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Establishment and follow-up of a monitoring network of farms to assess the impact of derogation on the water quality

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Summary

In the commission decision of 21 December 2007, the Commission of the European Communities approved the Belgian request, with regard to the region of Flanders, to allow a higher amount of livestock manure than provided in the Directive 91/676/EEC (i.e. 170 kg N per hectare originating from livestock manure). In the derogation decision a number of specific conditions were imposed on individual farms who apply derogation as well as on the competent authorities with regard to monitoring, control and reporting. The objective of the presented research project is the establishment and the follow-up of a monitoring network of at least 150 farms (target of 180 farms and 225 parcels) to assess the impact of the derogation on both the nitrogen and phosphorous losses from the soil and the water quality, as requested by the derogation decision (cfr. specifications). 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 (cfr. first objective in specifications).

The derogation monitoring network should provide data on 1) fertilization and farming practices, 2) nitrogen and phosphorous concentration in soil water, 3) mineral nitrogen in soil profile, 4) the corresponding nitrogen and phosphorous losses through the root zone into the groundwater and 5) nitrogen and phosphorous losses by surface and subsurface run-off. Based on these data, the impact on the water quality should be evaluated both under derogation and non derogation conditions. The different soil types, crops and fertilization practices, commonly present in Flanders, should be considered. However, a more intensive monitoring is required on sandy soils (cfr. specifications).

In Flanders the existing MAP monitoring network for groundwater was chosen as basis for the set-up of the derogation monitoring network. In contrast to the surface water monitoring network, it allows to link a MAP monitoring site to an individual parcel due to the smaller infiltration areas. The MAP monitoring network is a dense network of 2,100 measuring points distributed over Flanders. For every MAP monitoring site the infiltration area and the travel time for the water from the root zone to the MAP monitoring site was calculated. The selected parcels are lying in the infiltration area of a MAP monitoring site. Only MAP monitoring sites that are influenced by a single agricultural parcel were selected for the monitoring network. In this way the measured water quality in a MAP monitoring site is coupled to the agricultural parcel (and the agricultural management, especially fertilization). From the 2,100 MAP sampling points 121

parcels were selected. This selection was based on infiltration area, travel time, willingness of farmer to participate, soil type and cultivated crop.

However, the selection from the MAP monitoring sites did not result in a network of 225 parcels (as requested). Therefore, in the next step parcels were selected from candidate farmers. These farmers volunteered to participate in the network. Parcels from these farmers were chosen based on derogation, soil type, cultivated crop and shallow groundwater table. To measure the water quality on these parcels monitoring wells were placed. For the placement of these wells a hypothetical infiltration area was modulated in the middle of a number of parcels on different depths. As such it was possible to select a good depth and position for the monitoring well so that a parcel lies in the infiltration area of the monitoring well. By using the different criteria it was possible to create a network with the prescribed proportions of derogation, soil type and cultivated crops. Sandy and sandy loam soils are the most dominant soil types of the parcels participating in the network. More than half of the parcels in the network consist of sandy soils. Half of the parcels are cultivated with grass and approximately 30 per cent cultivated with maize. On this way the monitoring network is representative for the agricultural practices on derogation parcels in Flanders because derogation is mostly requested by dairy cow farmers on sandy soils cultivated with grass or maize.

Not all parcels in the network lie in the infiltration area of a MAP monitoring site or monitoring well. In these parcels the water quality is measured by sampling canals, ditches or drainages. On a selection of parcels with deeper groundwater soil samples are taken from 90 to 120 cm and from 120 to 150 cm. The nitrate and phosphorous measured in these samples are an indication of the amount of nitrate and phosphorous in the soil water.

After the selection of parcels several types of measurements are carried out. In order to characterize the parcels a standard soil sample is taken on each parcel. This standard soil sample gives information on soil type, pH, carbon and the quantity of the most important nutrients. In addition, each year a soil sample is taken from 0 to 90 cm in three layers to measure the amount of nitrate in the soil. This sample is taken before and after every growing season and gives information on the nitrate residue and the amount of nitrate leaching out towards the surface and groundwater. To investigate the quality of the surface and groundwater, water samples from the MAP sampling points and monitoring wells are taken. Also water samples from drains, ditches and canals are taken. Canals and ditches in Flanders are mostly influenced by a number of parcels so it is not possible to find a lot of canals and ditches influenced by only one single parcel. To measure the water quality on parcels with a deep water level (deeper than 1.5 m) a soil sample is taken in two layers from 90 to 120 cm and 120 to 150 cm. In this soil sample the amount of nitrate and phosphorous is measured and on a part of these soil samples the soil water is extracted by centrifugation in order to measure the different fractions of phosphorous (inorganic and organic phosphorous).

In order to find an explanation for the measured amount of nitrate and phosphorous, a nutrient balance on every parcel is calculated. Therefore, samples of the livestock manure applied on each parcel are taken in order to determine the amount of nutrients applied. Information on parcel management, fertilization practices, and yield and farm characteristics is provided by the farmers.

The results of all these measurements are used to compare derogation with no derogation in order to investigate the effect of derogation on the water quality. Furthermore, the gathered data as well as the evaluation of the impact on the water quality will be used as a scientific basis to support the request of Flanders to prolong the derogation request, which will be submitted in 2010.

Based on all measurements at the different moments of sampling, some conclusions can be drawn. Differences in fertilisation advice and nutrient levels in the soil profile are present among different cultivated crops and soil types but less between derogation and no derogation parcels. No significant differences are found between derogation and no derogation parcels for the nitrate in the soil profile (from 0 to 90 cm) at none of the sampling moments. Derogation and no derogation parcels were compared including all data as well as for specific combinations of cultivated crop and soil type. The most important conclusion for the soil sample from 0 to 90 cm is that no significant difference between derogation and no derogation parcels was observed at the end of 2009 and also at the end of 2010. Based on measurements of nitrate in the soil profile before winter, leaching during winter is also investigated using the Burns model. Based on results from the Burns model, no differences in the amount of nitrate leaching out the soil profile during winter were present between derogation and no derogation parcels.

Levels of nitrate in the water samples are characterized by a decreasing trend during the different moments of sampling. No significant differences were observed for the concentrations of nitrate in the sampling points (MAP sampling points and monitoring wells) between derogation and no derogation parcels. It is important to note that these concentrations, measured in the sampling points were coupled to individual parcels based on the travel time.

For phosphorous differences in concentrations were found between the different types of samples, with lowest values in MAP sampling points (many measurements below detection limit).

Higher levels of phosphorous are measured in canals and ditches. These high concentrations of phosphorous consist mostly of a high percentage inorganic phosphorous. Phosphorous measured in deep soil samples and MAP sampling points (lower concentrations) consists mainly of organic phosphorous. No significant differences were present between derogation and no derogation parcels for phosphorous concentrations measured in sampling points, drains, canals and ditches and deep soil layers linked to these parcels. Parcels with high levels of phosphorous measured by an ammonium lactate extract in the top soil layer are in general also characterized by higher levels of phosphorous in the deeper soil layers. A positive correlation is observed between P-AL in the top soil layer and the phosphate saturation degree of the parcel.

Derogation parcels are characterized by higher levels of fertilization. Fertilization on derogation parcels consist mainly of organic fertilization (animal manure). In addition, no lower levels of mineral fertilization are observed in derogation parcels. Together with a higher total input of nutrients on derogation parcels, more export of nutrients is observed in comparison with no derogation parcels. This higher export is especially present on parcels cultivated with maize and grass. The higher export is mostly realised by an extra cut of grass. A higher input of nutrients combined with higher levels of export for derogation parcels results in no significant differences in nitrate residue after the growing season in comparison with no derogation parcels.

So based on the extensive information of the monitoring network it is possible to conclude that derogation has no negative impact on the water quality in Flanders.

Samenvatting

In de derogatiebeschikking van 21 december 2007 keurde de Europese Commissie het Vlaamse verzoek goed om in bepaalde gevallen af te wijken van de algemene bemestingsnorm van 170 kg N per hectare uit dierlijke mest. In de derogatiebeschikking werden een aantal strikte voorwaarden ingebouwd enerzijds voor individuele bedrijven die derogatie toepassen en anderzijds voor de bevoegde instanties met betrekking tot monitoring, controle en rapportering. Het doel van dit onderzoek is de opzet en opvolging van een monitoringnetwerk van minstens 150 landbouwbedrijven (streefdoel is 180 landbouwbedrijven en 225 percelen) ter evaluatie van het effect van derogatie op de stikstof- en fosforverliezen uit de bodem op de kwaliteit van oppervlakte- en grondwater, zoals opgelegd in de beschikking (cfr. bestek). Indien derogatie een significante impact heeft op de waterkwaliteit is het belangrijk om de oorzaken te kunnen bepalen en de precieze impact(-factoren) op de waterkwaliteit vast te leggen (cfr. eerste doelstelling van het bestek).

Het derogatiemonitoringnetwerk moet gegevens leveren omtrent 1) de bemestings- en landbouwpraktijken, 2) de stikstof- en fosforconcentraties in het bodemwater, 3) de minerale stikstof in het bodemprofiel, 4) de stikstof- en fosforverliezen via de wortelzone naar het grondwater en 5) de stikstof- en fosforverliezen door afspoeling via het oppervlak en uitspoeling via de ondergrond. Op basis van de gegevens (metingen en berekeningen) dient een evaluatie te gebeuren van de impact op de waterkwaliteit, in situaties met en zonder derogatie. Deze evaluatie moet gebeuren voor de verschillende bodemtypes, gewassen en bemestingspraktijken die van toepassing zijn in Vlaanderen, waarbij op zandbodems een intensievere monitoring moet gebeuren (cfr. bestek).

Als basis voor de opzet van het derogatiemonitoringnetwerk werd het bestaande MAP meetnet voor grondwater gekozen. In tegenstelling tot het MAP oppervlaktewatermeetnet, zijn MAP grondwatermeetpunten in veel situaties te koppelen aan een beperkt aantal percelen door de kleinere intrekgebieden. Het MAP grondwaterrmeetnet bestaat uit ongeveer 2100 meetpunten, evenredig verdeeld over Vlaanderen. Voor ieder MAP grondwatermeetpunt werd het intrekgebied en de reistijd van het water van de wortelzone tot het meetpunt berekend. Geselecteerde percelen zijn gelegen in het intrekgebied van het MAP grondwatermeetpunt. Enkel MAP grondwatermeetpunten die beïnvloed worden door 1 of een beperkt aantal percelen werden geselecteerd voor het derogatiemonitoringnetwerk. Hierdoor kan de gemeten waterkwaliteit in het meetpunt gekoppeld worden aan een individueel perceel (landbouwpraktijk, bemesting). Er

werden 121 percelen geselecteerd die aan een MAP grondwatermeetpunt gekoppeld konden worden. Deze selectie was gebaseerd op het intrekgebied, de reistijd, bereidheid van landbouwer tot deelname, bodemtype en gewas.

Op basis van deze eerste selectie bevatte het monitoringnetwerk nog geen 225 percelen. In een tweede stap werden percelen geselecteerd bij kandidaat deelnemers. Dit waren landbouwers die graag wilden deelnemen aan het onderzoek. Percelen werden bij deze landbouwers geselecteerd op basis van derogatie, bodemtype, gewas en grondwatertafel. Om ook op deze percelen de waterkwaliteit te kunnen meten werden peilbuizen geplaatst. Voor de plaatsing van deze peilbuizen werd er voor verschillende percelen bij iedere landbouwer een hypothetisch intrekgebied gemodelleerd voor het midden van het perceel op verschillende dieptes. Op die manier was het mogelijk peilbuizen op de juiste diepte en plaats van het perceel te plaatsen zodat het perceel gelegen was binnen het intrekgebied van de peilbuis. Door rekening te houden met verschillende criteria kon een netwerk opgezet worden dat voldoet aan de vooropgestelde verdelingen van derogatie, bodemtype en gewas. Zand en zandleembodems zijn de meest voorkomende bodemtypes in het derogatiemonitoringnetwerk. Meer dan de helft van de percelen worden gekenmerkt door zandige bodems. De helft van de percelen is grasland en ongeveer 30 procent bestaat uit maïs. Op die manier is het derogatiemonitoringnetwerk representatief voor de toegepaste landbouwpraktijken in Vlaanderen omdat derogatie voornamelijk wordt aangevraagd op maïs en graslandpercelen van melkveebedrijven.

Niet alle percelen van het monitoringnetwerk zijn gelegen binnen het intrekgebied van een MAP grondwatermeetpunt of zelfgeplaatste peilbuis. Voor deze percelen wordt de waterkwaliteit gemeten aan de hand van een bemonstering van grachten en drainagesystemen. Op een selectie van percelen waar het grondwater dieper staat dan 150 cm worden bodemstalen genomen van 90 tot 150 cm. De gemeten hoeveelheden nitraat en fosfor in deze diepere bodemstalen geven een indicatie van de hoeveelheid nitraat en fosfaat dat uitspoelt.

Na de selectie van de percelen werden allerlei metingen uitgevoerd. Om de percelen te karakteriseren werd een standaardgrondontleding uitgevoerd. Deze ontleding geeft informatie over het bodemtype, de pH, het koolstofgehalte en de inhoud van de belangrijkste nutriënten. Daarnaast werd er voor ieder perceel per jaar een bodemstaal genomen van 0 tot 90 cm in 3 lagen om de hoeveelheid aan nitraat in het bodemprofiel op te volgen. Dit bodemstaal werd genomen voor en na ieder groeiseizoen waardoor het informatie geeft over het nitraatresidu voor de winter en de hoeveelheid nitraat dat uitspoelt naar oppervlakte -en grondwater tijdens de winter. Waterstalen afkomstig van de MAP grondwatermeetpunten en de zelfgeplaatste peilbuizen geven informatie over de kwaliteit van het grondwater. Daarnaast worden ook stalen genomen van drainage en grachten die gekoppeld zijn aan percelen van het derogatiemonitoringnetwerk. In Vlaanderen worden de meeste grachten beïnvloed door meerdere percelen zodat de link met een individueel perceel meestal moeilijk is. Om de waterkwaliteit op te volgen op percelen met een diepere grondwatertafel (dieper dan 150 cm) werd een bodemstaal genomen van 90 tot 120 cm en van 120 tot 150 cm. Fosfaat en nitraat werd gemeten op deze bodemstalen en op de helft van de stalen werd een hoeveelheid water gecentrifugeerd om de verschillende fracties (organisch en anorganisch) aan fosfor te meten.

Om de gemeten hoeveelheden aan nitraat en fosfaat te kunnen verklaren en om uitspraak te kunnen doen over derogatie (cfr. offerte) werd er voor ieder perceel een nutriëntenbalans berekend. Om de juiste hoeveelheden aan toegediende nutriënten te bepalen werden er analyses uitgevoerd van de toegediende organische meststoffen. Daarnaast werd informatie over de landbouwpraktijk, bemesting en opbrengst op perceelsniveau en bedrijfsgegevens opgevraagd bij de deelnemende landbouwers.

De resultaten van alle meetgegevens en berekeningen werden gebruikt om derogatie met niet derogatie te vergelijken en het effect van derogatie op de waterkwaliteit te onderzoeken. De evaluatie van de impact van derogatie op de waterkwaliteit, a.d.h.v. de bekomen gegevens, zijn ondermeer gebruikt als wetenschappelijke basis voor een aanvraag tot verlenging van derogatie voor Vlaanderen na 2010.

Op basis van de metingen vanaf 2009 tot 2011 konden enkele conclusies gertokken worden. Verschillen in bemestingsadvies en hoeveelheden aan nutriënten in het bodemprofiel zijn aanwezig tussen verschillende gewassen en verschillende bodemtypes maar veel minder tussen derogatie en niet-derogatiepercelen. In geen enkele bemonsteringsperiode werden er significante verschillen tussen derogatie en niet-derogatiepercelen gevonden wat betreft de hoeveelheid nitraat in het bodemprofiel van 0 tot 90 cm. De hoeveelheid nitraat in het bodemprofiel werd hierbij vergeleken tussen derogatie en niet-derogatiepercelen voor specifieke combinaties van bodemtype en gewas. Uitspoeling gedurende de winter werd niet enkel geëvalueerd aan de hand van de metingen maar ook op basis van berekeningen met het Burns model, uitgaande van het nitraatresidu voor de winter. Op basis van berekeningen met het Burns model werden geen significante verschillen tussen derogatie en niet-derogatiepercelen gevonden wat betreft hoeveelheid uitgespoeld nitraat uit het bodemprofiel.

Nitraatconcentraties in de waterstalen vertonen een dalende trend gedurende de periode van de monitoring. Er werden geen significante verschillen gevonden aan nitraatconcentraties in de meetpunten (MAP grondwatermeetpunten en peilbuizen) tussen derogatie en niet-derogatiepercelen. De gemeten nitraatconcentraties in een grondwatermeetpunt werden gekoppeld aan een individueel perceel in het monitoringnetwerk op basis van de reistijd en het intrekgebied.

Er werden verschillen vastgesteld aan fosforconcentraties tussen de verschillende soorten meetpunten. De laagste concentraties werden gemeten in de MAP grondwatermeetpunten en peilbuizen, hierbij werden regelmatig concentraties beneden detectielimiet gemeten. De hoogste concentraties aan fosfor werden gemeten in grachten en drainagesystemen. De hogere concentraties aan fosfor bestaan meestal uit anorganisch fosfor. De lagere concentraties aan fosfor, gemeten in de MAP grondwatermeetpunten en in water afkomstig van de diepere bodemlagen bestaat voor het grootste deel uit organisch fosfor. Er werden geen significante verschillen vastgesteld van fosforconcentraties tussen derogatie en niet-derogatiepercelen gemeten in grondwatermeetpunten, drainagesystemen, grachten en water afkomstig van de diepere bodemstalen die gekoppeld zijn aan individuele percelen. Percelen die gekenmerkt worden door hogere concentraties aan fosfor in een P-AL extract in de bouwlaag worden meestal ook gekenmerkt door hogere concentratie van fosfor in de diepere bodemlagen. Er is ook een positieve correlatie tussen P-AL in de bouwlaag en de fosfaatverzadigingsgraad van een perceel.

Derogatiepercelen worden gekenmerkt door hogere bemestingsniveaus. Bemesting op derogatiepercelen bestaat voor een groot gedeelte uit organische bemesting. Daarnaast worden derogatiepercelen niet gekenmerkt door een lagere minerale bemesting zodat de totale input aan stikstof op deze percelen op een hoger niveau ligt in vergelijking met niet-derogatiepercelen. Naarst de hogere input worden derogatiepercelen ook gekenmerkt door een hogere export van nutriënten in vergelijking met niet-derogatiepercelen. Deze hogere export is voornamelijk aanwezig op maïs en graslandpercelen en komt tot stand door extra afvoer van een snede gras. De hogere input van nutriënten in combinatie met een hogere export van nutriënten op derogatiepercelen resulteert niet in significante verschillen tussen derogatie en niet-derogatiepercelen wat betreft nitraatresidu.

Op basis van gegevens bekomen van het derogatiemonitoringnetwerk kan geconcludeerd worden dat "derogatie in Vlaanderen geen negatieve impact heeft op de waterkwaliteit".

Table of Contents

ABBREVIATIONS

AL	Ammonium Lactate
CF	Continuous Flow
DIP	Dissolved Inorganic Phosphorous
DOP	Dissolved Organic Phosphorous
EEC	European Economic Community
GIS	Geographical Information System
HHZ	Hydrogeologically Homogeneous Zones
IC	Ion Chromatography
ICP	Inductive Coupled Plasma
K.U. Leuven	Katholieke Universiteit Leuven
MAP	Manure Action Program
PSC	Phosphate Sorption Capacity
PSD	Phosphate Saturation Degree
SSB	Soil Service of Belgium
VLM	Flemish Land Agency
VMM	Flemish Environment Agency

1 Introduction

The first part of the report dealt with the selection of the different farms and parcels of the network. The different steps to identify 227 parcels and 180 farms are discussed as well as all the measurements that were going to be taken on these parcels. In a first phase those parcels, with the preferred conditions of soil type and cultivated crop and that are lying in the infiltration area of a MAP sampling point, were selected. In a second phase extra parcels were selected with the proposed characteristics (cultivated crop and soil type) but which are not lying in the infiltration area of a MAP sampling point. If possible, monitoring wells were placed on these parcels. This way it was possible to set up a network of parcels with a good distribution between derogation and no derogation, the different soil types and cultivated crops. Due to the monitoring wells and MAP sampling points it is possible in most cases to link the measurements of a parcel to measurements of the groundwater quality. Table 1 shows the 227 parcels in the network for the different combinations of soil type and cultivated crop. Table 2 illustrates the time scale of the different measurements that take place on the parcels. More details on the selection procedure and the different samples taken at parcel level are discussed in the first report.

The second part of the report will discuss the results of the field measurements at the end of the growing season 2009, at the beginning and the end of growing season 2010 and those at the beginning of 2011. Also some measurements are carried out during the growing season. Initially, every type of measurement is investigated separately. In a second step the measurements of the end of the season are compared with the measurements at the beginning of a season and comparisons are made between different years. For each measured parameter it is determined whether there were differences between derogation and no derogation parcels in general as well as for specific combinations of soil type and cultivated crop. By comparing of data for specific combinations, it is possible to exclude the possible effects of the cultivated crop and soil type. To measure the effect of agricultural practices on the water quality, the two most important parameters are **nitrate** and **phosphorous**. Those 2 parameters will be discussed extensively in this report.

To compare derogation with no derogation parcels and to investigate the effect of derogation on the water quality different samples are taken. Those different samples consist of 2 groups; **soil samples** and water samples. The first soil sample is **the nitrate sample**. This sample is taken from 0 to 90 cm in three layers (0-30, 30-60 and 60-90 cm). The amount of nitrate is determined in each layer. A second soil sample (**the deep soil sample**) is taken on a selection of parcels. In these parcels the soil is sampled from 90 to 150 cm in two layers (90-120 cm and 120-150 cm). In these samples both the amount of nitrate and phosphorous is measured. In addition, in 50 % of the deep soil samples the total amount of phosphorous as well as the different fractions (DIP and DOP) of phosphorous are determined. Beside the soil samples several **water samples** are taken. These samples are taken from canals, ditches and drainage, MAP sampling points and monitoring wells. Each sample is coupled to a specific parcel in the network. On these samples the amount of nitrate and phosphorous is measured. Also, in 25 % of the water samples the total amount of phosphorous as well as the different fractions (DIP and DOP) of the phosphorous is measured.

To investigate the difference between derogation and no derogation parcels for the different combinations of soil type and cultivated crop a statistical model is used. The effects are mostly investigated with a one-way ANOVA model. To use this model normality of the data and homogeneity of the variances is required. For most parameters a logarithmic transformation of the data is carried out to fulfil these conditions. The most important output of the ANOVA models are the p-values, this value is an indication of the signification level of the investigated effect. A 0.05 significancy level is used to decide whether derogation differed from no derogation for each of the investigated parameters.

Table 1: Overview of all the parcels in the monitoring network. Distinction is made between parcels lying in the infiltration area of a MAP sampling point and parcels selected with candidate farmers.

		DEROGATION									NO DEROGATION											
MAP sampling		grassland		maize		beets		winter wheat		**total**	grassland		maize		beets		winter wheat		other		**total**	**Total**
point		*deep*	*undeep*	*deep*	*undeep*	*deep*	*undeep*	*deep*	*undeep*		*deep*	*undeep*	*deep*	*undeep*	*deep*	*undeep*	*deep*	*undeep*	*deep*	*undeep*		
	Sand	5	7	5	6					23	5	10	3	20			1	2	2	4	47	
	Sandy loam	2	3		3					8	2		3	5	1		2		7	5	25	
	Loam											1	1	1	1	1		1			6	
	Clay											4		1			1	1		1	8	
	Total	7	10	5	9					**31**	7	15	7	27	2	1	4	4	9	10	**86**	**117**
Candidates		grassland		maize		beets		winter wheat		**total**	grassland		maize		beets		winter wheat		other		**total**	
monitoring well		*deep*	*undeep*	*deep*	*undeep*	*deep*	*undeep*	*deep*	*undeep*		*deep*	*undeep*	*deep*	*undeep*	*deep*	*undeep*	*deep*	*undeep*	*deep*	*undeep*		
ditches	Sand	4	24	2	15				1	46	6	6		3	1						16	
rivers	Sandy loam	3	7	2	6	1	2			21	3	2	2				1	1			9	
drainage	Loam		3	1	1					5	1	1	2	3							7	
	Clay			2		2				4	1							1			2	
	Total	7	36	5	24	1	2		1	**76**	11	9	4	6	1		1	2			**34**	**110**
TOTAAL	**Total**									**107**											**120**	**227**

Table 2: Time scale of measurements.

	Time scale																
	2009			2010												2011	
Month	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2
Soil samples																	
Standard BDB soil sample	×	×															
Nitrate sample	×	×		×	×			×*			×**		×	×		×	×
Deep soil sample	×	×		×	×								×	×		×	×
Water samples																	
MAP sample point		×			×									×			×
Monitoring wells		×			×									×			×
Drainage		×			×									×			×
Canals and ditches		×			×									×			×
Water from deep soil sample	×	×		×	×								×	×		×	×

* and **: Each parcel will be sampled during the growing season. The exact moment of sampling will depend on the cultivated crop.

2 Selection of 180 farms/225 parcels

2.1 Selection based on the MAP sampling points for groundwater

2.1.1 Introduction

Since 2003 the MAP-groundwater monitoring network is operational in Flanders. This network of approximately 2,100 locations is frequently sampled and analyzed for several parameters regarding the water quality and the hydraulic head. One of these parameters is nitrate, which is an important pollutant in phreatic groundwater. Through this monitoring network it is possible to follow up the evolution of the groundwater quality in Flanders and to evaluate the efforts made to meet the Nitrate Directive (91/676/EEC), which sets the maximum value for nitrates in any water body at 50 mg/l.

The MAP-groundwater monitoring network is set up in such a way that mainly agricultural areas are sampled and that vulnerable groundwater bodies are sampled more than those that are less susceptible to nitrate pollution (Figure 1).

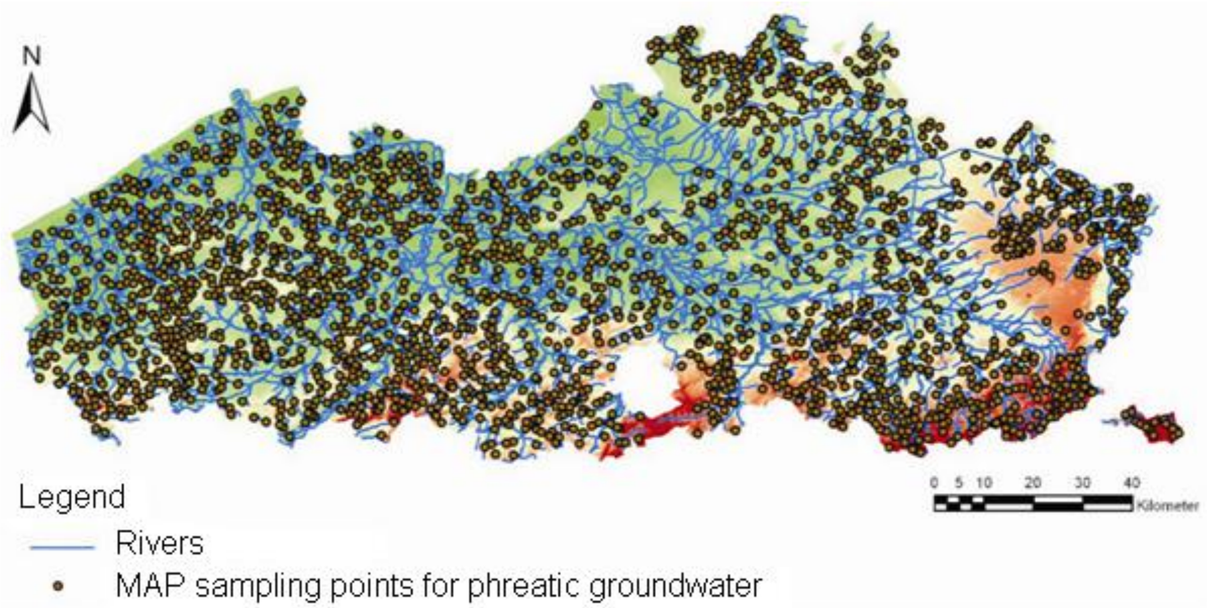

Figure 1: Location of the MAP sampling points for phreatic groundwater of the MAP-groundwater monitoring network in Flanders. Topography is set as background. (Source: AGIV, VMM)

Each location of the MAP-groundwater monitoring network consists of a multilevel well and usually consists of 3 separate wells with filters at different depths in the phreatic aquifer in order to be able to measure a vertical variation in the groundwater quality (Eppinger, 2005). The wells are equipped with one or more filter elements of 50 cm in length. Preferably, the first two wells were installed in the oxidized zone of the aquifer, where the third well was installed in the deeper reduced zone. The oxidized zone is rich in oxygen and therefore no microbial reduction of the nitrate will occur. The measured nitrate concentration in this zone can be easily linked to the amount of nitrate percolated out of the soil profile.

In the reduced zone of the phreatic aquifer, microbial reduction processes take place and nitrate will be used in these processes instead of oxygen and will be removed from the aquifer.

Thus the first two monitoring wells will give better insight in the pollution of the groundwater whereas the third filter will provide information on the background concentration of nitrate in the aquifer (Eppinger, 2005).

2.1.2 Oxido-reduction reactions in the saturated zone

Chemical reactions involving the transfer of ions will influence the behaviour of many ions and elements in the underground. The redox status of an element will be influenced by the amount of electrons in a chemical system (Essington, 2003). Therefore the redox status of the aquifer will highly influence the mobility and stability of ions and molecules in the aquifer.

Nitrogen can be present in the soil as an ion (NO_3^-, NO_2^- and NH_4^+) or in a gaseous state (N_2 and N_2O). The different states of nitrogen vary according to the position in the underground and its redox status.

As outlined before, a phreatic aquifer can be divided in two different zones, the oxidized top zone and the reduced lower zone. In the oxidized zone, dissolved oxygen is present. There it is being used in microbial oxido-reduction processes (mainly the breakdown of organic matter) and acts as an electron acceptor. Below this oxidized zone, a reduced layer is present, which is characterized by low oxygen content but where other electron acceptors like Fe^{III}-compounds, Mn^{IV}, NO_3^- are present. Due to the low oxygen content in this layer, NO_3^- and NO_2^- can be reduced to N_2, N_2O or NH_4^+ when organic matter or pyrite is oxidized.

Therefore the nitrate concentrations in groundwater should be preferably measured in the oxidized zone, before nitrate is removed from the water by microbial reduction processes.

Preferably the results of the first filter of each sample point will thus be used in the further research. Also the travel time of the groundwater, from root zone to filter, should not be too high, in order to be able to link fertilisation practices to the ground water quality. Furthermore only those sampling points are selected, for which the extracted water sample can be linked to an infiltration area that corresponds to a specific agricultural parcel with a certain statistical probability.

2.1.3 Infiltration area and travel time from root zone to filter

The water, sampled from a certain monitoring well, has travelled a long way through the underground, after it came down as precipitation on the soil surface. The exact location where this precipitation infiltrated in the soil, from where it moved further through the unsaturated and saturated zone, is of high importance in order to link the management practices of a parcel to the quality of the ground water.

To locate this infiltration area we first defined the infiltration point as the point in the field from where the water moves through the underground through the middle of the filter of the monitoring well (Figure 2).

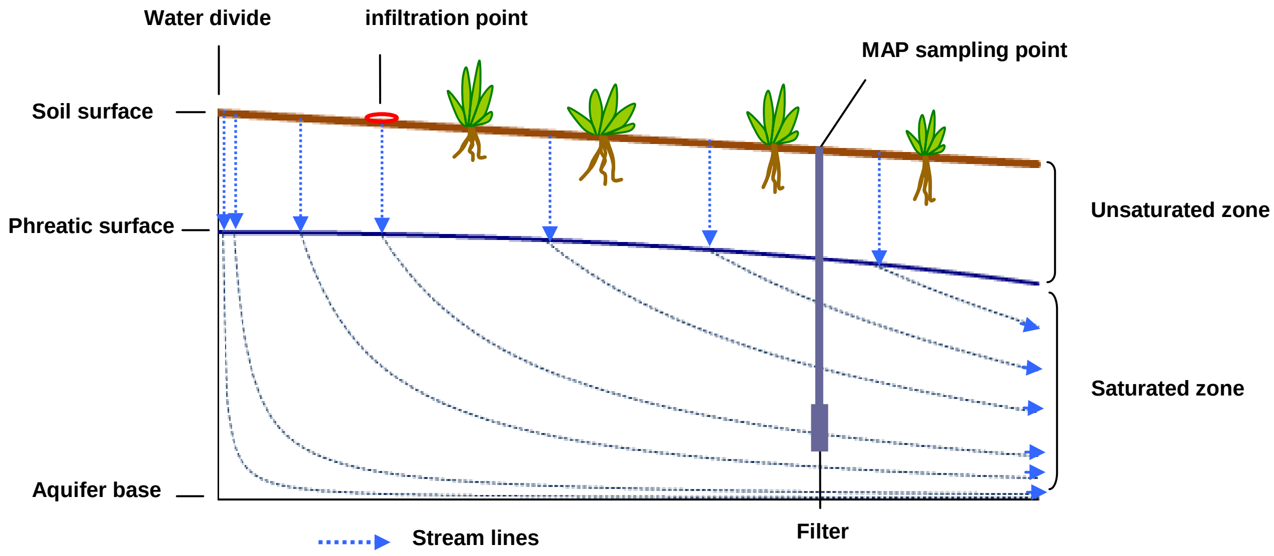

Figure 2: Schematic representation of soil and ground water flow ***(heights and distances are not to scale)***

Because of the dimensions of the filter, the actual location of the infiltrating water is not a single point, but more a cigar-shaped area along the vertical projection of the stream line. Furthermore statistical uncertainties of the aquifer properties, result in a statistical uncertainty of the exact location of this infiltration point. Therefore an elliptic area is statistically delineated around the infiltration point wherein the actual infiltration point is located with a certain statistical probability. This elliptic area is further called the "*infiltration area*" (Figure 3).

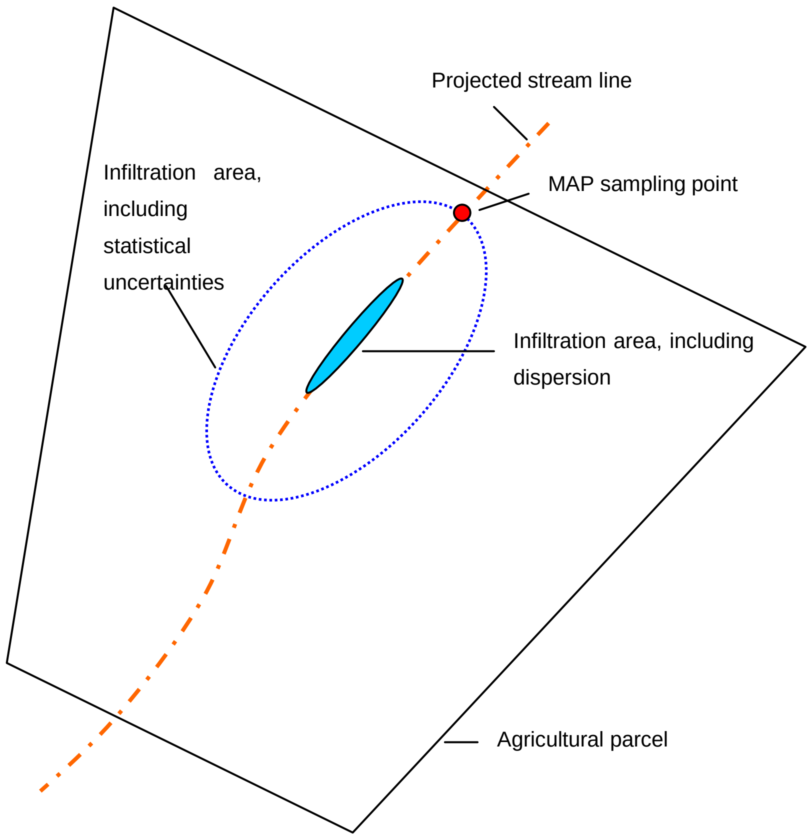

Figure 3: Hypothetical view on an agricultural parcel with a MAP- sampling point and its infiltration area.

Beside the location of the infiltration area, the total travel time for the sampled water needs to be calculated. The travel time is the average time needed for the nitrate in solution to travel from the bottom of the root zone (90 cm below surface) to the filter where the sample is taken at a certain moment in time. Based on the travel time we know which nitrate residue measurement (of which year) corresponds with a certain water sample.

The travel time consists of two components: the movement through the unsaturated zone and the movement through the saturated zone. Because nitrate moves as a conservative molecule (no sorption), the travel time of the nitrate is the same as the travel time of the water wherein it is dissolved.

Shortly, the delineation of the infiltration area and the calculation of the total travel time have been conducted as follows:

First the phreatic surface was modelled by means of Bayesian Data Fusion Methodology (BDF) (Fassbender *et al.*, 2008). With this methodology, geostatistical interpolation (kriging) of ca 2100 piezometric pressure heads was statistically combined with a simple groundwater model to come to a groundwater map which proofed, by means of cross validation, to globally perform better than any of the two constitutive models.

This groundwater map was then further used to calculate the path of the streamlines, flowing through the filters of the monitoring wells. This was performed using a "particle tracking algorithm", where by means of backward tracking over the steepest gradient the flow line was delineated for every monitoring well. This flow line typically ends at the water divide.

Next the location of the infiltration point was calculated. This was done by means of a simple formula (Cook and Böhlke, 1999) where the distance (D) from the infiltration point to the monitoring well divided by the length of the stream line (L) equals the depth (z) of the monitoring well divided by the total depth (h) of the aquifer:

$$\frac{D}{L} = \frac{z}{h}$$

The location (D) of the infiltration point was then calculated.

An area was further delineated around this infiltration point to account for the statistical uncertainties which originate from uncertainties of the aquifer properties. This area is a probabilistic zone around the infiltration point wherein the exact infiltration point can be found with a certain probability. In this specific case a probability of 0.75 was chosen, which results in an elliptic area with dimensions for the semimajor and semiminor axis of 1.02 and 0.59 times the distance from the well to the modelled infiltration area.

2.1.4 Analysis of the infiltration areas and selection of parcels

All MAP sampling points for groundwater with a travel time from soil surface to the filter element of the sampling point of maximum 3 years were selected. This travel time is important to link the fertilisation practices on a parcel with the measurements in a MAP sampling point. Because nitrate has the same travel time as the water, nitrate concentrations measured in a MAP sampling point can be coupled to a fertilisation year based on the travel time. A three years travel time allows to couple samples taken in a MAP sampling point in 2011 to the fertilization year 2008. To make relatively quick conclusions about the effect of fertilization on the groundwater quality it is not sufficient to use travel times older than three years.

Out of the 2,100 infiltration areas, 776 infiltration areas have a travel time of maximum 3 years. The MAP sampling points corresponding to these infiltration areas are spread over the different HHZ zones as defined by Eppinger *et al.* (2002).

2.1.4.1 Overlay of the infiltration areas with parcel maps

All 776 selected infiltration areas where overlaid with several maps. The parcel map was the most important. In the first step it was important to see if an infiltration area existed of only one parcel so that there was a direct link between fertilisation practices on the level of a parcel and the measurements in the MAP sampling point. Based on the parcel map every infiltration area received a code. The explanation of this code is given in Table 3.

Table 3: Explanation of the different codes assigned to the infiltration areas.

Code	Explanation of the code
100	Infiltration area completely in one parcel and large enough to be representative for that parcel
751	Infiltration area almost completely filled with one parcel (dominant), the centre of the infiltration area consists of the dominant parcel
75	Infiltration area with one dominant parcel in the centre. There are other parcels in the infiltration area but not in the middle. The other parcels represent a larger area than in the case of code 751. More than 1 dominant parcel can be present but then they have the same features (soil type, derogation and fertilization practice)
50	Infiltration area without one dominant parcel.
20	A lot of parcels in the infiltration area or no parcel in the infiltration area. There is no connection between a single parcel and the MAP sampling point

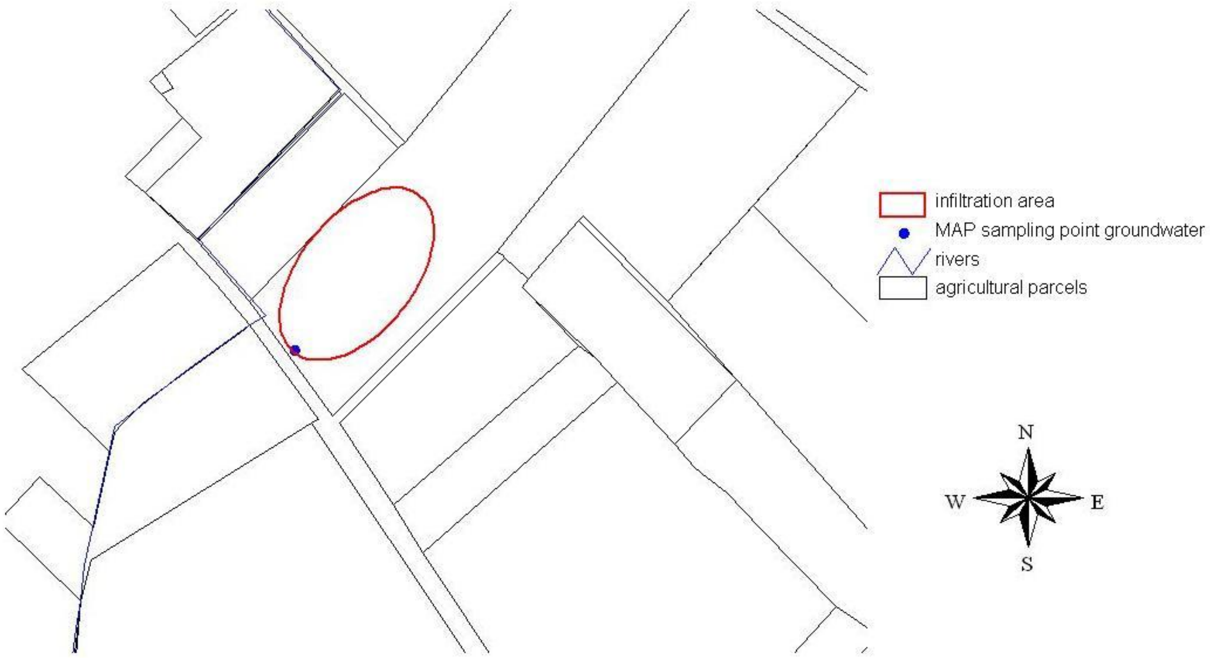

Figure 4: Infiltration area having code 100.

The different codes assigned to all the selected infiltration areas are illustrated in Figure 4 to Figure 8. Figure 4 illustrates an infiltration area with code 100 and Figure 5 one with code 751.

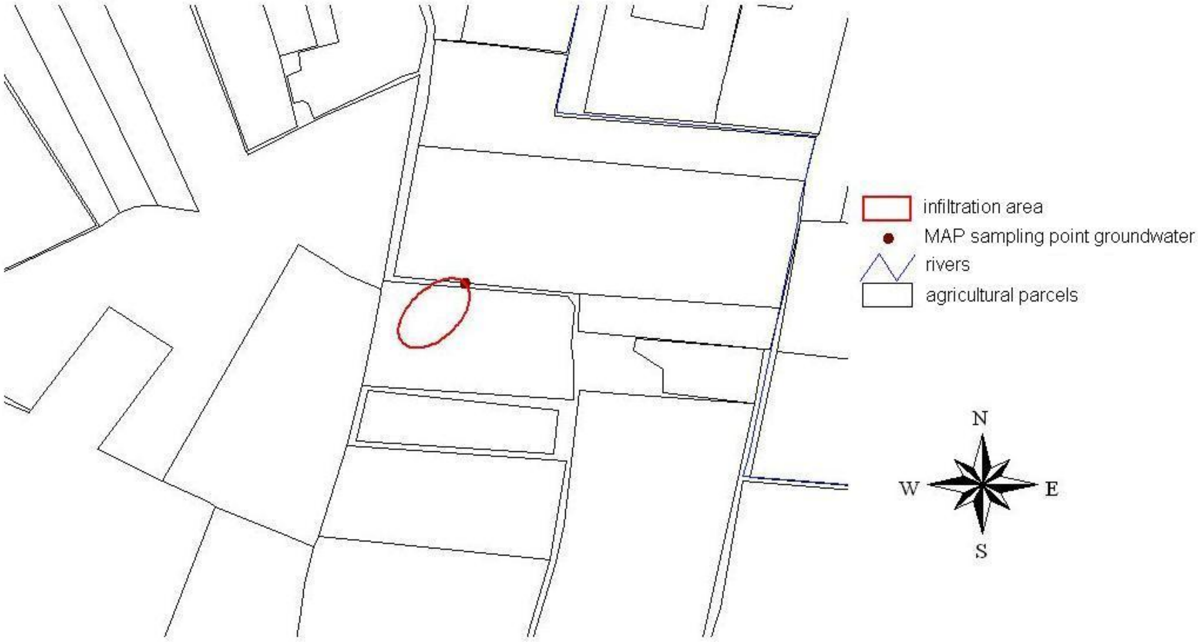

Figure 5: Infiltration area having code 751.

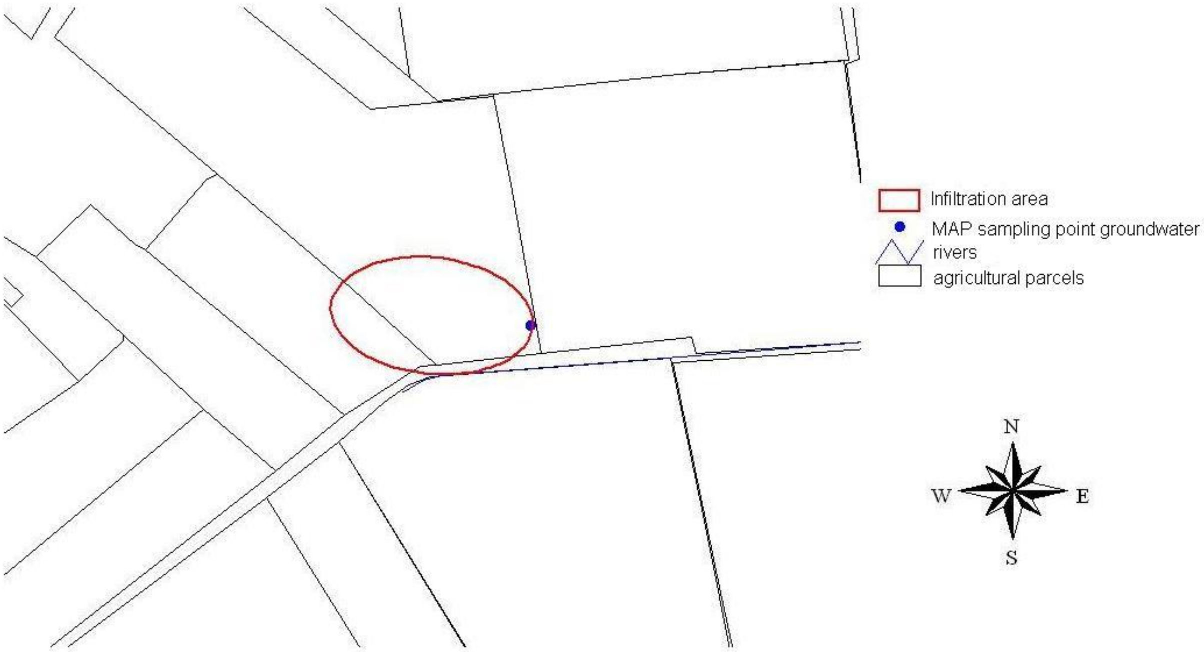

Figure 6: Infiltration area having code 75.

For infiltration areas like shown in Figure 7 some characteristics have been checked. If all dominant parcels in the infiltration area have the same soil type, derogation or no derogation and fertilisation practice than code 75 Figure 6 was assigned. In the other case the infiltration area kept code 50 and was not very useful.

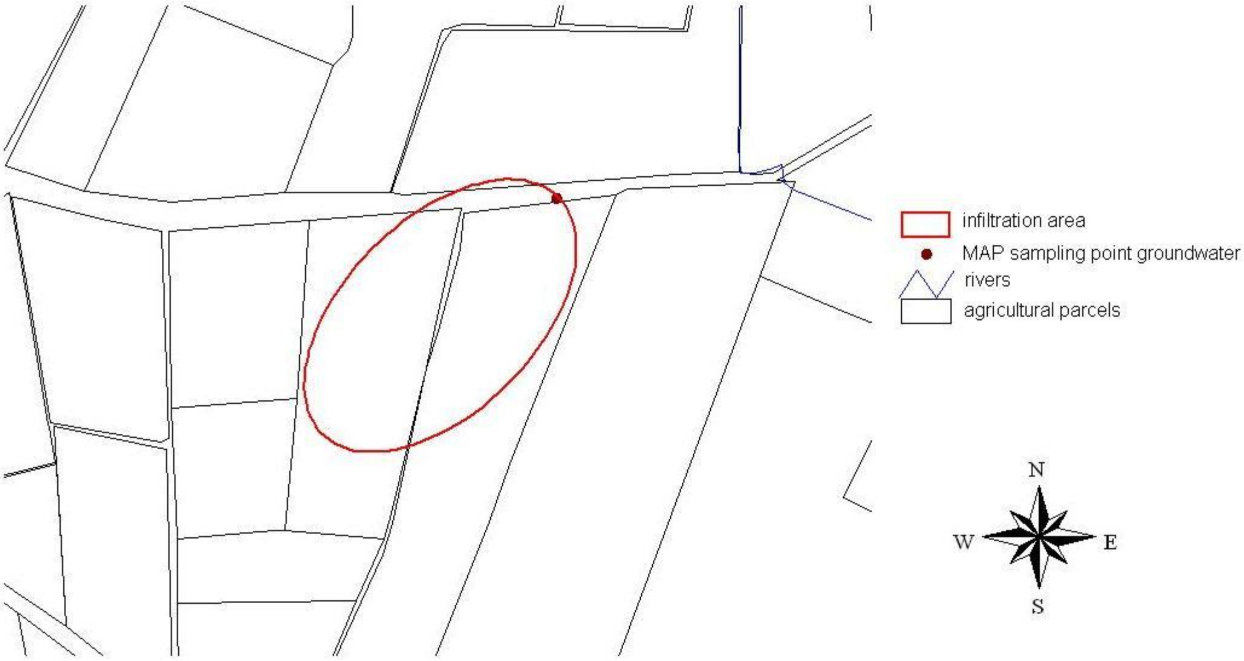

Figure 7: Infiltration area having code 50.

As can be seen in Figure 8 infiltration areas with code 20 are unusable. In these cases no link can be made between a single parcel and the water quality in the MAP sampling point.

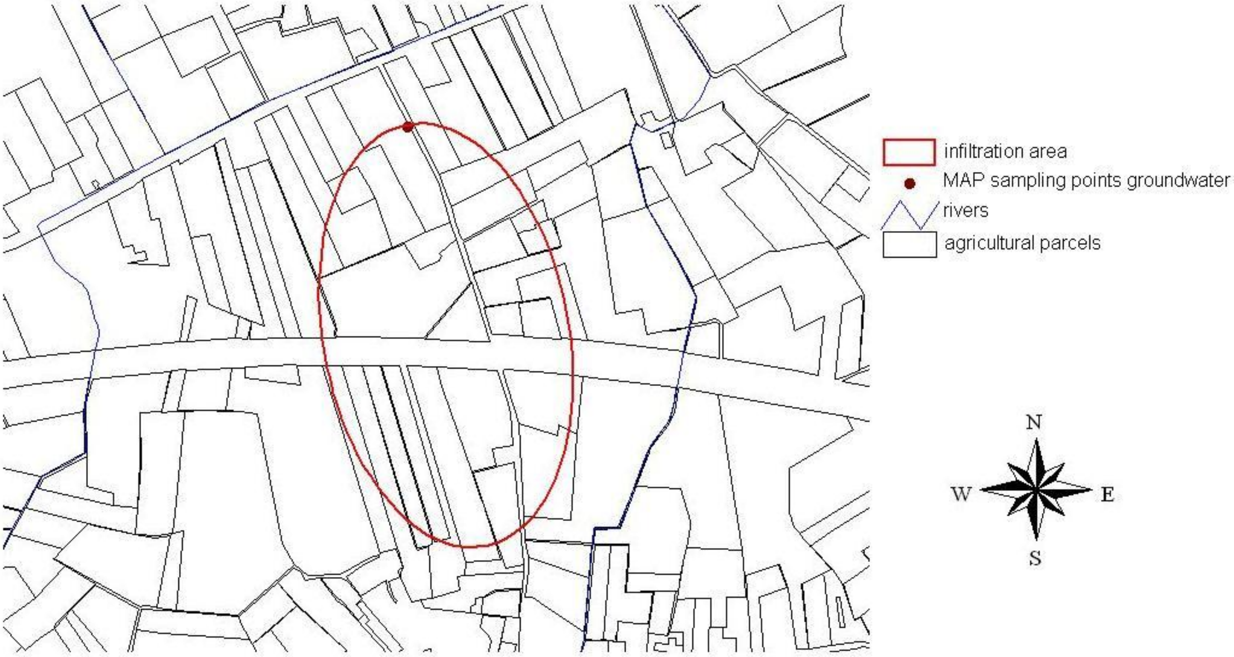

Figure 8: Infiltration area having code 20.

2.1.4.2 Summary of the characteristics of the infiltration areas

As a next step to select useful MAP sampling points, it was necessary to look at the parcel features. Together with the information of the MAP sampling points the information of all the parcels situated in the infiltration areas was compiled in an Access database. The most important information in the database was:

-at the level of the MAP sampling points:

Number assigned to the sampling point

The HHZ where the MAP sampling point was located

Assigned code of the infiltration area of the MAP sampling point

-at the level of the parcels:

Farmer: identification (initially this was a fictive number)

Crop, soil type, derogation, area

Area of the parcel lying in the infiltration area

It is important that a sufficient part of a parcel is lying in the infiltration area. As such the infiltration area is representative for the total area of the parcel. Corners and borders of parcels are not representative for the fertilization on a parcel. So if a little infiltration area is covered completely with the borders and corners of a parcel this infiltration area was not selected.

For all the infiltration areas with a maximum travel time of 3 years and code 100, 751, 75 and 50 this information was gathered in the database. In case an infiltration area covered several parcels, the information of all the parcels was added. Table 4 gives an overview of all 776 infiltration areas and the assigned code.

Table 4: Number of MAP sampling points for groundwater with a maximum travel time of 3 years for each code assigned to the infiltration areas.

Code	MAP sampling points
100	33
751	91
75	128
50	117
20	265
No infiltration area	142
Total	776

Table 4 shows that 142 MAP sampling points have no infiltration area. For these sampling points the developed model did not work. Only MAP sampling points with an infiltration area having code 100, 751 and 75 were selected, resulting in 252 useful infiltration areas, corresponding to 270 parcels. In a number of infiltration areas 2 parcels were dominant. If they had the same features (soil type, derogation and agricultural management), both parcels were selected.

Next it was important to determine whether farmers were interested to participate in the monitoring network. Using the contact data of farmers from selected parcels given by the authorities (VLM), it was possible to verify if they would like to participate. Most farmers were contacted by telephone and only few by email. Altogether this was a very time-consuming and labour-intensive process. Beside the willingness of farmers to participate the following information was asked:

Crop in the year 2009
Fertilisation (derogation or no derogation) in the year 2009
Representativity of the parcel

Based on this information a first group of parcels and farmers was selected to participate in the network. This selection resulted in 117 parcels, 31 derogation parcels and 86 no derogation parcels. During the selection process it was important to pay attention to the desired combinations of soil type and crops (listed in Table 5). It is necessary to have an even distribution between derogation and no derogation parcels.

Table 5: Proposed distribution for the different criterions (derogation, soil type and crop) of parcels in the monitoring network.

Criterion	Distribution
Derogation/No derogation	50/50
Sand/sandy loam/loam/clay	50/30/10/10
Grassland/maize/winter wheat/beets	50/30/15/5

In the final selection of parcels also parcels which are not cultivated with a derogation crop will be included. In reality, farmers rotate crops to have a higher yield. Only grassland and maize are often cultivated year after year on the same field. These crops don't experience a negative effect due to absence of rotation. Moreover they are often cultivated on fields that are not good enough for cultivating beets, winter wheat or other no derogation crops. Because the monitoring network has to represent the situation of the Flemish agriculture also parcels with no derogation crops were selected, especially when interesting fields were situated in the infiltration area of an existing MAP sampling point. For these parcels a lot of interesting information on the water quality will be available. After the cultivation of a no derogation crop, a derogation crop will be cultivated on these parcels.

During part 1 parcels lying in infiltrating areas of MAP sampling points for groundwater were selected. This resulted in the selection of 117 parcels, of which farmers were willing to participate in the monitoring network. However, this was insufficient since the monitoring network had to comprise at least 150 farms and 225 parcels.

2.2 Selection of parcels cultivated by candidate farmers

After selecting parcels that are lying in the infiltration areas of MAP sampling points for groundwater, there were still insufficient parcels for the monitoring network. Therefore an active search of candidate farmers and encouragement of these farmers to participate in the research project was performed.

Parcels cultivated by candidate farmers had no direct influence on a MAP sampling point for groundwater. Ideally the parcels were selected in such a way that a monitoring well could be placed in order to take a water sample influenced by the fertilization practices on that particular parcel.

2.2.1 Recruitment of farmers

To find and motivate farmers for participating in the monitoring network, we cooperated with the 3 most important Flemish agricultural organizations (BB, ABS and VAC). They gave their full support to the investigation. To inform farmers a couple of articles were published in the specific journals of these organizations. Besides giving information on the network, the importance of derogation for the Flemish agricultural sector was explained. Finally, to motivate farmers to participate, those farmers were granted several benefits (like soil analysis with fertilisation advice for the most important nutrients, specific nitrate fertilisation advice, exact composition of the livestock manure, permission to use fertilisation programs) to compensate for their cooperation in the network.

The majority of the candidates were farmers applying derogation. In order to obtain enough farmers with suitable parcels, we also personally contacted farmers, who were active clients of BDB. Since these farmers are very motivated, the chance of them participating was very big.

2.2.2 Selection of parcels

For the selection of parcels with candidate farmers' attention was being paid to the required distribution as mentioned in Table 5. The selection of parcels cultivated by candidate farmers was done stepwise. The several selection steps are summarized below:

- Candidate farmers confirm their participation
- Farmer number: necessary to locate their parcels on the parcel map
- Evaluation of the parcels on the parcel map and collection of information on the parcels. This information is necessary to establish a good balanced network as proposed in Table 5.
    - Area (between 0.5 and 2 hectare)
    - Crop: derogation crops and especially maize and grassland
    - Derogation
- Groundwater level: if possible parcels with a groundwater level of maximum 1.5 m were selected. On these parcels the parcel management has a more direct influence on quality of the water.

Based on these criteria a number (mostly 5) of parcels were selected for each farmer. The next step was to investigate whether it was possible to place a monitoring well on the parcel in order to take a water sample.

The suitable parcels of candidate farmers were selected in such a way that monitoring wells could be installed so that the parcels are lying in their infiltration area. The second step consisted of defining the optimal depth of the filters of the monitoring wells, in order to have reasonable infiltration areas and corresponding travel times. To define the optimal depth of the monitoring wells, the infiltration area and corresponding travel time for hypothetical monitoring wells at four different depths at the centre of each parcel were calculated. The hypothetical depths were chosen as 0.5 m, 1 m, 2 m and 3 m below the modelled mean phreatic head at that location. For each of these depths the particle tracking algorithm was ran and the infiltration areas and travel times were calculated (Figure 9).

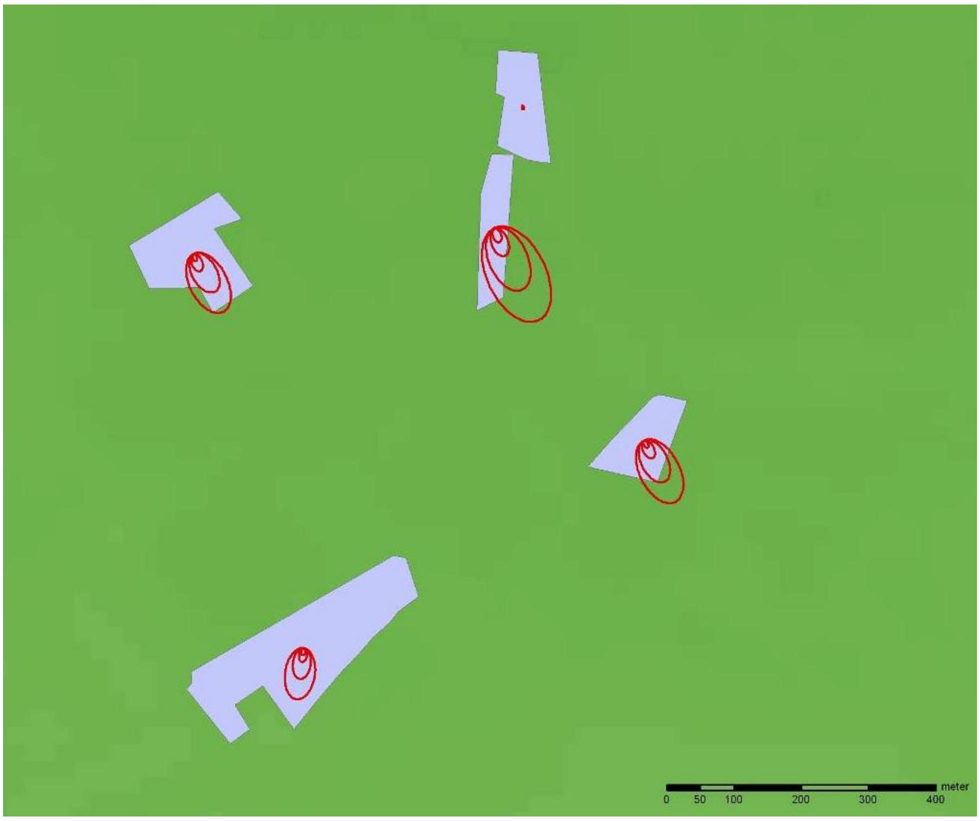

Figure 9: Some parcels (purple) with 4 corresponding infiltration areas (red ellipses).

Then, the best combination of infiltration area-size and corresponding travel time was chosen. The installation depth of the monitoring well and its location within the parcel were defined in such a way that the effects of fertilization practices on this parcel would be measured within the set time frame. The monitoring wells were installed according to the guidelines of the Flemish government in the offering.

In total 50 monitoring wells on 50 different parcels were installed. For the other parcels of the candidate farmers the selection was based on several other features like: derogation, crop, soil type and location.

2.3 Selection of additional parcels cultivated with grassland

To have 225 parcels and at least 150 farmers, automatically several farmers will participate with more than 1 parcel. The selection of parcels from MAP sampling points and with candidate farmers had resulted in a low number of parcels cultivated with grassland. Therefore additional parcels with grassland where selected from farmers already participating the network with another parcel (no grassland). Because additionally selected parcels did not lie in the infiltration area of a MAP sampling point some other measurements will be necessary to have an idea on the water quality. This way 13 parcels with no derogation and 5 with derogation were selected and added to the network.

