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Derogation monitoring network of farms under Directive 2008/64/EG (MAP 5)

Final report:

Period January 2016 – May 2020

Consortium:

Soil Service of Belgium and

Flanders Research Institute for Agriculture, Fisheries and Food

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List of abbreviations

AL	Ammonium-lactate
ILVO	Institute for Agricultural and Fisheries Research
MAP	Manure Action Program
SSB	Soil Service of Belgium
VLM	Flemish Land Agency
VMM	Flemish Environment Agency
%AcrGrass	Proportion of farm acreage cultivated with grass (%)
%AcrGrClov	Proportion of farm acreage cultivated with grass & less than 50% clover (%)
%AcrMaize	Proportion of farm acreage cultivated with maize (%)
%Dero	Proportion of farm acreage cultivated under derogation conditions (%)
%DeroGrass	Proportion of acreage grass cultivated under derogation conditions (%)
%DeroMaize	Proportion of acreage maize cultivated under derogation conditions (%)
$\%OC_{0\text{-}30cm}$	Percentage organic carbon of soil layer 0-30cm (%)
AcrFarm	Total farm acreage (ha)
AcrParc	Acreage of the parcel (ha)
AgrReg	Agricultural region
ConvM	Being a meadow converted during past 15 years: yes or no
Crop	Main crop
CropNRes	Crop sown/growing at sampling nitrate-N residue
Der	Request of derogation
Drain	Draining level
Focus	Parcel belongs to a focus farm or not
Grazing	Parcel being grazed or not
IntGrNRes	Interval last moment of grazing-moment of sampling nitrate-N residue (days)
IntMinNRes	Interval last moment of mineral fertiliser-moment of sampling nitrate-N residue (days)
IntOrgFNRes	Interval last moment of organic fertiliser-moment of sampling nitrate-N residue (days)

IntOrgNRes	Interval last moment of organic fertiliser/grazing-moment of sampling nitrate-N residue (days)
IntSCrNRes	The interval between tillage and/or sowing and sampling for the nitrate-N residue (days)
MinF	Application of mineral fertilisation (Y/N)
NEff	Applied amount of effective nitrogen (kg N/ha)
Nexp	Nitrogen export by harvest (kg N/ha)
Nmin	Applied amount of mineral nitrogen (kg N/ha)
Norg_TOT	Applied amount of total organic nitrogen (kg N/ha)
OrgF	Application of organic fertilisation (Y/N)
pH_{0-30cm}	pH of soil layer 0-30cm
ProdNOrgFarm	Net organic N-production at farm level/farm acreage (kg N/ha)
Rain	Amount of rainfall during 30 days before sampling for the nitrate-N residue (mm)
RatGrM	Ratio of acreage grass to acreage maize
RDef	The rainfall deficit cumulated over the hydrological summer (mm)
RespStandEffN	Respect of the fertilisation standard for total effective N (Y/N)
RespStandOrgN	Respect of the fertilisation standard for total organic N (Y/N)
SCrop	Second crop
$SPI3_{Spring}$	SPI-3 on July 1st compares the period of 1 April until 1 July to the reference period and is an indicator of the drought in the spring
$SPI3_{Summer}$	SPI-3 on October 1st compares the period of 1 July until 1 October to the reference period and is an indicator of the drought in the summer
StandEffN	Fertilisation standard for total amount of effective N (kg N/ha)
StandNres	Standard for the nitrate-N residue (kg NO3-N/ha)
StandOrgN	Fertilisation standard for amount of total organic N (kg N/ha)
SurpEffNFarm	Surplus of effective nitrogen at farm level (kg N/ha)
SurpOrgNFarm	Surplus of organic nitrogen at farm level (kg N/ha)
Temp	The average temperature during the period July-September (°C)
Text	Soil texture
TypOrg	Type of used organic fertiliser

UseNMinFarm	Use of mineral nitrogen at farm level/farm acreage (kg N/ha)
UseNOrgFarm	Use of organic nitrogen at farm level/farm acreage (kg N/ha)
UseNOthFarm	Use of nitrogen of other fertilisers at farm level/farm acreage (kg N/ha)
UseNTotFarm	Use of total nitrogen at farm level/farm acreage (kg N/ha)
Year	Year of monitoring
YrsConv	Years after conversion (years)

Summary

In September 2015 the European Commission granted the derogation requested by Belgium with regard to the region of Flanders pursuant to Council Directive 91/676/EEC. The derogation implies that under certain conditions a higher amount of livestock manure, higher than the general application standard of 170 kg N/ha, can be applied.

A key condition set for the competent authorities is the monitoring of the impact of derogation on the nitrogen and phosphorus losses from the soil and on the water quality. The objective of this research is the set-up and follow-up of a monitoring network of at least 150 farms in order to provide data on the impact of derogation.

As in the fifth action program – MAP 5 – the farm specific approach was introduced in the monitoring network. The new approach in combination with a larger number of possible derogation crops would result in a very large number of monitoring farms. Based on well considered decisions the monitoring focusses on the ten most relevant situations respecting representation of the different soil textures, crops and fertilisation practices commonly present in Flanders.

The former network of 175 farms and 225 parcels was the starting point of the network set-up for the period 2016-2019. After screening the former network in perspective of the monitoring network 2016-2019, 75 farms of the two former monitoring networks could be maintained. Other farms were recruited which resulted in a regionally well spread monitoring network of 164 farms.

The monitoring network provides data on production factors such as fertilisation and yield as well as monitoring data of nitrate and phosphorus in soil and water.

Nitrate in the soil is monitored as the nitrate-N residue in autumn. The nitrate-N is determined down to 90 cm in the soil layers 0-30, 30-60 and 60-90 cm. Phosphorus in the soil is monitored on a selection of 230 parcels which were laboured continuously without derogation or 7-9 years with derogation in the period 2008-2016. The phosphorus content is determined in ammonium-lactate extract per soil layer of 30 cm down to 90 cm. Monitoring of nitrate in the water is based on monitoring of nitrate in the soil water.

The network was set-up in spring of 2016 and in autumn 2016 the first field measurements were realised.

During the first year of monitoring the network proved to be robust. At each moment of comparison enough parcels or farms could be compared.

The first year of monitoring in the period of 2016-2019 was marked by exceptional climatological circumstances. More than ever it was needed to emphasize that climate conditions are as important as fertilisation for production and monitoring results.

For none of the monitoring parameters so far (nitrate-N residue, nitrate in soil water, difference of nitrate-N between winter and spring) derogation led to statistically significant differences compared to non-derogation practices, with a few exceptions at certain levels of comparison. When significant differences appeared between derogation and non-derogation conditions, the average values of both scenarios were low. The practical relevance of these minimal differences are therefore not of major importance.

The second year of monitoring, 2017, the results of all parameters were at a higher level. A clear year (and climate) effect appeared. On the global level, comparing derogation and no derogation regardless of soil or crop, there were no statistical significant differences unless the nitrate-N residue at parcel level. However, the difference was only 3 kg NO_3-N/ha between derogation and no derogation parcels. At certain levels, taking into account soil or both soil and crop, statistical differences appeared. As stated in 2016, it's important to evaluate not only the statistical results but also the practical relevance and importance.

In 2018, the third year of monitoring, derogation and no derogation parcels did not differ significantly on general. This was observed in the nitrate-N residue at parcel level, at farm level, in the difference in nitrate-N over the winter and in the nitrate-concentration in the soil water. All results were situated at the highest level of the 3 year of monitoring but significant differences were scarce. Where possible, fertilisation was adapted.

The last year of monitoring was a validation of the findings in the former years. The nitrate-N residue at farm level, the difference in nitrate-N over the winter and the nitrate-concentration in the soil water did not differ significantly between derogation and no derogation conditions. The nitrate-N residue at parcel level did not differ significantly, only on sandy soils cultivated with grass. Nitrogen fertilisation but also nitrogen export were higher on derogation parcels.

In the set-up of the monitoring network, the multivariate analysis indicated crop, climate, the type of organic fertiliser the amount of organic carbon and the amount of mineral fertiliser as determinant parameters for the nitrate-N residue.

Introduction

The Commission Implementing Decision 2015/1499 of 3 September 2015 stated that the derogation requested by Belgium with regard to the region of Flanders pursuant to Council Directive 91/676/EEC concerning the protection of waters against pollution caused by nitrates from agricultural sources, was granted. This granting however is subject to certain conditions.

Monitoring in general is a key condition.

The objective of this research is the set-up and follow-up of a monitoring network of at least 150 farms in order to provide data on the impact of derogation on nitrogen and phosphorus losses.

To guarantee a monitoring network without modifications during the period of applicability of the Decision 2015/1499 of 3 September 2015, 160 farms are gathered in a new monitoring network 2016-2019.

The monitoring network is focused on 10 important situations related to fertilisation strategy, soil texture and crop. Due to well considered decisions the monitoring network is representative for the different soil textures, crops and fertilisation practices commonly present in Flanders. To guarantee the continuity of the monitoring network, the situation at a farm will be maintained during the period 2016-2019. At each farm 3 parcels are monitored. This implies an expansion of the monitoring network compared to the former periods of monitoring.

The former monitoring network (Vandervelpen, *et al.,* 2011; Odeurs, *et al.*, 2015) was chosen as a basis for the set-up of the monitoring network 2016-2019. This network comprised 175 farms and 225 parcels. Due to the different design of the monitoring network not all farms could be retained but at the same time an expansion of 225 to 480 parcels is realised.

The monitoring network will provide data on fertilisation and farming practices on the parcels, nitrogen in the soil profile and nitrogen and phosphorus concentration in water leaving the root zone. In this way, the impact on water quality can be estimated, both under derogation and non-derogation conditions.

This report deals with the set-up of the monitoring network for the period 2016-2019, the results of the monitoring and the results of a multivariate analysis regarding the nitrate-N residue.

1 Monitoring network 2016-2019

1.1 Set-up of the derogation monitoring network 2016-2019

The derogation monitoring network for the period 2016-2019 needs to be set up from a different point of view regarding the former monitoring network.

In the former monitoring network, farms and parcels were selected starting from MAP sampling points groundwater and the selection of additional parcels related to the application of derogation, the soil texture, crop and groundwater level at candidate farms willing to participate. The monitoring network was set up in 2009 with the parcel as monitoring unit. In contrast the monitoring unit in the monitoring network 2016-2019 is the **crop at farm level, grown with or without derogation**, as in the fifth action program (MAP5), the farm is the unit in which nutrient flows are evaluated (the farm-specific approach). The modification of the monitoring unit from 'parcel' to 'crop at farm level' will allow comparing the effects of derogation and non-derogation in a new way.

Since the number of possible combinations of "crop", "derogation strategy" and "soil type" amounted very high (Figure 1), the number of combinations or groups, which form the monitoring network, was limited.

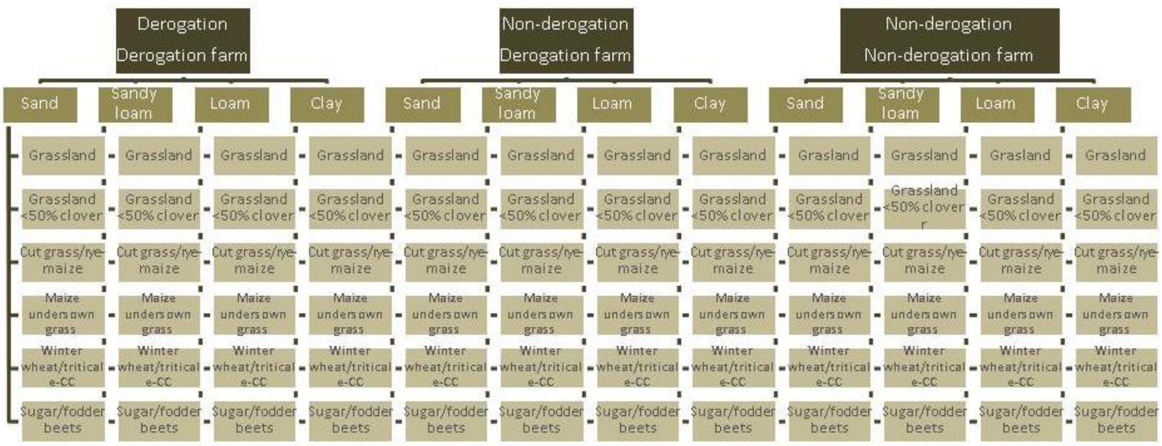


Figure 1: Overview of all possible combinations crop-derogation strategy-soil texture in the potential monitoring network.

The elimination should lead to a manageable network, representative for the region of Flanders and structured in the interest of a well-substantiated statistical analysis of the monitoring results.

To reduce the number of groups, the 3 elements of the combination "crop"-"derogation strategy"-"soil type" were evaluated.

Since derogation can be requested at parcel level in Flanders and derogation farms can have derogation and no derogation parcels, 3 "derogation strategies" can be distinguished.

- Parcel with request of derogation on a derogation farm
- Parcel without request of derogation on a derogation farm
- Parcel without derogation on a non-derogation farm.

Since the second strategy means the same as the last strategy, no request of derogation at the parcel, it was concluded that the second strategy should not be monitored actively. Two "derogation strategies" remained:

- Derogation at a derogation farm
- No derogation at a non-derogation farm

In terms of soil type, a further simplification could be carried out. In 2007 the Flemish agricultural acreage consisted of 48 % sandy soils and 33 % sandy loam soils. Silty soils and clay soils represent only 19 % of the Flemish agricultural acreage. The importance of sandy and sandy loam soils was clear. Moreover, in those regions with sandy or sandy loam soils more dairy farming is present as well as the often associated request of derogation. Even the former monitoring network, which had to be the starting point of the monitoring network 2016-2019, was more concentrated on sandy and sandy loam soils. Because of those reasons, silty soils and clay soils are not monitored in the derogation monitoring network 2016-2019. The monitoring network focuses on sandy and sandy loam soils.

Regarding to crop a last reduction of combinations was possible. In the derogation decision of 2015 it was possible to request derogation on 6 types of crops. Evaluation of the distribution of the acreage of potential derogation crops in 2013 showed that beets (sugar and fodder beets) and cereals (wheat and triticale) were limited in acreage and took only 5 and 11 % of the 525367 ha on which it was possible to request derogation. Moreover these are crops for which the application standard with derogation was not as high as 250 kg N/ha but limited to 200 kg N/ha, not that much different from the general standard of 170 kg N/ha. Therefore, beets and cereals were not included in the monitoring network. Grass and maize represented respectively 46 and

37 % of the acreage of derogation crops. In 2015 new derogation crops were included in the derogation decision, more specific maize undersown with grassland and grassland mixed with clover. Maize undersown with grassland was decided not to be included since the importance and the acreage of the crop was doubtable. Moreover, it was expected that the crop would only be present on derogation farms in order to meet legal conditions regarding biodiversity. On farms without derogation, where more different crops are grown, this crop was believed not to be important. Grassland mixed with clover on the other hand was a crop for which high interest is shown by the farmers and for which an expansion of the acreage was expected. Also, the Flemish authority demanded specifically to include this crop in the monitoring network. So 3 derogation crops were selected for monitoring: grass, maize and grassland mixed with clover.

The ten most relevant combinations were withheld:

- Grass, grown with derogation on sandy soil on a derogation farm
- Grass, grown without derogation on sandy soil on a farm without any derogation
- Grass, grown with derogation on sandy loam soil on a derogation farm
- Grass, grown without derogation on sandy loam soil on a farm without any derogation
- Grassland with less than 50 % clover, grown with derogation on sandy soil on a derogation farm
- Grassland with less than 50 % clover, grown without derogation on sandy soil on a farm without any derogation
- Maize, grown with derogation on sandy soil on a derogation farm
- Maize, grown without derogation on sandy soil on a farm without any derogation
- Maize, grown with derogation on sandy loam soil on a derogation farm
- Maize, grown without derogation on sandy loam soil on a farm without any derogation

This elimination of the omitted combinations was argued at the first steering committee meeting of February 24th 2016 (Figure 2). The more limited number of groups did not deprive the condition of representation of the Flemish situation but made it possible to set up a well-balanced network in which monitoring results could be used efficiently and would allow well-founded statistical analyses.

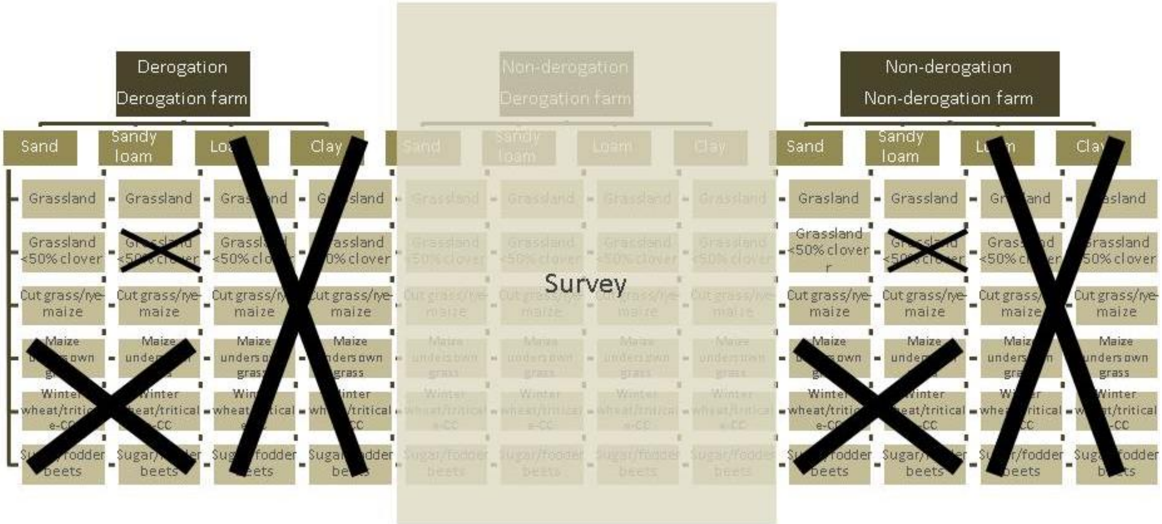


Figure 2: Overview of remaining combinations crop-derogation strategy-soil texture in the future monitoring network after well-considered elimination.

The survey indicated in Figure 2 is discussed in 1.5 Survey.

To establish a constant monitoring network of at least 150 farms for the period 2016-2019, 160 farms were postulated to be selected at the beginning of the monitoring period. The 160 farms had to be distributed over the network and the ten combinations as shown in Table 1.

Table 1: Overview of distribution of 160 farms in the future monitoring network

	Derogation on a derogation farm				No derogation on a farm without any derogation				Total
Derogation crop / Soil texture	Grass	Maize	Grassland with less than 50 % clover	Total	Grass	Maize	Grassland with less than 50 % clover	Total	
Sandy	18	17	10	**45**	18	17	10	45	**90**
Sandy loam	18	17	-	**35**	18	17	-	35	**70**
Total	**36**	**34**	**10**	**80**	**36**	**34**	**10**	**80**	**160**

As requested, as much farms as possible of the former monitoring network should be retained in the monitoring network 2016-2019. Since it was expected that some of the farms could not be withheld, also farms of former projects concerning grassland and maize were gathered in a first pool of selection.

Of these farms, information of their parcels was requested for the period 2011-2015 at the Flemish Land Agency.

The information requested at parcel level comprised:

- Year of production
- Number of the parcel
- Coordinates of the centre of the parcel
- Surface
- Agricultural region
- Municipality
- Sand/no sand
- Main crop
- Pre crop
- First crop after main crop
- Second crop after main crop
- Third crop after main crop
- Attribution of derogation
- Focus-area

Based on these figures and information, for each farm a year total of the last five years was made of:

- Acreage at farm level
- Acreage per agricultural region
- Acreage with attribution of derogation
- Acreage without attribution of derogation
- Acreage of grassland
- Acreage of grassland with attribution of derogation
- Acreage of grassland without attribution of derogation
- Acreage of maize
- Acreage of maize with attribution of derogation
- Acreage of maize without attribution of derogation
- Acreage of grassland with clover
- Acreage of grassland with clover with attribution of derogation
- Acreage of grassland with clover without attribution of derogation

Based on the year totals an average of the past five years was calculated of:

- Acreage at farm level
- Acreage per agricultural region
- Acreage with attribution of derogation
- Acreage without attribution of derogation
- Acreage of grassland
- Acreage of grassland with attribution of derogation
- Acreage of grassland without attribution of derogation
- Acreage of maize
- Acreage of maize with attribution of derogation
- Acreage of maize without attribution of derogation

These average figures were completed with an indication of participation in the former monitoring network and an indication of possibility of water measurements (monitoring well or MAP sampling point).

Farms were sorted in function of:

- Participation in the former network
- Water measurement in the former network
- Indication of collaboration in former network
- Acreage in Flemish sand region, Kempen or Dunes for farms on sandy soil
- Acreage in Sandy loam region for farms on sandy loam soil
- Acreage with/without derogation
- Acreage grassland total, with/without derogation
- Acreage maize total, with/without derogation

The former network comprised 175 farms at the ending in 2014. After screening, 74 farms of the former network could be retained in the network 2016-2019. In the following paragraphs, the selection procedure is described in detail.

Due to the restriction of the monitoring network 2016-2019 to sandy and sandy loam soils (Figure 2), farms on clay soils and in the loam region could often not be withheld. Because of the location related to agricultural region and because of soil texture, 25 farms were discarded (Table 3).

Table 2: Overview of parcels in the monitoring network, Flanders, 2014 (Odeurs et al., 2015).

Sand	127
Sandy loam	63
Loam	8
Clay	18
Total	216

Since the desired distribution of the farms in the monitoring network 2016-2019 related to soil texture (90 sandy soil - 70 sandy loam soil) (Table 1) differs significantly from the distribution of the parcels in the former network (127 sandy soil – 63 sandy loam soil) (Table 2), many farms with sandy soils could not be retained in the monitoring network 2016-2019. In this derogation monitoring network the number of farms in each group is defined and limited to the premised number. Because of these fixed numbers in the desired groups, 27 farms could not be retained (Table 3). These were all farms on sandy soils that request derogation.

Table 3: Screening and maintenance former monitoring network

<table>
<tr><th colspan="2"></th><th>Number of farms</th></tr>
<tr><td colspan="2">Start (farms former monitoring network)</td><td>175</td></tr>
<tr><td rowspan="8">Reason of not withholding</td><td>Agricultural region, soil texture</td><td>-25</td></tr>
<tr><td>Fixed number in premised groups</td><td>-27</td></tr>
<tr><td>Request of derogation: uncertain</td><td>-6</td></tr>
<tr><td>No more willing to participate</td><td>-10</td></tr>
<tr><td>No/not enough derogation crops</td><td>-5</td></tr>
<tr><td>Not enough acreage</td><td>-9</td></tr>
<tr><td>Regional distribution</td><td>-6</td></tr>
<tr><td>Experience former network</td><td>-13</td></tr>
<tr><td colspan="2">Farm participating only at the start of the former network</td><td>+1</td></tr>
<tr><td colspan="2">Maintenance former monitoring network</td><td>75</td></tr>
</table>

Since the request for a constant network over a period of 3 years implies that the selected farms need to be a derogation or a non-derogation farm from start to end, some farms could not participate in the network 2016-2019. On these farms the request of derogation depends of yearly influences such as the possibility of renting extra parcels or arrangements with neighbouring farmers to accept manure.

Ten farmers of the former monitoring network that were contacted were no longer willing to participate in the arising network (Table 3).

Because of the restriction of the monitoring network 2016-2019 to the derogation crops: grass, maize and grassland with less than 50 % clover and the condition of monitoring 3 parcels at each farm, some farms could not be withheld. Five farms cultivated none of these crops or do not have enough acreage of these crops to guarantee each year 3 parcels with the selected crop.

Nine farms were not withheld because of a rather small acreage or less representative character.

Although the parcels of the former monitoring network were well spread over the region of Flanders (Figure 3), an even more equal distribution over the agricultural regions Flemish sand region, Kempen and Sandy loam region was pursued (Figure 4 to Figure 7). Therefore 6 farms were not retained (Table 3).

Thirteen farms were not withheld because of former experiences with these farms (Table 3). From these farms, it was often hard to get (accurate) information about fertilisation and yield.

One farmer which was no participant of the former monitoring network at the end because he did not longer labour the specific parcel, was contacted and picked up again (Table 3).

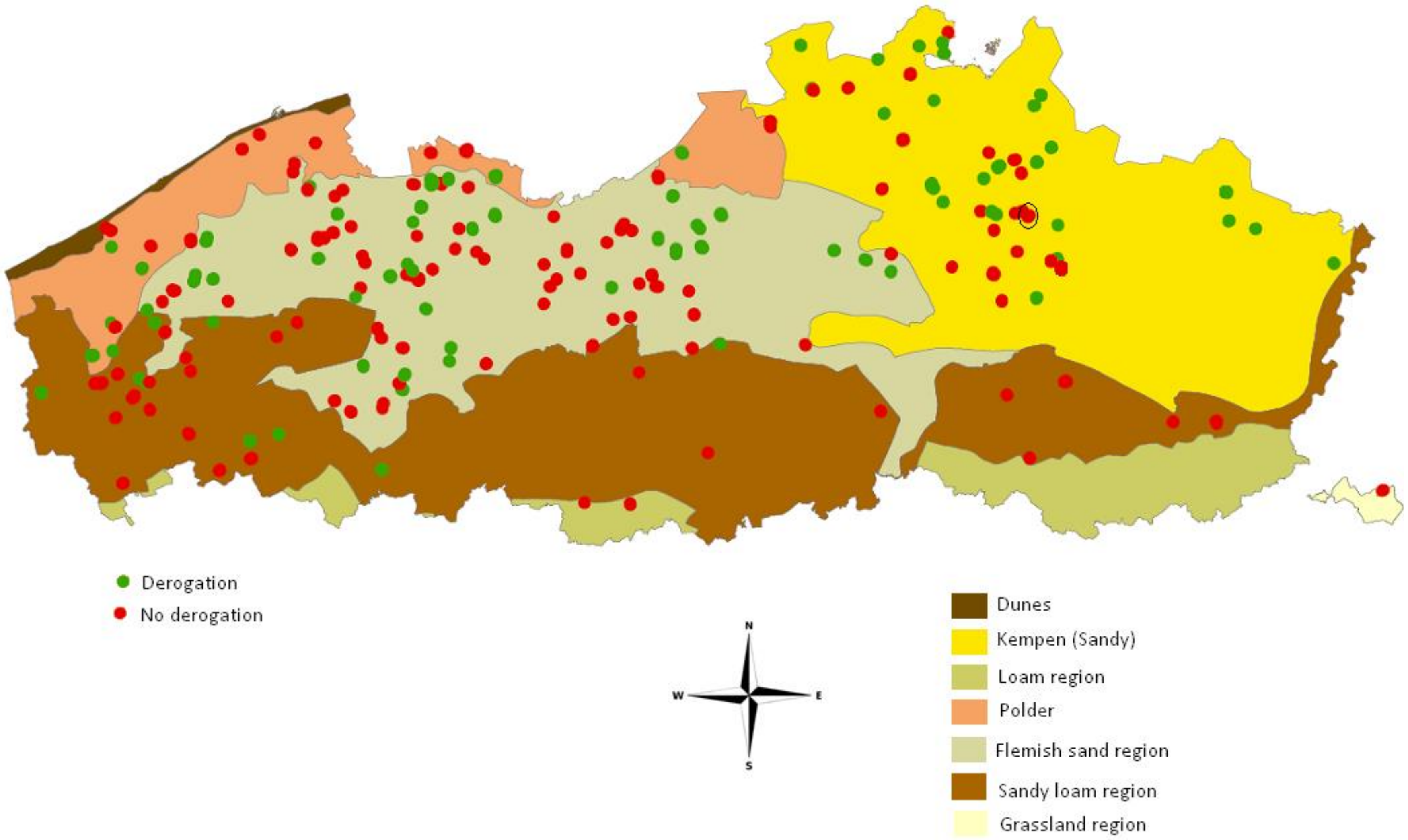


Figure 3: Location of the 217 parcels in the monitoring network in the agricultural regions of Flanders in 2011. The parcel marked with a black circle was discarded from the network since 2012. (Odeurs *et al.,* 2015)

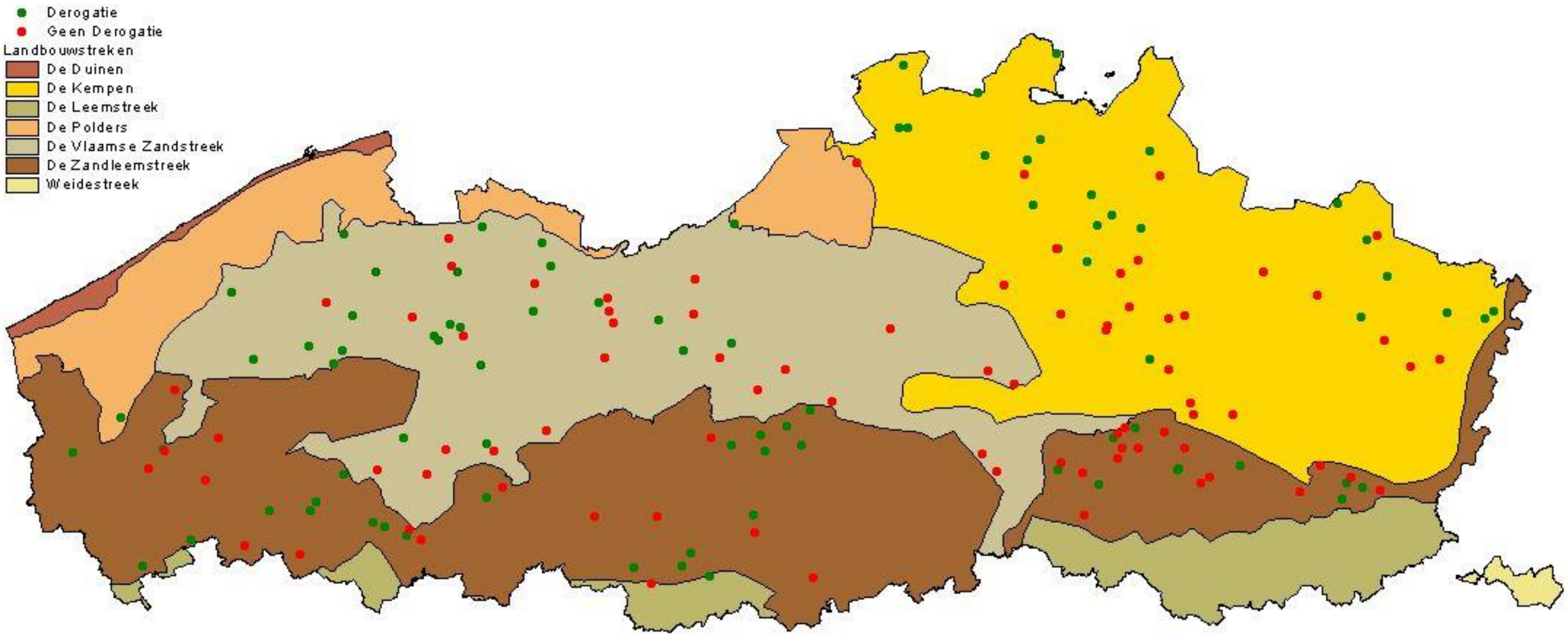


Figure 4: Location of the 164 farms in the monitoring network in the agricultural regions of Flanders in 2016, distinguished by the request of derogation or not.

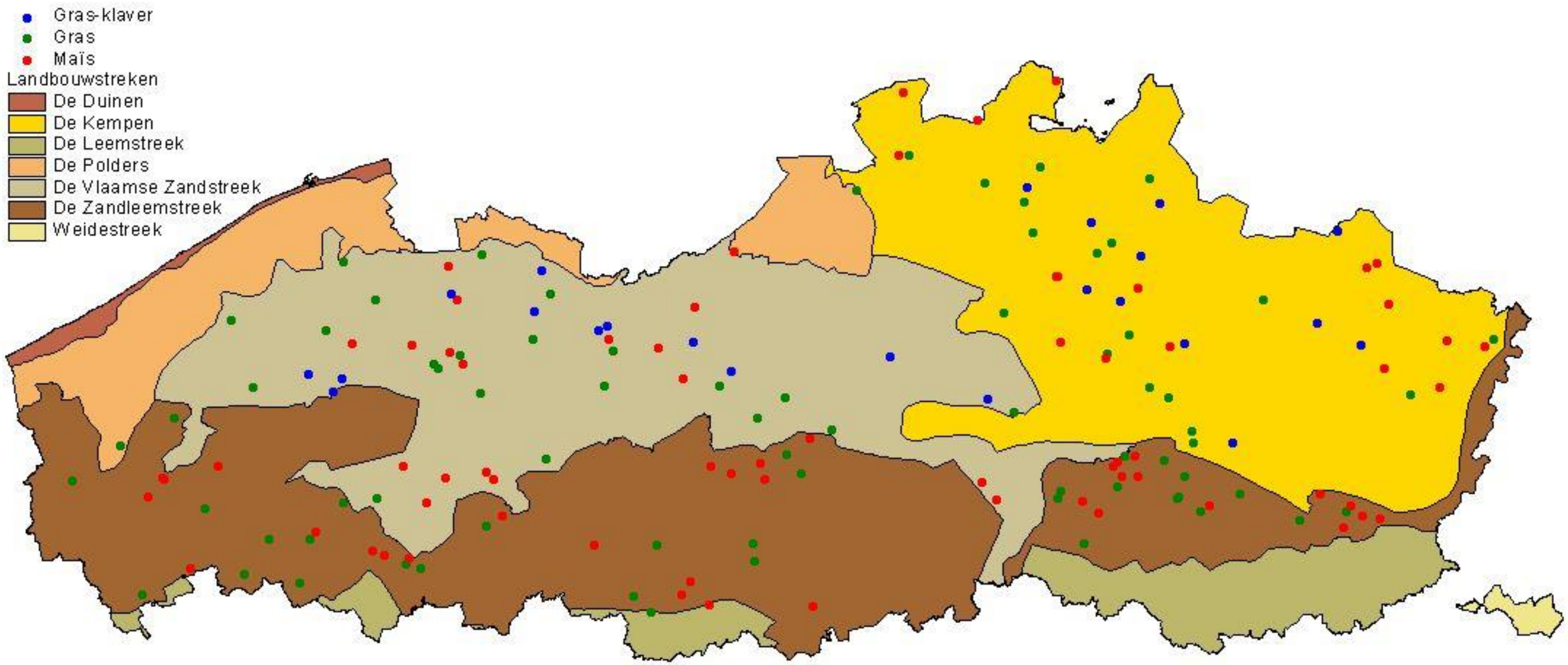


Figure 5: Location of the 164 farms in the monitoring network in the agricultural regions of Flanders in 2016, distinguished by crop.

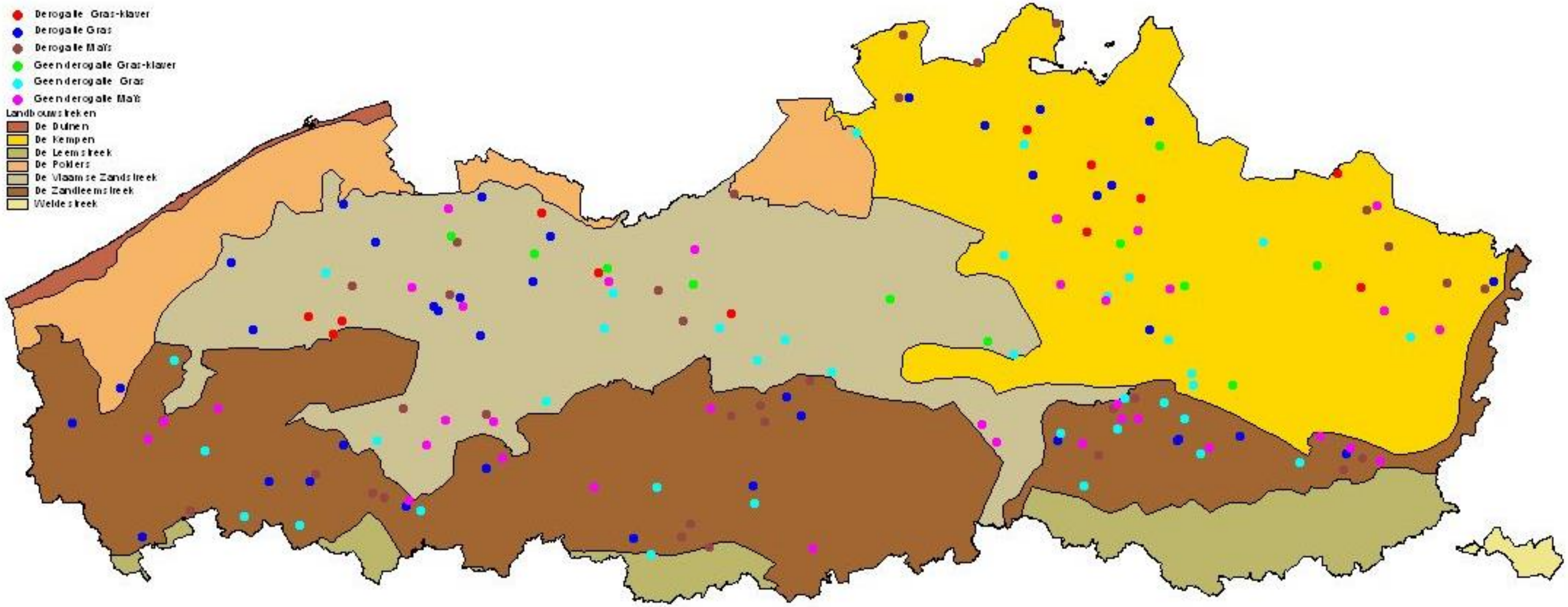


Figure 6: Location of the 164 farms in the monitoring network in the agricultural regions of Flanders in 2016, distinguished by crop and the request of derogation or not.

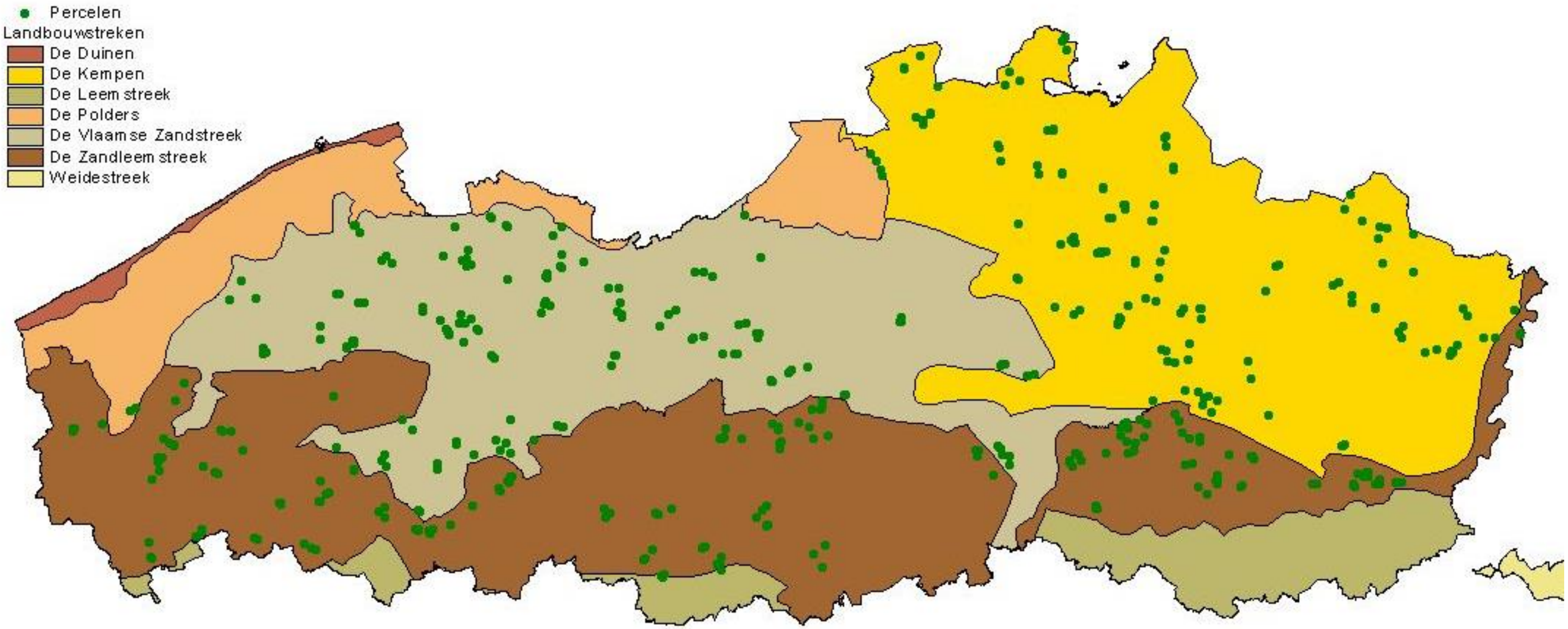


Figure 7: Location of the 480 parcels in the monitoring network in the agricultural regions of Flanders in 2016.

The monitoring network 2016-2019 started with 75 farms of the former monitoring networks.

In response to communication of the consortium about the project, 24 farmers contacted the partners of the consortium for further information and declared to be a candidate for the monitoring network. Unfortunately, 4 of these farms were already part of the former network. Thirteen of the tendering farms participate in the monitoring network 2016-2019 (Table 4).

As mentioned before, there were also farms of other research projects in the first pool of selection. Two of those farms also responded to the call of the consortium. Besides those two farms, 13 more farms out of former research projects are participating in the monitoring network 2016-2019 (Table 4).

As such, the network comprised already 101 farms. The remaining farms were found by appealing to a network of partners and by consulting the participating farmers. Since for grassland with less than 50 % clover derogation could be requested only since 2015, not all farms had already three parcels in 2016. To maintain the required number of sixty parcels grassland with less than 50 % clover (20 farms, 10 derogation and 10 without derogation, with each 3 parcels), more farms were selected. Finally, 23 farms were selected for grassland with less than 50 % clover, so **the new monitoring network 2016-2019 comprises 164 farms**.

Table 4: Recruitment of farms for the monitoring network 2016-2019

Origin	Number of farms
Former monitoring network	75
Spontaneous tendering	13
Former research project	13
Network of partners-counseling participating farms	63
New monitoring network 2016-2019	164

To realize this monitoring network and to reach 164 farms willing to participate, 234 farms were contacted. Seventy farms were or could not be withheld for different reasons.

The number of farms contacted to participate as a farm with grassland with less than 50 % clover and which were not visited, amounted for 25 farms. These farms appeared often not to be suited when getting more information or were not willing to participate. Three farms meant for grassland with clover, were visited but not withheld because of not finding suited parcels.

For maize and grassland an additional 45 farms were approached. Four of them were willing to participate and were visited. Because of age, finding no appropriate parcels or uncertainty about the future of the farm, they could not participate. Of the remaining farms, 8 farmers declared to be too old and/or were not sure if they would still continue the next 3 years. Six farmers mentioned that they did not request derogation each year or requested derogation for the first or last time, because of which those farms were not or less suited for the monitoring network 2016-2019.

Some declared not to be willing to participate without a clear reason. Most of them however declared not to be willing because of the poor financial situation in the agricultural sector and/or an administrative load, which is experienced as too high.

An overview of the number of farms in the network started in 2016 is given in Table 5.

Table 5: Overview of the number and distribution of farms in the monitoring network started in 2016.

	Derogation on a derogation farm				No derogation on a farm without any derogation				Total
Derogation crop / Soil texture	Grass	Maize	Grassland with less than 50 % clover	Total	Grass	Maize	Grassland with less than 50 % clover	Total	
Sandy	18	17	13	**48**	18	17	11	**46**	**94**
Sandy loam	18	17	-	**35**	18	17	-	**35**	**70**
Total	**36**	**34**	**13**	**83**	**36**	**34**	**11**	**81**	**164**

1.2 Network anno 2017

In November and December 2016 information about fertilisation, yield and crop management was gathered by means of questionnaires. The questionnaires and the obtained figures were discussed with the farmers when the researchers visited the farms in January-April 2017.

At that moment, some farmers communicated changes in farm management which implied that the farm could no longer participate in the monitoring network or that the farm could no longer belong to the group it was first assigned to. The circumstances are further explained below.

One farm, being characterised as "derogation; sandy loam; grass", transformed all parcels grass into parcels grass-clover by overseeding with clover. Since clover was not monitored on sandy-loam soils this farm will be no longer a part of the monitoring network.

At a second farm, which was characterised as "no derogation; sandy loam; grass", it is necessary to request derogation since 2017. As mentioned in 1.1 the condition of a constant network and by consequence the constant request of derogation or not was evaluated at the start and discussed with the farmers. However, changes in management are inevitable. Because of the loss of the first farm mentioned in the group "derogation; sandy loam; grass" this farm could be retained in the network and will be part of this group instead of the group "non- derogation; sandy-loam; grass" since 2017.

A third farm belonging to the group "no derogation; sand; grass&clover" mentioned he would request derogation from 2017. This farm could no longer be withheld since the premised number of parcels and farms in the group "derogation; sand; grass&clover" was filled in. To replace this farm another farm was selected and contacted. The farmer agreed to participate and the spreading over the region of Flanders and the agricultural regions as reached after set up in 2016 could be maintained.

A last farm could no longer participate in the monitoring network because of the family situation. This loss was compensated by contacting a neighbouring farmer who would also take care of the farm and parcels of het former farmer.

An overview of the network and the number of farms is shown in Table 6. The location of the 480 parcels monitored in 2017 is demonstrated in Figure 8.

During the visit in January-April, documents to register fertilisation (both organic and mineral) and yield at harvest in 2017 were provided to the farmers.

Table 6: Overview of the number and distribution of farms in the monitoring network in 2017.

	Derogation on a derogation farm				No derogation on a farm without any derogation				Total
Derogation crop / Soil texture	Grass	Maize	Grassland with less than 50 % clover	Total	Grass	Maize	Grassland with less than 50 % clover	Total	
Sandy	18	17	13	**48**	18	17	11	**46**	**94**
Sandy loam	18	17	-	**35**	18	17	-	**35**	**70**
Total	**36**	**34**	**13**	**83**	**36**	**34**	**11**	**81**	**164**

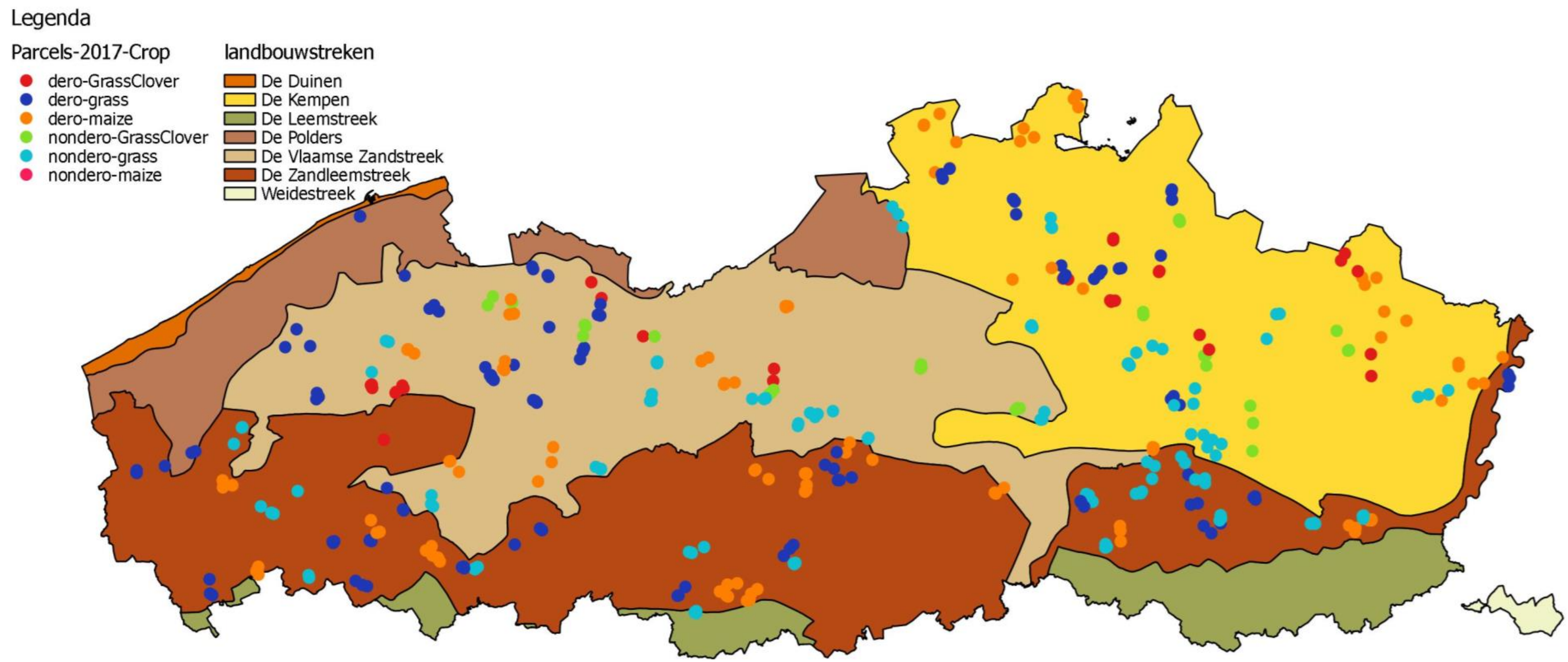


Figure 8: Location of the 480 parcels in the monitoring network in the agricultural regions of Flanders in 2017, distinguished by crop and the request of derogation or not.

1.3 Network anno 2018

For the year of production 2017, information about fertilizing, yield, crop and parcel management was gathered by means of questionnaires, which were distributed in November 2017. This besides the documents that were already left at the farms during the visit in spring 2017.

The questionnaires and the communicated information were discussed with the farmers when the research team visited the farms in January-April 2018.

At the moment of consultation some farmers communicated changes in farm management. This sometimes implied that the farm could no longer participate in the monitoring network in 2018 or it implied that the farm could no longer belong to the group of farms in which the farm started.

A first farmer indicated that derogation would be needed in the future. The farm belonged to the group of farms without derogation, on sandy soils and parcels with maize under monitoring.

A second farm, which was characterised as 'derogation; sand; maize", could not request derogation in 2018 since the evaluation of the nitrate-N residue was negative for the second time. The programme of measures of category 2 was imposed to the farm and the farmer was no longer allowed to request derogation. Those two farms could be switched from group and the set-up of the monitoring network remained unchanged. The farm mentioned first will be characterised as 'derogation; sand; maize" in 2018 and the second farm will be characterised as 'no derogation; sand; maize" in 2018.

On one farm monitored regarding grass with less than 50 % clover, all activities were stopped end 2017. On some farms, monitored for grass with less than 50 % clover, it was not possible to monitor 3 parcels at the start of the monitoring network. Since the number of parcels with grass and less than 50 % clover increased on some farms, it became possible to monitor 3 parcels. Therefore the parcels, lost by the activity stop, are replaced by parcels on farms already participating in the monitoring network.

Further two farms without derogation where maize parcels were monitored, indicated that all activities on the farm would be stopped. These two farms were situated on sandy and sandy loam soils.

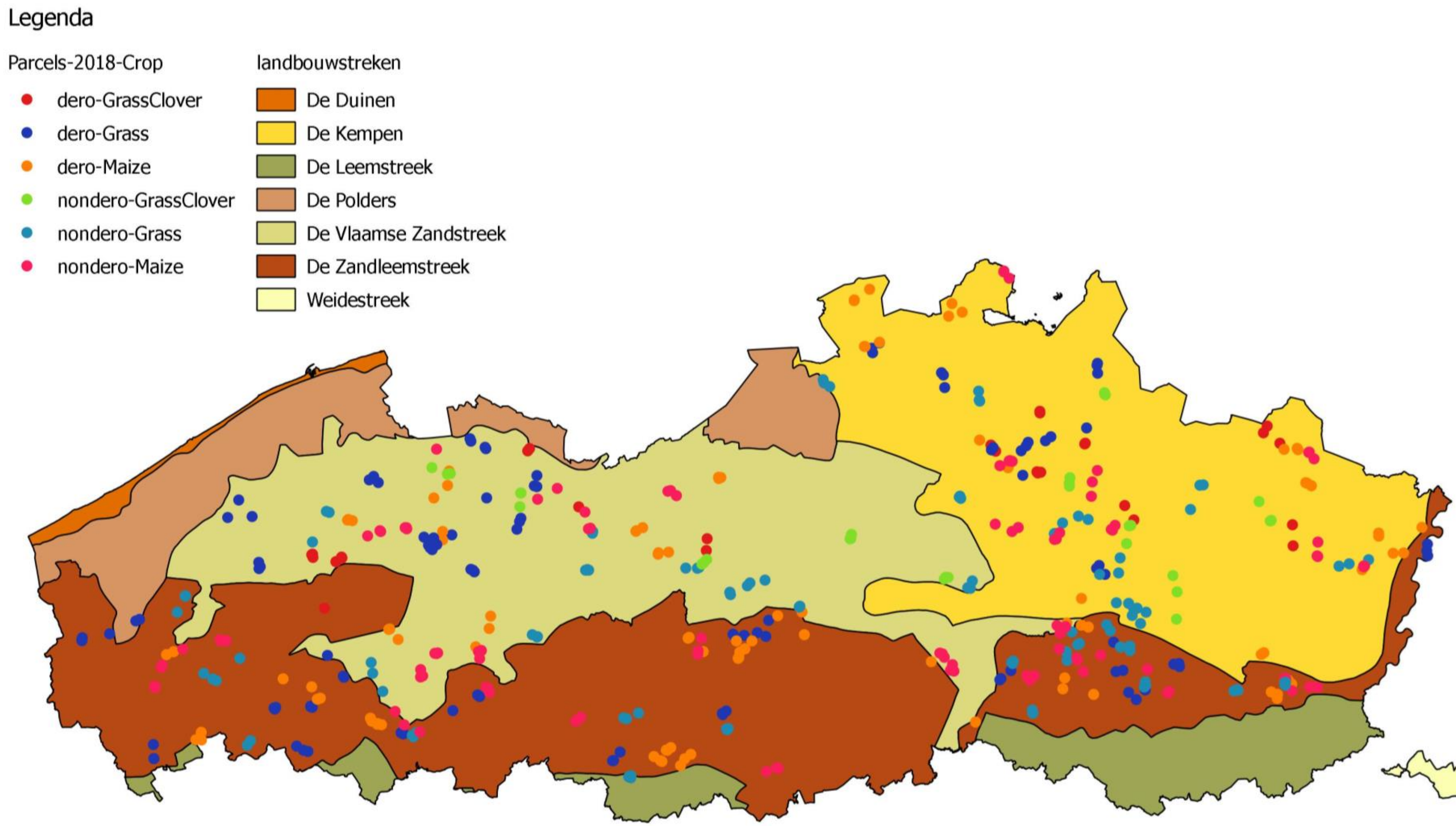


Figure 9: Location of the 480 parcels in the monitoring network in the agricultural regions of Flanders in 2018, distinguished by crop and the request of derogation or not

Three other derogation farms indicated other difficulties. A first derogation farm characterised initially as 'derogation; sandy loam; grass" indicated that no animals would be held anymore and derogation would no longer be necessary and no longer be requested. The 2 other derogation farms, on sandy and sandy loam soils indicated that the number of parcels with the main crop under monitoring would be reduced and not enough anymore for participation in the monitoring network.

The last 5 farms mentioned, were successfully replaced by new farms. So the set-up of the monitoring network could be maintained. An overview of the network and the number of farms is shown in Table 7. The location of the 480 parcels monitored in 2018 is shown in Figure 9.

Table 7: Overview of the number and distribution of farms in the monitoring network in 2018.

	Derogation on a derogation farm				No derogation on a farm without any derogation				Total
Derogation crop / Soil texture	Grass	Maize	Grassland with less than 50 % clover	Total	Grass	Maize	Grassland with less than 50 % clover	Total	
Sandy	18	17	13	**48**	18	17	10	**45**	**93**
Sandy loam	18	17	-	**35**	18	17	-	**35**	**70**
Total	**36**	**34**	**13**	**83**	**36**	**34**	**10**	**80**	**163**

1.4 Network anno 2019

The research team visited the farmers in the period January-April 2019 to discuss the results of 2018 and to agree upon the parcels that are suited for monitoring in 2019.

One farmer said he would no longer participate in 2019. It was a farm with grass on sandy soils under derogation conditions. This farm could be replaced by a farm which was already part of the monitoring network and which would operate under derogation conditions since 2019.

This last farm which was previously monitored in the category "no derogation; sand; grass", could be replaced by a farm which also already participated. This farm was previously characterised as "no derogation; sand; grass and less than 50% clover", but decided to cultivate no grass and clover in 2019. This farm was replaced by a new participating farm, situated on sandy soils and cultivating 27 % of its land with grass and clover.

One farmer in the category "derogation; sandy loam; grass" intended to retire. This farm was replaced by a farm of the same municipality. Another farm of the category "derogation; sandy loam; grass" decided to replace the crop of grass under derogation conditions by grass and less than 50% clover. This farm was replaced by a farm of the same village. On its turn it was categorised in 2019 in the category "derogation; sandy loam; maize".

In the category "derogation; sandy loam; maize" 2 farms needed to be replaced, one farm which had not enough parcels with maize under derogation conditions on sandy loam soils in 2019 and a second farm for which derogation offered no longer benefits. These farms were replaced by the farm that left the category "derogation; sandy loam; grass" and a new farm.

Three farms which were monitored regarding maize without derogation on sandy loam soils had no maize in 2019. Because of the poor yields and bad financial results of the previous years they decided to lease their land to farmers which grow potatoes, a crop for which a higher rent is paid. These farms were substituted by two 'new' farms and the farmer of the category "derogation; sandy loam; grass" who intended to retire. The farmer intending to retire, decided to grow a limited number of crops without derogation. The two 'new' farms were situated in the same region as the formers farms, situated on sandy loam soils. Maize represented 17 and 20 % of their acreage in 2019.

One farm of the category "no derogation; sand; maize" of 2018 supposed to be granted derogation again in 2019 and to be taken up in the category "derogation; sand; maize" in 2019. Therefore it was already replaced by a new farm in the category without derogation. The derogation however was still not granted and the farm remained in the category "no derogation; sand; maize". However, no farm of this category was rejected which resulted in 18 farms instead of 17 farms in this category in 2019.

Table 8: Overview of the number and distribution of farms in the monitoring network in 2019.

	Derogation on a derogation farm				No derogation on a farm without any derogation				Total
Derogation crop / Soil texture	Grass	Maize	Grassland with less than 50 % clover	Total	Grass	Maize	Grassland with less than 50 % clover	Total	
Sandy	18	17	13	**48**	18	18	10	**46**	**94**
Sandy loam	18	17	-	**35**	18	17	-	**35**	**70**
Total	**36**	**34**	**13**	**83**	**36**	**35**	**10**	**81**	**164**

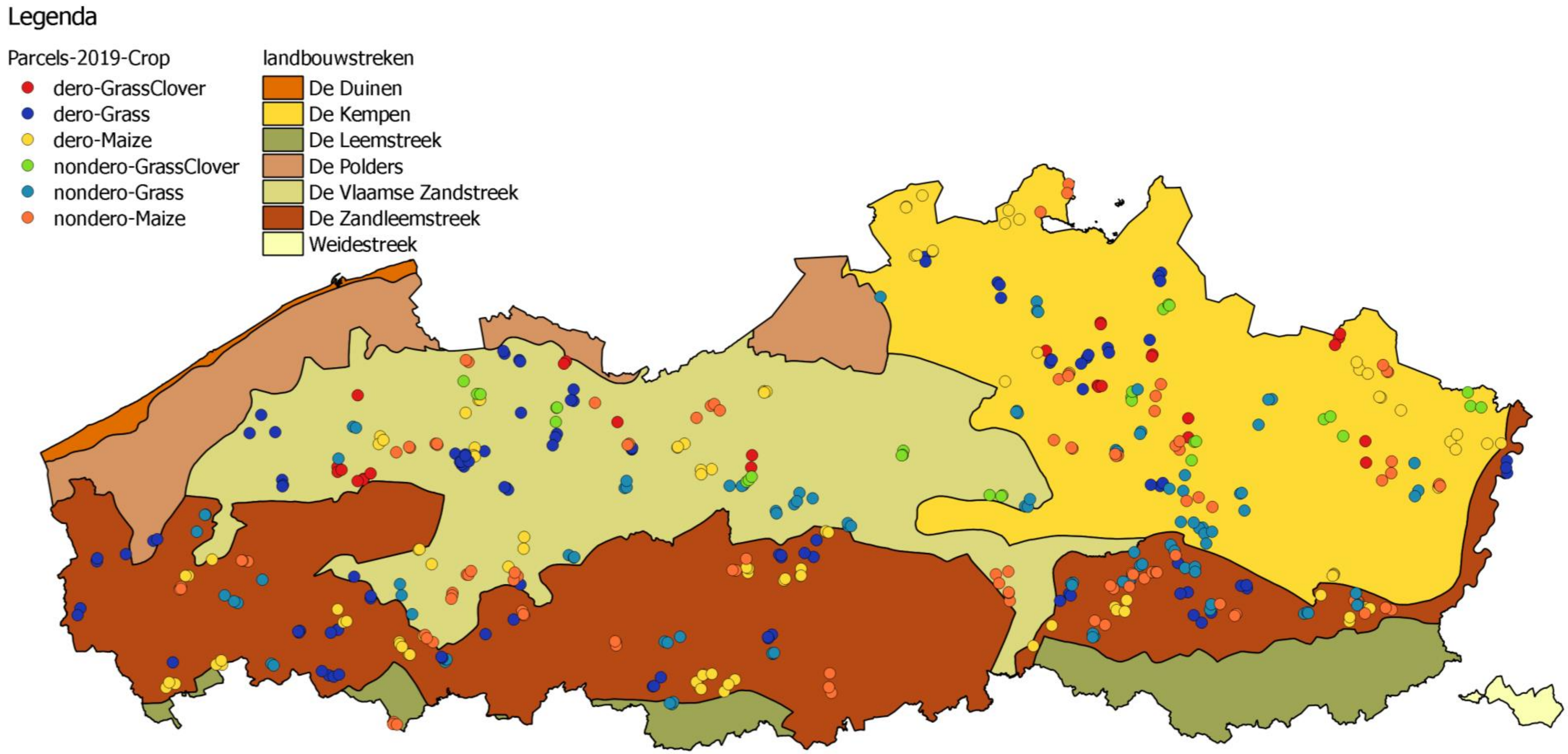


Figure 10: Location of the 483 parcels in the monitoring network in the agricultural regions of Flanders in 2019, distinguished by crop and the request of derogation or not.

It could be summarized that the changes in the management of the farms were well caught and that farms with a changed farm management were successfully replaced. Because of appreciation 1 farm in surplus of the envisaged number of farms was monitored in 2019. An overview of the network and the number of farms is shown in Table 8. The location of the parcels monitored in 2019 is shown in Figure 10.

1.5 Survey

Regarding parcels without derogation on derogation farms additional information was gathered. Reasons to not apply derogation on some parcels while derogation is applied at other parcels, were asked for on the derogation farms. The survey was realised in 2 phases: the farmers were asked for more information about their parcels without derogation by means of the questionnaire and at the farm visit. It was no multiple choice question, but one simple question 'Why do you not apply derogation on some parcels?".

In the monitoring network, 94 farmers that applied derogation were asked why derogation was not applied at all parcels. Five percent of those farmers did not give a clear indication of their reasons, 95 % of the farmers gave more explanation.

Those farmers however, gave often more than one reason. The reasons were categorised in 11 categories:

- Limited fertilisation standard
- Phosphate saturated area
- Converted grassland
- Exceedance of the nitrate-N residue standard the former year.
- No derogation crop
- Derogation crop but required fertilisation strategy is not feasible or believed in.
- Impossible to sow grass in autumn & the cut of grass cannot be realised before the maize; Parcel characteristics e.g. too long, too wet in spring and no early fertilisation possible.
- Distance between the parcel and the farm too large and too difficult for frequent manure transport.
- Rented land
- Also no derogation manure at the farm
- No need for more disposal margin for organic manure

In specific zones defined as vulnerable zones, no fertilisation is allowed or lower fertilisation standards are imposed. The prohibition or the reduction of fertilisation is not compatible with derogation. In phosphate saturated area, phosphate fertilisation is restricted: maximum 40 kg P_2O_5/ha can be applied. In the case of cattle slurry this means a maximum dose of 28.6 ton/ha, according to the standard value of 1.4 kg P_2O_5/ton. A dose of 28.6 ton cattle slurry however, results in 'only' 137 kg total organic N/ha. A higher dose of total organic N cannot be realised in phosphate saturated area. This means that on parcels marked as phosphate saturated, derogation cannot be applied. On converted grassland derogation cannot be applied, even so on parcels on which the nitrate-N residue standard was exceeded the year before.

On most of the farms that apply derogation more than only derogation crops are grown. Regularly some parcels are grown with potatoes or Lucerne is grown for the roughage diet. On the other hand derogation is not always applied on all derogation crops. Some farmers will not apply derogation on winter wheat since they do not apply slurry on the wheat in the spring. Other farmers will request derogation only for the parcels cultivated with grass, since they do not want to jeopardize the yield of the maize because of maize that is sown later after a cut of grass.

On some parcels a cut of grass cannot be realised by occasion, while other parcels are nearly always to wet to permit a cut of grass before the maize. Other barriers to apply derogation on derogation crops can be the distance or the renting of parcels. Parcels far away from the farm are less suited for frequent manure transport and some farmers indicated that they focus the application of derogation on their own parcels and that they prefer not to do it on parcels that are rented. The production of organic nitrogen that cannot be applied under derogation conditions e.g. pig slurry, can be another reason to not apply derogation on a selection of parcels. On some farms the produced organic nitrogen can all be applied under derogation conditions but the production exceeds only moderately the disposal margin making a little proportion under derogation conditions already enough to balance the production and the disposal margin.

The importance of the different reasons is reflected in Figure 11 as percentage of all mentioned reasons.

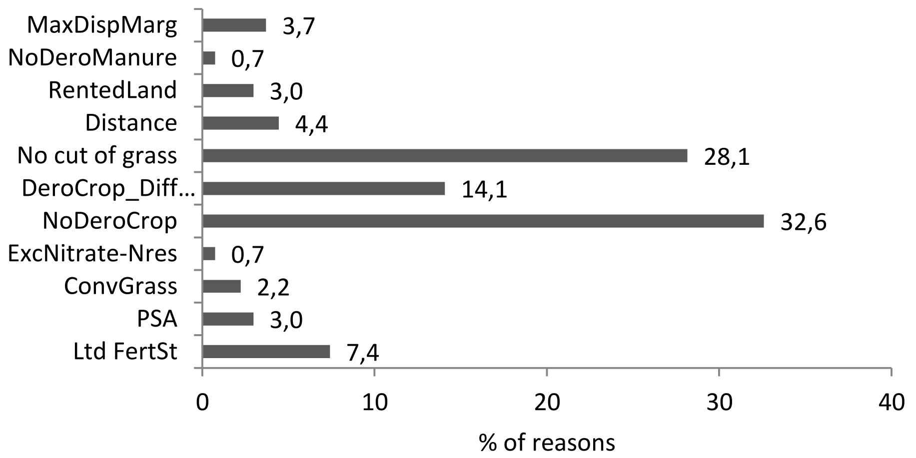


Figure 11: Frequency (%) of different reasons to not apply derogation on some parcels while derogation is applied at other parcels of the farm, according to the derogation farms of the derogation monitoring network 2016-2019.

The survey of these parcels made clear that the motives to not request derogation are often the same. Growing a crop for which derogation cannot be requested is the most important. The five categories first mentioned are parcels that are stipulated as parcels excluded for derogation by the Flemish Land Agency (VLM)

Besides that, important reasons to refrain from derogation for some parcels are:

- Impossible to sow grass in autumn and the cut of grass cannot be realised before the maize, Parcel characteristics e.g. too long, too wet in spring and no early fertilisation possible
- Derogation crop but required fertilisation strategy is not feasible or believed in.
- Distance between the parcel and the farm too large and too difficult for frequent manure transport.
- No need for more disposal margin for organic manure

Farmers stated that fertilisation standards are respected or these parcels are sometimes even less fertilised as allowed.

2 Production parameters

To frame the results of the monitoring the production parameters as climate, fertilisation and yield are discussed in this paragraph. Since they precede and affect the monitoring measurements, they are discussed first, before the monitoring results.

2.1 Climate

Weather and climatic conditions play a prominent role in agriculture. The weather has an impact on several moments, processes and parameters. It strongly influences crop growth, the crop management and the processes in soil, like mineralisation and leaching.

The crop management like sowing date, moment of fertilisation, moment of cutting/harvest, … is clearly function of the weather. But also soil processes like mineralisation, leaching, … are function of temperature and rainfall. End results like production or nitrate-N residue are definitely the result of more than fertilisation alone and need to be considered in a wider perspective.

Therefore, an overview is given of the climatic conditions during each cropping season. These conditions need to be considered when evaluating e.g. production and the amount of mineral nitrogen in the soil profile.

The values, figures and tables shown are observations at Brussels-Uccle, gathered by the Royal Meteorological Institute (KMI).

The "normal" values of the different parameters are the average values of the parameters in the period 1981-2010. This 30-year period is currently the reference period to determine the 'normal' values of Uccle. The degree of abnormality of values is based on the reference period 1981-2010.

2.1.1 Climate 2016

According to the average values of the evaluated climate parameters, such as average temperature, mean maximum temperature, mean minimum temperature, total rainfall, hours sunshine,…, the climate was normal in 2016.

Temperature in spring 2016 (March, April, May) was normal, just like rainfall observed in Uccle. The regional averages of rainfall on the contrary, were all higher as normal. Those regional averages deviated of the normal regional value by 105 % up to 142 %. For example, the deviation of the normal regional value was extreme in the Polders. The total amount of rainfall in spring per region ranged between 125 mm and 425 mm, indicating the regional differences. At some locations, 93.5 mm rainfall was measured in 24 hours on May 30th.

Average rainfall in summer 2016 (June, July, August) was also normal. Nevertheless, very extreme rainfall in June was compensated by subnormal rainfall in July and August making the total rainfall in summer normal.

In autumn 2016 (September, October, November) the average temperature was normal but September was warmer with a double number of days with temperatures above 20 °C. Rainfall was below normal. The regional averages of rainfall were all below normal values. These regional averages ranged between 49 and 94 % of the normal values.

To emphasize the extreme conditions and regional differences in May and June regarding to rainfall, some figures are added, indicating the amount and the regional spreading of the rainfall (Figure 15 and Figure 16).

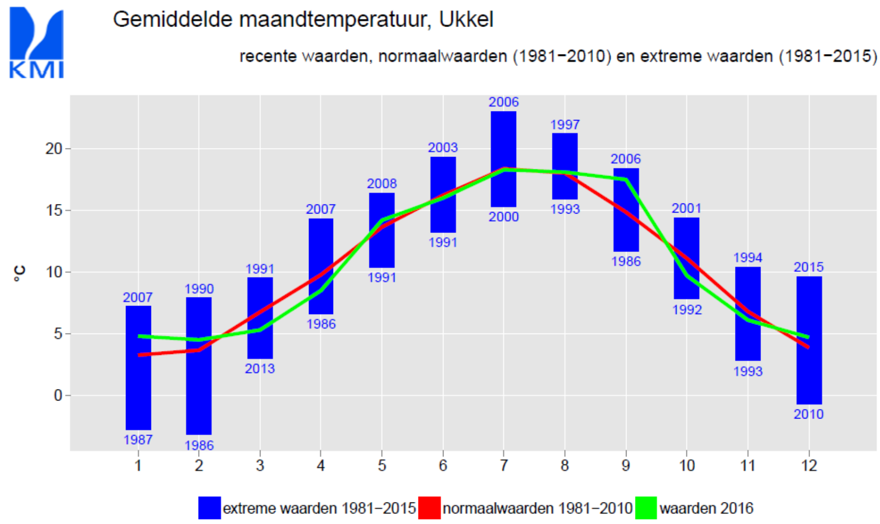


Figure 12: Evolution of average monthly temperature (°C) at Uccle in 2016 (green curve), indication of monthly normal values of the period 1981-2010 (red curve) and indication of the highest and lowest temperatures measured at Uccle since 1981 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be)

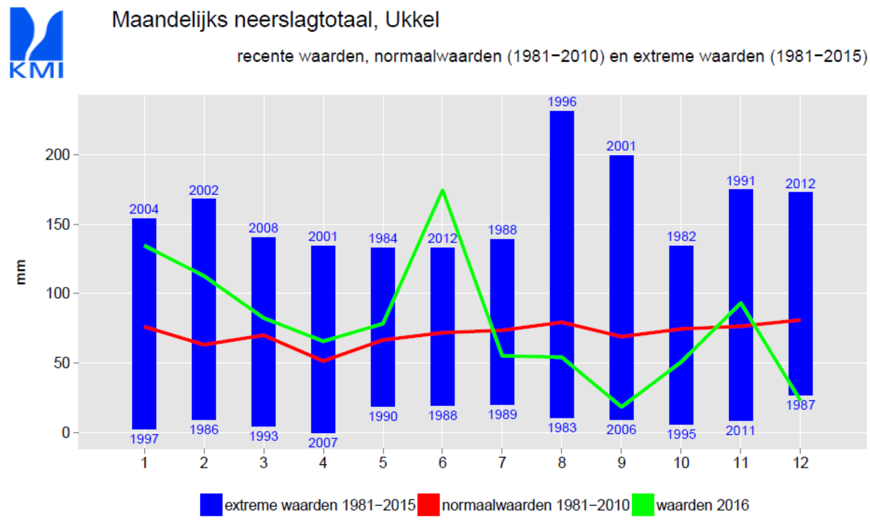


Figure 13: Evolution of monthly rainfall (mm) at Uccle in 2016 (green curve), indication of monthly normal values of the period 1981-2010 (red curve) and indication of the most and least rainfall measured at Uccle since 1981 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be)

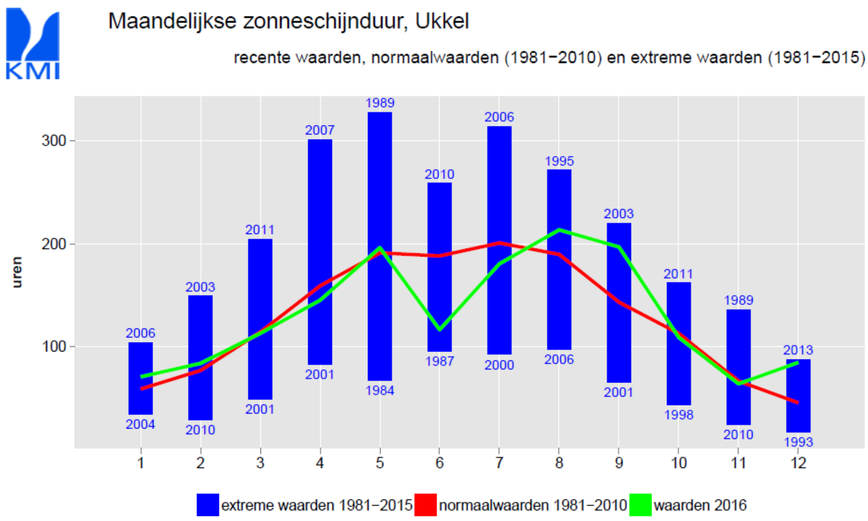


Figure 14: Evolution of monthly sunshine (hours) at Uccle in 2016 (green curve), indication of monthly normal values of the period 1981-2010 (red curve) and indication of the most and least hours of sunshine measured at Uccle since 1981 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be)

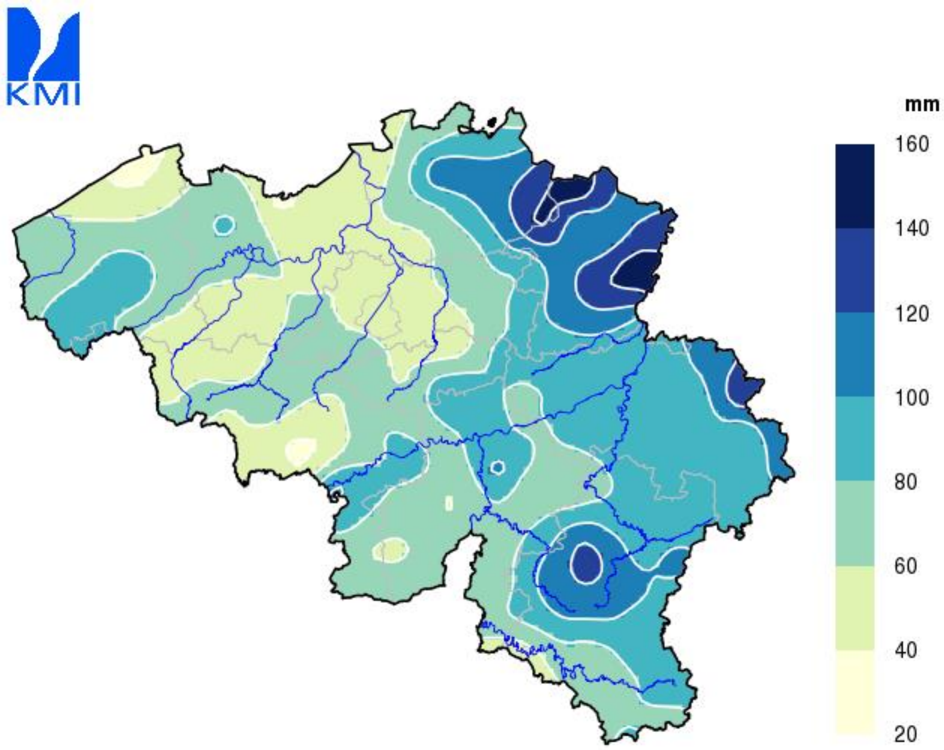
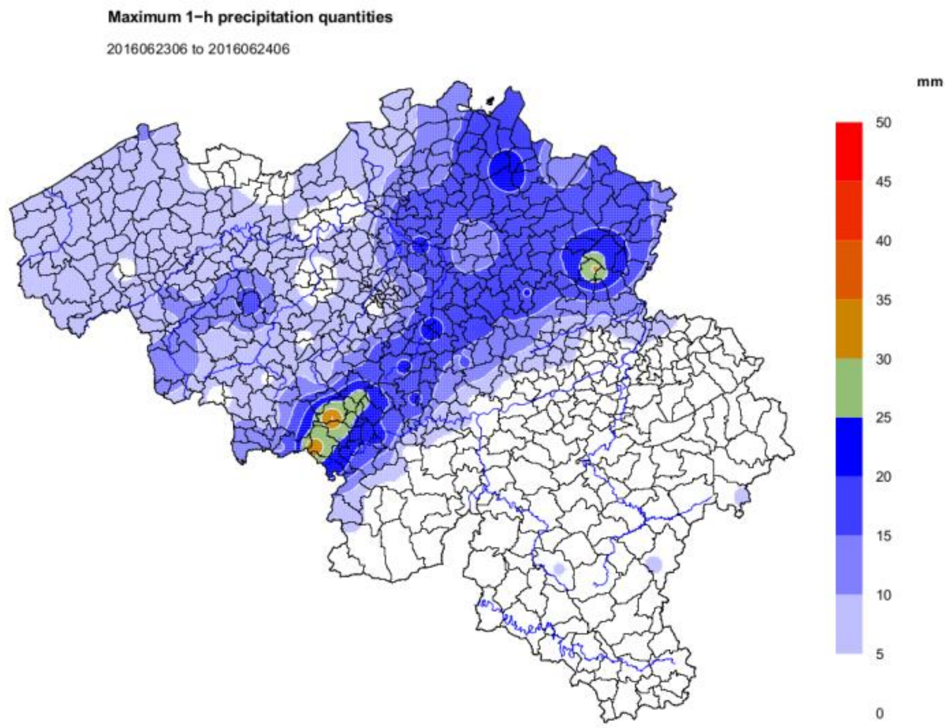


Figure 15: Total rainfall (mm) measured in Belgium between 27.05.2016 08:00 and 03.06.2016 08:00. (Source: KMI, www.meteo.be)



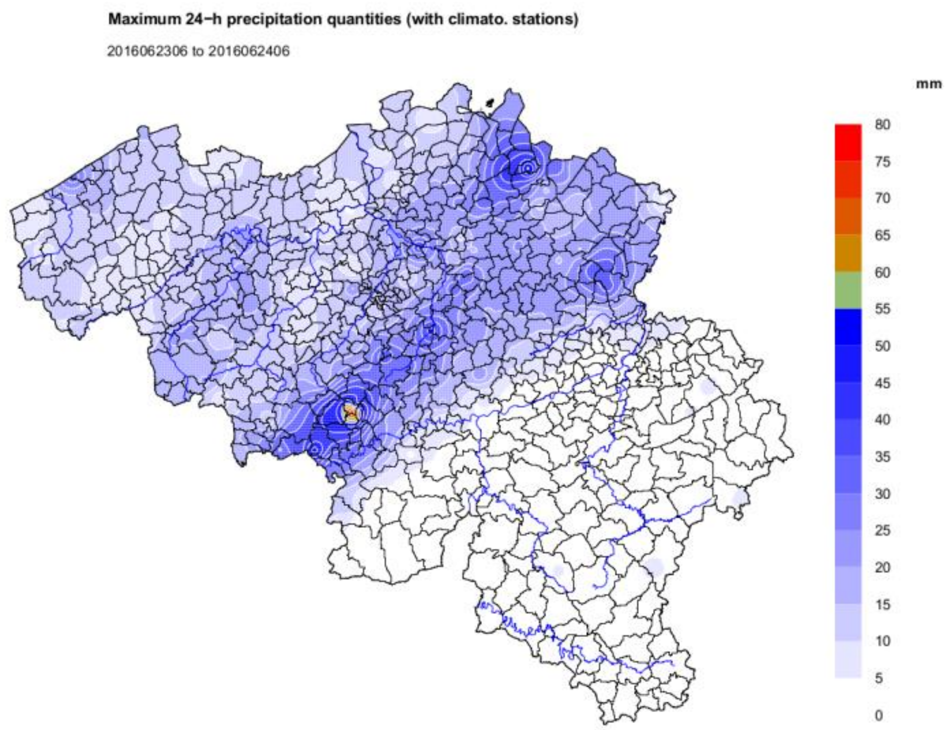


Figure 16: Maximum rainfall in 1 hour (top) and 24 hours (bottom) 23.06-24.06 in Belgium. (Source: KMI, www.meteo.be)

2.1.2 Climate 2017

For most of the evaluated climate parameters and based on the average values over the year, 2017 was a normal year. The climate parameters evaluated as abnormal, based on the annual average, were temperature and hours of sunshine.

The higher mean temperature is obvious in Figure 17. Almost from February until July, except April, the average monthly temperature was higher than normal.

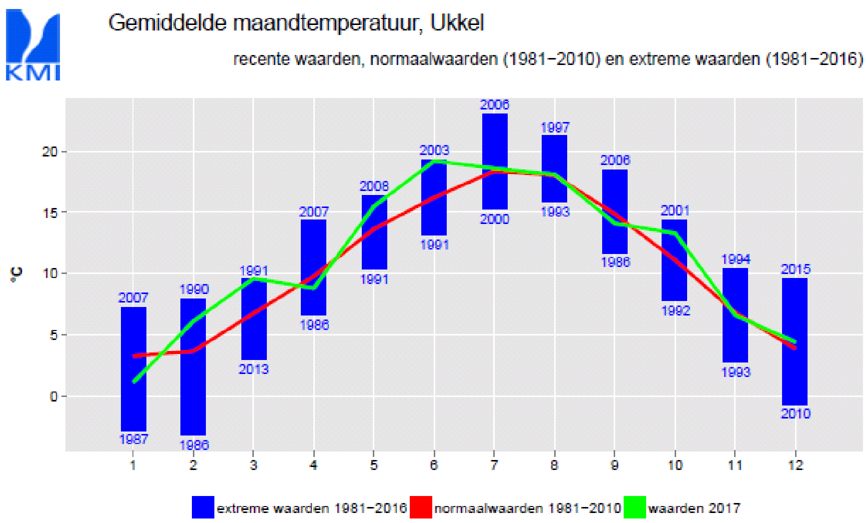


Figure 17: Evolution of the average monthly temperature (°C) at Uccle in 2017 (green curve), indication of monthly normal values of the period 1981-2010 (red curve) and indication of the highest and lowest temperatures measured at Uccle in the period 1981-2016 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be)

Although the yearly total of rainfall was evaluated as normal, it appears in Figure 18 that the monthly rainfall was at a lower level as normal for most part of the year and for a long period from January until August. In April, there was almost no rain.

The inferior amounts of rainfall went almost hand in hand with more sunshine (Figure 19).

These observations are summarized in Figure 20.

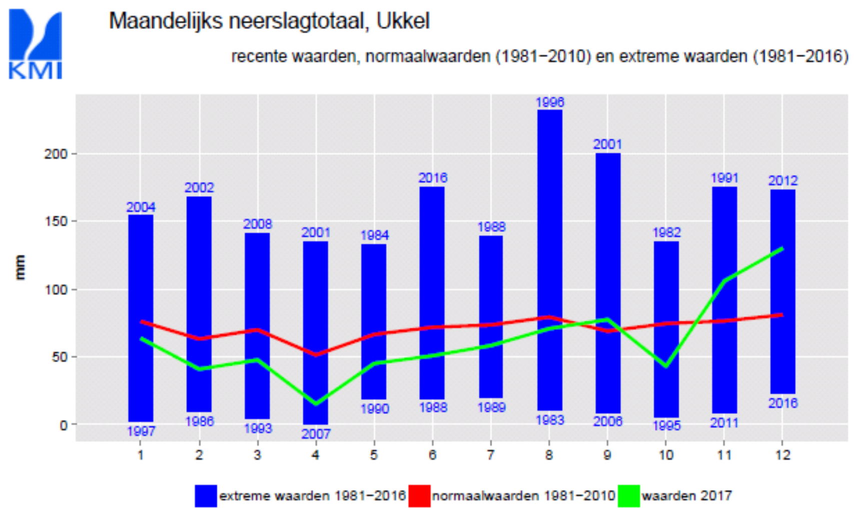


Figure 18: Evolution of monthly rainfall (mm) at Uccle in 2017 (green curve), indication of monthly normal values of the period 1981-2010 (red curve) and indication of the most and least rainfall measured at Uccle in the period 1981-2016 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be)

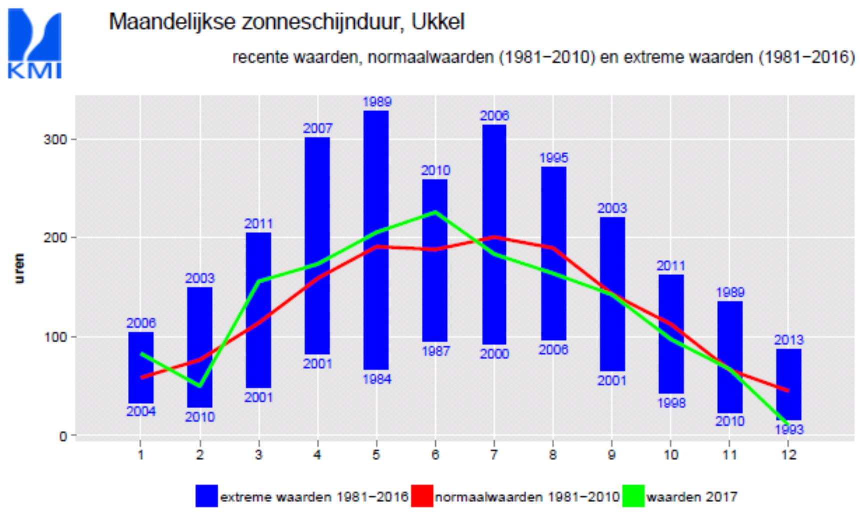


Figure 19: Evolution of monthly sunshine (hours) at Uccle in 2017 (green curve), indication of monthly normal values of the period 1981-2010 (red curve) and indication of the most and least hours of sunshine measured at Uccle in the period 1981-2016 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be)

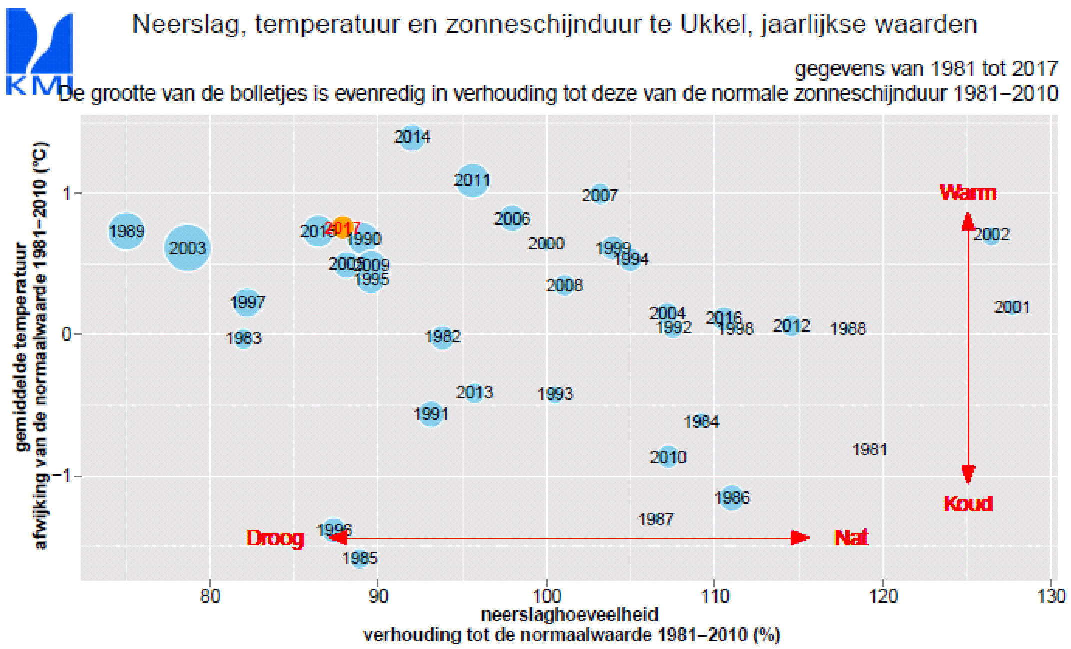


Figure 20: Indication of the amount of rainfall (ratio to the normal value (%)-X-axis), the mean temperature (deviation of the normal value (°C) - Y-axis) and the hours of sunshine (the size of the dots is in proportion to the normal value). The normal values were set for the period 1981-2010. (Source: KMI, www.meteo.be)

In contrast to spring 2016, drought was the problem in 2017. The period with less rain started already in summer 2016 and continued in spring 2017 (Figure 21). The Standardized Precipitation Index, characterises the drought only on basis of data of rainfall. The index compares the total rainfall of a certain period (SPI-3; period of 3 months) with a climatological reference period (1981-2010). The index represents the intensity of the drought in a shorter period. The regional distribution of the SPI-3 index for the period April–June is shown in Figure 22.

The areas that were judged to be exceptional dry in spring 2017, covered an important part of the monitoring network.

The drought in spring highly influenced the utilisation and efficiency of the fertilisation. Late rainfall after a very long period of drought resulted furthermore in a restart of mineralisation and at a high level of mineralisation.

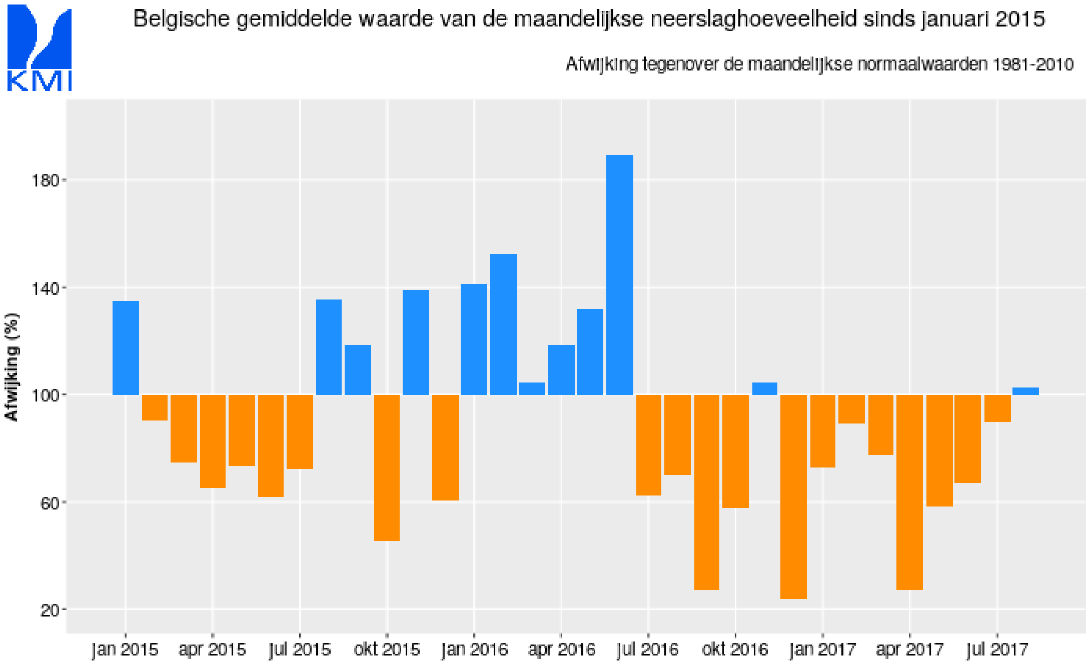


Figure 21: Monthly rainfall in Belgium in the period January 2015-september 2017, indicated as percentage of the normal monthly values. (Source: KMI, www.meteo.be)

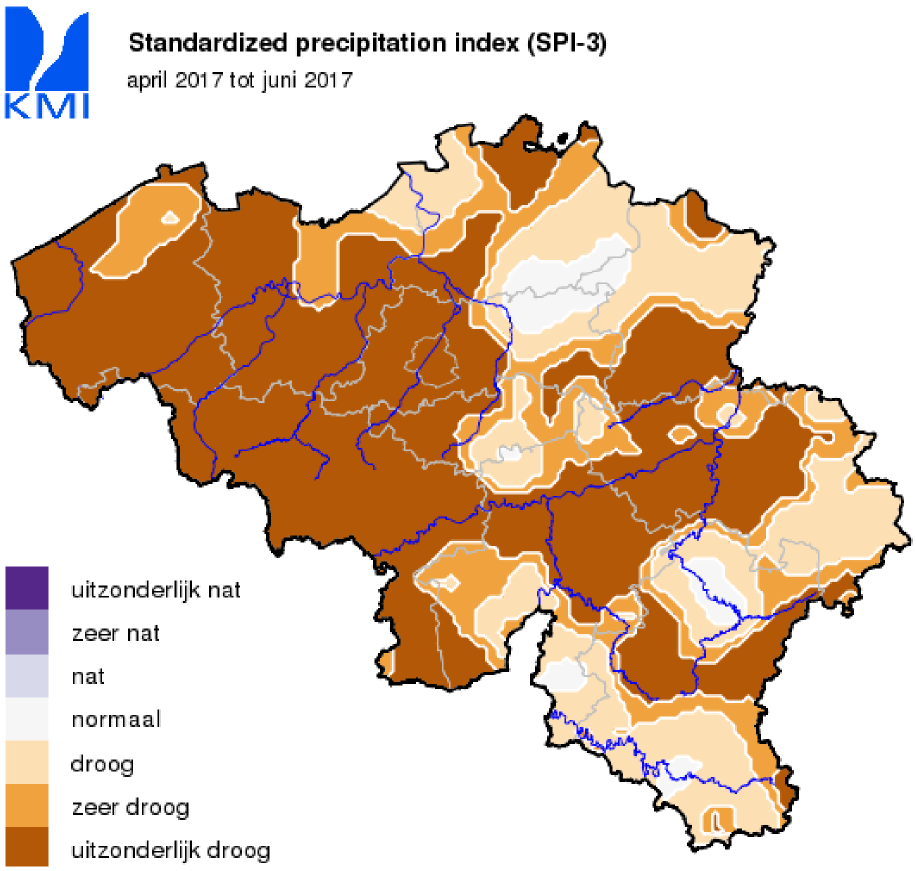


Figure 22: Regional spreading of the drought index SPI-3 of the period April-June 2017, Belgium. (Source: KMI, www.meteo.be)

2.1.3 Climate 2018

The climate of 2018 was rather exceptional.

The average temperature of 2018 amounted 11.9 °C, exceptionally high. Even so was the average maximum temperature and the average minimum temperature abnormally high. The average monthly temperature exceeded in 10 of the 12 months the normal average monthly temperature (Figure 23), most pronounced in the period April-August.

The total amount of rainfall on the other hand was very abnormally low. Such a low amount occurs only once in a period of 10-30 years. Since May, the monthly rainfall was constantly below normal monthly values (Figure 24). In some regions, only 30 mm of rain could be measured between May 1st and July 17th, a period of 2.5 months. The Standard Precipitation Index is a parameter that uses rainfall data to indicate periods of drought. The index compares rainfall data of a period of 3 months (SPI-3) to a reference period (1981-2010). At the beginning of September most parts of Flanders, and by extension Belgium, were characterised as extremely dry (Figure 26). As dry as occurs only once in a period of more than 50 years.

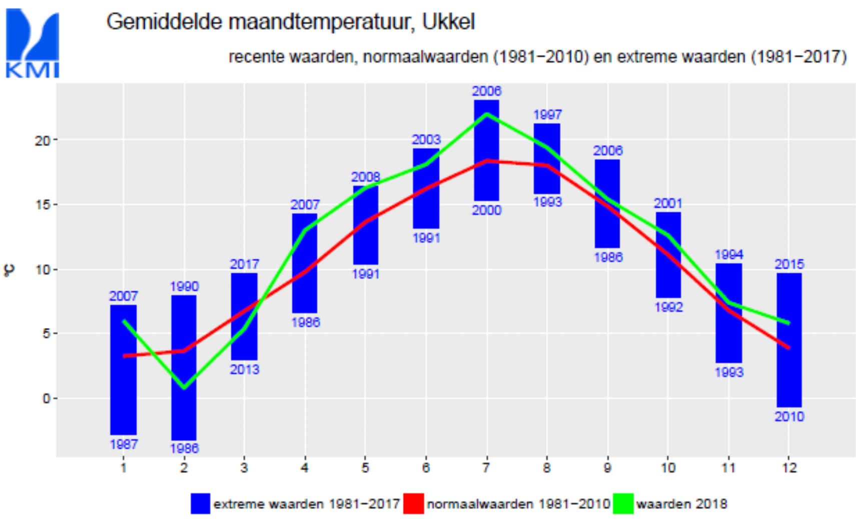


Figure 23: Evolution of the average monthly temperature (°C) at Uccle in 2018 (green curve), indication of monthly normal values of the period 1981-2010 (red curve) and indication of the highest and lowest temperatures measured at Uccle in the period 1981-2017 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be)

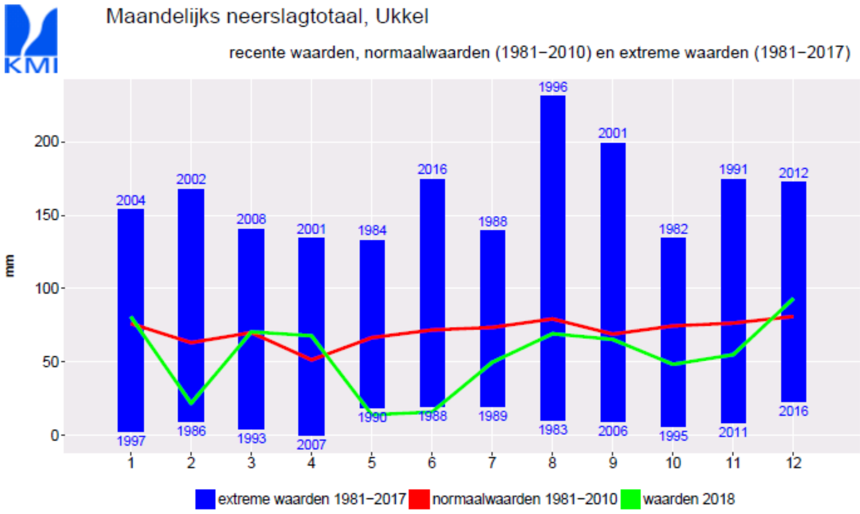


Figure 24: Evolution of monthly rainfall (mm) at Uccle in 2018 (green curve), indication of monthly normal values of the period 1981-2010 (red curve) and indication of the most and least rainfall measured at Uccle in the period 1981-2017 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be)

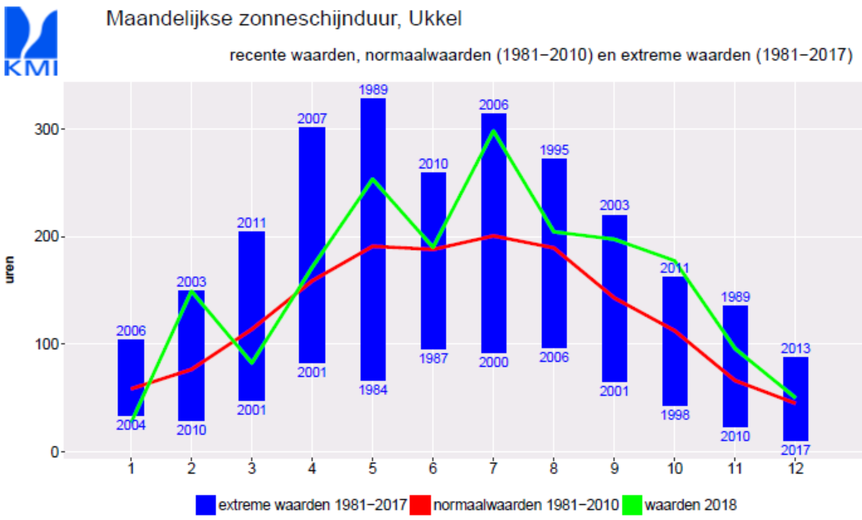


Figure 25: Evolution of monthly sunshine (hours) at Uccle in 2018 (green curve), indication of monthly normal values of the period 1981-2010 (red curve) and indication of the most and least hours of sunshine measured at Uccle in the period 1981-2017 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be)

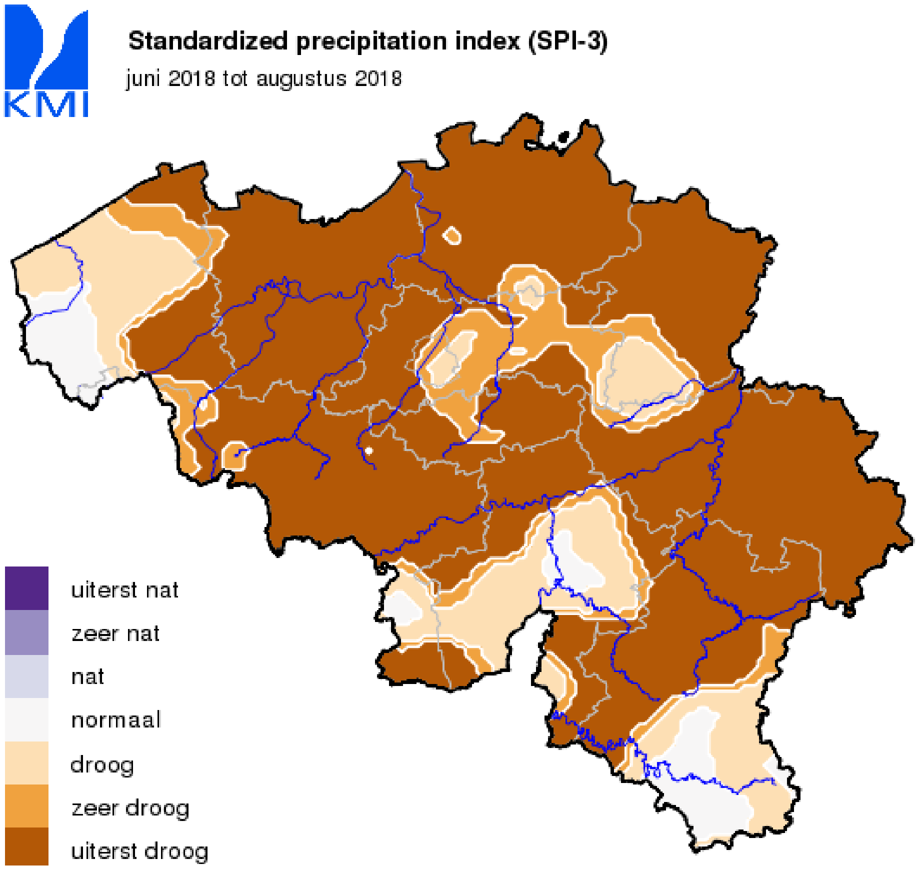


Figure 26: Regional spreading of the drought index SPI-3 of the period June-August 2018, Belgium. (Source: KMI, www.meteo.be) ('uiterst': 1 occurence/>50 years; 'zeer': 1 occurrence/30-50 years; 'nat'/'droog': 1 occurrence/10-30 years)

The lack of rainfall, the high temperatures and lots of sunshine resulted in a large rainfall deficit. This period of deficit lasted long and covered a large part of the cultivation period. Regionally, yield could be highly impacted by the drought. The large number of declarations of reduced yield by Flemish farmers confirmed the major impact.

2.1.4 Climate 2019

The year 2019 was warm, sunny and relatively dry.

The average temperature of 2019 was high (Figure 27). It amounted 11.5 °C, the fourth highest value since 1833. The normal average temperature since 1981 amounts 10.6 °C. Also for the parameters "average maximum temperature" and "average minimum temperature", the fourth highest value since 1833 was registered. The average maximum temperature amounted 15.5 °C, compared to a normal average maximum temperature of 14.2 °C in the period 1981-2010. The average minimum temperature amounted 7.8 °C in 2019, compared to the normal average minimum temperature of 6.9 °C in the period 1981-2010. The highest deviation of the normal values was noticeable in February and at the end of the summer months June, July and August. Those 3 months of summer ended by a heat wave.

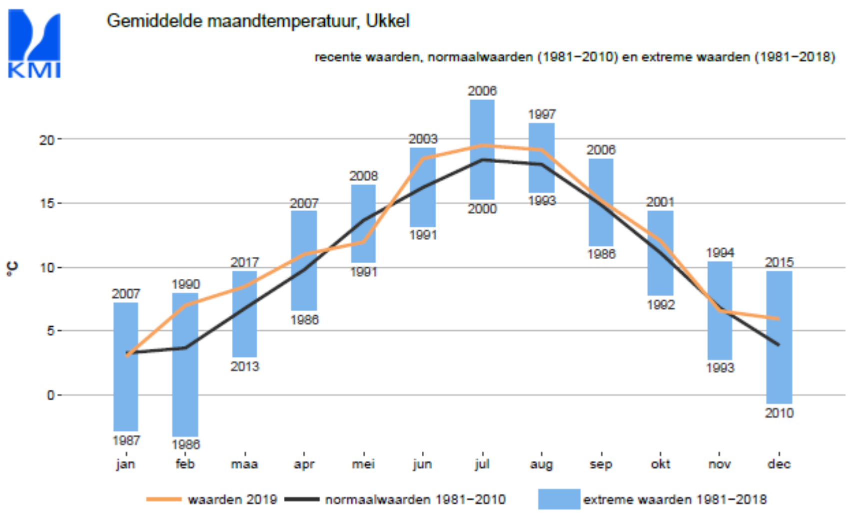


Figure 27: Evolution of the average monthly temperature (°C) at Uccle in 2019 (orange curve), indication of monthly normal values of the period 1981-2010 (black curve) and indication of the highest and lowest temperatures measured at Uccle in the period 1981-2018 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be)

The total amount of rainfall in 2019 tended to the normal value. The normal total amount of rainfall amounts 852 mm. In 2019 in total 799 mm of rainfall was measured in the centre of Belgium. For most of the months, rainfall was below normal (Figure 28). Only in February, March, June and October the monthly rainfall exceeded modestly the normal monthly rainfall. Practically the whole growing season, April-September, was marked by less rain than normal and drought. During summer in almost the entire monitoring network at least 20 % of normal rainfall was missing (Figure 29).

2019 was one of the five sunniest years since 1981. The sun was shining for 1757 hours in 2019, compared to 1544 hours normally in the period 1981-2010. The difference was mainly made in summer (Figure 30).

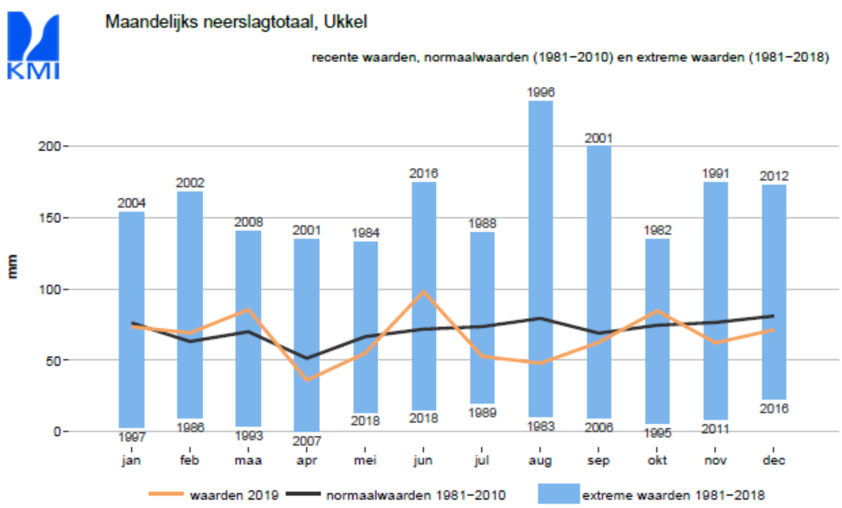


Figure 28: Evolution of monthly rainfall (mm) at Uccle in 2019 (orange curve), indication of monthly normal values of the period 1981-2010 (black curve) and indication of the most and least rainfall measured at Uccle in the period 1981-2018 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be)

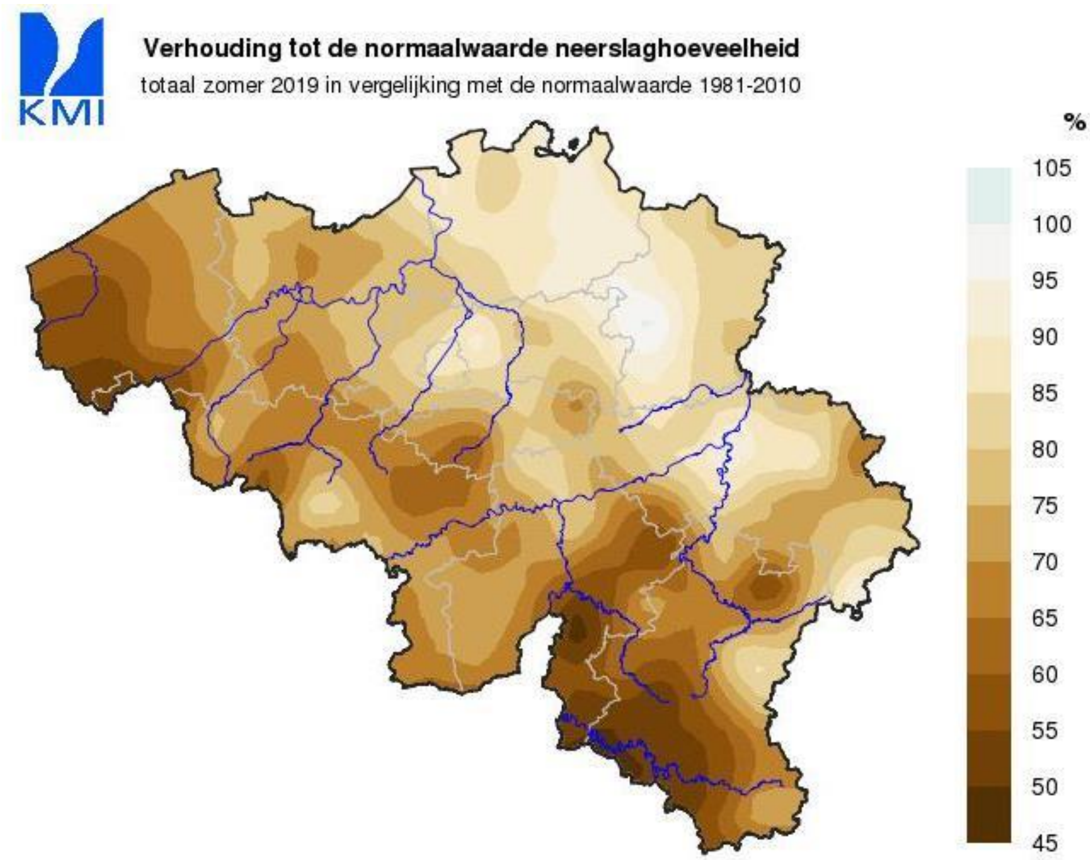


Figure 29: Ratio of the total amount of rainfall in Belgium during summer 2019 to the normal total amount of rainfall during summer in the period 1981-2010. (Source: KMI, www.meteo.be)

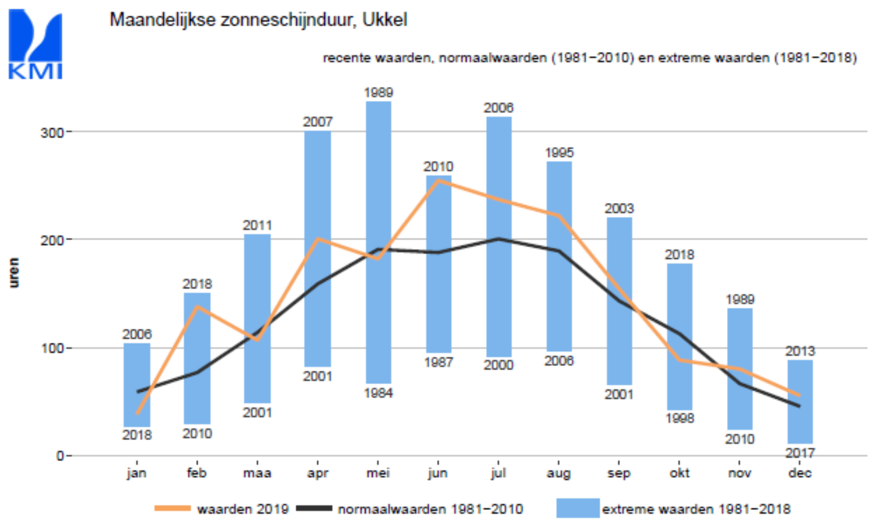


Figure 30: Evolution of monthly sunshine (hours) at Uccle in 2019 (orange curve), indication of monthly normal values of the period 1981-2010 (black curve) and indication of the most and least hours of sunshine measured at Uccle in the period 1981-2017 (ends of blue columns with indication of the record year). (Source: KMI, www.meteo.be)

2.2 Fertilisation

The monitoring network provides data on fertilisation and farming practices. In order to estimate the fertilisation and nutrient input as accurately as possible, the supplied livestock manure is sampled and the composition of nutrients present in the supplied manure is determined. Annually one manure sample is taken at each farm. The farmers receive the laboratory results of the manure samples and an advice concerning the fertilisation value of the manure.

The amounts of supplied mineral and organic nutrients are communicated by the farmers. In the questionnaire the following parameters relevant to estimate nutrient input are questioned:

- date of application
- type of fertiliser applied
- method of application
- composition of fertiliser
- amount of fertiliser

For parcels cultivated with grass or grass and less than 50 % clover data of following parameters are also questioned:

- period of grazing
- hours of grazing per day
- number of grazing animals
- type of grazing animals
- surface which is grazed if more parcels are being grazed

Based on these figures the average nutrient input in the monitoring network is quantified and derogation and no derogation practices are compared.

The input of N and P_2O_5 are discussed separately.

2.2.1 Fertilisation - 2016

2.2.1.1 Nitrogen

Since MAP 5 the manure policy and the fertilisation standards for nitrogen take into account the total amount of organic nitrogen and the total amount of nitrogen that will be available during the growing season ($N_{effective}$) and no longer the total amount of nitrogen (total N mineral plus total N organic). Therefore, only the total amount of organic nitrogen and the amount of nitrogen that will be available during the growing season ($N_{effective}$) are shown in following discussion (Table 9).

For mineral fertilisers, 100 % of the applied nitrogen will be available for crop growth. So the coefficient for plant available nitrogen is estimated 100 %. For organic fertilisers only a part of the applied nitrogen will be available for crop growth. Information about the effective amount of nitrogen is available on the analysis report of the manure samples taken at the monitoring farms.

In general, a coefficient of 60 % is used to calculate the plant available nitrogen from animal manure or other organic fertilisers. For solid manure, this coefficient is 30 %. For excretion by grazing cattle, the coefficient is 20 %.

Table 9: Average nitrogen input (kg N/ha) on derogation and no derogation parcels in 2016.

	Derogation					No derogation				
	Mineral	Organic			Total	Mineral	Organic			Total
		Manure	Grazing	**Total**	**N eff**		Manure	Grazing	**Total**	**N eff**
Grass	193	222	68	290	340	147	103	79	182	224
Grass & less than 50% clover	214	275	1	276	379	180	221	0.4	221	303
Maize	102	226	-	226	229	56	152	-	152	141

Grass

On parcels cultivated with grass on average 340 kg effective N/ha was applied on derogation parcels. Mineral fertilisation represented on those parcels on average 193 kg N/ha. The average amount of total organic nitrogen was 290 kg/ha, 222 kg N/ha by organic fertilisers and 68 kg N/ha by grazing cattle.

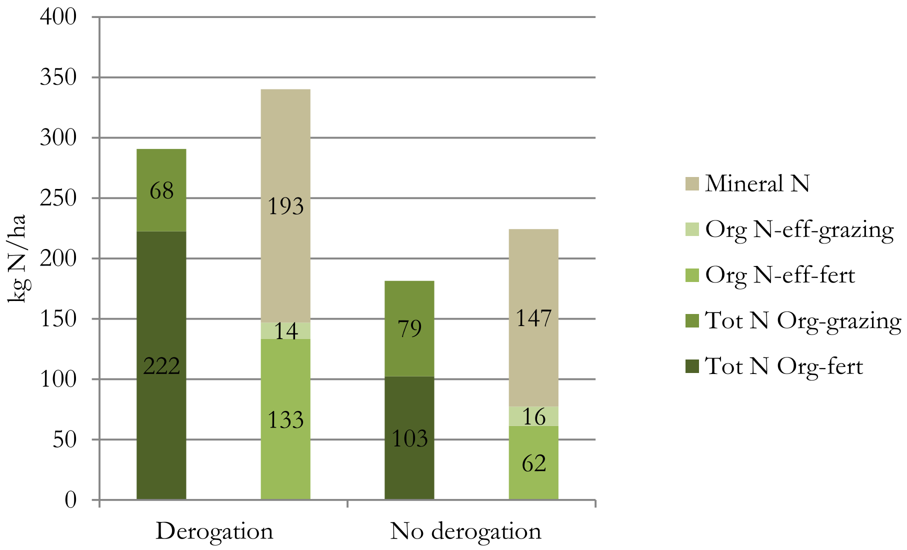


Figure 31: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org-N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was both only cut and cut and grazed on all soils in the monitoring network in 2016.

On the parcels without derogation on average 224 kg effective N/ha was applied. Mineral fertilisation represented on those parcels on average 147 kg N/ha. The average amount of total organic nitrogen was 182 kg N/ha, 103 kg N/ha by organic fertilisers and 79 kg N/ha by grazing cattle (Figure 31).

On sandy soils with grass and derogation 319 kg total organic N/ha was applied, 243 kg N/ha by organic fertilisers and 76 kg N/ha by grazing. The organic fertilisation and grazing was complemented with 182 kg mineral N/ha. On sandy soils with grass without derogation on average 223 kg total organic N/ha was applied, 137 kg N/ha by organic fertilisers and 86 kg N/ha by grazing. The organic fertilisation and grazing was complemented with 149 kg mineral N/ha, resulting in 248 kg effective N/ha (Figure 32).

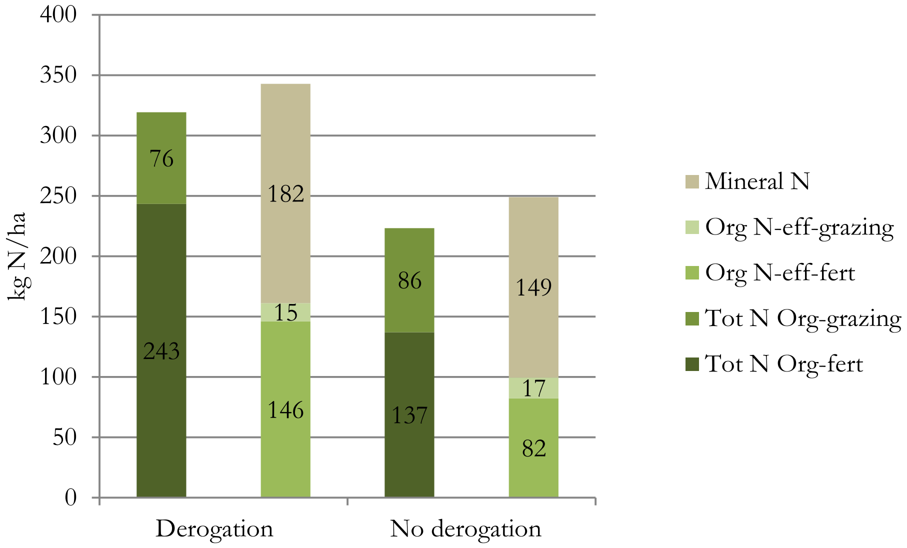


Figure 32: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org-N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was both only cut and cut and grazed on sandy soils in the monitoring network in 2016.

On sandy loam soils with grass and derogation 262 kg total organic N/ha was applied, 202 kg N/ha by organic fertilisers and 60 kg N/ha by grazing. The organic fertilisation and grazing was complemented with 205 kg mineral N/ha, resulting in 338 kg effective N/ha. On sandy loam soils with grass without derogation on average 135 kg total organic N/ha was applied, 64 kg N/ha by organic fertilisers and 71 kg N/ha by grazing. The organic fertilisation and grazing was complemented with 144 kg mineral N/ha, resulting in 197 kg effective N/ha (Figure 33).

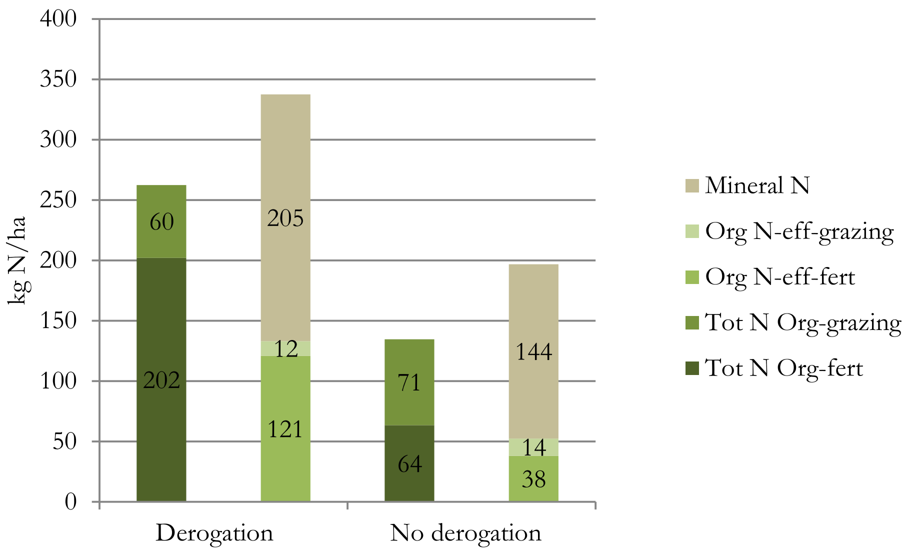


Figure 33: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org-N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was both only cut and cut and grazed on sandy loam soils in the monitoring network in 2016.

Because of differentiation of fertilisation standards regarding soil texture and management of the grass (Table 10, Annex 1 – Nitrogen fertilisation standards), the average fertilisation quantified in the monitoring network is further specified regarding to soil (sand and sandy loam (no sand)) and grass management (Table 11). Within the framework of the farm-specific approach, it is allowed to apply fertilisers till the double of the fertilisation standard at parcel level as long as the fertilisation standards at farm level are not exceeded.

Table 10: Overview of the nitrogen fertilisation standards regarding effective and organic nitrogen on derogation and no derogation parcels cultivated with grass or grass and less than 50% clover.

		Effective nitrogen		Organic nitrogen	
		Derogation / no derogation		Derogation	No derogation
Crop	Combination/ regime	Sandy soils	No sandy soils	All soils	
Grass or grass and <50% clover	Cutting	300	310	250	170
	Cutting & grazing	235	245	250	170

Table 11: Average nitrogen input (kg N/ha) on derogation and no derogation parcels in 2016.

	Derogation					No derogation				
	Mineral	Organic			**Total N eff**	Mineral	Organic			**Total N eff**
		Manure	Grazing	**Total**			Manure	Grazing	**Total**	
Grass	193	222	68	290	340	147	103	79	182	224
Grass, grazing cattle	169	160	132	292	292	130	81	128	209	204
Grass, only cutting	218	289	-	289	391	171	136	-	136	253
Grass, grazing cattle-sand	174	172	124	296	302	138	103	155	258	231
Grass, only cutting-sand	194	356	-	356	408	164	180	-	180	272
Grass, grazing cattle-SL	163	143	144	287	278	122	61	103	164	179
Grass, only cutting-SL	235	245	-	245	381	182	70	-	70	224

On sandy parcels with grass that was cut and grazed under derogation conditions (Figure 34) on average 302 kg effective N/ha was applied, the result of 174 kg mineral N/ha, 172 kg total N by organic fertilisers and 124 kg total N by grazing. On parcels without derogation on average 231 kg effective N/ha was applied, the result of 138 kg mineral N/ha, 103 kg total N by organic fertilisers and 155 kg total N by grazing. The difference in average effective N was the result of a different amount of organic and mineral fertilisers, not from a different amount of grazing.

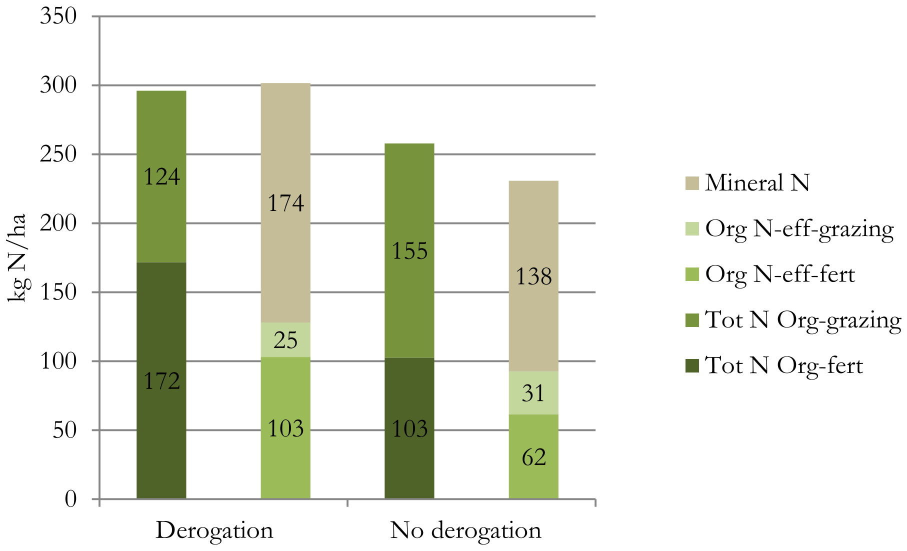


Figure 34: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and by grazing (Org-N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was cut and grazed on sandy soils in the monitoring network in 2016.

On sandy loam parcels with grass that were cut and grazed under derogation conditions (Figure 35) on average 278 kg effective N/ha was applied, the result of 163 kg mineral N/ha, 143 kg total N by organic fertilisers and 144 kg total N by grazing. On parcels without derogation on average 179 kg effective N/ha was applied, the result of 122 kg mineral N/ha, 61 kg total N by organic fertilisers and 103 kg total N by grazing. The difference in average effective N between derogation and no derogation parcels was some higher as on sandy soils. On sandy loam soils all 3 input positions (organic fertiliser, grazing, mineral fertiliser) were at a higher level on derogation parcels.

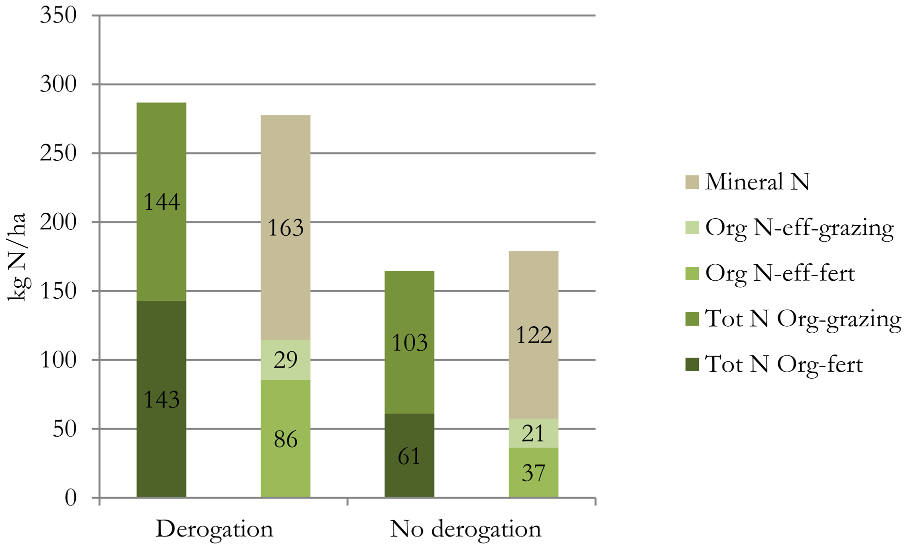


Figure 35: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and by grazing (Org-N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was cut and grazed on sandy loam soils in the monitoring network in 2016.

