2) the vertical distribution of the nitrate in the profile (measured distribution of nitrate over the 3 layers 0-30, 30-60 and 60-90cm) and (3) the factors that control the soil moisture content in the unsaturated zone over the winter time (mainly soil texture and groundwater depth).

Precipitation excess was calculated for each parcel. Each parcel of the network is linked to a combination of the 3 closest weather stations which were retained and the data are the result of a weighed average of the observations between the 3 weather stations. For each weather station it is important that the observed data are complete. Only the weather stations where 95 % or more of the rainfall data were available from October to March were retained. For the dates where no rainfall data were available from these stations, the mean of rainfall of the region of Flanders was used for that specific date. Calculations for ETo are available from different stations. However, stations without data of ETo, or if one date is missing, are replaced in this analysis by the mean ETo of the region of Flanders for a specific date. An overview of the different stations with observations for rainfall and evapotranspiration are listed in Table 73.

The soil map unit of each monitored field was derived from the Belgian Soil Map (scale 1:20000). Next, a representative synthetic soil profile (with most common horizon sequence and thickness, %sand, %silt, %clay, %C of each layer) was derived for each combination of soil map unit and physical soil region ("Centrale Vlaamse laagvlakte", "Kempische Cuesta", …), using the soil database Aardewerk (Van Orshoven et al., 1993; Beckers et al., 2011). Bulk density of each soil layer was estimated using the pedotransfer function of Rawls (1983) in combination with the mineral densities for the Belgian soil textural classes derived by Boon (1984) (See Van De Vreken et al., 2009, p. 53). Next the soil hydraulic properties (parameters of the van Genuchten-Mualem model) were calculated for each layer for each synthetic soil profile from %sand, %silt, %clay, %C and bulk density using the pedotransfer functions of Weynants et al. (2009).

Using this information, the vertical variation of the soil water content in the winter period was derived using the integral form of the Darcy equation (Jury and Horton, 2004, eq. 3.42), starting the upward integration from the measured phreatic surface, and assuming steady state flow conditions with the vertical downward flux (mm/day) calculated as the precipitation excess (mm) over the winter period (November 1st to March 31st) divided by the number of days in that period (151 days). An analytical solution of the convection dispersion model given by Torride et al. (1993; 1995) was finally used to calculate the evolution of the flux-averaged nitrate concentration at 90cm depth over the winter period (initial value problem with initial nitrate concentration derived from measured residual nitrate, and nitrate leaching under steady state flow conditions in a half-infinite soil column). This concentration was next integrated over the precipitation excess to obtain the average nitrate concentration at 90cm depth averaged over the winter period. All calculations were performed in Matlab R2013a (The MathWorks Inc., Natick, MA, USA). The full details of the procedures and theoretical background is given by Van Overtveld et al. (2011).

As the residual nitrate was measured in the fall of 2009, 2010, 2011, 2012, and 2013, the average nitrate concentrations of all monitored fields were calculated for the 5 winter periods that followed the 5 samplings.

14.1.3 Calculation of the process factors

The process factor was calculated as:

$$PF = \frac{[NO_3^{\,-}]_{-90cm,\ t}}{[NO_3^{\,-}]_{GW,\ t+\Delta t}}$$

where $[NO_3^{\,-}]_{-90cm,\ t}$ is the average concentration at the bottom of the root zone (-90cm) at time t, and $[NO_3^{\,-}]_{GW,\ t+\Delta t}$ is the concentration measured in the monitoring well at time $t + \Delta t$. Δt is the travel time of water (and hence of nitrate) from the bottom of the root zone to the filter of the monitoring well.

It means that if the travel time Δt is, say, 1.5 years, the average concentration at the bottom of the root zone over, say, the 2009-2010 winter period (i.e., centred around 15/1/2010), has to be compared with the nitrate concentration measured in the monitoring well around 15/7/2011 (1.5 years later). Nitrate concentrations in the monitoring wells were measured twice a year (in fall and spring, taken as November 1st and May 1st, respectively). To obtain a concentration in the well around 15/7/2011, a weighted average was made of the last measurement before and after that date (i.e. 1/5/2011 and 1/11/2011). The closer the target date is to one of the measurement dates, the more weight is given to the value. In case one of the two measurements was missing, the other measurement was used without any averaging.

Since residual nitrate was measured each fall from 2009 till 2014, and nitrate measurements in the monitoring wells were performed from fall 2009 till spring 2014, several PF values could be calculated for most of the fields, the number depending on the travel time of that field. These values were then averaged to obtain a single PF value for each field. Fields with a travel time longer than 4 ½ years were excluded as the monitoring period was too short to have a matching pair of nitrate concentrations.

Before performing the calculations, the recharge area of all the wells was calculated and compared with the field boundary in Google Earth. Only fields where the confidence ellipse largely falls within the field boundary were retained. For a few monitoring wells, the ellipse fell within 2 or 3 adjacent fields that were all monitored. In this case $[NO_3^{\,-}]_{-90cm,\ t}$ was averaged over these fields. A total of 110 wells (82 VMM wells, 26 wells installed for this study) were in this way linked to fields of the monitoring network, and could be used to calculate the PF.

14.2 Results and discussion

14.2.1 Relationship between measured residual nitrate content and soil solution nitrate concentration at -90cm

The residual nitrate content of the soil is the dominant factor that controls the calculated soil solution nitrate concentration at -90cm over the winter period, but the results also indicate differences between fields (soil texture, groundwater depth, precipitation excess), and small differences between years (precipitation excess and groundwater depth) (Figure 239). For a residual nitrate content of 90 kg NO_3^--N/ha (the main threshold in Flanders), soil solution nitrate concentration at -90 cm were predicted to range between 70 and 160 mg NO_3^-/L (horizontal dotted lines in Figure 239). In order to bring the nitrate concentration down from 70 mg NO_3^-/L to 50 mg NO_3^-/L in a groundwater monitoring well, the PF should have a value of at least 1.4 (=70/50). To bring the concentration down from 160 to 50 mg NO_3^-/L, the PF should be at least 3.2 (=160/50).

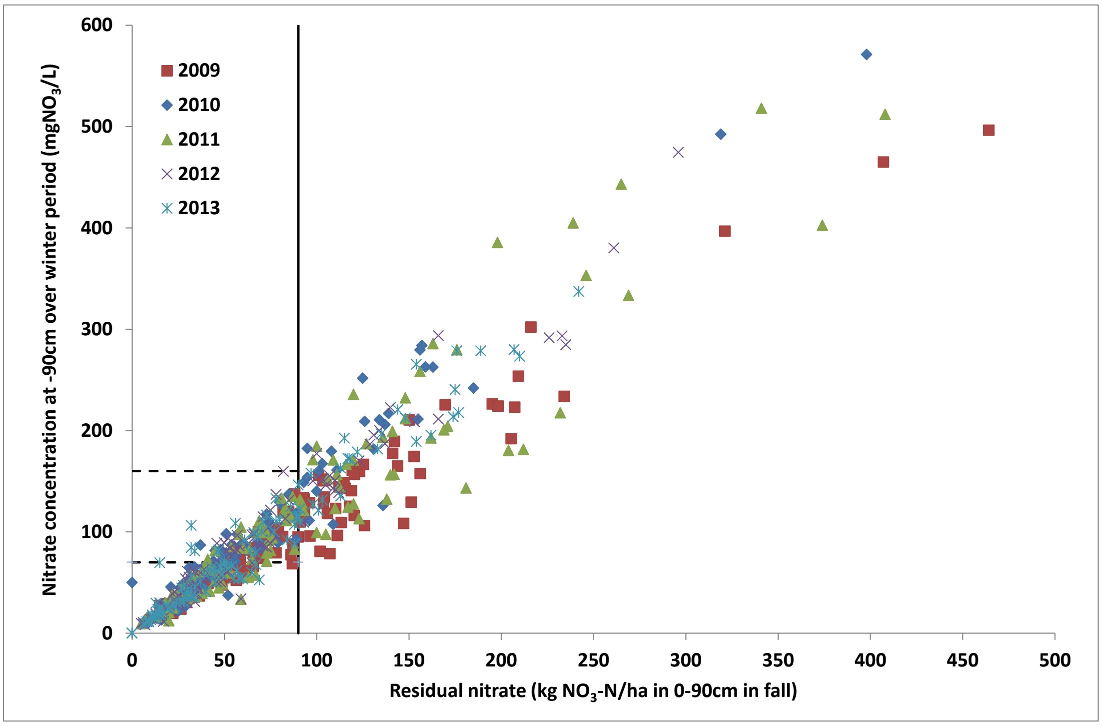


Figure 239: Relationship between the residual nitrate content measured in fall and the calculated average nitrate concentration in the soil water at a depth of -90cm (averaged over the winter period following the residual nitrate measurement) in 2009, 2010, 2011, 2012, and 2013 for 108 fields. The black vertical line indicates the threshold value for the residual nitrate in Flanders (90 kg NO_3^--N ha^{-1}). The horizontal dotted lines indicate that for a residual nitrate content of 90 kg NO3-N ha^{-1}, the nitrate concentration at the bottom of the root zone over the winter period varies between 70 and 160 mg NO_3^-/L.

14.2.2 Variation of the process factor for groundwater

The travel times of the 108 wells ranged between 0.5 and 4.2 years, having an average of 2.0 years. The PF varied between 0.34 and 1980, having an average of 235. The value 0.34 is an outlier, and other values start from around 1, as it should be. A PF equal to 1 means that no dilution and denitrification occurs. A value smaller than one would mean the nitrate concentration increase as the water (and nitrate) moves through vadose and saturated zone to the monitoring well, which is impossible. On a linear scale, the PF shows a very skewed distribution (graph not shown). When bin limits are defined in accordance with a log scale, the histogram shows an irregular bimodal distribution (Figure 240). Wells for which PF>50 are presumably wells where strong reducing conditions occur and almost all the nitrate is removed by denitrification.