2.4 Overview of farms and parcels in the monitoring network

Farms and parcels were selected starting from MAP sampling points for groundwater, the participation of candidate farmers and the selection of additional parcels grassland. In the next tables and figures the features of the selected parcels and farms will be discussed. The most important features are derogation, soil type and cultivated crops. Beside these features the geographical location of the parcels is also shown. All tables and figures are based on the parcel map of the agricultural year 2009.

2.4.1 Farms

Altogether the monitoring network consists of 188 different farmers. These farms are almost equally distributed between farms with a derogation request and farms without a derogation request in 2009 (Table 6).

Table 6: Number of farms that participate in the monitoring network, classified in derogation and no derogation farms in 2009.

	Derogation	No derogation	Total
Farms	91	97	188

One third of the derogation farms have a parcel lying in the infiltration area of a MAP sampling point for groundwater, which means that 2/3 of the derogation farms were selected among candidate farmers. Since farmers who request derogation need derogation and experience more the advantages of the derogation, they are very motivated to participate. In 2008 derogation was requested on 12% of the Flemish agricultural land. Therefore it is normal that there are more parcels with no derogation lying in the infiltration area of a MAP sampling point.

2.4.2 Parcels

In this phase the network consists of 227 parcels. It is possible that some parcels will be removed from the selection during the investigation due to their features. Figure 10 shows the geographical location of the 227 parcels in the monitoring network. Differentiation has been made between derogation (blue) and no derogation (red) parcels and also between parcels lying in the infiltration area of a MAP sampling point (bullets) for groundwater or not lying in an infiltration area of such a sampling point (flags). The 227 parcels are located all over the region of Flanders. However, most parcels are lying in sandy and sandy loam agricultural regions. Derogation occurs mostly in these regions so it was important to have the highest number of the parcels there. Since derogation as well as no derogation parcels are located in all regions, a comparison will be possible on different locations. In the eastern part of Flanders fewer parcels are lying in the infiltration area of a MAP sampling point. This region of Flanders is hillier, resulting in longer travel times and larger infiltration areas. In these cases it is less possible to link a single parcel with the water quality of a MAP sampling point. In spite of this, parcels will be followed up and water quality in these parcels will be investigated by using other measurements (drains, canals and ditches, deep soil samples or self placed monitoring wells (shallow)).

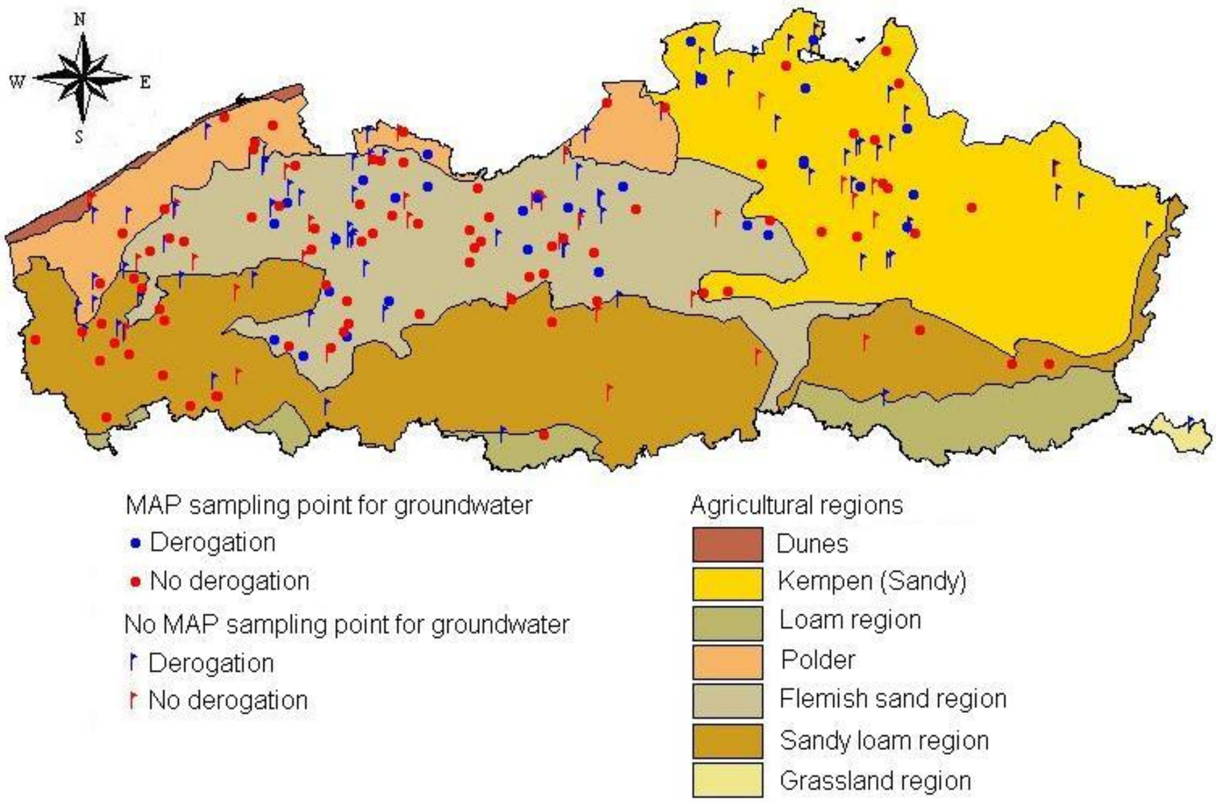

Figure 10: Location of the 227 parcels in the monitoring network on the agricultural regions of Flanders.

Table 7 and Table 8 show the different combinations of soil types and crops separately for the derogation and no derogation parcels. For 107 parcels (out of 227 selected parcels) derogation was requested in 2009. The different combinations of soil types and crops for derogation parcels are given in table 5. More than half of the parcels have as soil type sand and also more than half of the parcels have been cultivated with grassland. On the second place there are sandy loam soils. For crops maize is the second most important crop. For the year 2009, 99% of all the parcels wherefore derogation was requested in Flanders were cultivated with grassland and maize. For the other derogation crops (beets and winter wheat) it is difficult to satisfy the derogation conditions as assumed by the commission decision of 21 December 2007. Parcels with a request for derogation have to be cultivated with a derogation crop so the column other is empty in table 5.

Table 7: Number of derogation parcels for the different combinations of soil types and crops.

	Grassland	Maize	Beets	Winter wheat	Other	Total
Sand	40	28		1		69
Sandy loam	15	11	2	1		29
Loam	3	2				5
Clay	2	2				4
Total	60	43	2	2		107

In Table 8 the different combinations for the no derogation parcels are listed. There are 120 no derogation parcels in the monitoring network. On the no derogation parcels there are also other crops cultivated than just the derogation corps. Parcels with other crops have also been selected in the case they are laying in the infiltration area of a MAP sampling point for groundwater because on this way these parcels give very interesting information. Due to crop rotation it will be probable that the next year a derogation crop will be cultivated on these parcels.

Table 8: Number of no derogation parcels for the different combinations of soil types and crops.

	Grassland	Maize	Beets	Winter wheat	Other	Total
Sand	27	26	1	3	6	63
Sandy loam	8	13	1	4	11	37
Loam	3	4	2	1		10
Clay	5	1		3	1	10
Total	43	44	4	11	18	120

Table 8 shows that the combinations of sand and sandy loam with grassland and maize are the most important. This was also the case with the derogation parcels. Comparison between derogation and no derogation parcels can be made especially for these combinations.

2.4.3 MAP sampling points and monitoring wells

During the set-up of the monitoring network it was the idea to select as much as possible parcels that were lying in the infiltration area of an existing MAP sampling point for groundwater. This first selection procedure resulted in 117 parcels. On 50 parcels cultivated by candidate farmers a monitoring well was placed. Those parcels where marked by a low level of the groundwater. Figure 11 shows the location of those monitoring wells in the different agricultural regions of Flanders.

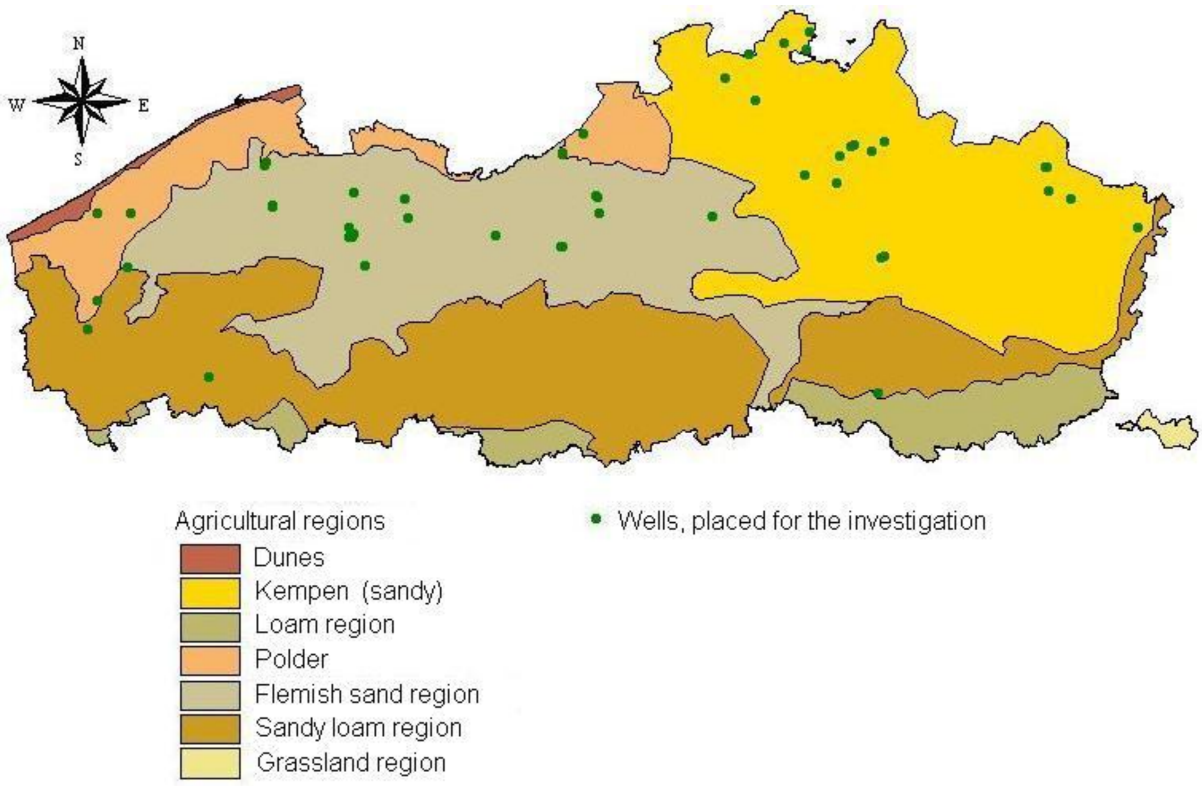

Figure 11: Location of the 50 monitoring wells placed on parcels not lying in the infiltration area of a MAP sampling point for groundwater.

167 parcels are lying in an infiltration area of a monitoring well or a MAP sampling point for groundwater. On these parcels water samples can be taken directly. The procedures for taking water samples from a monitoring well are as much as possible the same as for sampling MAP locations. The monitoring wells are placed on parcels with a specific combination of soil type and crop so that the derogation and no derogation parcels are proportionally divided for the most important combinations of soil type and crops. Table 9 shows the number of parcels that can be linked to a MAP sampling point or monitoring well for the different combinations of soil types and crops, separated for derogation and no derogation parcels.

There are 94 no derogation parcels, lying in an infiltration area of a monitoring well or a MAP sampling point for groundwater. This includes also 18 parcels where a no derogation crop was cultivated in 2009. So there are 76 no derogation parcels where a comparison is possible with derogation parcels for a specific combination of soil type and crop. The most important combinations of soil type and crops (sand or sandy loam cultivated with maize or grassland) exist both on derogation and no derogation parcels. There are also some less important combinations for which no comparison is possible (for example beets cultivated on a sandy soil). Because these combinations appear only rarely in practice, it is not relevant to compare.

Table 9: Number of parcels lying in the infiltration area of a MAP sampling point for groundwater or lying in the infiltration area of a monitoring well. These numbers are given for the different combinations of soil types and crops and separated for derogation and no derogation parcels.

	Derogation					No derogation					
	Grassland	Maize	Beets	Winter wheat	**Tot**	Grassland	Maize	Beets	Winter wheat	Other	**Tot**
Sand	29	23		1	**53**	17	25		3	6	**51**
Sandy loam	9	5		1	**15**	3	10	1	3	11	**28**
Loam	1	1			**2**	2	2	2	1		**7**
Clay	2	1			**3**	4	1		2	1	**8**
Total	41	30		2	**73**	26	38	3	9	18	**94**

2.4.4 Parcels with a deep groundwater level

Parcels with a winter groundwater level deeper than 150 cm are classified as parcels with a deep groundwater level. On these parcels there is a less direct effect on the quality of the groundwater. For these parcels the water quality will be measured by taking a soil sample in 2 layers: one from 90 to 120 cm and one from 120 to 150 cm. Measurements on these layers will be carried out on the soil sample and on water separated from the soil samples by centrifugation (measured parameters will be discussed in paragraph 3.4). The water level of all the parcels was generated from a model based on the measurements on the different MAP sampling points for groundwater located in Flanders. When the water level is deeper than 150 cm the travel time to the filter of a MAP sampling point often will be too large to use in a short time scale investigation. Table 10 shows the number of parcels classified as having a deep groundwater level and a shallow groundwater level. There are 85 parcels with a deep groundwater level and 142 with a shallow groundwater level. Because the selection of parcels with candidate farmers was based on parcels with shallow groundwater levels and candidate farmers are mostly derogation farmers there are more parcels in the network with a shallow groundwater level where derogation was requested.

Table 10: Number of derogation and no derogation parcels with a maximum groundwater (in winter) table deeper than 150 cm or not deeper than 150 cm.

	Derogation	No derogation	Total
Groundwater max > 150 cm	17	68	85
Groundwater max < 150 cm	90	52	142
Total	107	120	227

During the first selection procedure (starting from MAP sampling points) the most important condition was travel time. A travel time of maximum 3 years corresponds in certain cases with a groundwater level deeper than 150 cm.

The selection of parcels where a deep soil sample (from 90 to 120 cm and 120 to 150 cm) will be taken is based on a few rules:

- All the parcels with a deep groundwater level without a MAP sampling point or monitoring well
- Parcels with a deep groundwater level, with a MAP sampling point but with a travel time longer than 2.5 years.
- Parcels with a groundwater level around 150 cm and without the possibility to take any other water sample (MAP sampling point, monitoring well, drainage, canal or ditch)
- A good distribution between derogation and no derogation parcels so it is possible to make a comparison between both

Using these rules 72 parcels are selected to take a soil sample from 90 to 150 cm in two layers. These 72 parcels exist of 25 derogation and 47 no derogation parcels.

2.4.5 Canals, ditches and drainage

To measure the quality of the water influenced by agricultural practices it is also possible to take a sample from canals, ditches and drainage. In this case it is important to investigate whether the sample is influenced by a single parcel. In this way it is possible to link fertilisation practices to the measured values. Therefore a check on the field is necessary. In the case of drainage the effect of a single parcel is mostly very clear. For canals and ditches there is a greater chance that more than one parcel has an influence. Table 11 summarizes the number of parcels where a drainage, canal or ditch will be sampled. Again we tried to have a good distribution between derogation and no derogation parcels.

Table 11: Number of canals or ditches and drainage related to a parcel in the monitoring network. On this drainage, canals or ditches will be taken a water sample.

	Derogation	No derogation	Total
Drainage	7	7	14
Canal or ditch	15	11	26
Total	22	18	40

On 8 parcels with drainage and 23 parcels near a canal or ditch, no other possibility for measuring (MAP sampling point, monitoring well or deep soil sample) the water quality was present. For each of the 227 parcels in the monitoring network there will be taken a sample to investigate the quality of the water influenced by that parcel. This can be a sample from a MAP sampling point, monitoring well, drainage, canals, ditches or a soil sample from 90 to 150 cm. For each kind of measurement it will be possible to compare derogation parcels with no derogation parcels. To make sure that this comparison will be possible there are parcels where more than one kind of measurement of the water quality will be carried out.

2.4.6 Other features of the parcels in the monitoring network

Annex 1 shows the most important features of all the parcels in the monitoring network. This information can be used to decide which measurements are going to be taken on each parcel.

The most important features to describe the parcels in the monitoring network are:

- Derogation
- Soil type
- Crop
- Position in the infiltration area of a MAP sampling point or a monitoring well
- Ground water level, drainage and canals or ditches

Other important features of the parcels are:

- <u>Grassland near the farm</u>: in some cases these parcels will have a more intensive fertilization due to grazing livestock. 17 derogation and 16 no derogation parcels are typified as being grassland near the farm with a more intensive fertilization.
- <u>Derogation in 2007, 2008 and 2009</u>: on 73 parcels derogation has been applied for the last 3 years. On 76 parcels no derogation was applied in none of the three years.
- <u>Sensitivity for erosion</u>: most parcels are not sensitive for erosion, this can be important for pollution in canals and ditches by surface and subsurface run off.

3 Follow-up of the monitoring network

During the establishment and follow-up of the monitoring network a large amount of information has been and will be collected. Initially this information was necessary for the selection of the parcels, while during the monitoring phase the gathered information will allow characterization of the parcels and further interpretation of the results. The origin of the obtained information is very diverse: the authorities, the participating farmers and the consortium members. The most important information is mentioned below.

Information from the authorities:

- Parcel maps (derogation, crop, agricultural region, fertilization region, …)
- Soil maps (soil type, canal or ditch, drainage, …)
- Farm characteristics (identification, area, type, production of manure, amount of application of nitrogen from livestock manure, …)

Information from parcel and soil maps has been important for the establishment of the network. The farm characteristics can be used in a later part of the investigation to explain the results of measurements.

Information from farmers:

- Fertilisation practices and land management on parcel level
- Yield (necessary to calculate nutrient balances)
- Parcel characteristics

This information is exchangeable through telephone, fax, and mail or online by programs developed by the BDB.

Information from BDB:

- Information by field visits
- Experimental measurements on parcel level

3.1 Measurements

The different types of samples to be taken are discussed in the next paragraphs. The most important information is the different parameters and the number of parcels. Table 2 shows the time scale of the measurements. All water samples will be taken twice a year. The BDB standard soil sample will be measured only once during the project, while the nitrate sample will be measured every year before and after winter and once during the growing season. The deep soil sample will be taken twice a year. Annex 2 shows for each parcel in the monitoring network the kind of measurements that will be taken.

3.1.1 BDB standard soil sample

The standard soil sample has been developed by BDB. This sample is important to characterize the soil fertility of the different parcels in the monitoring network. It will be measured once on each parcel. The standard soil sample is a sample taken at a depth of 0 to 6 cm for grassland and 0 to 23 cm for other crops. The following parameters will be analysed:

- pH - KCl and %C
- P, K, Ca, Mg and Na (in ammonium lactate (AL) extract)

The pH has an effect on the availability of the nutrients. Carbon (%C) is important for mineralization. Both have an effect on the potential nutrients that can percolate to deeper soil profiles and to the surface and groundwater. P measured by the AL extract gives an indication for the amount of P that will be available to the crops. It also can be used as an indication for the phosphate saturation degree of a soil.

Based on the standard soil sample farmers can optimize their fertilization practices for a specific parcel. These analyses can also contribute to explain the measured values of nitrate in the soil profile. More information about this expert system can be found in the article ‘experience with fertilizer expert systems for balanced fertilizer recommendations’ (Vandendriessche *et al.,* 1996).

3.1.2 Nitrate in the soil profile (Nitrate sample)

Before (last week of October - first week of November) and after (last week of January - first week of February) winter a soil sample will be taken in three different layers (0-30 cm, 30-60 cm and 60-90 cm) to measure the nitrate in the soil profile. The measured parameter is:

- NO_3^-

Before winter these samples indicate the nitrate residue. This nitrate residue is an indication for the nitrate that can flush out during winter towards the groundwater. By sampling after winter the amount of nitrate that flushed out can be determined. Sampling after winter also indicates the amount of nitrate available for the new growing season. Thus, these analyses are also used to optimize the nitrogen fertilization for the different crops. Measurements during the growing season (in May and August) are used to optimize the fertilization and will give an indication of the nitrate that is already taken up by the crops. The moment of sampling in May or August is determined by the cultivated crop and the moment of fertilization. This sample will be taken on every parcel in the network.

3.1.3 Deep soil sample

These samples are taken on a selection of parcels as mentioned in paragraph 2.4.4. On this selection of parcels, deep soil samples are taken at the end and start of each year. The measured parameters are:

- NO_3^-
- P (in ammonium lactate (AL) extract)

Beside nitrate, phosphate will also be analyzed. Measuring the level of nitrate and phosphorus on this depth gives an indication of the amount of nutrients flushed out of the soil profile. The amount of nitrate in the soil sample is similar to the amount measured in a water sample taken from the soil. However, for phosphorus this is not the case. This nutrient occurs in different fractions and by measuring P in an AL extract no information on the different fractions is obtained. For this reason DIP and DOP are being measured (see paragraph 3.1.6).

3.1.4 MAP sampling points and monitoring wells

For the parcels lying in the infiltration area of a MAP sampling point or monitoring well a water sample from these measuring points can be taken. These water samples are used to investigate the effect of the parcel management on the water quality. Water samples are taken twice a year, at the end and start. The measured parameters are:

- NO_3^- and NH_4^+
- PO_4^{x-}

Parcels lying in such an infiltration area have a shallow water level. In those parcels the measured water quality is linked directly to the nutrients that flushed out of the soil profile. For a selection of these water samples DIP and DOP are also measured (see paragraph 3.1.6).

3.1.5 Drainage and canals or ditches

On a selection of parcels nutrient losses are quantified by measuring the water quality of a canal, ditch or drainage. The selection of these parcels was discussed in paragraph 2.4.5. On this selection of parcels, water samples of the canal, drainage or ditch will be taken twice a year, at the start and end. The measured parameters are:

- NO_3^- and NH_4^+
- PO_4^{x-}

On a part of these water samples DIP and DOP are also measured (paragraph 3.1.6).

3.1.6 DIP, DOP, total phosphorus and phosphate saturation

By measuring the total amount of phosphorus and orthophosphate present in the soil and water samples no information is available on the different fractions of phosphorus. However, it is interesting to know if the dissolved amount of phosphorus is organic (DIP) or inorganic (DOP). Moreover it is very interesting to know which fractions of phosphorus occur in deeper soil layers and in the groundwater. By measuring DIP and DOP information will be gathered on the origin of the dissolved fraction of phosphorus present in the samples. DOP will be an indication of the amount of phosphorus that originates from livestock manure. DIP and DOP will be measured on water samples. 35 water samples will be taken from 35 deep soil samples by centrifuging these soil samples. The other water samples are a selection of the samples taken from canals and ditches, drainage, monitoring wells or MAP sampling points. We intended to determine DIP and DOP in samples originating from a proportion of derogation and no derogation parcels. The numbers of samples are:

- Deep soil samples: 17 derogation and 18 no derogation
- Canals, ditches and drainage: 10 derogation and 10 no derogation
- MAP sampling points and monitoring wells: 14 derogation and 11 no derogation

On a selection of parcels (30) the degree of phosphorus saturation will be measured. The protocol of Van der Zee *et al* (1990) will be tested for these specific locations in Flanders. The measured phosphate saturation on these parcels will be linked to the other phosphorus measurements. All the information on the phosphorus measurements can be used to calculate phosphate balances at the parcel level.

3.1.7 Livestock manure

To calculate nutrient balances of each parcel it is necessary to know how much nutrients farmers supply to their fields. Therefore information on the supplied livestock manure will be incorporated in the analysis. Since the composition of livestock manure is very variable, each type of manure used on each parcel will be analyzed. The samples can be taken in storage or during application on the field.

4 Parcels characteristics based on the standard soil sample.

Each parcel in the monitoring network was sampled for a standard soil analysis at the end of 2009. This analysis is very useful in order to characterize the different parcels and to measure the soil fertility of each individual parcel. The most important parameters are soil type, pH-KCl, percentage carbon and amount of nutrients. An optimal pH is crucial for the availability of the different nutrients necessary for crop growth. The percentage of carbon is directly linked to the amount of organic matter in the soil (organic matter = percentage carbon multiplied with 1.72). This parameter is important for the amount of mineralization. Besides pH-KCl, soil type and percentage of carbon, the amount of P, K, Mg, Na and Ca are measured in the standard soil sample. Next to nitrate these are the most important nutrients for cultivated crops.

For a standard soil analysis, a standard soil sample is taken from 0 to 6 cm in grassland, because this is the layer where the density of the roots is maximal and thus an optimal fertilization status is important. In arable land the standard soil sample is taken from 0 to 23 cm, because arable land is mostly cultivated in the zone 0 to 23 cm. As a consequence optimal conditions for crop growth are necessary in that particular layer. For the different analyses on the standard soil sample an amount of soil of 600 gram is necessary. A standard soil sample is taken on homogenous parcels of maximum 2 hectares and has to be representative for whole the parcel. A representative sample is composed of different subsamples taken at different places in the parcel. For grassland one sample exists of 35 subsamples, for arable land 25 subsamples are sufficient to obtain a representative sample.

After sampling, the standard soil sample is transported to the analytical laboratory where it is dried for 24 hours on a temperature of 70 degrees Celsius. After drying the sample is pulverized (only necessary for soils with a certain percentage of clay) and sifted on a 2 mm sift. After this the sample is homogenized and ready for the next step. The pH is measured on a KCl solution and the amount of carbon 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 and Na are measured with an atomic absorption spectrophotometer. Phosphorous is measured colorimetrically. Finally, the soil type is determined manually by palpation.

4.1 The different soil fertility classes

In order to interpret the standard soil analyses and to give an optimal soil fertility advice, SSB relies on soil fertility classes. Based on extensive field trial research combined with many years of experience in the agricultural as well as the horticultural sector, SSB developed the soil fertility classes for the different soil fertility parameters (Boon *et al., 2009*). These soil fertility classes differ depending on soil texture, organic matter content and are different for both grassland and arable land.

For each parameter, seven soil fertility classes are distinguished ranging from very low (strongly acid for pH) to very high (peaty for percentage carbon). The middle class is the optimal zone, which means that it is the zone of optimal occurrence of that specific parameter. Within this zone most plants will show an optimal growth provided that rational fertilization and liming is applied. When the measured values of a parameter are above the optimal zone, the fertilization can be reduced and farmers can save on their fertilization. When the measured value of a parameter is below the optimal zone, the fertilization has to be increased in order to have an economically optimal yield and to keep the soil fertility at a sufficient high level. To have an economically optimal yield the different nutrients has to be available for the cultivated crop. The optimal zone used in the standard soil analysis for the different parameters is only valid for measurements in ammonium-lactate extracts and for a specific soil density of 1.3 for arable land.

It is very important to mention that the different soil fertility classes are dependent on the soil texture and organic matter in the soil. Therefore an optimal zone is specific for each individual parcel (each parcel is characterized by a specific carbon level and soil texture) and is also different for grassland and arable land. For arable land the classification of the different parameters in different soil fertility classes is independent of the cultivated crop.

Table 12 illustrates the soil fertility classes for pH-KCl for arable land for different soil types. The optimal level for pH-KCl is different for each soil type and is lower on sandy soils than on soils with higher levels of loam and clay. These levels are also different for arable land and grassland. In annex 2, the soil fertility classes for different parameters are illustrated for both arable land and grassland.

Table 12: Soil fertility classes for pH-KCl for arable land, depending on the soil type. (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

4.2 Fertilization and liming advice

After the analysis of the different parameters a parcel specific fertilization and liming advice is formulated. This advice is formulated for a rotation of 3 cultivated crops or for 3 growing-seasons for multi-annual crops. For the fertilization and liming advice a decision supporting expert system is developed by SSB, called BEMEX (BEMEstingsEXpertsysteem) (Geypens *et al.*, 1989; Vandendriessche *et al.*, 1996).

The liming advice is calculated based on the value of the measured pH-KCl, the soil texture, the organic matter content and the sensitivity of the cultivated crop for liming. Based on this sensitivity, liming is divided over the 3 years depending on the cultivated crops. The nitrate advice based on the standard soil analysis is function of the mineralization of soil organic matter (based on the amount of carbon) and mineralization of crop residues. Therefore this advice is based on the soil texture, organic matter content, the parcel history (organic manure, crop ...) and the needs of the cultivated crop. A more exact nitrate advice is formulated with the N-index method; therefore the amount of nitrate present in the soil just before sowing of the cultivated crop is measured.

To calculate fertilization advices based on the standard soil analysis different factors are taken into account: the measured soil fertility, relation between different nutrients, crop needs, crop rotation, parcel information (from farmer), sample date and the combination of date and nutrient leaching out from sampling date to sowing date. All these factors are combined with the measured values, field trial experience and expert knowledge.

In contrast with the different soil fertility classes the fertilization and liming advice are highly determined by the crops that will be cultivated the next 3 growing seasons. Fertilization is necessary to reach economical optimal yields but also to prevent soils from exhaustion and to keep them at an optimal soil fertility level. It is important to note that the fertilization advices are based on economical optimums, and that maximal fertilization levels as defined by the government are not taken into account. Also, the fertilization levels as advised by the standard soil analysis are based on effective levels for the nutrients. So if the farmer uses organic fertilizers, he has to take into account that only part of the organic fertilizer will be effective as a fertilizer the first year after application.

Annex 3 shows an example of a report from a standard soil analysis of parcel 3 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 fertilization (for the most important parameters) and liming advice for the different cultivated crops.

4.3 Standard soil sample for grassland.

In Table 13 the results for pH, C and phosphorous are shown. These are the average numbers for the different parcels cultivated with grass in the year 2009. Most of these parcels are already grassland for several years. Between derogation and no derogation parcels no differences can be observed for none of the parameters.

Table 13: Average pH, C and P measured in the standard soil sample (0-6 cm) for grassland. Values are given separately for derogation and no derogation parcels.

	Derogation	No derogation
n	60	40
pH	5.6	5.6
C (%)	3.3	3.1
P (mg P/100 g dry soil)	25.2	25.7

For the pH measured on the parcels cultivated with grassland 42 % of the parcels reach the optimum level (Table 14). This means that 42 % of the parcels reach the optimum specific for that parcel (depending on soil texture and organic carbon). 21 % of the parcels have a pH rather low and 17 % rather high. When the pH does not reach the optimum level for the next growing season, the potential yield can only be reached with a higher fertilization in comparison with the fertilization for the same parcel with parameters in the optimum level. When the pH is lower than the optimum level, liming before the growing season can be a solution.

Table 14: Percentage of parcels grassland in the different soil fertility classes for the pH.

Class	pH
strongly acid	2
Low	3
rather low	21
Optimal	42
rather high	17
High	8
very high	7

Table 15: Percentage of parcels grassland for the different soil fertility classes of carbon and phosphorous.

class	C	P
very low	6	3
low	27	7
rather low	18	19
optimal	34	20
rather high	14	33
high	1	15
very high	/	3

For carbon 34 % of the parcels cultivated with grassland reach the optimal level (optimums are specific for each parcel). 27 % of the parcels are characterized by a low level of carbon. Parcels with a percentage carbon below optimum have a lower mineralization and need more nutrient input.

For phosphorous 20 % of the parcels are in the optimum level. 52 % of the parcels have a phosphorous level above the optimum level. For these parcels it is possible to cultivate crops with a lower input for the parameter phosphor. However, when the value of a parameter reaches the optimal level maintenance fertilization is still necessary (in order to prevent that levels of nutrients, pH and carbon drop below the optimum level). The average fertilization advice for all parcels for the growing season 2010 is shown in Table 16. 16 % of the parcels cultivated with grassland do not require an additional fertilization with phosphorous. The average fertilization advice for this parameter is 50 kg P_2O_5 per hectare. Derogation parcels need 10 kg/ha more phosphorous than no derogation parcels. This difference between derogation and no derogation parcels is not caused by the amount of phosphorous present in the soil profile but by different agricultural practices on the parcels. Difference in advice is made between grassland characterized by only mowing or grazing and moving or only grazing and for grazing also difference is made between intensively of extensive grazing. In comparison with no derogation parcels, derogation parcels are characterized by extra mowing and more intensively grazing.

Table 16: Average phosphorous (P_2O_5) fertilization advice for the growing season 2010 for the parcels grassland in the monitoring network.

	Derogation	No derogation
n	60	40
P_2O_5 (kg/ha)	54	45

4.4 Standard soil sample for arable land.

For arable land small difference can be observed in average values between derogation and no derogation parcels (Table 17). In comparison with grassland, the pH and phosphorous levels are higher in arable land (Table 18 versus Table 13); while the level of carbon is lower for arable land than for grassland.

Table 17: Average amounts of pH, C and P measured on the standard soil sample (0-23 cm) for arable land. Values are separately given for derogation and no derogation parcels

	Derogation	No derogation
n	50	78
pH	5.8	6
C (%)	1.8	1.5
P (mg P/100 g dry soil)	31.9	38

In 46 % of the parcels the pH reaches the optimal zone for crop growth (Table 18). This is a higher frequency than in grassland. 25 and 15 % of the parcels are characterized by a pH value just below (rather low) or just above (rather high) the optimal level. Parcels not in one of these groups have a pH that deviates from the optimal level in such a way that it will tamper crop growth (insufficient uptake of nutrients) or that the crop will not reach its potential level of yield.

For the parameter C, more than half (55 %) of the parcels arable land reach the optimal level. Most of the other parcels (37 %) have a percentage C below optimum. For phosphorous only 5 % of the parcels reach the optimal level. 92 % of the parcels have a value of phosphorous above the optimal level. However, despite the high levels of phosphorous measured in the standard soil samples an additional P-fertilization is necessary. The average fertilization advice for the parameter phosphorous on arable land is 43 kg P_2O_5 per hectare, which is lower than on grassland.

Table 18: Percentage of parcels arable land in the different soil fertility classes for the pH.

Class	pH
strongly acid	1,5
Low	6
rather low	25
Optimal	46
rather high	15
High	5
very high	1

It is important to mention that not all P present in the soil is available to the plants. As a consequence it is possible that soils with high amounts of phosphorous still need an additional P fertilization that is relatively high.

Table 19: Percentage of parcels arable land for the different soil fertility classes of carbon and phosphorous.

	C	P
very low	4	
Low	13	1,5
rather low	19	2
optimal	55	5
rather high	9	34
high		48
very high		9

An overview of the average fertilization advice for P is given in Table 20. The fertilization advice for derogation and no derogation parcels is also given separately.

Table 20: Average phosphorous (P_2O_5) fertilization advice for the growing season 2010 for the parcels arable land in the monitoring network.

	Derogation	No derogation
n	50	78
P_2O_5 (kg/ha)	50	38

4.5 N-fertilization advice

During winter nitrate can leach out the soil profile or more nitrate can become available for plant uptake due to mineralization. To measure the amount of nitrate available to the crop a soil sample is taken after winter, just before the new growing season. Based on the measured values and some additional information (cultivated crop and cultivar, organic matter in the soil layer, cultivated crop in the past season, organic fertilization …) an N-fertilization advice is formulated for a specific parcel with a specific crop. Before the fertilization advice is formulated an N-index is calculated for each parcel. The N-index is an expert system developed by SSB to formulate mineral nitrate-N advices. The N-index calculates the amount of mineral N that is or will become available to the cultivated crop during the next growing season. For this N-index are 3 input data essential. First the measured mineral N is available from the soil sample. This soil sample is taken in layers of 30 cm. For crops with deep roots a soil sample is taken from 0 to 90 cm in three layers (for example winter wheat). Some 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. One soil sample for each parcel exists of 15 subsamples, this is necessary to create a representative sample. The mineral N is measured by continuous flow of a KCL extract. Second the amount of nitrogen that will become available during the growing season is important, therefore some parcels characteristics are necessary (percentage carbon, pH, history of the parcel, organic fertilisation in the past, liming …). The third group of factors has a negative effect on the N-index, these are leaching or no optimal conditions for pH. After this an N-index for that specific parcel is calculated. If the N-index is high, the nitrate-N advice for that parcel will be low. An evaluation of the N-index is given for each advice. The resulting nitrate-N fertilization advice is function of the N-index and the nitrate required by the cultivated crop. So additional information about the coming growing season is necessary (crop, variety of the crop, agricultural practice …). A fertilization advice by the N-index method is always an effective amount of nitrogen. So if a farmer uses organic fertilizers he has to calculate with the effective fraction of the fertilizer to fill up his fertilization advice.

4.5.1 Growing season 2010

For grassland the average advices are shown in Table 21 for different soil types. Also advices for parcels with grazing cattle against parcels without grazing cattle are given separately. The advices are given for each grass cutting, because after each harvest a new fertilization will be necessary. The first harvest of the season requires the highest fertilization. In general, sandy soils have a lower advice than loam and clay. Advices are given for the first 3 harvests of the grassland. When the grassland is more intensively cultivated (a lot of derogation parcels) with more harvests, more than 3 fertilizations are necessary. In these cases higher total fertilizations are necessary to have sufficient crop growth.

Table 21: Average nitrate-N (kg N/ha) fertilization advices for grassland on different soil types for the growing season 2010. The advices are given for different harvests (cut 1, cut 2 and cut 3) and separately for grassland with or without grazing cattle.

		n	cut 1	cut 2	cut 3
Grassland with grazing cattle	Sand	67	69	43	36
	Sandy loam	28	74	46	39
	Loam	7	75	47	40
	Clay	4	74	46	38
Grassland without grazing cattle	Sand	67	89	64	54
	Sandy loam	28	93	66	56
	Loam	7	95	68	57
	Clay	4	93	66	55

For grassland 44 % of the parcels were characterized by an N-index lower than normal, 43 % normal, 11 % very low and 2 % higher than normal. So for grassland the average N-index of the parcels was mostly normal or just below normal, resulting in a relatively high N fertilization advice (compared with other years). No statistical differences are present between nitrate-N advices between derogation and no derogation parcels for a single cutting. Derogation parcels are characterized by a higher number of cuttings. When an extra cutting is harvested, an extra fertilization was performed for this cutting.

Table 22: Average nitrate-N (kg N/ha) fertilization advices for parcels cultivated with maize in 2010. Values are given separately for derogation and no derogation parcels for different soil types.

	n	Derogation	n	No derogation
Sand	23	140	32	154
Sandy loam	8	137	8	150
Loam	1	104	4	163
Clay	0		2	159
Average		138		153

For parcels cultivated with maize in 2010, the nitrate-N advices are shown in Table 22. Most of the parcels have a sandy or sandy loam soil. The advices are given separately for derogation and no derogation parcels. There is little difference between both, although the average levels are a little higher for no derogation parcels. On derogation parcels one cut of grassland was harvested before the maize was sown. In some cases, fertilization occurred already on the grassland, but the advices shown in Table 22 are for maize only. For derogation parcels some extra nitrate will become available for the cultivated maize due to a higher mineralization caused by the grassland that is cultivated before the maize is sown. Therefore the fertilization advice for the maize can be lower for derogation parcels than for no derogation parcels.

76 % of the maize parcels have an N-index normal and 23 % lower than normal. For maize the nitrate fertilization is mostly before sowing and is given in 1 fraction for the mineral fertilization and 1 fraction for the organic fertilization. The average fertilization advice for all parcels is 146 kg nitrate-N per hectare.

Table 23 shows the fertilization advices for winter wheat, sugar beets, all no derogation crops together (including potatoes) and potatoes separately. In winter wheat the fertilization is mostly given in three fractions during the growing season. This way high yields are possible without quality losses. For the other crops fertilization 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 fertilization that can be applied on the parcel.

Table 23: Average nitrate-N fertilization (kg N/ha) advices for different crops for the growing season 2010. The total N-fertilization advices as well as the different fractions are given.

	fraction 1	fraction 2	fraction 3	total	n
Winter wheat	78	56	57	191	9
Sugar beets	147	24		170	3
Other	137	31		168	20
Potatoes	148	36		184	15

4.5.2 Growing season 2011

For grassland the average advices are shown in Table 24 for different soil types. Also advices for parcels with grazing cattle and without grazing cattle are given separately. The advices are given for each grass cutting, because after each harvest a new fertilization will be necessary. The first harvest of the season requires the highest fertilization. In general, the highest advices are calculated for clay soils. Advices are given for the first 3 harvests of the grassland. When the grassland is more intensely cultivated (a lot of derogation parcels) with more harvests, more than

3 fertilizations are necessary. In these cases higher total fertilizations are necessary to have sufficient crop growth. But for each cutting separately no difference in N fertilization advice are observed between derogation and no derogation parcels.

Table 24: Average nitrate-N (kg N/ha) fertilization advices for grassland on different soil types for the growing season 2011. The advices are given for different harvests (cut 1, cut 2 and cut 3) and separately for grassland with or without grazing cattle.

		n	cut 1	cut 2	cut 3
Grassland with grazing cattle	Sand	60	70	43	36
	Sandy loam	23	71	44	37
	Loam	5	68	45	38
	Clay	3	83	51	43
Grassland without grazing cattle	Sand	60	90	64	55
	Sandy loam	23	90	63	54
	Loam	5	87	66	56
	Clay	3	102	70	59

For grassland 24 % of the parcels were characterized by a very low N-index and 37 % with a lower than normal N-index. For 37 % of the parcels the N-index was normal and for 2 % of the parcels higher than normal. So for grassland the average N-index of the parcels was lower after winter 2010 in comparison with the N-index after winter 2009.

For parcels cultivated with maize in 2011, the nitrate-N advices are shown in Table 25. Most of the parcels have a sandy or sandy loam soil. The advices are given separately for derogation and no derogation parcels. There is little difference between both. On derogation parcels one cut of grassland was harvested before the maize was sown. In some cases, fertilization occurred already on the grassland, but the advices shown in Table 25 are for maize only. For derogation parcels some extra nitrate will become available for the cultivated maize due to a higher mineralization caused by the grassland that is cultivated before the maize is sown.

Table 25: Average nitrate-N (kg N/ha) fertilization advices for parcels cultivated with maize in 2011. Values are given separately for derogation and no derogation parcels for different soil types. Fodder maize and corn maize are considered separately.

	n	Derogation	n	No derogation, fodder maize	n	No derogation, corn maize
Sand	23	140	17	156	13	152
Sandy loam	6	148	8	142	6	150
Loam			5	151	1	143
Clay	1	178			1	158
Average		155		150		151

Therefore the fertilization advice for the maize can be lower for derogation parcels than for no derogation parcels, as can be seen from the table for sandy soils. 62 % of the maize parcels have an N-index categorized as normal and 37 % lower than normal. For maize the nitrate fertilization is mostly before sowing and is given in 1 fraction for the mineral fertilization and 1 fraction for the organic fertilization. The average fertilization advice for all parcels is 153 kg nitrate-N per hectare. Also for parcels cultivated with maize (like grassland) the average N-index is lower in 2011 compared with 2010.

Table 26 shows the fertilization advices for winter wheat, sugar beets, all no derogation crops and potatoes separately. In winter wheat the fertilization is mostly given in three fractions during the growing season. This way high yields are possible without quality losses. For the other crops fertilization in 2 fractions is advised. The advices are always based on the potential yield a crop can obtain and do not take into account conditions like legal restrictions concerning the amount of organic and mineral fertilization that can be applied on the parcel.

Table 26: Average nitrate-N fertilization (kg N/ha) advices for different crops for the growing season 2011. The total N-fertilization advices as well as the different fractions are given.

	fraction 1	fraction 2	fraction 3	total	n
Winter wheat	89	61	40	190	8
Sugar beets	145	29		174	5
Other	100	42	14	156	9
Potatoes	153	43		196	9

5 Fertilization

5.1 Livestock manure

Sampling livestock manure is necessary to determine the exact composition of nutrients present in the supplied manure. These analyses are very useful to calculate the correct input of nutrients when using livestock manure and are used to calculate nutrient balances at parcel level. The composition of livestock manure is highly variable and depends on the type of animals and farm (differences in food, storage of the manure, farm characteristics …). For each sample the farmer obtains the results for the most important nutrients and in addition an advice concerning the fertilization value of the manure.

In Table 27 the number of samples taken during the derogation investigation (end 2009 to beginning of 2011) is given for the different types of livestock manure. The analyses were used for the fertilization practices in 2010 and 2011. Derogation and no derogation farms are considered separately.

Table 27: Number of livestock manure samples taken in the period from end 2009 to the beginning of 2011, derogation and no derogation farms are considered separately.

	Derogation	No derogation	Total
Cattle slurry*	144	66	210
Cattle manure (solid)*	13	19	32
Pig slurry	4	23	27
Sows slurry	1	15	16
Other	2	7	9
Total	164	130	294

* Livestock manure that can be supplied on derogation parcels

In the Flemish derogation request only the 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 can be used on parcels with a derogation request. Table 27 shows that for a number of farms classified as derogation farms there are also analyses of no derogation manure. This is possible if a derogation farm has two parcels in the monitoring network and only one of those parcels is a derogation parcel.

In total, 294 samples were taken during the derogation investigation. On some parcels (mostly no derogation parcels), there is no input of livestock manure. In 2010 only 8 no derogation parcels received no organic fertilization. On all derogation parcels organic fertilization was carried out. In some cases, the same manure is applied on several parcels, especially when farms are participating in the network with more than one parcel. For the derogation farms the majority of the analysed manure is cattle slurry. This is logical because derogation is mostly requested by farmers having dairy cows. In contrast, almost none of the derogation farmers apply pig manure on the parcels participating in the investigation. More samples are taken from derogation farms, this is logical because on no derogation parcels livestock manure is not always supplied.

Sampling of livestock manure can occur in different ways; samples taken from storage and samples taken during application and transport of the manure. When sampling during storage, it is important to obtain a sufficient homogenous sample. This is possible when the livestock manure is mixed in the storage. If mixing is not possible, enough samples have to be taken on different places to create a homogenous sample. These problems are less important when the manure is sampled during application or transport. However, in that case communication between farmer and sampler is very important in order to limit time losses. In Table 28 the number of mixed samples is given. Mixing was done on 88 samples of the 174 samples taken during the storage.

Table 28: Number of manure samples and the place where they are taken, for the year 2010 and 2011. In addition, the number of samples where the manure was mixed before sampling is given.

Place	samples	mixed
storage	174	88
transport	20	

Table 29 shows for different manure types the average value of the most important nutrients. The nutrient content of the different manure types are categorized in different levels: average, lower than average, low and very low, higher than average, high and very high. Most of the values measured during the past two years are in the range of the average values. Based on their own sample, farmers receive an individual evaluation and fertilization value. 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 30). In general, the nutrient composition of the cattle slurry samples is average when comparing with the data from the "Mestwegwijzer" (Coppens *et al., 2009*). Only Na_2O and the amount of mineral nitrogen in no derogation farms is categorized as lower than average. For no derogation farms, all the values are slightly lower in comparison with derogation farms.

Table 29: Average characteristics of different types of livestock manure to be used for fertilization during the monitoring project. For each type the number of samples and unit is also given.

Manure	n	Dry matter	Organic matter	N Tot	N Min	P_2O_5	K_2O	MgO	CaO	Na_2O	C/N	Unit
Cattle slurry	210	79.04	60.45	4.15	1.90	1.24	4.32	0.93	1.47	0.70	8.77	kg/1000 kg
Cattle manure (solid)	32	220.45	172.37	5.86	1.38	2.82	7.43	1.48	3.70	0.77	18.13	kg/1000 kg
Pigs slurry	27	73.72	53.66	6.47	3.47	3.78	4.07	1.86	4.04	1.32	4.76	kg/1000 kg
Sows slurry	16	39.61	27.49	4.61	2.69	2.23	3.05	1.03	1.98	1.01	3.19	kg/1000 kg
Other	9	118.31	88.49	5.12	1.94	1.84	5.31	0.92	4.40	1.04	24.62	kg/1000 kg

Table 30: Average characteristics together with standard deviation of cattle slurry to be used for fertilization in 2010 and 2011. Values are separately given for derogation and no derogation farms.

DA	n	Dry matter	Organic matter	N Tot	N Min	P_2O_5	K_2O	MgO	CaO	Na_2O	C/N	Unit
Derogation	143	80.54	61.89	4.33	1.99	1.26	4.38	0.97	1.48	0.76	8.55	kg/1000 kg
Standard deviation		18.11	14.33	1.14	0.75	0.30	0.90	0.27	0.47	0.35	2.27	
No derogation	67	75.03	56.54	3.84	1.66	1.19	4.18	0.82	1.40	0.54	8.72	kg/1000 kg
Standard deviation		21.53	17.07	1.24	0.67	0.37	1.12	0.27	0.57	0.25	1.98	

Table 31: Average characteristics together with standard deviation of cattle slurry to be used for fertilization in 2010 and 2011. Values are separately given for mixed and not mixed samples.

	n	Dry matter	Organic matter	N Tot	N Min	P_2O_5	K_2O	MgO	CaO	Na_2O	C/N	Unit
Mixed	100	81.43	62.39	4.39	1.97	1.27	4.35	0.97	1.52	0.76	8.51	kg/1000 kg
Standard deviation		16.41	12.87	1.13	0.60	0.28	0.85	0.25	0.53	0.32	1.93	
Not mixed	110	76.77	58.41	4.03	1.81	1.22	4.28	0.88	1.40	0.63	8.65	kg/1000 kg
Standard deviation		21.55	17.16	1.22	0.85	0.35	1.08	0.31	0.48	0.35	2.39	

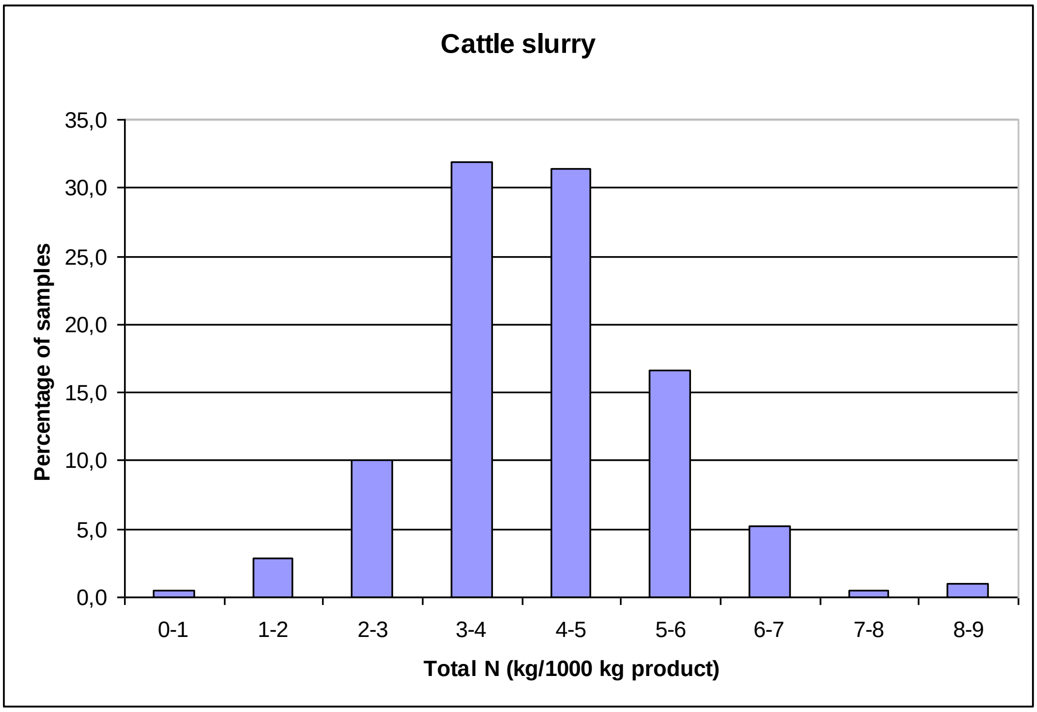

Figure 12: Histogram of the amount of Total N (kg/1000 kg product) for the different samples taken from cattle slurry in the period 2010 – 2011 in the monitoring network.

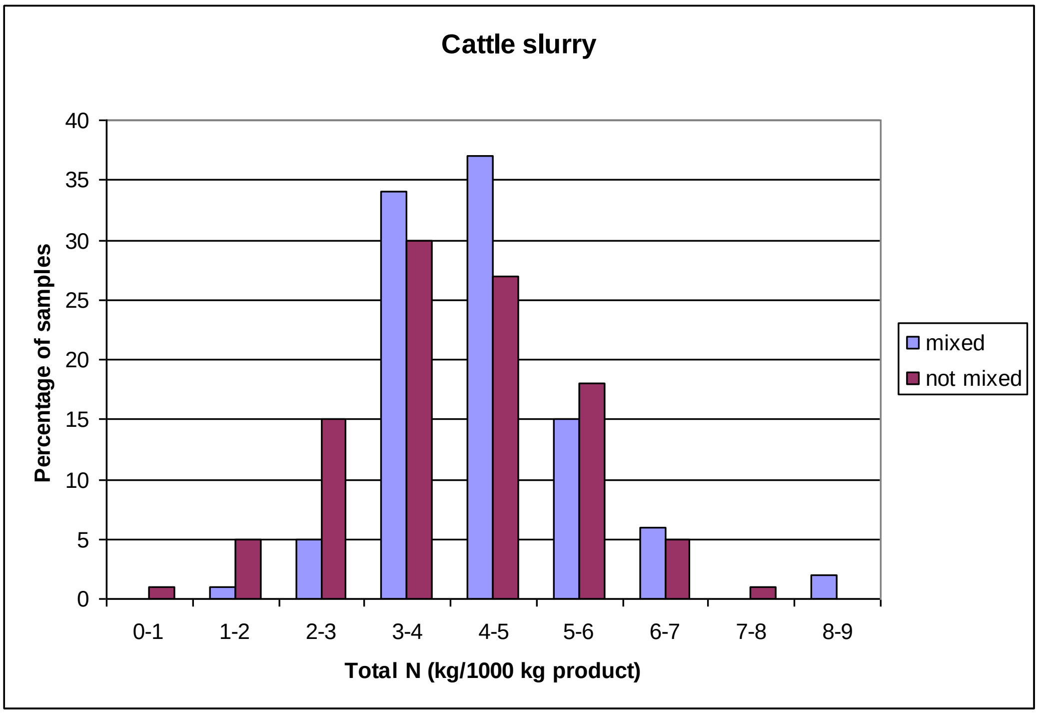

Figure 13: Histogram of the amount of Total N (kg/1000 kg product) for the different samples taken from cattle slurry in the period 2010 – 2011 in the monitoring network. Values are separately given for mixed and not mixed manure (before sampling).

Starting from the end of 2010, the unit for the different parameters measured on the manure samples is kg/1000 kg product. This was due to governmental restrictions. Before the different parameters were expressed in kg/1000 l product which is more practical and more logical form agricultural perspective. To makeTable 29, Table 30 and Table 31 values of the beginning from 2010 are recalculated from kg/1000 l product to kg/1000 kg and results of all manure samples are put together in the tables.

To illustrate the importance of manure samples, the variation on the different samples is shown in Figure 12. This figure shows the variation of the cattle slurry samples taken during the derogation investigation. About 60 % of the samples have a level of total nitrogen close to the average level of 4.2 kg total N in 1000 kg slurry. 40 % of the samples have levels of total nitrogen that differ clearly from the average; this has very important consequences for the fertilization. In some cases farmers will fertilize too much, with increasing risks of high nitrate residues before a winter period. In some other cases farmers will fertilize too little, resulting in low yields. It is also important to have a representative sample. This is possible by mixing the manure or by taken a number of subsamples at different places in the storage. The difference between both is shown in Figure 13. The variation on mixed samples is lower in comparison with no mixed samples. But by taking a number of subsamples also on no mixed samples the variation is reduced to the minimum.

The purpose of the derogation study is to investigate the effect of derogation on the water quality. Therefore different measurements are carried out to see if there are differences in amounts of nitrate and phosphorous in soil and water samples. Fertilization practices are one of the major factors that will influence the amounts of nitrate and phosphorous in the soil and in the water. Not only the supplied amounts of nutrients but also the agricultural practices (moment of fertilization, dose …) can have an influence. By making the comparison between derogation and no derogation parcels in function of the total amount of supplied nutrients it is also possible to see if the derogation parcels are characterized by an effectively higher organic fertilization.

In order to obtain information concerning the amount of supplied nutrients and the different agricultural practices, different information channels are used. Firstly, the farmers participating in the monitoring network could register the necessary information related to fertilization practices for their parcels online in 'BDBNET' or by email. Not more than 20 % of the farmers used this channel to provide the requested information. Secondly, for each individual parcel all farmers received information sheets, where they had to fill in information on their fertilization practices. Still, for 20 % of the participating farmers it was necessary to phone them in order to get the information through an interview. Finally, a significant amount of information is obtained by the SSB sampling teams during sampling in the different parcels of the monitoring network.

5.2 Amount of supplied nutrients

5.2.1 2009

The major input of nutrients on the parcels is by fertilization. Fertilization is possible in different ways; by mineral fertilizers, organic fertilizers or organic input by grazing cattle. The different fertilizers used on the parcels in 2009 are listed in Table 32. Mineral and organic fertilization is shown separately, the total input is also given. On grassland it is possible that part of the supplied N and P is originating from grazing cattle, which is also organic fertilization. The values in Table 32 are the amounts of supplied nutrients reduced with losses by emission of ammoniac during the moment of fertilization, this is only important for the organic fertilization and is function of the different agricultural practices (see next paragraph). The used emission losses are shown in Table 35.

For all cultivated crops, the amount of organic fertilization is higher on derogation parcels (except the amount of phosphorous on grassland). This is a very important fact because it means that derogation in not only requested on some parcels but is also effectively applied. The higher amount of phosphorous by organic fertilization on grassland for no derogation parcels in comparison with derogation parcels is due to the agricultural practice. On no derogation parcels more pig slurry is used and pig slurry has a higher proportion of phosphorous (in comparison with the amount of N) than cattle slurry (used on derogation parcels).

Table 32: Nutrient (Total N and Total P in kg/ha) input for derogation and no derogation parcels by fertilization on the parcels in 2009. Values are separately given for the different cultivated crops. Distinction is made between total fertilization, mineral fertilization, organic fertilization and organic fertilization by grazing cattle.

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	146	2	130	48	109	41	239	89	385	91
Grass, only mowing	125	1	239	90	0	0	239	90	364	91
maize and 1 cut of grass	50	2	222	80			222	80	272	82
sugar beets	38	0	222	77			222	77	260	77
winter wheat	94	0	205	81			205	81	299	81
	no derogation parcels									
Grass	110	2	96	55	117	45	213	100	323	102
Maize	47	8	163	82			163	82	210	90
sugar beets	77	0	192	132			192	132	269	132
winter wheat	132	2	103	55			103	55	235	57
Potatoes	124	2	168	99			168	99	292	101

On grassland, part of the organic fertilization can originate from grazing cattle. This amount is higher for no derogation parcels. Derogation parcels are more intensively cultivated, with more cuts of the grass each year. When harvesting the grassland it is easier to keep the cattle in stalls. For no derogation parcels, 79 % of the grassland is fertilized by grazing cattle and 21 % of the parcels do not receive organic fertilization from grazing cattle. For derogation parcels, 60 % of the parcels receive at least a minimum of organic fertilization originating from grazing cattle while 40 % of the parcels do not receive any organic fertilization from grazing cattle.

Table 32 shows that on most parcels phosphorous fertilization did not occur by mineral fertilization, which coincide with the governmental regulations and limitations. When comparing the mineral and total fertilization on grassland and maize between derogation and no derogation parcels, both the mineral and total fertilization of N is higher on derogation parcels. So not only a larger part of the fertilization is filled up by organic fertilization but also the mineral fertilization is higher on the derogation parcels. This is not necessarily a negative situation because on derogation parcels more cuts of grass are harvested, so more nutrients are removed from the fields. For derogation parcels cultivated with maize an extra cut of grass is harvested, which requires also nutrients. In many cases, grassland with a request for derogation is more intensively cultivated with more harvests in one year. As such more nutrients are removed from the parcels.

For sugar beets and winter wheat (both derogation crops), derogation and no derogation parcels do not differ in total input of nutrients. When looking at the different fractions of fertilization, a larger part of the total fertilization is filled up with organic fertilization on derogation parcels while a larger part is filled up with mineral fertilization on no derogation parcels for these cultivated crops.

5.2.2 2010

The results for the growing season 2010 are shown in Table 33. The total amount of supplied nutrients (N and P) as well as the different fractions (mineral, organic and organic by grazing cattle) is given separately for derogation and no derogation parcels and for each cultivated crop. The levels for organic fertilization in Table 33 are already deducted for the emission losses during application. These emission losses are discussed more in detail in paragraph 5.1.3. Based on Table 33 some important conclusions can be drawn. For all derogation crops the amount of nitrogen originating from organic fertilisation is higher for derogation parcels. This indicates that derogation is not only requested by farmers but also put into practice. For grassland not only the organic fertilisation reaches a higher level but also the mineral fertilisation, resulting in a higher total input for derogation parcels cultivated with grassland. When excluding the grassland characterized by only mowing the amount of nutrients originating from grazing cattle is almost the same for derogation (80 kg N/ha) as no derogation (71 kg N/ha) parcels. In general grassland with derogation is mostly more intensively cultivated resulting in a higher input and normally also a higher export of nutrients (see next paragraph).

Table 33: Nutrient (Total N and Total P_2O_5 in kg/ha) input for derogation and no derogation parcels by fertilization on the parcels in 2010. Values are separately given for the different cultivated crops. Distinction is made between total input by fertilization, mineral fertilization, organic fertilization and organic fertilization by grazing cattle.

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	146	2	174	57	80	29	254	86	400	88
Grass, only mowing	114	0	261	85	0	0	261	85	375	85
Maize and 1 cut of grass	62	5	227	77	0	0	227	77	289	82
Sugar beets	34	0	226	73	0	0	226	73	260	73
Winter wheat	142	0	162	43	0	0	162	43	304	43
	no derogation parcels									
Grass	94	2	87	36	71	28	158	64	252	66
Corn maize	36	7	159	74	0	0	159	74	195	81
Fodder maize	57	1	175	75	0	0	175	75	232	76
Sugar beets	0	0	122	80	0	0	122	80	122	80
Winter wheat	194	3	72	40	0	0	72	40	266	43
Potatoes	101	2	150	68	0	0	150	68	251	70

For maize the total fertilisation on derogation parcels is higher which is logical because an extra cut of grass is harvested on these parcels. This is mostly not the case for no derogation parcels. This extra cut of grass results in a higher amount of organic fertilization for derogation parcels and almost the same level of mineral fertilization when excluding no derogation parcels cultivated with corn maize.

It is very important to mention that derogation parcels are characterized by higher average input levels of organic and total fertilizers, especially for grassland and maize. These higher input levels do not result in higher nitrate residue levels after the growing season (paragraph 2). We will see in the next paragraphs that on derogation parcels the export of nutrients is also on a higher level for these crops.

5.3 Fertilization practices

5.3.1 2009

Beside the total amount of fertilization it is also interesting to look at the different fertilization practices (data, dose and method of supplying). An interesting parameter is the date of fertilization, especially the date of the first and the last fertilization.