On sandy parcels with grass that was cut and not grazed under derogation conditions (Figure 36) on average 408 kg effective N/ha was applied, the result of 194 kg mineral N/ha and 356 kg total N by organic fertilisers. On parcels without derogation on average 272 kg effective N/ha was applied, the result of 164 kg mineral N/ha and 180 kg total N by organic fertilisers. For both derogation and no derogation parcels, the nitrogen fertilisation on cut parcels was at a higher level compared to the parcels cut and grazed. However, on the derogation parcels the difference between 100 % cut and grazed parcels was larger in derogation circumstances as without derogation. The difference between derogation and no derogation parcels that are only cut originated mainly from a different amount of organic fertilisers; 356 kg total N/ha on average compared to 180 kg total N/ha.

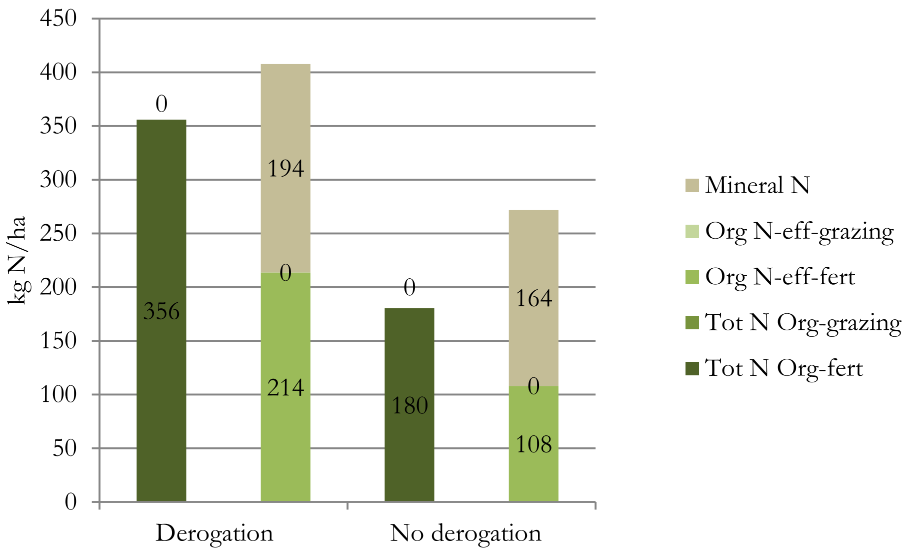


Figure 36: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with grass that was only cut on sandy soils in the monitoring network in 2016.

On sandy loam parcels with grass that was only cut under derogation conditions (Figure 37) on average 381 kg effective N/ha was applied, the result of 235 kg mineral N/ha and 245 kg total N by organic fertilisers. On parcels without derogation on average 224 kg effective N/ha was applied, the result of 182 kg mineral N/ha and 70 kg total N by organic. As also on the parcels with sandy soils appeared, nitrogen fertilisation on parcels with grass under cutting conditions is at a higher level as on parcels with grass which is grazed and cut, both with and without derogation conditions. In addition, the difference between derogation and no derogation cut parcels is larger as the difference between derogation and no derogation cut and grazed parcels. Compared to sandy soils the difference between cut parcels with and without derogation is some bit larger on sandy loam soils.

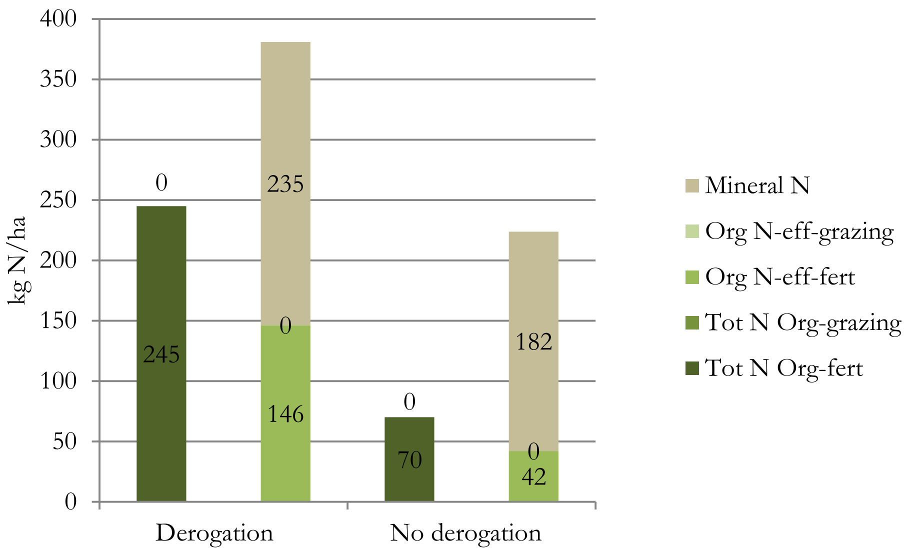


Figure 37: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with grass that was only cut on sandy loam soils in the monitoring network in 2016.

Grass and less than 50 % clover

Grass with less than 50 % clover was monitored only on sandy soils. Therefore, no further distinction regarding to soil type needs to be shown. On parcels with derogation organic fertilisation represented 275 kg total organic N/ha. Since only a few parcels were grazed, the average amount of organic nitrogen by grazing is very little (Table 9). On average, the organic fertilisation was complemented with 214 kg mineral nitrogen per hectare. On the parcels without derogation both less mineral and organic nitrogen was applied. The average amount of total organic nitrogen was 221 kg N/ha. The mineral fertilisation amounted 180 kg N/ha, resulting together with the organic fertilisation in 303 kg N/ha available that year.

Because of the few number of parcels, only 3, cultivated with grass and less than 50 % clover that were grazed and cut, it's not representative to show these figures separately. The average fertilisation on the parcels that were only cut, is shown in Figure 38.

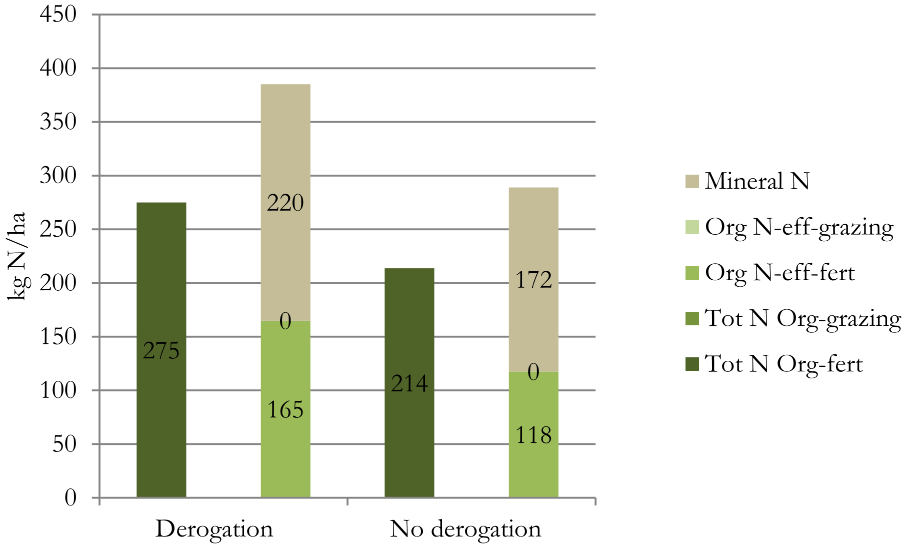


Figure 38: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with grass and less than 50 % clover that was only cut, not grazed on sandy soils in the monitoring network in 2016.

Maize

Also for maize parcels the distinction between derogation and no derogation parcels is clear. On derogation parcels with maize, both more mineral and organic fertilisers are applied.

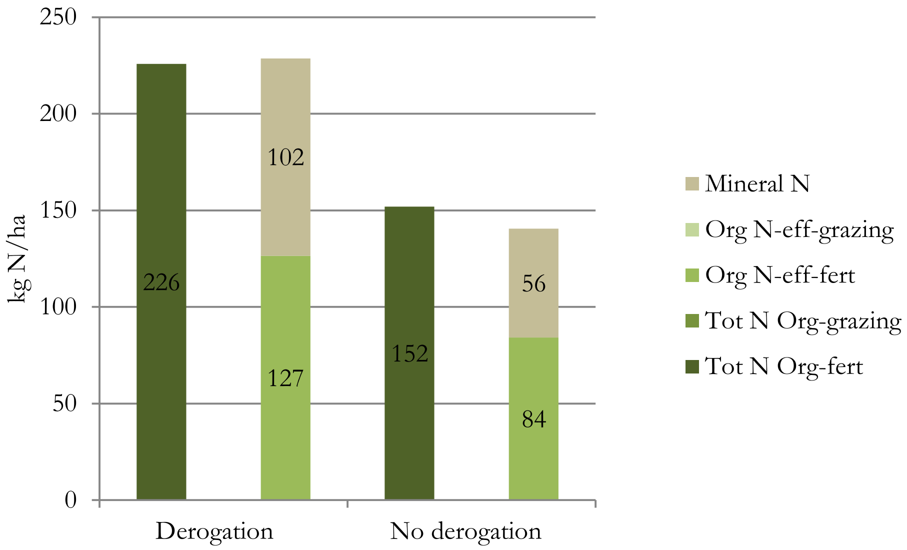


Figure 39: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with maize on all soils in the monitoring network in 2016.

Mineral fertilisation amounted on average 102 kg N/ha on derogation parcels compared to 56 kg N/ha on average on parcels without derogation. Organic fertilisation represented 226 kg total organic N/ha on derogation parcels and 152 kg total organic N/ha on parcels without derogation.

Also for both 'soil types', sandy and sandy loam (other soils, no sand), the difference between derogation and no derogation parcels was clear (Figure 40 and Figure 41).

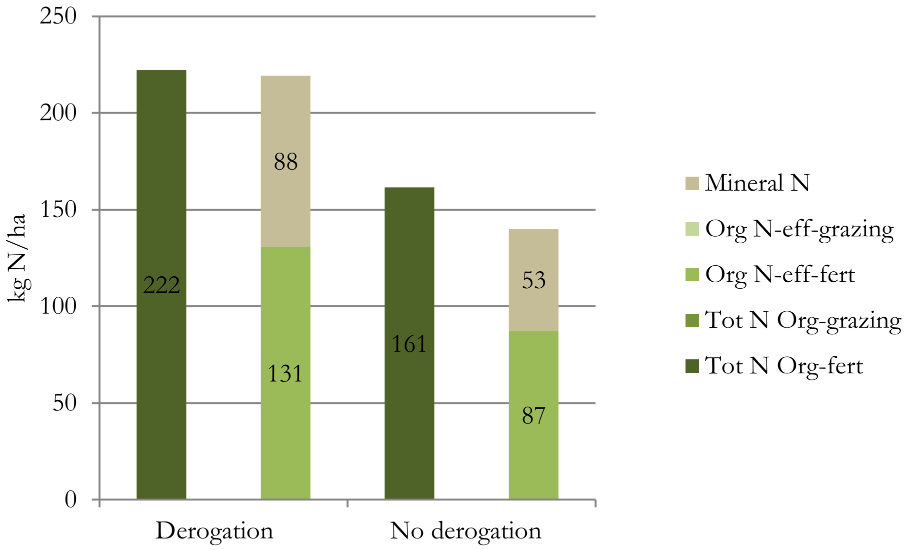


Figure 40: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with maize on sandy soils in the monitoring network in 2016.

On sandy soils cultivated with maize under derogation conditions on average 222 kg total organic nitrogen and 88 kg mineral nitrogen was applied, meaning 219 kg nitrogen/ha available the year of application (Figure 40). On the parcels on sandy soils with maize without derogation 161 and 53 kg total organic and mineral nitrogen was applied, resulting in 140 kg nitrogen/ha available in 2016.

On sandy loam soils (Figure 41) the average amount of total organic nitrogen amounted 230 kg N/ha on derogation parcels and 142 kg N/ha on parcels without derogation. The applied nitrogen available for the crop in 2016 represented 239 kg N/ha on derogation parcels and 141 kg N/ha on parcels without derogation.

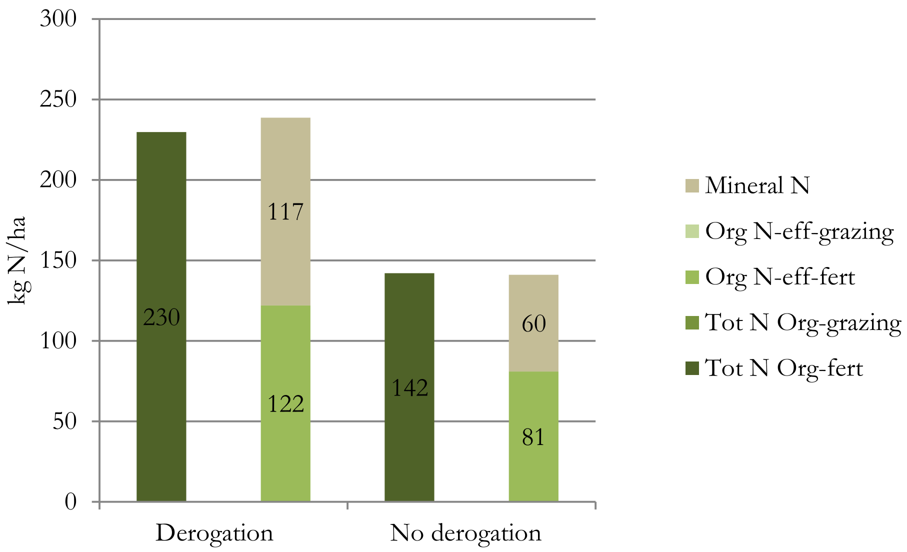


Figure 41: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with maize on sandy loam soils in the monitoring network in 2016.

For maize, fertilisation standards are differentiated regarding soil texture, more specific sand or other soils, and the presence of a preceding cut of grass (Table 12, Annex 1 – Nitrogen fertilisation standards). Therefore, the average fertilisation quantified in the monitoring network is further specified regarding to soil texture and cropping.

Table 12: Overview of the nitrogen fertilisation standards regarding effective and organic nitrogen on derogation and no derogation parcels cultivated with maize.

		Effective nitrogen		Organic nitrogen	
		Derogation / no derogation		Derogation	No derogation
Crop	Combination/ regime	Sandy soils	No sandy soils	All soils	
Maize	No cut of grass	-/135	-/150	250	170
	Cut of grass	200	230	250	170

Since maize grown without derogation conditions is often not preceded by grass or grass that is cut, the number of parcels without derogation and a cut of grass preceding the maize is limited: 7 parcels on sandy soils and 9 parcels on sandy loam soils. This should be kept in mind when comparing the figures of average fertilisation. However the figures indicate that the organic fertilisation was still higher on derogation parcels but the difference between derogation and no derogation practices became smaller (Table 13). The average fertilisation on parcels without derogation and no grass harvested before maize is based on a more extended group of parcels. When no grass was present and harvested before maize the nitrogen fertilisation is clearly at a lower level. Both mineral and organic fertilisers are applied less.

Table 13: Average nitrogen input (kg N/ha) on derogation and no derogation parcels in 2016.

	Derogation					No derogation				
	Mineral	Organic			**Total N eff**	Mineral	Organic			**Total N eff**
		Manure	Grazing	**Total**			Manure	Grazing	**Total**	
Maize	102	226	-	226	229	56	152	-	152	141
Maize & grass	102	226	-	226	229	116	159	-	159	198
Maize without grass before	-	-	-	-	-	44	146	-	146	129
Maize-sand	88	222	-	222	219	53	161	-	161	140
Maize & grass-sand	88	222	-	222	219	98	167	-	167	189
Maize without grass before	-	-	-	-	-	45	161	-	161	132
Maize-SL	117	230	-	230	239	60	142	-	142	141
Maize & grass-SL	117	230	-	230	239	130	154	-	154	205
Maize without grass before	-	-	-	-	-	44	140	-	140	126

2.2.1.2 Phosphorus

The fertilisation standards for phosphorus are differentiated regarding to crop and crop management not regarding to soil texture. Therefore, no distinction is made between sandy and sandy loam soils in the further discussion.

Table 14: Average phosphorus input (kg P_2O_5/ha) on derogation and no derogation parcels in 2016.

	Derogation					No derogation				
	Mineral	Organic			**Total**	Mineral	Organic			**Total**
		Manure	Grazing	Total			Manure	Grazing	Total	
Grass	1	73	22	95	96	2	41	29	70	72
Grass, grazing cattle	1	56	44	100	101	2	35	47	82	84
Grass, only cutting	2	91	-	91	93	1	51	-	51	52
Grass & less than 50 % clover	1	104	0.3	104	105	2	88	0.1	88	90
Grass & less than 50 % clover only cutting	1	104	-	104	105	2	87	-	87	89
Maize	2	79	-	79	81	10	82	-	82	92
Maize & grass	2	79	-	79	81	6	84	-	84	100
Maize without grass before	-	-	-	-	-	10	81	-	81	91

On grass, nearly no mineral phosphorus is applied, both on derogation and no derogation parcels. The input of organic phosphorus is evidently higher on derogation parcels because of a higher input of organic fertilisers. As concluded for nitrogen, the difference between derogation and no derogation parcels is most clear on parcels, which are not grazed and only cut.

Parcels cultivated with grass and less than 50 % clover seem to be exploited rather intensive, also without derogation conditions.

Strictly following the manure policy, no mineral phosphorus can be used on derogation parcels. The very low amounts of mineral phosphorus on derogation parcels with maize coincide with these regulations and are the result of the use of a mineral blend containing phosphorus at the sowing of the maize on some parcels. On parcels without derogation, mineral phosphorus is more applied resulting in an average input of 10 kg mineral P_2O_5/ha. On parcels with maize, the amount of applied organic phosphorus seemed to be higher on no derogation parcels. However, for organic nitrogen the applied amount was lower on no derogation parcels compared to derogation parcels. The diverging differences for organic nitrogen and phosphorus on parcels cultivated with maize are the result of the type of organic fertiliser that is used. The farms with grass have often also cattle at the farm and will use cattle slurry for fertilisation of the parcels with grass. The use of different types of organic fertilisers will therefore not be so pronounced in the figures of average fertilisation on grass. For maize however there will be more farms that have no cattle and that will use pig slurry for fertilisation of the parcels with maize. Because of the higher frequency of pig slurry in fertilisation of maize on no derogation parcels, the difference is more pronounced on maize parcels as on parcels with grass.

2.2.2 Fertilisation - 2017

2.2.2.1 Nitrogen

Consistent with the manure policy and the fertilisation standards for nitrogen the total amount of organic N and the total amount of nitrogen that will be available during the growing season ($N_{effective}$) are reported.

A first summary of the nitrogen input in 2017 is given in Table 15, without distinction regarding soil texture.

Table 15: Average nitrogen input (kg N/ha) on derogation and no derogation parcels in 2017.

	Derogation					No derogation				
	Mineral	Organic			**Total N eff**	Mineral	Organic			**Total N eff**
		Manure	Grazing	**Total**			Manure	Grazing	**Total**	
Grass	214	205	62	267	349	142	106	79	185	221
Grass & less than 50% clover	224	284	1	285	395	169	170	0	170	270
Maize	108	238	-	238	243	61	156	-	156	146

Grass

The average amount of effective nitrogen on parcels cultivated with grass was highly comparable with the amounts of effective nitrogen registered in 2016. In 2016 the amount of effective nitrogen was 340 kg N/ha on derogation parcels and 224 kg N/ha on parcels without derogation.

In 2017 on average 349 kg effective nitrogen was applied on derogation parcels. This was the result of 267 kg total organic nitrogen, 205 kg N/ha by manuring and 62 kg total organic N/ha by grazing. The organic fertilisation was supplemented with 214 kg mineral N/ha. On the parcels without derogation both the amount of mineral and organic nitrogen was less. On those parcels 142 kg mineral N/ha was applied. The total dose organic nitrogen was 185 kg N/ha on no derogation parcels: 106 kg N/ha by manuring and 79 kg N/ha by excretion of grazing animals.

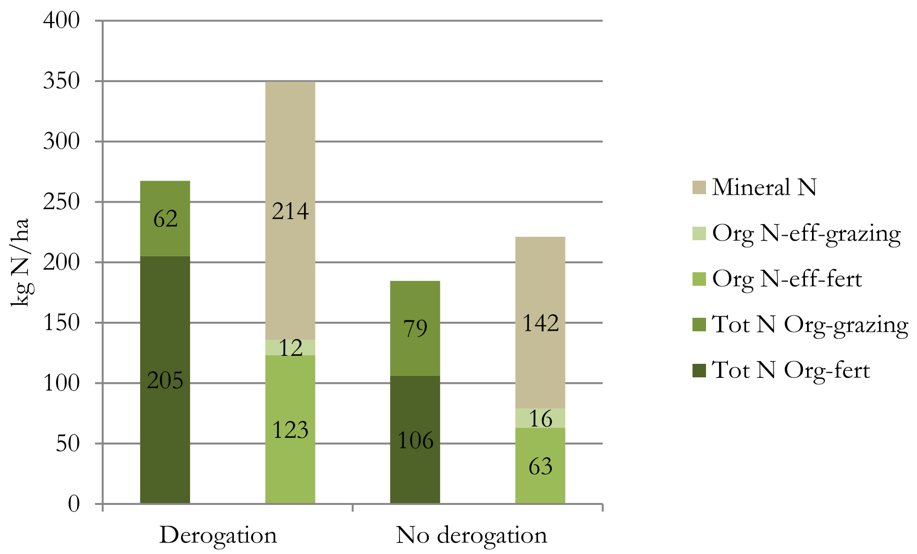


Figure 42: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was only cut, cut and grazed or only grazed on all soils in the monitoring network in 2017.

On sandy soils with grass under derogation, the amount of effective nitrogen was 375 kg N/ha. The most important part was nitrogen of mineral fertilisers, more specific 229 kg N/ha. The total organic nitrogen amounted 288 kg N/ha, 220 kg N/ha by manuring and 68 kg N/ha by grazing. On parcels without derogation 218 kg total organic N/ha was applied, 129 kg N/ha by manuring and 89 kg N/ha by grazing. The organic nitrogen was supplemented by 135 kg N/ha. The total dose of effective nitrogen was clearly less, 229 kg N/ha.

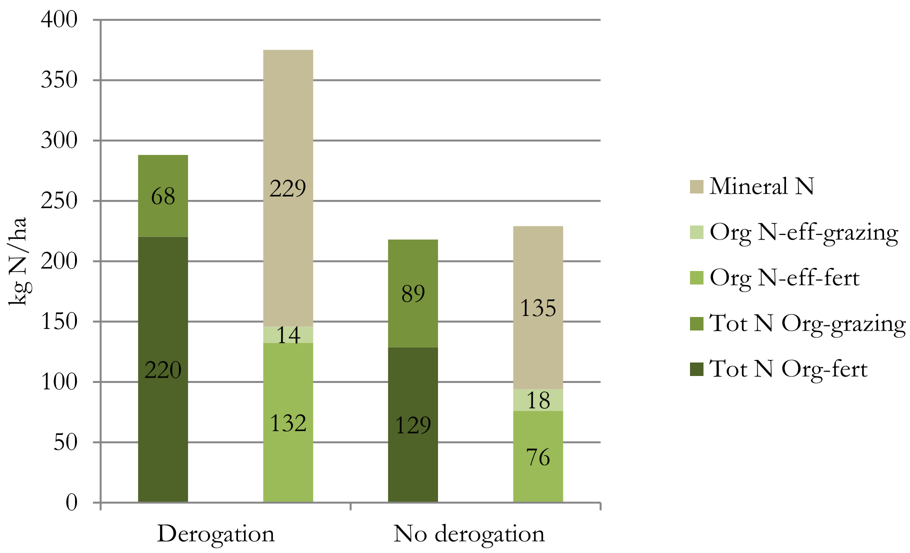


Figure 43: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was only cut, cut and grazed or only grazed on sandy soils in the monitoring network in 2017.

On sandy loam soils, nitrogen fertilisation on parcels cultivated with grass tended to be at some lower level as on sandy soils. On parcels with grass on sandy loams soils under derogation conditions 247 kg total organic nitrogen was applied per hectare, 191 kg N/ha by manuring and 56 kg N/ha by grazing. Mineral fertilisers provided further 199 kg N/ha. In total 324 kg effective nitrogen was applied on derogation parcels cultivated with grass on sandy loam soils. Without derogation the total amount of effective nitrogen was 213 kg N/ha, whereof 150 kg N/ha by mineral fertilisers.

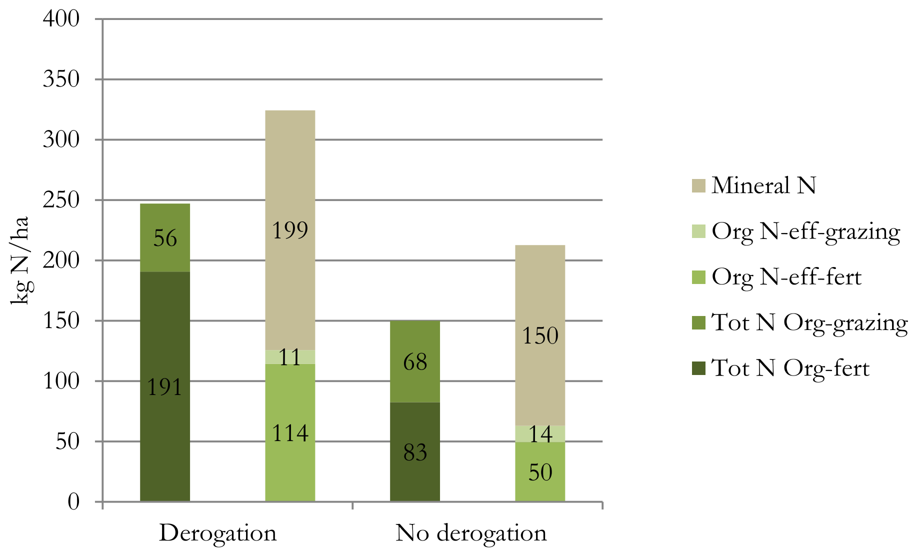


Figure 44: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was only cut, cut and grazed or only grazed on sandy loam soils in the monitoring network in 2017.

Because of differentiation of fertilisation standard regarding to soil texture and management of the grass (Table 10, Annex 1 – Nitrogen fertilisation standards), the average fertilisation quantified in the monitoring network is further specified regarding to soil and grass management.

Table 16: Average nitrogen input (kg N/ha) on derogation and no derogation parcels cultivated with grass in 2017.

	Derogation					No derogation				
	Mineral	Organic			**Total N eff**	Mineral	Organic			**Total N eff**
		Manure	Grazing	**Total**			Manure	Grazing	**Total**	
Grass	214	205	62	267	349	142	106	79	185	221
Grass, grazing cattle	173	161	133	294	296	124	78	132	210	197
Grass, only cutting	250	245	-	245	396	169	147	-	147	256
Grass, grazing cattle-sand	184	179	124	303	316	133	102	156	258	225
Grass, only cutting-sand	284	270	-	270	446	137	165	-	165	233
Grass, grazing cattle-SL	158	135	145	280	268	114	55	110	165	169
Grass, only cutting-SL	225	226	-	226	360	206	127	-	127	282

On sandy parcels with grass in cutting and grazing regime under derogation condition, on average 316 kg effective nitrogen was applied per hectare (Figure 45, Table 16). Without derogation conditions the total dose of effective nitrogen was 226 kg N/ha. On the sandy parcels with grass, less mineral nitrogen was applied, there was less manured and grazing was more important.

On sandy loam parcels cultivated with grass which is cut and grazed, the nitrogen fertilisation was at a lower level as on sandy soils. Under derogation conditions the total amount of effective N was 268 kg N/ha, based on 158 kg N/ha by mineral fertilisers and 280 kg total organic nitrogen (Figure 46). The total organic nitrogen was about 50-50 of manuring and grazing. Since the lower efficiency of organic nitrogen of grazing, this organic nitrogen has a smaller impact on the total amount of effective nitrogen. Without derogation conditions there was clearly less manured. Only 55 kg total organic N/ha was applied by manuring. The total dose of effective nitrogen was about 100 kg N/ha less as with derogation conditions.

The difference between the total dose of effective nitrogen between derogation and no derogation conditions for parcels cultivated with grass which is cut and grazed, was similar on sandy (91 kg N/ha) and sandy loam soil (99 kg N/ha).

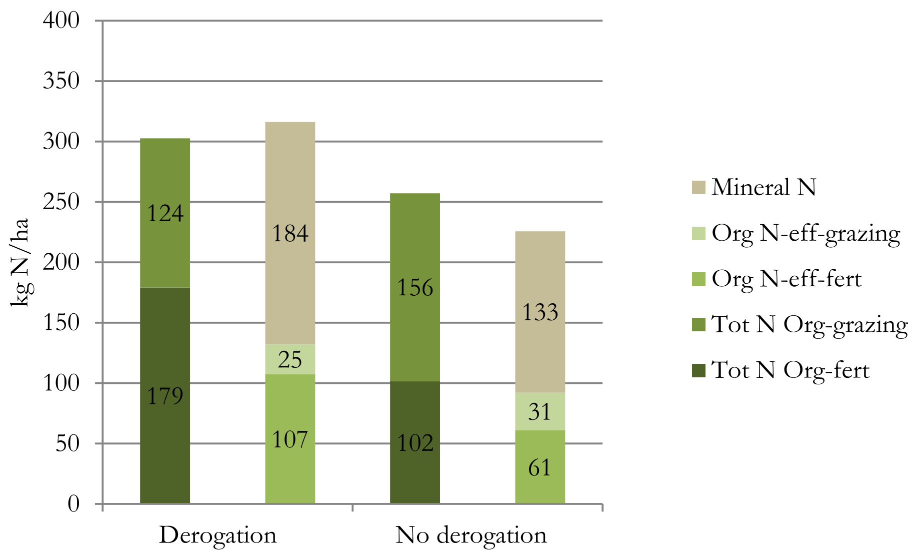


Figure 45: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was cut and grazed or only grazed on sandy soils in the monitoring network in 2017.

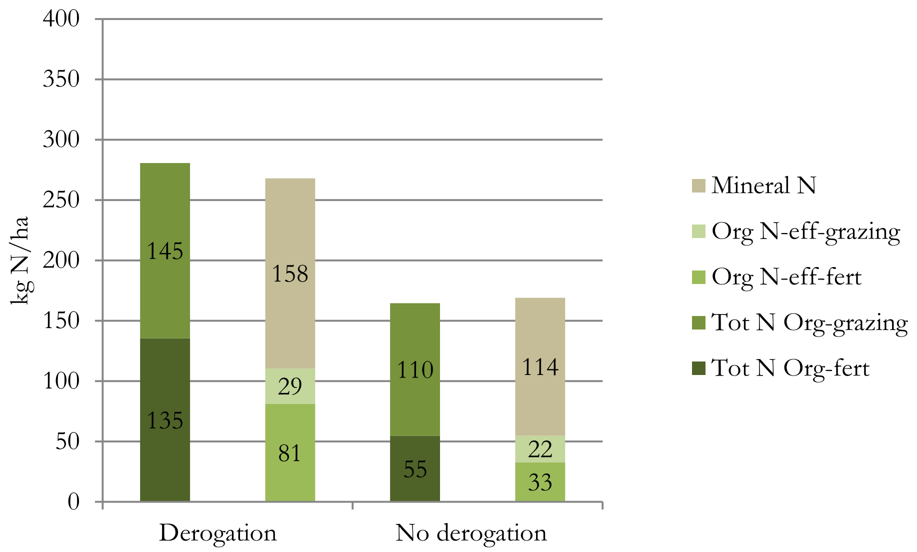


Figure 46: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was cut and grazed or only grazed on sandy loam soils in the monitoring network in 2017.

On grass parcels that are only cut, the nitrogen fertilisation is always at a higher level, regardless of soil or request of derogation.

On sandy soils with grass that is not grazed and only cut under derogation conditions, 270 kg total organic nitrogen per hectare was applied on average (Figure 47, Table 16). The organic nitrogen was supplemented with mineral fertilisers which provided 284 kg N/ha. Both types of nitrogen input resulted in 446 kg effective N/ha. Without derogation 137 kg mineral N/ha and 165 kg total organic N/ha resulted in 234 kg effective N/ha. Evaluation of the fertilisation data showed one farm with very high levels of fertilisation. Therefore, the average fertilisation on derogation parcels with grass was also considered without this outlying fertilisation. On sandy soils the total dose of effective nitrogen on cut parcels with derogation amounted without the outlying fertilisation 394 kg N/ha, 240 kg N/ha by mineral fertilisers and on average 256 kg total organic nitrogen per hectare (Table 17).

Table 17: Average nitrogen input (kg N/ha) on derogation parcels cultivated with grass in 2017- without outlying fertilisation of one farm.

	Derogation				
	Mineral	Organic			**Total N eff**
		Manure	Grazing	**Total**	
Grass	203	201	64	265	336
Grass, grazing cattle					
Grass, only cutting	231	238	-	238	373
Grass, grazing cattle-sand					
Grass, only cutting-sand	240	256	-	256	394
Grass, grazing cattle-SL					
Grass, only cutting-SL					

On sandy loam soils, the difference in total dose of effective nitrogen between derogation and no derogation parcels, with grass that is only cut, was not so pronounced as on sandy soils (Figure 48). On derogation parcels on sandy loam soils 225 kg N/ha was applied by mineral fertilisers. Additional 226 kg total organic N is applied, resulting in 360 kg effective N/ha. On parcels without derogation the average nitrogen fertilisation strategy comprised 206 kg N/ha of mineral fertilisers and 127 kg total organic N/ha or 283 kg effective N/ha.

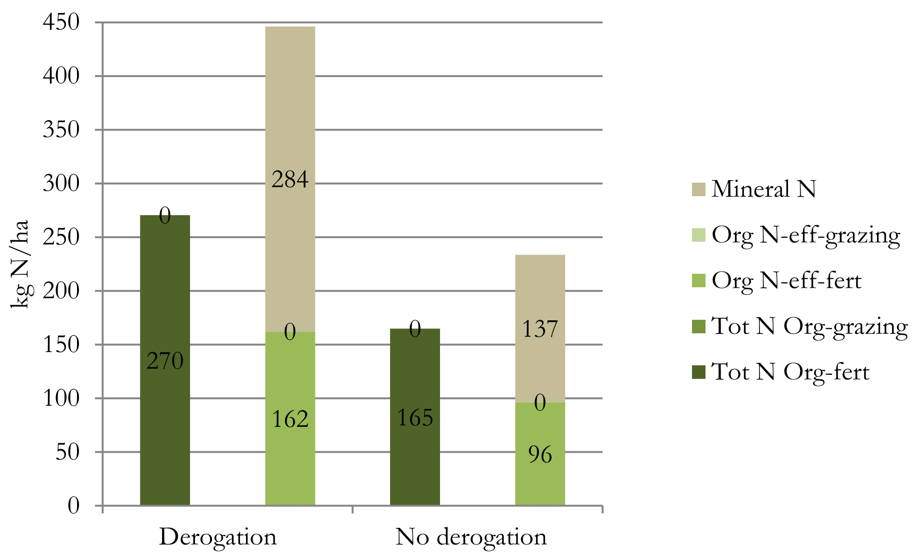


Figure 47: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with grass that was only cut on sandy soils in the monitoring network in 2017.

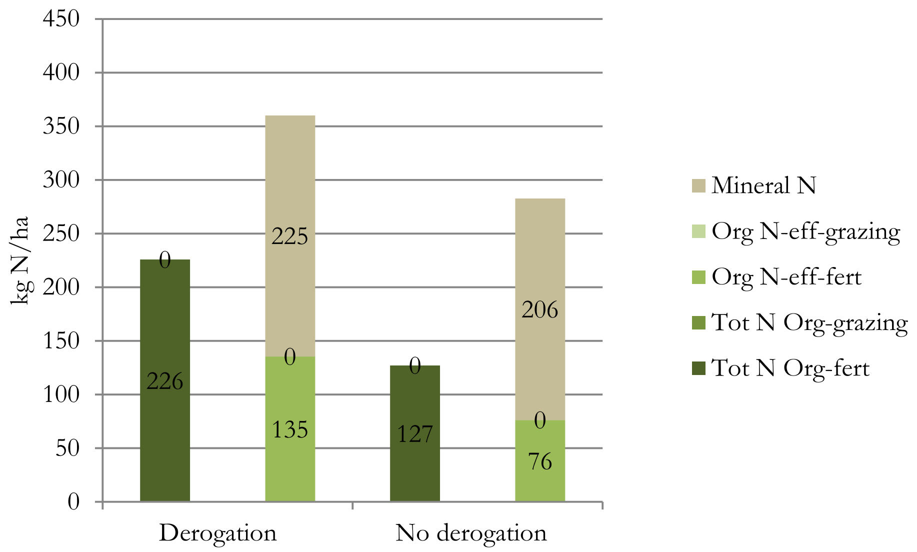


Figure 48: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with grass that was only cut on sandy loam soils in the monitoring network in 2017.

Grass and less than 50 % clover

Only 2 parcels cultivated with grass and less than 50 % clover were also grazed and not only cut. The figures of the applied effective N on parcels cultivated with grass and less than 50 % clover in Table 15 include all parcels.

On derogation parcels on average 284 kg total organic N/ha was applied. On parcels without derogation the average dose of total organic N was exactly 170 kg N/ha. The organic N was complemented by 224 and 169 kg mineral N/ha on respectively derogation and no derogation parcels. On derogation parcels this resulted in 395 kg effective N/ha. On parcels without derogation the total amount of effective N was 270 kg N/ha.

In Figure 49 the fertilisation of only the cut parcels is shown. Since the very few number of parcels cultivated with grass and less than 50 % clover that were grazed and cut, it is not meaningful to show these figures separately.

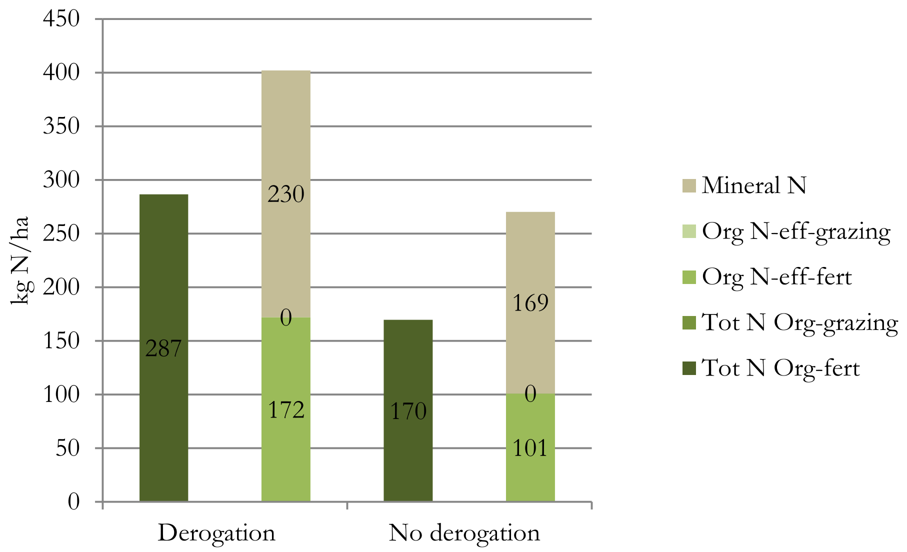


Figure 49: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with grass and less than 50 % clover that was only cut, not grazed on sandy soils in the monitoring network in 2017.

Maize

The average nitrogen fertilisation in the monitoring network 2017 covered 194 kg effective N, based on 85 kg N/ha by mineral fertilisers and 110 kg effective N of organic manure. The organic manure contained 196 kg total N/ha.

A clear difference between the fertilisation with and without derogation was noticeable (Figure 50, Table 18).

Regardless of soil, on average 243 kg effective N/ha was applied on derogation parcels cultivated with maize. Without derogation the total dose effective nitrogen amounted 146 kg N/ha. On parcels without derogation less mineral fertiliser and less manure were applied. Mineral fertilisation represented only 61 kg N/ha without derogation compared to 108 kg N/ha under derogation conditions. Manure was dosed at an average rate of 156 kg total organic N/ha on parcels without derogation whereas at an average rate of 238 kg total organic N/ha on derogation parcels.

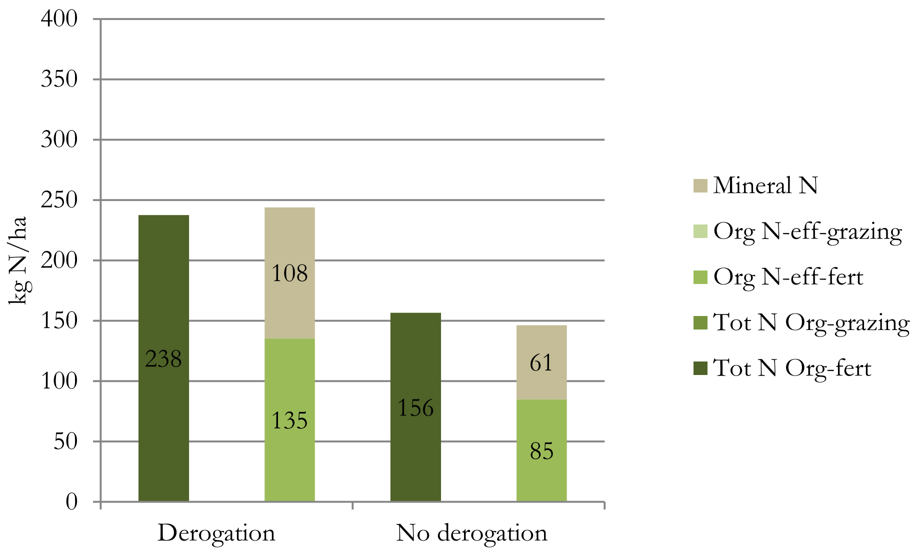


Figure 50: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with maize on all soils in the monitoring network in 2017.

The difference between derogation and no derogation parcels regarding nitrogen fertilisation was clear, whatever soil was evaluated.

In the monitoring network 2017 on average 250 kg total organic nitrogen per hectare was applied on sandy soils with maize under derogation conditions (Figure 51). This meant 141 kg nitrogen/ha available that year. The manure was complemented with 100 kg nitrogen of mineral fertilisers, resulting in a total dose of 241 kg available nitrogen in 2017. On parcels without derogation only 47 kg mineral nitrogen was supplied. The organic dose was on average kept to 159 kg total organic nitrogen/ha. The average total dose of effective nitrogen on parcels without derogation on sandy soils was 131 kg N/ha.

On sandy loam soils with maize under derogation conditions, the nitrogen fertilisation was similar to the nitrogen fertilisation on sandy soils with maize under derogation conditions. The total amount of nitrogen available in the year of application was 246 kg N/ha, a result of 117 kg N/ha by mineral fertilisers and 225 kg total organic nitrogen (Figure 52). On sandy loam soils with maize without derogation conditions, the nitrogen fertilisation was slightly higher as on sandy parcels with maize without derogation conditions. The total dose of effective nitrogen on sandy loam parcels with maize without derogation conditions was 161 kg N/ha, consisting of 75 kg N/ha of mineral fertilisers and 86 kg effective N of organic fertilisation.

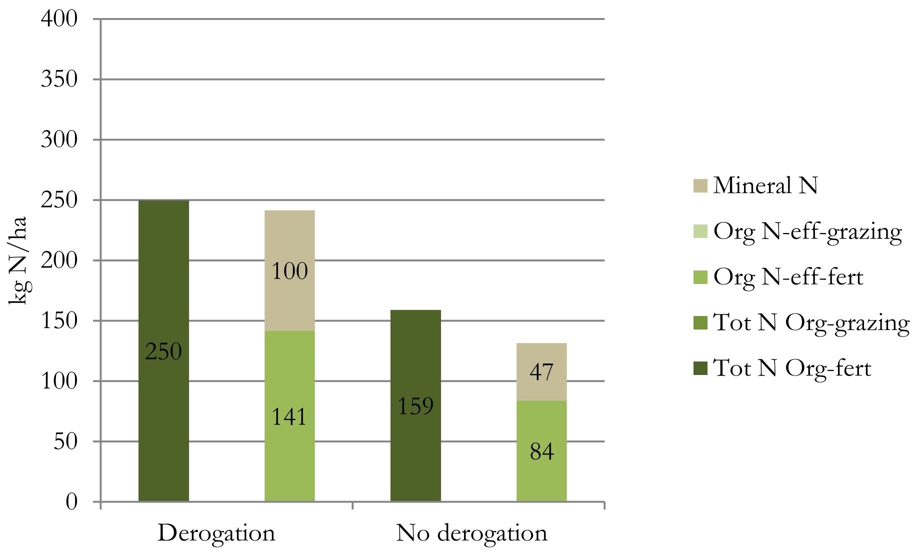


Figure 51: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with maize on sandy soils in the monitoring network in 2017.

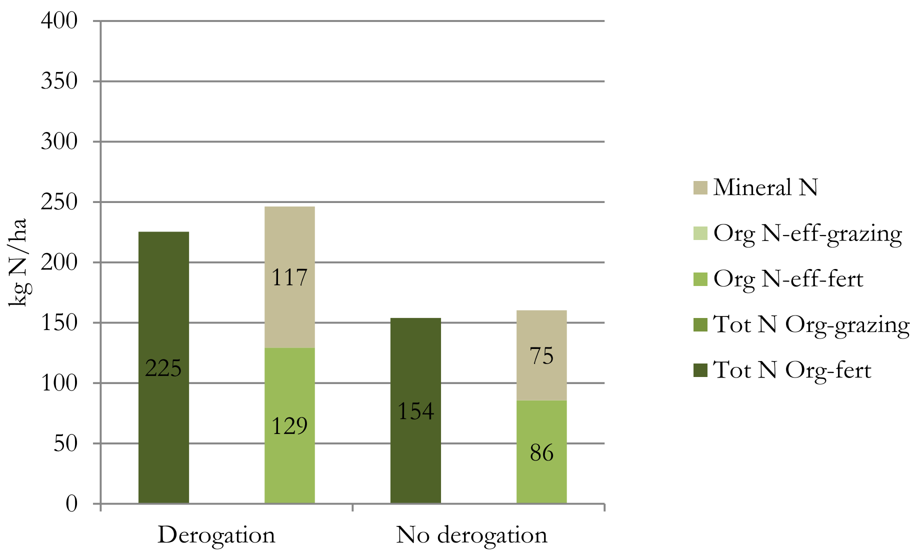


Figure 52: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with maize on sandy loam soils in the monitoring network in 2017.

The fertilisation standards for maize are differentiated regarding to soil texture, sand or other soils, and the presence of a cut of grass before the maize (Table 12, Annex 1 – Nitrogen fertilisation standards). However, for maize grown without derogation, a situation without a cut of grass before the main crop maize is more evident.

The registered fertilisation of the monitoring network is further specified regarding the presence or absence of grass and a cut of grass before the main crop maize.

Table 18: Average nitrogen input (kg N/ha) on derogation and no derogation parcels cultivated with maize in 2017.

	Derogation					No derogation				
	Mineral	Organic			Total N eff	Mineral	Organic			Total N eff
		Manure	Grazing	Total			Manure	Grazing	Total	
Maize	108	238	-	238	243	61	156	-	156	146
Maize & grass	108	238	-	238	243	101	166	-	166	189
Maize without grass before	-	-	-	-	-	50	152	-	152	132
Maize-sand	100	250	-	250	241	47	159	-	159	131
Maize & grass-sand	100	250	-	250	241	77	161	-	161	167
Maize without grass before	-	-	-	-	-	33	153	-	153	112
Maize-SL	117	225	-	225	246	75	154	-	154	161
Maize & grass-SL	117	225	-	225	246	151	176	-	176	237
Maize without grass before	-	-	-	-	-	62	151	-	151	148

When evaluating the figures of Table 18, it should be kept in mind that the number of parcels without derogation but with still a cut of grass preceding the maize, is limited. In 2017, only 15 parcels on sandy soils and 7 parcels on sandy loam soils could be evaluated that way.

However, on sandy loam soils the impact of derogation on the fertilisation of the crop 'grass-maize' is clear. An equal total dose of effective N is achieved with and without derogation. With derogation, a greater part is filled in with manure while on the parcels without derogation the norm of 170 kg total organic nitrogen/ha is respected and more mineral fertilisers are used.

2.2.2.2 Phosphorus

The fertilisation standards for phosphorus are differentiated regarding to crop and crop management not regarding to soil texture. Therefore, no distinction is made between sandy and sandy loam soils in the further discussion.

The lowest amount of mineral phosphorus is applied on parcels with grass or grass and less than 50 % clover (Table 19). On derogation parcels cultivated with grass and less than 50 % clover, no mineral phosphorus at all was used. On derogation parcels cultivated with grass a mineral fertiliser containing a small percentage of phosphorus was used by occasion.

Table 19: Average phosphorus input (kg P_2O_5/ha) on derogation and no derogation parcels in the monitoring network-2017.

	Derogation					No derogation				
	Mineral	Organic			**Total**	Mineral	Organic			**Total**
		Manure	Grazing	Total			Manure	Grazing	Total	
Grass	2	70	21	91	93	2	52	28	80	82
Grass, grazing cattle	3	56	44	100	103	2	46	47	93	95
Grass, only cutting	1	82	-	82	83	2	62	-	62	64
Grass & less than 50% clover	0	101	1	102	102	2	62	0	62	64
Grass & less than 50% clover only cutting	0	102	-	102	102	2	62	-	62	64
Maize	5	78	-	78	83	6	87	-	87	93
Maize & grass	5	78	-	78	83	5	73	-	73	78
Maize without grass before	-	-	-	-	-	6	90	-	90	96

As in 2016, the higher input of manure resulted in a higher input of organic phosphorus for parcels cultivated with grass. On parcels cultivated with grass and less than 50 % clover, the difference in organic phosphorus was more pronounced in 2017 than in 2016. On parcels cultivated with grass, the difference in organic phosphorus on derogation and no derogation parcels was smaller in 2017 than in 2016.

On parcels cultivated with maize, the effect of type of manure or organic fertiliser appears again. On derogation parcels cultivated with maize, clearly more organic nitrogen was applied (Table 18). The higher input of organic nitrogen on parcels cultivated with maize did not result in a higher input of organic phosphorus. On parcels cultivated with maize without derogation often pig slurry is preferred, more than on parcels cultivated with grass without derogation. On parcels cultivated with grass cattle manure will be used more often. Because of the different N/P ratio of both slurry types, the effect of derogation on the input of organic phosphorus is different for parcels cultivated with grass or maize.

2.2.3 Fertilisation - 2018

2.2.3.1 Nitrogen

As previously, the total amount of organic N and the total amount of nitrogen that will be available during the growing season ($N_{effective}$) are reported. Table 20 gives a first indication of the nitrogen input in 2018, regardless of soil texture.

Table 20: Average nitrogen input (kg N/ha) on derogation and no derogation parcels in 2018.

	Derogation					No derogation				
	Mineral	Organic			**Total**	Mineral	Organic			**Total**
		Manure	Grazing	**Total**	**N eff**		Manure	Grazing	**Total**	**N eff**
Grass	177	214	61	275	318	140	109	71	180	219
Grass & less than 50% clover	195	227	31	258	337	171	140	0	140	253
Maize	114	220	-	220	240	68	169	-	169	166

Grass

The average amount of effective N applied on parcels cultivated with grass in 2018 was comparable with the average amounts reported in 2016 and 2017.

In 2018 on average 207 kg effective nitrogen was applied on parcels cultivated with grass, as the result of 163 kg total organic nitrogen by manuring, 66 kg total organic nitrogen by grazing and 159 kg mineral nitrogen.

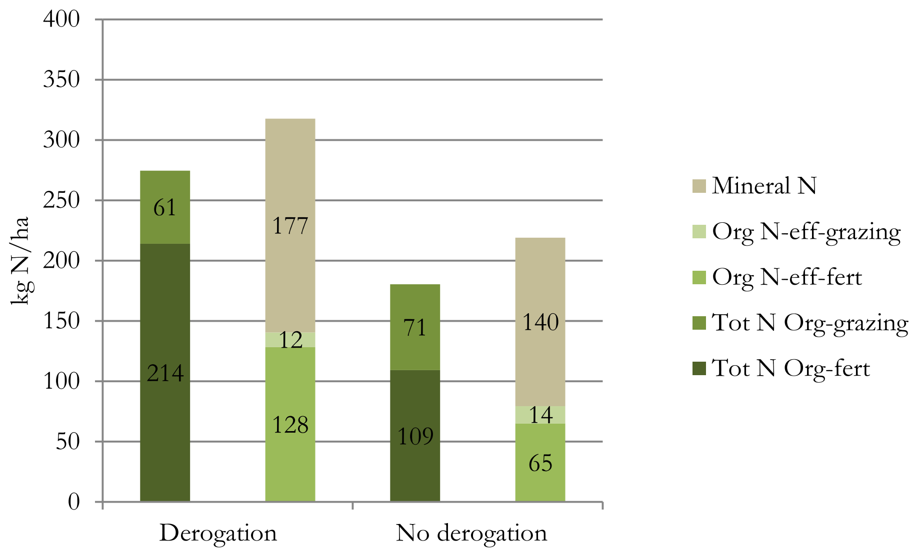


Figure 53: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was only cut, cut and grazed or only grazed on all soils in the monitoring network in 2018.

On derogation parcels cultivated with grass 318 kg effective nitrogen was applied. The average amount of total organic nitrogen amounted 275 kg N/ha, 214 kg N/ha by manuring and 61 kg N/ha by grazing (Figure 53). This amount was supplemented by 177 kg mineral nitrogen per hectare. On the parcels without derogation, less effective nitrogen was applied like the years before. The average applied amount of effective nitrogen was 219 kg N/ha, provided by 109 kg total organic nitrogen of manuring, 71 kg total organic nitrogen of grazing and 140 kg mineral N.

On sandy soils cultivated with grass under derogation conditions on average 335 kg effective nitrogen was applied in 2018 in the monitoring network. Mineral and organic nitrogen were of equal importance. By manuring and grazing respectively 236 and 82 kg total organic N/ha or 142 and 16 effective N/ha were applied. In addition 177 kg mineral N/ha was applied. Without derogation, 218 kg total organic N/ha was applied: 141 kg N/ha by manuring and 77 kg N/ha by grazing. The mineral fertilisation was 134 kg N/ha. In total 233 kg effective N/ha was used.

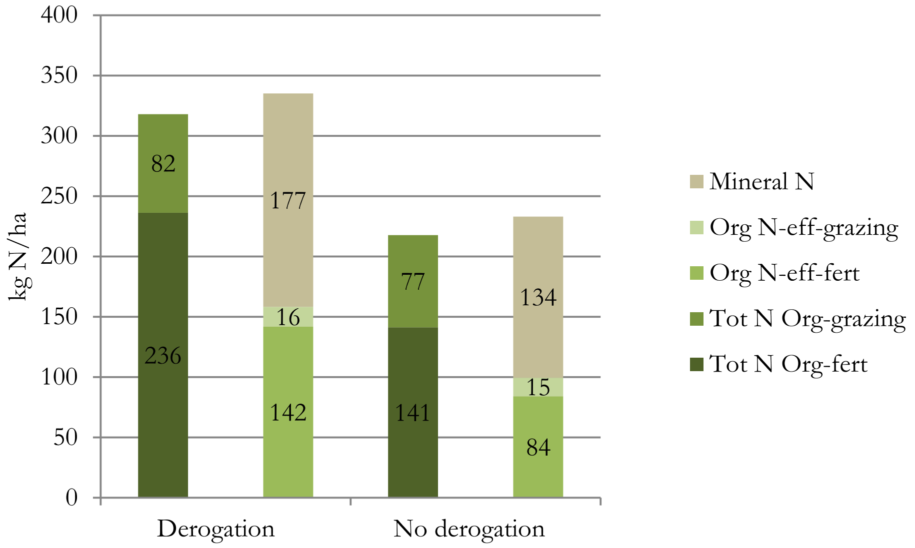


Figure 54: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was only cut, cut and grazed or only grazed on sandy soils in the monitoring network in 2018.

As said in 2017, the nitrogen fertilisation on sandy loam soils cultivated with grass tends to be some lower as on sandy soils. The average amount of effective nitrogen on sandy loam soils cultivated with grass under derogation conditions was 301 kg N/ha in 2018. Mineral fertilisation covered 178 kg N/ha. By manuring and grazing was respectively 192 and 39 kg total organic N/ha applied, which supplied 115 and8 kg effective N/ha. On parcels without derogation 203 kg effective N/ha was applied, 147 kg N/ha of mineral fertilisers, 44 kg effective N by manuring and 13 kg effective N/ha of grazing.

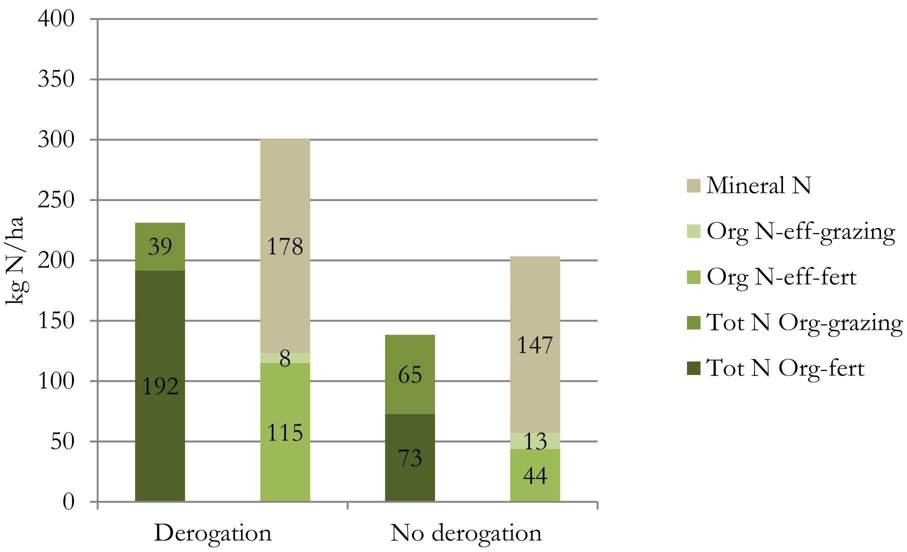


Figure 55: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was only cut, cut and grazed or only grazed on sandy loam soils in the monitoring network in 2018.

The average fertilisation quantified in the monitoring network is further specified regarding soil texture and grass management, in line with the fertilisation standards (Annex 1 – Nitrogen fertilisation standards). On grazed parcels more organic nitrogen but less effective nitrogen is applied.

Table 21: Average nitrogen input (kg N/ha) on derogation and no derogation parcels cultivated with grass in 2018.

	Derogation					No derogation				
	Mineral	Organic			**Total N eff**	Mineral	Organic			**Total N eff**
		Manure	Grazing	**Total**			Manure	Grazing	**Total**	
Grass	177	214	61	275	318	140	109	71	180	219
Grass, grazing cattle	156	186	117	303	291	120	85	132	217	196
Grass, only cutting	200	244	-	244	346	163	137	-	137	246
Grass, grazing cattle-sand	155	203	126	329	302	117	124	138	262	218
Grass, only cutting-sand	218	298	-	298	396	154	163	-	163	252
Grass, grazing cattle-SL	159	158	101	259	274	123	38	125	163	171
Grass, only cutting-SL	190	213	-	213	318	172	111	-	111	239

On sandy parcels with grass in cutting and grazing regime and derogation conditions on average 302 kg effective N/ha was applied in 2018 (Figure 56). Without derogation 218 kg effective

N/ha was applied on sandy parcels in cutting and grazing regime. The amount of organic N by grazing is rather comparable but less mineral and organic fertilisers are used without derogation.

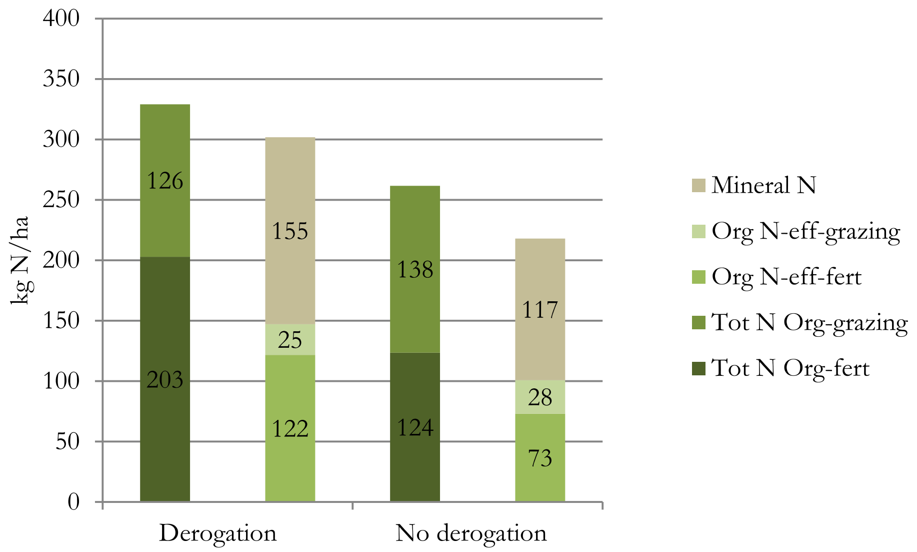


Figure 56: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was cut and grazed or only grazed on sandy soils in the monitoring network in 2018.

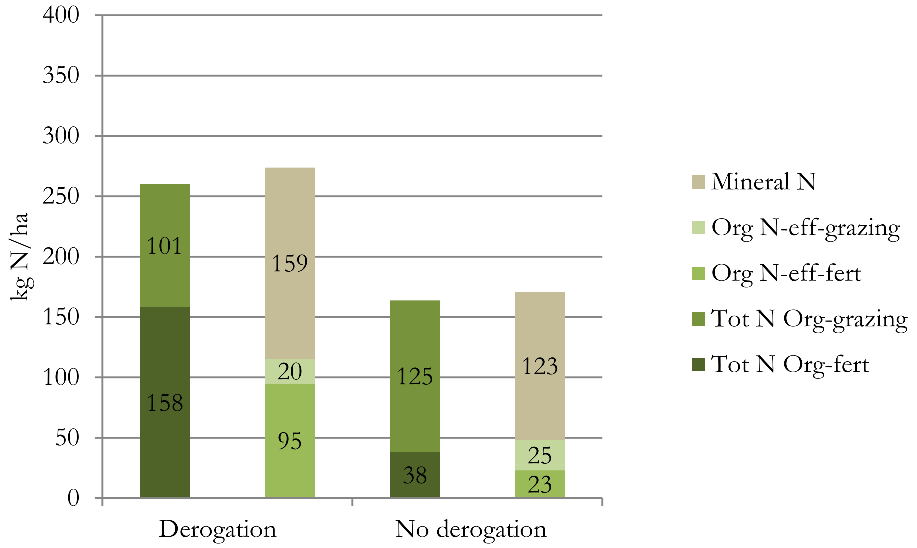


Figure 57: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was cut and grazed or only grazed on sandy loam soils in the monitoring network in 2018.

On sandy loam soils cultivated with grass in cutting and grazing regime, the average dose of effective N was 274 kg N/ha under derogation conditions (Figure 57). This is the result of 159 kg mineral N/ha, 158 kg total organic N/ha by manuring and 101 kg total organic N by grazing. On cut and grazed parcels without derogation on sandy loam soils on average 171 kg effective N/ha was applied. Just as on sandy soils the amount of organic N by grazing was rather comparable but less mineral and organic fertilisers were used without derogation.

The difference in dosage of effective N between derogation and no derogation parcels, which are cultivated with grass that is cut and grazed, was comparable for sandy and sandy loam soils.

In a cutting regime on average more mineral fertilisers are used. The total amount of organic N is less on cut parcels because of the lack of grazing but higher doses of organic fertilisers are used. Because of the higher coefficient for applied organic fertilisers than for grazing, the total amount of effective N ends at a higher level on cut parcels.

On sandy soils with grass that is only cut, on average 396 kg effective N/ha was applied under derogation conditions in 2018 in the monitoring network (Figure 58). The average dose of total organic N by manuring was 298 kg N/ha, complemented by 218 kg mineral N/ha. Without derogation the average amount of effective N/ha was 252 kg N/ha, 154 kg mineral N/ha and 163 kg total organic N/ha by manuring.

On sandy loam soils with grass that was not grazed 318 kg effective N/ha was applied on average under derogation conditions (Figure 59). Mineral N was applied at an average dose of 190 kg N/ha and on average 213 kg total organic N/ha was applied by organic fertilisers. On cut parcels on sandy loam soils without derogation, the average amount of effective N was 239 kg N/ha. Mineral fertilisation covered 172 kg N/ha and manuring provided 66 kg effective N/ha.

For parcels cultivated with grass that is only cut the difference in dose of effective N between derogation and no derogation parcels tended to be larger on sandy soils. Mainly the difference in mineral N was larger on sandy soils than on sandy loam soils.

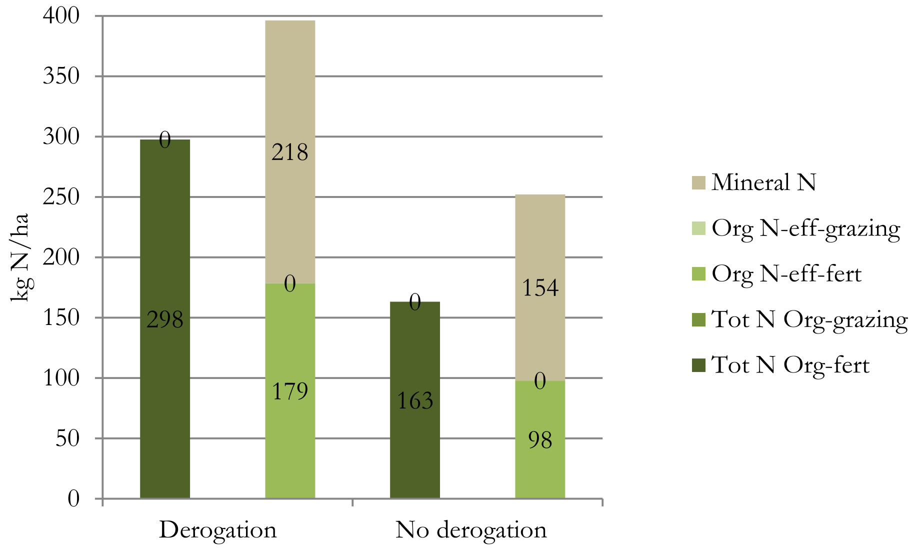


Figure 58: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with grass that was only cut on sandy soils in the monitoring network in 2018.

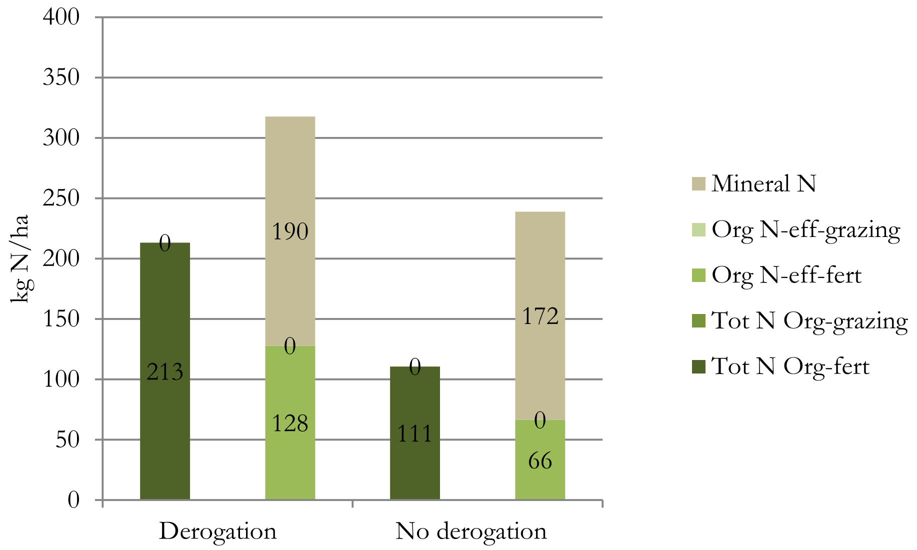


Figure 59: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with grass that was only cut on sandy loam soils in the monitoring network in 2018.

Grass and less than 50 % clover

Only 3 parcels cultivated with grass and less than 50 % clover, were not only cut but also grazed. All 3 were derogation parcels. These grazed parcels are included in the calculation of the results in Table 20.

In 2018 on average 258 kg total organic N/ha was applied on derogation parcels cultivated with grass and less than 50 % clover in the monitoring network. Without derogation on average 140 kg total organic N/ha was applied. The average dose of mineral N amounted 195 and 171 kg N/ha on derogation and no derogation parcels. The resulting average dose of effective N was 337 kg N/ha under derogation conditions and 253 kg N/ha without derogation (Table 20).

Figure 60 shows the average fertilisation of the parcels that were only cut. Because of the very few parcels with grass and less than 50 % clover that were cut and grazed, these figures are not shown separately.

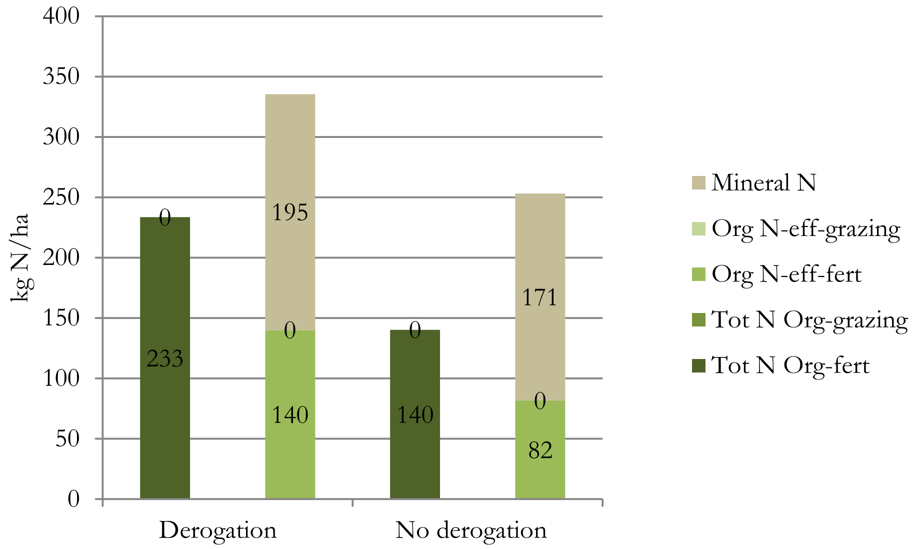


Figure 60: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with grass and less than 50 % clover that was only cut on sandy soils in the monitoring network in 2018.

Maize

In the monitoring network, the average nitrogen fertilisation in maize amounted 203 kg effective N/ha in 2018. On average 194 kg total organic N/ha was applied, complemented with 91 kg mineral N/ha.

Under derogation conditions 240 kg effective N was applied, 114 kg N/ha by mineral fertilisation and 220 kg total organic N/ha. Without derogation less mineral as well as less organic fertilisers were used. Through organic fertilisers 99 kg effective N/ha was provided. Mineral fertilisers were applied at an average dose of 68 kg N/ha, resulting in 167 kg effective N/ha.

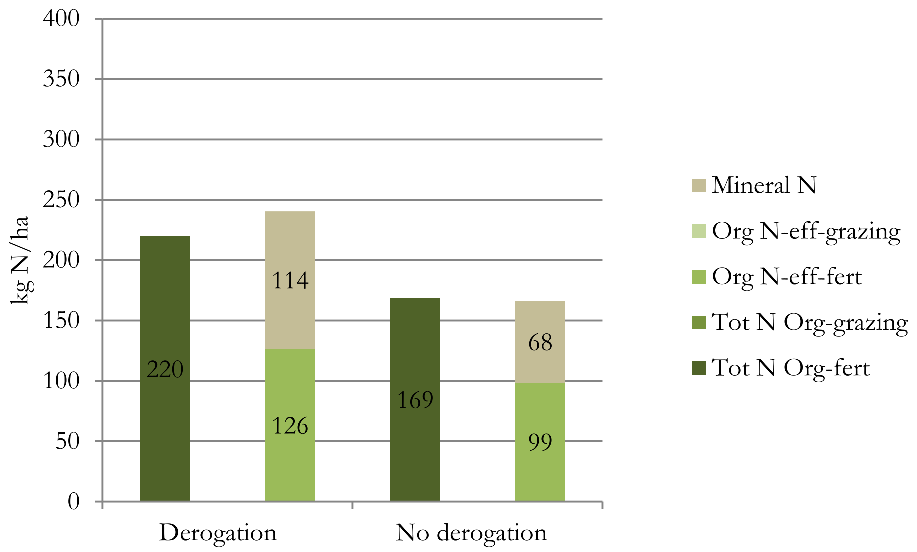


Figure 61: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with maize on all soils in the monitoring network in 2018.

On sandy and sandy loams soils the same differences appeared. On sandy soils on average 238 kg effective N/ha was applied for maize under derogation conditions. The average dose of organic fertiliser provided 226 kg total organic N/ha meaning 130 kg effective N/ha. The mineral complement amounted 108 kg N/ha. Without derogation the organic fertilisation was limited to 160 kg total organic N/ha on average. By mineral fertilisation on average 66 kg N/ha was added, resulting in a total amount of 161 kg effective N/ha.

On sandy loam soils the fertilisation of maize under derogation conditions in 2018 in the monitoring network included 214 kg total organic N, providing 123 kg effective N/ ha, and 120 kg N/ha by mineral fertilisers. The average total amount of effective N was 243 kg N/ha that way. Without derogation the average total amount of effective N for maize on sandy loam soils was 171 kg N/ha in 2018. Provided by 69 kg N/ha of mineral fertilisers and 102 kg effective N/ha of organic fertilisers. The amount of total organic N was 178 kg N/ha.

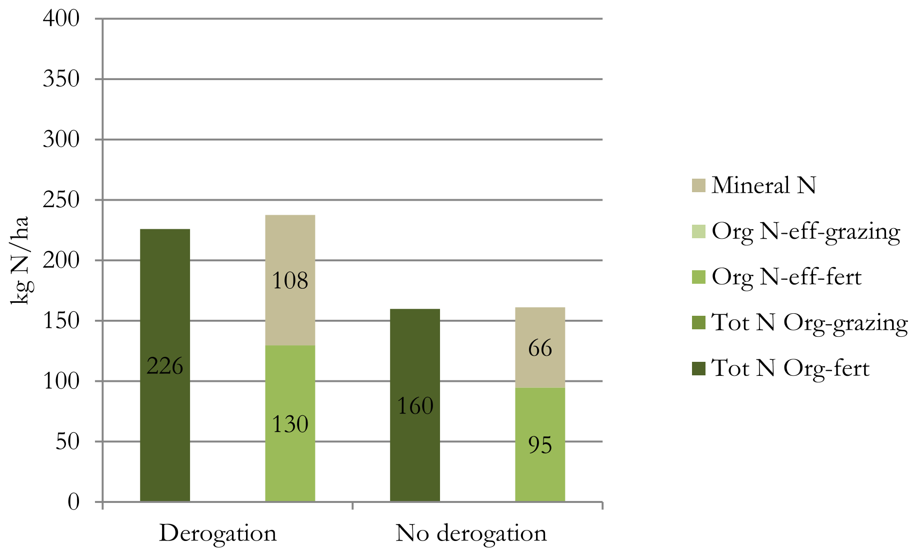


Figure 62: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with maize on sandy soils in the monitoring network in 2018.

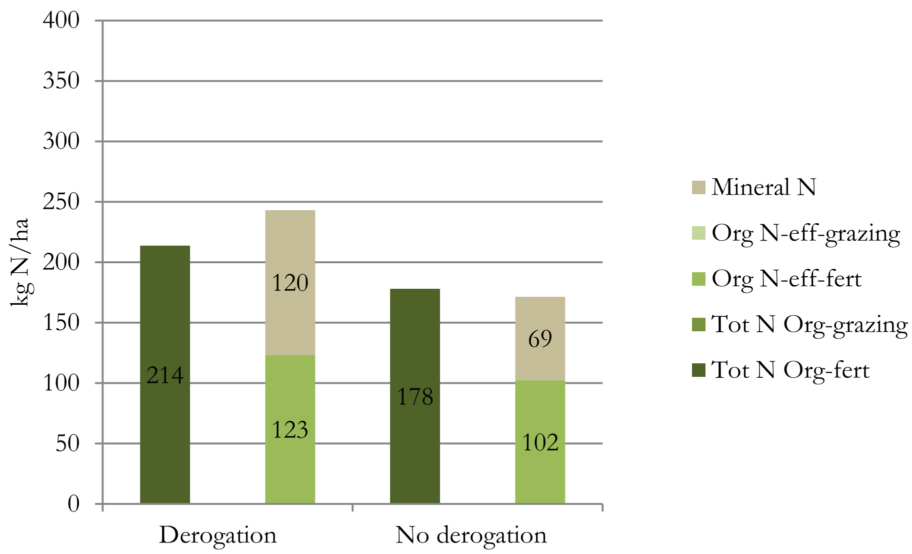


Figure 63: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with maize on sandy loam soils in the monitoring network in 2018.

In the comparison of parcels cultivated with maize with and without derogation, both parcels with and without a cut of grass before the main crop of maize were included. The preceding cut of grass is a prerequisite to acquire derogation. Without derogation however, maize is often grown without a preceding cut of grass. Therefore, fertilisation is also evaluated separately for parcels with and without a preceding cut of grass.

Comparing derogation and no derogation parcels both with a cut of grass preceding the maize shows that the difference in the amount of effective nitrogen decreases. This can be observed on sandy and sandy loam soils. The preceding cut of grass results in a higher dose of effective N but under derogation conditions more organic fertilisers tend to be used.

Table 22: Average nitrogen input (kg N/ha) on derogation and no derogation parcels cultivated with maize in 2018.

	Derogation					No derogation				
	Mineral	Organic			**Total N eff**	Mineral	Organic			**Total N eff**
		Manure	Grazing	**Total**			Manure	Grazing	**Total**	
Maize	114	220	-	220	240	68	169	-	169	166
Maize & grass	114	220	-	220	240	98	182	-	182	204
Maize without grass before	-	-	-	-	-	54	163	-	163	149
Maize-sand	108	226	-	226	238	66	160	-	160	161
Maize & grass-sand	108	226	-	226	238	96	191	-	191	205
Maize without grass before	-	-	-	-	-	47	140	-	140	133
Maize-SL	120	214	-	214	243	69	178	-	178	171
Maize & grass-SL	120	214	-	214	243	102	166	-	166	202
Maize without grass before	-	-	-	-	-	60	182	-	182	163

2.2.3.2 Phosphorus

The fertilisation standards for phosphorus are differentiated regarding to crop, crop management and soil content. No distinction is made regarding soil texture.

As reported in the monitoring network before, mineral phosphorus is least used on parcels cultivated with grass and grass with less than 50 % clover. The minor doses of mineral phosphorus on derogation parcels result from the occasional use of composite mineral fertilisers.

Table 23: Average phosphorus input (kg P_2O_5/ha) on derogation and no derogation parcels in the monitoring network-2018.

	Derogation					No derogation				
	Mineral	Organic			**Total**	Mineral	Organic			**Total**
		Manure	Grazing	Total			Manure	Grazing	Total	
Grass	1	69	20	89	90	2	41	27	68	70
Grass, grazing cattle	1	59	39	98	90	2	37	50	87	89
Grass, only cutting	1	80	0	80	81	3	46	0	46	49
Grass & less than 50 % clover	0	67	10	77	77	0	47	0	47	47
Grass & less than 50 % clover only cutting	0	67	0	67	67	0	47	0	47	47
Maize	5	72	-	72	77	6	84	-	84	90
Maize & grass	5	72	-	72	77	3	84	-	84	97
Maize without grass before	-	-	-	-	-	7	85	-	85	92

On grass and grass with less than 50 % clover, the higher input of organic fertilisers results in a higher P-input. On parcels cultivated with grass the higher input is most pronounced on parcels that are only cut. The use of organic fertilisers is the highest on parcels cultivated with grass that is only cut.

On parcels cultivated with maize, the higher input of organic N on derogation parcels (Table 22) does not result in a higher input of organic phosphorus. On derogation parcels, only cattle slurry is allowed. On parcels without derogation there are no prerequisites regarding the used organic fertiliser. On these parcels often pig slurry is used. Pig slurry has a different N/P ratio than cattle slurry, with less organic nitrogen more organic P is introduced.

2.2.4 Fertilisation - 2019

2.2.4.1 Nitrogen

A first indication of the nitrogen fertilisation in the monitoring network in 2019 is given in Table 24. It is an indication not specified for soil texture or crop management. As previously, the total amount of organic N and the total amount of nitrogen that will be available during the growing season ($N_{effective}$) are reported.

Table 24: Average nitrogen input (kg N/ha) on derogation and no derogation parcels in 2019.

	Derogation					No derogation				
	Mineral	Organic			**Total N eff**	Mineral	Organic			**Total N eff**
		Manure	Grazing	**Total**			Manure	Grazing	**Total**	
Grass	188	219	43	262	328	136	108	64	172	214
Grass & less than 50% clover	186	245	3	276	340	167	186	0	186	279
Maize	109	222	-	222	242	67	189	-	189	180

Grass

In 2019, on average 274 kg effective nitrogen was applied on parcels cultivated with grass. This is the result of the application of 220 kg total organic nitrogen, 167 kg N/ha by manuring and 53 kg N/ha by grazing, and the application of 164 kg mineral nitrogen.

Under derogation conditions, on average 328 kg effective nitrogen was applied per hectare on parcels cultivated with grass. On average 262 kg total organic nitrogen, 219 kg N/ha by manuring and 43 kg N/ha by grazing, and 188 kg mineral N/ha was used. Without derogation, on average 214 kg effective nitrogen was used. Both mineral and organic fertilisation are used some less. The amount of mineral nitrogen amounted on average 136 kg N/ha on the parcels cultivated with grass without derogation. The average amount of total organic nitrogen on those parcels was 172 kg N/ha, 108 kg N/ha by manuring and 64 kg N/ha by grazing.

In the monitoring network, the nitrogen fertilisation, merely the organic fertilisation, is some higher on sandy soils cultivated with grass compared to sandy loam soils. On sandy soils, on average 354 and 246 kg effective nitrogen was applied under respectively derogation and no derogation conditions (Figure 65). The amount of total organic nitrogen, manuring and grazing included, was respectively 318 and 202 kg N/ha. The average amount of mineral nitrogen was respectively 185 and 147 kg N/ha.

On sandy loam soils cultivated with grass, the average amount of effective nitrogen was 302 kg N/ha under derogation conditions and 178 kg N/ha without derogation (Figure 66). The amount of total organic nitrogen was 206 kg N/ha under derogation conditions, 175 kg N/ha by manuring and 31 kg N/ha by grazing. Without derogation conditions, the amount of total organic nitrogen was 139 kg N/ha, 64 kg N/ha by manuring and 75 kg N/ha by grazing. Mineral nitrogen was applied at average doses of 191 and 125 kg N/ha with and without derogation.

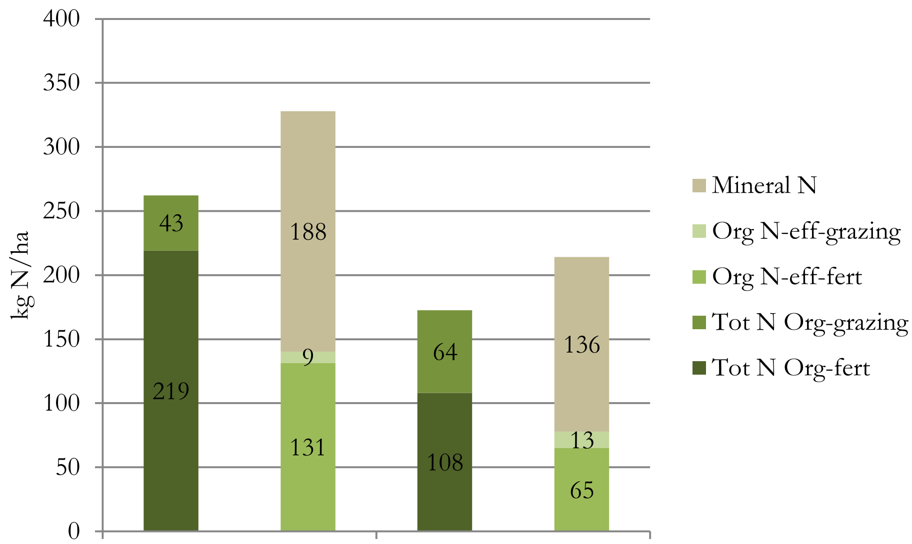


Figure 64: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was only cut, cut and grazed or only grazed on all soils in the monitoring network in 2019.

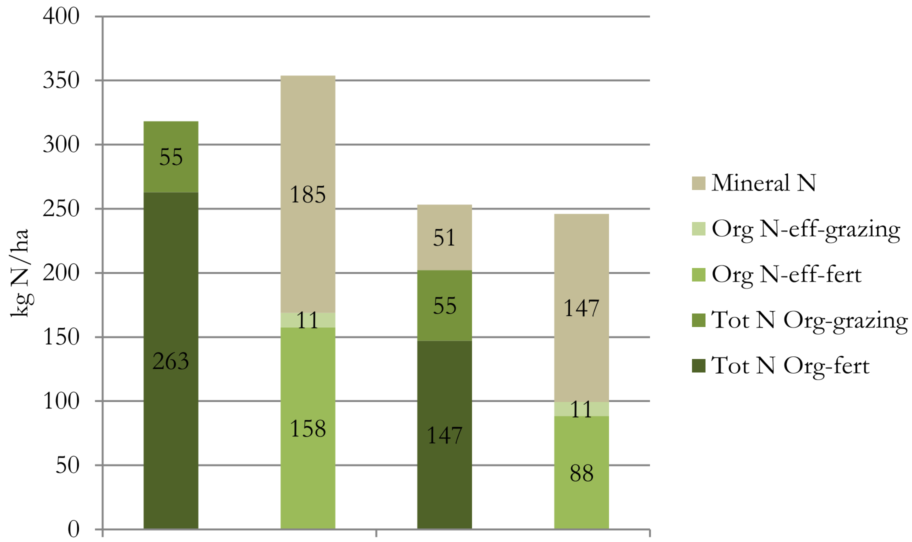


Figure 65: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was only cut, cut and grazed or only grazed on sandy soils in the monitoring network in 2019.

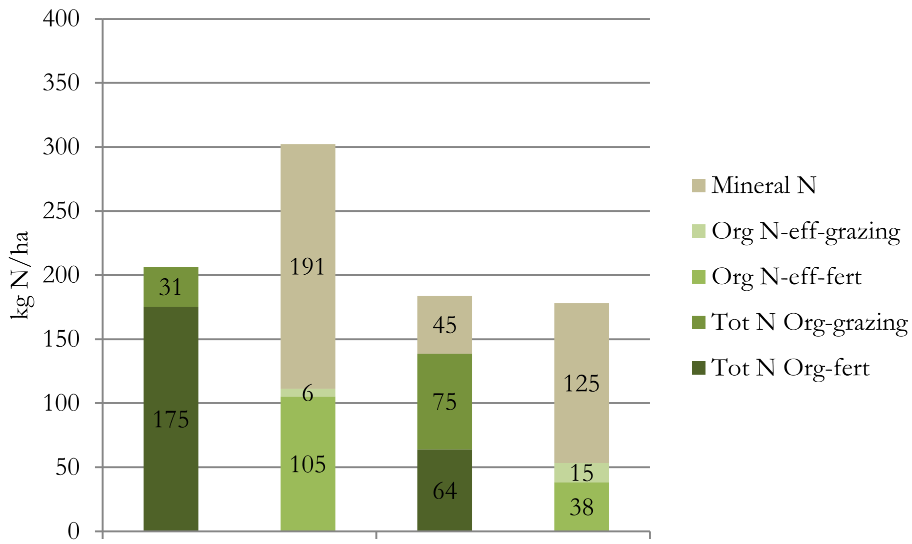


Figure 66: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was only cut, cut and grazed or only grazed on sandy loam soils in the monitoring network in 2019.

As in the former years of monitoring and in line with the fertilisation standards (Annex 1 – Nitrogen fertilisation standards), the average fertilisation in the monitoring network is further specified regarding soil texture and grass management (Table 25).

Table 25: Average nitrogen input (kg N/ha) on derogation and no derogation parcels cultivated with grass in 2019.

	Derogation					No derogation				
	Mineral	Organic			**Total N eff**	Mineral	Organic			**Total N eff**
		Manure	Grazing	**Total**			Manure	Grazing	**Total**	
Grass	188	219	43	262	328	136	108	64	172	214
Grass, grazing cattle	170	180	95	276	297	119	78	137	215	193
Grass, only cutting	203	251	-	251	353	152	135	-	135	233
Grass, grazing cattle-sand	175	236	111	347	339	143	108	122	230	232
Grass, only cutting-sand	194	290	-	290	368	150	179	-	179	257
Grass, grazing cattle-SL	163	112	76	188	246	95	46	153	199	153
Grass, only cutting-SL	210	219	-	219	341	153	81	-	81	202

On grazed parcels, less mineral nitrogen is used and less effective nitrogen is applied.

In a cutting and grazing regime, grazing is more extended on parcels without derogation. On sandy soils cultivated with grass that are cut and grazed under derogation conditions, on average

339 kg effective nitrogen was applied in 2019 (Figure 67). The average dose of mineral and total organic nitrogen are respectively 175 and 347 kg N/ha. The 347 kg total organic N is the result of 236 kg N/ha by manuring and 111 kg N/ha by grazing. Without derogation the average amount of effective nitrogen is 232 kg N/ha; the result of 230 kg total organic nitrogen, 108 kg N/ha by manuring and 122 kg N/ha by grazing, and 143 kg mineral N/ha.

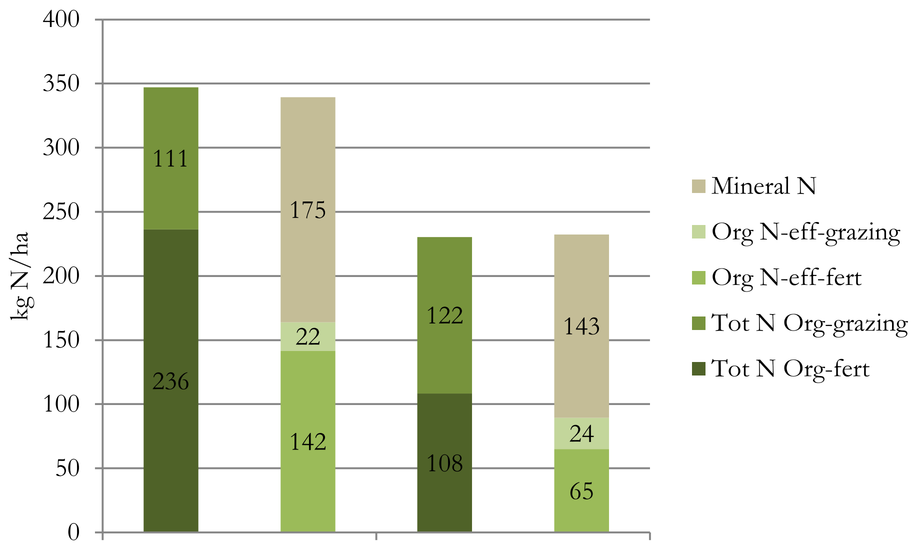


Figure 67: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was cut and grazed or only grazed on sandy soils in the monitoring network in 2019.

On sandy loam soils cultivated with grass in cutting and grazing regime and derogation conditions, on average 246 kg effective N was applied (Figure 68). The organic fertilisation included 112 kg total organic nitrogen by manuring and 76 kg total organic nitrogen by grazing. This was supplemented by 163 kg mineral N/ha. Without derogation, the amount of effective nitrogen was 153 kg N/ha. Manuring and grazing provided 199 kg total organic nitrogen, respectively 46 and 153 kg N/ha. By mineral fertilizers 95 kg N/ha was supplied.

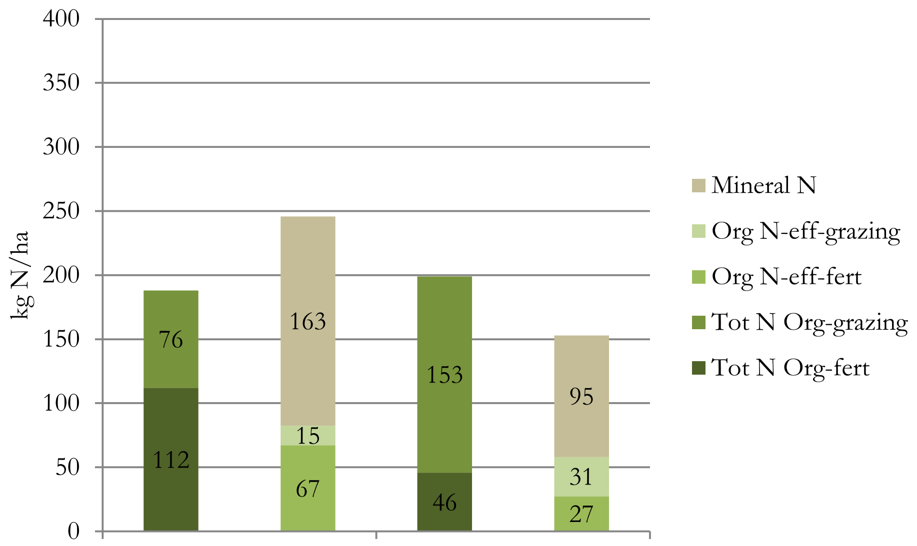


Figure 68: Average amount of applied total organic N by fertilisation (Tot N Org-fert) and grazing (Tot N Org-grazing), organic N available during the growing season by organic fertilisation (Org N-eff-fert) or by grazing (Org N-eff-grazing) and mineral N on derogation and no derogation parcels cultivated with grass that was cut and grazed or only grazed on sandy loam soils in the monitoring network in 2019.

In a cutting regime, the applied amount of effective N is some higher as in a cutting and grazing regime, both on sandy and sandy loam soils, and both with and without derogation.

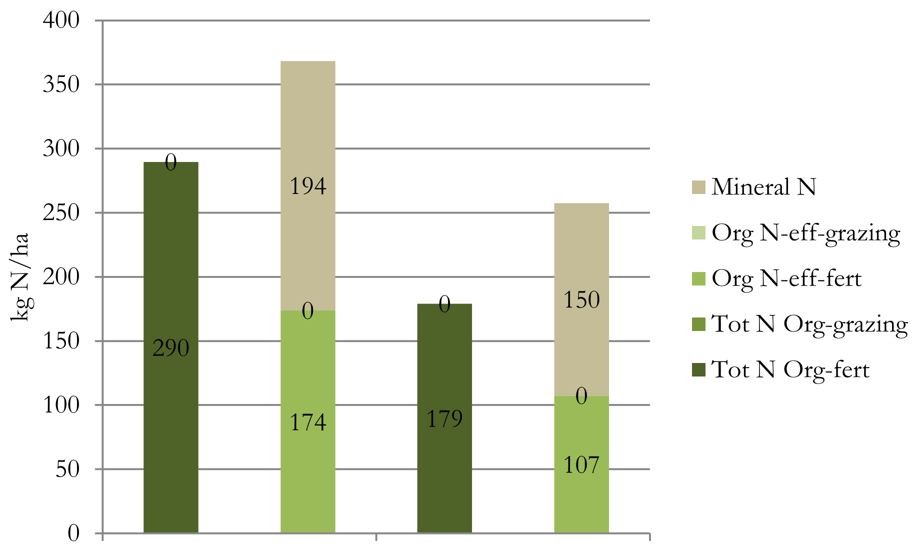


Figure 69: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with grass that was only cut on sandy soils in the monitoring network in 2019.

On sandy parcels with grass that is only cut under derogation conditions, 368 kg effective N/ha is applied. Without derogation, the amount of effective N is 257 kg N/ha. The amount of total organic nitrogen is 290 and 179 kg N/ha on respectively derogation and no derogation parcels. Mineral fertilization amounted respectively 194 and 150 kg N/ha.

On sandy loam soils, on average 341 kg effective N/ha is applied on cut parcels under derogation conditions. Without derogation, the nitrogen fertilization was 202 kg effective N/ha. By manuring, 219 and 81 kg total organic nitrogen was applied on derogation and no derogation parcels. Mineral fertilization was 210 and 153 kg N/ha.

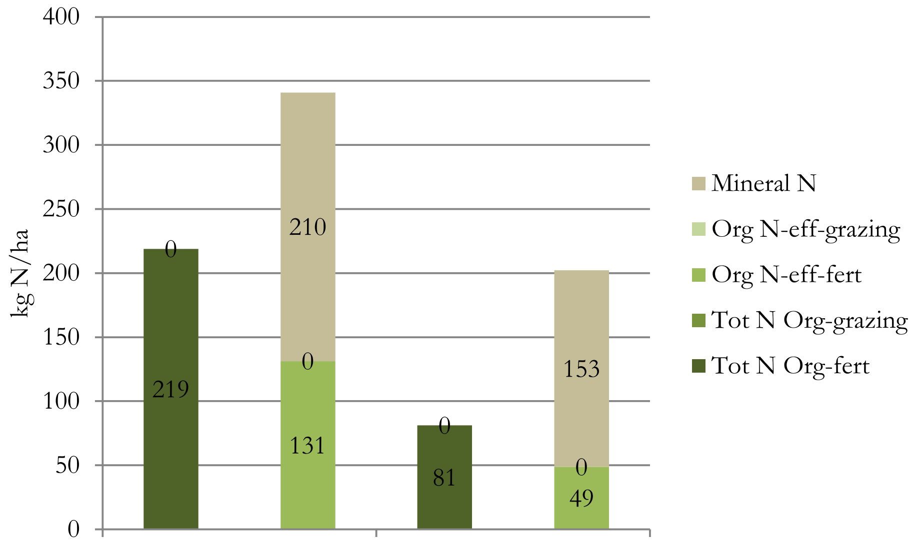


Figure 70: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with grass that was only cut on sandy loam soils in the monitoring network in 2019.

Grass and less than 50 % clover

Most parcels cultivated with grass and less than 50 % clover were only cut. Only 5 parcels were not only cut but also grazed, all derogation parcels. The average fertilisation data given in Table 24 include all parcels.

On derogation parcels cultivated with grass and less than 50 % clover, on average 276 kg total organic N/ha was applied. Without derogation, 186 kg total organic N/ha was applied. The mineral fertilisation amounted on average 186 kg N/ha on derogation parcels and 167 kg N/ha on parcels without derogation. This resulted in average doses N of 340 and 279 kg effective N/ha respectively with and without derogation.

The average fertilisation of the parcels with grass and less than 50 % clover that were only cut is given in Figure 71.

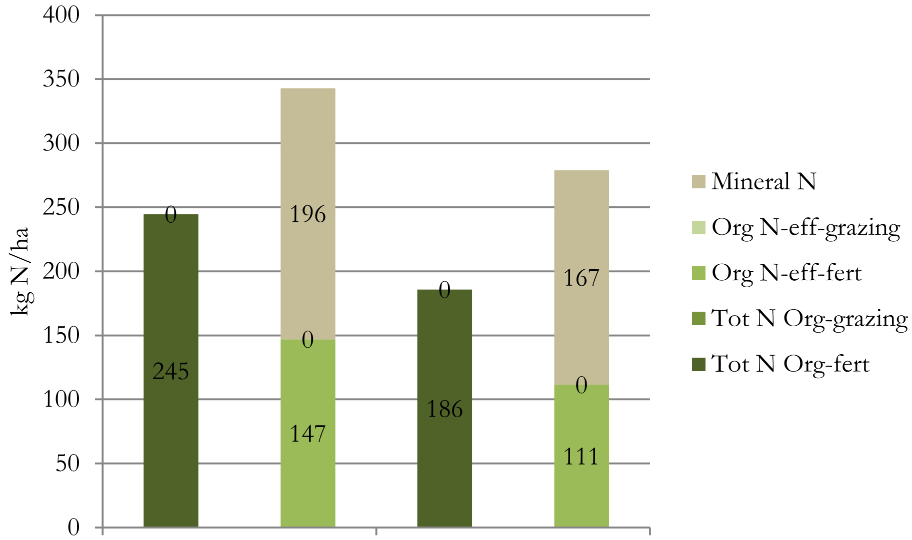


Figure 71: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with grass and less than 50 % clover that was only cut on sandy soils in the monitoring network in 2019.

Fertilisation on parcels cultivated with grass and less than 50 % clover was similar to the average fertilisation on parcels cultivated with grass, since the occurrence of clover was not sufficient to rely on its nitrogen fixating capacity and to reduce the nitrogen fertilisation.

Maize

In 2019, the average nitrogen fertilisation amounted 212 kg effective N/ha on parcels cultivated with maize in the monitoring network. Averagely 206 kg total organic N and 88 kg mineral N was applied per hectare on the maize parcels of the network.

Under derogation conditions, the average amount of 222 kg total organic N/ha was supplemented with 109 kg mineral N/ha. This resulted in an application of 242 kg effective N/ha. Without derogation, on average 180 kg effective N/ha was applied in 2019 on parcels cultivated with maize. Sixty-seven kg N/ha was provided by mineral fertilisers. Organic fertilisers were applied at an average dose of 189 kg total organic N/ha.

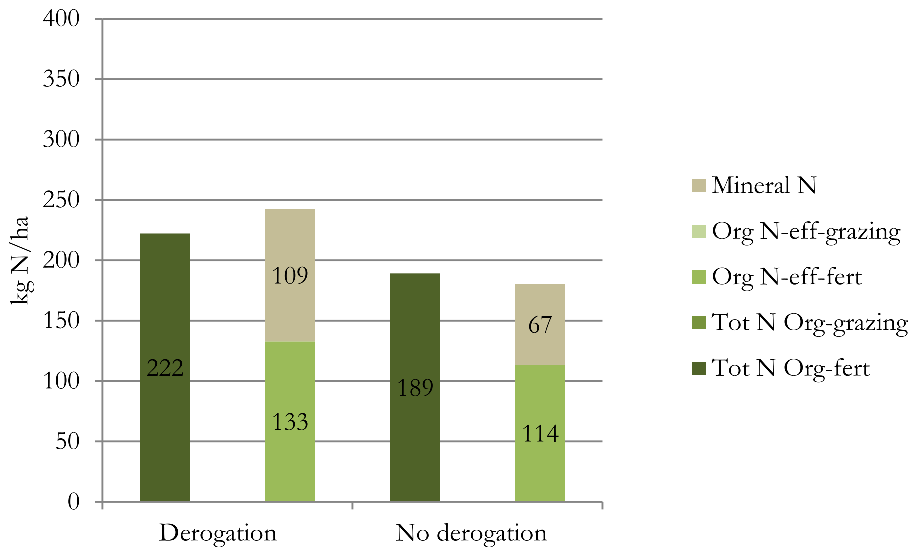


Figure 72: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with maize on all soils in the monitoring network in 2019.

On sandy soils, 237 kg total organic N/ha was applied on parcels cultivated with maize under derogation conditions. The mineral complement amounted 98 kg N/ha. Without derogation 63 kg mineral N was applied in addition to 183 kg total organic N/ha. Consequently the effective nitrogen amounted 239 kg N/ha under derogation conditions and 173 kg N/ha without derogation (Figure 73).

On sandy loam soils (Figure 74), the organic nitrogen amounted 207 kg N/ha under derogation conditions. Mineral fertilization provided 120 kg N/ha. On average 245 kg effective N/ha was provided that way under derogation. On no derogation parcels the organic and mineral component of the fertilization amounted respectively 195 kg total organic N/ha and 71 kg N/ha. This meant on average 188 kg effective N/ha.

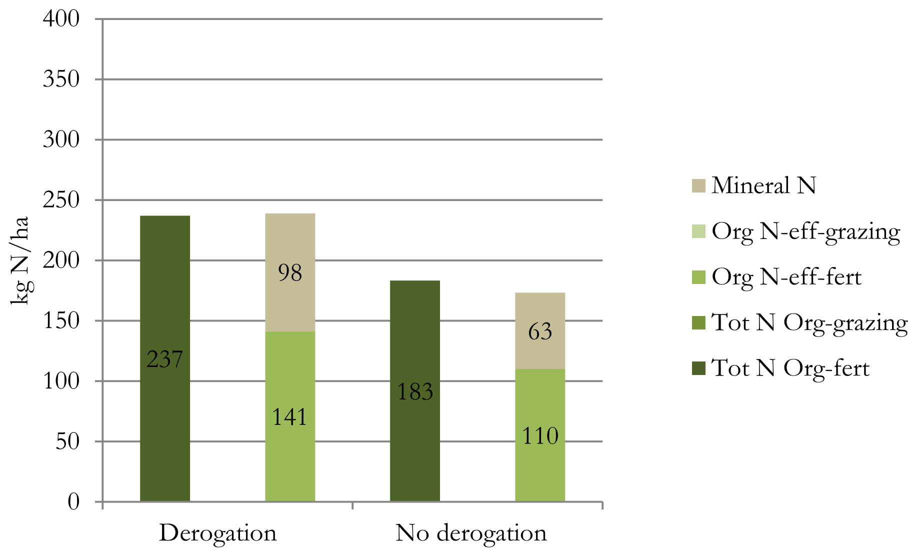


Figure 73: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with maize on sandy soils in the monitoring network in 2019.

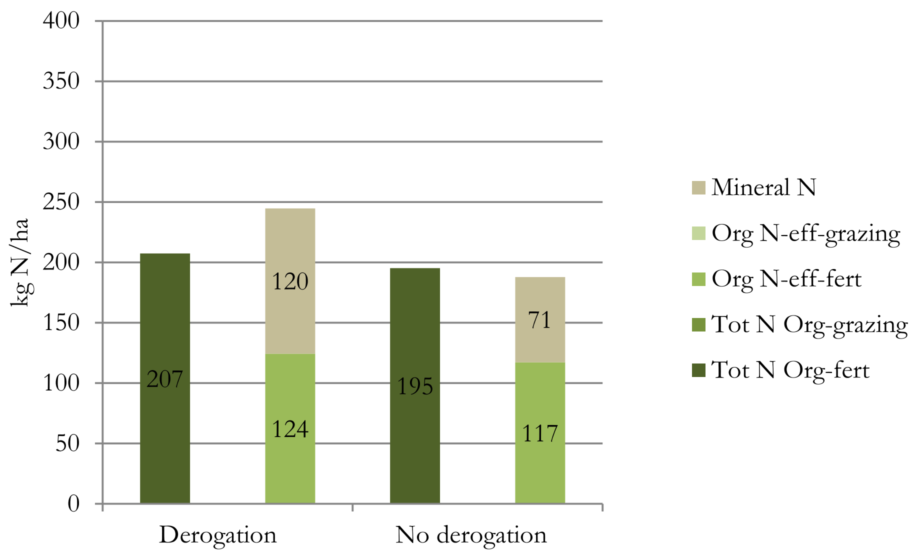


Figure 74: Average amount of applied total organic N by fertilisation (Tot N Org-fert), organic N available during the growing season by organic fertilisation (Org N-eff-fert) and mineral N on derogation and no derogation parcels cultivated with maize on sandy loam soils in the monitoring network in 2019.

For no derogation conditions, the fertilisation can be further specified for parcels with and without a cut of grass before the main crop maize (Table 26). The nitrogen fertilisation on parcels with a preceding cut of grass amounted on average 242 kg effective N/ha under derogation conditions and 252 kg effective N/ha without derogation.

Table 26: Average nitrogen input (kg N/ha) on derogation and no derogation parcels cultivated with maize in 2019.

	Derogation					No derogation				
	Mineral	Organic			**Total N eff**	Mineral	Organic			**Total N eff**
		Manure	Grazing	**Total**			Manure	Grazing	**Total**	
Maize	109	222	-	222	242	67	189	-	189	180
Maize & grass	109	222	-	222	242	120	220	-	220	252
Maize without grass before	-	-	-	-	-	46	177	-	177	152
Maize-sand	98	237	-	237	239	63	183	-	183	173
Maize & grass-sand	98	237	-	237	239	108	199	-	199	228
Maize without grass before	-	-	-	-	-	38	175	-	175	143
Maize-SL	120	207	-	207	245	71	195	-	195	188
Maize & grass-SL	120	207	-	207	245	140	257	-	257	295
Maize without grass before	-	-	-	-	-	52	179	-	179	159

2.2.4.2 Phosphorus

The phosphorus fertilisation in the monitoring network is differentiated regarding crop and crop management. In line with the fertilisation standards for phosphorus, no distinction is made regarding soil texture.

Table 27: Average phosphorus input (kg P_2O_5/ha) on derogation and no derogation parcels in the monitoring network-2019.

	Derogation					No derogation				
	Mineral	Organic			**Total**	Mineral	Organic			**Total**
		Manure	Grazing	Total			Manure	Grazing	Total	
Grass	1	72	15	87	88	2	46	23	69	71
Grass, grazing cattle	0	65	33	98	98	1	41	48	89	90
Grass, only cutting	1	78	0	78	79	2	50	0	50	52
Grass & less than 50 % clover	0	71	11	82	82	0	64	0	64	64
Grass & less than 50 % clover only cutting	0	69	0	69	69	0	64	0	64	64
Maize	4	71	-	71	75	6	90	-	90	96
Maize & grass	4	71	-	71	75	5	91	-	91	96
Maize without grass before	-	-	-	-	-	7	90	-	90	97

Phosphorus input by mineral fertilisers is very limited, certainly on parcels cultivated with grass or grass and less than 50 % clover. The occasional use of composite mineral fertilisers on derogation parcels cultivated with grass that is only cut, results in a minor mineral input even though the restriction on those parcels.

On parcels cultivated with maize, the input of mineral phosphorus is also small. It is usually a limited in row application.

Focusing on the organic part of the phosphorus input, it can be stated for the parcels with grass and grass with less than 50 % clover, that the higher input of organic fertilisers resulted in a higher P-input. The higher input under derogation conditions is most pronounced on parcels with grass that is only cut.

For parcels cultivated with maize, the situation regarding the input of organic phosphorus is opposite. The rather modest difference in organic N-fertilisation, compared to grass and grass with less than 50 % clover, and the use of different organic manure on derogation and no derogation parcels, bring about a higher organic P-input on parcels without derogation. On parcels without derogation pig slurry is often used. Pig slurry has a different N/P ratio than cattle slurry, with less organic nitrogen more organic P is introduced.

Comparison of the **fertilisation of the past 4 years** shows an average higher fertilisation under derogation conditions, both mineral and organic. Comparison of the fertilisation of 2016 and 2017 showed that the nitrogen input under derogation conditions in 2017 was comparable to slightly higher than in 2016. Without derogation, the average nitrogen input was lower than in 2016. The fertilisation of 2019 was rather comparable to the situation of 2018. The grass management was determinant in the amount of fertilisation on parcels cultivated with grass. On grazed parcels, the N-fertilisation was very similar the past 4 years, both for derogation and no derogation parcels. On purely cut parcels, the N-fertilisation was reduced under derogation conditions in the dry year 2018 and to a certain extent in 2019, also a year with a long period of drought. Without derogation conditions, the average N-fertilisation in 2018 was only slightly lower than in 2017. It was further reduced in 2019. On derogation parcels, the reduction was realised by reduction of mineral fertilisation. On parcels without derogation, the little reduction was primarily realised by reduction of organic fertilisers.

In maize, where fertilisation happens in spring before and at sowing, the drought of 2018 could not be taken into account. On parcels cultivated with grass however, the fertilisation during the season could be adapted and reduced according to the drought. This adjustment was most pronounced under derogation circumstances.

2.3 Yield – nutrient export

As experienced in the former monitoring networks (Vandervelpen, *et al.,* 2011; Odeurs, *et al.*, 2015) yield is an important parameter to compare derogation and non-derogation practices. The monitoring network 2016-2019 provides data on yield both under derogation and non-derogation conditions. Each year farmers were asked to assess and judge the yield of the parcels that are monitored. The importance of these yield figures was clearly and strongly explained to the farmers. A more intensive approach was planned for 2017, 2018 and 2019. These 3 years the research team organised yield samplings at a selection of monitored parcels.

2.3.1 Yield – nutrient export – 2016

In 2016, the yield monitoring was proposed to be based on figures reported by the farmers. Farmers were questioned and yield figures were communicated.

For silage maize the exact yield (kg/ha) of each parcel is not always available. These yield figures are estimates or indications of the farmers. For corn maize often exact yield figures and moisture content are available. Based on average dry matter, nitrogen and phosphorus content, the amount of exported nutrients is calculated, using the figures shown in Table 28 and Table 29.

Table 28: Amount of nitrogen and phosphorous exported by the harvest of silage maize (above-ground) for different classes of yield.

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

Table 29: Amount of nitrogen and phosphorous for each ton dry matter and fresh weight of corn-maize (moisture content of the harvested crop is given). Source: "Ontwerp actieprogramma nitraatrichtlijn 2011-2014".

		Dry matter (DM)		Yield		
		kg N /ton DM	kg P /ton DM	kg N /ton yield	P_2O_5 /ton yield	Moisture (%)
Corn maize	Corn	15.1	3.3	13	6.5	14

For grassland different possibilities are present (cutting, cutting and grazing cattle or only grazing cattle). The farmers provide 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 30) are used.

Table 30: Amount of nitrogen and phosphorous exported by the grassland (above-ground) for each cutting with a specific level of yield.

Yield (above-ground)	Dry matter (ton/ha)	N (kg/ha)	P (kg P_2O_5/ha)
Very poor	2.0	60	17.4
Poor	2.5	75	21.8
Good	3.0	90	26.1
Very good	3.5	105	30.5

It needs to be mentioned that because of the extreme weather conditions and the very difficult circumstances to grow and manage the crops, it was even more difficult to quantify yield.

For grass it was even more difficult to estimate the impact on the yield. For many parcels one cutting was missed, parcels could not be grazed for a while or parcels were not accessible at the moment that the second cut had to be harvested with yield and quality loss as the result.

For maize, the impact of the specific weather conditions seemed to be clearer. The yield losses experienced in the monitoring network are indicated in Figure 75. Farmers indicated themselves the loss of yield or yield figures were compared with average yield figures to estimate the loss of yield.

This indication supports the overall opinion and experience of the research team that yield was highly influenced by the specific weather conditions of 2016, much more than by the implementation of derogation or not. There were extreme regional differences and culture management like e.g. moment of sowing was much more important than normal.

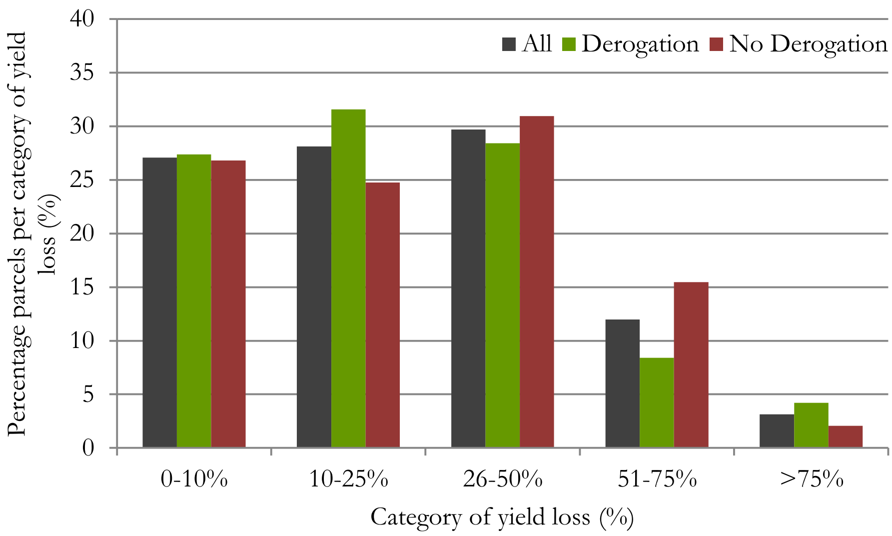


Figure 75: Percentage parcels cultivated with maize (all (grey), with derogation (green) and without derogation (red)) per category of yield loss.

Nevertheless, nutrient export in derogation and no derogation conditions is compared. Since quite a few assumptions are made for calculating the nutrient export, the **estimated** nutrient export is mentioned but the comparison is indicated by relative figures. The estimated (as described before) nutrient export without derogation conditions is set as the standard (100 %). The estimated nutrient export under derogation conditions is set against the nutrient export without derogation conditions and is indicated relatively.

Grass

The estimated average N-export in the monitoring network in 2016 on the parcels cultivated grass was 290 kg N/ha. Regardless of grass management (cutting, grazing or combination of both) the estimated average N-export on derogation parcels was 328 kg N/ha. On parcels without derogation the average N-export was estimated to amount 252 kg N/ha. The export on derogation parcels was 30 % higher as on no derogation parcels (Figure 76).

For further discussion a distinction is made between parcels that were only cut and parcels that were grazed or grazed and cut.

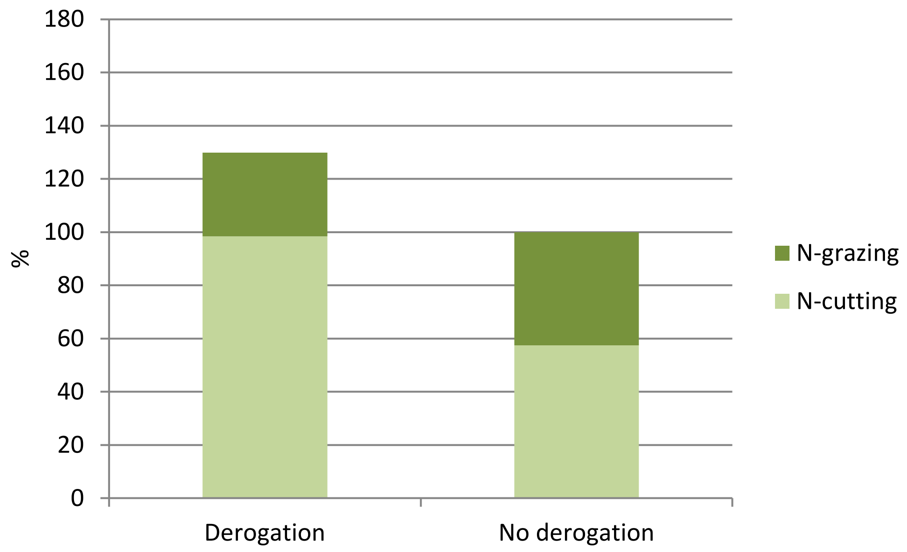


Figure 76: N-export on derogation and no derogation parcels cultivated with grass (only cutting, only grazing or both), relative to N-export on noderogation parcels cultivated with grass (only cutting, only grazing or both) (%) on all soils in the monitoring network in 2016.

When parcels were only cut, the average N-export on derogation parcels was 33 % higher as on parcels without derogation (Figure 77). Under derogation conditions the average N-export was estimated around 361 kg N/ha. Without derogation the estimation of the N-export was 89 kg N/ha lower and amounted 272 kg N/ha. This was the result of both more cuttings and a higher average yield per cutting.

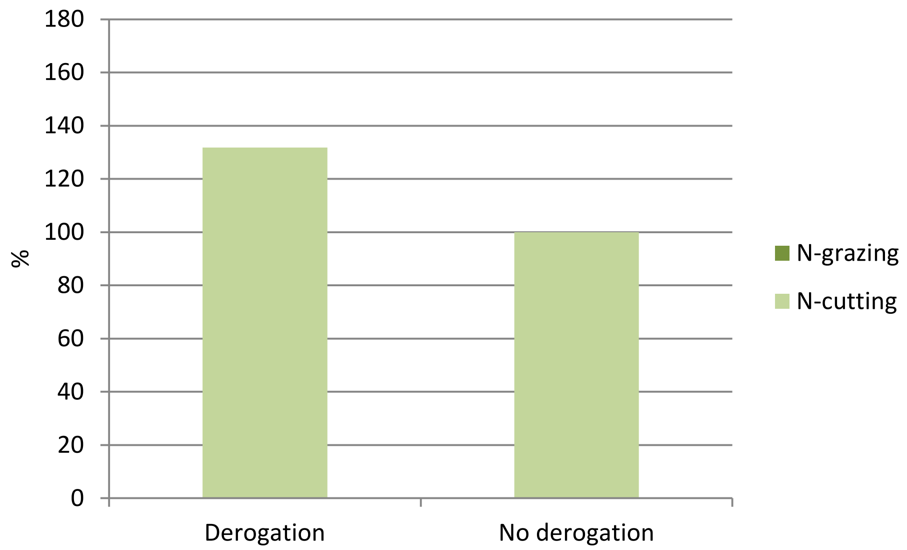


Figure 77: N-export on derogation and no derogation parcels cultivated with grass (only cutting), relative to N-export on no derogation parcels cultivated with grass (only cutting) (%) on all soils in the monitoring network in 2016.

On sandy soils, the difference of N-export between derogation and no-derogation parcels was 29 %. On sandy loam soils, the estimated N-export was 39 % higher on parcels with derogation.

The estimated average N-export of derogation parcels with grass that was cut and grazed was 298 kg N/ha, approximately half by grazing and half by cutting. Without derogation the estimated average N-export under grazing and cutting conditions was 241 kg N/ha. Without derogation, the cutting was less important. Approximately 170 kg N/ha was exported by grazing and 71 kg N/ha by cutting.

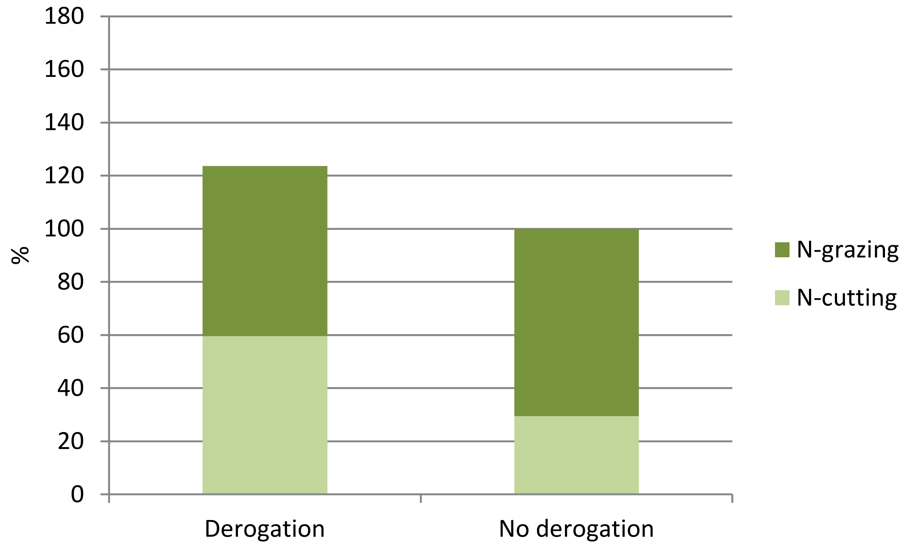


Figure 78: N-export on derogation and no derogation parcels cultivated with grass (cutting and grazing or grazing), relative to N-export on no derogation parcels cultivated with grass (cutting and grazing or grazing) (%) on all soils in the monitoring network in 2016.

As for the parcels with grass that were only cut, also on the parcels that were cut and grazed the difference in N-export between derogation and no derogation parcels was a little higher on sandy loam soils. Under grazing and cutting conditions, the difference in N-export on sandy loams soils amounted 27 %. On sandy soils, the N-export of derogation parcels was 21 % higher.

Grass and less than 50 % clover

On parcels with grass and less than 50 % clover, the export of nutrients under derogation conditions was higher as without derogation conditions. When only cut, the nitrogen export of derogation parcels cultivated with grass and less than 50 % clover was 27 % higher as on no derogation parcels (Figure 79).

When parcels were not grazed and only cut, the estimated average export on derogation and no derogation parcels amounted 390 and 308 kg N/ha, respectively. Including grazed parcels, on average 393 kg N/ha export was estimated on derogation parcels. On grazed and cut parcels with grass and less than 50 % clover without derogation the average N-export was estimated at 313 kg N/ha.

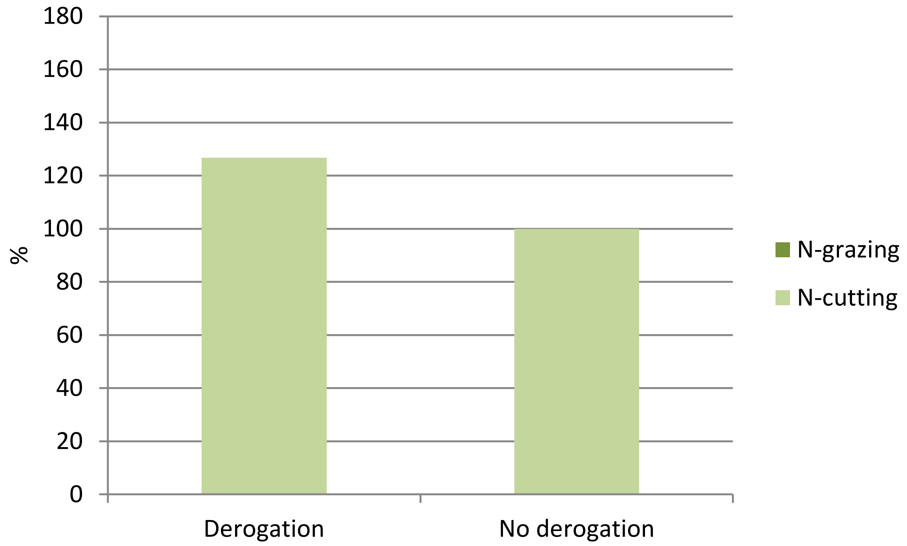


Figure 79: N-export on derogation and no derogation parcels cultivated with grass and less than 50 % clover, relative to N-export on no derogation parcels cultivated with grass and less than 50 % clover (%) on sandy soils in the monitoring network in 2016.

Maize

For maize, the estimated average N-export of derogation and no derogation parcels was clearly different. Under derogation conditions the export was 62 % higher than without derogation conditions (Figure 80), 251 kg N/ha compared to 155 kg N/ha.

The obligatory cut of grass before the maize under derogation conditions was the most important reason for the higher N-export. However, the N-export by the maize was also higher under derogation conditions. The second parameter for the higher N-export under derogation conditions was the type of maize that is grown. Under derogation conditions, mostly silage maize is grown while more corn maize is grown without derogation.

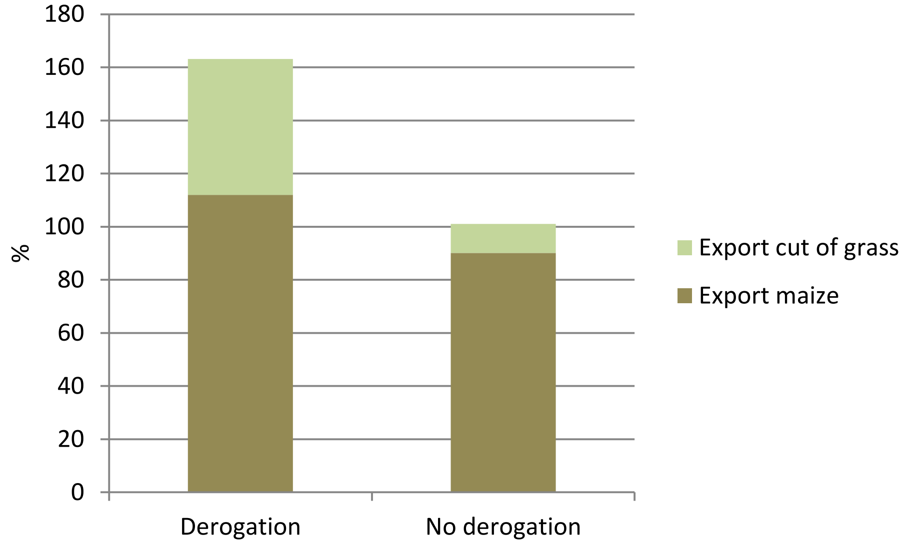


Figure 80: N-export on derogation and no derogation parcels cultivated with maize, relative to N-export on no derogation parcels cultivated with maize on all soils in the monitoring network in 2016.

Evaluation of parcels cultivated with maize preceded by a cut of grass, showed that the N-export with and without derogation on such parcels was comparable (Figure 81). The N-export on derogation parcels was only 2 % higher compared to parcels without derogation. Under derogation conditions the export by the cut of grass is more important than on parcels without derogation.