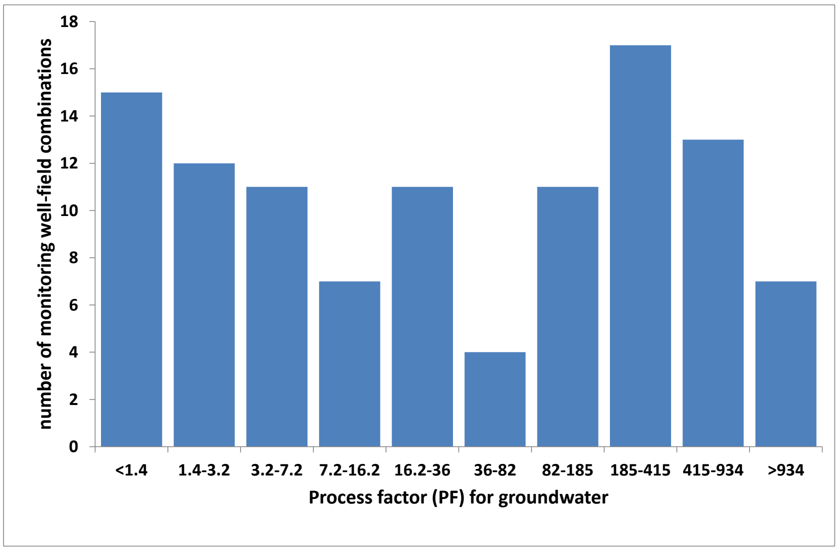


Figure 240: Histogram of the PF observed for the 108 plots with matching residual nitrate contents and nitrate concentrations in the groundwater monitoring well. Boundaries for the bins were defined in accordance with the observation that assuming PF varies over a logarithmic scale.

The cumulative distribution of the observed PF values (Figure 241) indicates that 14 % of the fields had a PF<1.4, the value at least needed to ensure that all fields result in a nitrate concentration in the groundwater smaller than the EU threshold of 50 mg NO_3^-/L provided the residual nitrate content remains below 90 kg NO_3^--N/ha (see section 14.2.1). Twenty-five % of the fields had a PF<3.2.

The distribution is similarly shaped as the distribution observed by Van Overtveld et al. (2009) (gray dots in Figure 241), except that there are fewer wells with a PF smaller than 1, which is presumably because in the present study the nitrate residue was always measured, while in the previous study it was in most cases estimated, thus creating more variation in PF values (and a wider distribution) and more values below one. A value below one is presumably an artefact occurring when residual nitrate content in the soil and hence the soil solution nitrate concentration at the bottom of the root zone is underestimated. The new distribution is also shifted to the right (Figure 241).

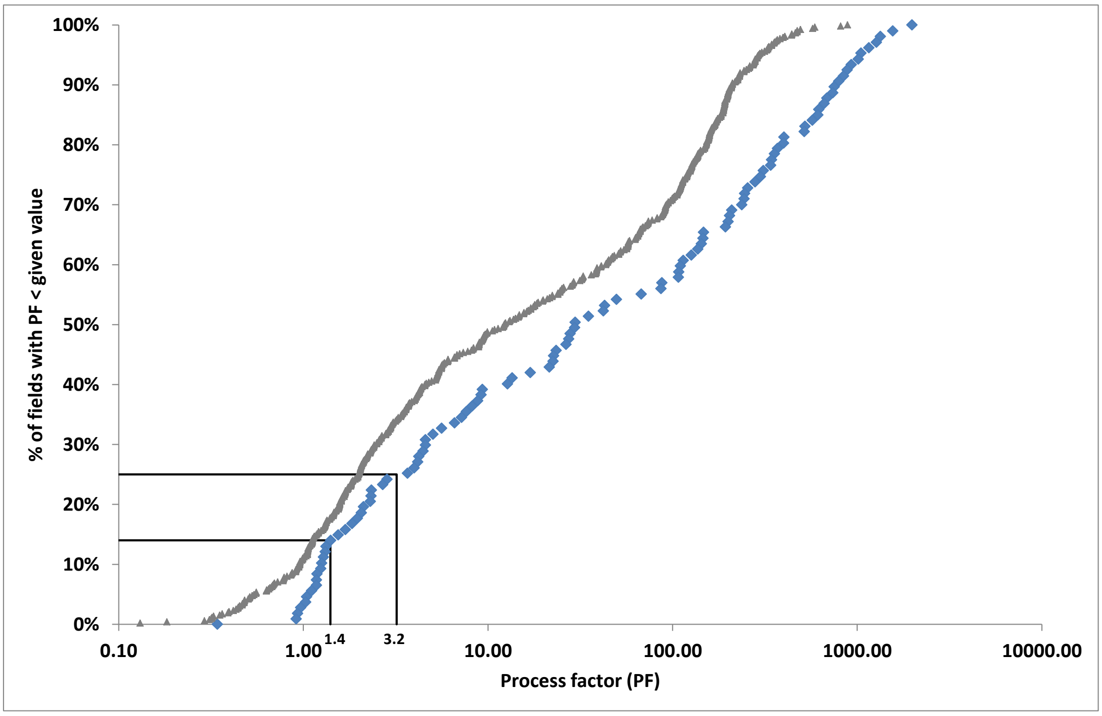


Figure 241: Cumulative distribution of the PF observed for the 110 plots with matching residual nitrate contents and nitrate concentrations in the groundwater monitoring well (blue symbols). For comparison the distribution observed by Van Overtveld et al. (2009) for 525 monitoring wells is also shown (gray symbols). The black lines vertical indicate the % of fields with pF< 1.4 and pF<3.2.

A map showing the spatial distribution of the PF in Flanders (Figure 242) shows that the PF is highly variable in space and does not show a clear spatial pattern. This was already observed in the study by Van Overtveld *et al.* (2011) (Figure 243).

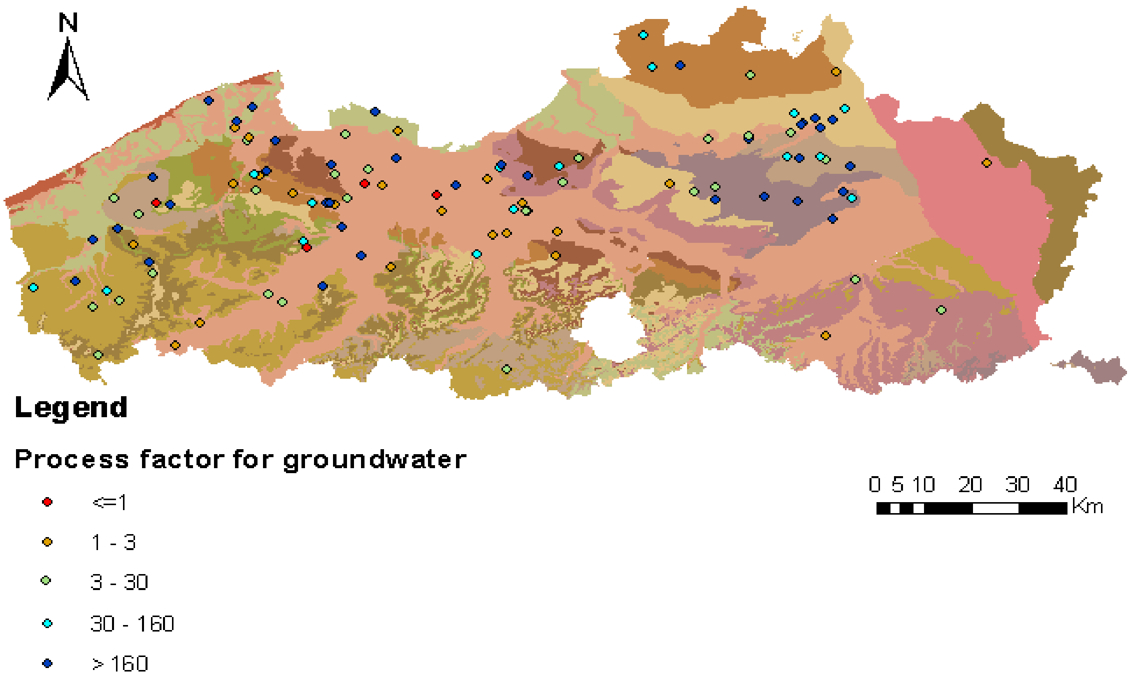


Figure 242: Spatial distribution of the PF groundwater (value shown with color code) observed for the 108 plots with matching residual nitrate contents and nitrate concentrations in the groundwater monitoring well. For comparison we used the same bin boundaries as in the study by Van Overtveld (2009, p. 112). The hydrogeologically homogeneous zones in Flanders are shown as background colors.

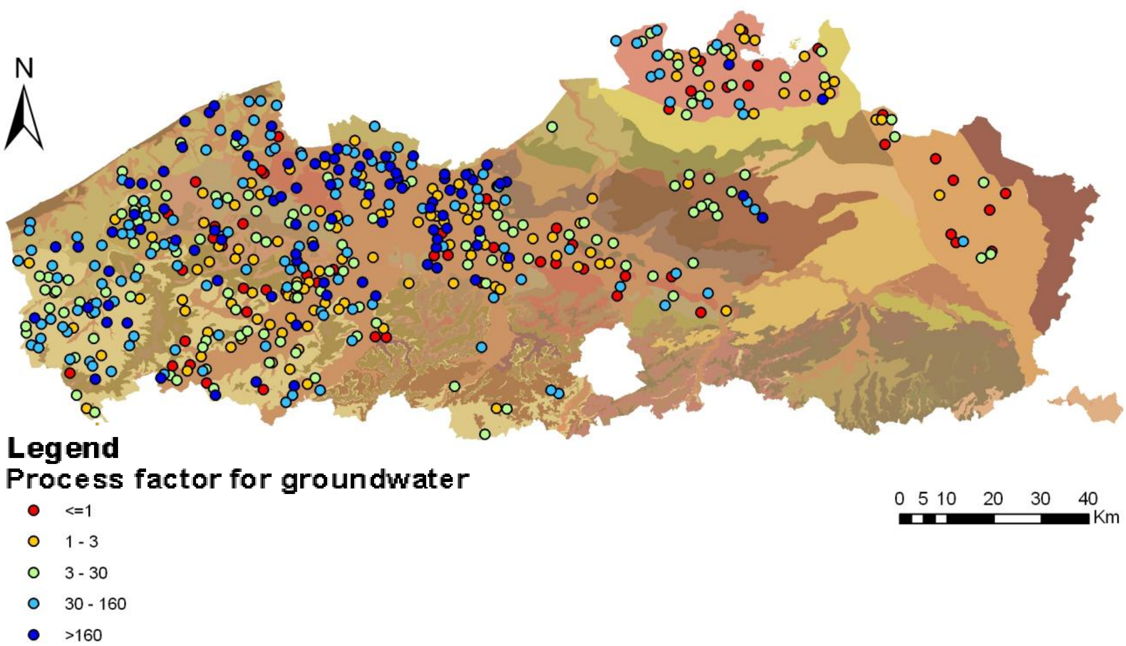


Figure 243: Spatial distribution of the PF groundwater (value shown with color code) observed for the 525 monitoring wells in the study by Van Overtveld (2009, p. 112). The hydrogeologically homogeneous zones in Flanders are shown as background colors.