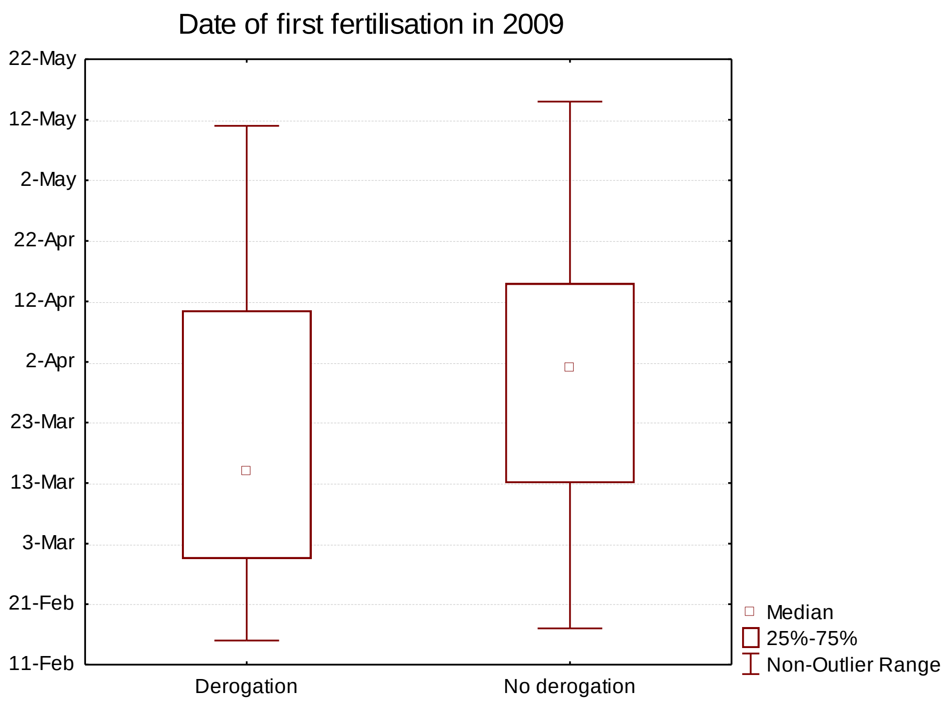

Figure 14: Box plot of the date of first fertilization on the parcels in 2009, separately given for derogation (D) and no derogation (ND) parcels.

Figure 14 shows the date of first fertilization with an organic or mineral fertilizer on the different parcels in the network. This date of first fertilization is separately given for derogation and no derogation parcels. Figure 15 illustrates for all parcels in the network the last date of fertilization with an organic or mineral fertilizer. Figure 14 and Figure 15show that a greater percentage of parcels are fertilized earlier for the first time and later for the last time on the derogation parcels in comparison with the no derogation parcels. For different parcels the first date of fertilization coincides with the last date of fertilization because for some cultivated crops (like maize) the fertilization for the coming growth season is supplied in one application. These differences are explained more in detail (for the different cultivated crops) in the next table.

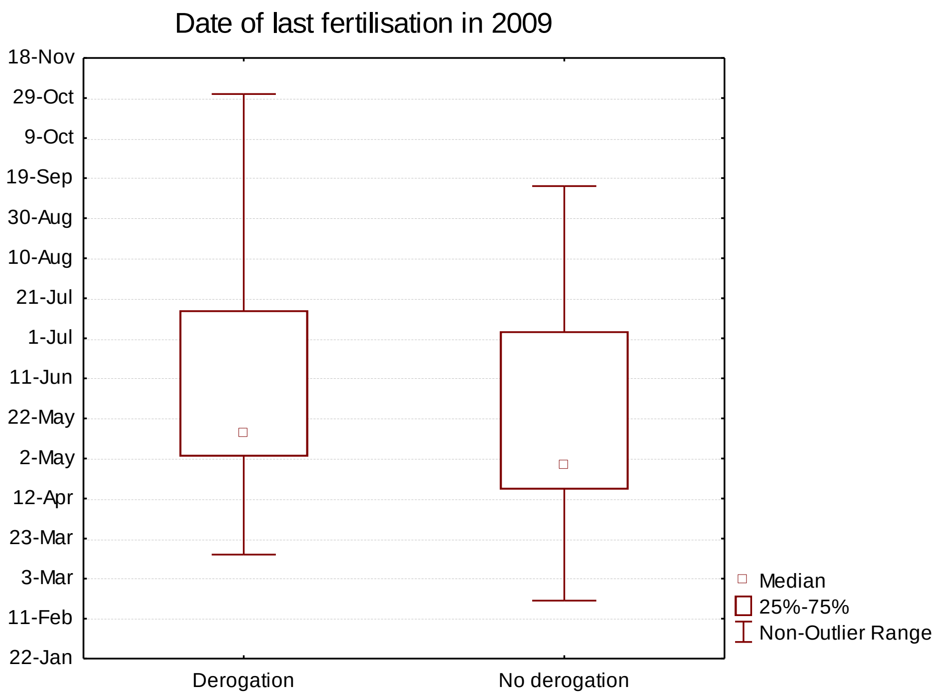

Figure 15: Box plot of the date of last fertilization in 2009, separately given for derogation (D) and no derogation (ND) parcels.

Table 34 shows the percentage of parcels fertilized the first time in a particular month and separately given for grass and maize in derogation and no derogation parcels. Percentages are calculated separately for mineral and organic fertilization by dividing the number of parcels with a first fertilization in a specific month by the total number of parcels for a specific combination of derogation condition and cultivated crop. For grassland an early organic fertilization occurs in February, the percentage of parcels fertilized in February is greater for derogation parcels. The first mineral fraction is supplied also earlier for derogation parcels. For maize the results are also logical. On a part of the derogation parcels an early organic fertilization already occurs in February and a large part of the parcels receive a mineral fertilization in March. This early fertilization is for the grass present on these parcels, this grass is present before the maize, which is a derogation condition. A great part of the derogation parcels is characterized by an organic fertilization in May. This is later then for the no derogation parcels. Maize on derogation parcels is sown later than on no derogation parcels because there has to be harvested one cut of grassland on the derogation parcels before the maize. This cut of grassland is not present on no derogation parcels, therefore the fertilization on no derogation parcels cultivated with maize is concentrated in April. For the last date of fertilization on grassland, a higher percentage of derogation parcels is fertilized on a later date, this difference is greater for organic fertilizers. Also on derogation parcels the last cut of the grassland is on a later date, so the later fertilization is well considered.

Table 34: Percentage* of parcels with the first fertilization practice (organic or mineral) in a specific month of 2009. Numbers are separately given for derogation and no derogation with grass or maize.

		% of parcels with their first fertilization							
		February		March		April		May	
	n	organic	mineral	organic	mineral	organic	mineral	organic	mineral
grass, derogation	60	39		35	40	8	46	10	6
grass, no derogation	41	17		29	33	8	54	8	4
maize, derogation	42	12		20	32	24	22	44	32
maize, no derogation	46			27	9	58	45	9	21

*** Percentages are calculated by dividing the number of parcels with fertilization (mineral or organic) in a specific month by the total number of parcels for a specific combination of derogation condition and cultivated crop. These percentages are separately calculated for organic and mineral fertilization.**

Next to time of fertilizer application, the method used to supply fertilizers is also an interesting parameter. There are three different agricultural practices to apply the organic fertilizers on the parcels; spreading, trailing hoses and injection. Due to governmental rules and regulations it is not possible to spread organic fertilizers on grassland. As a consequence, the only possible methods on grassland are trailing hoses and injection.

On grassland, part of the organic fertilization can originate from grazing cattle. During grazing the emission is estimated at 8 % of the total manure-N production. To calculate this emission, information concerning the grazing period is necessary. This information is obtained from the farmers. 75 % of the organic fertilizers are supplied by injection and 25 % by trailing hoses. For the other cultivated crops, 57 % is supplied by spreading, 29 % by injection and 14 % by trailing hoses. The most important consequences are the emission losses (Table 35).

Table 35: Emission factors (NH3-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.

For arable land these losses are the lowest with injection and the highest with spreading. When spreading, there is a large effect of the time between spreading and incorporation into the soil. Also the weather has a significant impact on the losses. When it is warm and sunny, the losses are higher. However, it is not possible to ask all this information from the farmers. Therefore mean values for the emission losses are taken into account. The percentages present in Table 35 are reduced from the mineral fraction of the total nitrogen present in the organic fertilizer. The amount of mineral fraction present in organic fertilizers is depending on the type of fertilizer.

5.3.2 2010

Beside the total amount of fertilization it is also interesting to look at the different fertilization practices (data, dose and method of supplying). An interesting parameter is the date of fertilization. Figure 16 shows the date of first fertilization with an organic fertilizer on the different parcels in the network, cultivated with grass in 2010. This date of first fertilization is given separately for derogation and no derogation parcels. Figure 17 illustrates the date of first organic fertilization for parcels cultivated with maize in 2010. Figure 16 and Figure 17 show that a greater percentage of parcels are fertilized earlier for the first time on derogation parcels in comparison with the no derogation parcels. For grassland this earlier fertilization results in a higher yield (mostly more cuttings) of the grass.

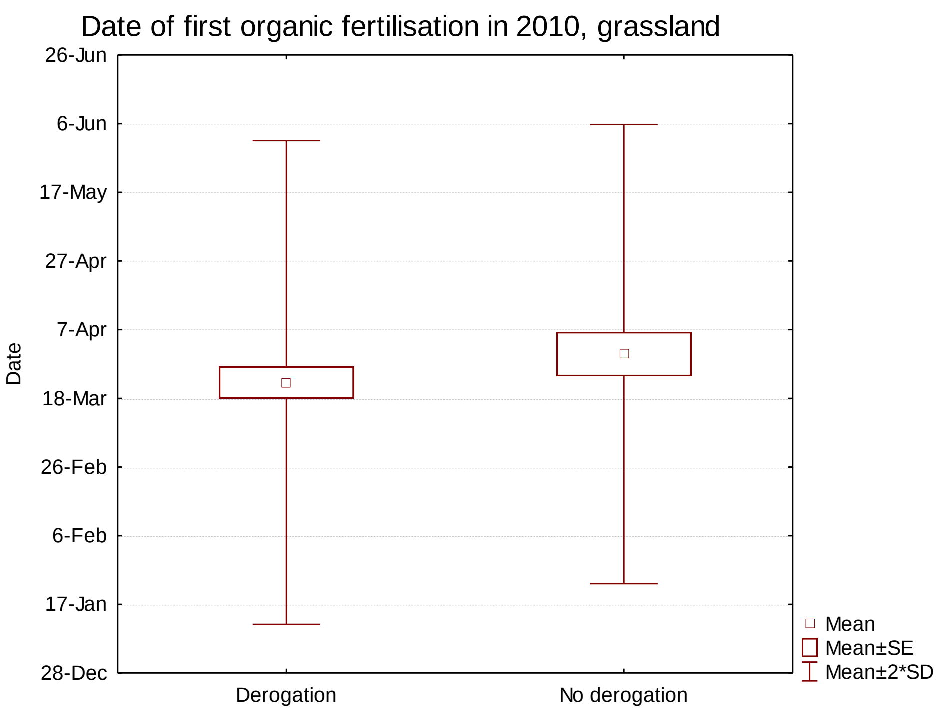

Figure 16: Box plot of the date of first fertilization with an organic fertilizer on the parcels cultivated with grass in 2010, given separately for derogation (D) and no derogation (ND) parcels.

On derogation parcels cultivated with maize, the early fertilization (March) is used by the growing grass. This grass is harvested before the maize is sown. The first fertilization with mineral fertilizers is almost on the same date for derogation and no derogation parcels for grassland. On parcels cultivated with maize, the date of first fertilization with mineral fertilizers is earlier on derogation parcels. This early mineral fertilization is also used by the grass, which is grown prior to the maize.

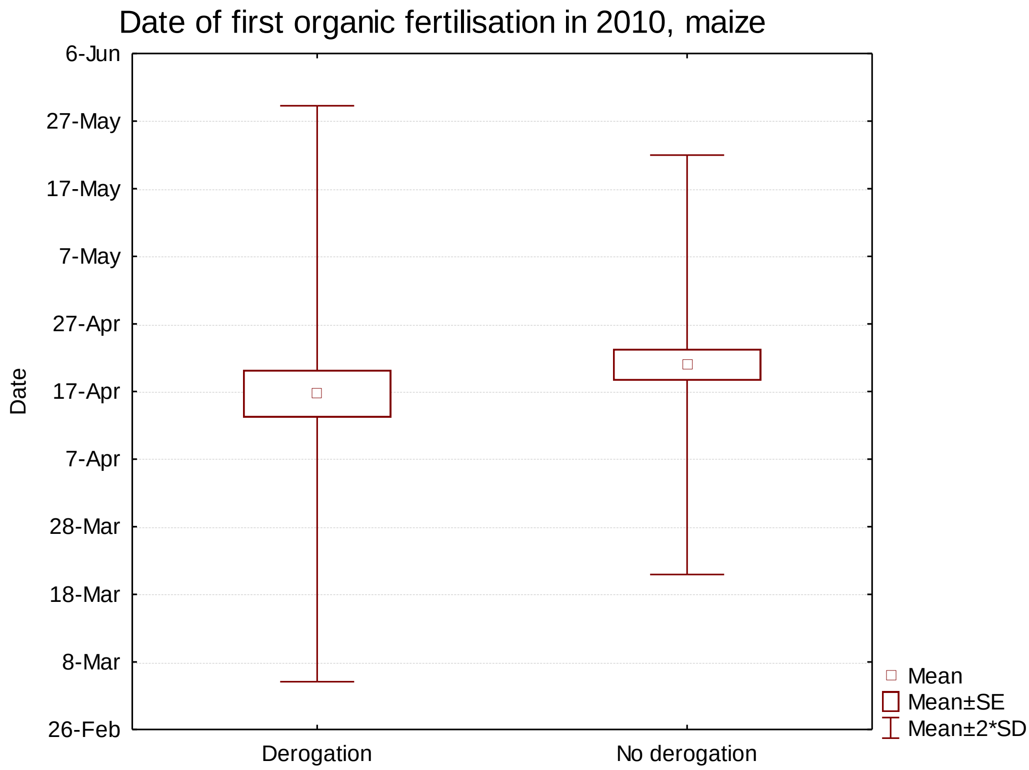

Figure 17: Box plot of the date of first fertilization with an organic fertilizer in 2010 for parcels cultivated with maize, given separately for derogation (D) and no derogation (ND) parcels.

A part of the derogation parcels, cultivated with maize, is characterized by an organic fertilization in May, which is a much later date compared with no derogation parcels. Maize on derogation parcels is sown later than on no derogation parcels because one cut of grassland has to be harvested before the maize is sown. This cut of grassland is not present on no derogation parcels, therefore the fertilization on no derogation parcels cultivated with maize is concentrated in April.

Besides the first date of fertilization it could be interesting to look at the harvest of grassland, especially the number of cuttings. These numbers are shown in Table 36 for derogation and no derogation parcels separately. From this table it can be seen that parcels with the most cuttings are derogation parcels. On no derogation parcels a high percentage of parcels (38 %) are characterized by only grazing. 30 % of the parcels have 1 cutting and 22 % 3 cuttings. For derogation parcels, 78 % of the parcels have at least 1 cutting. 39 % of the derogation parcels have more than 3 cuttings. It seems that the higher fertilization (mineral, organic and total) on derogation parcels results mostly in more cuttings during the season and a higher total yield. This higher yield explains the low nitrate levels on grassland at the end of the growing season.

Table 36: Number and percentage of parcels with the number of harvests (cuttings) of the grassland during the growing season 2010. Numbers are separately given for derogation and no derogation parcels, together with the nitrate residue of 2010.

	Derogation			No derogation		
cut	parcels	% parcels	nitrate residue	parcels	% parcels	nitrate residue
0	14	22	33	14	38	40
1	8	13	39	11	30	53
2	6	10	36	2	5	52
3	11	17	52	8	22	33
4	10	16	67	1	3	43
5	6	10	52	1	3	27
6	5	8	45			
7	1	2	21			
8	2	3	39			

6 Nitrate in the soil profile

To measure the nitrate in the soil profile a soil sample is taken; i.e. the nitrate sample. The nitrate sample is taken on all parcels in the network at different moments. By measuring the amount of nitrate in the soil profile at different moments the evolution of the amount of nitrate as well as the distribution of the nitrate in the soil profile can be monitored. The nitrate in the soil profile is influenced by different processes. The most important process is leaching. Nutrients can leach out of the soil profile towards the surface and groundwater. This leaching has a negative impact on the water quality and has to be reduced to a minimum. Other processes in the soil profile are: mineralization, nitrification, denitrifcation and nutrient take-up by the cultivated crops.

6.1 Nitrate sample before winter 2009: the nitrate residue

The amount of nitrate measured in the nitrate sample taken from the soil profile in the first three soil layers (0-30 cm, 30-60 cm and 60-90 cm) is known as the nitrate residue. The first nitrate sample is taken at the end of 2009 (from 25 October to 15 November). The measured amount of nitrate before a winter period gives an indication of the amount of nitrate that can leach out of the soil profile. During winter there is little nitrate uptake by cultivated crops and leaching is the most important process. So it is important to investigate if there are differences in nitrate residue before winter between derogation and no derogation parcels.

Table 37 shows the average value of the nitrate residue for each combination of soil type, cultivated crop and derogation. The nitrate residue is given for the total soil layer (0-90 cm) and for each 30-cm layer separately. For each combination the number of parcels is also given.

Table 37: Average nitrate-N (kg/ha) in the soil profile (0-90 cm) and for each soil layer (lay1: 0-30 cm, lay2: 30-60 cm, lay3: 60-90 cm) for the different combinations of crop, soil type and derogation (J: derogation, N: no derogation) at the end of 2009. For each combination the number (n) of parcels is given.

	Soil	Crop	n	Nitrate-N (kg/ha)			
				0-30 cm	30-60 cm	60-90 cm	0-90 cm
Derogation							
	Clay	beets	-	-	-	-	-
		grass	1	75	40	21	135
		maize	2	35	22	14	71
		winter wheat	-	-	-	-	-
	Loam	beets	-	-	-	-	-
		grass	**3**	96	66	26	**188**
		maize	**2**	69	30	12	**110**
		winter wheat	-	-	-	-	-
	Sand	beets	-	-	-	-	-
		grass	40	28	18	11	57
		maize	28	41	45	23	109
		winter wheat	1	19	14	13	45
	sandy loam	beets	2	28	26	7	61
		grass	14	38	18	13	68
		maize	11	42	24	14	80
		winter wheat	**1**	70	54	25	**149**
No Derogation							
	Clay	beets	-	-	-	-	-
		grass	4	50	48	21	120
		maize	**1**	18	60	40	**118**
		other	1	20	28	21	69
		winter wheat	3	32	40	23	95
	Loam	beets	2	44	16	11	71
		grass	3	28	20	7	54
		maize	4	38	18	13	69
		other	-	-	-	-	-
		winter wheat	**1**	78	25	4	**107**
	Sand	beets	1	19	9	4	31
		grass	27	25	15	10	51
		maize	26	33	37	22	93
		other	**5**	57	63	41	**161**
		winter wheat	**3**	42	34	31	**106**
	sandy loam	beets	1	15	4	4	22
		grass	7	49	23	12	85
		maize	13	38	24	15	77
		other	**10**	77	45	26	**148**
		winter wheat	4	40	41	19	100

In the next paragraph an explanation is formulated for the values in bold

-The combination grass-loam with derogation: 2 of the 3 parcels are characterised with a higher fertilization and a relatively high carbon percentage (4.41 % and 5.09 %) in comparison with the no derogation parcels.

-The combination maize-loam with derogation: 1 of the 2 parcels has a higher carbon percentage and a high total input for nitrogen. This can be negative for the nitrate residue.

-The parcel with winter wheat on sandy loam: it is only 1 parcel and no abnormalities can be found in other measurements or fertilization practices.

-The combination maize-clay on no derogation parcels: only 1 parcel for this combination, no abnormalities can be found for this parcel.

-The combination winter wheat-loam on no derogation parcels: only 1 parcel, no catch crop present. A catch crop can decrease the nitrate residue.

-The combination winter wheat-sand on no derogation parcels: on 2 parcels an organic fertilization occurred at the end of August with a high dose. A catch crop was present but not well developed.

-The nitrate residue for the combination with other crops on sandy and sandy loam soils for no derogation parcels is high for different parcels. These crops are potatoes and vegetables which are very sensitive for leaching out of nutrients due to their shallow roots.

6.1.1 General

First the global difference between derogation and no derogation parcels is made by comparing the total amount of nitrate residue for all parcels. In both derogation and no derogation parcels, the nitrate measurement shows a large variation. The average level of nitrate residue is somewhat higher for no derogation parcels (87 kg/ha) than for derogation parcels (81 kg/ha) but there is no significant difference between both. With respect to the distribution of the nitrate residue over the three sampled soil layers, no differences are observed between derogation and no derogation parcels. Table 37 shows that the highest levels of nitrate residue are measured on parcels cultivated with no derogation crops. In 2009 more than half of the group other crops consisted of potatoes. Beside potatoes the group other crops consisted of vegetables. Because these cultivated crops have mostly short roots, they are very sensitive to climate effects and leaching out of nutrients from the soil profile. Also, they are not able to take up nitrate from deeper soil layers.

To determine the specific effect of derogation, the further analysis is limited to parcels with derogation crops (maize, grass, beets and winter wheat) only (Figure 19). There is still great variance between the different samples but there is no statistically significant difference between derogation (81 kg/ha) and no derogation parcels (77 kg/ha).

Nitrate in the first (0-30 cm) soil layer can leach out to the next layer but is still available to the cultivated crop. However, cultivated crops have difficulties to take up nitrate in the deepest soil layer (60-90 cm). This nitrate (present in 60-90 cm) will leach out to the groundwater during winter. Therefore, with respect to the water quality, higher levels of nitrate in the upper layers are more favorable than high levels in the deeper layers. Figure 20 demonstrates that more than 80 % of the nitrate residue is present in the upper soil layers (from 0-30 cm and 30-60 cm). The nitrate residue present in those layers does not differ significantly.

So far no significant differences in nitrate residue are found between derogation and no derogation parcels. However, because the nitrate residue is influenced by the soil type, the differences in nitrate residue between derogation and no derogation parcels will be analysed for specific soil types.

Since derogation mainly occurs on sandy and sandy loam soils, this will be discussed in detail in the next two paragraphs (4.1.2 and 4.1.3). For the other soil types, data are listed in Table 37. However, due to the limited number of parcels, a statistical analysis was not possible for the other soil types. The box plot is based on the log-transformed data for the nitrate residue. The data were log-transformed in order to require homogeneity of the data (a condition necessary to apply one-way ANOVA). In order to link the log-transformed values with real nitrate-N values, a second Y-axis was added on the right (Figure 19). However, it's important to note that the mean of log-transformed data differs from the log-transformed mean nitrate-N value.

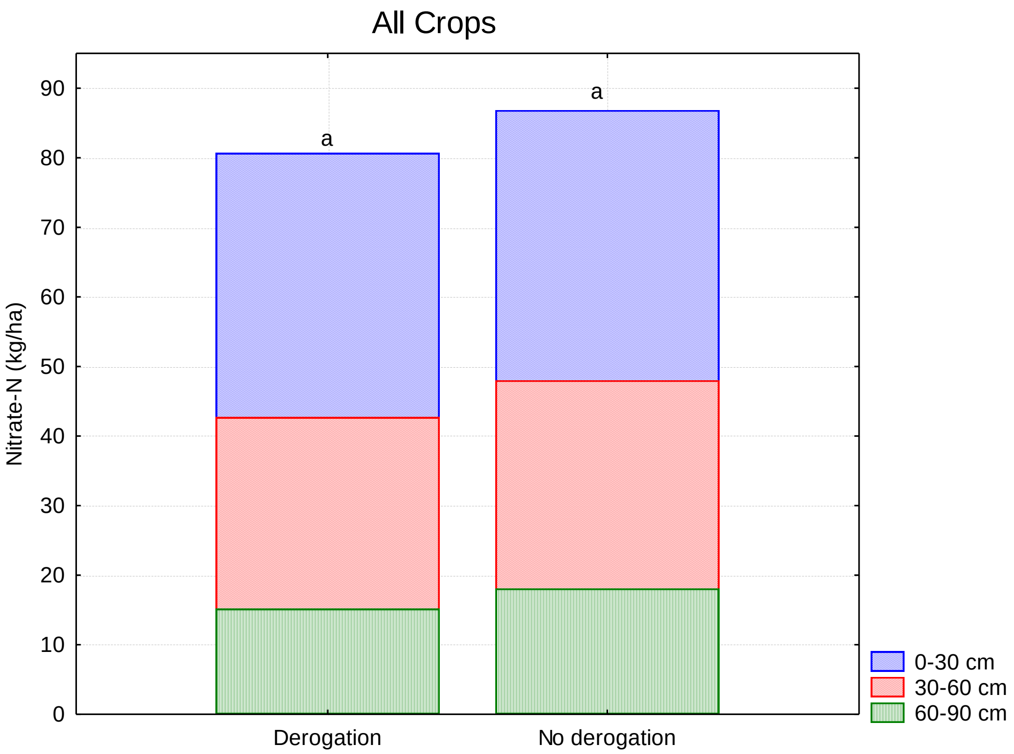

Figure 18: Average nitrate-N (kg/ha) for all derogation and no derogation parcels before winter 2009. The nitrate is cumulatively given for the 3 soil layers.

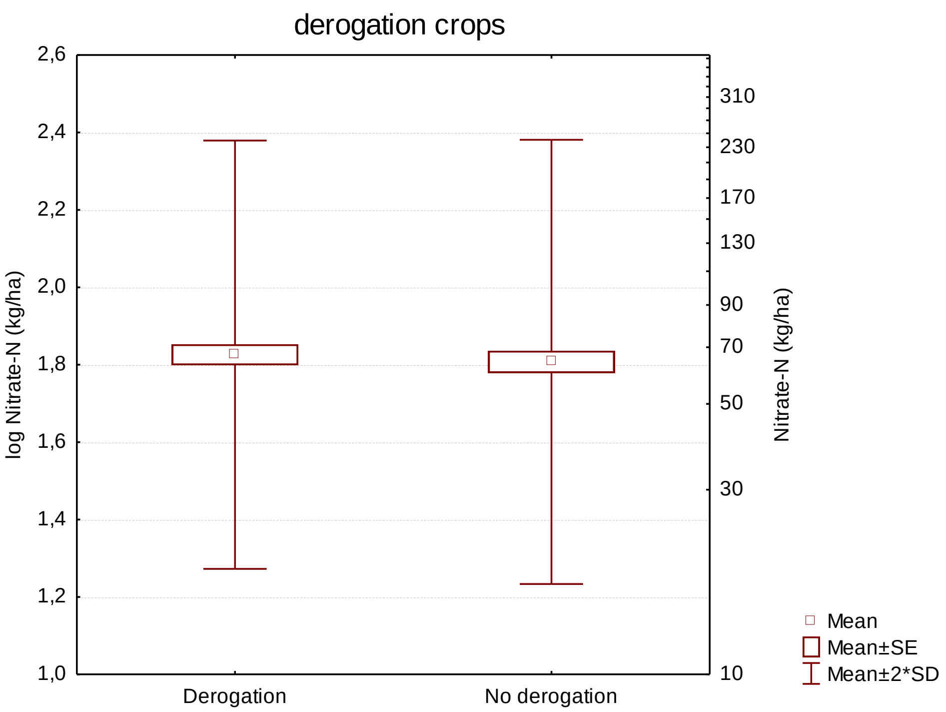

Figure 19: Box plot of log nitrate-N (kg/ha) for all derogation and no derogation parcels cultivated with a derogation crop (maize, grass, beets and winter wheat) before winter 2009.

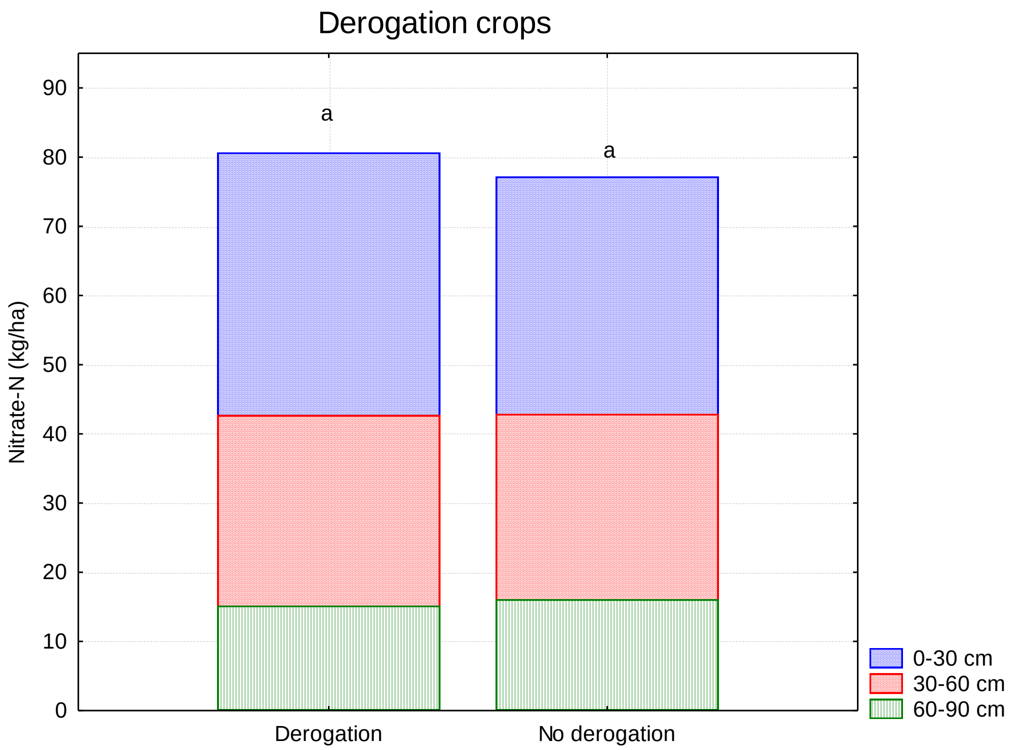

Figure 20: Average nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with a derogation crop (maize, grass, beets and winter wheat) before winter 2009. The nitrate is cumulatively given for the 3 soil layers.

6.1.2 Sandy soils

Table 37 shows that derogation is mostly requested on sandy soils. Since the cultivated crop has an effect on the residual nitrate (Table 37), the analysis on sandy soils is limited to parcels cultivated with derogation crops only. The results are shown in Figure 21 and Figure 22. Even when excluding the no derogation crops, no significant differences were found between derogation (77 kg/ha) and no derogation (73 kg/ha) parcels. Because of the characteristics of a sandy soil (low water retention capacity) the available nutrients are very sensitive for leaching out. Therefore it is important to determine in which soil layer the major amount of nitrate residue is present. In none of the three soil layers, there are differences in nitrate residue between derogation and no derogation parcels (Figure 22).

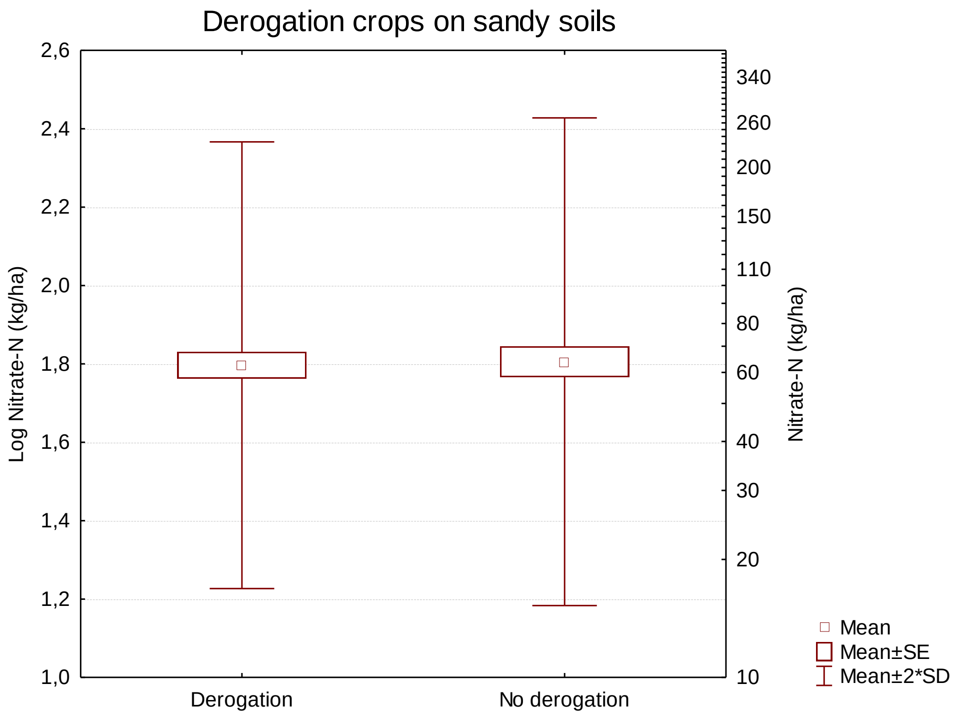

Figure 21: Box plot of log Nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with a derogation crop (maize, grass, beets and winter wheat) for sandy soils, before winter 2009.

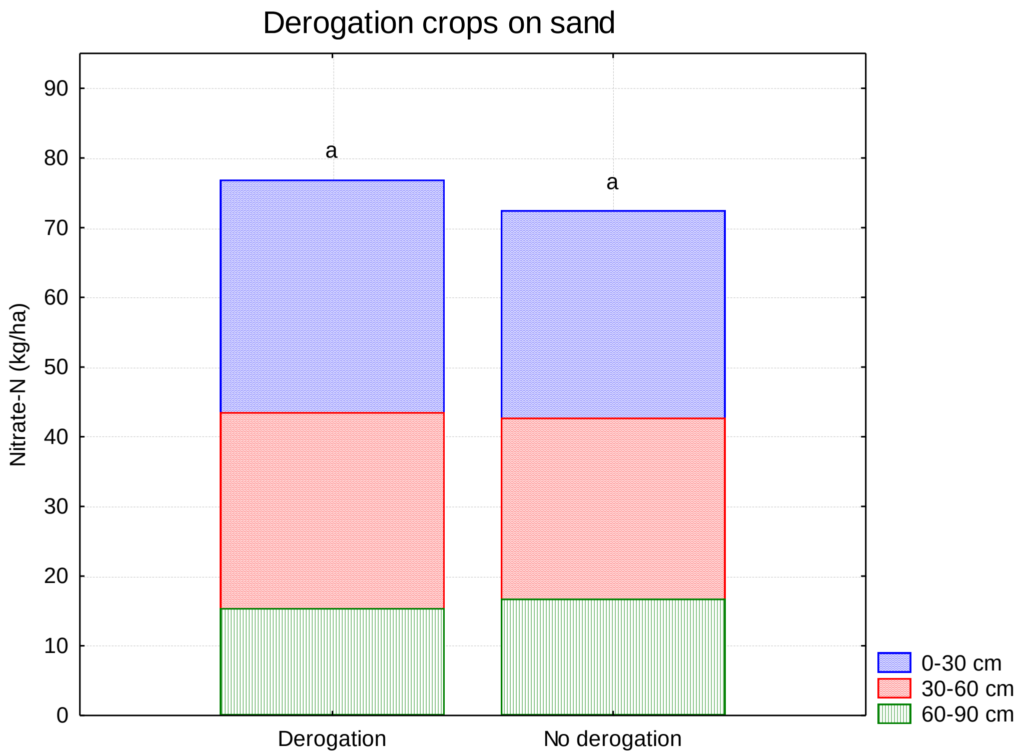

Figure 22: Average nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with a derogation crop (maize, grass, beets and winter wheat) on sandy soils, before winter 2009. The nitrate is cumulatively given for the 3 soil layers.

6.1.2.1 Grass and maize on sandy soils

The cultivated crop has a large effect on the nitrate residue in the soil profile after the growing season. Therefore it is interesting to determine the difference between derogation and no derogation parcels for specific combinations of soil type and cultivated crop. Table 37 shows that the majority of derogation parcels exists of sandy soils cultivated with grass or maize. The average nitrate residue levels for theses different combinations are shown in Figure 23. It is clear that there are difference in nitrate residue between grass and maize. These differences are larger than the difference between derogation and no derogation parcels for one single crop. The differences between derogation and no derogation parcels for sandy soils are separately analysed for grass and maize.

For grass the derogation parcels have a somewhat higher average level of nitrate residue than the no derogation parcels, 57 kg/ha for derogation versus 51 kg/ha for no derogation. The derogation parcels cultivated with maize have an average nitrate residue of 109 kg/ha versus 93 kg/ha for no derogation parcels cultivated with maize. None of the difference between derogation and no derogation parcels cultivated with grass or maize is statistically significant (Figure 23).

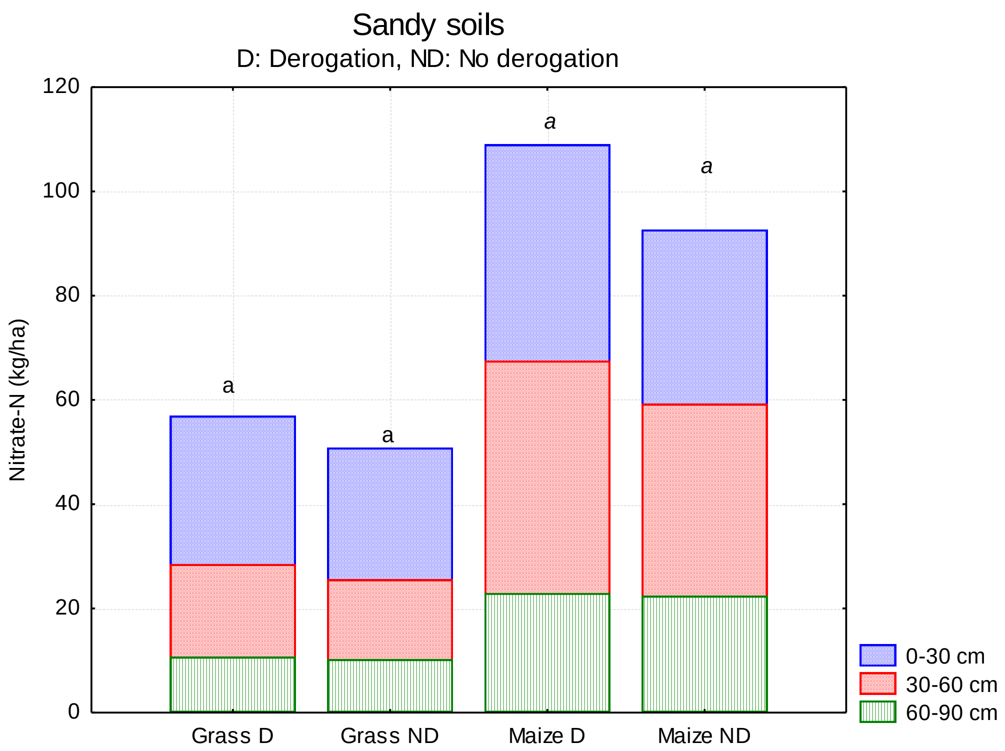

Figure 23: Average nitrate-N (kg/ha) for sandy soils cultivated with grass or maize, before winter 2009. The nitrate is cumulatively given for the 3 soil layers.

For each combination of soil type and cultivated crop the nitrate residue is also investigated for each soil layer. Figure 23 shows that the largest amounts of nitrate residue are present in the two top soil layers, for both grass and maize. For none of the 3 soil layers, significant differences in nitrate residue were found between derogation and no derogation parcels.

6.1.3 Sandy loam soils

Besides on sandy soils, derogation is also frequently requested on sandy loam soils. Therefore a detailed analysis is carried out for sandy loam soils only. Results for derogation crops on sandy loam soils are shown in Figure 24 and Figure 25. There are no significant differences between derogation (75 kg/ha) and no derogation (81 kg/ha) parcels. The variation in the nitrate levels is still high (Figure 24).

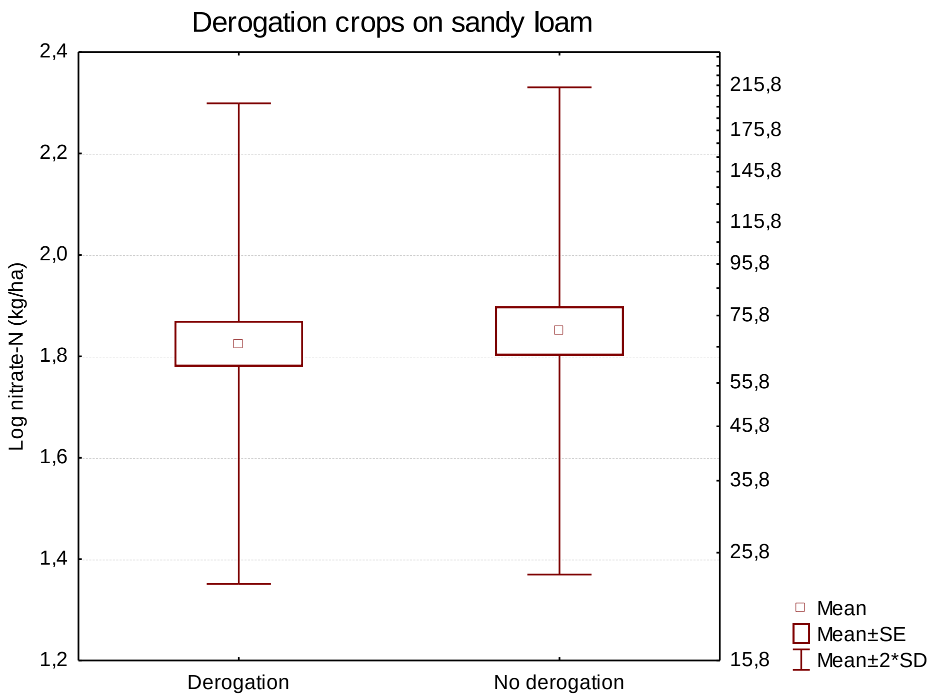

Figure 24: Box plot of log nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with derogation crops (maize, grass, beets and winter wheat) on sandy loam soils, before winter 2009.

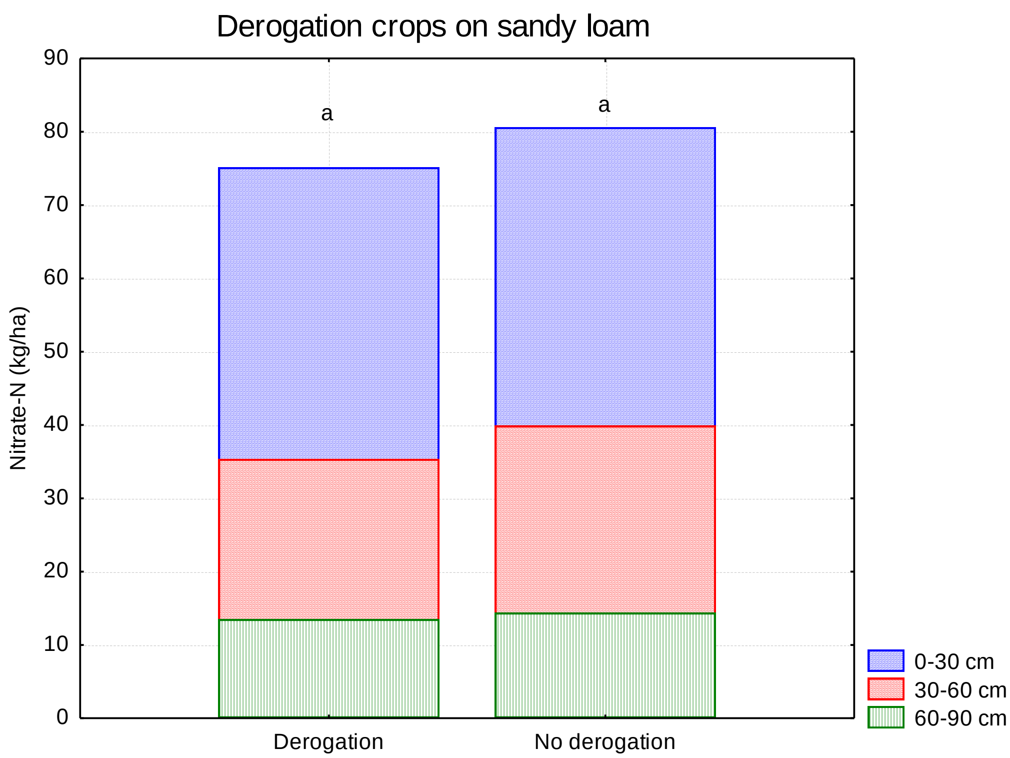

Figure 25: Average nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with derogation crops (maize, grass, beets and winter wheat) on sandy loam soils, before winter 2009. The nitrate is cumulatively given for the 3 soil layers.

6.1.3.1 Grass and maize on sandy loam soils

Because there are no significant differences between derogation and no derogation parcels for sandy loam soils when taking into account all crops or only derogation crops it could be interesting to investigate the effect of derogation for specific combinations of soil type and crop. Table 37 shows that the most frequently occurring combinations for a sandy loam soil are those with grass and maize. The average values for grass and maize with and without derogation for a sandy loam soil are shown in Figure 26. The statistical analysis is carried out separately for parcels cultivated with grass and those cultivated with maize. The average level of nitrate-N for derogation parcels cultivated with grass is 68 kg/ha versus 85 kg/ha for no derogation parcels. So in the soil profile of a sandy loam soil cultivated with grass the largest amount of nitrate is measured in no derogation parcels, this difference is not significant. For parcels cultivated with maize there is no statistically significant difference between derogation (80 kg nitrate-N/ha) and no derogation (77 kg nitrate-N/ha) parcels.

It is also interesting to investigate whether there are differences for individual soil layers. For none of the different combinations there are significant differences between soil layers for derogation and no derogation parcels for the specific combinations of soil type and cultivated crop. For all combinations the largest amount of nitrate residue is measured in the top layer (0-30 cm) of the soil profile.

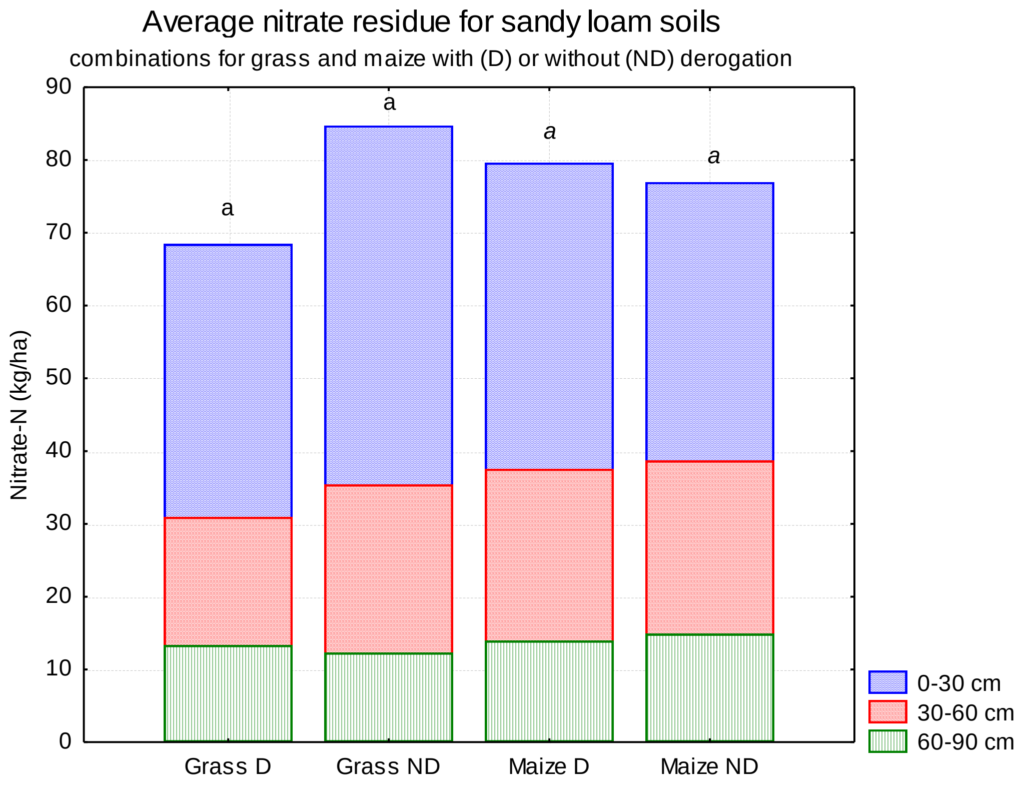

Figure 26: Average nitrate-N residue (kg/ha) for sandy loam soils cultivated with grass or maize with (D) or without (GD) derogation, before winter 2009. The total nitrate residue is shown as well as the amount of nitrate in the different soil layers.

6.1.4 Nitrate in the deeper soil layers

For a selection of parcels an additional soil sample has been taken from 90 to 150 cm in two layers. In these layers the amount of nitrate is measured. First the difference between those two layers is investigated. The correlation between both layers is very strong. There is also a positive correlation between the amount of nitrate present in the soil profile from 0-90 cm and the nitrate present in the soil profile from 90-150 cm. So when there is a high nitrate residue (0-90 cm) it is expectable that there is also a higher amount of nitrate in the deeper soil layers. This is shown in Figure 27. The amount of nitrate in the soil layer from 90-120 cm reaches the same level as the amount of nitrate in the layer from 120-150 cm.

No significant difference was found between nitrate-N (kg/ha) for derogation (average value of 12 kg/ha) and no derogation (average value of 13 kg/ha) parcels for both soil layers (from 90-120 cm and from 120-150 cm). Because 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 type and cultivated crop. This comparison is only possible on sandy soils. For this specific soil type there are no significant differences between derogation and no derogation parcels between the nitrate-N in the soil layers from 90-120 cm and 120-150 cm. The average value for the soil layer from 90-120 cm is 17 kg/ha nitrate-N for parcels cultivated with maize and 10 kg/ha for parcels cultivated with grass. When the nitrate in the soil profile from 0-90 cm is high, the amounts of nitrate in the deeper soil layers are also on a high level. This is true for both the layers from 90-120 cm and from 120-150 cm. This effect is illustrated for sandy soils in Figure 28 but is applicable to all soil types and cultivated crops.

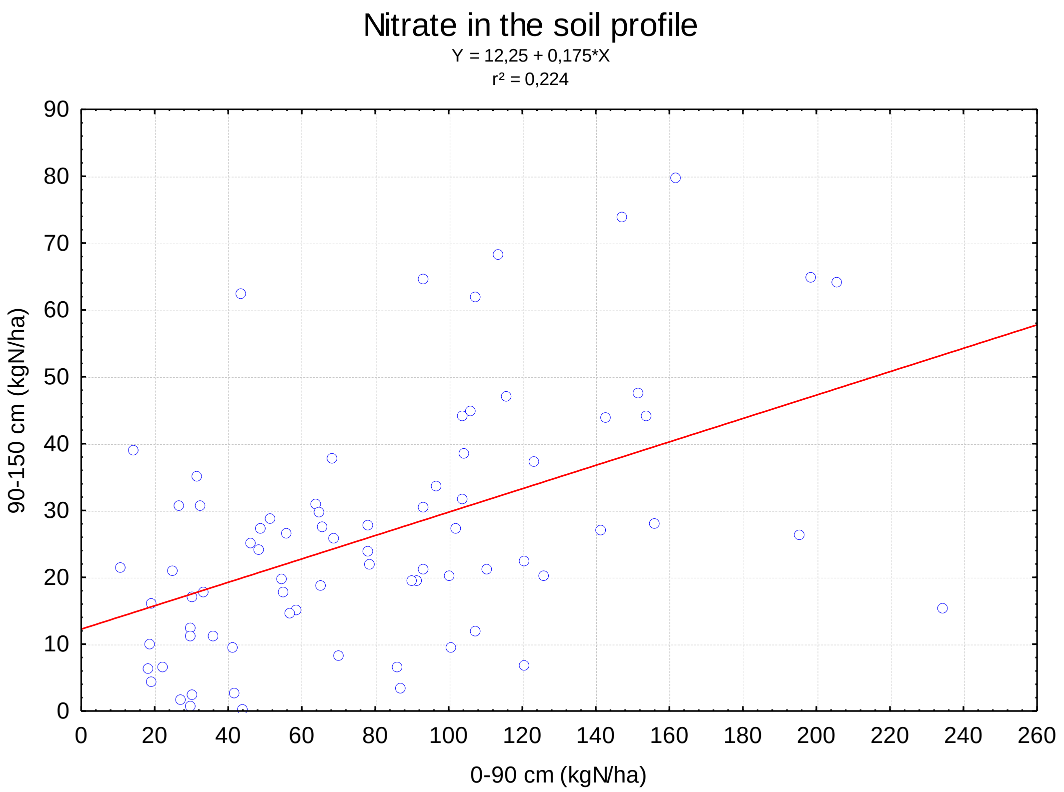

Figure 27: Scatterplot of the nitrate-N (kg/ha) in the soil profile from 0-90 cm versus the nitrate-N (kg/ha) in the soil profile from 90-150 cm, before winter 2009.

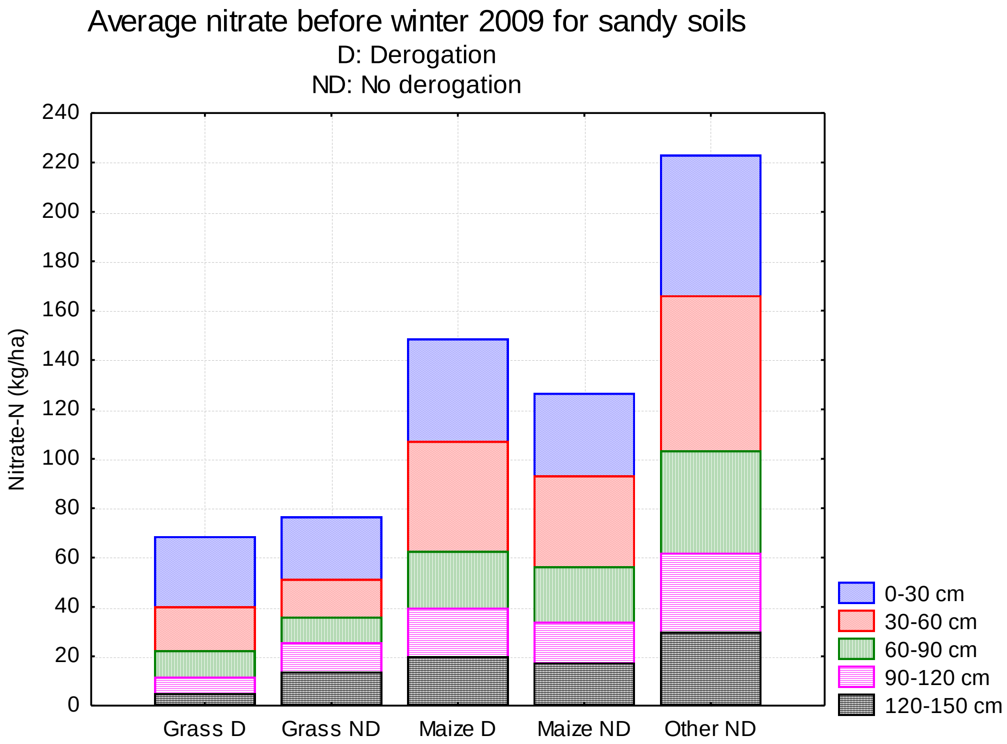

Figure 28: Average nitrate-N (kg/ha) for the 5 soil layers for derogation and no derogation parcels on a sandy soil cultivated with grass or maize, before winter 2009.

6.2 Nitrate sample after winter 2009

In each parcel in the monitoring network a nitrate sample has been taken after winter (from 25 January to 15 February). This is the second nitrate sample taken on the parcels in the monitoring network. This nitrate sample, taken in three layers (0-30 cm, 30-60 cm and 60 to 90 cm), gives information on the amount of nitrate that is still available in the soil profile after winter and that will be available for the cultivated crops for the coming growing season. Based on this information every farmer gets a specific nitrate fertilization advice. 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 important to estimate the amount of nitrate that will be released by mineralization. It is also very important in which soil layer the nitrate is available; more nitrate in the top layer is better, since a lot of crops cannot get the nitrate out of the bottom layer (60-90 cm). Beside information for the next fertilization year the nitrate sample taken after winter is an indication for the amount of nitrate that leached out during winter (especially when compared with the nitrate measured before winter). Therefore it is

Table 38: Average levels of nitrate-N (kg/ha) in the soil profile after winter 2009. The nitrate-N is given for the different combinations of soil type, cultivated crop and derogation. For each combination the total amount of nitrate is given as well as for each soil layer (lay 1: 0-30 cm, lay 2: 30-60 cm and lay 3: 60-90 cm). For each combination also the number (n) of parcels is given.

	soil	crop	n	Nitrate-N (kg/ha)			
				0-30 cm	30-60 cm	60-90 cm	0-90 cm
Derogation							
	Clay	beets	-	-	-	-	-
		grass	2	11.2	13.1	11.1	35.4
		maize	2	13.5	16.3	17.4	47.2
		winter wheat	-	-	-	-	-
	Loam	beets	-	-	-	-	-
		grass	3	25.7	16.7	9.7	52.1
		maize	**2**	43.4	23.4	19.9	**86.7**
		winter wheat	-	-	-	-	-
	Sand	beets	-	-	-	-	-
		grass	39	16.9	11	9.9	37.8
		maize	29	13.4	13.9	16.6	43.8
		winter wheat	1	10.7	7.4	5.2	23.3
	sandy loam	beets	2	20.3	13.8	11.9	46.1
		grass	15	21.6	13.9	9.9	45.4
		maize	11	12.6	12.3	12.8	37.6
		winter wheat	1	20.5	17.4	28.2	**66.1**
No derogation							
	Clay	beets	-	-	-	-	-
		grass	4	22.5	17.6	16.2	56.3
		maize	**1**	22.4	28.6	23.8	**74.8**
		other	1	14.2	12.4	10.8	37.4
		winter wheat	3	21.6	18	15	54.7
	Loam	beets	**2**	21.3	18.8	19.2	59.2
		grass	3	10.2	7	3.2	20.4
		maize	4	13.4	12.5	13.4	39.3
		other	-	-	-	-	-
		winter wheat	1	18.1	21.2	17.1	56.5
	Sand	beets	1	11.4	10.4	11.8	33.6
		grass	27	16.7	12.6	10.2	39.6
		maize	26	13.4	14	14.7	42.1
		other	6	12	10.1	14	36.1
		winter wheat	3	12.7	13.5	8	34.2
	sandy loam	beets	1	12.3	20.8	22	55.2
		grass	7	23.4	15	10.2	48.5
		maize	13	12.4	10.3	14.1	36.9
		other	10	16.8	16.7	23.9	57.4
		winter wheat	3	11.2	6.4	4.5	22.1

important to see whether there are differences between derogation and no derogation parcels at this moment of the growing season. The average levels of nitrate measured in the soil samples after winter 2009 are shown in Table 38. The amounts of nitrate are given for the different combinations of derogation, soil type and cultivated crop. The amount of nitrate is given for the total soil profile (0-90 cm) as well as for each soil layer of 30 cm. For each combination the number of parcels is given.

The values in bold in Table 38 are combinations with high levels of nitrate. All these combinations had also high levels of nitrate before winter 2009 (Table 37). Not all nitrate present before winter leached out of the soil profile and is still present. Some of the parcels have high levels of carbon, for this parcels the process of mineralization can be important.

6.2.1 General

Firstly, the comparison is made between derogation and no derogation parcels. No significant differences in nitrate were found between derogation and no derogation parcels. The average nitrate-N is 42 kg N/ha for derogation parcels and 43 kg N/ha for no derogation parcels. The nitrate is equally divided between the 3 soil layers, (Figure 29).

Figure 29: Average nitrate-N (kg/ha) for derogation and no derogation parcels measured after winter 2009. The nitrate is cumulatively given for the 3 soil layers.

The following step is the comparison of derogation and no derogation parcels cultivated with derogation crops only. Still, the measured nitrate values are highly variable (Figure 30). No significant difference was found between nitrate measured in derogation (42 kg N/ha) and no derogation (41 kg N/ha) parcels.

The nitrate in individual layers was also examined. As already could be seen from Figure 30 there are no significant differences in nitrate between derogation and no derogation parcels for each soil layer separately. The soil layers from 30-60 cm and 60-90 cm contain each approximately 30 % of the total amount of nitrate in the soil profile. The top soil layer (0-30 cm) contains about 40 % of the total amount of nitrate in the soil profile.

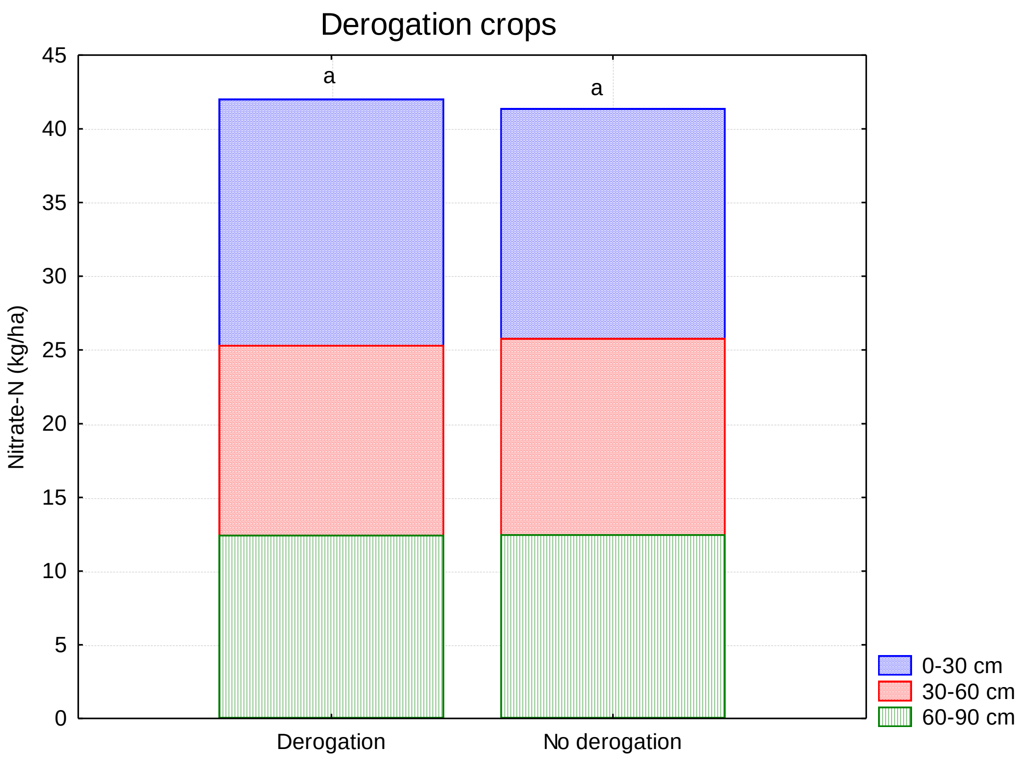

Figure 30: Average nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with derogation crops (maize, grass, beets and winter wheat) only. The nitrate is cumulatively given for the 3 soil layers and measured after winter 2009.