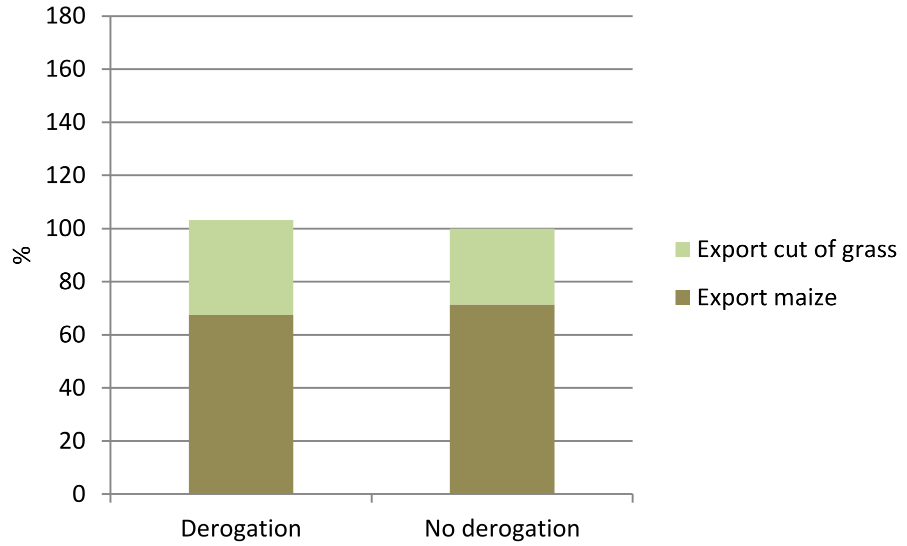


Figure 81: N-export on derogation and no derogation parcels cultivated with maize and grass cut before maize, relative to N-export on no derogation parcels cultivated with maize and grass cut before maize on all soils in the monitoring network in 2016.

Since the relation between export and input was overruled by weather conditions in 2016, it is incorrect to relate both parameters with each other. As stated before, yield was clearly influenced by more than only fertilization. In addition the results of the monitoring discussed in the following paragraphs 3.2.1.1, 3.2.1.2 and 3.3.1.1 will have to be considered in this perspective.

2.3.2 Yield – nutrient export – 2017

In 2017, the assessment of yield and nutrient export was subject of a twin-track approach. As in 2016, the yield monitoring in 2017 was still primarily based on figures reported by the farmers. Farmers were questioned and asked to report yield figures. In addition to those figures (2.3.2.1) experimental harvests were organised on a selection of monitored parcels (2.3.2.2).

2.3.2.1 Practical approach

The yield and nutrient export quantified in the practical approach are the parameters of the monitoring network that are the most susceptible for interpretation and assumptions. Since some assumptions need to be made for calculating the nutrient export, the estimated nutrient export is shown relatively. The estimated nutrient export without derogation conditions is set as the standard (100 %).

Grass

Regardless of the management of the grass, soil or derogation strategy, the average nitrogen export in the monitoring network 2017 of parcels cultivated with grass was quantified as 288 kg N/ha. Differentiating the parcels cultivated with grass regarding the application of derogation or not, showed that the average nitrogen export of derogation parcels was estimated on 317 kg N/ha. Without derogation the result was 258 kg N/ha. The export of derogation parcels was 23 % higher as of no derogation parcels (Figure 82).

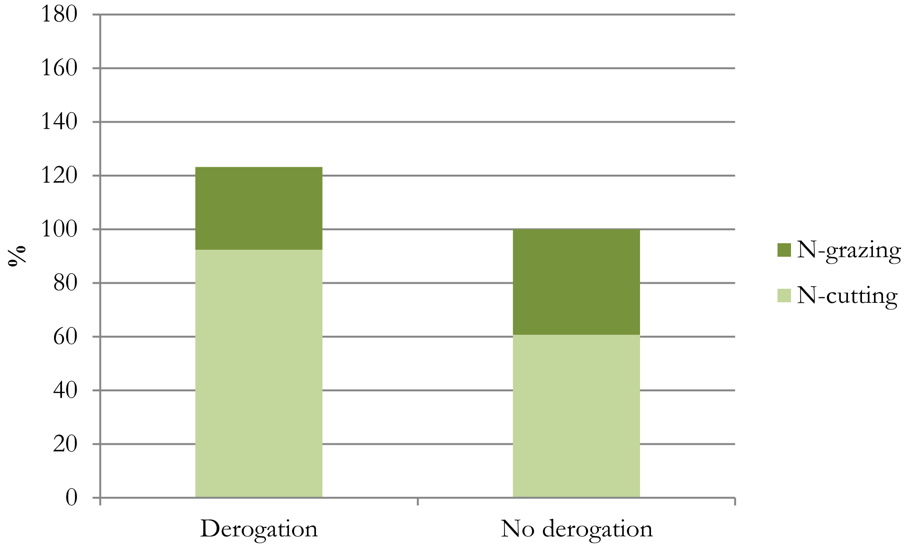


Figure 82: N-export on derogation and no derogation parcels cultivated with grass (only cutting, only grazing or both), relative to N-export on no derogation parcels cultivated with grass (only cutting, only grazing or both) (%) on all soils in the monitoring network in 2017.

Specifically on parcels with grass that was cut and grazed, or only grazed, the nitrogen export was estimated on 276 kg N/ha in the monitoring network in 2017. The nitrogen export of parcels with and without derogation differed 18 % (Figure 83). Under derogation and grazing and cutting conditions the average nitrogen export was 302 kg N/ha, 132 kg N/ha by cutting and 170 kg N/ha by grazing. The difference between the derogation and no derogation parcels originated from the cutting part. On parcels without derogation under cutting and grazing conditions the nitrogen export by grazing was also estimated on 170 kg N/ha but the nitrogen export by cutting was 86 kg N/ha.

On sandy soils, the difference in N-export between derogation and no derogation parcels in a cutting and grazing regime was only 7 %, 291 kg N/ha compared to 272 kg N/ha. On sandy loam soils, the N-export of parcels with and without derogation differed 32 %, 317 kg N/ha compared to 241 kg N/ha. Each time more nitrogen was exported under derogation conditions.

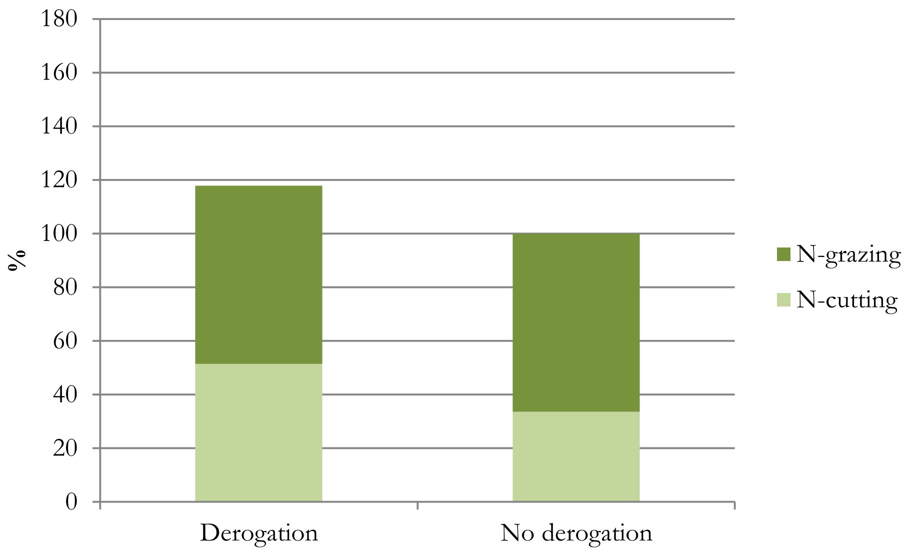


Figure 83: N-export on derogation and no derogation parcels cultivated with grass (cutting and grazing or grazing), relative to N-export on no derogation parcels cultivated with grass (cutting and grazing or grazing) (%) on all soils in the monitoring network in 2017.

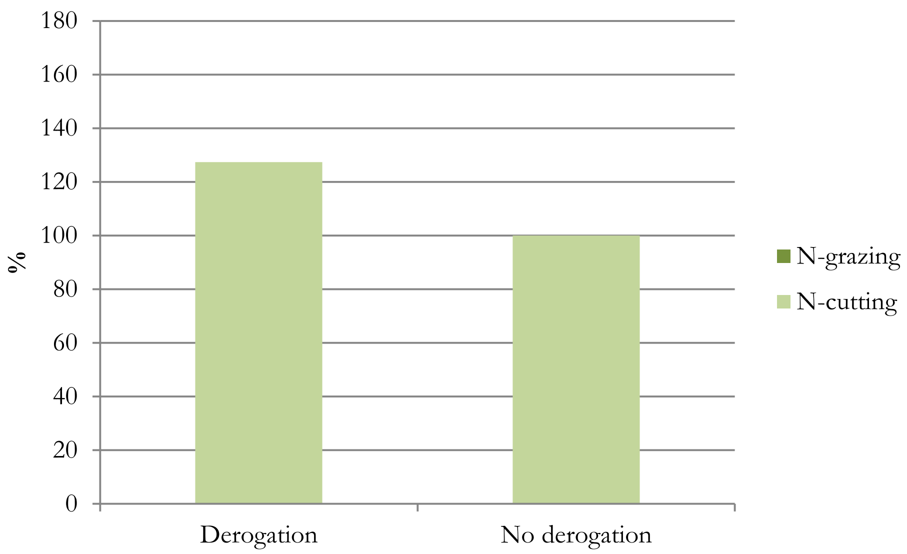


Figure 84: N-export on derogation and no derogation parcels cultivated with grass (only cutting), relative to N-export on no derogation parcels cultivated with grass (only cutting) (%) on all soils in the monitoring network in 2017.

A more efficient exploitation of parcels cultivated with grass is a 100 % cutting regime. The average nitrogen export of the cut parcels of the monitoring network was quantified on 301 kg N/ha. The nitrogen export was 27 % higher under derogation conditions (Figure 84), 331 kg N/ha under derogation conditions and 260 kg N/ha without derogation.

On sandy soils, the difference was higher. On average 42 % more N was exported of derogation parcels, 357 kg N/ha compared to 250 kg N/ha. On sandy loam soils, the difference was 15 %, 313 kg N/ha compared to 271 kg N/ha. On average derogation parcels were cut one more time than parcels without derogation. In 2017 derogation parcels were cut 5 times and no derogation parcels 4 times.

Grass and less than 50 % clover

The average nitrogen export of parcels cultivated with grass and less than 50 % clover under derogation conditions was 21 % higher than of parcels without derogation. Since only 2 parcels with grass and less than 50 % clover were cut and grazed, the difference between derogation and no derogation parcels regarding nitrogen export did not change when the comparison is restricted to the parcels which were not grazed and only cut. The comparison of nitrogen export of the parcels of the monitoring network cultivated with grass and less than 50 % clover, which are only cut, is demonstrated in Figure 85.

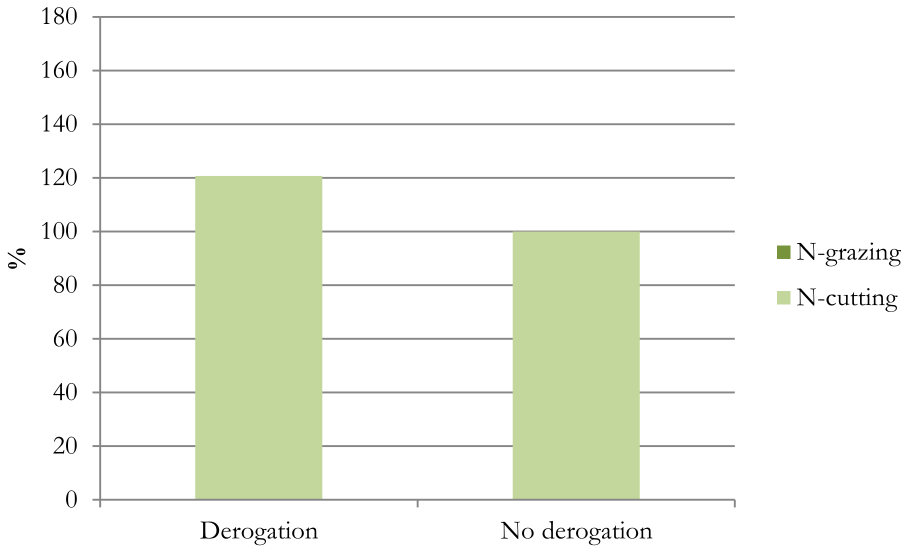


Figure 85: N-export on derogation and no derogation parcels cultivated with grass and less than 50 % clover, relative to N-export on no derogation parcels cultivated with grass and less than 50 % clover (%) on sandy soils in the monitoring network in 2017.

The nitrogen export on derogation and no derogation parcels cultivated with grass and less than 50 % clover that was only cut, was estimated on respectively 337 and 279 kg N/ha.

Maize

For the parcels cultivated with maize in the monitoring network the average nitrogen export was estimated at 253 kg N/ha, 51 kg N/ha by the cut of grass and 202 kg N/ha by the maize. The rather low average nitrogen export by the preceding cut of grass is the result of averaging export on parcels with a preceding cut of grass and zero export on parcels without a cut of grass. The difference in N-export between derogation and no derogation conditions is the most pronounced for the crop of maize. The nitrogen export under derogation conditions is 57 % higher than without derogation conditions (Figure 86), respectively 310 and 198 kg N/ha. The crop management under derogation and no derogation conditions is partly obligatory distinct. Farmers without derogation are not obliged to the cut of grass before the maize. For them it is often a possibility and a free choice while farmers with derogation on maize are obliged to have a cut of grass before the maize. In the group of parcels without derogation, most parcels have no preceding cut of grass. This cut of grass is the most important parameter for the higher nitrogen export under derogation conditions.

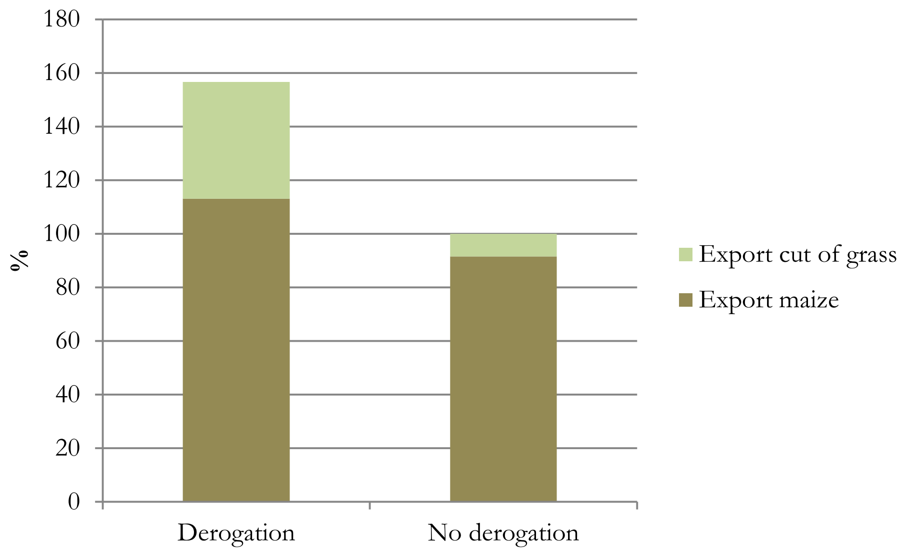


Figure 86: N-export on derogation and no derogation parcels cultivated with maize, relative to N-export on no derogation parcels cultivated with maize (%) on all soils in the monitoring network in 2017.

Although Figure 86 shows that also the maize on its own was already important for the difference in nitrogen export. This is caused by a different type of maize that is grown on derogation or no derogation farms. On derogation farms, the maize is most often grown to feed the animals, which means they grow silage maize. On farms without derogation, both silage maize and corn maize can be grown but often corn maize will be chosen.

A comparison of both groups with only parcels with 'grass-maize' shows a more moderate difference of 5 % (Figure 87).

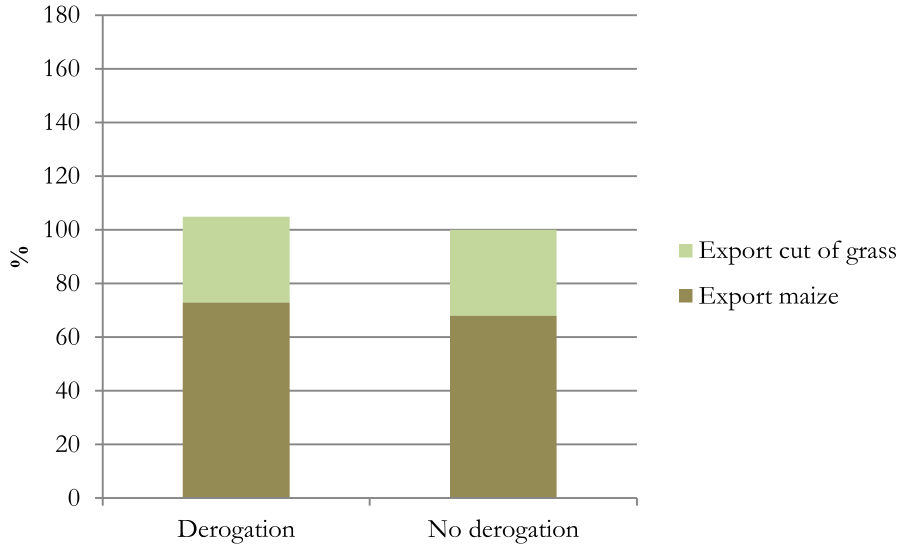


Figure 87: N-export on derogation and no derogation parcels cultivated with maize and grass cut before maize, relative to N-export on no derogation parcels cultivated with maize and grass cut before maize (%) on all soils in the monitoring network in 2017.

2.3.2.2 Experimental approach

The experimental approach planned yield sampling on 50 parcels. The distribution of these 50 parcels regarding to derogation, crop and soil texture is shown in Table 31.

Table 31: Overview of the distribution of the 50 experimentally harvested parcels.

	Derogation			No derogation		
Crop / Soil texture	Grass	Maize	Grass and <50% clover	Grass	Maize	Grass and <50% clover
Sand	5	5	5	5	5	5
Sandy loam	5	5	-	5	5	-

Since parcels with grass or maize can be farmed in different ways, the organization of yield sampling shown in Table 31 was more refined. Parcels cultivated with grass can be only cut, only grazed or cut and grazed. Also in the monitoring network all types of management of parcels cultivated with grass were present. On parcels cultivated with maize the main crop maize can or cannot be preceded by a cut of grass. On derogation parcels the cut of grass is an obligation but on parcels without derogation the preceding cut of grass is an open possibility (with consequently different fertilizer limits). In the organization of the experimental harvests, attention was paid to the crop management.

For parcels cultivated with grass it is obvious that yield is very difficult to determine on grazed parcels. On such parcels, the height of the grass needs to be determined at the start and the end of the grazing period. Still this would be a difficult yield assessment. Since the experimental harvests were meant to gather more exact data, grazed parcels were not preferred for yield sampling.

However parcels that are cut and grazed are relevant and often an important part of the yield is realised in the cutting part. In January 2017, a provisional inventory showed that 39 % of the parcels with grass in the monitoring network are parcels which are only cut and 42 % of the parcels are parcels that are cut and grazed. Also the proportion of both types of parcels regarding to the request of derogation and soil was evaluated (Table 32).

Table 32: Estimation of the proportion of parcels cultivated with grass that are cut, cut and grazed or grazed, with and without derogation - 20.01.2017

	Management	Derogation		No derogation	
		Number	%	Number	%
All soils		108		108	
	Cutting	48	45	36	33
	Cutting and grazing	51	47	39	36
	Grazing	9	8	33	31
Sandy soil		54		54	
	Cutting	23	43	16	30
	Cutting and grazing	25	46	25	46
	Grazing	6	11	13	24
Sandy loam soil		54		54	
	Cutting	25	46	20	37
	Cutting and grazing	26	48	14	26
	Grazing	3	6	20	37

Farmers without derogation indicated that on average 1 cut is realised before grazing. On derogation parcels, it would be on average 2 cuts before grazing. The research team has the experience that 3 or minimal 2 cuts should be sampled to estimate the production as accurate as possible. The relevance of the combined management and the disadvantages regarding yield sampling were weighed against each other. Parcels with grass that are cut and grazed are taken up in the selection but in minor extent. In the monitoring network, the combined management seemed to be applied more frequently on sandy soils. Therefore, yield sampling on parcels with combined management is organised on sandy soils (Table 34).

For the yield sampling of maize cultivated without derogation it needed to be decided whether parcels with a preceding cut of grass would be included in the experimental approach and if so to which extent.

In the planning and organisation of the yield sampling, the occurrence of a preceding cut of grass in the monitoring network was evaluated. In January 2017, the information regarding the cut of grass communicated by the farmers and gathered when visiting the farmers, was analysed (Table 33).

Table 33: Estimation of the proportion of parcels cultivated with maize preceded by a cut of grass on farms without derogation - 20.01.2017

	Management	Number of parcels	%
All soils		102	
	Cut of grass before maize	19	19
	Grass not cut or no grass present	83	81
Sandy soil		51	
	Cut of grass before maize	8	16
	Grass not cut or no grass present	43	84
Sandy loam soil		51	
	Cut of grass before maize	11	22
	Grass not cut or no grass present	40	78

On approximately 20 % of the parcels cultivated with maize without derogation in the monitoring network, a cut of grass precedes the main crop maize. This ratio would be applied to the yield sampling on no derogation parcels cultivated with maize.

Since on both sandy and sandy loam soils 5 yield samplings were planned, on each soil texture a parcel with maize preceded by a cut of grass could be surveyed. By circumstances and the willingness of the farmers to agree with a yield sampling, 2 sandy parcels and 1 sandy loam parcel grass-maize without derogation were sampled.

Table 34: Intended set-up of the yield sampling

	Derogation			No derogation		
Derogation crop / Soil texture	Grass	Maize	Grass with less than 50 % clover	Grass	Maize	Grass with less than 50 % clover
Sandy	5 1 combination 4 cutting	5 Grass- maize	5	5 1 combination 4 cutting	5 1 grass-maize 4 maize	5
Sandy loam	5 cutting	5 Grass-maize	-	5 cutting	5 1 grass-maize 4 maize	-

Besides crop and soil also special care was taken of a sufficient regional distribution (Figure 88).

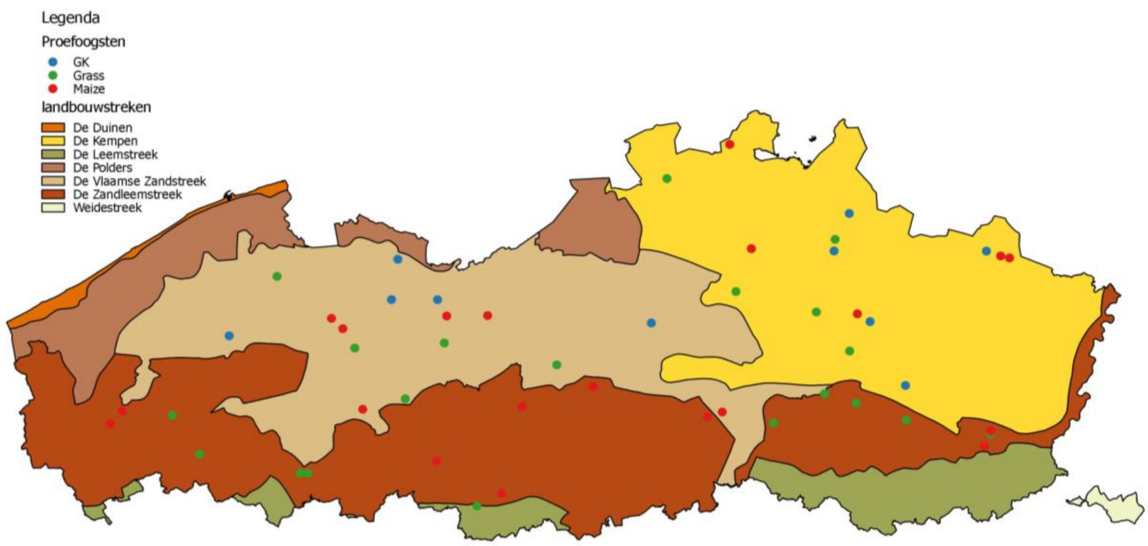


Figure 88: Location of the 50 parcels with yield sampling in 2017, distinguished by crop.

The yield sampling on parcels cultivated with grass or grass and less than 50 % clover was organised in the same way. Farmers were contacted regularly and were asked to inform the research team when they planned to harvest. The grass/grass and clover was harvested at 3 random locations (3 replicates) on the parcel. Per replicate, the harvested surface (length and width) was measured and the fresh weight of the grass was determined. Per replicate, 7 to 12 m² was cut. At each replicate, the crop was sampled. The crop samples were analysed for dry matter content, N-content and P-content. So yield (fresh, dry matter), nutrient export and nutrient content could be compared between derogation and no derogation parcels.

On parcels cultivated with maize preceded by a cut of grass, the cut of grass was sampled identically to the parcels cultivated with grass.

The parcels cultivated with maize were also sampled in 3 replicates. Per replicate, 2 rows of 4-6 m long were harvested. The crop was chopped and sampled. The crop samples were analysed for dry matter content, N-content and P-content.

Since the rather limited number of parcels that are compared in the experimental approach and because of conflict with normality and homogeneity of variances, a non-parametric test was preferred. Since only two groups (derogation and no derogation) need to be compared, the Mann-Whitney U Test is applied.

Grass

Twenty parcels cultivated with grass were selected and followed in this set-up, both 10 derogation and no derogation parcels.

Despite all efforts, not each cut of grass done by the farmer could be preceded by an experimental harvest. Consequently the total production could not be covered by the experimental harvests on all parcels. Therefore, the total yield on derogation and no derogation parcels will not be compared.

The comparison of derogation and no derogation parcels in the given set-up and circumstances can be presented per cut and after 4 cuttings. After 4 cuttings still 5 derogation and 5 no derogation parcels can be compared.

At no time, evaluation of yield, N-content and N-export showed that the surveyed derogation and no derogation parcels differed statistically. The variation of these parameters and the averages of these parameters at each cutting are demonstrated in Figure 89, Figure 90 and Figure 91.

Table 35: Results of the yield sampling on parcels cultivated with grass in the monitoring network in 2017. Dry matter (DM) yield (ton DM/ha), N-content (g N/100 g DS) and N-export (kg N/ha) at each cut. Total dry matter yield and N-export after 4 cuts and average N-content of 4 cuts.

		n	Dry matter yield		N-content		N-export	
			(ton DM/ha)	p-value	(g N/100 g DM)	p-value	(kg N/ha)	p-value
Cut 1	Derogation	10	4,16	0.94	2,8	0.79	110	0.82
	No derogation	10	4,04		2,8		104	
Cut 2	Derogation	8	3,06	0.59	3,0	0.33	87	0.48
	No derogation	10	3,21		2,7		78	
Cut 3	Derogation	9	1,78	0.96	2,9	0.96	52	0.83
	No derogation	9	1,57		3,0		43	
Cut 4	Derogation	7	1,98	0.57	2,9	0.68	56	0.68
	No derogation	5	2,37		2,7		62	
Cut 1-4	Derogation	5	10,67	0.46	3,0	0.17	308	0.92
	No derogation	5	11,85		2,6		289	

Evaluation after 4 cuttings showed also that the *total* dry matter yield, the average N-content and the *total* N-export on the surveyed derogation and no derogation parcels did not differ statistically. However, on the parcels with derogation still more cuts followed after the fourth cut. On average 1 cut was left, ranging from no cut anymore to 2 cuts afterwards. On the parcels without derogation on average no cut followed anymore after the fourth cut, ranging from no cut to 1 cut left. The higher return or the surplus cut on derogation parcels was not reflected in the yield sampling of 2017.

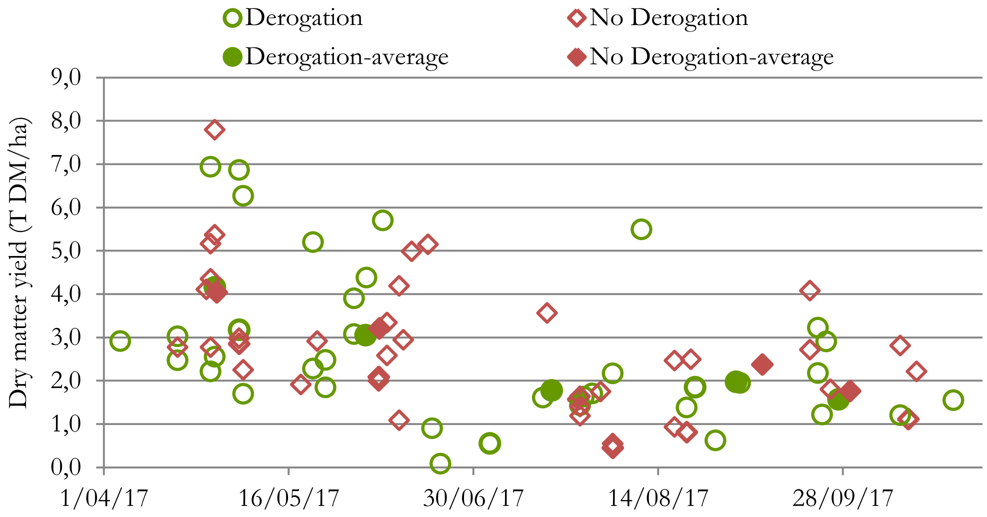


Figure 89: Dry matter yield (ton DM/ha) by yield sampling on derogation and no derogation parcels cultivated with grass in the monitoring network-2017. Yield of individual parcels (empty marks) and average yield of derogation and no derogation parcels (filled marks).

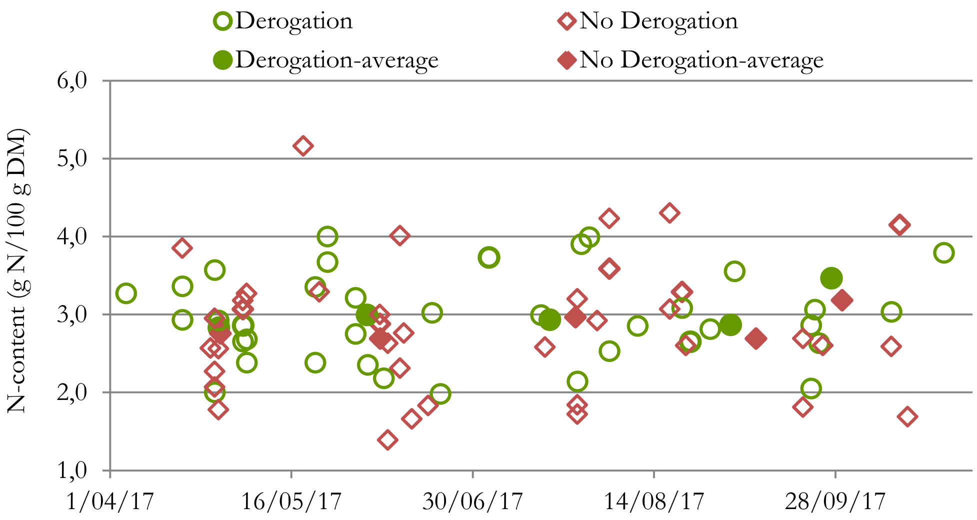


Figure 90: N-content (g N/100 g DM) of the grass by yield sampling on derogation and no derogation parcels cultivated with grass in the monitoring network-2017. N-content at individual parcels (empty marks) and average N-content on derogation and no derogation parcels (filled marks).

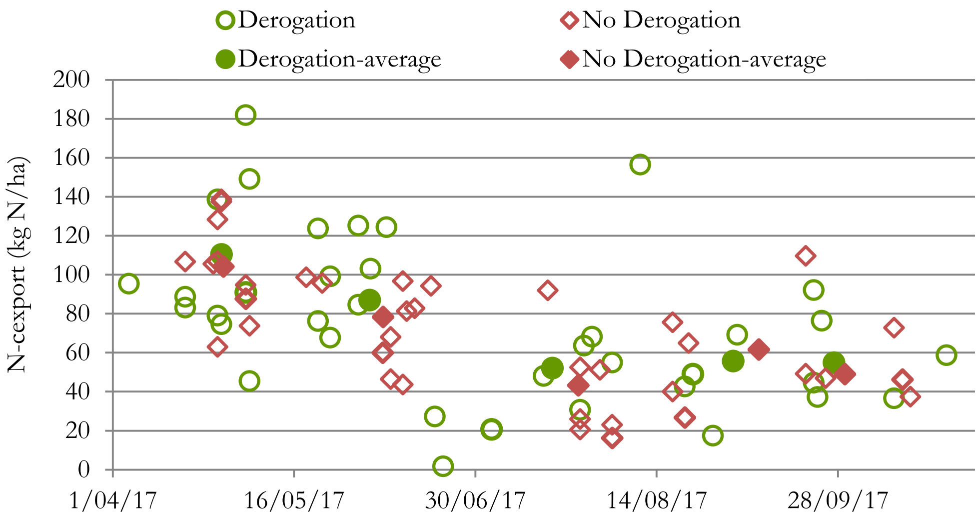


Figure 91: N-export (kg N/ha) by yield sampling on derogation and no derogation parcels cultivated with grass in the monitoring network-2017. N-export of individual parcels (empty marks) and average N-export of derogation and no derogation parcels (filled marks).

Grass and less than 50 % clover

Ten parcels cultivated with grass and less than 50% clover were subject of the experimental approach, 5 derogation parcels and 5 parcels without derogation.

As for the parcels cultivated with grass not each cut done by the farmer could be preceded by an experimental harvest, despite all efforts. This means that the experimental harvests do not cover the total production for all surveyed parcels. Derogation and no derogation parcels were compared at each cutting and after 4 cuttings. After 4 cuttings still 8 parcels could be compared: 4 derogation parcels and 4 parcels without derogation.

The dry matter yield did not differ statistically between derogation and no derogation parcels, nor per cut, nor in total after 4 cuttings (Table 36). The variation between the parcels regarding to dry matter yield is demonstrated in Figure 92.

The lack of difference between derogation and no derogation parcels in the yield sampling of grass with less than 50 % clover was not surprisingly when fertilisation was involved. In the group of 8 parcels which were sampled until the fourth cut, the fertilisation of the parcels without derogation was even higher than on the derogation parcels. On the parcels with derogation on average 223 kg N/ha was applied by mineral fertilisers and 227 kg total organic N was applied, resulting in a dose of 359 kg effective nitrogen/ha. On the parcels without derogation 239 kg N/ha was applied by mineral fertilisers and 253 kg total organic N was applied, resulting in a dose of 390 kg effective nitrogen/ha. After the fourth cut one more cut had to be realised on derogation parcels and 2 more cuts on parcels without derogation. These observations point out that the farm and parcel management are important.

Table 36: Results of the yield sampling on parcels cultivated with grass and less than 50% clover in the monitoring network in 2017. Dry matter (DM) yield (ton DM/ha), N-content (g N/100 g DS) and N-export (kg N/ha) at each cut. Total dry matter yield and N-export after 4 cuts and average N-content of 4 cuts.

		n	Dry matter yield		N-content		N-export	
			(ton DM/ha)	p-value	(g N/100 g DM)	p-value	(kg N/ha)	p-value
Cut 1	Derogation	5	4,29	0.60	2,4	0.25	92	0.60
	No derogation	5	3,78		2,9		103	
Cut 2	Derogation	5	3,33	0.33	2,4	0.09	76	0.35
	No derogation	4	2,53		3,3		78	
Cut 3	Derogation	5	2,57	0.35	3,2	0.75	80	0.12
	No derogation	5	1,78		3,1		49	
Cut 4	Derogation	4	2,20	0.22	3,1	0.33	64	0.46
	No derogation	5	1,78		3,6		63	
Cut 1-4	Derogation	4	12,93	0.56	2,7	0.25	309	0.56
	No derogation	4	10,73		3,3		318	

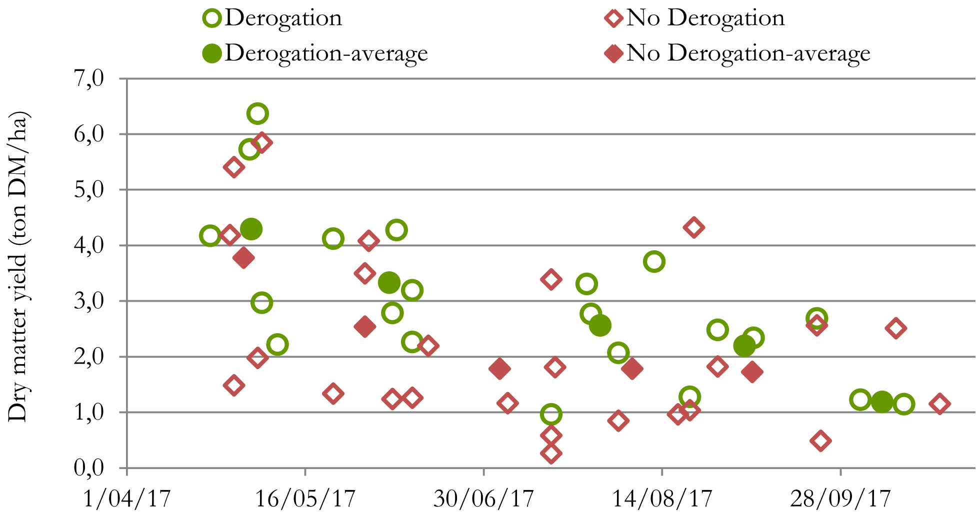


Figure 92: Dry matter yield (ton DM/ha) by yield sampling on derogation and no derogation parcels cultivated with grass and less than 50 % clover in the monitoring network-2017. Yield of individual parcels (empty marks) and average yield of derogation and no derogation parcels (filled marks).

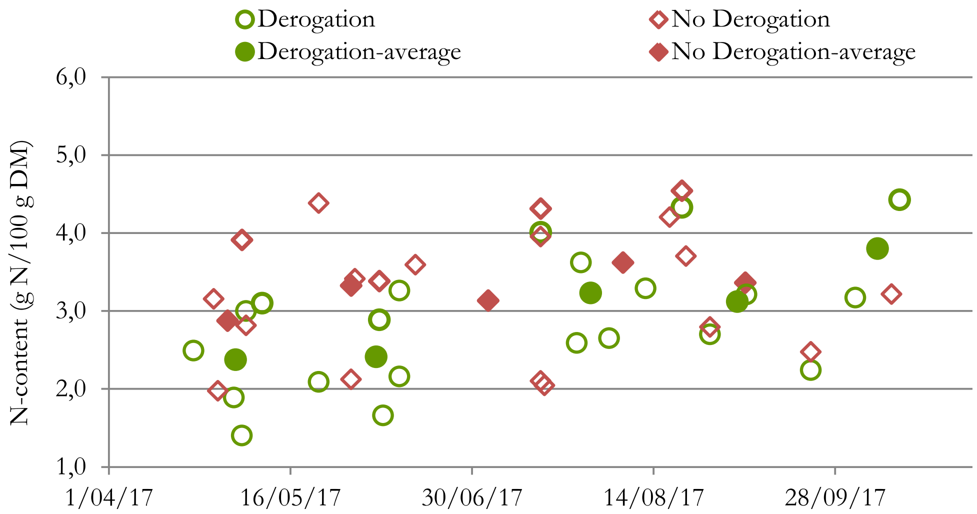


Figure 93: N-content (g N/100 g DM) of the grass and clover by yield sampling on derogation and no derogation parcels cultivated with grass and less than 50 % clover in the monitoring network-2017. N-content at individual parcels (empty marks) and average N-content on derogation and no derogation parcels (filled marks).

In addition the N-content of the grass and clover (per cut or in average over the 4 cuttings) and the N-export (per cut or in total after 4 cuttings) was not statistically different between the derogation and no derogation parcels (Table 36). The variation in N-content and N-export between the parcels and during the sampling season appears in Figure 93 and Figure 94.

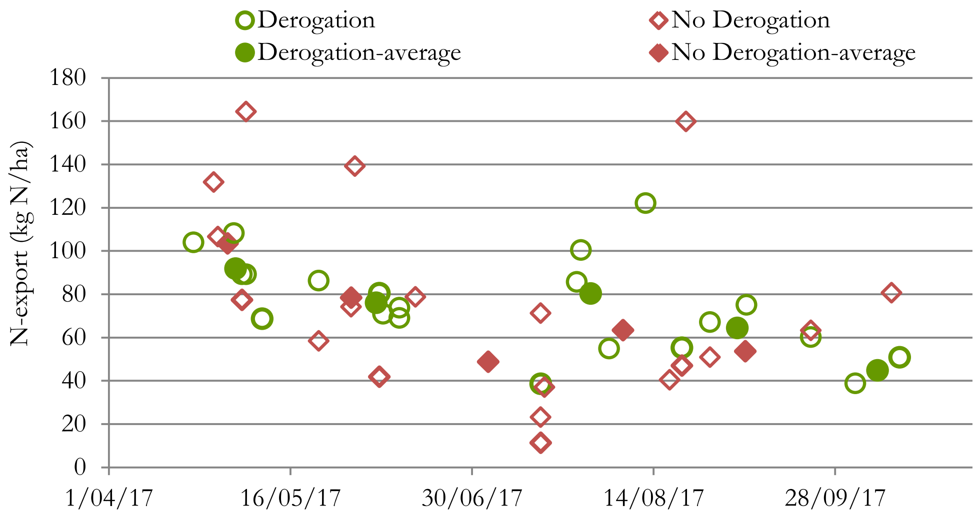


Figure 94: N-export (kg N/ha) by yield sampling on derogation and no derogation parcels cultivated with grass and less than 50 % clover in the monitoring network-2017. N-export of individual parcels (empty marks) and average N-export of derogation and no derogation parcels (filled marks).

Maize

Yield sampling was organised on 20 parcels, equally distributed as derogation and no derogation parcels. Among the parcels without derogation, there were 3 parcels with a cut of grass before the main crop maize.

Table 37: Results of the yield sampling on parcels cultivated with maize in the monitoring network in 2017. Dry matter (DM) yield (ton DM/ha), N-content (g N/100 g DS) and N-export (kg N/ha) of the grass and the maize. Total dry matter yield and N-export of grass and maize together.

		n	Dry matter yield		N-content		N-export	
			(ton DM/ha)	p-value	(g N/100 g DM)	p-value	(kg N/ha)	p-value
Grass	Derogation	10	3,53	0.11	2,6	0.87	89	0.11
	No derogation	10	1,86		2,7		50	
Maize	Derogation	10	19,19	0.76	1,1	0.33	215	0.71
	No derogation	10	18,32		1,2		215	
Total	Derogation	10	22,72	0.06	-		304	0.07
	No derogation	10	20,18		-		265	

The smaller dry matter yield and nitrogen export of the cut of grass on no derogation parcels is caused by the parcels without a cut of grass. The demonstrated average dry matter yield and nitrogen export is the average of 3 parcels with a preceding cut of grass and 7 parcels with zero dry matter yield for the cut of grass since there was no cut of grass. The same is done for the nitrogen export.

Because of the high variability on both derogation and no derogation parcels (Figure 95, Figure 96, Figure 97), nor yield, nor N-content nor N-export differed statistically on derogation or no derogation parcels (Table 37). Despite the lack of a statistically significant difference, it should be stressed that the cut of grass is still an important contribution. Comparison of the derogation parcels and the parcels without derogation and without a cut of grass shows that the total dry matter yield on derogation parcels differed statistically from those parcels without derogation (Table 38). Consequently, the N-export on parcels without derogation and without a cut of grass is significantly lower as on derogation parcels cultivated with maize.

Figure 95: Dry matter yield (ton DM/ha) by yield sampling on derogation and no derogation parcels cultivated with maize in the monitoring network-2017. Yield of individual parcels (empty marks) and average yield of derogation and no derogation parcels (filled marks), of the cut of grass, of the main crop and in total).

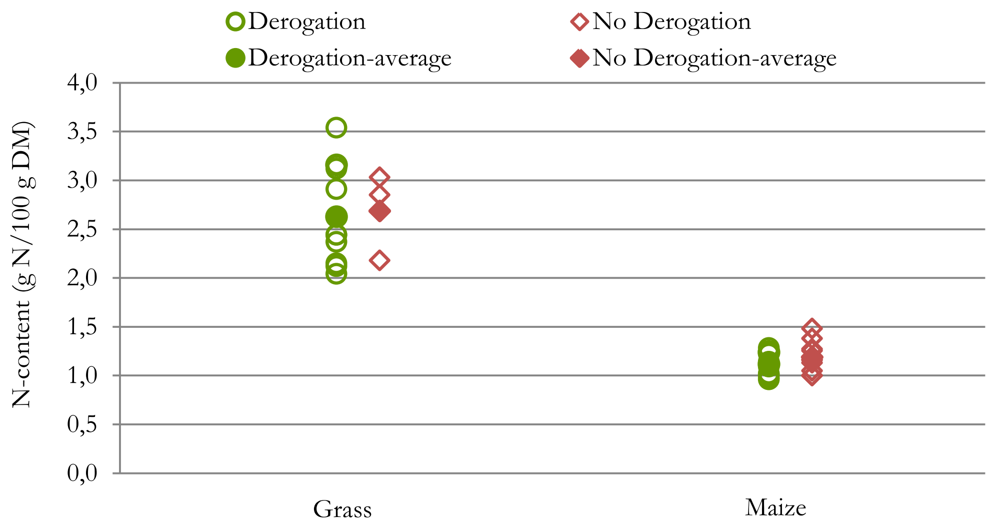


Figure 96: N-content (g N/100 g DM) of the crop by yield sampling on derogation and no derogation parcels cultivated with maize in the monitoring network-2017. N-content at individual parcels (empty marks) and average N-content on derogation and no derogation parcels (filled marks) of the grass and the maize.

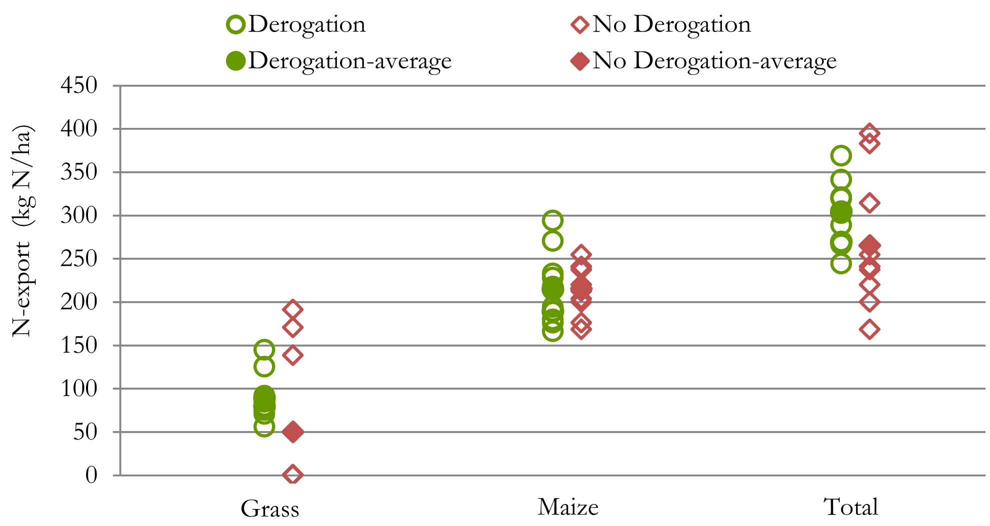


Figure 97: N-export (kg N/ha) by yield sampling on derogation and no derogation parcels cultivated with maize in the monitoring network-2017. N-export of individual parcels (empty marks) and average N-export of derogation and no derogation parcels (filled marks), by the cut of grass, by the main crop and in total.

Table 38: Results of the yield sampling on parcels cultivated with maize in the monitoring network in 2017 only no derogation parcels without a cut of grass. Dry matter (DM) yield (ton DM/ha), N-content (g N/100 g DS) and N-export (kg N/ha) of the grass and the maize. Total dry matter yield and N-export of grass and maize together.

		n	Dry matter yield		N-content		N-export	
			(ton DM/ha)	p-value	(g N/100 g DM)	p-value	(kg N/ha)	p-value
Grass	Derogation	10	3,53	0.00	2,6	-	89	0.00
	No derogation	7	0		-		0	
Maize	Derogation	10	19,19	0.77	1,1	0.20	215	0.38
	No derogation	7	18,40		1,2		223	
Total	Derogation	10	22,72	0.01	-	-	304	0.00
	No derogation	7	18,40		-		223	

2.3.3 Yield – nutrient export – 2018

As in 2017, the assessment of yield and nutrient export in 2018 was also subject of a twin-track approach. The yield monitoring was still primarily based on figures reported by the farmers, just as in 2016 and 2017. Farmers were questioned and asked to report yield figures. In addition to those figures (2.3.3.1) experimental harvests were organised on a selection of monitored parcels (2.3.3.2).

2.3.3.1 Practical approach

Grass

In 2018 the average nitrogen export of parcels cultivated with grass was quantified as 241 kg N/ha, regardless of soil, derogation or grass management. Under derogation conditions the quantification resulted in an average nitrogen export of 262 kg N/ha. Without derogation the result was 218 kg N/ha. The estimated nutrient export without derogation conditions set as the standard (100 %), shows that the export of parcels cultivated with grass under derogation conditions was 21 % higher in 2018.

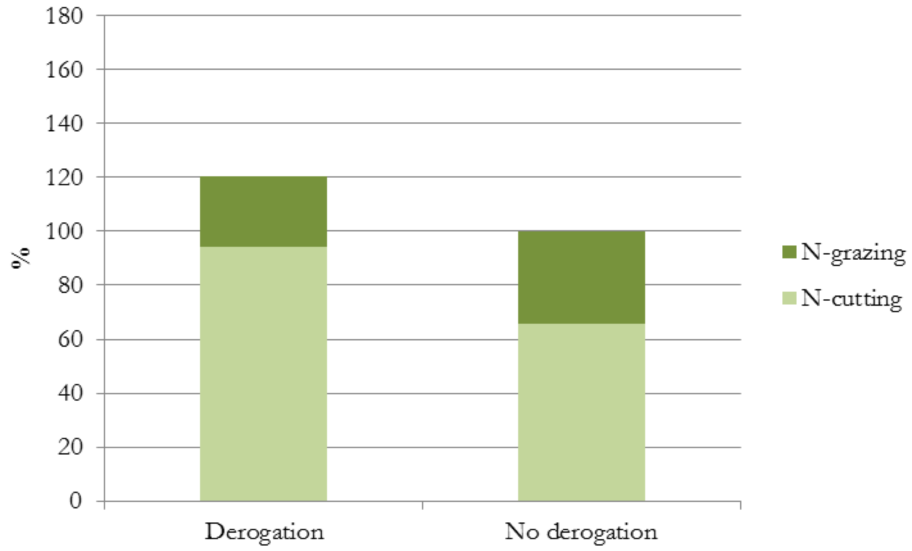


Figure 98: N-export on derogation and no derogation parcels cultivated with grass (only cutting, only grazing or both), relative to N-export on no derogation parcels cultivated with grass (only cutting, only grazing or both) (%) on all soils in the monitoring network in 2018.

Further specification for parcels cultivated with grass regarding the grass management is appropriate. The average nitrogen export of parcels cultivated with gras in a cutting and grazing regime was estimated on 231 kg N/ha in 2018. The cutting part covered on average 106 kg N/ha and the grazing part 125 kg N/ha. The nitrogen export of derogation parcels was estimated 21 % higher than without derogation (Figure 99). Under derogation and grazing and cutting conditions the average nitrogen export was 253 kg N/ha, 142 kg N/ha by cutting and 111 kg N/ha by grazing. Without derogation but still in grazing and cutting regime, the nitrogen export was quantified as 209 kg N/ha, 70 kg N/ha by cutting and 139 kg N/ha by grazing. On parcels without derogation, the grazing part was like the previous years more important for export than on parcels with derogation.

On sandy soils, the export under cutting and grazing regime differed 22 % between derogation and no derogation parcels. Under derogation conditions the nitrogen export was quantified on 266 kg N/ha and without derogation on 218 kg N/ha. On sandy loam soils, the nitrogen export tended to be a bit lower, 232 kg N/ha under derogation and 199 kg N/ha without derogation. Derogation parcels seemed to be 16 % more productive.

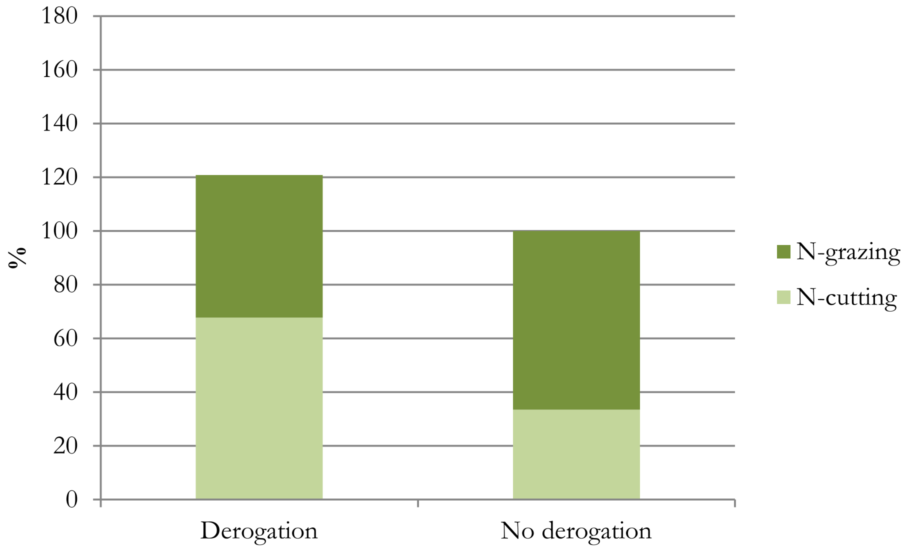


Figure 99: N-export on derogation and no derogation parcels cultivated with grass (cutting and grazing or grazing), relative to N-export on no derogation parcels cultivated with grass (cutting and grazing or grazing) (%) on all soils in the monitoring network in 2018.

In a 100 % cutting regime, the average nitrogen exported was estimated on 251 kg N/ha, about 50 kg N/ha less than in 2017. The difference in nitrogen export between derogation and no derogation parcels in a cutting regime was 20 % (Figure 100). Without derogation, on average 228 kg N/ha was exported and with derogation 273 kg N/ha. On sandy and sandy loam soils, the nitrogen export of derogation parcels was respectively 18 and 25 % higher than without derogation.

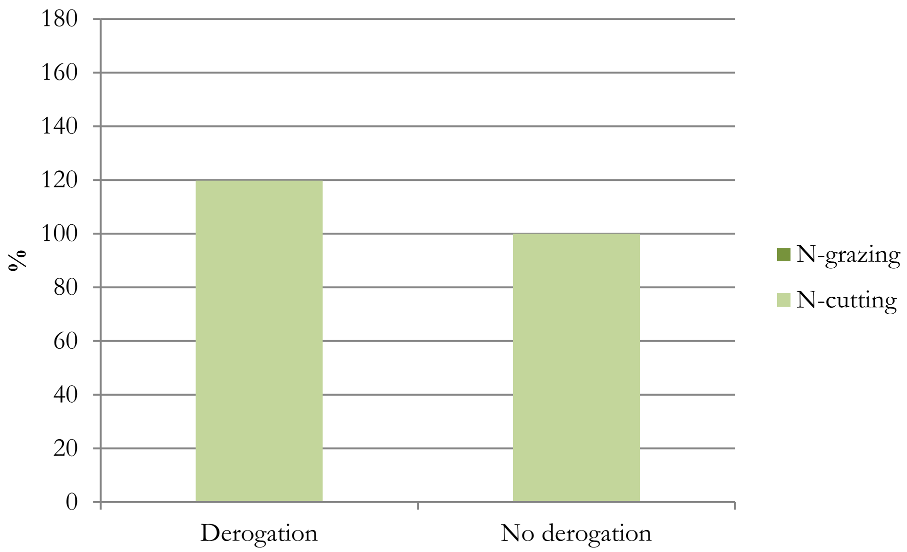


Figure 100: N-export on derogation and no derogation parcels cultivated with grass (only cutting), relative to N-export on no derogation parcels cultivated with grass (only cutting) (%) on all soils in the monitoring network in 2018.

Grass and less than 50 % clover

In 2018, the nitrogen export of parcels cultivated with grass and less than 50 % clover was estimated 277 kg N/ha. With and without derogation the export was quantified as 317 and 236 kg N/ha. Since only 3 parcels with grass and less than 50 % clover were cut and grazed, the average nutrient export did not change when only cut parcels are evaluated.

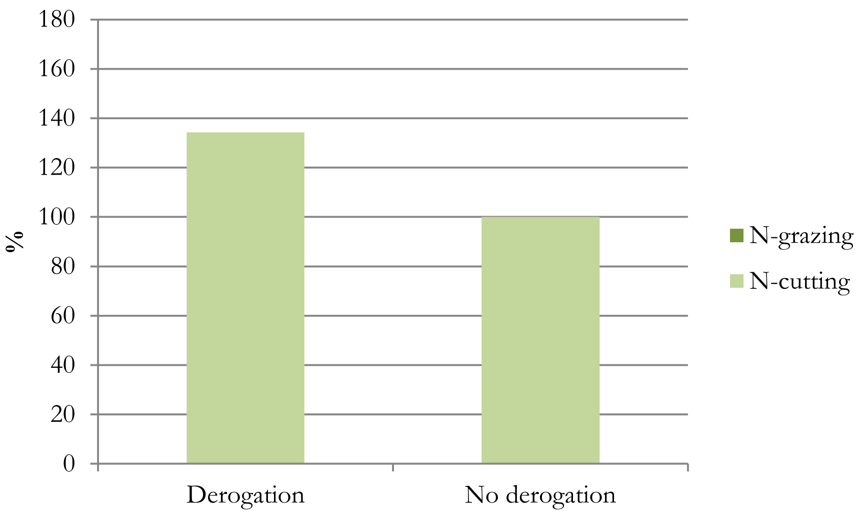


Figure 101: N-export on derogation and no derogation parcels cultivated with grass and less than 50 % clover (only cutting), relative to N-export on no derogation parcels cultivated with grass and less than 50 % clover (only cutting) (%) on sandy soils in the monitoring network in 2018.

The difference in nitrogen export between derogation and no derogation parcels amounted 34 % in 2018 when grass and less than 50 % clover was cultivated. Figure 101 shows the comparison of nitrogen export of the parcels of the monitoring network cultivated with grass and less than 50 % clover that are only cut.

Maize

The average nitrogen export of the parcels cultivated with maize in the monitoring network was quantified on 259 kg N/ha in 2018. By the cut of grass on average 89 kg N/ha was exported and 169 kg N/ha by the maize. The nitrogen export under derogation conditions was 61 % higher than without derogation conditions. The nitrogen export was estimated to be respectively 259 and 160 kg N/ha.

The crop management under derogation and no derogation conditions is partly obligatory distinct. Farmers with derogation on maize are obliged to have a cut of grass before the maize while it is often a possibility and a free choice for farmers who do not request derogation. In the group of parcels without derogation, many parcels do not have a preceding cut of grass. This cut of grass is an important reason for the higher nitrogen export under derogation conditions.

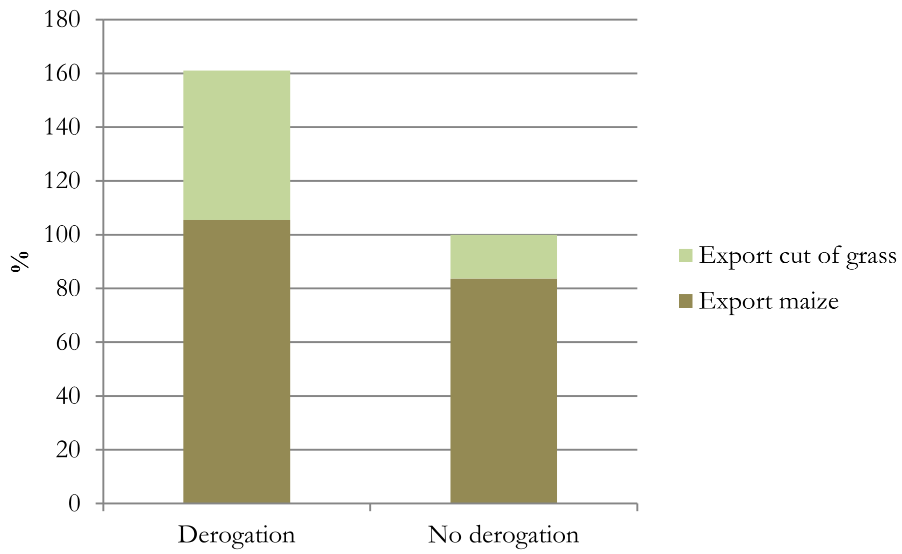


Figure 102: N-export on derogation and no derogation parcels cultivated with maize, relative to N-export on no derogation parcels cultivated with maize (%) on all soils in the monitoring network in 2018.

The comparison of derogation and no derogation parcels cultivated with maize and a preceding cut of grass is shown in Figure 103. The total nitrogen export with or without derogation does not differ when only parcels with 'grass-maize' are evaluated.

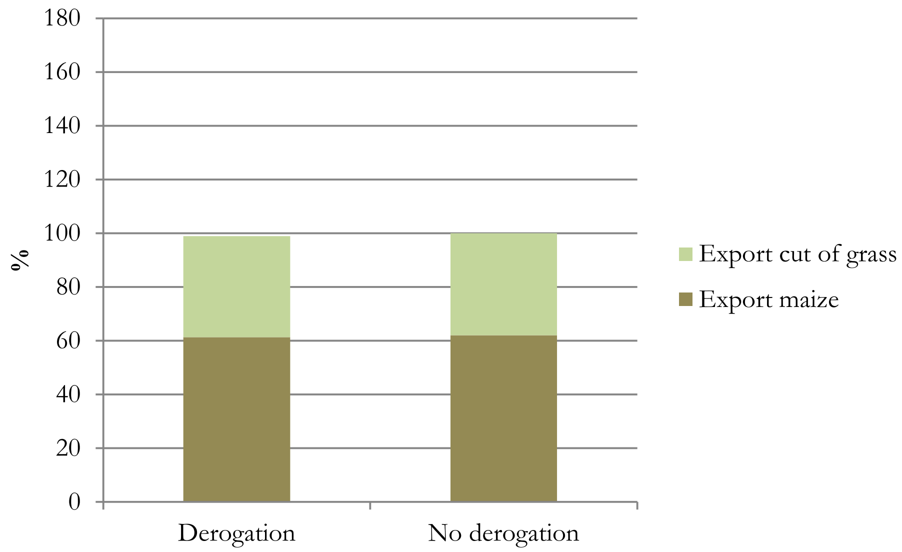


Figure 103: N-export on derogation and no derogation parcels cultivated with maize and grass cut before maize, relative to N-export on no derogation parcels cultivated with maize and grass cut before maize (%) on all soils in the monitoring network in 2018.

2.3.3.2 Experimental approach

The experimental approach in 2018 was carried out as described in 2.3.2.2. Fifty two parcels were followed up (Figure 104). Since the rather limited number of parcels that are compared in the experimental approach, a non-parametric test was preferred. The Mann-Whitney U Test is applied since only two groups (derogation and no derogation) need to be compared.

Grass

Twenty parcels cultivated with grass were selected for this set-up, 10 parcels cultivated under derogation conditions and 10 parcels without derogation.

On two parcels only one cut could be realised, these results will not be used in the following discussion, 9 parcels with and without derogation remain to be discussed.

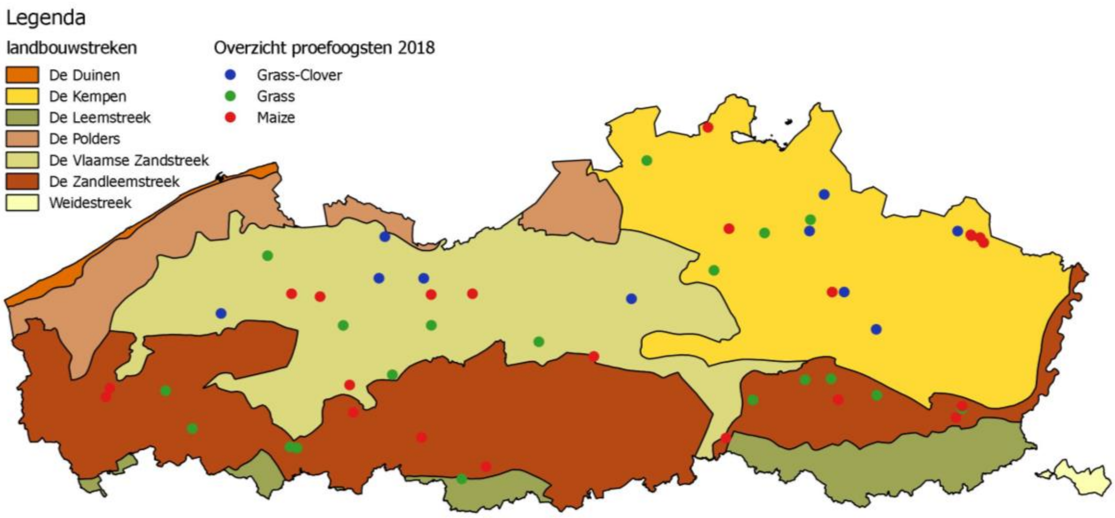


Figure 104: Location of the parcels with yield sampling in 2018, distinguished by crop.

On nearly all parcels, 3 experimental cuts were realised and on 10 parcels even a 4th experimental cut was performed. The 4th experimental cut was mostly on derogation parcels. The experimental cuts covered on average 92 % of the cuts realised in practice, 91 % on derogation parcels and 93 % on parcels without derogation.

Table 39: Results of the yield sampling on parcels cultivated with grass in the monitoring network in 2018. Dry matter (DM) yield (ton DM/ha), N-content (g N/100 g DS) and N-export (kg N/ha) at each cut. Total dry matter yield and N-export after 4 cuts and average N-content of 4 cuts.

		n	Dry matter yield		N-content		N-export	
			(ton DM/ha)	p-value	(g N/100 g DM)	p-value	(kg N/ha)	p-value
Cut 1	Derogation	9	3,10	0.20	3,2	0.20	97	0.96
	No derogation	9	3,89		2,6		97	
Cut 2	Derogation	9	2,22	0.03	3,4	0.03	77	0.35
	No derogation	9	3,15		2,8		85	
Cut 3	Derogation	8	2,60	0.15	3,2	0.06	82	0.06
	No derogation	9	1,83		2,6		47	
Cut 4	Derogation	7	1,95	0.82	3,5	0.09	67	0.73
	No derogation	3	1,82		3,9		71	
Cut 1-4	Derogation	9	9,16	0.86	3,3	0.04	298	0.27
	No derogation	9	9,48		2,8		253	

Yield was summarized and compared after 4 cuttings. This means that, under derogation conditions, 90 % of the cuts in practice were covered and 10 % was not. Without derogation summarizing at 4 cuts meant in 2018 that 96 % of the cuts in practice was covered and 4 % was not.

The dry matter yield of the second cut on derogation parcels was significantly lower (p = 0.03) than on parcels without derogation. The nitrogen content of the grass on the other hand, at the second cut on derogation parcels, was significantly higher than on parcels without derogation. By consequence the nitrogen export realised at the second cut did not differ significantly between derogation and no derogation parcels. The variation in yield, nitrogen content and nitrogen export throughout the season and between the parcels is shown in Figure 105, Figure 106 and Figure 107.

Evaluating the experimental yields after 4 cuts in 2018 showed that the nitrogen content of grass grown under derogation conditions was significantly higher than grass grown without derogation (p = 0.04). The dry matter yield (p = 0.86) and the nitrogen export (p = 0.27) did not differ significantly at that moment (Table 39). However, on derogation parcels 10 % of the cuts realised in practice was not covered while on parcels without derogation only 4 % was not included. On 6 out of 9 no derogation parcels of the experimental approach also in practice only 3 cuts were realised.

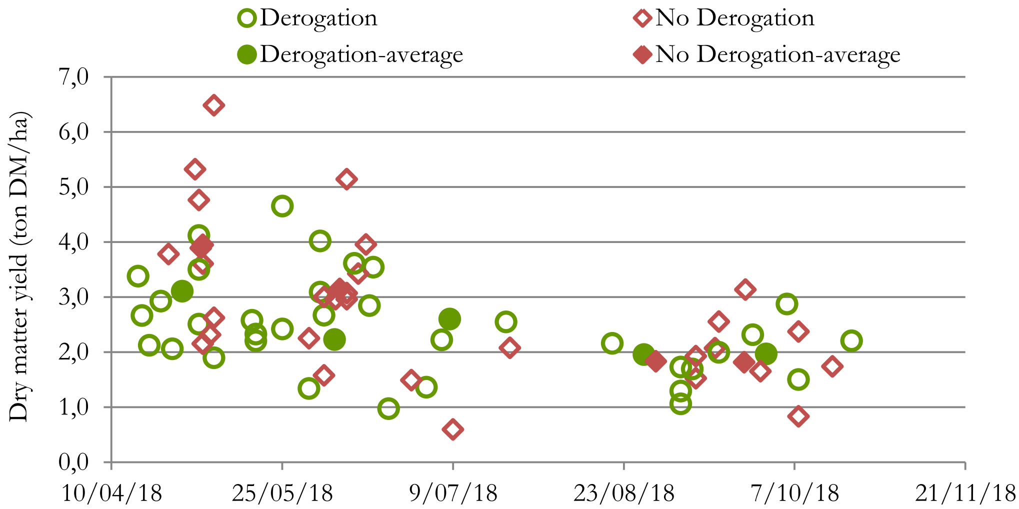


Figure 105: Dry matter yield (ton DM/ha) by yield sampling on derogation and no derogation parcels cultivated with grass in the monitoring network-2018. Yield of individual parcels (empty marks) and average yield of derogation and no derogation parcels (filled marks).

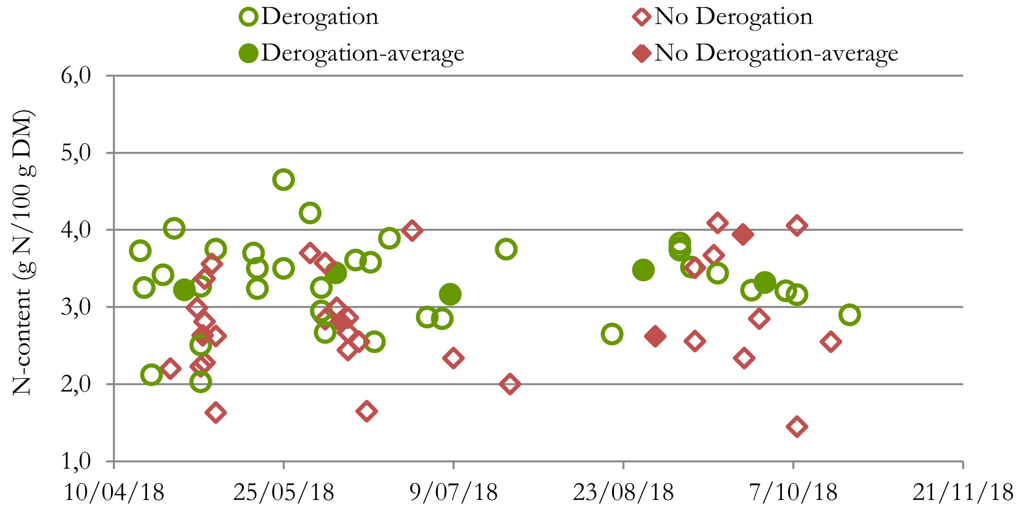


Figure 106: N-content (g N/100 g DM) of the grass by yield sampling on derogation and no derogation parcels cultivated with grass in the monitoring network-2018. N-content at individual parcels (empty marks) and average N-content on derogation and no derogation parcels (filled marks).

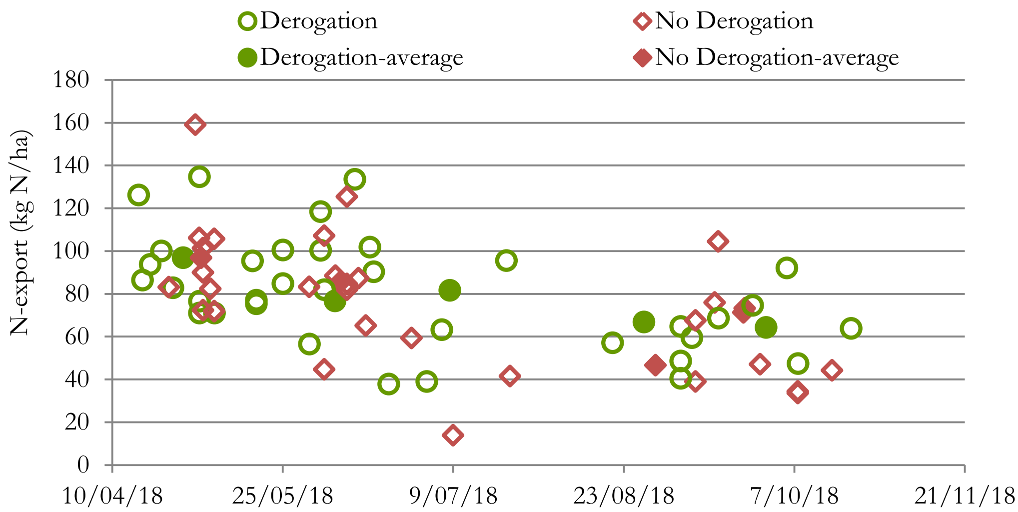


Figure 107: N-export (kg N/ha) by yield sampling on derogation and no derogation parcels cultivated with grass in the monitoring network-2018. N-export of individual parcels (empty marks) and average N-export of derogation and no derogation parcels (filled marks).

At the end of the growing season not the nitrate-N residue ($p = 0.96$) nor the applied amount of effective nitrogen ($p = 0.12$) differed significantly between those derogation and no derogation parcels.

Grass and less than 50 % clover

Ten parcels cultivated with grass and less than 50 % clover were included in the set-up of yield sampling. Five parcels with and 5 parcels without derogation were subject of the experimental approach.

Table 40: Results of the yield sampling on parcels cultivated with grass and less than 50% clover in the monitoring network in 2018. Dry matter (DM) yield (ton DM/ha), N-content (g N/100 g DS) and N-export (kg N/ha) at each cut. Total dry matter yield and N-export after 3 cuts and average N-content of 3 cuts.

		n	Dry matter yield		N-content		N-export	
			(ton DM/ha)	p-value	(g N/100 g DM)	p-value	(kg N/ha)	p-value
Cut 1	Derogation	5	4,40	0.35	2,9	0.92	128	0.35
	No derogation	5	3,79		3,0		111	
Cut 2	Derogation	5	2,41	0.75	3,5	0.92	81	0.75
	No derogation	5	2,67		3,4		85	
Cut 3	Derogation	4	2,99	0.77	2,7	1.00	81	0.39
	No derogation	4	2,10		2,8		53	
Cut 1-3	Derogation	4	9,59	0.46	3,0	0.81	279	0.09
	No derogation	5	8,14		3,1		239	

On both derogation and no derogation parcels on average 3 experimental harvests were realised. In practice 2 to 6 cuts were realised, on average 4. If the dry matter yield realised after 3 cuttings, is considered on average 76 % of the cuttings in practice was covered. Under derogation conditions, 29 % of the cuttings had still to be realised in 2018 after 3 cuttings. Without derogation, 20 % of the cuttings had still to be realised on these parcels in 2018.

After 3 cuts, dry matter yield did not differ significantly between derogation and no derogation parcels ($p = 0.46$), nor at any time of sampling before ($p = 0.35$-0.77).

Not N-content nor N-export was significantly different between derogation and no derogation parcels. The variation in N-content and N-export on the sampled derogation and no derogation parcels during the sampling season of 2018 appears in Figure 109 and Figure 110.

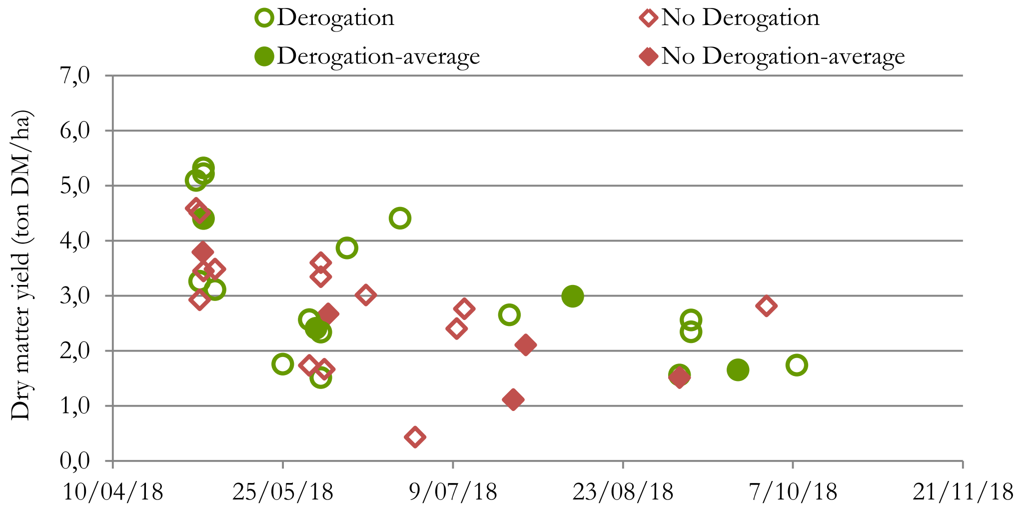


Figure 108: Dry matter yield (ton DM/ha) by yield sampling on derogation and no derogation parcels cultivated with grass and less than 50 % clover in the monitoring network-2018. Yield of individual parcels (empty marks) and average yield of derogation and no derogation parcels (filled marks).

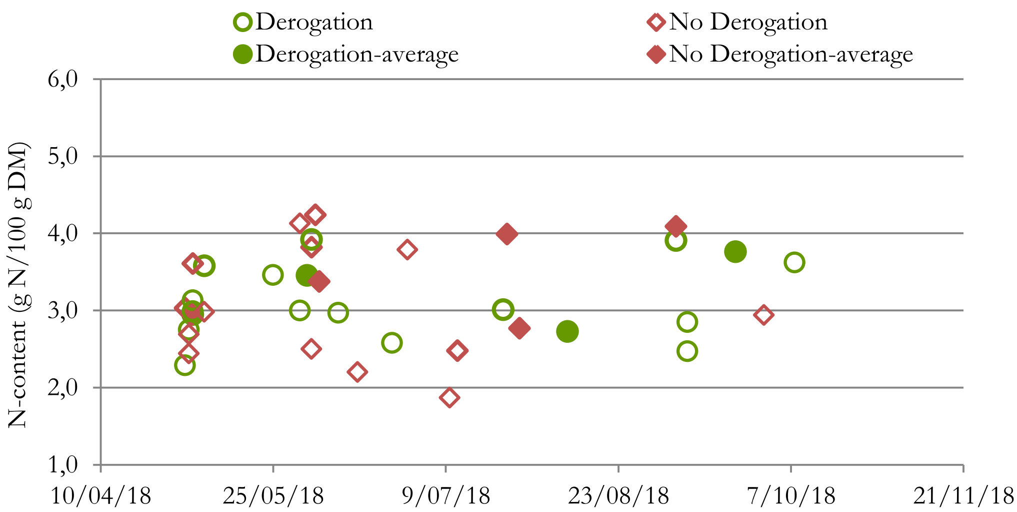


Figure 109: N-content (g N/100 g DM) of the grass and clover by yield sampling on derogation and no derogation parcels cultivated with grass and less than 50 % clover in the monitoring network-2018. N-content at individual parcels (empty marks) and average N-content on derogation and no derogation parcels (filled marks).

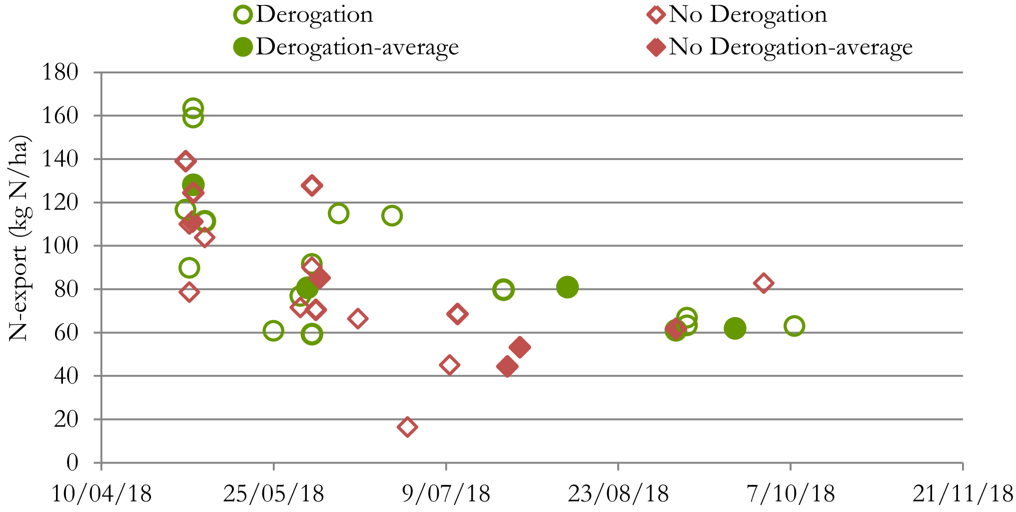


Figure 110: N-export (kg N/ha) by yield sampling on derogation and no derogation parcels cultivated with grass and less than 50 % clover in the monitoring network-2018. N-export of individual parcels (empty marks) and average N-export of derogation and no derogation parcels (filled marks).

Fertilisation considered over the whole year did not differ significantly ($p = 0.81$) between these intensively monitored parcels with and without derogation.

Maize

In 2018, yield sampling in maize was organised on 22 parcels, equally distributed as derogation and no derogation parcels. Among the parcels without derogation, there were 3 parcels with a cut of grass before the main crop maize.

For parcels without derogation, the dry matter yield and nitrogen export of the cut of grass shown in Table 41 are the average of 3 parcels with a preceding cut of grass and 8 parcels without a cut of grass and zero dry matter yield and zero nitrogen export.

Despite the significant difference of dry matter yield of the first crop on derogation and no derogation parcels, the total dry matter yield did not differ significantly. The nitrogen content of the grass and the maize did not differ significantly between derogation and no derogation parcels. The total nitrogen export of the sampled derogation parcels was significantly higher than the total nitrogen export of the parcels without derogation.

Table 41: Results of the yield sampling on parcels cultivated with maize in the monitoring network in 2018. Dry matter (DM) yield (ton DM/ha), N-content (g N/100 g DS) and N-export (kg N/ha) of the grass and the maize. Total dry matter yield and N-export of grass and maize together.

		n	Dry matter yield		N-content		N-export	
			(ton DM/ha)	p-value	(g N/100 g DM)	p-value	(kg N/ha)	p-value
Grass	Derogation	11	3,99	0,01	2,9	0,70	116	0,01
	No derogation	11	1,22		3,3		38	
Maize	Derogation	11	15,72	0,49	1,2	0,45	191	0,53
	No derogation	11	16,90		1,1		199	
Total	Derogation	11	19,70	0,34	-		308	0,02
	No derogation	11	18,12		-		236	

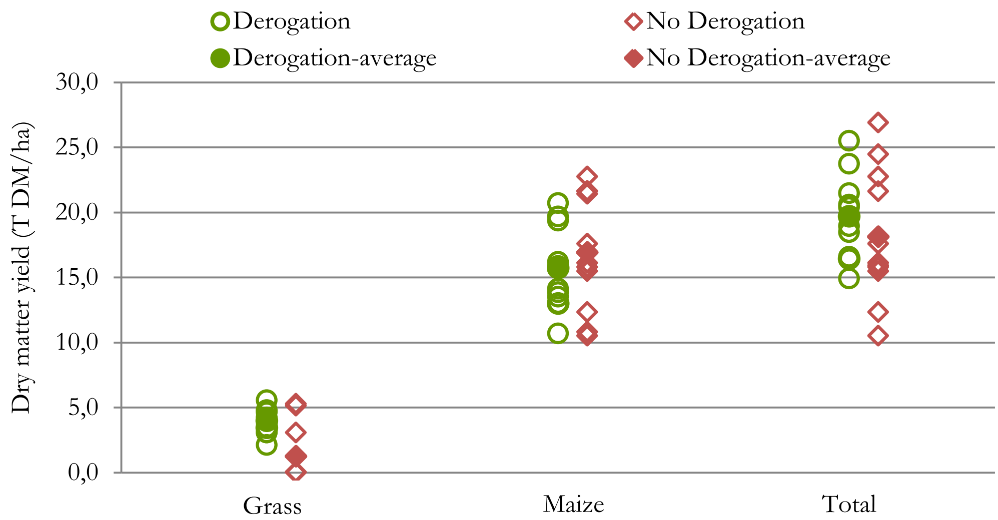


Figure 111: Dry matter yield (ton DM/ha) by yield sampling on derogation and no derogation parcels cultivated with maize in the monitoring network-2018. Yield of individual parcels (empty marks) and average yield of derogation and no derogation parcels (filled marks), of the cut of grass, of the main crop maize and in total).

Considering only the no derogation parcels without a cut of grass, the difference in total N-export between parcels with and without derogation increased evidently. The average total N-export on parcels without derogation and without a cut of grass amounted 193 kg N/ha in the experimental approach of 2018. On the derogation parcels on average 308 kg N was exported per hectare.

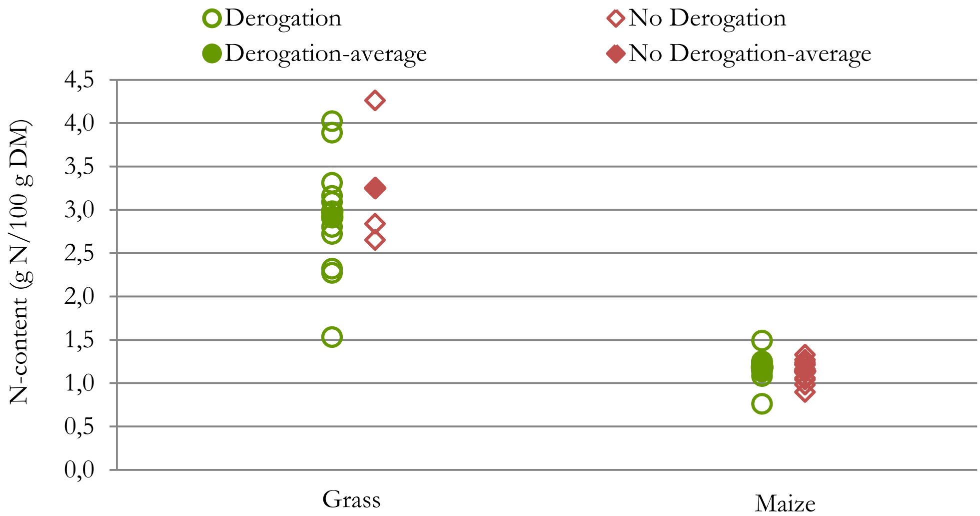


Figure 112: N-content (g N/100 g DM) of the crop by yield sampling on derogation and no derogation parcels cultivated with maize in the monitoring network-2018. N-content at individual parcels (empty marks) and average N-content on derogation and no derogation parcels (filled marks) of the grass and the maize.

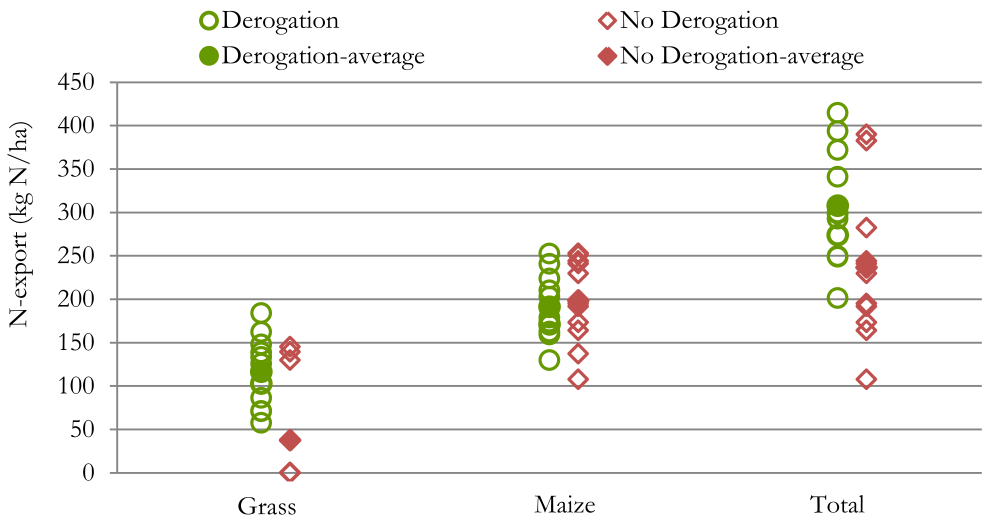


Figure 113: N-export (kg N/ha) by yield sampling on derogation and no derogation parcels cultivated with maize in the monitoring network-2018. N-export of individual parcels (empty marks) and average N-export of derogation and no derogation parcels (filled marks), by the cut of grass, by the main crop and in total.

2.3.4 Yield – nutrient export – 2019

The assessment of yield and nutrient export was approached in two ways. The twin-track approach of 2017 and 2018 was repeated. The estimated yields, reported by the farmers, represent the basis for the evaluation of the yield and nutrient export under derogation and no derogation conditions. The estimations of the yields in practice are complemented by experimental harvests on a selection of monitored parcels (2.3.4.2).

2.3.4.1 Practical approach

Grass

Regardless of soil, derogation or crop management the average nitrogen export of parcels cultivated with grass was quantified as 269 kg N/ha in 2019. Under derogation conditions the result was 292 kg N/ha. Without derogation, an average nitrogen export of 244 kg N/ha was quantified. Setting the conditions without derogation as a standard (100 %), shows a 20 % higher nitrogen export on derogation parcels (Figure 114).

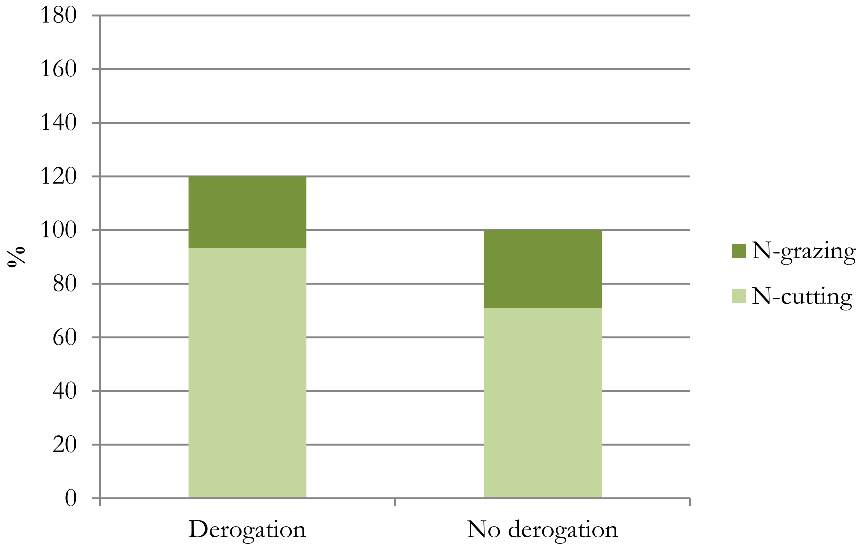


Figure 114: N-export on derogation and no derogation parcels cultivated with grass (only cutting, only grazing or both), relative to N-export on no derogation parcels cultivated with grass (only cutting, only grazing or both) (%) on all soils in the monitoring network in 2019.

The nitrogen export of parcels cultivated with grass is further specified in relation to the grass management. The nitrogen export is discussed for cut and grazed or grazed parcels and for parcels that are only cut.

On parcels with grass in a cutting and grazing regime, the average nitrogen export was estimated on 264 kg N/ha in 2019, on average 117 kg N/ha by cutting and 147 kg N/ha by grazing. Under derogation conditions, the cutting part and the grazing part were rather equal in the quantification. By cutting 141 kg N/ha was exported, by grazing on average 143 kg N/ha, resulting in an estimated total nitrogen export of 284 kg N/ha. Without derogation the cutting part covered on average 90 kg N/ha while the grazing part was more important with an estimated nitrogen export of 151 kg N/ha. Consequently the total nitrogen export on no derogation parcels cultivated with grass that is cut and grazed was estimated on 241 kg N/ha. In 2019, parcels cultivated with grass that is cut and grazed or grazed under derogation conditions were estimated to have a higher nitrogen export of 18 % compared to no derogation parcels (Figure 115).

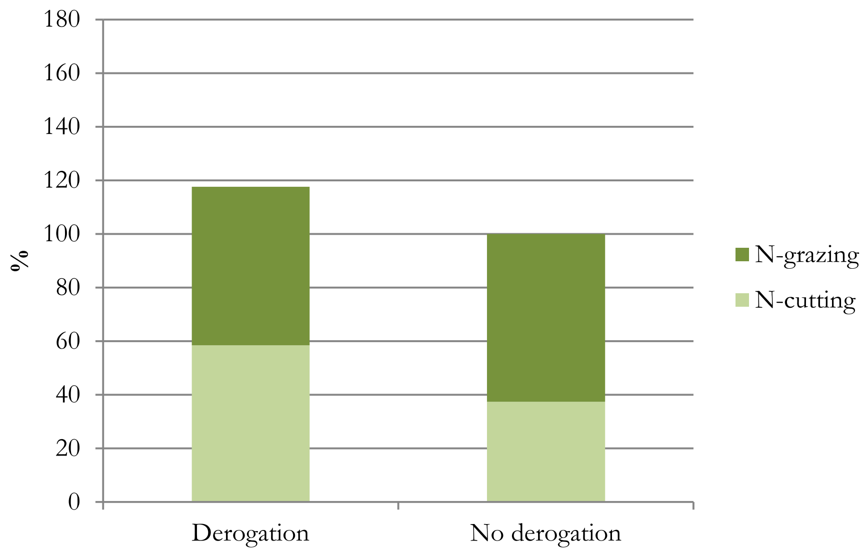


Figure 115: N-export on derogation and no derogation parcels cultivated with grass (cutting and grazing or grazing), relative to N-export on no derogation parcels cultivated with grass (cutting and grazing or grazing) (%) on all soils in the monitoring network in 2019.

On sandy soils the nitrogen export of derogation and no derogation parcels was quantified on respectively 305 and 251 kg N/ha. The export on derogation parcels was on average 21 % higher than on parcels without derogation. On sandy loam soils, the difference in nitrogen export between derogation and no derogation parcels was estimated on 12 %. The nitrogen export on both categories of parcels was quantified on respectively 259 and 231 kg N/ha.

On parcels with grass that is only cut, not grazed, the average nitrogen export was quantified on 274 kg N/ha in 2019. I n this regime the difference in nitrogen export between derogation and no derogation parcels was 22 %. In derogation conditions on average 299 kg N/ha was exported, without derogation 246 kg N/ha. On sandy and sandy loam soils, the difference amounted respectively 25 and 24 %.

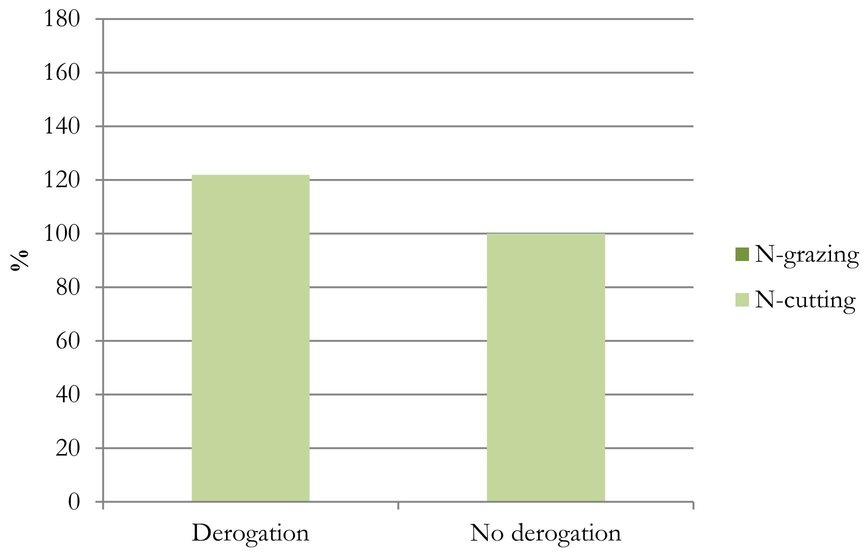


Figure 116: N-export on derogation and no derogation parcels cultivated with grass (only cutting), relative to N-export on no derogation parcels cultivated with grass (only cutting) (%) on all soils in the monitoring network in 2019.

Grass and less than 50 % clover

The nitrogen export of parcels cultivated with grass and less than 50 % clover was estimated on 325 kg N/ha in 2019.

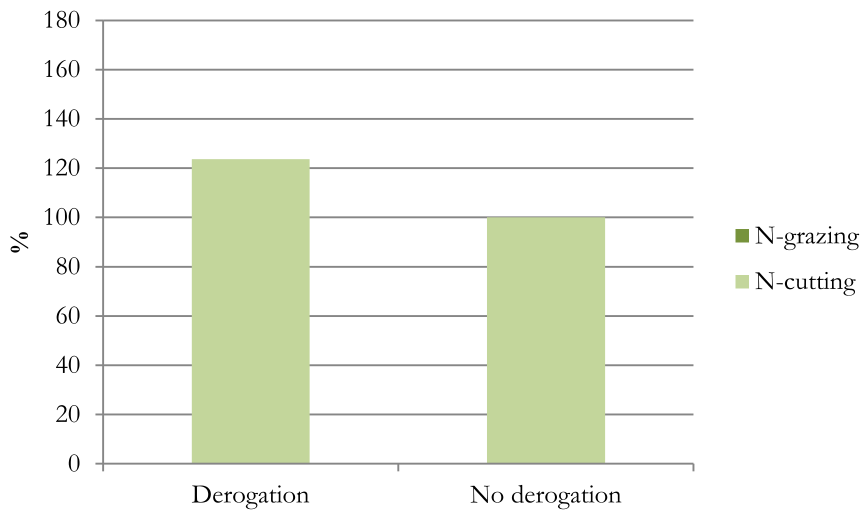


Figure 117: N-export on derogation and no derogation parcels cultivated with grass and less than 50 % clover (only cutting), relative to N-export on no derogation parcels cultivated with grass and less than 50 % clover (only cutting) (%) on sandy soils in the monitoring network in 2019.

With and without derogation the average nitrogen export was quantified on respectively 360 and 290 kg N/ha. Without the derogation parcels that were also grazed, the average nitrogen export under derogation conditions was estimated at 359 kg N/ha. In 2019, derogation parcels that were cultivated with grass and less than 50 % clover and that were only cut, had a higher nitrogen export of 24 % compared to parcels without derogation (Figure 117).

Maize

In 2019, the nitrogen export of parcels with main crop maize was estimated at 253 kg N/ha in the monitoring network. The cut of grass covered on average an export of 64 kg N/ha, while the export by the maize was quantified on 189 kg N/ha. The quantification for derogation and no derogation parcels separate was an average nitrogen export of respectively 306 and 196 kg N/ha. The export of derogation parcels was estimated to be 56 % higher than on parcels without derogation.

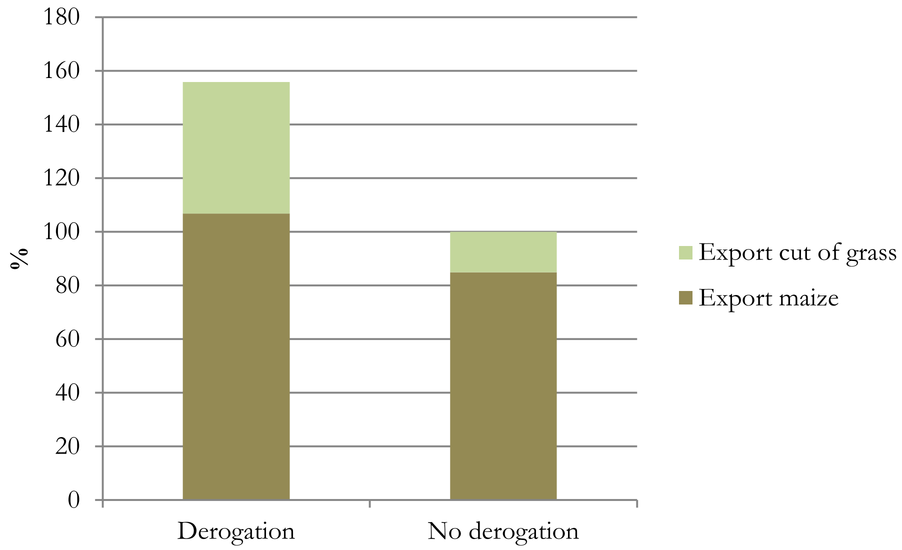


Figure 118: N-export on derogation and no derogation parcels cultivated with maize, relative to N-export on no derogation parcels cultivated with maize (%) on all soils in the monitoring network in 2019.

The obligatory preceding cut of grass was a determinant parameter for the 56 % higher nitrogen export under derogation conditions. Considering only maize parcels with a preceding cut of grass, a difference in nitrogen export of only 4 % was quantified.

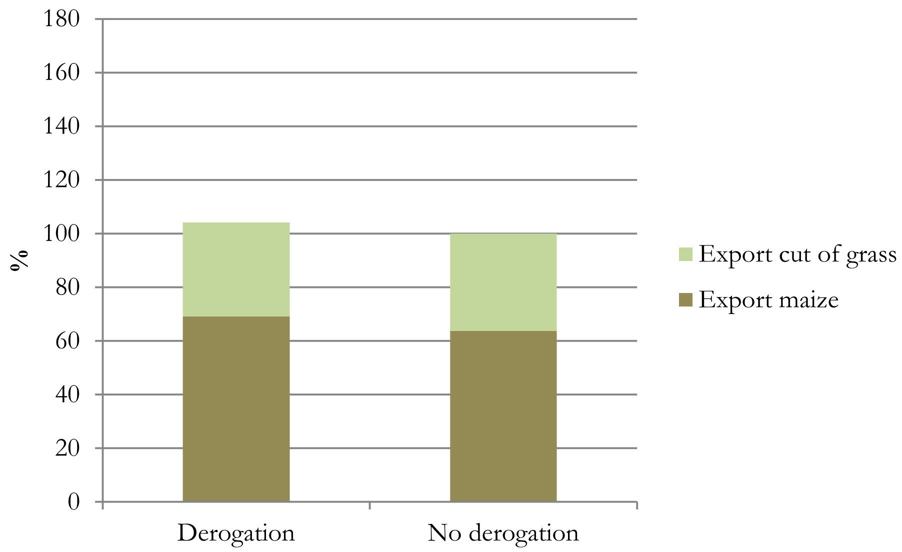


Figure 119: N-export on derogation and no derogation parcels cultivated with maize and grass cut before maize, relative to N-export on no derogation parcels cultivated with maize and grass cut before maize (%) on all soils in the monitoring network in 2019.

2.3.4.2 Experimental approach

The experimental approach in 2019 was similar to the approach of 2017 and 2018. It was carried out as described in 2.3.2.2. Fifty-three parcels were followed up in the experimental approach of 2019, well regionally distributed (Figure 120).

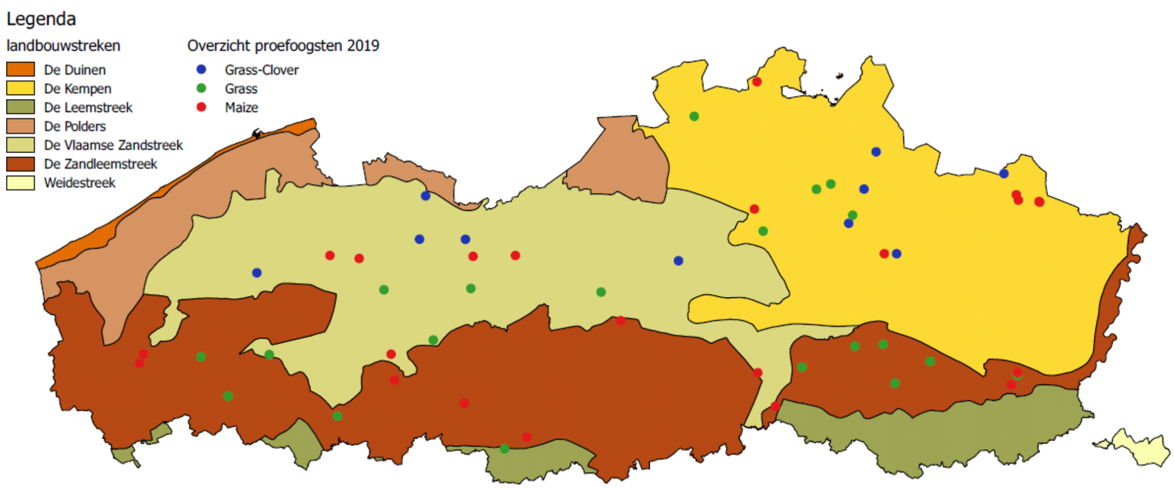


Figure 120: Location of the parcels with yield sampling in 2019, distinguished by crop.

Since the rather limited number of parcels that are compared in the experimental approach, a non-parametric test was preferred. As in 2017 and 2018, the Mann-Whitney U Test is applied since only two groups (derogation and no derogation) need to be compared.

Grass

In 2019, 21 parcels cultivated with grass were included for the experimental approach.

At one parcel without derogation, the yield samplings were insufficient to represent reality; these results will not be used in the further discussion. Eleven derogation parcels and 9 parcels without derogation can be compared at different moments.

On nearly all parcels, the first 4 cuttings were measured. The results of the first 4 cuttings and the total and average values after 4 cuttings are given in Table 42.

Table 42: Results of the yield sampling on parcels cultivated with grass in the monitoring network in 2019. Dry matter (DM) yield (ton DM/ha), N-content (g N/100 g DS) and N-export (kg N/ha) at each cut. Total dry matter yield and N-export after 4 cuts and average N-content of 4 cuts.

		n	Dry matter yield		N-content		N-export	
			(ton DM/ha)	p-value	(g N/100 g DM)	p-value	(kg N/ha)	p-value
Cut 1	Derogation	11	4,21	0.68	3,5	0.00	131	0.22
	No derogation	8	4,43		2,4		107	
Cut 2	Derogation	10	3,04	0.24	3,1	0.90	90	0.25
	No derogation	9	3,65		2,9		104	
Cut 3	Derogation	10	2,45	0.25	3,1	0.06	78	0.03
	No derogation	9	2,13		2,5		52	
Cut 4	Derogation	8	1,54	0.83	3,0	0.07	48	0.46
	No derogation	8	1,61		2,5		39	
Cut 1-4	Derogation	9	11,11	0.63	3,1	0.01	334	0.43
	No derogation	7	11,82		2,5		297	

Summarizing after the first 4 cuts meant on the 9 and 7 parcels that on average respectively 88 and 97 % of the cuttings in practice were covered. This means that the yield in reality is more underestimated by the summary after 4 cuttings under derogation conditions as for conditions without derogation.

During the season, no significant differences in dry matter yield were noticed (p = 0.24-0.83). Even so after 4 cuttings, no significant different dry matter yield was noticed on derogation and no derogation parcels (p = 0.63). The nitrogen content of the grass tended as the years before to be higher under derogation conditions. It was even significant at the first cut (p = 0.00) and the average content of the first 4 cuts differed significantly (p = 0.01)

Differences in nitrogen export were merely not significant. The nitrate-N residue as well as the applied amount of effective nitrogen did also not differ significantly between the derogation and no derogation parcels.

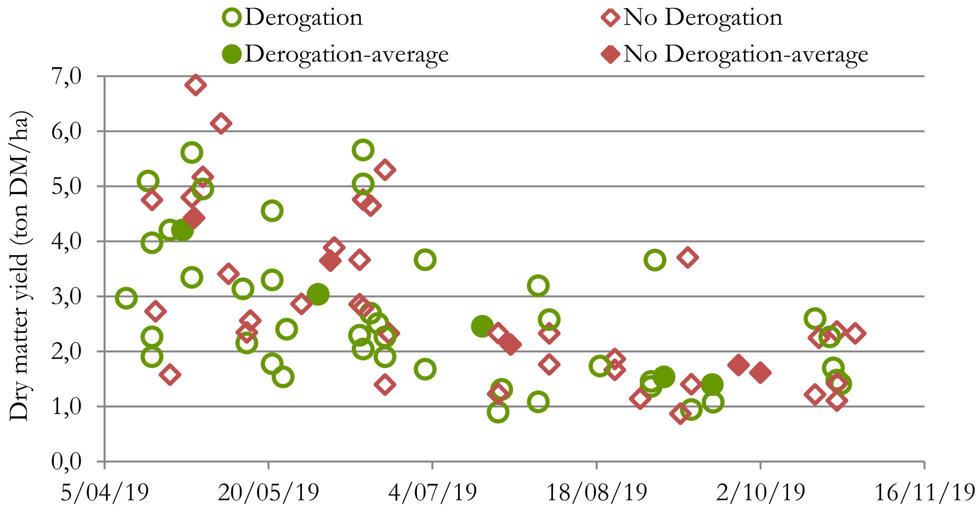


Figure 121: Dry matter yield (ton DM/ha) by yield sampling on derogation and no derogation parcels cultivated with grass in the monitoring network-2019. Yield of individual parcels (empty marks) and average yield of derogation and no derogation parcels (filled marks).

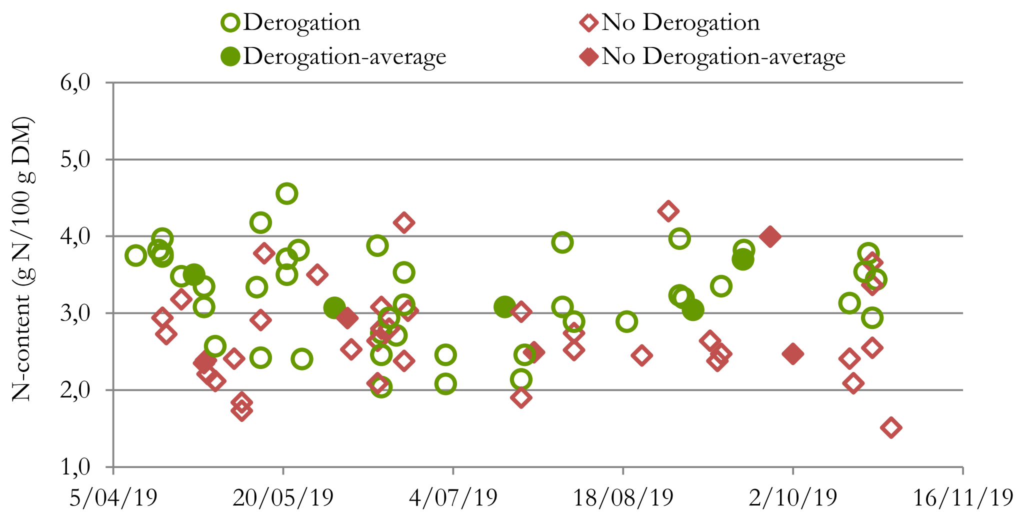


Figure 122: N-content (g N/100 g DM) of the grass by yield sampling on derogation and no derogation parcels cultivated with grass in the monitoring network-2019. N-content at individual parcels (empty marks) and average N-content on derogation and no derogation parcels (filled marks).

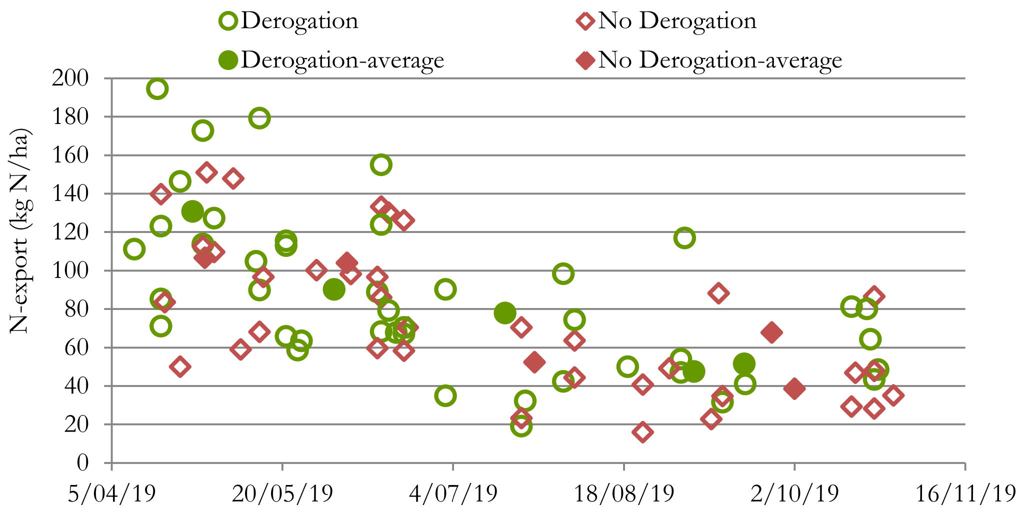


Figure 123: N-export (kg N/ha) by yield sampling on derogation and no derogation parcels cultivated with grass in the monitoring network-2019. N-export of individual parcels (empty marks) and average N-export of derogation and no derogation parcels (filled marks).

Grass and less than 50 % clover

Ten parcels cultivated with grass and less than 50 % clover were subject of the yield sampling. Five parcels with and 5 parcels without derogation were included in the experimental approach.

In practice three to six cuts were realised, on average 5. The experimental harvests covered 2 to 5 cuts, on average 4. Derogation and no derogation parcels were compared at each cutting and after 4 cuttings.

Despite all efforts, the experimental harvests covered only half of the cuts in practice on two parcels. On one parcel, the first cut was missed. Because of the importance of the first cut and the limited number of cuts, those 3 parcels are not included in the comparison after 4 cuts. On the compared parcels, 4 cuts cover on average 87 % of the cuts in practice.

At any moment of , dry matter yield ($p = 0.16$-1.00), nitrogen content ($p = 0.08$-0.81) or nitrogen export ($p = 0.16$-0.72) differed between derogation and no derogation parcels. The dry matter yield considered after 4 cuttings was significantly higher on derogation parcels ($p = 0.03$). The experimental harvests on derogation parcels with grass and less than 50 % clover in 2019 indicated a dry matter yield of 13.48 ton/ha after 4 cuttings while the experimental harvests on parcels without derogation indicated an average dry matter yield of 9.94 ton/ha also after 4 cuttings. Despite the significant higher dry matter yield and comparable nitrogen content, the nitrogen export after 4 cuts was not significantly higher on the sampled derogation parcels.

The nitrogen export after 4 cuts amounted 363 and 283 kg N/ha on the sampled derogation and no derogation parcels.

Table 43: Results of the yield sampling on parcels cultivated with grass and less than 50% clover in the monitoring network in 2019. Dry matter (DM) yield (ton DM/ha), N-content (g N/100 g DS) and N-export (kg N/ha) at each cut. Total dry matter yield and N-export after 4 cuts and average N-content of 4 cuts.

		n	Dry matter yield		N-content		N-export	
			(ton DM/ha)	p-value	(g N/100 g DM)	p-value	(kg N/ha)	p-value
Cut 1	Derogation	5	4,66	1,00	2,8	0.81	123	0.62
	No derogation	4	4,70		2,8		124	
Cut 2	Derogation	5	3,54	0.92	2,9	0.75	104	0.60
	No derogation	5	3,33		3,0		100	
Cut 3	Derogation	4	2,58	0.72	2,5	0.08	64	0.72
	No derogation	3	1,91		3,4		58	
Cut 4	Derogation	4	2,50	0.16	2,9	0.72	69	0.16
	No derogation	3	1,63		2,8		47	
Cut 1-4	Derogation	4	13,48	0.03	2,8	0.48	363	0.48
	No derogation	3	9,94		3,0		283	

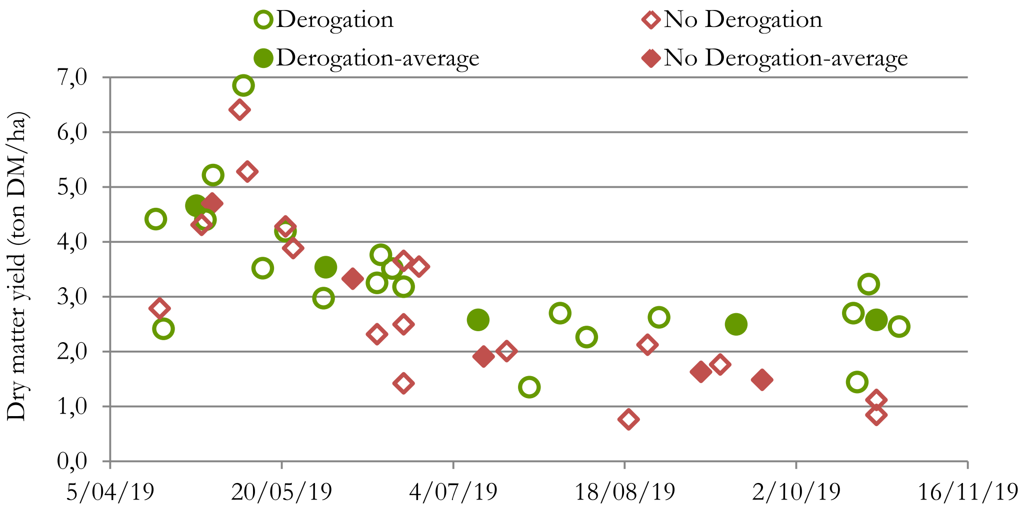


Figure 124: Dry matter yield (ton DM/ha) by yield sampling on derogation and no derogation parcels cultivated with grass and less than 50 % clover in the monitoring network-2019. Yield of individual parcels (empty marks) and average yield of derogation and no derogation parcels (filled marks).

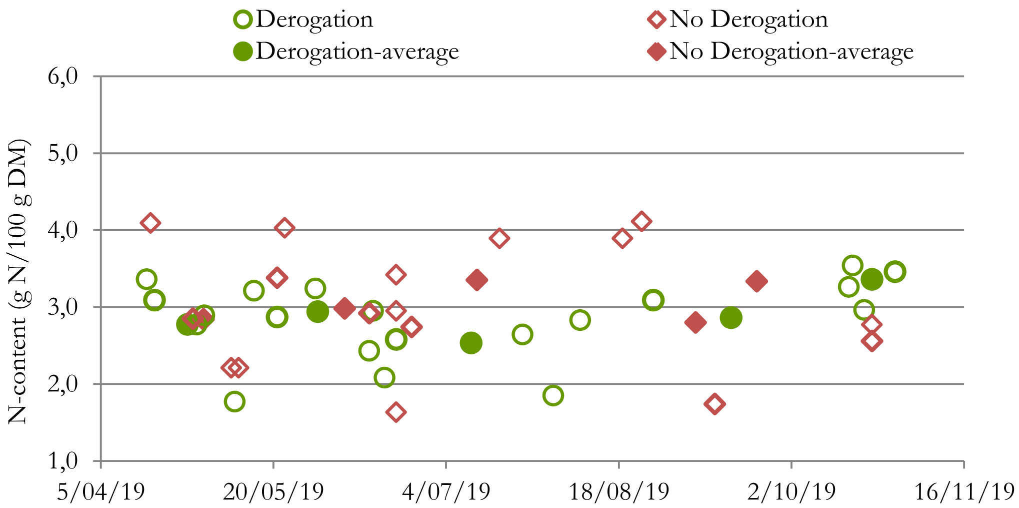


Figure 125: N-content (g N/100 g DM) of the grass and clover by yield sampling on derogation and no derogation parcels cultivated with grass and less than 50 % clover in the monitoring network-2019. N-content at individual parcels (empty marks) and average N-content on derogation and no derogation parcels (filled marks).

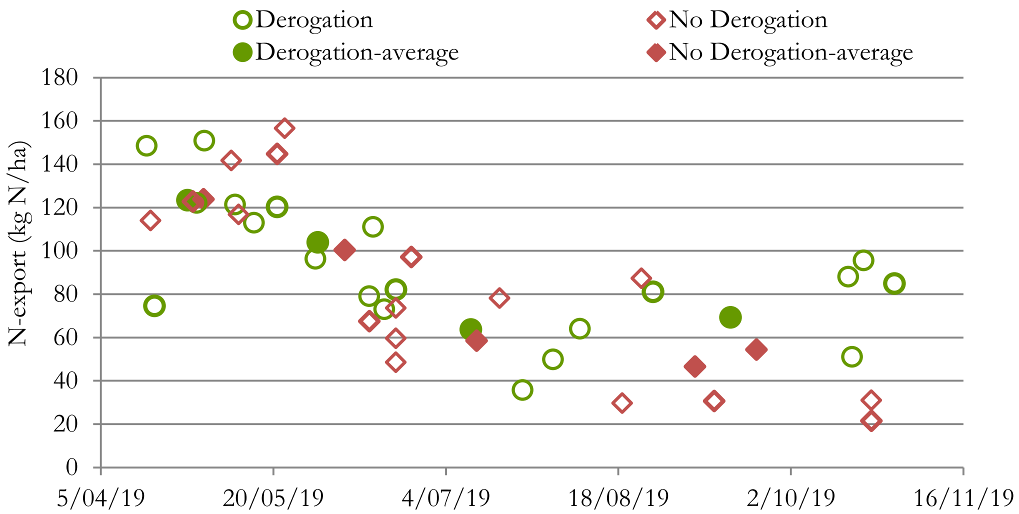


Figure 126: N-export (kg N/ha) by yield sampling on derogation and no derogation parcels cultivated with grass and less than 50 % clover in the monitoring network-2019. N-export of individual parcels (empty marks) and average N-export of derogation and no derogation parcels (filled marks).

Maize

Yield sampling in maize was organised on 22 parcels in 2019. The sampled parcels were equally distributed as derogation and no derogation parcels. There were 2 parcels with a cut of grass before the main crop of maize among the parcels without derogation.

For parcels without derogation, the dry matter yield and nitrogen export of the cut of grass shown in Table 44 are the average of 2 parcels with a preceding cut of grass and 9 parcels without a cut of grass and zero dry matter yield and zero nitrogen export.

On two derogation parcels, an error occurred during the yield sampling of the cut of grass. This resulted in unrealistic and incorrect yields. Therefore, the results of those 2 parcels are excluded of the comparison.

Table 44: Results of the yield sampling on parcels cultivated with maize in the monitoring network in 2019. Dry matter (DM) yield (ton DM/ha), N-content (g N/100 g DS) and N-export (kg N/ha) of the grass and the maize. Total dry matter yield and N-export of grass and maize together.

		n	Dry matter yield		N-content		N-export	
			(ton DM/ha)	p-value	(g N/100 g DM)	p-value	(kg N/ha)	p-value
Grass	Derogation	9	3,73	0,00	2,9	0,16	106	0,00
	No derogation	11	0,59		3,4		20	
Maize	Derogation	9	17,86	0,38	1,2	0,27	208	0,68
	No derogation	11	19,18		1,1		208	
Total	Derogation	9	21,59	0,24	-		314	0,01
	No derogation	11	19,77		-		228	

The yield of the first crop differed significantly between the sampled parcels with and without derogation ($p = 0.00$). The total dry matter yield was not significantly different ($p= 0.24$). The nitrogen content did not differ significantly for the cut of grass nor for the maize. The nitrogen export of the main crop maize did not differ between the sampled derogation and no derogation parcels. The total nitrogen export however was significantly higher on the sampled derogation parcels compared to the parcels without derogation.

When only the parcels without a cut of grass are considered at the no derogation level, the differences in total dry matter yield and total nitrogen export obviously increase. The average total N-export of the sampled no derogation parcels without a preceding cut of grass amounted 199 kg N/ha. It confirms the important contribution of the cut of grass.

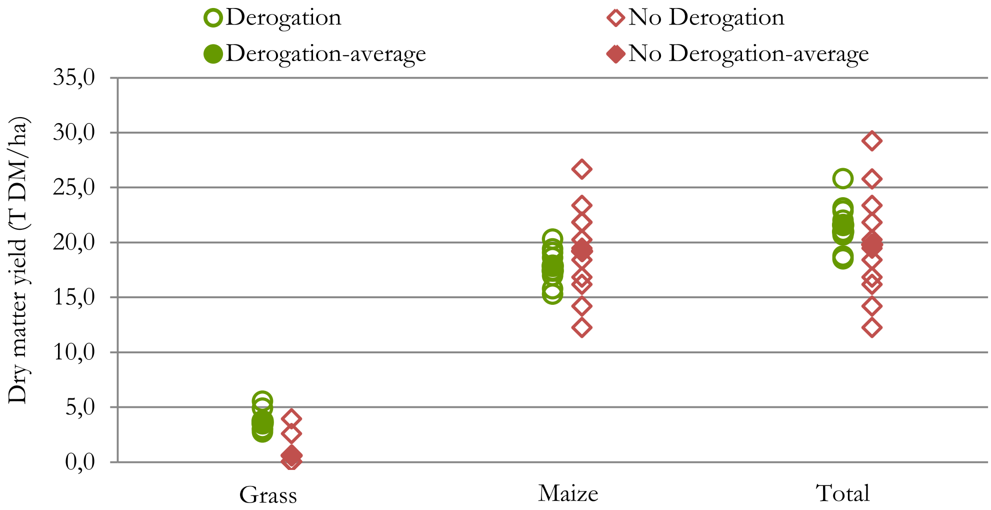


Figure 127: Dry matter yield (ton DM/ha) by yield sampling on derogation and no derogation parcels cultivated with maize in the monitoring network-2019. Yield of individual parcels (empty marks) and average yield of derogation and no derogation parcels (filled marks), of the cut of grass, of the main crop maize and in total).

Figure 128: N-content (g N/100 g DM) of the crop by yield sampling on derogation and no derogation parcels cultivated with maize in the monitoring network-2019. N-content at individual parcels (empty marks) and average N-content on derogation and no derogation parcels (filled marks) of the grass and the maize.

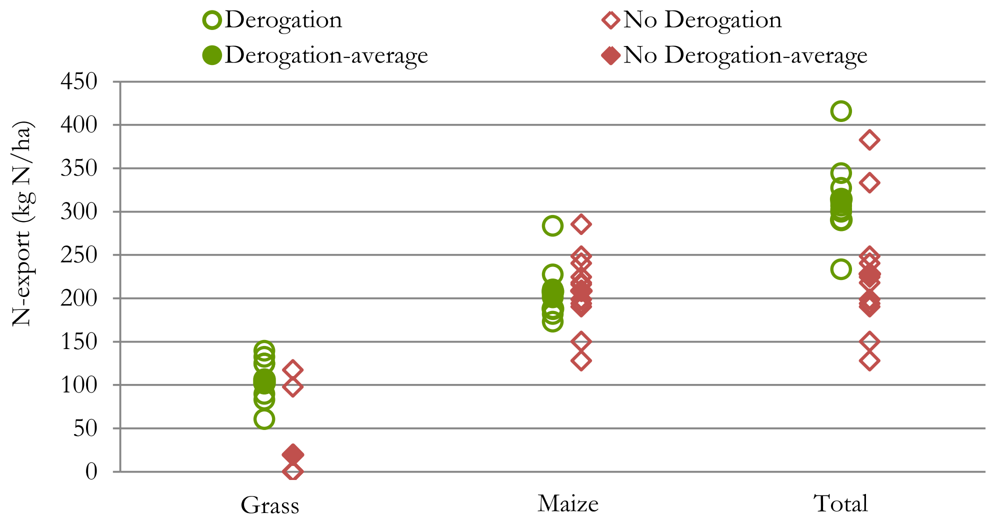


Figure 129: N-export (kg N/ha) by yield sampling on derogation and no derogation parcels cultivated with maize in the monitoring network-2019. N-export of individual parcels (empty marks) and average N-export of derogation and no derogation parcels (filled marks), by the cut of grass, by the main crop and in total.

Yield and nutrient export were always some higher under derogation conditions during the **period 2016-2019**. The difference in nitrogen export between derogation and no derogation parcels however was evidently strongly determined by the weather conditions. This was most marked on parcels cultivated with grass that was only cut, especially in 2018 and 2019. On these parcels, the effect of drought was most visible. In the set-up of yield sampling, no significant different production could be determined. However, on parcels cultivated with grass or grass and less than 50 % clover, more cuts had still to be realised under derogation conditions. Moreover, the fertilisation level was the same on the followed derogation and no derogation parcels. The average nitrogen content of grass was consequently lower without derogation, whether or not statistically significant.

3 Monitoring

In order to compare derogation and non-derogation conditions and to investigate the effect of derogation on water quality, soil samples, water samples and soil water samples were intended.

As mentioned in article 10-paragraph 4 of the Implementing Decision 2015/1499 the concentration of nitrogen and phosphorus in the soil water, the amount of mineral nitrogen in the soil profile and the occurring nitrogen and phosphorus losses through the root zone to the groundwater, both in situations with and without derogation, need to be measured.

3.1 Statistical methodology

For comparison of both derogation and non-derogation practices an analysis of variance is given priority. At first, the conditions to apply ANOVA, being normality of data and homogeneity of variances, are controlled. If one or both conditions are not met, an appropriate transformation of the data will be used. After transformation of the data the conditions are controlled again.

Since some parameters are measured or quantified at 3 parcels of the same farm, a statistical approach a bit different and more appropriate regarding to the set-up of the monitoring network was recommended by Prof. Goos of KULeuven.