15 Conclusion

Comparable to the results of 2009-2011 (Vandervelpen *et al.*, 2011), derogation did not lead to statistical significant differences in nutrients, nor in soil nor in water.

In the monitoring network soil and water samples were taken at different times (from autumn 2011 until autumn 2014). The most important parameters analysed on these samples are nitrogen and phosphorous. For both types of samples (soil and water), no statistically significant differences could be found between derogation and no derogation parcels. No statistical differences were observed for leached amount of nutrients during winter between derogation and no derogation parcels.

In general, derogation parcels are characterized by higher levels of fertilisation by organic and mineral fertilisers. Moreover, the amount of nutrients exported on derogation parcels are on higher levels, mainly by the export of an extra cut of grassland. This higher yield is the reason why higher levels of fertilisation do not result in higher nitrate residue levels or higher concentrations of phosphorous and nitrate-N in surface water and groundwater originating from derogation parcels.

Even for long term derogation and no-derogation parcels no statistical significant differences are found. Linking parcel characteristics and the resulting water samples, showed no statistical difference between derogation and no derogation parcels.

The process factor was evaluated for the parcels of the network, when a monitoring well or a MAP sampling point was present. It is confirmed again that the process factor groundwater is highly variable without a clear spatial pattern.

Based on this extensive network of parcels and the variety of measurements on parcels and in the water, derogation in Flanders has no negative impact on the water quality.

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Annex 1

Table 108: Different soil fertility classes for pH-KCl for arable land for different soil textures (only valid with normal carbon levels).

Class	pH-KCl Sand	pH-KCl Sandy-loam	pH-KCl Loam	pH-KCl Polder
Strongly acid	< 4.0	< 4.5	< 5.0	< 5.5
Low	4.0 - 4.5	4.5 - 5.5	5.0 - 6.0	5.5 - 6.4
Rather low	4.6 - 5.1	5.6 - 6.1	6.1 - 6.6	6.5 - 7.1
Optimal level	5.2 - 5.6	6.2 - 6.6	6.7 - 7.3	7.2 - 7.7
Rather high	5.7 - 6.2	6.7 - 6.9	7.4 - 7.7	7.8 - 7.9
High	6.3 - 6.8	7.0 - 7.4	7.8 - 8.0	8.0 - 8.1
Very high	> 6.8	> 7.4	> 8.0	> 8.1

Table 109: Different soil fertility classes for pH-KCl for grassland for different soil textures (only valid with normal carbon levels).

Class	pH-KCl Sand	pH-KCl Sandy loam - loam	pH-KCl Polder
Strongly acid	< 4.4	< 4.6	< 4.9
Low	4.4 - 4.7	4.6 - 5.1	4.9 - 5.3
Rather low	4.8 - 5.0	5.2 - 5.6	5.4 - 5.6
Optimal level	5.1 - 5.6	5.7 - 6.2	5.7 - 6.4
Rather high	5.7 - 5.9	6.3 - 6.5	6.5 - 6.8
High	6.0 - 6.4	6.6 - 7.0	6.9 - 7.2
Very high	> 6.4	> 7.0	> 7.2

Table 110: Different soil fertility classes for percentage carbon for arable land for different soil textures.

Class	%C Sand	%C Sandy loam-loam	%C Polder
Very low	< 1.2	< 0.8	< 1.0
Low	1.2 - 1.4	0.8 - 0.9	1.0 - 1.2
Rather low	1.5 - 1.7	1.0 - 1.1	1.3 - 1.5
Optimal level	1.8 - 2.8	1.2 - 1.6	1.6 - 2.6
Rather high	2.9 - 4.5	1.7 - 3.0	2.7 - 4.5
High	4.6 - 10.0	3.1 - 7.0	4.6 - 10.0
Peaty	> 10.0	> 7.0	> 10.0

Table 111: Different soil fertility classes for percentage carbon for grassland for different soil textures.

Class	%C All soil textures, except loam	%C Loam
Very low	< 2.0	< 1.5
Low	2.0 - 2.9	1.5 - 2.0
Rather low	3.0 - 3.5	2.1 - 2.5
Optimal level	3.6 - 5.5	2.6 - 4.2
Rather high	5.6 - 7.0	4.3 - 6.5
High	7.1 - 10.0	6.6 - 9.0
Peaty	> 10.0	> 9.0

Table 112: Different soil fertility classes for phosphorus for arable land (only valid for soils with a specific gravity of 1.3).

Class	mg P/100 g dry soil (A.L.-extract) all soil textures
Very low	< 5
Low	5 - 8
Rather low	9 - 11
Optimal level	12 - 18
Rather high	19 - 30
High	31 - 50
Very high	> 50

Table 113: Different soil fertility classes for phosphorus for grassland (only valid for soils with a specific gravity of 1.3).

Class	mg P/100 g dry soil (A.L.-extract) all soil textures
Very low	< 8
Low	8 - 13
Rather low	14 - 18
Optimal level	19 - 25
Rather high	26 - 40
High	41 - 60
Very high	> 60

Table 114: Different soil fertility classes for K for arable land for different soil textures (only valid for soils with a specific gravity of 1.3).Table 115: Different soil fertility classes for K for arable land for different soil textures (only valid for soils with a specific gravity of 1.3).

Class	mg K/100 g dry soil (A.L.-extract) Sand	mg K/100 g dry soil (A.L.-extract) Sandy loam-loam	mg K/100 g dry soil (A.L.-extract) Polder
Very low	< 5	< 6	< 8
Low	5 - 8	6 - 10	8 - 12
Rather low	9 - 11	11 - 13	13 - 15
Optimal level	12 - 18	14 - 20	16 - 25
Rather high	19 - 30	21 - 35	26 - 40
High	31 - 50	36 - 60	41 - 70
Very high	> 50	> 60	> 70

Table 116: Different soil fertility classes for K for grassland for different soil textures (only valid for soils with a specific gravity of 1.06).

Class	mg K/100 g dry soil (A.L.-extract) All soil textures except polder	mg K/100 g dry soil (A.L.-extract) Polder
Very low	< 4	< 7
Low	4 - 6	7 - 11
Rather low	7 - 11	12 - 19
Optimal level	12 - 20	20 - 28
Rather high	21 - 28	29 - 36
High	29 - 45	37 - 50
Very high	> 45	> 50

Table 117: Different soil fertility classes for Mg for arable land for different soil textures (only valid for soils with a specific gravity of 1.06).

Class	mg Mg/100 g dry soil (A.L.-extract) Sand	mg Mg/100 g dry soil (A.L.-extract) Sandy loam-loam	mg Mg/100 g dry soil (A.L.-extract) Polder
Very low	< 3	< 4	< 7
Low	3 - 4	4 - 5	7 - 11
Rather low	5 - 6	6 - 8	12 - 16
Optimal level	7 - 10	9 - 14	17 - 25
Rather high	11 - 15	15 - 18	26 - 35
High	16 - 25	19 - 30	36 - 45
Very high	> 25	> 30	> 45

Table 118: Different soil fertility classes for Mg for grassland for different soil textures (only valid for soils with a specific gravity of 1.06).

Class	mg Mg/100 g dry soil (A.L.-extract) Sand	mg Mg/100 g dry soil (A.L.-extract) Sandy loam-loam	mg Mg/100 g dry soil (A.L.-extract) Polder
Very low	< 5	< 6	< 9
Low	5 - 8	6 - 10	9 - 14
Rather low	9 - 13	11 - 16	15 - 20
Optimal level	14 - 19	17 - 25	21 - 29
Rather high	20 - 25	26 - 32	30 - 38
High	26 - 35	33 - 40	39 - 48
Very high	> 35	> 40	> 48

Table 119: Different soil fertility classes for Ca for arable land for different soil textures (only valid for soils with a specific gravity of 1.3).

Class	mg Ca/100 g dry soil (A.L.-extract) Sand	mg Ca/100 g dry soil (A.L.-extract) Sandy loam	mg Ca/100 g dry soil (A.L.-extract) Loam	mg Ca/100 g dry soil (A.L.-extract) Polder
Very low	< 20	< 40	< 60	< 200
Low	20 - 39	40 - 69	60 - 109	200 - 449
Rather low	40 - 69	70 - 99	110 - 159	450 - 749
Optimal level	70 - 140	100 - 240	160 - 350	750 - 2500
Rather high	141 - 180	241 - 360	351 - 600	2501 - 6500
High	181 - 260	361 - 450	601 - 1000	6501 - 10000
Very high	> 260	> 450	> 1000	> 10000

Table 120: Different soil fertility classes for Ca for grassland for different soil textures. (only valid for soils with a specific gravity of 1.06).

Class	mg Ca/100 g dry soil (A.L.-extract) Sand	mg Ca/100 g dry soil (A.L.-extract) Sandy loam	mg Ca/100 g dry soil (A.L.-extract) Loam	mg Ca/100 g dry soil (A.L.-extract) Polder
Very low	< 20	< 50	< 70	< 250
Low	20 - 39	50 - 89	70 - 129	251 - 599
Rather low	40 - 79	90 - 129	130 - 179	600 - 899
Optimal level	80 - 160	130 - 300	180 - 400	900 - 3000
Rather high	161 - 200	301 - 380	401 - 600	3001 - 7000
High	201 - 260	381 - 500	601 - 1000	7001 - 10000
Very high	> 260	> 500	> 1000	> 10000

Table 121: Different soil fertility classes for Na for arable land (only valid for soil textures with a specific gravity of 1.3).

Class	mg Na/100 g dry soil (A.L.-extract) all soil textures
Very low	< 1.0
Low	1.0 - 2.0
Rather low	2.1 - 3.0
Optimal level	3.1 - 6.0
Rather high	6.1 - 10.0
High	10.1 - 20.0
Very high	> 20.0

Table 122: Different soil fertility classes for Na for grassland (only valid for soil textures with a specific gravity of 1.06).