6.2.2 Sandy soils

The next step is to see whether there are differences between derogation and no derogation parcels for the most important soil types. Table 38 shows that the most important soil type is sand. The average value of nitrate-N for both derogation and no derogation parcels on sandy soils is 40 kg/ha.

The analysis was limited to derogation and no derogation parcels in sandy soils cultivated with derogation crops. The variation between the measurements is large (Figure 31). Also, the nitrate measured in sandy soils in derogation parcels does not differ significantly from the nitrate measured in no derogation parcels (Figure 32). Also, for the different soil layers separately no significant differences between derogation and no derogation parcels were found. For all parcels the largest amount of nitrate is present in the soil layer from 0 to 30 cm.

Figure 31: Box plot of log nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with a derogation crop (maize, grass, beets and winter wheat) on sandy soils, after winter 2009.

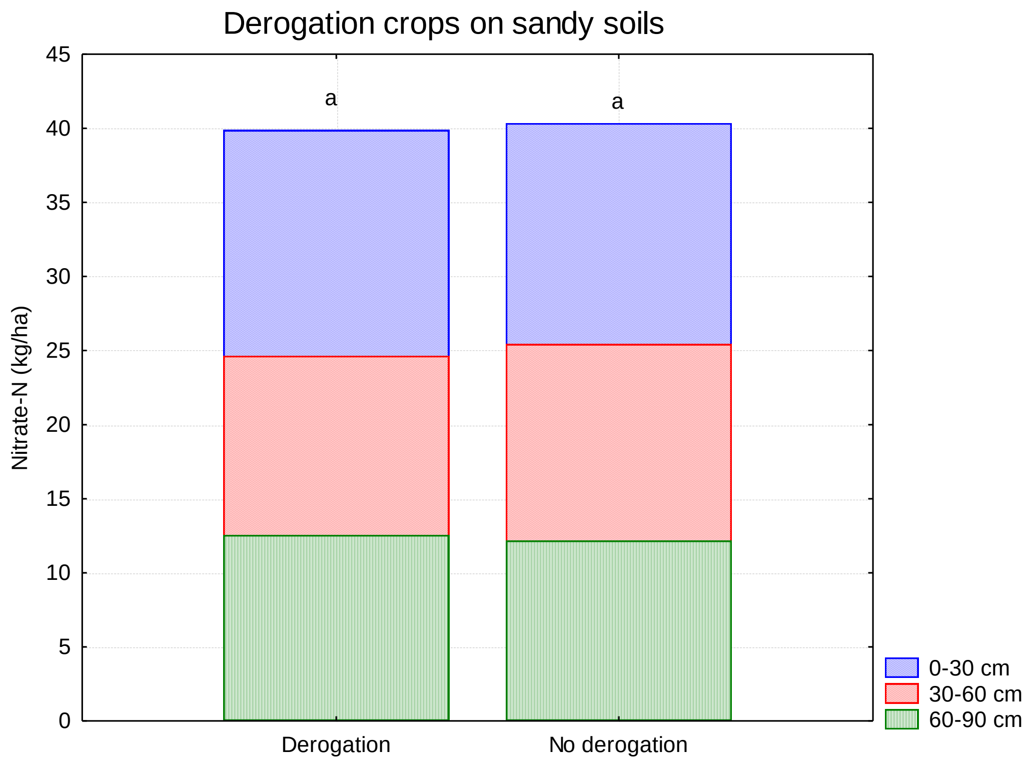

Figure 32: Average nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with derogation crops (maize, grass, beets and winter wheat) on sandy soils, after winter 2009. The nitrate is cumulatively given for the 3 soil layers.

6.2.2.1 Grass and maize on sandy soils

So far no significant differences were found between derogation and no derogation parcels in general and for sandy soils specifically. Because grass and maize are the most cultivated crops on sandy soils, it is interesting to compare the nitrate values for the specific combinations of grass with sandy soils and maize with sandy soils. The analyses were carried out separately for grass and maize; the results are shown together in Figure 33. For grass there is no significant difference between derogation (38 kg N/ha) and no derogation (40 kg N/ha) parcels.

Also for maize no significant difference in nitrate was found between derogation parcels and no derogation parcels, with an average nitrate-N of 44 kg N/ha for derogation and 42 kg N/ha for no derogation parcels. Moreover, for both cultivated crops no significant differences between derogation and no derogation parcels were found when examining each soil layer separately. In parcels cultivated with maize a larger part of the nitrate is present in the soil layer 60-90 cm, approximately 35 % of the total amount of nitrate. This is approximately 30 % for the other soil layers. For grass the largest amount of nitrate is present in the top soil layer.

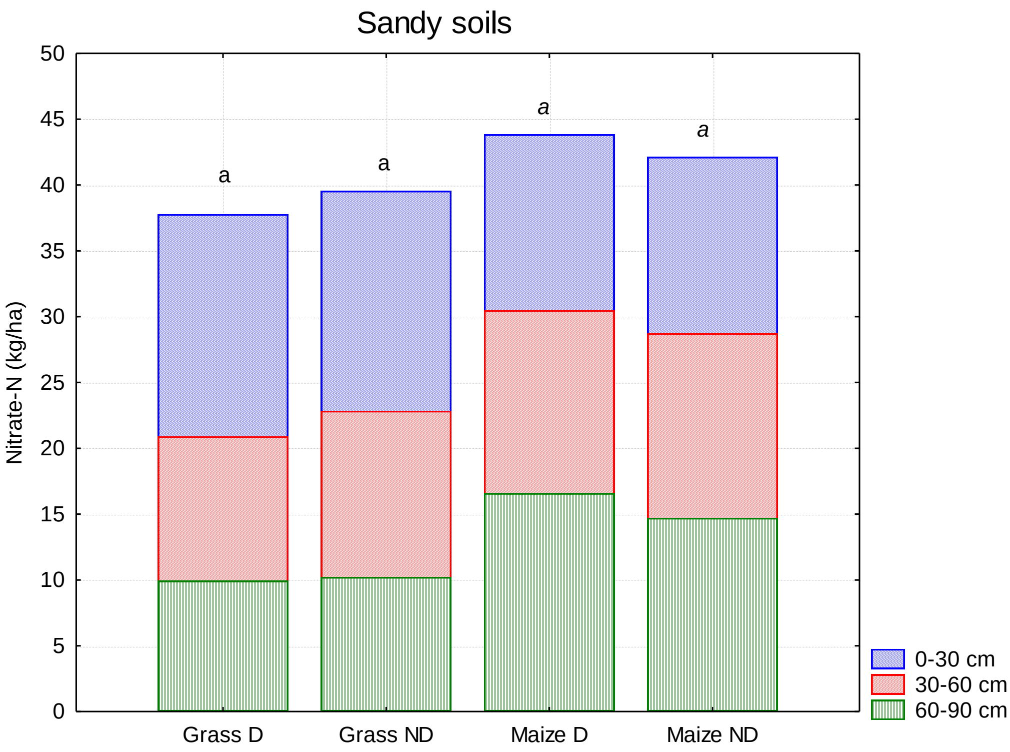

Figure 33: Average nitrate-N (kg/ha) levels for sandy soils cultivated with grass or maize with (D) or without (ND) derogation, after winter 2009. The nitrate is cumulatively given for the different soil layers (lay 1: 0-30 cm, lay 2: 30-60 cm and lay 3: 60-90 cm).

6.2.3 Sandy loam soils

Beside on sandy soils the majority of parcels in the monitoring network occur on sandy loam soils. In Figure 34 and Figure 35 the analysis is carried out for parcels with derogation crops only. The variability of the measured nitrate is high. On average the nitrate measured in no derogation parcels decreased from 45 kg/ha to 39 kg/ha by excluding the no derogation crops. No significant difference was found between derogation and no derogation crops on sandy loam soils. 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.

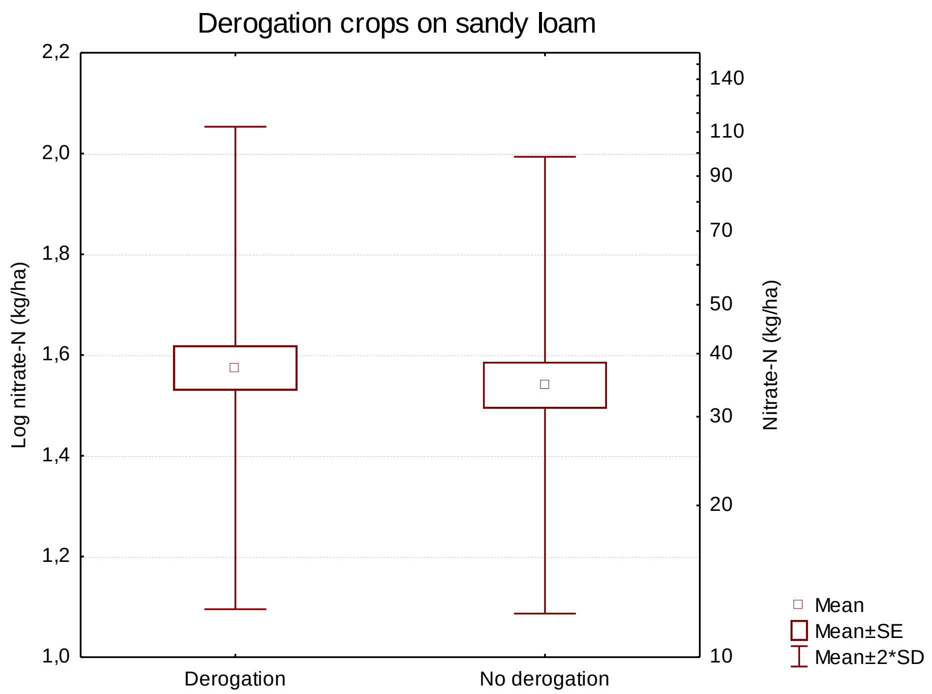

Figure 34: Box plot of log nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with derogation crops (maize, grass, beets and winter wheat) on sandy loam soils, after winter 2009.

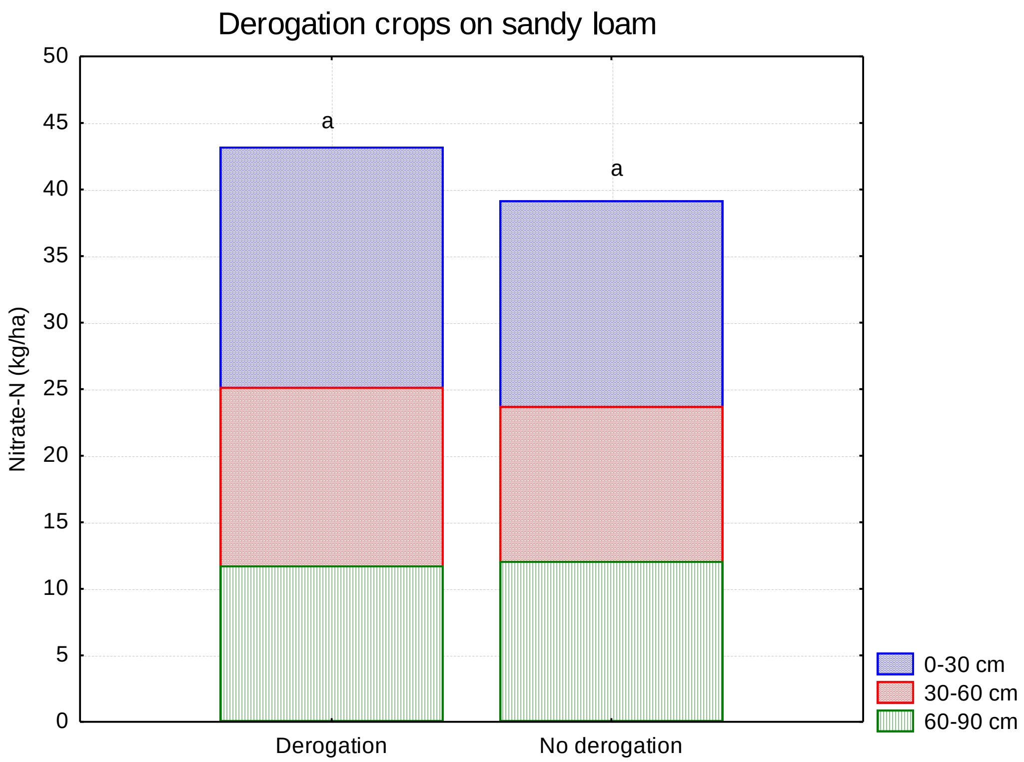

Figure 35: Average nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with derogation crops (maize, grass, beets and winter wheat) on sandy loam soils, after winter 2009. The nitrate is cumulatively given for sandy loam soils.

6.2.3.1 Maize and grass on sandy loam soils

Figure 36 shows the average values of nitrate-N for the total soil profile and the different soil layers separately. These average values are shown for grass and maize in combination with or without derogation on sandy loam soils. The statistical analysis was carried out separately for maize and grass. For grass there are no significant differences between derogation parcels (41 kg N/ha) and no derogation (44 kg N/ha) parcels. Also, for grass no significant differences were found between the individual soil layers. However the largest amount of nitrate is present in the soil layer 0-30 cm.

For maize the average nitrate level in derogation parcels (38 kg N/ha) did not differ significantly from the nitrate level in no derogation parcels (37 kg N/ha). In addition, for parcels cultivated with maize no significant differences were found between derogation and no derogation parcels for the different soil layers.

In derogation parcels the nitrate is evenly distribute between the 3 soil layers, while in no derogation parcels the highest level of nitrate was present in the soil layer 60-90 cm.

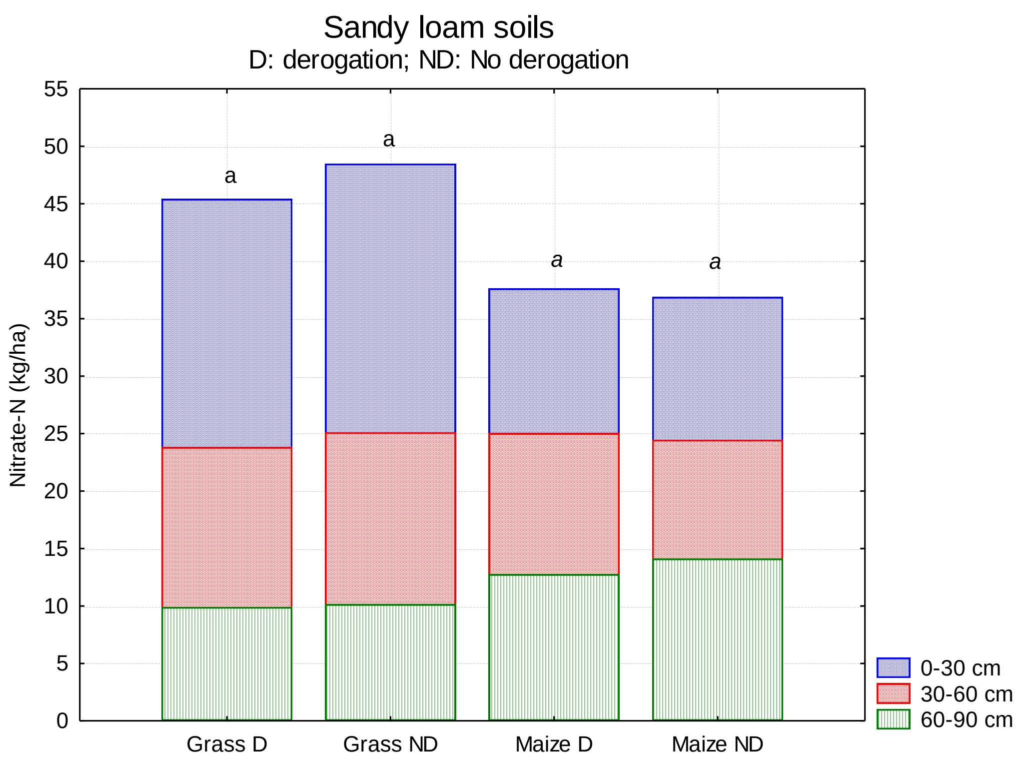

Figure 36: Average nitrate-N (kg/ha) levels for sandy loam soils cultivated with grass or maize with (D) or without (ND) derogation, after winter 2009. The nitrate is cumulatively given for the different soil layers (lay 1: 0-30 cm, lay 2: 30-60 cm and lay 3: 60-90 cm).

6.2.4 Nitrate in the deeper soil layers

After winter also a number of parcels are sampled from 90 to 150 cm in two layers of 30 cm. In these soil layers the amount of nitrate-N is measured. In 70 % of the parcels with a deep soil sample taken before winter a second deep soil sample was taken after winter. These deep soil samples are taken at the same moment as the nitrate sample (from 0 to 90 cm). First the differences between the layer from 90-120 cm and the layer from 120-150 cm are investigated. The levels of nitrate-N are almost the same for both layers (Figure 38). There is no significant difference between both.

When comparing the nitrate levels present in the soil profile from 0 to 90 cm with the levels present in the profile from 90 to 150 cm after winter, the relation is less strong between both than before winter 2009. Due to leaching out of nitrate, this nitrate is more evenly distributed among the different soil layers. In most cases the top soil layer (0-30cm) has a lower amount of nitrate in comparison with values before winter. The deepest layers have still the lowest levels but the differences with the other soil layers are smaller than before winter.

There are no significant differences between derogation and no derogation parcels for none of the two layers. The average value for nitrate-N is 16 kg/ha for no derogation parcels and 9 kg/ha for derogation parcels for the layer from 90 to 120 cm. For the soil layer from 120 to 150 cm the average nitrate-N is 13 kg/ha for no derogation and 8 kg/ha for derogation parcels. Statistical analysis is done between derogation and no derogation parcels for the different combinations of sand and sandy loam soils with grass and maize. In none of those combinations statistical differences between derogation and no derogation parcels were found for the amount of nitrate-N present in the soil layers from 90 to 150 cm after winter 2009. The correlation between the different soil layers is illustrated for sandy loam soils in Figure 39.

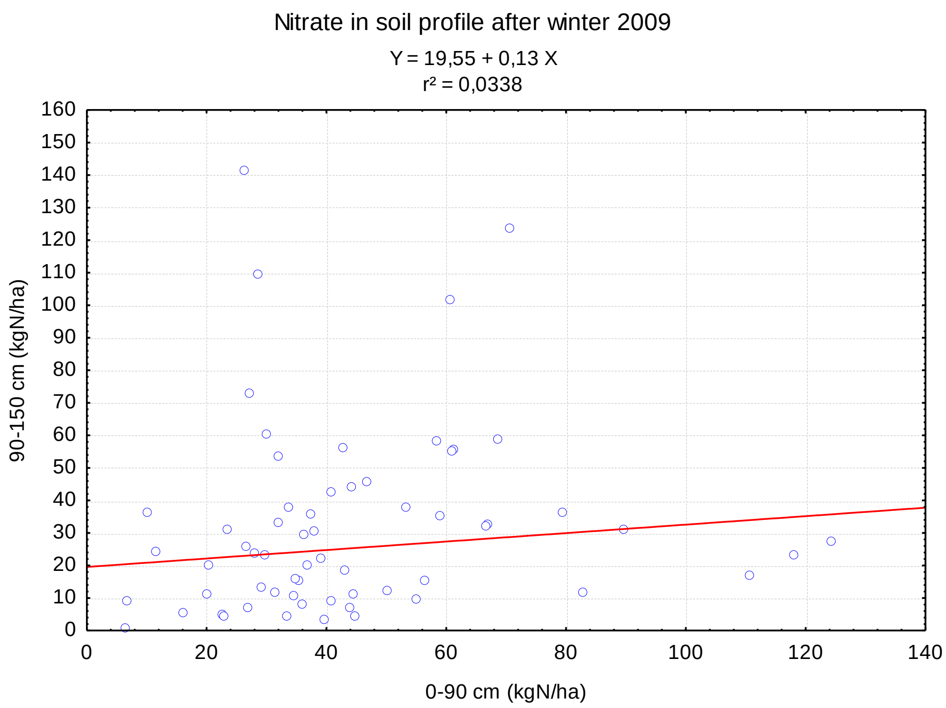

Figure 37: Scatterplot of nitrate in the soil profile from 0 to 90 cm versus the nitrate in the profile from 90 to 150 cm, after winter 2009.

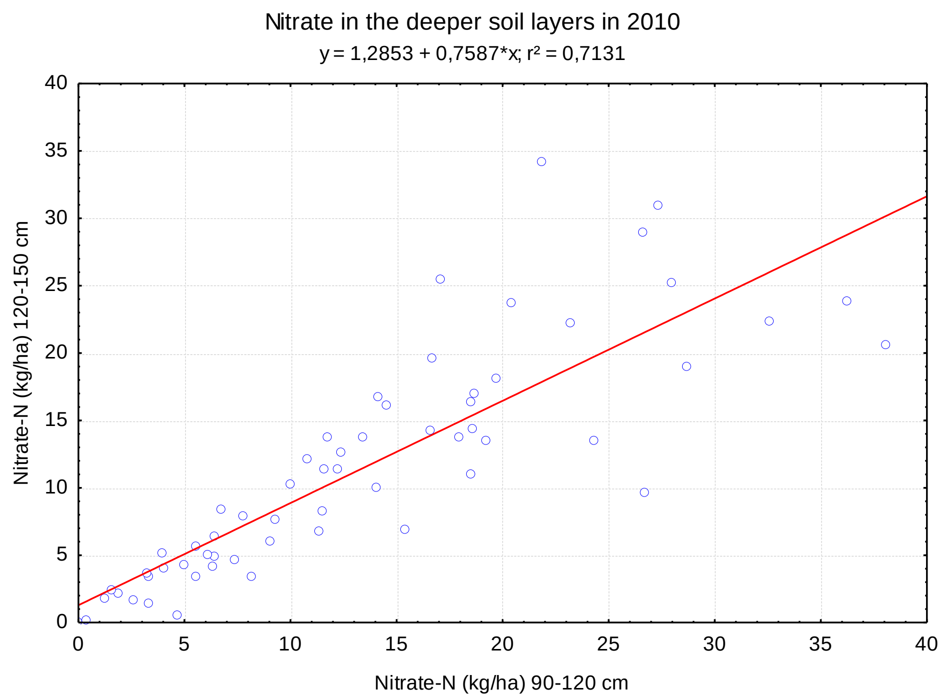

Figure 38: Scatter plot of the amount of nitrate-N (kg/ha) for the soil layer from 90-120 cm against the amount of nitrate-N (kg/ha) for the layer 120-150 cm, after winter 2009.

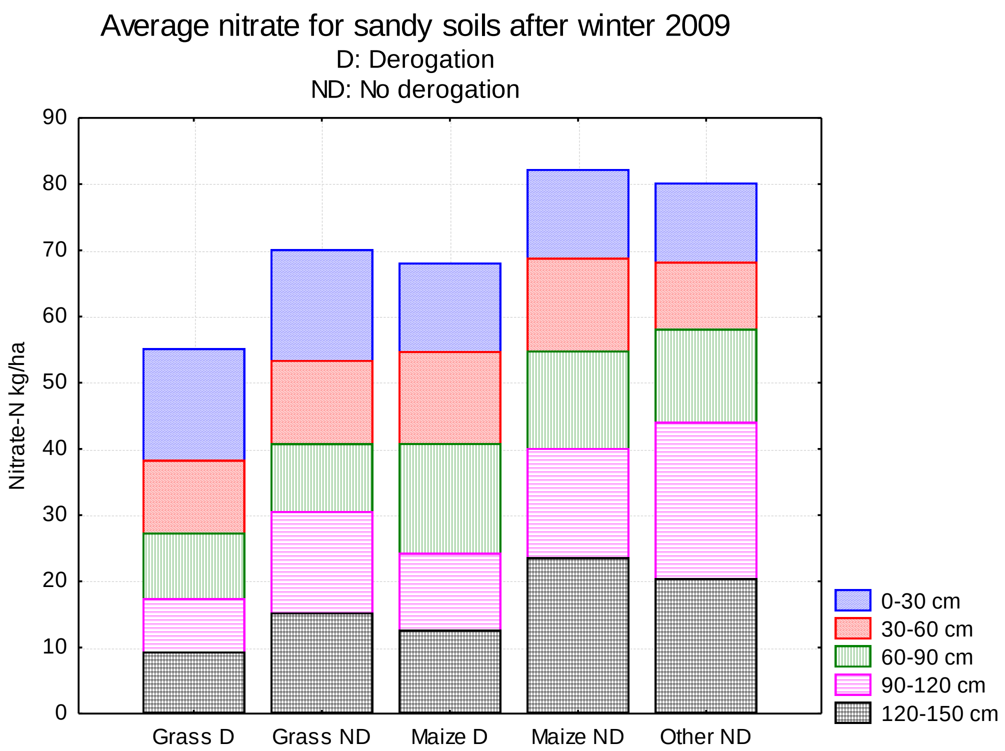

Figure 39: Average levels of nitrate-N (kg/ha) on sandy loam soils for the different soil layers and combinations of cultivated crop and derogation, after winter 2009.

6.3 Nitrate sample before winter 2010: the nitrate residue

The amount of nitrate measured in the nitrate sample taken from the soil profile in the first three soil layers (0-30 cm, 30-60 cm and 60-90 cm) is known as the nitrate residue. In the next paragraphs the nitrate residue before winter 2010 (20 October to 15 November) is discussed. Differences in nitrate residue between derogation and no derogation parcels are investigated. Table 39 illustrates the differences between different cultivated crops for derogation and no derogation parcels. For none of these combinations a difference is made between the different soil types. The largest differences can be seen between the different cultivated crops, the highest nitrate levels are measured on parcels cultivated with maize and no derogation crops. The lowest levels are present on parcels cultivated with beets and grassland. The differences between derogation and no derogation parcels are very small. For grassland the nitrate levels are lower when parcels are only mowed, compared with parcels which are grazed and mowed. This can only be seen on derogation parcels because there were almost no observations of only mowing on no derogation parcels. On no derogation parcels two types of maize can be sown (theoretical also possible on derogation parcels); corn maize and fodder maize. No derogation parcels cultivated with corn maize have a significantly lower nitrate residue in comparison with the no derogation parcels cultivated with fodder maize.

Table 39: Average concentration of nitrate-N (kg/ha) measured in the soil profile at the end of 2010. Levels of nitrate are given separately for derogation and no derogation parcels for the different cultivated crops.

	Crop	n	Nitrate-N (kg/ha)			
			0-30 cm	30-60 cm	60-90 cm	0-90 cm
Derogation		106				
	grass (mowing + grazing)	40	18	16	16	50
	grass (only mowing)	26	17	13	9	39
	fodder maize	36	26	30	20	76
	beets	2	12	10	7	29
	winter wheat	2	18	12	10	40
No Derogation		116				
	grass (mowing + grazing)	37	17	14	12	43
	fodder maize	30	28	31	23	82
	corn maize	13	19	22	18	59
	beets	1	14	12	7	33
	winter wheat	10	15	15	19	49
	other	25	18	25	27	70

The differences in nitrate residue are more specified in Table 40, average values are given for specific combinations of soil type, cultivated crop and derogation. The nitrate residue is given for the total soil layer (0-90 cm) and for each 30-cm layer separately. For each combination the number of parcels is also given. It is important to mention that the average levels in Table 39 and Table 40 are based on all parcels in the network except 3. For these 3 (no derogation) parcels extreme nitrate levels were measured. One parcel cultivated with maize had a nitrate level of 319 kg N/ha, a second parcel cultivated with potatoes had 314 kg N/ha and a third parcel cultivated with leek was characterized by a nitrate level of 398 kg N/ha.

For some combinations of soil type and cultivated crop there are very low numbers of parcels. For these combinations it is not possible to make a statistical comparison between derogation and no derogation parcels. Due to the lower number of observations for these combinations, average levels in Table 40 have to be interpreted with care. Some combinations are shown in bold, for these an explanation was evaluated:

-The combination maize-loam with derogation: Only 1 parcel. The fertilization on this parcel was not extremely high but the grassland sown before the maize was not harvested because it showed poor development. As a consequence fewer nutrients were exported from the parcel.

Table 40: Average nitrate-N (kg/ha) in the soil profile (0-90 cm) and in each soil layer (lay1: 0-30 cm, lay2: 30-60 cm, lay3: 60-90 cm) for the different combinations of crop, soil type and derogation at the end of 2010. For each combination the number (n) of parcels is given.

	Soil	Crop	n	Nitrate-N (kg/ha)			
				0-30 cm	30-60 cm	60-90 cm	0-90 cm
Derogation			106				
	Clay	beets	-	-	-	-	-
		grass	3	15	13	15	43
		maize	-	-	-	-	-
		winter wheat	1	13	8	3	24
	Loam	beets	-	-	-	-	-
		grass	3	22	15	13	50
		maize	**1**	37	47	29	**113**
		winter wheat	-	-	-	-	-
	Sand	beets	-	-	-	-	-
		grass	45	17	15	15	47
		maize	22	26	31	20	77
		winter wheat	1	23	16	17	56
	sandy loam	beets	2	12	10	7	29
		grass	16	21	13	7	41
		maize	12	25	28	21	74
		winter wheat	**-**	-	-	-	**-**
No Derogation			115				
	Clay	beets	-	-	-	-	-
		grass	1	10	3	3	16
		maize	3	15	27	30	72
		other	**2**	20	46	30	**96**
		winter wheat	2	22	16	22	60
	Loam	beets	-	-	-	-	-
		grass	4	12	7	6	25
		maize	4	23	24	19	66
		other	-	-	-	-	-
		winter wheat	3	15	16	18	49
	Sand	beets	-	-	-	-	-
		grass	24	13	12	14	39
		maize	28	26	30	22	78
		other	10	17	20	27	64
		winter wheat	1	16	18	17	51
	sandy loam	beets	1	15	4	4	23
		grass	8	32	23	11	66
		maize	8	29	26	15	70
		other	12	19	26	27	72
		winter wheat	4	11	14	19	44

An extra explanation is formulated for the values shown in bold

-The combination other crops-clay with no derogation: One of the two parcels was cultivated with potatoes, this parcel had a nitrate residue of 113 kg N/ha.

In the next paragraphs all results are analysed statistically. The 3 parcels with extreme nitrate levels are considered outliers and further excluded for statistical analysis.

6.3.1 General

First the global difference between derogation and no derogation parcels is investigated by comparing the total amount of nitrate residue for all parcels. The average level of nitrate residue is higher for no derogation parcels (61 kg/ha) than for derogation parcels (57 kg/ha) but there is no significant difference between both. With respect to the distribution of the nitrate residue over the three sampled soil layers, no differences are observed between derogation and no derogation parcels. Table 40 shows that the highest levels of nitrate residue are measured on parcels cultivated with no derogation crops and maize. In 2010 the group other crops consisted of potatoes (19 parcels), vegetables (4 parcels) and also 3 parcels cultivated with summer wheat. To determine the specific effect of derogation, the analysis is limited to parcels with derogation crops (maize, grass, beets and winter wheat) only (Figure 40 and Figure 41). The measurements show a large variation but there is no statistically significant difference between derogation (57 kg/ha) and no derogation parcels (59 kg/ha).

Nitrate in the first (0-30 cm) soil layer can leach out to the next layer but is still available to the cultivated crop. However, cultivated crops have difficulties to take up nitrate in the deepest soil layer (60-90 cm). This nitrate (present in 60-90 cm) will leach out to the groundwater during winter. Therefore, with respect to the water quality, higher levels of nitrate in the upper layers are more favorable than high levels in the deeper layers. Figure 41 demonstrates that more than 70 % of the nitrate residue is present in the upper soil layers (from 0-30 cm and 30-60 cm). The nitrate residue present in those layers does not differ significantly.

So far no significant differences in nitrate residue are found between derogation and no derogation parcels. However, because the nitrate residue is influenced by the soil type, the differences in nitrate residue between derogation and no derogation parcels will be analysed for specific soil types (next paragraphs). For the other soil types, data are listed in Table 40. However, due to the limited number of parcels, a statistical analysis was not possible for the other soil types. The box plot is based on the log-transformed data for the nitrate residue. The data were log-transformed in order to require homogeneity of the data (a condition necessary to apply one-way ANOVA).

Figure 40: Box plot of log nitrate-N (kg/ha) for all derogation and no derogation parcels cultivated with a derogation crop (maize, grass, beets and winter wheat) measured before winter 2010.

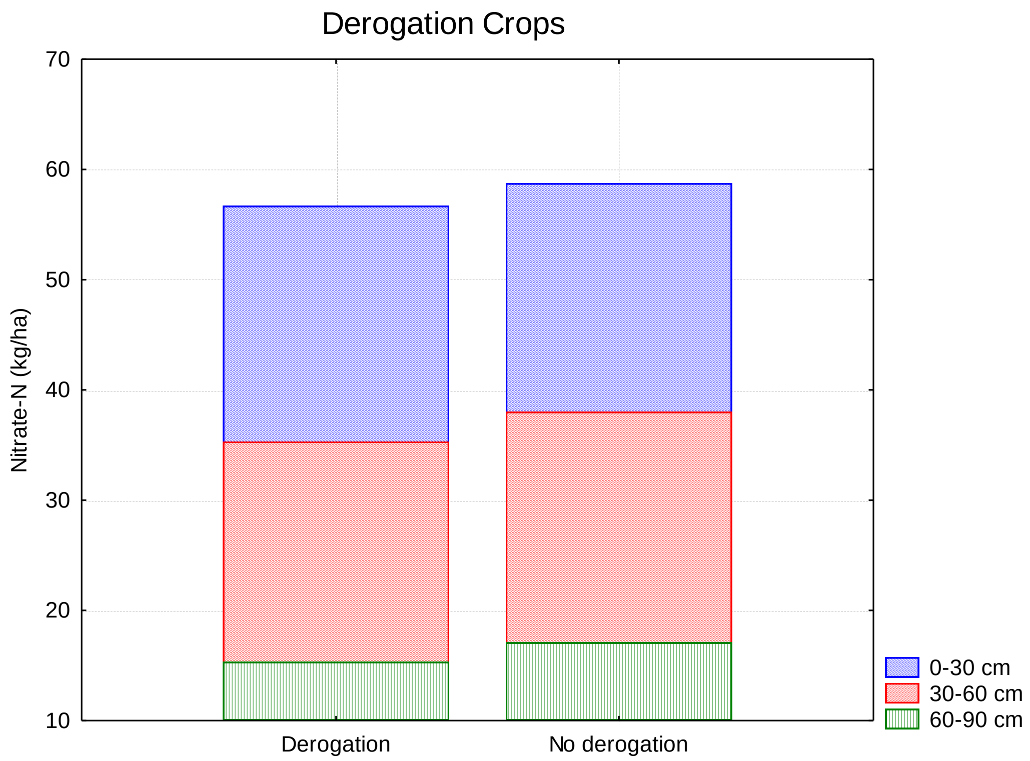

Figure 41: Average nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with a derogation crop (maize, grass, beets and winter wheat) measured before winter 2010. The nitrate is cumulatively given for the 3 soil layers.

6.3.2 Sandy soils

Table 40 shows that derogation is mostly requested on sandy soils. When taking all cultivated crops into account, the nitrate residue in both derogation and no derogation parcels show a large variation and no significant differences were found between derogation (58 kg/ha) and no derogation (61 kg/ha) parcels.

Since the cultivated crop has an effect on the residual nitrate (Table 40), the further analysis on sandy soils is limited to parcels cultivated with derogation crops only. By using the same combinations of cultivated crop and soil type, it is possible to investigate the effect of derogation (and less the combined effect of no derogation and other cultivated crops). The results are shown in Figure 42 and Figure 43. No significant differences were found between derogation (58 kg/ha) and no derogation (60 kg/ha) parcels. Because of the characteristics of a sandy soil (low water retention capacity) the available nutrients are very sensitive for leaching out. Therefore it is important to determine in which soil layer the major amount of nitrate residue is present. In none of the three soil layers, differences in nitrate residue were observed between derogation and no derogation parcels (Figure 43).

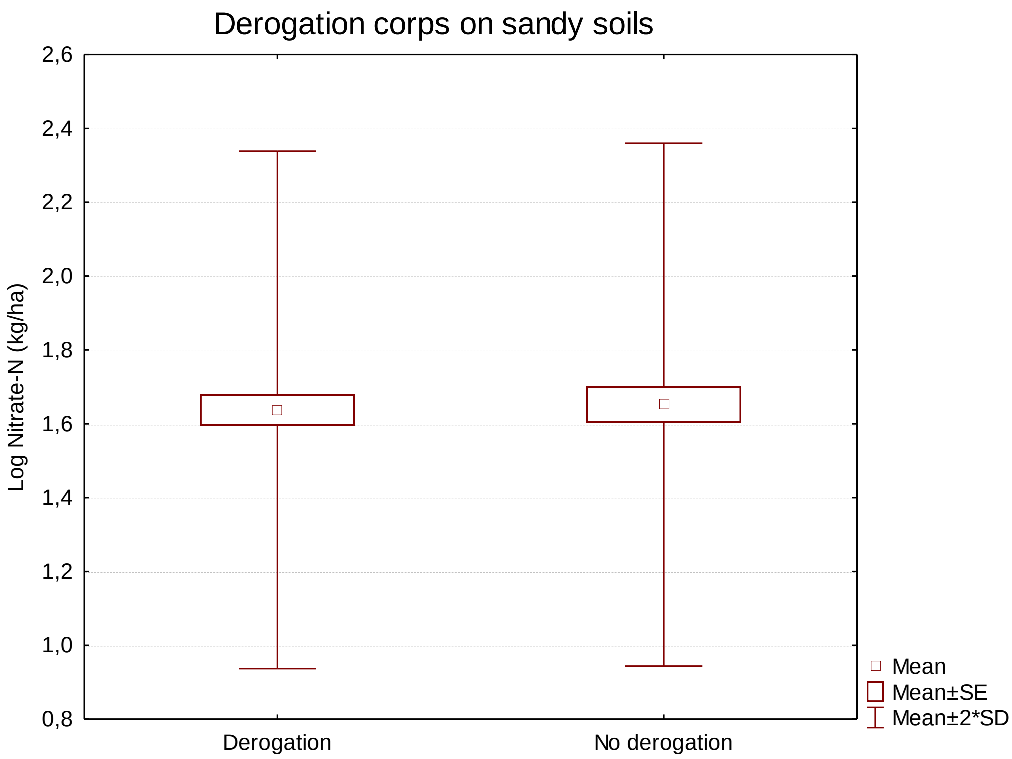

Figure 42: Box plot of log Nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with a derogation crop (maize, grass, beets and winter wheat) for sandy soils, measured before winter 2010.

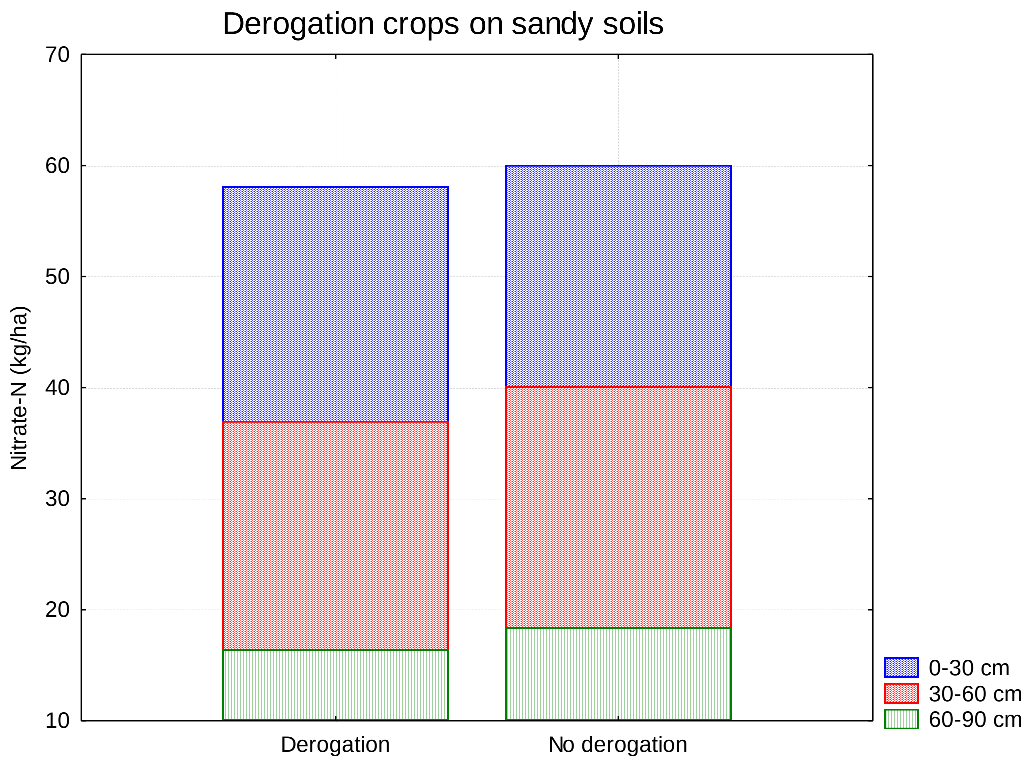

Figure 43: Average nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with a derogation crop (maize, grass, beets and winter wheat) on sandy soils, measured before winter 2010. The nitrate is cumulatively given for the 3 soil layers.

6.3.2.1 Grass and maize on sandy soils

The cultivated crop has an important effect on the nitrate residue in the soil profile after the growing season. Therefore it is interesting to determine the difference between derogation and no derogation parcels for specific combinations of soil type and cultivated crop. Table 40 shows that the majority of derogation parcels exists of sandy soils cultivated with grass or maize. The average nitrate residue levels for these different combinations are shown in Figure 44. It is clear that there are difference in nitrate residue between grass and maize (Table 40). The differences between derogation and no derogation parcels for sandy soils are analysed separately for grass and maize.

For grass the derogation parcels have a higher average level of nitrate residue than the no derogation parcels, 50 kg/ha for derogation versus 40 kg/ha for no derogation. The derogation parcels cultivated with maize have an average nitrate residue of 77 kg/ha versus 78 kg/ha for no derogation parcels cultivated with maize. However, none of the differences between derogation and no derogation parcels cultivated with grass or maize are statistically significant.

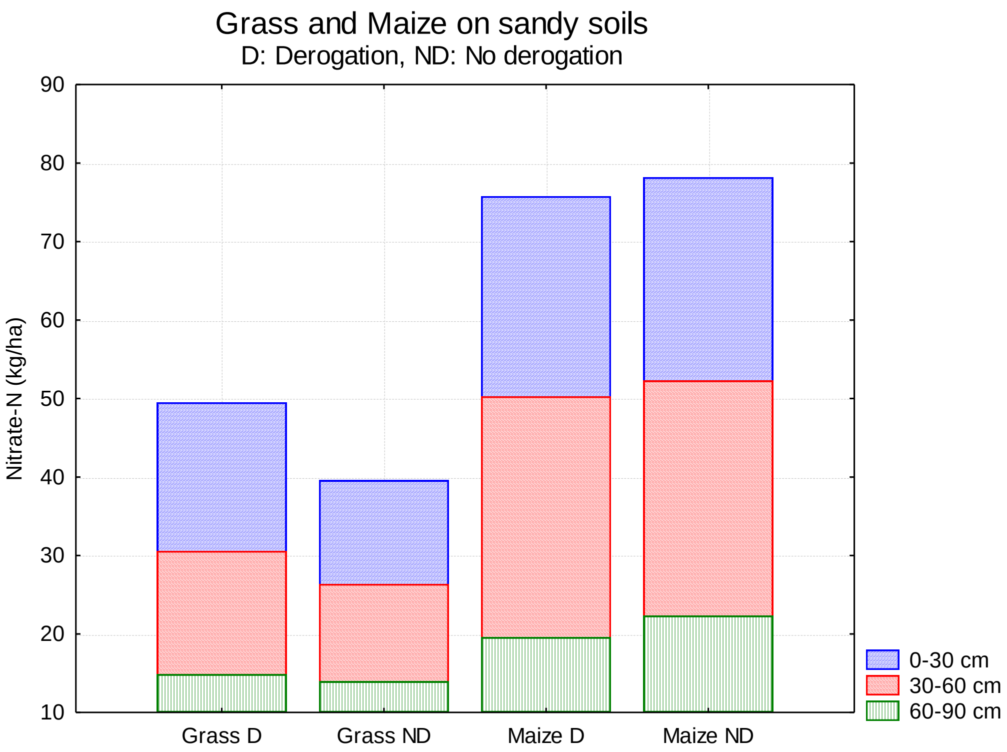

Figure 44: Average nitrate-N (kg/ha) for sandy soils cultivated with grass or maize, measured before winter 2010. The nitrate is cumulatively given for the 3 soil layers.

For each combination of soil type and cultivated crop the nitrate residue is also investigated for each soil layer. Figure 44 shows that the largest amounts of nitrate residue are present in the two top soil layers, for both grass and maize. For none of the 3 soil layers, significant differences in nitrate residue were found between derogation and no derogation parcels.

6.3.3 Sandy loam soils

Besides on sandy soils, derogation is also frequently requested on sandy loam soils. Therefore a detailed analysis is carried out for sandy loam soils only. The differences are investigated for derogation crops. These results are shown in Figure 45 and Figure 46. There is a small difference between derogation (55 kg/ha) and no derogation (62 kg/ha) parcels but by excluding the no derogation crops the average value for nitrate-N is decreased with 4 kg/ha for the no derogation parcels. There are no significant differences between derogation and no derogation parcels. The variation in the nitrate levels is still high (Figure 46).

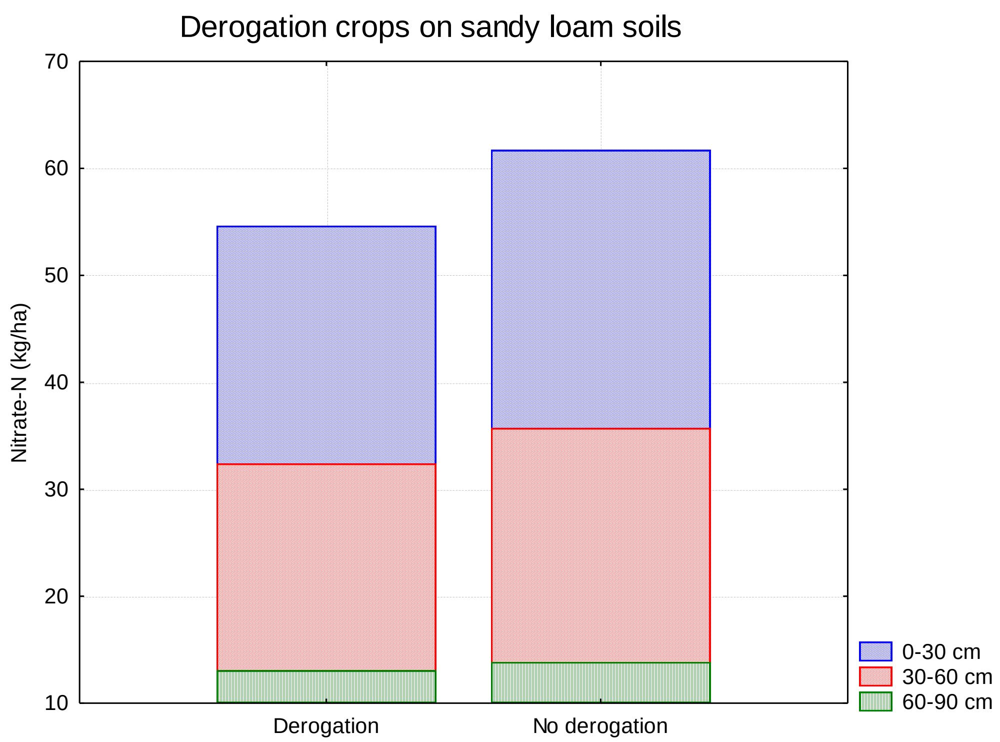

Figure 45: Average nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with derogation crops (maize, grass, beets and winter wheat) on sandy loam soils, measured before winter 2010. The nitrate is cumulatively given for the 3 soil layers.

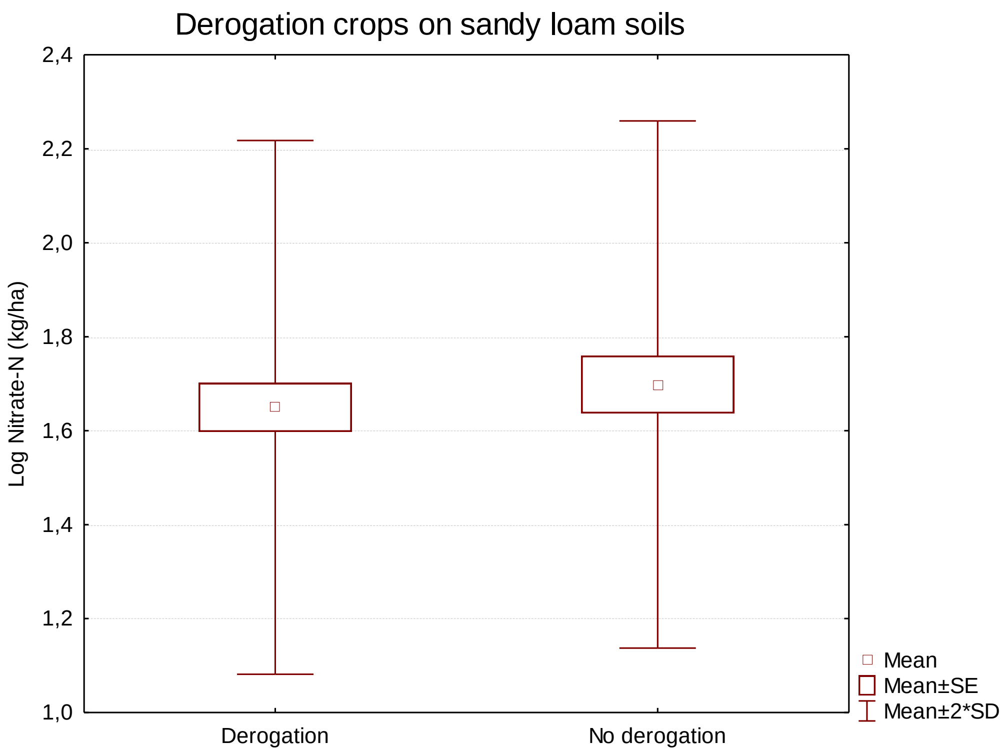

Figure 46: Box plot of log nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with derogation crops (maize, grass, beets and winter wheat) on sandy loam soils, measured before winter 2010.

6.3.3.1 Grass and maize on sandy loam soils

Because there are no significant differences between derogation and no derogation parcels for sandy loam soils when taking into account all crops or only derogation crops it could be interesting to investigate the effect of derogation for specific combinations of soil type and crop. Table 40 shows that the most frequently occurring combinations for a sandy loam soil are those with grass and maize. The average values for grass and maize with and without derogation for a sandy loam soil are shown in Figure 47. The statistical analysis is carried out separately for parcels cultivated with grass and those cultivated with maize. The average level of nitrate-N for derogation parcels cultivated with grass is 41 kg/ha versus 66 kg/ha for no derogation parcels. Although in the soil profile of a sandy loam soil cultivated with grass the largest amount of nitrate is measured in no derogation parcels, this difference is not significant. Also for parcels cultivated with maize there is no statistically significant difference between derogation (74 kg nitrate-N/ha) and no derogation (70 kg nitrate-N/ha) parcels.

It is also interesting to investigate whether there are differences for individual soil layers. However for none of the different combinations of soil type and cultivated crop, significant differences were found between soil layers for derogation and no derogation parcels.

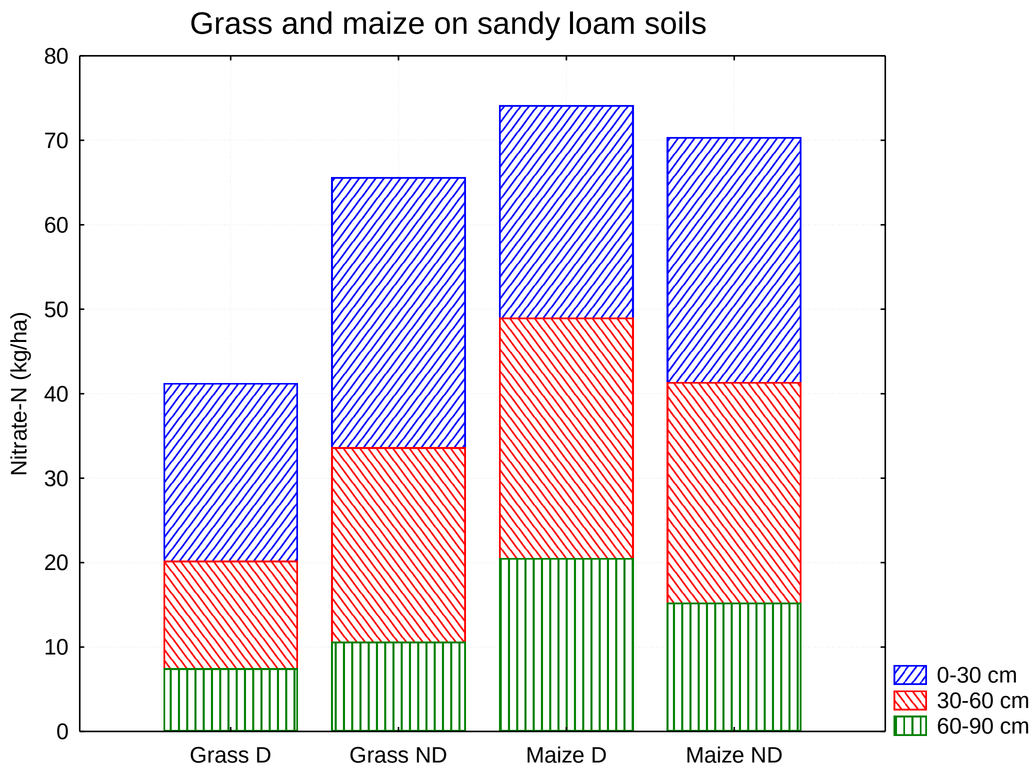

Figure 47: Average nitrate-N residue (kg/ha) for sandy loam soils cultivated with grass or maize with (D) or without (GD) derogation, measured before winter 2010. The total nitrate residue is shown as well as the amount of nitrate in the different soil layers.

6.3.4 Conclusions

There are no statistical differences between derogation and no derogation parcels in nitrate residue after the growing season 2010. These differences were investigated in general and for specific combinations of soil type and cultivated crop. Also no statistical differences were found for the different soil layers (0-30 cm, 30-60 cm and 60-90 cm) separately.

Between the cultivated crops differences were present. Maize and other crops (mostly potatoes) have higher levels of nitrate residue in comparison with parcels cultivated with grassland. For derogation parcels nitrate levels are higher on grassland characterized by mowing and grazing in comparison with only mowing. On no derogation parcels, parcels cultivated with corn maize have lower nitrate residue levels in comparison with parcels cultivated with fodder maize.

In general the nitrate residue levels of 2010 are lower in comparison with 2009. The growing season of 2010 is characterized by good nutrient uptake by the cultivated crops and a large amount of rainfall starting from August. 2009 was very dry from summer to winter, which results in poor nutrient take up by some cultivated crops, resulting in higher nitrate residue levels after the growing season.

6.3.5 Nitrate in the deeper soil layers

Together with the nitrate sample (0 to 90 cm) a deep soil sample (90 to 150 cm, in 2 layers) was taken before winter 2010. This sample was taken on a selection of parcels, which were sampled after winter 2009. When comparing the deep soil samples of derogation and no derogation parcels, only the most important combinations of soil type and cultivated crop were considered: grass and maize on sandy or sandy loam soils. Figure 49 and Figure 49 shows the average amounts of nitrate before winter 2010 in the different soil layers. For sandy soils, the largest differences were observed in the soil layers from 0 to 60 cm. The total amount of nitrate is higher on parcels cultivated with maize compared to parcels with grassland. For grassland on sandy loam soils (Figure 49) more than 30 % of the total amount of nitrate is present in the soil layer from 0 to 30 cm and more than 60% in the soil profile from 0 to 60 cm. For parcels cultivated with maize on sandy loam soils, a higher percentage of the nitrate is present in the deeper soil layers.

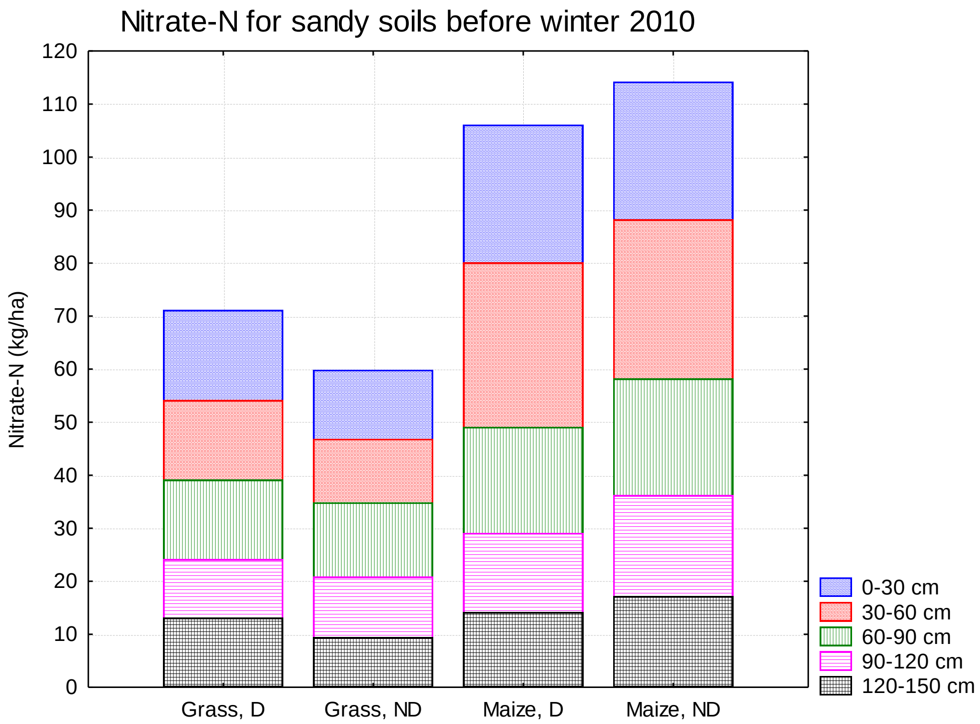

Figure 48: Average levels of nitrate-N (kg/ha) on sandy soils for the different soil layers (0 to 150 cm) and combinations of cultivated crop and derogation, before winter 2010. D: derogation, ND: no derogation.

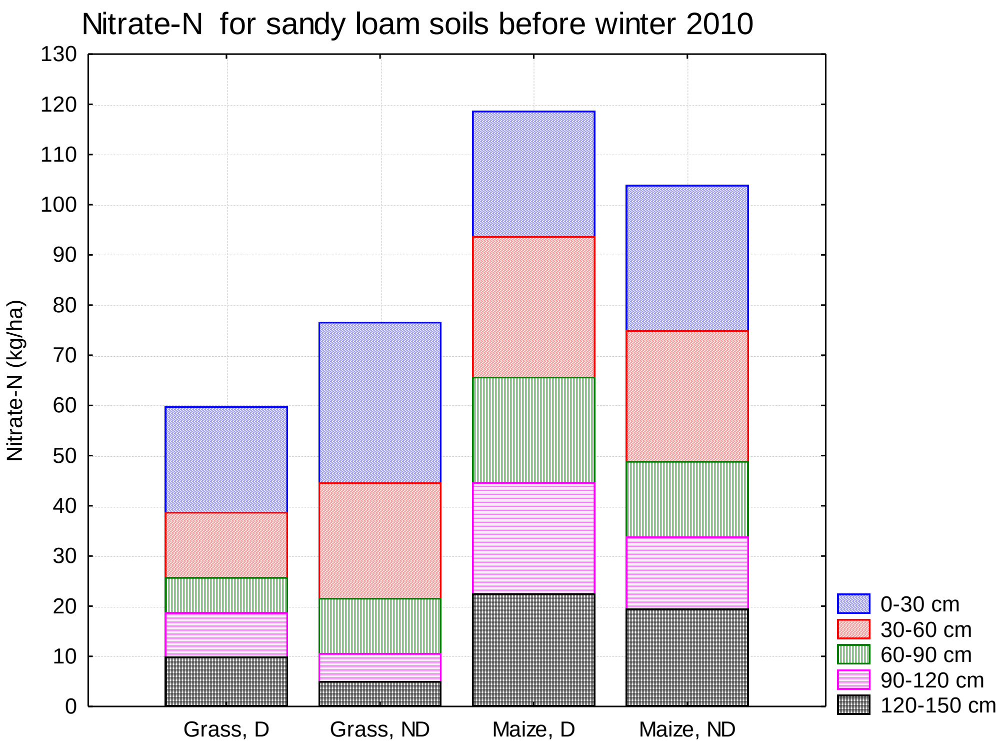

Figure 49: Average levels of nitrate-N (kg/ha) on sandy soils for the different soil layers (0 to 150 cm) and combinations of cultivated crop and derogation, before winter 2010. D: derogation, ND: no derogation.

For the calculation of the average levels of nitrate in the deeper soil layers and to carry out a statistical analysis, 2 parcels are excluded. One parcel with a nitrate residue (0 to 90 cm) of 390 kg/ha was characterized by an amount of nitrate of 141kg N/ha in the layer from 90 to 120 cm and 154 kg N/ha for the deepest layer (120 to 150 cm). A second parcel with a nitrate residue (0 to 90 cm) of 151 kg/ha was characterized by nitrate levels of 71 kg N/ha and 48 kg N/ha for the layers from 90 to 120 cm and 120 to 150 cm respectively.

A statistical analysis was carried out to compare derogation with no derogation parcels. No significant differences were found between derogation and no derogation parcels in general, for derogation crops only and for the specific combinations of grass and maize with sandy or sandy loam soils. For these specific combinations, the analysis was carried out for grass and maize separately. Same conclusion as after winter 2009 can be drawn; a higher nitrate residue in the soil profile from 0 to 90 cm results mostly in a higher amount of nitrate in the deeper soil layers. This correlation is shown in Figure 50.