When more parcels of a specific farm are sampled for a specific parameter, the measurements on the 3 parcels should be considered as repeated measurements on that farm and the factor 'Farm' should be included in the statistical analysis. Therefore, a General Linear Model is used. The measured parameter (transformed if needed), is the dependent variable and is set against the predictor variables. Since the network is set up to compare derogation and non-derogation conditions the request of derogation is a predictor variable. "Derogation" ('Yes or No') will be a fixed categorical predictor, this is the factor of our main interest.

"Farm" on the other hand is a factor that is inherent to the set-up of the monitoring network but is not the factor of concern. Therefore the factor "Farm" (A, B, C, …) needs to be included in the statistical analysis as a random factor, a random categorical predictor variable.

As indicated by Prof. Goos, the dataset is very robust as it consists of results from 480 parcels. Because of this robustness, it was proposed not to exclude outlying values. Nevertheless outlying values are mentioned when necessary for a correct interpretation of the shown results.

The data will be presented in different types of graphs. When data transformation was needed, the variation, means and median values will be shown using the transformed data. For comprehensiveness, the actual amounts or units in which the parameter is used to be measured will also be shown.

As a last resort, when no transformation results in meeting with the conditions of normality and/or homogeneity of variances, a non-parametric approach is preferred.

Detailed information about transformations, the used statistical analysis and the presentation of the results is specified further for each parameter.

3.2 Soil monitoring

3.2.1 Mineral nitrogen

The Flemish Land Agency (VLM) stated that the amount of mineral nitrogen in the soil profile should be monitored by the residual nitrate. The residual nitrate-N is the amount of nitrogen that remains in the soil profile as nitrate in the autumn after the cropping season.

Since the nitrate-N residue is influenced by fertilisation and cultural practices, the nitrate-N residue is an indicator for the performed fertilisation strategy. Moreover, the nitrate-N residue is a first possible indicator to estimate possible differences in the risk of nitrogen losses by leaching to the groundwater during winter.

The nitrate-N residue is measured in the soil profile down to 90 cm and is expressed in kilogram nitrate-N per hectare. In these soil samples, the nitrate-N is measured in three soil layers, 0 to 30 cm, 30 to 60 cm and 60 to 90 cm. Each parcel is sampled once in autumn between October 1st and November 15th.

The conditions to apply ANOVA, more specific normality of data and homogeneity of variances, were controlled. These were not met and a logarithmic transformation of the data transforms the data into a dataset suited for an analysis of variance (ANOVA).

In the derogation monitoring network set up in 2016, 3 parcels at each farm are sampled. For statistical analysis the three parcels of a farm should be considered as repeated measurements. Therefore, "farm" is included in the statistical analysis as a random factor as proposed by Prof. Goos of KULeuven (personal communication). The log-transformed nitrate-N residue is the dependent variable versus two categorical predictors, "derogation" ('Yes or No') and "Farm" (A, B, C,…).

The data are visualised using box plots and bar graphs. The boxplots are based on the log-transformed data since the statistical analysis is performed on the log-transformed data. The boxplots are presented both by the mean and the median value.

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

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

where m is the sample mean

n is the sample size

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

$$SE = s / \sqrt{m}$$

where s is the standard deviation

m is the sample mean

The box plots based on the median contain the median, the first and third quartile and the indication of the non-outlier range.

The bar graphs show the actual amount of nitrate-N in the soil profile and the distribution of the nitrate-N through the soil profile (0-30 cm, 30-60 cm, 60-90 cm).

3.2.1.1 Mineral nitrogen - at parcel level-autumn 2016

Between October 1st and November 15th, the 480 parcels of the monitoring network 2016 were sampled. Because of difficult circumstances for sampling caused by the lack of rain since July, 4 parcels could only be sampled down to 60 cm. These parcels were all parcels cultivated with maize, both with (2 parcels) and without derogation (2 parcels) and both on sandy (3 parcels) and sandy loam soils (1 parcel). These parcels were discarded from further analysis.

For further investigation **476 parcels sampled down to 90 cm remained**.

Especially for 2016, climate conditions were determinant. Substandard yields were common; however, some farms did not suffer that much from weather conditions and obtained standard yields while on other farms the crop plan changed drastically. On these farms crops could not be sown, had to be sown a second time, could not be harvested or yield was negligible. The specific weather conditions of 2016 were discussed more in detail in 2.1.1.

After questioning the farmers, 14 parcels appeared unsuitable for the comparison of derogation and non-derogation practices. To be complete the amount of nitrate-N measured on these parcels is presented in Figure 130 to Figure 132.

Since the specific and difficult weather conditions of 2016, maize could not be sown on 4 parcels. All 4 parcels were on sandy loam soil, 3 of them intended for derogation request and 1 parcel without derogation. On the parcels with derogation intended for maize the farmer waited for a cut of grass that was worth it. However heavy rainfall and bad weather conditions followed, resulting in the impossibility to sow the maize. These parcels were cultivated with grass in 2016 instead, the parcel without derogation remained fallow (Figure 130).

On 6 other parcels with maize, the crop development was poor that maize could not be harvested and was cut in summer. These were two parcels on sandy loam soil without derogation and 4 parcels on sandy soils, 1 with derogation and 3 without derogation (Figure 131).

Four parcels with grass were not suited for comparison of derogation and non-derogation practices. Three parcels were laboured and sown again in summer. These were 2 sandy parcels, 1 with and 1 without derogation and 1 sandy loam parcel with derogation. The second parcel on sandy soil with derogation was switched to a much less intensive grazed parcel with sheep (Figure 132).

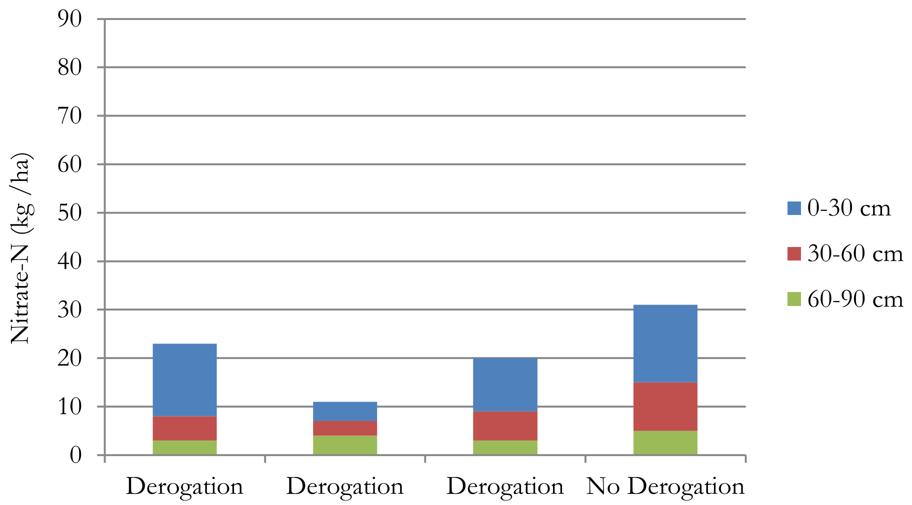


Figure 130: Nitrate-N (kg/ha) on parcels on sandy loam soil on which maize could not be sown.

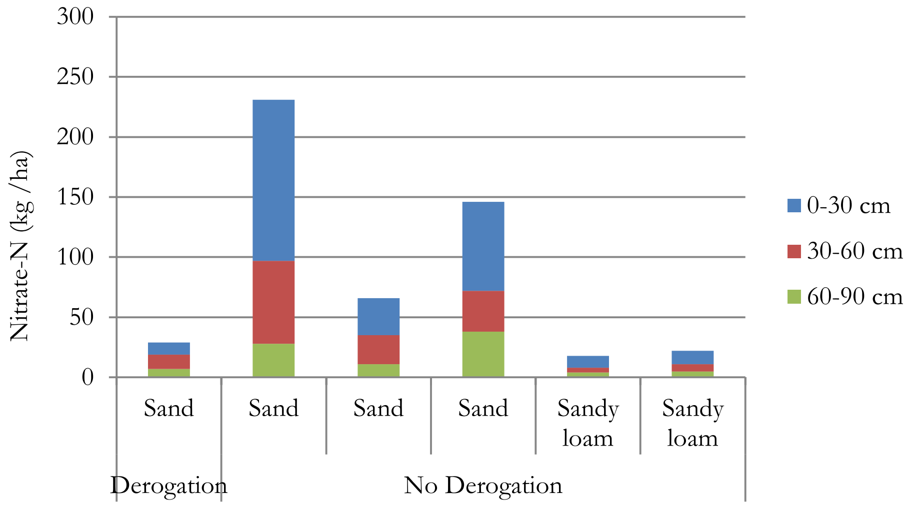


Figure 131: Nitrate-N (kg/ha) on parcels on parcels cultivated with maize which could not be harvested.

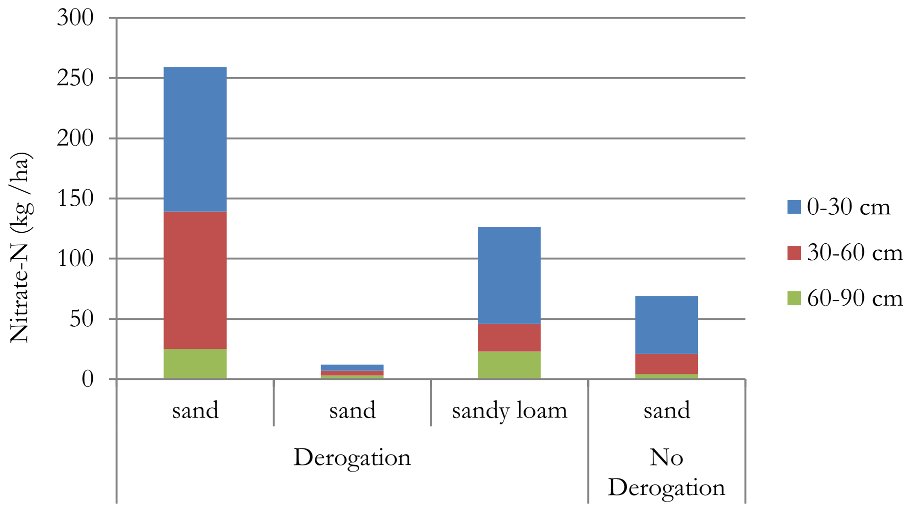


Figure 132: Nitrate-N (kg/ha) on parcels on parcels cultivated with grass which could not be harvested.

For comparison of the nitrate-N residue under derogation and no-derogation practices **462 parcels remained**.

The average nitrate-N residue on those 462 parcels represented 50 ± 41 kg NO_3-N/ha. The average nitrate-N residue in the monitoring network in autumn 2016 was very low.

The variation in the amount of nitrate-N in the 462 parcels is shown in Figure 133. Further statistical analysis, however, is performed on the logarithm of the nitrate-N residue as shown in Figure 134.

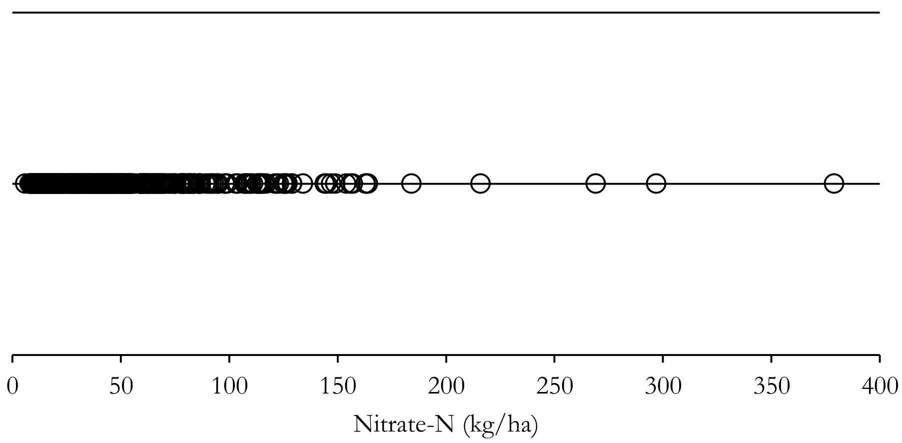


Figure 133: Spreading of the amount of nitrate-N in 462 parcels suited for comparison of derogation and non-derogation practices in autumn 2016.

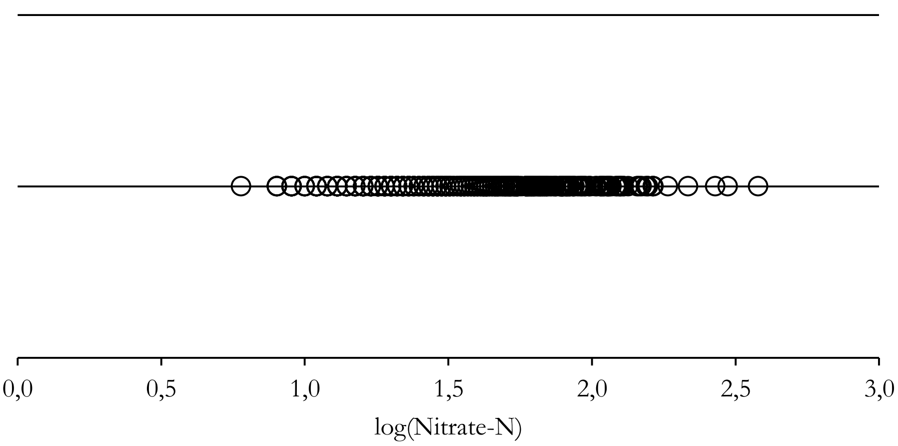


Figure 134: Spreading of the log-transformed nitrate-N (log(Nitrate-N)) in 462 parcels suited for comparison of derogation and non-derogation practices in autumn 2016.

Table 45: Average nitrate-N in the soil profile (0-90 cm) and per soil layer (0-30 cm, 30-60 cm and 60-90 cm) and median value of nitrate-N for the 462 parcels combined at different levels of comparison in autumn 2016. The number of parcels included in the comparison is indicated by 'n'.

			Nitrate-N (kg/ha)						p-value
			n	0-30 cm	30-60 cm	60-90 cm	0-90 cm	Median	
Overall mean monitoring network			462	23	16	12	50	40	-
Derogation			231	25	16	11	53	43	0.06
No derogation			231	20	15	12	47	35	
Derogation	Sandy soil		131	24	19	13	56	49	0.45
No derogation			129	22	18	14	54	42	
Derogation	Sandy loam		100	28	13	9	49	41	0.02
No derogation			102	18	11	9	38	26	
Derogation	Sandy soil	Grass	52	23	17	10	51	37	0.06
No derogation			53	19	9	7	36	23	
Derogation	Sandy soil	Grass <50% clover	30	20	14	7	40	34	0.92
No derogation			30	18	12	9	39	36	
Derogation	Sandy soil	Maize	49	27	24	19	70	66	0.22
No derogation			46	27	33	26	85	67	
Derogation	Sandy loam	Grass	53	26	9	6	41	28	0.03
No derogation			54	15	7	5	27	18	
Derogation	Sandy loam	Maize	47	30	17	12	58	47	0.20
No derogation			48	22	15	13	50	47	

Regardless of crop or soil type, the comparison of the nitrate N-residue with or without derogation practices was made on 231 parcels with derogation and 231 parcels without derogation. In autumn 2016 the average nitrate-N residue on derogation parcels was 53 ± 38 kg NO_3-N/ha (Figure 135).

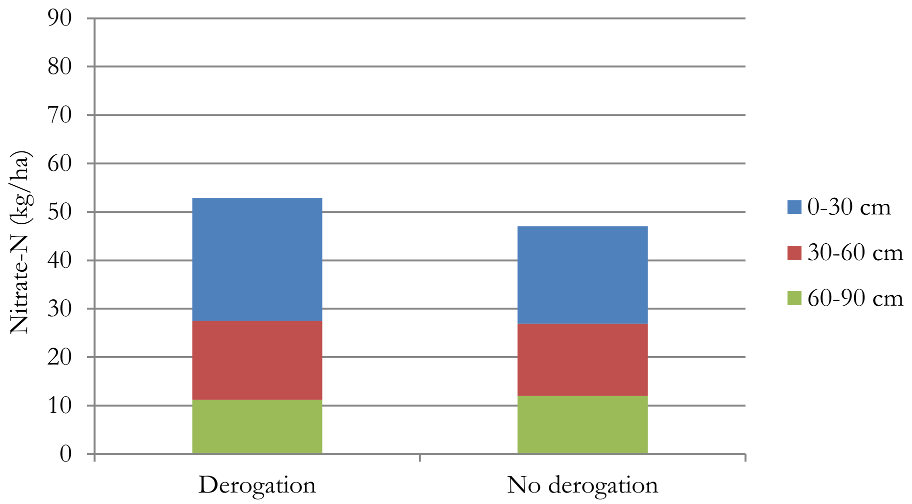


Figure 135: Average nitrate-N (kg/ha) on derogation and no derogation parcels with all crops on all soils in the monitoring network in autumn 2016.

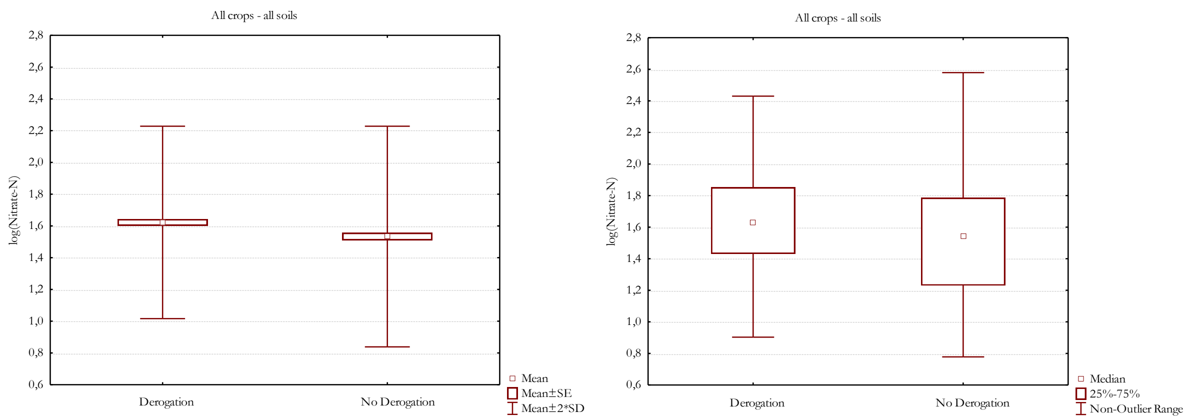


Figure 136: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with all crops and all soil textures in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

On parcels without derogation, the average nitrate-N residue in the monitoring network amounted 47 ± 44 kg NO_3-N/ha. The average nitrate-N residue on derogation and no derogation parcels did not differ statistically significant ($p = 0.06$). The variation in nitrate-N residue is shown in the boxplots, with indication of the mean nitrate-N residue and the median value of the nitrate-N residue shown as the log-transformed data (Figure 136).

The situation of the nitrate-N residue in the monitoring network is further specified in Figure 137. The percentage parcels is indicated per category of nitrate-N residue for derogation and no derogation conditions separately. The curves show the cumulative percentage of parcels for derogation and no derogation conditions separately which respect a certain level of nitrate-N residue. For both derogation and no derogation conditions, the large proportion of parcels with a moderate nitrate-N residue is clear. With respect to the categories of nitrate-N residue as shown in Figure 137, 50 % of the derogation parcels have a nitrate-N residue of less than 50 kg NO_3-N/ha and 50 % of the parcels without derogation have a nitrate-N residue of less than 40 kg NO_3-N/ha.

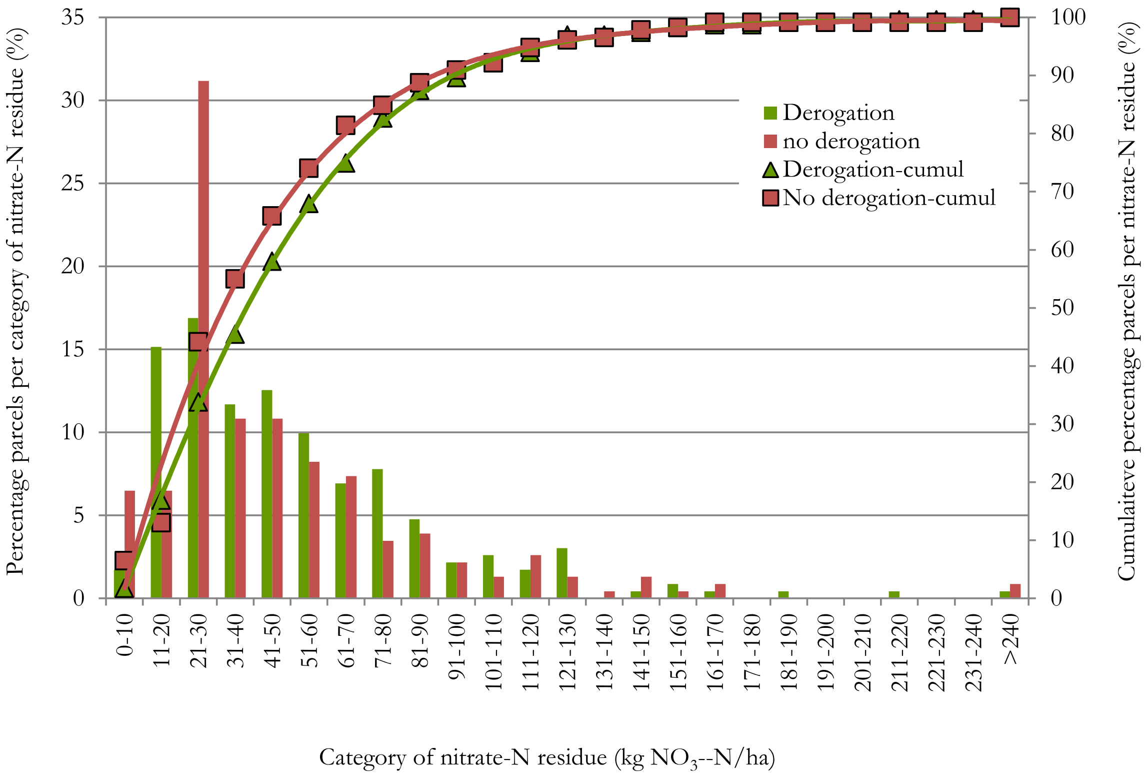


Figure 137: Distribution of the derogation (green columns) and no derogation parcels (red columns) (%) of the monitoring network in the different categories of nitrate-N residue (kg NO_3-N/ha) and cumulative percentage of derogation (green curve) and no derogation (red curve) parcels of the monitoring network which respect a certain value of nitrate-N residue.

In the dataset of the nitrate-N residues of the 462 remaining parcels 5 outliers were detected. Three nitrate-N residues measured on derogation parcels and 2 nitrate-N residues on parcels without derogation. On the derogation parcels, the nitrate-N residues amounted 184, 216 and 269 kg NO_3-N/ha. On the parcels without derogation, the nitrate-N residues amounted 297 and 379 kg NO_3-N/ha. The outliers will be discussed in more detail in the following paragraphs when they are part of the discussed groups. As indicated before those outliers were withheld in the dataset. Nevertheless, the difference in nitrate-N residue would remain 6 kg NO_3-N/ha between parcels with and without derogation if the outlying values would be discarded.

All crops on sandy soils

Because of the loss of some parcels suited for evaluation of the nitrate-N residue, the comparison of the nitrate-N residue of parcels with and without derogation on sandy soils is performed on 131 parcels with derogation and 129 parcels without derogation.

When derogation was requested, the average nitrate-N residue on sandy soils amounted 56 ± 38 kg NO_3-N/ha (Figure 138). Without derogation, this was 54 ± 50 kg NO_3-N/ha. The difference is not statistically significant (p = 0.45).

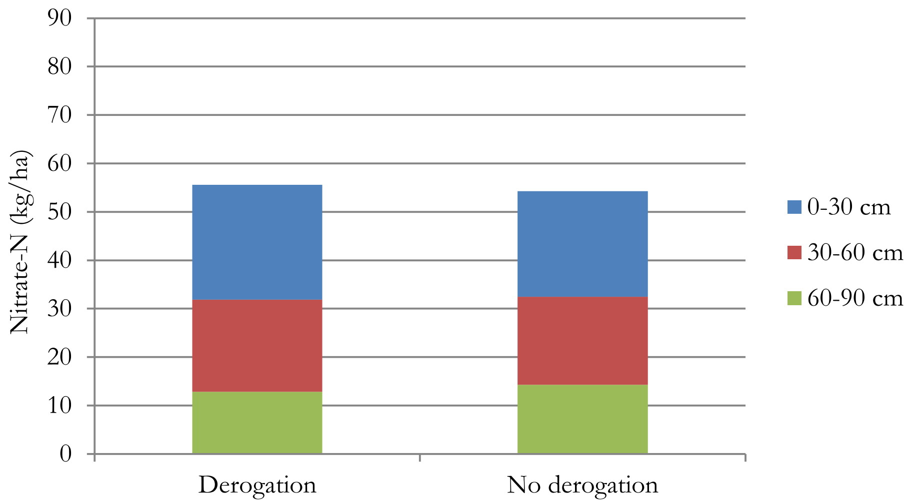


Figure 138: Average nitrate-N (kg/ha) on derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2016.

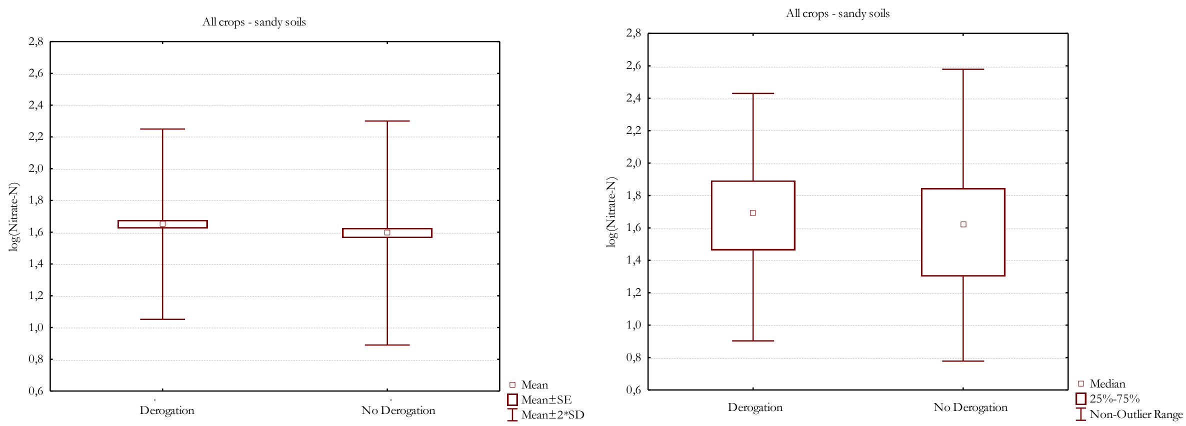


Figure 139: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

On sandy soils 3 of the 5 mentioned outlying values were detected, 1 under derogation conditions and 2 without derogation conditions. The derogation parcel was cultivated with grass, the parcels without derogation were cultivated with maize.

Grass on sandy soils

Focusing on grass cultivated on sandy soils with or without derogation, the comparison of the nitrate-N residue with or without derogation is based on 52 parcels with derogation and 53 parcels without derogation.

On parcels with derogation and grass on sandy soils, the average nitrate-N residue amounted 51 ± 44 kg NO_3-N/ha (Figure 140). Without derogation, the average nitrate-N residue amounted 36 ± 33 kg NO_3-N/ha. The average nitrate-N residue on parcels with grass on sandy soils with or without derogation did not differ statistically significant (p = 0.06).

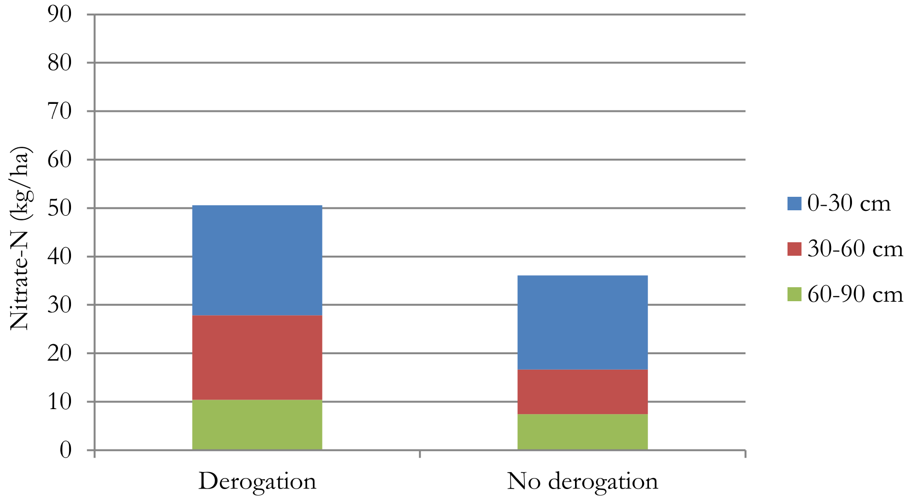


Figure 140: Average nitrate-N (kg/ha) on derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2016.

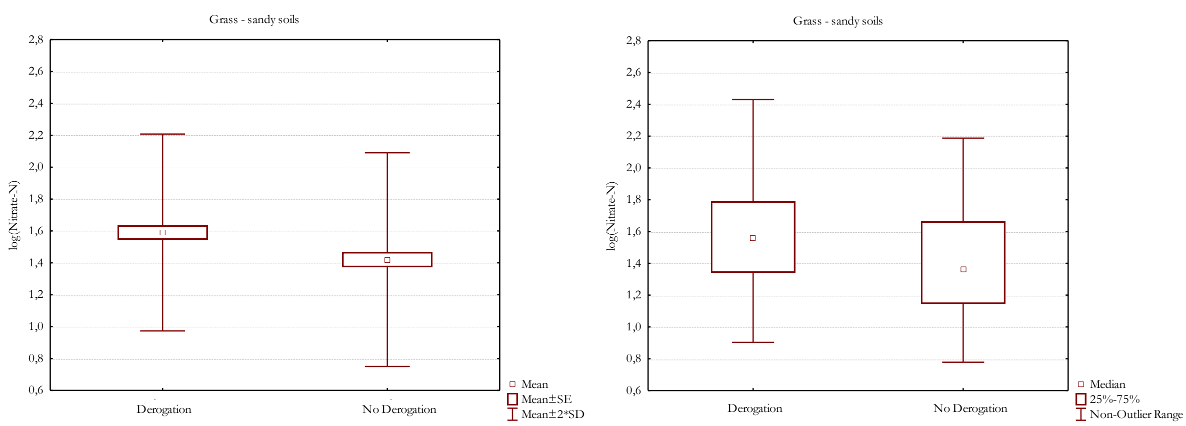


Figure 141: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

On one parcel with derogation an outlying amount of nitrate-N was measured, 269 kg NO_3-N/ha. An indication of a possible explanation for the high nitrate-N residue could not be obtained since this nitrate-N residue was measured at the farm that could no longer participate because of a family situation. Without this parcel, the difference in nitrate-N residue between derogation and no derogation parcels would be reduced to 10 kg NO_3-N/ha.

Grass with less than 50 % clover on sandy soils

In the set-up of the monitoring network, the monitoring of grass with less than 50 % clover was restricted to sandy soils. The number of parcels cultivated with grass and less than 50 % clover was limited to 30 parcels with and without derogation. The evaluation of the nitrate-N residue on parcels cultivated with grass and less than 50 % clover is based on 30 parcels with and without derogation since all parcels were judged to be suited for further analysis after questioning the farmers.

On parcels cultivated with grass and less than 50 % clover and request of derogation, the average nitrate-N residue was 40 ± 27 kg NO_3-N/ha (Figure 142). Without derogation the average nitrate-N residue on sandy soils cultivated with grass and less than 50 % clover was 39 ± 23 kg NO_3-N/ha in the monitoring network.

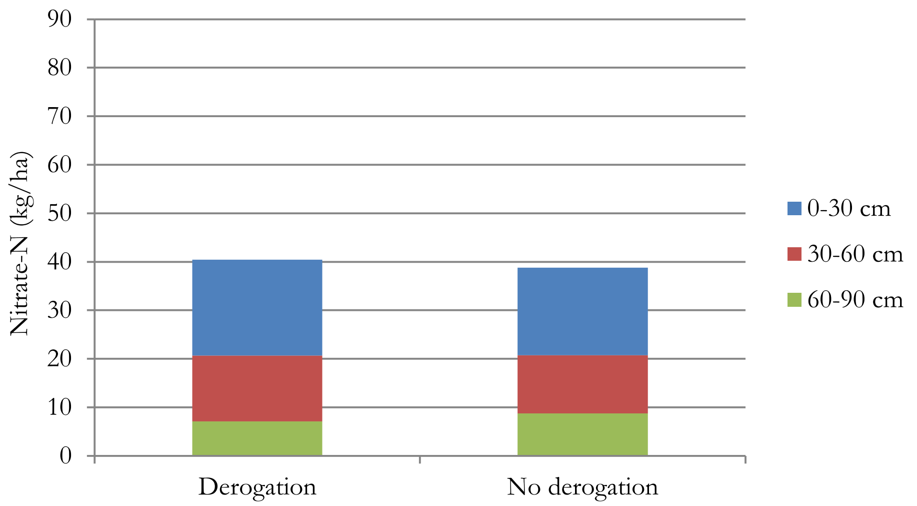


Figure 142: Average nitrate-N (kg/ha) on derogation and no derogation parcels with grass and less than 50 % clover on sandy soils in the monitoring network in autumn 2016.

The average nitrate-N residue on sandy parcels cultivated with grass and less than 50 % clover did not differ statistically significant between parcels with or without derogation (p = 0.92).

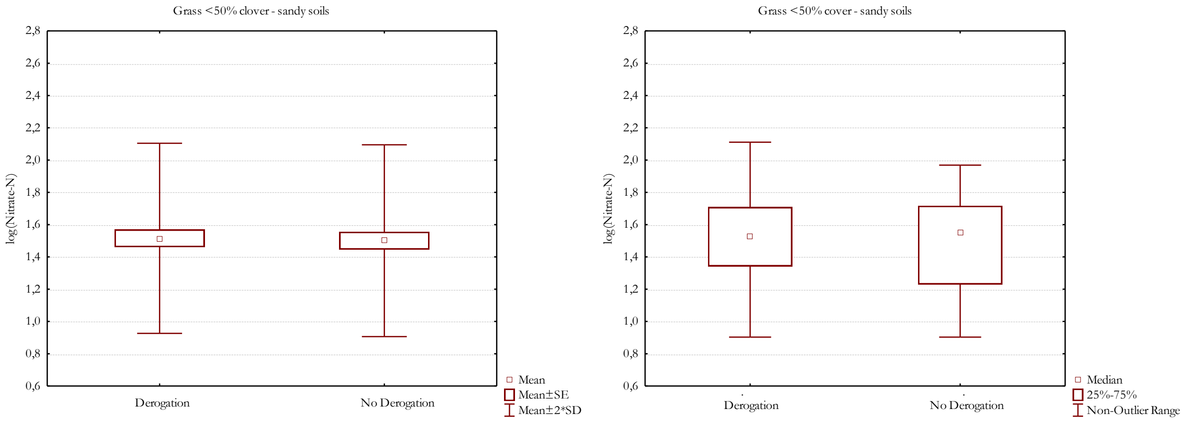


Figure 143: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with grass and less than 50% clover on sandy soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Maize on sandy soils

For maize on sandy soils, the comparison of the nitrate-N residue on parcels with and without derogation is based on 49 parcels with derogation and 46 parcels without derogation.

On the parcels with derogation, the average nitrate-N residue amounted 70 ± 31 kg NO_3-N/ha (Figure 144).

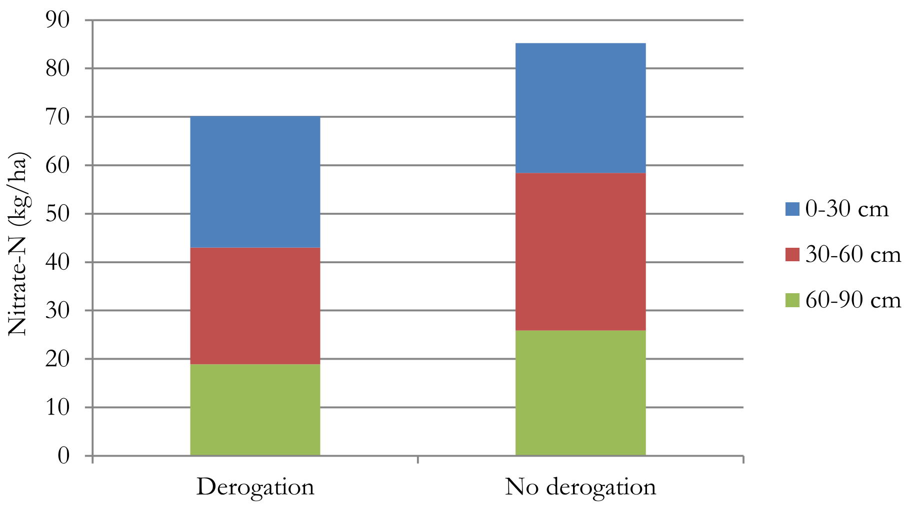


Figure 144: Average nitrate-N (kg/ha) on derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2016.

On the parcels without derogation, the average nitrate-N residue was 85 ± 64 kg NO_3-N/ha. The difference between the maize parcels on sandy soils with or without derogation regarding the nitrate-N residue was not statistically significant (p = 0.22).

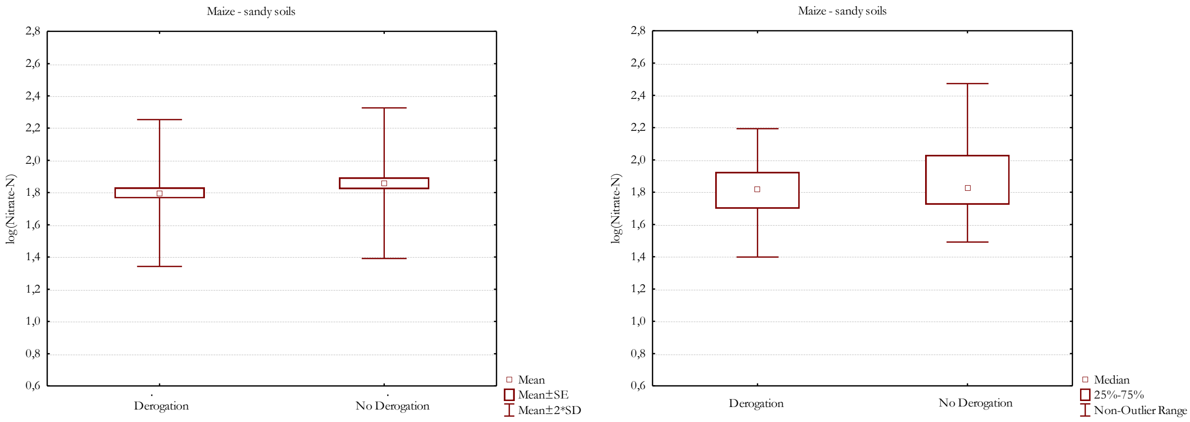


Figure 145: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Two outliers were detected on sandy parcels cultivated with maize without derogation. The nitrate-N residues amounted 297 and 379 kg NO_3-N/ha. On both parcels yield was reduced by approximately 50 %. The parcel with the nitrate-N residue of 297 kg NO_3-N/ha was situated in a region with extreme high rainfall of about 300 l/m² in 3 weeks. Moreover, this parcel received lots of run off from a neighbouring bush. On the parcel with the nitrate-N residue of 379 kg NO_3-N/ha maize was sown in July because of impossible conditions before and consequently yield was halved.

All crops on sandy loam soils

On the sandy loam soils of the monitoring network, the average nitrate-N residue was 44 ± 35 kg NO_3-N/ha in autumn 2016. 202 parcels were evaluated, 100 parcels with derogation and 102 parcels without derogation. The average nitrate-N residue of parcels with request of derogation on sandy loam soils amounted 49 ± 39 kg NO_3-N/ha (Figure 146). On parcels without derogation, the average nitrate-N residue was 38 ± 31 kg NO_3-N/ha.

The difference in nitrate-N residue between both types of parcels, with and without derogation, was statistically significant (p = 0.02). However, on both derogation and no derogation parcels the average nitrate-N residue was low.

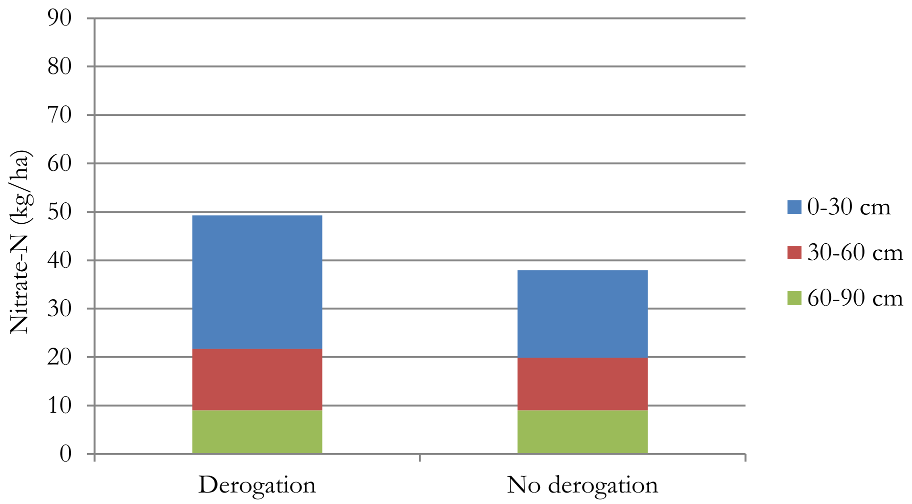


Figure 146: Average nitrate-N (kg/ha) on derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network in autumn 2016.

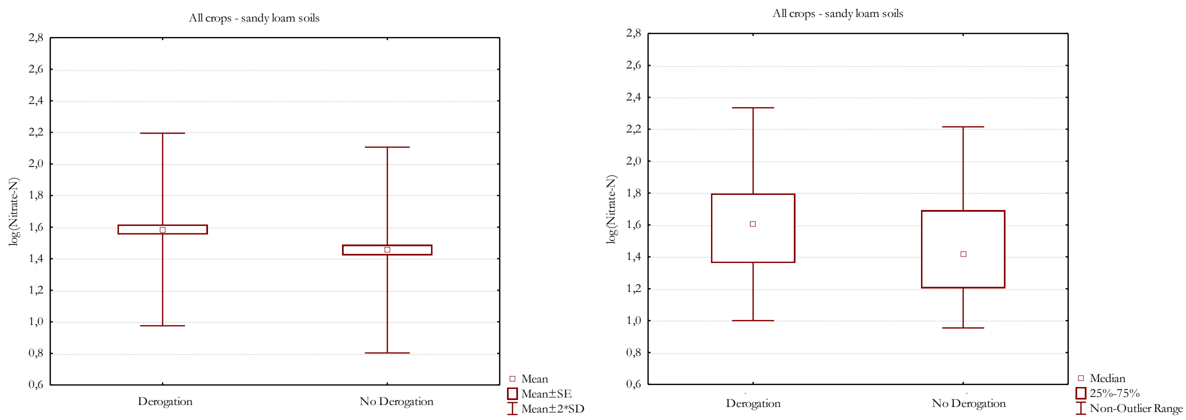


Figure 147: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

On sandy loam soils 2 outlying nitrate-N residues were detected, one parcel with derogation and one parcel without derogation. Without these outlying values, the difference in nitrate-N residue between derogation and no derogation parcels would amount 8 kg NO_3-N/ha, comparable to the reported difference of 9 kg NO_3-N/ha

Grass on sandy loam soils

For grass on sandy loam soils 53 parcels with derogation and 54 parcels without derogation were suited for comparison. On the sandy loam parcels cultivated with grass with derogation, the average nitrate-N residue was 41 ± 41 kg NO_3-N/ha (Figure 148). On the parcels without derogation, the average nitrate-N residue amounted 27 ± 30 kg NO_3-N/ha. The average nitrate-N residue on parcels with and without derogation differed significantly ($p = 0.03$). The significance of this difference needs to be considered against higher standard deviations. Moreover, the practical relevance of a difference of 14 kg NO3-N/ha needs to be questioned.

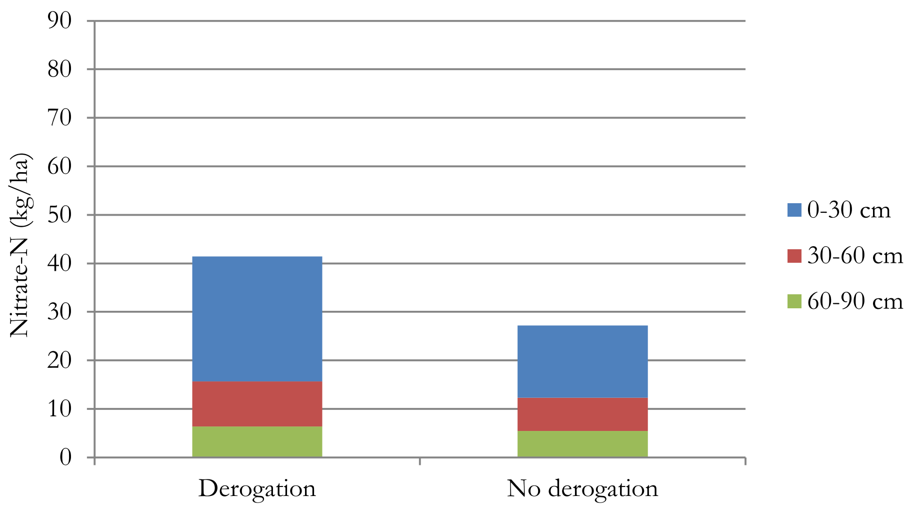


Figure 148: Average nitrate-N (kg/ha) on derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2016.

One outlier was situated in the derogation group. The nitrate-N residue was 216 kg NO_3-N/ha. In the top soil layer of 0-30 cm 123 kg NO_3-N/ha was measured. However, this parcel was cut 4 times, a last time at the end of October, and all application standards were respected. The amount of total organic N was even limited to 90 kg N/ha and was applied in March. The last mineral fertilisation was realised at the end of August, two months before the last cut.

Without this outlier, the average nitrate-N residue under derogation conditions would have been 38 kg NO_3-N/ha and the difference between parcels with and without derogation would be 9 kg NO_3-N/ha.

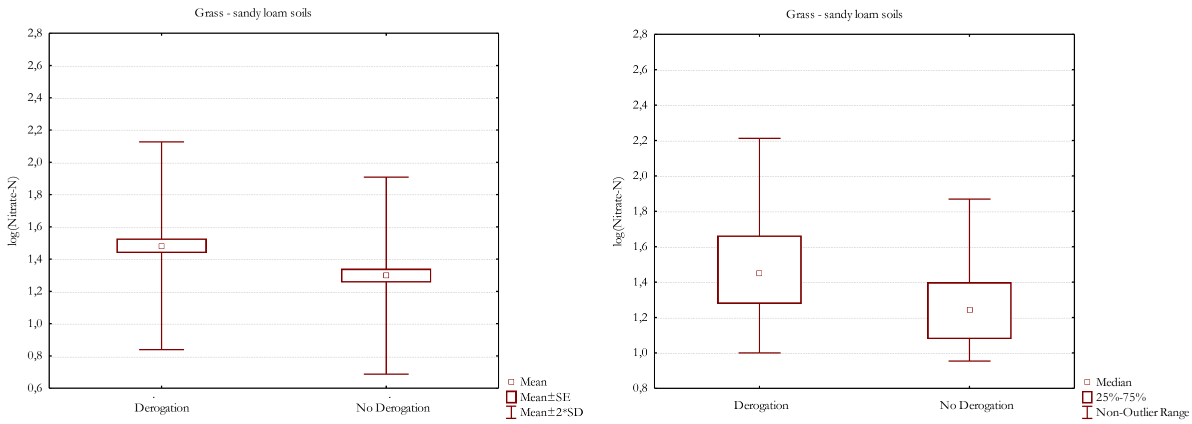


Figure 149: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Maize on sandy loam soils

For maize on sandy loam soils 47 parcels with derogation and 48 parcels without derogation were suited for comparison. On the sandy loam parcels cultivated with maize under derogation conditions, the average nitrate-N residue was 58 ± 34 kg NO_3-N/ha (Figure 150). On the parcels without derogation, the average nitrate-N residue amounted 50 ± 29 kg NO_3-N/ha. The average nitrate-N residue on parcels with and without derogation did not differ significantly ($p = 0.20$).

In the derogation group, one outlier was detected. The nitrate-N residue amounted 184 kg NO_3-N/ha. Nevertheless, the yield was very good and was not reduced.

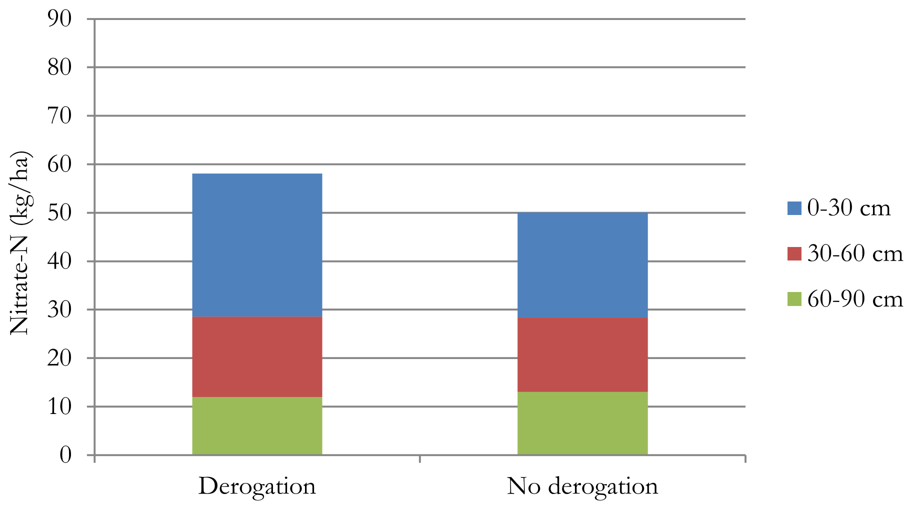


Figure 150: Average nitrate-N (kg/ha) on derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2016.

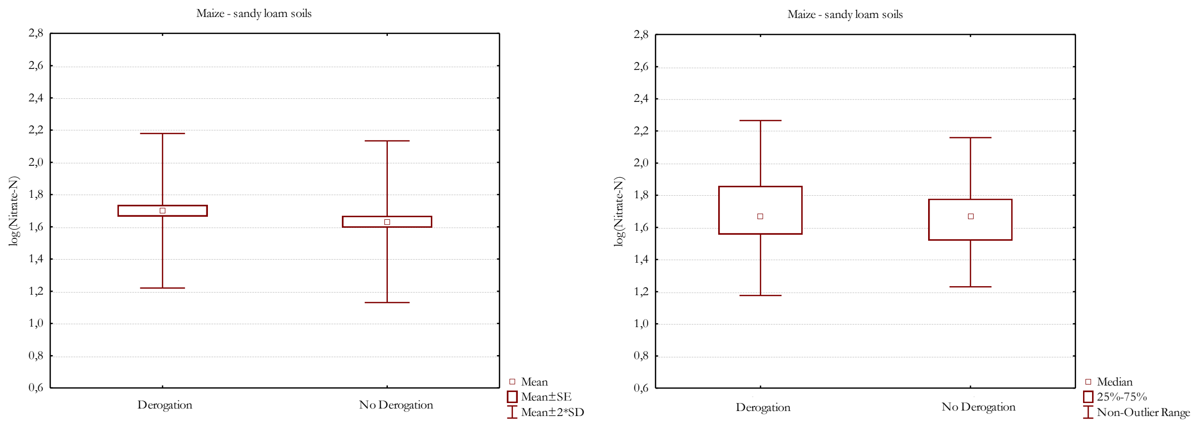


Figure 151: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Despite the different set-up of the former and the current monitoring network the results of the nitrate-N residue of both periods are compared (Table 46).

In the period 2011-2014 as well as in the first year of monitoring in the monitoring network 2016-2019 the nitrate-N residue on parcels cultivated with derogation crops with or without derogation did not differ significantly. Moreover, there even isn't a trend for a consistently 'higher' nitrate-N residue with derogation or without derogation noticeable (Table 46, Figure 152).

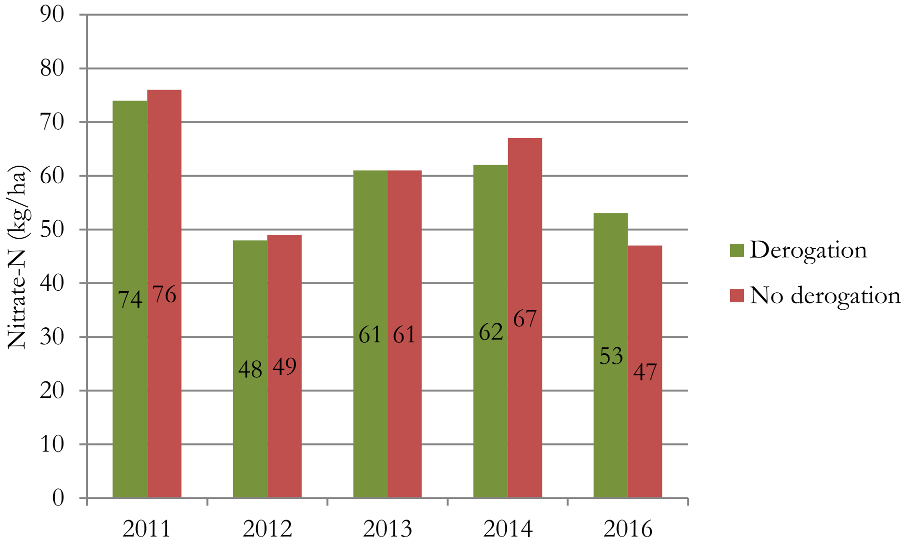


Figure 152: Nitrate-N residue in the soil profile (0-90 cm) on derogation and no derogation parcels cultivated with derogation crops in the monitoring network of 2011-2014 and in autumn 2016.

The same can be said when focusing per soil type. On sandy soils, no statistically significant difference between the nitrate-N residue on derogation and no derogation parcels could be found (Table 46, Figure 153). The difference between the average nitrate-N residue on derogation and no derogation parcels was at each moment of comparison very small.

On sandy loam soils, only in 2016, the average nitrate-N residue on derogation parcels differed statistical significantly of the average nitrate-N residue on parcels without derogation (Table 46, Figure 154). Nevertheless, the difference amounted only 11 kg NO_3-N/ha, while the difference between both average nitrate-N residues amounted 15 kg NO_3-N/ha in 2014, a difference that was not statistically significant.

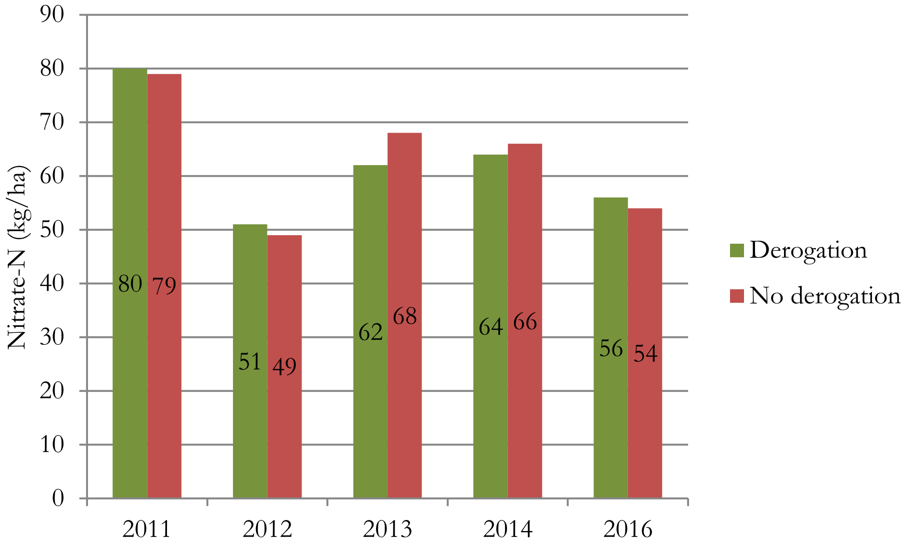


Figure 153: Nitrate-N residue in the soil profile (0-90 cm) on derogation and no derogation parcels cultivated with derogation crops on sandy soils in the monitoring network of 2011-2014 and in autumn 2016.

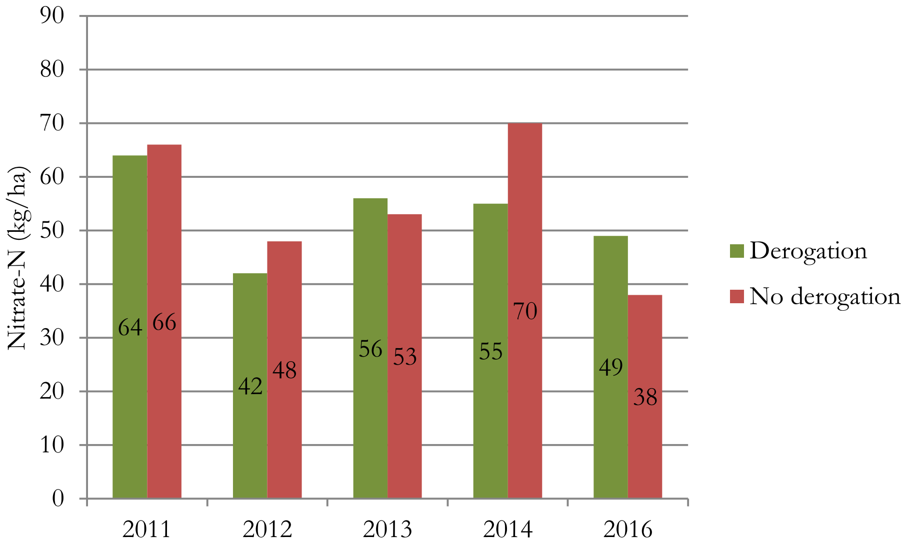


Figure 154: Nitrate-N residue in the soil profile (0-90 cm) on derogation and no derogation parcels cultivated with derogation crops on sandy loam soils in the monitoring network of 2011-2014 and in autumn 2016.

Table 46: Nitrate-N residue in the soil profile (0-90 cm) for the different levels of comparison (derogation, soil texture, crop) in the monitoring network of 2011-2014 and in autumn 2016. Indication of the average nitrate-N residue ± standard deviation, the number of parcels included in the comparison by 'n' and the p-value.

			Nitrate-N (kg/ha)															
			2011			2012			2013			2014			2016		
			n	0-90 cm	p-value	n	0-90 cm	p-value	n	0-90 cm	p-value	n	0-90 cm	p-value	n	0-90 cm	p-value
Derogation			85	74±54	0.80	87	48±37	0.91	106	61±47	0.90	80	62±41	0.91	231	53±38	0.06
No derogation			110	76±57		100	49±33		78	61±46		116	67±49		231	47±44	
Derogation	Sandy soil		52	80±59	0.99	55	51±38	0.70	72	62±48	0.80	55	64±43	0.80	131	56±38	0.45
No derogation			67	79±60		62	49±36		47	68±59		65	66±46		129	54±50	
Derogation	Sandy loam		25	64±46	0.72	24	42±35	0.53	24	56±51	0.63	16	55±35	0.54	100	49±39	0.02
No derogation			27	66±45		38	48±29		36	53±32		37	70±53		102	38±31	
Derogation	Sandy soil	Grass	34	64±52	0.31	34	41±33	0.23	41	52±45	0.37	37	60±42	0.31	52	51±44	0.06
No derogation			32	51±51		27	32±23		20	54±58		22	54±45		53	36±33	
Derogation	Sandy soil	Grass <50% clover	-	-	-	-	-	-	-	-	-	-	-	-	30	40±27	0.92
No derogation			-	-	-	-	-	-	-	-	-	-	-	-	30	39±23	
Derogation	Sandy soil	Maize	11	108±61	0.82	20	68±42	0.36	29	71±46	0.65	18	70±48	0.52	49	70±31	0.22
No derogation			31	112±58		25	57±36		14	74±41		37	75±45		46	85±64	
Derogation	Sandy loam	Grass	14	31±14	0.23	16	24±10	0.05	11	43±45	0.95	10	45±36	0.90	53	41±41	0.03
No derogation			8	40±18		7	38±22		10	34±23		12	46±40		54	27±30	
Derogation	Sandy loam	Maize	11	106±38	0.43	8	80±36	0.06	12	65±56	0.56	4	80±28	0.84	47	58±34	0.20
No derogation			13	94±56		20	54±30		15	66±33		21	88±57		48	50±29	

3.2.1.2 Mineral nitrogen - farm average - autumn 2016

In accordance to the Manure Decree and the fifth Action Programme that approaches fertilisation both at parcel level and at farm level, the amount of residual nitrate-N was also evaluated at farm level in the monitoring network. From this point of view, the monitoring network was set up with 3 parcels of the same crop and same soil texture per farm. The approach of comparing the mean nitrate-N residue measured at a farm is from statistical point of view not the preferred strategy to compare the impact of derogation on the nitrate-N residue. Therefore, to counter statistical concerns as an unequal number of parcels to calculate the mean, only farms of which all three parcels were representative and withheld in the former discussion of the nitrate-N residue, are withheld for evaluation of the farm average nitrate-N residue.

This means that some farms will not be part of the evaluation of the farm average nitrate-N residue. Since the amount of nitrate-N is already an average figure per farm, also no outlier detection was carried out at this point. As in the former discussion of the nitrate-N residue, also the statistical analysis of the farm average nitrate-N residue is carried out on the log-transformed farm average nitrate-N residues.

Table 47: Mean farm average nitrate-N in the soil profile (0-90 cm) and specified per soil layer (0-30 cm, 30-60 cm and 60-90 cm) for the 143 farms combined at different levels of comparison in autumn 2016. The number of farms taken up in the comparison is indicated by 'n'.

				Nitrate-N (kg/ha)				p-value
			n	0-30 cm	30-60 cm	60-90 cm	0-90 cm	
Overall farm average			143	23	16	12	50	-
Derogation			69	26	17	12	54	0.03
No derogation			74	20	15	12	47	
Derogation	Sandy soil		37	24	20	14	58	0.18
No derogation			41	21	18	14	54	
Derogation	Sandy loam		32	28	13	9	50	0.06
No derogation			33	18	11	9	38	
Derogation	Sandy soil	Grass	17	23	18	11	51	0.01
No derogation			17	18	8	7	33	
Derogation	Sandy soil	Grass <50% clover	5	18	11	7	36	-
No derogation			9	17	12	9	39	
Derogation	Sandy soil	Maize	15	28	25	20	73	0.25
No derogation			15	27	33	26	86	
Derogation	Sandy loam	Grass	17	27	10	7	43	0.046
No derogation			18	15	7	5	27	
Derogation	Sandy loam	Maize	15	29	16	12	58	0.45
No derogation			15	22	16	13	51	

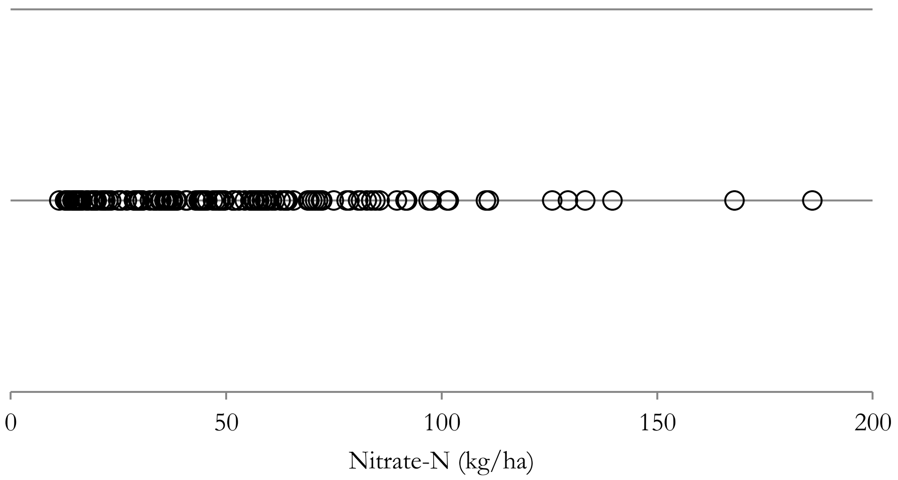


Figure 155: Spreading of the farm average nitrate-N residue of 143 farms of the monitoring network in autumn 2016.

In 2016, 143 farms were part of the evaluation of the farm average nitrate-N residue. The overall farm average nitrate-N residue of 2016 amounted 50 ± 31 kg NO_3-N/ha.

The farm average nitrate-N residue on farms with and without derogation amounted in autumn 2016 respectively 54 ± 30 kg NO_3-N/ha and 47 ± 32 kg NO_3-N/ha (Figure 156).

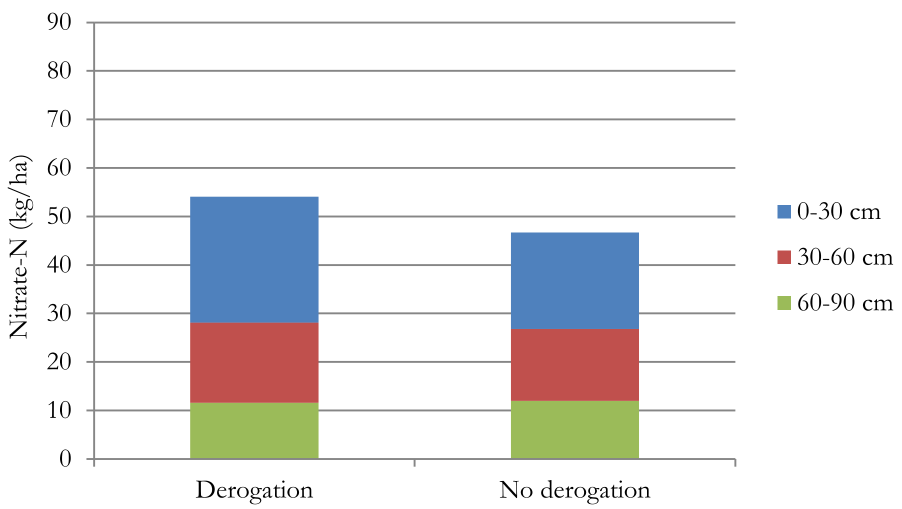


Figure 156: Farm average nitrate-N residue (kg/ha) on derogation and no derogation farms with all crops on all soils in the monitoring network in autumn 2016.

Although the large overlap (Figure 157) of the farm average nitrate-N residue on farms with and without derogation, the difference between the farm average nitrate-N residue of both types of farms was statistically significant (p = 0,03). Nevertheless, both mean values were small. The standard deviation and error of the farm average nitrate-N residue in both groups as well as the mean and median in both groups is reflected in the boxplots in Figure 158.

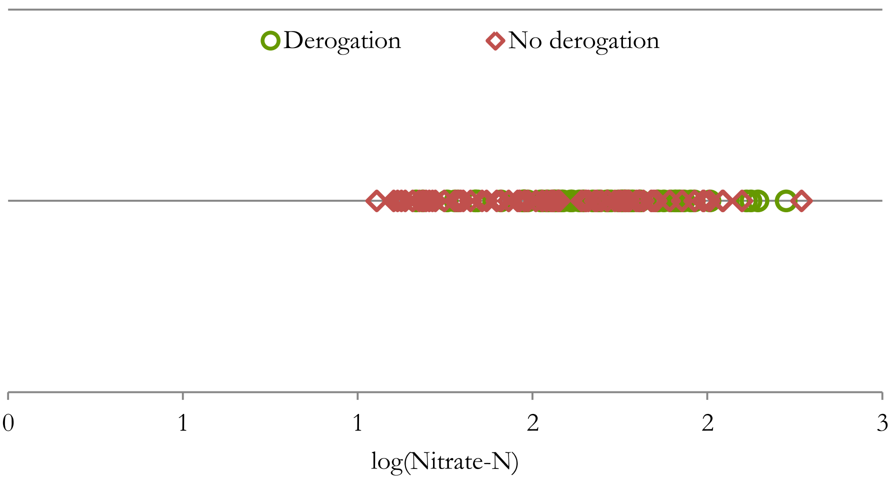


Figure 157: Spreading of the log(farm average nitrate-N) of derogation (green) and no derogation (red) farms of the monitoring network in autumn 2016.

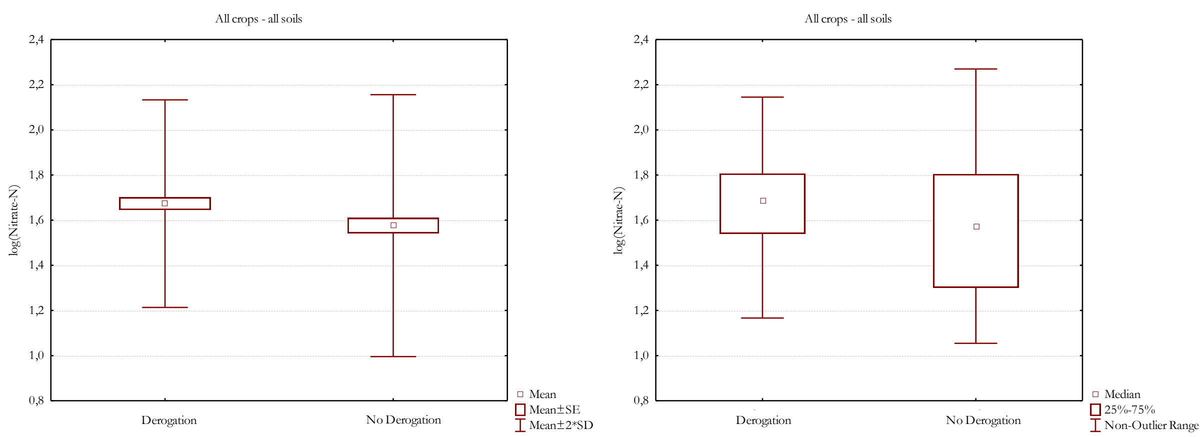


Figure 158: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation farms with all crops on all soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

All crops on sandy soils

On sandy soils, the farm average nitrate-N residue in the monitoring network amounted 56 ± 33 kg NO_3-N/ha. The mean farm average nitrate-N residue on derogation farms in autumn 2016 was 58 ± 28 kg N/ha (Figure 159). On farms without derogation this mean amounted 54 ± 37 kg NO_3-N /ha. The mean farm average nitrate-N residues did not differ significantly on sandy soils ($p = 0.18$). The variation of the farm average nitrate-N residue in both groups on sandy soils as well as the mean and median in both groups is reflected in the boxplots in Figure 160.

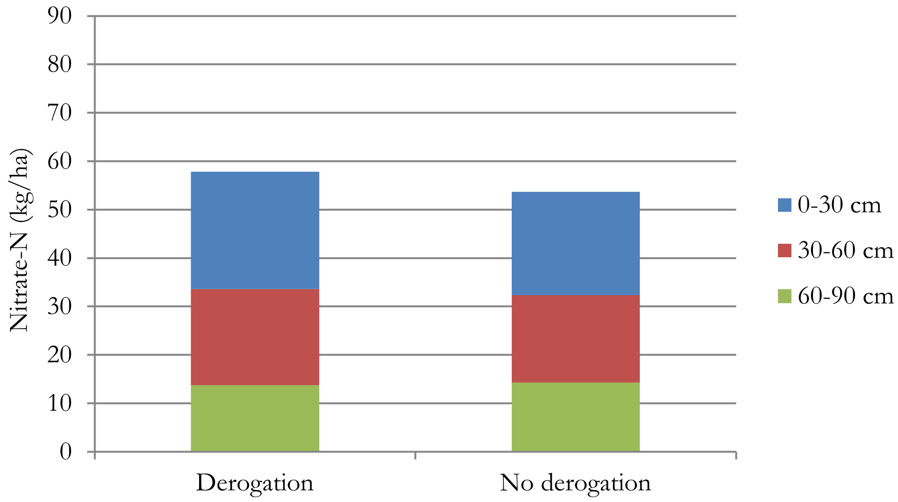


Figure 159: Farm average nitrate-N residue (kg/ha) on derogation and no derogation farms with all crops on sandy soils in the monitoring network in autumn 2016.

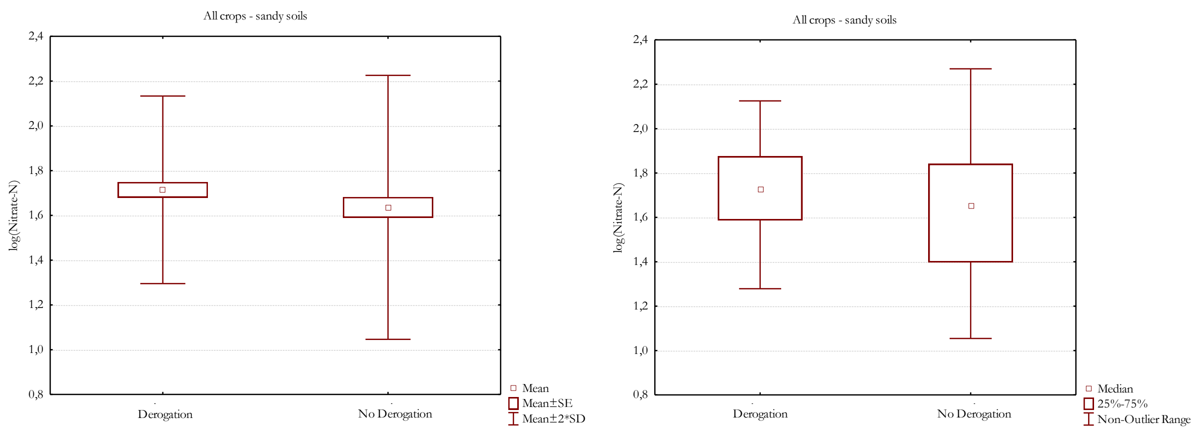


Figure 160: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation farms with all crops on sandy soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Grass on sandy soils

In autumn 2016 for both derogation and no derogation practices 17 farm average nitrate-N residues of parcels cultivated with grass on sandy soils are compared. The farm average nitrate-N residue with derogation practice was 51 ± 27 kg NO_3-N/ha (Figure 161). Without derogation practice, the farm average nitrate-N residue on sandy soils with grass was 33 ± 23 kg NO_3-N/ha.

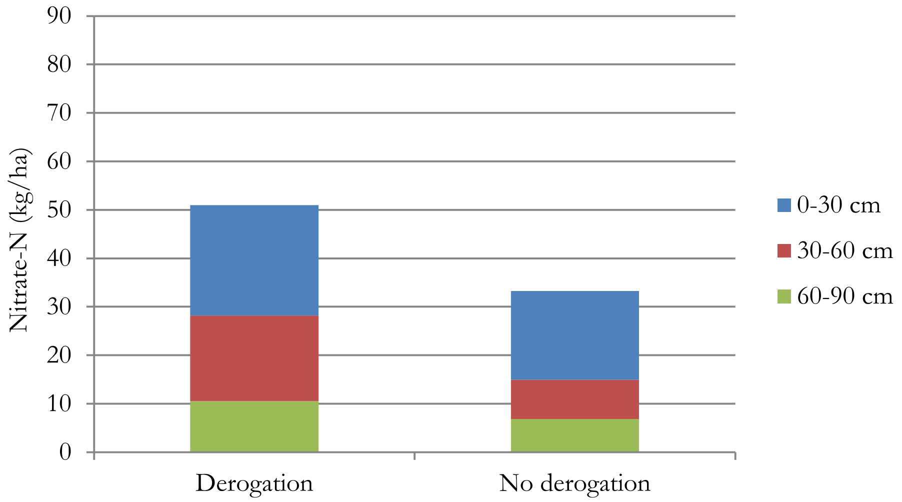


Figure 161: Farm average nitrate-N residue (kg/ha) on derogation and no derogation farms with grass on sandy soils in the monitoring network in autumn 2016.

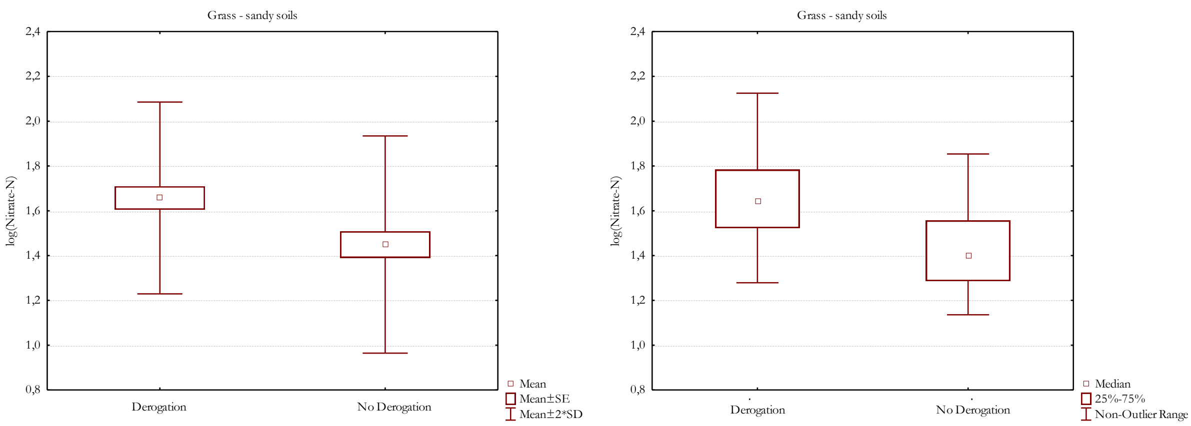


Figure 162: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation farms with grass on sandy soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

The difference between the mean farm average nitrate-N residue on derogation and no derogation farms on sandy soils with grass was statistically significant ($p = 0.01$). On both farms however, with and without derogation, the farm average nitrate-N residue is clearly below 90 kg NO_3-N/ha.

Grass with less than 50 % clover on sandy soils

When restricting to farms with 3 parcels for the comparison of the farm average nitrate-N residue the number of farms which are evaluated for the culture of grass with less than 50 % clover, is limited to 5 farms with derogation and 9 farms without derogation. On the derogation farms, the farm average nitrate-N residue was 36 ± 13 kg NO_3-N/ha (Figure 163). The mean farm average nitrate-N residue of farms without derogation was 39 ± 17 kg NO_3-N/ha. Because of the limited number of farms for this comparison, no statistical analysis was carried out.

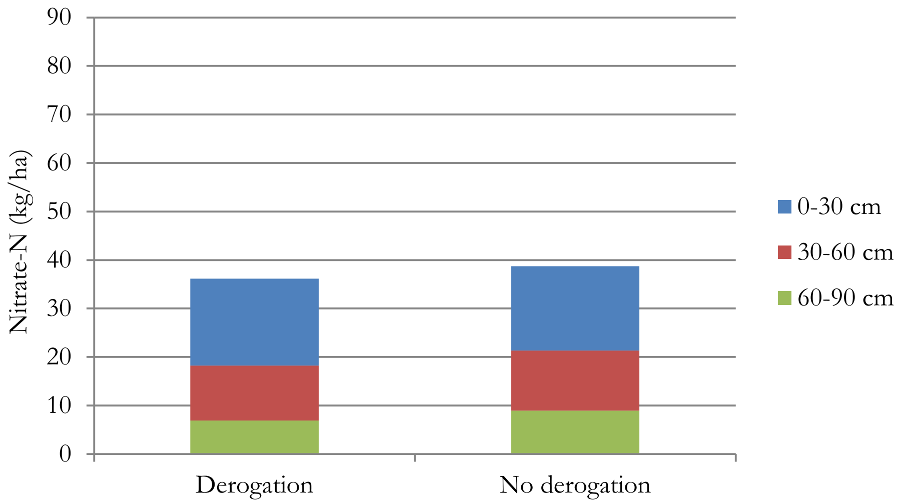


Figure 163: Farm average nitrate-N residue (kg/ha) on derogation and no derogation farms with grass and less than 50 % clover on sandy soils in the monitoring network in autumn 2016.

Maize on sandy soils

The average nitrate-N residues of 30 farms selected for the crop of maize on sandy soils were compared, 15 derogation farms and 15 farms without derogation. The farm average nitrate-N residue with derogation practice was 73 ± 25 kg NO_3-N/ha (Figure 164). Without derogation practice the farm average nitrate-N residue on sandy soils with maize was 86 ± 21 kg NO_3-N/ha.

The difference between the mean farm average nitrate-N residue on derogation and no derogation farms on sandy soils with maize was not statistically significant ($p = 0.25$).

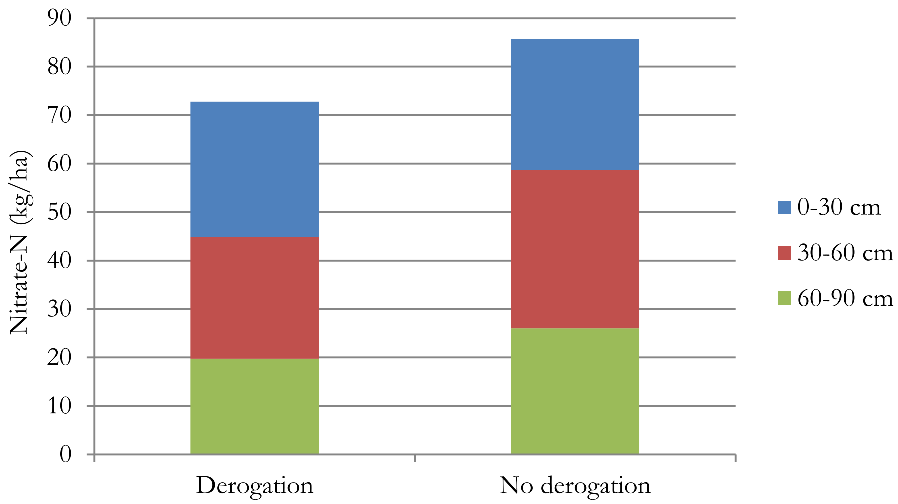


Figure 164: Farm average nitrate-N residue (kg/ha) on derogation and no derogation farms with maize on sandy soils in the monitoring network in autumn 2016.

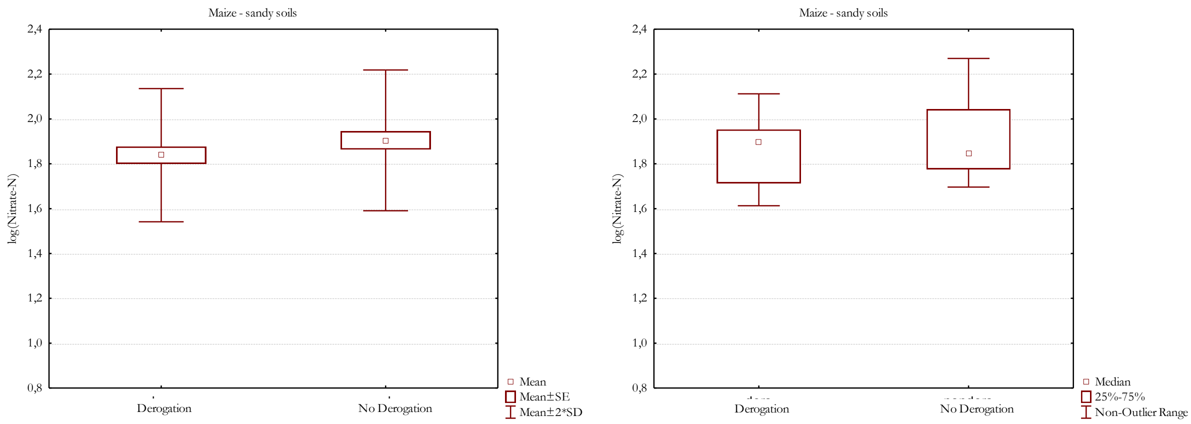


Figure 165: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation farms with maize on sandy soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

All crops on sandy loam soils

In the monitoring network, the farm average nitrate-N residue amounted 44 ± 29 kg NO_3-N/ha on sandy loam soils. On sandy loam soils, the comparison of the farm average nitrate-N residue was done between 32 farms with derogation and 33 farms without derogation. The mean farm average nitrate-N residue on derogation farms in autumn 2016 was 50 ± 33 NO_3-N/ha (Figure 166). On farms without derogation, the mean farm average nitrate-N residue amounted 38 ± 23 kg NO_3-N/ha. The mean farm average nitrate-N residues did not differ significantly on sandy loam soils ($p = 0.06$).

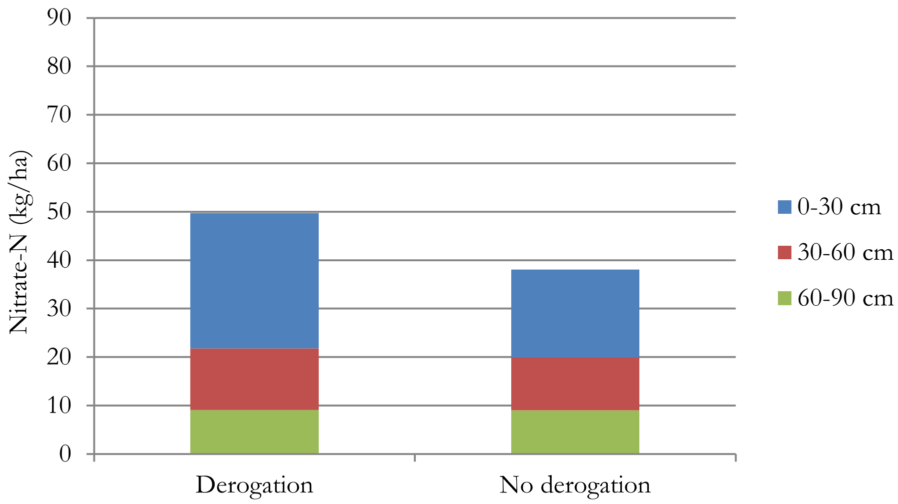


Figure 166: Farm average nitrate-N residue (kg/ha) on derogation and no derogation farms with all crops on sandy loam soils in the monitoring network in autumn 2016.

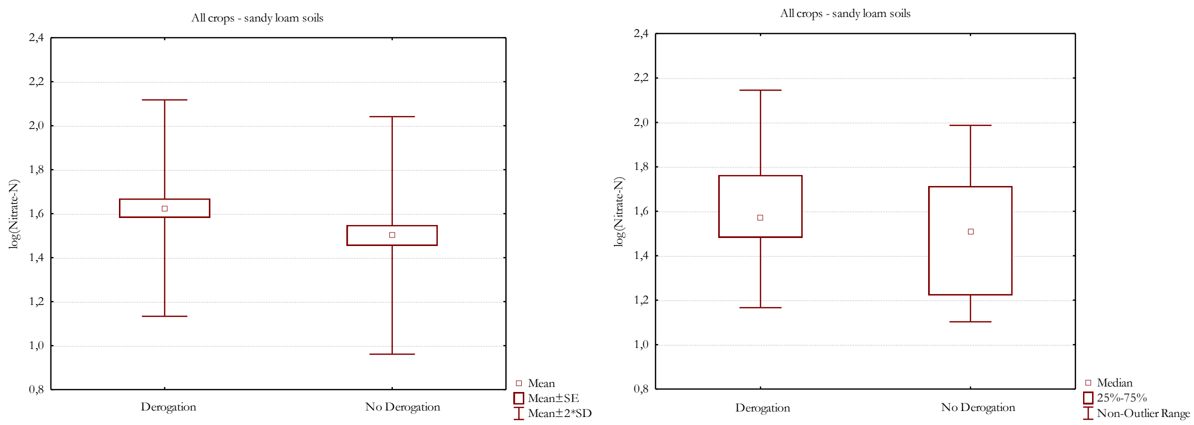


Figure 167: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation farms with all crops on sandy loam soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Grass on sandy loam soils

The farm average nitrate-N residue for grass on sandy loam soils with derogation practice was 43 ± 37 kg NO_3-N/ha. Without derogation practice, the farm average nitrate-N residue on sandy loam soils with grass was 27 ± 21 kg NO_3-N/ha.

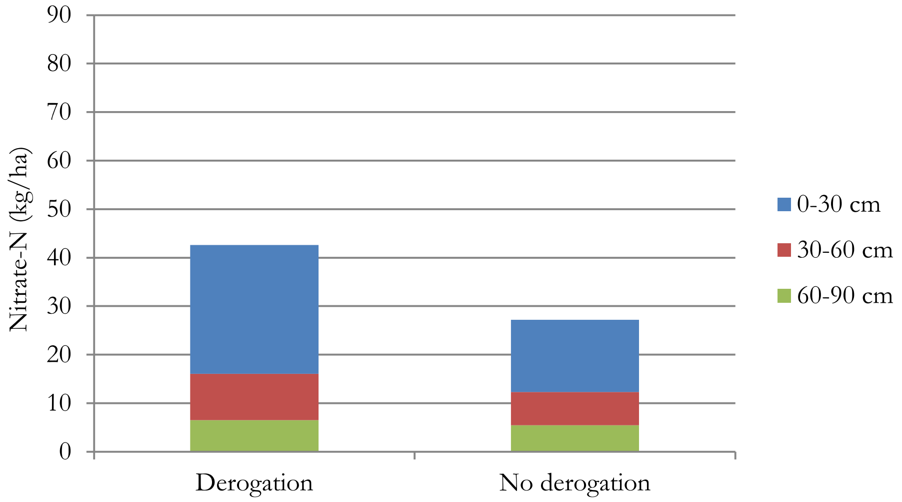


Figure 168: Farm average nitrate-N residue (kg/ha) on derogation and no derogation farms with grass on sandy loam soils in the monitoring network in autumn 2016.

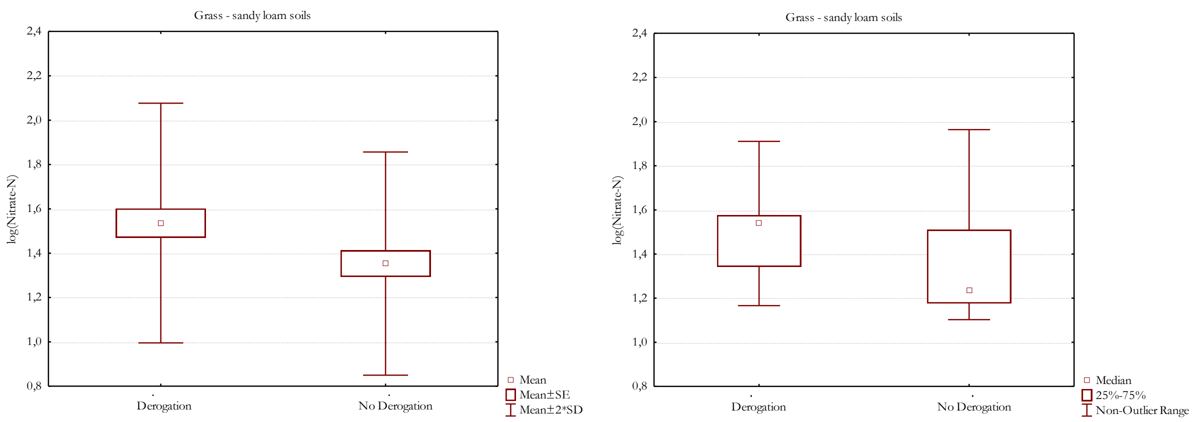


Figure 169: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation farms with grass on sandy loam soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

The difference between the mean farm average nitrate-N residue on derogation and no derogation farms on sandy loam soils with grass was statistically significant ($p = 0.046$). The comparison was made between 17 farms with derogation and 18 farms without derogation. The resulting p-value is very near the significance level of 0.05 therefore it is certainly necessary to emphasize that both, derogation and no derogation, farm average nitrate-N residues were below the applicable threshold values.

Maize on sandy loam soils

For maize on sandy loam soils, the farm average nitrate-N residue was compared between both 15 farms with and without derogation.

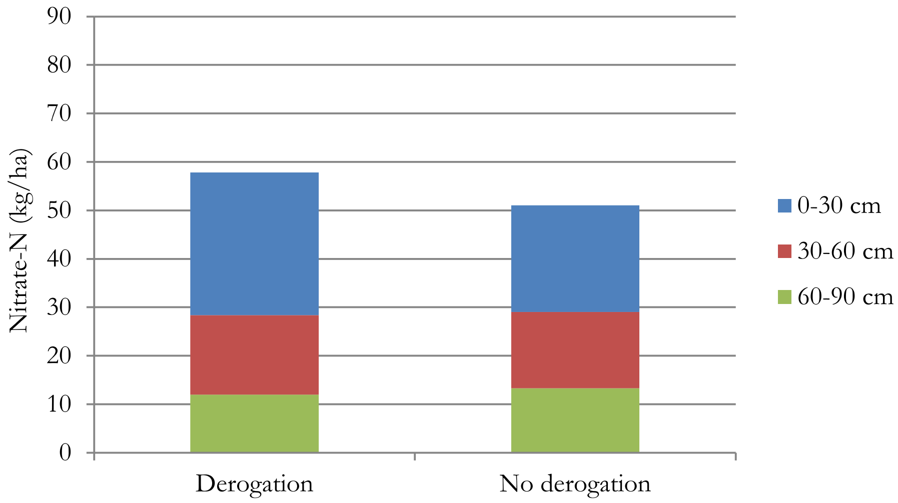


Figure 170: Farm average nitrate-N residue (kg/ha) on derogation and no derogation farms with maize on sandy loam soils in the monitoring network in autumn 2016.

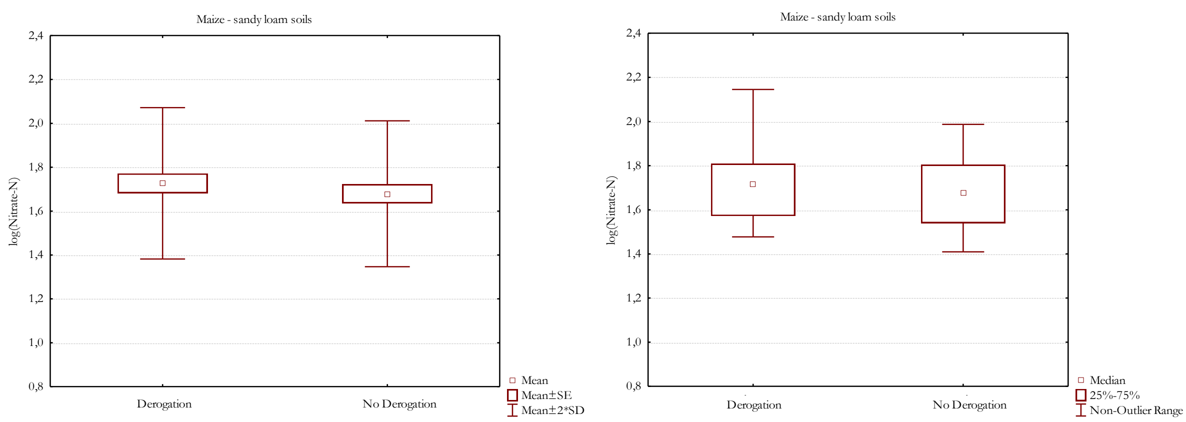


Figure 171: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation farms with maize on sandy loam soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

The mean farm average nitrate-N residue on farms with derogation amounted 58 ± 27 kg NO_3-N/ha. Without derogation, the mean farm average nitrate-N residue was about 51 ± 19 kg NO_3-N/ha. This limited difference between the mean farm average nitrate-N residues was not statistically significant ($p = 0.45$).

As discussed before, some parcels could not be selected for analysis. However, among the remaining parcels some are still less representative but these parcels were cultivated with the planned crop and the crop was harvested. Because of the presence and harvest of the planned crop, these parcels were maintained. After all the set-up and the intention of the monitoring network is to monitor reality. From this perspective, no outliers were removed and suboptimal parcels were included in the analysis. Examples of maintained suboptimal parcels are parcels on a derogation farm that appeared to be "rich" or "good" parcels when discussed with the farmer in the winter or parcels without derogation on which maize was sown twice. The first crop was sown at a normal moment but was lost by heavy rain. After a while, it became clear that the crop would not succeed and the maize was ploughed and a new crop was sown but obviously at a (too) late moment. The maize was harvested but the yield was of course influenced by the course of events.

3.2.1.3 Mineral nitrogen - difference autumn 2016 and spring 2017

Soil samples were taken in autumn and spring at each parcel to investigate the difference in nitrate-N realised during winter. The samples taken in autumn, which determine the nitrate-N residue, are discussed in the previous paragraph.

Comparison of the amounts of nitrate-N in autumn and spring will indicate how much nitrate-N was out of the profile between the two sampling moments. This comprises however much more than leaching alone since processes like mineralisation or immobilisation are not taken into account. Therefore, the discussed results are not discussed as the leaching but as the difference of nitrate-N. The difference of nitrate-N between the two sampling moments is expressed in kg NO_3-N/ha and is calculated as "nitrate-N residue (kg NO_3-N/ha; 0-90 cm) – nitrate-N reserve after winter (kg NO_3-N/ha; 0-90 cm)".

The statistical analysis was performed analogue to the statistical analysis of the nitrate-N residue. The only difference between both analyses is the fact that the dependent variable in this analysis "nitrate-N difference" was not log-transformed because the conditions for a variance analysis were met. "Derogation" (Yes or No) and "Farm" were still used in the general linear model as predictor variables; "Derogation" as a fixed categorical predictor variable and "Farm" as a random categorical predictor variable.

The data are presented by bar graphs showing the amount of nitrate-N (kg NO_3-N/ha) per soil layer (0-30 cm, 30-60 cm and 60-90 cm) in autumn and spring for derogation and no derogation parcels. This presentation allows estimating the difference of nitrate-N realised between the two moments of sampling and shows the redistribution of the nitrate-N over the soil profile.

To indicate the variation in nitrate-N difference between the two sampling moments box plots are shown. These boxplots are based on the effective figures of nitrate-N difference (kg NO_3-N/ha).

Evaluation of the parcels and the analysis resulted in 449 parcels judged representative and suited for evaluation of the possible impact of derogation practices. The average nitrate-N difference was 13 ± 32 kg NO_3-N/ha.

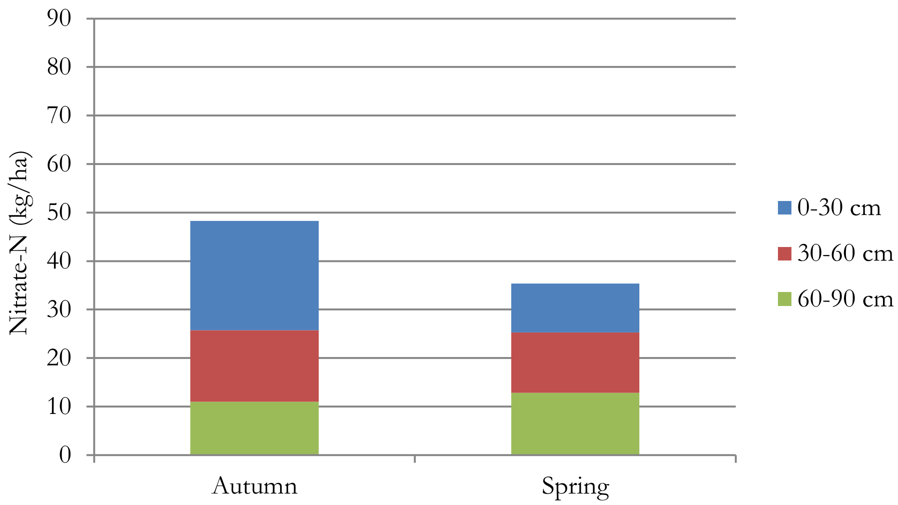


Figure 172: Average nitrate-N (kg/ha) on 449 parcels of the monitoring network in autumn 2016 and spring 2017, indicating the average nitrate-N difference-winter 2016-2017.

Comparison of the nitrate-N difference on derogation and no derogation parcels was performed on 226 derogation parcels and 223 no derogation parcels. The average nitrate-N difference on derogation parcels was 15 ± 32 kg NO_3-N/ha (Figure 173). On parcels without derogation the average nitrate-N difference was 11 ± 33 kg NO_3-N /ha. The difference in average nitrate-N difference between derogation and no derogation parcels was not statistically significant (p = 0.61).

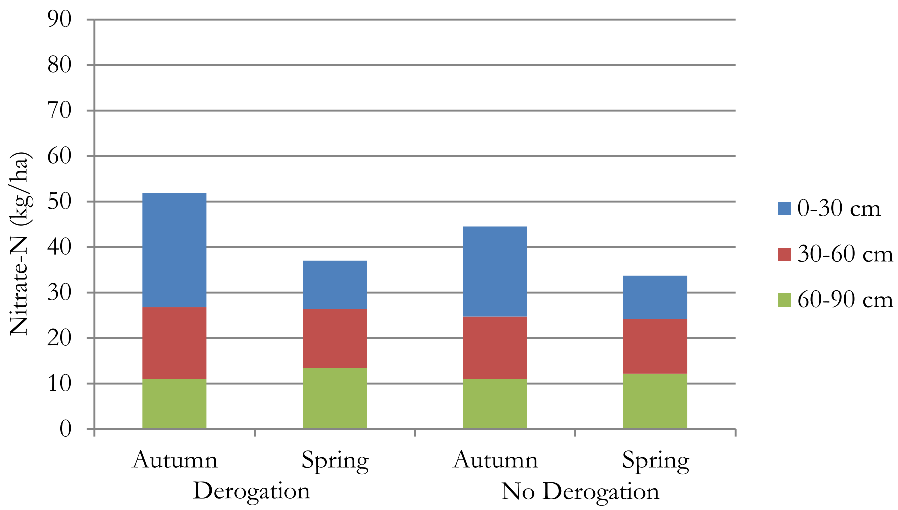


Figure 173: Average nitrate-N (kg/ha) in autumn 2016 and spring 2017 on derogation and no derogation parcels of the monitoring network, indicating the average nitrate-N difference-winter 2016-2017 on derogation and no derogation parcels.

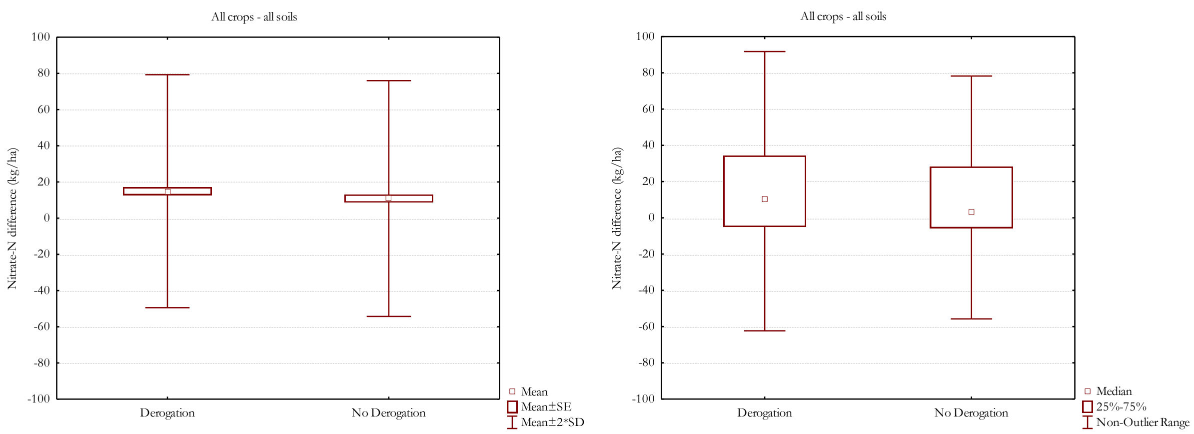


Figure 174: Boxplot of the nitrate-N difference-winter 2016-2017 (kg/ha) on derogation and no derogation parcels with all crops on all soil textures in the monitoring network. Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Despite all efforts to sample all parcels before February 15th, the date from which all sorts of fertilisers can be applied on both derogation and no derogation parcels on no focus farms, some parcels were sampled later.

Restricting the comparison to parcels sampled until February 15th, 389 parcels remain to evaluate the possible impact of derogation practices. The restriction of final sampling date to February 15th is the most stringent restriction regarding to the possibility of fertilisation, the restart of mineralisation in the soil and the restart of nutrient uptake by the plants. The average nitrate-N difference quantified on those 389 parcels was 10 ± 31 kg NO_3-N/ha.

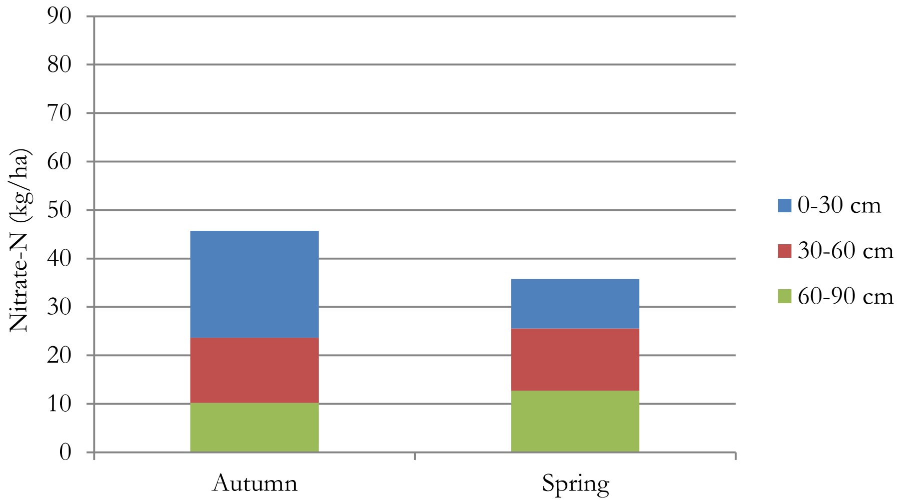


Figure 175: Average nitrate-N (kg/ha) on 389 parcels of the monitoring network in autumn 2016 and spring 2017 (sampled until 15.02.2017), indicating the average nitrate-N difference-winter 2016-2017.

The difference between the average nitrate-N differences quantified on all 449 parcels (13 ± 32 kg NO_3-N/ha) and the 389 early sampled parcels (10 ± 31 kg NO_3-N/ha) was not that large. However to avoid possible influencing parameters as restarted plant growth and nutrient uptake or early fertilisation, only parcels sampled until February 15th 2016 were withheld.

The further comparison of average change of nitrate-N on derogation and no derogation parcels will be based on the parcels sampled before mid-February (Table 48). Regardless of crop or soil type, the comparison of the average nitrate-N difference on derogation and no derogation parcels was made on 189 parcels with derogation and 200 parcels without derogation.

Table 48: Average nitrate-N difference-winter 2016-2017 (kg/ha) based on parcels sampled until February 15th, combined at different levels of comparison. The number of parcels included in the comparison is indicated by 'n'.

			Difference of nitrate-N (kg/ha)		
			n	Average	p-value
Overall mean monitoring network			389	10 ± 31	-
Derogation			189	11 ± 29	0.55
No derogation			200	9 ± 32	
Derogation	Sandy soil		98	20 ± 28	0.33
No derogation			103	12 ± 37	
Derogation	Sandy loam		91	1 ± 28	0.30
No derogation			97	6 ± 25	
Derogation	Sandy soil	Grass	34	15 ± 22	0.33
No derogation			47	8 ± 37	
Derogation	Sandy soil	Grass <50% clover	30	11 ± 20	0.79
No derogation			27	-2 ± 34	
Derogation	Sandy soil	Maize	34	33 ± 34	0.86
No derogation			29	31 ± 32	
Derogation	Sandy loam	Grass	50	4 ± 27	0.76
No derogation			54	6 ± 24	
Derogation	Sandy loam	Maize	41	-3 ± 29	0.31
No derogation			43	6 ± 26	

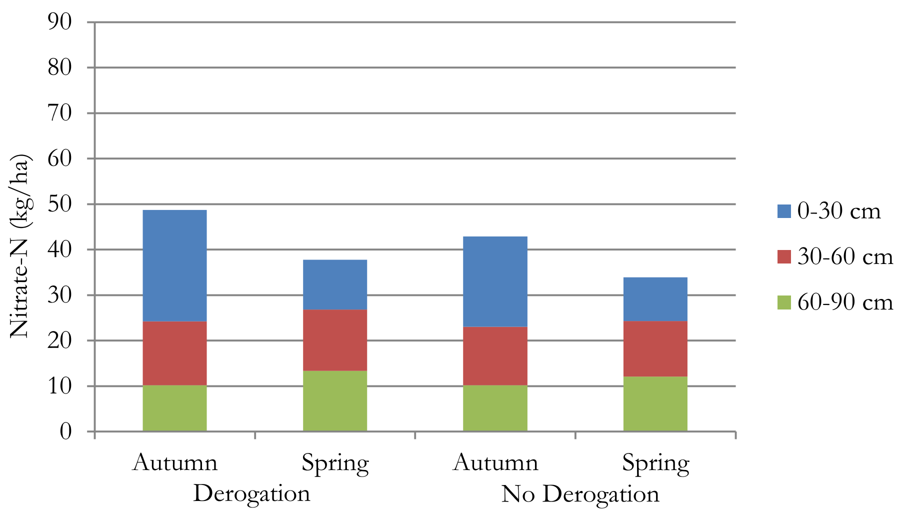


Figure 176: Average nitrate-N (kg/ha) in autumn 2016 and spring 2017 on derogation and no derogation parcels of the monitoring network, indicating the average nitrate-N difference during winter 2016-2017 on derogation and no derogation parcels. Sampling in spring until 15.02.2017

In winter 2016-2017, the average nitrate-N difference on derogation parcels was 11 ± 29 kg NO_3-N/ha. On parcels without derogation, the average nitrate-N difference in the monitoring network amounted 9 ± 32 kg NO_3-N/ha (Figure 176). The average nitrate-N difference on derogation and no derogation parcels did not differ statistically significant ($p = 0.55$).

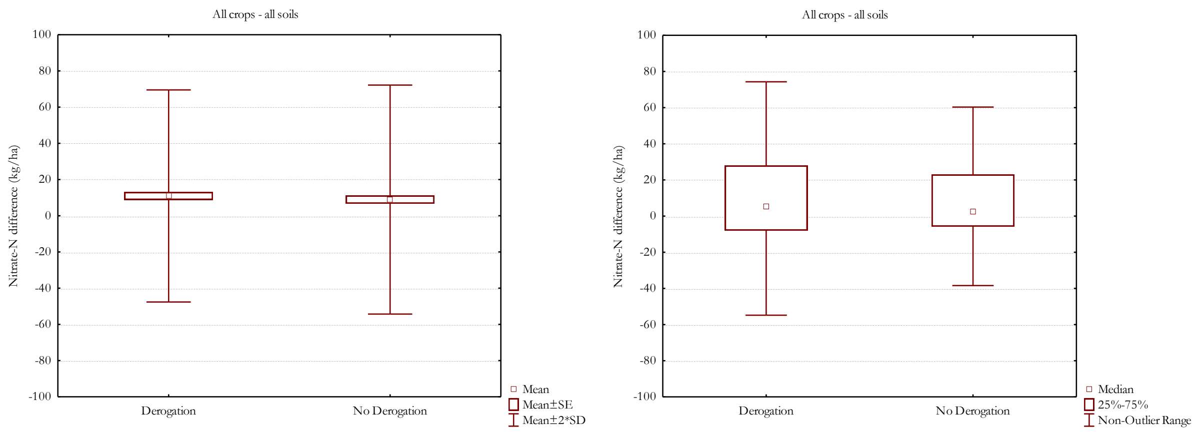


Figure 177: Boxplot of the nitrate-N difference-winter 2016-2017 (kg/ha) on derogation and no derogation parcels with all crops on all soil textures in the monitoring network. Sampling in spring until 15.02.2017 Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

All crops on sandy soils

On sandy soils, the average nitrate-N difference during winter 2016-2017 in the monitoring network was 16 ± 33 kg NO_3-N/ha.

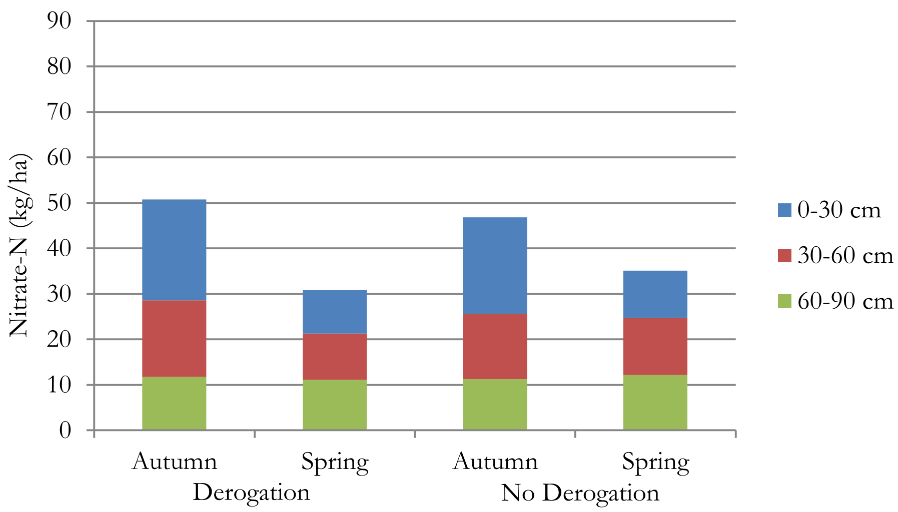


Figure 178: Average nitrate-N (kg/ha) in autumn 2016 and spring 2017 on derogation and no derogation parcels on sandy soils of the monitoring network, indicating the average nitrate-N difference during winter 2016-2017 on derogation and no derogation parcels on sandy soils. Sampling in spring until 15.02.2017

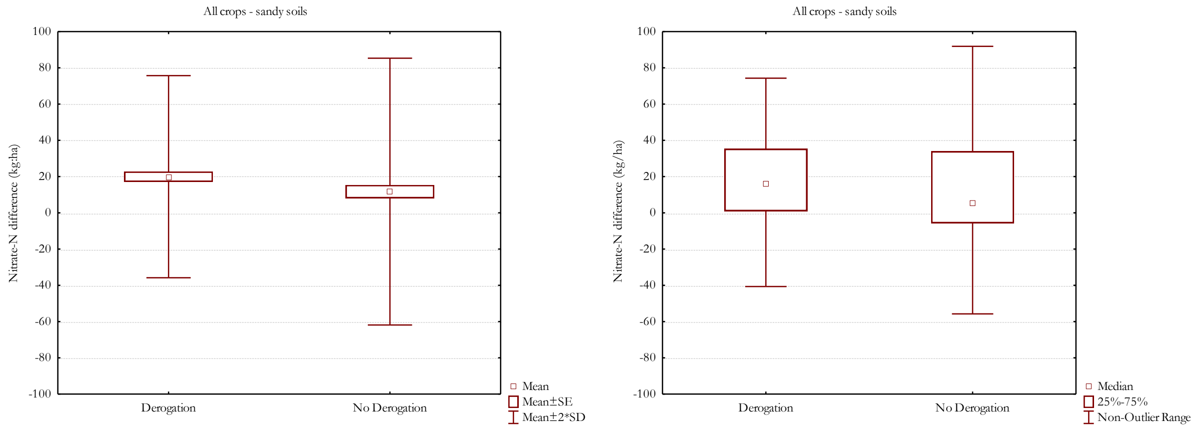


Figure 179: Boxplot of the nitrate-N difference-winter 2016-2017 (kg/ha) on derogation and no derogation parcels with all crops on sandy soils in the monitoring network. Sampling in spring until 15.02.2017 Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

On derogation parcels on sandy soils, this average nitrate-N difference was 20 ± 28 kg NO_3-N/ha. On sandy parcels without derogation, the average nitrate-N difference was 12 ± 37 kg NO_3-N/ha. The difference between derogation parcels and parcels without derogation on sandy soils regarding to the nitrate-N difference during winter 2016-2017 was not statistically significant ($p = 0.33$).

Grass on sandy soils

On sandy soils, 34 parcels cultivated with grass under derogation conditions were compared to 47 parcels without derogation. On the derogation parcels, the amount of nitrate-N in early spring was on average 15 ± 22 kg NO_3-N/ha lower as in autumn 2016. On the parcels cultivated with grass without derogation, the average nitrate-N difference was 8 ± 37 kg NO_3-N/ha.

The average nitrate-N difference on the sandy soils cultivated with grass under derogation conditions did not differ statistically significant of the average nitrate-N difference on the parcels without derogation ($p = 0.33$).

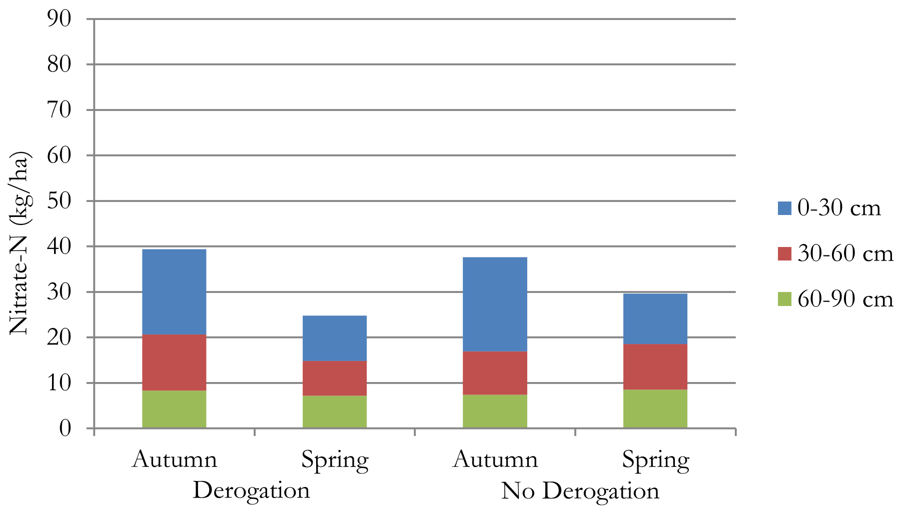


Figure 180: Average nitrate-N (kg/ha) in autumn 2016 and spring 2017 on derogation and no derogation parcels on sandy soils cultivated with grass of the monitoring network, indicating the average nitrate-N difference during winter 2016-2017 on derogation and no derogation parcels on sandy soils cultivated with grass. Sampling in spring until 15.02.2017

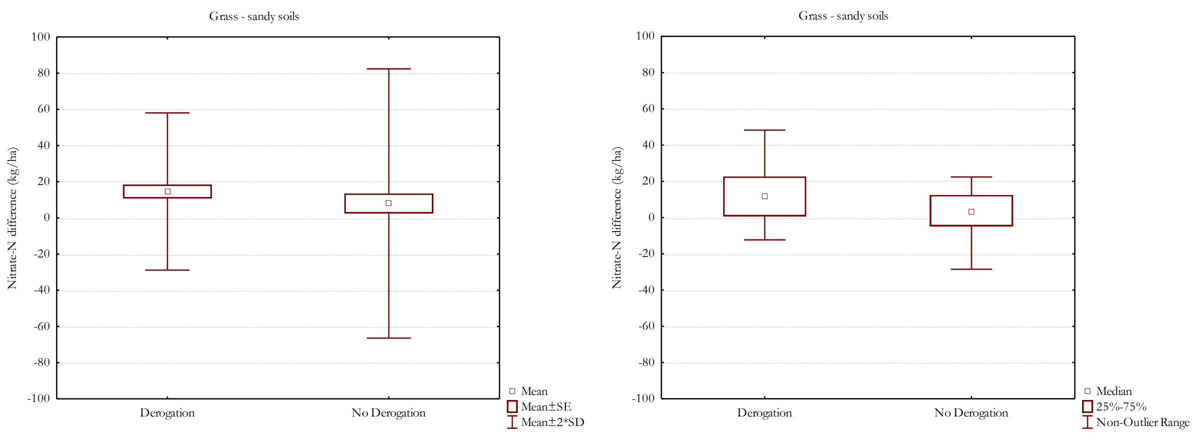


Figure 181: Boxplot of the nitrate-N difference-winter 2016-2017 (kg/ha) on derogation and no derogation parcels with grass on sandy soils in the monitoring network. Sampling in spring until 15.02.2017 Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Grass with less than 50 % clover on sandy soils

The average nitrate-N difference-winter 2016-2017 on sandy soils cultivated with grass and less than 50 % clover could be evaluated on 30 derogation parcels and 27 no derogation parcels. On the derogation parcels, the average nitrate-N difference was 11 ± 20 kg NO_3-N/ha. On the parcels without derogation, the calculated nitrate-N difference was -2 ± 34 kg NO_3-N/ha.

However, the average nitrate-N difference of 11 kg NO_3-N/ha on the derogation parcels did not differ significantly of the unchanged situation on the parcels without derogation ($p = 0.79$).

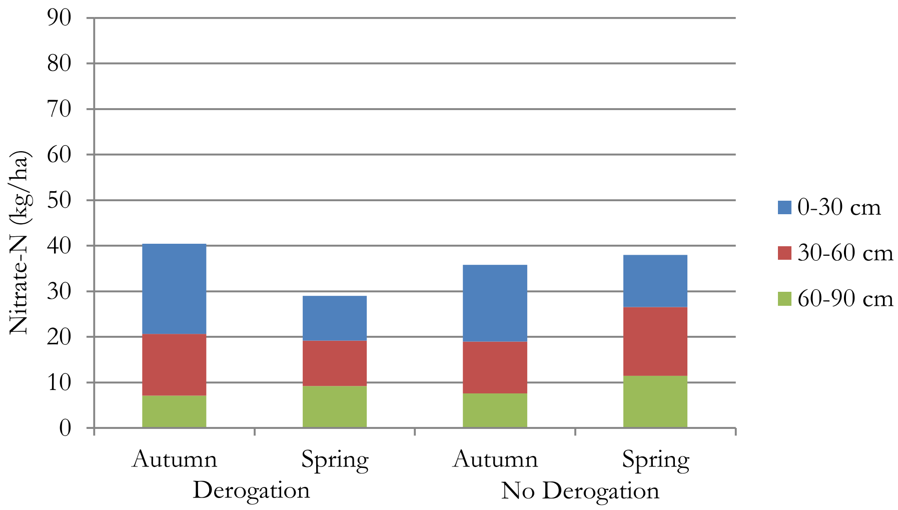


Figure 182: Average nitrate-N (kg/ha) in autumn 2016 and spring 2017 on derogation and no derogation parcels on sandy soils cultivated with grass and less than 50 % clover of the monitoring network, indicating the average nitrate-N difference during winter 2016-2017 on derogation and no derogation parcel on sandy soils cultivated with grass and less than 50 % clover. Sampling in spring until 15.02.2017

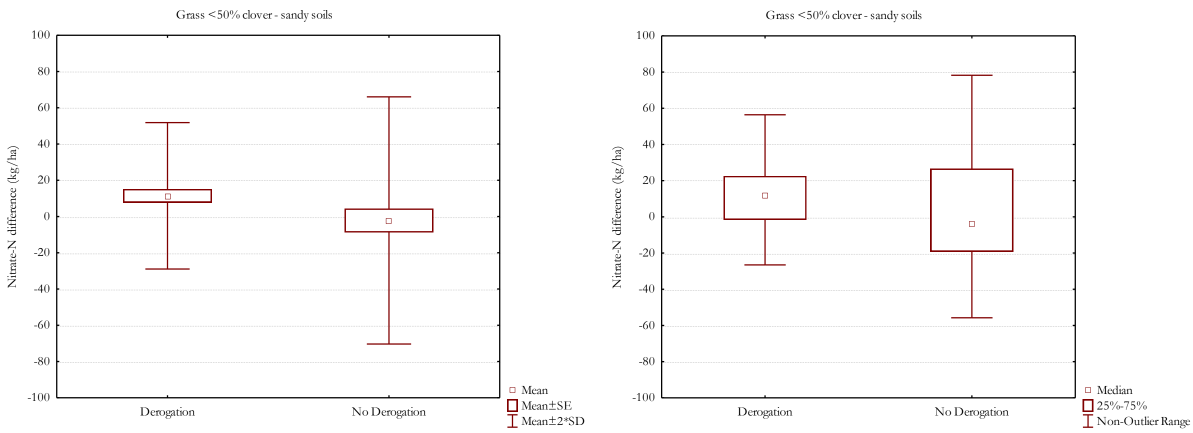


Figure 183: Boxplot of the nitrate-N difference-winter 2016-2017 (kg/ha) on derogation and no derogation parcels with grass and less than 50 % clover on sandy soils in the monitoring network. Sampling in spring until 15.02.2017 Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Maize on sandy soils

The evaluation of the nitrate-N difference on sandy soils cultivated with maize was realised on 63 parcels, 34 parcels with derogation and 29 parcels without derogation.

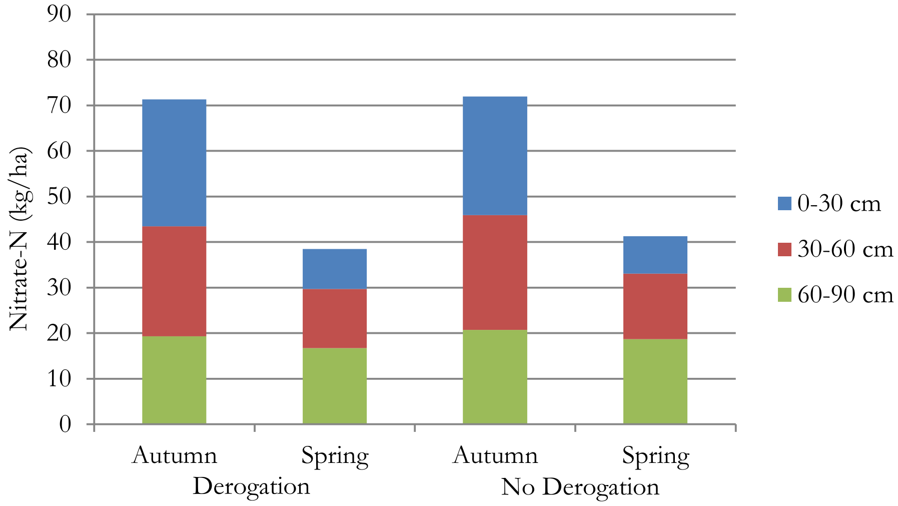


Figure 184: Average nitrate-N (kg/ha) in autumn 2016 and spring 2017 on derogation and no derogation parcels on sandy soils cultivated with maize of the monitoring network, indicating the average nitrate-N difference during winter 2016-2017 on derogation and no derogation parcels on sandy soils cultivated with maize. Sampling in spring until 15.02.2017

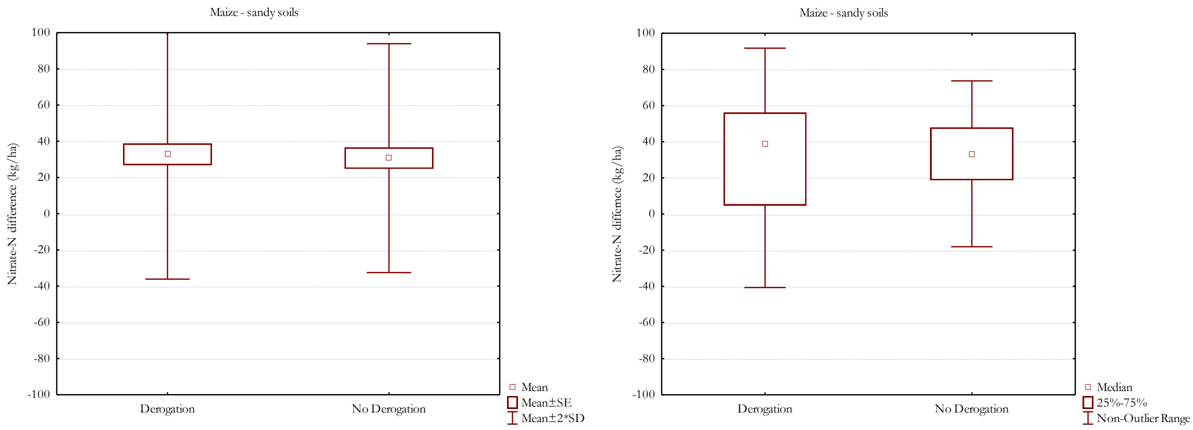


Figure 185: Boxplot of the nitrate-N difference-winter 2016-2017 (kg/ha) on derogation and no derogation parcels with maize on sandy soils in the monitoring network. Sampling in spring until 15.02.2017 Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

On the parcels with derogation, the average nitrate-N difference during winter 2016-2017 was 33 ± 35 kg NO_3-N/ha. Without derogation, the average nitrate-N difference on sandy parcels cultivated with maize was 31 ± 32 kg NO_3-N/ha. This little difference of nitrate-N difference between derogation and no derogation parcels was not statistically significant ($p = 0.86$). On the sandy parcels cultivated with maize, the average nitrate-N difference was highest (Table 48).

All crops on sandy loam soils

During winter 2016-2017, the average nitrate-N difference on sandy loam soils was 4 ± 26 kg NO_3-N/ha in the monitoring network. For the possible impact of derogation, 91 parcels with derogation could be compared with 97 parcels without derogation. The average nitrate-N difference on the sandy loams parcels with derogation was 1 ± 28 kg NO_3-N/ha. Without derogation, the average nitrate-N difference was 6 ± 25 kg NO_3-N/ha. For both groups of parcels the average nitrate-N difference was little and did not differ significantly between derogation and no derogation parcels ($p = 0.30$).