Class	mg Na/100 g dry soil (A.L.-extract) all soil textures
Very low	< 1.1
Low	1.1 - 2.4
Rather low	2.5 - 3.9
Optimal level	4.0 - 6.0
Rather high	6.1 - 10.0
High	10.1 - 25.0
Very high	> 25.0

Annex 2

Example of a standard soil analysis with a liming and fertilisation advice for the 3 next growing seasons.

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Bankrekening: 736-4030300-14
P.R.: 000-0499123-58
B.T.W.: BE 420.415.024

Perceelsnaam : **2**
Landbouwernummer:
Perceelsnummer: 2011_14
Bemonsteringsdiepte: 23 cm

Heverlee, 3/ 4/2012

ONTLEDINGSUITSLAGEN EN BEOORDELING

Bepaling		Uitslag ontleding	Streefzone	Beoordeling volgens BEMEX
Grondsoort		**25**	- - -	Lichte zandleem
pH-KCl	099 B	**5.8**	5.8 - 6.2	Gunstig
C in % (humus)	473	**0.97**	1.2 - 1.6	Tamelijk laag
Fosfor (P)	376 B	**46**	12 - 18	Hoog
Kalium (K)	376 B	**25**	14 - 20	Tamelijk hoog
Magnesium (Mg)	376 B	**15**	9 - 14	Tamelijk hoog
Calcium (Ca)	376 B	**99**	100 - 241	Tamelijk laag
Natrium (Na)	376 B	**1.3**	3.1 - 6.1	Laag
Boor		---	--- - ---	

De streefzone is individueel per perceel.

BEKALKINGSVOORSCHRIFT

1100 z.b.w. per ha

Deze streefzone geldt voor de meeste teelten. Voor een aantal teelten ligt de optimale pH lager of kunnen er zich bij bekalking kwaliteitsproblemen voordoen. Zie per teelt voor eventuele specifieke opmerkingen.

ORGANISCHE KOOLSTOF

Het organisch koolstofgehalte (C in %) van dit perceel is tamelijk laag.Op rotatieniveau dient ernaar gestreefd om meer organische stof aan te voeren dan er jaarlijks wordt afgebroken.

De voor dit perceel berekende jaarlijkse afbraakis: 840 kg organische koolstof/ha.

Via de tabel op bijgevoegde verklarende nota kan u nagaan op welke manier deze afbraak kan gecompenseerd worden.

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Bankrekening: 736-4030300-1
P.R.: 000-0499123-5
B.T.W.: BE 420.415.02

Perceelsnaam : 2 Volgnummer S0968366 (2/4) 3/ 4/201

De kolommen naast het bemestingsadvies kan u gebruiken om de bemesting van dit perceel nauwkeurig op te volgen (zie algemene bemerking).

EERSTE TEELT 10/2011		Door u in te vullen		
raaigras, 2 of 3 sneden		organische bemesting	minerale bemesting	saldo
Kalk	0 z.b.w./ha			
Stikstof	Zie N-index			
Posfor	30 kg P_2O_5/ha			
Kali	80 kg K_2O/ha (2)			
Magnesium	50 kg MgO/ha			
Natrium	80 kg Na_2O/ha			
Boor	-			

De hoger vermelde streefzone is de pH-streefzone voor de meeste teelten zoals bv. suikerbieten, gerst. Daar de raaigras, twee of drie sneden reeds gezaaid is, raden wij aan voor deze teelt geen bekalking meer uit te voeren.
(1) De aangegeven dosis N is de dosis voor de eerste snede.
Voor de tweede snede 110 kg N en per volgende snede 90 kg N toedienen.
(2) De aangegeven dosis K_2O is de dosis voor de eerste snede.
Voor de tweede snede 80 kg K_2O en per volgende snede 80 kg K_2O toedienen.
De natriumbemesting is niet noodzakelijk voor een hogere opbrengst, maar wel om het natriumgehalte in het gras te verbeteren.

TWEEDE TEELT 5/2012		Door u in te vullen		
korrelmaïs		organische bemesting	minerale bemesting	saldo
Kalk	0 z.b.w./ha			
Stikstof	150 kg N/ha			
Posfor	30 kg P_2O_5/ha			
Kali	110 kg K_2O/ha			
Magnesium	30 kg MgO/ha			
Natrium	0 kg Na_2O/ha			
Boor	-			

De hoger vermelde streefzone is de pH-streefzone voor de meeste teelten zoals suikerbieten, gerst... Voor de teelt van korrelmaïs moet hier geen bekalking uitgevoerd worden.
De fosforbemesting kan geheel of gedeeltelijk onder de vorm van organische bemesting worden toegediend. De minerale bemesting dient dan uiteraard evenredig te worden verminderd. Wanneer een gedeelte van de fosforbemesting in de rij wordt toegediend, moet het dubbele van de hoeveelheid die als rijenbemesting werd toegepast in mindering worden gebracht van de totale dosis. Bij breedwerpige toediening van het volledige fosforadvies onder vorm van organische of minerale meststoffen is rijenbemesting met startfosfor overbodig.

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Perceelsnaam : 2 Volgnummer S0968366 (3/4) 3/ 4/2012

De kolommen naast het bemestingsadvies kan u gebruiken om de bemesting van dit perceel nauwkeurig op te volgen (zie algemene bemerking).

DERDE TEELT 10/2012 **raaigras, één snede**			Door u in te vullen		
			organische bemesting	minerale bemesting	saldo
Kalk	0	z.b.w./ha			
Stikstof	130	kg N/ha			
Posfor	30	kg P_2O_5/ha			
Kali	100	kg K_2O/ha			
Magnesium	60	kg MgO/ha			
Natrium	80	kg Na_2O/ha			
Boor	-				

De hoger vermelde streefzone is de pH-streefzone voor de meeste teelten zoals suikerbieten, gerst... Voor de teelt van raaigras, één snede moet hier geen bekalking uitgevoerd worden.
De natriumbemesting is niet noodzakelijk voor een hogere opbrengst, maar wel om het natriumgehalte in het gras te verbeteren.

STAALNAME

Uw contactpersoon :

Het staal werd genomen op 13/ 3/2012. Het grondstaal is aangekomen op 14/ 3/2012 bij de Bodemkundige Dienst in Heverlee. De analysedatum is 14/ 3/2012.
De ontledingsuitslag en beoordeling werden vrijgegeven door Stan Deckers, adviseur Land- en Tuinbouw.
Indien vóór de grondstaalname reeds organische of minerale meststoffen werden toegediend voor de eerstvolgende teelt, dan dienen deze in mindering te worden gebracht van het bemestingsadvies. Een gemiddelde bemestingswaarde van organische mest is vermeld in tabel 2 van de verklarende nota.
Voor een evenwichtige en optimale bemesting moet de som van de bemestingswaarden van alle toegediende bemestingen gelijk zijn aan het advies.

De **STIKSTOFBEMESTINGSADVIEZEN** die bij de verschillende teelten gegeven worden, zijn richtinggevende waarden.
Het hoger vermelde bemestingsadvies KAN in tegenspraak zijn met de wettelijk toegelaten dosis op dit perceel. Het advies dat hier geformuleerd staat, is gericht op een landbouwkundig optimaal rendement. Het houdt dus geen rekening met de specifiek geldende bemestingsnormen op dit perceel.

MINIMAAL MTR-ADVIES
De Bodemkundige Dienst van België is als laboratorium erkend in de discipline bodem, deeldomein bodembescherming. Volgende analyseresultaten kunnen in het kader van de MTR-voorwaarden als geldige analyseresultaten voorgelegd worden tot en met 13/ 3/2015.
Het identificatienummer van het perceel is

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B.T.W.: BE 420.415.024

Perceelsnaam : 2 Volgnummer S0968366 (4/4) 3/ 4/2012

OC-gehalte:	0.97 % OC (volgens ISO 14235 / METH 473)
Textuur:	Zandleem
pH-KCl:	5.7 (volgens ISO 10390 / METH 053 B)

De MTR-limietwaarden voor het C-gehalte en de pH-KCl zijn raadpleegbaar in de bijgevoegde verklarende nota MTR.

Dit advies werd u eveneens per e-mail bezorgd.

Onderzoek wordt verricht en adviezen worden verstrekt op voorwaarden dat de aanvrager afstand doet van ieder recht op aansprakelijkstelling.

AANGEWENDE ANALYSE- EN ADVIESMETHODEN

099: pH-KCl, BDB-methode, uitgedrukt in Sörensen 25°C
473: organische koolstofgehalte, volgens ISO 14235, uitgedrukt in %.
376: AL-extractie en bepaling minerale elementen (P, K, Ca, Mg, Na) met ICP, BDB-methode - gebaseerd op Egnér, Riehm, Domingo, uitgedrukt in mg/100g grond.
B : Analyse BELAC-geaccrediteerd onder certificaat nr. 127-TEST. Meetonzekerheden van de BELAC-geaccrediteerde methodes kunnen aangevraagd worden.
BEMEX : Bemestingsexpertsysteem Bodemkundige Dienst van België vzw. Voor de beoordelingsmethodiek zie bijgevoegde verklarende nota.
De analyseresultaten hebben uitsluitend betrekking op de geanalyseerde objecten.
Het verslag mag niet worden gereproduceerd, behalve in volledige vorm, zonder de schriftelijke toestemming van de Bodemkundige Dienst van België vzw.
Einde verslag

Annex 3

Since weather and climate conditions influence strongly the processes in soil, like mineralisation, leaching, crop growth, an overview is given of climate conditions in the years 2011-2014, the time period covered by this project. The values, figures and tables shown are observations at Brussels-Ukkel, gathered by the Royal Meteorological Institute.

The "normal" values of the different parameters, are the average values of the parameters in the period 1981-2010. This period of 30 years is chosen as the latest reference period to determine the 'normal' values of Ukkel. The degree of abnormality of values is based on the reference period 1981-2010.

It needs to be noticed that the figures and values shown below are observations at Brussels-Ukkel as mentioned before. For calculations at individual parcels for example of leaching (Burns) the weighed average of rainfall and ET0 of the 3 closest weather stations is taken into account as mentioned before in paragraph 11.1.

Climate 2011

The year 2011 was the warmest year at Brussels-Ukkel, ever since the start of the continuous meteorological observations in 1833.