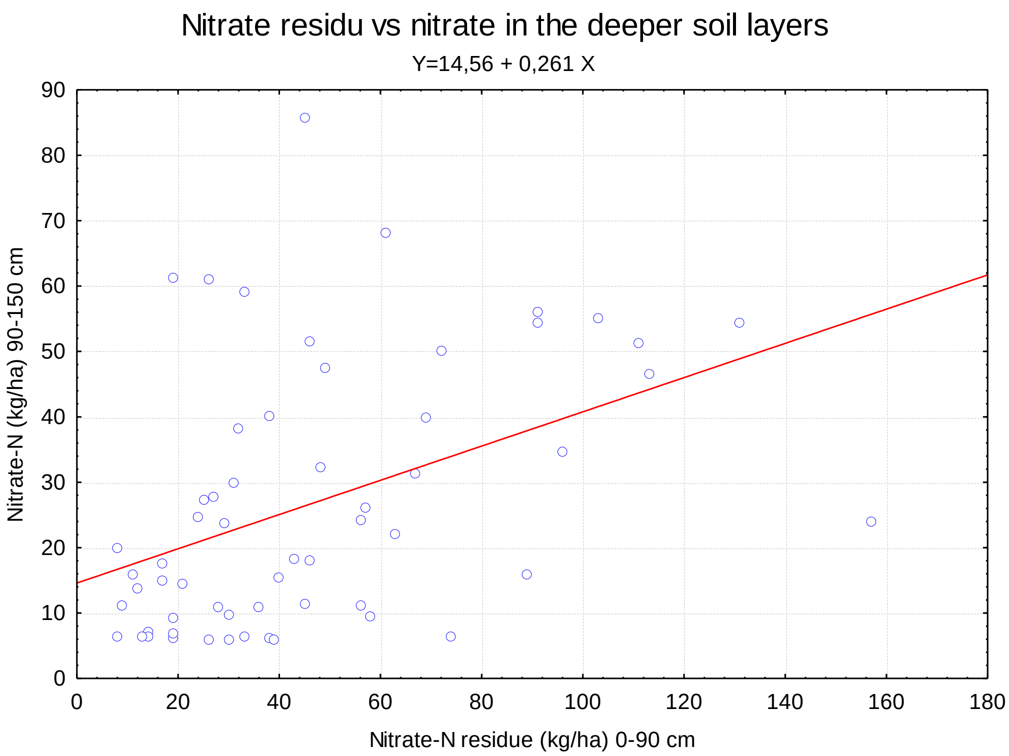

Figure 50: Scatterplot of Nitrate residue (kg NO_3-N/ha) from 0-90 cm versus nitrate-N (kg/ha) from 90-150 cm before winter 2010.

For the soil layer from 90 to 120 cm, 24 % of the samples were characterized with an amount of nitrate below detection limit. This was 30 % for the soil layer from 120 to 150 cm. For these samples half of the detection limit was used in the above analysis.

6.4 Nitrate sample after winter 2010

In each parcel in the monitoring network a nitrate sample has been taken after winter (most parcels were sampled between 25 January and 15 February). The nitrate sample after a winter period, taken in three layers (0-30 cm, 30-60 cm and 60-90 cm), gives information on the amount of nitrate that is still available in the soil profile after winter and that will be available for the cultivated crops for the coming growing season. Based on this information every farmer gets a specific nitrate fertilization advice. This advice is function of the amount of nitrate in the soil profile, the cultivated crop (different crops need 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 important to estimate the amount of nitrate that will be released by mineralization. It is also very important in which soil layer the nitrate is available; the more nitrate in the top layer the better, since a lot of crops cannot take up the nitrate from the bottom layer (60-90 cm). Beside information for the next fertilization year, the nitrate sample taken after winter is an indication for the amount of nitrate that leached out during winter (especially when compared with the nitrate measured before winter). This type of nitrate sample was taken both after winter 2009 and winter 2010. The data gathered after winter 2010 will be discussed in the following paragraphs.

Table 41: Average nitrate-N (kg/ha) after winter 2010 for different crops separately given for derogation and no derogation parcels. Average values are given for the total soil layers and for each layer of 30 cm separately.

Crop		n	Nitrate-N (kg/ha)			
			0-30 cm	30-60 cm	60-90 cm	0-90 cm
Derogation		93				
	grass	55	19	12	9	39
	fodder maize	34	16	11	14	41
	beets	**2**	8	8	7	24
	winter wheat	**2**	13	8	6	27
No Derogation		110				
	grass	32	19	13	9	41
	fodder maize	30	16	15	17	49
	corn maize	13	15	12	11	38
	beets	**1**	29	23	16	67
	winter wheat	11	14	12	12	37
	other	23	18	17	20	55

Table 41 shows, for the most important combinations of derogation and cultivated crop, the nitrate level after winter 2010. 24 of the 226 parcels of the monitoring network are characterized by an early fertilization, before the sampling date. As a consequence these parcels are excluded from the analysis because the measured nitrate on these parcels is not only the nitrate still present after a winter period. Due to leaching the differences between the parcels are smaller compared with measured nitrate levels before a winter period. Table 41 does not show important differences between derogation and no derogation parcels, especially not for the combinations with grassland and maize. Average levels of nitrate measured in the soil samples after winter 2010 are shown, in detail, in Table 42. The amounts of nitrate are given for the different combinations of derogation, soil type and cultivated crop. The amount of nitrate is given for the total soil profile (0-90 cm) as well as for each soil layer of 30 cm. For each combination the number of parcels is indicated.

The values in bold in Table 42 are combinations with higher levels of nitrate in comparison with average values of other combinations. All theses combinations also had high levels of nitrate before winter 2010. Not all this nitrate leached out of the soil profile and a part is still present. Some of the parcels have high levels of carbon, for these parcels the process of mineralization can be important. To analyse the results of the different measurements, the parcel characteristics of 2010 (derogation and cultivated crop) are taken into account. Mostly, the combinations with higher levels of nitrate after the winter period are those characterized by a loam or clay soil. To investigate the difference between derogation and no derogation parcels a statistical analysis is carried out and discussed in the next paragraphs.

Table 42: Average levels of nitrate-N (kg/ha) in the soil profile after winter 2010. The nitrate-N is given for the different combinations of soil type, cultivated crop and derogation. For each combination the total amount of nitrate is given as well as for each soil layer (lay 1: 0-30 cm, lay 2: 30-60 cm and lay 3: 60-90 cm). For each combination the number (n) of parcels is indicated.

	soil	crop	n	Nitrate-N (kg/ha)			
				0-30 cm	30-60 cm	60-90 cm	0-90 cm
Derogation							
	Clay	beets	-	-	-	-	-
		grass	3	21	17	15	53
		maize	-	-	-	-	-
		winter wheat	1	16	13	10	39
	Loam	beets	-	-	-	-	-
		grass	3	49	32	27	**108**
		maize	-	-	-	-	-
		winter wheat	-	-	-	-	-
	Sand	beets	-	-	-	-	-
		grass	37	16	10	7	33
		maize	22	16	11	13	40
		winter wheat	1	9	3	2	14
	Sandy loam	beets	2	8	8	7	24
		grass	12	18	13	7	38
		maize	12	16	12	16	43
		winter wheat	-				
No derogation							
	Clay	beets	-	-	-	-	-
		grass	1	15	7	7	30
		maize	3	19	14	13	47
		other	2	14	14	26	54
		winter wheat	2	12	12	11	35
	Loam	beets	-	-	-	-	**-**
		grass	3	14	10	6	30
		maize	4	18	16	17	52
		other	-	-	-	-	-
		winter wheat	2	16	14	13	42
	Sand	beets	-	-	-	-	-
		grass	20	22	14	11	46
		maize	28	15	14	16	45
		other	8	13	12	17	42
		winter wheat	1	13	28	10	50
	Sandy loam	beets	1	29	23	16	**67**
		grass	7	15	12	8	36
		maize	9	16	15	13	44
		other	14	20	21	21	62
		winter wheat	5	13	8	9	30

6.4.1 General

No significant differences in nitrate were found between derogation and no derogation parcels, in general. The average nitrate-N is 40 kg N/ha for derogation parcels and 46 kg N/ha for no derogation parcels. The nitrate is more equally divided between the 3 soil layers in comparison with the nitrate residue before the winter period (Figure 51).

The following step is the comparison of derogation and no derogation parcels cultivated with derogation crops only. Still, the measured nitrate values are highly variable (Figure 52). No significant difference was found between nitrate measured in derogation (40 kg N/ha) and no derogation (43 kg N/ha) parcels (Figure 53).

The nitrate in individual layers was also examined. As already could be seen from Figure 53 there are no significant differences in nitrate between derogation and no derogation parcels for each soil layer separately. The soil layers from 30-60 cm and 60-90 cm contain each approximately 30 % of the total amount of nitrate in the soil profile. The top soil layer (0-30 cm) contains about 40 % of the total amount of nitrate in the soil profile.

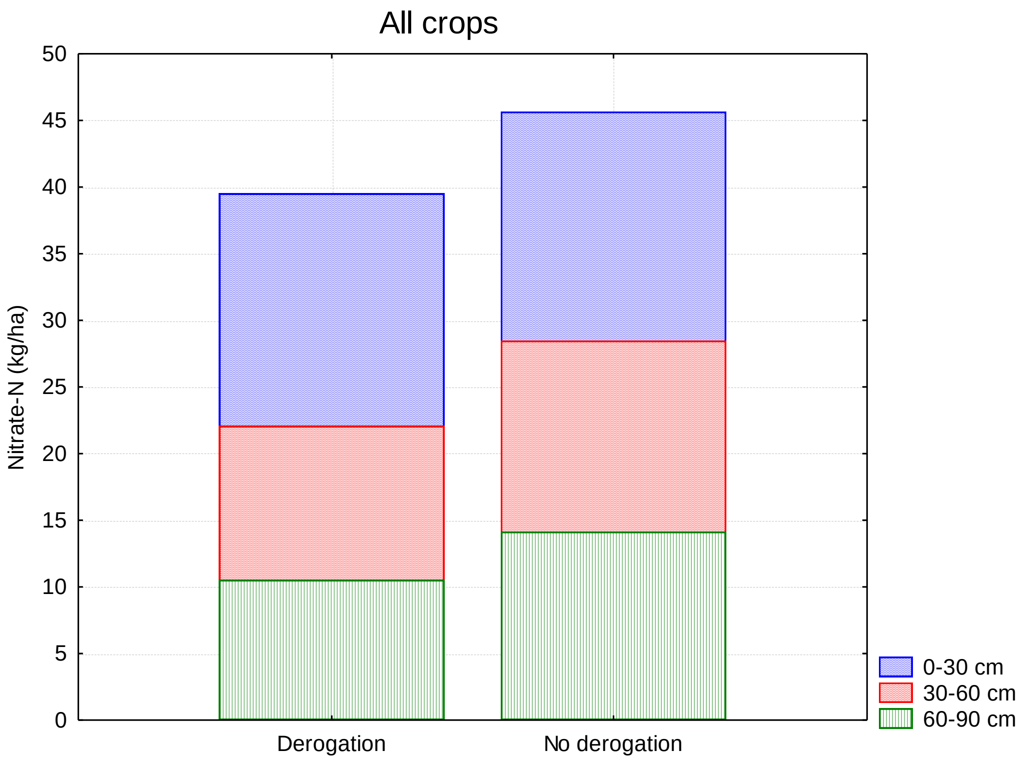

Figure 51: Average nitrate-N (kg/ha) for derogation and no derogation parcels measured after winter 2010. The nitrate is cumulatively given for the 3 soil layers.

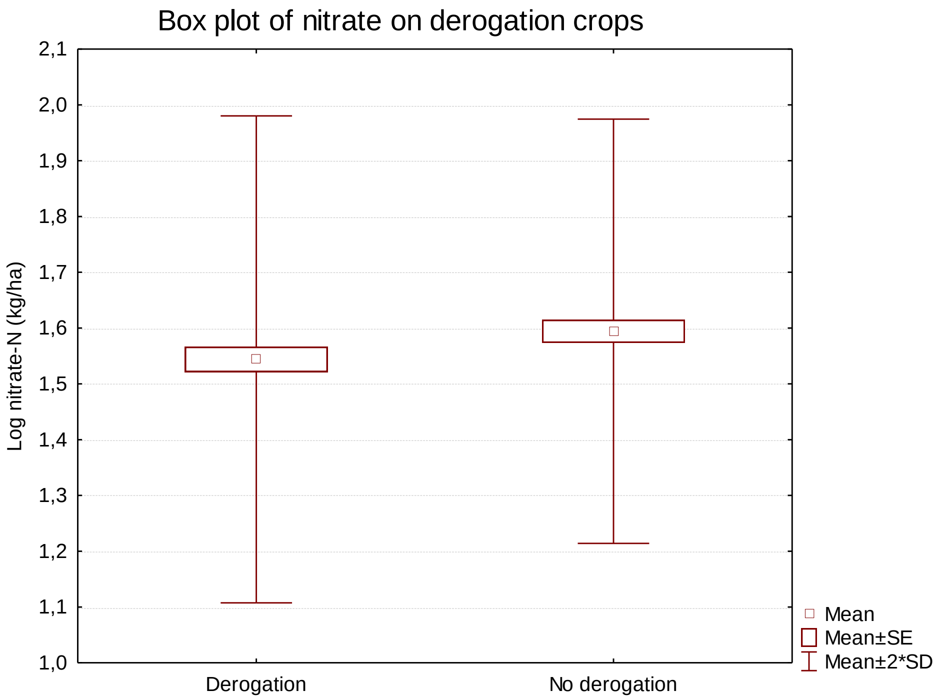

Figure 52: Box plot of log nitrate-N (kg/ha) for derogation and no derogation parcels where the cultivated crop is a derogation crop (maize, grass, beets and winter wheat). Samples taken after winter 2010.

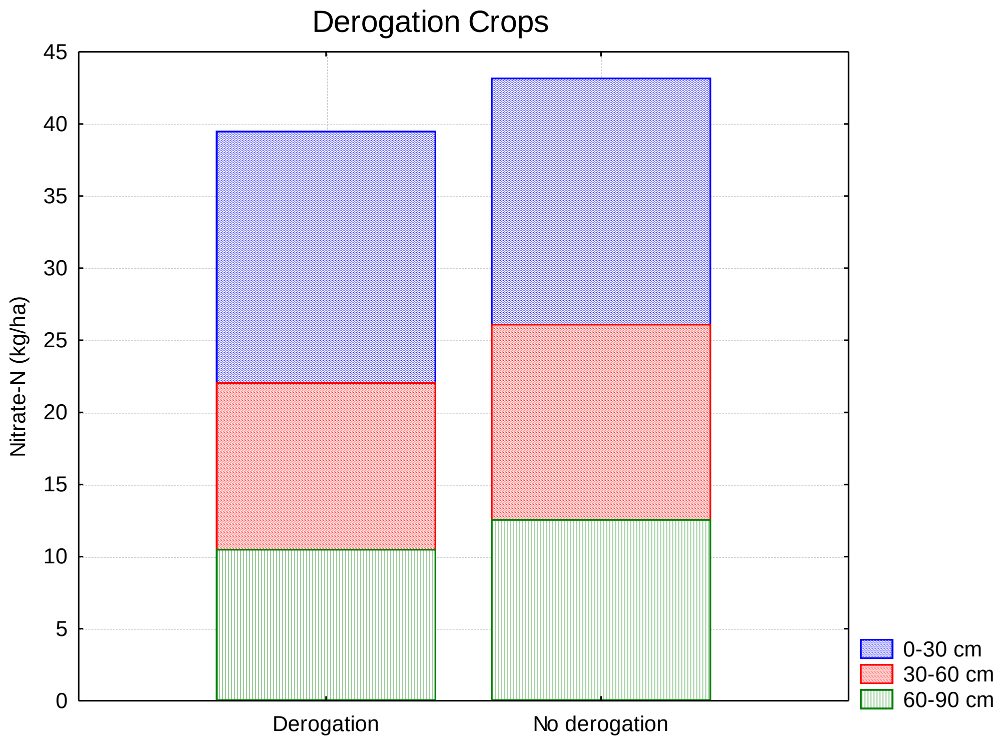

Figure 53: Average nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with derogation crops (maize, grass, beets and winter wheat) only. The nitrate is cumulatively given for the 3 soil layers and measured after winter 2010.

6.4.2 Sandy soils

The next step is to see whether there are differences between derogation and no derogation parcels for the most important soil types. Table 42 shows that the most important soil type is sand. For sandy soils, a significant difference in nitrate in the soil profile after winter is observed. The average value of nitrate-N for derogation parcels on sandy soils is 36 kg/ha and 45 kg/ha for no derogation parcels.

Next the analysis was limited to derogation and no derogation parcels in sandy soils cultivated with derogation crops only. Similar to the previous observations, the variation between the measurements is large. Also, the nitrate measured in sandy soils in derogation parcels is significantly different from the nitrate measured in no derogation parcels (Figure 55). No specific reason is present for this difference. The exclusion of the no derogation crops did not have an important influence on the average nitrate value. Generally, in sandy soils the largest amount of nitrate is present in the soil layer from 0 to 30 cm.

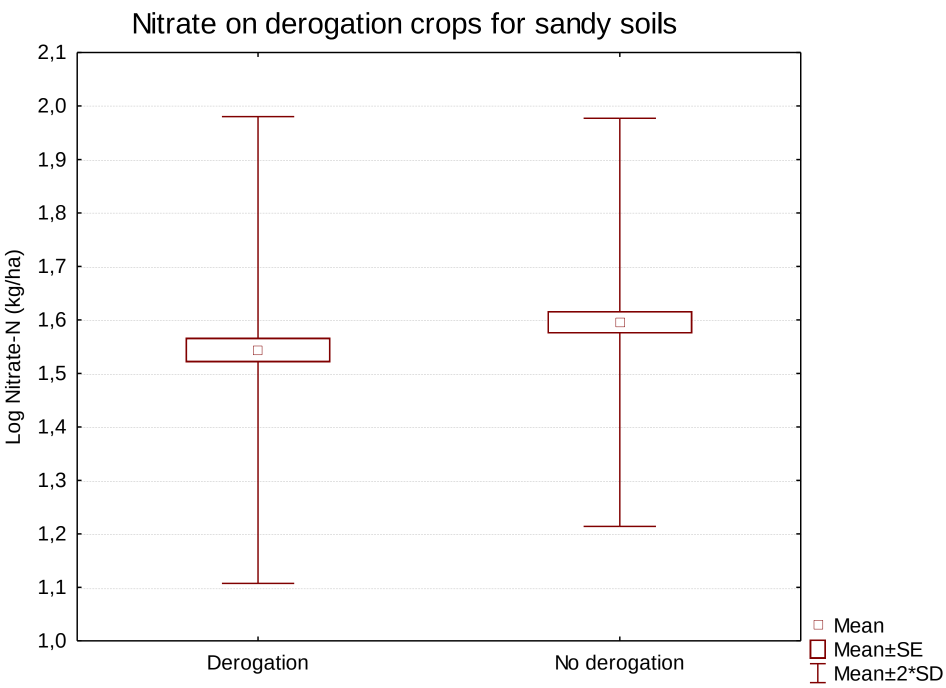

Figure 54: Box plot of log nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with a derogation crop only (maize, grass, beets and winter wheat) on sandy soils, after winter 2010.

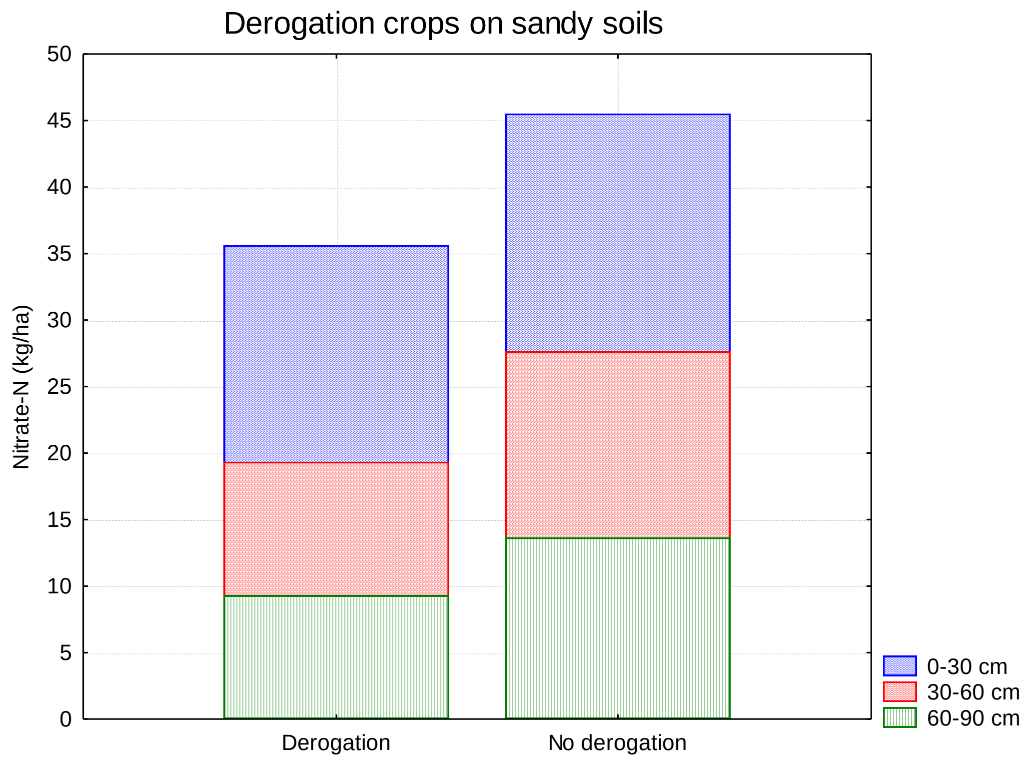

Figure 55: Average nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with derogation crops (maize, grass, beets and winter wheat) on sandy soils, after winter 2010. The nitrate is cumulatively given for the 3 soil layers.

6.4.2.1 Grass and maize on sandy soils

It is interesting to see for which specific combination of soil type and cultivated crop the largest differences are observed. Because grass and maize are the most cultivated crops on sandy soils, the nitrate values were compared for the specific combinations of grass and maize cultivated on sandy soils. The analyses were carried out separately for grass and maize; the results are shown together in Figure 56. For grass s a significant difference is observed between derogation (33 kg N/ha) and no derogation (46 kg N/ha) parcels. For maize no significant difference in nitrate was found between derogation and no derogation parcels, with an average level of nitrate-N of 40 kg N/ha for derogation and 45 kg N/ha for no derogation parcels.

Moreover, for both cultivated crops no significant differences between derogation and no derogation parcels were found when examining each soil layer separately. In parcels cultivated with maize a larger part of the nitrate is present in the soil layer 60-90 cm, approximately 35 % of the total amount of nitrate. This is approximately 30 % for the other soil layers. For parcels cultivated with grass the largest amount of nitrate is present in the top soil layer.

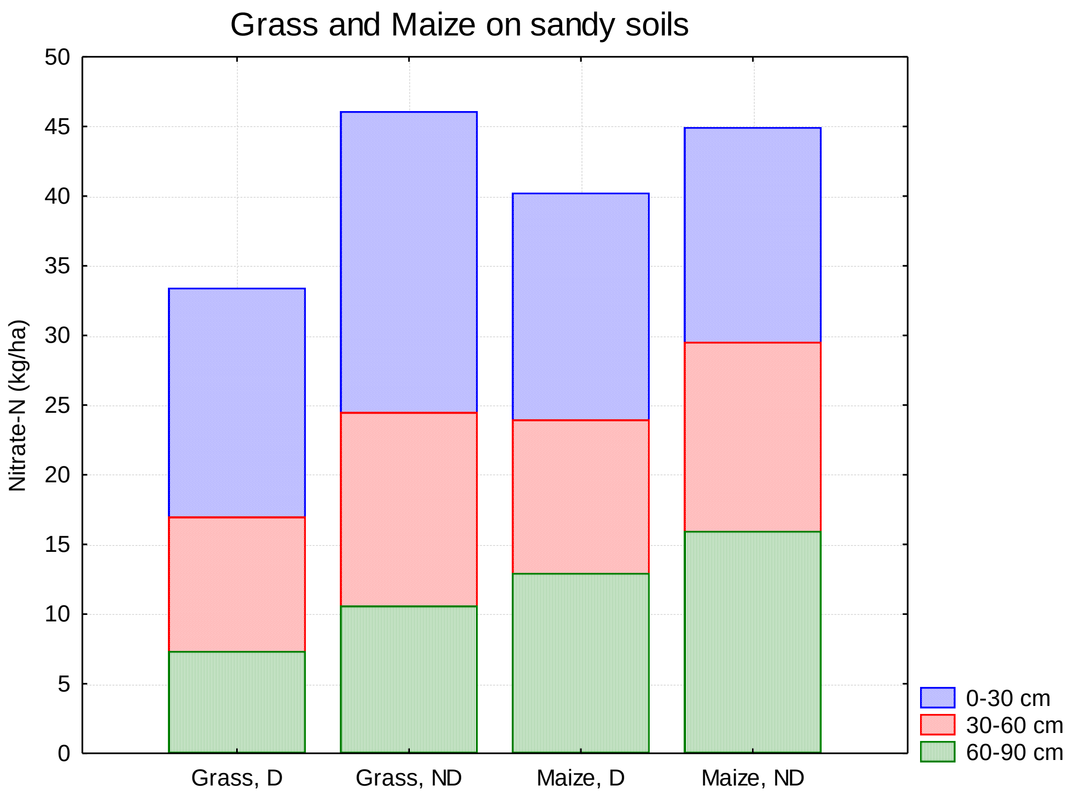

Figure 56: Average nitrate-N (kg/ha) levels for sandy soils cultivated with grass or maize with (D) or without (ND) derogation, after winter 2010. The nitrate is cumulatively given for the different soil layers (lay 1: 0-30 cm, lay 2: 30-60 cm and lay 3: 60-90 cm).

6.4.3 Sandy loam soils

Beside on sandy soils the majority of parcels in the monitoring network occur on sandy loam soils. In Figure 57 and Figure 58 the analysis is carried out for parcels with derogation crops only. The variability of the measured nitrate is high. No significant difference was found between derogation (39 kg nitrate-N/ha) and no derogation (39 kg nitrate-N/ha) parcels on sandy loam soils. Also, for the individual layers, the measured nitrate did not differ between derogation and no derogation parcels for the sandy loam soils, when only derogation crops were considered.

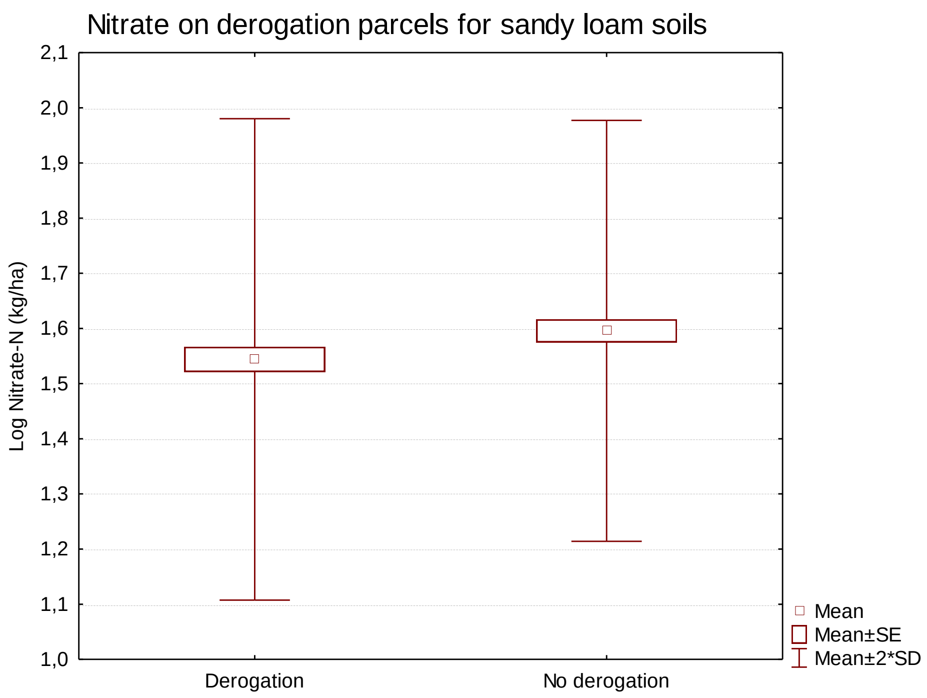

Figure 57: Box plot of log nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with derogation crops (maize, grass, beets and winter wheat) on sandy loam soils, after winter 2010.

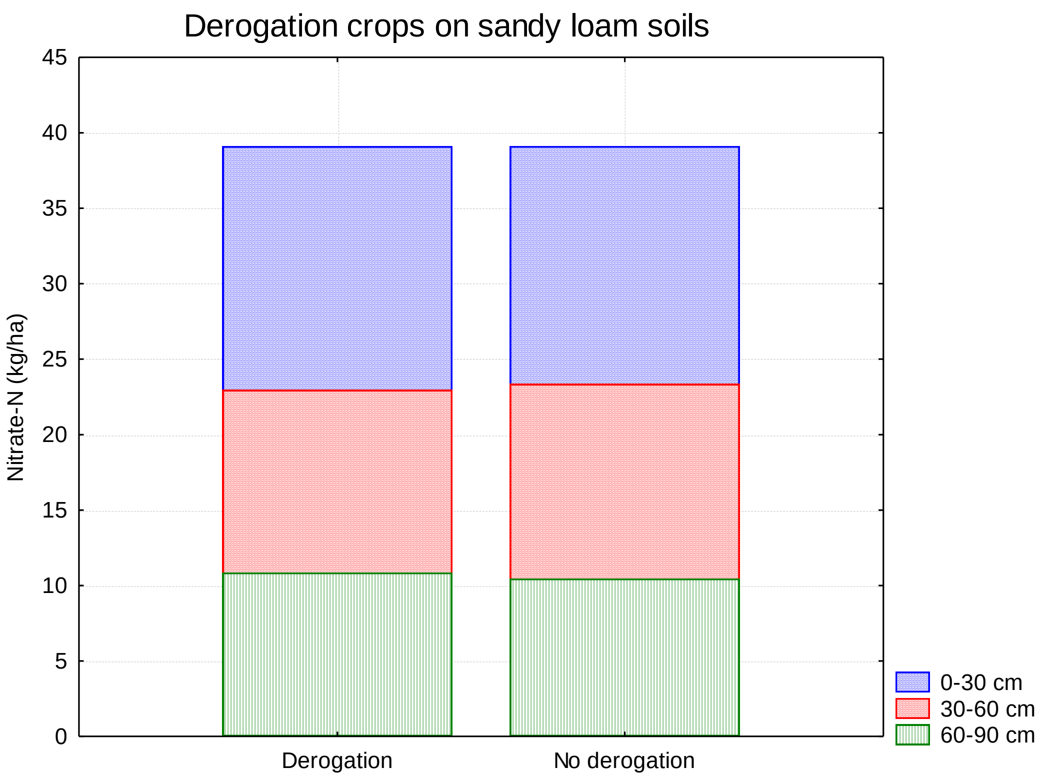

Figure 58: Average nitrate-N (kg/ha) for derogation and no derogation parcels cultivated with derogation crops (maize, grass, beets and winter wheat) on sandy loam soils, after winter 2010. The nitrate is cumulatively given for sandy loam soils.

6.4.3.1 Maize and grass on sandy loam soils

Figure 59 shows the average values of nitrate-N for the total soil profile and the different soil layers separately. These average values are shown for grass and maize in combination with or without derogation on sandy loam soils. The statistical analysis was carried out for maize and grass separately. For grass no significant differences were found between derogation (38 kg N/ha) and no derogation (36 kg N/ha) parcels. Also, for grass no significant differences were found between the individual soil layers. However the largest amount of nitrate is present in the soil layer 0-30 cm.

For maize the average nitrate level in derogation parcels (43 kg N/ha) did not differ significantly from the nitrate level in no derogation parcels (44 kg N/ha). In addition, for parcels cultivated with maize no significant differences were found between derogation and no derogation parcels for the different soil layers. Parcels cultivated with maize are characterized with an amount of nitrate-N more evenly distributed over the 3 soil layers. A larger part of the nitrate is also present in the soil layer 60 to 90 cm in comparison with parcels cultivated with grass.

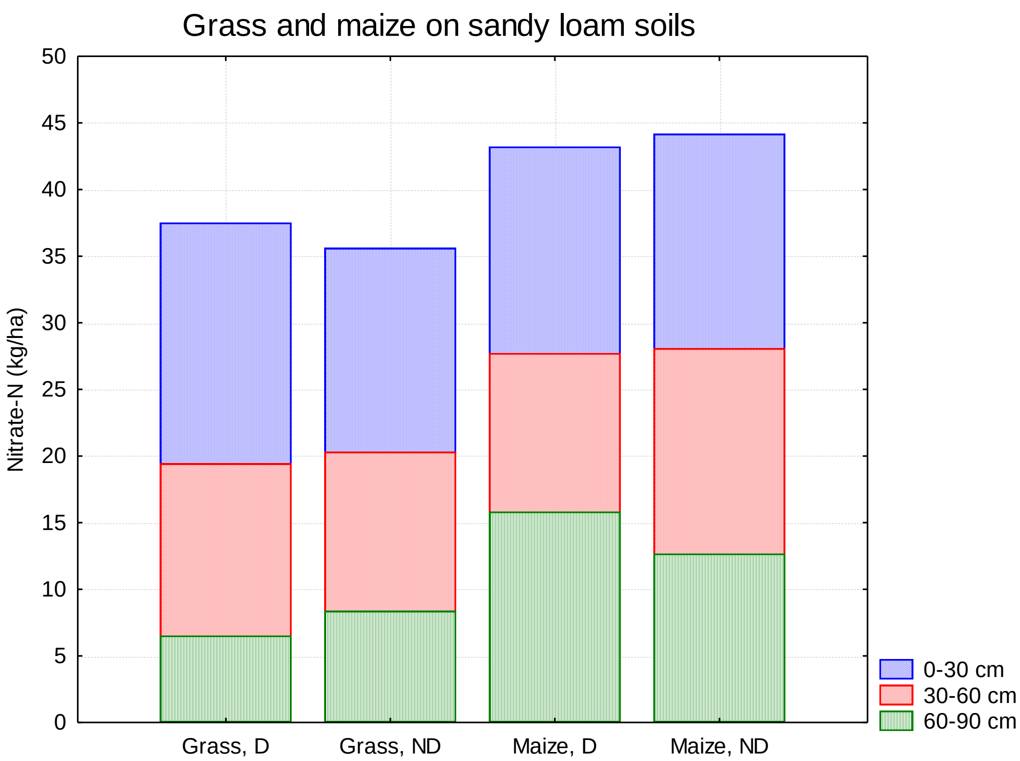

Figure 59: Average nitrate-N (kg/ha) levels for sandy loam soils cultivated with grass or maize with (D) or without (ND) derogation, after winter 2010. The nitrate is cumulatively given for the different soil layers (lay 1: 0-30 cm, lay 2: 30-60 cm and lay 3: 60-90 cm).

6.4.4 Nitrate in the deeper soil layers

After the winter period also a number of parcels (same parcels as before winter) are sampled from 90 to 150 cm in two layers of 30 cm. In these soil layers the amount of nitrate-N is measured. The amount of nitrate-N in both layers reaches the same level (Figure 60 and Figure 61). Mostly the deepest layer is characterised by a higher amount of nitrate but this difference is not significant.

When comparing the nitrate levels present in the soil profile from 0 to 90 cm with the levels present in the profile from 90 to 150 cm after winter, the relation is less strong than before winter 2010. Due to leaching out of nitrate, this nitrate is more evenly distributed among the different soil layers. In most cases the top soil layer (0-30cm) has a lower amount of nitrate in comparison with values before winter.

No significant differences were found between derogation and no derogation parcels for none of the two layers. The average value for nitrate-N is 15 kg/ha for no derogation parcels and 10 kg/ha for derogation parcels for the layer from 90 to 120 cm. For the soil layer from 120 to 150 cm the average nitrate-N is 16 kg/ha for no derogation and 11 kg/ha for derogation parcels. Statistical analysis is done between derogation and no derogation parcels for the different combinations of sand and sandy loam soils with grass and maize. In none of those combinations statistical differences between derogation and no derogation parcels were found for the amount of nitrate-N present in the soil layers from 90 to 150 cm after winter 2010. From the samples taken after winter 2010, 5 % of the parcels have a nitrate level below detection limit for the soil layer from 90 to 120 cm and 23 % for the soil layer from 120 to 150 cm.

For the statistical analysis 2 samples were excluded. The first parcel had a nitrate residue of 398 kg N/ha, a nitrate level of 103 kg N/ha after winter and levels of 71 kg N/ha and 59 kg N/ha for the soil layers from 90 to 120 and 120 to 150 respectively. The second parcel was excluded because the measured levels of nitrate were 73 kg N/ha and 57 kg N/ha for the deepest soil layers, the nitrate residue was 91 kg N/ha before winter and 41 kg N/ha after winter 2010. There is no direct explanation for the high levels of nitrate in the deeper soil layers.

The amount of nitrate present in the soil profile before winter is an indication of the amount of nitrate that could leach out during winter by rainfall. The amount of nitrate leaching out the profile from 0 to 90 cm during winter leads to higher levels of nitrate after winter in the deeper soil layers. This is shown in Figure 62.

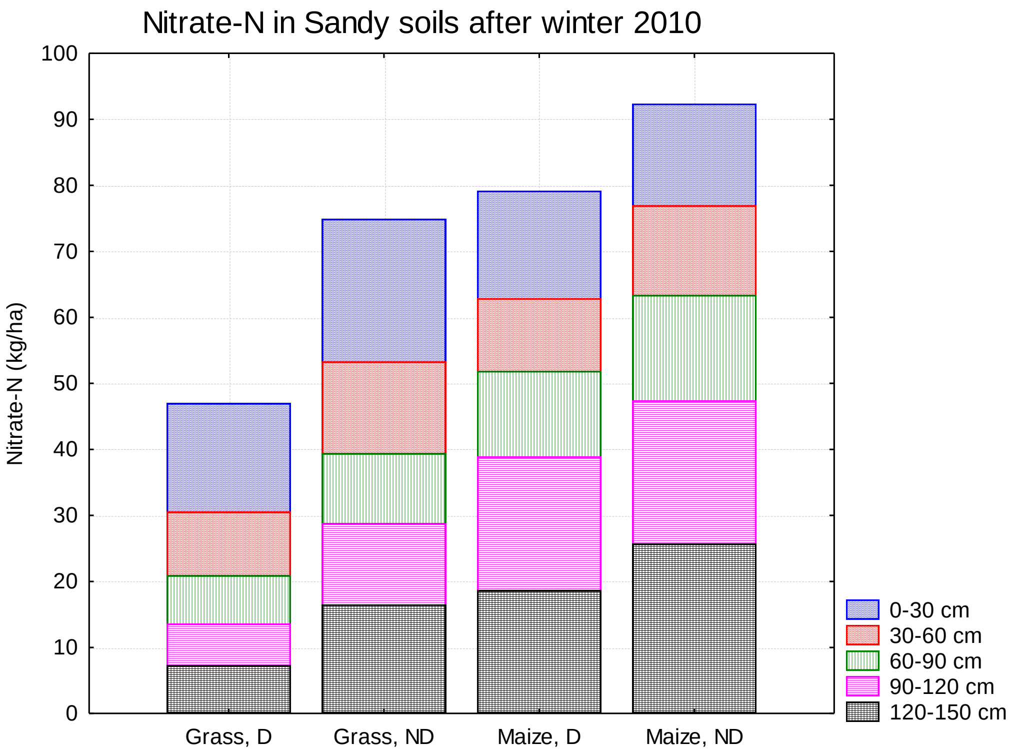

Figure 60: Average levels of nitrate-N (kg/ha) on sandy soils for the different soil layers and combinations of cultivated crop and derogation, after winter 2010. D: derogation, ND: no derogation.

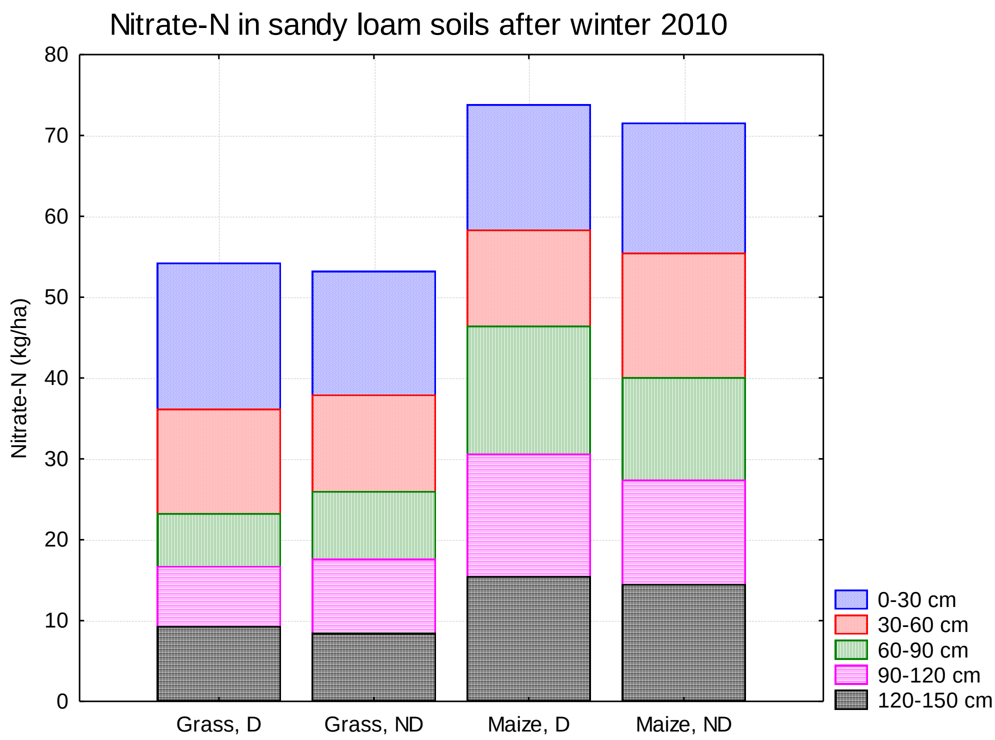

Figure 61: Average levels of nitrate-N (kg/ha) on sandy loam soils for the different soil layers and combinations of cultivated crop and derogation, after winter 2010. D: derogation, ND: no derogation.

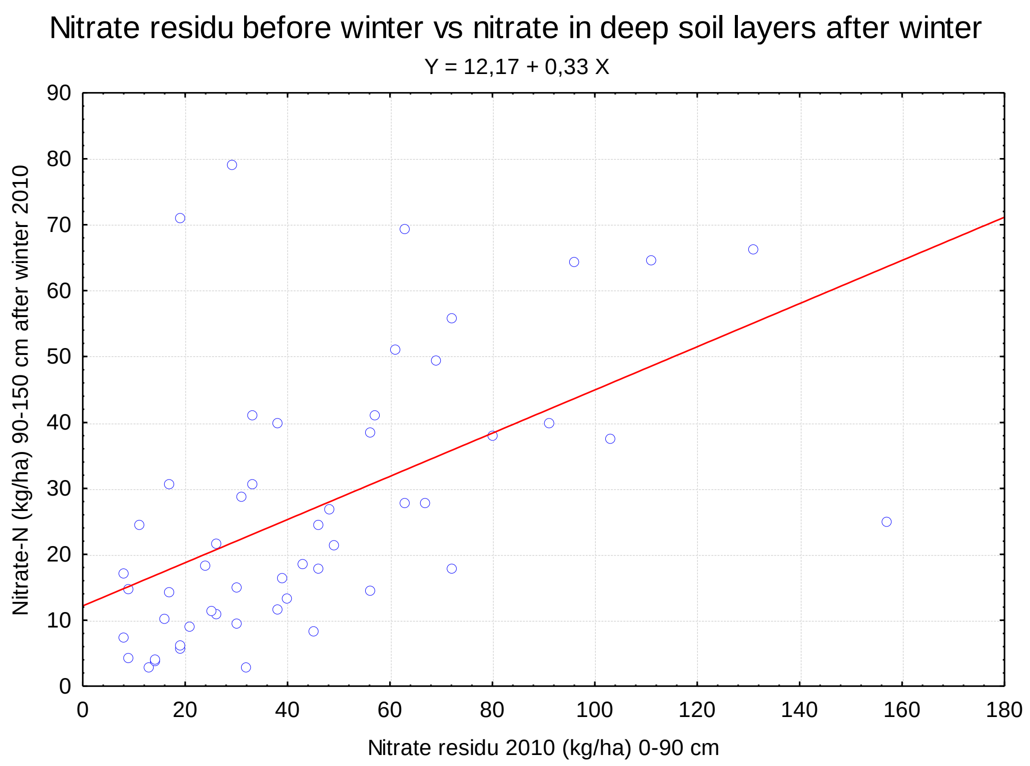

Figure 62: Scatterplot of nitrate residue (kg NO_3-N/ha) 2010, from 0 to 90 cm, versus the amount of nitrate (kg NO_3-N/ha) in the soil profile from 90 to 150 cm after winter 2010.

6.5 Overview of the nitrate in the soil profile (2009-2011)

The amount of nitrate-N is measured at different moments during the monitoring project (November 2009-February 2011). The average levels of nitrate-N in the soil profile from 0 to 90 cm are shown in Table 43 for the different moments of sampling.

Table 43: Summary of nitrate-N (kg/ha) in the soil profile from 0 to 90 cm at different moments for the most important combinations of soil type and cultivated crop for derogation and no derogation parcels.

Derogation	Soil type	Crop	Nov 2009	Feb 2010	Nov 2010	Feb 2011
Yes	Sand	Grass	57	38	47	33
		Maize	109	44	77	40
	Sandy loam	Grass	68	45	41	38
		Maize	80	38	74	43
No	Sand	Grass	51	40	39	46
		Maize	93	42	78	45
	Sandy loam	Grass	85	49	66	36
		Maize	77	37	70	44

The soil profile from 0 to 90 cm is analysed 4 times during the monitoring project: after the growing season 2009 and 2010 and before the growing season 2010 and 2011. In Table 43 only nitrate levels for grass and maize on sandy or sandy loam soils are shown. These combinations are the most important for derogation and the majority of the parcels in the network belong to one of these combinations. Levels of nitrate-N are higher before a winter period in comparison with levels after winter. For most combinations grassland is characterized by lower levels of nitrate-N in comparison with parcels cultivated with maize. Between derogation and no derogation parcels no statistical differences are present. Variation between different combinations is lower after a winter period than before winter due to leaching during winter. Also important to mention are the lower levels of nitrate-N in November 2010 in comparison with November 2009.

7 Nitrate in the surface and groundwater

The purpose of the investigation is to determine if derogation has a negative effect on the water quality of the different parcels in the network. Therefore different water samples related to these parcels 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. For a number of these parcels a water sample is taken from the canal, ditch or drain. 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 can be easily influenced by more than one parcel or by other non-agricultural practices (typical for the rivers in Flanders). The average amounts of nitrate measured in the samples are shown in Table 44.

Table 44: Average values of nitrate (mg/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 the parcels is given (n) as well as the moment of sampling.

			Nitrate (mg/l)				
		n	**November**	(min, max)	**n**	**February**	(min, max)
	Year		*2009*			*2010*	
Drains							
	Derogation	5	90	(28, 200)	6	52	(12, 101)
	No derogation	2	65	(dl, 130)	5	54	(dl, 102)
Canals and ditches							
	Derogation	19	25	(dl, 94)	17	21	(dl, 63)
	No derogation	14	38	(dl, 150)	11	20	(dl, 151)
	Year		*2010*			*2011*	
Drains							
	Derogation	4	20	(0.7; 40)	1	dl	(dl, dl)
	No derogation	6	42	(0.3; 111)	5	21,3	(dl, 61)
Canals and ditches							
	Derogation	18	24	(dl, 94)	23	13	(dl, 84)
	No derogation	9	14	(dl, 55)	13	14	(dl, 64)

dl: detection limit (0.2 mg/l nitrate for groundwater)

For the measurements at the end of 2009 and beginning of 2010, parcel characteristics of 2009 are used while for measurements at the end of 2010 and the beginning of 2011; parcels characteristics of 2010 are used. All samples at the end of a year are taken the second week of November and those after winter from 15 to 20 February. The first samples are taken at the end of 2009 and the last samples at the beginning of 2011. Due to the low number of samples (especially for drains) it is not desirable to compare derogation versus no derogation statistically. Moreover, the measurements of the different samples are highly variable, as can be seen from the minimum and maximum values.

The concentrations measured in the water samples of drains are always higher in comparison with measurements in canals and ditches. Especially at the end of 2009 and the beginning of 2010 concentrations of nitrate in drains have levels above 50 mg/l. Table 44 shows that for all measurements a decreasing trend in the concentration of nitrate is present over/during the different years. In 2009 higher concentrations are observed in comparison with 2010 and the lowest concentrations are present in 2011. This decreasing trend is a positive effect for the water quality and it is very interesting to evaluate this trend during the next years. Besides average levels of nitrate, also maximum levels and number of samples with high levels of nitrate show a decreasing trend.

The concentrations of nitrate in the water samples of drains, canals and ditches are primarily indicative. There is a large influence of the moment of sampling (recently rainfall) in these systems. The effect of agricultural practices on a single parcel and the relation to the nitrate concentration measured in a canal or ditch is not always very clear due to the influence of a large number of parcels. It is also important to mention that the number of observations is not the same in 2009 as in 2010. Besides the number of observations, the cultivated crop and derogation conditions are not the same for all parcels in 2009 as in 2010. Therefore the water samples of drains, canals and ditches are indicative and could not be used to make comparisons between derogation and no derogation parcels.

7.2 Shallow groundwater (MAP sampling points and monitoring wells)

A very important parameter to measure the impact of derogation on the water quality is the nitrate concentration measured in the MAP sampling points and monitoring wells. Water present in the monitoring wells and MAP sampling points is shallow groundwater. In the first phase of the investigation, parcels were chosen which are lying in the infiltration area of a MAP sampling point and on some other parcels a monitoring well is placed. The water quality measured in those sampling points is mostly influenced by a single agricultural parcel and could therefore be linked to the characteristics (fertilization practices and cultivated crop) of this parcel.

Table 45: Average nitrate concentration (mg/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 (n) of sampling points is also given. (dl: detection limit, 0.2 mg/l nitrate for groundwater)

	Nitrate (mg/l)					
	n	M	(min, max)	n	W	(min,max)
2007_1	109	39	(dl, 316)		n.a.	
2007_2	109	34	(dl, 321)		n.a.	
2008_1	110	34	(dl, 253)		n.a.	
2008_2	108	26	(dl, 184)		n.a.	
2009_1	110	28	(dl, 268)		n.a.	
2009_2	84	25	(dl, 260)	42	25	(dl, 320)
2010_1	104	28	(dl, 220)	49	35	(dl, 202)
2010_2	102	27	(dl, 180)	42	25	(dl, 224)
2011_1		n.a.		43	27	(dl, 159)

n.a. not available

For each parcel linked to a MAP sampling point or monitoring well detailed information is summarized in annex 1. For each parcel the cultivated crop, derogation, soil type and amount of nitrate in the water is listed for the years 2007, 2008, 2009 and 2010. Next to this information, the estimated travel time for each monitoring point is also given. By using the estimated travel time, the measured nitrate in the water can be linked to the parcel characteristics (derogation and cultivated crop) of a specific year.

Table 45 shows the average nitrate concentration measured in the MAP sampling points and monitoring wells which can be linked to a parcel in the monitoring network. Measurements for the MAP sampling points are shown starting from the year 2007; the self placed monitoring wells were sampled for the first time at the end of 2009. For the MAP sampling points a slight decrease in the concentration of nitrate is observed from an average concentration of 39 mg/l in 2007 to a concentration of 27 mg/l before winter 2010. This decreasing trend is also observed for the average nitrate concentration for all MAP sampling points in Flanders. There is a large variation between the different sampling points: concentrations from detection limit to very high maximum values are measured.

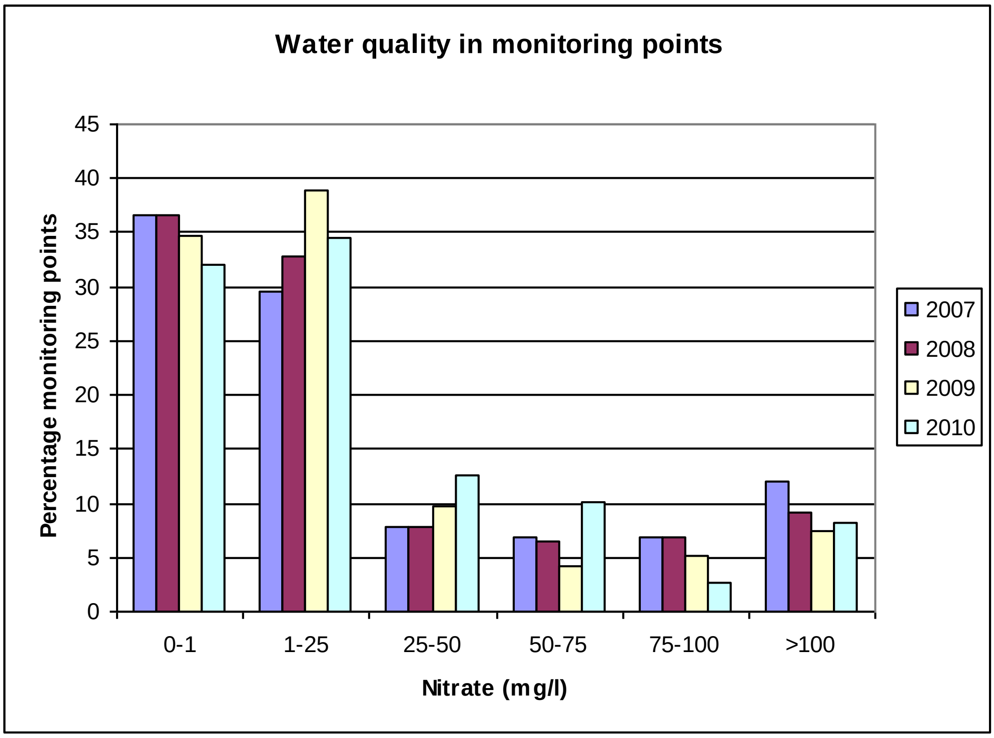

Figure 63: Percentage of sampling points in a specific range of nitrate (mg/l). For each year an average is made between the samples before and after winter.

Figure 63 shows that a great percentage of sampling points is characterized by low levels of nitrate. However, every year a smaller number of sampling points has very high concentrations of nitrate, but this number is decreasing over the 4 years. This decreasing trend is not only observed in the monitoring points in the derogation network but also for all MAP sampling points in Flanders. The percentage of sampling points with a concentration of nitrate below 50 mg/l was respectively 74, 77, 83 and 79 % for the years 2007, 2008, 2009 and 2010. The percentage of sampling points with very high (>75 mg/l) concentrations of nitrate is decreased from 19 % in 2007 to 11 % in 2010. In 2008 and 2009, respectively 16 % and 12 % of the sampling points had very high concentrations.

Table 46 shows the average nitrate concentration of the MAP sampling points that are linked to parcels with the same cultivated crop and the same condition of derogation for the years 2007, 2008 and 2009. The values linked to parcels cultivated with grassland are in general lower than those cultivated with maize. Over the years the nitrate concentration in the water tends to decrease (this trend was also present in Table 45). Between the different sampling points the variation is very large (as can be seen from the maximum and minimum values). Some sampling points have very low measured values of nitrate, while others have very high concentrations. The different groups of parcels (combination of cultivated crop and derogation condition) are not clustered in specific regions of Flanders. So differences in nitrate levels are not caused by specific conditions of those regions.

Table 46: Average nitrate concentration (mg/l) in MAP sampling points for different years and different combinations of cultivated crop and derogation (D: derogation, ND: no derogation) for parcels with the same crop and derogation for the years 2007, 2008 and 2009. For each combination the number (n) of parcels and variation (min, max) is also given.

				Nitrate (mg/l)				
year	n	Grass D	n	Grass ND	n	Maize D	n	Maize ND
2007_1	14	23	15	10	6	21	22	48
		(dl, 177)		(dl, 39)		(3, 73)		(dl, 147)
2007_2	12	15	15	7	6	30	22	38
		(dl, 109)		(dl, 45)		(dl, 85)		(dl, 110)
2008_1	12	12	15	11	6	37	22	40
		(dl, 60)		(dl, 39)		(1, 117)		(dl, 151)
2008_2	14	11	15	7	6	31	22	27
		(dl, 47)		(dl, 42)		(dl, 94)		(dl, 118)
2009_1	13	11	17	6	6	12	22	34
		(dl, 48)		(0.5; 22)		(1, 26)		(dl, 119)
2009_2	11	9	15	10	5	7	18	21
		(dl, 59)		(dl, 71)		(dl, 20)		(dl, 97)
2010_1	13	9	17	14	6	14	19	33
		(dl, 39)		(dl,54)		(dl, 32)		(dl, 120)
2010_2	13	15	13	17	6	12	18	33
		(dl, 140)		(dl, 83)		(dl, 33)		(dl, 140)

dl: detection limit, 0.2 mg/l nitrate for groundwater

When comparing derogation with no derogation parcels with the same cultivated crop and for the same year, differences are not statistically significant. Starting from the second half of 2009, there are also measurements in the self placed monitoring wells. The results from the monitoring wells are presented in Table 47. Average concentrations are given for parcels with the same crop and derogation condition for the years 2008, 2009 and 2010. It is important to mention that the monitoring wells are mostly situated on derogation parcels, and no observations are present for no derogation parcels cultivated with maize. The same conclusions can be drawn from Table 47 as for Table 46. Nitrate concentrations linked to parcels cultivated with maize are in general higher. However a comparison between derogation and no derogation parcels is not possible for the monitoring wells separately due to the low number of observations for no derogation parcels.

An Important conclusion from Table 47 is that nitrate concentrations are on the same level as in the MAP sampling points (Table 46).

Table 47: Average nitrate concentration (mg/l) in monitoring wells for different years and different combinations of cultivated crop and derogation (D: derogation, ND: no derogation) for parcels with the same crop and derogation for the years 2008, 2009 and 2010. For each combination the number (n) of parcels and variation (min, max) is also given. dl: detection limit, 0.2 mg/l nitrate for groundwater.

				Nitrate (mg/l)				
year	n	Grass D	N	Grass ND	n	Maize D	n	Maize ND
2009_2	16	8	2	52	9	10	0	
		(dl, 40)		(49, 54)		(dl, 65)		
2010_1	20	19	2	61	9	24	0	
		(dl, 70)		(45, 76)		(dl, 131)		
2010_2	17	11	2	53	7	13	0	
		(dl, 43)		(68, 38)		(dl, 61)		
2011_1	17	20	2	36	9	11	0	
		(dl, 126)		(28, 44)		(dl, 78)		

The number of no derogation parcels is very low and not representative for the whole group.

Results in Table 45, Table 46 and Table 47 give an overview of nitrate concentrations measured in the different sampling points measured in a specific period (after and before a winter period). It is very important to mention that the water sampled in a sampling point has a specific travel time, so the results of the water samples taken in the sampling points in one specific year are linked to parcel characteristics of another year based on the travel time. When we compare the concentrations in the sampling points measured in one year, we are actually comparing water originating from different years. Because the average travel time for the MAP sampling points is 2.18 years and for the monitoring wells 1.5 years, especially the measurements of 2009 and 2010 are of great interest. The results of those years can be coupled to the parcel characteristics of 2008 and 2009. At this moment the results for the MAP sampling points for the beginning of 2011 are not yet known. Because the rules for derogation have changed starting from 2008, the results of the water measurements coupled to the parcel characteristics of 2008, 2009 and 2010 are of great interest. By coupling the measured water quality in a sampling point to specific parcel characteristics of a specific year it is possible to compare the water measurements for specific combinations of soil type, cultivated crop and derogation.

The analysis based on the parcel characteristics of 2008 are summarized in Table 48. There are no significant differences between derogation and no derogation parcels. The analysis is based on

Table 48: Average nitrate (mg/l) of monitoring points linked (based on the travel time) to the parcel characteristics of 2008. n.s. indicates that no significant statistical difference was found.

	Nitrate (mg/l)				
	n	Derogation	n	No derogation	
All crops	47	25	66	29	n.s.
Grass	31	27	18	25	n.s.
Maize	16	20	37	26	n.s.

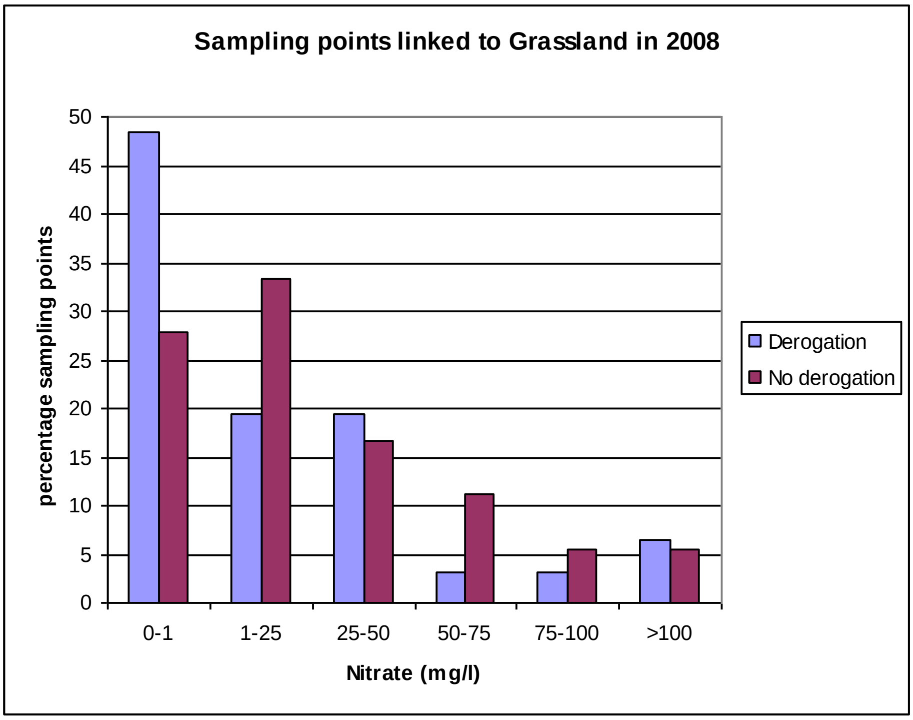

Figure 64: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcels of 2008 cultivated with grass, based on the travel time.

113 parcels, 47 derogation and 66 no derogation parcels. All average concentrations are below the nitrate limit of 50 mg/l. Because the purpose is to have a nitrate concentration below 50 mg/l in every sampling point the percentages of sampling points in a specific range of nitrate are shown in Figure 64 for grassland and in Figure 65 for maize. For parcels cultivated with grass the percentage of sampling points with concentrations below 50 mg/l of nitrate is 87 % for derogation parcels and 78 % for no derogation parcels. For maize, 88 % of derogation parcels are below the nitrate limit of 50 mg/l and 78 % for no derogation parcels. For all combinations a large proportion of the sampling points have low concentrations of nitrate, but still a number of sampling points are characterized by amounts of nitrate exceeding the 50 mg/l limit. When comparing derogation with no derogation parcels, no statistical differences are present in general and for grass and maize separately.