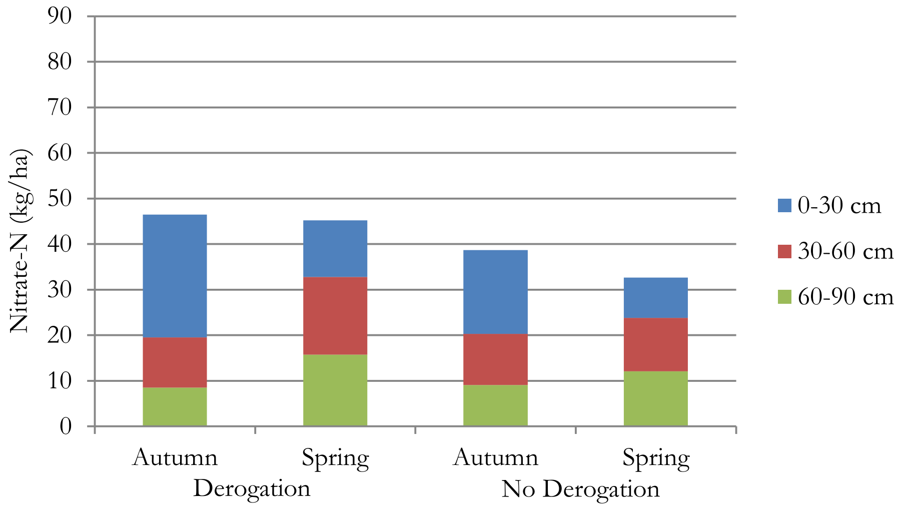


Figure 186: Average nitrate-N (kg/ha) in autumn 2016 and spring 2017 on derogation and no derogation parcels on sandy loam soils of the monitoring network, indicating the average nitrate-N difference during winter 2016-2017 on derogation and no derogation parcels on sandy loam soils. Sampling in spring until 15.02.2017

In Figure 186, the reallocation of the nitrate-N over the different soil layers of the soil profile during winter 2016-2017 is perfectly noticeable. The upper layer became poorer in nitrate-N while the layers below were enriched with nitrate-N.

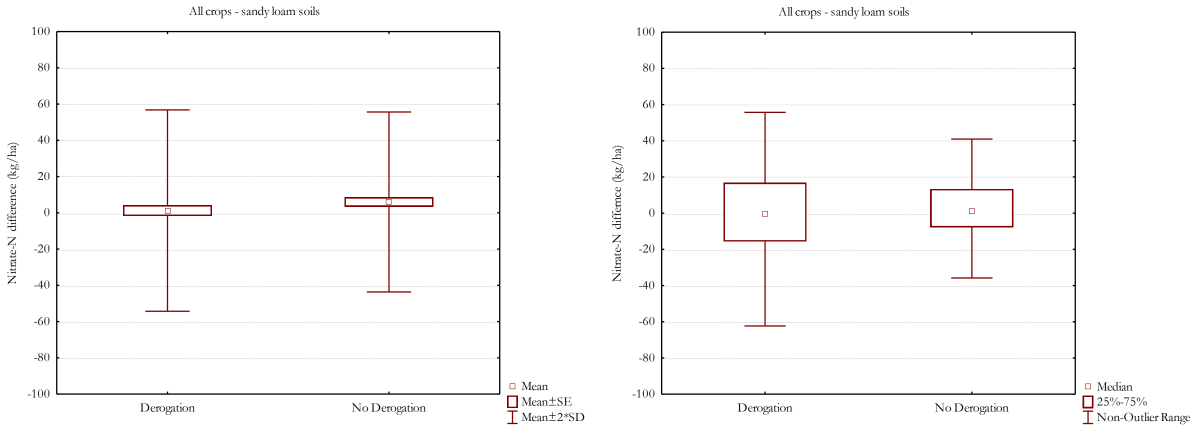


Figure 187: Boxplot of the nitrate-N difference-winter 2016-2017 (kg/ha) on derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network. Sampling in spring until 15.02.2017 Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Grass on sandy loam soils

Grass on sandy loam soils is evaluated by comparing 50 parcels with derogation and 54 parcels without derogation. Under derogation conditions, the average nitrate-N difference on sandy loam soils with grass was 4 ± 27 kg NO_3-N/ha (Figure 188). Without derogation, the average nitrate-N difference was 6 ± 24 kg NO_3-N/ha. This small difference in average nitrate-N difference was not statistically significant ($p = 0.76$).

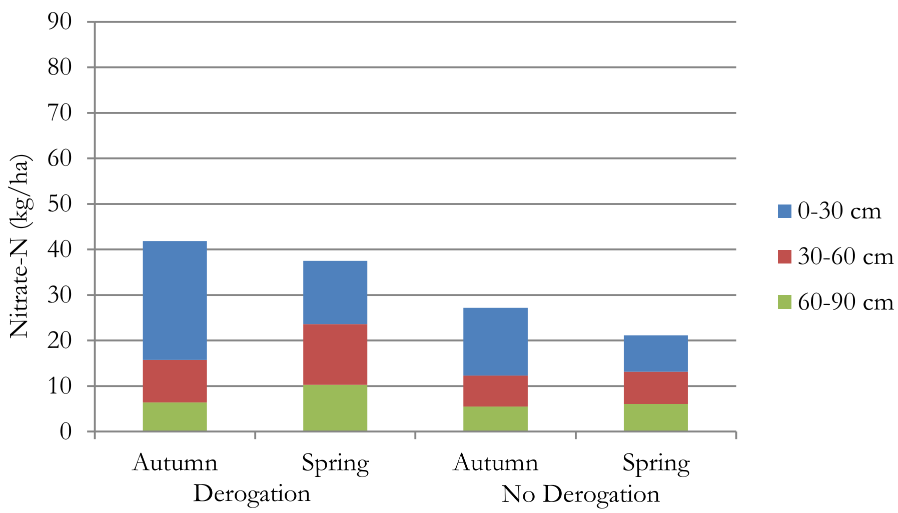


Figure 188: Average nitrate-N (kg/ha) in autumn 2016 and spring 2017 on derogation and no derogation parcels on sandy loam soils cultivated with grass of the monitoring network, indicating the average nitrate-N difference during winter 2016-2017 on derogation and no derogation parcels on sandy loam soils cultivated with grass. Sampling in spring until 15.02.2017

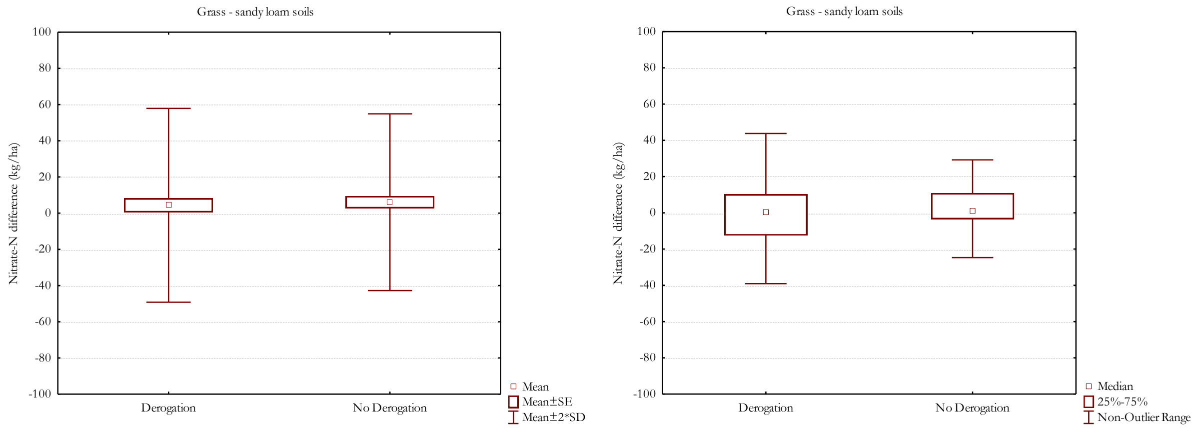


Figure 189: Boxplot of the nitrate-N difference-winter 2016-2017 (kg/ha) on derogation and no derogation parcels with grass on sandy loam soils in the monitoring network. Sampling in spring until 15.02.2017 Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Maize on sandy loam soils

On sandy loam soils cultivated with maize in 2016, 41 parcels with derogation were compared with 43 parcels without derogation to monitor the possible impact of derogation on the nitrate-N difference.

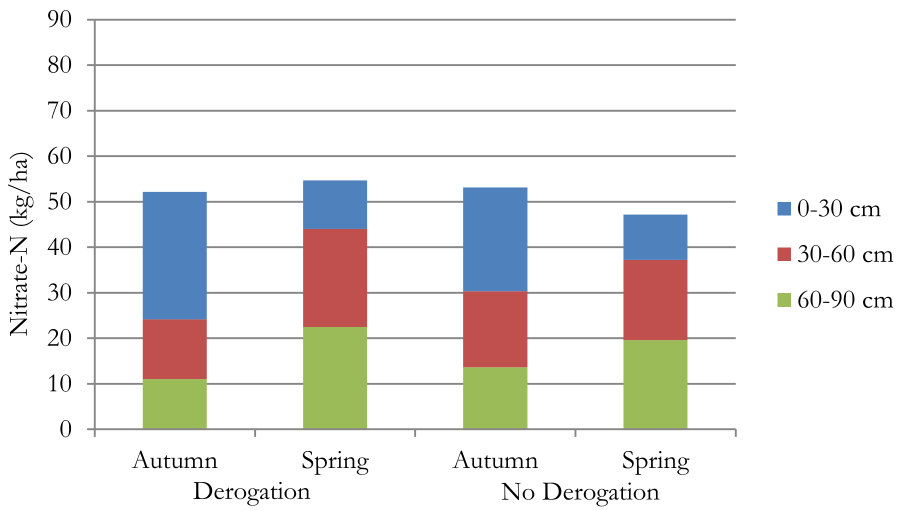


Figure 190: Average nitrate-N (kg/ha) in autumn 2016 and spring 2017 on derogation and no derogation parcels on sandy loam soils cultivated with maize of the monitoring network, indicating the average nitrate-N difference during winter 2016-2017 on derogation and no derogation parcels on sandy loam soils cultivated with maize. Sampling in spring until 15.02.2017

On the derogation parcels nearly nothing changed, the average nitrate-N difference was -3 ± 29 kg NO_3-N/ha. The average nitrate-N difference on parcels without derogation was 6 ± 26 kg NO_3-N/ha. Derogation and no derogation parcels on sandy loam soils cultivated with maize in 2016 did not differ significantly regarding to the nitrate-N difference between autumn 2016 and early spring 2017 ($p = 0.31$).

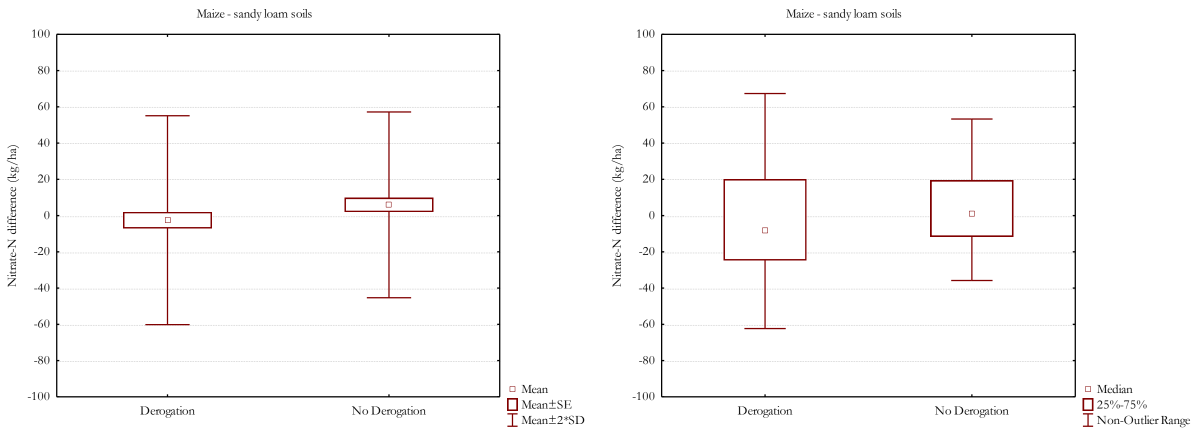


Figure 191: Boxplot of the nitrate-N difference-winter 2016-2017 (kg/ha) on derogation and no derogation parcels with maize on sandy loam soils in the monitoring network. Sampling in spring until 15.02.2017 Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Out of the scope of the monitoring network but worth to show, are the average nitrate-N differences on sand and sandy loam soils and the average nitrate-N differences on parcels cultivated with grass, grass and less than 50 % clover and maize in the monitoring network between sampling in autumn 2016 and early spring 2017.

On sandy soils the average nitrate-N difference was 16 ± 33 kg NO_3-N/ha between autumn 2016 and early spring 2017 in the monitoring network, based on 201 evaluated parcels (Figure 192). To determine the average nitrate-N difference on sandy loam soils 188 parcels were evaluated. The average nitrate-N difference on sandy loam soils was 4 ± 26 kg NO_3-N/ha in the monitoring network.

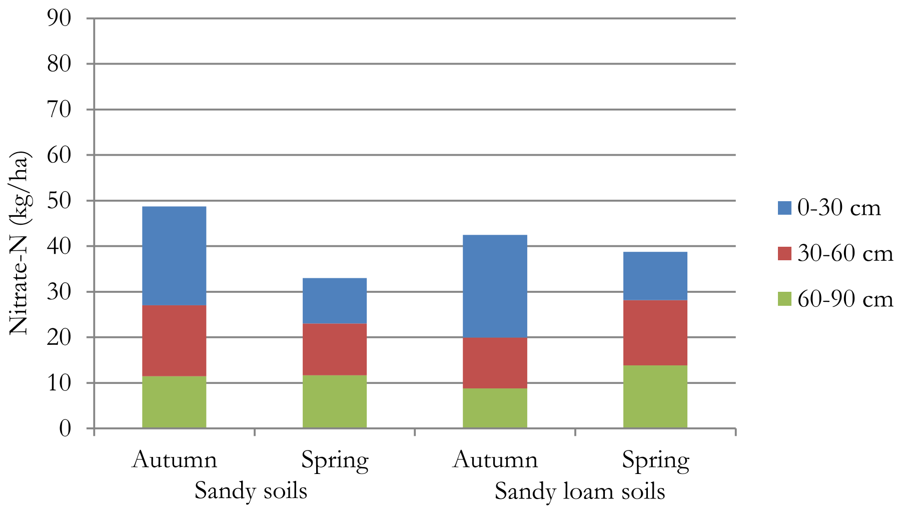


Figure 192: Average nitrate-N (kg/ha) in autumn 2016 and spring 2017 on sandy and sandy loam soils of the monitoring network, indicating the average nitrate-N difference during winter 2016-2017 on sandy and sandy loam soils cultivated with all crops. Sampling in spring until 15.02.2017

On parcels cultivated with grass and grass with less than 50 % clover, the average nitrate-N residue was small in autumn 2016 and little changed until spring 2017 in the monitoring network. On parcels cultivated with maize, the average nitrate-N residue in autumn 2016 was higher than on the parcels cultivated with grass or grass with less than 50 % clover but was still at a low level. The average nitrate-N difference on those parcels was 15 ± 33 kg NO_3-N/ha. For these comparisons 185 parcels cultivated with grass, 57 parcels cultivated with grass and less than 50 % clover and 147 parcels cultivated with maize were evaluated.

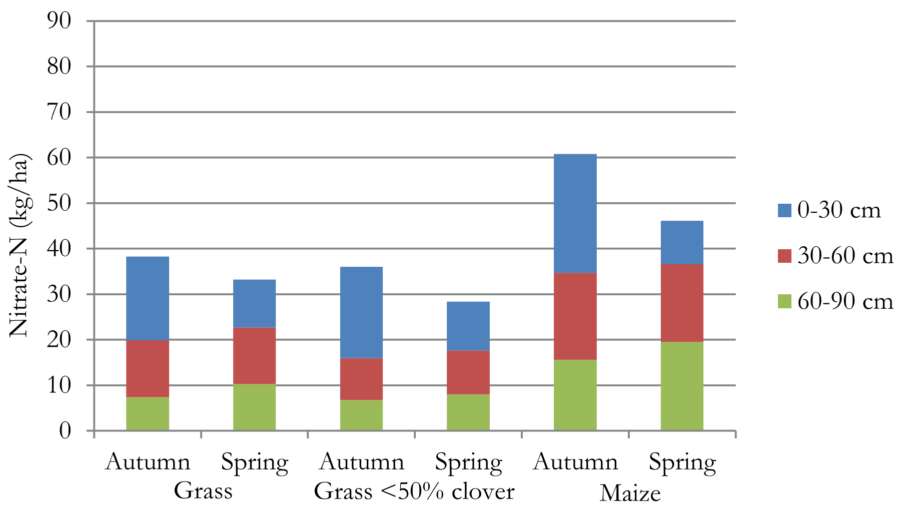


Figure 193: Average nitrate-N (kg/ha) in autumn 2016 and spring 2017 on parcels cultivated with grass, grass and less than 50 % clover or maize of the monitoring network, indicating the average nitrate-N difference during winter 2016-2017 on parcels cultivated with grass, grass and less than 50 % clover or maize on all soils. Sampling in spring until 15.02.2017

3.2.1.4 Mineral nitrogen - at parcel level - autumn 2017

All 480 of the monitoring network 2017 were sampled between October 1st and November 15th. Because of drought in 2017, 16 parcels could not be sampled down to 90 cm: 14 parcels cultivated with grass, 1 parcel cultivated with grass and less than 50 % clover and 1 parcel cultivated with maize; 8 derogation parcels and 8 parcels without derogation on both sandy soils (9 parcels) and sandy loam soils (7 parcels). Those 16 parcels were discarded from further analysis.

For further evaluation 464 parcels sampled down to 90 cm remained.

Before evaluation of the possible impact of derogation regarding to the nitrate-N residue, the main crop, the crop and culture management were reviewed. Six parcels were judged not to be suited for the comparison of derogation and non-derogation practices and were discarded for the further process. On two parcels, the main crop was changed without warning the research team. These parcels were a parcel with derogation on sandy soil and a parcel without derogation on sandy loam soil. The 4 other parcels were parcels cultivated with grass which were converted and sown again. Two of them were derogation parcels on sandy soils and the other 2 were parcels without derogation on sandy loam soils.

For comparison of the **nitrate-N residue of autumn 2017** under derogation and no derogation practices **458 parcels** remained.

The variation of the nitrate-N residue on those parcels is indicated in Figure 194. The statistical analysis of the data of the nitrate-N residue is performed on the logarithm of the nitrate-N residue. The variation of the log-transformed data is shown in Figure 195.

The average nitrate-N residue on the 458 finally evaluated parcels was 73 ± 59 kg NO_3-N/ha (Table 49). Unlike 2016, the average nitrate-N residue in the monitoring network was rather high in autumn 2017. A clear effect of year and thus climate appears.

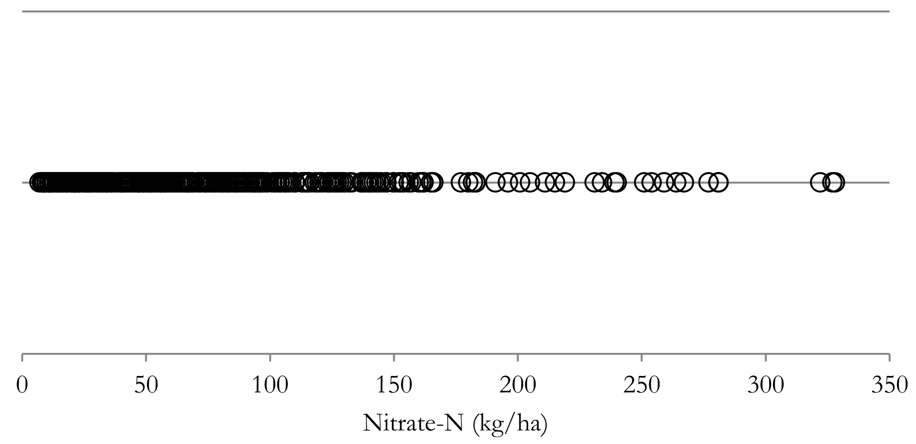


Figure 194: Spreading of the amount of nitrate-N in 458 parcels suited for comparison of derogation and non-derogation practices in autumn 2017.

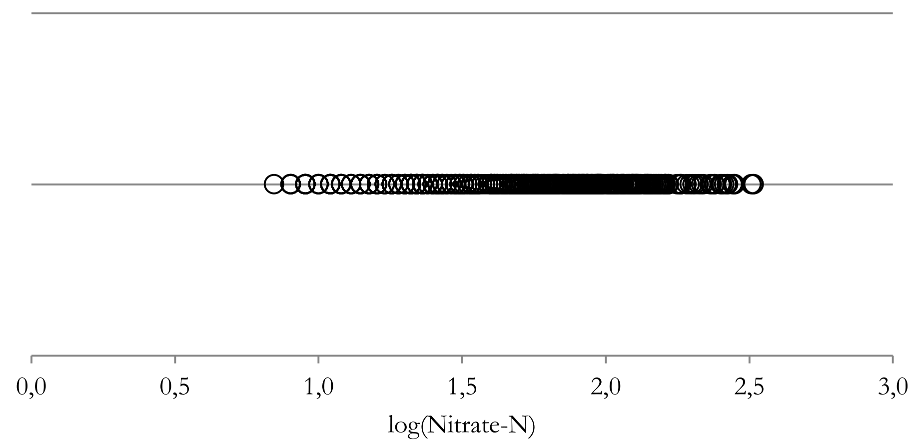


Figure 195: Spreading of the log-transformed nitrate-N (log(Nitrate-N)) in 458 parcels suited for comparison of derogation and non-derogation practices in autumn 2017.

Table 49: Average nitrate-N in the soil profile (0-90 cm) and per soil layer (0-30 cm, 30-60 cm and 60-90 cm) and median value of nitrate-N for the 458 parcels combined at different levels of comparison in autumn 2017. The number of parcels included in the comparison is indicated by 'n'.

			Nitrate-N (kg/ha)						p-value
			n	0-30 cm	30-60 cm	60-90 cm	0-90 cm	Median	
Overall mean monitoring network			458	34	24	14	73	58	-
Derogation			229	36	24	14	74	63	0.03
No derogation			229	32	24	14	71	53	
Derogation	Sandy soil		128	30	29	17	77	63	0.13
No derogation			130	30	27	16	73	53	
Derogation	Sandy loam		101	43	17	9	70	65	0.14
No derogation			99	35	21	13	69	53	
Derogation	Sandy soil	Grass	49	24	27	18	69	61	0.07
No derogation			50	23	18	12	52	33	
Derogation	Sandy soil	Grass <50% clover	29	17	21	16	54	45	0.44
No derogation			30	16	21	15	52	37	
Derogation	Sandy soil	Maize	50	45	36	18	98	91	0.91
No derogation			50	46	39	21	106	92	
Derogation	Sandy loam	Grass	50	33	14	8	55	40	0.02
No derogation			48	20	8	7	35	22	
Derogation	Sandy loam	Maize	51	53	21	11	85	78	0.71
No derogation			51	50	34	18	101	80	

The comparison of the nitrate-N residue on derogation and no derogation parcels, regardless of crop or soil type, was performed with 229 parcels with derogation and 229 parcels without derogation. On derogation parcels, the average nitrate-N residue amounted 74 ± 51 kg NO_3-N/ha in autumn 2017 (Figure 196). On the parcels without derogation, the average nitrate-N residue was 71 ± 65 kg NO_3-N/ha. Despite the very small difference of only 3 kg NO_3-N/ha, it appears to be statistically significant (p = 0.03). Since the statistical analysis is performed on the log-transformed data, the variation of the nitrate-N residue is shown in the boxplots of the log-transformed nitrate-N residue (Figure 197).

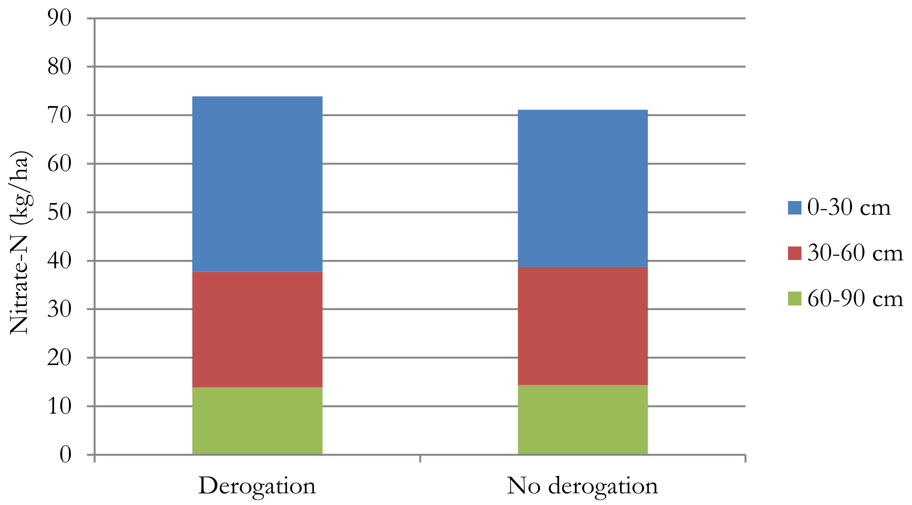


Figure 196: Average nitrate-N (kg/ha) on derogation and no derogation parcels with all crops on all soils in the monitoring network in autumn 2017.

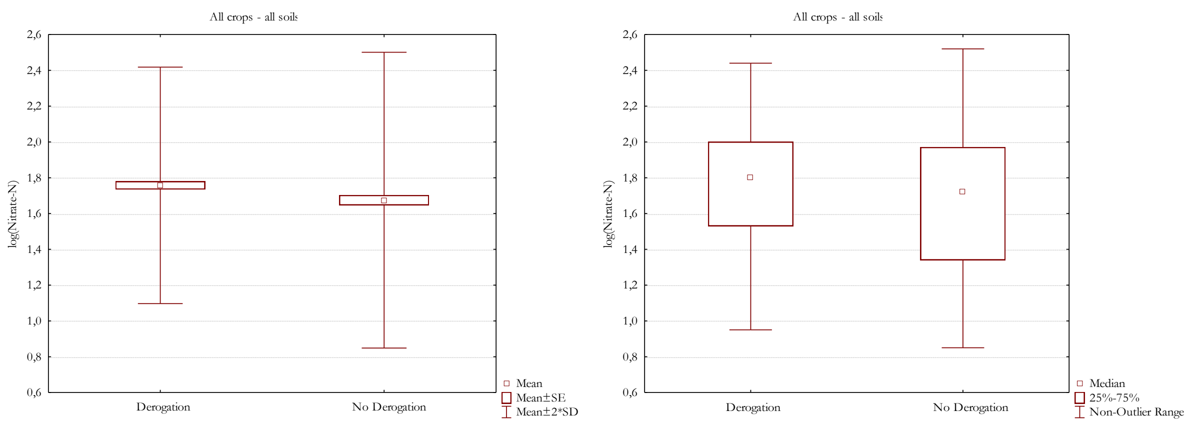


Figure 197: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with all crops on all soil textures in the monitoring network in autumn 2017. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

The impact of derogation or not on the nitrate-N residue in the monitoring network is also visualised in Figure 198. Per category of nitrate-N residue the percentage derogation and no derogation parcels is indicated. These results are cumulative presented by the curves, which indicate which percentage of the parcels respects a certain level of nitrate-N residue.

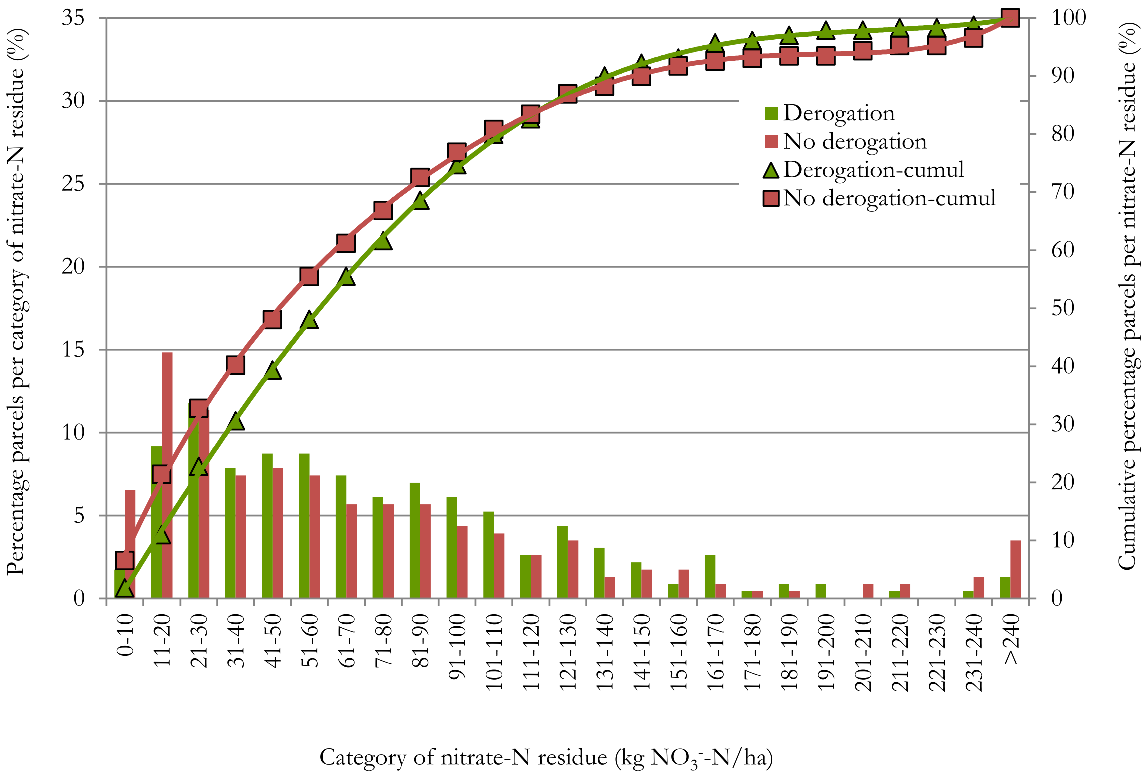


Figure 198: Distribution of the derogation (green columns) and no derogation parcels (red columns) (%) of the monitoring network in the different categories of nitrate-N residue (kg NO3-N/ha) and cumulative percentage of derogation (green curve) and no derogation (red curve) parcels of the monitoring network which respect a certain value of nitrate N-residue. Autumn 2017.

Without derogation, more parcels with very low amounts of nitrate-N to a maximum of 20 kg NO_3-N/ha were registered. More derogation parcels had a nitrate-N residue between 31 kg NO_3-N/ha and 100 kg NO_3-N/ha in comparison with no derogation parcels. Forty eight % of the parcels without derogation had a nitrate-N residue of maximum 50 kg NO_3-N/ha. On 48 % of the parcels with derogation, the nitrate-N residue was maximum 60 kg NO_3-N/ha. Ninety percent of the derogation parcels showed a maximal nitrate-N residue of 140 kg NO_3-N/ha. On 90 % of the parcels without derogation, the maximal nitrate-N residue was 150 kg NO_3-N/ha.

Within the nitrate-N residues of the 458 parcels, 3 outlying values were detected. All three values were measured on parcels without derogation conditions, cultivated with grass, grass and less than 50 % clover and maize, on sandy soils (2 parcels, grass with and without clover) and on sandy loam soil (1 parcel-maize). The outlying nitrate-N residues amounted 322, 327 and 328 kg NO_3-N/ha. The outliers will be discussed in more detail in the following paragraphs when the parcels are part of discussed groups. Again, the outliers are not discarded but withheld in the analysed dataset.

All crops on sandy soils

The comparison between derogation and no derogation parcels on sandy soils involves 258 parcels, 128 derogation parcels and 130 parcels without derogation. On sandy soils, the average nitrate-N residue in autumn 2017 in the monitoring network was 75 ± 60 kg NO_3-N/ha. When derogation was requested the average nitrate-N residue on sandy soils amounted 77 ± 54 kg NO_3-N/ha (Figure 199).Without derogation the average nitrate-N residue was 73 ± 56 kg NO_3-N/ha. There was no statistical significant difference (p = 0.13).

On sandy soils, 2 outlying nitrate-N residues were detected, both on parcels without derogation. The main crop of these parcels was grass or grass and less than 50 % clover.

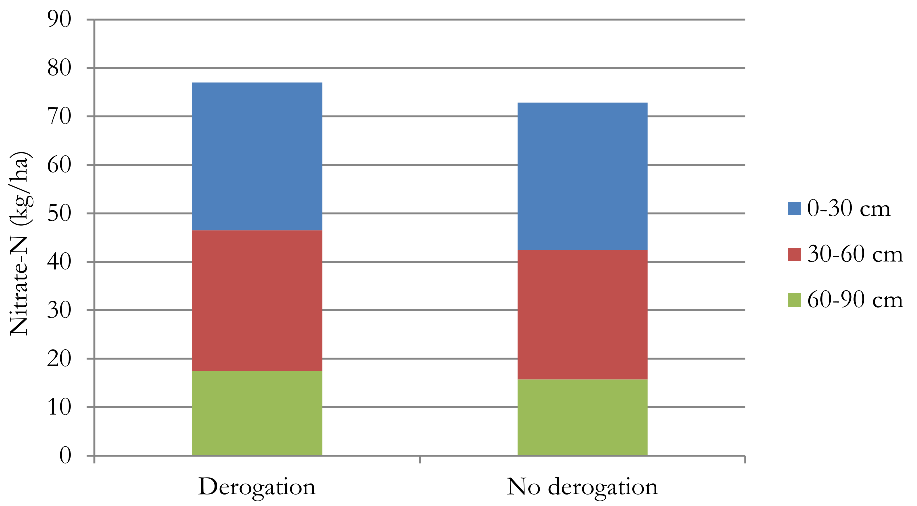


Figure 199: Average nitrate-N (kg/ha) on derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2017.

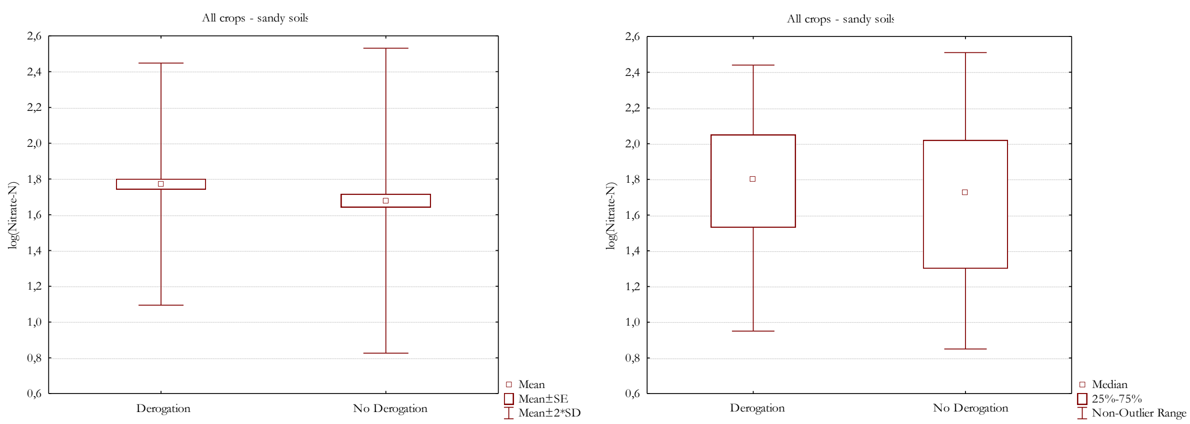


Figure 200: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Grass on sandy soils

On sandy soils, 99 parcels remained for the comparison of the nitrate-N residue with or without derogation. The average nitrate-N residue of the 49 derogation parcels was 69 ± 50 kg NO_3-N/ha (Figure 201). On the 50 parcels cultivated with grass on sandy soils without derogation, the average nitrate-N residue was 52 ± 54 kg NO_3-N/ha. The difference in nitrate-N residue between derogation and no derogation parcels cultivated with grass on sandy soils was not statistically significant (p = 0.07).

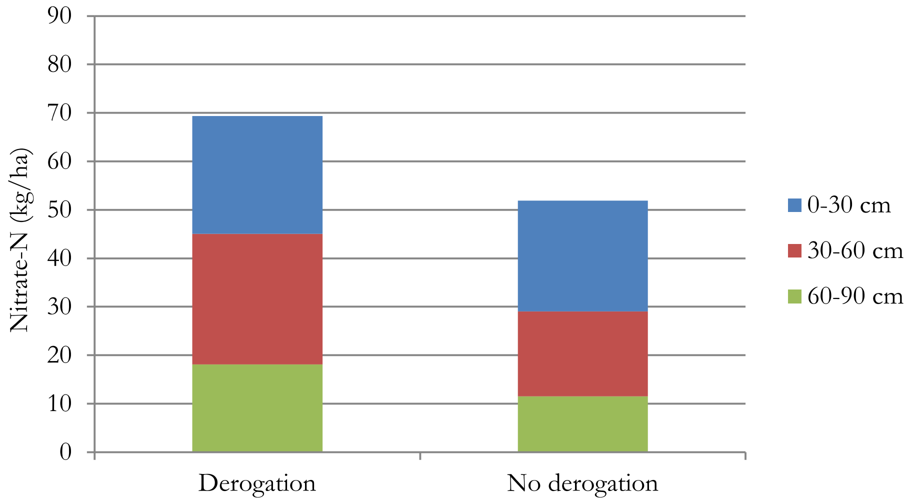


Figure 201: Average nitrate-N (kg/ha) on derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2017.

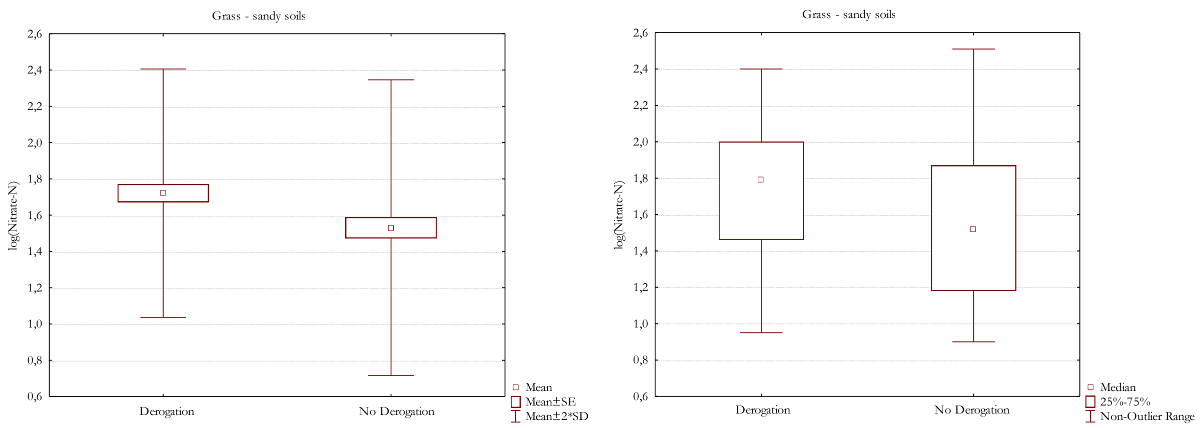


Figure 202: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

One of the detected outlying nitrate-N residues was measured on a parcel cultivated with grass on sandy soil without derogation. The nitrate-N residue on this parcel amounted 322 kg NO_3-N/ha. The majority of the load of nitrate-N was situated in the upper soil layer of 30 cm (241 kg NO_3-N/ha). It was a rather intense grazed parcel and it was grazed until shortly before sampling for the nitrate-N residue. No elevated levels of ammonium-N were measured. Without this outlier, the difference increases to 23 kg NO_3-N/ha.

Grass with less than 50 % clover on sandy soils

The evaluation of derogation on parcels cultivated with grass and less than 50 % clover is restricted to sandy soils. In autumn 2017, 29 derogation and 30 parcels without derogation could be compared. On derogation parcels, the average nitrate-N residue was 54 ± 46 kg NO_3-N/ha (Figure 203). On no derogation parcels, it was 52 ± 62 kg NO_3-N/ha. The average nitrate-N residue on sandy parcels cultivated with grass and less than 50 % clover did not differ statistically between derogation and no derogation parcels ($p = 0.44$) in the monitoring network in autumn 2017.

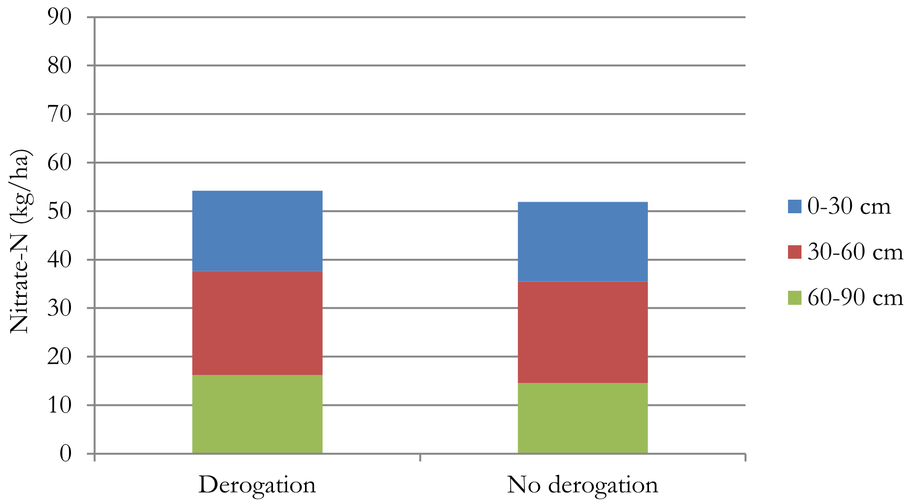


Figure 203: Average nitrate-N (kg/ha) on derogation and no derogation parcels with grass and less than 50 % clover on sandy soils in the monitoring network in autumn 2017.

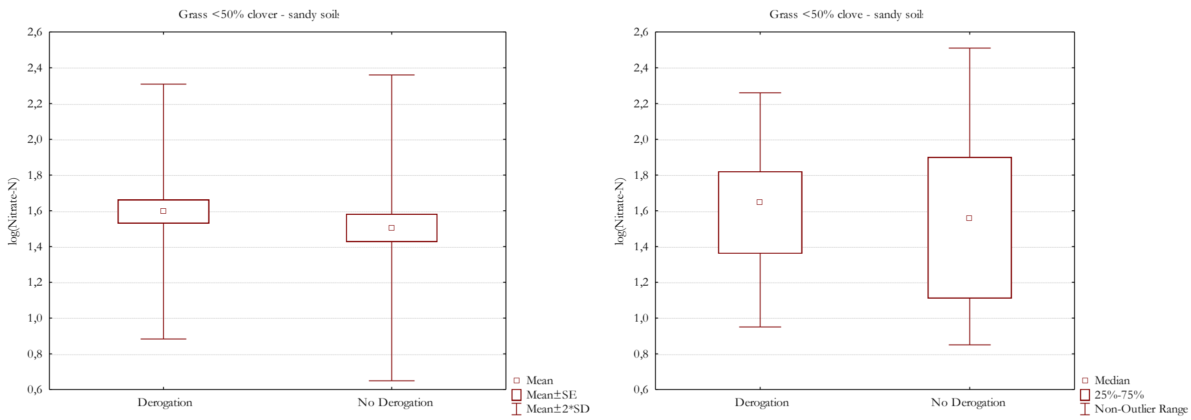


Figure 204: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with grass and less than 50 % clover on sandy soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

One of the outliers of the nitrate-N residue among the 458 values was measured on a parcel cultivated with grass and less than 50 % clover without derogation. The nitrate-N residue amounted 327 kg NO_3-N/ha. Notwithstanding no derogation is requested, the parcels at this farm are managed intensively, both regarding to fertilisation and production. A clear reason for the high nitrate-N residue could not be found since the level of fertilisation and production was the same as on the other monitored parcels on which the nitrate-N residues amounted 9 and 87 kg NO_3-N/ha. Without the outlier the average nitrate-N residue on no derogation parcels cultivated with grass and less than 50 % clover was 42 ± 35 kg NO_3-N/ha. Still derogation and no derogation parcels did not differ statistically regarding to the nitrate-N residue ($p = 0.31$).

Maize on sandy soils

On sandy soils of both 50 derogation and 50 no derogation parcels the nitrate-N residue could be compared. The average nitrate-N residue on sandy parcels cultivated with maize was 102 ± 61 kg NO_3-N/ha in the monitoring network in autumn 2017. When derogation was requested, the average nitrate-N residue was 98 ± 55 kg NO_3-N/ha (Figure 205). Without derogation, the average nitrate-N residue was 106 ± 67 kg NO_3-N/ha on sandy parcels cultivated with maize. The difference between derogation and no derogation parcels was not statistically significant ($p = 0.91$).

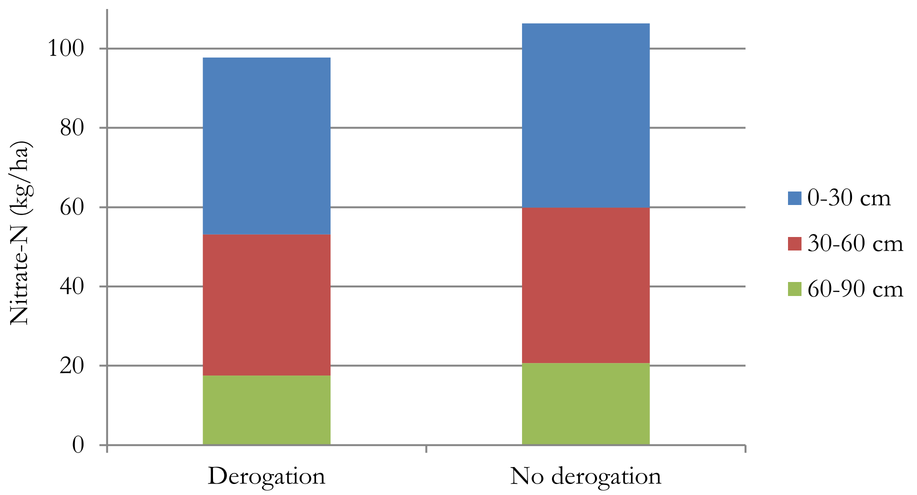


Figure 205: Average nitrate-N (kg/ha) on derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2017.

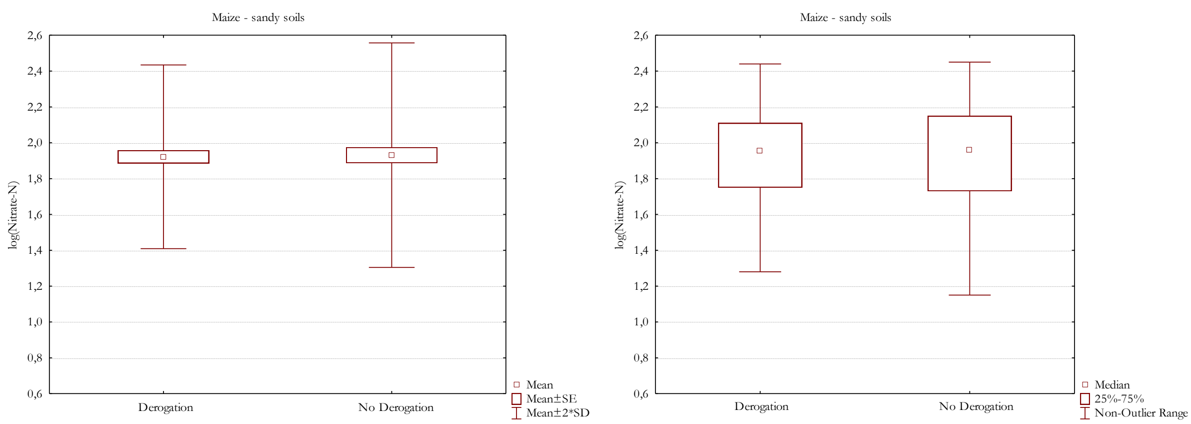


Figure 206: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

All crops on sandy loam soils

On sandy loam soils, the nitrate-N residue of 200 parcels could be evaluated. The average nitrate-N residue on sandy loam soils in the monitoring network in autumn 2017 was 69 ± 56 kg NO_3-N/ha. The comparison of derogation and no derogation practices in this group was based on 101 parcels with derogation and 99 parcels without derogation. With derogation, the average nitrate-N residue was 70 ± 48 kg NO_3-N/ha, without derogation 69 ± 64 kg NO_3-N/ha (Figure 207). This little difference between derogation and no derogation parcels was not statistically significant (p = 0.14).

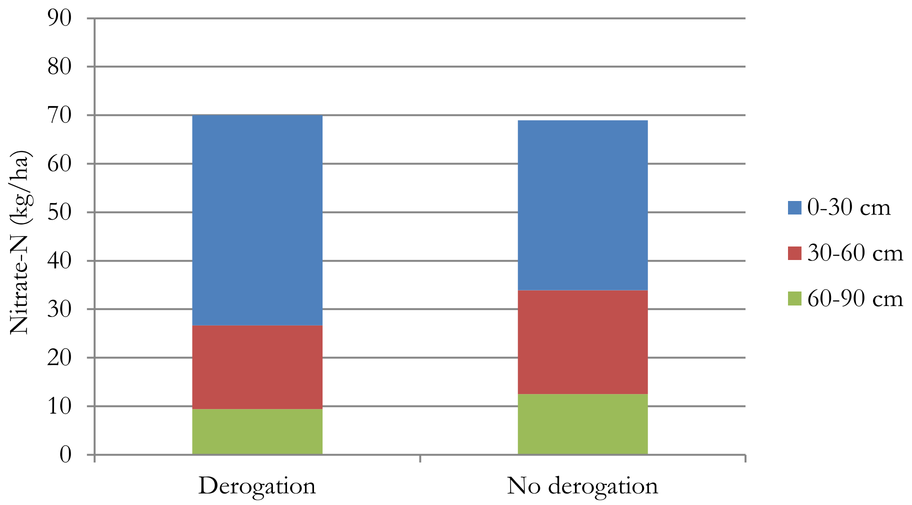


Figure 207: Average nitrate-N (kg/ha) on derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network in autumn 2017.

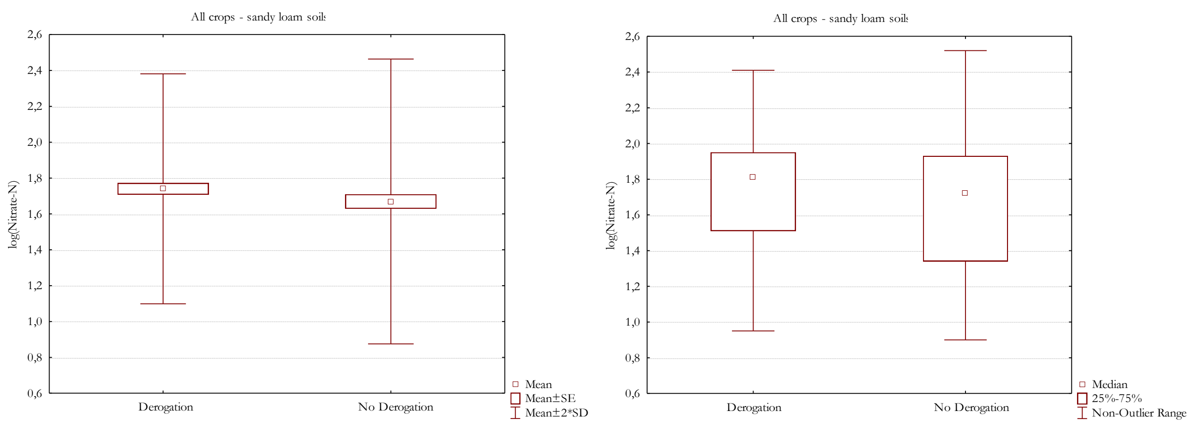


Figure 208: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

On sandy loam soils, 1 outlier was detected: a parcel cultivated with maize without derogation. Without the outlying value, the average nitrate-N residue on sandy loam soils was 68 ± 53 kg NO_3-N/ha. On sandy loam parcels without derogation, the average nitrate-N residue was 66 ± 59 kg NO_3-N/ha. The difference between derogation and no derogation parcels was not statistically significant ($p = 0.12$).

Grass on sandy loam soils

The comparison of the nitrate-N residue on sandy loam parcels cultivated with grass with or without derogation was performed on 98 parcels, 50 parcels with derogation and 48 parcels without derogation. On the derogation parcels, the average nitrate-N residue was 55 ± 51 kg NO_3-N/ha (Figure 209). On the sandy loam parcels with grass without derogation, the average nitrate-N residue was 35 ± 29 kg NO_3-N/ha. The average nitrate-N residue on sandy loam parcels cultivated with grass was significantly different between derogation and no derogation parcels ($p = 0.02$).

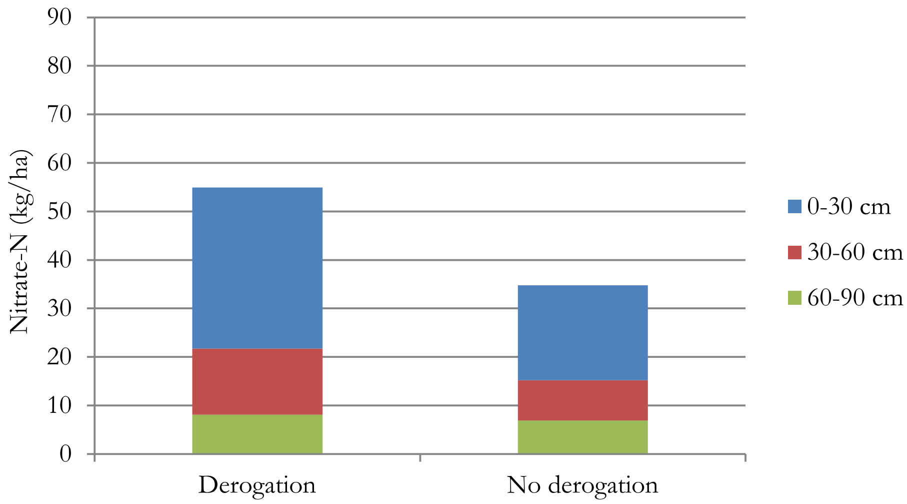
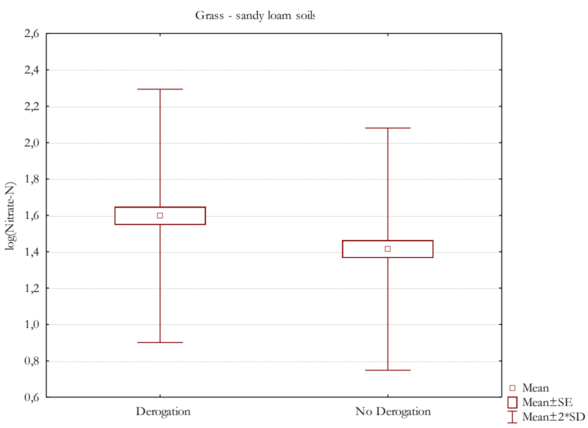


Figure 209: Average nitrate-N (kg/ha) on derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2017.



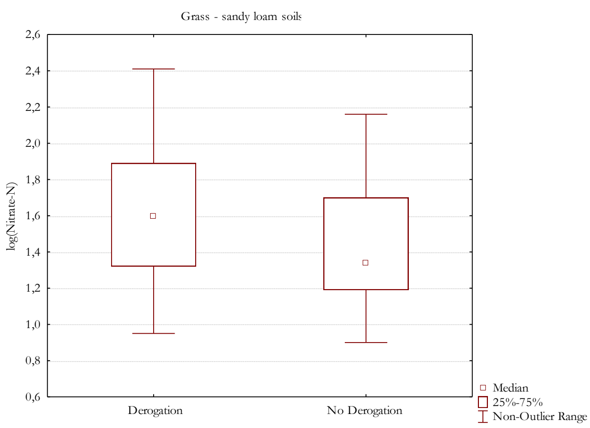


Figure 210: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Although none of the detected outlying values was a sandy loam parcel cultivated with grass, the data were further explored (Figure 211). Four higher values measured on derogation parcels have an important influence. Two parcels of those four, the parcels with the highest nitrate-N residues in Figure 211, were parcels that were only cut. They belong to the same farm. Moreover, in 2016 one of the parcels with an outlying value belonged also to this farm. This finding supports the importance of the parameter 'Farm', which is, moreover, included in the statistical analysis as a random categorical factor.

The other two parcels of the group of 4 higher values, were both parcels that were only grazed and very intensively. They were both the pastures adjacent to the farm. The pasture adjacent to the farm often involves a higher risk of more elevated nitrate-N residues, with or without derogation, because of periods with a denser occupation of the parcels with cattle and because daily traffic of the cattle throughout the pasture

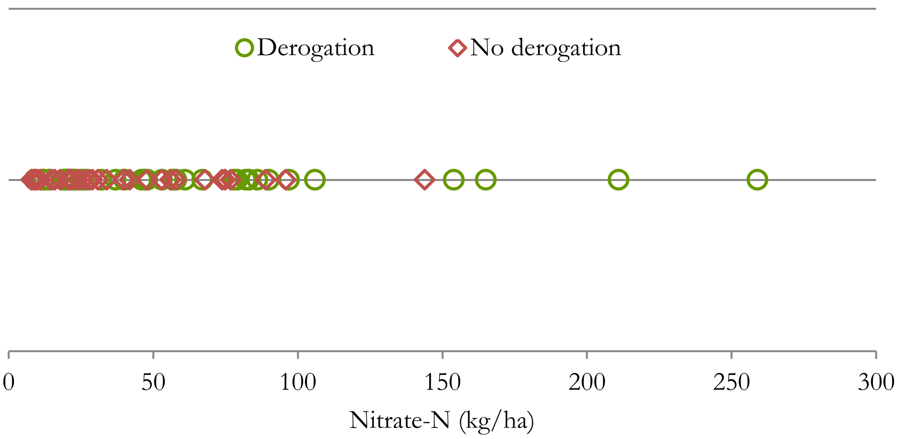


Figure 211: Spreading of the nitrate-N residue of derogation (green) and no derogation (red) parcels on sandy loam soils cultivated with grass.

Since for 2 of the parcels the parameter 'farm' was determinant and because 2 parcels were a pasture adjacent to the farm, the comparison of derogation and no derogation parcels with grass on sandy loam soils was reassessed excluding those 4 parcels. The average nitrate-N residue on derogation parcels lowered to 43 ± 27 kg NO_3-N/ha. This average nitrate-N residue was not significantly different of the average nitrate-N residue on parcels without derogation ($p = 0.06$).

Maize on sandy loam soils

Focusing on maize cultivated on sandy loam soils with or without derogation, the comparison of the nitrate-N residue with or without derogation is based on 102 parcels, 51 parcels with derogation and 51 parcels without derogation.

On parcels with derogation, the average nitrate-N residue was 85 ± 39 kg NO_3-N/ha in autumn 2017 in the monitoring network (Figure 212). Without derogation on sandy loam soils and after main crop maize, the average nitrate-N residue amounted 101 ± 72 kg NO_3-N/ha. The difference between both groups of parcels had no statistical significance ($p = 0.71$).

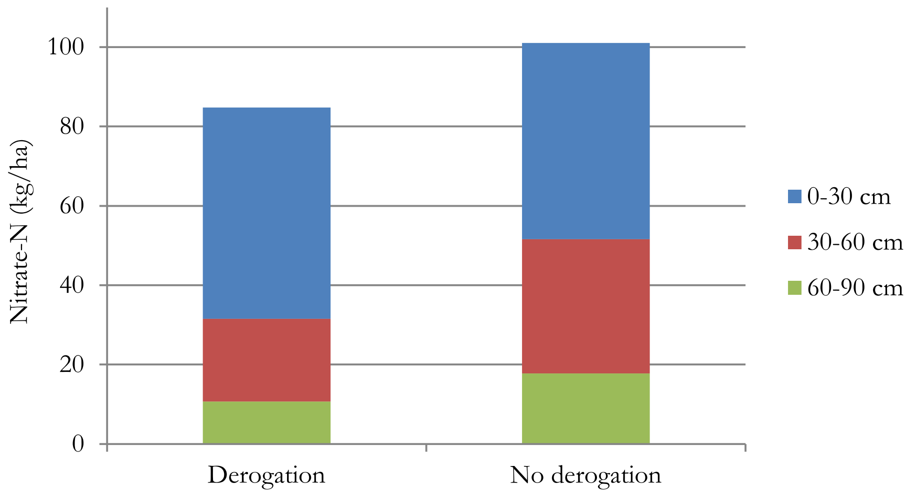


Figure 212: Average nitrate-N (kg/ha) on derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2017.

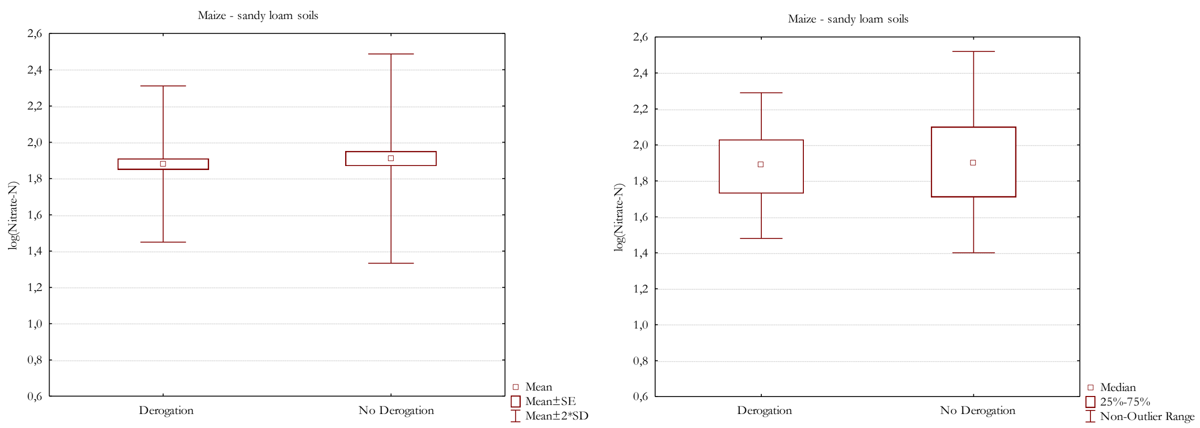


Figure 213: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

One of the detected outliers was a parcel on sandy loam soil cultivated with maize without derogation. The nitrate-N residue was 328 kg NO_3-N/ha of which 190 kg NO_3-N/ha in the upper 30 cm. Nor fertilisation nor yield was abnormal. Nevertheless, on the other parcels of the farm the nitrate-N residues were also rather high, more specific 125 and 267 kg NO_3-N/ha. Without this outlying value and regardless of the request of derogation the average nitrate-N residue on sandy loam parcels cultivated with maize was 91 ± 53 kg NO_3-N/ha. More specific, on parcels without derogation the average nitrate-N residue was 97 ± 65 kg NO_3-N/ha without the outlying value.

To summarize, an overview of the nitrate-N residues monitored since 2011 is given.

The last 6 years of monitoring show that the difference in nitrate-N residue between derogation and no derogation conditions is continuously small (Figure 214). The largest difference that was noticed, appeared in 2016. The nitrate-N residue under derogation conditions was 6 kg NO_3-N/ha higher as on parcels without derogation. Nevertheless, in 2014 the average nitrate-N residue without derogation was 5 kg NO_3-N/ha higher as on parcels with derogation. The nitrate-N residue in 2017, both with and without derogation conditions, was higher compared to the years before. It was comparable to the results of the monitoring in 2011. The overview split up per soil type leads to the same conclusions.

On sandy soils (Figure 215), the nitrate-N residue of 2017 was most comparable with the nitrate-N residue of the monitoring in 2011. Throughout the years, the difference in average nitrate-N residue on sandy soils between derogation and no derogation parcels was maximal 6 kg NO_3-N/ha. This was noticed in 2013 when the nitrate-N residue on parcels without derogation was 6 kg NO_3-N/ha higher as on parcels without derogation.

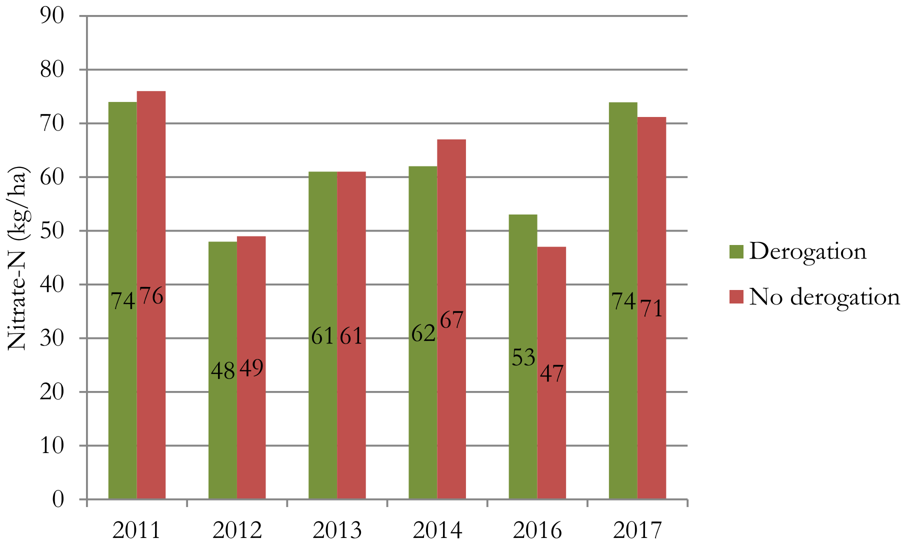


Figure 214: Nitrate-N residue in the soil profile (0-90 cm) on derogation and no derogation parcels cultivated with derogation crops in the monitoring network of 2011-2014 and the latest monitoring network 2016-2017.

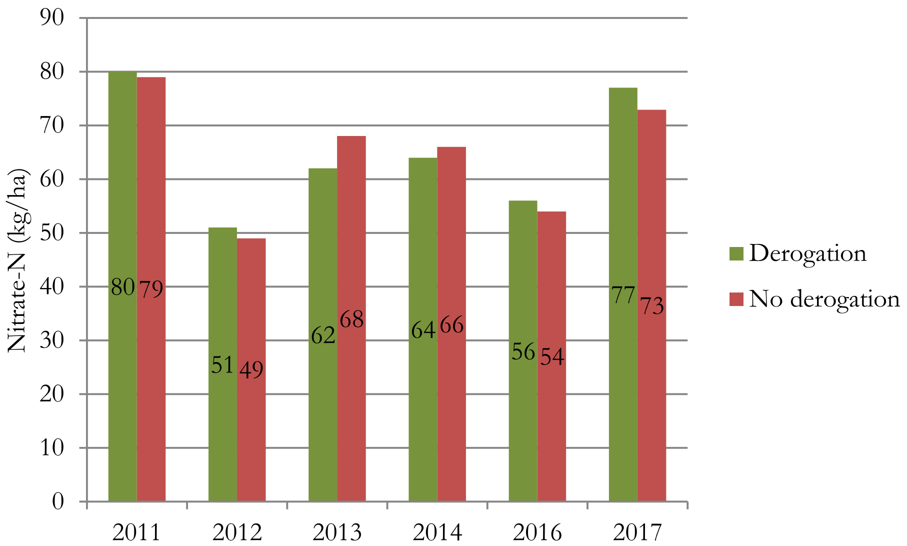


Figure 215: Nitrate-N residue in the soil profile (0-90 cm) on derogation and no derogation parcels cultivated with derogation crops on sandy soils in the monitoring network of 2011-2014 and the latest monitoring network 2016-2017.

Table 50: Nitrate-N residue in the soil profile (0-90 cm) for the different levels of comparison (derogation, soil texture, crop) in the monitoring network of 2011-2014 and the latest monitoring network 2016-2017. Indication of the average nitrate-N residue ± standard deviation, the number of parcels included in the comparison by 'n' and the p-value.

			Nitrate-N (kg/ha)																	
			2011			2012			2013			2014			2016			2017		
			n	0-90 cm	p-value	n	0-90 cm	p-value	n	0-90 cm	p-value	n	0-90 cm	p-value	n	0-90 cm	p-value	n	0-90 cm	p-value
Overall mean monitoring network			217		-	203		-	205		-	215		-	462	50±41	-	458	73 ± 59	-
Derogation			85	74±54	0.80	87	48±37	0.91	106	61±47	0.90	80	62±41	0.91	231	53±38	0.06	229	74 ± 51	0.03
No derogation			110	76±57		100	49±33		78	61±46		116	67±49		231	47±44		229	71 ± 65	
Derogation	Sandy soil		52	80±59	0.99	55	51±38	0.70	72	62±48	0.80	55	64±43	0.80	131	56±38	0.45	128	77 ± 54	0.13
No derogation			67	79±60		62	49±36		47	68±59		65	66±46		129	54±50		130	73 ± 66	
Derogation	Sandy loam		25	64±46	0.72	24	42±35	0.53	24	56±51		16	55±35	0.54	100	49±39	0.02	101	70 ± 48	0.14
No derogation			27	66±45		38	48±29		36	53±32		37	70±53		102	38±31		99	69 ± 64	
Derogation	Sandy soil	Grass	34	64±52	0.31	34	41±33	0.23	41	52±45	0.37	37	60±42	0.31	52	51±44	0.06	49	69 ± 50	0.07
No derogation			32	51±51		27	32±23		20	54±58		22	54±45		53	36±33		50	52 ± 54	
Derogation	Sandy soil	Grass <50% clover	-	-	-	-	-	-	-	-	-	-	-	-	30	40±27	0.92	29	54 ± 46	0.44
No derogation			-	-	-	-	-	-	-	-	-	-	-	-	30	39±23		30	52 ± 62	
Derogation	Sandy soil	Maize	11	108±61	0.82	20	68±42	0.36	29	71±46	0.65	18	70±48	0.52	49	70±31	0.22	50	98 ± 55	0.91
No derogation			31	112±58		25	57±36		14	74±41		37	75±45		46	85±64		50	106 ± 67	
Derogation	Sandy loam	Grass	14	31±14	0.23	16	24±10	0.05	11	43±45	0.95	10	45±36	0.90	53	41±41	0.03	50	55 ± 51	0.02
No derogation			8	40±18		7	38±22		10	34±23		12	46±40		54	27±30		48	35 ± 29	
Derogation	Sandy loam	Maize	11	106±38	0.43	8	80±36	0.06	12	65±56	0.56	4	80±28	0.84	47	58±34	0.20	51	85 ± 39	0.71
No derogation			13	94±56		20	54±30		15	66±33		21	88±57		48	50±29		51	101 ± 72	

On sandy loam soils, the highest difference in average nitrate-N residue between derogation and no derogation conditions amounted 15 kg NO_3-N/ha. It was noticed in 2014 and the highest average value was measured on parcels without derogation.

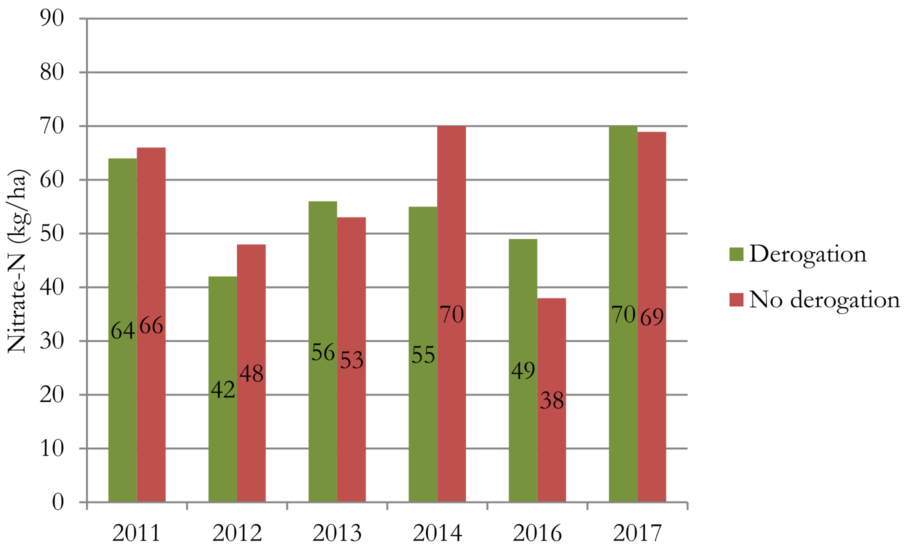


Figure 216: Nitrate-N residue in the soil profile (0-90 cm) on derogation and no derogation parcels cultivated with derogation crops on sandy loam soils in the monitoring network of 2011-2014 and the latest monitoring network 2016-2017.

3.2.1.5 Mineral nitrogen - farm average - autumn 2017

In autumn 2017, the nitrate-N residue could be evaluated at farm level in the monitoring network for the second time. In accordance with the first evaluation in 2016 also in 2017 only farms of which all three parcels were representative and withheld in the former discussion of the nitrate-N residue at parcel level, are withheld for evaluation of the farm average nitrate-N residue. Statistical concerns about an unequal number of parcels per farm and per farm average nitrate-N residue can be countered this way. As for the nitrate-N residue, the statistical analysis of the farm average nitrate-N residue is carried out on the log-transformed data.

Guaranteeing 3 parcels per farm for the farm average nitrate-N residue lead to 137 farms suitable for the evaluation of the farm average nitrate-N residue in autumn 2017. The mean farm average nitrate-N residue in the monitoring network in autumn 2017 amounted 75 ± 48 kg NO_3-N/ha.

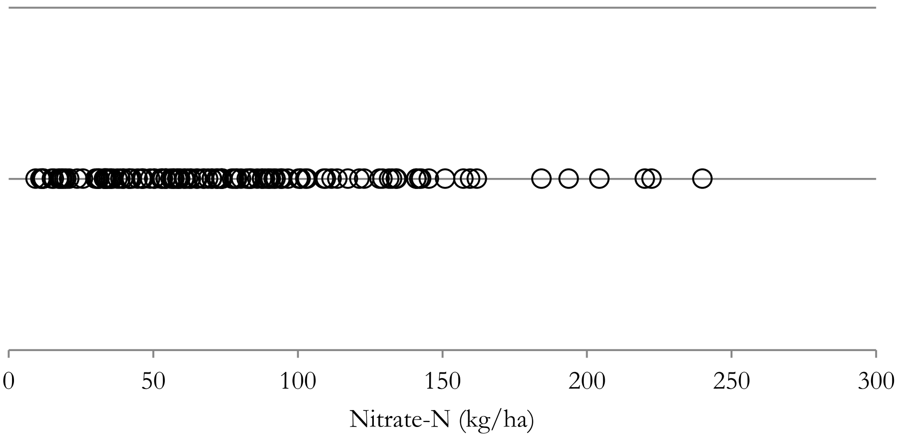


Figure 217: Spreading of the farm average nitrate-N residue of 137 farms of the monitoring network in autumn 2017.

Table 51: Mean farm average nitrate-N in the soil profile (0-90 cm) and specified per soil layer (0-30 cm, 30-60 cm and 60-90 cm) for the 137 farms combined at different levels of comparison in autumn 2017. The number of farms taken up in the comparison is indicated by 'n'.

			Nitrate-N (kg/ha)					p-value
			n	0-30 cm	30-60 cm	60-90 cm	0-90 cm	
Overall farm average			137	36	25	14	75	-
Derogation			68	38	24	13	75	0.21
No derogation			69	34	25	15	74	
Derogation	Sandy soil		35	33	30	17	80	0.20
No derogation			39	32	28	16	76	
Derogation	Sandy loam		33	43	17	9	70	0.65
No derogation			30	37	23	13	73	
Derogation	Sandy soil	Grass	14	25	27	18	70	0.09
No derogation			14	24	18	11	53	
Derogation	Sandy soil	Grass <50% clover	5	15	19	16	50	-
No derogation			9	18	22	15	55	
Derogation	Sandy soil	Maize	16	45	36	18	99	0.85
No derogation			16	47	39	21	106	
Derogation	Sandy loam	Grass	16	33	14	8	55	0.10
No derogation			13	19	9	7	35	
Derogation	Sandy loam	Maize	17	53	21	11	85	0.52
No derogation			17	49	34	18	101	

The farm average nitrate-N residue on farms with derogation, regardless of soil or crop, was 75 ± 41 kg NO_3-N/ha in autumn 2017 (Figure 218). On farms without derogation, the farm average nitrate-N residue amounted 74 ± 54 kg NO_3-N/ha. This comparison involved 68 derogation farms and 69 farms without derogation. The farm average nitrate-N residue did not differ between derogation and no derogation farms ($p = 0.21$).

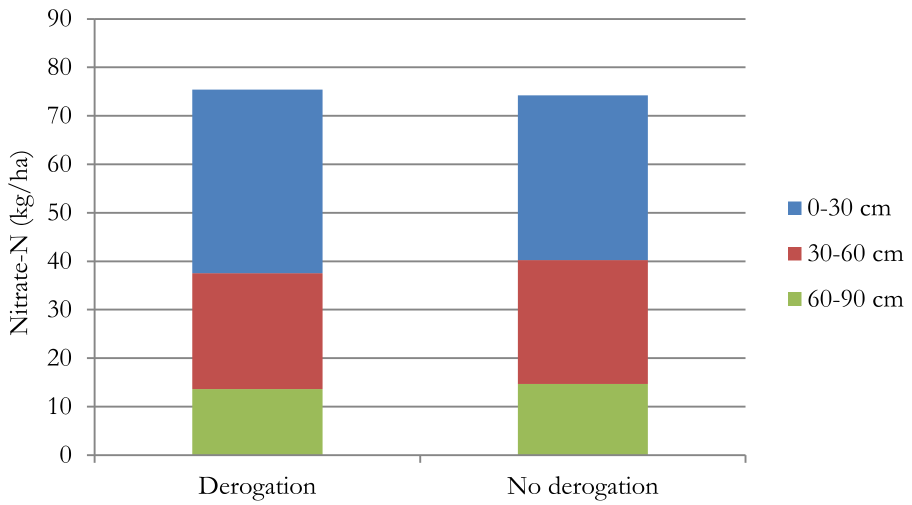


Figure 218: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with all crops on all soils in the monitoring network in autumn 2017.

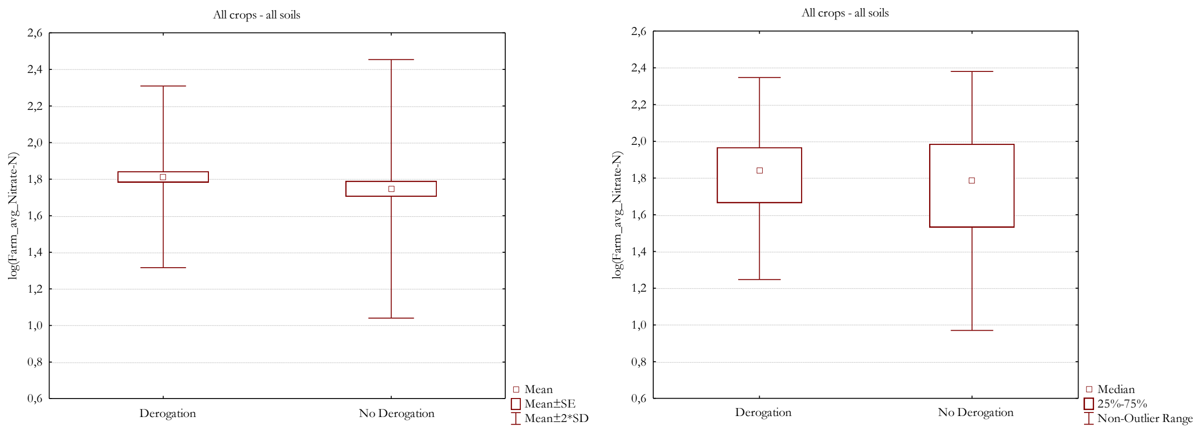


Figure 219: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with all crops on all soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

All crops on sandy soils

The farm average nitrate N-residue on sandy soils in autumn 2017 amounted 78 ± 49 kg NO_3-N/ha. The farm average nitrate-N residue of 35 derogation farms and 39 farms without derogation could be compared. On derogation farms on sandy soils, the mean farm average nitrate-N residue was 80 ± 43 kg NO_3-N/ha (Figure 220). On farms without derogation, this mean was 76 ± 54 kg NO_3-N/ha. The mean farm average nitrate-N residue was not significant different on derogation and no derogation farms (p = 0.20).

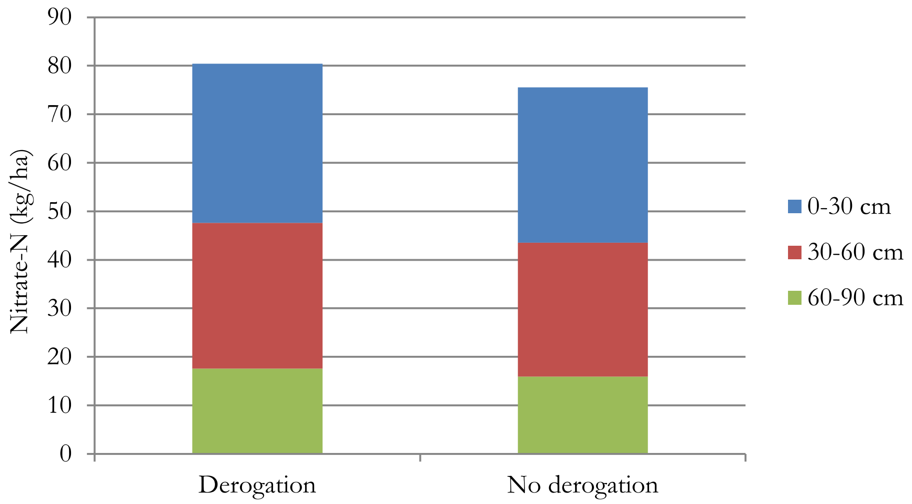
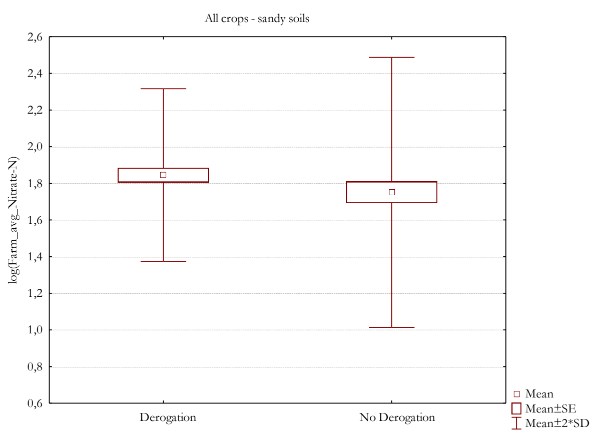


Figure 220: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2017.



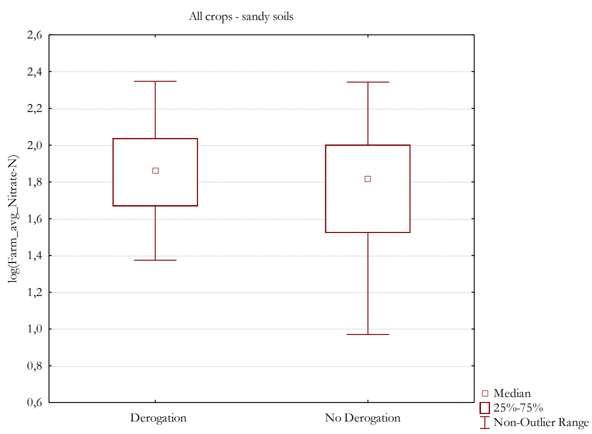


Figure 221: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Grass on sandy soils

On sandy soils, the farm average nitrate-N residue of parcels cultivated with grass was compared between 14 derogation and 14 no derogation farms. The mean farm average nitrate-N residue with derogation was 70 ± 33 kg NO_3-N/ha (Figure 222). Without derogation, the mean farm average nitrate-N residue amounted 53 ± 41 kg NO_3-N/ha on sandy soils with grass. The mean farm average nitrate-N residue on derogation and no derogation farms on sandy soils with grass was not statistically significant different (p = 0.09).

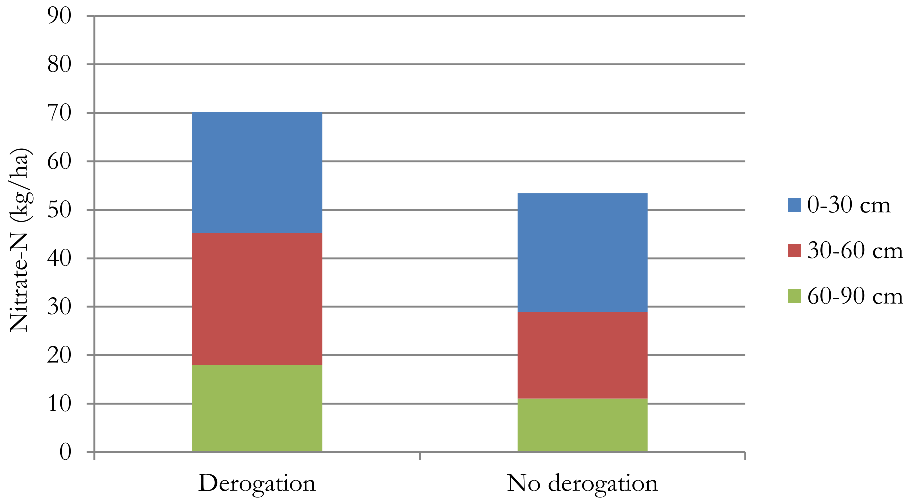


Figure 222: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2017.

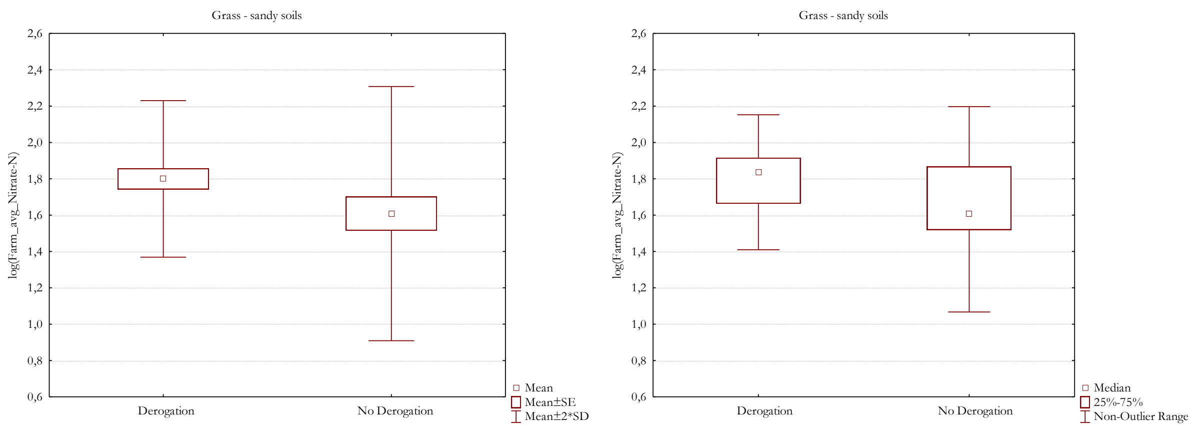


Figure 223: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Grass with less than 50 % clover on sandy soils

The number of farms with grass and less than 50 % clover on sandy soils suited for comparison of the farm average nitrate-N residue was 14 in autumn 2017, 5 derogation farms and 9 farms without derogation. The mean farm average nitrate-N residue on the farms with derogation amounted 50 ± 23 kg NO_3-N/ha (Figure 224). Without derogation request, the mean farm average nitrate-N residue was 55 ± 42 kg NO_3-N/ha. The difference was not significant ($p = 0.75$).

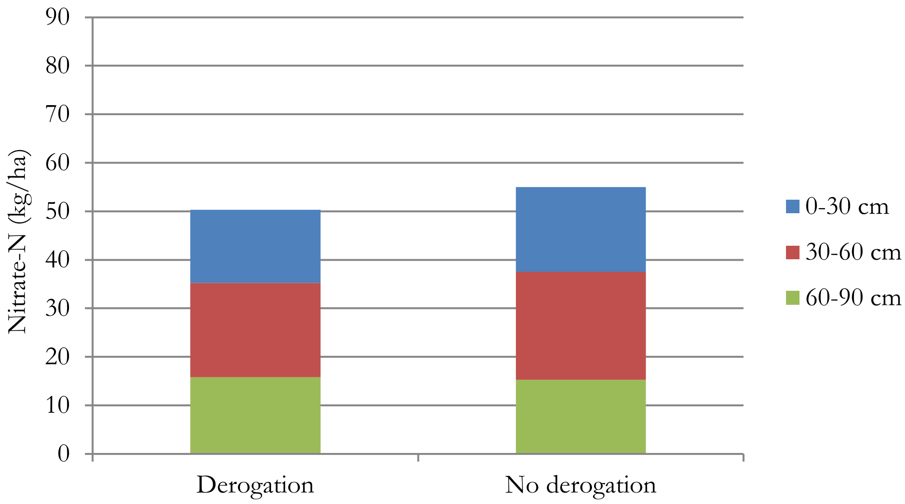


Figure 224: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with grass and less than 50 % clover on sandy soils in the monitoring network in autumn 2017.

Maize on sandy soils

On sandy soils, the mean farm average nitrate-N residue of the parcels cultivated with maize was 103 ± 52 kg NO_3-N/ha, determined on 32 farms. Both 16 farms with and without derogation were compared. On derogation farms on sandy soils, the mean farm average nitrate-N residue of the parcels cultivated with maize was 99 ± 49 kg NO_3-N/ha. On farms without derogation, the mean farm average nitrate-N residue of the parcels cultivated with maize was 106 ± 56 kg NO_3-N/ha. The difference between derogation and no derogation farms regarding to the farm average nitrate-N residue were not statistically significant ($p = 0.85$).

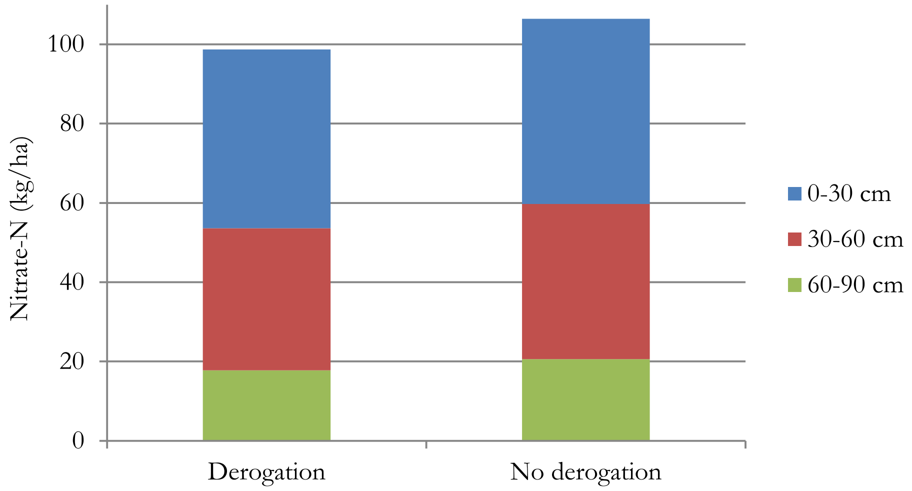


Figure 225: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2017.

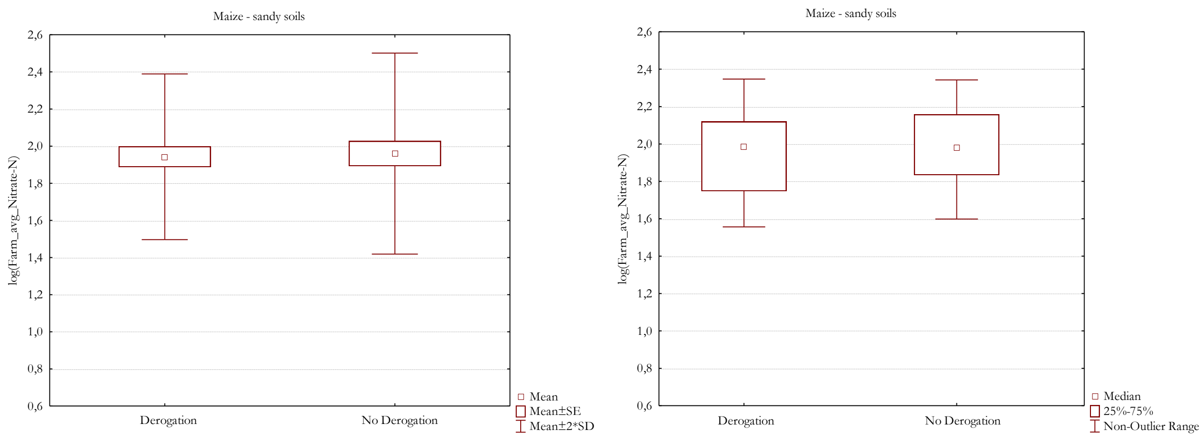


Figure 226: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

All crops on sandy loam soils

In autumn 2017 the mean farm average nitrate-N residue on sandy loam soils, regardless of crop or derogation practice, was 71 ± 46 kg NO_3-N/ha. This mean farm average nitrate-N residue was based on the results of 63 farms, 33 farms with derogation and 30 farms without derogation.

On the farms with sandy loam parcels which requested derogation the mean farm average nitrate-N residue was 70 ± 39 kg NO_3-N/ha in autumn 2017 (Figure 227). On the farms without derogation the mean farm average nitrate-N residue was 73 ± 55 kg NO_3-N/ha.

The farm average nitrate-N residues of derogation and no derogation farms were not significantly different (p = 0.65).

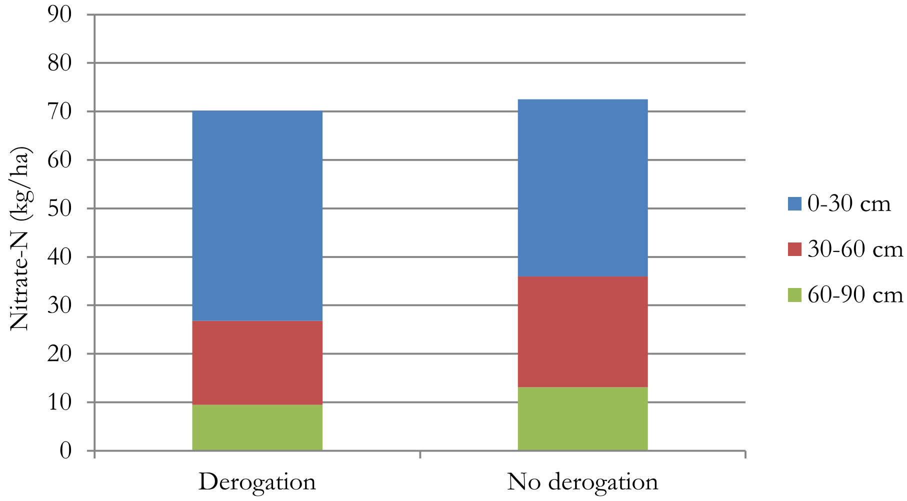


Figure 227: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network in autumn 2017.

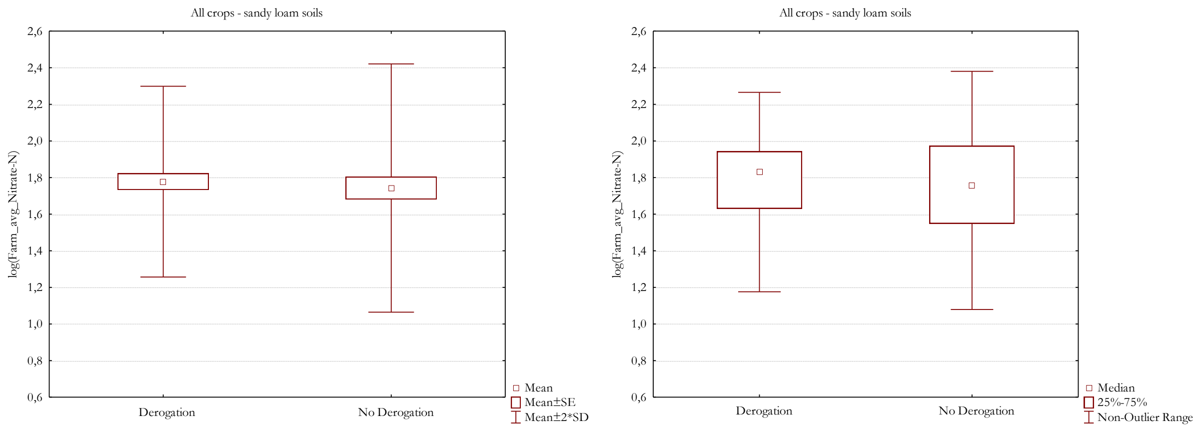


Figure 228: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Grass on sandy loam soils

On sandy loam soils the farm average nitrate-N residue of parcels cultivated with grass, of 16 and 13 derogation and no derogation farms was compared in autumn 2017. The farm average nitrate-N residue with derogation practice was 55 ± 41 kg NO_3-N/ha (Figure 229). Without derogation practice, the farm average nitrate-N residue on sandy loam soils with grass was 35 ± 19 kg NO_3-N/ha. There was no statistically significant (p = 0.10) difference between farms with and without derogation regarding the farm average nitrate-N residue on sandy loam soils with grass.

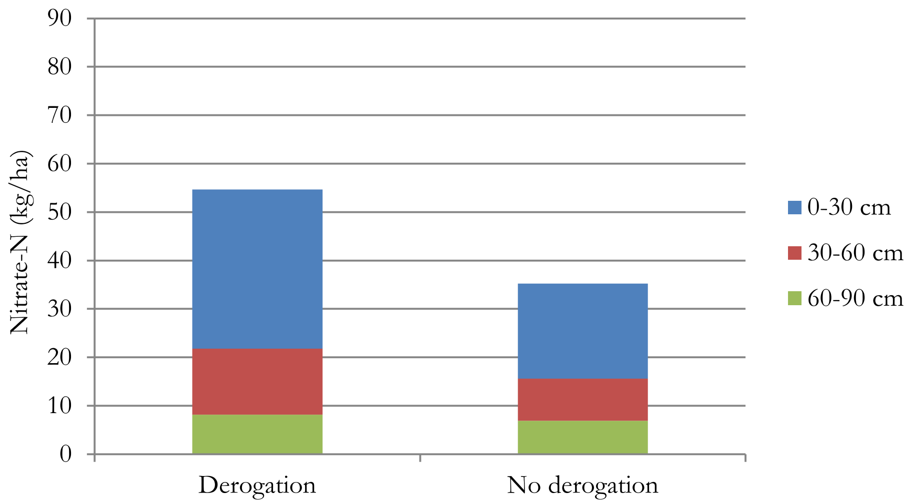


Figure 229: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2017.

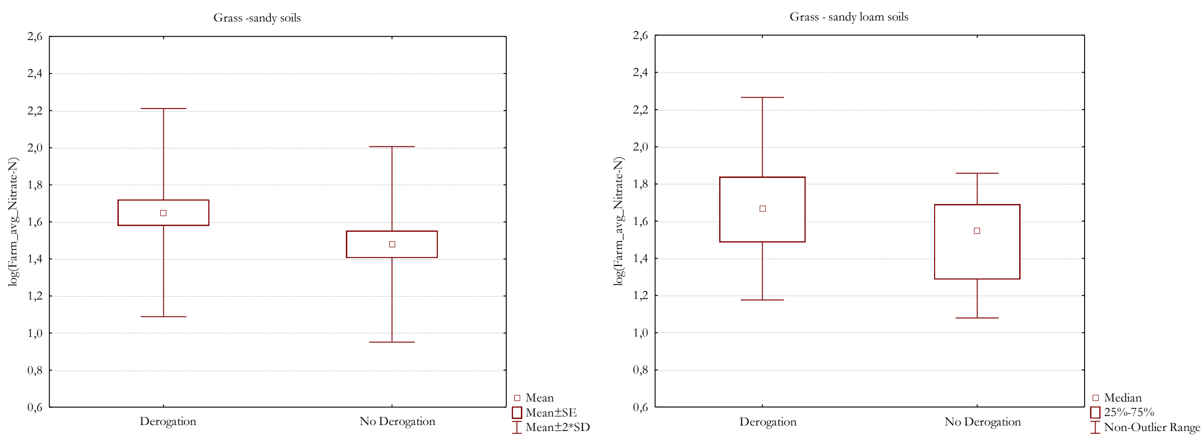


Figure 230: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Maize on sandy loam soils

The evaluation of the farm average nitrate-N residue on sandy loam soils with maize was performed on 34 parcels, both 17 derogation and no derogation farms. The mean farm average nitrate-N residue on sandy loam soils with maize was 93 ± 45 kg NO_3-N/ha in autumn 2017 in the monitoring network. Under derogation circumstances, this mean farm average nitrate-N residue was 85 ± 31 kg NO_3-N/ha (Figure 231). On farms without derogation, the mean farm average nitrate-N residue was 101 ± 56 kg NO_3-N/ha. Nevertheless the farm average nitrate-N residue of farms on sandy loam soils with maize with or without derogation was not significantly different ($p = 0.52$).

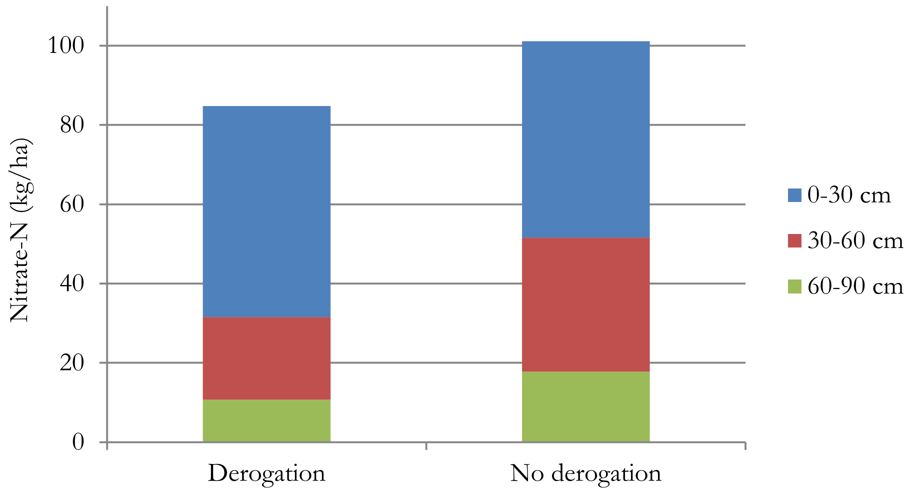


Figure 231: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2017.

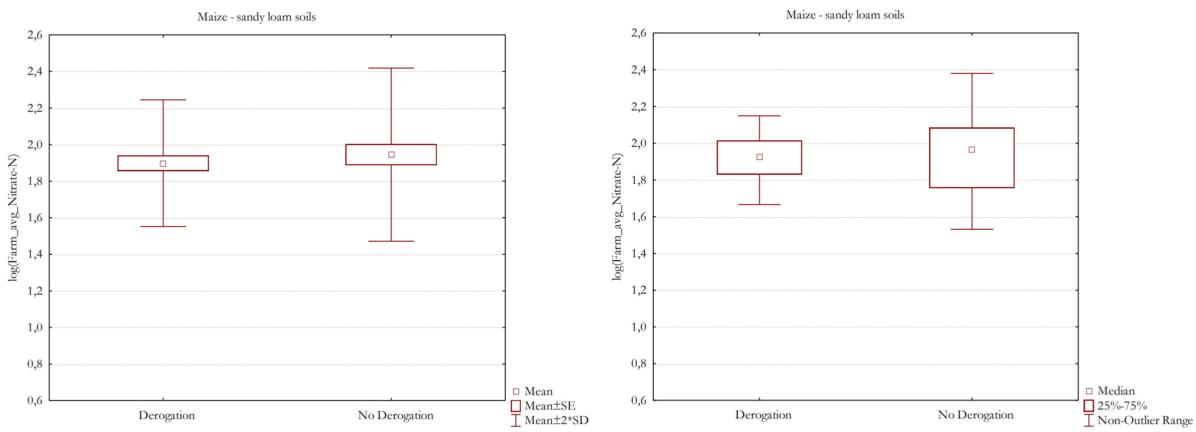


Figure 232: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

3.2.1.6 Mineral nitrogen - difference autumn 2017 and spring 2018

The difference in nitrate-N realised in winter 2017-2018 was estimated by comparing the nitrate-N residue of autumn 2017 and the amount of nitrate-N in the soil profile in late winter 2017-early spring 2018. The samples taken in autumn 2017 that represent the nitrate-N residue are discussed in a previous paragraph.

This difference approximates the amount of nitrate-N out of the soil profile between the two sampling moments and comprises more processes than only leaching. The difference of nitrate-N between the two sampling moments is expressed in kg NO_3-N/ha and is calculated as "nitrate-N residue (kg NO_3-N/ha; 0-90 cm) – nitrate-N reserve after winter (kg NO_3-N/ha; 0-90 cm)".

The statistical analysis is performed analogous to the statistical analysis of the nitrate-N residue. However, the dependent variable in this analysis "nitrate-N difference", was not log-transformed because the conditions for a variance analysis were met. "Derogation" (Yes or No) and "Farm" were still used in the general linear model as predictor variables. "Derogation" as a fixed categorical predictor variable and "Farm" as a random categorical predictor variable.

The data are presented by bar graphs showing the amount of nitrate-N (kg NO_3-N/ha) per soil layer (0-30 cm, 30-60 cm and 60-90 cm) in autumn and spring for derogation and no derogation parcels. This presentation allows to estimate the difference of nitrate-N realised between the two moments of sampling and shows the redistribution of the nitrate-N over the soil profile during this period.

Box plots, based on the effective figures of nitrate-N difference (kg NO_3-N/ha), are shown to indicate the variation in nitrate-N difference.

The discussion of the nitrate-N difference of winter 2017-2018 is based on 380 parcels of the monitoring network. Parcels which could not be sampled down to 90 cm in autumn 2017, parcels which were judged not to be suited for evaluation of the possible impact of derogation practices in autumn 2017 and parcels which were sampled after February 21st were excluded for the discussion of the nitrate-N difference.

Because of the wet condition of the fields and the late winter, there was no massive start of manuring at February 16th. On February 23rd, the Flemish Land Agency remembered farmers the prohibition of manuring on frozen soil. Farmers had waited for a period of frost allowing to access the parcels without damaging soil structure. The fact that such a period had to be waited for supports the bad condition of the fields before and the delay of manuring. Therefore, parcels sampled between February 15th and February 21st (21st included) can still be included in the analysis of the nitrate-N difference of winter 2017-2018.

The average nitrate-N difference in winter 2017-2018 was 40 ± 51 kg NO_3-N/ha (Figure 233). The difference over winter 2017-2018 was higher than the nitrate-N difference in winter 2016-2017, which amounted 10 ± 32 kg NO_3-N/ha. The larger nitrate-N difference over winter 2017-2018 had a double cause. The nitrate N-residues in autumn 2017 were clearly higher than in autumn 2016. More nitrogen susceptible for leaching was present in the soil profile. Additional there was more rainfall in the period November-February as normal. In the period November 2016-February 2017, total rainfall amounted only 220.5 mm. In the same period over winter 2017-2018 (November 2017-February 2018), total rainfall was 338.5 mm. Normal rainfall in this period amounts 296.6 mm. Winter 2016-2017 was abnormally dry.

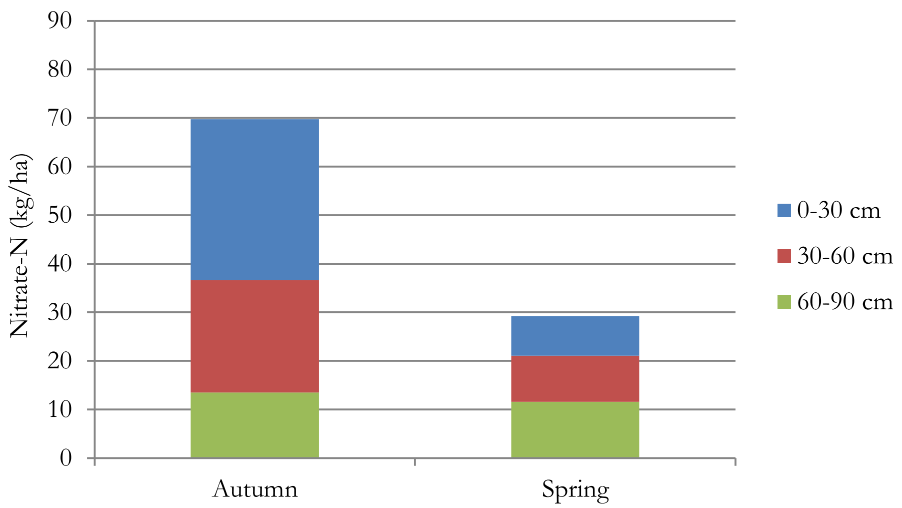


Figure 233: Average nitrate-N (kg/ha) on 380 parcels of the monitoring network in autumn 2017 and spring 2018 (sampled until 22.02.2018), indicating the average nitrate-N difference-winter 2017-2018.

Table 52: Average nitrate-N difference-winter 2017-2018 (kg/ha) based on parcels sampled until February 22nd, combined at different levels of comparison. The number of parcels included in the comparison is indicated by 'n'.

			Difference of nitrate-N (kg/ha)		
			n	Average	p-value
Overall mean monitoring network			380	40 ± 51	-
Derogation			186	43 ± 50	0.96
No derogation			194	38 ± 53	
Derogation	Sandy soil		108	52 ± 54	0.55
No derogation			103	39 ± 51	
Derogation	Sandy loam		78	29 ± 41	0.046
No derogation			91	38 ± 54	
Derogation	Sandy soil	Grass	40	42 ± 50	0.02
No derogation			48	17 ± 35	
Derogation	Sandy soil	Grass <50% clover	27	36 ± 53	0.53
No derogation			20	23 ± 31	
Derogation	Sandy soil	Maize	41	73 ± 53	0.73
No derogation			35	79 ± 58	
Derogation	Sandy loam	Grass	37	12 ± 32	0.81
No derogation			46	10 ± 26	
Derogation	Sandy loam	Maize	41	45 ± 42	0.05
No derogation			45	66 ± 61	

The nitrate-N difference over winter 2017-2018 is discussed for 186 derogation parcels and 194 no derogation parcels.

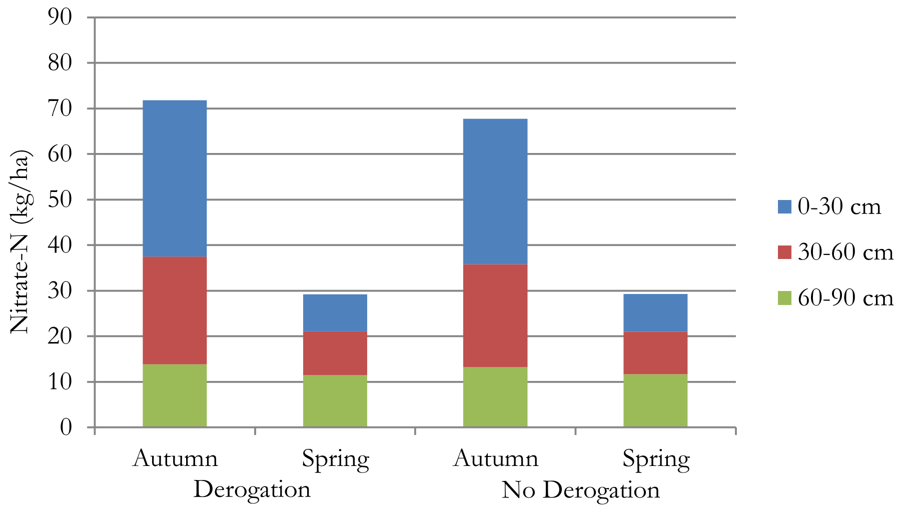


Figure 234: Average nitrate-N (kg/ha) in autumn 2017 and spring 2018 (sampled until 22.02.2018) on derogation and no derogation parcels of the monitoring network, indicating the average nitrate-N difference during winter 2017-2018 on derogation and no derogation parcels.

On parcels without derogation, the average nitrate-N difference was 38 ± 53 kg NO_3-N/ha (Figure 234). On parcels with derogation, the average nitrate-N difference was 43 ± 50 kg NO_3-N/ha. In both groups of parcels, derogation and no derogation, the variation in nitrate-N difference was high (Figure 235) and the average nitrate-N difference on derogation and no derogation parcels did not differ statistically significant ($p = 0.96$).

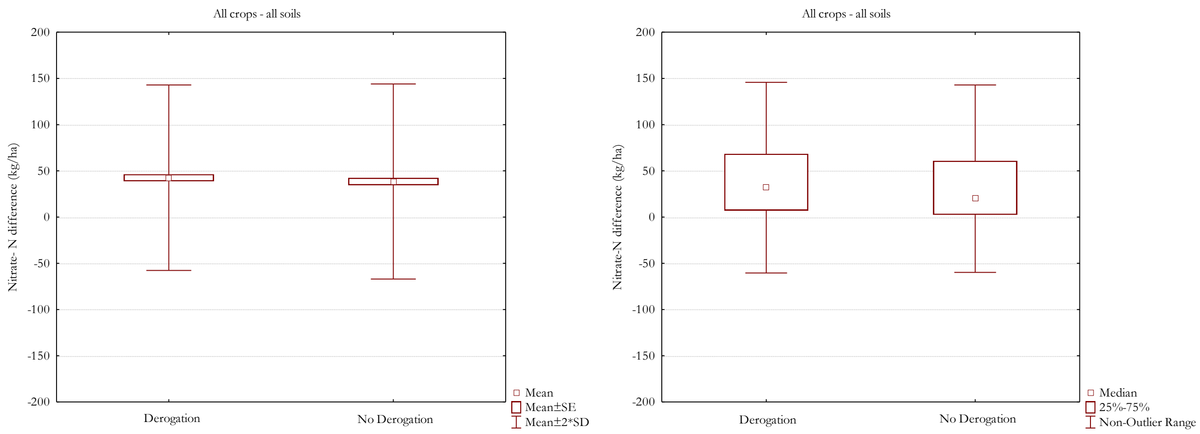


Figure 235: Boxplot of the nitrate-N difference-winter 2017-2018 (kg/ha) on derogation and no derogation parcels with all crops on all soil textures in the monitoring network. Sampling in spring until 22.02.2018 Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

All crops on sandy soils

In winter 2017-2018, the average nitrate-N difference on sandy soils amounted 46 ± 53 kg NO_3-N/ha. On sandy soils, the difference of nitrate-N was evaluated on 211 parcels, 108 parcels cultivated with derogation and 103 parcels without derogation. On derogation parcels on sandy soils, the average nitrate-N difference in winter 2017-2018 amounted 52 ± 54 kg NO_3-N/ha. On sandy parcels without derogation, the nitrate-N difference was 39 ± 51 kg NO_3-N/ha in winter 2017-2018. Derogation and no derogation parcels on sandy soils did not differ statistically ($p = 0.55$) regarding to the nitrate-N difference during winter 2017-2018.

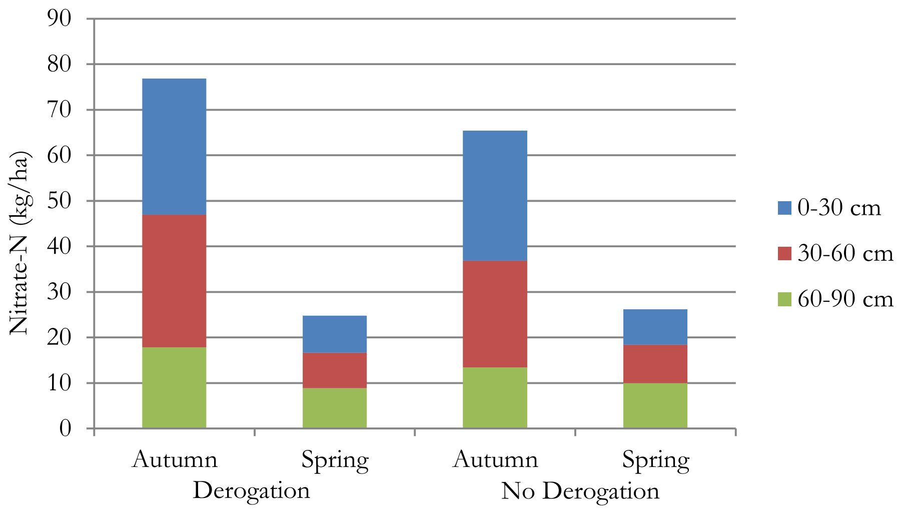


Figure 236: Average nitrate-N (kg/ha) in autumn 2017 and spring 2018 (sampled until 22.02.2018) on derogation and no derogation parcels on sandy soils of the monitoring network, indicating the average nitrate-N difference during winter 2017-2018 on derogation and no derogation parcels on sandy soils.

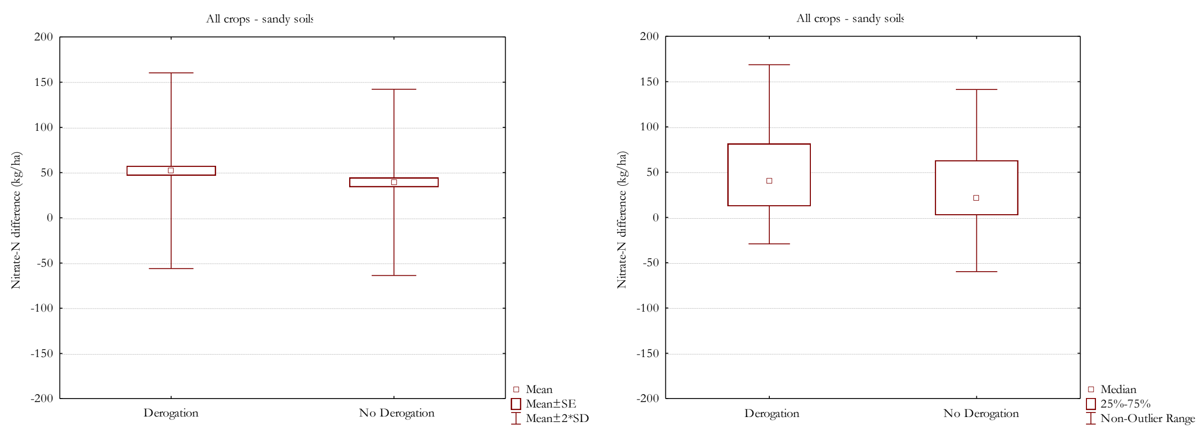


Figure 237: Boxplot of the nitrate-N difference-winter 2017-2018 (kg/ha) on derogation and no derogation parcels with all crops on sandy soils in the monitoring network. Sampling in spring until 22.02.2018 Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Grass on sandy soils

On sandy soils, 40 parcels cultivated with grass under derogation conditions were compared to 48 parcels without derogation. Under derogation conditions, the average nitrate-N difference was 42 ± 50 kg NO_3-N/ha on sandy parcels cultivated with grass (Figure 238). Without derogation, the nitrate-N difference amounted 17 ± 35 kg NO_3-N/ha. Derogation and no derogation parcels cultivated with grass on sandy soils differed statistically regarding to the nitrate-N difference over winter 2017-2018 ($p = 0.02$).

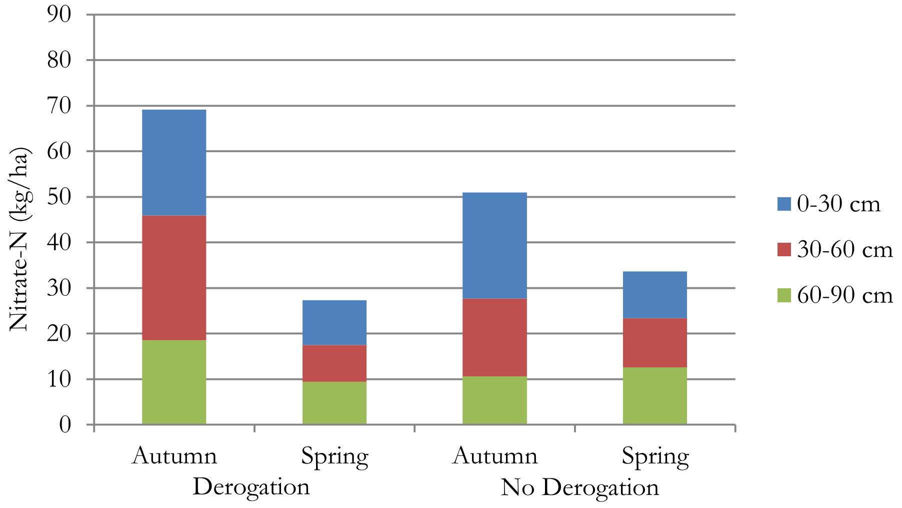


Figure 238: Average nitrate-N (kg/ha) in autumn 2017 and spring 2018 (sampled until 22.02.2018) on derogation and no derogation parcels on sandy soils cultivated with grass of the monitoring network, indicating the average nitrate-N difference during winter 2017-2018 on derogation and no derogation parcels on sandy soils cultivated with grass.

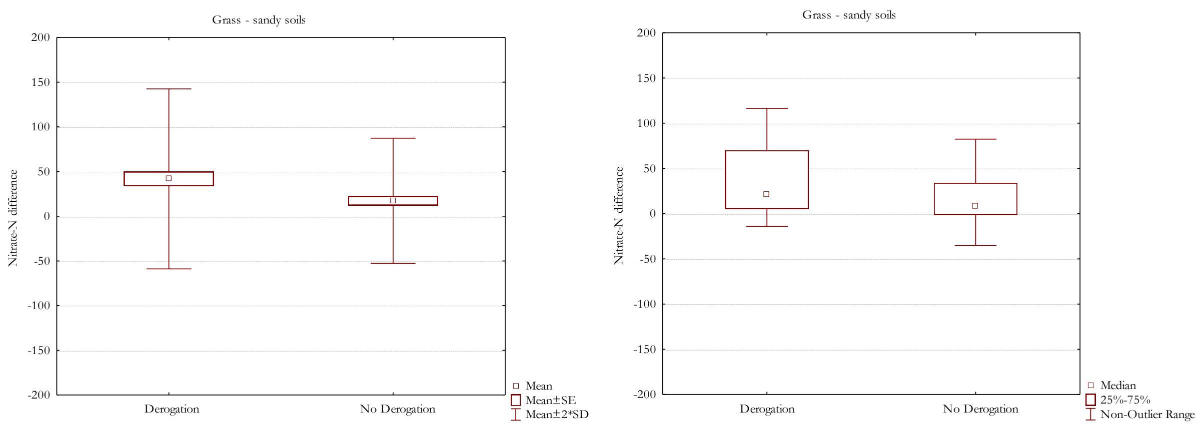


Figure 239: Boxplot of the nitrate-N difference-winter 2017-2018 (kg/ha) on derogation and no derogation parcels cultivated with grass on sandy soils in the monitoring network. Sampling in spring until 22.02.2018 Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Grass with less than 50 % clover on sandy soils

The comparison of the average nitrate-N difference over winter 2017-2018 on sandy soils cultivated with grass and less than 50 % clover comprised 27 derogation parcels and 20 parcels without derogation. The average nitrate-N difference on sandy derogation parcels cultivated with grass and less than 50 % clover was 36 ± 53 kg NO_3-N/ha. On the parcels without derogation, this difference amounted 23 ± 31 kg NO_3-N/ha. The average nitrate-N difference on derogation and no derogation parcels cultivated with grass and less than 50 % clover on sandy soils was not statistically different (p = 0.53).

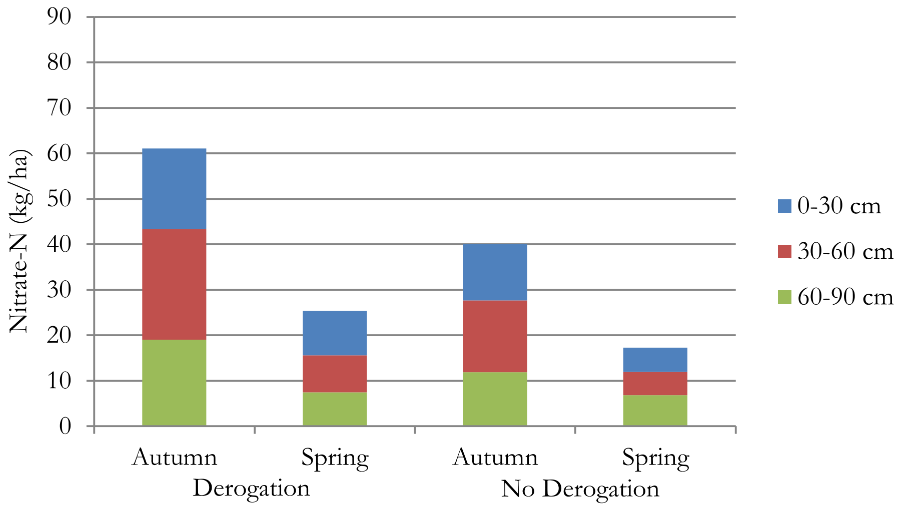


Figure 240: Average nitrate-N (kg/ha) in autumn 2017 and spring 2018 (sampled until 22.02.2018) on derogation and no derogation parcels on sandy soils cultivated with grass and less than 50 % clover of the monitoring network, indicating the average nitrate-N difference during winter 2017-2018 on derogation and no derogation parcels on sandy soils cultivated with grass and less than 50 % clover.

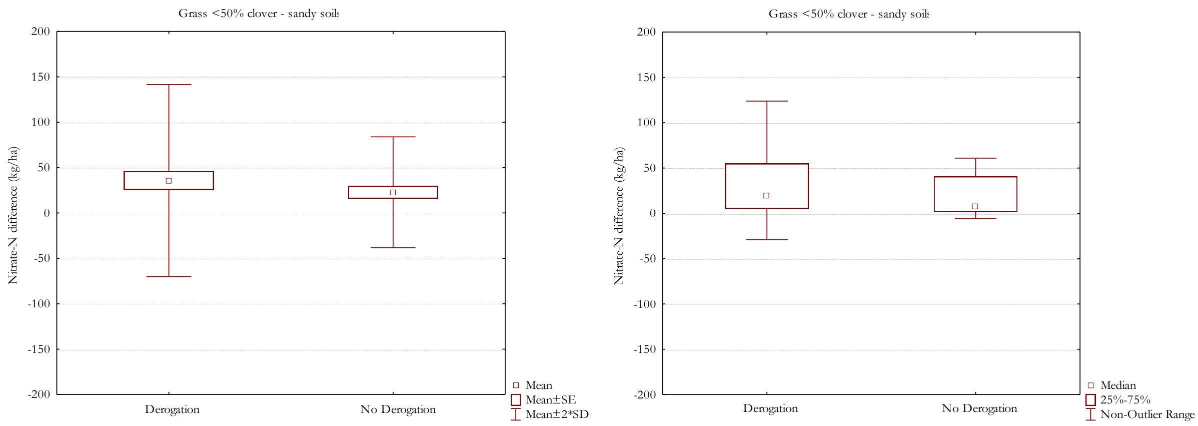


Figure 241: Boxplot of the nitrate-N difference-winter 2017-2018 (kg/ha) on derogation and no derogation parcels cultivated with grass and less than 50 % clover on sandy soils in the monitoring network. Sampling in spring until 22.02.2018 Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Maize on sandy soils

The evaluation of the nitrate-N difference over winter 2017-2018 on sandy soils cultivated with maize was realised on 76 parcels, 41 parcels with derogation and 35 parcels without derogation. On the parcels with derogation, the average nitrate-N difference during winter 2017-2018 was 73 ± 53 kg NO_3-N/ha. On the parcels without derogation, the average nitrate-N difference during winter 2017-2018 was 79 ± 58 kg NO_3-N/ha, not statistically different ($p = 0.73$) of the average difference measured on the derogation parcels.

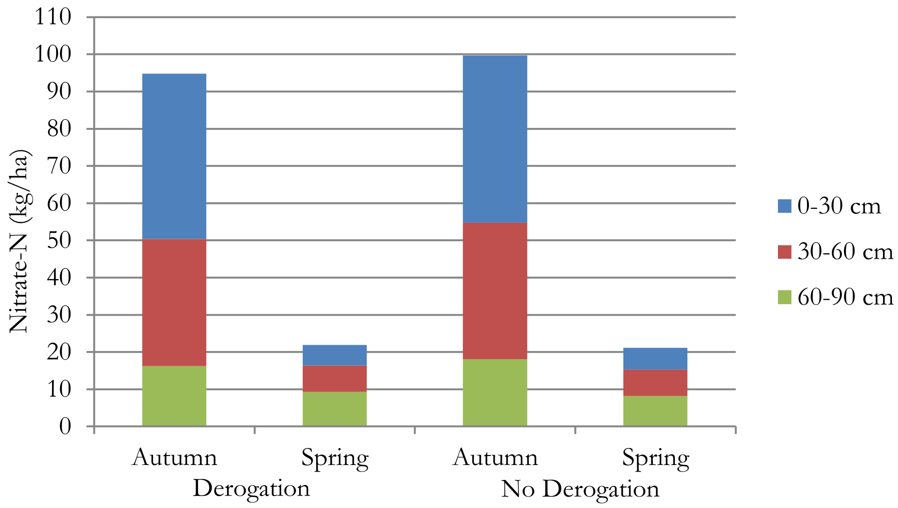
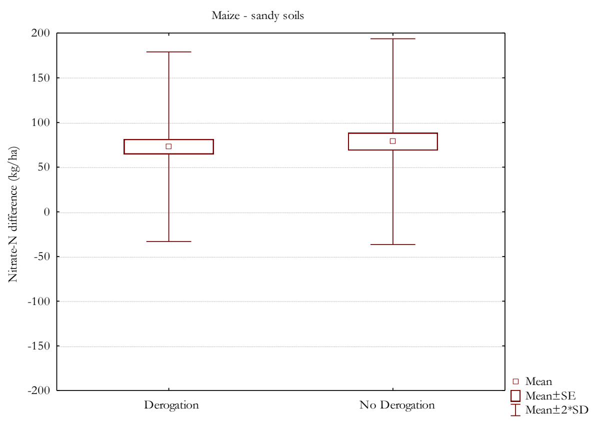


Figure 242: Average nitrate-N (kg/ha) in autumn 2017 and spring 2018 (sampled until 22.02.2018) on derogation and no derogation parcels on sandy soils cultivated with maize of the monitoring network, indicating the average nitrate-N difference during winter 2017-2018 on derogation and no derogation parcels on sandy soils cultivated with maize.