In autumn 2011 (defined in meteorological terms as period September-November), the number of days with rainfall was most exceptional small. Only 37 days with precipitation compared to a normal value of 51 days. Also the total amount of rainfall was exceptional low, 140.4 mm compared to 219.9 mm as normal value in the period 1981-2010 (Figure 244). Most prominent was November 2011. The lowest amount of rainfall ever was measured, 8.5 mm. Besides the minor rainfall, the abundance of sunshine was remarkable (Figure 246). Autumn 2011 was the fifth most sunniest autumn since 1887, 450 h (normal value: 322 h). At last autumn 2011 was also exceptional warm (Figure 245). The average temperature was 12.4 °C, compared to 10.9 °C as normal value. December however was also warm but rainfall was high.

The higher temperatures, the lack of rain and longer period with sunshine in November 2011, explain the negative values for the water balance in November 2011 shown in Table 74.

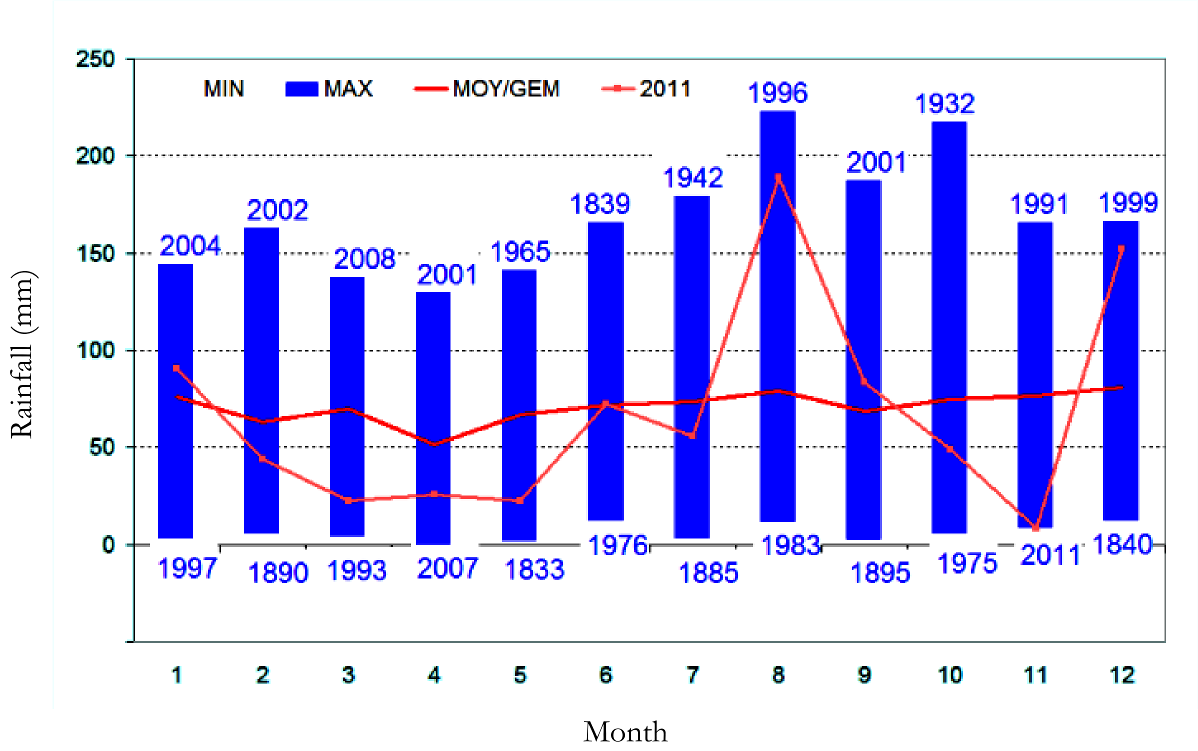

Figure 244: Evolution of rainfall (mm) at Ukkel in 2011 (pink curve), indication of monthly normal values (red curve), indication of highest and lowest values ever measured at Ukkel since 1833 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be)

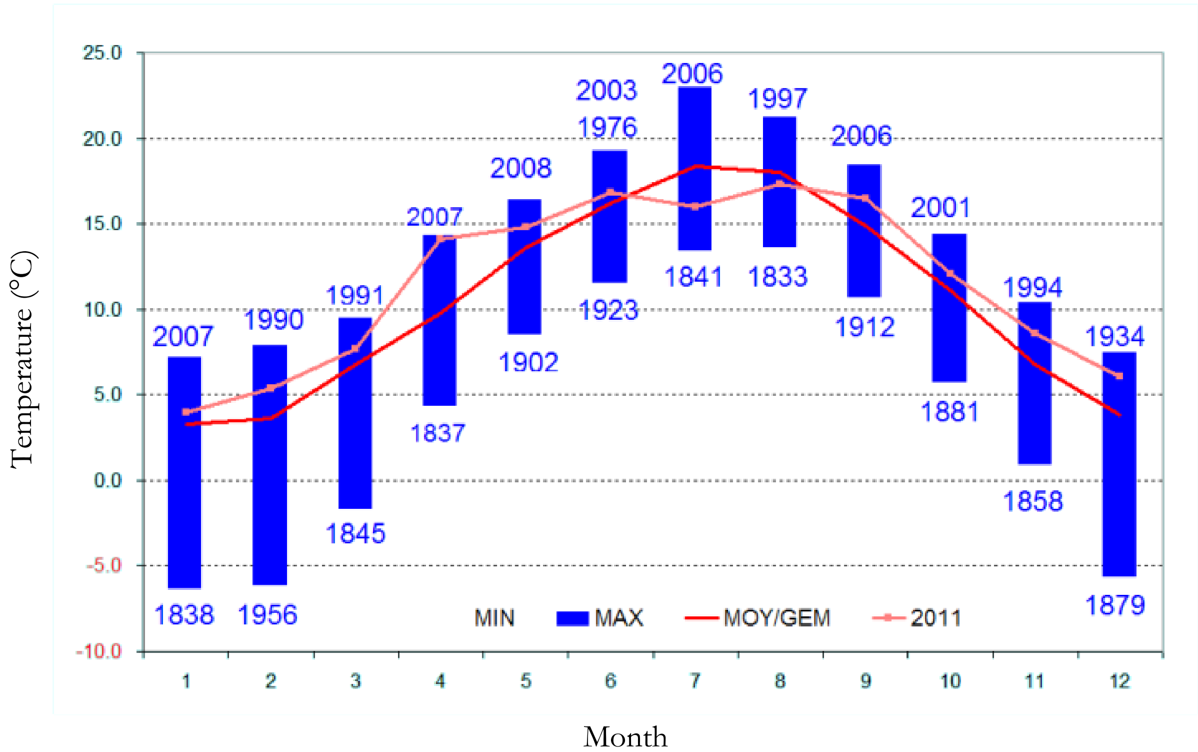

Figure 245: Evolution of temperature (°C) at Ukkel in 2011 (pink curve), indication of monthly normal values (red curve), indication of highest and lowest values ever measured at Ukkel since 1833 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be)

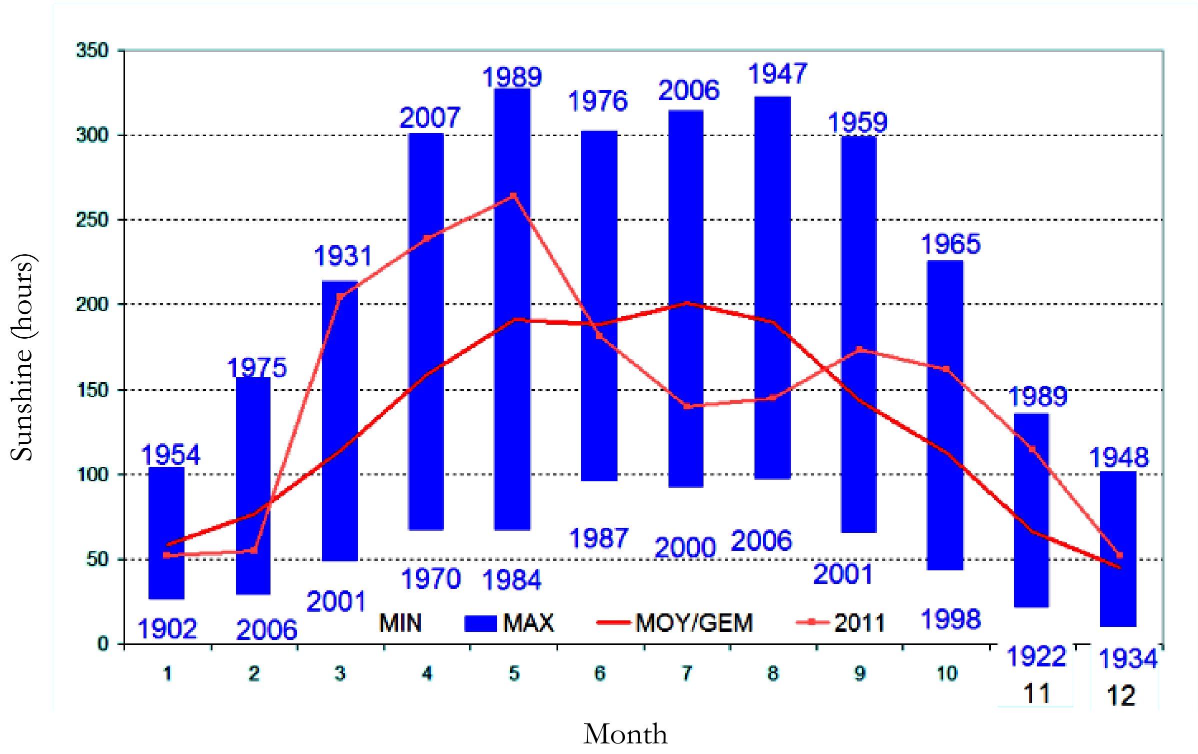

Figure 246: Evolution of monthly sunshine (hours) at Ukkel in 2011 (pink curve), indication of monthly normal values (red curve), indication of highest and lowest values ever measured at Ukkel since 1887 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be)

Climate 2012

Base on meteorological data the year 2012 was relatively normal. However rainfall was highly variable around the normal values. In December rainfall was very high and a new record was established (Figure 247). In August it was very dry and in October it was more rainy as usual. In October 2011 water balance showed high positive values (Table 75). The average temperature each month was always near the normal values except in February when it was colder than normal (Figure 248). The number of hours of sunshine per month was close to the normal values. Only in March was exceptional sunny.