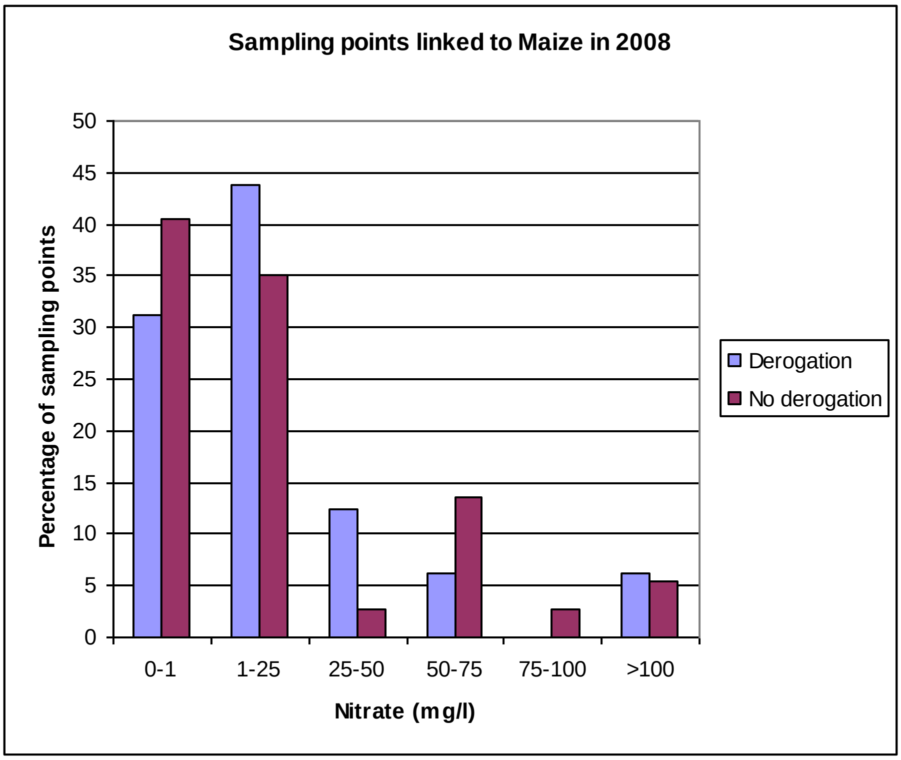

Figure 65: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcels of 2008 cultivated with maize, based on the travel time.

The same analysis is carried out for the parcel characteristics of 2009. Again the parcels are linked to the corresponding measurement in the sampling point based on the travel time. Because the average travel time for the MAP sampling points is 2.18 years, the number of observations is lower in Table 49 than in Table 48. Measurements of nitrate in the MAP sampling points at the beginning of 2011 are not yet known at this moment. The measurements in the monitoring wells for the beginning of 2011 are already used in Table 49.

Table 49: Average nitrate (mg/l) of monitoring points linked (based on the travel time) to the parcel characteristics of 2009. The significance of the different combinations is also given (n.s.: not significant).

	n	Derogation	n	No derogation	
All crops	40	31	25	20	n.s.
Grass	24	16	10	16	n.s.
Maize	14	51	14	16	n.s.

The percentage sampling points in a specific range of nitrate concentration are given for derogation and no derogation parcels separately in Figure 66. Because the lower number of observations at this moment no distinction is made between cultivated crops. 80 % of sampling points linked to derogation parcels have a nitrate concentration below 50 mg/l while 76 % of sampling points linked to no derogation parcels have a nitrate concentration below 50 mg/l. For the no derogation parcels the number of observations is low because the results of end 2010 are not yet available for the MAP sampling points for groundwater. Between the sampling points there is a lot of variation and in some of the sampling points very high concentrations (> 100 mg/l) are measured. The previous analysis has to be overdone at the end of 2011, at that moment the results from all MAP sampling points of the beginning of 2011 are known. On that moment the number of observations for Table 49 will be higher.

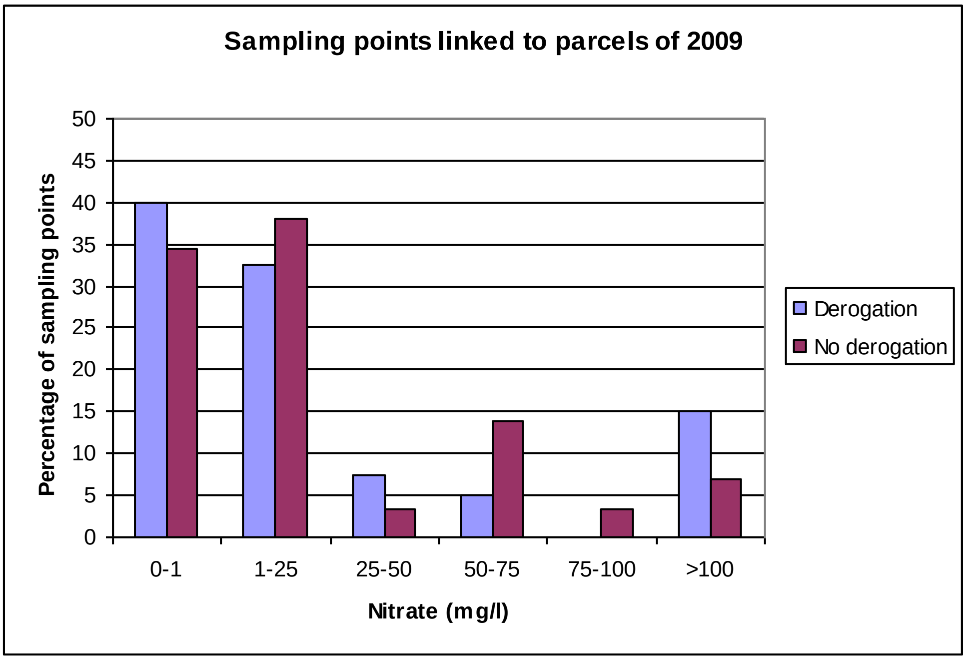

Figure 66: Percentage of sampling points in a specific range of nitrate (mg/l) linked to the parcels of 2009, for all crops. Distinction is made between derogation and no derogation parcels.

7.3 Nitrate in the soil water

In a limited number of parcels a soil sample from 90 to 150 cm (in two layers: 90-120 cm and 120-150 cm) is taken. Most of these parcels have a lower groundwater level. As a consequence it is not possible to take water samples from these parcels from MAP sampling points or monitoring wells with short 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. Therefore the amount of nitrate measured in the soil profile is recalculated to a concentration taking into account the moisture content of the soil. In most of these parcels no other direct measurements are available to investigate the water quality linked to these parcels.

Table 50: Average value for the nitrate (mg/l) concentration measured and recalculated in the deep soil layers for the different moments of sampling. Difference is made between derogation and no derogation parcels.

Date	Depth	Crop	Derogation	No derogation	significance
November 2009	90-120 cm	All crops	77	95	n.s.
		Derogation crops	77	78	n.s.
	120-150 cm	All crops	83	96	n.s.
		Derogation crops	83	82	n.s.
February 2010	90-120 cm	All crops	64	92	n.s.
		Derogation crops	64	64	n.s.
	120-150 cm	All crops	59	91	n.s.
		Derogation crops	59	62	n.s.
November 2010	90-120 cm	All crops	64	77	n.s.
		Derogation crops	64	57	n.s.
	120-150 cm	All crops	62	85	n.s.
		Derogation crops	62	59	n.s.
February 2011	90-120 cm	All crops	48	76	n.s.
		Derogation crops	48	61	n.s.
	120-150 cm	All crops	47	75	n.s.
		Derogation crops	47	66	n.s.

The first deep soil samples are taken at the end of 2009, together with the nitrate sample. Again the difference is made between derogation and no derogation parcels. This difference is made separately for the soil layers from 90-120 cm and from 120-150 cm. For none of these layers a significant difference was found between derogation and no derogation parcels. The average values are shown in Table 50.

Beside all crops, the comparison between derogation and no derogation parcels is also done for derogation crops only. For the first layer (90-120 cm) a large variation in measurements was observed (Figure 67) and no significant difference was found. This variation is present for all moments of sampling. The comparison between derogation and no derogation crops is also done for the soil layer from 120 to 150 cm. In these layers the results are similar to the results for the soil layer from 90-120 cm.

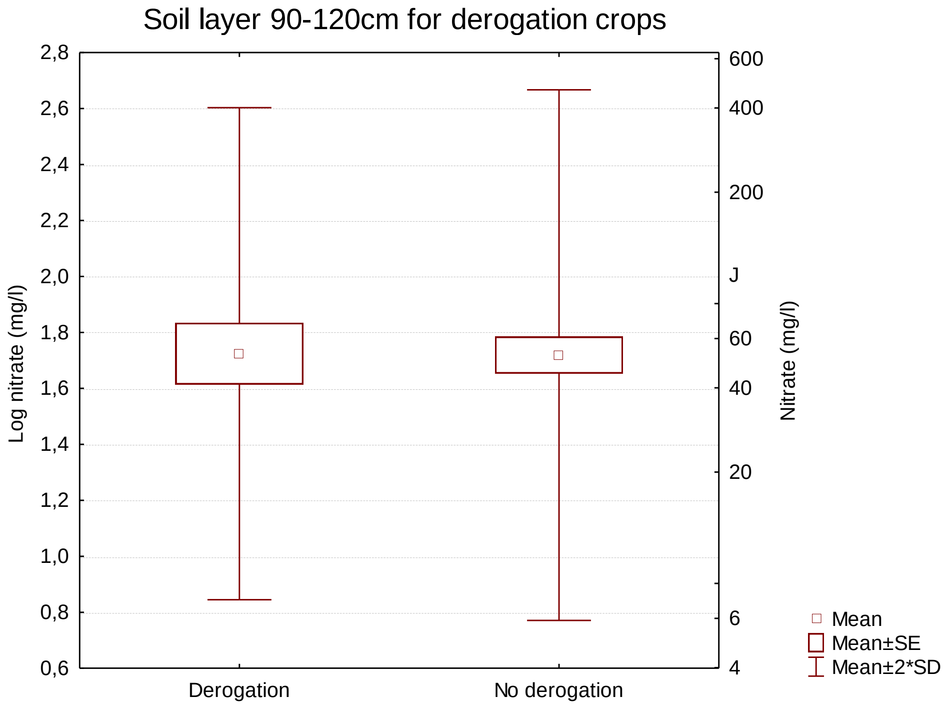

Figure 67: Box plot of log nitrate (mg/l) for the soil layer from 90-120 cm for derogation crops before winter 2009.

After winter of 2009 the next deep soil samples are taken for the second time, again on a limited number of parcels in the network. It is important to mention that not all parcels sampled after winter 2009 are identical to those sampled before winter. Again there are no significant differences between derogation and no derogation parcels for the different combinations (Table 50).

Also at the end of 2010 end at the beginning of 2011 a deep soil sample is taken on almost the same parcels as at the beginning of 2010. Results are also shown in Table 50. No significant differences are found between derogation and no derogation parcels. From the data of the beginning of 2011, one observation was excluded from the analysis. This parcel was characterized by a concentration of 319 mg/l in the soil layer from 90 to 120 cm and 270 mg/l for the soil layer from 120 to 150 cm. In general, during the different moments (4) of sampling a decreasing trend is present in the average values of nitrate measured in the deeper soil layers. This decreasing trend could be expected because the amount of nitrate in the soil layer from 0 to 90 cm reached a lower level at the end of 2010 in comparison with the end of 2009.

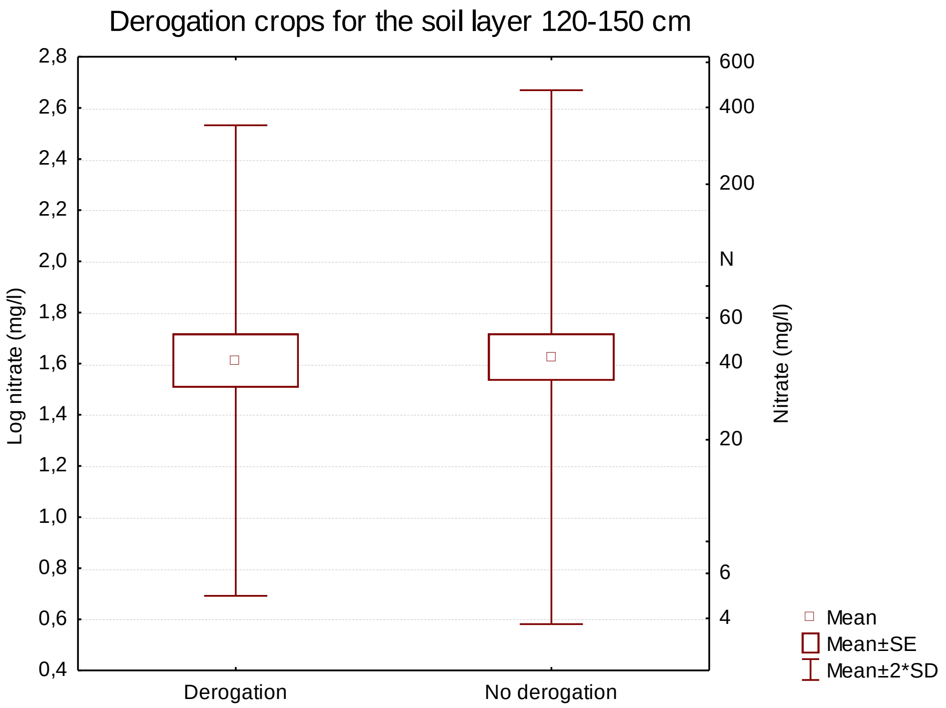

Figure 68: Box plot of log nitrate (mg/l) for derogation and no derogation parcels cultivated with derogation crops only. The nitrate is given for the soil layer from 120-150 cm, after winter 2009.

8 Phosphorous

8.1 Phosphorous in the soil sample

8.1.1 P-AL in the standard soil sample

In all parcels of the network a standard soil sample was taken. This standard soil sample is necessary to characterize the different parcels. In these samples the amount of phosphorous was determined. Based on the standard soil sample a fertilization advice was formulated for the farmers for the next 3 years for the most important nutrients (K, P, Mg, Ca and Na). The amounts of phosphorous measured in the standard soil sample are shown in Figure 69 and Figure 70 for grassland and maize, respectively. Because a standard soil sample is taken from 0 to 6 cm for grassland and from 0 to 23 cm for maize the results are given separately for both crops. Phosphorous on the standard soil sample is measured in an ammonium-lactate (AL) extract.

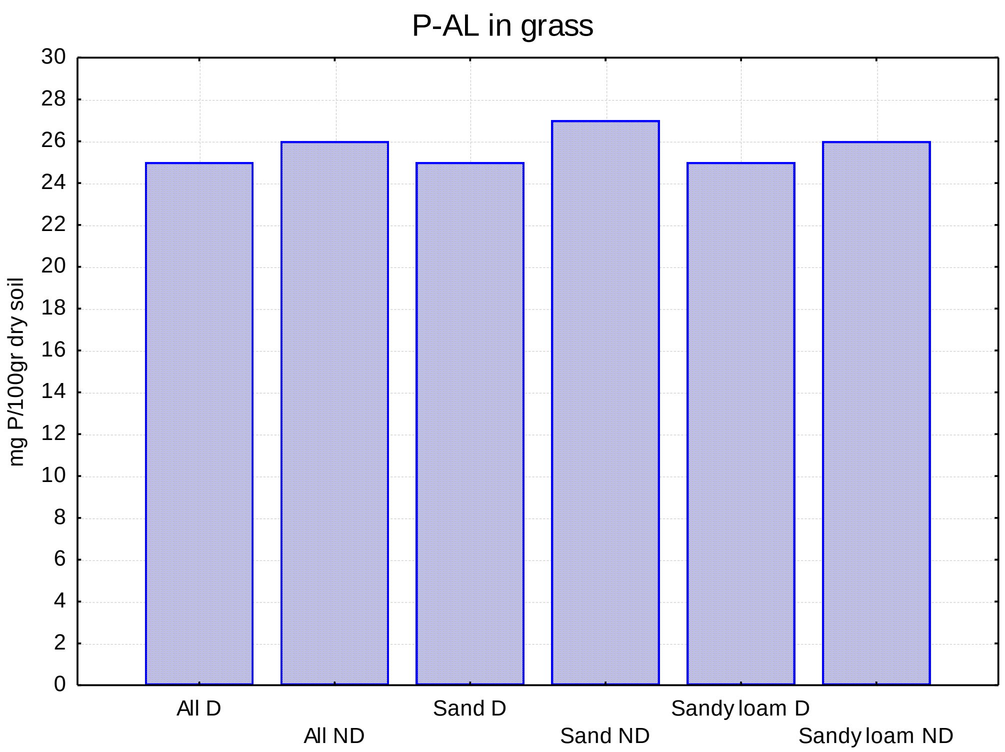

Figure 69: Average value of phosphorous measured in an AL-extract in soils cultivated with grass. Different combination of grass with soil types (all soil types, sandy and sandy loam) are shown for derogation and no derogation parcels.

Beside the fertilization advice and parcel characteristics the phosphorous measured in this standard soil sample can be indicative to choose a number of parcels to measure the phosphate saturation degree.

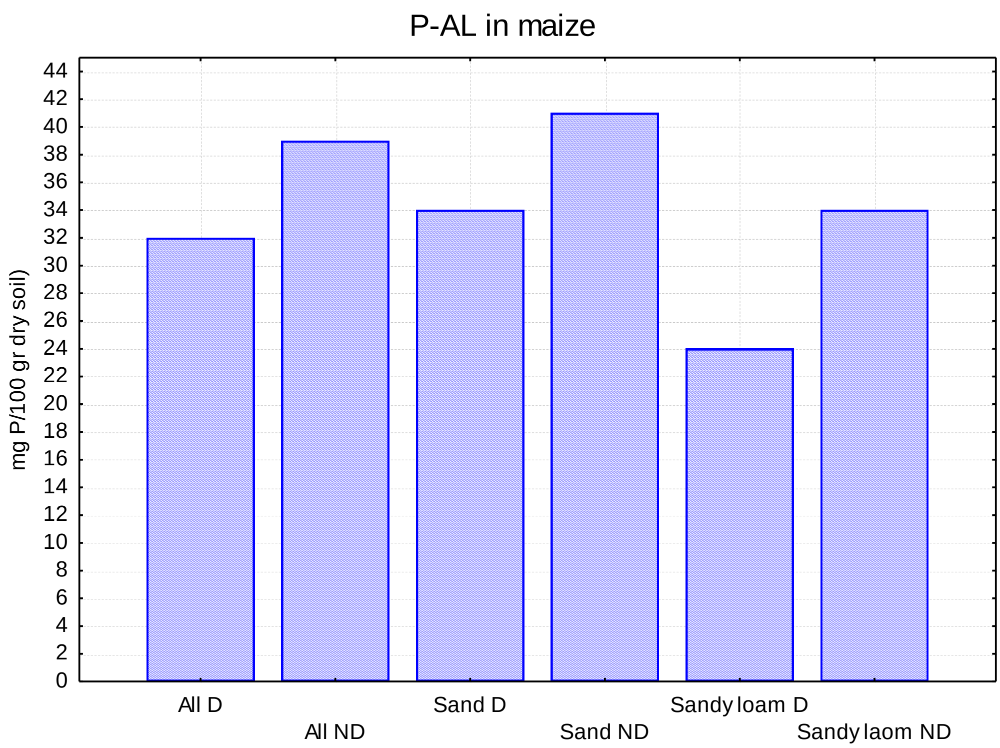

Figure 70: Average value of phosphorous measured in an AL-extract on soils cultivated with maize. Different combination of maize with soil types (all soil types, sand and sandy loam) are shown for derogation and no derogation parcels.

8.1.2 P-AL in the deeper soil layers

In all deep soil samples (from 90 to 150 cm) the amount of phosphorous is also measured in an ammonium lactate extract. However in approximately 80 % of the samples the amount of phosphorous is below the detection limit of 4 mg P/100 g dry soil for the measurements at the end of 2009. This is 67 % for the measurements in February 2010, 60 % at the end of 2010 and 63 % for the measurements in February 2011. In a few parcels (always less than 10 %) the measured phosphorous is high (>10 mg P/100 g dry soil). These parcels also have high levels of phosphorous measured in the top soil layer (0-6 cm for grass and 0-23 cm for cultivated crops). Mostly the same parcels have high levels of phosphorous in the deep soil layers during the different moments of sampling. On some of these parcels also measurements of total P, DIP and DOP are carried out. For these parcels also the measurement of total P is on a high level and consists around 50 % of more of DIP. For other parcels with high levels of P-AL, the measurement of total P is high in 2009 and 2010 but on a lower level in 2011. More details about DIP and DOP are present in the next paragraph (phosphorous in the water samples).

8.1.3 Phosphate Saturation Degree

It is not desirable to have high concentrations of phosphorous in surface and groundwater. Too high phosphorous concentrations in surface water result in eutrophication. A general limit for eutrophication is an amount of ortho-phosphate of 0.1 mg P/l (Schouwens, 2004). A good management of the amount of phosphorous in the soil is necessary to prevent risks of excessive phosphorous leaching out. When the import of phosphorous for a single agricultural parcel is higher than the uptake by the cultivated crop, phosphorous will accumulate in the soil and the risk for leaching will increase.

Soils have a certain phosphate sorption capacity, when phosphorous accumulates in the soil a larger part of the total phosphate sorption capacity is used, less binding capacity is available and eventually phosphate will leach out the soil profile. The amount of phosphate leaching out is function of the total accumulation in the soil, the soil binding capacity and the hydrological characteristics of the soil. Van der Zee et al. (1990 a, b) developed a protocol based on routine lab procedures to test whether a soil is phosphate saturated or not. This protocol is used for acidic sandy soils. In acidic sandy soils phosphate is mostly absorbed by iron and aluminium oxides and hydroxides. When soils are calcareous, phosphorous will form insoluble complexes with calcium and not only the amount of iron and aluminium is of importance to calculate the phosphate sorption capacity (PSC). By an ammonium oxalate oxalic acid extraction the amount of phosphorous that is absorbed on aluminium and iron oxides and hydroxides can be 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).

$$PSD = Pox/PSC * 100\ (\%)$$

PSC is the total amount of phosphate that a soil can bind and is calculated from the oxalate extractable iron and aluminium. So the phosphate saturation degree (PSD) is the relation between the actual accumulation of phosphate in the soil and the maximum amount of phosphate that a soil can contain. A critical PSD is quantified as the level of PSD where an amount of phosphate will leach out the soil profile and has a negative effect on the water quality. In Flanders the critical PSD of 35 % is used to decide if a soil is phosphate saturated.

Table 51: The phosphate saturation degree measured at 30 parcels of the derogation network at the end of 2010. The selected parcels are cultivated with grass or maize and are characterised with or without derogation. The results for oxalate extractable phosphorus (Pox), Phosphate Saturation Degree (PSD) and Phosphate Sorption Capacity (PSC) are shown.

	Derogation 2009 and 2010	Crop 2009 and 2010	PAL-extract (mg/100g DS)	Pox (0-90cm) mmol/kg	PSC 0-90cm (mmolP/kg)	Phosphate saturated	PSD (total) % DS
1	Y	Grass	15	16.4	131.8	N	12.5
2	Y	Grass	24	36.2	97.8	Y	37.1
3	Y	Grass	20	34.5	121.6	N	28.3
4	Y	Grass	29	37.5	159.4	N	23.5
5	Y	Grass	15	32.4	143.2	N	22.6
	Average		**21**	**31.4**	**130.7**		**24.8**
6	N	Grass	27	72.8	236.0	N	30.8
7	N	Grass	16	19.2	87.8	N	21.9
8	N	Grass	22	36.2	84.7	Y	42.7
9	N	Grass	24	93.7	215.3	Y	43.5
10	N	Grass	31	43.1	118.3	Y	36.4
	Average		**24**	**53.0**	**148.4**		**35.1**
11	Y	Maize	45	64.9	213.6	N	30.4
12	Y	Maize	23	39.8	133.3	N	29.8
13	Y	Maize	28	192.0	266.3	Y	72.1
14	Y	Maize	15	26.5	89.2	N	29.7
15	Y	Maize	16	123.1	503.1	N	24.5
16	Y	Maize	22	56.0	123.6	Y	45.4
17	Y	Maize	60	49.6	77.6	Y	63.9
18	Y	Maize	43	67.6	112.7	Y	60.0
19	Y	Maize	29	39.1	145.5	N	26.9
20	Y	Maize	22	72.5	349.8	N	20.7
	Average		**30**	**73.1**	**201.5**		**40.3**
21	N	Maize	60	45.0	99.9	Y	45.0
22	N	Maize	20	24.0	77.8	N	30.9
23	N	Maize	39	47.5	108.5	Y	43.8
24	N	Maize	31	57.1	173.6	N	32.9
25	N	Maize	36	67.9	167.2	Y	40.6
26	N	Maize	47	50.0	139.8	Y	35.8
27	N	Maize	34	72.1	190.2	Y	37.9
28	N	Maize	151	142.8	156.5	Y	91.3
29	N	Maize	30	45.1	105.6	Y	42.7
30	N	Maize	43	58.1	146.6	Y	39.6
	Average		**49**	**61**	**137**		**44**

On 30 parcels of the network the Phosphate saturation degree is measured at the end of 2010. These 30 parcels are characterized by sandy soil types and are mostly acid, so the model of Van Der Zee can be used to calculate the PSD. In order to calculate the PSD different parameters are listed in Table 51; oxalate extractable phosphorus (Pox), total phosphate sorption capacity (PSC) and phosphate saturation degree (PSD).

Based on Table 51 two important conclusions can be drawn. First, 16 of the 30 parcels are phosphate saturated, which is more than half of the sampled parcels. It means that on half of the parcels phosphate can leach out the soil profile and ortho-phosphate concentrations in the surface water will exceed the eutrophication level of 0.1 mg P/l. Second, the parcels exceeding the phosphate saturation level are both no derogation and derogation parcels. In absolute numbers more no derogation parcels are phosphate saturated than derogation parcels. We can expect a large influence of fertilization on the phosphate situation of an agricultural parcel. For derogation parcels the input of nitrogen is higher but due to the specifications of the supplied fertilizers (organic fertilizers from cattle for derogation parcels, from pigs for no derogation parcels) there is no extra input of phosphate in comparison with no derogation parcels. For maize there is little difference in PSD between derogation and no derogation parcels. Some derogation parcels cultivated with maize are characterized by a high level of PSC; therefore the larger amounts of Pox do not lead to a phosphate saturated parcel. 8 out of 10 no derogation parcels cultivated with maize are phosphate saturated against 4 out of 10 for the derogation parcels. On derogation parcels the input of nitrogen is higher but phosphate input reaches the same level as no derogation parcels. A lot of no derogation parcels cultivated with maize are fertilised with organic fertilizers originating from pigs, having higher levels of phosphate for the same level of nitrogen.

In future, the effect of phosphate will become more important. Measuring all parameters to calculate the PSD is interesting to understand the processes influencing the phosphate situation of a parcel but this is very expensive. Therefore it is useful to have some parameters that are relatively easy to measure and that will tell something about the phosphate situation of a single parcel. The relation between PSD and Pox is shown in Figure 71 and Figure 72. We see a positive correlation between both parameters; this correlation is stronger on grassland than for maize. It is important to mention that R^2 numbers are based on a low number of observations.

Another interesting correlation is shown in Figure 73 and Figure 74. Both figures show the relation between PAL and PSD for grassland and maize separately. It is important to mention that PAL on grassland is measured from 0 to 6 cm and for maize from 0 to 23 cm. Pox is measured from 0 to 30 cm and PSD is calculated for the total soil profile (0 to 90 cm). It is also important to mention that PAL is measured on the standard soil sample at the end of 2009 and the PSD is measured at the end of 2010. So the PAL numbers are not originating from the same sample as the other parameters. Based on this information, one can expect that the correlation will be higher when measuring on the same samples. Due to the positive correlation, PAL can give a good indication of the phosphate situation of a soil and the potential impact of phosphate on the water quality (Table 51).

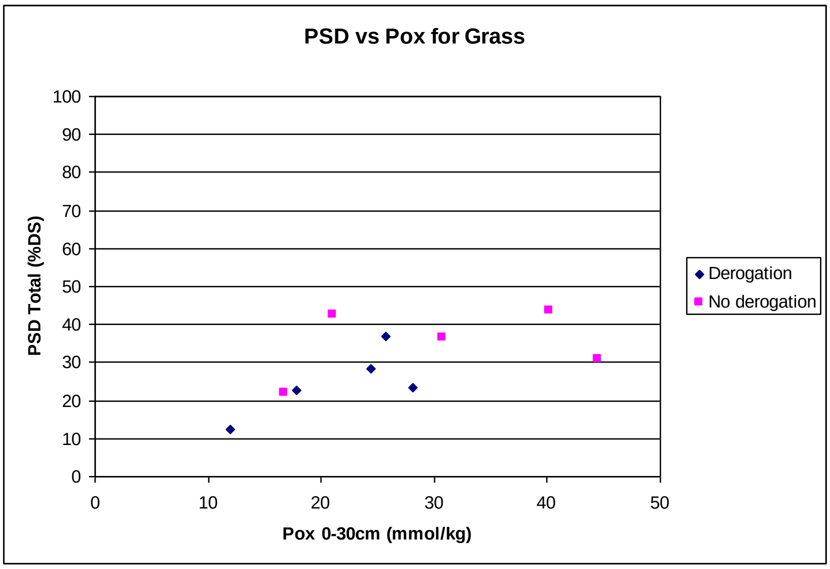

Figure 71: The relation between Pox and PSD for derogation (R^2=0.57) and no derogation (R^2=0.10) parcels cultivated with grass.

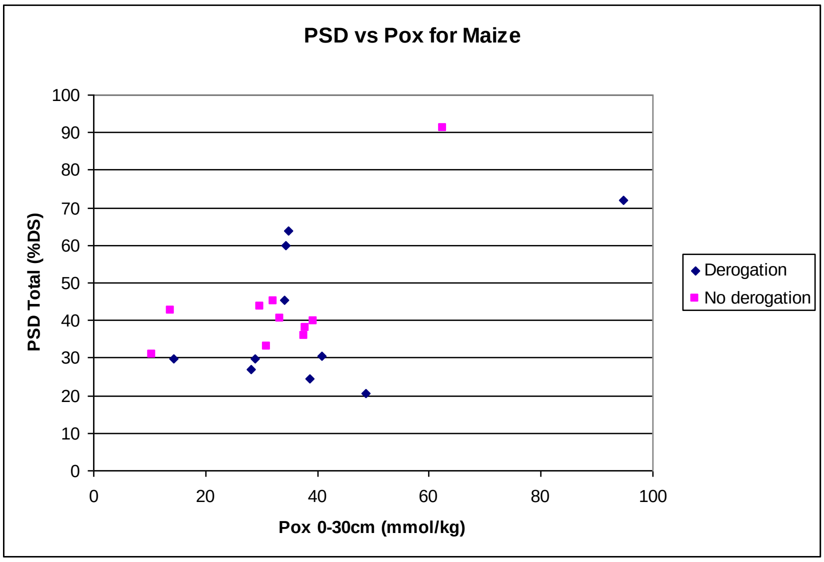

Figure 72: The relation between Pox and PSD for derogation (R^2=0.27) and no derogation (R^2=0.55) parcels cultivated with maize.

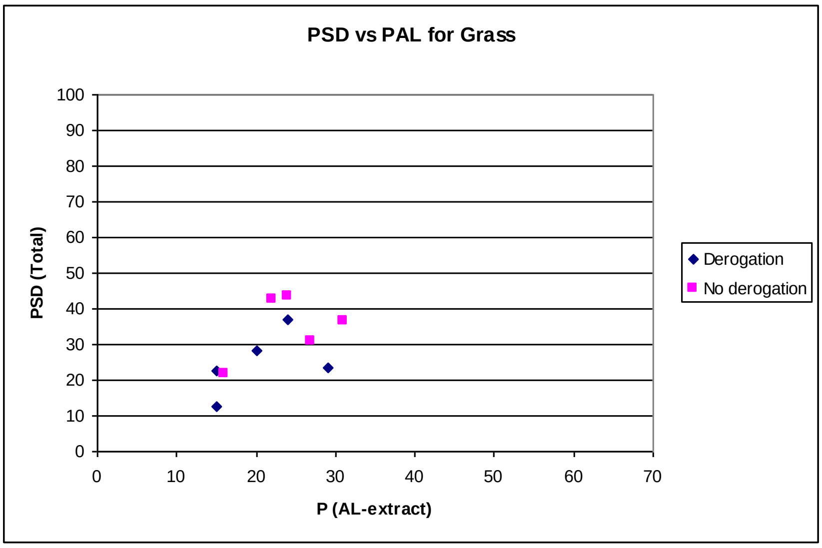

Figure 73: The relation between P (AL-extract) and PSD for derogation (R^2=0.26) and no derogation (R^2=0.19) parcels cultivated with grassland. PAL is measured on soil samples of 2009 and PSD on samples of 2010, both from the same parcels.

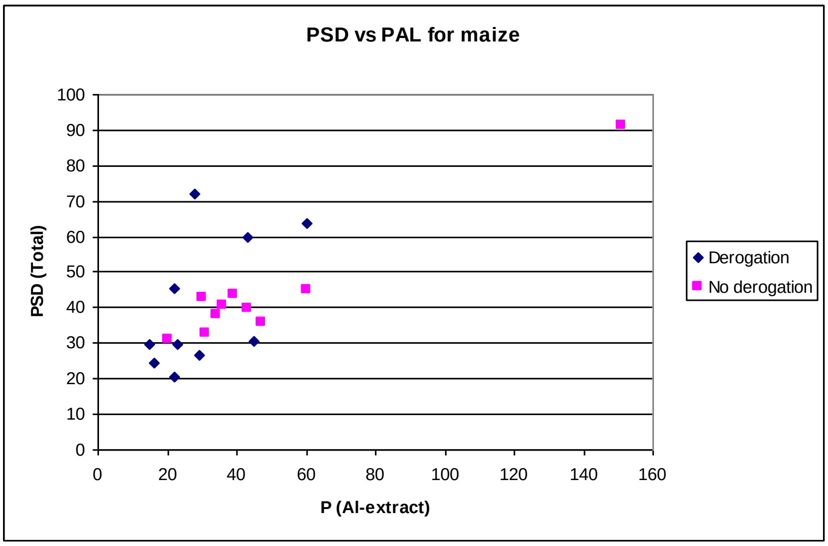

Figure 74: The relation between P (AL-extract) and PSD for derogation (R^2=0.30) and no derogation (R^2=0.94) parcels cultivated with maize. PAL is measured on soil samples of 2009 and PSD on samples of 2010, both from the same parcels.

8.2 Water samples

8.2.1 Drains, canals, ditches and sampling points

In all water samples (from canals, ditches, drains, MAP sampling points and monitoring wells) of the monitoring network the amount of phosphorous is measured by using a continuous flow system. The results are summarized in Table 52. The sampling points exist of MAP sampling points and self placed monitoring wells.

Table 52: Average values for orthophosphate-P (mg P/l) measured in the different water samples with continuous flow. Difference is made between derogation and no derogation parcels. Samples are taken in different years, in November (Nov) and February (Feb).

		PO$_4$-P mg/l			
		n	Derogation	n	No derogation
2009 Nov	Drains	5	0.28	1	0.66
	Canals and ditches	20	0.55	16	0.63
	Sampling points*	56	0.14	66	0.08
2010 Feb	Drains	6	0.24	4	0.26
	Canals and ditches	17	0.48	12	0.47
	Sampling points*	68	0.18	86	0.10
2010 Nov	Drains	4	0.29	6	0.16
	Canals and ditches	18	0.29	9	0.13
	Sampling points*	59	0.09	81	0.10
2011 Feb	Drains	4	0.24	1	0.03
	Canals and ditches	23	0.23	13	0.12
	Sampling points*	32	0.09	17	0.07

***More than half of the sampling points have a concentration below detection limit. For this, half of the detection limit (0.04 mg/l orthophosphate) is used for the calculations.**

During the different years, the highest concentrations of phosphorous are measured in drains, canals and ditches representing surface water samples. Only small differences were observed between derogation and no derogation parcels. The concentration in drains is an average of a small number of samples. For drains, canals and ditches the concentrations reach a lower level at the end of 2010 than at the beginning of 2010, and also a lower level than before winter 2009. For 2010 about 20 % of the measurements in drains, canals and ditches are below detection limit. At the beginning of 2011 this was 30 %. For all measurements the lowest concentrations are present in February of 2011.

The lowest concentrations are measured in the MAP sampling points, representing shallow groundwater. In this analysis, the parcel characteristics of 2009 are taken into account for the measurements before and after winter 2009 and those of 2010 for the measurements at the end of 2010 and the beginning of 2011. Based on the parcel characteristics difference is made between derogation and no derogation conditions for the water samples. For this analysis no travel time is used to link parcel characteristics of one specific year to measurements of phosphorous in the water samples. Parcel characteristics from the season before the sampling moment are used.

For MAP sampling points, the results of the beginning of 2011 are not yet available. Most measurements of sampling points at the beginning of 2011 originate from the self placed monitoring wells. From the samples taken from the sampling points in 2009, 39 % of the measurements are below the detection limit; this was 53 % at the beginning of 2010 and 47 % at the end of 2010. For the measurements of February 2011 this was 70 %. For these sampling points half of the detection limit is used for the calculation and comparison between derogation and no derogation parcels.

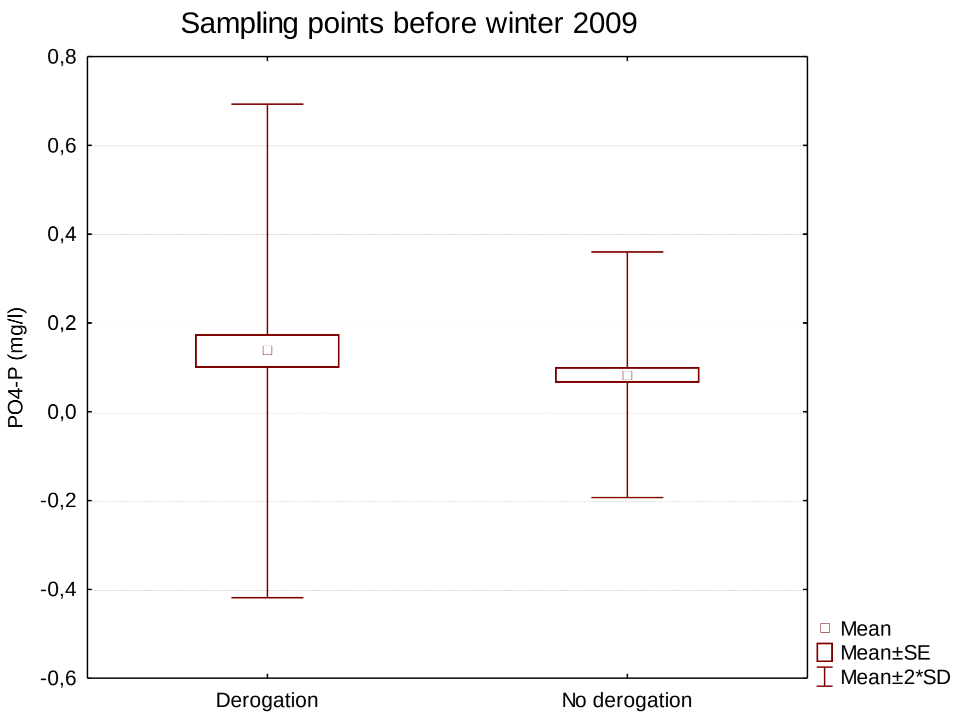

Figure 75: Box plot of the average concentration of orthophosphate (mg P/l) measured with continuous flow for the sampling points at the end of 2009.

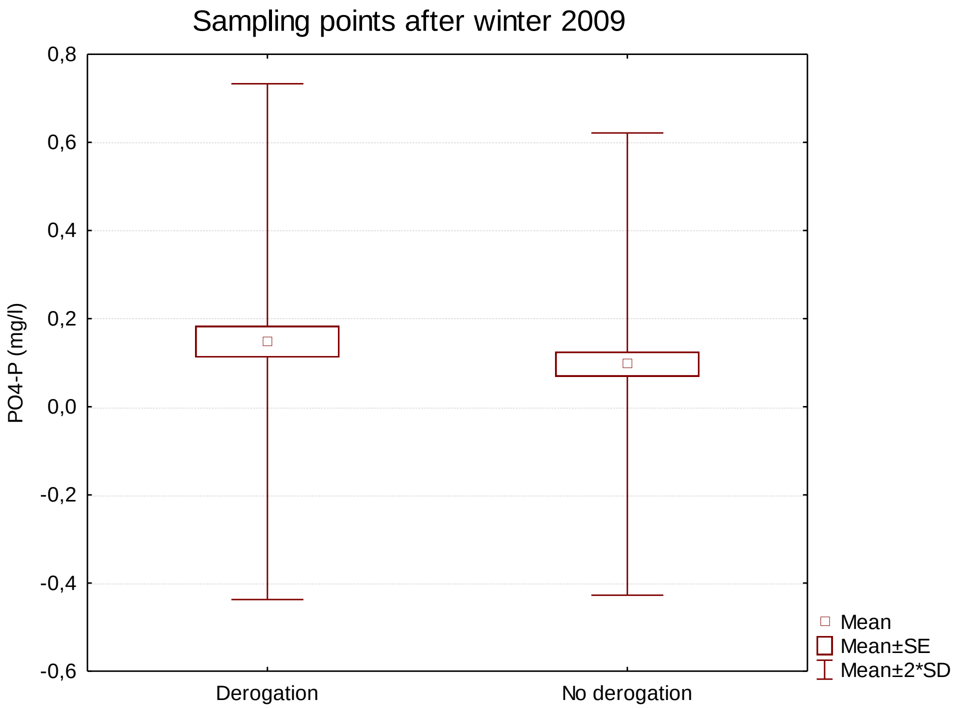

Figure 76: Box plot of the average concentration of orthophosphate (mg P/l) measured with continuous flow for the sampling points after winter 2009.

Figure 75 and Figure 76 show the variation between the different sampling points for winter 2009, no statistical difference was found between derogation and no derogation parcels. Also for winter 2010 the variation between measurements was large and no statistical differences were present between derogation and no derogation parcels. The variation in measurements shown in Figure 75 and Figure 76 is not only present in the sampling points but also in canals, drains and ditches. During the different years the concentration of phosphorous has decreased. To confirm this decreasing trend it is important to follow up the different measuring points during the next years.

8.2.2 DIP, DOP and Total P

In 50% of all the water samples the total amount of phosphorous is measured by ICP (Inductive Coupled Plasma). In these samples the fraction of DIP and DOP are determined by measuring the amount of DIP with IC (Ion Chromatography). By making the difference between the total amount of P and DIP the amount of DOP is calculated. By determining the amount of DIP and DOP from the total amount of phosphorous in a sample it is possible to investigate which fraction of P is the most important, the organic fraction (DOP) or the inorganic (DIP) fraction. The results of these measurements are shown in Table 53. For all periods, the concentrations of phosphorous are the highest for canals and ditches. The measured phosphorous consisted mainly of inorganic phosphorous (DIP). Samples taken from drains have high levels of DIP before winter but have very little DIP after winter. For these water samples the average level of phosphorous is higher than the limit for eutrophication.

Table 53: Average amount of Total phosphorous (TP), DIP and DOP for the different water samples. For each combination the number (n) of samples is given as well as the number of samples with a measurement below detection limit (<d.l.).

		n	TP mg/l	DIP mg/l	DOP mg/l	**% DIP**	**% DOP**	< d.l.*
2009 Nov	Drains	6	0.28	0.16	0.12	**57**	**43**	
	Canals and ditches	12	0.73	0.5	0.23	**68**	**32**	
	Sampling points	25	0.08	0.02	0.07	**22**	**78**	
	Soil water (90-120 cm)	23	0.2	0.04	0.16	**22**	**78**	
	Soil water (120-150 cm)	22	0.17	0.02	0.15	**12**	**88**	
2010 Feb	Drains	6	0.06	0.01	0.05	**16**	**84**	
	Canals and ditches	9	0.48	0.37	0.11	**77**	**23**	
	Sampling points	28	0.02	0.005	0.015	**25**	**75**	14
	Soil water (90-120 cm)	39	0.22	0.02	0.2	**9**	**91**	
	Soil water (120-150 cm)	35	0.19	0.02	0.17	**7**	**93**	
2010 Nov	Drains	10	0.22	0.13	0.10	**57**	**43**	5
	Canals and ditches	12	0.27	0.13	0.13	**50**	**50**	1
	Sampling points	22	0.09	0.02	0.07	**22**	**78**	15
	Soil water (90-120 cm)	32	0.07	0.02	0.05	**29**	**71**	16
	Soil water (120-150 cm)	32	0.08	0.02	0.06	**25**	**75**	15
2011Feb	Water samples							87 %
	Soil water							93 %

* **for the calculation of values below detection limit, half of the detection limit is used**

In 50% of the water samples taken from sampling points, the different fractions of phosphorous are also determined. In November 2009, the average value of phosphorous is 0.08 mg P/l, existing for 78 % of DOP. In February 2010, on half (14) of the samples the measured concentration for total phosphorous was below the detection limit of 0.02 mg P/l, for the calculations half of the detection limit is used. 75% of the total amount of phosphorous, measured in the water samples originating from the MAP sampling points and monitoring wells, is organic (DOP). In November 2010 this was 78 %. In general, concentrations measured in MAP sampling points are lower in comparison with measurements of canals, ditches, drains and deep soil water.

In 50% of the deep soil samples (90-120 cm and 120-150 cm) the soil water is extracted by centrifugation. This is done the first time before winter 2009. At the moment of sampling (20 October to 10 November) the soil conditions were very dry. As a consequence not enough soil water could be centrifuged from all soil samples in order to do the analysis. When sampling after winter 2009 this was not a problem. Only small differences can be observed between the different layers. In these deep soil samples, the total amount of phosphorous measured in the extracted soil water consists mainly of organic phosphorous (DOP). However, these results need to be interpreted with care, because one can expect that extracting soil water by centrifugation will have an impact on the measured phosphorous. This is mainly important for the organic phosphorous, some phosphorous present in clay fractions of the soil will be released by the centrifugation and measured as mobile phosphorous but will never be released in real conditions. At the end of 2010 on more than half of the measurements the concentrations are below detection limit.

For all samples of the measuring points, canals and ditches and soil water the concentrations of phosphorous are lower at the end of 2010 compared with concentrations at the beginning of 2010 or the end of 2009. For the measurements at the beginning of 2011, 87 % of the concentrations measured on sampling points, canals, ditches and drains are below the detection limit of total phosphorous. For the samples originating from deep soil water, 93 % was below detection limit.

Between the different samples variation is high. This variation in total P is illustrated in Figure 77 for the measurements in the sampling points at the end of 2009. Same variation is observed for other measurements (drains, canals, ditches and soil water).

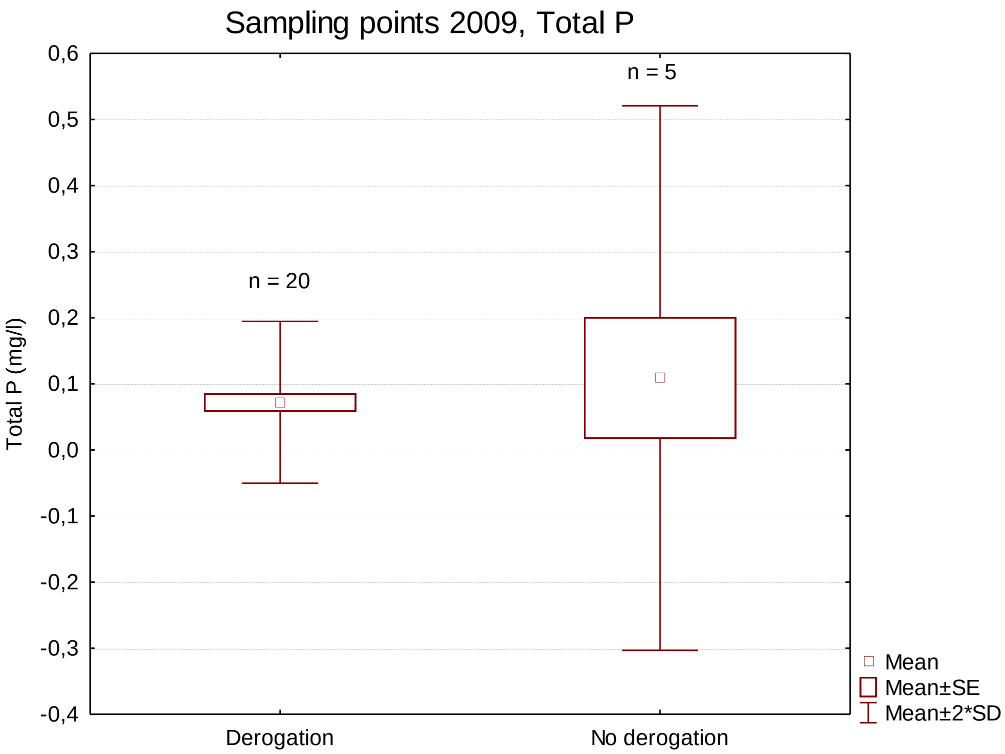

Figure 77: Box plot of Total phosphorous measured with ICP for the sampling points at the end of 2009.

When comparing the amount of phosphorous measured with the continuous flow system (0.04 mg P/l for the sampling points and 0.21 mg P/l for drains, canals and ditches, for the end of 2010) with the measurements of DIP and total phosphorous on the same water samples, concentrations measured with the CF are between the values for DIP and total phosphorous. This is logical because the CF measurement should be an indication of the amount of DIP in the water samples but due to the method of analyzing with the CF not only the inorganic fraction of phosphorous is measured. The measurement with the CF is based on a colour reaction, but besides the inorganic fraction also a part of the organic fraction of phosphorous causes a reaction.

9 Burns Model

The most important process during winter is leaching; this process is very dependent of the amount of rainfall. The amount of water and nitrate that leach out the soil profile is influenced by different factors. First of all, during winter there is almost no uptake by the cultivated crops. Secondly the effect of mineralisation is highly temperature dependent and is mainly important during summer and at the beginning and the end of winter. Also denitrification occurs (major influence of soil type).

9.1 Introduction

To investigate the leaching of nitrate during winter, a soil sample is taken before and after winter; these soil samples are discussed and compared in the previous paragraphs. Often when studying leaching, the Burns model (Burns, 1974; Burns, 1980) is used to predict the movement of soluble unabsorbed anions, such as nitrate, in freely drained soils. Because most parcels in the monitoring network consist of sandy and sandy loam soils, this model is used to estimate the amount of nitrate flushing out the soil profile during winter. The nitrate transfer is calculated from the amount of water movement to 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).

9.2 Input parameters

The Burns model needs different parameters as input. These parameters are specific for each parcel in the monitoring network. The most important and necessary parameters are:

-water balance (rainfall and evaporation)

-nitrate in the soil profile

-thickness of the different soil layers

-field capacity (depending of soil texture and important for the water retention capacity)

-sampling date

Based on these parameters leaching out calculated over a specific period. Leaching starts when the soil profile is saturated. Therefore it is also important to know the moisture content of the soil samples at the moment of sampling (nitrate residue).

9.3 Input from the monitoring network

One of the parameters necessary for the model is the amount of nitrate in the profile before winter, which accounts for the amount of nitrate that can leach out of the soil. Therefore the nitrate residues measured at the end of 2009 are used for calculations about winter 2009 and those from the end of 2010 for winter 2010. Results of these nitrate residue measurements are discussed earlier. On each parcel in the network a nitrate sample was taken during the period 1 to 15 November. The total amount of nitrate is known as well as the nitrate in the different soil layers of 30 cm (layer 1: 0-30 cm, layer 2: 30-60 cm and layer 3: 60-90 cm). So the thickness of the different soil layers used in the model is 30 cm.

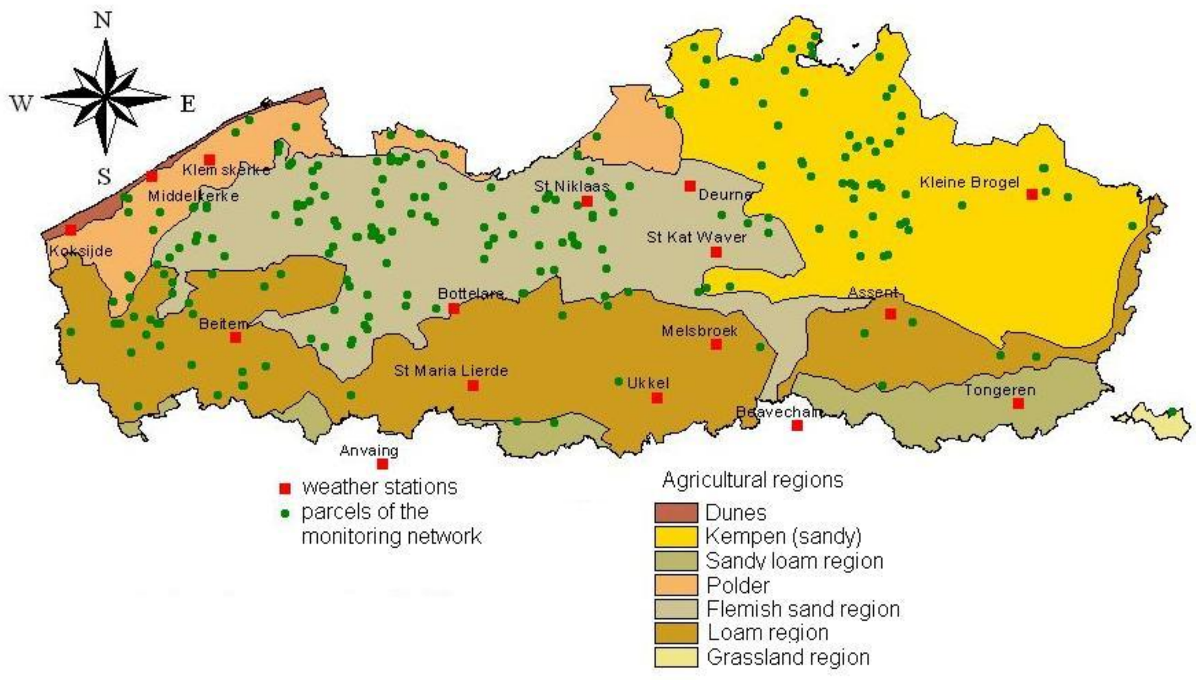

Figure 78: Location of the selected weather stations and the different parcels of the monitoring network on the agricultural regions of Flanders.

Nitrate only leaches out if water is supplied to the soil; therefore rainfall is a very important parameter. A water balance is calculated for each parcel in the monitoring network. For this balance every parcel of the network is coupled to specific rainfall observations. These observations originate from different weather stations. Each parcel of the network is coupled to a combination of the 3 closest stations and the data are the result of a weighted average of the observations between the 3 stations. The location of the different stations and the different parcels in the network for winter 2009 is shown in Figure 78. Figure 78 shows the weather stations used for winter 2009. For winter 2010 some extra stations were taken into account; Kruishoutem, Bierset, Essen, Stabroek and Moerbeke-Waas

For each station it is important that the observed data are complete. Only stations with at least 95 % of complete observations for rainfall, for the winter period, were selected. For winter 2010 data of the extra selected stations are more complete in comparison with winter 2009. Another important factor for the water balance on the parcel is the evaporation. Calculations for ETo are available from different stations. Stations without data of ETo are replaced in this analysis by the nearest station with ETo calculations. For the missing observations the mean of the two closest stations were taken. An overview of the different stations with observations for rainfall and evaporation are listed in Table 54.

Table 54: Overview of the selected stations for the weather observations for rainfall and evaporation (ETo).

Rainfall	ETo
Koksijde	Koksijde
Middelkerke	Middelkerke
Klemskerke	Middelkerke
Beitem	Semmerzake
Anvaing	Semmerzake
St Maria Lierde	Semmerzake
Bottelare	Semmerzake
St Niklaas	Deurne
Deurne	Deurne
St Kat Waver	Deurne
Melsbroek	Melsbroek
Ukkel	Ukkel
Beauvechain	Beauvechain
Assent	Melsbroek
Tongeren	Bierset
Kleine Brogel	Kleine Brogel
Semmerzake	Semmerzake
Kruishoutem	Semmerzake
Bierset	Bierset
Essen	Deurne
Stabroek	Deurne
Moerbeke-Waas	Deurne

The field capacity and nitrate residue are known for each soil layer of 30 cm. By adding rainfall (proportional) the model calculates the amount of nitrate that leaches out of the soil profile from

0 to 90 cm. The result is a nitrate residue in each soil layer of 30 cm and the total amount of nitrate that leached out of the zone of 0-90 cm.

Table 55: Water balances (rainfall – evaporation, L/m²) for the different weather stations for different months and summarized for the period November 2009 to February 2010.

	Sept/09	Oct/09	Nov/09	Dec/09	Jan/10	Feb/10	March/10	Apr/10	Nov-Feb
Koksijde	-86.8	77.2	162.4	98.5	26.4	64.5	-15.6	-21.1	351.9
Middelkerke	-81.5	48.2	148.4	74.7	25.3	58.8	-2.4	-13.3	304.8
Klemskerke	-57.5	47.1	128.8	58.6	20.8	38.6	-4.0	-15.2	242.8
Beitem	-90.9	56.6	145.5	68.3	36.7	75.1	2.7	-11.6	328.3
Anvaing	-56.2	37.9	110.2	82.7	39.7	65.3	7.9	-6.0	305.8
St Maria Lierde	-78.9	29.6	121.9	82.3	35.7	60.1	20.5	-11.2	320.5
Bottelare	-79.7	67.4	131.5	100.5	39.5	66.3	23.7	-10.4	361.5
St Niklaas	-81.9	40.1	124.0	91.0	45.7	60.7	10.1	-14.4	331.5
Deurne	-68.1	44.5	89.9	87.8	35.4	49.4	-10.0	-15.6	252.5
St Kat Waver	-73.3	46.7	63.6	76.9	27.7	52.0	24.9	-17.4	245.1
Melsbroek	-75.2	64.5	53.7	59.8	29.0	48.1	3.8	-18.3	194.2
Ukkel	-81.4	71.3	69.3	69.2	35.5	58.1	3.2	-17.3	235.3
Beavechain	-84.3	46.6	61.8	54.4	21.0	44.6	-9.7	-13.5	172.0
Assent	-65.8	70.8	64.6	72.3	11.4	46.1	3.3	-15.3	197.7
Tongeren	-73.5	28.6	37.4	42.2	12.4	25.0	-6.1	-8.6	110.9
Kleine Brogel	-78.0	75.9	103.0	86.3	23.7	70.3	19.5	-12.8	302.6

The water balance (rainfall – evaporation) for each weather station is summarized in Table 55, for winter 2009 and in Table 56 for winter 2010 for the most important months during winter. Mostly the water balance is positive for the months October, November, December, January and February. In these months leaching will be the dominant process in the transport of nitrate in the soil profile. By summarizing the period from November to February there are differences between the different weather stations. For winter 2009, the stations in Assent, Beauvechain and Tongeren have a water balance below 200 mm, those in Koksijde and Bottelare above 350 mm. For winter 2010 (Table 56) the water balance is below 200 mm for Koksijde and Beauvechain and almost 300 mm for Moerbeke-Waas and Anvaing. The differences between the weather stations will have an impact on the amount of nitrate leached out of the soil profile for the different parcels of the monitoring network.

Table 56: Water balances (rainfall – evaporation) for the different weather stations for different months and summarized for the period November 2010 to February 2011. Numbers are shown in liter/m².

L/m²	Sep 2010	Oct 2010	Nov 2010	Dec 2010	Jan 2011	Feb 2011	March 2011	Apr 2011	Nov-Feb
Middelkerke	18.2	54.0	83.8	29.5	71.6	25.5	-23.7	-60.5	210.4
Koksijde	34.7	51.9	81.1	36.2	50.2	23.7	-18.3	-48.4	191.1
Beitem	41.7	54.4	105.5	37.1	58.1	22.5	-28.1	-64.6	223.3
Anvaing	59.8	77.2	125.1	58.9	75.0	37.4	-21.3	-55.3	296.4
Semmerzake	60.1	61.1	115.5	35.7	47.2	26.8	-26.3	-73.5	225.2
Kruishoutem	54.9	64.2	105.1	45.1	67.6	27.2	-28.8	-61.9	245.1
Beauvechain	9.9	4.8	97.8	40.7	54.6	4.2	-29.4	-56.2	197.2
Ukkel	56.6	36.1	109.8	69.6	80.3	26.3	-23.4	-56.0	286.0
St Kat Waver	52.1	44.8	107.1	50.1	53.2	16.4	-22.7	-65.3	226.8
Melsbroek	21.2	20.0	88.8	50.6	48.4	13.2	-24.1	-64.5	201.1
Kleine Brogel	33.1	39.6	107.7	66.8	69.2	34.5	-6.1	-53.5	278.2
Bierset	-2.2	4.5	72.8	59.4	65.9	16.2	-30.1	-53.8	214.2
Essen	29.5	83.6	105.7	51.7	71.4	35.8	-22.7	-62.0	264.6
Stabroek	69.9	87.0	104.6	52.8	71.1	31.6	-24.6	-64.2	260.1
Deurne	66.6	61.1	111.1	51.1	57.9	20.5	-26.6	-69.1	240.6
Moerbeke-Waas	82.0	71.5	135.4	61.0	79.5	31.0	-23.9	-68.6	306.9

9.4 Results, winter 2009

The estimation using the Burns model is done for the period from the moment of sampling in November 2009 to 15 February 2010 because on most parcels of the monitoring network a nitrate sample is taken in the first half of February 2010.

The estimation with the Burns model results in an amount of nitrate-N leaching out, for each soil layer of 30 cm. Table 57 shows the average amounts of nitrate-N before and after leaching out the total soil layer (0-90 cm) and for each soil layer of 30 cm separately. Values are given for each soil type. After winter, the lowest levels are present in sandy soils and highest in loam and clay.

Table 57: Average amounts of nitrate-N (kg N/ha) measured in the soil profile before winter 2009 and average amounts of nitrate-N after leaching out as estimated with the Burns model (without corrections for mineralisation and denitrification), separately for different soil types.

	Measured				Calculated (Burns)			
	Nitrate-N (kg/ha) before winter 2009				Nitrate-N (kg/ha) after leaching out			
	0-30 cm	30-60 cm	60-90 cm	0-90 cm	0-30 cm	30-60 cm	60-90 cm	0-90 cm
sand	32.0	27.1	16.2	75.3	1.7	4.4	7.6	13.7
sandy loam	46.0	27.0	15.9	88.9	6.7	13.6	16.1	36.3
loam	55.1	29.8	13.3	98.2	11.4	19.1	18.7	49.1
clay	44.2	47.9	24.1	116.2	9.9	22.1	24.9	56.9

For this first analysis no corrections for mineralisation and denitrification are considered because the period from November to February was cold (less mineralisation) and relatively short (less denitrification). In the next step those 2 factors are taken into account.

In Table 58 the estimated values of nitrate-N are shown when a correction for mineralisation and denitrification is taken into account. When we compare these results with the values measured in February 2010, values calculated with the Burns model are mostly lower. This difference is largest for sandy soils. On sandy and sandy loam soils the estimation with the Burns model results in a large leaching out of nitrate for the first soil layer (0-30 cm). The calculations with the Burns model are an underestimation of the effective measured nitrate in the soil profile after winter, certainly in sandy soils.