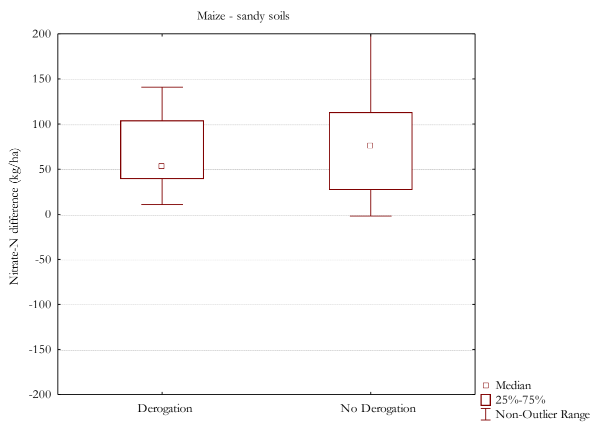


Figure 243: Boxplot of the nitrate-N difference-winter 2017-2018 (kg/ha) on derogation and no derogation parcels cultivated with maize on sandy soils in the monitoring network. Sampling in spring until 22.02.2018 Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

All crops on sandy loam soils

On sandy loam soils, 169 parcels could be evaluated during winter 2017-2018 regarding to the nitrate-N difference. The average nitrate-N difference on those sandy loam soils was 34 ± 49 kg NO_3-N/ha in winter 2017-2018.

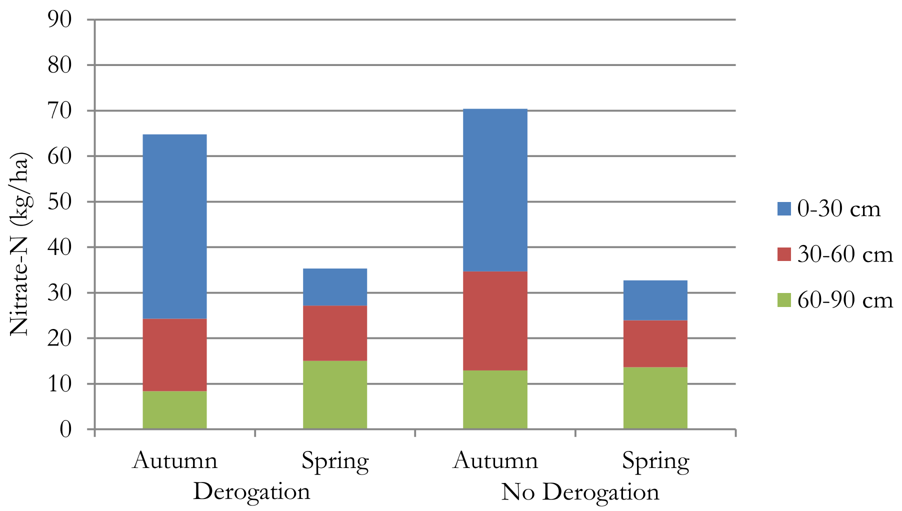


Figure 244: Average nitrate-N (kg/ha) in autumn 2017 and spring 2018 (sampled until 22.02.2018) on derogation and no derogation parcels on sandy loam soils of the monitoring network, indicating the average nitrate-N difference during winter 2017-2018 on derogation and no derogation parcels on sandy loam soils.

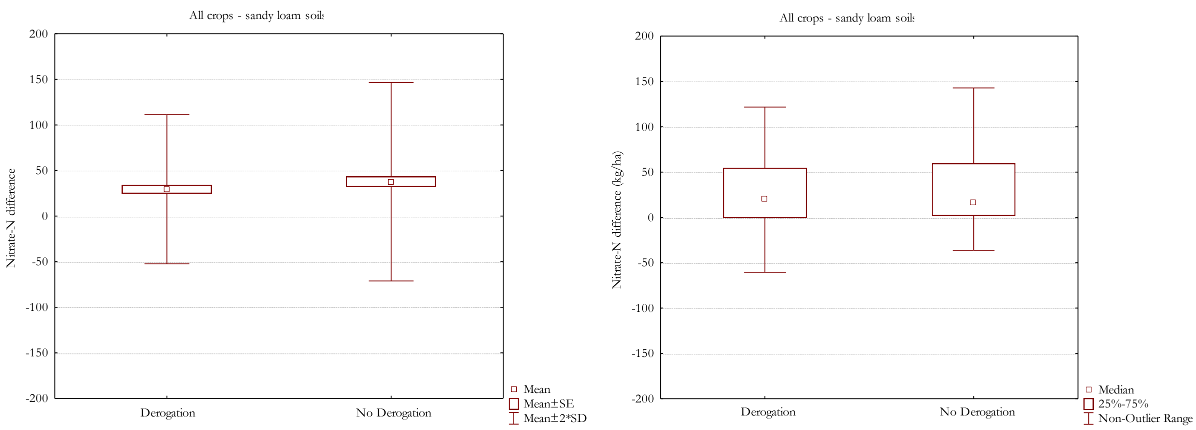


Figure 245: Boxplot of the nitrate-N difference-winter 2017-2018 (kg/ha) on derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network. Sampling in spring until 22.02.2018 Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

The comparison between derogation and no derogation on sandy loam soils concerning the nitrate-N difference over winter 2017-2018 included 78 derogation parcels and 91 no derogation parcels. On the sandy loam derogation parcels, the average nitrate-N difference was 29 ± 41 kg NO_3-N/ha in winter 2017-2018. On the sandy loam parcels without derogation the average nitrate-N difference was 38 ± 54 kg NO_3-N/ha in winter 2017-2018. The average nitrate-N difference did differ statistically significant between derogation and no derogation parcels on sandy loam soils this winter ($p = 0.046$). As in winter 2016-2017 also in winter 2017-2018 the reallocation of the nitrate-N over the different soil layers of the soil profile is clearly noticeable on the sandy loam soils (Figure 244).

Grass on sandy loam soils

On sandy loam soils cultivated with grass in 2017, the average nitrate-N difference over winter 2017-2018 was evaluated on 83 parcels, 37 parcels with derogation and 46 parcels without derogation. Under derogation conditions, the average nitrate-N difference was 12 ± 32 kg NO_3-N/ha on sandy loam soils cultivated with grass (Figure 246). On the parcels cultivated with grass on sandy loam soils without derogation, the average nitrate-N difference was 10 ± 26 kg NO_3-N/ha. The average nitrate-N difference during winter 2017-2018 on sandy loam soils cultivated with grass did not differ statistically under derogation and no derogation conditions ($p = 0.81$).

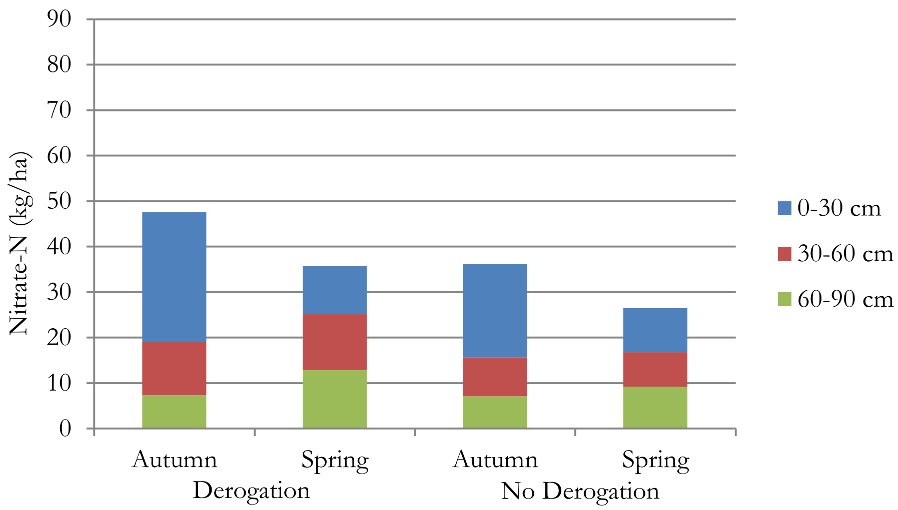


Figure 246: Average nitrate-N (kg/ha) in autumn 2017 and spring 2018 (sampled until 22.02.2018) on derogation and no derogation parcels on sandy loam soils cultivated with grass of the monitoring network, indicating the average nitrate-N difference during winter 2017-2018 on derogation and no derogation parcels on sandy loam soils cultivated with grass.

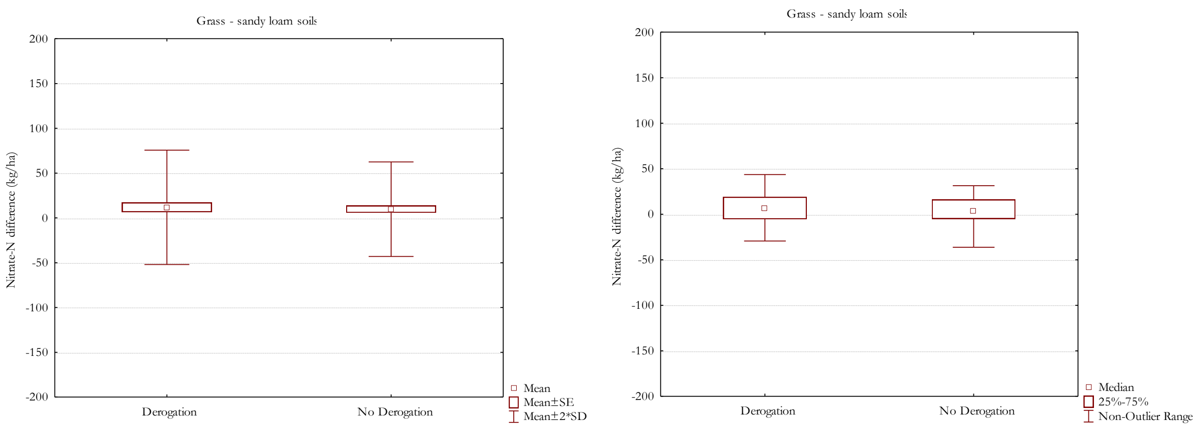


Figure 247: Boxplot of the nitrate-N difference-winter 2017-2018 (kg/ha) on derogation and no derogation parcels cultivated with grass on sandy loam soils in the monitoring network. Sampling in spring until 22.02.2018 Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Maize on sandy loam soils

Maize on sandy loam soils is evaluated by comparing 41 parcels with derogation and 45 parcels without derogation. With derogation, the average nitrate-N difference over winter 2017-2018 was 45 ± 42 kg NO_3-N/ha. Without derogation, the average nitrate-N difference over winter 2017-2018 was 66 ± 61 kg NO_3-N/ha on sandy loam parcels cultivated with maize.

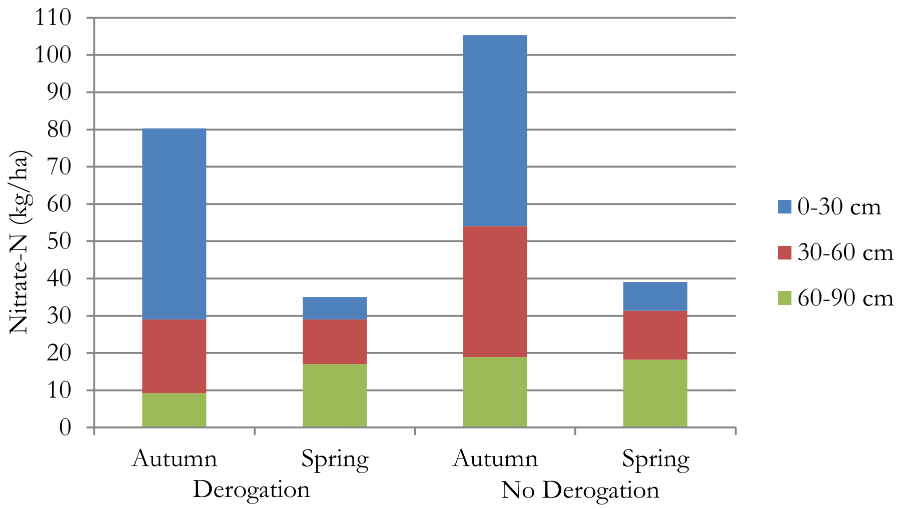


Figure 248: Average nitrate-N (kg/ha) in autumn 2017 and spring 2018 (sampled until 22.02.2018) on derogation and no derogation parcels on sandy loam soils cultivated with maize of the monitoring network, indicating the average nitrate-N difference during winter 2017-2018 on derogation and no derogation parcels on sandy loam soils cultivated with maize.

The sandy loam parcels cultivated with maize under derogation or no derogation conditions did not differ statistically significant regarding to the average nitrate-N difference over winter 2017-2018 (p = 0.05).

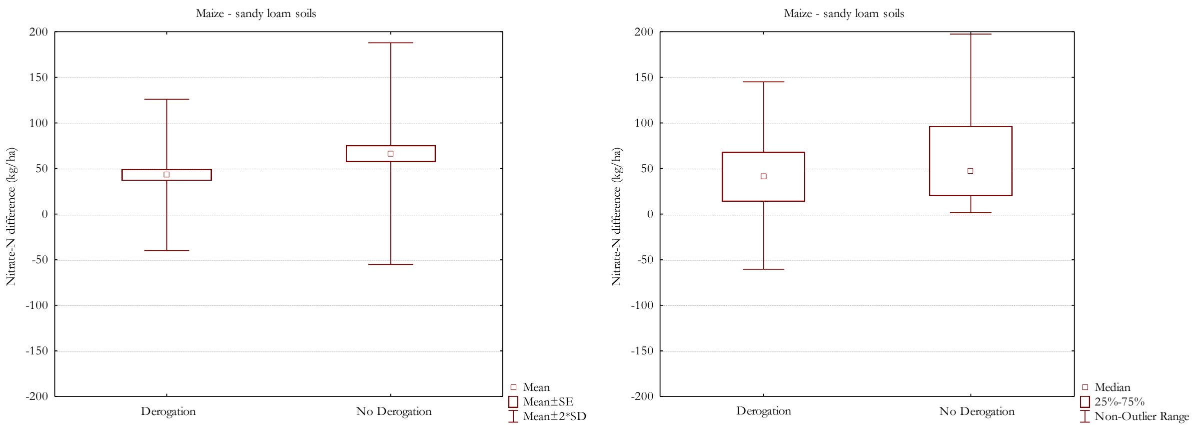


Figure 249: Boxplot of the nitrate-N difference-winter 2017-2018 (kg/ha) on derogation and no derogation parcels cultivated with maize on sandy loam soils in the monitoring network. Sampling in spring until 22.02.2018 Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

3.2.1.7 Mineral nitrogen - at parcel level - autumn 2018

Between October 1st and November 15th, the parcels of the monitoring network 2018 were sampled. Because of the extreme dry conditions in 2018, as mentioned in 2.1.3, sampling to 90 cm was extremely difficult. Three parcels cultivated with grass could not be sampled at all. All 3 parcels were situated on sandy loam soil, 2 were cultivated under derogation conditions and 1 without derogation.

Unlike other years, a lot of parcels could not be sampled to 90 cm. Only 63 % of the parcels of the monitoring network was sampled until 90 cm while 28 and 9 % of the parcels was sampled to respectively 60 and 30 cm. In line with the evaluation of the residual nitrate-N by the VLM and in consultation with VLM, all samples were withheld, regardless of depth of sampling.

Withholding the results of all sampling depths implies that the average nitrate-N per soil layer is related to a different number of samples. In averaging the nitrate-N per soil layer missing data caused by impossible sampling, are NOT supposed to be 0. This will mean that the sum of the average amounts of nitrate-N per soil layer will not be equal to the average of the nitrate-N residues. The sum of the average amounts of nitrate-N per soil layer will overestimate the average nitrate-N residue. The bar graphs show the average amount of nitrate-N per soil layer of the parcels that could be sampled until the respective depth and in overlay the black box demonstrates the average of the measured nitrate-N residues.

Statistical analysis is performed on the log-transformed nitrate-N residue. At each level of comparison, it is verified that both groups have a comparable amount of parcels sampled till 90, 60 or only 30 cm. This can be verified in Table 54 and the reported average depth of sampling.

Before evaluation of the possible impact of derogation on the nitrate-N residue, the main crop, the crop and culture management were reviewed. On two parcels meant for maize in 2018, maize could not be sown. It concerns 1 derogation parcel on sandy soil and 1 parcel on sandy loam soil without derogation. The parcels were discarded for further evaluation. Because of drought, more parcels with grass as usual had to be converted and sown again. On 9 parcels with grass and 7 parcels with grass and less than 50 % clover the nitrate-N residue was clearly influenced by this necessary intervention and not or less by the crop management and fertilisation throughout the year. Two parcels cultivated with maize were not harvested because yield was too little and not worth to harvest, they were excluded for further analysis.

Finally, one parcel with maize on sandy loam soils and cultivated without derogation conditions was excluded. The nitrate-N residue amounted 632 kg NO_3-N/ha; this remarkable value was excluded.

For comparison of the **nitrate-N residue** on derogation and no derogation parcels in **autumn 2018**, **456 parcels** remained.

Figure 250 visualizes the variation of the nitrate-N residue on the 456 parcels in autumn 2018. The statistical analysis of the nitrate-N residue is performed on the logarithm of the nitrate-N residue. The variation of the log-transformed data is shown in Figure 251.

The overall average nitrate-N residue in the monitoring network in autumn 2018, regardless of crop, soil texture or derogation, amounted 95 ± 75 kg NO_3-N/ha.

Although no outliers were discarded for the further statistical analysis, an outlier detection was performed. One outlying value was detected: a parcel cultivated with grass and less than 50% clover on sandy soils without derogation conditions. There will be come back to this outlier at the point where it is most relevant.

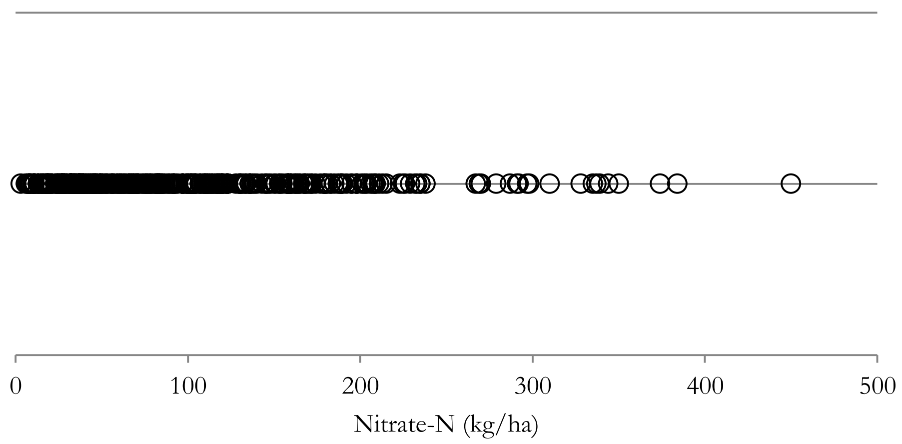


Figure 250: Spreading of the amount of nitrate-N in 456 parcels suited for comparison of derogation and non-derogation practices in autumn 2018.

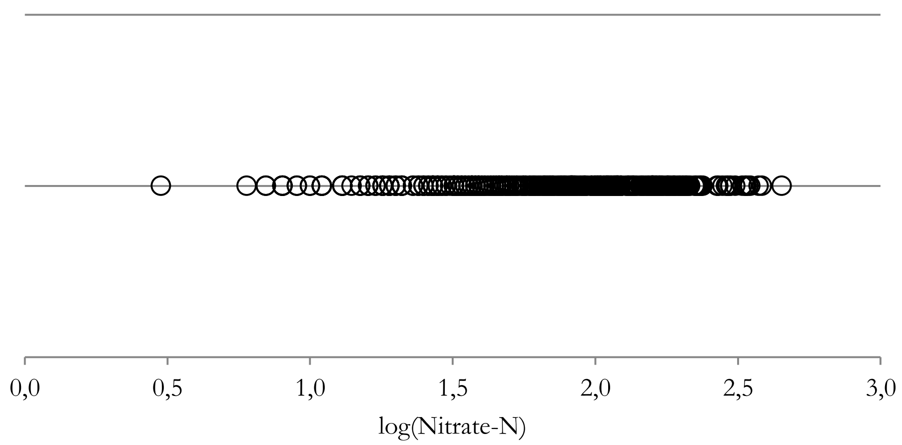


Figure 251: Spreading of the log-transformed nitrate-N (log(Nitrate-N)) in 456 parcels suited for comparison of derogation and non-derogation practices in autumn 2018.

Table 53: Average nitrate-N in the soil profile (0-90 cm) and per soil layer (0-30 cm, 30-60 cm and 60-90 cm) and median value of nitrate-N for the 456 parcels combined at different levels of comparison in autumn 2018. The number of parcels included in the comparison of the nitrate-N residue (0-90 cm) is indicated by 'n'.

			Nitrate-N (kg/ha)						p-value
			n	0-30 cm	30-60 cm	60-90 cm	0-90 cm	Median	
Overall mean monitoring network			456	57	31	16	95	78	-
Derogation			230	54	29	16	91	75	0.44
No derogation			226	59	34	16	99	83	
Derogation	Sandy soil		130	41	31	16	84	68	0.69
No derogation			127	57	39	18	106	89	
Derogation	Sandy loam		100	71	26	15	100	83	0.45
No derogation			99	61	28	14	90	71	
Derogation	Sandy soil	Grass	52	34	19	13	65	50	0.93
No derogation			52	50	22	12	79	64	
Derogation	Sandy soil	Grass <50% clover	28	33	32	16	74	52	0.19
No derogation			25	35	26	11	68	28	
Derogation	Sandy soil	Maize	50	52	43	19	109	97	0.04
No derogation			50	77	62	28	154	152	
Derogation	Sandy loam	Grass	49	71	25	16	97	61	0.21
No derogation			51	44	18	13	64	43	
Derogation	Sandy loam	Maize	51	72	27	15	104	97	0.49
No derogation			48	80	37	14	117	114	

Table 54: Number of parcels taken into account for the average values in Table 53. Average depth of sampling (cm) for the 456 parcels combined at different levels of comparison in autumn 2018.

			Number of parcels				Sampling depth (cm)
			0-30 cm	30-60 cm	60-90 cm	0-90 cm	
Overall mean monitoring network			456	415	284	456	76
Derogation			230	215	152	230	78
No derogation			226	200	132	226	74
Derogation	Sandy soil		130	127	108	130	84
No derogation			127	118	92	127	80
Derogation	Sandy loam		100	88	44	100	70
No derogation			99	82	40	99	67
Derogation	Sandy soil	Grass	52	52	48	52	88
No derogation			52	48	38	52	80
Derogation	Sandy soil	Grass <50% clover	28	26	21	28	80
No derogation			25	24	18	25	80
Derogation	Sandy soil	Maize	50	49	39	50	83
No derogation			50	46	36	50	79
Derogation	Sandy loam	Grass	49	39	21	49	67
No derogation			51	41	21	51	66
Derogation	Sandy loam	Maize	51	49	23	51	72
No derogation			48	41	19	48	68

The nitrate-N residue of 230 parcels with derogation and 226 parcels without derogation could be compared in autumn 2018. On derogation parcels, the average nitrate-N residue was 91 ± 69 kg NO_3-N/ha. Without derogation, the average nitrate-N residue was 99 ± 80 kg NO_3-N/ha in autumn 2018. The difference in nitrate-N residue between derogation and no derogation parcels was statistically insignificant (p = 0.44). The variation of the nitrate-N residue (log-transformed) in both groups of parcels is shown in Figure 253.

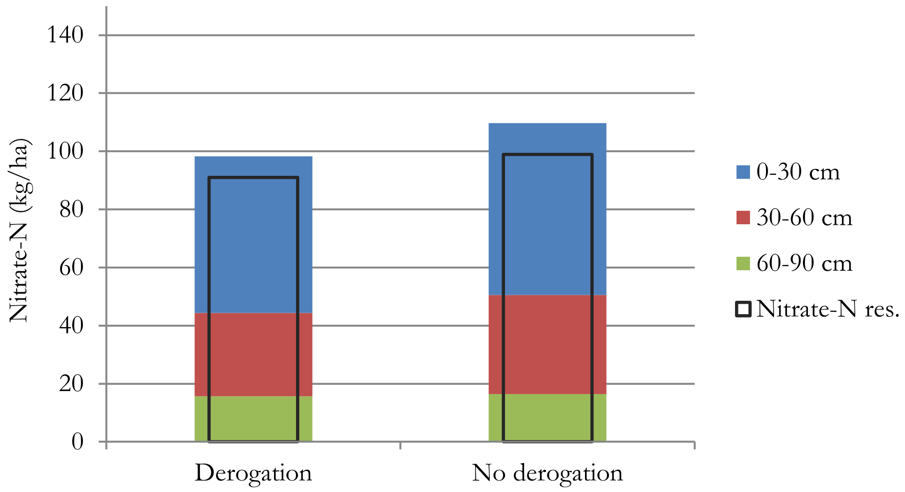


Figure 252: Average nitrate-N residue (kg/ha) on derogation and no derogation parcels with all crops on all soils in the monitoring network in autumn 2018.

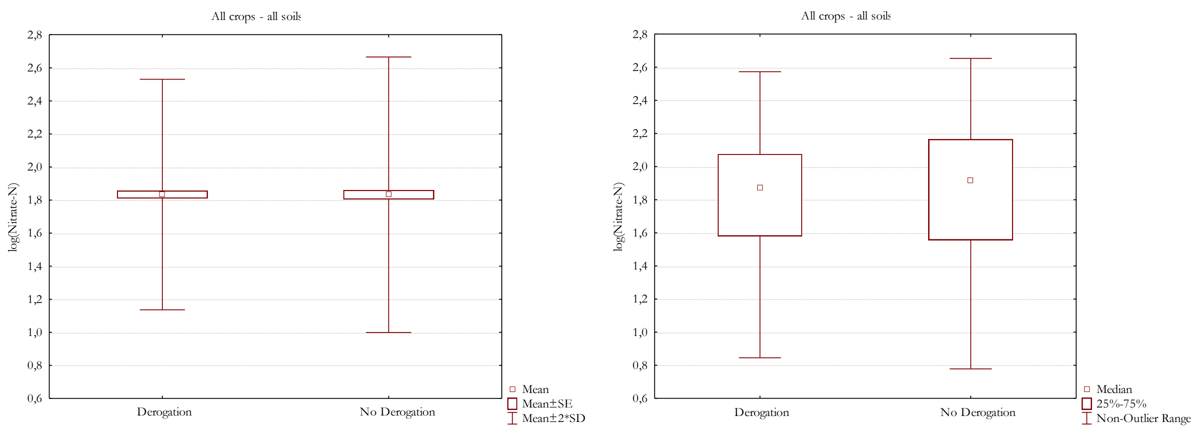


Figure 253: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with all crops on all soils in the monitoring network in autumn 2018. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

The effect of derogation on the nitrate-N residue in the monitoring network in 2018 is visualised in Figure 254. The percentage derogation and no derogation parcels is indicated per category of nitrate-N residue. The curves present the same results in a cumulative manner. Each point on the curve indicates the percentage of parcels that respect the corresponding level of nitrate-N residue.

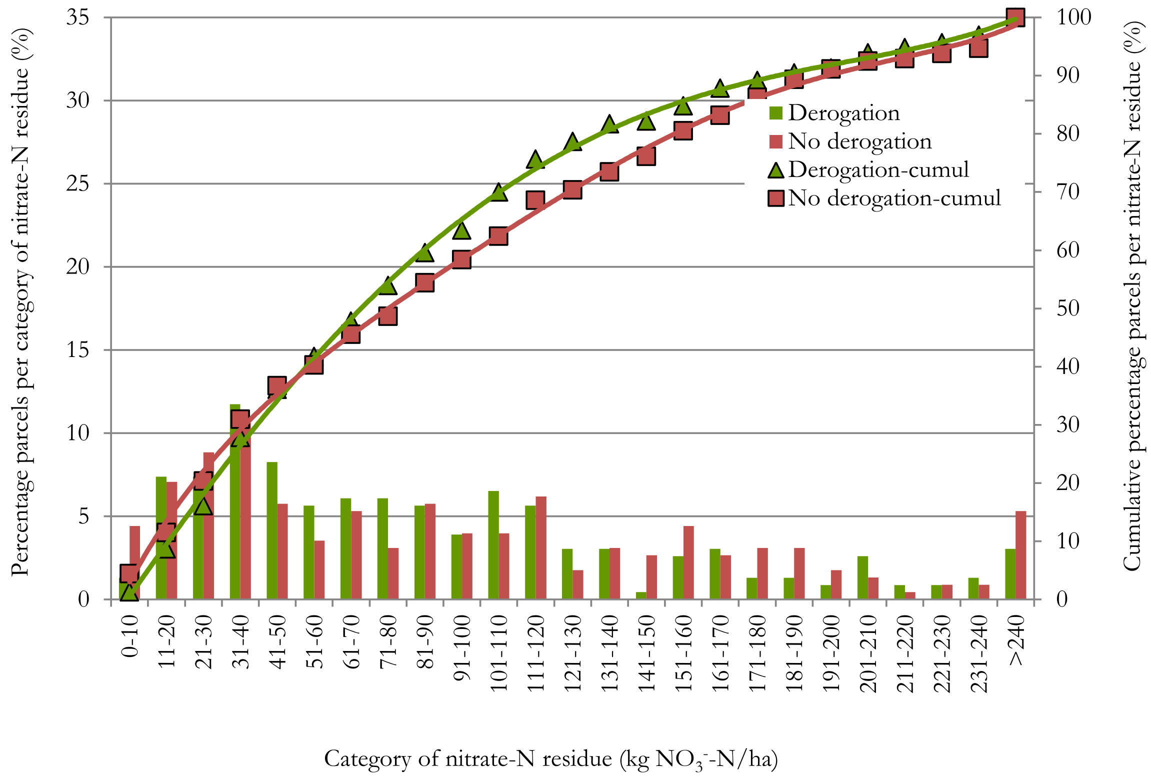


Figure 254: Distribution of the derogation (green columns) and no derogation parcels (red columns) (%) of the monitoring network in the different categories of nitrate-N residue (kg NO_3-N/ha) and cumulative percentage of derogation (green curve) and no derogation (red curve) parcels of the monitoring network which respect a certain value of nitrate N-residue. Autumn 2018.

Compared to the former years of comparison 2016 and 2017, the cumulative curve needs longer 'to build up'. This is caused by the higher nitrate-N residues of 2018. On an equal percentage of derogation (36 %) and no derogation parcels (37 %) the nitrate-N residue is limited to 50 kg NO_3-N/ha. The nitrate-N residue standard of 90 kg NO_3-N/ha was respected on 60 % of the derogation parcels and 54 % of the parcels without derogation. Values of more than 150 kg NO_3-N/ha for the nitrate-N residue were most observed without derogation.

All crops on sandy soils

On sandy soils, the comparison of derogation and no derogation involved 257 parcels, 130 parcels with derogation and 127 parcels without derogation. Under derogation conditions, the average nitrate-N residue amounted 84 ± 62 kg NO_3-N/ha (Figure 255). Without derogation conditions the average nitrate-N residue amounted 106 ± 87 kg NO_3-N/ha. There was no statistical difference (p = 0.69). On sandy soils, the only outlier was detected.

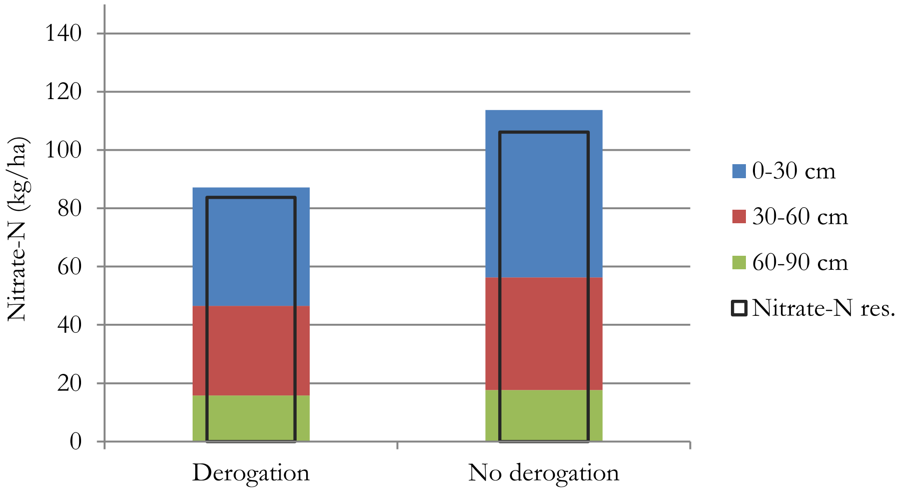
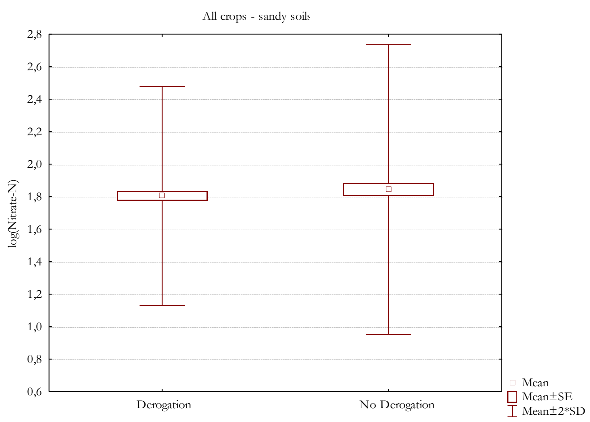


Figure 255: Average nitrate-N residue (kg/ha) on derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2018.



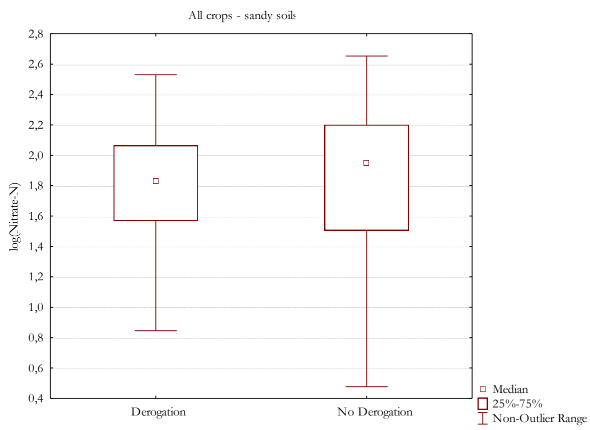


Figure 256: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2018. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Grass on sandy soils

On sandy soils, 104 parcels cultivated with grass were evaluated, both 52 parcels with and without derogation. On the parcels with derogation the nitrate-N residue was 65 ± 44 kg NO_3-N/ha. Without derogation, the nitrate-N residue amounted 79 ± 68 kg NO_3-N/ha on sandy soil cultivated with grass. The difference was not statistically significant (p = 0.93).

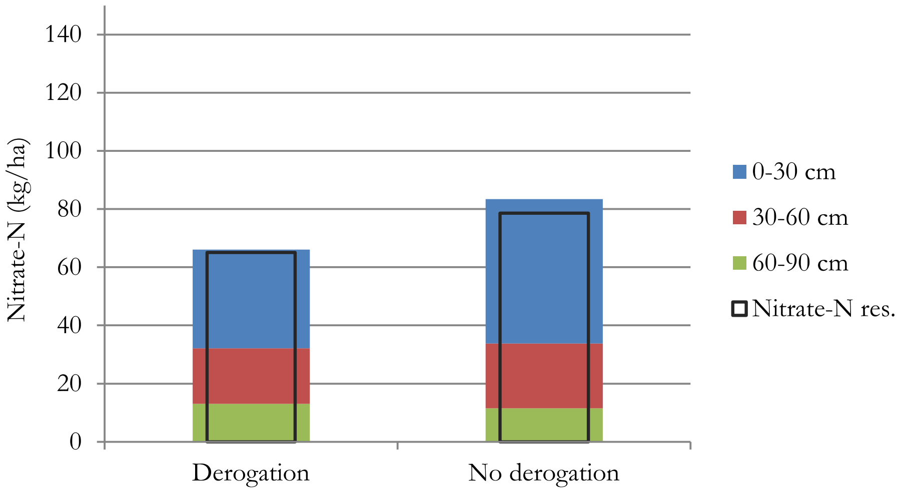
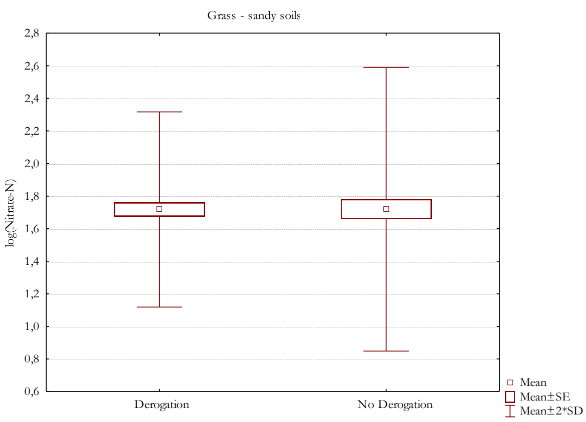


Figure 257: Average nitrate-N residue (kg/ha) on derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2018.



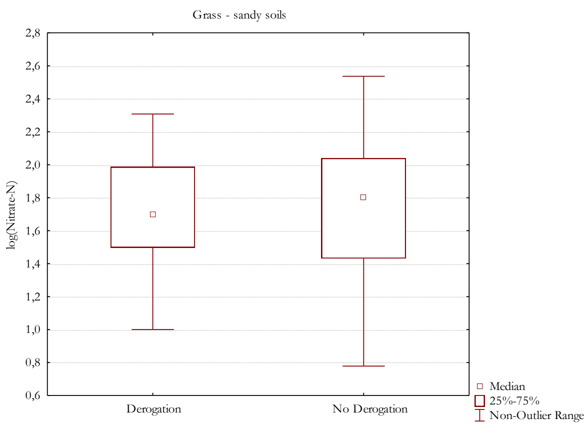


Figure 258: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2018. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Grass with less than 50 % clover on sandy soils

The evaluation of derogation on parcels with grass and less than 50 % clover is restricted to sandy soils. In autumn 2018, 53 parcels could be compared, 28 parcels under derogation conditions and 25 parcels without derogation. The nitrate-N residue was 74 ± 72 kg NO_3-N/ha on the parcels with derogation and 68 ± 99 kg NO_3-N/ha on the parcels without derogation. The difference was not statistically significant (p = 0.19).

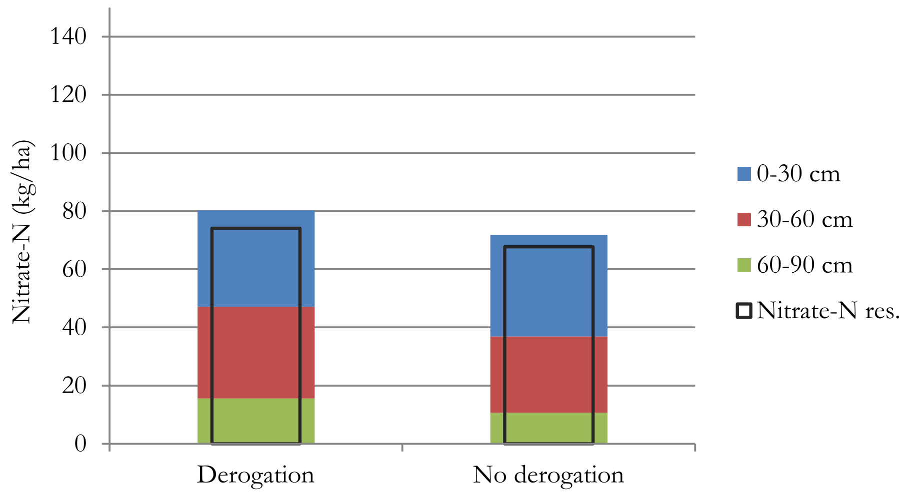


Figure 259: Average nitrate-N residue (kg/ha) on derogation and no derogation parcels with grass and less than 50 % clover on sandy soils in the monitoring network in autumn 2018.

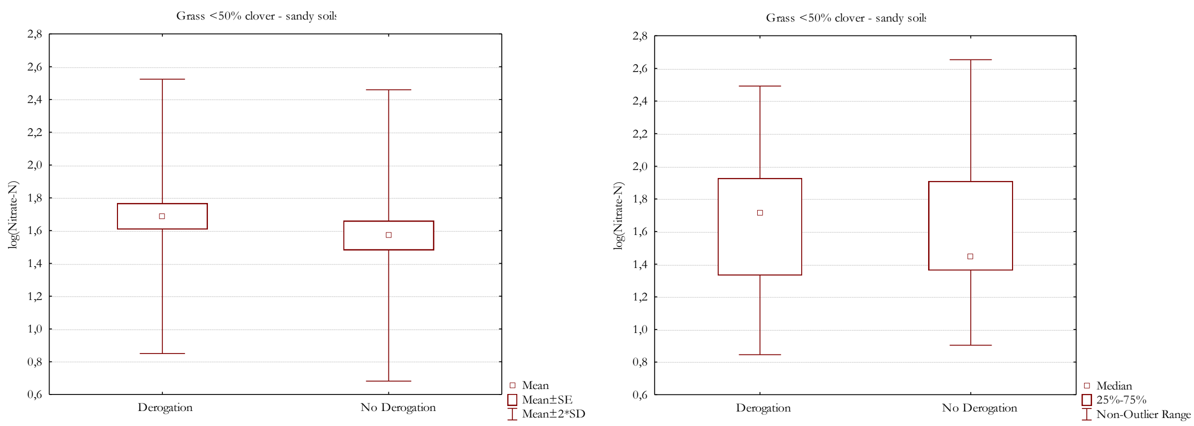


Figure 260: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with grass and less than 50 % clover on sandy soils in the monitoring network in autumn 2018. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Without the outlying parcel 24 parcels without derogation remained. The average nitrate-N residue on sandy parcels cultivated with grass and less than 50 % clover without derogation conditions amounted without the outlier 52 ± 60 kg NO_3-N/ha. The difference between derogation and no derogation parcels was still insignificant (p = 0.15).

Maize on sandy soils

Both 50 parcels with and without derogation cultivated with maize on sandy soils could be compared regarding the nitrate-N residue in autumn 2018. On the parcels cultivated under derogation conditions, the nitrate-N residue was 109 ± 65 kg NO_3-N/ha. On the parcels without derogation, the nitrate-N residue was 154 ± 77 kg NO_3-N/ha. The difference in nitrate-N residue between parcels with and parcels without derogation was statistically significant (p = 0.04).

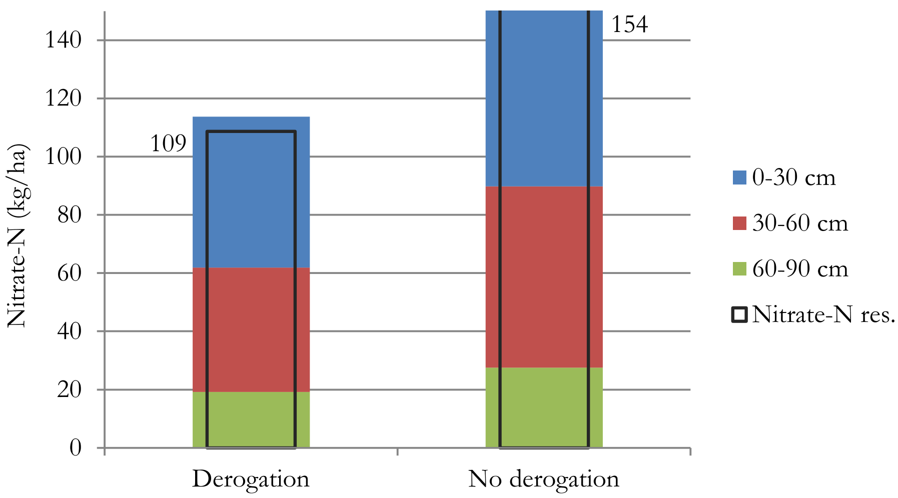


Figure 261: Average nitrate-N residue (kg/ha) on derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2018.

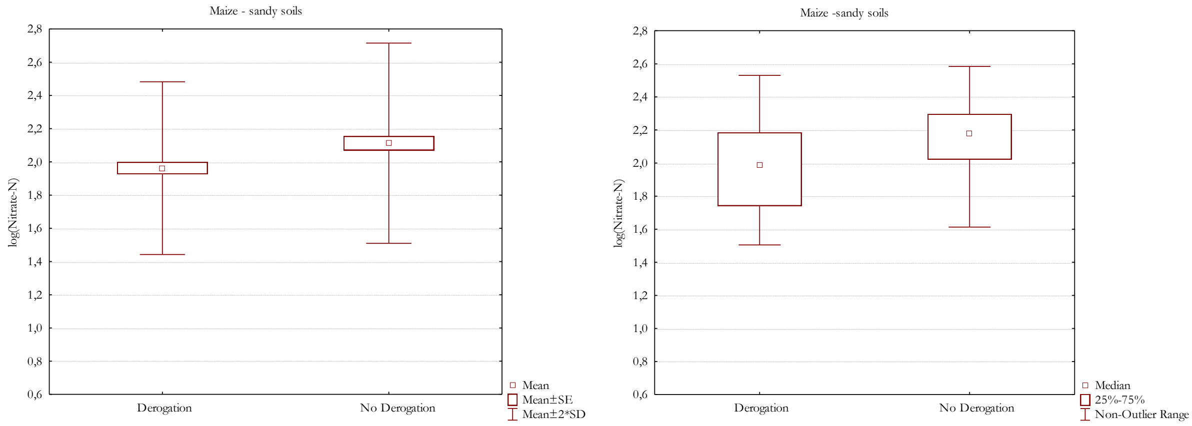


Figure 262: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2018. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

All crops on sandy loam soils

Regardless of crop or derogation the nitrate N-residue on sandy loam soils amounted 95 ± 73 kg NO_3-N/ha, evaluated on 199 parcels. Under derogation conditions, 100 parcels were evaluated. The average nitrate-N residue amounted 100 ± 77 kg NO_3-N/ha. Without derogation, the nitrate-N residue was 90 ± 69 kg NO_3-N/ha. There was no statistically significant difference (p = 0.45) between the nitrate-N residue of derogation and no derogation parcels on sandy loams soils in autumn 2018.

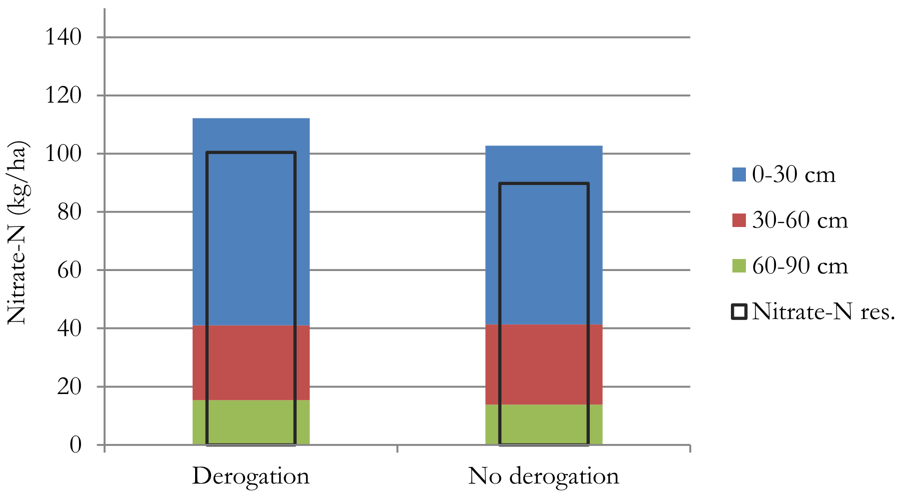


Figure 263: Average nitrate-N residue (kg/ha) on derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network in autumn 2018.

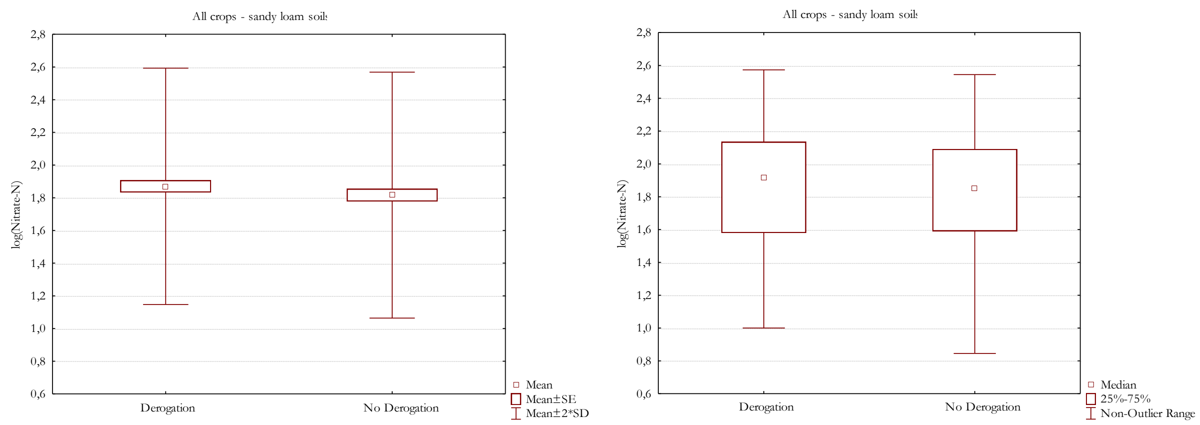


Figure 264: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network in autumn 2018. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Grass on sandy loam soils

On sandy loam soils, 100 parcels cultivated with grass were compared, 49 parcels with derogation and 51 parcels without derogation. The nitrate-N residue under derogation conditions was 97 ± 91 kg NO_3-N/ha. Without derogation, the nitrate-N residue was 64 ± 59 kg NO_3-N/ha. The nitrate-N residue of derogation and no derogation parcels on sandy loam soils cultivated with grass did not differ significantly in autumn 2018 (p = 0.21).

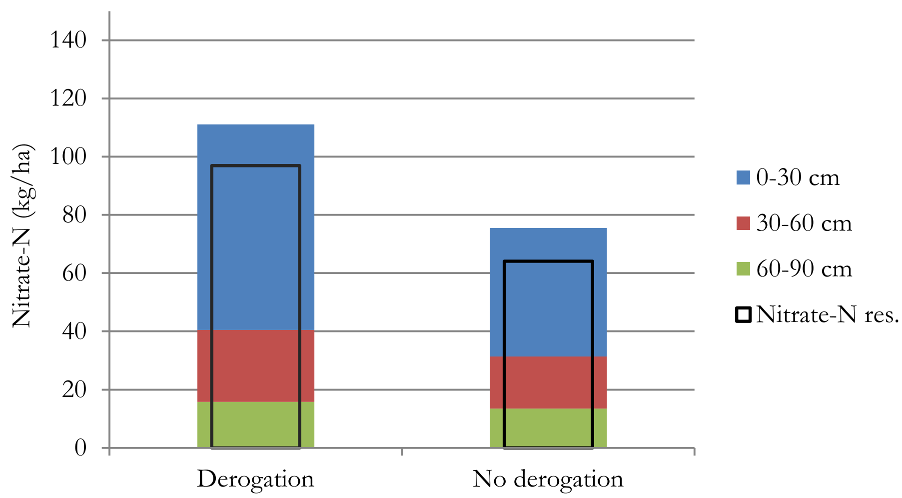


Figure 265: Average nitrate-N residue (kg/ha) on derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2018.

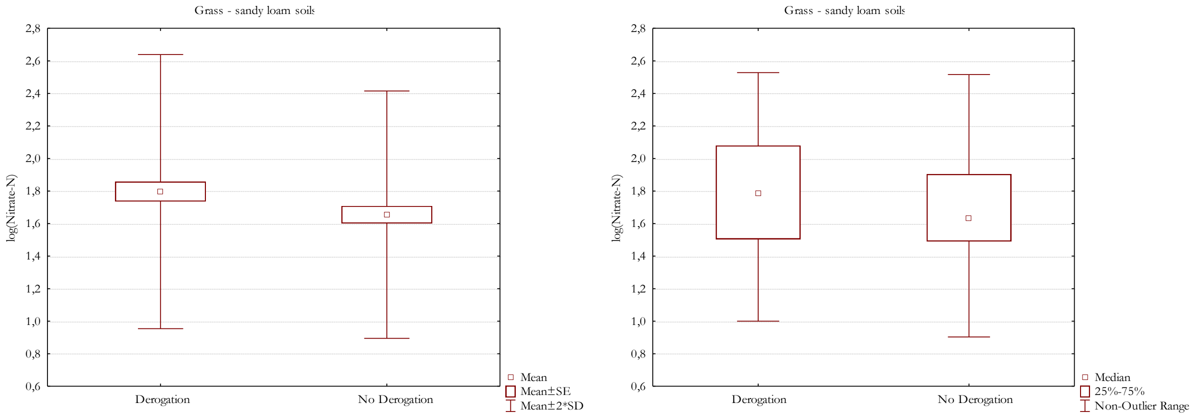


Figure 266: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2018. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Maize on sandy loam soils

Ninety-nine parcels cultivated with maize on sandy loam soils were evaluated in autumn 2018 in the derogation monitoring network. The nitrate-N residue under derogation conditions was 104 ± 61 kg NO_3-N/ha, based on 51 parcels. The average nitrate-N residue of the 48 parcels without derogation amounted 117 ± 69 kg NO_3-N/ha. There was no significant difference ($p = 0.49$) between the derogation and no derogation parcels cultivated with maize on sandy loam soils in autumn 2018.

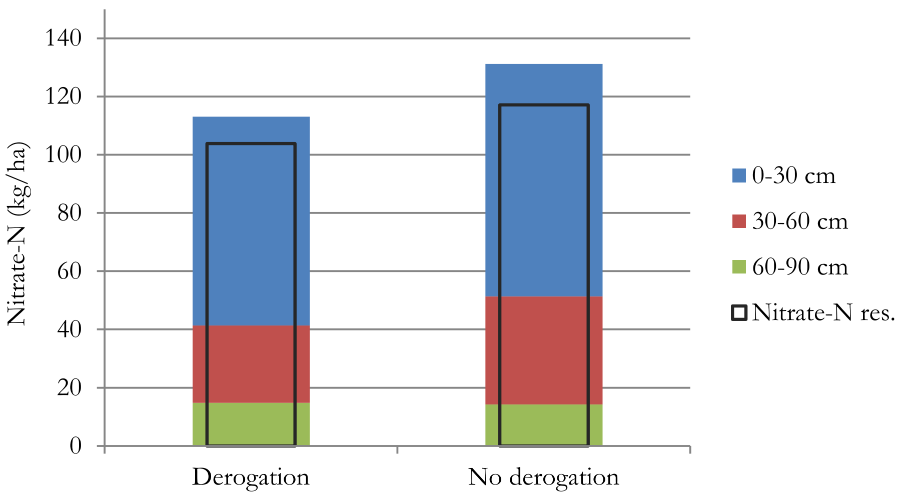


Figure 267: Average nitrate-N residue (kg/ha) on derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2018.

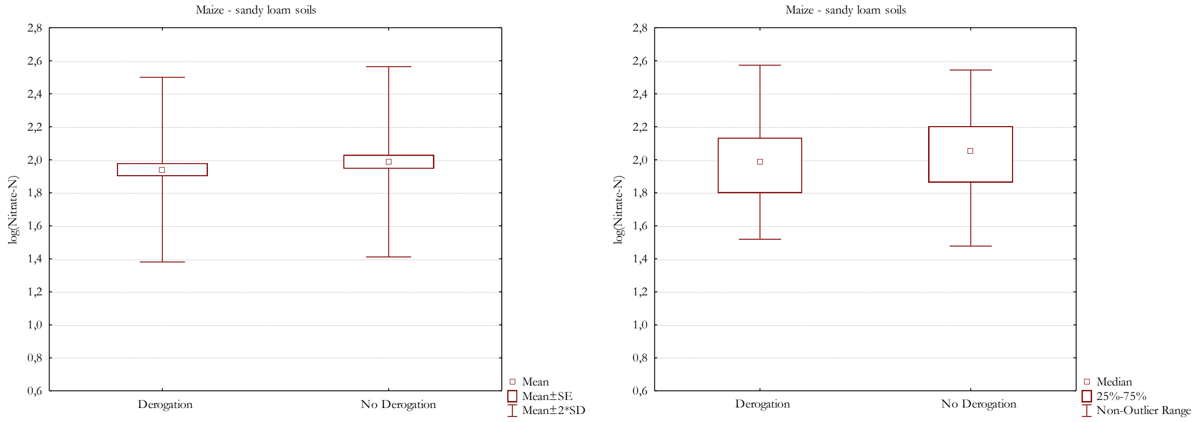


Figure 268: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2018. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

A summary of the nitrate-N residue at parcel level since 2011 is given in Table 55.

In 2018 the highest average nitrate-N residues occurred. However, the difference in nitrate-N residue between derogation and no derogation parcels remains small. The difference in average nitrate-N residue on derogation and no derogation parcels (average nitrate-N residue on derogation parcels - average nitrate-N residue on no derogation parcels) varies between -8 and 6 kg NO_3-N/ha. The average difference between the average nitrate-N residues over the past 7 years is thus -1 kg NO_3-N/ha. On average, the average nitrate-N residue on no derogation parcels is 1 kg NO_3-N/ha more than on parcels with derogation.

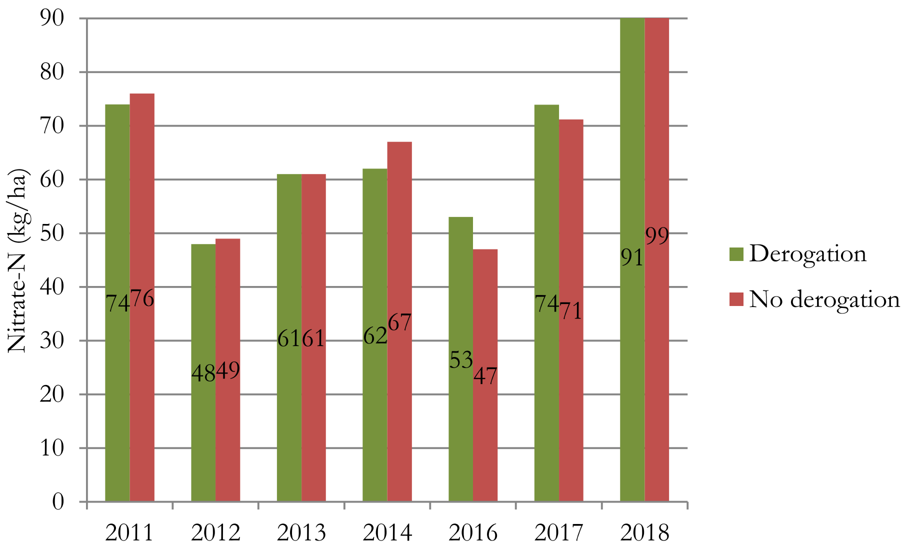


Figure 269: Nitrate-N residue in the soil profile (0-90 cm) on derogation and no derogation parcels cultivated with derogation crops in the monitoring network of 2011-2014 and the latest monitoring network 2016-2018.

On sandy soils, the average difference over the past 7 years amounts -3 kg NO_3-N/ha. On sandy loam soils, the average difference over the past 7 years is 0 kg NO_3-N/ha.

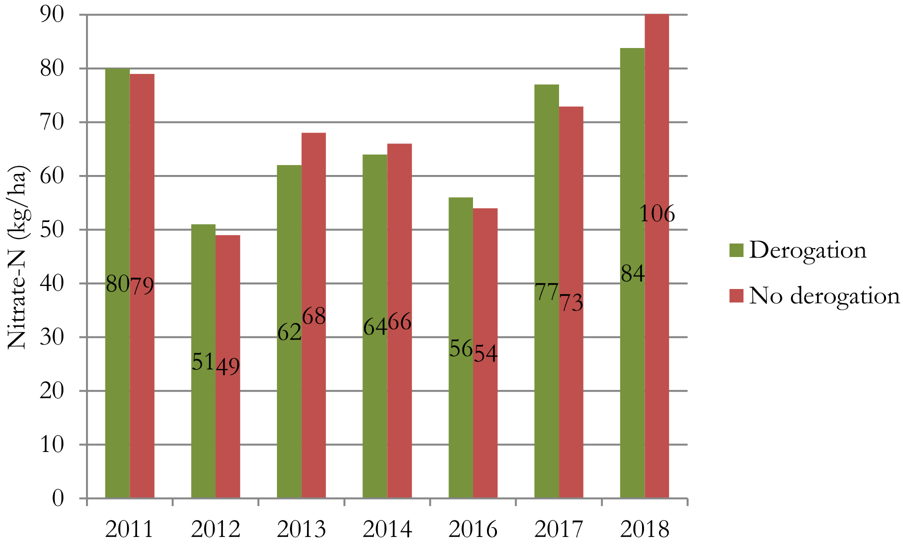


Figure 270: Nitrate-N residue in the soil profile (0-90 cm) on derogation and no derogation parcels cultivated with derogation crops on sandy soils in the monitoring network of 2011-2014 and the latest monitoring network 2016-2018.

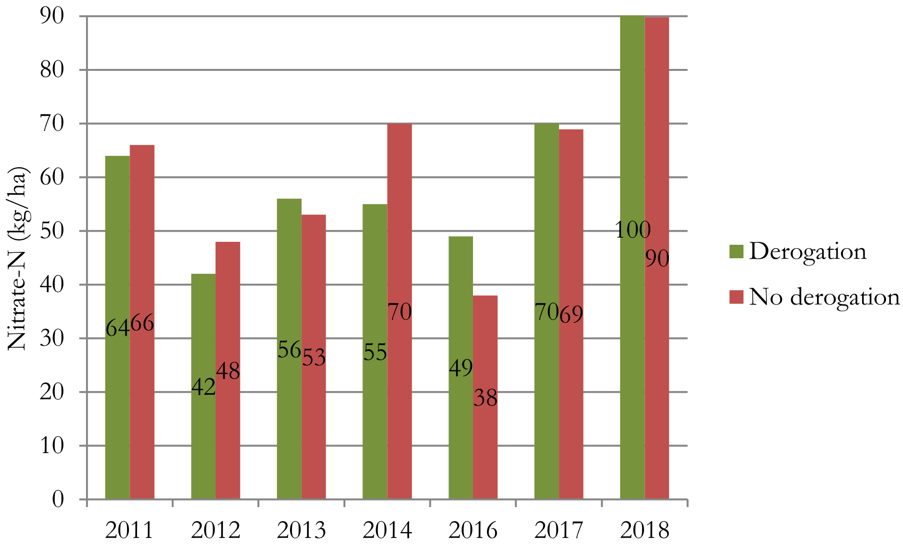


Figure 271: Nitrate-N residue in the soil profile (0-90 cm) on derogation and no derogation parcels cultivated with derogation crops on sandy loam soils in the monitoring network of 2011-2014 and the latest monitoring network 2016-2018.

Table 55: Nitrate-N residue in the soil profile (0-90 cm) for the different levels of comparison (derogation, soil texture, crop) in the monitoring network of 2011-2014 and the latest monitoring network 2016-2018. Indication of the average nitrate-N residue ± standard deviation and the p-value.

			Nitrate-N (kg/ha)													
			2011		2012		2013		2014		2016		2017		2018	
			0-90 cm	p-value	0-90 cm	p-value	0-90 cm	p-value	0-90 cm	p-value	0-90 cm	p-value	0-90 cm	p-value	0-90 cm	p-value
Overall mean monitoring network				-		-		-		-	50±41	-	73 ± 59	-	95 ± 75	-
Derogation			74±54	0.80	48±37	0.91	61±47	0.90	62±41	0.91	53±38	0.06	74 ± 51	0.03	91 ± 69	0.44
No derogation			76±57		49±33		61±46		67±49		47±44		71 ± 65		99 ± 80	
Derogation	Sandy soil		80±59	0.99	51±38	0.70	62±48	0.80	64±43	0.80	56±38	0.45	77 ± 54	0.13	84 ± 62	0.69
No derogation			79±60		49±36		68±59		66±46		54±50		73 ± 66		106 ± 87	
Derogation	Sandy loam		64±46	0.72	42±35	0.53	56±51		55±35	0.54	49±39	0.02	70 ± 48	0.14	100 ± 77	0.45
No derogation			66±45		48±29		53±32		70±53		38±31		69 ± 64		90 ± 69	
Derogation	Sandy soil	Grass	64±52	0.31	41±33	0.23	52±45	0.37	60±42	0.31	51±44	0.06	69 ± 50	0.07	65 ± 44	0.93
No derogation			51±51		32±23		54±58		54±45		36±33		52 ± 54		79 ± 68	
Derogation	Sandy soil	Grass <50% clover	-	-	-	-	-	-	-	-	40±27	0.92	54 ± 46	0.44	74 ± 72	0.19
No derogation			-	-	-	-	-	-	-	-	39±23		52 ± 62		68 ± 99	
Derogation	Sandy soil	Maize	108±61	0.82	68±42	0.36	71±46	0.65	70±48	0.52	70±31	0.22	98 ± 55	0.91	109 ± 65	0.04
No derogation			112±58		57±36		74±41		75±45		85±64		106 ± 67		154 ± 77	
Derogation	Sandy loam	Grass	31±14	0.23	24±10	0.05	43±45	0.95	45±36	0.90	41±41	0.03	55 ± 51	0.02	97 ± 91	0.21
No derogation			40±18		38±22		34±23		46±40		27±30		35 ± 29		64 ± 59	
Derogation	Sandy loam	Maize	106±38	0.43	80±36	0.06	65±56	0.56	80±28	0.84	58±34	0.20	85 ± 39	0.71	104 ± 61	0.49
No derogation			94±56		54±30		66±33		88±57		50±29		101 ± 72		117 ± 69	

3.2.1.8 Mineral nitrogen - farm average - autumn 2018

As for the evaluation of the farm average residual nitrate in 2016 and 2017, only farms of which all three parcels were representative and withheld in the discussion of the residual nitrate at parcel level, are withheld. In accordance with the nitrate-N residue of 2018, all representative samples are withheld, regardless of depth of sampling. Withholding the results of all sampling depths implies that the average nitrate-N per soil layer is related to a different number of parcels and farms. The sum of the average amounts of nitrate-N per soil layer will overestimate the mean farm average nitrate-N residue. The discussion regarding the farm average mineral nitrogen in autumn 2018 is based on the farm average being the average of 3 residues. It is identified in the bar graphs as 'Nitrate-N res.', the black box in overlay with the average amounts of nitrate-N per soil layer. At each level of comparison, it is verified that both groups have a comparable depth of sampling, reported in Table 57.

Statistical analysis of the farm average nitrate-N residue is performed on the log-transformed data.

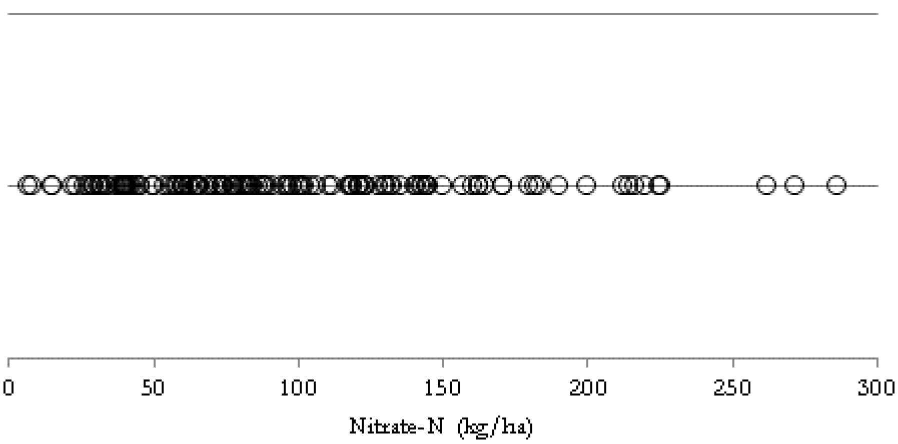


Figure 272: Spreading of the farm average nitrate-N residue of 136 farms of the monitoring network in autumn 2018.

The farm average nitrate-N residue of 2018 was evaluated on 136 farms. The mean farm average nitrate-N residue of 2018 was clearly higher as in autumn 2016 and 2017, it amounted 96 ± 58 kg NO_3-N/ha.

Table 56: Mean farm average nitrate-N in the soil profile (0-90 cm) and specified per soil layer (0-30 cm, 30-60 cm and 60-90 cm) for the 136 farms combined at different levels of comparison in autumn 2018. The number of farms taken up in the comparison of the nitrate-N residue (0-90 cm) is indicated by 'n'.

				Nitrate-N (kg/ha)				p-value
			n	0-30 cm	30-60 cm	60-90 cm	0-90 cm	
Overall farm average			136	57	31	17	96	-
Derogation			68	55	29	16	92	0.94
No derogation			68	59	34	18	100	
Derogation	Sandy soil		36	41	31	18	85	0.42
No derogation			39	58	40	21	108	
Derogation	Sandy loam		32	70	25	14	99	0.44
No derogation			29	61	26	13	90	
Derogation	Sandy soil	Grass	16	32	19	13	63	0.87
No derogation			16	46	21	14	75	
Derogation	Sandy soil	Grass <50% clover	4	31	34	24	77	-
No derogation			7	39	34	11	75	
Derogation	Sandy soil	Maize	16	52	43	20	108	0.02
No derogation			16	77	63	32	155	
Derogation	Sandy loam	Grass	15	69	24	14	94	0.35
No derogation			15	46	17	11	67	
Derogation	Sandy loam	Maize	17	72	27	14	104	0.84
No derogation			14	77	35	15	114	

Table 57: Number of farms taken into account for the average values in Table 56. These farms had at least one sample at the respective depth of sampling. Average depth of sampling (cm) for the 136 farms combined at different levels of comparison in autumn 2018.

			Number of farms				Sampling depth (cm)
			0-30 cm	30-60 cm	60-90 cm	0-90 cm	
Overall farm average			136	134	106	136	76
Derogation			68	67	54	68	78
No derogation			68	67	52	68	74
Derogation	Sandy soil		36	36	33	36	85
No derogation			39	38	33	39	79
Derogation	Sandy loam		32	31	21	32	69
No derogation			29	29	19	29	68
Derogation	Sandy soil	Grass	16	16	15	16	88
No derogation			16	16	13	16	79
Derogation	Sandy soil	Grass <50% clover	4	4	4	4	83
No derogation			7	7	5	7	79
Derogation	Sandy soil	Maize	16	16	14	16	83
No derogation			16	15	15	16	79
Derogation	Sandy loam	Grass	15	14	10	15	66
No derogation			15	15	10	15	69
Derogation	Sandy loam	Maize	17	17	11	17	72
No derogation			14	14	9	14	68

On farms with derogation, the mean farm average nitrate-N residue was 92 ± 54 kg NO_3-N/ha in autumn 2018. On farms without derogation, the mean farm average nitrate-N residue amounted 100 ± 62 kg NO_3-N/ha. The comparison of derogation farms, regardless of soil or crop, involved both 68 farms with and without derogation. Sampling depth was comparable for both groups and was not an issue for comparison the mean farm average nitrate-N residue. The mean farm average nitrate-N residue did not differ significantly between derogation and no derogation farms (p = 0.94).

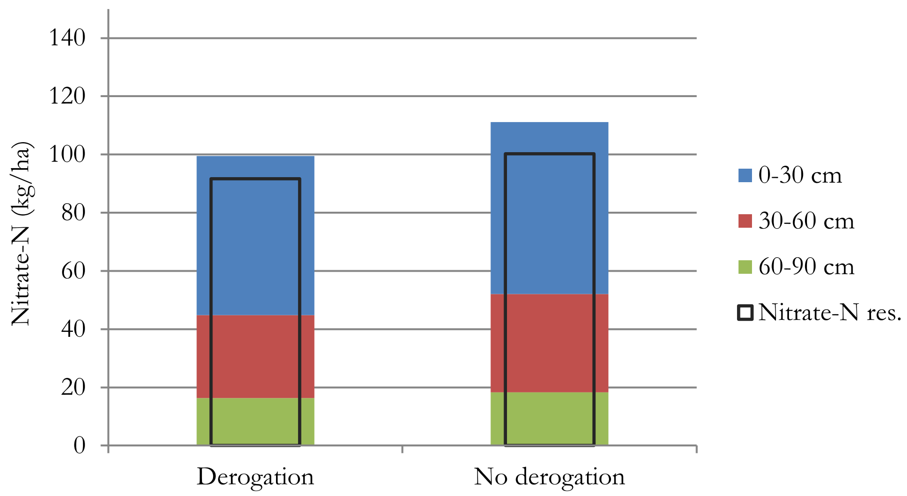


Figure 273: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with all crops on all soils in the monitoring network in autumn 2018.

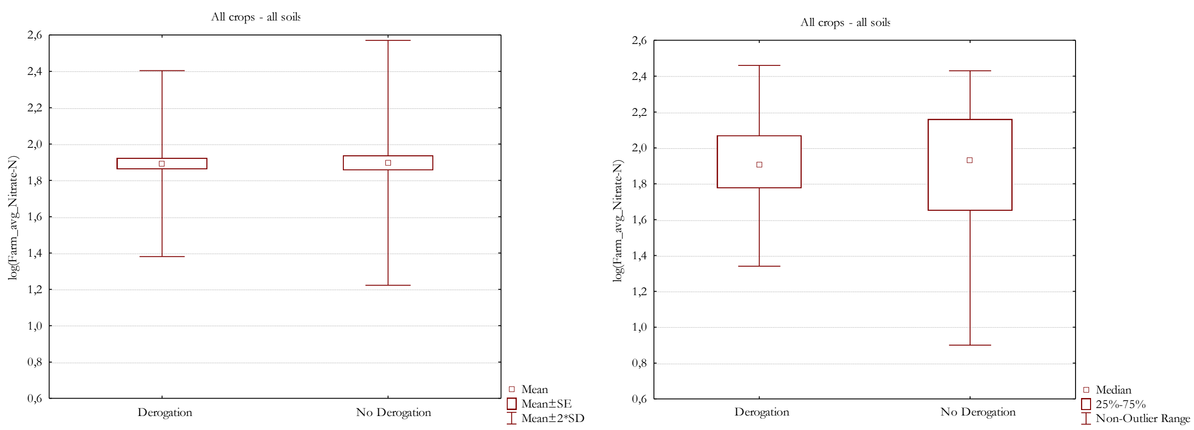


Figure 274: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with all crops on all soils in the monitoring network in autumn 2018. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

All crops on sandy soils

On sandy soils, the farm average Nitrate-N residue of 37 derogation farms and 43 farms without derogation was compared. The mean farm average nitrate-N residues amounted respectively 85 ± 47 kg NO_3-N/ha and 108 ± 65 kg NO_3-N/ha. The difference between derogation and no derogation farms was not statistically significant ($p = 0.42$). Irrespective of derogation or crop, the mean farm average nitrate-N residue on sandy soils amounted 97 ± 58 kg NO_3-N/ha in the monitoring network in autumn 2018.

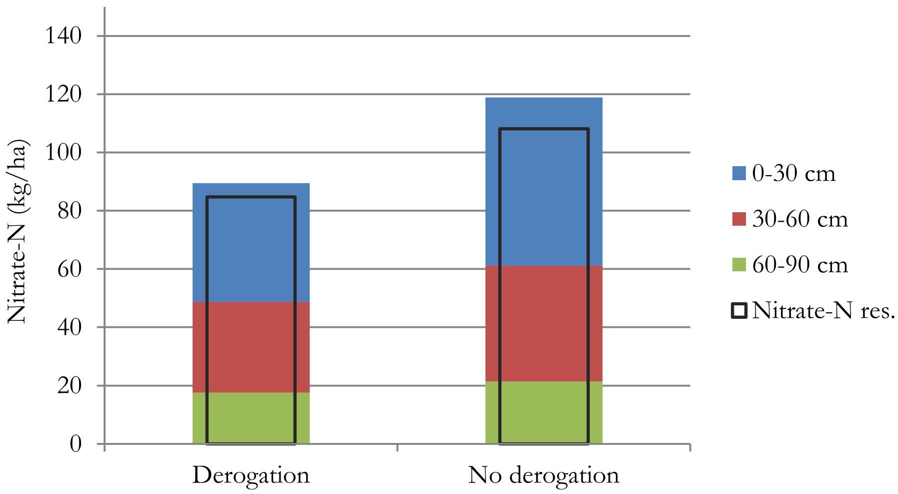


Figure 275: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2018.

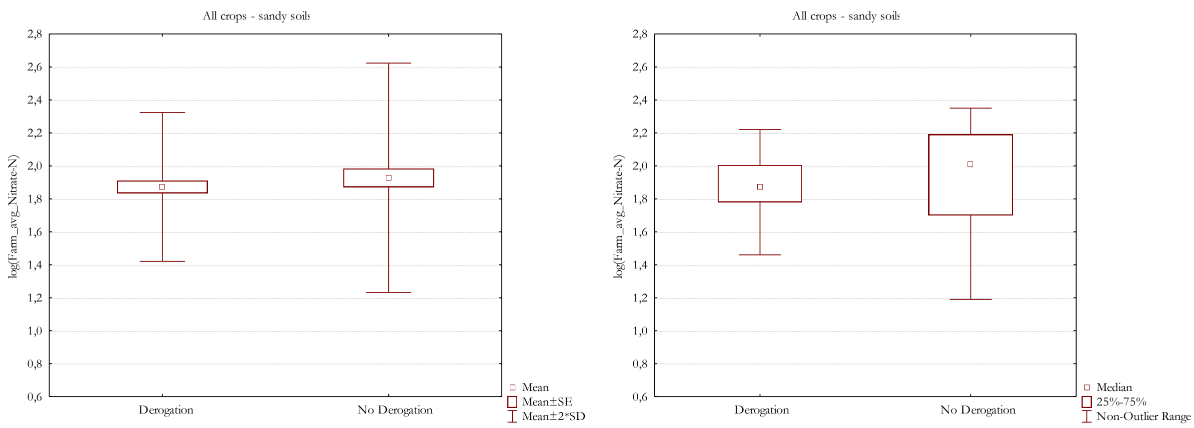


Figure 276: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2018. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Grass on sandy soils

The mean farm average nitrate-N residue on sandy soils cultivated with grass was 69 ± 40 kg NO_3-N/ha. Therefore 32 farms could be evaluated, both 16 derogation farms and 16 farms without derogation. Under derogation conditions, the mean farm average nitrate-N residue of sandy parcels cultivated with grass was 63 ± 29 kg NO_3-N/ha. Without derogation, the mean farm average nitrate-N residue was 76 ± 48 kg NO_3-N/ha. The mean farm average nitrate-N residue on sandy soils cultivated with grass did not differ significantly ($p = 0.87$) between derogation and no derogation farms.

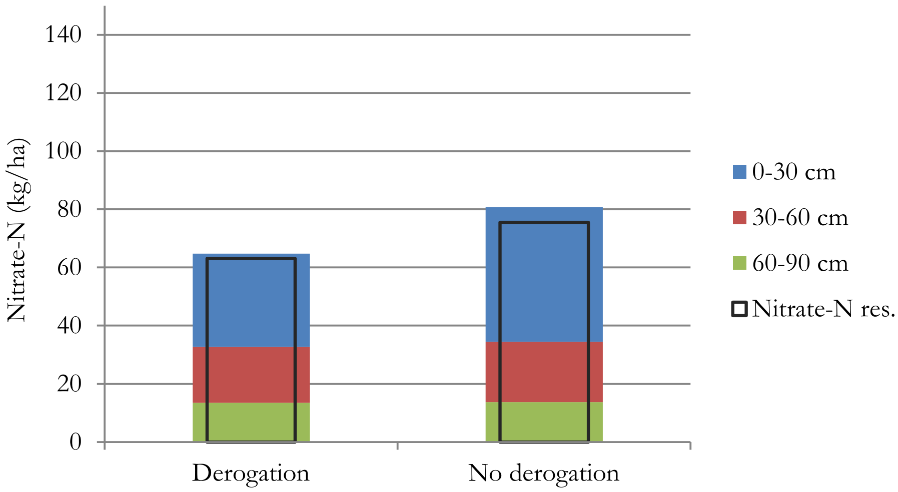


Figure 277: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2018.

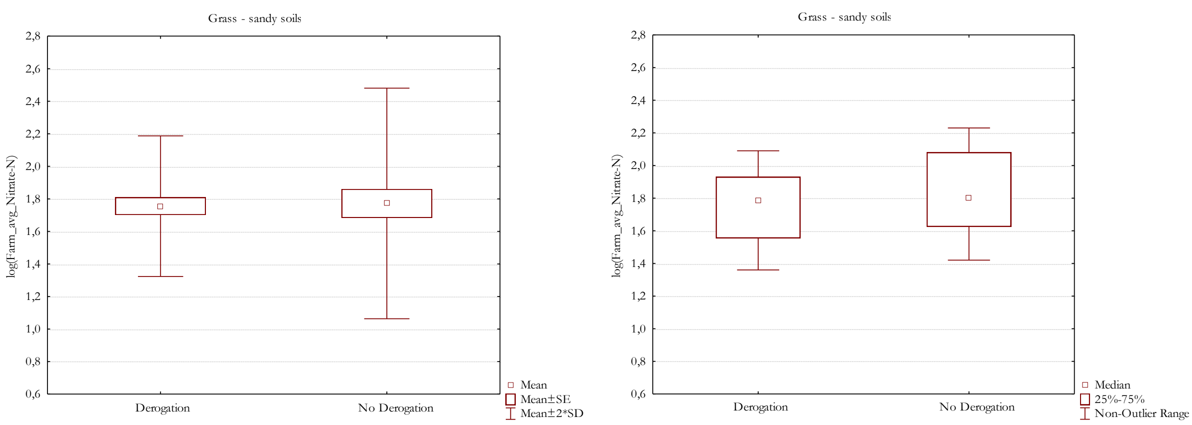


Figure 278: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2018. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Grass with less than 50 % clover on sandy soils

The farm average nitrate-N residue for parcels cultivated with grass and less than 50 % clover on sandy soils was compared between 4 farms with derogation and 7 farms without derogation. Under derogation conditions, the mean farm average nitrate-N residue was 77 ± 17 kg NO_3-N/ha. Without derogation, it amounted 75 ± 62 kg NO_3-N/ha (Figure 279).

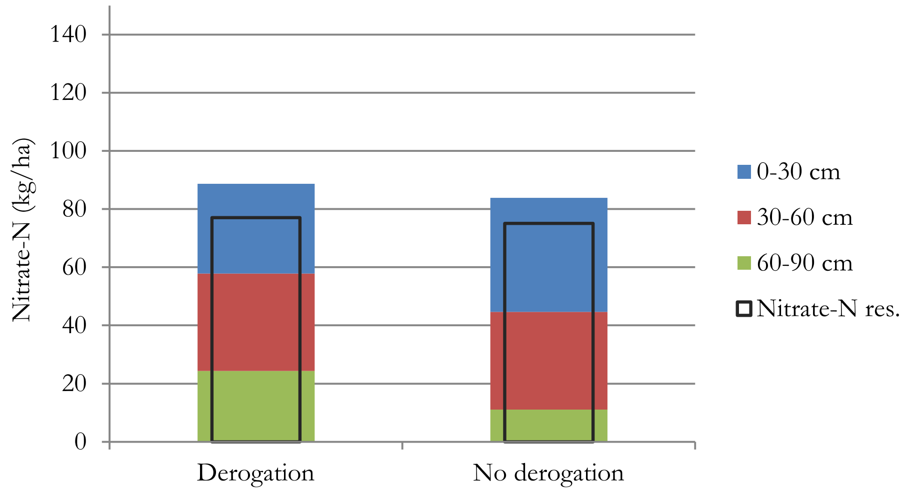


Figure 279: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with grass and less than 50 % clover on sandy soils in the monitoring network in autumn 2018.

Maize on sandy soils

On sandy soils, the farm average nitrate-N residue of parcels cultivated with maize was determined for 32 farms, 16 derogation farms and 16 farms without derogation. Regardless of the request of derogation, the mean farm average nitrate-N residue of sandy parcels cultivated with maize amounted 132 ± 58 kg NO_3-N/ha. On derogation farms, the mean farm average nitrate-N residue of the parcels cultivated with maize was 108 ± 55 kg NO_3-N/ha. On the farms without derogation, the mean farm average nitrate-N residue of the parcels cultivated with maize was 155 ± 53 kg NO_3-N/ha. The mean farm average nitrate-N residue of farms without derogation was significantly higher than on derogation farms ($p = 0.01$).

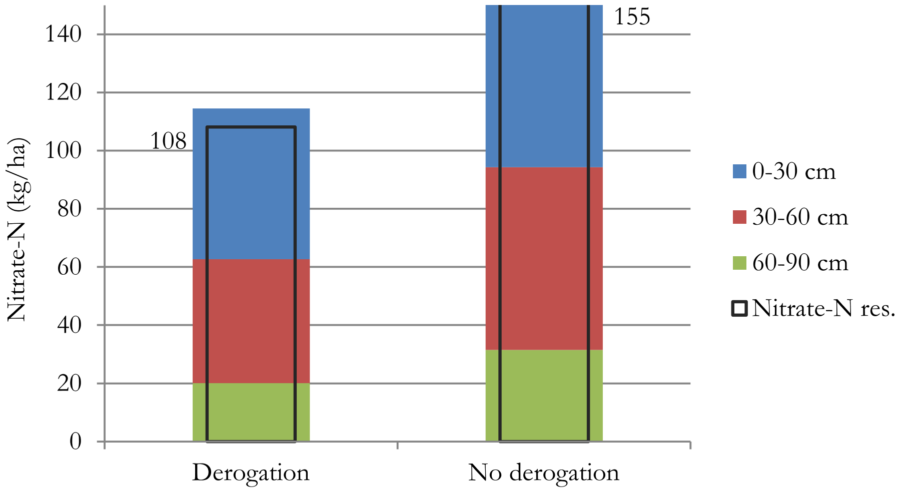


Figure 280: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2018.

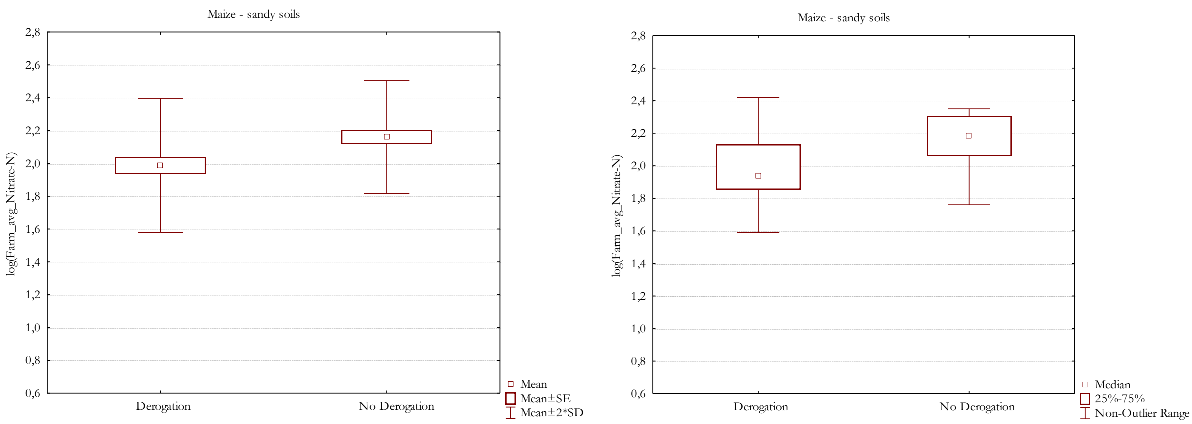


Figure 281: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2018. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

All crops on sandy loam soils

On sandy loam soils, the mean farm average nitrate-N residue amounted 95 ± 59 kg NO_3-N/ha, all crops and both derogation and no derogation included. This evaluation in autumn 2018 comprised 61 farms, 32 farms with derogation and 29 farms without derogation.

The mean farm average nitrate-N residue of sandy loam parcels cultivated with derogation was 99 ± 61 kg NO_3-N/ha (Figure 282). Without derogation the mean farm average nitrate-N residue of sandy loam parcels was 90 ± 59 kg NO_3-N/ha.

The mean farm average nitrate-N residue on sandy loam soils did not differ significantly between derogation and no derogation farms ($p = 0.44$).

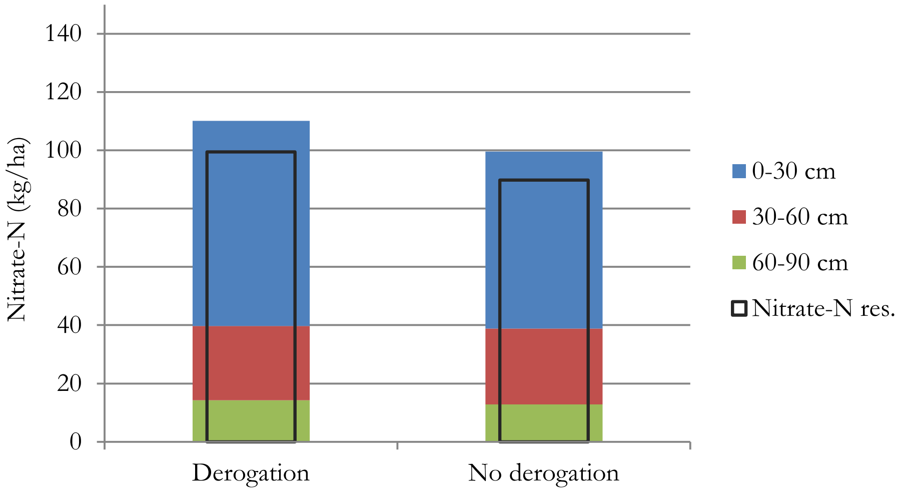


Figure 282: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network in autumn 2018.

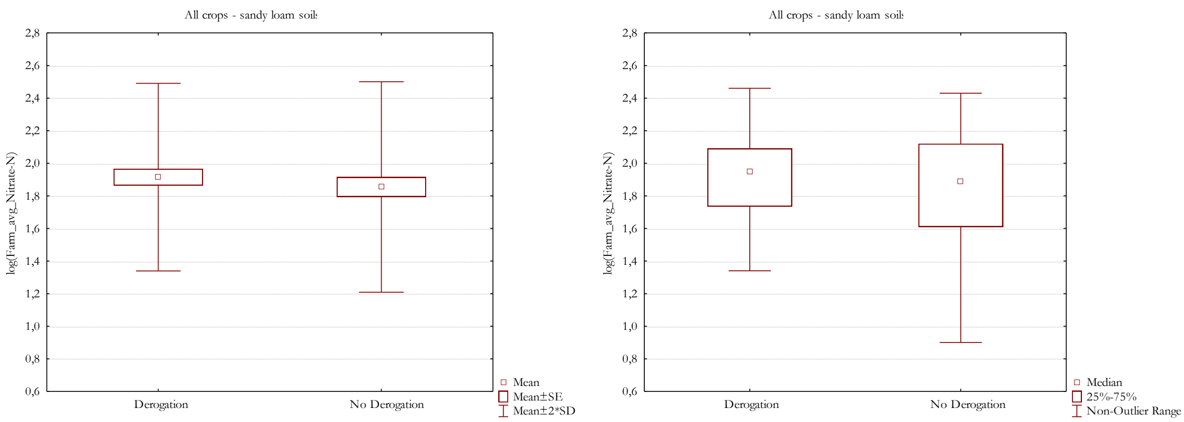


Figure 283: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network in autumn 2018. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Grass on sandy loam soils

The farm average nitrate-N residue of sandy loam parcels cultivated with grass could be compared between 15 farms with derogation and 15 farms without derogation. With derogation, the mean farm average nitrate-N residue amounted 94 ± 77 kg NO_3-N/ha. Without derogation, the mean farm average nitrate-N residue amounted 67 ± 46 kg NO_3-N/ha. The difference between derogation and no derogation farms regarding the mean farm average nitrate-N residue of sandy loams parcels cultivated with grass was not statistically significant ($p = 0.35$).

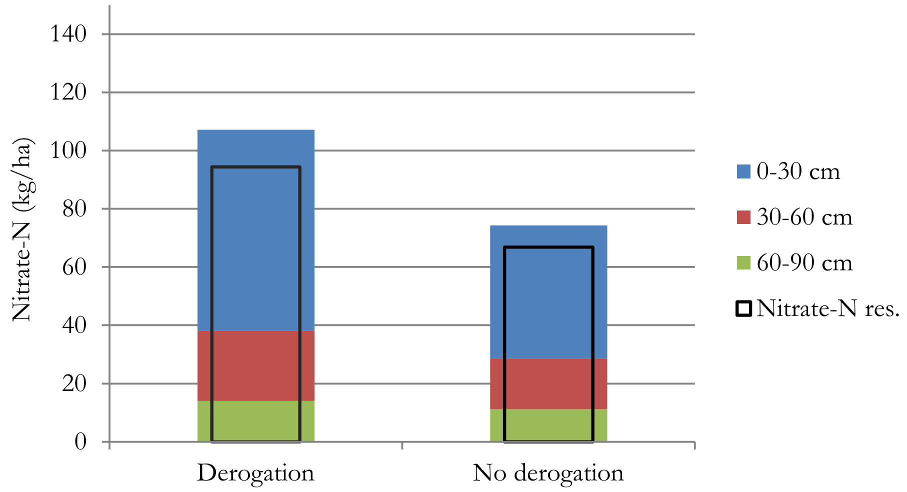


Figure 284: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2018.

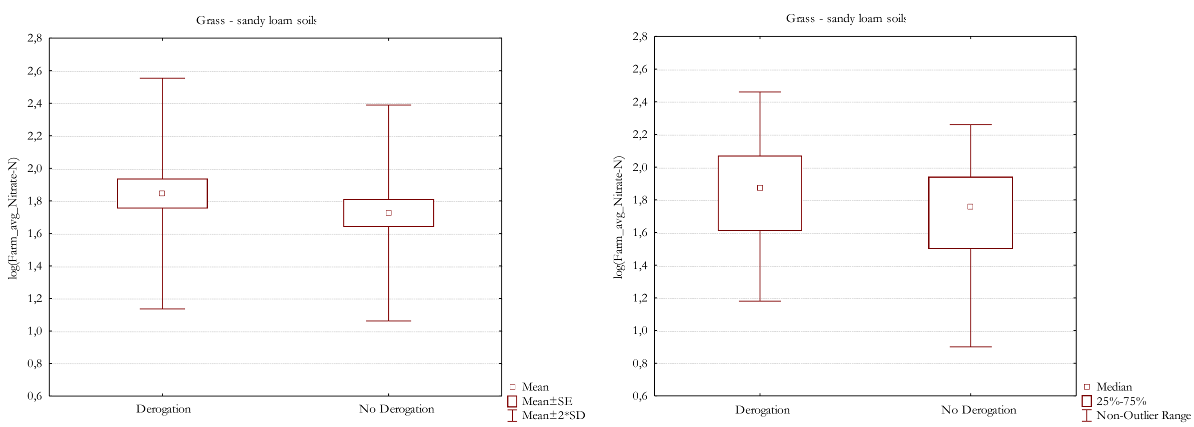


Figure 285: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2018. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Maize on sandy loam soils

On sandy loam soils, the farm average nitrate-N residue of parcels cultivated with maize was evaluated on 31 farms, 17 farms under derogation conditions and 14 farms without request of derogation. Irrespective of derogation, the mean farm average nitrate-N residue of sandy loam parcels cultivated with maize was 109 ± 52 kg NO_3-N/ha. Under derogation conditions, this mean farm average nitrate-N residue was 104 ± 43 kg NO_3-N/ha (Figure 286). On farms without derogation, the mean farm average nitrate-N residue was 114 ± 62 kg NO_3-N/ha. There was no statistically significant difference ($p = 0.84$) between farms with and without derogation regarding the farm average nitrate-N residue on sandy loam soils cultivated with maize.

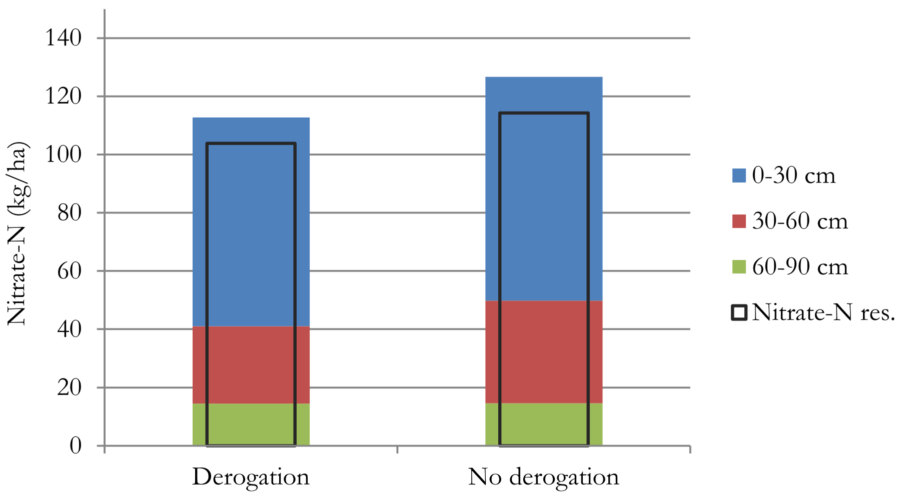


Figure 286: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2018.

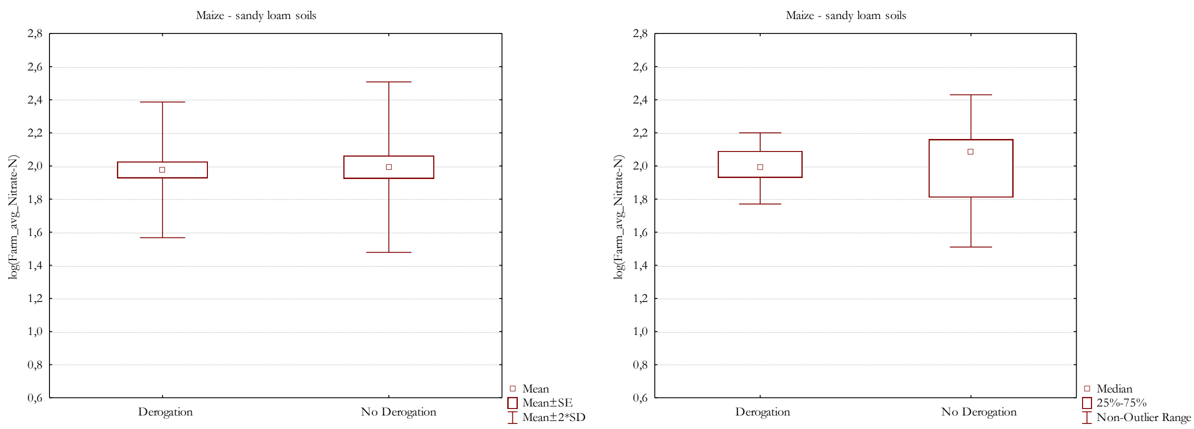


Figure 287: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2018. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

3.2.1.9 Mineral nitrogen - difference autumn 2018 and spring 2019

As for the previous winters, the difference in nitrate-N before and after winter was estimated. The difference in nitrate-N realised during winter 2018-2019 was estimated by comparing the nitrate-N residue of autumn 2018 and the amount of nitrate-N in the soil profile in late winter 2018-early spring 2019. The samples taken in autumn 2018 that represent the nitrate-N residue are discussed in a previous paragraph.

The difference over winter is only defined for parcels which were sampled until 90 cm. Parcels sampled more shallow were excluded for this analysis. Likewise are parcels cultivated with grass of which was known that they were ploughed after sampling for the nitrate-N residue.

The difference over winter approximates the amount of nitrate-N out of the soil profile between the two sampling moments and comprises more processes than only leaching. The difference of nitrate-N between the two sampling moments is expressed in kg NO_3-N/ha and is calculated as "nitrate-N residue (kg NO_3-N/ha; 0-90 cm) – nitrate-N reserve after winter (kg NO_3-N/ha; 0-90 cm)".

The statistical analysis for winter 2018-2019 is performed with a non-parametric test, the Kruskal-Wallis test. The dependent variable in this analysis "nitrate-N difference", was not log-transformed.

The amount of nitrate-N (kg NO_3-N/ha) per soil layer (0-30 cm, 30-60 cm and 60-90 cm) in autumn and spring for derogation and no derogation parcels is presented by the bar graphs. This presentation allows estimating the difference of nitrate-N realised between the two moments of sampling and shows the redistribution of the nitrate-N over the soil profile during this period.

The variation in nitrate-N difference is indicated by the box plots, based on the effective figures of nitrate-N difference (kg NO_3-N/ha).

The nitrate-N difference of winter 2018-2019 is discussed based on 272 parcels. This rather limited number point out the large impact of the drought in 2018. Outliers were not discarded for this discussion but were however detected and are mentioned when relevant. Fourteen values were marked as outlier.

Table 58: Average nitrate-N difference-winter 2018-2019 (kg/ha) based on parcels sampled to 90 cm, combined at different levels of comparison. The number of parcels included in the comparison is indicated by 'n'. P-value based on the non-parametric Kruskal-Wallis test.

			Difference of nitrate-N (kg/ha)		
			n	Average	p-value
Overall mean monitoring network			272	56 ± 67	-
Derogation			143	58 ± 63	0.55
No derogation			129	54 ± 71	
Derogation	Sandy soil		101	53 ± 59	0.12
No derogation			89	67 ± 73	
Derogation	Sandy loam		42	70 ± 71	0.001
No derogation			40	24 ± 54	
Derogation	Sandy soil	Grass	43	33 ± 41	0.70
No derogation			38	40 ± 48	
Derogation	Sandy soil	Grass <50% clover	21	41 ± 64	0.71
No derogation			15	11 ± 63	
Derogation	Sandy soil	Maize	37	83 ± 63	0.02
No derogation			36	120 ± 67	
Derogation	Sandy loam	Grass	21	59 ± 71	0.06
No derogation			21	19 ± 64	
Derogation	Sandy loam	Maize	21	82 ± 70	0.01
No derogation			19	29 ± 43	

During winter 2018-2019, the average nitrate-N difference amounted 56 ± 67 kg NO_3-N/ha, evaluated on 272 parcels (Figure 288). The average nitrate-N difference over winter has increased each winter. In winter 2016-2017 the average nitrate-N difference amounted 10 ± 32 kg NO_3-N/ha and in winter 2017-2018 it was 40 ± 51 kg NO_3-N/ha. The high nitrate-N residues in autumn 2018 are a determinant parameter for the larger difference during winter 2018-2019.

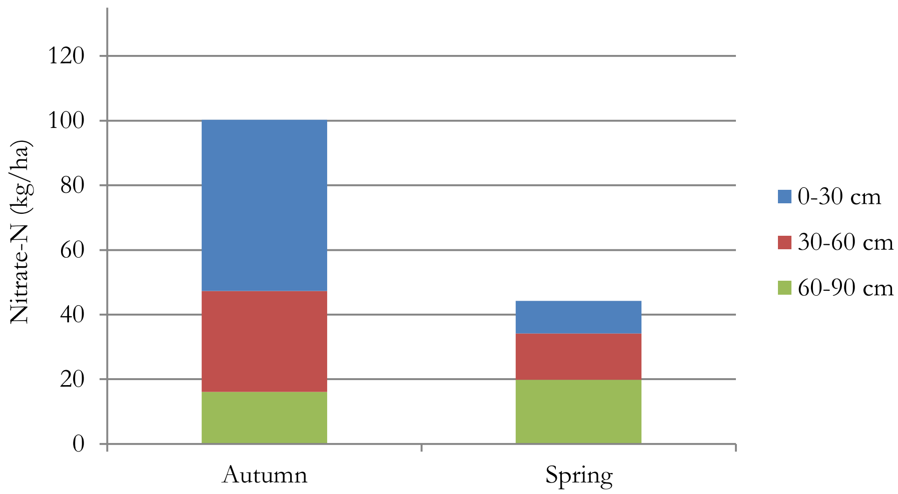


Figure 288: Average nitrate-N (kg/ha) on 272 parcels of the monitoring network in autumn 2018 and spring 2019, indicating the average nitrate-N difference-winter 2018-2019.

The over winter evaluation 2018-2019 comprised 143 derogation parcels and 129 parcels without derogation. The average nitrate-N difference on derogation parcels amounted 58 ± 63 kg NO_3-N/ha. On parcels without derogation, the average nitrate-N difference was 54 ± 71 kg NO_3-N/ha. In both groups, the variation in nitrate-N difference was high. The nitrate-N difference on derogation and no derogation parcels was not significant different (p = 0.55).

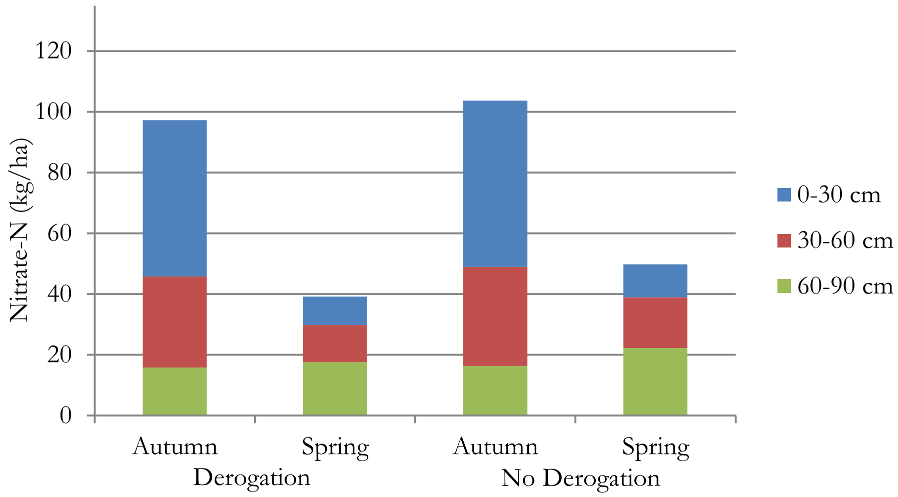


Figure 289: Average nitrate-N (kg/ha) in autumn 2018 and spring 2019 on derogation and no derogation parcels of the monitoring network, indicating the average nitrate-N difference during winter 2018-2019 on derogation and no derogation parcels.

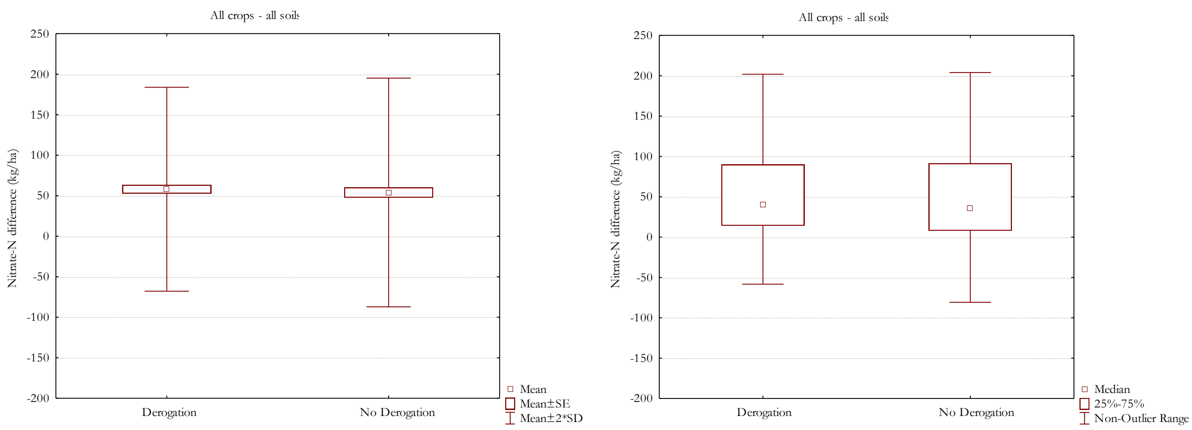


Figure 290: Boxplot of the nitrate-N difference-winter 2018-2019 (kg/ha) on derogation and no derogation parcels with all crops on all soil textures in the monitoring network. Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

All crops on sandy soils

On sandy soils, the average nitrate-N difference was evaluated on 190 parcels, 101 parcels under derogation conditions and 89 parcels without derogation conditions. Regardless of derogation or crop the average nitrate-N difference on sandy soils amounted 60 ± 66 kg NO_3-N/ha in winter 2018-2019 in the monitoring network.

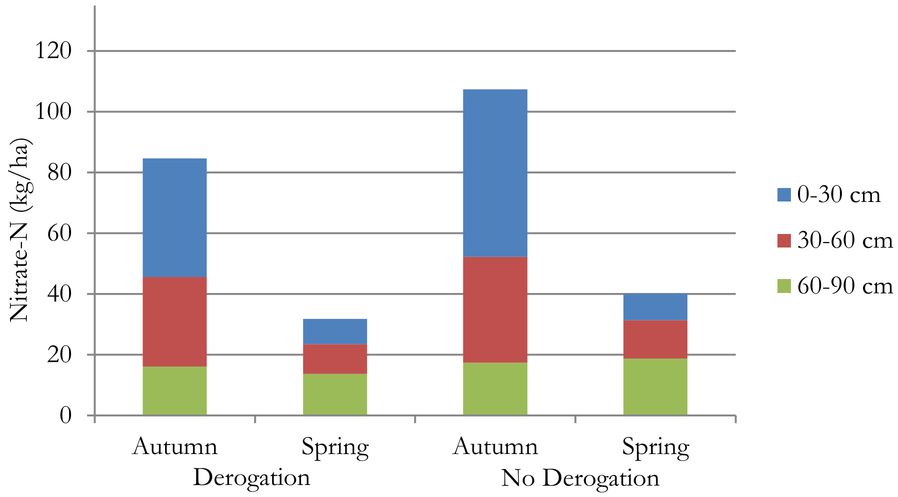


Figure 291: Average nitrate-N (kg/ha) in autumn 2018 and spring 2019 on derogation and no derogation parcels on sandy soils of the monitoring network, indicating the average nitrate-N difference during winter 2018-2019 on derogation and no derogation parcels on sandy soils.

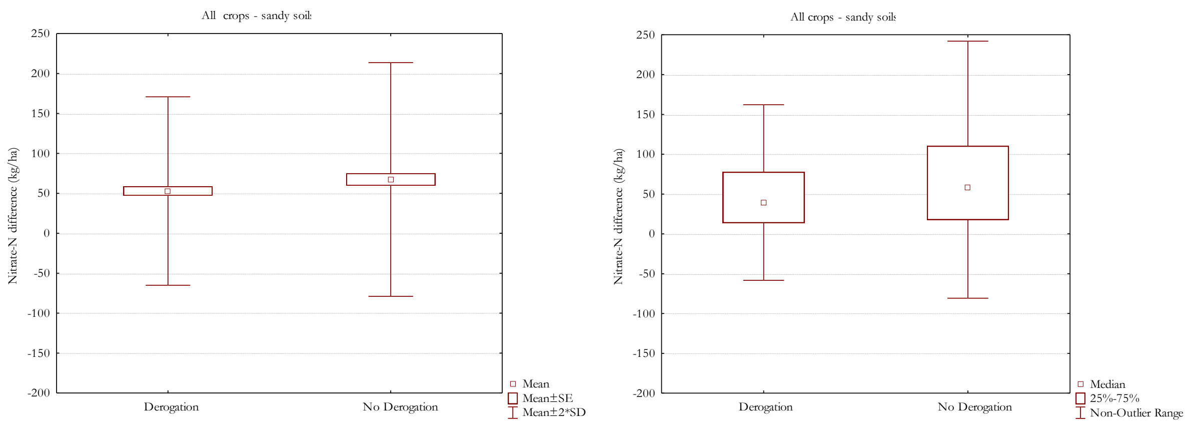


Figure 292: Boxplot of the nitrate-N difference-winter 2018-2019 (kg/ha) on derogation and no derogation parcels with all crops on sandy soils in the monitoring network. Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Under derogation conditions, the average nitrate-N difference on sandy soils was 53 ± 59 kg NO_3-N/ha (Figure 291). Without derogation conditions, the average nitrate-N difference on sandy soils was 67 ± 73 kg NO_3-N/ha. There was no significant difference in nitrate-N difference over winter 2018-2019 between derogation and no derogation parcels ($p = 0.12$).

Grass on sandy soils

On sandy soils, 43 parcels cultivated with grass under derogation conditions and 38 parcels cultivated with grass without derogation were compared regarding the nitrate-N difference over winter 2018-2019. On the parcels with derogation, the average nitrate-N difference amounted 33 ± 41 kg NO_3-N/ha and 40 ± 48 kg NO_3-N/ha without derogation. The average nitrate-N difference was not significant different between derogation and no derogation parcels ($p = 0.70$).

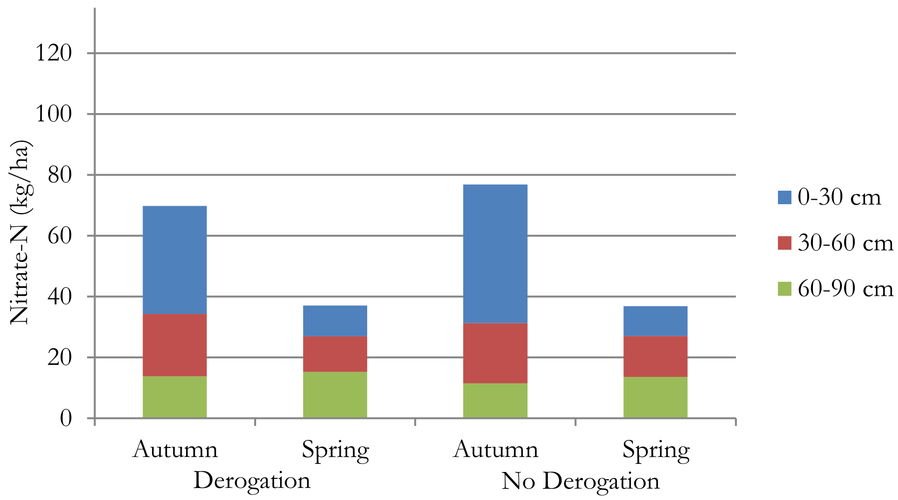
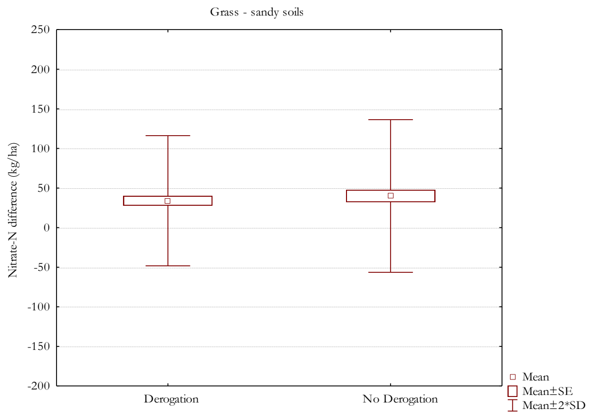


Figure 293: Average nitrate-N (kg/ha) in autumn 2018 and spring 2019 on derogation and no derogation parcels on sandy soils cultivated with grass of the monitoring network, indicating the average nitrate-N difference during winter 2018-2019 on derogation and no derogation parcels on sandy soils cultivated with grass.



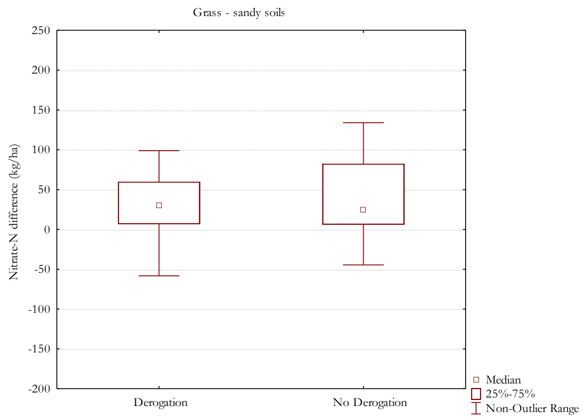


Figure 294: Boxplot of the nitrate-N difference-winter 2018-2019 (kg/ha) on derogation and no derogation parcels with grass on sandy soils in the monitoring network. Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Grass with less than 50 % clover on sandy soils

The average nitrate-N difference on parcels cultivated with grass and less than 50 % clover was evaluated on 36 parcels in winter 2018-2019. Under derogation conditions, 21 parcels were evaluated and the average nitrate-N difference was 41 ± 64 kg NO_3-N/ha. The average nitrate-N difference of the 15 parcels without derogation was 11 ± 63 kg NO_3-N/ha. Derogation and no derogation parcels did not differ significantly (p = 0.71) regarding the nitrate-N difference over winter 2018-2019.

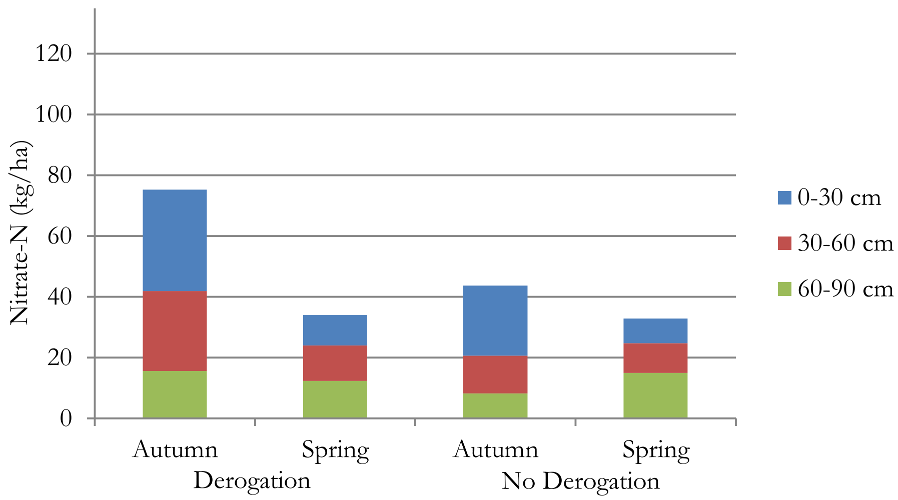


Figure 295: Average nitrate-N (kg/ha) in autumn 2018 and spring 2019 on derogation and no derogation parcels on sandy soils cultivated with grass and less than 50 % clover of the monitoring network, indicating the average nitrate-N difference during winter 2018-2019 on derogation and no derogation parcels on sandy soils cultivated with grass and less than 50 % clover.

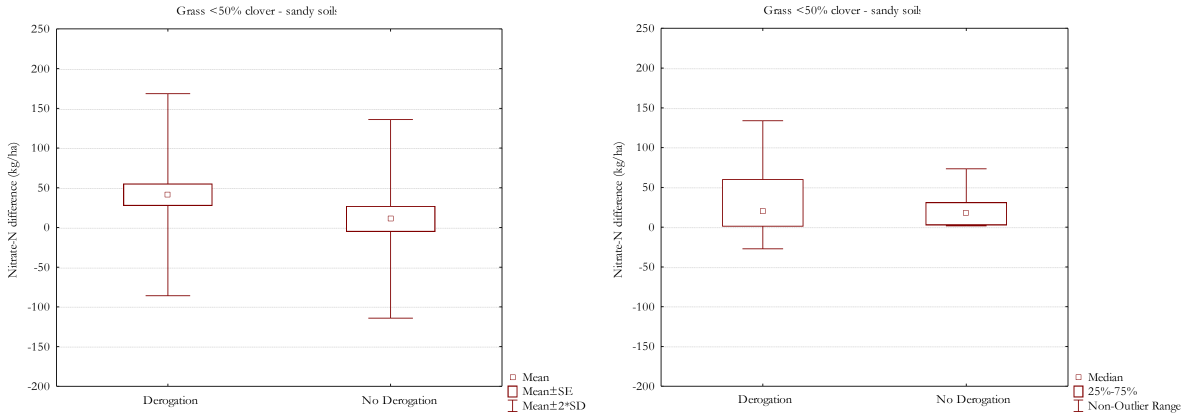


Figure 296: Boxplot of the nitrate-N difference-winter 2018-2019 (kg/ha) on derogation and no derogation parcels with grass and less than 50 % clover on sandy soils in the monitoring network. Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

One parcel cultivated with grass and less than 50 % clover was detected as an outlier. It concerns a parcel cultivated under derogation conditions. Nothing particularly could be detected in the parcel data. Also without the outlying value derogation and no derogation parcels did not differ significantly ($p = 0.89$) regarding the nitrate-N difference over winter 2018-2019.

Maize on sandy soils

The comparison of the nitrate-N difference in winter 2018-2019 on sandy soils cultivated with maize included 73 parcels, 37 with derogation and 36 without derogation.

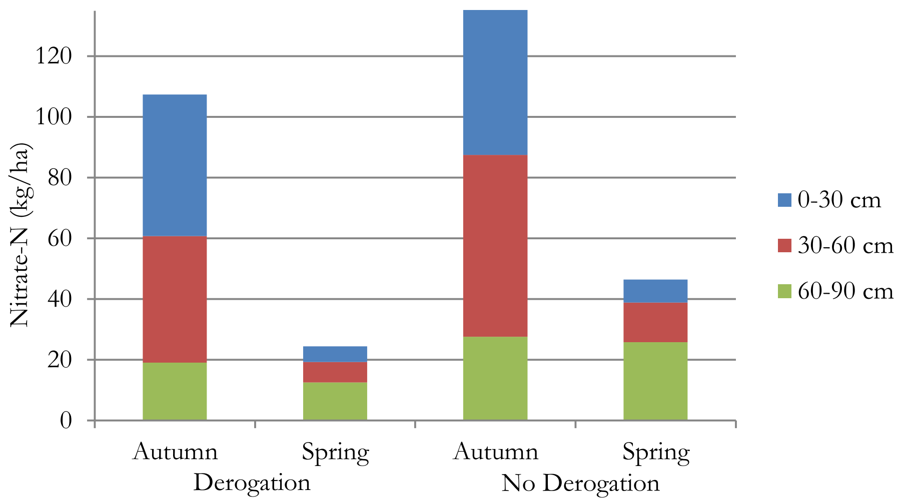


Figure 297: Average nitrate-N (kg/ha) in autumn 2018 and spring 2019 on derogation and no derogation parcels on sandy soils cultivated with maize of the monitoring network, indicating the average nitrate-N difference during winter 2018-2019 on derogation and no derogation parcels on sandy soils cultivated with maize.

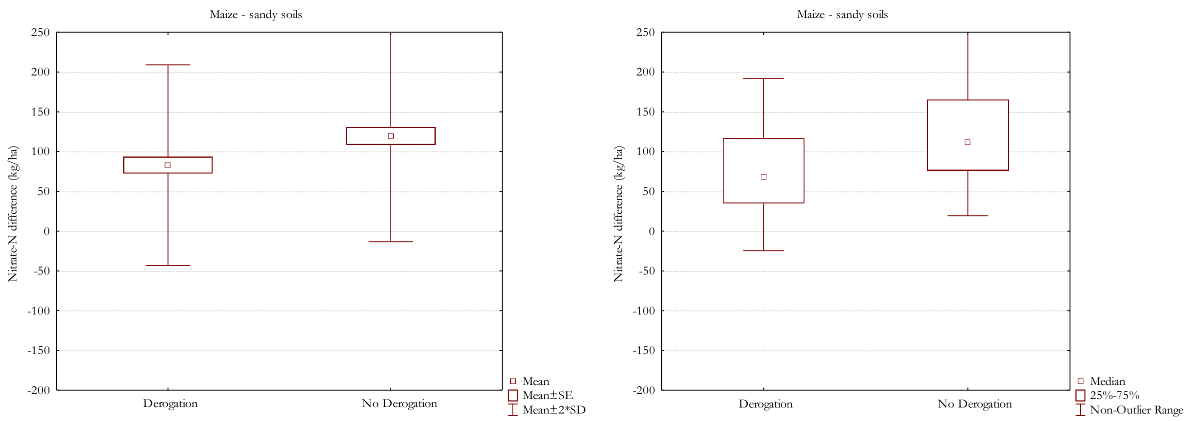


Figure 298: Boxplot of the nitrate-N difference-winter 2018-2019 (kg/ha) on derogation and no derogation parcels with maize on sandy soils in the monitoring network. Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

With derogation, the average nitrate-N difference amounted 83 ± 63 kg NO_3-N/ha, without derogation 120 ± 67 kg NO_3-N/ha. The average nitrate-N difference over winter on sandy soils cultivated with maize was significantly higher on parcels without derogation than on parcels with derogation. ($p = 0.02$) (Figure 298).

Nine parcels cultivated with maize on sandy soils were detected as outlying values: 3 parcels with derogation and 6 without derogation. Without the outlying values 34 parcels with derogation and 30 parcels without derogation were compared. The average nitrate-N difference amounted that way respectively 71 ± 49 kg NO_3-N/ha and 98 ± 46 kg NO_3-N/ha. The difference between derogation and no derogation parcels was still statistically significant ($p = 0.01$). All nine parcels were covered during winter, whether with grass, grass and less than 50 % clover, barley or triticale.

All crops on sandy loam soils

On sandy loam soils, the nitrate-N difference of 82 parcels was compared. Regardless of crop or derogation, the average nitrate-N difference on sandy loam soils over winter 2018-2019 was 48 ± 67 kg NO_3-N/ha (Figure 299). Under derogation conditions, determined on 42 parcels, the average nitrate-N difference was 70 ± 71 kg NO_3-N/ha. On 40 parcels, the nitrate-N difference on sandy loam soils without derogation was determined. The difference amounted on average 24 ± 54 kg NO_3-N/ha. The average nitrate-N difference measured on derogation and no derogation parcels differed significantly ($p = 0.001$).

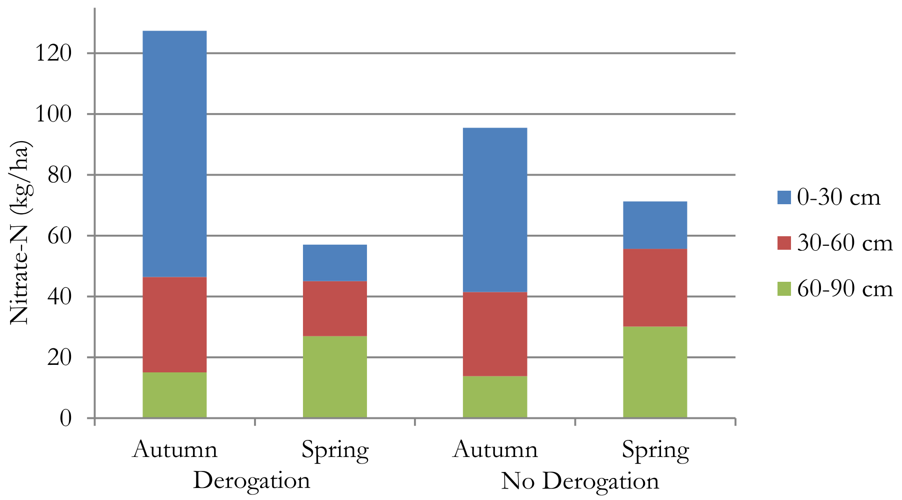


Figure 299: Average nitrate-N (kg/ha) in autumn 2018 and spring 2019 on derogation and no derogation parcels on sandy loam soils of the monitoring network, indicating the average nitrate-N difference during winter 2018-2019 on derogation and no derogation parcels on sandy loam soils.