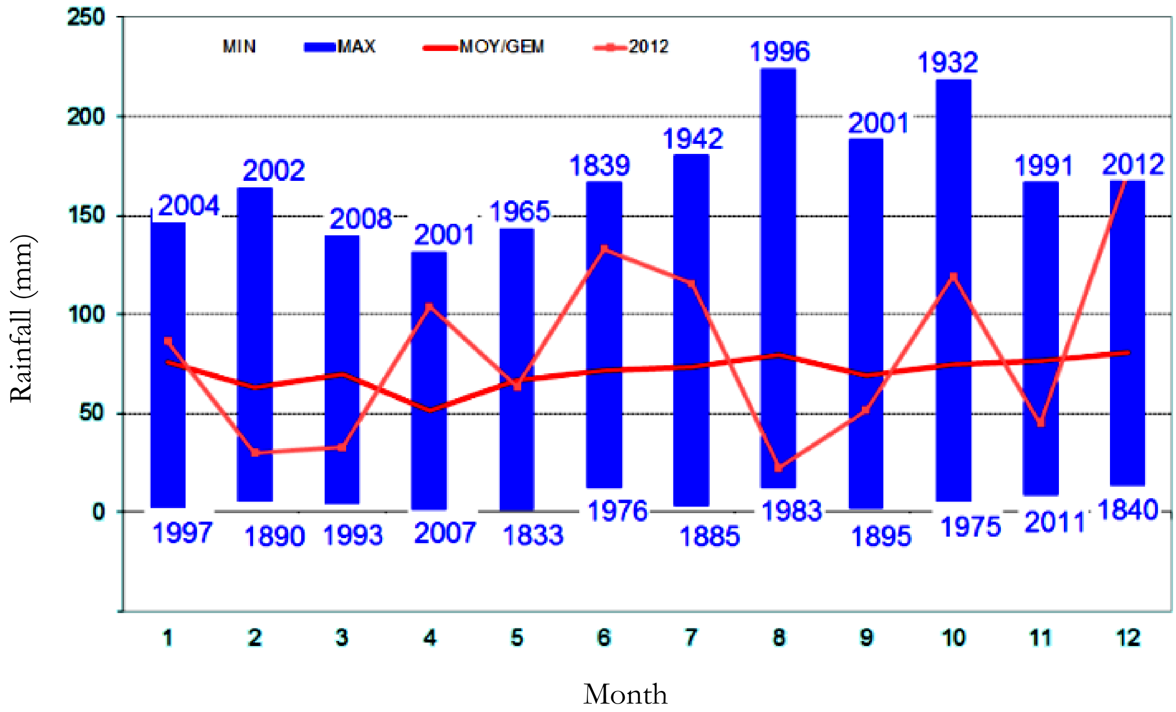

Figure 247: Evolution of rainfall (mm) at Ukkel in 2012 (pink curve), indication of monthly normal values (red curve), indication of highest and lowest values ever measured at Ukkel since 1833 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be).

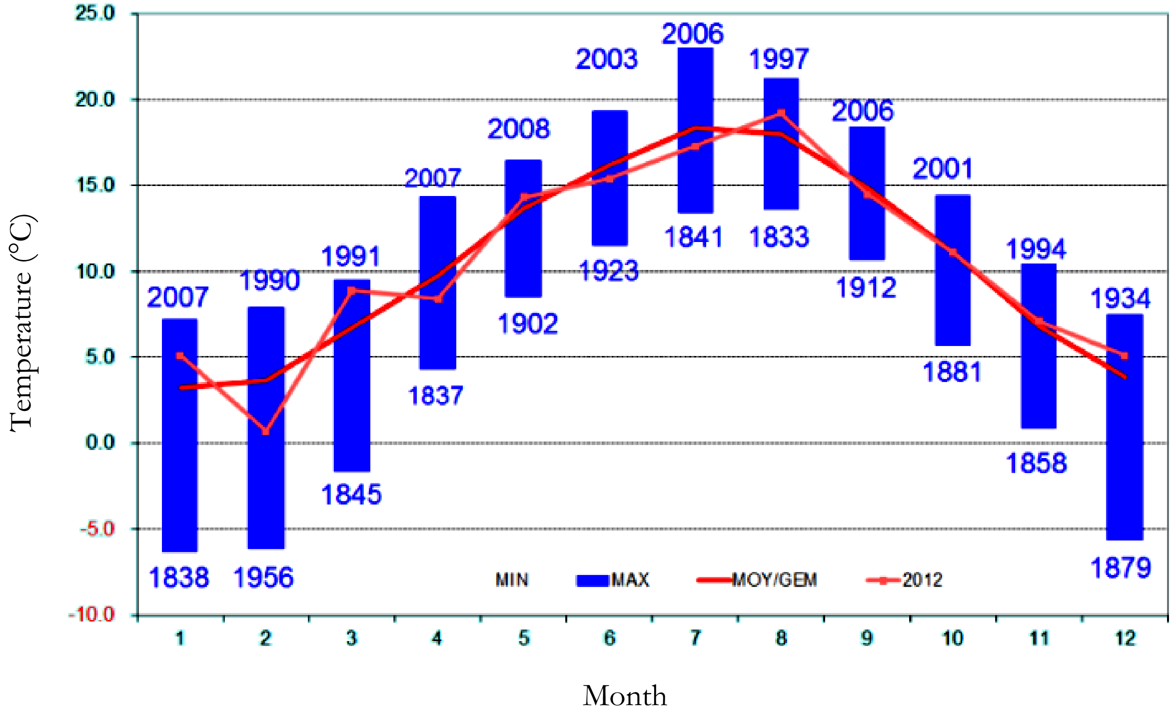

Figure 248: Evolution of temperature (°C) at Ukkel in 2012 (pink curve), indication of monthly normal values (red curve), indication of highest and lowest values ever measured at Ukkel since 1833 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be).

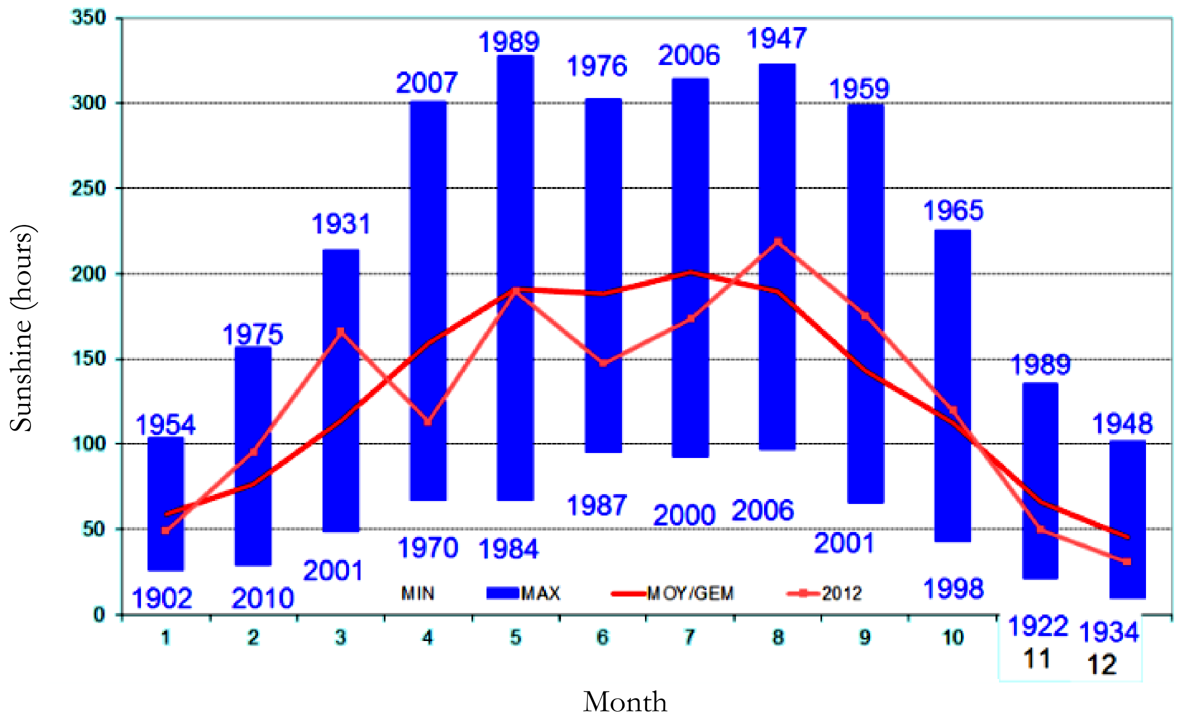

Figure 249: Evolution of monthly sunshine (hours) at Ukkel in 2012 (pink curve), indication of monthly normal values (red curve), indication of highest and lowest values ever measured at Ukkel since 1887 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be).

Climate 2013

In 2013 rainfall was often more limited than in normal conditions. The difference however was rather small. In May, however, rainfall was abundant and more than the double of normal rainfall was observed (Figure 250). Until June, average temperature in 2013 was some lower than normal. Since august temperature was normal. In December, however, it was warmer than normal and a warm winter began (Figure 251). Not only temperature but also sunshine was less in the first months of 2013 (Figure 252).