Table 58: Average amounts of nitrate-N (kg N/ha) estimated with the Burns model for different soil types, including mineralisation and denitrification. The average amounts of nitrate-N (kg N/ha) measured in spring 2010 are also given.

mineralisation	Nitrate-N (kg/ha) after leaching out (BURNS)			
	0-30 cm	30-60 cm	60-90 cm	0-90 cm
sand	2.8	6.7	10.6	20.1
sandy loam	10.1	18.6	20.7	49.4
loam	16.3	25.2	23.3	64.7
clay	15.2	28.5	29.6	73.3

mineralisation and denitrification	Nitrate-N (kg/ha) after leaching out (BURNS)			
	0-30 cm	30-60 cm	60-90 cm	0-90 cm
sand	2.8	6.7	10.6	20.1
sandy loam	10.1	18.6	20.7	49.4
loam	16.3	25.2	23.3	38.1
clay	15.2	28.5	29.6	43.1

measured	Nitrate-N (kg/ha) in spring 2010			
	0-30 cm	30-60 cm	60-90 cm	0-90 cm
sand	15.0	12.5	12.5	40.0
sandy loam	16.9	13.3	13.8	43.9
loam	20.6	15.1	12.5	48.2
clay	18.5	17.3	15.5	51.3

During leaching out, 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. When only leaching out is considered, most of the nitrate-N in the soil profile after winter is present in the soil layer from 60 to 90 cm. The result of the Burns model is an amount of nitrate leaving the upper soil layer and enriching the lower soil layer. 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 for winter 2009 are summarized in Table 59.

Table 59: Results of the calculations by the Burns model in comparison with measured amounts of nitrate-N (kg/ha) in the soil profile, for winter 2009. Numbers are given separately for different soil types.

			Calculated with the Burns model (Nitrate-N kg/ha)			Measured
Soil	n	D	Percentage nitrate after winter, in the soil profile	Calculated after winter (without mineralisation)	Calculated after winter (including mineralisation)	Measured nitrate after winter
Sand	67	Y	31	15	22	38
Sand	61	N	23	12	17	40
Sandy loam	29	Y	54	30	42	42
Sandy loam	34	N	57	42	56	48
Loam and Clay	9	Y	66	81	99	55
Loam and Clay	19	N	63	39	55	47

D = derogation; Y = yes N = no

The amount of nitrate leaching out of the soil profile (0 to 90 cm) depends on different factors. One important factor is the amount of nitrate present in the soil profile before winter. The correlation between the nitrate present before winter and the amount of nitrate leaching out (estimated with Burns model) is shown in Figure 79.

Higher levels of nitrate-N before winter result in higher levels of nitrate that leach out the soil profile. If there is a higher amount of nitrate-N present in the deeper soil layers (60 to 90 cm), more nitrate-N will leach out the soil profile.

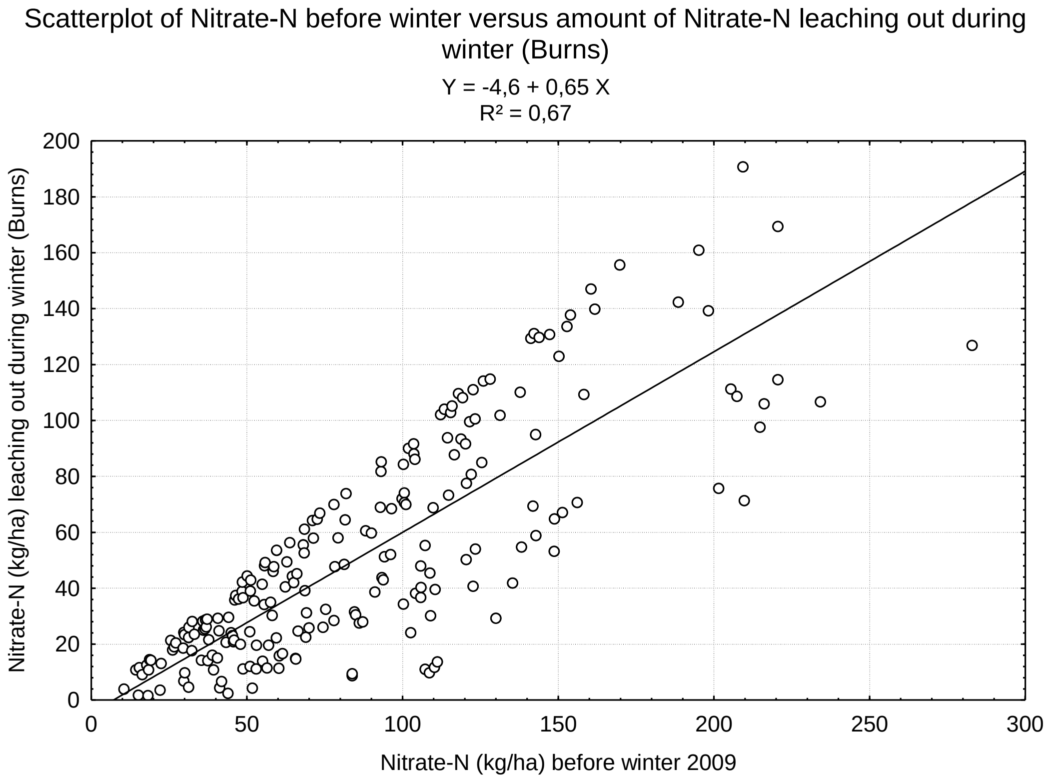

Figure 79: Nitrate-N (kg/ha) before winter versus the amount of nitrate-N (kg/ha) leaching out the soil profile (0-90 cm) during winter 2009 as estimated with the Burns model.

Another determining factor is the amount of rainfall during winter. Without rainfall there will be no leaching out of nitrate. Together with the amount of nitrate in the soil profile before winter, the amount of rainfall during winter and the soil texture are 3 very important factors for leaching.

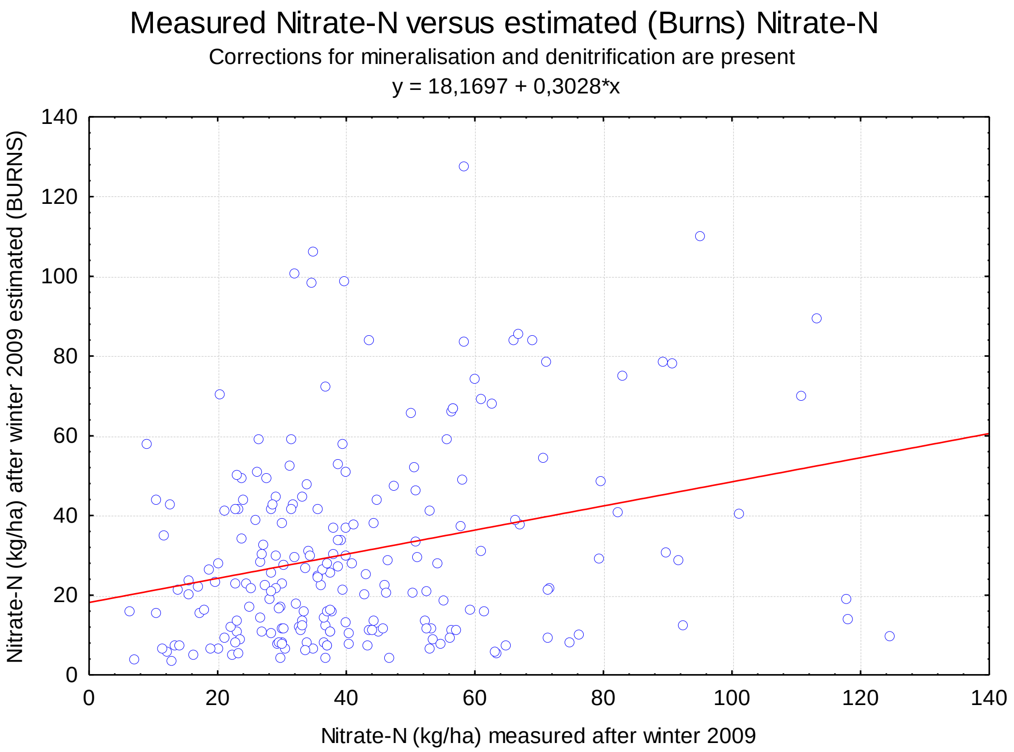

Figure 80: Scatter plot of Nitrate-N (kg/ha) measured after winter 2009 versus the Nitrate-N (kg/ha) estimated by the Burns model with corrections for mineralisation and denitrification.

Figure 80 illustrates the relation between the measured and the estimated amount of Nitrate-N (kg/ha) with the Burns model, after winter 2009. For this, corrections for mineralisation and denitrification were taken into account. When we compare these results, the Burns model makes an over estimation of the leaching of nitrate-N. This was also seen with the means in Table 58. The correlation in Figure 80 is not very high.

It is interesting to investigate if there are differences between the estimated values of leaching between derogation and no derogation parcels. Therefore a statistical analysis is done for the different parcels of the monitoring network. Firstly, differences are investigated for all parcels. Consequently, differences are investigated for each soil type separately. For the statistical analysis the log transformed data are used. No significant differences are found between derogation and no derogation parcels. There is a large variation between the estimate values, as can be seen from Figure 81.

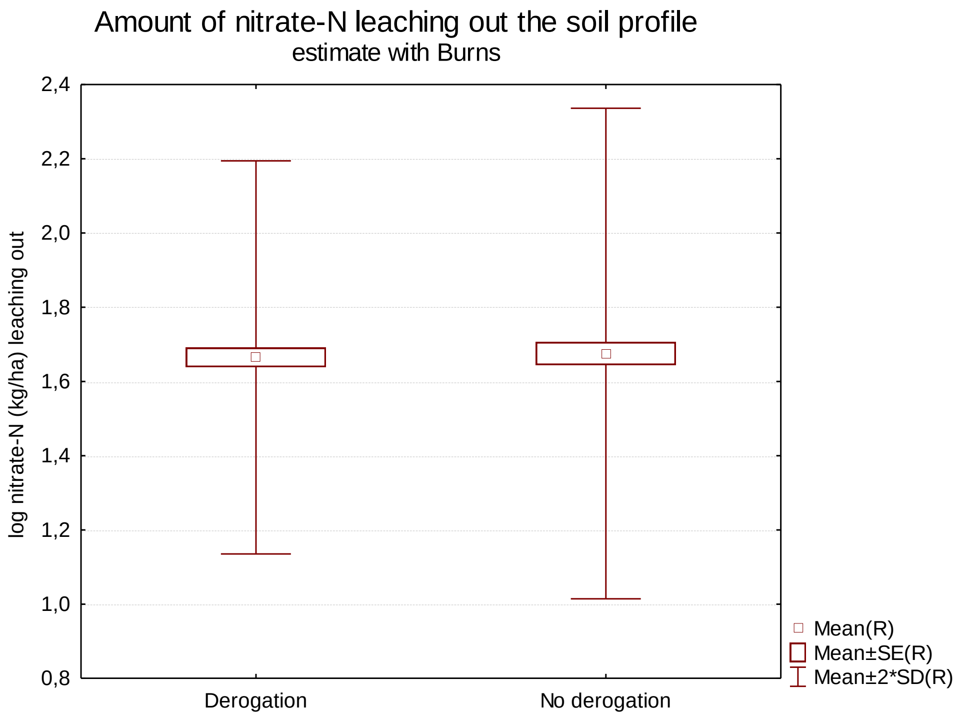

Figure 81: Box plot of log nitrate-N (kg/ha) leaching out the soil profile, estimate with the Burns model for derogation and no derogation parcels during winter 2009.

In the next step, differences are investigated for different combinations of soil type and cultivated crop. This is not possible for all combinations. For the most important combinations (grass and maize with sandy and sandy loam soils) no significant differences were found between derogation and no derogation parcels for the amount of nitrate-N leaching out the soil profile.

Because the amount of nitrate leaching is different for the different soil layers the previous analyses were repeated for each soil layer separately. For none of the soil layers significant differences were observed for the amount of nitrate-N leaching out the soil profile. Apparently other parameters have a more important influence on leaching out than derogation. These parameters are for example soil type and the amount of nitrate present in the soil profile before winter.

9.5 Comparisons for winter 2009

9.5.1 Amount of Nitrate leaching out

In the previous paragraphs results of the Burns model are evaluated based on the amount of nitrate still present in the soil profile after winter 2009. In the next figures the amount of nitrate leached out the soil profile is evaluated.

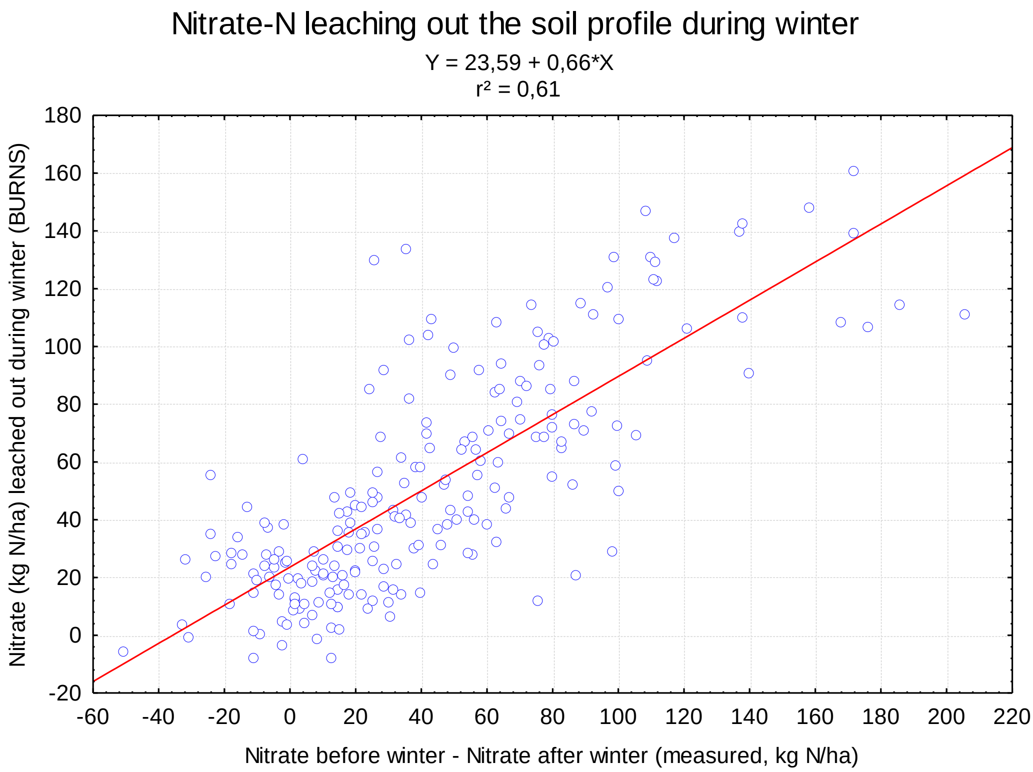

Figure 82: Amount of nitrate-N (kg N/ha) leaching out the soil profile estimated with the Burns model versus the difference between the amount of nitrate-N measured before and after winter 2009.

In Figure 82 the amount of nitrate leached out the soil profile as estimated with the Burns model (including corrections for mineralisation and denitrification) is compared with the difference between the nitrate measured before and after winter 2009. In this way it is possible to evaluate the calculations from the Burns model. There is a positive correlation between both. The r^2 is 0.61; this value is 0.55 when only mineralisation is taken into account and 0.64 if no corrections are used for denitrification and mineralisation. Better correlations between measured and estimated values of nitrate leaching out the soil profile are possible when making the same analysis for different soil types separately. The best correlation is possible for sandy soils (no correction for denitrification), with an r^2 of 0.71 (Figure 83). On sandy soils denitrification is less important and has not taken into account.

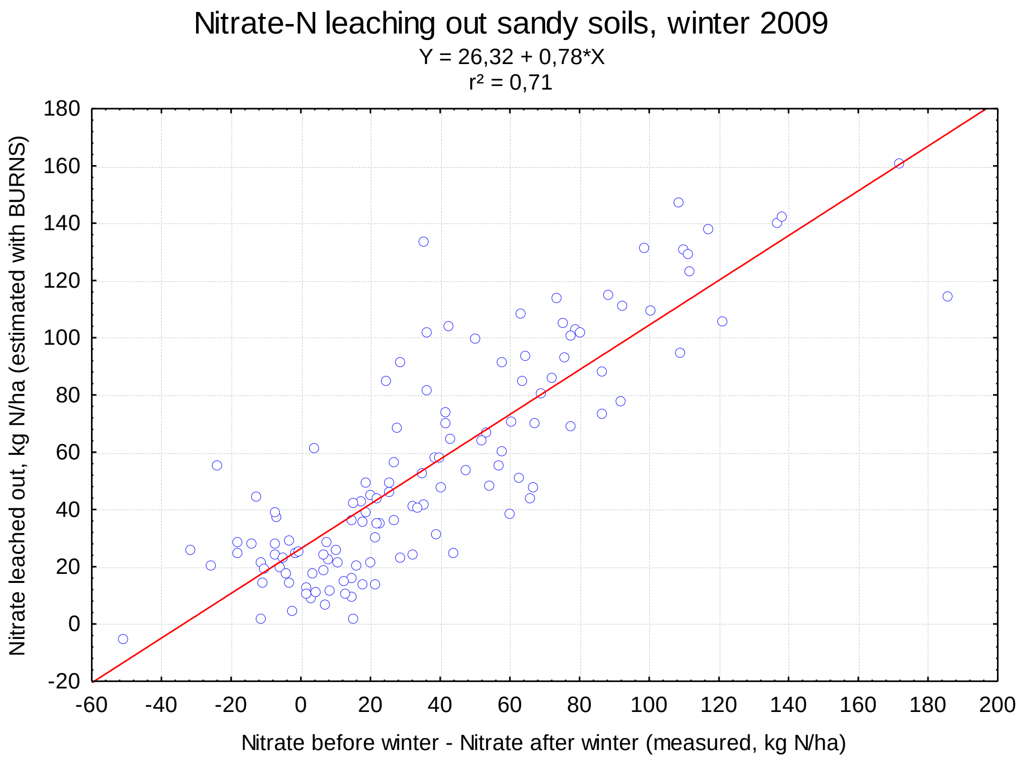

Figure 83: Amount of nitrate-N (kg N/ha) leaching out the soil profile estimated with the Burns model versus the difference between the amount of nitrate-N measured before and after winter 2009 for sandy soils.

9.5.2 Nitrate in the soil water

For some parcels in the network a soil sample is taken from the deep soil layers (90-120 cm and 120 to 150 cm). For these soil layers the amount of nitrate was calculated as a concentration. The estimation with the Burns model is an amount of nitrate leaching out of the soil profile from 0-90 cm. In this paragraph, the relation between the estimated amount of nitrate leached out of the soil profile (Burns model) and the amount of nitrate measured in the deeper soil layers is investigated. The correlation between the estimated (Burns) amount of nitrate leached out the soil profile (-90 cm) is higher with the amount of nitrate (in the deeper soil layers) present before winter than after winter 2009 (Figure 84 and Figure 85). From previous paragraphs it is known that higher levels of nitrate present before winter in the soil profile (0 to 90 cm) results in higher levels of nitrate present in the soil layers from 90 to 150 cm. Higher levels of nitrate in the soil profile (0 to 90 cm) are positively correlated with the amount of nitrate leaching out during winter. The correlation between the amounts of nitrate leached out of the soil profile is not very strong with the concentration of nitrate in the soil water after winter 2009 (Figure 85).

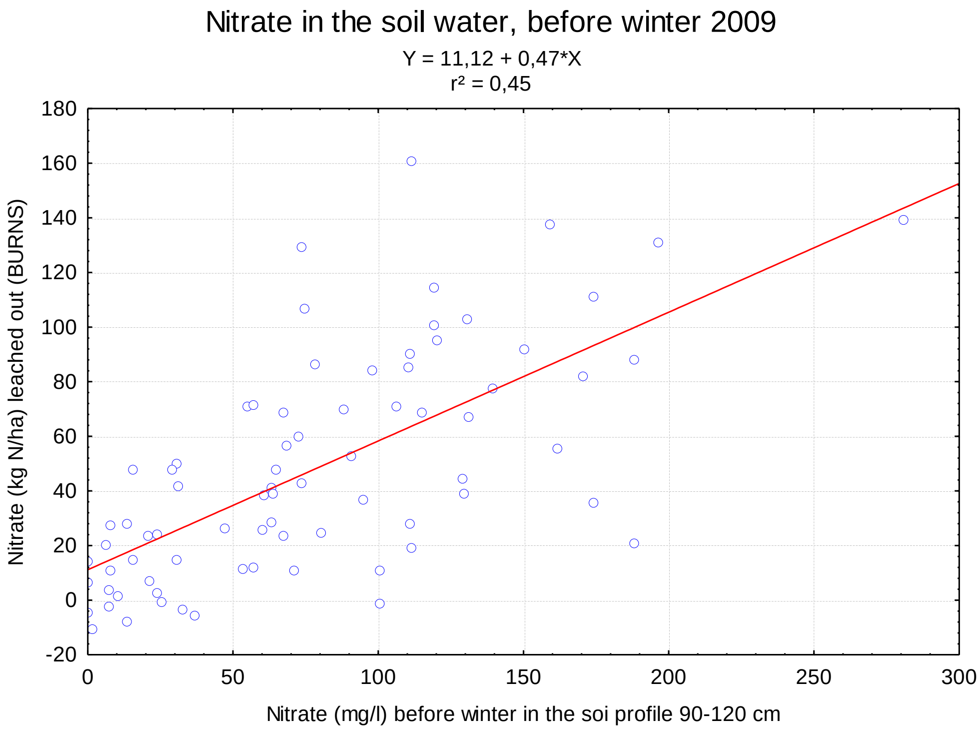

Figure 84: Comparison between the amount of nitrate (kg N/ha) leaching out the soil profile during winter, as estimated with the Burns model, against the amount of nitrate (mg/l) present in the soil water before winter 2009.

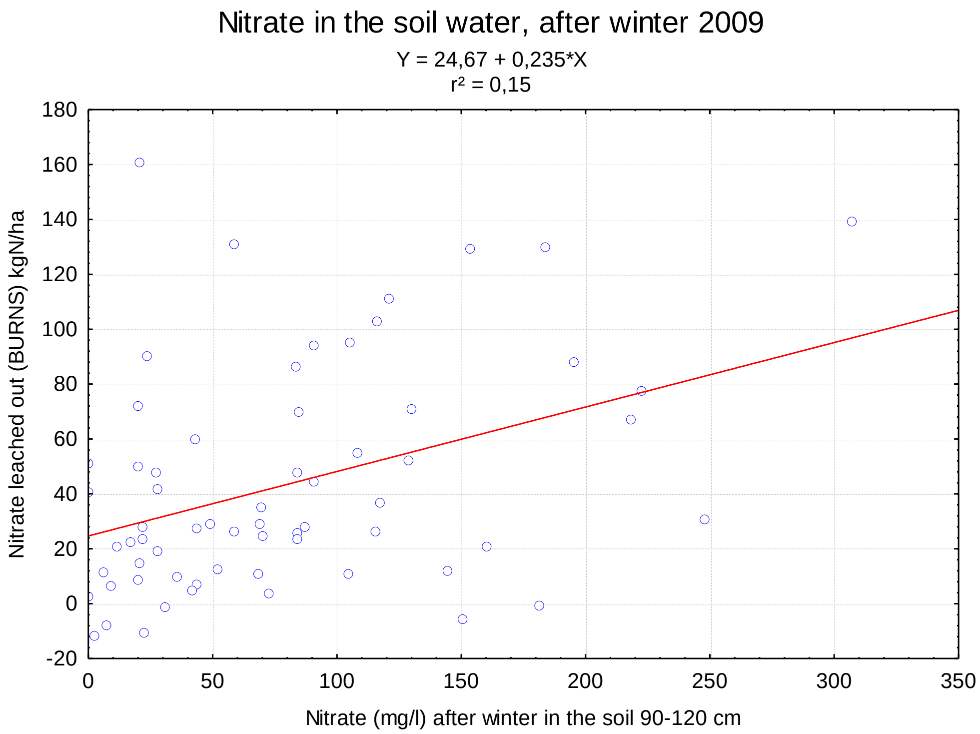

Figure 85: Comparison between the amount of nitrate (kg N/ha) leaching out the soil profile during winter, as estimated with the Burns model, against the amount of nitrate (mg/l) present in the soil water after winter 2009.

9.6 Results, winter 2010

For winter 2010 identical analyses were carried out as for winter 2009. Calculations with the Burns model result in an amount of nitrate in the soil profile after winter for each soil layer of 30 cm. The amount of nitrate-N leached out the soil profile during winter is calculated with the Burns model. This calculation is done for every parcel in the monitoring network and can be compared with the measured amount of nitrate before winter 2010 reduced with the measured amount of nitrate in the soil profile after winter 2010. This comparison is shown in Figure 86, without corrections for mineralisation. The R^2 value for this comparison is 0.776. To obtain better results, some corrections for mineralisation are taken into account. These corrections are specific for each parcel in the network, with soil texture and percentage carbon as important parameters.

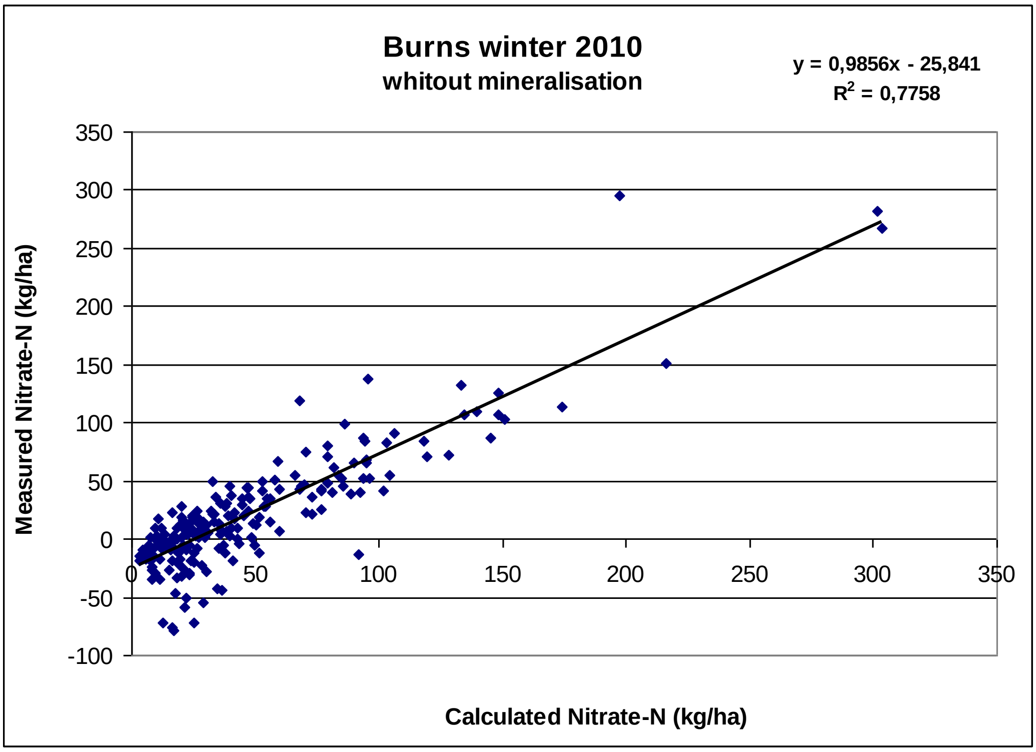

Figure 86: Measured (amount of nitrate before winter in the soil profile – amount of nitrate after winter) amount of nitrate-N (kg N/ha) leached out during winter 2010 versus calculated (Burns model) amount of nitrate-N (kg N/ha) leached out during winter 2010.

Results from calculations including mineralisation are shown in Figure 87. The R^2 of the equation is higher than for Figure 86 (no corrections for mineralisation). The positive results from the Burns model confirm the leaching during winter. When comparing the measured amounts of nitrate before and after winter also negative results are present. For these parcels other processes, like mineralisation, are very important.

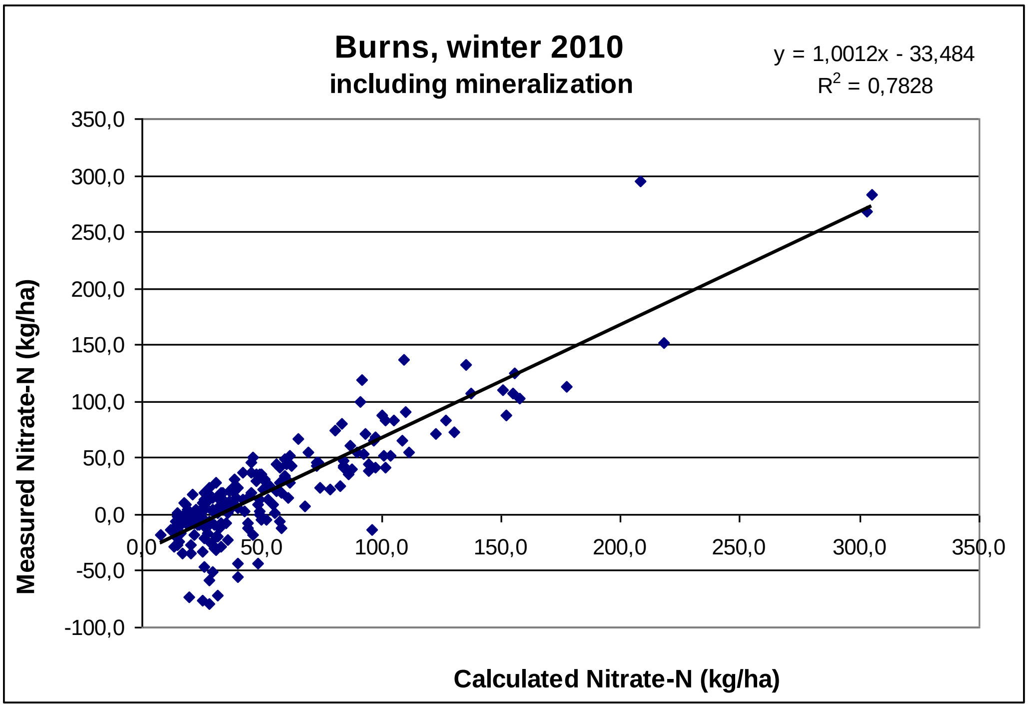

Figure 87: Measured (amount of nitrate before winter in the soil profile – amount of nitrate after winter) amount of nitrate-N (kg N/ha) leached out during winter 2010 versus calculated (Burns model) amount of nitrate-N (kg N/ha) leached out during winter 2010, including corrections for mineralisation.

Results of the calculations with the Burns model for winter 2010 are summarised in Table 60. Difference is made between soil type and derogation condition. Table 60 shows amounts of nitrate measured in the soil profile after winter, the values of nitrate after winter calculated with the Burns model and the calculated values with the Burns model including corrections for mineralisation.

Table 60: Results (percentage and nitrate-N, kg/ha) of the calculations by the Burns model in comparison with measured amounts of nitrate-N (kg N/ha) in the soil profile, for winter 2010. Numbers are given separately for different soil types and derogation.

			Calculated with the Burns model (Nitrate-N kg/ha)			Measured
Soil	n	D	Percentage nitrate after winter, in the soil profile	Calculated after winter (without mineralisation)	Calculated after winter (including mineralisation)	Measured nitrate after winter
Sand	75	Y	19	9	26	37
Sand	72	N	18	11	28	46
Sandy loam	26	Y	44	24	37	34
Sandy loam	32	N	45	32	39	48
Loam and Clay	7	Y	59	25	44	73
Loam and Clay	13	N	56	32	48	51

D = derogation; Y = yes N = no

It seems that calculations on sandy soils result in an overestimation of the leaching process. More leaching is calculated with the Burns model than effectively measured. For parcels with a soil texture loam and clay, the calculations are sometimes less good in comparison with calculations for the soil texture sandy loam. In the first column also the percentage of nitrate still present in the soil profile after winter is shown in relation to the amount of nitrate present in the soil profile before winter 2010. It is clear that proportionally more nitrate leaches out on sandy soils and less on loamy or clay soils.

For this investigation it is important to know if differences are present between derogation and no derogation parcels. Therefore a statistical analysis is carried out. When comparing the calculated amount of nitrate leaching out the soil profile no significant differences were found ($p=0.29$) between derogation and no derogation parcels. When only considering sandy soils the p value is 0.37 and therefore there is no significant difference in leaching out of nitrate from the soil profile between derogation and no derogation parcels, for winter 2010.

9.7 Analytical model

During the same period as the derogation study another study, 'Procesfactoren' (Van Overtveld *et. al,* 2011*)* was carried out by the same consortium. During this study the leaching of nitrate from the soil profile (-90 cm) during winter period was calculated with different models.

The model used in the 'Procesfactoren' study is a statistical model. Therefore, the flushing out of nitrate from the soil profile (at -90 cm) is calculated by the analytical solution of a convection-dispersion equation. This equation describes the transport of nutrients like nitrate, solved in the soil water. The solution of the equation gives the amount of nitrate leaching out the soil profile below 90 cm, calculated from the nitrate residue. Besides the nitrate residue before the winter period, the water balance (rainfall – evaporation), soil texture, groundwater level and deep soil characteristics are the most important input factors for the analytical model. In this paragraph the calculations with the analytical model are compared with calculations from the Burns model, for the parcels in the monitoring network.

Also for the analytical model, calculations are carried out separately for corrections with and without mineralisation. The results for winter 2010 are shown in Figure 88 and Figure 89. Results from both models are very similar, which confirms the levels of nitrate leaching out of the soil profile as calculated with the Burns model.

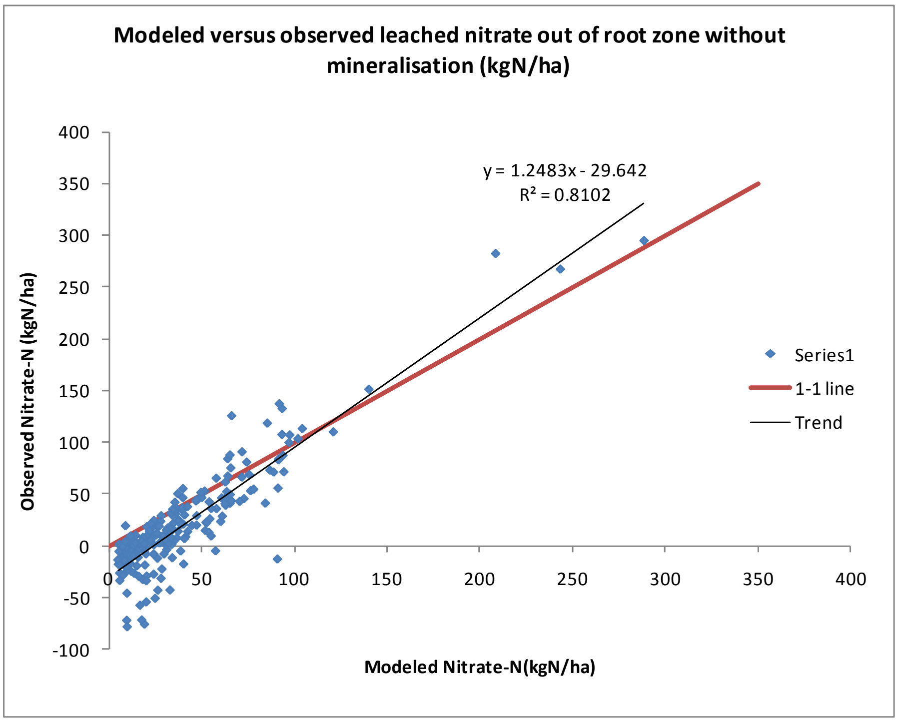

Figure 88: Observed (nitrate residue before winter reduced with nitrate measured in the soil profile after winter) versus modelled (with the analytical model) levels of nitrate leaching out of the root zone for winter 2010, no corrections for mineralisation were made in the model.

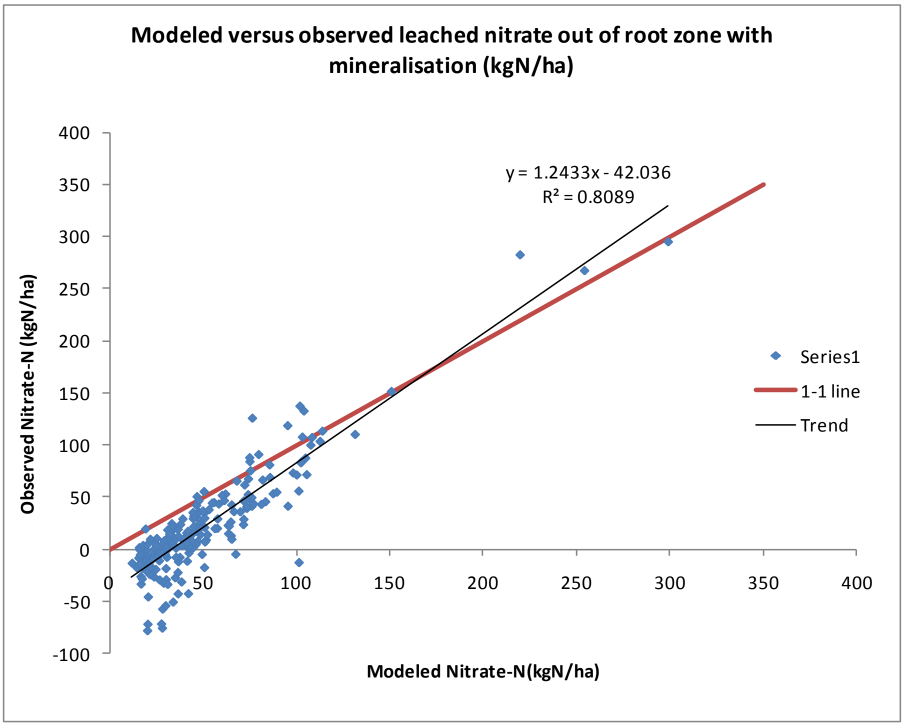

Figure 89: Observed (nitrate residue before winter diminished with nitrate measured in the soil profile after winter) versus modelled (with the analytical model) levels of nitrate leached out of the root zone for winter 2010, corrections for mineralisation were made in the model.

9.8 Conclusions

Both models (Burns model and analytical model) are good tools to estimate the amount of nitrate present in the soil profile after a winter period. No large differences are present between the 2 models.

When comparing the amounts of nitrate measured after a winter period with calculated (Burns or analytical model) values of nitrate, results of the models are good when comparing mean values for all parcels or mean values for a group of parcels with the same soil type. For the soil type sand, modelled values of nitrate are mostly an overestimation, larger levels of nitrate-N are measured in the soil profile in comparison with calculated values.

For individual parcels, large differences between calculated and measured levels are sometimes present. For parcels with large differences between calculated and measured levels of nitrate, leaching is not the only important process. Denitrification and especially mineralisation will be very important on these parcels. Denitrification will be important for loamy soils and parcels with soil texture clay. Mineralisation is very important for parcels with higher levels of carbon.

10 Nutrient balance

For each parcel in the monitoring network a nutrient balance is calculated. By the calculation of a nutrient balance measurements of nitrate residue levels and concentrations in water samples will be explained, not all of them because not all processes in the soil are completely known. This is certainly the case for the mineralization and also for denitrification and deposition. Anyway these calculations could provide useful information to investigate the differences between derogation and no derogation parcels. Two different approaches are used to calculate a nutrient balance: the input/output balance and a nitrogen-soil balance.

10.1 Input/output balance

This first approach is a balance where the difference is made between the effective input of nutrients on the level of a single parcel with the effective output of nutrients. This is shown in Figure 90. The input consists of organic and mineral fertilizers as well as atmospheric deposition. The most important output factor is the harvested crop, since this is the way nutrients are exported from the field. Also considered emission losses during application of organic fertilizers, are an output factor. The balance result of this approach will be an indicator for the enrichment or uptake of nutrients from the soil profile.

Input	Output
Organic fertilizers	Harvested crop
Mineral fertilizers	Emission during fertilisation
Atmospheric deposition	
Balance = input - output	

Figure 90: Schematic presentation of the nutrient balance for the input/output method.

10.1.1 Organic and mineral fertilizer

Information about the fertilisation on the level of the different parcels is discussed earlier in paragraph 3.2.2. The results for the growing season 2010 are shown in Table 33. The total amount of supplied nutrients (N and P) as well as the different fractions (mineral, organic and organic by grazing cattle) is given separately for derogation and no derogation parcels and for each cultivated crop.

10.1.2 Atmospheric deposition

For all the parcels in the monitoring network atmospheric deposition occurs during the season. This atmospheric deposition has the same level for all parcels in the monitoring network and has a value of 30 kg N/ha each year.

10.1.3 Emission losses

During application of organic manure some emission losses will occur. Therefore the method of fertilization is the most important parameter. These emission losses are discussed in detail in paragraph 3.1.1 and shown in Table 35.

10.1.4 Export by the harvested crops

The most important factor for exporting nutrients is the harvest of the cultivated crops. For all cultivated crops the yield consists of an amount of dry matter. For each kilogramme of dry matter the amount of nutrients (N and P) is known. So based on data about dry matter content of the yield for each parcel, the exported nutrients can be calculated. The most important data is the yield for each parcel. These data are reported by the participating farmers.

Table 61: Amount of nitrogen and phosphorous 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".

		Dry matter (DM)		Yield weight		
		N/ton DM	P/ton DM	N/ton yield	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 62: Amount of nitrogen and phosphorous exported by the harvest of silage maize (above-ground) for different classes of yield.

Yield (above-ground)	N (kg/ha)	P (P_2O_5/ha)	Dry matter (kg/ha)
Very poor	200	82	16.7
Poor	220	90	18.3
Good	240	98	20
Very good	260	106	21.7

For winter wheat, sugar beets, potatoes and corn maize the yield was mostly given in an amount of kilogramme for each parcel. By using Table 61 an amount of kilogramme nitrogen and phosphorous exported by the cultivated crops can be calculated for each parcel. For silage maize the exact kilogramme for each parcel is not always available, farmers do not know this in a lot of cases. The silage maize is harvested and stored together for many parcels. In some cases an exact kilogramme is known but for the other parcels it's an estimation and yield classes are used to estimate the yield of the different parcels. Therefore the numbers in Table 62 are used.

Another difficult crop to estimate the yield is grassland. For grassland some different possibilities are present (cutting, cutting and grazing cattle or only grazing cattle). Farmers give the required information. When cutting the grassland 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 63) are used.

Table 63: Amount of nitrogen and phosphorous exported by the grassland (above-ground) for each cutting with a specific level of yield.

Yield	dry matter (kg/ha)	kg N	Kg P_2O_5
Very poor	2000	60	17.4
Poor	2500	75	21.8
Good	3000	90	26.1
Very good	3500	105	30.5

- When cutting is the only practice, the total yield on the parcel is the sum of the yields of every single cutting. When not all necessary information is known, total yield is compared with the yield in Figure 91. The graph show the relation between fertilization, agricultural practice (cutting or grazing cattle) and yield based on data from field experiments. This agricultural practice (only cutting the grassland) has the highest yield, in comparison with cutting and grazing cattle.

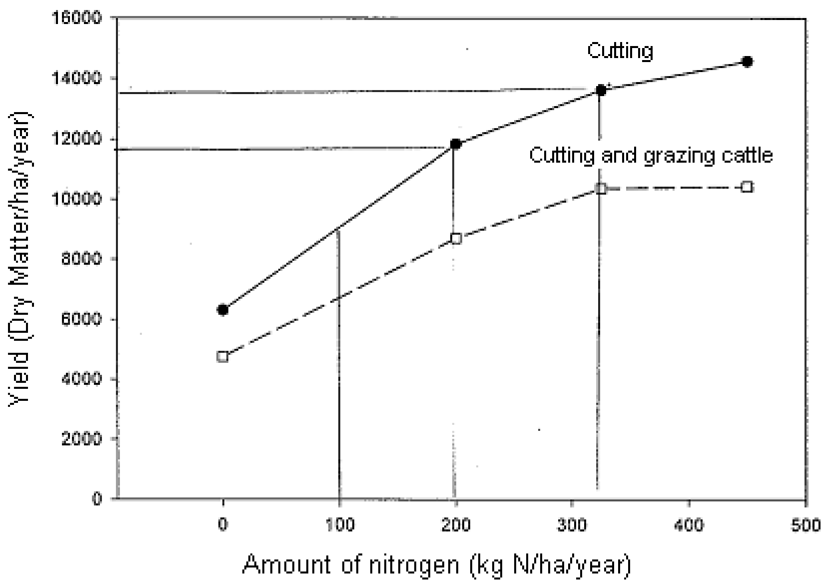

Figure 91: Different levels of yield in relation to N-fertilization rate, based on data from SSB.

- When the grassland is cut one time and then grazed by cattle, yields reach a lower level. The first cut has the same export numbers as in Table 63. When the grazing cattle grazes only a few days on the parcel, this period can be seen as a cut of the grassland and the same numbers as in the table are used. When the grazing cattle remains on the parcel for a whole season, export numbers are compared with those in Figure 91 based on the parcel information (from the farmers).
- When the grassland is only grazed by cattle, a difference is made between grazing for a whole season or grazing for a couple of days and this several times each year. In the last case every period is a cut and numbers of export are taken from the table, in the other case numbers from Figure 91 are taken.

It is not very easy to use exact yield data for grassland (especially when the parcel is only grazed). By distinguishing intensively used parcels (only cutting) and more extensive parcels (grazing cattle) based on the information from farmers (number of cuttings, periods of grazing, number of animals, sort of animals, yield of the grassland and fertilization) together with field experiments, a valid attempt was made to differ between the different parcels.

Besides the cultivated crop, nutrient export is also possible by the catch crop sown after harvest. To estimate the nutrient take up by the catch crop Table 64 is used.

Table 64: 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)

Table 65: Average levels of nutrients (kg/ha) exported from the parcels by the cultivated crops or the catch crop. Levels are separately given for derogation and no derogation crops.

	Export of nutrients by the harvested crop					
	N crop	P_2O_5 crop	N grass cutting or catch crop	P_2O_5 grass cutting or catch crop	N total	P_2O_5 total
	Derogation parcels					
Winter wheat	193	76	20	6	213	82
Fodder maize	239	100	78	23	317	122
Grassland	356	103			356	103
	No derogation parcels					
Winter wheat	205	80	26	8	232	88
Fodder maize	229	97	21	6	250	103
Corn maize	142	71	11	3	153	74
Grassland	259	75			259	75
Potatoes	171	48	1	1	172	49

Table 65 shows export levels (for N and P_2O_5) for derogation and no derogation parcels for different cultivated crops. Some important conclusions can be made. The export levels for maize and grassland are higher on derogation parcels. From Table 33 it is known that for these combinations of cultivated crop and derogation the fertilization of nitrogen and phosphorous was also higher in comparison with no derogation parcels. The higher input of nutrients on derogation parcels in combination with higher export levels can be an explanation that there are no differences in nitrate residue levels between derogation and no derogation parcels. In 2010 the average yield for potatoes in Flanders was on a lower level (rainfall conditions), resulting in lower export numbers for nitrogen and phosphorous.

10.1.5 Balance result

When taking all previous factors (fertilization, atmospheric deposition, yield and emission losses) into account for each single parcel the balance difference can be made between input and export. Results are very variable; some parcels have positive values for the balance and others negative. In relation to the nitrate residue, it is possible to investigate if there are differences between derogation and no derogation parcels in general and for specific combinations of soil type and cultivated crops. When comparing average figures of the balance for specific combinations of soil type and cultivated crop, no statistical significant differences can be found between derogation and no derogation parcels.

Only looking at the amount of nutrients supplied on the different parcels resulted in a low correlation with the nitrate residue or water quality. By making the comparison between the balance result and the nitrate residue this correlation is stronger. This is logical because a higher fertilization (higher input) in combination with a higher yield (higher output) results in normal levels of nitrate residue.

Table 66: Balance result (input-output) for the most important derogation and no derogation crops.

	N (input-export)	P_2O_5 (input-export)	Nitrate residue
		Derogation	
Winter wheat	121	-39	40
Fodder maize	3	-40	77
Grassland, only mowing	39	-21	38
Grassland, mowing and grazing	75	-14	47
		No derogation	
Winter wheat	64	-45	49
Fodder maize	12	-26	82
Corn maize	72	7	59
Grassland	30	-8	43
Potatoes	109	21	90

Table 66 shows a negative balance result for phosphorous for all combinations except for potatoes and corn maize. When looking to individual parcels the correlation between nitrate residue and the balance result is not very strong (Figure 92). Possibly some processes not taken into account in this balance model are important to link the nitrate residue to the fertilization on the level of the parcels. These processes are discussed in the next paragraph (nitrogen/soil balance).

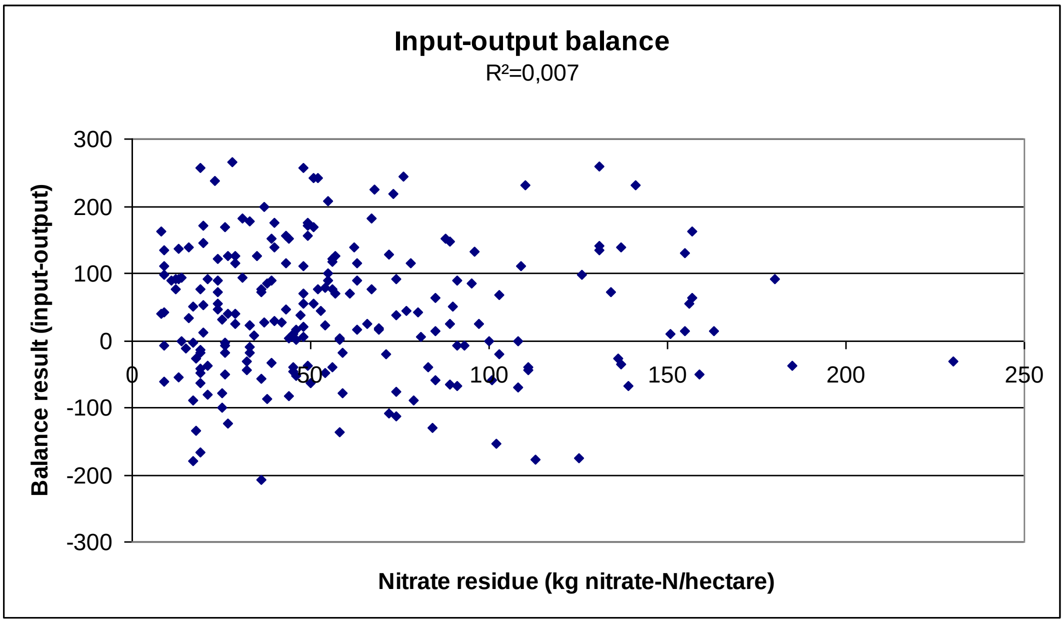

Figure 92: Balance result (input – output) versus nitrate residue for the growing season of 2010 for all parcels in the network.

10.2 Nitrate-N/soil balance

In this second approach the nitrate-N in the soil profile is monitored during the growing season, starting with the amount of nitrate at the beginning of the season (measured between 1 and 15 February) and ending with the nitrate residue at the end of the season (measured between 1 October and 15 November).

Table 67: Schematic presentation of the different factors which influence the nitrate-N evolution in the soil profile during the growing season.

Input	Output
N in soil profile in February	N uptake by cultivated crop
N from mineral fertilizer	Leaching out of N
N from organic fertilizer	N in soil profile end season (nitrate residue)
N from atmospheric deposition	
Mineralization (organic matter)	
input – output = balance result	

Different processes during the season are taken into account (Table 67). For each process only the efficient amount of nitrogen is taken into account. For example, for organic fertilization not the total nitrogen is taken into account but only the part that is available for the cultivated crop during the first year after application (mineral fraction and part of the organic fraction available after mineralization).

10.2.1 Nitrate in the soil profile (before the growing season)

The starting point for the nitrogen/soil balance is the nitrate in the soil profile before the new growing season. The nitrate is measured on all parcels of the monitoring network at the beginning of 2010 (between 1 and 15 February). The samples are taken from 0 to 90 cm in three layers. The results (statistical analysis between derogation and no derogation parcels) of these measurements were discussed earlier. Mostly, at this moment fertilizers are not yet applied to the fields. This nitrate sample gives information about the amount of nitrogen in the soil profile available for the cultivated crop. Based on some additional information (agricultural practice, cultivated crop, mineralization, leaching …) farmers receive a fertilization advice for their parcels.

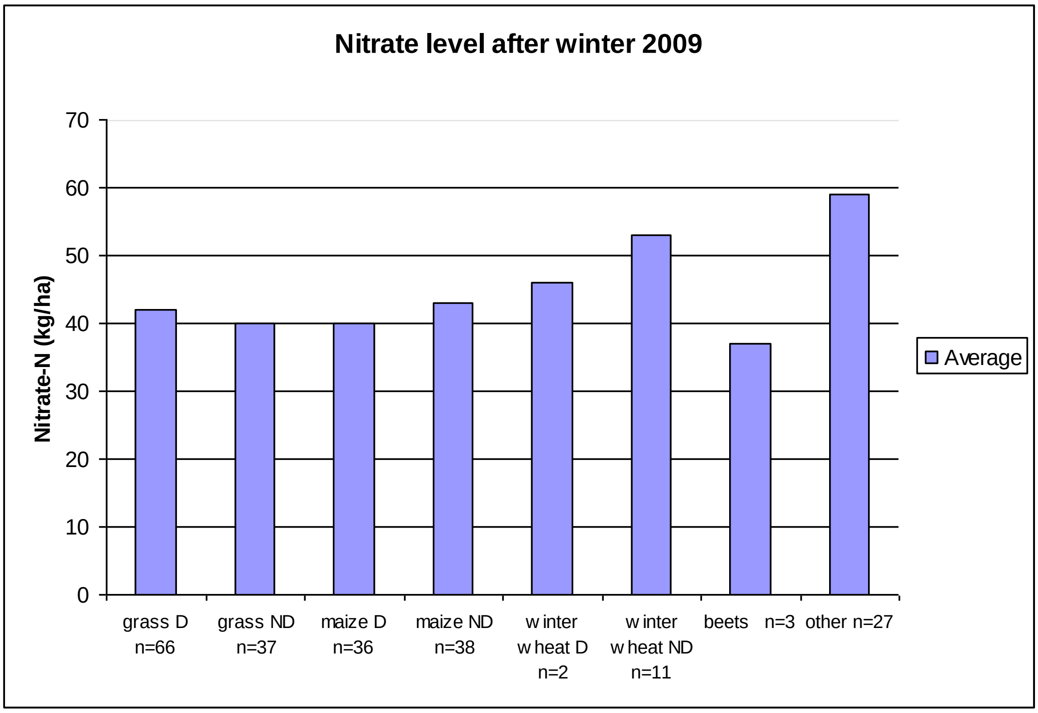

Figure 93: Nitrate level after winter 2009 for different cultivated crops with (D) or without (ND) derogation. Average levels of nitrate-N (kg/ha) are shown.

Figure 93 shows no large differences between average levels of nitrate after winter 2009 for the different combinations of cultivated crop and derogation condition. The statistical analysis already indicated that no significant differences were present between derogation and no derogation parcels both in general and for specific combinations of cultivated crop and derogation condition. The average level of nitrate ranges between 37 and 59 kg nitrate-N/ha. For most combinations the variation between individual parcels is large.

The importance of the level of nitrate present in the soil profile at the start of the growing season is shown in Figure 94. Higher levels of nitrate in the soil profile at the start of the growing season result in lower fertilization advices. This correlation shows the importance of sampling the soil profile at the start of the growing season and the value of a parcel specific fertilization advice. Because also other, parcel specific, factors are important (mineralization, fertilization history, cultivated crop …) the correlation in Figure 94 is not very strong ($R^2 = 0.21$).

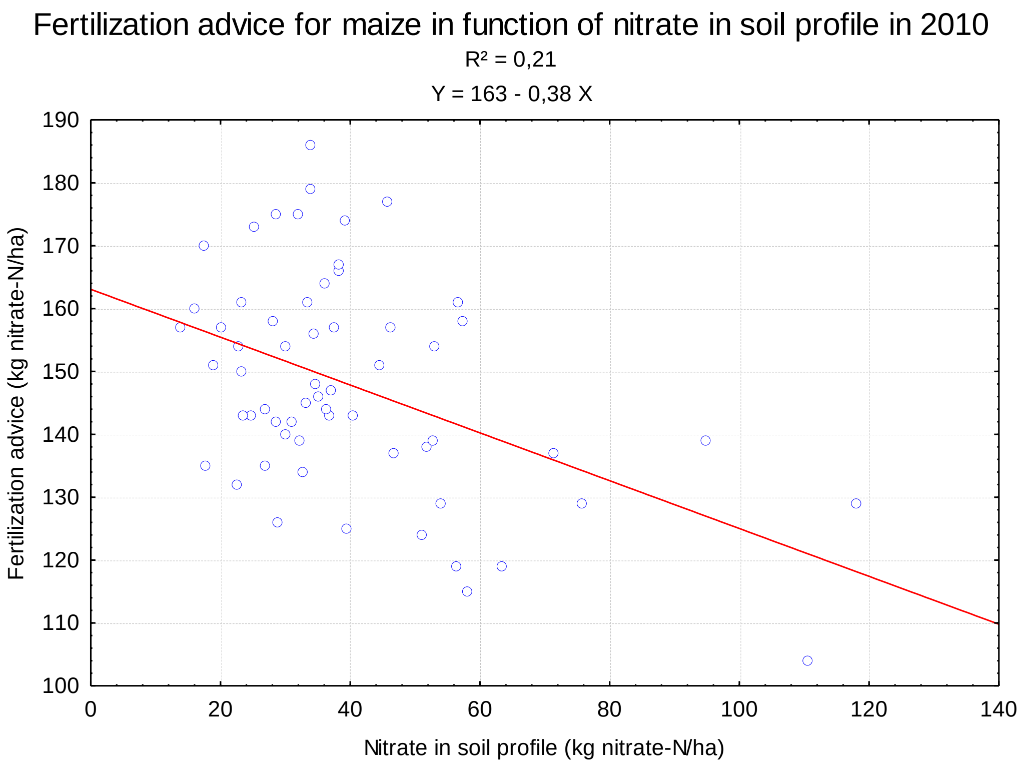

Figure 94: Scatterplot of fertilization advice (for parcels cultivated with maize in 2010) in function of nitrate in the soil profile (0-90 cm) before growing season 2010.

10.2.2 Fertilisation (organic and mineral)

A very important factor is the amount of nitrogen that will become available during the growing season originating from organic (organic fertilizers and grazing cattle) and mineral fertilisation. In the first approach (input/output balance) the total amount of nitrogen supplied on the parcels was taken into account. For this second approach plant available amounts of nitrogen during the first year after application of the fertilizer are important, this is the efficient nitrogen. For organic fertilizers, information about the efficient nitrogen is present in the analysis report of the manure samples (taken by SSB for the different types of organic manure). In general a working coefficient of 60 % is used to calculate the plant available nitrogen from animal manure or other organic fertilizers. For solid manure a working coefficient of 30 % is used. For excretion by grazing cattle, a working coefficient of 20 % is used. For mineral fertilizers a working coefficient of 100 % is used. Besides the working coefficient, the total amount of nitrogen measured in the manure is used to calculate the amount of efficient nitrogen.

Levels of efficient nitrogen supplied on the parcels in 2010 are presented in Table 68 for the different cultivated crops and separately for derogation and no derogation parcels. Derogation parcels cultivated with grass or maize are characterized by higher amounts of efficient nitrogen in comparison with no derogation parcels (cultivated with the same crop). It is important to mention that on derogation parcels cultivated with maize one grass cutting is harvested before the maize is sown.

Table 68: Average nutrient input by fertilization; total N, total P_2O_5 and efficient N (kg/ha) for derogation and no derogation parcels by fertilization in 2010. Values are separately given for the different cultivated crops.

Nutrient input	Total input		Efficient N
	N (kg/ha)	P_2O_5 (kg/ha)	N (kg/ha)
Derogation parcels			
Grass, grazing cattle	**400**	**88**	**282**
Grass, only mowing	**375**	**85**	**282**
Maize and 1 cut of grass	**289**	**82**	**206**
Sugar beets*	**260**	**73**	**186**
Winter wheat*	**304**	**43**	**229**
No derogation parcels			
Grass	**252**	**66**	**172**
Corn maize	**195**	**81**	**138**
Fodder maize	**232**	**76**	**159**
Sugar beets*	**122**	**80**	**85**
Winter wheat	**266**	**43**	**227**
Potatoes	**251**	**70**	**201**

* **only 2 observations were present**

On derogation parcels not only the input of organic fertilizers in on a higher level but also the mineral fraction is on the same or on a higher level than on no derogation parcels. This observation confirms that derogation is not only requested on the different derogation parcels but also applied, resulting not only in a higher input of total nitrogen but also in a higher input of efficient nitrogen. So the most important conclusion from the fertilization data is a higher input of nutrients on derogation parcels in comparison with no derogation parcels. Information on fertilization practices on the parcel level is obtained from the farmers. The farmers supplied levels of organic or mineral fertilization together with date of fertilization, agricultural practice and other information that could be important to calculate amounts of efficient nitrate supplied on the parcels.

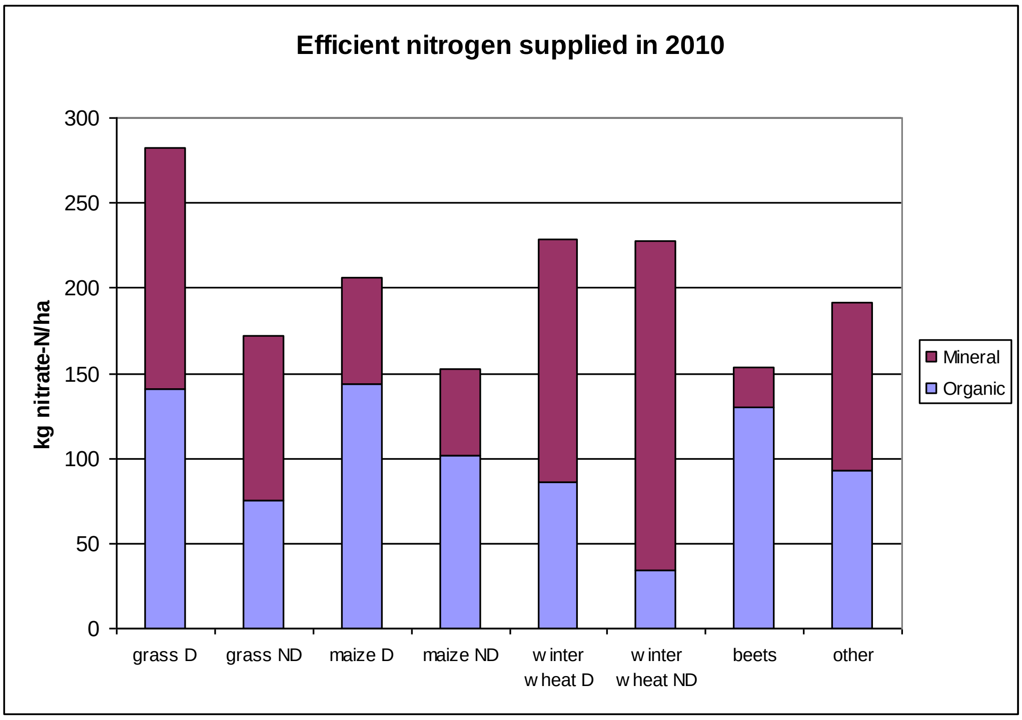

Figure 95: Average levels of efficient nitrogen (kg nitrate-N/ha) supplied on the parcels by fertilization. Average levels of efficient nitrogen as well as the fraction originating from organic and mineral fertilizers are shown.