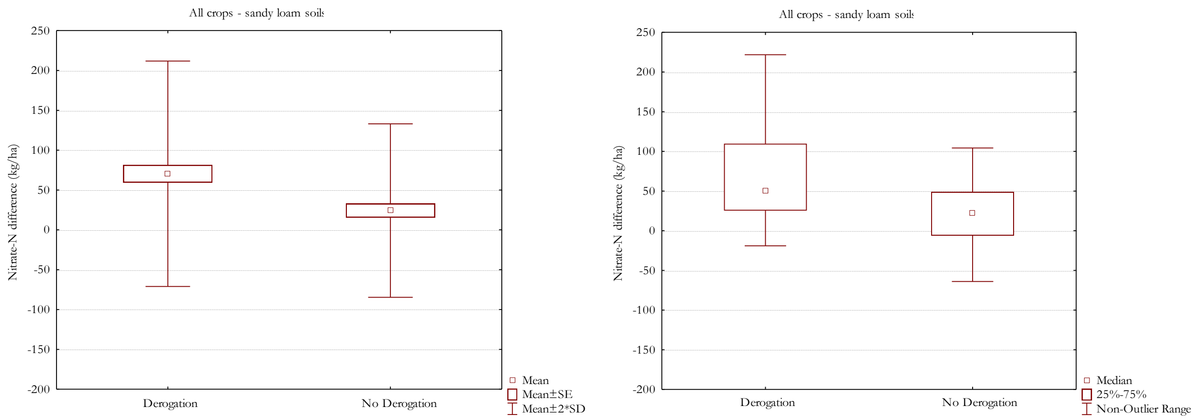


Figure 300: Boxplot of the nitrate-N difference-winter 2018-2019 (kg/ha) on derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network. Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Four out of 14 outliers were detected on sandy loam soils, 3 with derogation and one without derogation. Without the outlying values the average nitrate-N difference amounted with and without derogation respectively 57 ± 49 kg NO_3-N/ha and 19 ± 42 kg NO_3-N/ha. The difference between derogation and no derogation parcels regarding the nitrate-N difference over winter 2018-2019 was still significant (p = 0.001).

Grass on sandy loam soils

The nitrate-N difference over winter 2018-2019 on sandy loam soils cultivated with grass was evaluated on 42 parcels, both 21 with and without derogation. The average nitrate-N difference under derogation conditions on sandy loam soils cultivated with grass amounted 59 ± 71 kg NO_3-N/ha. Without derogation, the average nitrate-N difference on such parcels was 19 ± 64 kg NO_3-N/ha over winter 2018-2019 (Figure 301). The nitrate-N difference over winter 2018-2019 on sandy loam soils cultivated with grass did not differ significantly ($p = 0.06$) between derogation and no derogation parcels.

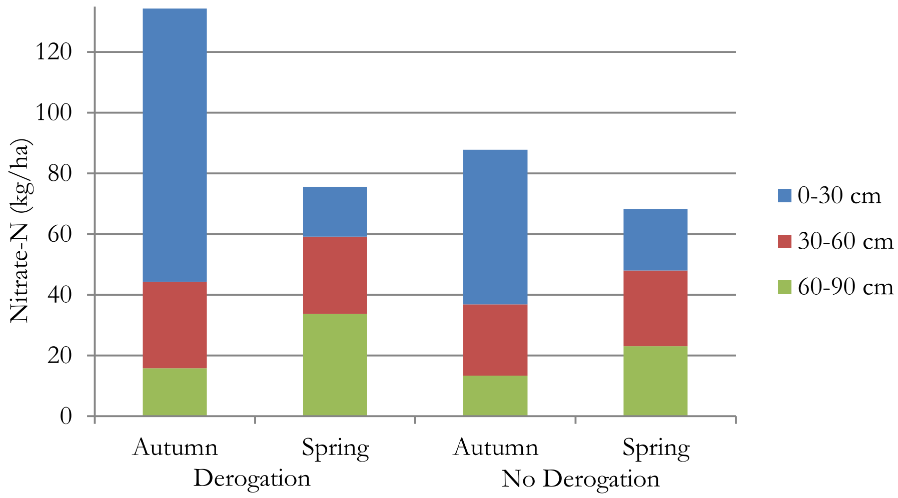


Figure 301: Average nitrate-N (kg/ha) in autumn 2018 and spring 2019 on derogation and no derogation parcels on sandy loam soils cultivated with grass of the monitoring network, indicating the average nitrate-N difference during winter 2018-2019 on derogation and no derogation parcels on sandy loam soils cultivated with grass.

Three of the detected outliers concerned sandy loam parcels cultivated with grass, 1 without derogation and 2 with derogation. Without these outlying values, 19 derogation parcels and 20 parcels without derogation were compared. Still, the nitrate-N difference over winter 2018-2019 on sandy loam soils cultivated with grass did not differ significantly ($p = 0.06$) between derogation and no derogation parcels. Nothing unusual was found out in the parcel data.

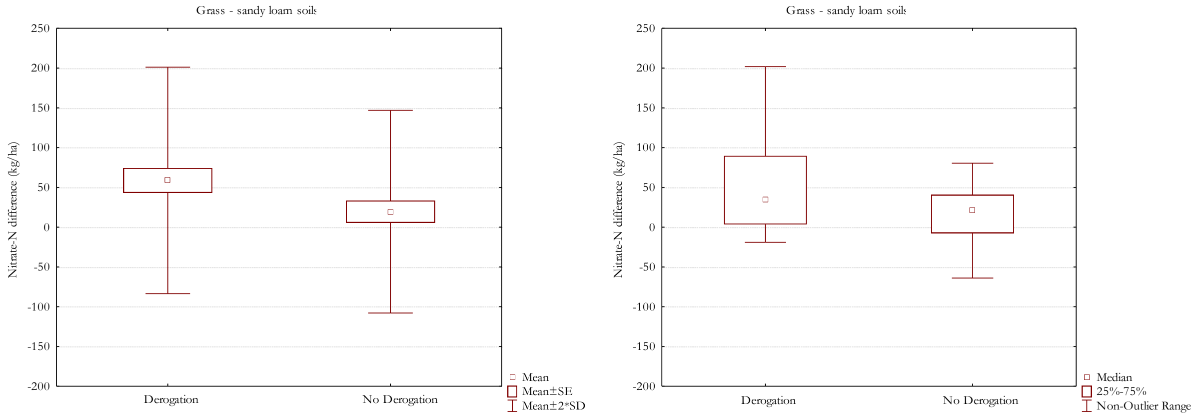


Figure 302: Boxplot of the nitrate-N difference-winter 2018-2019 (kg/ha) on derogation and no derogation parcels with grass on sandy loam soils in the monitoring network. Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Maize on sandy loam soils

On 40 parcels cultivated with maize on sandy loam soils, the nitrate-N difference over winter 2018-2019 was evaluated. It concerned 21 parcels with and 19 parcels without derogation. The average nitrate-N difference on these derogation parcels amounted 82 ± 70 kg NO_3-N/ha. On the parcels without derogation, the average nitrate-N difference was 29 ± 43 kg NO_3-N/ha (Figure 303). Derogation and no derogation parcels differed significantly regarding the nitrate-N difference over winter 2018-2019 on sandy loam soils cultivated with maize ($p = 0.01$).

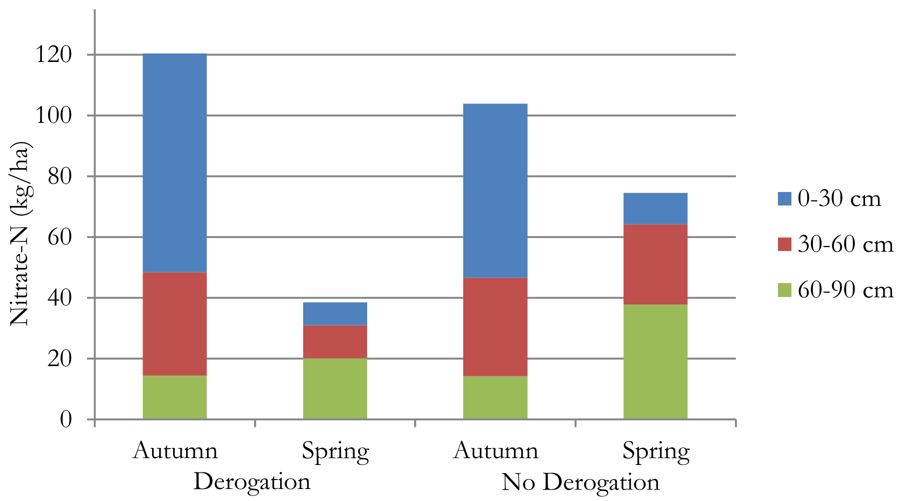


Figure 303: Average nitrate-N (kg/ha) in autumn 2018 and spring 2019 on derogation and no derogation parcels on sandy loam soils cultivated with maize of the monitoring network, indicating the average nitrate-N difference during winter 2018-2019 on derogation and no derogation parcels on sandy loam soils cultivated with maize.

One parcel cultivated with maize on sandy loam soils was detected as an outlying value. The parcel was cultivated under derogation conditions. It concerned an early harvested parcel maize on which cattle slurry was applied at the end of August. Grass was sown as second crop some days later. Due to the late fertilisation and tillage, the nitrate-N residue on this parcel was raised. The early sown grass had still a long period to take up nitrogen and was cut in November. Without this outlying value the nitrate-N difference over winter 2018-2019 on sandy loam parcels cultivated with maize was still significantly different (p = 0.01) between derogation and no derogation parcels.

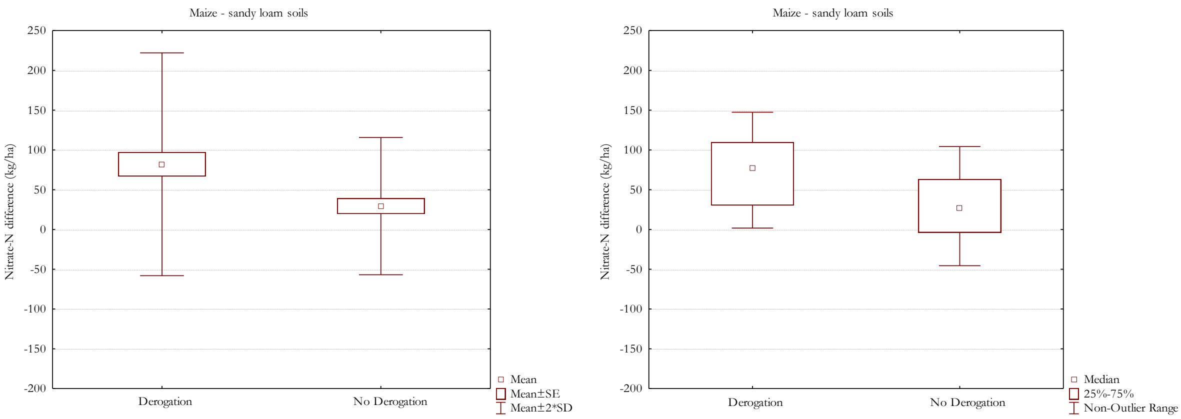


Figure 304: Boxplot of the nitrate-N difference-winter 2018-2019 (kg/ha) on derogation and no derogation parcels with maize on sandy loam soils in the monitoring network. Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

3.2.1.10 Mineral nitrogen - at parcel level - autumn 2019

The parcels of the monitoring network 2019 were sampled for the nitrate-N residue between October 1st and November 15th. The drought during the growing season of 2019, mentioned in 2.1.4, made sampling to 90 cm often difficult. As in 2018, a lot of parcels could not be sampled to 90 cm. Seventy percent of the parcels of the monitoring network was sampled to 90 cm while 22 and 8 % of the parcels was sampled to respectively 60 and 30 cm. In line with the evaluation of the residual nitrate-N by the VLM, all samples were withheld, regardless of depth of sampling.

Withholding the results of all sampling depths implies that the average nitrate-N per soil layer is related to a different number of samples. In averaging the nitrate-N per soil layer missing data caused by impossible sampling, are NOT supposed to be 0. This will mean that the sum of the average amounts of nitrate-N per soil layer will not be equal to the average of the nitrate-N residues. The sum of the average amounts of nitrate-N per soil layer will overestimate the average nitrate-N residue. The bar graphs show the average amount of nitrate-N per soil layer of the parcels which could be sampled until the respective depth and in overlay the black box demonstrates the average of the measured nitrate-N residues.

Statistical analysis is performed on the log-transformed nitrate-N residue. At each level of comparison, it is verified that both groups have a comparable amount of parcels sampled till 90, 60 or only 30 cm. At some levels of comparison, the average sampling depth differed significantly between derogation and no derogation parcels. The derogation parcels however, were sampled deeper, whether or not significantly. Therefore, at different sampling depth it could be stated that 'derogation' is not privileged. The number of parcels sampled until 90, 60 or only 30 cm and the average sampling depth can be verified in Table 54.

Before evaluation of the possible impact of derogation on the nitrate-N residue, the main crop, the crop and culture management were reviewed. On two parcels meant for maize in 2019, finally no maize was sown and grassland remained. Both parcels were on sandy loam soils: one parcel with derogation and one parcel without derogation. The parcels were discarded for further evaluation. One parcel cultivated with grass on sandy soils without derogation had to be destroyed in August because of drought damage and Italian ryegrass was sown mid-September. This parcel was also discarded for further evaluation. A second grass parcel could not be withheld for further analysis. It concerned a parcel on sandy loam soils under derogation conditions, resown in April with little yield. In addition a third parcel cultivated with grass could not be withheld, grass on sandy loam soil without derogation. The grass was destroyed and tilled in August because of weed abundance and grass was sown in October. The nitrate-N residues on those 3 latter parcels that were not withheld amounted respectively 110, 99 and 294 kg NO_3-N/ha.

Finally, one parcel with grass and less than 50 % clover on sandy soil, cultivated under derogation conditions was excluded. The nitrate-N residue amounted 532 kg NO_3-N/ha. The accompanying higher ammonium values, the large difference with the other nitrate-N residues measured in 2019 at the farm and a nitrate-N reserve after winter that was low and comparable to the nitrate-N reserve of the low residue parcels, did decide to exclude the parcel for the evaluation of the nitrate-N residue.

For comparison of the **nitrate-N residue** of **autumn 2019** under derogation and no derogation conditions practices **477 parcels** remained. The average nitrate-N residue in the monitoring network amounted 78 ± 61 kg NO_3-N/ha in autumn 2019.

The variation in the nitrate-N residue in 2019 is visualized in Figure 305. The statistical analysis of the nitrate-N residue is performed on the logarithm of the nitrate-N residue. Figure 306 shows the variation of the log-transformed data.

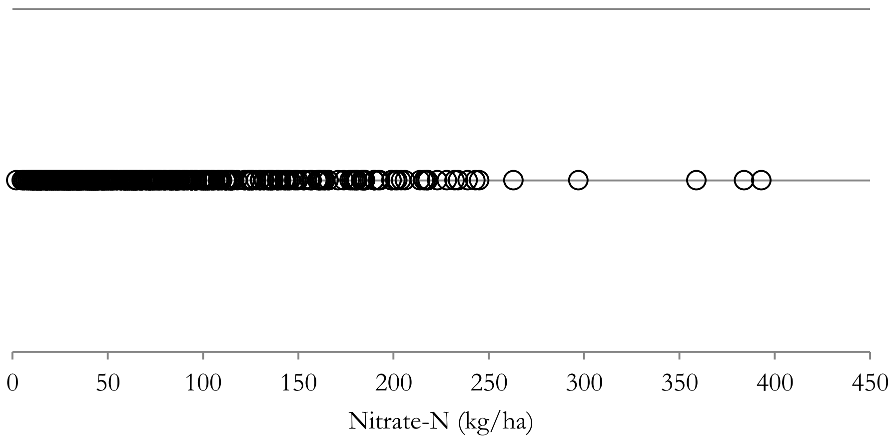


Figure 305: Spreading of the amount of nitrate-N in 477 parcels suited for comparison of derogation and non-derogation practices in autumn 2019.

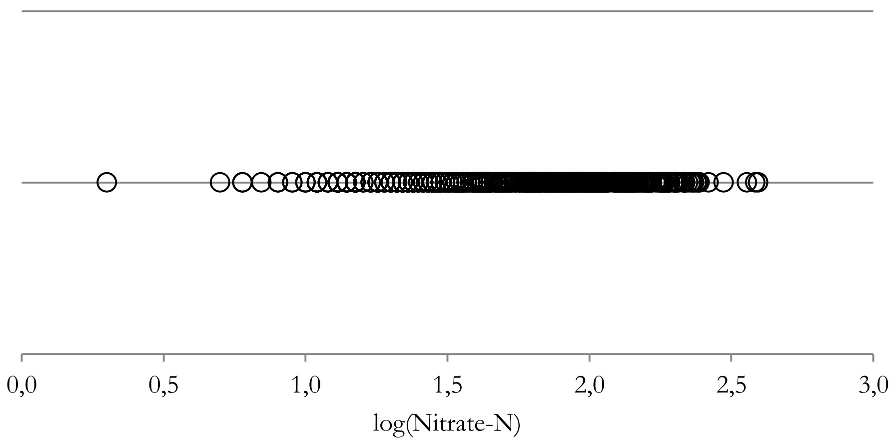


Figure 306: Spreading of the log-transformed nitrate-N (log(Nitrate-N)) in 477 parcels suited for comparison of derogation and non-derogation practices in autumn 2019.

As stated the former years, no outliers are discarded for the statistical analysis of the nitrate-N residue. Nevertheless, outliers were detected. Three outliers were observed, all three parcels cultivated with maize. The nitrate-N residues amounted 359, 384 and 393 kg NO_3-N/ha. Outliers will be discussed in more detail in the following paragraphs when most relevant.

Table 59: Average nitrate-N in the soil profile (0-90 cm) and per soil layer (0-30 cm, 30-60 cm and 60-90 cm) and median value of nitrate-N for the 477 parcels combined at different levels of comparison in autumn 2019. The number of parcels included in the comparison of the nitrate-N residue (0-90 cm) is indicated by 'n'.

			Nitrate-N (kg/ha)						p-value
			n	0-30 cm	30-60 cm	60-90 cm	0-90 cm	Median	
Overall mean monitoring network			477	32	32	24	78	63	-
Derogation			237	33	32	23	82	64	0.12
No derogation			240	31	32	25	74	60	
Derogation	Sandy soil		134	27	31	24	78	60	0.33
No derogation			137	29	35	27	77	55	
Derogation	Sandy loam		103	40	34	21	86	77	0.21
No derogation			103	34	28	21	71	62	
Derogation	Sandy soil	Grass	54	23	22	20	64	44	0.05
No derogation			53	21	26	21	54	31	
Derogation	Sandy soil	Grass <50% clover	29	23	25	22	62	45	0.80
No derogation			30	21	28	22	59	43	
Derogation	Sandy soil	Maize	51	34	42	28	102	76	0.65
No derogation			54	41	46	35	109	94	
Derogation	Sandy loam	Grass	53	34	27	21	71	48	0.31
No derogation			53	28	19	15	53	35	
Derogation	Sandy loam	Maize	50	47	41	21	103	94	0.48
No derogation			50	40	37	27	91	77	

Table 60: Number of parcels taken into account for the average values in Table 59. Average depth of sampling (cm) for the 477 parcels combined at different levels of comparison in autumn 2019.

			Number of parcels				Sampling depth (cm)
			0-30 cm	30-60 cm	60-90 cm	0-90 cm	
Overall mean monitoring network			477	439	334	477	79
Derogation			237	228	186	237	82
No derogation			240	211	148	240	75
Derogation	Sandy soil		134	134	116	134	86
No derogation			137	122	85	137	75
Derogation	Sandy loam		103	94	70	103	78
No derogation			103	89	63	103	74
Derogation	Sandy soil	Grass	54	54	51	54	88
No derogation			53	44	29	53	71
Derogation	Sandy soil	Grass <50% clover	29	29	18	29	79
No derogation			30	28	17	30	75
Derogation	Sandy soil	Maize	51	51	47	51	88
No derogation			54	50	39	54	79
Derogation	Sandy loam	Grass	53	45	33	53	74
No derogation			53	43	31	53	72
Derogation	Sandy loam	Maize	50	49	37	50	82
No derogation			50	46	32	50	77

The evaluation of the impact of derogation on the nitrate-N residue in autumn 2019 was based on the comparison of 237 parcels with derogation and 240 parcels without derogation. The average nitrate-N residue of the parcels with derogation amounted 82 ± 59 kg NO_3-N/ha at an average sampling depth of 82 cm. Without derogation and regardless of crop or soil type, the average nitrate-N residue was 74 ± 62 kg NO_3-N/ha in the monitoring network, at an average sampling depth of 75 cm. The nitrate-N residue of derogation and no derogation parcels did not differ significantly (p = 0.12) in the network in autumn 2019.

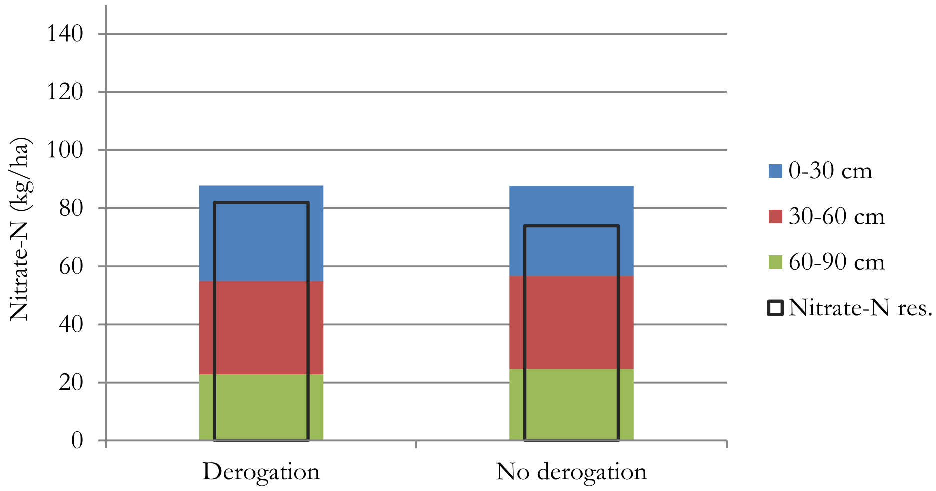


Figure 307: Average nitrate-N residue (kg/ha) on derogation and no derogation parcels with all crops on all soils in the monitoring network in autumn 2019.

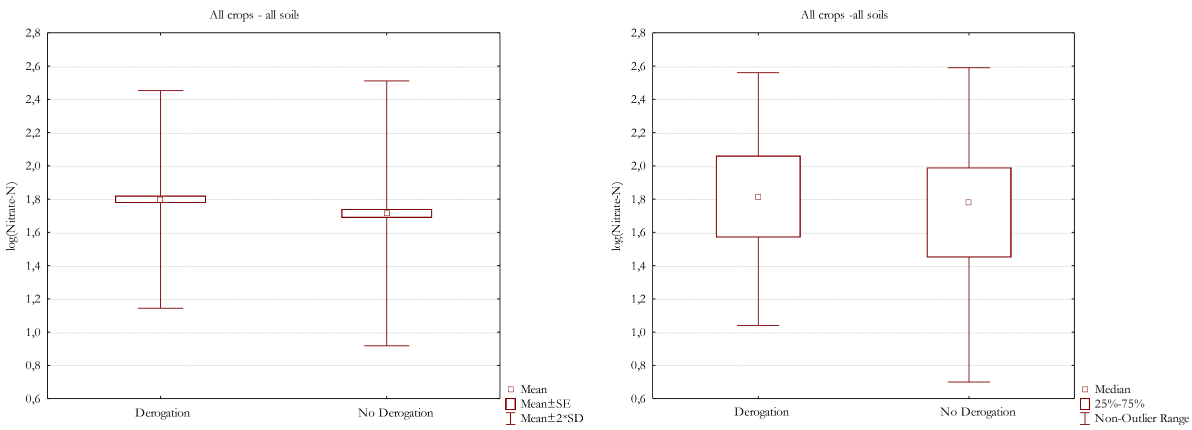


Figure 308: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with all crops on all soils in the monitoring network in autumn 2019. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Figure 309 demonstrates in some other way the nitrate-N residue in the monitoring network in autumn in 2019 regarding the request of derogation. The figure indicates per category of nitrate-N residue the percentage derogation and no derogation parcels with a nitrate-N residue belonging to that category. The curves present the results cumulatively. The points of the curve indicate the total percentage of parcels that respect the end value of the corresponding nitrate-N category.

A nitrate-N residue of 60 kg NO_3-N/ha, being the lowest nitrate-N residue standard in autumn 2019, was respected on 46 % of the derogation parcels and 51 % of the no derogation parcels. Flanders, being categorised in zone types since 2019, imposed nitrate-N residue standards of 80 and 85 kg NO_3-N/ha for grass and maize on sandy and no sandy soils. In the monitoring network the standard of 80 kg NO_3-N/ha was respected on 60 and 64 % of the parcels respectively with and without derogation conditions.

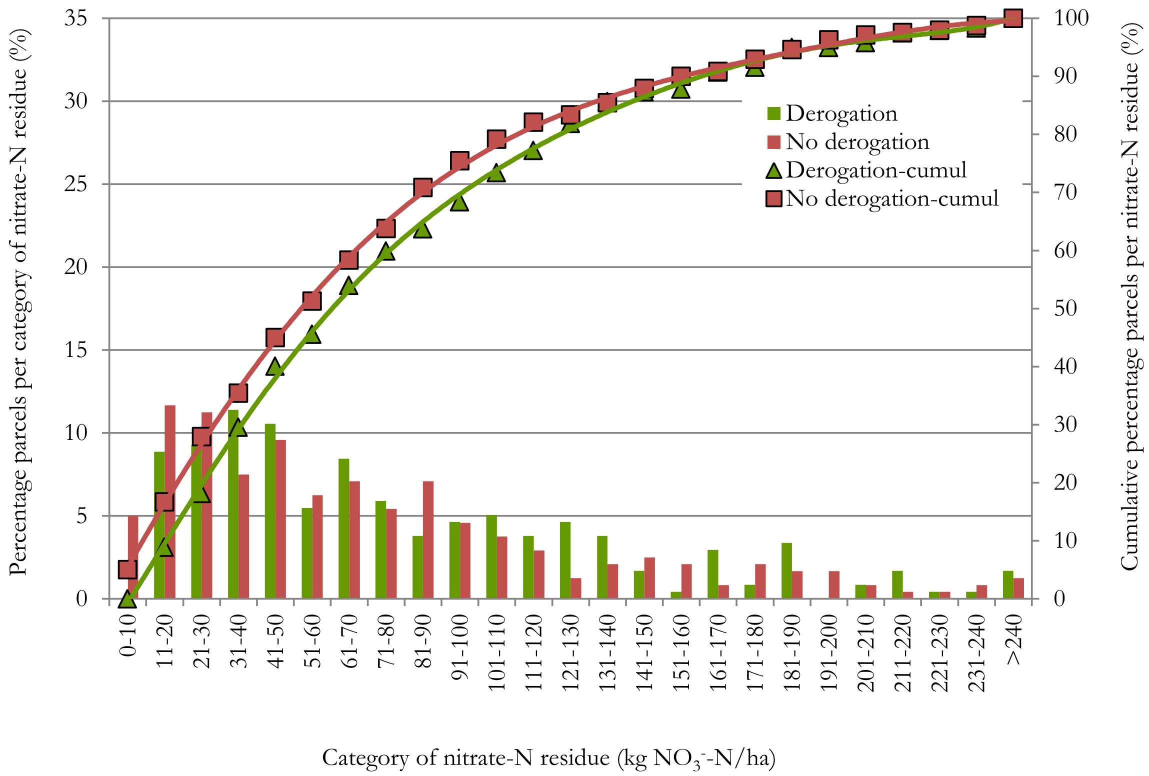


Figure 309: Distribution of the derogation (green columns) and no derogation parcels (red columns) (%) of the monitoring network in the different categories of nitrate-N residue (kg NO_3-N/ha) and cumulative percentage of derogation (green curve) and no derogation (red curve) parcels of the monitoring network which respect a certain value of nitrate N-residue. Autumn 2019.

All crops on sandy soils

The comparison of derogation and no derogation parcels on sandy soils involved 271 parcels, 134 parcels with and 137 parcels without derogation. On the parcels with derogation, an average nitrate-N residue of 78 ± 57 kg NO_3-N/ha was measured. On the parcels without derogation, an average of 77 ± 66 kg NO_3-N/ha was measured. Both values were not statistically different (p = 0.33).

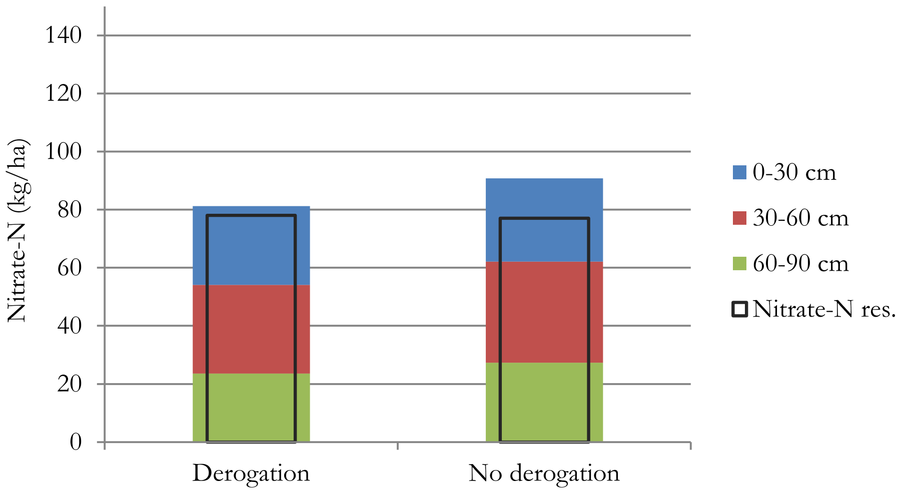


Figure 310: Average nitrate-N residue (kg/ha) on derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2019.

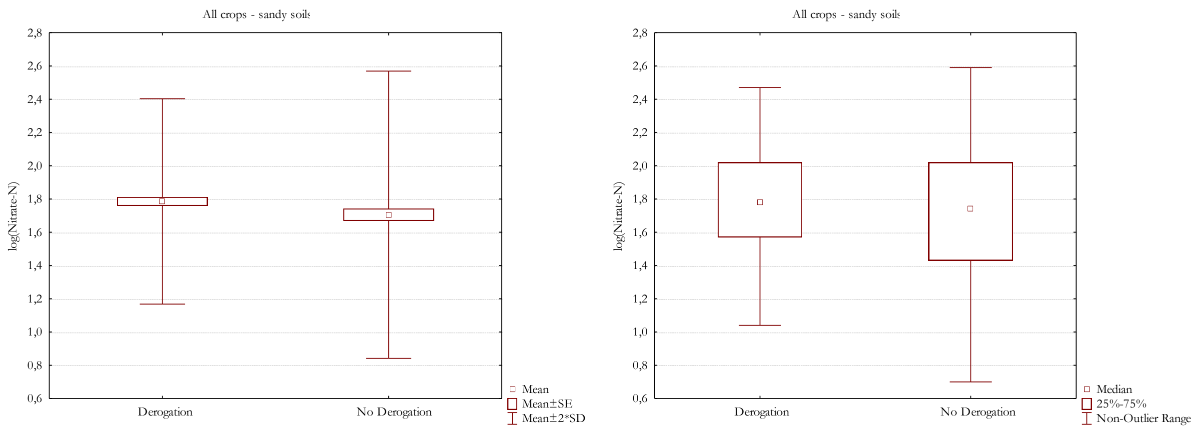


Figure 311: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2019. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Grass on sandy soils

One hundred and seven parcels were involved in the evaluation on sandy soils cultivated with grass. Under derogation conditions, 54 parcels were monitored. The average nitrate-N residue on those parcels amounted 64 ± 46 kg NO_3-N/ha. Without derogation, cultivated with grass on sandy soils, 53 parcels were monitored. The average nitrate-N residue in this situation amounted 54 ± 59 kg NO_3-N/ha. The difference between derogation and no derogation parcels on sandy soils cultivated with grass was statistically significant in autumn 2019 (p = 0.05).

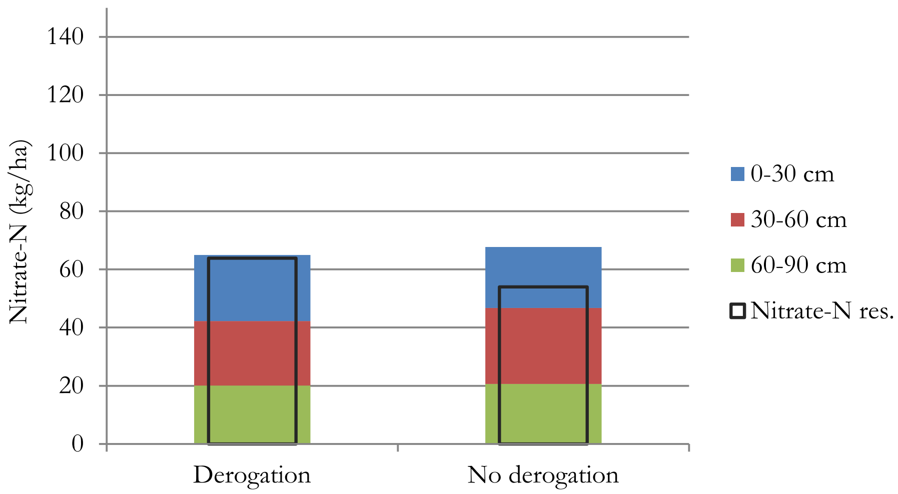


Figure 312: Average nitrate-N residue (kg/ha) on derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2019.

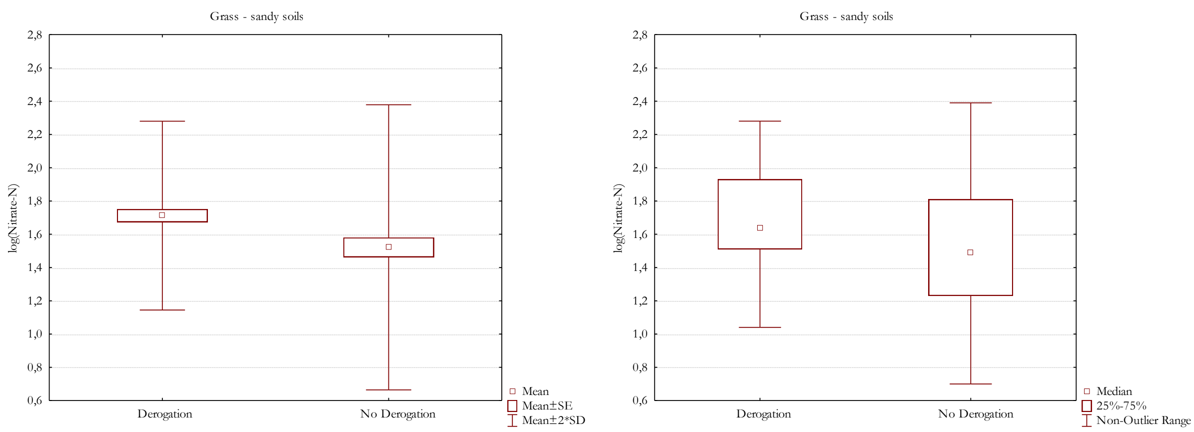


Figure 313: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2019. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Grass with less than 50 % clover on sandy soils

On sandy soils, 59 parcels cultivated with grass and less than 50 % clover were evaluated, 29 parcels with derogation and 30 parcels without derogation. On the parcels with derogation, the nitrate-N residue was 62 ± 52 kg NO_3-N/ha. On the parcels without derogation, the nitrate-N residue amounted 59 ± 54 kg NO_3-N/ha. The difference was not statistically significant (p = 0.80).

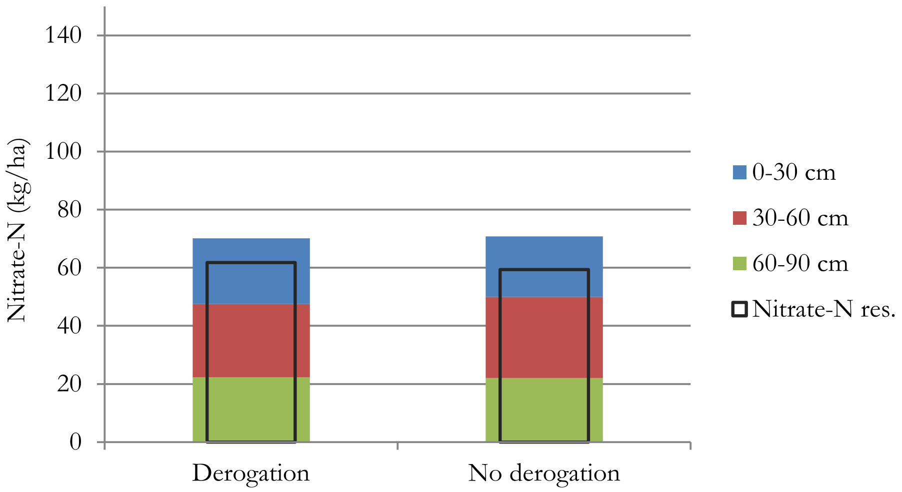


Figure 314: Average nitrate-N residue (kg/ha) on derogation and no derogation parcels with grass and less than 50 % clover on sandy soils in the monitoring network in autumn 2019.

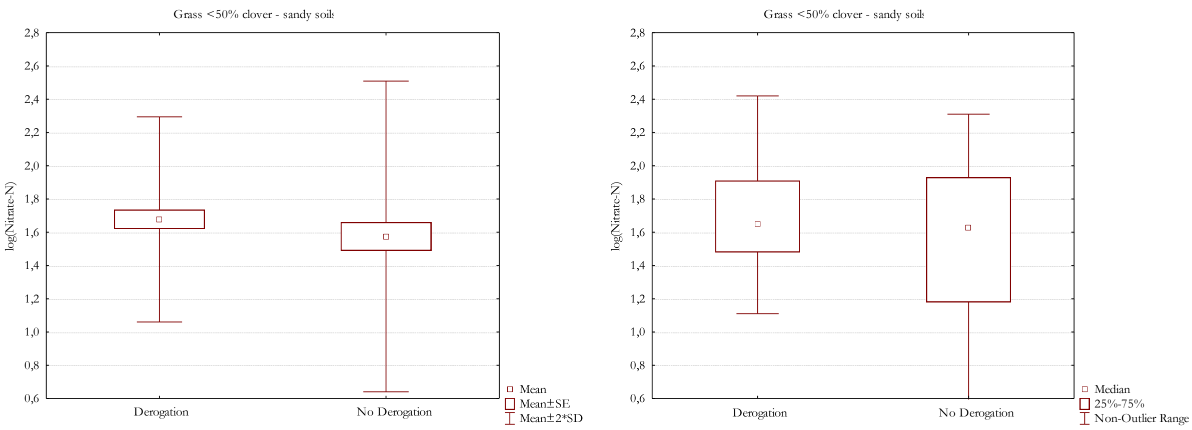


Figure 315: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with grass and less than 50 % clover on sandy soils in the monitoring network in autumn 2019. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Maize on sandy soils

On sandy soils cultivated with maize, the nitrate N-residue of 51 parcels with derogation and 54 parcels without derogation could be compared. Under derogation conditions, the average nitrate-N residue amounted 102 ± 64 kg NO_3-N/ha. Without derogation conditions, the average nitrate-N residue on sandy soils cultivated with maize was 109 ± 67 kg NO_3-N/ha. The difference was statistically insignificant ($p = 0.65$).

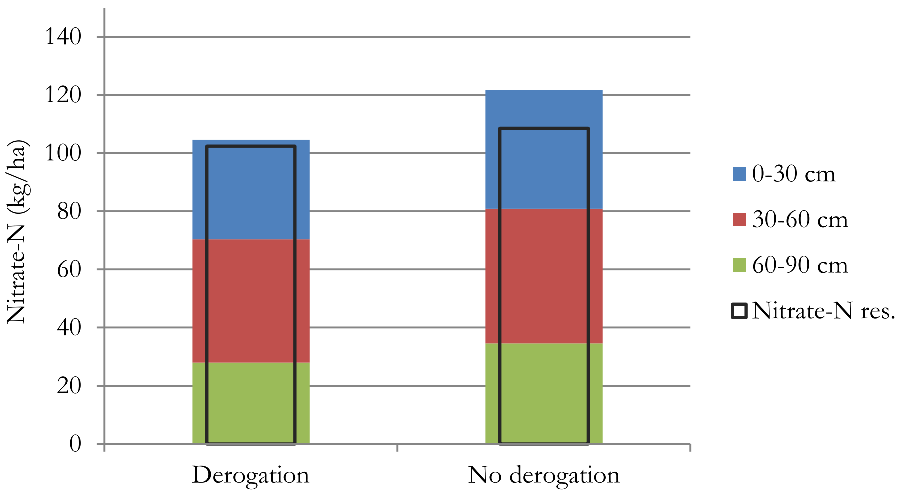


Figure 316: Average nitrate-N residue (kg/ha) on derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2019.

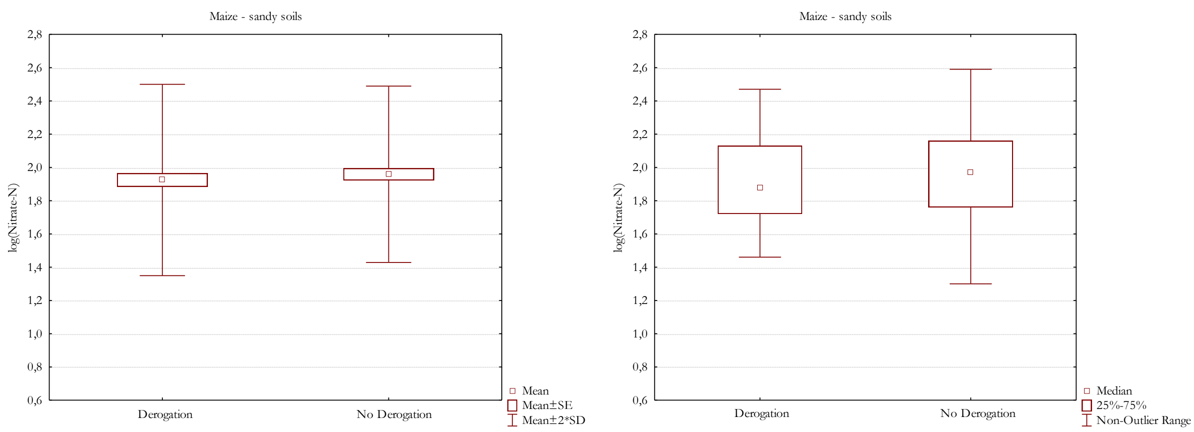


Figure 317: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2019. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

One of the detected outliers was a parcel cultivated with maize without derogation on sandy soils. Without the outlying value, the average nitrate-N residue on the parcels on sandy soils with maize without derogation amounted 103 ± 55 kg NO_3-N/ha. Obviously, there was still no significant difference between derogation and no derogation parcels ($p = 0.69$).

All crops on sandy loam soils

On sandy loam soils, the nitrate-N residue of 206 parcels could be evaluated. The average nitrate-N residue of the 103 parcels with derogation was 86 ± 62 kg NO_3-N/ha. On the 103 parcels without derogation, an average nitrate-N residue of 71 ± 57 kg NO_3-N/ha was measured. The difference between derogation and no derogation parcels on sandy loam soils was not statistically significant ($p = 0.21$).

On sandy loam soils 2 outliers were detected, both parcels cultivated with maize, one with and one without derogation. Without the outlying values the average nitrate-N residues with and without derogation amounted respectively 84 ± 56 kg NO_3-N/ha and 68 ± 48 kg NO_3-N/ha. The difference between derogation and no derogation parcels on sandy loam soils was also without the outlying values insignificant ($p = 0.19$).

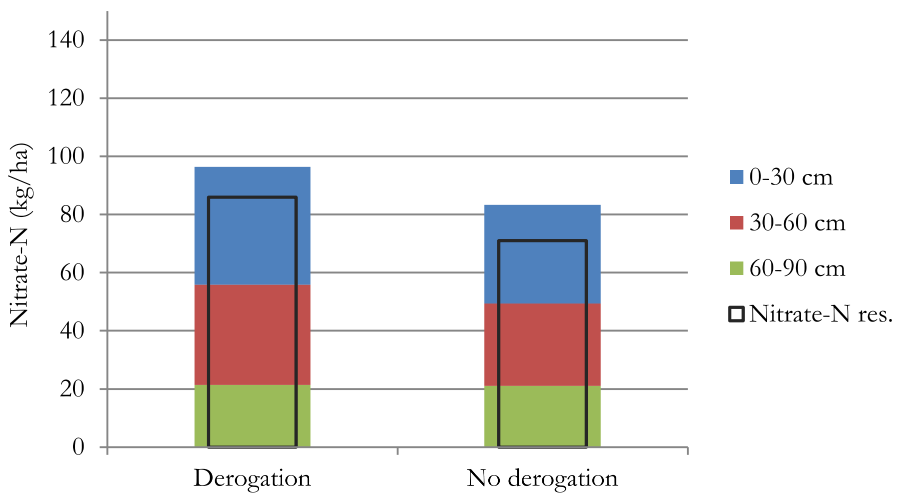


Figure 318: Average nitrate-N residue (kg/ha) on derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network in autumn 2019.

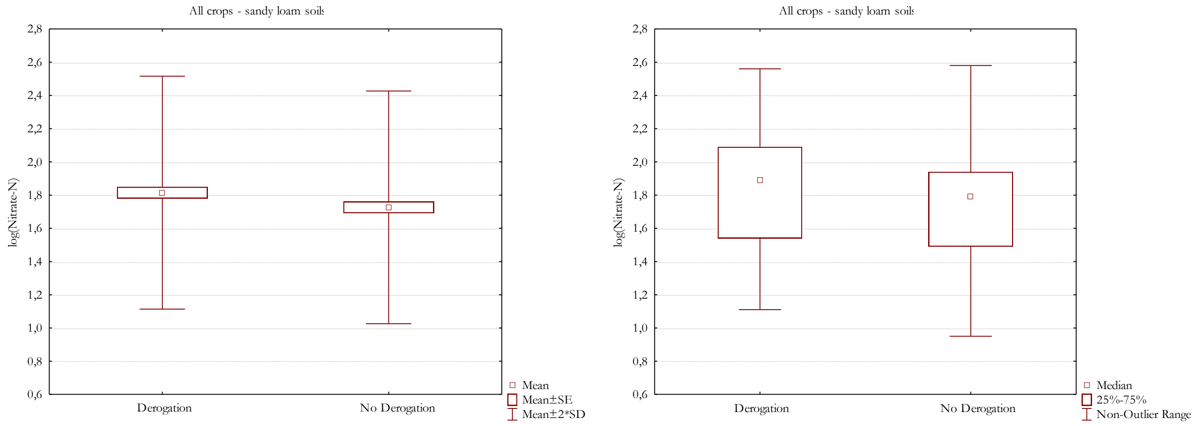


Figure 319: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with all crops on sandy loams soils in the monitoring network in autumn 2019. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Grass on sandy loam soils

Focusing on grass on sandy loam soils with or without derogation, the comparison was based on 106 parcels, both 53 parcels with derogation and without derogation.

On the parcels with derogation, the average nitrate-N residue was 71 ± 57 kg NO_3-N/ha in autumn 2019. On the sandy loam parcels with grass and without derogation, the average nitrate-N residue was 52 ± 41 kg NO_3-N/ha. The difference between both groups of parcels had no statistical significance ($p = 0.31$).

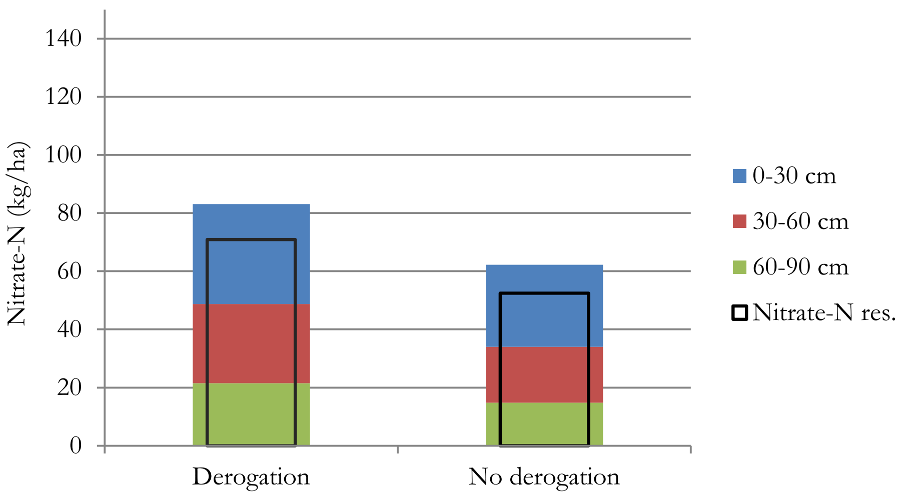


Figure 320: Average nitrate-N residue (kg/ha) on derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2019.

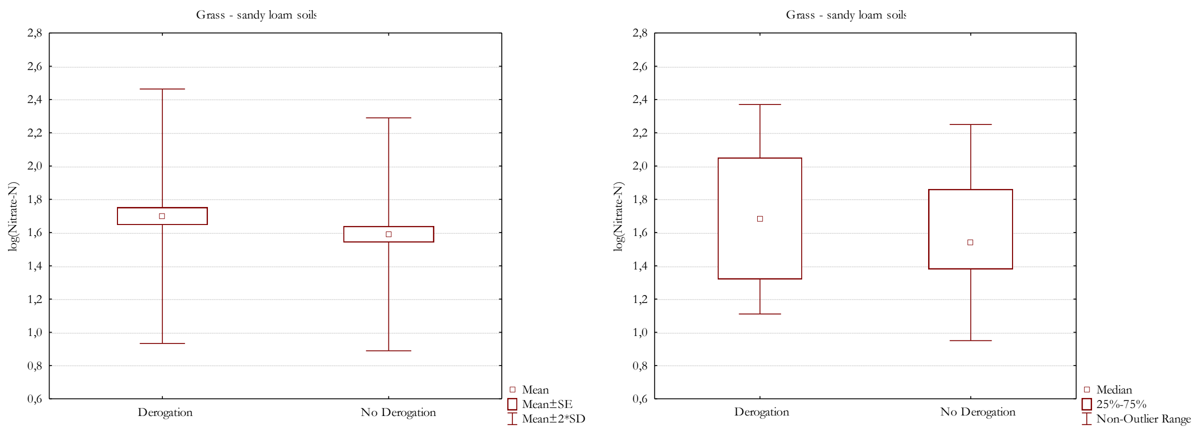


Figure 321: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2019. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Maize on sandy loam soils

The evaluation of the nitrate-N residue on sandy loam parcels with main crop maize was performed on 100 parcels, both 50 with and without derogation. The average nitrate-N residue under derogation conditions amounted 103 ± 63 kg NO_3-N/ha. It was not significantly different ($p = 0.48$) of the mean average of 91 ± 64 kg NO_3-N/ha without derogation conditions.

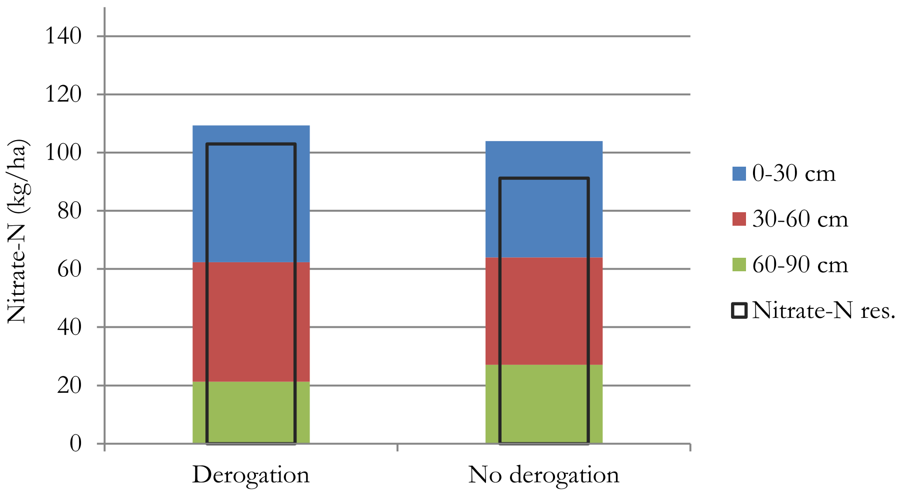


Figure 322: Average nitrate-N residue (kg/ha) on derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2019.

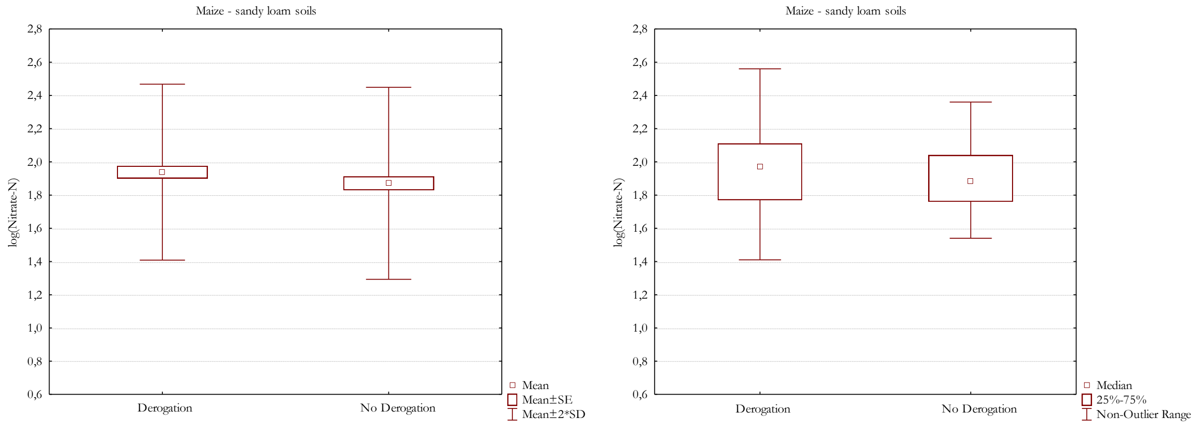


Figure 323: Boxplot of log(Nitrate-N) for derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2019. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Among the sandy loam parcels with maize, two outliers were pointed out. Without the outlying values, the average nitrate-N residues were 98 ± 52 kg NO_3-N/ha and 85 ± 49 kg NO_3-N/ha with and without derogation. The difference between the derogation and no derogation parcels was statistically insignificant ($p = 0.42$).

To summarize the results of the nitrate-N residue at parcel level, an overview of the nitrate-N residues monitored since 2011 is given in Table 61.

In 2018, the highest average nitrate-N residues were measured. The average nitrate-N residues measured in 2019 were the second highest values. The difference in average nitrate-N residue between derogation and no derogation parcels of 2019 is comparable to the difference noticed in 2016. In both those years, 2016 and 2019, the difference was not statistically significant ($p = 0.06$ and $p = 0.13$). The average difference between the average nitrate-N residues over the past 8 years is 0 kg NO_3-N/ha.

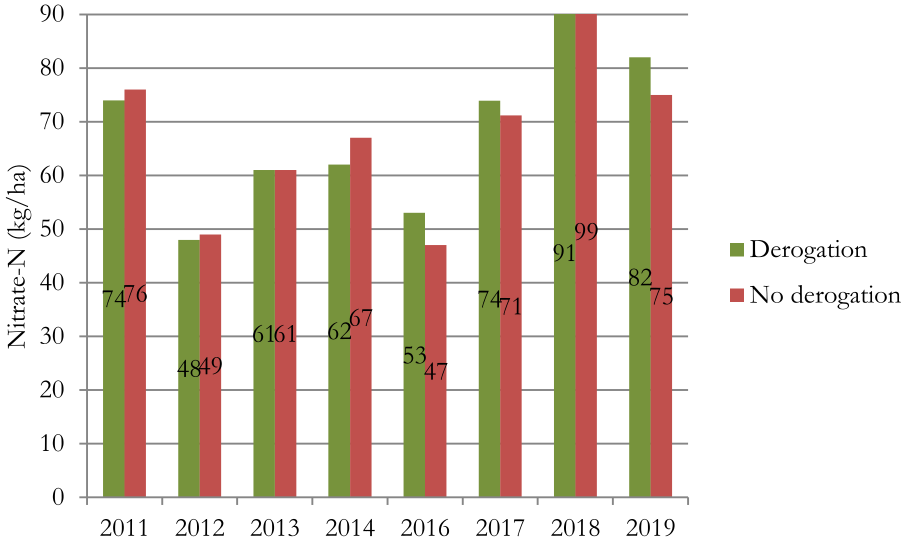


Figure 324: Nitrate-N residue in the soil profile (0-90 cm) on derogation and no derogation parcels cultivated with derogation crops in the monitoring network of 2011-2014 and the latest monitoring network 2016-2019.

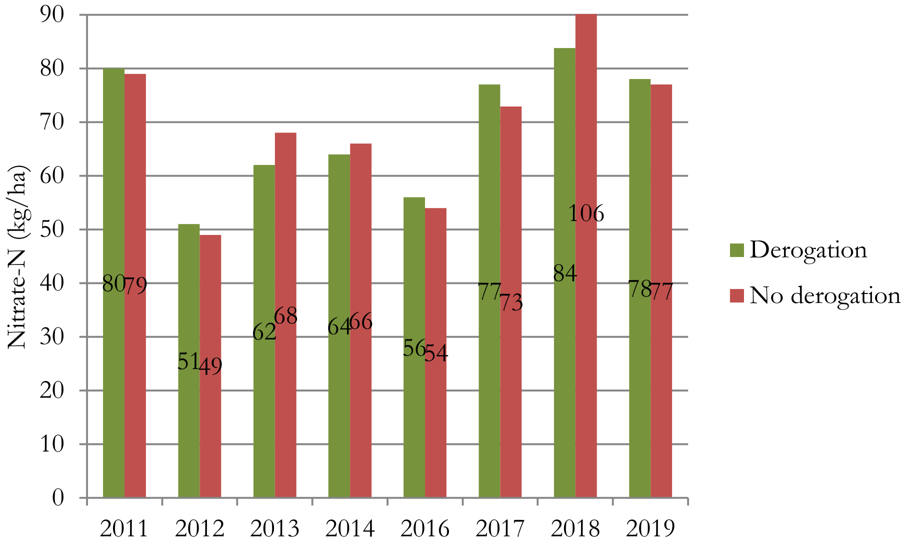


Figure 325: Nitrate-N residue in the soil profile (0-90 cm) on derogation and no derogation parcels cultivated with derogation crops on sandy soils in the monitoring network of 2011-2014 and the latest monitoring network 2016-2019.

On sandy soils, the average nitrate-N residues of 2019 are comparable to those of 2011 and 2017. The average difference between derogation and no derogation parcels, regardless of crop, over the past 8 years amounts -3 kg NO_3-N/ha. This means that the average nitrate-N residue on sandy derogation parcels was on average 3 kg lower than the average nitrate-N residue on sandy parcels without derogation in the subsequent networks. On sandy loam soils, the average difference between derogation and no derogation parcels, regardless of crop, over the past 8 years amounts 2 kg NO_3-N/ha.

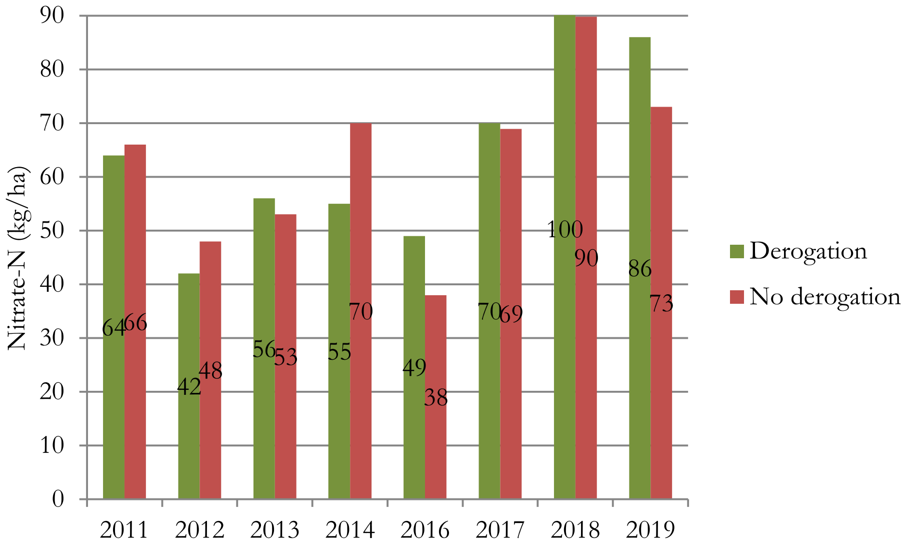


Figure 326: Nitrate-N residue in the soil profile (0-90 cm) on derogation and no derogation parcels cultivated with derogation crops on sandy loam soils in the monitoring network of 2011-2014 and the latest monitoring network 2016-2019.

Table 61: Nitrate-N residue in the soil profile (0-90 cm) for the different levels of comparison (derogation, soil texture, crop) in the monitoring network of 2011-2014 and the latest monitoring network 2016-2019. Indication of the average nitrate-N residue ± standard deviation and the p-value.

			Nitrate-N (kg/ha)															
			2011		2012		2013		2014		2016		2017		2018		2019	
			0-90 cm	p-value	0-90 cm	p-value	0-90 cm	p-value	0-90 cm	p-value	0-90 cm	p-value	0-90 cm	p-value	0-90 cm	p-value	0-90 cm	p-value
Overall mean monitoring network				-		-		-		-	50±41	-	73 ± 59	-	95 ± 75	-	78 ± 62	-
Derogation			74±54	0.80	48±37	0.91	61±47	0.90	62±41	0.91	53±38	0.06	74 ± 51	0.03	91 ± 69	0.44	82 ± 59	0.13
No derogation			76±57		49±33		61±46		67±49		47±44		71 ± 65		99 ± 80		75 ± 64	
Derogation	Sandy soil		80±59	0.99	51±38	0.70	62±48	0.80	64±43	0.80	56±38	0.45	77 ± 54	0.13	84 ± 62	0.69	78 ± 57	0.32
No derogation			79±60		49±36		68±59		66±46		54±50		73 ± 66		106 ± 87		77 ± 66	
Derogation	Sandy loam		64±46	0.72	42±35	0.53	56±51		55±35	0.54	49±39	0.02	70 ± 48	0.14	100 ± 77	0.45	86 ± 62	0.24
No derogation			66±45		48±29		53±32		70±53		38±31		69 ± 64		90 ± 69		73 ± 60	
Derogation	Sandy soil	Grass	64±52	0.31	41±33	0.23	52±45	0.37	60±42	0.31	51±44	0.06	69 ± 50	0.07	65 ± 44	0.93	64 ± 46	0.05
No derogation			51±51		32±23		54±58		54±45		36±33		52 ± 54		79 ± 68		54 ± 59	
Derogation	Sandy soil	Grass <50% clover	-	-	-	-	-	-	-	-	40±27	0.92	54 ± 46	0.44	74 ± 72	0.19	62 ± 52	0.80
No derogation			-	-	-	-	-	-	-	-	39±23		52 ± 62		68 ± 99		59 ± 54	
Derogation	Sandy soil	Maize	108±61	0.82	68±42	0.36	71±46	0.65	70±48	0.52	70±31	0.22	98 ± 55	0.91	109 ± 65	0.04	103 ± 63	0.66
No derogation			112±58		57±36		74±41		75±45		85±64		106 ± 67		154 ± 77		109 ± 67	
Derogation	Sandy loam	Grass	31±14	0.23	24±10	0.05	43±45	0.95	45±36	0.90	41±41	0.03	55 ± 51	0.02	97 ± 91	0.21	71 ± 57	0.36
No derogation			40±18		38±22		34±23		46±40		27±30		35 ± 29		64 ± 59		57 ± 52	
Derogation	Sandy loam	Maize	106±38	0.43	80±36	0.06	65±56	0.56	80±28	0.84	58±34	0.20	85 ± 39	0.71	104 ± 61	0.49	103 ± 63	0.48
No derogation			94±56		54±30		66±33		88±57		50±29		101 ± 72		117 ± 69		91 ± 64	

3.2.1.11 Mineral nitrogen - farm average - autumn 2019

The farm average residual nitrate is only determined for the farms of which all three parcels were withheld for the discussion of the residual nitrate at parcel level. As for the nitrate-N residue of 2018, in 2019 all representative samples are withheld, regardless of depth of sampling. Withholding the results of all sampling depths implies that the average nitrate-N per soil layer is related to a different number of parcels and farms. The sum of the average amounts of nitrate-N per soil layer will overestimate the mean farm average nitrate-N residue. The evaluation of the farm average mineral nitrogen in autumn is based on the farm average being the average of 3 residues. It is identified in the bar graphs as 'Nitrate-N res.', the black box in overlay with the average amounts of nitrate-N per soil layer. At each level of comparison, it is verified that both groups have a comparable depth of sampling, reported in Table 63.

Statistical analysis of the farm average nitrate-N residue is performed on the log-transformed data.

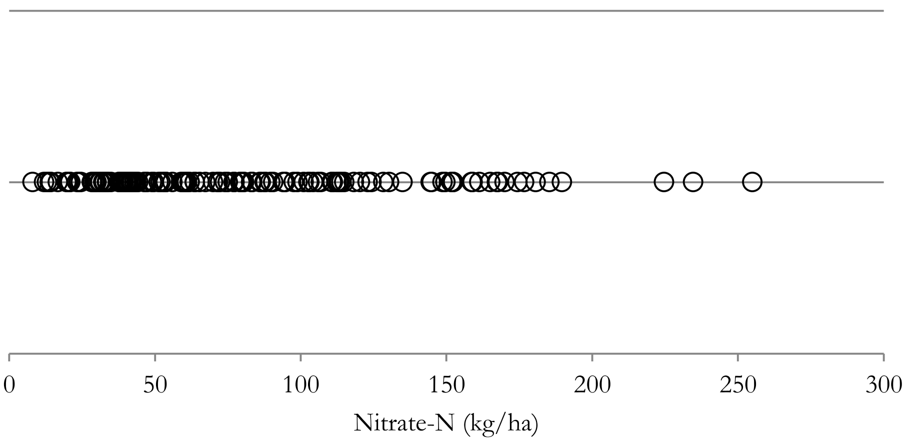


Figure 327: Spreading of the farm average nitrate-N residue of 150 farms of the monitoring network in autumn 2019.

The evaluation of the farm average residual nitrate-N in autumn 2019 is based on 150 farms. Regardless of derogation, crop or soil type the farm average nitrate-N residue amounted 79 ± 51 kg NO_3-N/ha in autumn 2019.

Table 62: Mean farm average nitrate-N in the soil profile (0-90 cm) and specified per soil layer (0-30 cm, 30-60 cm and 60-90 cm) for the 150 farms combined at different levels of comparison in autumn 2019. The number of farms taken up in the comparison of the nitrate-N residue (0-90 cm) is indicated by 'n'.

			Nitrate-N (kg/ha)					p-value
			n	0-30 cm	30-60 cm	60-90 cm	0-90 cm	
Overall farm average			150	32	32	25	79	-
Derogation			72	34	33	24	84	0.07
No derogation			78	31	32	25	74	
Derogation	Sandy soil		39	28	32	24	82	0.19
No derogation			45	29	34	26	77	
Derogation	Sandy loam		33	41	33	23	87	0.23
No derogation			33	33	27	24	70	
Derogation	Sandy soil	Grass	18	23	22	20	64	0.15
No derogation			17	21	27	24	54	
Derogation	Sandy soil	Grass <50% clover	4	30	32	33	79	-
No derogation			10	21	27	17	59	
Derogation	Sandy soil	Maize	17	34	42	28	102	0.73
No derogation			18	41	45	34	109	
Derogation	Sandy loam	Grass	17	35	26	22	70	0.33
No derogation			17	27	18	14	50	
Derogation	Sandy loam	Maize	16	48	41	25	105	0.37
No derogation			16	40	37	33	92	

Table 63: Number of farms taken into account for the average values in Table 56. These farms had at least one sample at the respective depth of sampling. Average depth of sampling (cm) for the 150 farms combined at different levels of comparison in autumn 2019.

			Number of farms				Sampling depth (cm)
			0-30 cm	30-60 cm	60-90 cm	0-90 cm	
Overall farm average			150	147	122	150	78
Derogation			72	71	64	72	82
No derogation			78	76	58	78	74
Derogation	Sandy soil		39	39	35	39	87
No derogation			45	44	33	45	75
Derogation	Sandy loam		33	32	29	33	77
No derogation			33	32	25	33	74
Derogation	Sandy soil	Grass	18	18	17	18	88
No derogation			17	16	11	17	71
Derogation	Sandy soil	Grass <50% clover	4	4	2	4	75
No derogation			10	10	8	10	75
Derogation	Sandy soil	Maize	17	17	16	17	88
No derogation			18	18	14	18	79
Derogation	Sandy loam	Grass	17	16	14	17	74
No derogation			17	16	12	17	71
Derogation	Sandy loam	Maize	16	16	15	16	81
No derogation			16	16	13	16	76

Seventy-two farms with derogation were compared with 78 farms without derogation for the farm average nitrate-N residue, regardless of crop or soil type. Under derogation conditions, the mean farm average nitrate-N residue was 84 ± 49 kg NO_3-N/ha. Without derogation, it was 74 ± 52 kg NO_3-N/ha. The mean farm average nitrate-N residue did not differ significantly ($p = 0.07$) between derogation and no derogation farms.

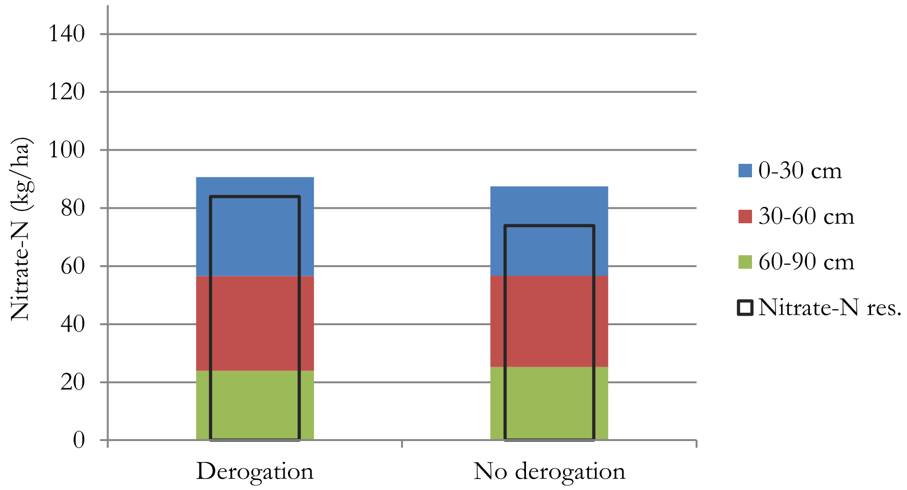


Figure 328: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with all crops on all soils in the monitoring network in autumn 2019.

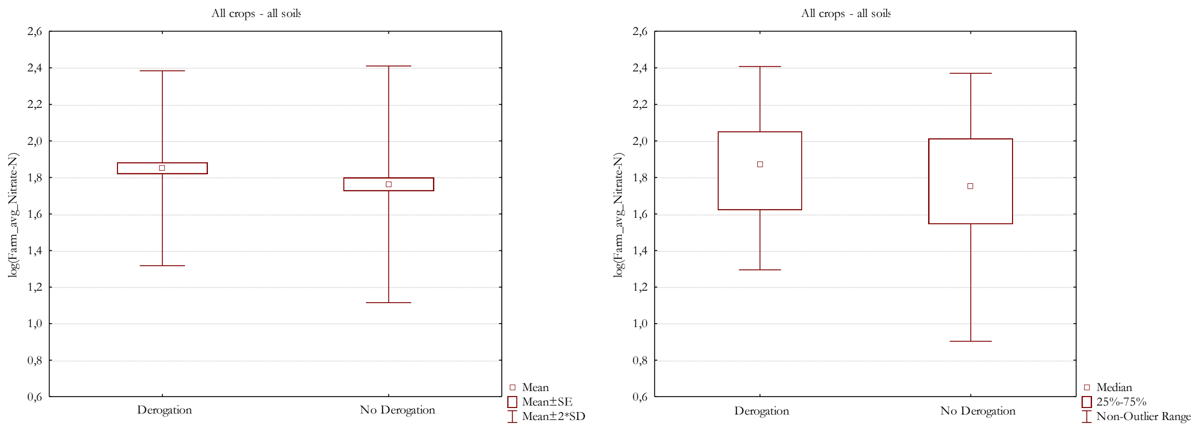


Figure 329: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with all crops on all soils in the monitoring network in autumn 2019. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

All crops on sandy soils

On sandy soils, 84 farms were involved for the comparison of the farm average nitrate-N residue, 39 farms with derogation and 45 farms without derogation. On farms with derogation, the mean farm average nitrate-N residue was 82 ± 45 kg NO_3-N/ha in autumn 2019. On farms without derogation, the mean farm average nitrate-N residue amounted 77 ± 56 kg NO_3-N/ha. There was no statistically significant difference in mean farm average nitrate-N residue for farms on sandy soils in the monitoring network (p = 0.19).

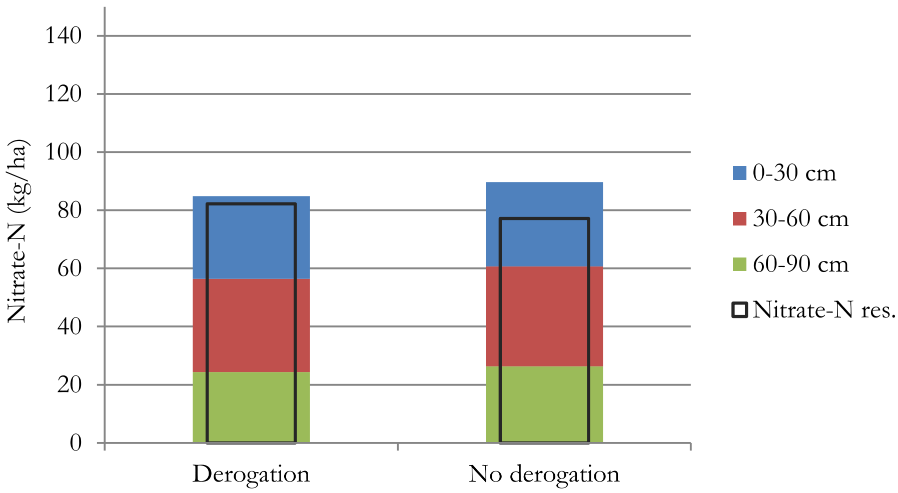


Figure 330: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2019.

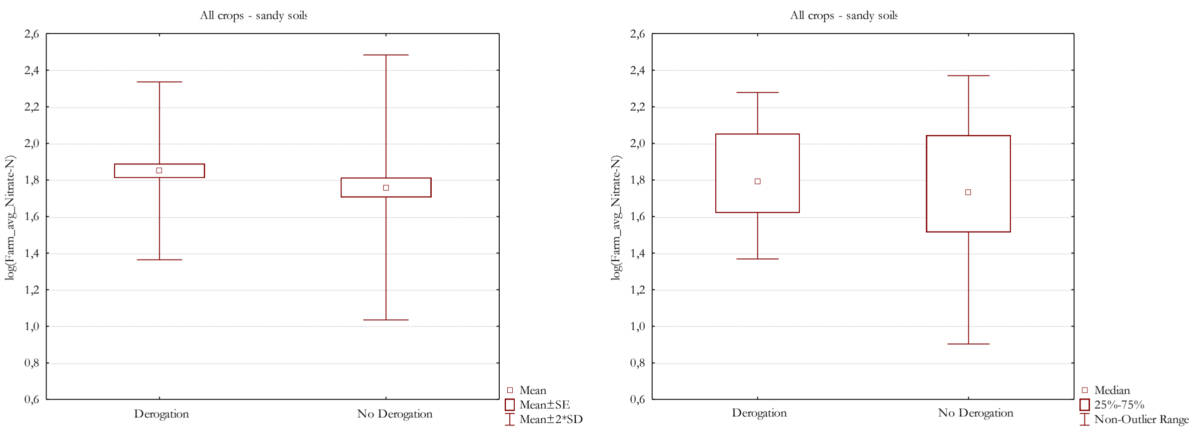


Figure 331: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2019. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Grass on sandy soils

The farm average nitrate-N residue of sandy soils cultivated with grass was compared between 18 farms with derogation and 17 farms without derogation. The mean farm average nitrate-N residues amounted respectively 64 ± 33 kg NO_3-N/ha and 54 ± 46 kg NO_3-N/ha. The difference between derogation and no derogation farms was not statistically significant ($p = 0.15$).

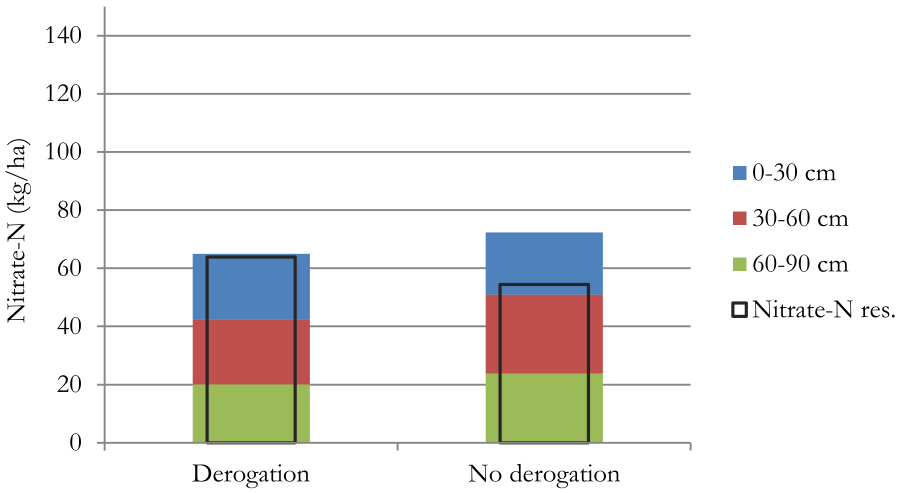


Figure 332: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2019.

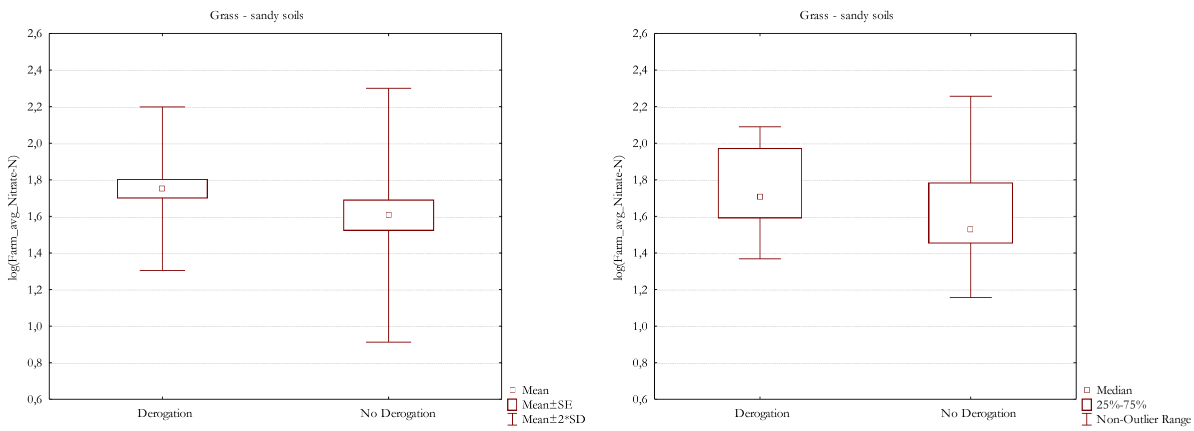


Figure 333: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2019. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Grass with less than 50 % clover on sandy soils

On sandy soils, the farm average nitrate-N residue of parcels cultivated with grass and less than 50 % clover could be determined for only 14 farms, 4 farms with derogation and 10 farms without derogation. The mean farm average nitrate-N residue amounted 79 ± 47 kg NO_3-N/ha with derogation and 59 ± 51 kg NO_3-N/ha without derogation.

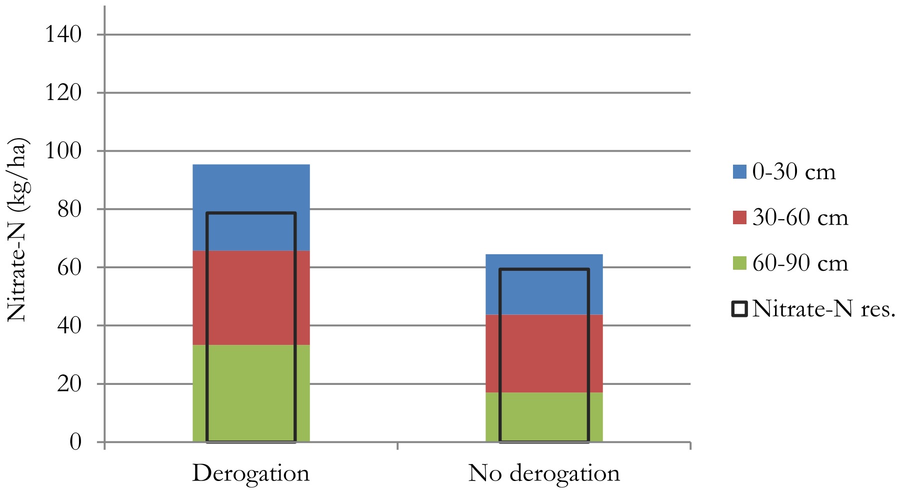


Figure 334: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with grass and less than 50 % clover on sandy soils in the monitoring network in autumn 2019.

Maize on sandy soils

For 35 farms on sandy soils, the farm average nitrate-N residue of parcels cultivated with maize was evaluated. Seventeen derogation farms and 18 no derogation farms were involved.

On derogation farms, the mean farm average nitrate-N residue was 102 ± 50 kg NO_3-N/ha. Without derogation, the mean farm average nitrate-N residue of the parcels cultivated with maize was 109 ± 55 kg NO_3-N/ha. The mean farm average nitrate-N residue of parcels cultivated with maize on sandy soils did not differ significantly ($p = 0.73$) between derogation and no derogation farms.

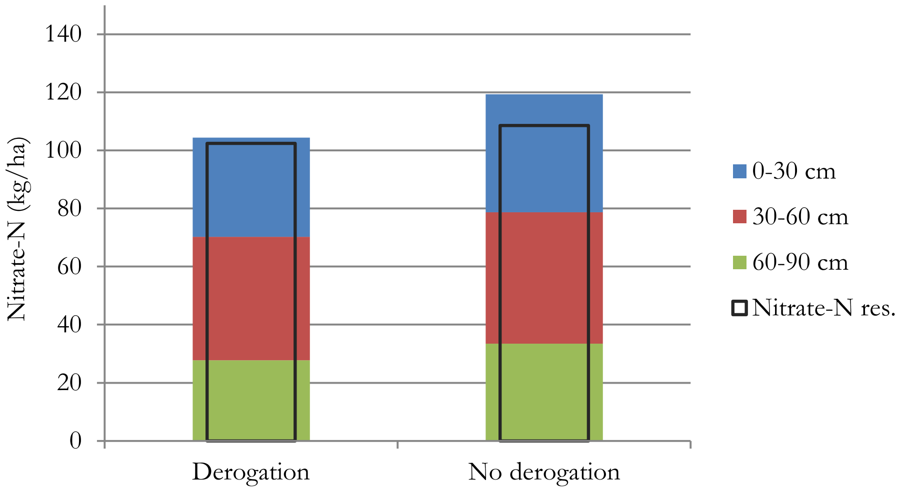


Figure 335: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2019.

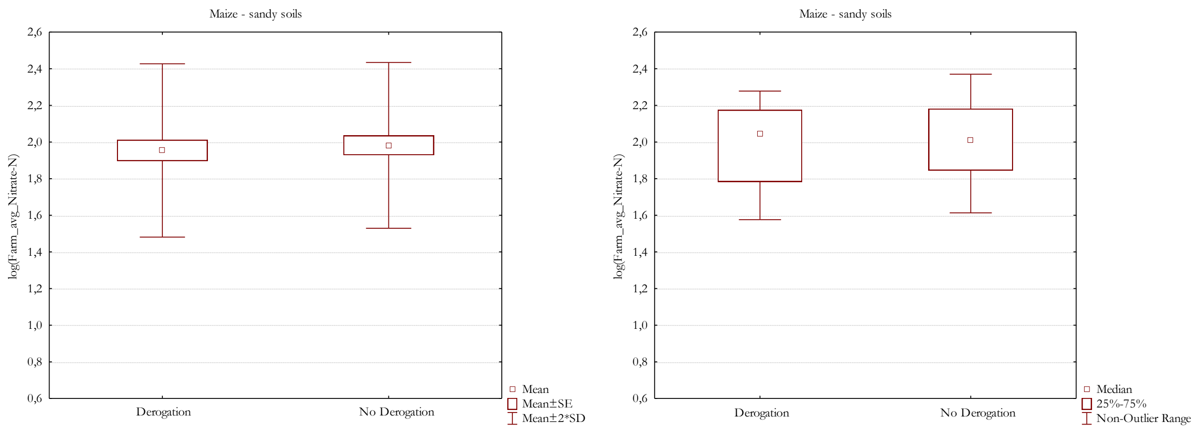


Figure 336: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2019. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

All crops on sandy loam soils

The evaluation of the farm average nitrate-N residue on sandy loam soils comprised 66 farms, 33 farms with derogation and 33 farms without derogation. The mean farm average nitrate-N residue under derogation conditions regardless of crop was 87 ± 54 kg NO_3-N/ha in autumn 2019. Without derogation, it was 70 ± 47 kg NO_3-N/ha. Derogation and no derogation farms on sandy loams soils did not differ significantly ($p = 0.23$) regarding the farm average nitrate-N residue.

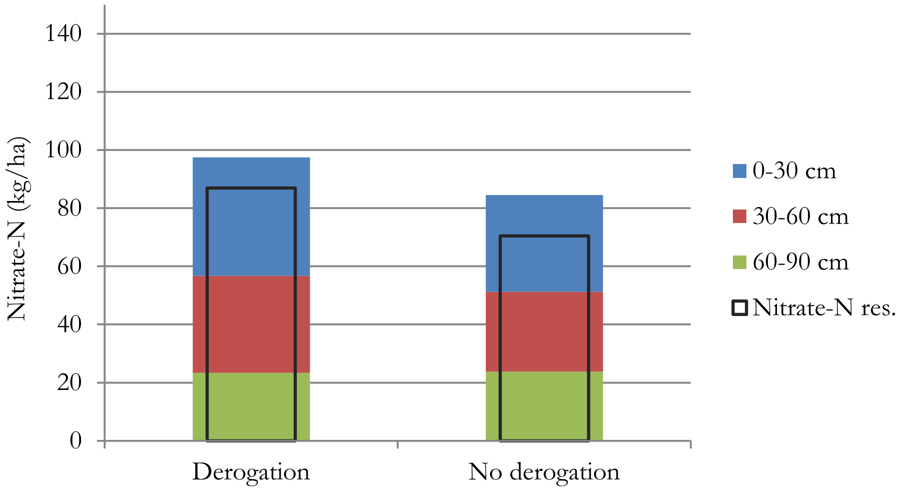


Figure 337: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network in autumn 2019.

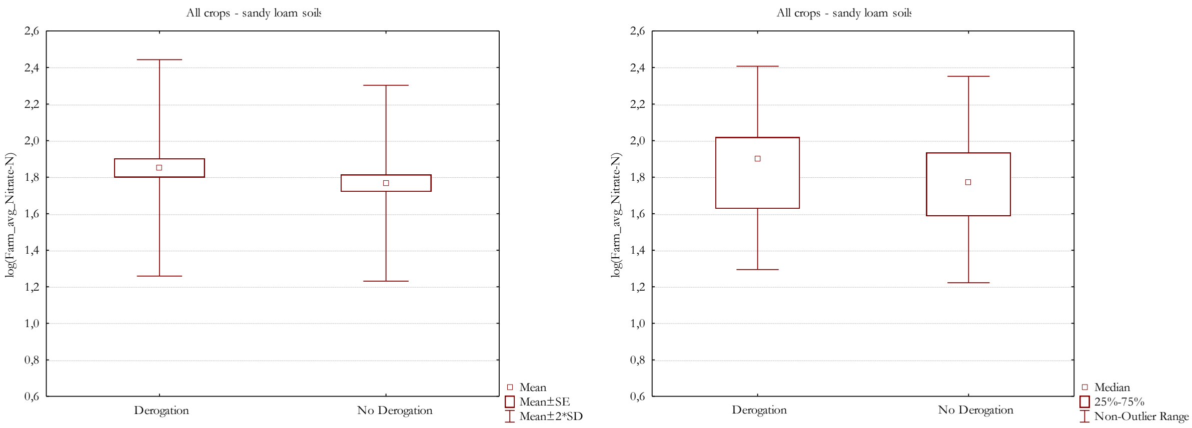


Figure 338: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network in autumn 2019. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Grass on sandy loam soils

On sandy loam soils, the farm average nitrate-N residue of parcels cultivated with grass was compared for 17 farms with derogation and 18 farms without derogation. The mean farm average nitrate-N residues of both type of farms amounted respectively 70 ± 51 kg NO_3-N/ha and 50 ± 32 kg NO_3-N/ha in autumn 2019. The difference between derogation and no derogation farms was not statistically significant ($p = 0.33$).

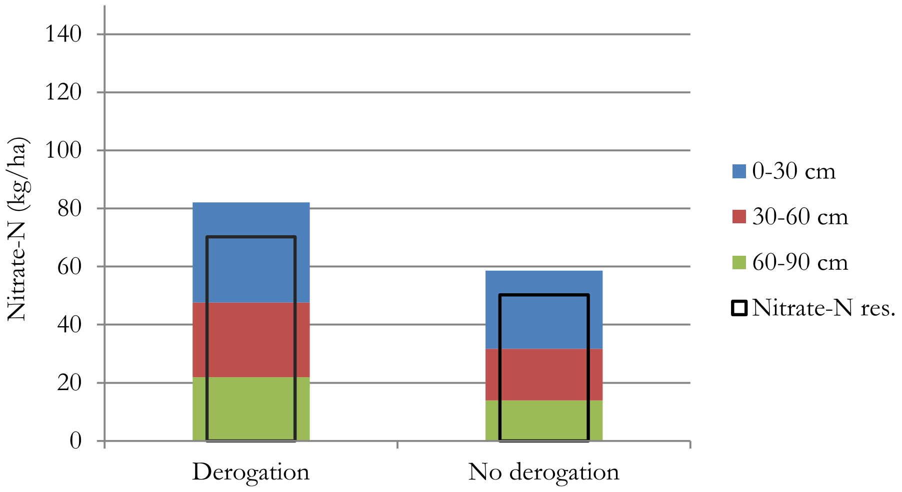


Figure 339: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2019.

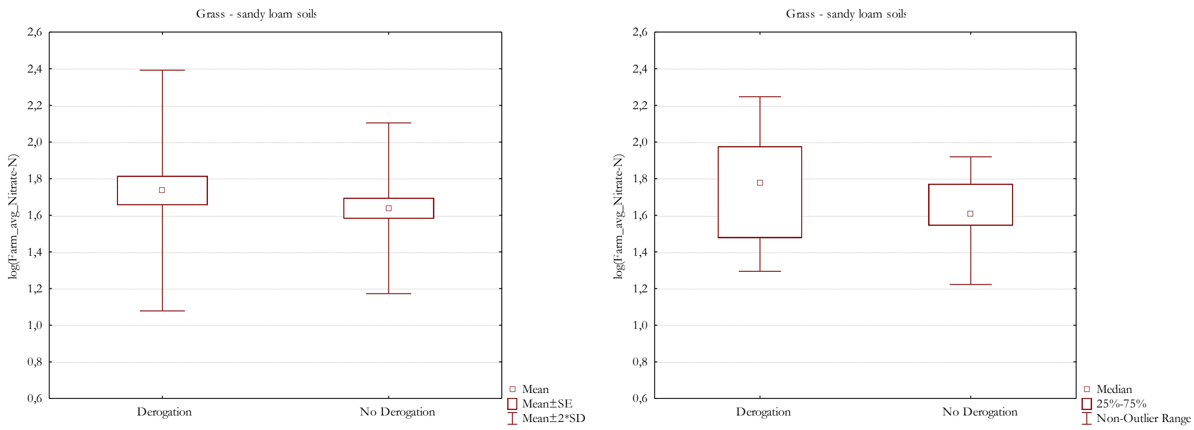


Figure 340: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2019. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

Maize on sandy loam soils

The farm average nitrate-N residue of parcels cultivated with maize on sandy loam soils was determined for 16 derogation and 16 no derogation farms. On derogation farms, the mean farm average nitrate-N residue was 105 ± 54 kg NO_3-N/ha. Without derogation conditions, the mean farm average nitrate-N residue amounted 92 ± 51 kg NO_3-N/ha. The mean farm average nitrate-N residue of parcels cultivated with maize on sandy loam soils did not differ significantly ($p = 0.37$) between derogation and no derogation farms.

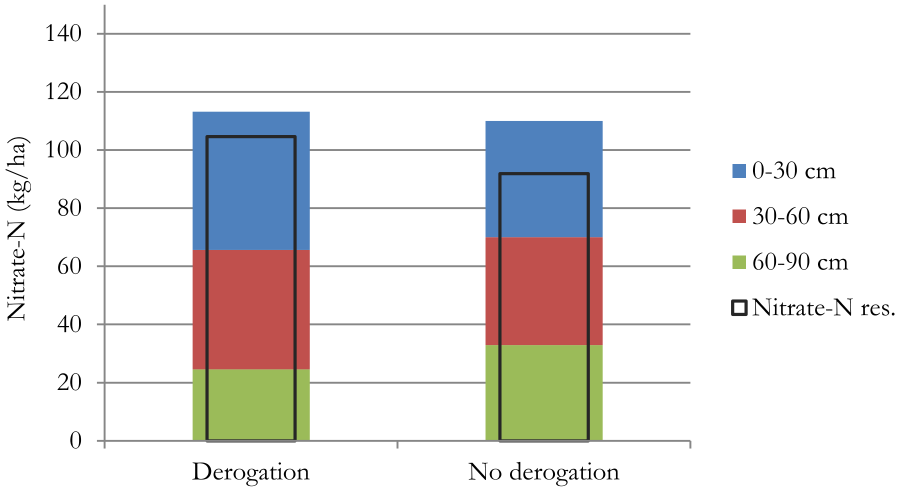


Figure 341: Farm average nitrate-N residue (kg/ha) on derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2019.

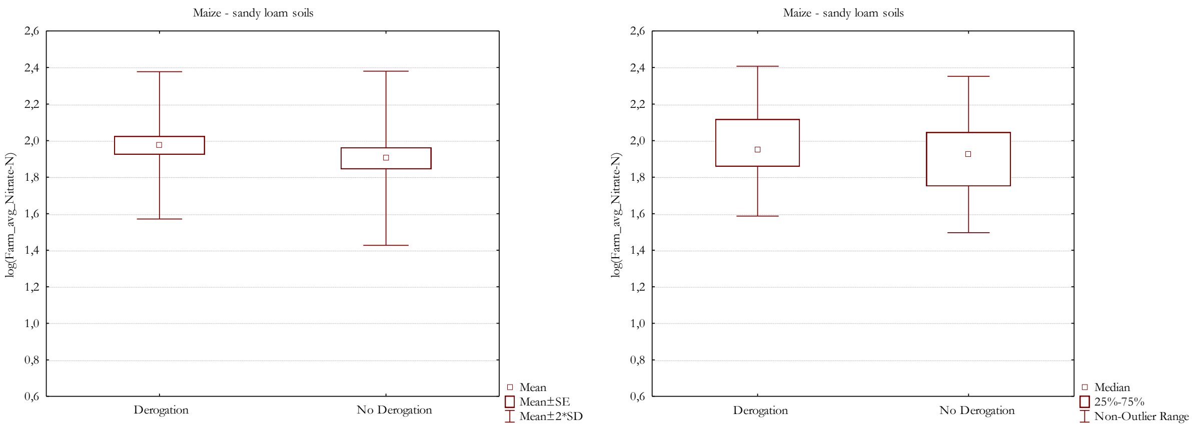


Figure 342: Boxplot of log(Farm average Nitrate-N) for derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2019. Mean: left. Median: right. SE: Standard Error of the mean. SD: Standard Deviation

3.2.1.12 Mineral nitrogen - difference autumn 2019 and spring 2020

Comparing the amount of nitrate-N in the soil profile at late winter 2019-early spring 2020 to the nitrate-N residue in autumn 2019 gives an estimation of the difference in nitrate-N in the soil profile before and after winter. The samples for the nitrate-N residue in autumn 2019 were previously discussed in 3.2.1.10.

The difference over winter approximates the amount of nitrate-N out of the soil profile between the two sampling moments. It comprises more processes than only leaching. The difference of nitrate-N between the two sampling moments is expressed in kg NO_3-N/ha and is calculated as "nitrate-N residue (kg NO_3-N/ha; 0-90 cm) – nitrate-N reserve after winter (kg NO_3-N/ha; 0-90 cm)". Since the difference over winter is defined for parcels that were sampled until 90 cm, the parcels sampled more shallow were excluded for the further analysis.

The statistical analysis for winter 2019-2020 is performed with a non-parametric test, the Kruskal-Wallis test. The dependent variable in this analysis, "nitrate-N difference", was not log-transformed.

The bar graphs show the average amount of nitrate-N (kg NO_3-N/ha) per soil layer (0-30 cm, 30-60 cm and 60-90 cm) in autumn and spring for derogation and no derogation parcels. This presentation visualizes the difference of nitrate-N realised between the two moments of sampling and the redistribution of the nitrate-N over the soil profile during this period.

The box plots, based on the effective figures of nitrate-N difference (kg NO_3-N/ha), visualize the variation in nitrate-N difference.

Table 64: Average nitrate-N difference-winter 2019-2020 (kg/ha) based on parcels sampled to 90 cm, combined at different levels of comparison. The number of parcels included in the comparison is indicated by 'n'. P-value based on the non-parametric Kruskal-Wallis test.

			Difference of nitrate-N (kg/ha)		
			n	Average	p-value
Overall mean monitoring network			313	47 ± 55	-
Derogation			167	48 ± 52	0.25
No derogation			146	45 ± 58	
Derogation	Sandy soil		99	48 ± 51	1.00
No derogation			83	53 ± 64	
Derogation	Sandy loam		68	47 ± 53	0.09
No derogation			63	35 ± 49	
Derogation	Sandy soil	Grass	40	33 ± 50	0.23
No derogation			29	21 ± 52	
Derogation	Sandy soil	Grass <50% clover	15	37 ± 52	0.75
No derogation			16	43 ± 46	
Derogation	Sandy soil	Maize	44	67 ± 48	0.38
No derogation			38	82 ± 66	
Derogation	Sandy loam	Grass	31	35 ± 42	0.55
No derogation			31	31 ± 42	
Derogation	Sandy loam	Maize	37	58 ± 59	0.08
No derogation			32	39 ± 56	

Parcels that were judged not suited for evaluation of the impact of derogation on the nitrate-N residue (see 3.2.1.10; i.e. parcels that were not sampled down to 90 cm and some parcels that were only sampled at mid spring 2020), were excluded for the discussion of the nitrate-N difference over winter 2019-2020.

The discussion of the nitrate-N difference over winter 2019-2020 is performed for 313 parcels.

The average nitrate-N difference on those 313 parcels was 47 ± 55 kg NO_3-N/ha (Figure 343). The lower nitrate-N residue in autumn 2019 compared to autumn 2018, results in a lower nitrate-N difference over winter for 2019-2020 compared to 2018-2019.

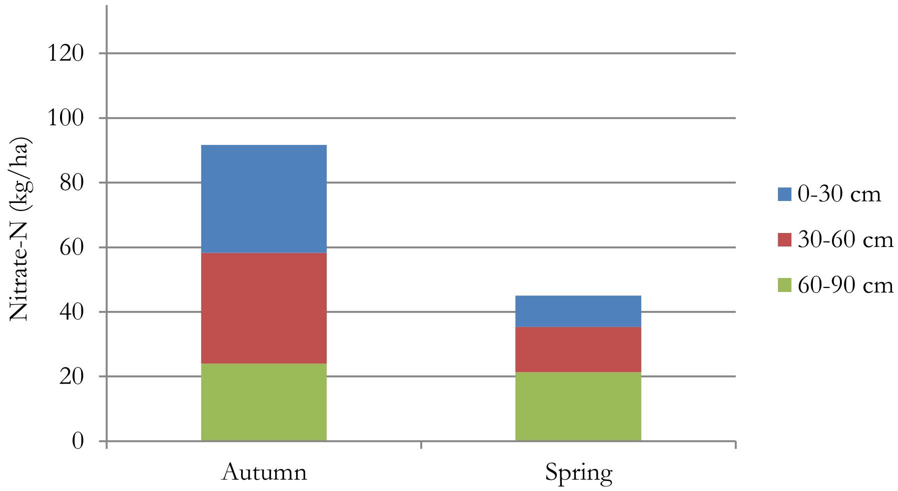


Figure 343: Average nitrate-N (kg/ha) on 313 parcels of the monitoring network in autumn 2019 and spring 2020, indicating the average nitrate-N difference-winter 2019-2020.

The 313 parcels as basis for this evaluation were 167 parcels with derogation and 146 parcels without derogation. On the parcels with derogation, the average nitrate-N difference was 48 ± 52 kg NO_3-N/ha. On parcels without derogation, the average nitrate-N difference was 45 ± 58 kg NO_3-N/ha. The nitrate-N difference over winter did not differ significantly ($p = 0.25$) between derogation and no derogation parcels in the monitoring network in winter 2019-2020.

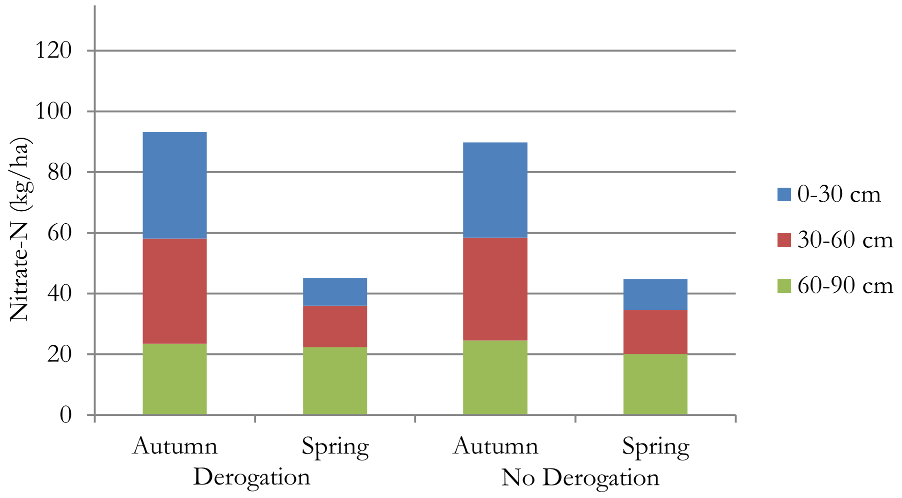


Figure 344: Average nitrate-N (kg/ha) in autumn 2019 and spring 2020 on derogation and no derogation parcels of the monitoring network, indicating the average nitrate-N difference during winter 2019-2020 on derogation and no derogation parcels.

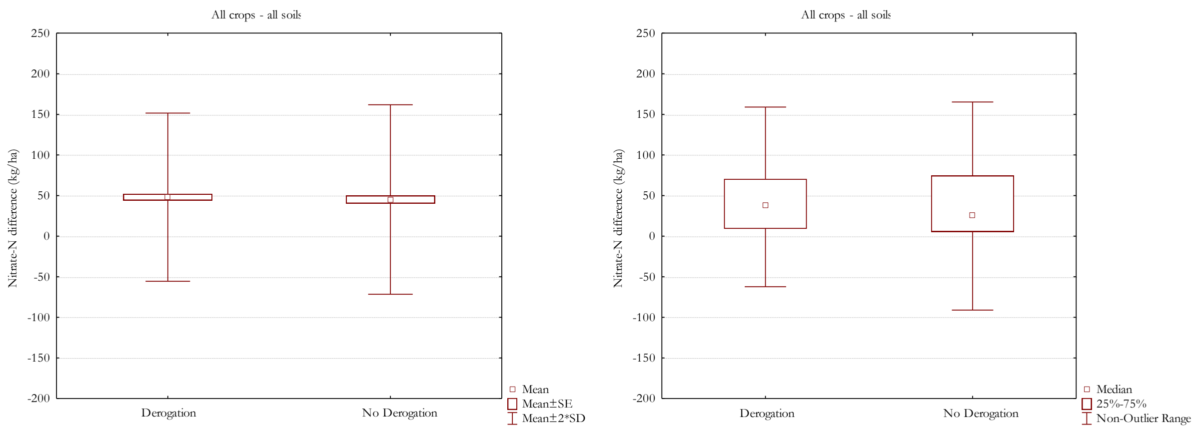


Figure 345: Boxplot of the nitrate-N difference-winter 2019-2020 (kg/ha) on derogation and no derogation parcels with all crops on all soil textures in the monitoring network. Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

All crops on sandy soils

In winter 2019-2020, the average nitrate-N difference on sandy soils amounted 50 ± 57 kg NO_3-N/ha. The evaluation included 182 parcels, 99 with derogation and 83 without derogation. Under derogation conditions, the average nitrate-N difference was 48 ± 51 kg NO_3-N/ha. Without derogation, the average nitrate-N difference amounted 53 ± 64 kg NO_3-N/ha. Derogation and no derogation parcels on sandy soils did not differ statistically ($p = 1.00$) regarding the nitrate-N difference during winter 2019-2020.

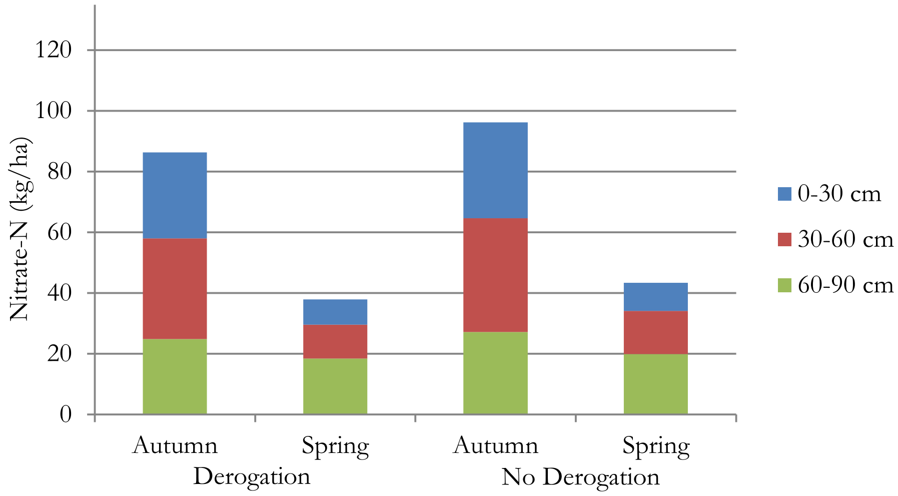


Figure 346: Average nitrate-N (kg/ha) in autumn 2019 and spring 2020 on derogation and no derogation parcels on sandy soils of the monitoring network, indicating the average nitrate-N difference during winter 2019-2020 on derogation and no derogation parcels on sandy soils.

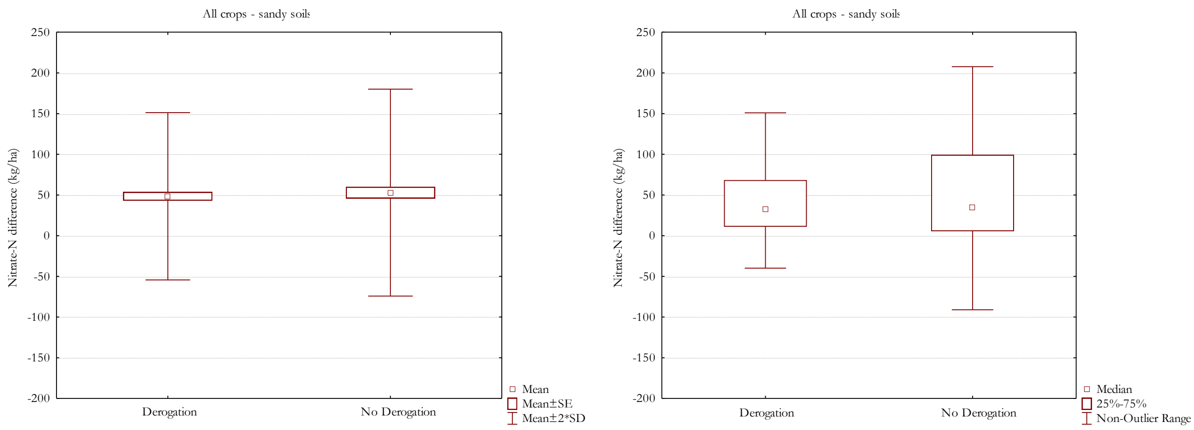


Figure 347: Boxplot of the nitrate-N difference-winter 2019-2020 (kg/ha) on derogation and no derogation parcels with all crops on sandy soils in the monitoring network. Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Grass on sandy soils

Focusing on parcels cultivated with grass on sandy soils, 69 parcels could be evaluated. Forty parcels with and 29 parcels without derogation were compared. The average nitrate-N difference over winter 2019-2020 amounted respectively 33 ± 50 kg NO_3-N/ha and 21 ± 52 kg NO_3-N/ha. The difference between derogation and no derogation parcels was statistically insignificant ($p = 0.23$).

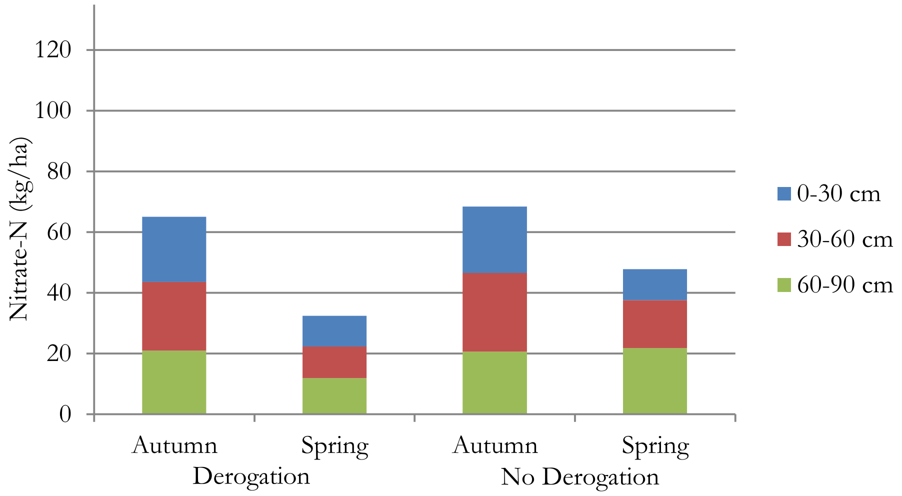


Figure 348: Average nitrate-N (kg/ha) in autumn 2019 and spring 2020 on derogation and no derogation parcels on sandy soils cultivated with grass of the monitoring network, indicating the average nitrate-N difference during winter 2019-2020 on derogation and no derogation parcels on sandy soils cultivated with grass.

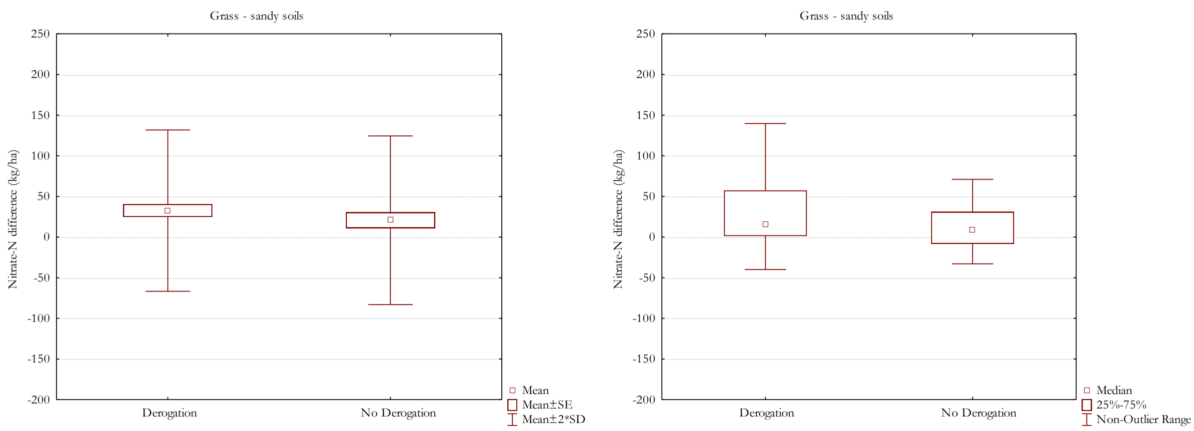


Figure 349: Boxplot of the nitrate-N difference-winter 2019-2020 (kg/ha) on derogation and no derogation parcels with grass on sandy soils in the monitoring network. Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Grass with less than 50 % clover on sandy soils

The evaluation of the nitrate-N difference over winter 2019-2020 on sandy soils cultivated with grass was realised on 31 parcels, 15 parcels with derogation and 16 parcels without derogation. The nitrate-N difference on the derogation parcels was on average 37 ± 52 kg NO_3-N/ha. The average difference on the parcels without derogation was 43 ± 46 kg NO_3-N/ha, not significantly different ($p = 0.75$) of the average difference measured on the derogation parcels.

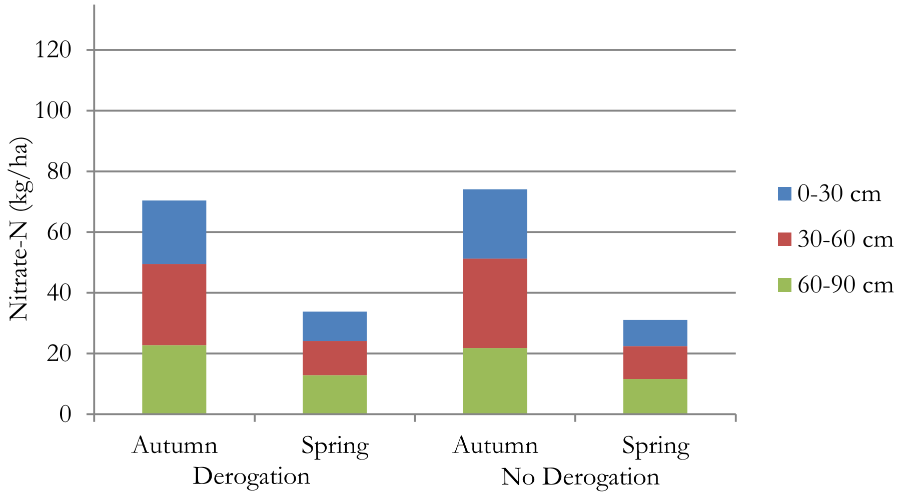


Figure 350: Average nitrate-N (kg/ha) in autumn 2019 and spring 2020 on derogation and no derogation parcels on sandy soils cultivated with grass and less than 50 % clover of the monitoring network, indicating the average nitrate-N difference during winter 2019-2020 on derogation and no derogation parcels on sandy soils cultivated with grass and less than 50 % clover.

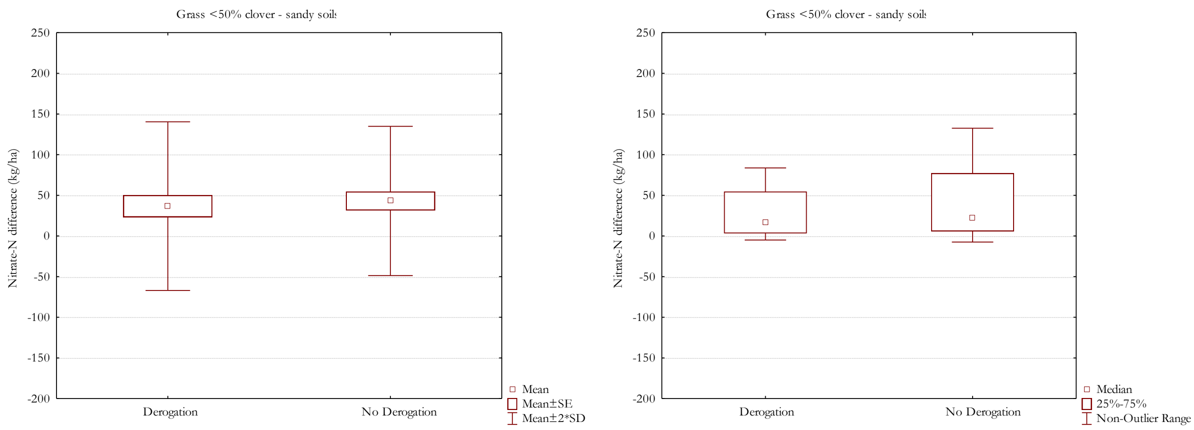


Figure 351: Boxplot of the nitrate-N difference-winter 2019-2020 (kg/ha) on derogation and no derogation parcels with grass and less than 50 % clover on sandy soils in the monitoring network. Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Maize on sandy soils

The nitrate-N difference over winter 2019-2020 was determined for 82 sandy parcels cultivated with maize. Under derogation conditions (44 parcels), the average nitrate-N difference was 67 ± 48 kg NO_3-N/ha. Without derogation (38 parcels), an average nitrate-N difference of 82 ± 66 kg NO_3-N/ha was measured. The nitrate-N difference over winter 2019-2020 on parcels cultivated with maize on sandy soils was not impacted by the request of derogation ($p = 0.38$)

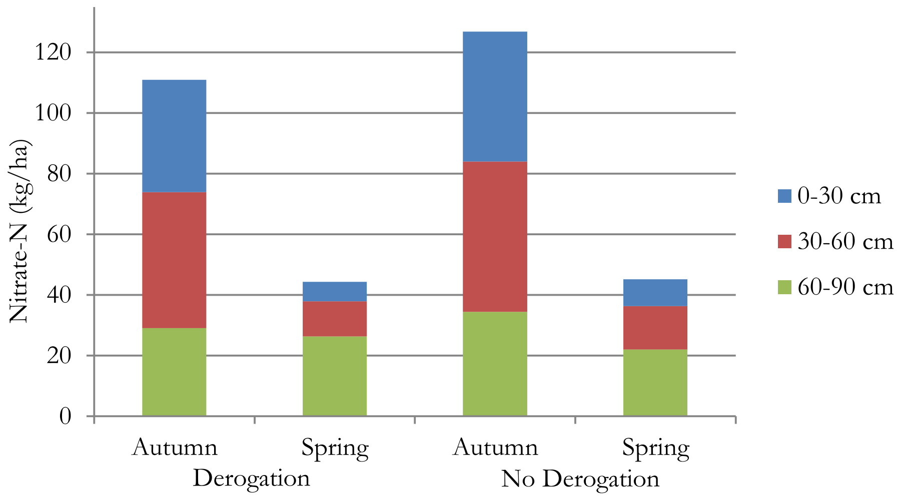


Figure 352: Average nitrate-N (kg/ha) in autumn 2019 and spring 2020 on derogation and no derogation parcels on sandy soils cultivated with maize of the monitoring network, indicating the average nitrate-N difference during winter 2019-2020 on derogation and no derogation parcels on sandy soils cultivated with maize.

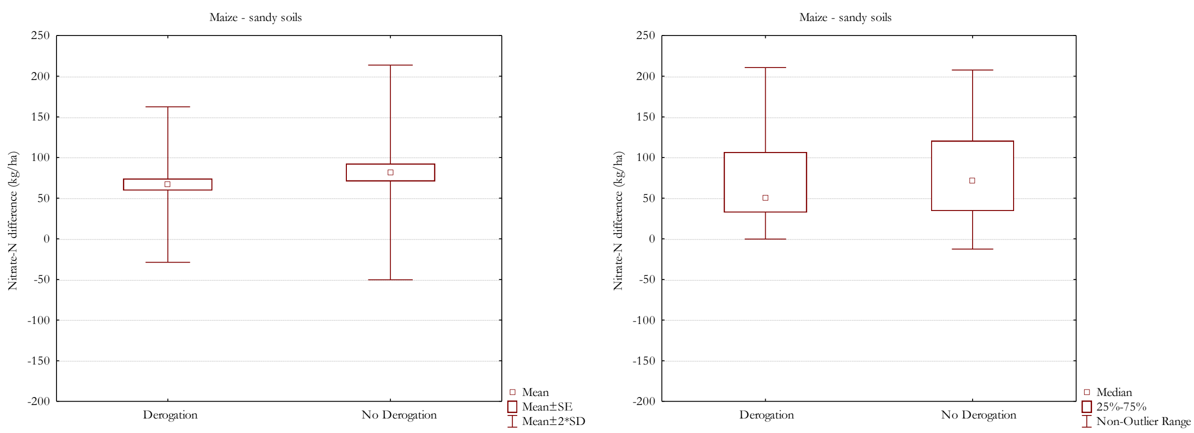


Figure 353: Boxplot of the nitrate-N difference-winter 2019-2020 (kg/ha) on derogation and no derogation parcels with maize on sandy soils in the monitoring network. Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

All crops on sandy loam soils

On sandy loam soils, the average nitrate-N difference over winter 2019-2020 amounted 41 ± 51 kg NO_3-N/ha, measured on 131 parcels. To evaluate a possible impact of derogation on the nitrate-N difference, 68 derogation parcels were compared to 63 no derogation parcels. On the derogation parcels, the average nitrate-N difference amounted 47 ± 53 kg NO_3-N/ha. Without derogation, the average nitrate-N difference was 35 ± 49 kg NO_3-N/ha.

The average nitrate-N difference over winter 2019-2020 did not differ significantly ($p = 0.09$) between derogation and no derogation parcels on sandy loam soils.

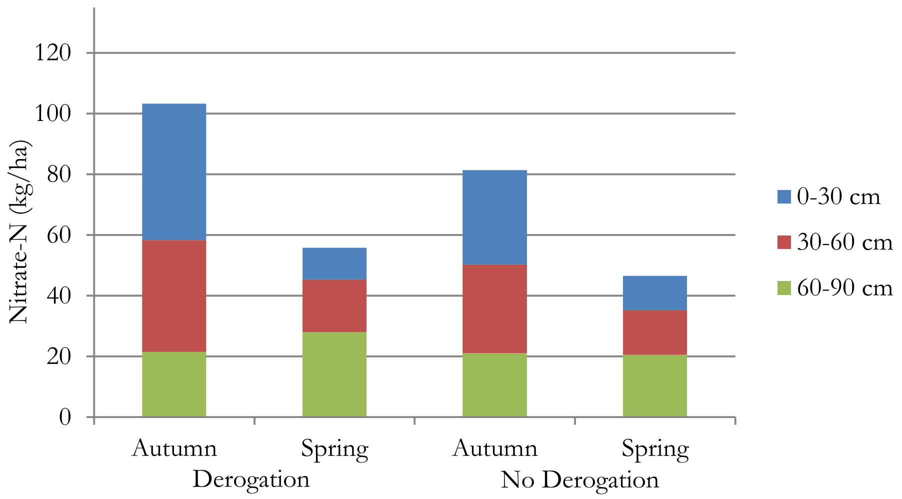


Figure 354: Average nitrate-N (kg/ha) in autumn 2019 and spring 2020 on derogation and no derogation parcels on sandy loam soils of the monitoring network, indicating the average nitrate-N difference during winter 2019-2020 on derogation and no derogation parcels on sandy loam soils.

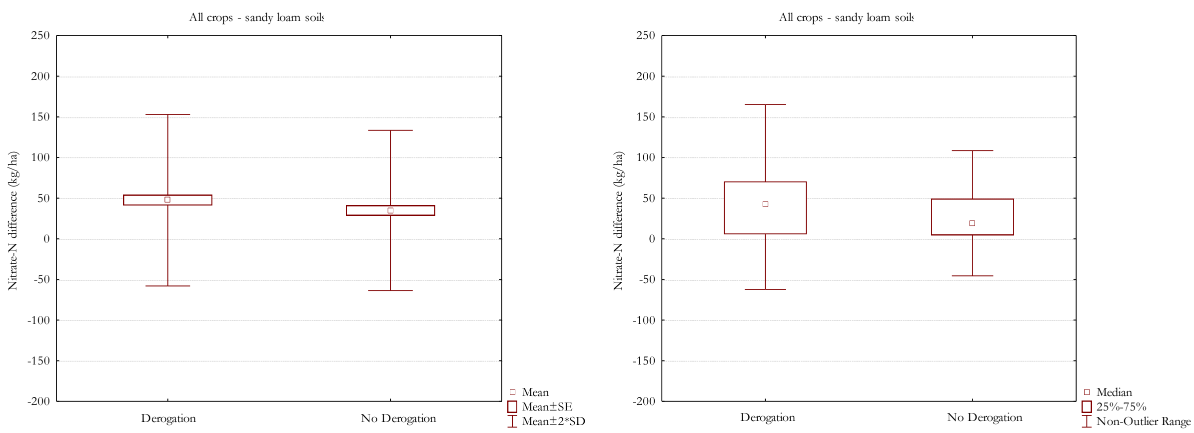


Figure 355: Boxplot of the nitrate-N difference-winter 2019-2020 (kg/ha) on derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network. Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Grass on sandy loam soils

On sandy loam soils, 31 parcels cultivated with grass under derogation conditions were compared to 31 parcels with grass without derogation. Under derogation conditions, the average nitrate-N difference was 35 ± 42 kg NO_3-N/ha, without derogation it was 31 ± 42 kg NO_3-N/ha.

On sandy loam soils, derogation and no derogation parcels cultivated with grass did not differ statistically regarding the nitrate-N difference ($p = 0.55$).

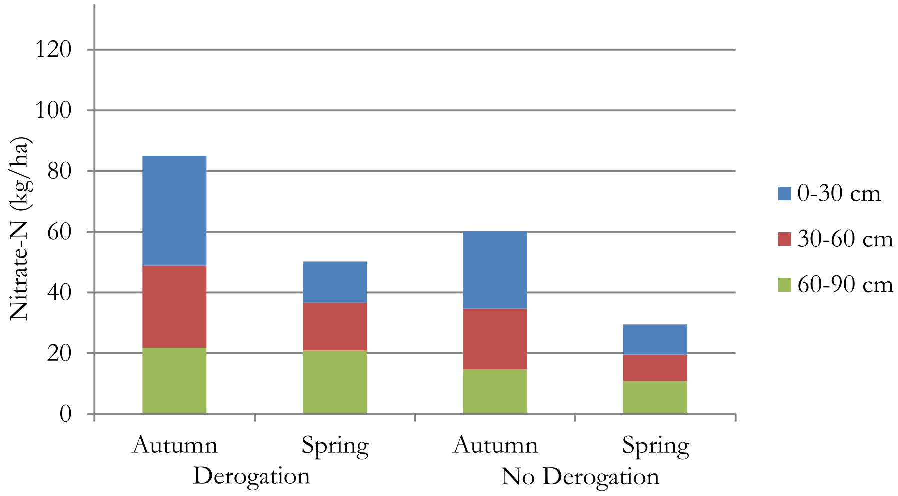


Figure 356: Average nitrate-N (kg/ha) in autumn 2019 and spring 2020 on derogation and no derogation parcels on sandy loam soils cultivated with grass of the monitoring network, indicating the average nitrate-N difference during winter 2019-2020 on derogation and no derogation parcels on sandy loam soils cultivated with grass.

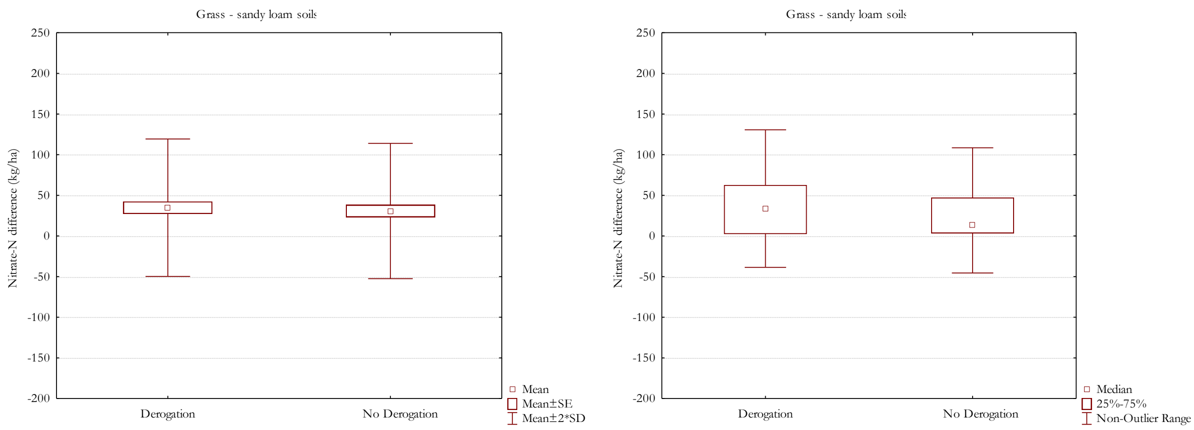


Figure 357: Boxplot of the nitrate-N difference-winter 2019-2020 (kg/ha) on derogation and no derogation parcels with grass on sandy loam soils in the monitoring network. Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

Maize on sandy loam soils

Focusing on sandy loam soils cultivated with maize, 69 parcels were evaluated for the nitrate-N difference over winter 2019-2020. The average nitrate-N difference on those parcels was 49 ± 58 kg NO_3-N/ha. With derogation (37 parcels), the average nitrate-N difference was 58 ± 59 kg NO_3-N/ha. Without derogation (32 parcels), an average nitrate-N difference of 39 ± 56 kg NO_3-N/ha was measured for winter 2019-2020. The difference between derogation and no derogation parcels was statistically insignificant (p = 0.08).