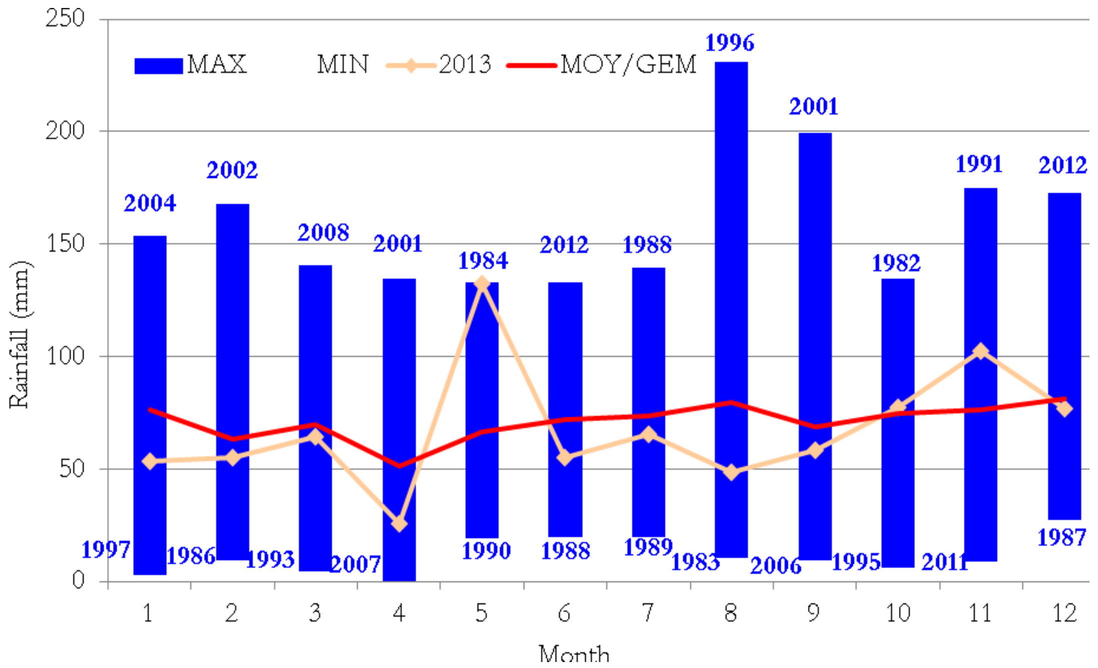

Figure 250: Evolution of rainfall (mm) at Ukkel in 2013 (pink curve), indication of monthly normal values (red curve), indication of highest and lowest values ever measured at Ukkel since 1833 (ends of blue columns with indication of the record year). (Source: KMI).

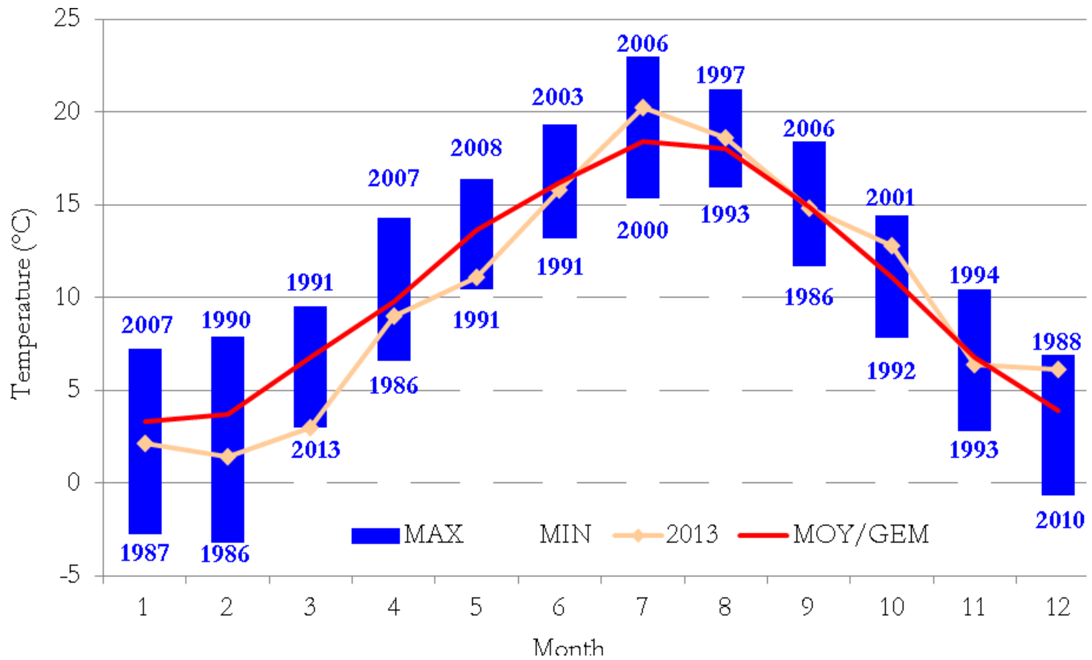

Figure 251: Evolution of temperature (°C) at Ukkel in 2013 (pink curve), indication of monthly normal values (red curve), indication of highest and lowest values ever measured at Ukkel since 1833 (ends of blue columns with indication of the record year). (Source: KMI).

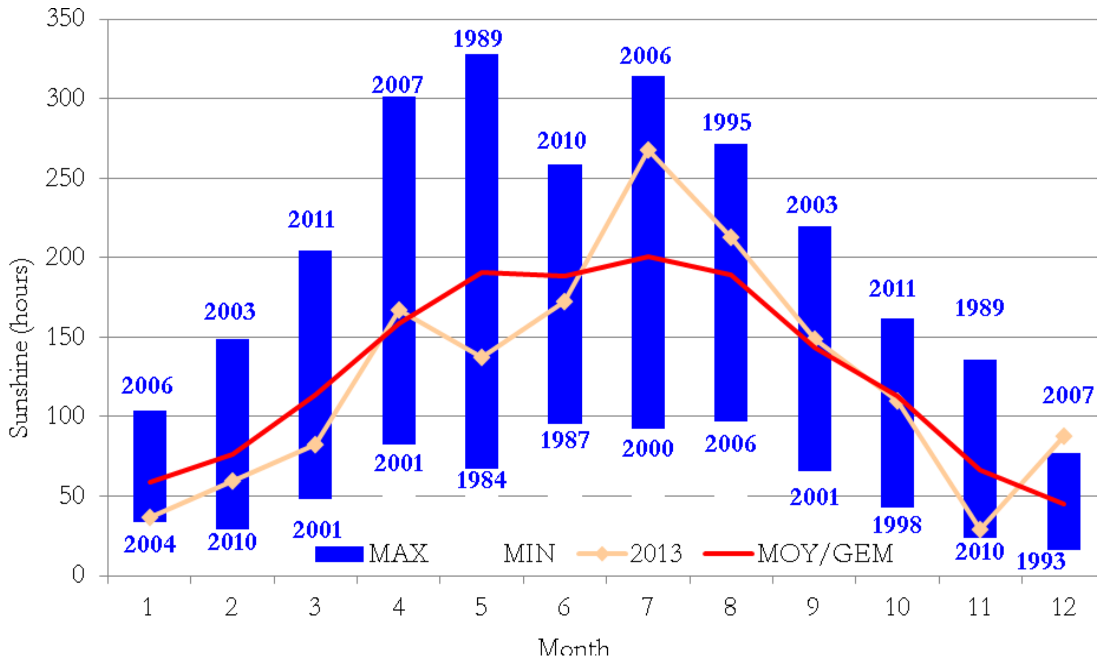

Figure 252: Evolution of monthly sunshine (hours) at Ukkel in 2013 (pink curve), indication of monthly normal values (red curve), indication of highest and lowest values ever measured at Ukkel since 1887 (ends of blue columns with indication of the record year). (Source: KMI).

Climate 2014

In 2014 longer periods with less or more rainfall as normal were noticed. In spring, March and April, there was clearly less rainfall as normal. However in the periode June-August the amount of precipitation was higher as normal, especially in August. Autumn 2014 was dryer as normal. As well in September, October and November the rainfall was lower as normal but it was most expceptional in September. In September 2014 there was only 15.1 mm rainfall at Ukkel compared to 68.9 mm as normal value for Ukkel in September. Rainfall in autumn 2014 amounted for 113.7 mm (normal value: 219.9), considered as abnormal since such a value occurs once in 10 years. Winter 2013-2014 ended in January and February with higher temperature as normal. These higher temperatures continued in March and April. In summer the temperature was normal but since September temperature was each month until November clearly higher as normal. The average temperature in autumn 2014 was 13 °C, compared to 10.9 °C as normal value. This was considered as exceptional since such an average value occurs once in 30 years. It was the second warmest autumn since 1833. Sunshine was almost normal. In March there was clearly more sunshine as normal but in August there was less sunshine as normal.

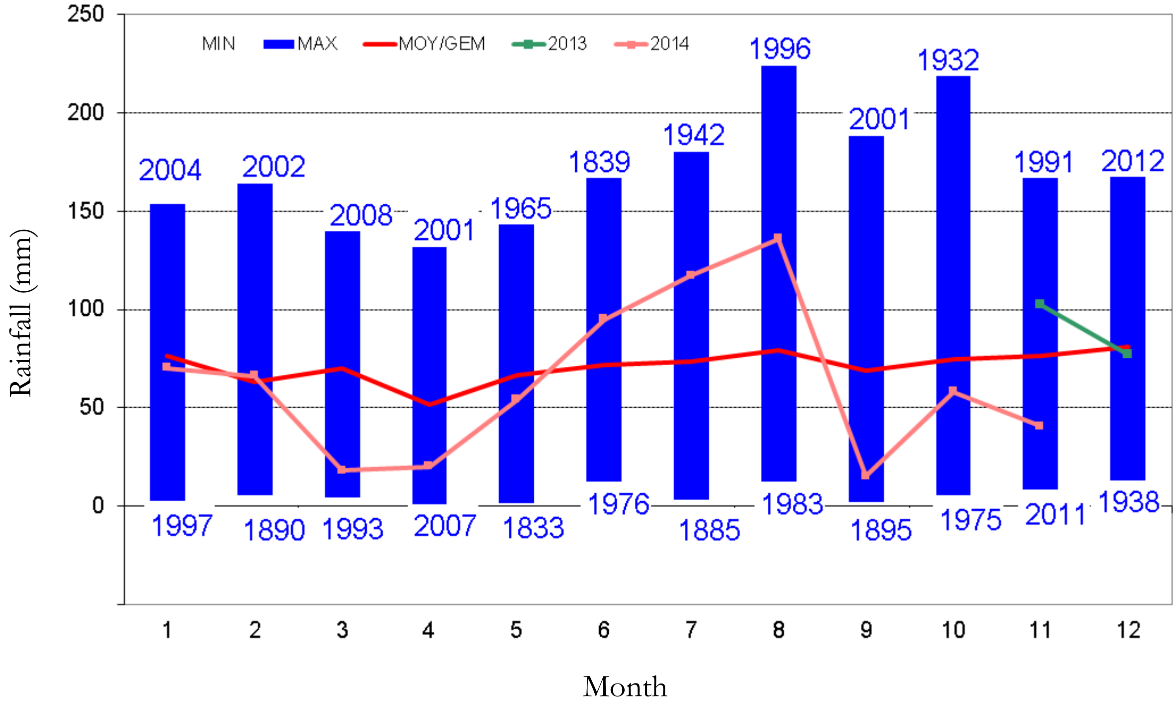

Figure 253: Evolution of rainfall (mm) at Ukkel in 2014 (pink curve), indication of monthly normal values (red curve), indication of highest and lowest values ever measured at Ukkel since 1833 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be).