Figure 95 shows average levels of mineral, organic and total efficient nitrogen supplied by organic or mineral fertilizers on the parcels in the derogation network during the growing season of 2010. Levels are presented for different combinations of cultivated crop and derogation condition. Derogation parcels cultivated with grass have the highest average fertilization. For parcels cultivated with maize or grass the organic fraction is higher on derogation in comparison with no derogation parcels. For all combinations, also the mineral fraction is important.

10.2.3 Mineralization

Organic fertilization

An important amount of nitrogen will become available during the growing season by mineralization. Some of the nitrogen present in the organic fertilizers is only plant available after mineralization has occurred. This amount is calculated by the working coefficients of the organic manure and results in an amount of efficient nitrogen (Table 68). The amount of efficient nitrogen exists of the mineral fraction, directly plant available, and the fraction coming available during the growing season by mineralization. For solid manure an important fraction becomes available by mineralization during the second year after application. In 2009, on 22 parcels an organic fertilization with solid manure occurred. Some additional mineralization during 2010 is taken into account when calculating the nutrient balance for these parcels. For 19 parcels this was cattle manure with an average mineralization of 17 kg nitrate-N/ha during the growing season 2010. For 3 parcels solid poultry manure was used, the average mineralization for these parcels was 31 kg nitrate-N/ha during the growing season 2010. Levels of mineralization are originating from the BEMEX (Geypens *et al.,* 1989) expert system of SSB.

Catch crop

A second source of mineralization is the catch crop sown after the cultivated crop in 2009. Mineralized nutrients will become available for the cultivated crops during 2010. Information of the catch crop is used to calculate the amount of mineralization. Amounts of nitrogen originating from mineralization of the catch crop are based on Table 69. For all parcels cultivated with maize, beets, winter wheat or a no derogation crop, a catch crop can be present on the parcels. Mineralization of the catch crop is not calculated for parcels cultivated with grassland. For derogation parcels cultivated with maize the presence of a catch crop is an important condition. On almost all derogation parcels cultivated with maize grassland is present during winter. Because this grassland is harvested before the maize is sown, mineralization is not very high. The mean level is 20 kg nitrate-N/ha. On no derogation parcels cultivated with maize, grassland is present during winter on 40 % of the parcels cultivated with fodder maize. Mostly also on this parcels the grassland is harvest and as a consequence the average level of mineralization on this parcels is 22 kg nitrate-N/ha. For parcels cultivated with beets, winter wheat or no derogation crops, about half of the parcels have a catch crop. The average level of mineralization for these parcels was 25 kg nitrate-N/ha. Mineralization of the catch crop is taken into account for the calculation of the nitrate balance. For each individual parcel mineralization is calculated in function of type of catch crop, development and date of incorporation.

Table 69: N release by different catch crops (source: Wageningen UR, 2005).

Type	Length (cm)	Efficient N (kg/ha) released for different moments 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

The third source of mineralization taken into account for the calculation of the nutrient balance is the mineralization of crop residues. This factor is only important for some cultivated crops and depends on the time between harvest of the cultivated crop and sampling of the parcel after winter. If harvest is more than 2 months before sampling date, a lot of the nitrate is already mineralized and is measured in the profile at the beginning of the growing season. Especially for beets, cauliflower, sprouts, peas and beans mineralization of crop residues is important. For these crop residues the C/N ratio is low. When the sampling date is more than 2 months after harvest the level of mineralization for these crop residues ranges between 20 and 30 kg nitrate-N/ha. When the harvest is less than 2 months before sampling date, the level of mineralization is higher. This level is evaluated for each parcel separately in function of cultivated crop of 2009 and date of incorporation.

Soil organic matter

The most important source of mineralization is nitrogen released from the soil organic matter. The amount of nitrogen released during the growing season is influenced by different parameters. The two most important parameters are soil texture and the percentage of carbon. By using data originating from the N-(eco)^2 project (Herelixka *et al.,* 2002) (Table 70), it is possible to estimate the amount of N released from the soil organic matter in function of soil type, percentage carbon and sampling date (from nitrate sample after winter 2010 to nitrate residue). The importance of soil type is illustrated in Figure 96. The highest levels of mineralization are found in the clay soils and sandy soils; the lowest levels in sandy loam and loam soils. Based on Table 70, nitrate from mineralization of soil organic matter is calculated for each parcel in the monitoring network.

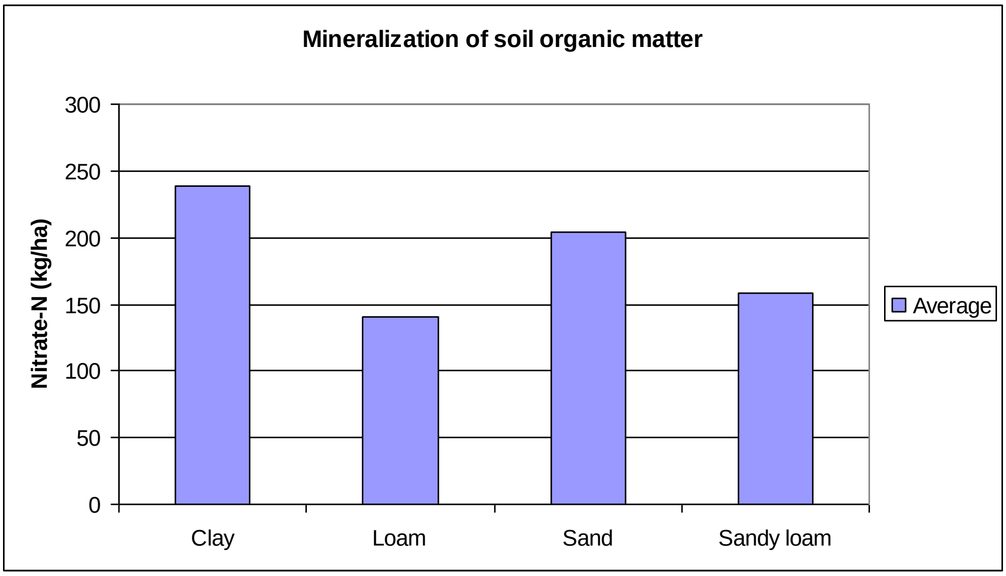

Figure 96: Mineralization of nitrate-N (kg nitrate-N/ha) for the year 2010 for different soil types. Average level of mineralization is given.

Table 70: Estimated monthly N mineralization (kg N/ha) of soil organic matter in function of percentage carbon and soil type (source: N-(eco)²). Levels are presented for optimal conditions of soil humidity and temperature.

Soil type	%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	31.4	20.9	15.8	12.5	273
	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	215.6
	1.3	6.9	6.9	9.9	11.8	16.1	20	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	10.1	8	190.8
	1.1	6.4	6.4	9.2	12.2	16.8	21	23.2	22.8	18.5	13	8.8	6.9	165.3
	0.7	3.9	3.9	5.7	7.5	10.3	13	14.3	14.1	11.4	8	5.4	4.3	101.7
loam														
	1.4	6.5	6.5	9.4	12.4	17.2	21.5	23.7	23.3	18.9	13.3	9	7.1	169
	1.2	5.9	5.9	8.5	11.2	15.5	19.4	21.4	21.1	17.1	12	8.1	6.4	152.6
	0.9	4.4	4.4	6.3	8.3	11.5	14.4	15.9	15.6	12.7	8.9	6	4.7	113.2
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	19.7	16	11.2	7.5	6	142.4
	0.9	4	4	5.8	7.7	10.6	13.3	14.6	14.4	11.7	8.2	5.5	4.4	104.2

For each parcel the percentage carbon and soil type are known. The mineralization of soil organic matter is calculated for the period between the nitrate sample at the beginning of the season (after winter 2009) and the nitrate residue sample at the end of the growing season (before winter 2010). This way the mineralization of soil organic matter for the year 2010 is calculated for each individual parcel. Results are shown in Figure 97.

The variation of average levels of mineralization between different cultivated crops is relatively low, with a minimum of 129 kg nitrate-N/ha for winter wheat on derogation parcels and a maximum of 206 kg nitrate-N/ha for grassland on derogation parcels. Differences between the cultivated crops are relative low because the most important factor for mineralization of soil organic matter is soil type and percentage of carbon.

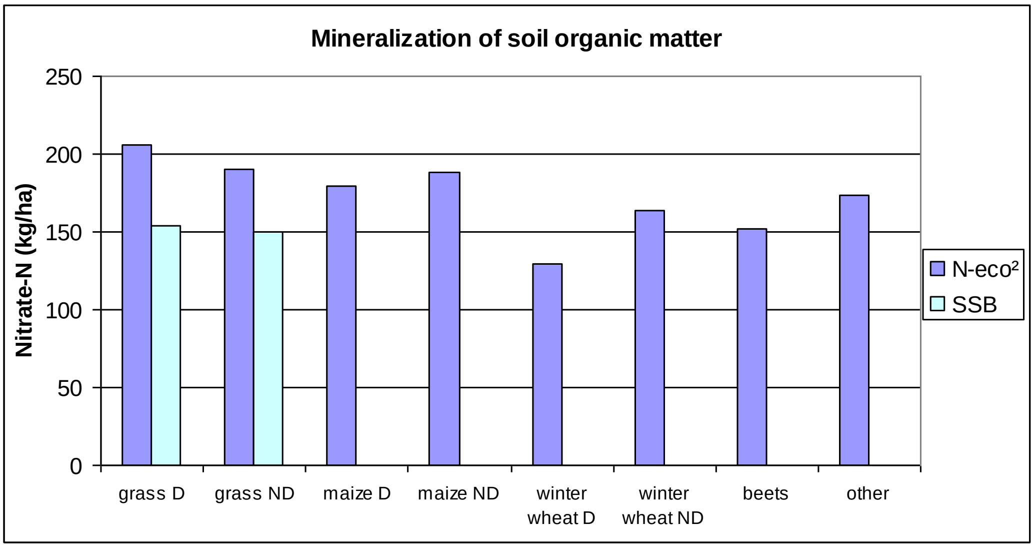

Figure 97: Average levels for mineralization of soil organic matter. Calculations are based on table 18 (N-eco²) or based on the nitrate supplying capacity for grassland. This is calculated in the N-index from SSB for all parcels in the monitoring network cultivated with grassland.

Levels in Figure 96 and Figure 97 are an estimation of the maximum mineralization under optimal conditions of humidity and temperature. For some parcels this will be an overestimation of the actual mineralization. For grassland, SSB has developed another factor (in the N-index) for the calculation of mineralization of soil organic matter. This factor is called the nitrate supplying capacity and is based on field trials during several years for different soil types. The nitrate supplying capacity is used to calculate the nitrate balance in this second approach. Levels of the nitrate supplying capacity for grassland are shown in Figure 97. The nitrate supplying capacity is based on field trials under non optimal conditions of humidity and therefore more correct than numbers based on Table 70. If the humidity content of every parcel during the summer months is known, more correct calculations of the mineralization of soil organic matter are possible.

10.2.4 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 2010 (February) to 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 the 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 at this moment.

10.2.5 Uptake by the cultivated crop

In the first approach it was important to know how many nutrients were exported from the field by the harvested crop. In this second approach it is important to know how many nutrients are taken up from the soil profile. Both the amount of nitrogen exported by the harvest and the amounts of nitrogen taken up by the parts of the cultivated crops that are not harvested are taken into account (Table 71).

Table 71: 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	

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. Nitrate present in these leaves can become available during winter by mineralization and can leach out of the soil profile.

During the growing season the different cultivated crops actively take up nutrients from the soil. Based on yield information, levels of nutrient uptake were calculated. Export of nutrients by the harvest was discussed in detail in the input/output balance (intermediate report of March 2011). After harvest some additional nutrient uptake by the catch crop is possible. Figure 98 shows average nitrate export levels for different combinations of cultivated crop and derogation condition. Average levels as well as the harvest fractions are shown. Same conclusions as in the input/output balance can be drawn. Export levels are higher on derogation parcels cultivated with grassland or maize in comparison with the same cultivated crop on no derogation parcels. For derogation parcels cultivated with grassland or maize in combination with 1 cut of grassland, highest yields are present. In the combinations maize with derogation or no derogation, the cut of grassland harvested before the maize is sown, is present in the harvest fraction. For potatoes low yields for the year 2010 can explain the lower levels of nutrient export.

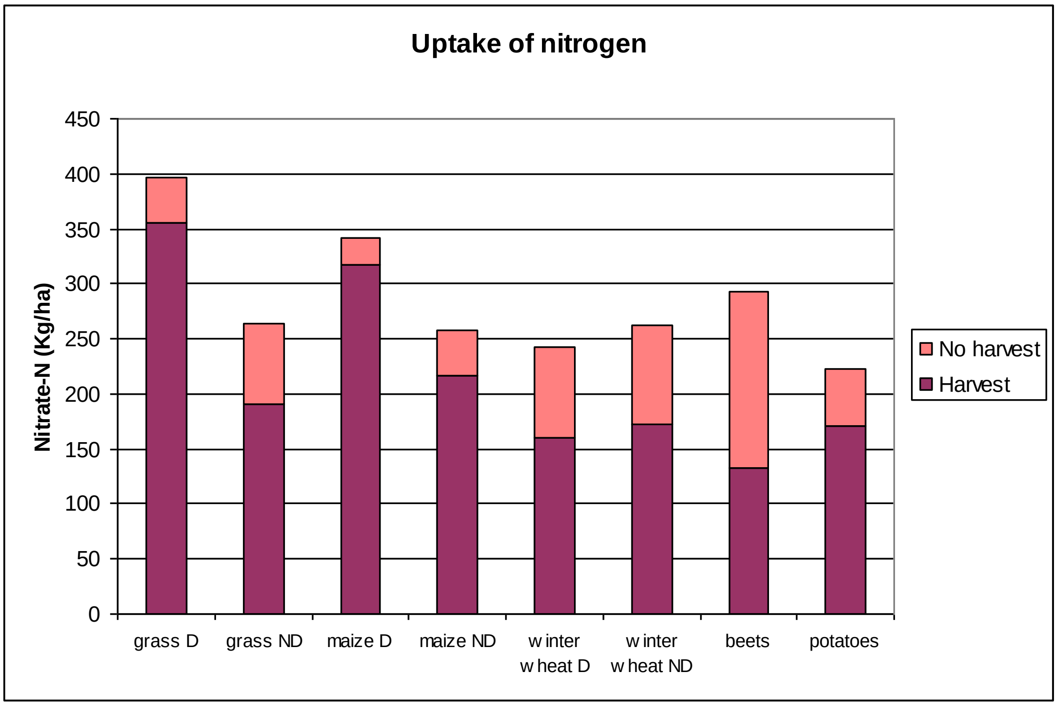

Figure 98: Levels of nitrate exported by the cultivated crop. Average levels are based on export numbers of the total crop, not only the harvested parts. Export by catch crop is also taken into account.

10.2.6 Nitrate residue

The statistical analysis of the nitrate residue before winter 2010 was reported in the intermediate report, March 2011. For the most important cultivated crops, the results are summarized in Figure 99. Two important conclusions were drawn: in 2010 lower levels of nitrate residue were measured in comparison with 2009 and no statistical differences were present between derogation and no derogation parcels. Between different cultivated crops, differences were present. For the statistical analysis, 3 parcels with nitrate residue levels above 300 kg nitrate-N/ha were not taken into account. For the calculation of the nutrient balance, these parcels are not excluded because the nutrient balance could give an explanation for these extremely high nitrate levels.

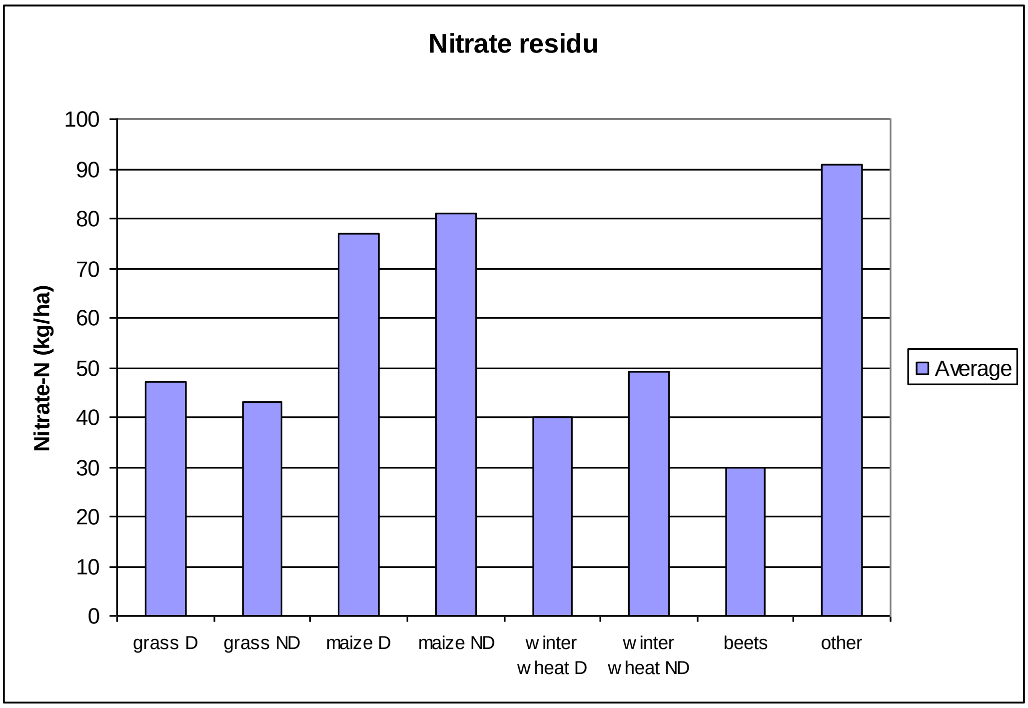

Figure 99: Average levels of nitrate-N (kg/ha) before winter 2010. Levels are given for different combinations of soil type and cultivated crop.

10.2.7 Results

For each parcel in the monitoring network the different parameters are calculated. At the end of the season the balance result (input – output) is calculated. Results of the calculations are shown in Table 72 and Figure 100.

Table 72: Average balance results (input – output) for different combinations of cultivated crop and derogation condition. Balance result for grassland is based on the soil organic mineralization on the nitrate supplying capacity as used in the expert system of SSB.

Crop	Derogation	Balance result
Grass	J	34
Grass	N	18
Maize	J	23
Maize	N	51
Winter wheat	J	134
Winter wheat	N	147
Beets	J/N	39
Potatoes	N	112

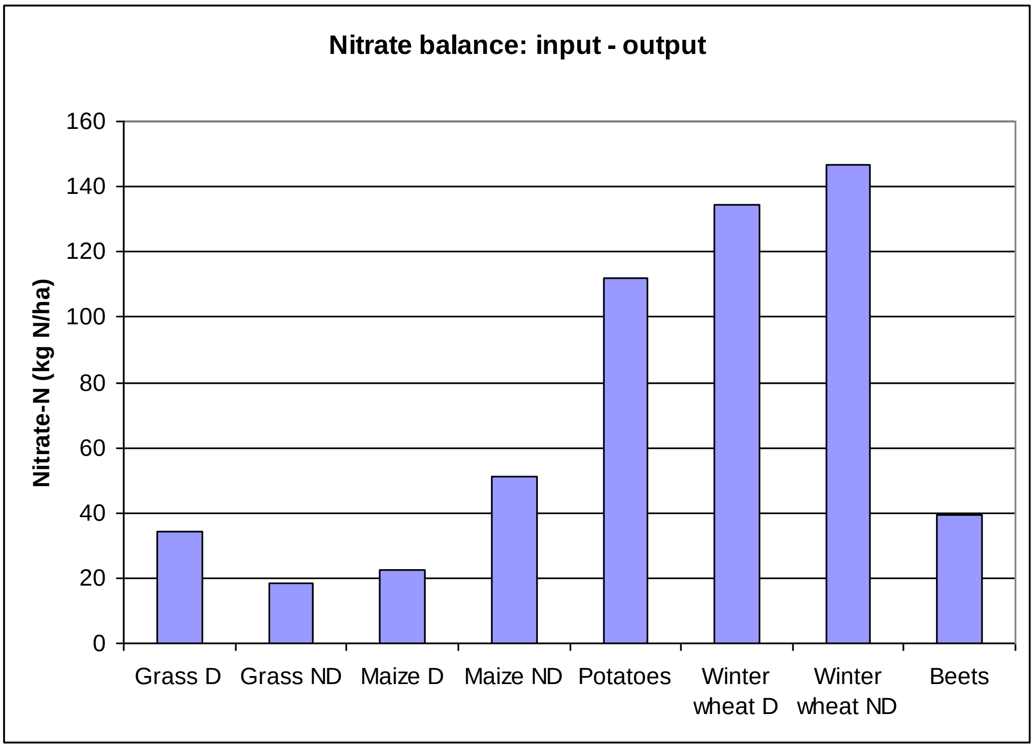

Figure 100: Average balance result for different combinations of derogation and cultivated crop. Balance result for grassland is based on the soil organic mineralization on the nitrate supplying capacity as used in the expert system of SSB.

For all combinations of cultivated crop and derogation condition, average levels of the nutrient balance are positive. This means an overestimation of the nitrate in the soil profile is present.

Some explanations can be given. Firstly, mineralization of soil organic matter based on numbers of Table 70 is an overestimation. These numbers are based on conditions of optimal temperature and humidity. For grassland this factor is also estimated by the nitrate supplying capacity which is estimation under non optimal conditions of humidity. For grassland the nitrate supplying capacity gives better results in comparison with the levels of mineralization in Table 70, indicating an overestimation of mineralization for the other parcels not cultivated with grass. Secondly, there is no factor for nutrient losses during the growing season and atmospheric deposition. For some parcels those factors could be important.

For maize and grassland relative good averages are present. For individual parcels some very good balance results but also very poor results are present. For grassland the estimation of the yield was sometimes a problem. When harvest is by grazing cattle it is difficult to estimate exact export levels of nitrogen and phosphorous. When the harvest of the parcel is weighted or only a small area is harvested and weighted more correct levels of yield could be used to calculate the balance. The same problem occurs for parcels cultivated with fodder maize. For other cultivated crops, like corn maize, it is easier to get exact numbers of yield from the farmers.

For winter wheat and potatoes the balance result is not good. Possibly a low estimation of the yield could be an explanation. When comparing average levels of yield with numbers used in other investigations, those in Figure 98 are low and could be an underestimation of real export levels. For potatoes, leaching before and during growing season could be an important factor due to the shallow roots. For winter wheat, on 6 of the 11 parcels, no catch crop was present. So it is possible that leaching was also important on these parcels.

Table 73: Example of a nutrient balance calculated for a parcel on a sandy soil cultivated with grassland. Efficient levels of nitrate-N are shown in kg/ha.

Grassland, derogation, sandy soil					
Nitrate February 2010		32	Nitrate November 2010		45
Fertilization			Export	harvest	330
	organic	44		roots	40
	grazing cattle	7			
	mineral	162			
Mineralization					
	soil organic matter	177			
	solid manure 2009				
	catch crop				
	crop residue				
		422			415
Balance result					**7**

Table 73, Table 74 and Table 75 are examples of the calculation of nutrient balances for individual parcels. Table 73 is an example of a derogation parcel cultivated with grassland. The mineralization of soil organic matter (177 kg) is originating from the nitrate supplying capacity. For this parcel the calculated nitrate residue is 52 kg nitrate-N/ha (422-370) in comparison with a measured nitrate residue of 45 kg nitrate-N/ha.

Table 74: Example of a nutrient balance calculated for a derogation parcel on a sandy soil cultivated with maize. Grassland was harvested before the maize was sown. Efficient levels of nitrate-N are given in kg/ha.

Maize, derogation, sandy soil					
Nitrate February 2010		33	Nitrate November 2010		89
Fertilization			Export maize	harvest	240
	organic	175		roots	25
	mineral	68			
Mineralization			Export grassland		90
	soil organic matter	182			
	solid manure 2009				
	catch crop	15			
	crop residue				
		473			444
Balance result					**29**

The balance presented in Table 74 is a calculation for fodder maize on a sandy soil under derogation conditions. For this balance the calculated nitrate residue was (473-240-25-90) 118 kg nitrate-N/ha in comparison with a measured residue of 89 kg nitrate-N/ha. In Table 75 the situation is different from that in Table 74 due to the lower export by the first cut of grassland. Also the levels of fertilization are relative high compared with the first calculation.

Table 75: Example of a nutrient balance calculated for a derogation parcel on a sandy loam soil cultivated with maize. Grassland was harvested before the maize was sown. Efficient levels of nitrate-N are given in kg/ha.

Maize, derogation, sandy loam soil					
Nitrate February 2010		12	Nitrate November 2010		54
Fertilization			Export maize	harvest	260
	organic	151		roots	25
	mineral	145			
Mineralization			Export grassland		75
	soil organic matter	169			
	solid manure 2009				
	catch crop	15			
	crop residue				
		492			414
Balance result					**78**

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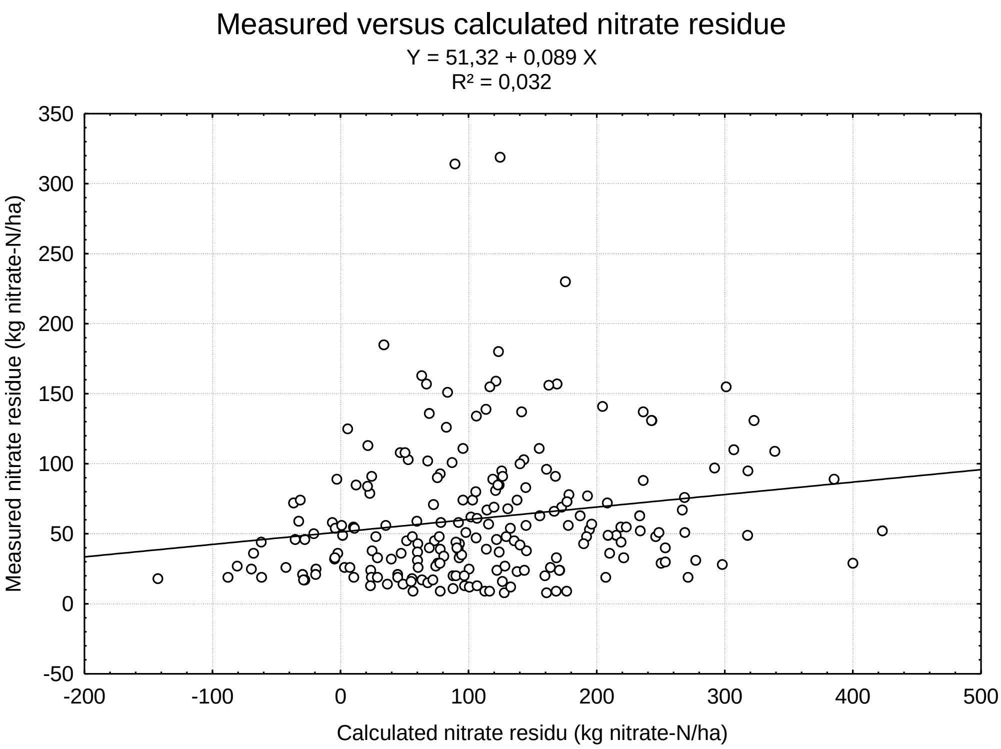

Figure 101: Scatterplot of measured nitrate residue (kg nitrate-N/ha) versus the calculated nitrate residue (kg nitrate-N/ha) based on the nitrate balance.

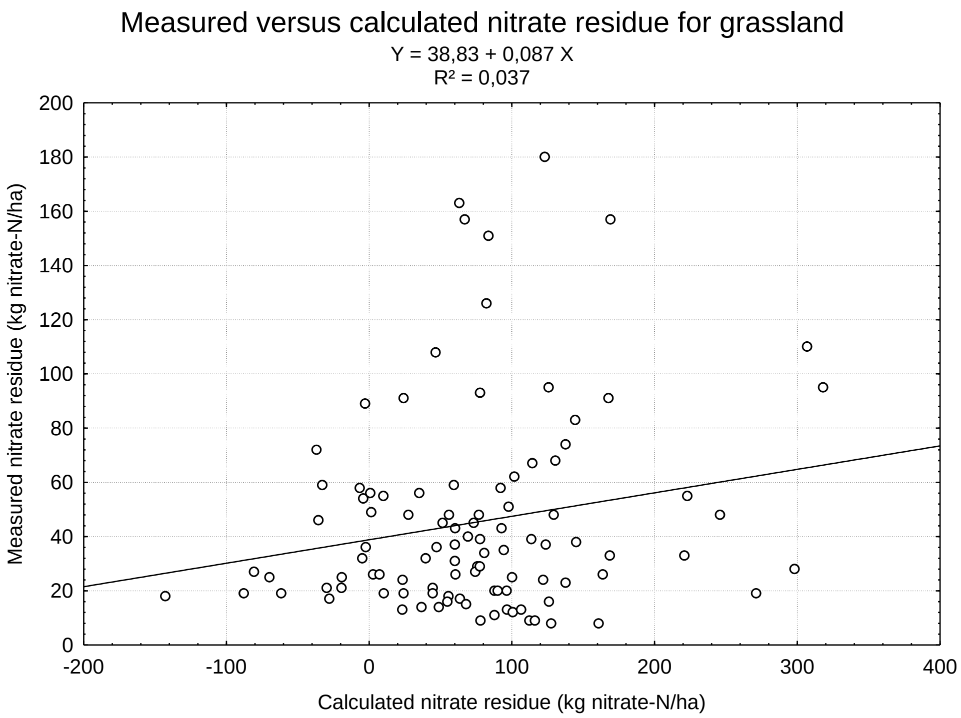

Figure 102: Scatterplot of measured nitrate residue (kg nitrate-N/ha) versus the calculated nitrate residue (kg nitrate-N/ha) for parcels cultivated with grassland, based on the nitrate balance.

Figure 101 shows the measured versus the calculated nitrate residue for all parcels in the monitoring network. The calculated nitrate residue is the balance result without the measured nitrate residue. When all factors of the nutrient balance are very good estimated, the calculated nitrate residue equals the calculated nitrate residue for a single parcel. In Figure 102 this relation is shown for parcels cultivated with grassland only, for these parcels the results are better in comparison with Figure 101.

11 Conclusion

During the derogation monitoring network soil and water samples are taken at different moments on the same parcels or sampling points. Most important parameters analysed on these samples are nitrogen and phosphorous. For both samples (soil and water) no statistically significant differences are present between derogation and no-derogation parcels. Differences are found between different cultivated crops and parcels with different soil types. No statistical differences are observed between leached amount of nutrients during winter between derogation and no derogation parcels. In order to explain the different measurements, nutrient balances are calculated based on measurements and information on yield and fertilisation.

In general, derogation parcels are characterized by higher levels of fertilization by organic and mineral fertilizers. So a higher total input of nitrogen is present on derogation parcels. Besides fertilization also export numbers for nitrogen and sometimes phosphorous are on higher levels for derogation parcels, mainly by the export of an extra cut of grassland. This higher yield is the reason that higher levels of fertilization do not result in higher nitrate residue levels or higher concentrations of phosphorous and nitrate-N in surface and groundwater for derogation parcels. Based on this the end conclusion of the monitoring network could be made: derogation in Flanders has no negative impact on the water quality.

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13 Annex

13.1 Annex 1

ID(1)	SOIL TYPE	D(2)	CROP 07	D(3)	CROP 08	D(4)	CROP 09	(5)	NO3 07_1 (mg/l)	NO3 07_2 (mg/l)	NO3 08_1 (mg/l)	NO3 08_2 (mg/l)	NO3 09_1 (mg/l)	NO3 09_2 (mg/l)	NO3 10_1 (mg/l)	Travel time (years)	NO3(6) (mg/l)
156	sand	J	grass	J	grass	J	grass	W						0.15	4.2	0.5	
209	sandy loam	J	grass	J	grass	J	grass	W						0.93	4.7	0.5	
190	sand	J	grass	J	grass	J	grass	M	0.66		0.80	0.66	0.50			0.75	0.50
6	sand	J	maize	J	maize	J	maize	W						0.53	0.65	0.8	
111	sand	J	grass	J	grass	J	grass	W						0.3	0.3	0.8	
43	sand	J	grass	J	grass	J	grass	W						22	23	1	
197	sand	J	grass	J	grass	J	grass	W						27	70	1.15	27
20	sand	J	maize	J	maize	J	maize	W						49	171	1.2	49
80	sand	J	maize	J	maize	J	maize	W						32	11	1.2	
201	sand	J	grass	J	grass	J	grass	W						0.15	0.3	1.3	0.15
90	sandy loam	J	maize	J	maize	J	maize	W						0.15	6.5	1.4	0.15
139	sand	J	maize	J	maize	J	maize	W						0.15	15	1.4	0.15
56	sand	J	grass	J	grass	J	grass	M	0.49	0.20	0.53	0.62	0.62	0.39		1.47	0.39
231	sand	J	maize	J	maize	J	maize	W						1.33	2.4	1.52	1.33
26	sandy loam	J	grass	J	grass	J	grass	M	27.70			40.70		30.00		1.57	30.00
13	sandy loam	J	grass	J	grass	J	grass	M	50.70	0.44	23.20	2.00	43.10	0.20		1.57	0.20
108	sand	J	grass	J	grass	J	grass	W							0.3	1.6	
237	sand	J	maize	J	maize	J	maize	W						0.15	7.7	1.6	0.15
120	sandy loam	J	grass	J	grass	J	grass	M	0.58	1.00	0.49	35.50	40.60			1.61	
175	sand	J	maize	J	maize	J	maize	M	73.00	74.00	117.00	94.00	22.10	13.00		1.63	13.00
28	sand	J	grass	J	grass	J	grass	W							34	1.7	
52	sandy loam	J	grass	J	grass	J	grass	W							6.4	1.7	
89	sand	J	grass	J	grass	J	grass	W						1.15	7.7	1.7	1.15
109	sand	J	grass	J	grass	J	grass	W						48	49	1.7	48
208	sandy loam	J	grass	J	grass	J	grass	M	177.00	109.00	49.00	14.00	1.20	53.00		1.75	53.00
193	sand	J	grass	J	grass	J	grass	W						16	2.7	1.8	16
12	sand	J	grass	J	grass	J	grass	M	0.53	0.53	1.10	0.80	0.20	1.30		1.88	1.30
199	sandy loam	J	grass	J	grass	J	grass	W						40	27	2	40
232	sand	J	grass	J	grass	J	grass	W							21	2	
152	sand	J	grass	J	grass	J	grass	M	0.00	1.00	0.00	0.00	0.53	0.20		2.14	0.20
100	sand	J	maize	J	maize	J	maize	M	3.00	2.00	1.00	0.00	1.20	0.20		2.25	
101	sand	J	grass	J	grass	J	grass	M	3.00	2.00	1.00	0.00	1.20	0.20		2.25	
207	sand	J	grass	J	grass	J	grass	M	1.00	0.00	0.00	1.00	3.90	0.20		2.30	
138	sand	J	grass	J	grass	J	grass	W						9.7	0.3	2.4	0.3

ID(1)	SOIL TYPE	D(2)	CROP 07	D(3)	CROP 08	D(4)	CROP 09	(5)	NO3 07_1 (mg/l)	NO3 07_2 (mg/l)	NO3 08_1 (mg/l)	NO3 08_2 (mg/l)	NO3 09_1 (mg/l)	NO3 09_2 (mg/l)	NO3 10_1 (mg/l)	Travel time (years)	NO3(6) (mg/l)
150	clay	J	grass	J	grass	J	grass	W						1.7	24	2.4	24
161	sandy loam	J	grass	J	grass	J	grass	W						4.7	1.35	2.4	1.35
24	sandy loam	J	maize	J	maize	J	maize	M	9.57	19.80	20.90	14.60	20.63	20.00		2.48	
131	sand	J	maize	J	maize	J	maize	W						65	131	2.5	131
178	sand	J	grass	J	grass	J	grass	M	57.60	60.70	60.20	47.40	48.21	39.00		2.53	
57	sand	J	grass	J	grass	J	grass	M	6.00	7.00	19.00	9.00	1.60	0.20		2.71	
4	sandy loam	J	grass	J	grass	J	grass	M	0.58	0.89	1.20	2.10	0.65	1.50		2.94	
75	clay	J	grass	J	grass	J	grass	W						1.8	3.7	6.76	
62	sand	N	grass	N	grass	N	grass	W						54	76	1	
227	sand	N	grass	N	grass	N	grass	M	0.44	0.44	0.44	0.31	1.19	1.19		1.29	1.19
73	sand	N	grass	N	grass	N	grass	M	0.89	0.71	0.80	0.62	0.25			1.46	
74	loam	N	maize	N	maize	N	maize	M	0.89	0.71	0.80	0.62	0.25			1.46	
67	sand	N	maize	N	maize	N	maize	M	1.00	0.00	0.00	0.00	0.20			1.55	
60	sand	N	maize	N	maize	N	maize	M	92.00	57.50	66.40	22.90	82.60	1.00		1.63	1.00
77	clay	N	maize	N	maize	N	maize	M	84.90	90.20	80.10	85.30	90.62	84.00		1.68	84.00
130	sand	N	grass	N	grass	N	grass	M	0.53	0.66	0.58	0.66	0.46	0.20		1.84	0.20
189	sand	N	maize	N	maize	N	maize	M	0.66	0.71	0.58	0.62	0.26	0.20		1.87	0.20
65	sand	N	maize	N	maize	N	maize	M	69.00	24.00	71.00	11.00	0.35			1.92	
14	sand	N	grass	N	grass	N	grass	M	0.00	1.00	7.00	0.00	5.10	21.00		1.93	21.00
2	sand	N	maize	N	maize	N	maize	M	21.30	33.30	32.60	15.90	13.90			1.94	
205	sand	N	maize	N	maize	N	maize	M	15.00	18.00	11.00	19.00	28.40	11.00		2.02	11.00
86	sandy loam	N	grass	N	grass	N	grass	M	0.00	1.00	1.00	3.00	114.00	1.19		2.02	1.19
210	sandy loam	N	maize	N	maize	N	maize	M	193.00	106.00	119.00	22.20	42.20	15.00		2.03	15.00
121	sand	N	maize	N	maize	N	maize	M	0.40	0.75	0.53	0.44	0.37	0.91		2.21	
3	sand	N	maize	N	maize	N	maize	M	103.00	110.00	90.50	118.00	119.00	14.00		2.29	
213	sand	N	grass	N	grass	N	grass	M	32.80	45.20	35.80	19.40	22.00	18.00		2.43	
87	sand	N	grass	N	grass	N	grass	M		0.00			1.40	0.20		2.67	
157	sand	N	maize	N	maize	N	maize	M	147.00	70.80	151.00	57.60	112.00	47.00		2.70	
158	sand	N	maize	N	maize	N	maize	M	147.00	70.80	151.00	57.60	112.00	47.00		2.70	
159	sand	N	maize	N	maize	N	maize	M	147.00	70.80	151.00	57.60	112.00	47.00		2.70	
234	sandy loam	N	grass	N	grass	N	grass	M				1.60	0.50	0.20		2.76	
47	sand	N	grass	N	grass	N	grass	M	39.30	35.30	36.10	42.00	22.44	1.19		2.79	
202	**sandy loam**			**J**	**maize**	**J**	**maize**	**W**						**0.15**	**0.3**	**1.2**	**0.15**
33	**loam**			**N**	**grass**	**N**	**grass**	**M**	**0.00**	**1.00**	**0.00**	**0.00**	**16.80**	**0.20**		**1.49**	**0.20**
155	sand	J	grass	J	grass	N	maize	W						1.8	0.3	0.5	
167	*sand*	*J*	*grass*	*J*	*grass*	*J*	*grass*	*W*						*0.3*	*72*	*0.7*	
79	**sand**	**J**	**clover**	**J**	**grass**	**J**	**grass**	**W**						**2.9**	**49**	**0.85**	
61	sandy loam	J	grass	J	maize	N	maize	W						0.15	0.61	1.1	0.15
76	*clay*	*J*	*grass*	*N*	*grass*	*N*	*grass*	*M*	*19.00*		*39.00*		*1.40*			*1.13*	

ID(1)	SOIL TYPE	D(2)	CROP 07	D(3)	CROP 08	D(4)	CROP 09	(5)	NO3 07_1 (mg/l)	NO3 07_2 (mg/l)	NO3 08_1 (mg/l)	NO3 08_2 (mg/l)	NO3 09_1 (mg/l)	NO3 09_2 (mg/l)	NO3 10_1 (mg/l)	Travel time (years)	NO3(6) (mg/l)
113	sand	J	maize	N	maize	N	potatoes	M		12.80	10.70	1.90	8.40			1.16	
180	sandy loam	J	Winter wheat	J	maize	N	winter wheat	W						125	101	1.2	125
91	**sand**	**J**	**grass**	**J**	**grass**	**J**	**maize**	**W**							**202**	**1.3**	
44	sandy loam	J	beets	J	maize	N	maize	M	0.44	0.53	10.00	0.75	2.20	8.80		1.35	8.80
51	loam	J	maize	N	maize	N	maize	M	44.20	42.00	33.40	25.60	17.50			1.37	
136	loam	J	grass	N	grass	J	grass	W							6.2	1.4	
181	sand	J	grass	N	maize	N	potatoes	M	1.30	0.58	3.00	1.10	3.40	0.20		1.43	0.20
153	sand	J	grass	N	grass	J	grass	M	0.44	0.75	0.31	0.49	2.40			1.44	
225	sand	J	grass	J	grass	N	grass	M	9.00	14.00	49.00	164.00	0.52	88.00		1.47	88.00
32	**sand**	**J**	**maize**	**J**	**maize**	**J**	**maize**	**W**						**2.3**	**3.9**	**1.5**	**2.3**
173	sand	J	maize	N	maize	J	maize	W						0.15	0.63	1.5	0.15
233	sand	J	maize	N	maize	J	grass	W						11.6	5.6	1.5	11.6
98	sandy loam	J	Winter wheat	N	potatoes	N	maize	M		1.70	10.60	0.53	1.90			1.58	
174	**sand**	**J**	**maize**	**J**	**grass**	**J**	**grass**	**W**						**1.06**	**3**	**1.7**	**1.06**
226	sand	J	maize	N	maize	J	maize	M	316.00	321.00	253.00		268.40	260.00		1.71	260.00
82	sandy loam	J	maize	N	maize	N	maize	M	0.00	1.00	3.00	0.00	0.64	0.20		1.71	0.20
35	sand	J	grass	N	grass	N	grass	W						49	45	1.8	49
236	sand	J	maize	N	maize	N	maize	M	4.30	1.60	0.53	2.60	14.00	0.20		1.95	0.20
164	sand	J	grass	N	grass	J	grass	M	24.30	24.40	48.00	38.00	28.80			1.96	
36	sand	J	grass	N	grass	N	grass	M	36.70	5.00	26.00	33.90	6.50	31.00		1.98	31.00
11	sand	J	maize	N	maize	N	maize	M								1.99	
93	sand	J	maize	J	maize	N	winter wheat	M	12.00	98.70	6.30	3.00	3.50			1.99	
19	**sand**	**J**	**clover**	**J**	**maize**	**J**	**maize**	**W**						**22**	**47**	**2**	**22**
179	loam	J	maize	J	grass	N	grass	W						48	38	2	48
15	sand	J	maize	J	maize	N	maize	M	119.00	80.20	107.00	107.00	113.00	92.00		2.07	92.00
230	sand	J	grass	N	grass	N	grass	M	0.75	0.53	0.66	0.49	0.45	0.20		2.11	0.20
217	sand	J	grass	N	grass	N	grass	M	15.00	1.00	20.00	0.00	21.20	0.20		2.13	0.20
125	sandy loam	J	maize	N	maize	N	maize	W						78	62	2.13	78
224	sand	J	grass	J	grass	J	grass	W						0.97	33	2.2	0.97
142	sand	J	grass	N	grass	N	grass	M	0.00	6.00	1.00	0.00	0.42	0.20		2.23	
163	sand	J	maize	N	maize	N	maize	M	56.50	58.10	52.90	34.10	13.10	16.00		2.23	
104	sand	J	grass	N	grass	N	grass	M	0.44	0.44	0.71	0.20	0.75	1.19		2.26	
105	sand	J	maize	N	maize	N	maize	M	3.50	0.62	2.20	1.00	4.80	1.80		2.28	
45	sandy loam	J	maize	N	potatoes	J	maize	M	218.00	225.00	231.00	184.00	229.00	220.00		2.29	
88	sand	J	maize	N	maize	J	maize	M	7.00	22.00	0.00	67.00	14.70	18.00		2.31	
235	sand	J	grass	J	grass	N	grass	M	87.90	32.70	55.20	20.80	43.40	24.00		2.34	
187	sand	J	maize	N	beets	J	maize	M	112.00	160.00	138.00	131.00	128.00	150.00		2.37	
170	sand	J	maize	J	maize	N	potatoes	M	42.00	9.00	22.00	22.00		23.00		2.39	
128	sand	J	grass	J	grass	N	maize	M	0.44	0.66	0.93	0.53	0.38	0.20		2.41	

ID(1)	SOIL TYPE	D(2)	CROP 07	D(3)	CROP 08	D(4)	CROP 09	(5)	NO3 07_1 (mg/l)	NO3 07_2 (mg/l)	NO3 08_1 (mg/l)	NO3 08_2 (mg/l)	NO3 09_1 (mg/l)	NO3 09_2 (mg/l)	NO3 10_1 (mg/l)	Travel time (years)	NO3(6) (mg/l)
211	sand	J	maize	N	winter wheat	J	maize	M	66.80	0.20	25.60	0.44	18.50			2.53	
172	**sand**	**J**	**maize**	**J**	**grass**	**J**	**grass**	**M**								**2.59**	
212	*sand*	*J*	*grass*	*N*	*grass*	*N*	*grass*	*M*	*0.27*	*0.62*	*1.20*	*3.10*	*12.30*	*3.00*		*2.66*	
133	sandy loam	J	beets	N	winter wheat	N	potatoes	M	1.50	1.30	3.20	0.35	2.90			2.67	
85	loam	J	maize	J	maize	N	beets	M	27.50	14.50	11.50		9.10			2.70	
143	*sandy loam*	*J*	*maize*	*N*	*maize*	*J*	*maize*	*M*	*0.00*	*0.00*	*0.00*	*0.00*	*0.61*	*0.20*		*2.72*	
169	sandy loam	J	maize	N	maize	N	potatoes	M	3.90	2.30	1.10	0.31	8.50	1.40		2.97	
126	loam	J	beets	N	winter wheat	J	maize	W						28	71	3	
70	*sand*	*N*	*maize*	*J*	*maize*	*N*	*maize*	*W*						*0.15*	*0.97*	*0.5*	
38	sand	N	Winter barley	J	maize	J	winter wheat	W							6	1.2	32
135	*sandy loam*	*N*	*maize*	*N*	*maize*	*J*	*winter wheat*	*W*						*320*	*166*	*1.2*	*320*
218	clay	N	Spinach	N	maize	J	maize	W						54	114	1.4	54
23	*sand*	*N*	*maize*	*N*	*maize*	*J*	*maize*	*M*	*0.44*	*0.44*	*0.44*	*0.35*	*0.58*	*1.19*		*1.42*	*1.19*
94	sand	N	potatoes	J	grass	N	potatoes	M	256.00	189.00	156.00	177.00	187.00			1.56	
171	**sand**	**N**	**potatoes**	**N**	**maize**	**N**	**maize**	**M**	**59.00**	**54.00**	**68.00**	**59.00**	**52.20**			**1.56**	
25	**sand**	**N**	**maize**	**N**	**barley**	**N**	**maize**	**M**	**9.88**	**11.70**	**11.20**	**10.00**	**29.53**	**25.00**		**1.72**	**25.00**
134	**sandy loam**	**N**	**onion**	**N**	**Spinach**	**N**	**Carrots**	**M**	**1.50**	**0.89**	**15.20**	**3.50**	**6.80**			**1.82**	
116	**sandy loam**	**N**	**Winter wheat**	**N**	**chicory**	**N**	**spinach**	**M**	**140.00**	**78.00**	**78.00**	**72.60**	**63.20**			**1.82**	
30	**clay**	**N**	**Wheat**	**N**	**maize**	**N**	**potatoes**	**M**	**0.20**	**0.97**	**1.20**	**0.84**	**1.80**			**1.90**	
27	**clay**	**N**	**wheat**	**N**	**barley**	**N**	**grass**	**M**								**1.95**	
41	**sand**	**N**	**potatoes**	**N**	**maize**	**N**	**winter wheat**	**M**	**0.53**	**0.75**	**0.93**	**0.27**	**0.20**	**0.20**		**1.96**	**0.20**
16	sand	N	Winter wheat	J	maize	J	maize	M	0.80	0.71	0.93	0.44	0.92	0.20		1.99	0.20
229	**sandy loam**	**N**	**Winter wheat**	**N**	**maize**	**N**	**maize**	**M**	**0.62**	**1.20**	**0.58**	**0.97**	**0.53**	**0.20**		**2.10**	**0.20**
228	**sand**	**N**	**potatoes**	**N**	**maize**	**N**	**maize**	**M**	**47.00**	**79.00**	**88.00**	**60.00**	**17.00**	**54.00**		**2.13**	**54.00**
196	**sandy loam**	**N**	**potatoes**	**N**	**Spinazie**	**N**	**potatoes**	**M**	**0.75**	**0.84**	**0.62**	**3.00**	**0.71**			**2.15**	
188	sand	N	potatoes	J	maize	J	maize	M	0.53	0.89	0.71	0.58	0.32	0.20		2.18	0.20
97	**sandy loam**	**N**	**potatoes**	**N**	**winter wheat**	**N**	**maize**	**M**	**8.06**	**22.60**	**18.70**	**82.30**	**11.33**			**2.21**	
195	**sandy loam**	**N**	**potatoes**	**N**	**maize**	**N**	**maize**	**M**	**2.20**	**7.10**	**3.00**	**4.10**	**3.50**			**2.23**	
34	**sand**	**N**	**vegetables**	**N**	**leek**	**N**	**leek**	**M**	**17.20**	**15.70**	**7.49**	**8.40**	**7.20**	**7.90**		**2.24**	
66	*sand*	*N*	*grass*	*J*	*grass*	*J*	*grass*	*M*	*0.00*	*0.00*	*1.00*	*0.00*	*0.20*	*0.20*		*2.37*	
222	**sandy loam**	**N**	**leek**	**N**	**califlower**	**N**	**potatoes**	**M**	**35.10**	**21.10**	**25.70**	**22.10**	**18.60**	**19.00**		**2.42**	
148	**sand**	**N**	**Winter wheat**	**N**	**beets**	**N**	**winter wheat**	**M**	**196.00**	**220.00**	**149.00**					**2.42**	
49	**clay**	**N**	**Winter wheat**	**N**	**maize**	**N**	**winter wheat**	**M**	**0.75**	**1.10**	**1.20**	**0.53**	**0.59**	**0.20**		**2.45**	
129	**sand**	**N**	**Maize**	**N**	**Wintergerst**	**N**	**maize**	**M**	**85.30**	**92.60**	**55.10**	**82.60**	**78.90**	**97.00**		**2.48**	
203	**sandy loam**	**N**	**vegetables**	**N**	**potatoes**	**N**	**califlower**	**M**	**1.60**	**1.20**	**1.70**	**1.60**	**3.00**			**2.52**	
50	**sandy loam**	**N**	**potatoes**	**N**	**grass**	**N**	**califlower**	**M**	**208.00**	**196.00**	**196.00**	**165.00**	**158.00**	**110.00**		**2.58**	
37	**clay**	**N**	**maize**	**N**	**maize**	**N**	**winter wheat**	**M**	**0.49**	**0.53**	**0.80**	**0.58**	**0.23**	**0.20**		**2.58**	
1	**sandy loam**	**N**	**beets**	**N**	**winter wheat**	**N**	**maize**	**M**	**89.40**	**84.64**	**102.00**	**94.50**	**73.84**	**99.00**		**2.63**	
127	**sand**	**N**	**maize**	**N**	**winter wheat**	**N**	**maize**	**M**	**106.00**	**95.60**	**89.40**	**75.80**	**1.30**	**55.10**		**2.69**	

ID(1)	SOIL TYPE	D(2)	CROP 07	D(3)	CROP 08	D(4)	CROP 09	(5)	NO3 07_1 (mg/l)	NO3 07_2 (mg/l)	NO3 08_1 (mg/l)	NO3 08_2 (mg/l)	NO3 09_1 (mg/l)	NO3 09_2 (mg/l)	NO3 10_1 (mg/l)	Travel time (years)	NO3(6) (mg/l)
83	loam	N	potatoes	N	winter wheat	N	beets	M	18.90	60.60	21.30	21.50	23.46	28.00		2.71	
214	sand	N	potatoes	N	beets	J	maize	M	42.00	84.20	29.40	75.90	29.30	87.00		2.72	
182	sandy loam	N	onion	N	winter wheat	N	potatoes	M	0.97	0.58	1.00	0.89	0.42	0.20		2.82	
107	sand	N	maize	N	maize	N	potatoes	M	0.00	1.00	0.00	1.00	16.10	0.20		2.82	
146	sandy loam	N	califlower	N	califlower	N	potatoes	M	0.62	0.66	1.00	0.58	1.00	1.40		2.88	
147	sandy loam	N	potatoes	N	califlower	N	califlower	M	0.62	0.66	1.00	0.58	1.00	1.40		2.88	
17	sand	N	grass	J	maize	J	maize	M	41.70	84.70	83.80	76.00	25.50			2.93	
40	clay	N	Winter wheat	N	winter wheat	N	grass	M	0.75	0.71	0.80	0.97	0.36	0.20		2.98	
216	sandy loam	N	Winter wheat	N	chicory	N	beets	M	4.80	7.20	6.40	3.00	11.00	16.00		3.00	
39	sandy loam	N	beets	N	potatoes	N	potatoes	M	111.00	103.00	97.90	20.30	88.27	7.20		3.00	
99	sandy loam	N	sprout	N	potatoes	N	winter wheat	M	0.71	1.10	0.75	0.58	0.88			3.03	
220	sandy loam	N	Winter wheat	N	maize	N	winter wheat	M	0.44	0.49	0.44	0.44	39.95	1.19		3.08	
162	sand	N	wheat	N	maize	N	maize	M	6.42	10.60	5.45	0.97	4.52	64.00		3.18	
118	loam	N	maize	N	maize	N	winter wheat	M	2.00	0.00	1.00	0.00	1.19	3.30		3.20	

(1): Parcel ID, every parcel in the monitoring network has an unique number

(2): Derogation condition for the year 2007, N: no derogation, J: derogation

(3): Derogation condition for the year 2008, N: no derogation, J: derogation

(4): Derogation condition for the year 2009, N: no derogation, J: derogation

(5): MAP sampling point (M) or monitoring well (W)

(6): Nitrate concentration (mg/l) for the measuring points coupled to the parcel characteristics of 2008 based on the travel time

Subscript_1: samples are taken at the beginning of a year (spring)

Subscript_2: samples are taken at the end of a year (autumn)

13.2 Annex 2

Table 76: different soil fertility classes for pH-KCl for arable land for different soil types (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 zone	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 77: different soil fertility classes for pH-KCl for grassland for different soil types (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 zone	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 78: different soil fertility classes for percentage carbon for arable land for different soil types.

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 zone	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 79: different soil fertility classes for percentage carbon for grassland for different soil types.

Class	%C All soil types, 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 zone	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 80: different soil fertility classes for phosphorous 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 types
Very low	< 5
low	5 - 8
rather low	9 - 11
optimal zone	12 - 18
rather high	19 - 30
high	31 - 50
very high	> 50

Table 81: different soil fertility classes for phosphorous 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 types
Very low	< 8
low	8 - 13
rather low	14 - 18
optimal zone	19 - 25
rather high	26 - 40
high	41 - 60
very high	> 60

Table 82: different soil fertility classes for K for arable land for different soil types (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 zone	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 83: different soil fertility classes for K for grassland for different soil types (only valid for soils with a specific gravity of 1.06).

Class	mg K/100 g dry soil (A.L.-extract) All soil types 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 zone	12 - 20	20 - 28
rather high	21 - 28	29 - 36
high	29 - 45	37 - 50
very high	> 45	> 50

Table 84: different soil fertility classes for Mg for arable land for different soil types (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 zone	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 85: different soil fertility classes for Mg for grassland for different soil types (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 zone	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 86: different soil fertility classes for Ca for arable land for different soil types (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 zone	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 87: different soil fertility classes for Ca for grassland for different soil types. (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 zone	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 88: different soil fertility classes for Na for arable land (only valid for soil types with a specific gravity of 1.3).

Class	mg Na/100 g dry soil (A.L.-extract) all soil types
Very low	< 1.0
low	1.0 - 2.0
rather low	2.1 - 3.0
optimal zone	3.1 - 6.0
rather high	6.1 - 10.0
high	10.1 - 20.0
very high	> 20.0

Table 89: different soil fertility classes for Na for grassland (only valid for soil types with a specific gravity of 1.06).

Class	mg Na/100 g dry soil (A.L.-extract) all soil types
Very low	< 1.1
low	1.1 - 2.4
rather low	2.5 - 3.9
optimal zone	4.0 - 6.0
rather high	6.1 - 10.0
high	10.1 - 25.0
very high	> 25.0

13.3 Annex 3

Example of an standard soil analysis with an liming and fertilization advice for the 3 next growing seasons.

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Perceelsnaam : **PERCEEL 3**
Landbouwernummer:
Perceelsnummer: 2008_2
Heverlee, 16/11/2009

ONTLEDINGSUITSLAGEN EN BEOORDELING.

Bepaling			Uitslag ontleding	Streefzone	Beoordeling volgens BEMEX
Grondsoort	458		**15**	- - -	Fijn zand
pH-KCl	089	B	**4.1**	5.3 - 5.7	Laag
C in % (humus)	452	B	**1.7**	1.8 - 2.8	Normaal
Fosfor (P)	376	B	**60**	11 - 18	Zeer hoog
Kalium (K)	376	B	**30**	11 - 18	Tamelijk hoog
Magnesium (Mg)	376	B	**7**	6 - 10	Normaal Te laag t.o.v. kalium
Calcium (Ca)	376	B	**44**	69 - 139	Tamelijk laag
Natrium (Na)	376	B	**2.5**	3.0 - 6.0	Tamelijk laag
Boor			---	--- - ---	

De streefzone is individueel per perceel.

BEKALKINGSVOORSCHRIFT

3075 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 STOF

Het organische stofgehalte (C in %) ligt binnen de streefzone. Op rotatieniveau dient ernaar gestreefd dat de aanvoer van organische stof minstens de natuurlijke afbraak compenseert zodat het huidige niveau behouden blijft.

Voor dit perceel berekende jaarlijkse afbraak : 2640 kg organische stof/ha

Via de tabel op bijgevoegde verklarende nota kan je nagaan op welke manier deze afbraak kan gecompenseerd worden.

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Perceelsnaam : PERCEEL 3 Volgnummer **S0887214** (2/4) 16/11/2009

De kolommen naast het bemestingsadvies kan U gebruiken om de bemesting van dit perceel nauwkeurig op te volgen (zie algemene bemerking).

EERSTE TEELT 5/2010		**Door U in te vullen**		
deeg- of voedermaïs		organische bemesting	minerale bemesting	saldo
Kalk	2175 z.b.w./ha			
Stikstof	190 kg N/ha			
Fosfor	0 kg P_2O_5/ha			
Kali	160 kg K_2O/ha			
Magnesium	130 kg MgO/ha			
Natrium	0 kg Na_2O/ha			
Boor	-			

De hoger vermelde streefzone is de pH-streefzone voor de meeste teelten zoals bv. suikerbieten, gerst.. Voor de teelt van deeg- of voedermaïs moet hier 2175 kg zbw/ha gegeven worden. De bekalking wordt het best enkele maanden voor de zaai gegeven, onmiddellijk na de oogst van de vorige teelt. De geadviseerde kalkdosis goed mengen met de bouwlaag. Daarom de helft geven vóór het ploegen, de andere helft na het ploegen. Indien de vorige deegrijpe maïs werd gedorsen als korrelmaïs, dient het kalibemestingsadvies te worden verminderd met 90 kg K_2O/ha.

TWEEDE TEELT 5/2011		**Door U in te vullen**		
deeg- of voedermaïs		organische bemesting	minerale bemesting	saldo
Kalk	0 z.b.w./ha			
Stikstof	190 kg N/ha			
Fosfor	0 kg P_2O_5/ha			
Kali	210 kg K_2O/ha			
Magnesium	85 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 deeg- of voedermaïs moet hier geen bekalking uitgevoerd worden. Indien de vorige deegrijpe maïs werd gedorsen als korrelmaïs, dient het kalibemestingsadvies te worden verminderd met 90 kg K_2O/ha.

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Perceelsnaam : PERCEEL 3 Volgnummer **S0887214** (3/4) 16/11/2009

De kolommen naast het bemestingsadvies kan U gebruiken om de bemesting van dit perceel nauwkeurig op te volgen (zie algemene bemerking).

DERDE TEELT 5/2012 **deeg- of voedermaïs**		**Door U in te vullen** organische bemesting	minerale bemesting	saldo
Kalk	0 z.b.w./ha			
Stikstof	190 kg N/ha			
Fosfor	30 kg P_2O_5/ha			
Kali	240 kg K_2O/ha			
Magnesium	85 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 deeg- of voedermaïs moet hier geen bekalking uitgevoerd worden.
Voor de toelichting bij de fosforbemesting verwijzen wij naar de bemerking bij de eerste teelt.
Indien de vorige deegrijpe maïs werd gedorsen als korrelmaïs, dient het kalibemestingsadvies te worden verminderd met 90 kg K_2O/ha.

STAALNAME

Uw contactpersoon : MARTENS HANS
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Het staal werd genomen op 5/11/2009. Het grondstaal is aangekomen op 6/11/2009 bij de Bodemkundige Dienst in Heverlee.
De ontledingsuitslag en beoordeling werden vrijgegeven door SDECKERS 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. Meer nauwkeurige stikstofbemestingsadviezen kunnen alleen bekomen worden op basis van de **N-INDEX**-bepaling van het perceel.
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

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Perceelsnaam : PERCEEL 3 Volgnummer **S0887214** (4/4) 16/11/2009

bodem, deeldomein bodembescherming. De bovenvermelde analyseresultaten voldoen aan de vereisten van de MTR-randvoorwaarden en zijn geldig tot 5/11/2012 .
Het identificatienummer van het perceel is ...._2008_2
Het MTR-advies is slechts een minimaal advies en vervangt geenszins het bemestingsadvies van de Bodemkundige Dienst.
Het MINIMAAL MTR-ADVIES : 1000 zuurbindende waarde/ha. Zie teeltcategorieën in bijlage. Noteer de toegediende bekaling en de bekalkingsdatum in de bovenstaande tabellen bij de teelten.

Onderzoek wordt verricht en adviezen worden verstrekt op voorwaarden dat de aanvrager afstand doet van ieder recht op aansprakelijkstelling.
AANGEWENDE ANALYSE- EN ADVIESMETHODEN
458: bepaling van textuur, BDB-methode, weergegeven onder de vorm van digitale codering en omschrijving
089: bepaling van pH-KCl, BDB-methode, uitgedrukt in Sörensen 25°C
452: bepaling organische koolstof, BDB-methode, gebaseerd op de dichromaatmethode - gelijkwaardig met ISO10694 en ISO14235, 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.