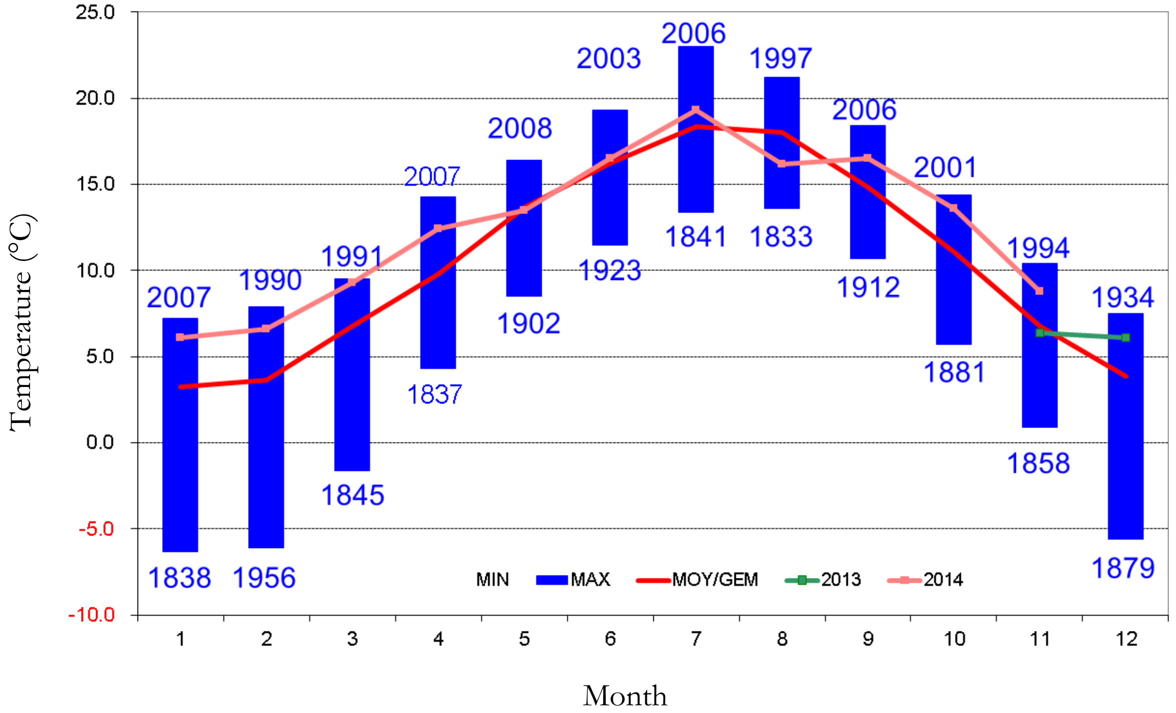

Figure 254: Evolution of temperature (°C) at Ukkel in 2014 (pink curve), indication of monthly normal values (red curve), indication of highest and lowest values ever measured at Ukkel since 1833 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be).

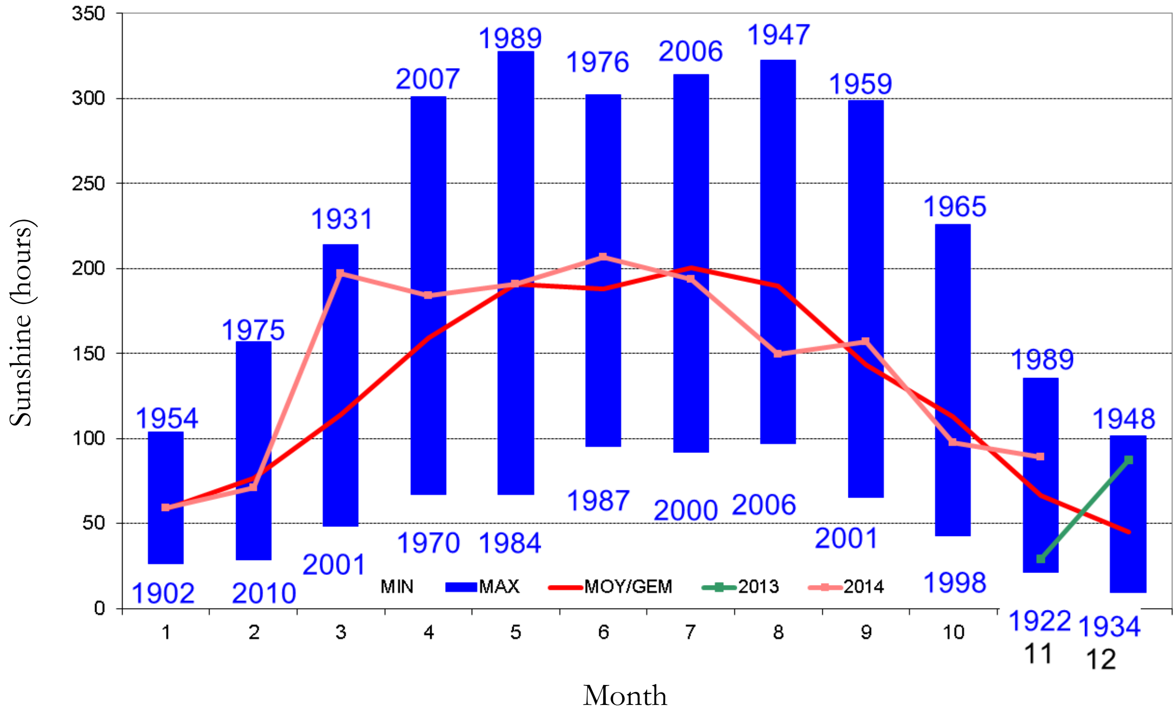

Figure 255: Evolution of monthly sunshine (hours) at Ukkel in 2014 (pink curve), indication of monthly normal values (red curve), indication of highest and lowest values ever measured at Ukkel since 1887 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be).

In Figure 256 all autumns at Ukkel since 1960 are positioned regarding rainfall, temperature and sunshine. Rainfall and temperature are compared to the normal values observed in the period 1981-2010. It can be seen that autumn 2011 and 2014 are more or less comparable.

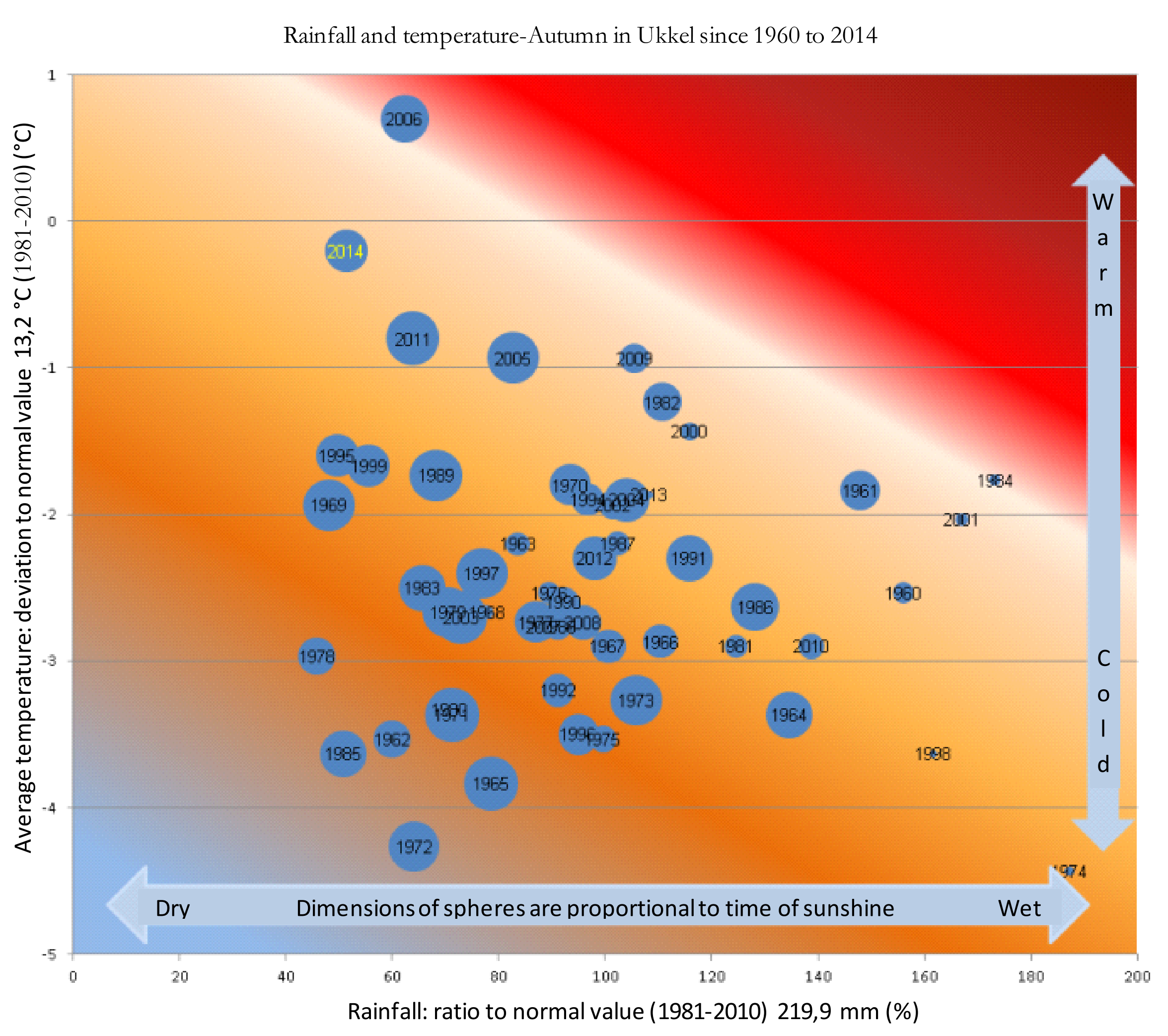

Figure 256: Position of autumns at Ukkel since 1960 to 2014 regarding to rainfall, temperature and sunshine compared to normal values of temperature (13.2 °C) and rainfall (219.9 mm) (period 1981-2010) (Source: KMI, www.meteo.be).