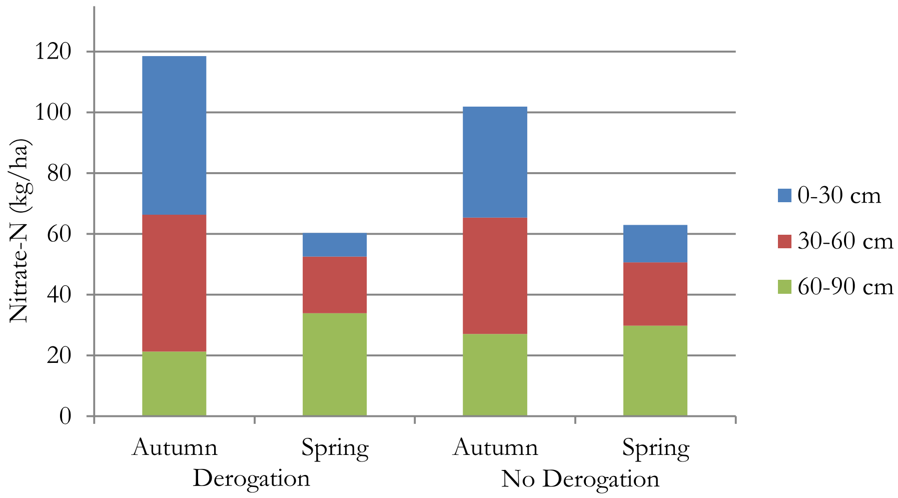


Figure 358: Average nitrate-N (kg/ha) in autumn 2019 and spring 2020 on derogation and no derogation parcels on sandy loam soils cultivated with maize of the monitoring network, indicating the average nitrate-N difference during winter 2019-2020 on derogation and no derogation parcels on sandy loam soils cultivated with maize.

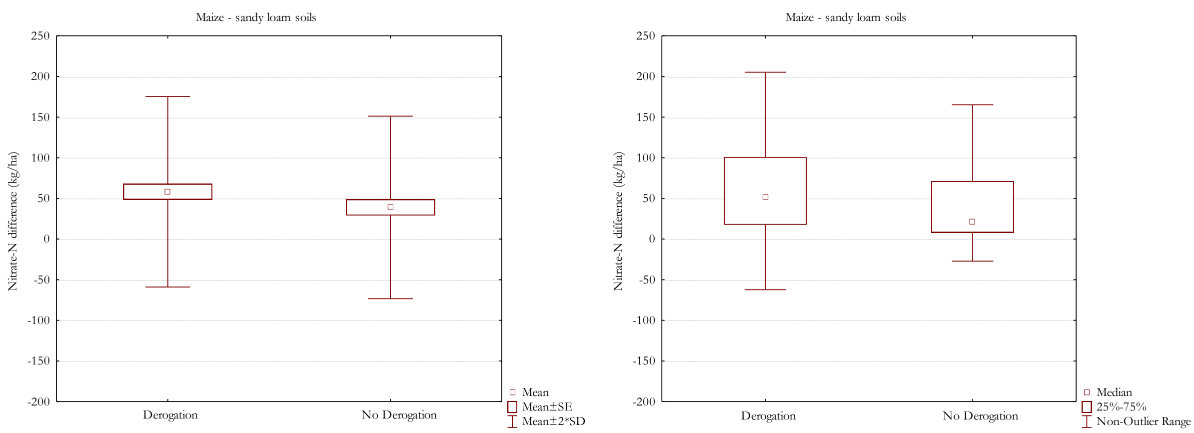


Figure 359: Boxplot of the nitrate-N difference-winter 2019-2020 (kg/ha) on derogation and no derogation parcels with maize on sandy loam soils in the monitoring network. Mean: left; Median: right. SE: standard error of the mean. SD: Standard Deviation

3.2.2 Phosphorus in the soil

Originally, the monitoring of phosphorus in the soil regarding to derogation and no derogation practices was suggested as a one-time determination of the phosphorus content (P-AL, extraction in ammonium-lactate) of the soil layer 0-30 cm of all parcels in the monitoring network with regard to the application of derogation in the year before.

Since the phosphorus status of a parcel is often a result of a long-term policy of parcel management it was proposed from scientific perspective to investigate the phosphorus status of the parcels down to 90 cm regarding to the frequency of implementation of derogation at the parcels. This alternative approach to monitor phosphorus in the soil regarding to long-term derogation and no derogation practices was discussed in the steering committee that evaluates the derogation monitoring in Flanders.

To make a distinction as clear as possible, it was suggested to focus on parcels managed continuously under derogation conditions or continuously without derogation conditions. To evaluate the possibility of the alternative approach, the derogation history of the 480 parcels of the network set up in 2016 was reconstructed. The number of continuous derogation parcels and continuous no derogation parcels was assessed.

For 395 parcels, the derogation history could be completely reconstructed. Fifty parcels appeared to be continuously under derogation for 9 years since 2008, while 174 parcels were 9 years continuously without derogation. An overview of the number of parcels with information on the frequency of the implementation of derogation is given in Table 65.

Table 65: Overview of the number of parcels in the monitoring network and their derogation history and frequency in the period 2008-2016.

	n
Continuous derogation	50
8 years	43
7 years	22
6 years	18
5 years	18
4 years	15
3 years	16
2 years	20
1 year	19
Continuous no derogation	174

Although the number of continuous derogation parcels and continuous no derogation parcels was already considerable, it was agreed with the steering committee to unite the parcels which were cultivated 7-9 years under derogation conditions in the period 2008-2016 as 'long-term derogation parcels'. Before uniting those parcels in one group, it was verified that there were no statistically significant differences between parcels cultivated under derogation conditions for 7, 8 or 9 years (Table 66). The phosphorus content (P-AL, extraction in ammonium-lactate) was determined in each soil layer of 30 cm down to 90 cm in autumn 2016. Results of P-AL below the limit of quantification (limit of quantification = 4 mg P/100 g dry soil) were replaced by the half, being 2 mg P/100g dry soil.

The phosphorus status of the parcels down to 90 cm is verified and demonstrated in two ways. Once as the average P-AL over the soil profile of 0-90 cm (the average of P-AL of the soil layers 0-30 , 30-60 and 60-90 cm) and on the other hand as the total amount of kg P/ha in the soil profile (0-90 cm; P-content$_{0\text{-}90cm}$).

For the conversion of P-AL to kg P/ha a soil density of 1500 kg/m³ was taken into account for the soil layers 30-60 and 60-90 cm for all soils. For the soil layer 0-30 cm the calculation was done with a soil density of 1250 kg/m³ and 1450 kg/m³ for respectively sandy and sandy loam soils.

The statistical analysis of the average P-AL and the P-content over 0-90 cm is carried out by a non-parametric analysis. Since three independent groups have to be compared the non-parametric Kruskal-Wallis test was applied. The p-values mentioned in the discussion of the P-status regarding to the length of derogation application, are the result of the Kruskal-Wallis test.

Table 66: Average P-AL over the soil profile (0-90 cm) (mg P/100 g dry soil) and P-content$_{0\text{-}90cm}$ (kg P/ha in the soil profile of 0-90 cm) for the 115 parcels cultivated 7, 8 or 9 years continuously under derogation conditions. The number of parcels is indicated by 'n'.

	n	Average P-AL 0-90 cm (mg P/100 g dry soil)	P-content $_{0\text{-}90cm}$ (kg P/ha)
7	22	16	2037
8	43	13	1564
9	50	16	1927
p-value		0,20	0,18

The average P-AL concentration in the soil profile to 90 cm (p= 0.20) and the amount of P in the soil profile to 90 cm (p = 0.18) did not differ statistically between parcels which were cultivated 7, 8 or 9 years with derogation.

Therefore, it was justified to unite those 3 groups to one group of 'long-term derogation parcels'. The average P-AL concentration in the soil profile to 90 cm of the long-term derogation parcels amounted 15 ± 8 mg P/100g dry soil. The average P-content in the soil profile to 90 cm of the long-term derogation parcels amounted 1813 ± 1022 kg P/ha.

The monitoring of phosphorus in the soil, as agreed with the steering committee, will thus comprise 230 parcels: 115 parcels that were cultivated 7-9 years under derogation conditions in the period 2008-2016 and 115 parcels cultivated continuously without derogation. The crop rotation of the 115 long-term derogation parcels could be reconstructed for the last 7 years (2010-2016).

Table 67: Overview of the crop rotation during the last 7 years (2010-2016) on the parcels 7, 8 or 9 years under derogation the past 9 years and the number of parcels per crop rotation.

	n
Continuous grass	51
6 years grass*-1 year maize	5
6 years grass-1 year other crop**	4
5 years grass-2 years maize	5
5 years grass-1 year maize	4
4 years grass-3 years maize	2
4 years grass-2 years maize	4
2 years grass -2 years maize	1
2 year maize -2 year grass	1
4 years maize-3 years grass	4
4 years maize-2 years grass	1
4 years maize-3 years other crop	1
5 years maize-2 years other crop	2
6 years maize-1 year grass	2
6 years maize-1 year other crop	2
Continuous maize	26

*grass is grass or grass with less than 50 % clover
**other crops: wheat, beets, potatoes, others ….

On the 174 parcels continuous without derogation, the crop rotation is obviously different and more variable than on the parcels continuously under derogation. A larger crop rotation is inherent for parcels without derogation. Still 48 parcels are continuously cultivated with grass the past 7 years and 14 parcels were continuously cultivated with maize. On 82 parcels, it was always a derogation crop during the past 7 years, being grass, maize, grass and less than 50% clover, wheat or beets.

For the comparison of 'long-term derogation' (LT D) and 'long-term no derogation' (LT ND), the parcels cultivated without derogation will be selected in view of a similar distribution of crop rotation in both the non-derogation as the derogation group. The similar crop rotation on the selection of long-term derogation and no derogation parcels is shown in Table 68. Regarding to other crops the selection of the long-term no derogation parcels was focused on derogation crops to maximize the similarity between both groups.

Table 68: Overview of the crop rotation during the last 7 years (2010-2016) and the number of parcels per crop rotation on the long-term derogation parcels and the selection of long-term no derogation parcels.

	Derogation	No derogation
	n	n
Continuous grass	51	48
6 years grass*-1 year maize	5	0
6 years grass-1 year other crop**	4	4
5 years grass-2 years maize	5	1
5 years grass-1 year maize	4	3
5 years grass-2 years other crop**	0	4
4 years grass-3 years maize	2	0
4 years grass-2 years maize	4	1
4 years grass-1 year maize	0	2
4 years grass-3 years other crop**	0	2
3 years grass -2 years maize	1	0
3 years grass -3 years maize	0	1
2 year maize -2 year grass	1	1
4 years maize-3 years grass	4	3
4 years maize-2 years grass	1	0
4 years maize-3 years other crop	1	3
5 years maize-2 years other crop	2	6
6 years maize-1 year grass	2	5
6 years maize-1 year other crop	2	7
Continuous maize	26	14

*grass is grass or grass with less than 50 % clover
**other crops: wheat, beets, potatoes, others ….

Besides crop, soil texture is considered in the selection of long-term no derogation parcels. A similar ratio of sandy and sandy loam soils in both groups of long-term derogation and long-term no derogation parcels was achieved (Table 69).

Table 69: Overview of the percentage sandy and sandy loam parcels in the groups of long-term derogation parcels and long-term no derogation parcels.

	Sandy soils	Sandy loam soils
Long-term derogation	66	34
Long-term no derogation	63	37

The discussion of the P-status regarding the long-term application of derogation or not is based on a non-parametric analysis. Since two unpaired groups of data need to be compared, the Mann-Whitney U test is used. The mentioned p-values are the result of the Mann-Whitney U test.

On the selected 230 parcels, the mean average P-AL in the soil profile to 90 cm was 14 ± 8 mg P/100 g dry soil. The average amount of P in the soil profile to 90 cm in kg/ha amounted 1761 ± 1031 kg P/ha. Both the average P-AL concentration in the soil profile to 90 cm ($p = 0.40$) and the amount of P in the soil profile to 90 cm ($p = 0.37$) did not differ statistically significant between long-term derogation and long-term no derogation parcels (Table 71, Figure 360).

Table 70: P-AL (mg P/100g dry soil) in the soil profile. In average over the soil profile 0-90 cm and specified per soil layer (0-30 cm, 30-60 cm and 60-90 cm) for the long-term derogation and no derogation parcels. The number of parcels is indicated by 'n'.

	n	Average P-AL 0-90 cm	P-AL		
			0-30 cm	30-60 cm	60-90 cm
Long-term derogation	115	15	26	12	6
Long-term no derogation	115	14	26	11	4
p-value		0.40			

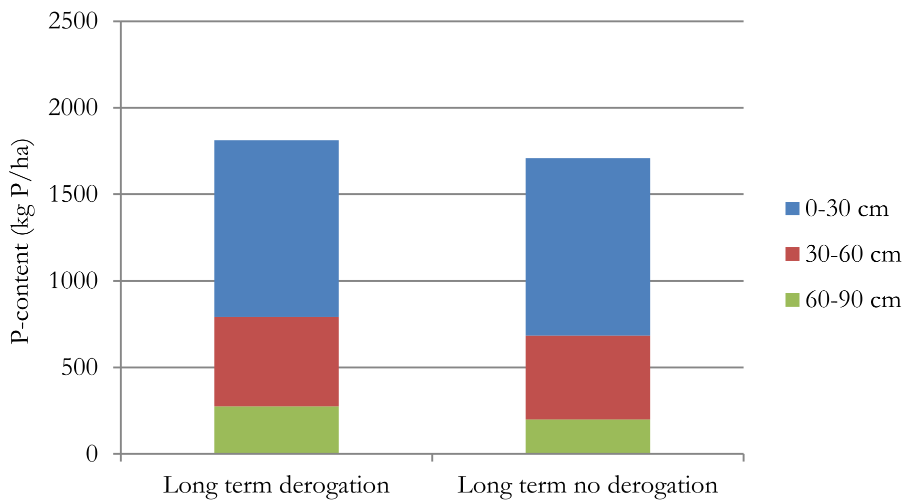


Figure 360: P-content$_{0\text{-}90cm}$ (kg P/ha in the soil profile of 0-90 cm) for long-term derogation and long-term no derogation parcels in the monitoring network.

Table 71: P-content (kg P/ha) in the soil profile of 0-90 cm. In total over the soil profile 0-90 cm and specified per soil layer (0-30 cm, 30-60 cm and 60-90 cm) for the long-term derogation and no derogation parcels. The number of parcels is indicated by 'n'.

	n	Total P-content 0-90 cm	P-content		
			0-30 cm	30-60 cm	60-90 cm
Long-term derogation	115	1812	1020	517	275
Long-term no derogation	115	1709	1025	484	199
p-value		0.37			

The lack of a statistical difference of the accumulation of P between long-term derogation and long-term no derogation parcels appears also in the boxplots shown in Figure 361.

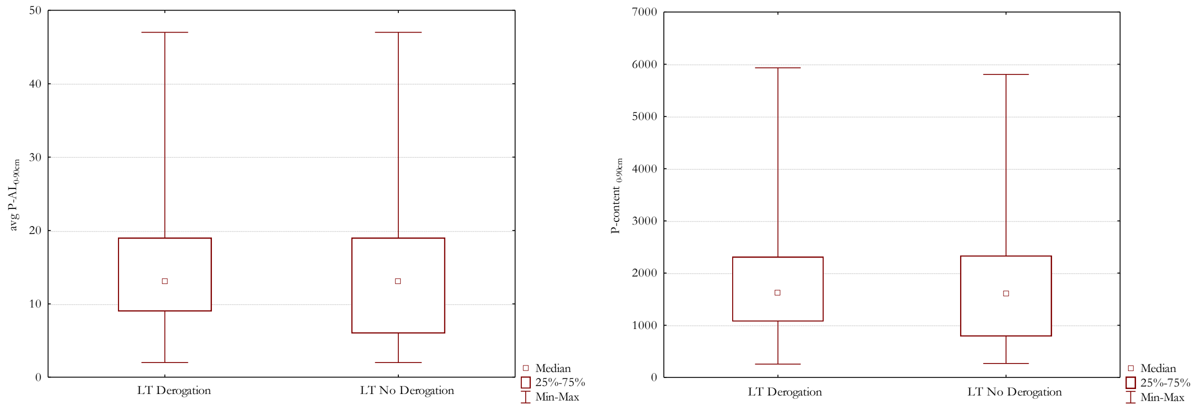


Figure 361: Boxplot of the average P-AL (mg P/100 g dry soil) over the soil profile of 0-90 cm (avg $P\text{-}AL_{0\text{-}90cm}$) (right) and boxplot of the $P\text{-}content_{0\text{-}90cm}$ (kg P/ha in the soil profile of 0-90 cm) (left) for long-term (LT) Derogation and No derogation parcels in the monitoring network.

Sandy soils

On sandy soils, 149 parcels were compared, 76 long-term derogation parcels and 73 parcels cultivated without derogation in the period 2008-2016. The mean average P-AL in the soil profile to 90 cm was 17 ± 9 mg P/100 g dry soil on the sandy parcels. The average amount of P in the soil profile to 90 cm in kg/ha amounted 2023 ± 1079 kg P/ha.

Table 72: P-AL (mg P/100g dry soil) in the soil profile. In average over the soil profile 0-90 cm and specified per soil layer (0-30 cm, 30-60 cm and 60-90 cm) for the long-term derogation and no derogation parcels on sandy soils. The number of parcels is indicated by 'n'.

	n	Average P-AL 0-90 cm	P-AL		
			0-30 cm	30-60 cm	60-90 cm
Long-term derogation	76	17	29	14	8
Long-term no derogation	73	16	31	14	5
p-value		0.82			

Table 73: P-content (kg P/ha) in the soil profile of 0-90 cm. In total over the soil profile 0-90 cm and specified per soil layer (0-30 cm, 30-60 cm and 60-90 cm) for the long-term derogation and no derogation parcels on sandy soils. The number of parcels is indicated by 'n'.

	n	Total P-content 0-90 cm	P-content		
			0-30 cm	30-60 cm	60-90 cm
Long-term derogation	76	2053	1075	639	338
Long-term no derogation	73	1991	1155	610	226
p-value		0.73			

Neither the average P-AL concentration in the soil profile to 90 cm ($p = 0.82$) nor the amount of P in the soil profile to 90 cm ($p = 0.73$) did differ statistically between long-term derogation and long-term no derogation parcels on sandy soils (Table 72, Table 73, Figure 362).

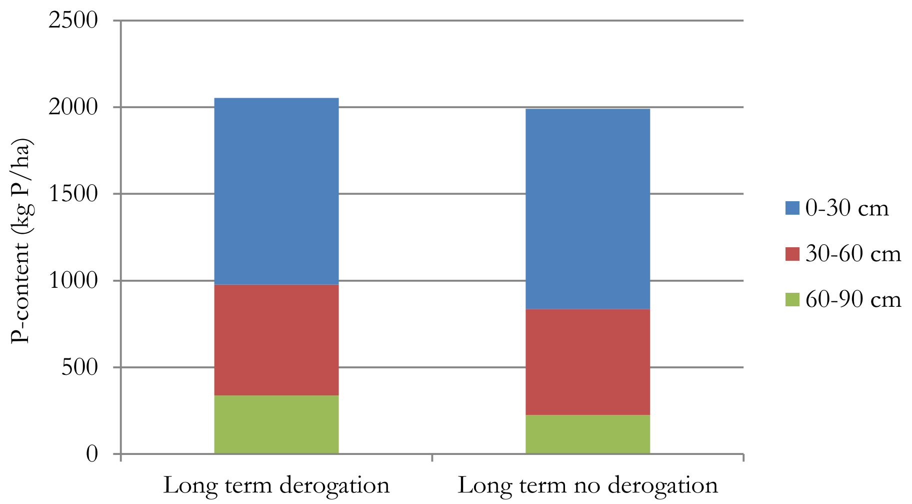


Figure 362: P-content$_{0\text{-}90cm}$ (kg P/ha in the soil profile of 0-90 cm) for long-term derogation and long-term no derogation parcels in the monitoring network on sandy soils.

The boxplots in Figure 363 confirm the lack of a statistical difference in P-status between long-term derogation and long-term no derogation parcels on sandy soils.

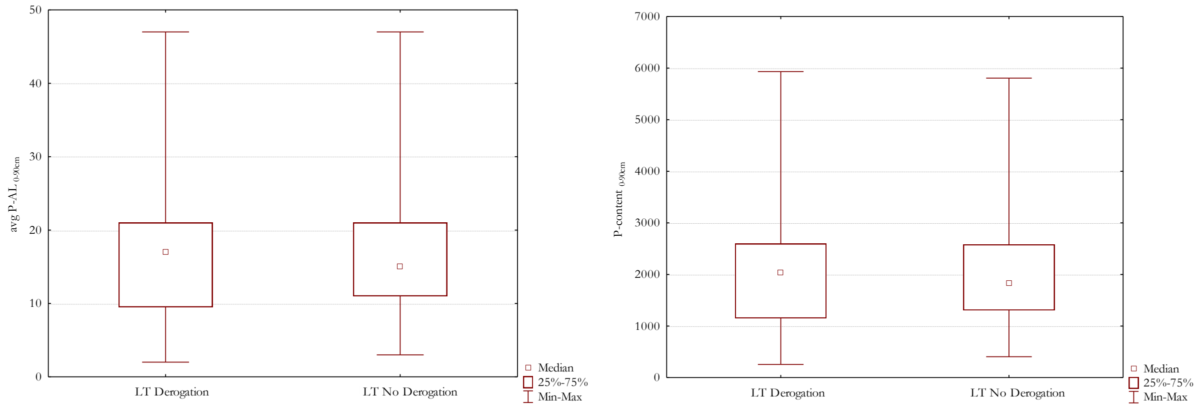


Figure 363: Boxplot of the average P-AL (mg P/100 g dry soil) over the soil profile of 0-90 cm (avg P-AL$_{0-90cm}$) (right) and boxplot of the P-content$_{0-90cm}$ (kg P/ha in the soil profile of 0-90 cm)(left) for long-term (LT) Derogation and No derogation parcels in the monitoring network on sandy soils.

Sandy loam soils

On sandy loam soils, 39 long-term derogation parcels are compared to 42 parcels cultivated without derogation in the period 2008-2016. The mean average P-AL in the soil profile to 90 cm was 10 ± 5 mg P/100 g dry soil on the sandy loam parcels. The average amount of P in the soil profile to 90 cm in kg/ha amounted 1279 ± 726 kg P/ha.

Table 74: P-AL (mg P/100g dry soil) in the soil profile. In average over the soil profile 0-90 cm and specified per soil layer (0-30 cm, 30-60 cm and 60-90 cm) for the long-term derogation and no derogation parcels on sandy loam soils. The number of parcels is indicated by 'n'.

	n	Average P-AL 0-90 cm	P-AL		
			0-30 cm	30-60 cm	60-90 cm
Long-term derogation	39	10	21	6	3
Long-term no derogation	42	9	18	6	3
p-value		0.13			

Table 75: P-content (kg P/ha) in the soil profile of 0-90 cm. In total over the soil profile 0-90 cm and specified per soil layer (0-30 cm, 30-60 cm and 60-90 cm) for the long-term derogation and no derogation parcels on sandy loam soils. The number of parcels is indicated by 'n'.

	n	Total P-content 0-90 cm	P-content		
			0-30 cm	30-60 cm	60-90 cm
Long-term derogation	39	1344	914	279	151
Long-term no derogation	42	1218	799	267	152
p-value		0.15			

Both the average P-AL concentration in the soil profile to 90 cm (p = 0.13) and the amount of P in the soil profile to 90 cm (p = 0.15) did not differ statistically significant between long-term derogation and long-term no derogation parcels (Table 74, Table 75, Figure 364). The lack of a statistical difference in P-status between long-term derogation and long-term no derogation parcels on sandy loam soils is also suggested by the boxplots shown in Figure 365.

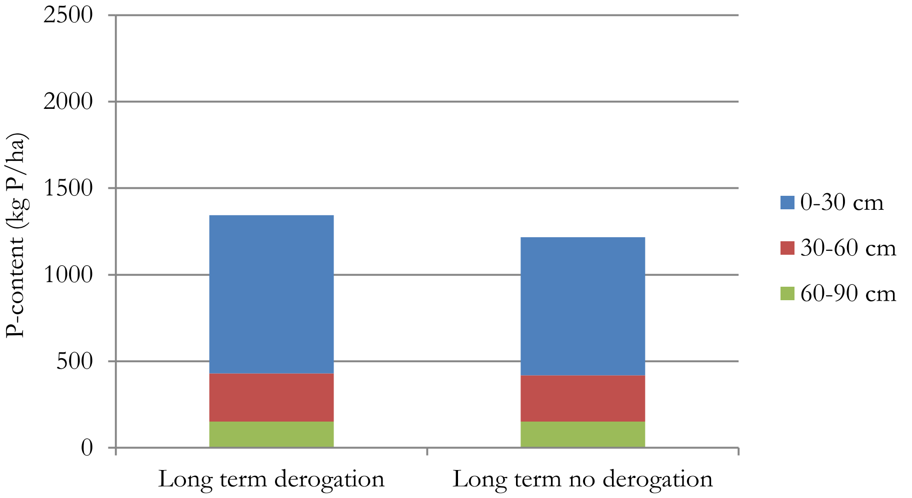


Figure 364: P-content$_{0\text{-}90cm}$ (kg P/ha in the soil profile of 0-90 cm) for long-term derogation and long-term no derogation parcels in the monitoring network on sandy loam soils.

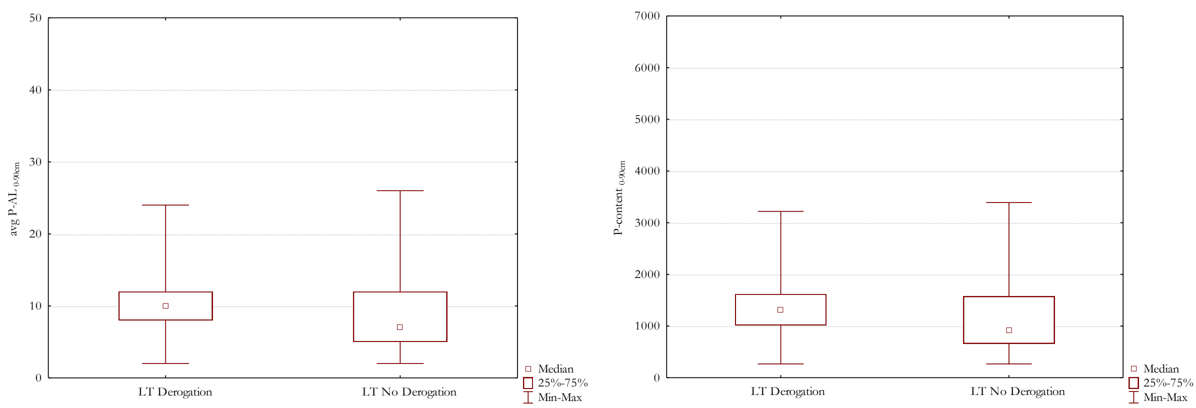


Figure 365: Boxplot of the average P-AL (mg P/100 g dry soil) over the soil profile of 0-90 cm (avg P-AL$_{0\text{-}90cm}$) (right) and boxplot of the P-content$_{0\text{-}90cm}$ (kg P/ha in the soil profile of 0-90 cm) (left) for long-term (LT) Derogation and No derogation parcels in the monitoring network on sandy loam soils.

Summarizing the data of the **soil monitoring** of the period 2016-2019, shows a rather low average nitrate-N residue in 2016, higher average amounts in 2017, very high residues in 2018. The nitrate-N residues of 2019 were situated between those of 2017 and 2018. The nitrate-N residue was in 3 of the 4 years not significant different on derogation and no derogation parcels. In 2017, the difference in nitrate-N residue appeared statistically significant but amounted only 3 kg NO_3-N/ha. In 2018, a significant difference could be only identified on sandy soils cultivated with maize. The nitrate-N residue was significantly higher without derogation. In 2019, a significant higher nitrate-N residue was observed on sandy soils cultivated with grass.

Regardless of crop or soil texture, the farm average nitrate-N residue of derogation and no derogation farms appeared only in 2016 to be significant different. In 2017, 2018 and 2019 the farm average nitrate-N residues of derogation farms appeared to be not significantly higher than the farm average nitrate-N residues of farms without derogation. The significant difference in farm average nitrate-N residue observed between farms with and without derogation in 2016 was only 7 kg NO_3-N/ha.

The nitrate-N difference over winter was the highest in winter 2018-2019, due to the high nitrate-N residues but even so by the growthful weather and late N-export. On parcels cultivated with grass or grass and less than 50 % clover there was no significant difference in nitrate-N difference over winter between derogation and no derogation parcels. On parcels cultivated with maize, the difference appeared to be significant. On sandy soils, the largest difference over winter was measured on parcels without derogation while the largest difference over winter on sandy loam soils was measured on derogation parcels.

The P-content in the soil profile of 0-90 cm did not differ on derogation and no derogation parcels.

3.3 Water monitoring

To monitor and gather data on nitrate and phosphorus concentration in water leaving the root zone and entering the groundwater and surface water system, the VLM requested a monitoring based on water samples at drains and deep soil water samples. Since the former monitoring network, which included MAP sampling points ground water and monitoring wells, was the starting point of the monitoring network 2016-2019, some of these sampling points and monitoring wells could be retained. The number of measuring points that could be retained, however, appeared to be rather small because of the different design of the monitoring network for the period 2016-2019.

The former network comprised at the end 46 monitoring wells on 32 farms. In the network unfolded in 2016, 21 farms with at least one monitoring well on the farm were withheld, which resulted in 32 monitoring wells that could possibly be retained. Because of the new conditions to select parcels, e.g. one crop at a farm, request of derogation on a derogation farm, only 7 monitoring wells of the former network could be retained. These are parcels with grassland on sandy soils on derogation farms and one parcel grassland on sandy loam soil on a derogation farm. Because of the very limited number of measuring points and the resulting impossibility to draw conclusions, no monitoring wells will be sampled in the monitoring network 2016-2018.

MAP sampling points ground water were more present in the former monitoring network. In the former periods of monitoring 105 MAP sampling points were incorporated in the monitoring network. These MAP sampling points ground water were situated at 102 farms. In the recently unfolded network, 36 farms remained with a MAP sampling point ground water on the farm. After selection of adequate parcels, 11 parcels and MAP sampling points groundwater of the former network were retained. These are 5 parcels on sandy soil cultivated with maize on farms with no derogation request, 1 parcel on sandy soil with maize on a non-derogation farm, 1 parcel on sandy loam soil with maize on a non-derogation farm, 2 parcels grassland under derogation on sandy soil, 1 parcel maize under derogation conditions on sandy soil and 1 parcel grassland with less than 50% clover under derogation conditions on sandy soil. The data of the MAP sampling points can be reported. However, because of the limited number of measurements at MAP sampling points no profound comparison of derogation and no derogation conditions can be carried out, as specified for the monitoring wells. Moreover because of change of parcels in order to maintain the correct combination "(no) derogation-soil texture-crop" for the farm, the number of MAP sampling points is uncertain throughout the current monitoring period.

Since sampling and monitoring of drains in the monitoring network was requested, the number of drained parcels in the monitoring network 2016-2019 was evaluated. Twenty-one parcels appear to be drained. These parcels are situated in different groups as shown in Table 76.

The limited number of water measurements possible in the monitoring network 2016-2019 and the unequal distribution of the measurements make it difficult to guarantee a profound monitoring.

Table 76: Distribution of drained parcels in the starting monitoring network-2016

Derogation crop / Soil texture	Derogation on a derogation farm				No derogation on a farm without any derogation				Total
	Grass	Maize	Grassland <50 % clover		Grass	Maize	Grassland < 50 % clover	Total	
Sandy	8	3	-	**11**	1	1	-	2	**13**
Sandy loam	2	-	-	**2**	4	2	-	6	**8**
Total	**10**	**3**	**-**	**13**	**5**	**3**	**-**	**8**	**21**

Consequently, the requested sampling of the deep soil water offers an opportunity to realise a more substantiated comparison and monitoring.

Because of the focus on grass and maize in the derogation monitoring network, the rooting zone is limited to a depth of 60 cm. Ruysschaert *et al.* (2014) determined for Italian ryegrass a rooting depth of 50-60 cm. The rooting depth of maize will be deeper than 60 cm in certain conditions. However, nutrients below 60 cm may not be recovered by grass and often not by maize. Therefore, deep soil water was proposed to be sampled in the soil layer 60-90 cm. Moreover, in the former network a good correlation was found between the amount of nitrate-N in the soil layer 60-90 cm and the deep soil layer 90-120 cm (Figure 366) (Odeurs *et al.,* 2015).

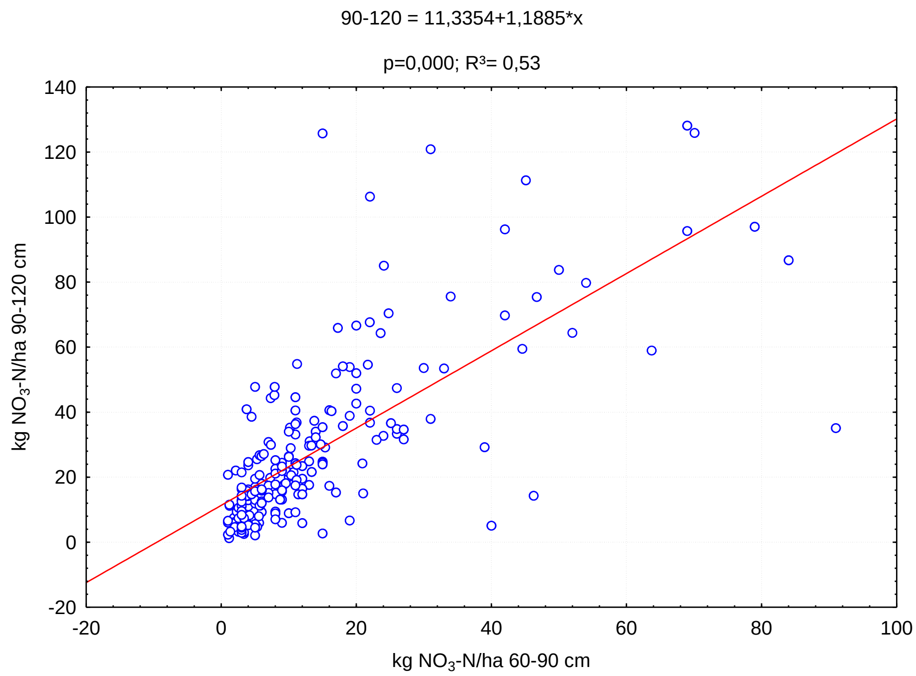


Figure 366: Scatterplot of the nitrate-N (kg/ha) in the soil layer 90-120 cm versus the nitrate-N (kg/ha) in the soil layer 60-90 cm. (Odeurs *et al.,* 2015).

3.3.1 Nitrate & water

The amount of nitrate in the soil water was proposed to be measured by water extraction. The approach to monitor nitrate in water by an extraction makes it possible to have results of all parcels and the assurance of an adequate comparison at each moment since the set-up of the monitoring network guarantees always a sufficient number of samples.

Based on the experience and knowledge of experts in nutrient management in soils, which evaluate the derogation monitoring in Flanders and some of which take an advisory role for VLM, an extraction with potassium chloride was judged to be as efficient as an extraction with water. However, before deciding for one of both extraction methods, the correlation between both extraction methods was evaluated on Flemish soils (Annex 2 – Nitrate in soil water). The results of both extraction methods were significantly correlated. Therefore, it was decided to determine the amount of nitrate in the soil water with a potassium chloride extraction. In addition, this method to determine nitrate in soil water provides continuity with measurements in former monitoring periods.

By taking into account the moisture content at field capacity, the moment at which additional moisture results in leaching, the amount of nitrate measured in the soil profile is recalculated to the nitrate concentration in the soil water.

Normality of data and homogeneity of variances were evaluated. A logarithmic transformation of the data made the data appropriate for an analysis of variance (ANOVA).

As mentioned at the evaluation of the nitrate-N residue (3.2.1), the three parcels or measurements at a farm should be considered as repeated measurements for statistical analysis. Also, for this analysis, "Farm" is included as a random factor as proposed by Prof. Goos of KULeuven. The log-transformed nitrate concentration in the soil water is the dependent variable versus two categorical predictors, "derogation" ('Yes or No') and "Farm" (A, B, C,…). "Derogation" is a fixed categorical predictor and "Farm" is a random categorical predictor.

The data are visualised using box plots, based on the log-transformed data since the statistical analysis is performed on the log-transformed data.

3.3.1.1 Nitrate in soil water autumn 2016

The nitrate concentration in the soil water is determined in the soil layer 60-90 as was agreed by the advising experts. Therefore parcels sampled down to 60 cm are not included in the following discussion since no results of the soil layer 60-90 cm are available.

Parcels that were assessed not to be suited for evaluation of the nitrate-N residue as discussed before (3.2.1.1) were also excluded from the evaluation of the nitrate in the soil water. For comparison of the nitrate in the soil water under derogation and no-derogation practices 462 parcels remained.

The **average concentration of nitrate in the soil water on** those **462 parcels was 58 ± 63 mg NO_3/l.**

The variation in the concentration of nitrate in the soil water in the 462 parcels is shown in Figure 367. Further statistical analysis of the nitrate concentration in the soil water is performed on the log-transformed nitrate concentration in the soil water as shown in Figure 368.

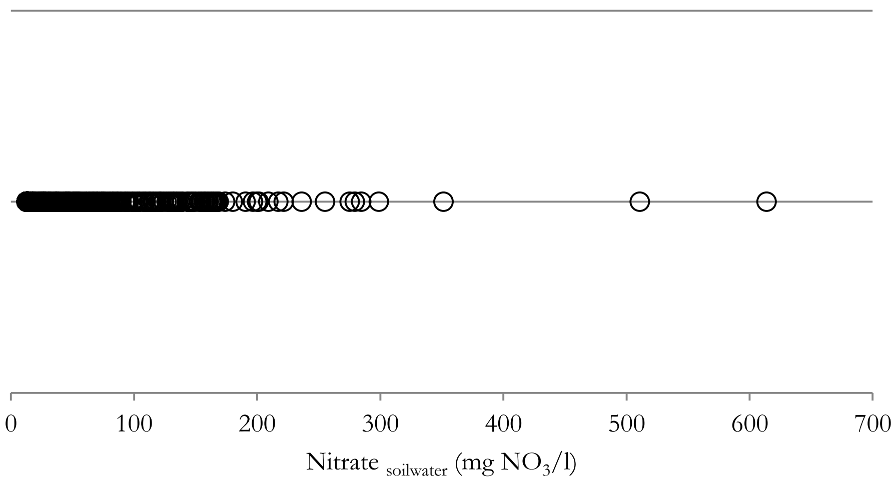


Figure 367: Spreading of the nitrate concentration in soil water (mg NO_3/l) in 462 parcels suited for comparison of derogation and non-derogation practices in autumn 2016.

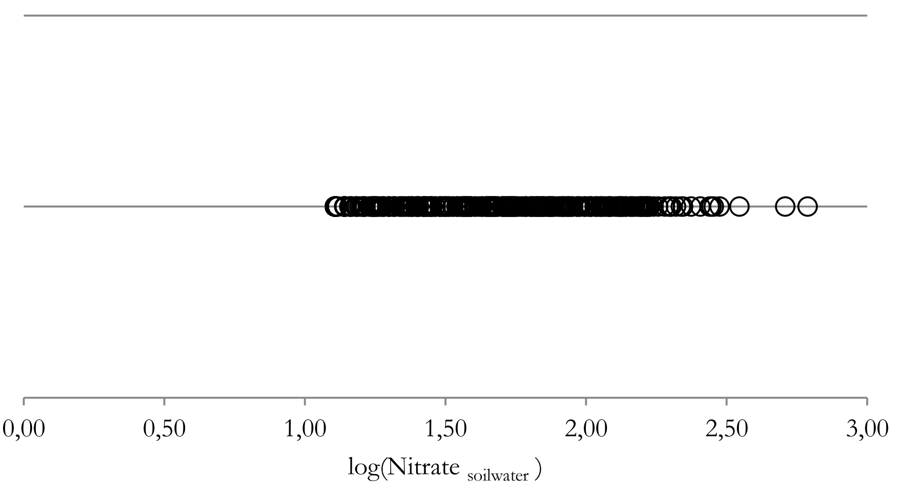


Figure 368: Spreading of the log-transformed nitrate concentration in the soil water (log($Nitrate_{Soilwater}$)) in 462 parcels suited for comparison of derogation and non-derogation practices in autumn 2016.

Table 77: Nitrate concentration in the soil water (mg NO_3/l), mean (± standard deviation) and median values of the 462 parcels of the monitoring network at different levels of comparison in autumn 2016. The number of parcels included in the comparison is indicated by 'n'.

			Nitrate (mg/l) in the soil water			
			n	Average	Median	p-value
Overall mean monitoring network			462	58 ± 63	36	-
Derogation			231	56 ± 53	37	0.67
No derogation			231	60 ± 73	35	
Derogation	Sandy soil		131	67 ± 55	52	0.73
No derogation			129	74 ± 88	43	
Derogation	Sandy loam		100	41 ± 45	24	0.82
No derogation			102	42 ± 40	25	
Derogation	Sandy soil	Grass	52	53 ± 54	38	0.02
No derogation			53	37 ± 43	22	
Derogation	Sandy soil	Grass <50% clover	30	36 ± 26	31	0.25
No derogation			30	45 ± 39	31	
Derogation	Sandy soil	Maize	49	100 ± 53	87	0.09
No derogation			46	135 ± 113	111	
Derogation	Sandy loam	Grass	53	28 ± 27	15	0.30
No derogation			54	25 ± 33	13	
Derogation	Sandy loam	Maize	47	56 ± 56	37	0.18
No derogation			48	61 ± 40	53	

The results of the nitrate concentration in the soil water (Table 77) cannot be verified with the quality threshold value of 50 mg NO_3/l since no process factors were yet involved. Process factors are present for surface water and groundwater. A process factor is an empirical "black box" factor that includes all processes (e.g. denitrification, ….) that occur between the leaching of nitrate from the soil profile and the measured nitrate concentrations in surface water or groundwater (Van Overtveld *et al.*, 2011). The process factor imposes a link between the nitrate leached out of the soil and water quality measurements in surface water or ground water.

Regardless of crop or soil type, the comparison of the nitrate concentration in soil water with or without derogation practices was made on 231 parcels with derogation and 231 parcels without derogation. In autumn 2016 the average nitrate concentration in the soil water under derogation conditions was 56 ± 53 mg NO_3/l. The median value of 36 mg NO_3/l however shows that the nitrate concentration in the soil water of the majority of the parcels was at a lower level. Without derogation, the average nitrate concentration in the soil water in the monitoring network amounted 60 ± 73 mg NO_3/l. The average nitrate concentration in soil water of derogation and no derogation parcels did not differ statistically significant ($p = 0.67$).

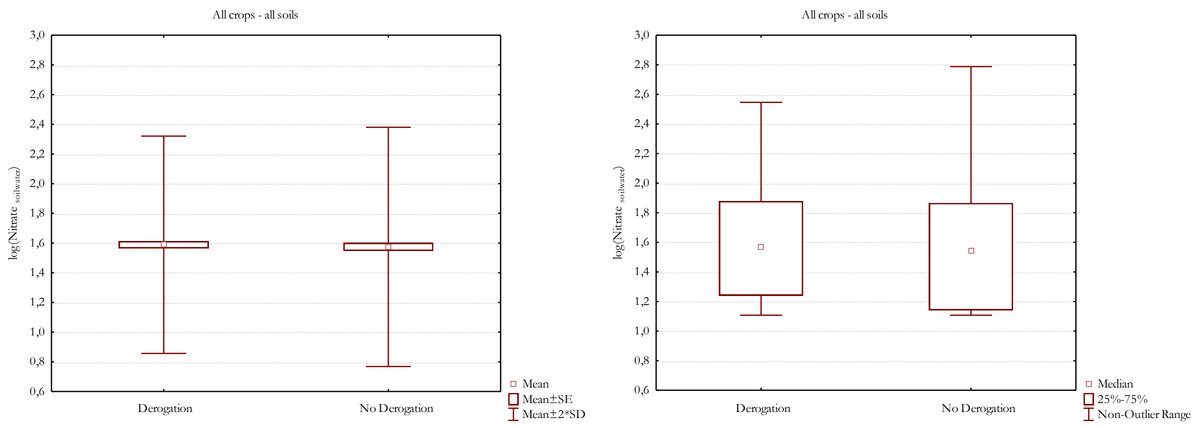


Figure 369: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with all crops on all soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

All crops on sandy soils

On sandy soils, the average nitrate concentration in the soil water amounted 70 ± 73 mg NO_3/l. On 131 sandy parcels with derogation, the average nitrate concentration in the soil water was 67 ± 55 mg NO_3/l. On 129 parcels without derogation, the average nitrate concentration in the soil water was 74 ± 88 mg NO_3/l. This difference between derogation and no derogation conditions is not statistically significant ($p = 0.73$).

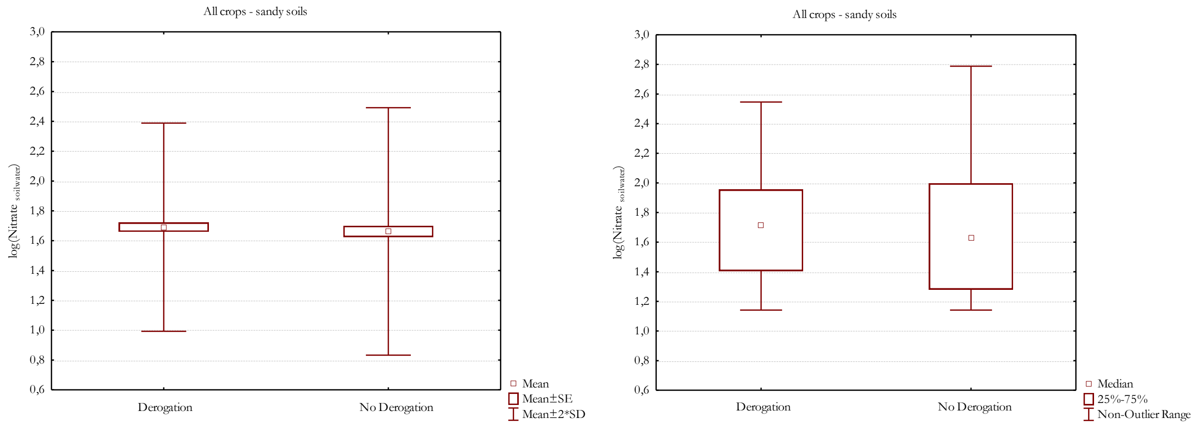


Figure 370: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

On sandy soils, however, 7 outliers were detected, all parcels cultivated with maize, 1 under derogation conditions and 6 without derogation. On the derogation parcel, 285 mg NO_3/l soil water was measured. On the derogation parcel, the cut of grass and the harvest of the corn maize were successful. The yield of the corn maize, 12 ton/ha at a moisture content of 30 %, was good considering the circumstances of 2016. The fertilisation did not exceed the application standards, nor for total N nor for organic N. The amount of organic N was 190 kg N/ha.

On the parcels without derogation, the outlying results of nitrate in the soil water ranged between 115 mg NO_3/l and 613 mg NO_3/l. On the parcel with the highest amount of nitrate in the soil water, the yield of the silage maize approached only 25 ton/ha. At the end of May, beginning of June about 300 l/m² of rain fell in 3 weeks. Also on the parcel with the smallest outlying value of nitrate in the soil water, the yield of the silage maize was halved because of extreme weather conditions and a late sowing date.

Grass on sandy soils

Of 52 sandy soils cultivated with grass under derogation conditions, the average nitrate concentration in the soil water was 53 ± 54 mg NO_3/l. Without derogation, the average nitrate concentration in the soil water of 53 parcels cultivated with grass on sandy soils was 37 ± 43 mg NO_3/l. The average nitrate concentration in the soil water on sandy soils differed significantly between derogation and no derogation conditions ($p = 0.02$).

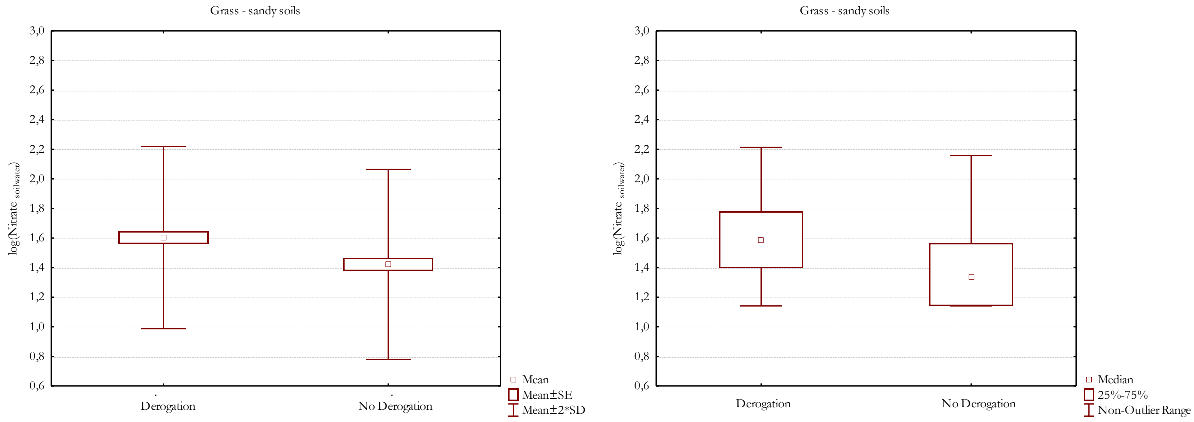


Figure 371: Boxplot of log(Nitrate $_{soilwater}$) for derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Grass with less than 50 % clover on sandy soils

The nitrate concentration in the soil water of parcels cultivated with grass and less than 50 % clover could be compared between 30 parcels under derogation conditions and 30 parcels without derogation. The average nitrate concentration in the soil water of the derogation parcels cultivated with grass and less than 50 % clover was 36 ± 26 mg NO_3/l. Without derogation conditions the average nitrate concentration in the soil water of the parcels cultivated with grass and less than 50 % clover was 45 ± 40 mg NO_3/l.

This difference between derogation and no derogation conditions on sandy soils cultivated with grass and less than 50 % clover was not statistically significant ($p = 0.25$).

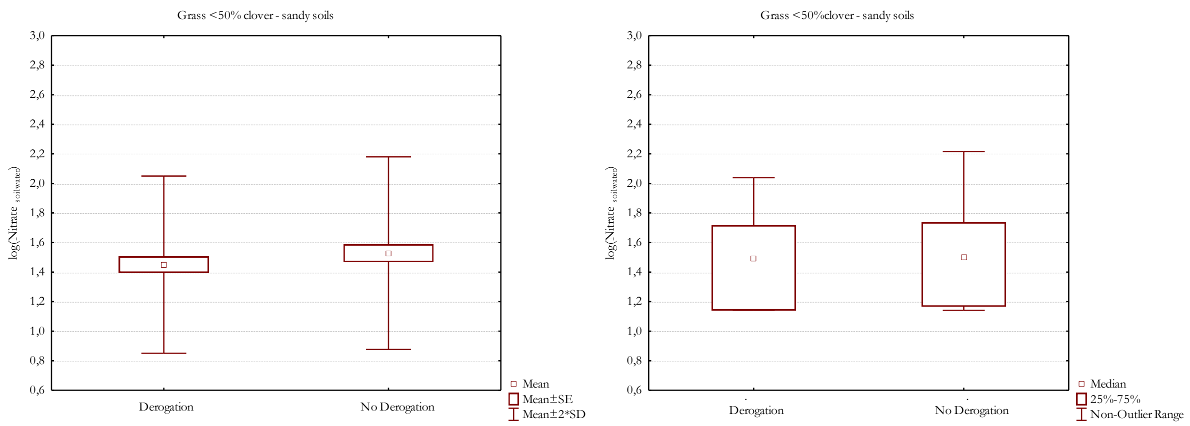


Figure 372: Boxplot of log(Nitrate$_{soilwater}$) for derogation and no derogation parcels with grass and less than 50% clover on sandy soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Maize on sandy soils

For maize on sandy soils, the comparison of the nitrate concentration in the soil water with and without derogation conditions could be performed on 49 parcels with derogation and 46 parcels without derogation. The average nitrate concentration in the soil water of the derogation parcels cultivated with maize was 100 ± 53 mg NO_3/l. Without derogation conditions, the average nitrate concentration in the soil water of the parcels cultivated with maize was 135 ± 113 mg NO_3/l.

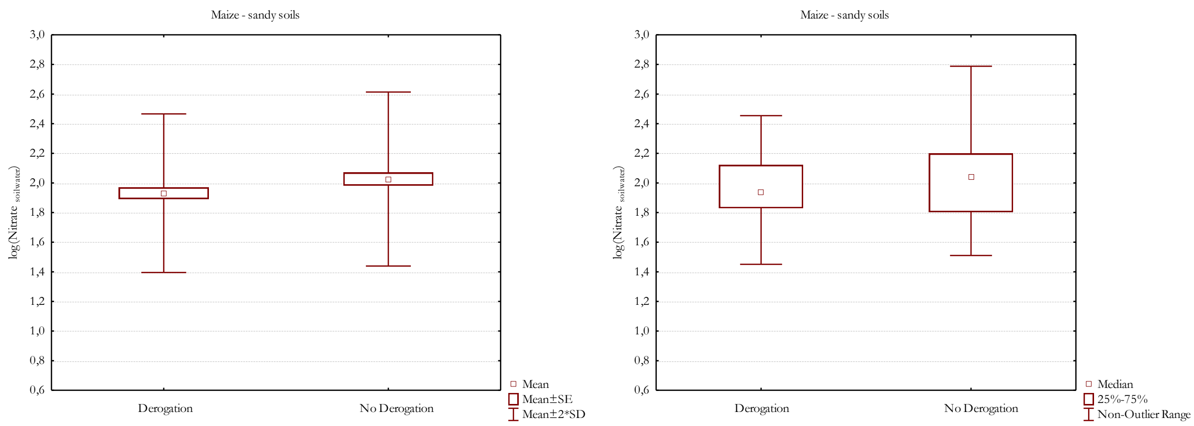


Figure 373: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

The average nitrate concentration in the soil water of sandy soils cultivated with maize did not differ significantly ($p = 0.09$) between derogation and no derogation conditions.

In both management scenarios, derogation and non-derogation, outlying values of nitrate concentration in the soil water were detected. Six outlying values under non-derogation conditions and 1 under derogation conditions. On all 7 parcels, yield was substandard and reduced up to 60 % of normal production.

All crops on sandy loam soils

The average nitrate concentration in the soil water of the 202 parcels on sandy loam soils was 42 ± 43 mg NO_3/l. On derogation parcels (100 parcels), the average nitrate concentration in the soil water amounted 41 ± 45 mg NO_3/l. Without derogation on sandy loam soil (102 parcels, the average nitrate concentration in the soil water was 42 ± 40 mg NO_3/l.

This limited difference between the average nitrate concentration in the soil water with and without derogation conditions was not statistically significant ($p = 0.82$).

On sandy loam soils, one outlier was detected. This parcel was cultivated with maize. The nitrate concentration in the soil water of this parcel amounted 299 mg NO_3/l. The amount of nitrate-N in the soil profile was rather high and was more concentrated in the deeper soil layers resulting in a higher nitrate concentration in the soil water.

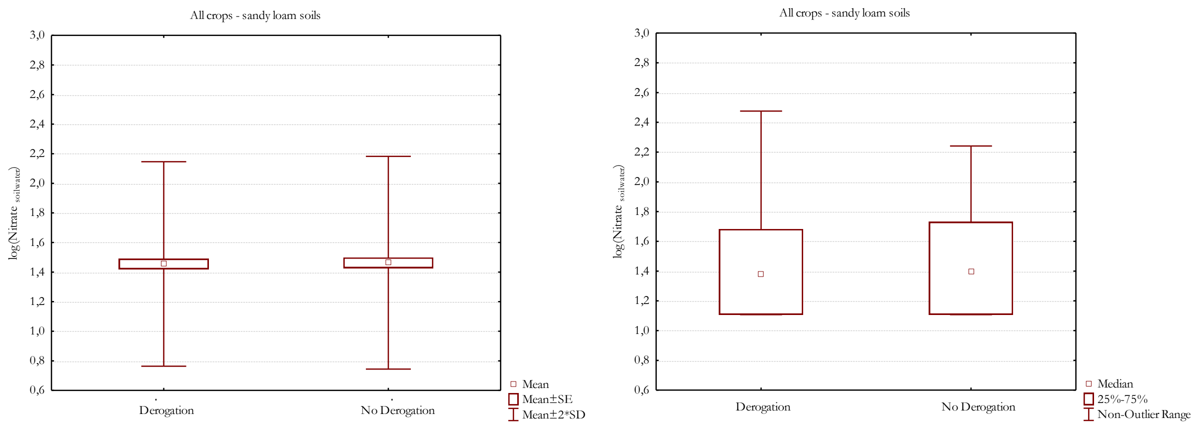


Figure 374: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Grass on sandy loam soils

Under grass with derogation on sandy loam soils the average nitrate concentration in the soil water was 28 ± 27 mg NO_3/l in the monitoring network in autumn 2016. Without derogation under grass on sandy loam soils the average nitrate concentration in the soil water was 25 ± 33 mg NO_3/l.

Even when focused on grass on sandy loam soils the difference in average nitrate concentration in the soil water with and without derogation practices is limited and not statistically significant ($p = 0.30$).

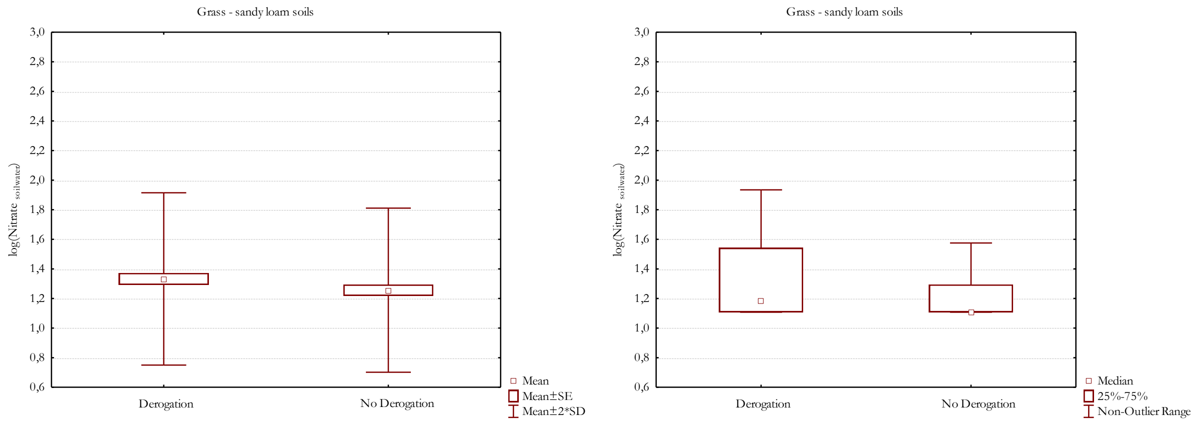


Figure 375: Boxplot of log(Nitrate$_{soilwater}$) for derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Maize on sandy loam soils

On sandy loam parcels cultivated with maize and request of derogation, the average nitrate concentration in the soil water was 56 ± 56 mg NO_3/l. Without derogation, the average nitrate concentration in the soil water was 61 ± 40 mg NO_3/l under maize on sandy loam soils.

Also for maize on sandy loam soils the difference in average nitrate concentration in the soil water with and without derogation practices is limited and not statistically significant ($p = 0.18$).

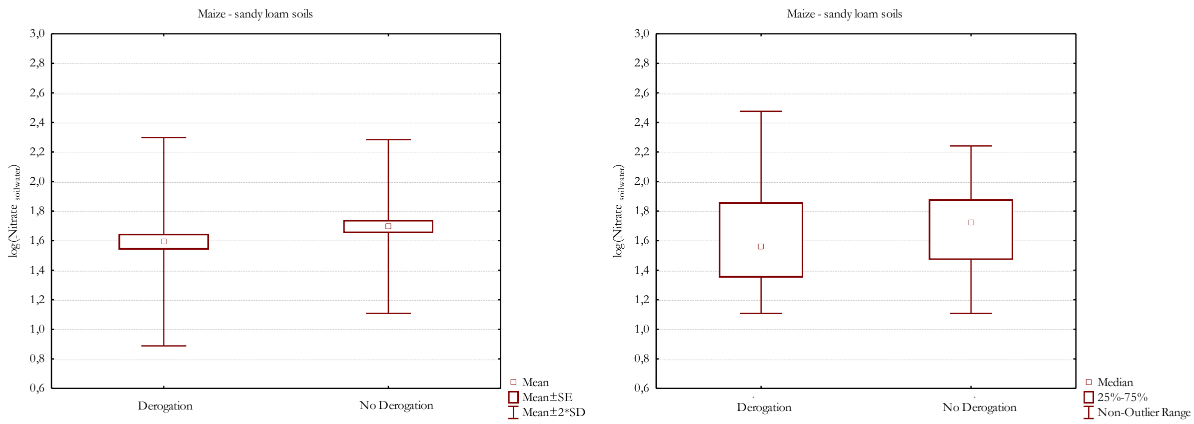


Figure 376: Boxplot of log(Nitrate$_{soilwater}$) for derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2016. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

In the group of sandy loam soils cultivated with maize under derogation conditions there was one outlier. The nitrate concentration in the soil water of this parcel amounted 299 mg NO_3/l. At this parcel, the crop of maize after the cut of grass had failed. The yield of this silage maize was limited to 10 ton fresh matter/ha. Without the outlying value, the difference in nitrate concentration in the soil water between derogation and no derogation conditions would enlarge.

3.3.1.2 Nitrate in soil water autumn 2017

The nitrate concentration in the soil water is determined in the soil layer 60-90. Therefore, parcels which could not be sampled down to 90 cm, cannot be included in the evaluation of nitrate in the soil water since no results of the soil layer 60-90 cm are available.

Parcels that were assessed not to be suited for evaluation of the nitrate-N residue as discussed before (3.2.1.4), were neither taken up in the evaluation of the nitrate in the soil water. For comparison of the nitrate in the soil water under derogation and no-derogation practices 458 parcels remained.

The **average concentration of nitrate in the soil water on** those **458 parcels was 70 ± 72 mg NO_3/l.** The median concentration of nitrate in the soil water was 47 mg NO_3/l.

As the standard deviation indicates, the concentration of nitrate in the soil water is variated. The variation is demonstrated in Figure 377. The log-transformed data, shown in Figure 378, are used to perform the statistical analysis of the nitrate concentration in the soil water.

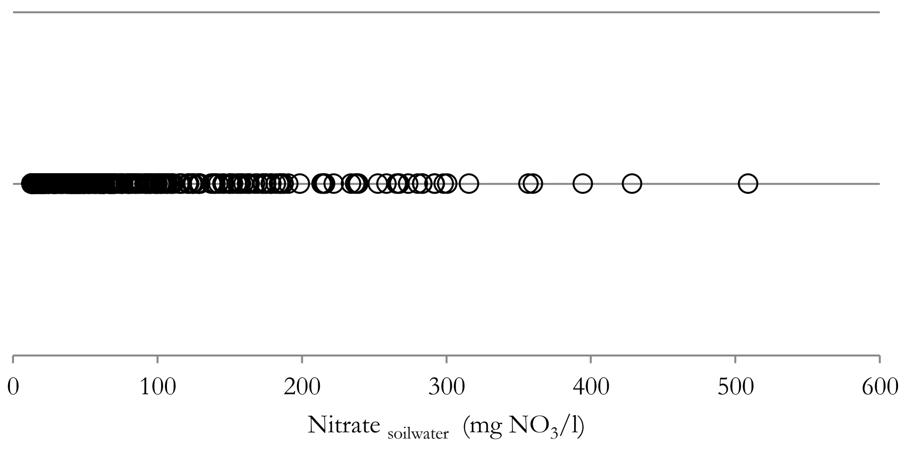


Figure 377: Spreading of the nitrate concentration in soil water (mg NO_3/l) in 458 parcels suited for comparison of derogation and non-derogation practices in autumn 2017.

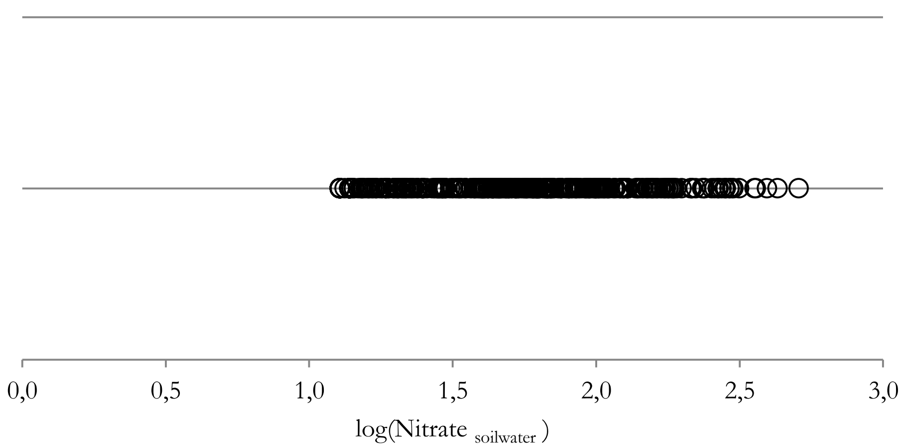


Figure 378: Spreading of the log-transformed nitrate concentration in soil water (log($Nitrate_{Soilwater}$)) in 458 parcels suited for comparison of derogation and non-derogation practices in autumn 2017.

Table 78: Nitrate concentration in the soil water (mg NO_3/l), mean (± standard deviation) and median values of the 458 parcels of the monitoring network at different levels of comparison in autumn 2017. The number of parcels included in the comparison is indicated by 'n'.

			Nitrate (mg/l) in the soil water			
			n	Average	Median	p-value
Overall mean monitoring network			458	70 ± 72	47	-
Derogation			229	69 ± 66	50	0.93
No derogation			229	71 ± 78	44	
Derogation	Sandy soil		128	89 ± 75	63	0.12
No derogation			130	81 ± 85	56	
Derogation	Sandy loam		101	44 ± 41	38	0.61
No derogation			99	59 ± 67	29	
Derogation	Sandy soil	Grass	49	91 ± 84	63	0.03
No derogation			50	59 ± 71	30	
Derogation	Sandy soil	Grass <50% clover	29	84 ± 84	53	0.56
No derogation			30	74 ± 88	47	
Derogation	Sandy soil	Maize	50	92 ± 60	72	0.76
No derogation			50	106 ± 91	77	
Derogation	Sandy loam	Grass	50	38 ± 45	26	0.40
No derogation			48	32 ± 39	14	
Derogation	Sandy loam	Maize	51	50 ± 36	46	0.18
No derogation			51	83 ± 78	50	

As indicated before, the results of the nitrate concentration in the soil water (Table 78) cannot be cross-checked directly with the quality threshold value of 50 mg NO_3/l. The nitrate leached out of the soil is still exposed to a process factor.

The 458 parcels suited for evaluation of the possible impact of derogation on the nitrate concentration in the soil water, were both 229 derogation and 229 no derogation parcels. In autumn 2017 the average nitrate concentration in the soil water on derogation parcels was 69 ± 66 mg NO_3/l. On no derogation parcels, the average nitrate concentration in the soil water amounted 71 ± 78 mg NO_3/l. This difference in average nitrate concentration in the soil water between derogation and no derogation practices was not statistically significant ($p = 0.93$).

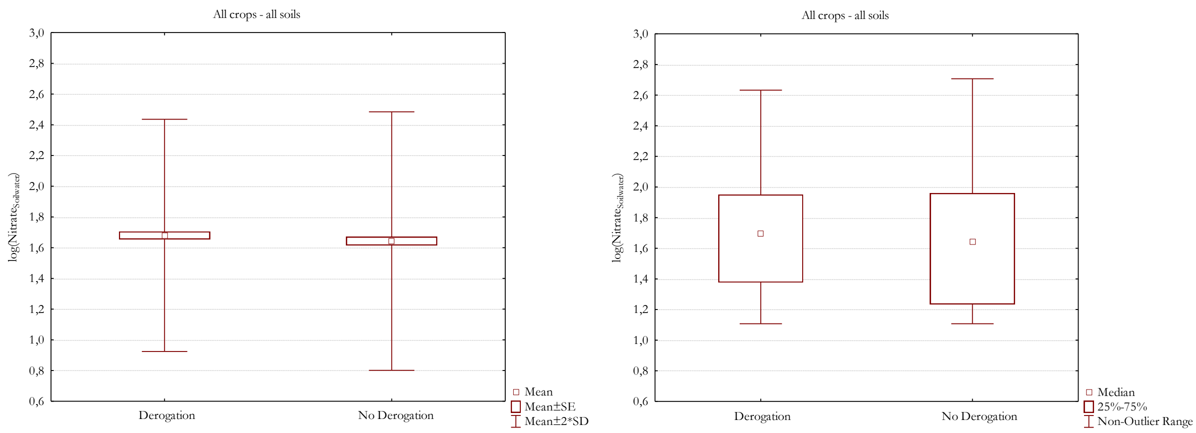


Figure 379: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with all crops on all soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: standard error of the mean. SD: Standard Deviation.

Although no outliers are discarded for the statistical analysis or for the results of Table 78, an outlier detection was conducted. Ten outlying values were observed, 8 on sandy soils and 2 on sandy loam soils. On sandy loam soils it were both parcels without derogation and main crop maize. On sandy soils it were 4 parcels with derogation and 4 parcels without derogation, 2 parcels cultivated with maize, 4 parcels cultivated with grass and 2 parcels cultivated with grass and less than 50 % clover. The outliers are further discussed in the group they belong to.

All crops on sandy soils

The comparison of the nitrate concentration on sandy soils in autumn 2017 included 258 data, 128 data of derogation parcels and 130 data of parcels without derogation. The average nitrate concentration on sandy soils, regardless of crop or derogation, was 85 ± 80 mg NO_3/l. Under derogation conditions, the average nitrate concentration in the soil water on sandy soils was 89 ± 75 mg NO_3/l. Without derogation on sandy soils the average nitrate concentration in the soil water was 81 ± 85 mg NO_3/l. The difference in nitrate concentration in the soil water between derogation and no derogation conditions was not statistically significant ($p = 0.12$).

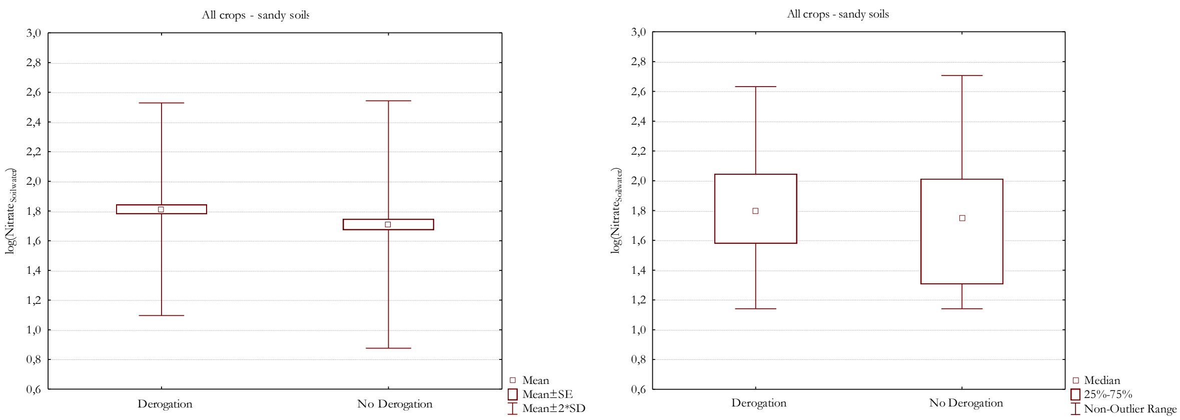


Figure 380: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: standard error of the mean. SD: Standard Deviation.

On sandy soils, 8 of the 10 outlying values were detected. The nitrate concentration in the soil water of these outliers ranged between 292 and 509 mg NO_3/l. For the derogation outliers the nitrate concentration in the soil water ranged between 292 and 428 mg NO_3/l. The range of outlying values on parcels without derogation was 357-509 mg NO_3/l.

Grass on sandy soils

On sandy soils cultivated with grass, the nitrate concentration in the soil water of 49 parcels with and 50 parcels without derogation could be compared. On derogation parcels, the average nitrate concentration in the soil water was 91 ± 84 mg NO_3/l in autumn 2017. For parcels on sandy soils cultivated with grass without derogation, the average nitrate concentration in the soil water was 59 ± 71 mg NO_3/l. The nitrate concentration on sandy soils cultivated with grass differed statistically significant between derogation and no derogation parcels (p = 0.03).

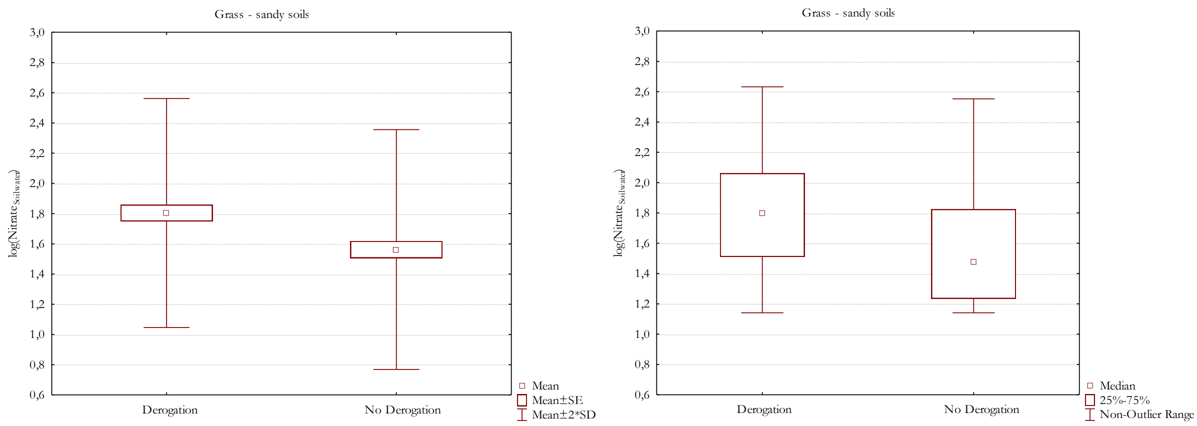


Figure 381: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: standard error of the mean. SD: Standard Deviation.

Four of the outliers were sandy parcels cultivated with grass, 3 with derogation and 1 without derogation. All 3 derogation parcels had been irrigated during the season. The parcel without derogation was not irrigated. Without the outlying values the average nitrate concentration in the soil water on sandy soils cultivated with grass was 63 ± 57 mg NO_3/l, with derogation 75 ± 52 mg NO_3/l and 53 ± 57 mg NO_3/l without derogation.

Grass with less than 50 % clover on sandy soils

Fifty nine parcels cultivated with grass and less than 50 % clover were evaluated regarding the nitrate concentration in the soil water, 29 parcels with derogation and 30 parcels without derogation. Of sandy parcels cultivated with grass and less than 50 % clover, the average nitrate concentration in the soil water was 78 ± 85 mg NO_3/l in autumn 2017 in the monitoring network. The average nitrate concentration in the soil water of the derogation parcels was 82 ± 84 mg NO_3/l and 74 ± 88 mg NO_3/l of the parcels without derogation. The difference between those two groups was statistically insignificant (p = 0.56).

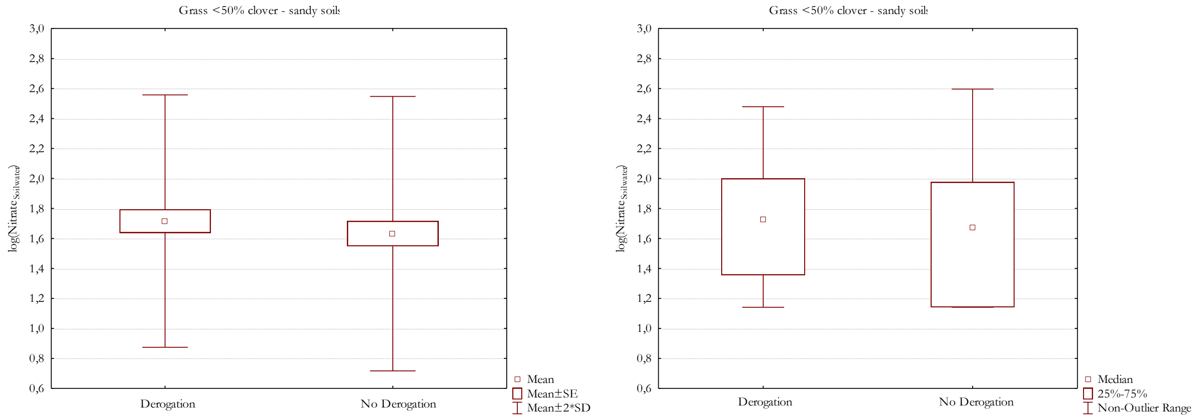


Figure 382: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with grass and less than 50 % clover on sandy soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: standard error of the mean. SD: Standard Deviation.

Two parcels cultivated with grass and less than 50 % clover were identified as outliers. The nitrate concentration in the soil water was 301 mg NO_3/l on the derogation outlier and 395 mg NO_3/l on the outlier without derogation. Again, one parcel, the parcel without derogation, was irrigated during the season. Nevertheless, the other parcels of this farm were also irrigated without outlying values regarding the nitrate concentration in the soil water as a result. Without the outlying values the average nitrate concentration in the soil water of parcels cultivated with grass and less than 50 % clover was 68 ± 69 mg NO_3/l, 74 ± 74 mg NO_3/l with derogation and 63 ± 64 mg NO_3/l without derogation. Derogation and no derogation parcels were still not statistically significant different (p = 0.48).

Maize on sandy soils

The nitrate concentration in the soil water on sandy soils under main crop maize could be evaluated for 100 parcels, both 50 derogation and no derogation parcels. Regardless of derogation or not, the average nitrate concentration in the soil water of sandy parcels cultivated with maize was 99 ± 77 mg NO_3/l. Under derogation conditions, this average was 92 ± 60 mg NO_3/l. Without derogation conditions, the average nitrate concentration in the soil water was 106 ± 91 mg NO_3/l. There was no statistically significant difference in the average nitrate concentration in soil water with or without derogation (p = 0.76).

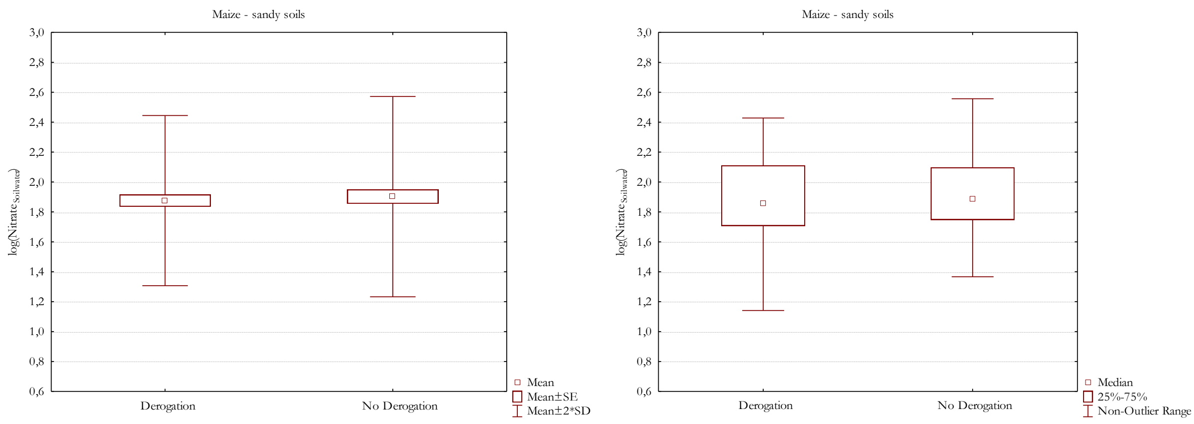


Figure 383: Boxplot of log(Nitrate$_{soilwater}$) for derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: standard error of the mean. SD: Standard Deviation.

The outlying values of maize on sandy soils were noted on parcels without derogation. The outlying values amounted 360 and 509 mg NO_3/l. Without those high and outlying values, the average nitrate concentration in the soil water of sandy parcels cultivated with maize diminished lightly to 92 ± 60 mg NO_3/l. Without derogation conditions, the average nitrate concentration in the soil water was 93 ± 60 mg NO_3/l without the outliers. There was no statistically significant difference ($p = 0.94$).

All crops on sandy loam soils

On sandy loam soils, the nitrate concentration in the soil water of 200 parcels could be evaluated regarding derogation. On average, the nitrate concentration in the soil water of sandy loam soils amounted 51 ± 55 mg NO_3/l in autumn 2017 in the monitoring network. For the 101 derogation parcels, the average nitrate concentration in the soil water was 44 ± 41 mg NO_3/l. For the 99 parcels without derogation on sandy loam soils, the average nitrate concentration in the soil water was 59 ± 67 mg NO_3/l. The difference between both groups of parcels, with or without derogation, was not statistically significant ($p = 0.61$).

On sandy loam soils, 2 outlying values were observed, both without derogation and cultivated with maize. The nitrate concentration in the soil water of these parcels amounted 292 mg NO_3/l and 298 mg NO_3/l.

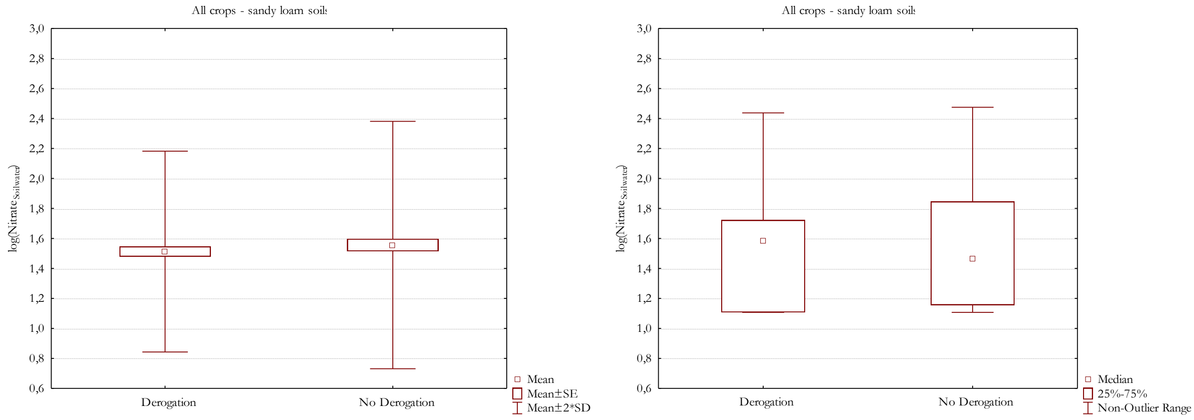


Figure 384: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: standard error of the mean. SD: Standard Deviation.

Grass on sandy loam soils

For grass on sandy loam soils, the comparison of the nitrate concentration in the soil water with and without derogation conditions could be performed on 50 parcels with derogation and 48 parcels without derogation. Cultivating grass on sandy loam soils with derogation resulted in the monitoring network in an average nitrate concentration in the soil water of 38 ± 45 mg NO_3/l. Without derogation, the average nitrate concentration in the soil water was 32 ± 39 mg NO_3/l in autumn 2017. The nitrate concentration in the soil water of sandy loam soils cultivated with grass did not differ statistically significant between derogation and no derogation conditions ($p = 0.40$).

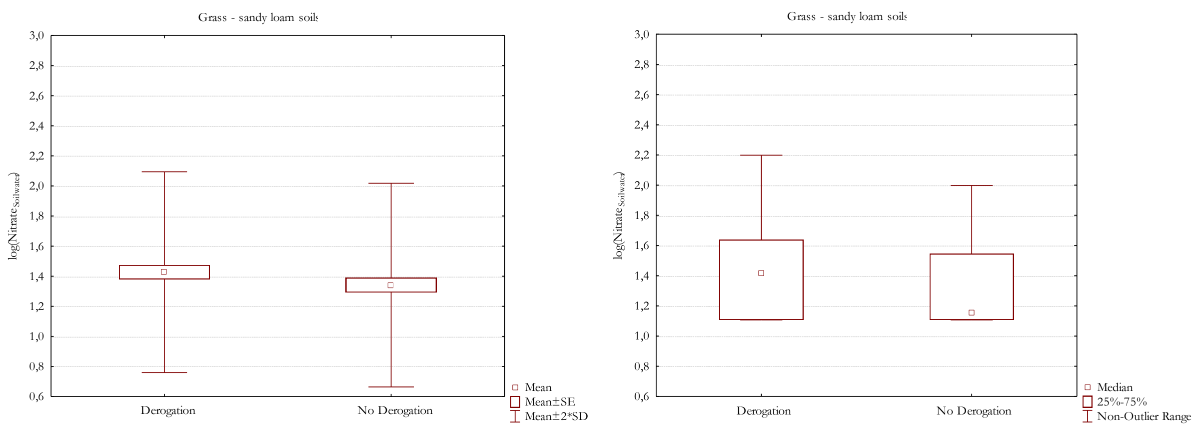


Figure 385: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: standard error of the mean. SD: Standard Deviation.

Maize on sandy loam soils

The average nitrate concentration in the soil water of 102 parcels cultivated with maize on sandy loam soils was 67 ± 62 mg NO_3/l. On derogation parcels (51 parcels), the average nitrate concentration in the soil water amounted 50 ± 36 mg NO_3/l. Without derogation and main crop maize on sandy loam soils, the average nitrate concentration in the soil water was 83 ± 78 mg NO_3/l. The difference between the average nitrate concentration in the soil water with and without derogation was not statistically significant ($p = 0.18$).

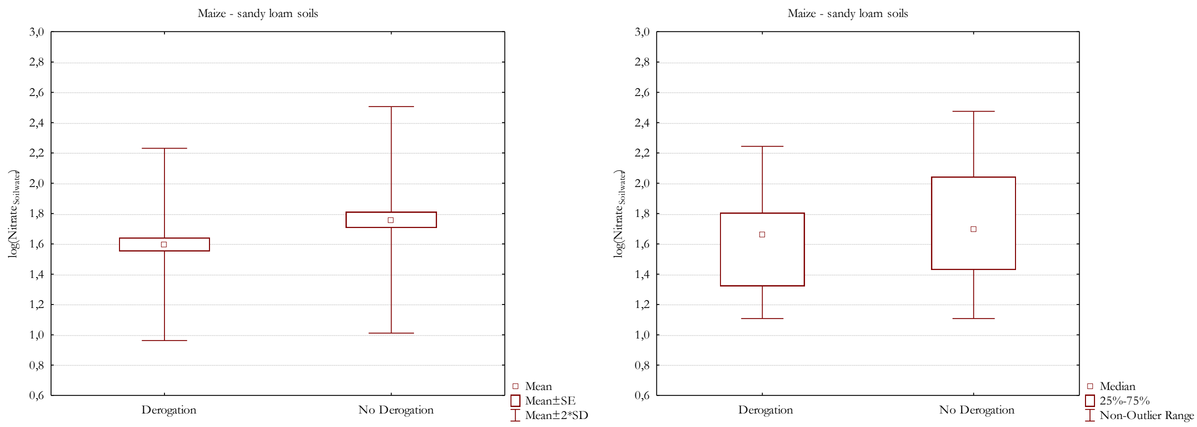


Figure 386: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2017. Mean: left. Median: right. SE: standard error of the mean. SD: Standard Deviation.

On sandy loam soils cultivated with maize, 2 outliers were detected, both without derogation. Obvious similarities between both parcels could not be found immediately.

Without the outliers the average nitrate concentration on sandy loam soils cultivated with maize was 62 ± 54 mg NO_3/l, and more specific without derogation it was 74 ± 66 mg NO_3/l. Still the difference between derogation and no derogation conditions regarding the nitrate concentration in the soil water was not statistically significant ($p = 0.21$).

3.3.1.3 Nitrate in soil water autumn 2018

Since the nitrate concentration in the soil water is determined for the soil layer 60-90 cm, parcels that could not be sampled to 90 cm are not included in the evaluation of nitrate in the soil water. Parcels that were assessed not suited for evaluation of the nitrate-N residue as discussed before (3.2.1.7), were also excluded from the evaluation of the nitrate concentration in the soil water.

For comparison of the nitrate concentration in the soil water under derogation and no-derogation practices 284 parcels remained.

The **average concentration of nitrate in the soil water** on those **284 parcels** was **83 ± 75 mg NO_3/l** in **autumn 2018**.

The variation of the nitrate concentration in the soil water, already indicated by the higher value of the standard deviation, is also demonstrated in Figure 387. The statistical analysis of the nitrate concentration in the soil water is performed on the log-transformed data shown in Figure 388.

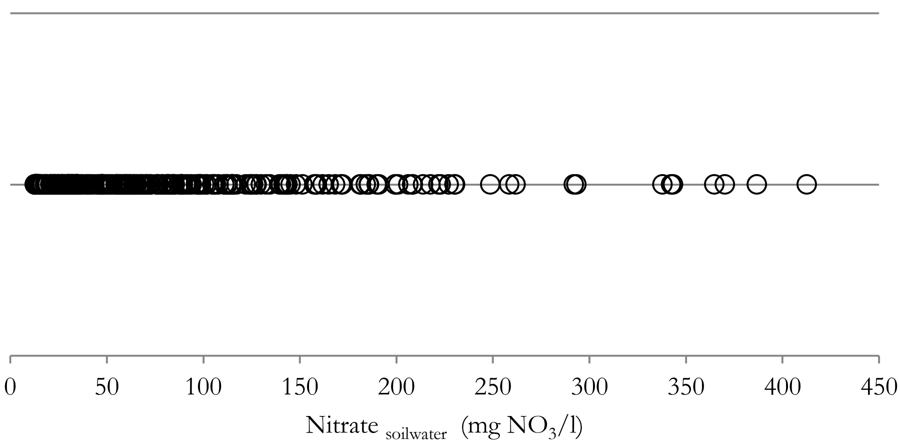


Figure 387: Spreading of the nitrate concentration in soil water (mg NO_3/l) in 291 parcels suited for comparison of derogation and non-derogation practices in autumn 2018.

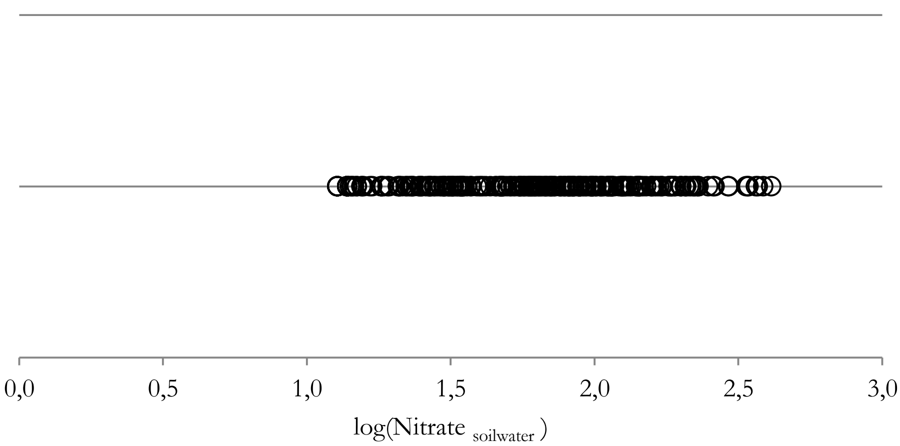


Figure 388: Spreading of the log-transformed nitrate concentration in soil water (log($Nitrate_{Soilwater}$)) in 291 parcels suited for comparison of derogation and non-derogation practices in autumn 2018.

Table 79: Nitrate concentration in the soil water (mg NO_3/l), mean (± standard deviation) and median values of the 284 parcels of the monitoring network at different levels of comparison in autumn 2018. The number of parcels included in the comparison is indicated by 'n'.

				Nitrate (mg/l) in the soil water		
			n	Average	Median	p-value
Overall mean monitoring network			284	83 ± 75	61	-
Derogation			152	80 ± 67	67	0.12
No derogation			132	86 ± 84	55	
Derogation	Sandy soil		108	83 ± 70	68	0.75
No derogation			92	94 ± 91	57	
Derogation	Sandy loam		44	72 ± 58	62	0.73
No derogation			40	67 ± 62	48	
Derogation	Sandy soil	Grass	48	68 ± 60	59	0.40
No derogation			38	60 ± 59	35	
Derogation	Sandy soil	Grass <50% clover	21	79 ± 54	73	0.64
No derogation			18	60 ± 75	37	
Derogation	Sandy soil	Maize	39	104 ± 83	79	0.06
No derogation			36	147 ± 102	132	
Derogation	Sandy loam	Grass	21	74 ± 66	55	0.58
No derogation			21	65 ± 74	47	
Derogation	Sandy loam	Maize	23	71 ± 52	76	0.57
No derogation			19	69 ± 47	68	

As indicated each time before for the results of the nitrate concentration in the soil water, also the results of the nitrate concentration in the soil water of autumn 2018 (Table 79) cannot be cross-checked directly with the quality threshold value of 50 mg NO_3/l. The nitrate leached out of the soil is still exposed to an attenuating factor.

The possible impact of derogation on the nitrate concentration in the soil water could be evaluated in autumn 2018 by comparison of 152 derogation parcels and 132 parcels without derogation. The average nitrate concentration in the soil water in autumn 2018 on derogation parcels was 80 ± 67 mg NO_3/l. On the parcels without derogation, the average nitrate concentration in the soil water amounted 86 ± 84 mg NO_3/l. Both average values were not significantly different ($p = 0.12$).

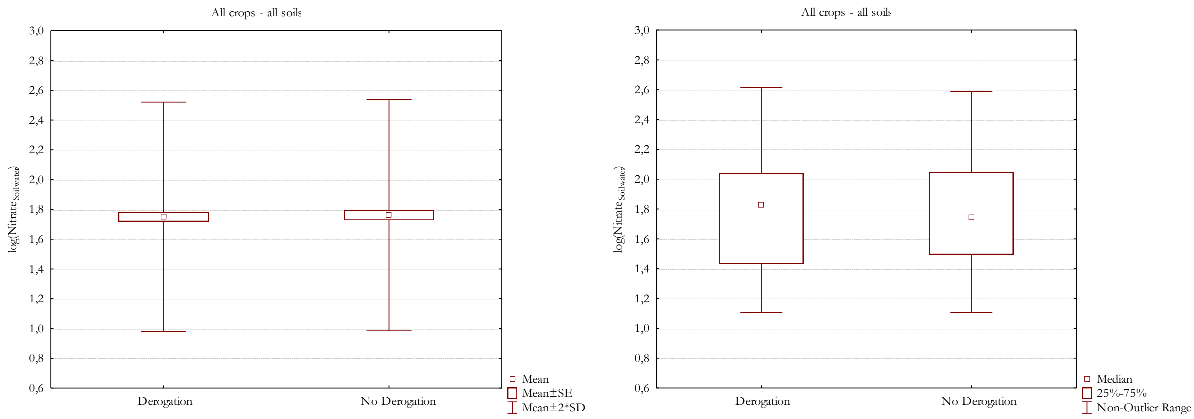


Figure 389: Boxplot of log(Nitrate$_{soilwater}$) for derogation and no derogation parcels with all crops on all soils in the monitoring network in autumn 2018. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

For the statistical analysis and calculation of the average values as demonstrated in Table 79, no outliers were discarded. Nevertheless, outliers were detected and identified. Seven outlying values were observed, 6 on sandy soils and 1 on a sandy loam soil. On the sandy loam soil grass was cultivated without derogation. On the sandy soils, 4 parcels cultivated with maize, 1 with derogation and 3 without derogation, 1 parcel grown with grass and less than 50 % clover without derogation and 1 parcel cultivated with grass under derogation conditions were considered as outliers. The outliers are discussed when they are most relevant.

All crops on sandy soils

The nitrate concentration in the soil water on sandy soils in autumn 2018 was evaluated on 200 parcels, 108 parcels with derogation and 92 parcels without derogation. Regardless of crop or derogation request, the average nitrate concentration in the soil water on sandy parcels in the monitoring network amounted 88 ± 80 mg NO_3/l in autumn 2018. With request of derogation, the average nitrate concentration in the soil water on sandy parcels was 83 ± 70 mg NO_3/l. Without derogation on sandy soils, the average nitrate concentration in the soil water was 94 ± 91 mg NO_3/l. The average concentrations with and without derogation were not significantly different ($p = 0.75$).

Six out of seven outlying values were detected on sandy soils, 2 with derogation and 4 without derogation. Without the outlying values, the average nitrate concentration in the soil water on sandy soils amounted 80 ± 64 mg NO_3/l, 78 ± 57 mg NO_3/l with derogation and 82 ± 72 mg NO_3/l without derogation conditions.

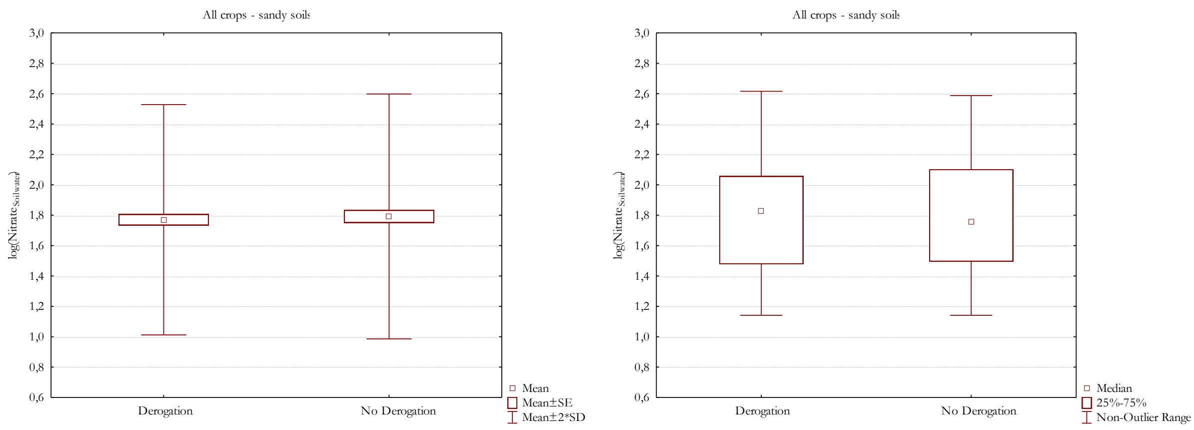


Figure 390: Boxplot of log(Nitrate$_{soilwater}$) for derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2018. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Grass on sandy soils

On sandy soils cultivated with grass, the average nitrate concentration in the soil water was 65 ± 59 mg NO_3/l in autumn 2018. The comparison of sandy soils cultivated with grass comprised 48 parcels with derogation and 38 parcels without derogation. Under derogation conditions, the average nitrate concentration in the soil water was 68 ± 60 mg NO_3/l. Without derogation, the average nitrate concentration in the soil water was 60 ± 59 mg NO_3/l. The difference in nitrate concentration in the soil water between derogation and no derogation parcels was not statistically significant ($p = 0.40$).

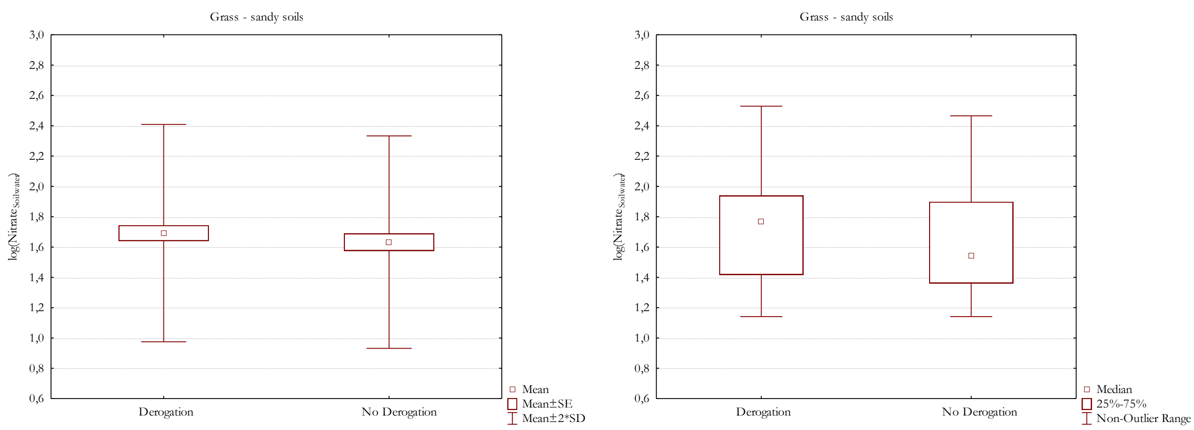


Figure 391: Boxplot of log(Nitrate $_{soilwater}$) for derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2018. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

One detected outlying value was situated on grass on sandy soils, cultivated under derogation conditions. Without the outlying value, the average nitrate concentration in the soil water on parcels with derogation was 62 ± 46 mg NO_3/l.

Grass with less than 50 % clover on sandy soils

The nitrate concentration in the soil on sandy soils cultivated with grass and less than 50 % clover was evaluated on 39 parcels, 21 parcels with and 18 parcels without derogation. On parcels with derogation, the average nitrate concentration in the soil water amounted 79 ± 54 mg NO_3/l. On parcels cultivated with grass and less than 50 % clover without derogation on sandy soils, the average nitrate concentration in the soil water was 60 ± 75 mg NO_3/l. The difference between derogation and no derogation parcels was statistically insignificant ($p = 0.64$).

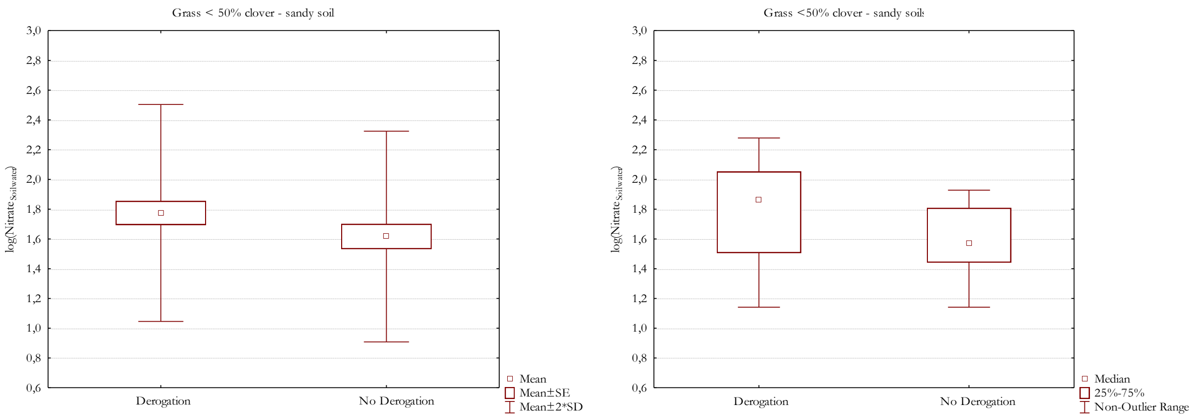


Figure 392: Boxplot of log(Nitrate$_{soilwater}$) for derogation and no derogation parcels with grass and less than 50 % clover on sandy soils in the monitoring network in autumn 2018. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

One outlying value originated in a sandy parcel cultivated with grass and less than 50 % clover without derogation. Also without the outlying value, the difference in nitrate concentration in the soil water between derogation and no derogation parcels was statistically insignificant ($p = 0.61$).

Maize on sandy soils

Seventy-five parcels cultivated with maize on sandy soils could be evaluated regarding the nitrate concentration in the soil water, 39 parcels with derogation and 36 parcels without derogation. The average nitrate concentration in the soil water on sandy parcels cultivated with maize in the monitoring network was 125 ± 95 mg NO_3/l in autumn 2018. Under derogation conditions, the average value was 104 ± 83 mg NO_3/l, without derogation it was 147 ± 102 mg NO_3/l. The average nitrate concentration in the soil water on parcels cultivated with maize on sandy soils did not differ significantly between derogation and no derogation parcels ($p = 0.06$).

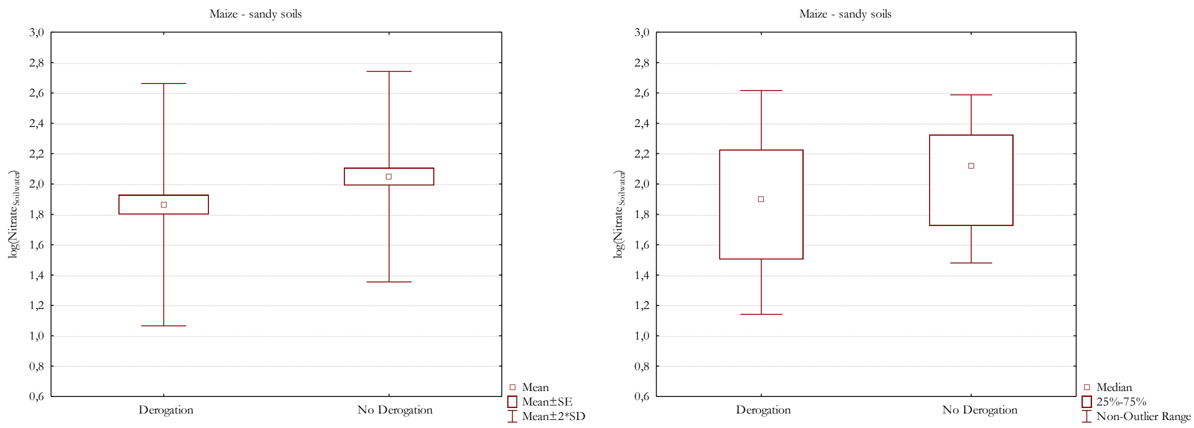


Figure 393: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2018. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Four sandy parcels cultivated with maize were detected as outliers regarding the nitrate concentration in the soil water. One parcel was cultivated under derogation conditions and 3 parcels without derogation conditions. Without the outlying values, 38 and 33 parcels respectively with and without derogation could be compared. It was still concluded that the nitrate concentration in the soil water of sandy parcels cultivated with maize did not differ significantly between derogation and no derogation conditions ($p = 0.12$).

All crops on sandy loam soils

Data of the nitrate concentration in the soil water on sandy loam parcels are available for 84 parcels of the monitoring network. The average nitrate concentration in the soil water on sandy loam parcels, regardless crop or derogation, was 70 ± 59 mg NO_3/l in autumn 2018. The comparison includes 44 parcels with derogation and 40 parcels without derogation. Under derogation conditions, the average nitrate concentration in the soil water on sandy loams soils amounted 72 ± 58 mg NO_3/l. Without derogation, the average nitrate concentration in the soil water on sandy loams soils was 67 ± 62 mg NO_3/l. The average values did not differ significantly between derogation and no derogation conditions ($p = 0.73$).

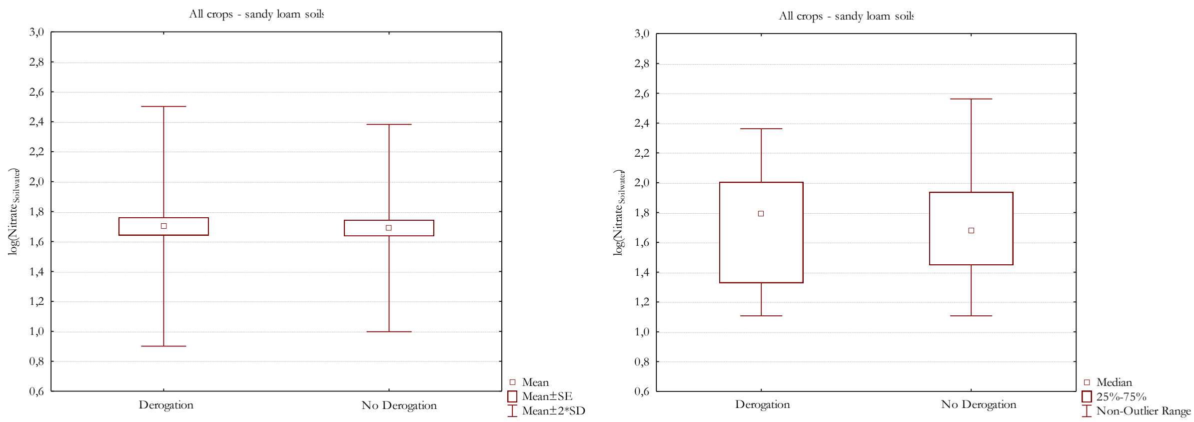


Figure 394: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network in autumn 2018. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Grass on sandy loam soils

In 2018, the possible impact of derogation on the nitrate concentration in the soil water on sandy loam soils cultivated with grass could be evaluated by comparison of both 21 parcels with and without derogation. Grass on sandy loam soils under derogation conditions resulted in 2018 in the monitoring network in an average nitrate concentration in the soil water of 74 ± 66 mg NO_3/l. Without derogation, the average nitrate concentration in the soil water of 65 ± 74 mg NO_3/l. The average nitrate concentration in the soil water on sandy loams soils cultivated with grass did not differ significantly regarding the request of derogation ($p = 0.58$).

One outlying value was measured on a parcel cultivated with grass on sandy loam soils without derogation. Even without the outlying value, the average nitrate concentration in the soil water on sandy loams soils cultivated with grass did not differ significantly regarding the request of derogation ($p = 0.46$).

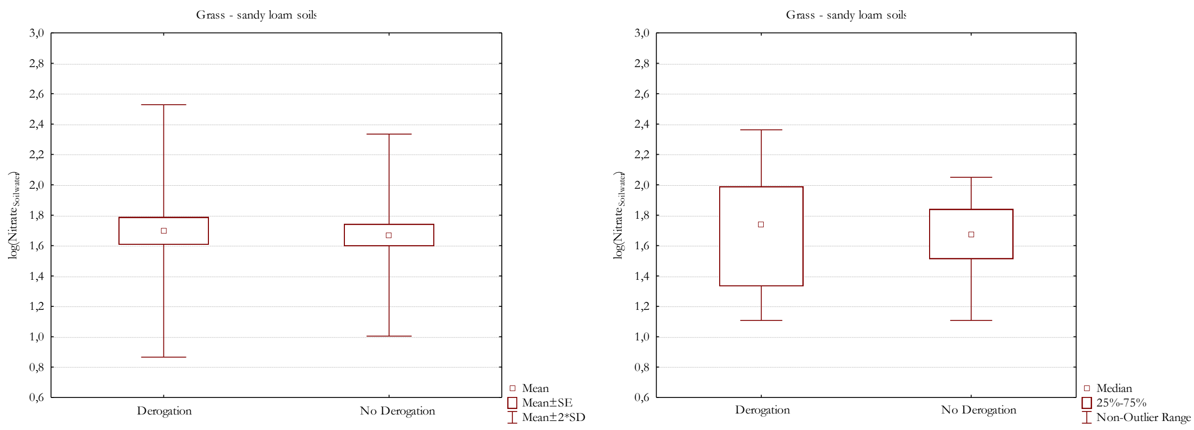


Figure 395: Boxplot of log(Nitrate$_{soilwater}$) for derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2018. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Maize on sandy loam soils

On sandy loam soils cultivated with maize, the average nitrate concentration in the soil water was 70 ± 49 mg NO_3/l in the monitoring network in 2018. On derogation parcels (23 parcels), the average nitrate concentration in the soil water was 71 ± 52 mg NO_3/l. Without derogation, the average nitrate concentration in the soil water was 69 ± 47 mg NO_3/l. The difference in average nitrate concentration in the soil water on derogation and no derogation parcels was statistically insignificant ($p = 0.57$).

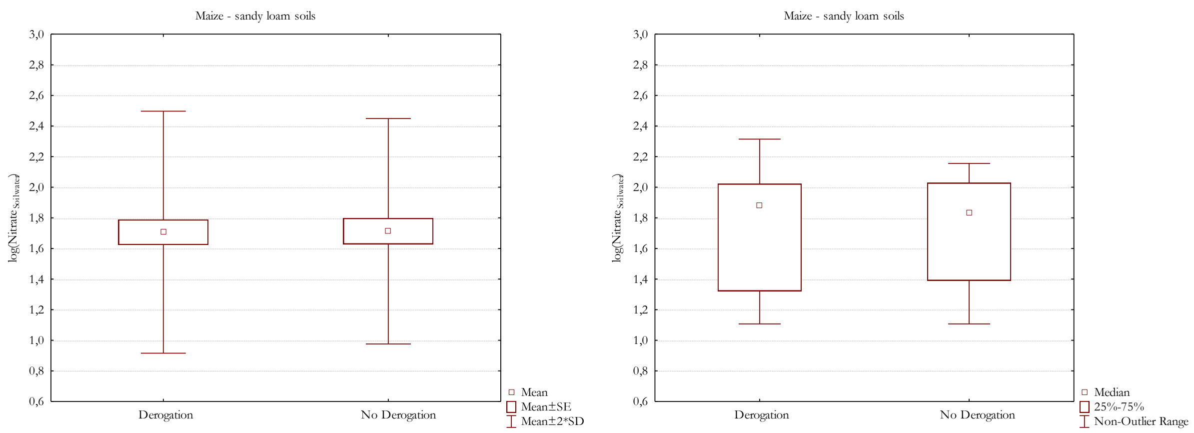


Figure 396: Boxplot of log(Nitrate$_{soilwater}$) for derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2018. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

3.3.1.4 Nitrate in soil water autumn 2019

Parcels that could not be sampled to 90 cm in autumn 2019 are not included in the evaluation of nitrate in the soil water because the nitrate concentration in the soil water is determined precisely in that soil layer of 60-90 cm.

Parcels that were assessed not suited for evaluation of the nitrate-N residue, as discussed before (3.2.1.10), were also excluded from the evaluation of the nitrate concentration in the soil water. The nitrate concentration in the soil water in autumn 2019 could be evaluated on 334 parcels of the derogation monitoring network.

The **average concentration of nitrate in the soil water** on those **334 parcels** was **116 ± 114 mg NO_3/l**. The median concentration of nitrate in the soil water was 81 mg NO_3/l in autumn 2019.

The range and the variation of the nitrate concentration in the soil water are shown in Figure 397. For the statistical analysis of the nitrate concentration in the soil water, the log-transformed data are used. The variation of the log-transformed data is demonstrated in Figure 398**.**

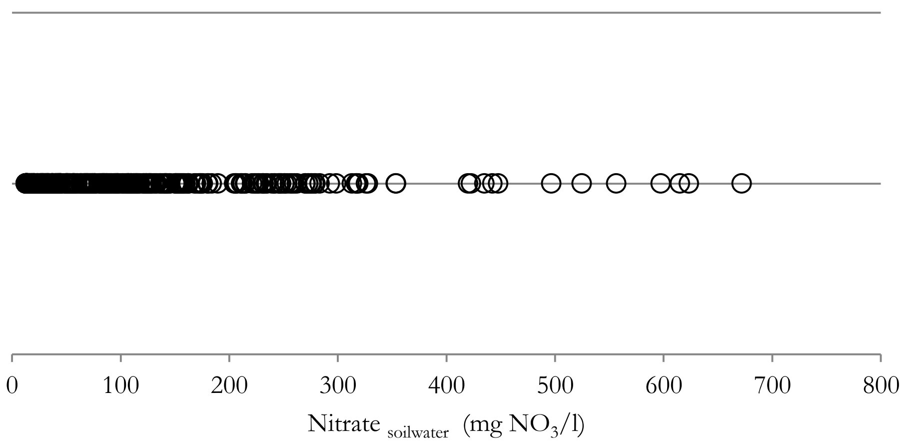


Figure 397: Spreading of the nitrate concentration in soil water (mg NO_3/l) in 334 parcels suited for comparison of derogation and non-derogation practices in autumn 2019.

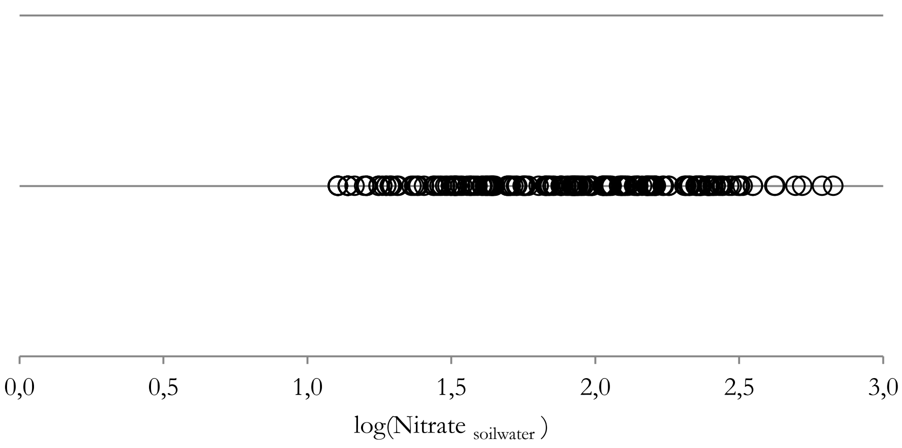


Figure 398: Spreading of the log-transformed nitrate concentration in soil water (log($Nitrate_{Soilwater}$)) in 334 parcels suited for comparison of derogation and non-derogation practices in autumn 2019.

Table 80: Nitrate concentration in the soil water (mg NO_3/l), mean (± standard deviation) and median values of the 334 parcels of the monitoring network at different levels of comparison in autumn 2019. The number of parcels included in the comparison is indicated by 'n'.

			Nitrate (mg/l) in the soil water			
			n	Average	Median	p-value
Overall mean monitoring network			334	116 ± 114	81	-
Derogation			186	113 ± 106	83	0.97
No derogation			148	120 ± 124	75	
Derogation	Sandy soil		116	122 ± 116	85	0.83
No derogation			85	137 ± 130	98	
Derogation	Sandy loam		70	100 ± 87	79	0.62
No derogation			63	97 ± 113	63	
Derogation	Sandy soil	Grass	51	103 ± 108	68	0.98
No derogation			29	105 ± 137	43	
Derogation	Sandy soil	Grass <50% clover	18	114 ± 128	55	0.13
No derogation			17	103 ± 101	80	
Derogation	Sandy soil	Maize	47	145 ± 117	112	0.34
No derogation			39	176 ± 127	155	
Derogation	Sandy loam	Grass	33	98 ± 97	70	0.12
No derogation			31	67 ± 72	40	
Derogation	Sandy loam	Maize	37	101 ± 78	83	0.37
No derogation			32	125 ± 137	90	

As mentioned each time in the discussion of the reported nitrate concentration in the soil water, it needs to be pointed out that the reported nitrate concentration in the soil water (Table 80) cannot be cross-checked directly with the quality threshold of 50 mg NO_3/l. The nitrate leaching out of the soil is still exposed to an attenuating factor.

As for the evaluation of the nitrate-N residue, no outliers are discarded for the statistical analysis of the nitrate concentration in the soil water. Nevertheless, an outlier detection was done. Five outlying values were observed, 2 on sandy loams soils and 3 on sandy soils. On the sandy loams soils, the 2 outliers were both parcels with main crop maize without derogation. On the sandy soils, the outlier was one parcel cultivated with grass without derogation and 2 parcels cultivated with maize both with and without derogation. The outliers and their impact is discussed in the further paragraphs.

In autumn 2019, the nitrate concentration in the soil water was compared between 186 derogation parcels and 148 no derogation parcels. On derogation parcels, the average nitrate concentration in the soil water was 113 ± 106 mg NO_3/l. On the parcels without derogation, the average nitrate concentration in the soil water amounted 120 ± 124 mg NO_3/l. There was no significant difference ($p = 0.97$) between derogation and no derogation conditions regarding the nitrate concentration in the soil water in autumn 2019.

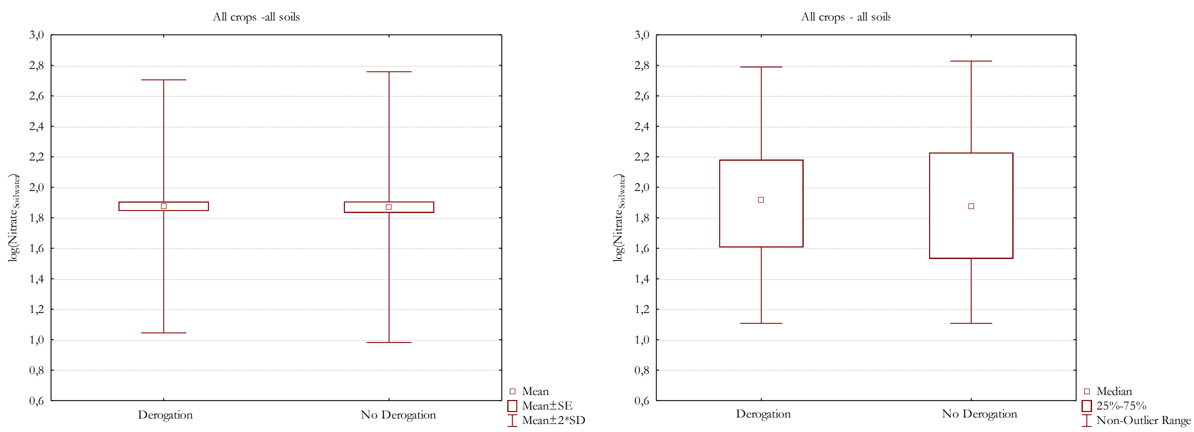


Figure 399: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with all crops on all soils in the monitoring network in autumn 2019. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

All crops on sandy soils

On sandy soils, the evaluation included 201 parcels, 116 results of derogation parcels and 85 results of parcels without derogation. Regardless of crop or derogation, the nitrate concentration on sandy soils was on average 128 ± 122 mg NO_3/l in the monitoring network in autumn 2019. Under derogation conditions, the average nitrate concentration in the soil water was 122 ± 116 mg NO_3/l. Without derogation conditions, the average nitrate concentration in the soil water was 137 ± 130 mg NO_3/l. The difference in nitrate concentration in the soil water between derogation and no derogation conditions was not statistically significant ($p = 0.83$).

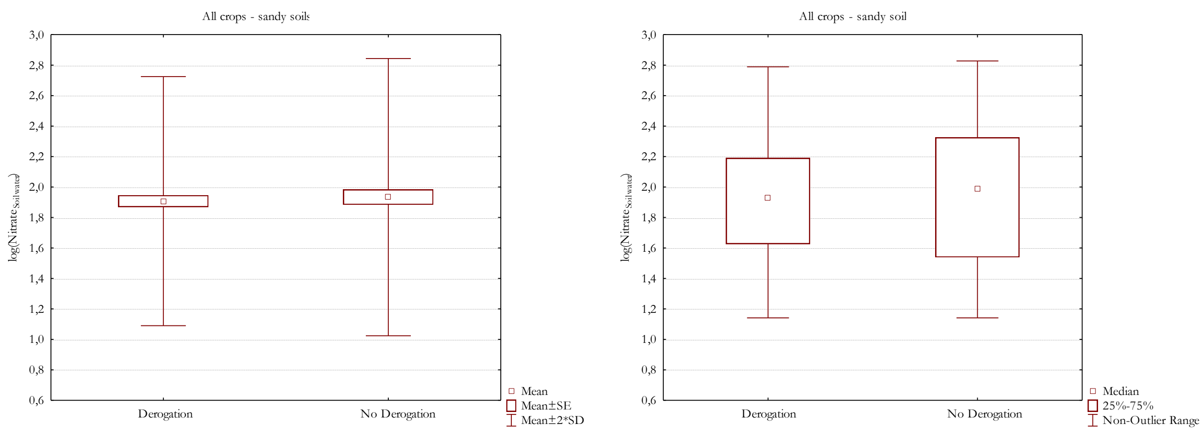


Figure 400: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with all crops on sandy soils in the monitoring network in autumn 2019. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Three of the five outlying values were detected on sandy soils. The nitrate concentration of those 3 outliers exceeded 500 mg NO_3/l. Without these outliers, the average nitrate concentration in the soil water on sandy soils amounted 121 ± 106 mg NO_3/l, 117 ± 107 mg NO_3/l with derogation and 125 ± 105 mg NO_3/l without derogation.

Grass on sandy soils

The evaluation on sandy soils cultivated with grass was performed on 80 parcels, merely derogation parcels. Twenty-nine parcels without derogation and 51 parcels with derogation could be compared. On derogation parcels, an average nitrate concentration in the soil of 103 ± 108 mg NO_3/l was measured. On parcels without derogation, the average was 105 ± 137 mg NO_3/l.

The nitrate concentration on sandy soils cultivated with grass did not differ significantly between derogation and no derogation parcels ($p = 0.98$).

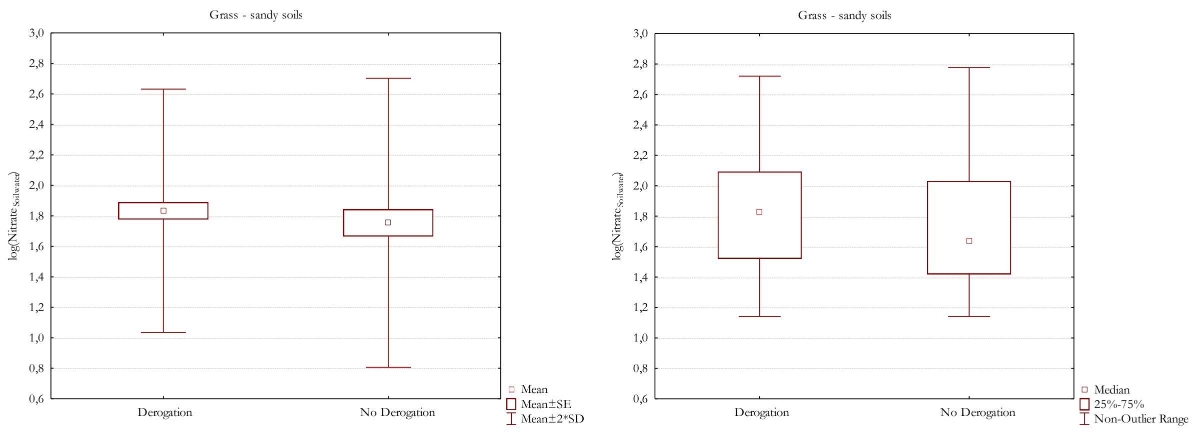


Figure 401: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with grass on sandy soils in the monitoring network in autumn 2019. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

One parcel on sandy soils cultivated with grass without derogation was detected as an outlier. Without this parcel, the average nitrate concentration in the soil water of no derogation parcels on sandy soils cultivated with grass was 88 ± 101 mg NO_3/l.

Grass with less than 50 % clover on sandy soils

On sandy soils cultivated with grass and less than 50 % clover, 35 parcels were evaluated regarding the nitrate concentration in the soil water, 18 parcels with derogation and 17 parcels without derogation. The average nitrate concentration in het soil water was 114 ± 128 mg NO_3/l at the derogation parcels and 103 ± 101 mg NO_3/l at the parcels without derogation. The difference was statistically insignificant ($p = 0.13$).

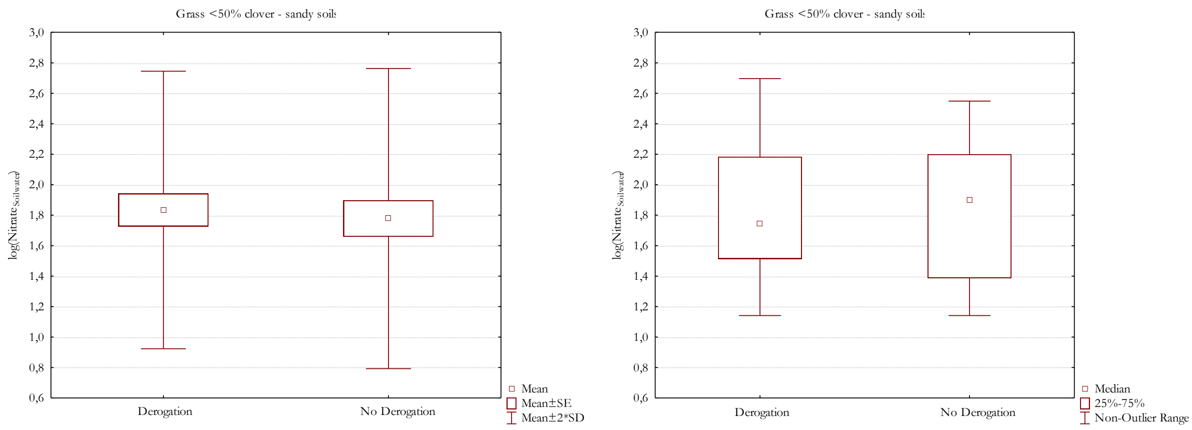


Figure 402: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with grass and less than 50 % clover on sandy soils in the monitoring network in autumn 2019. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Maize on sandy soils

Under main crop maize on sandy soils, the nitrate concentration in the soil water was evaluated for 86 parcels in autumn 2019. The average nitrate concentration in the soil water was 159 ± 122 mg NO_3/l on those parcels, regardless of derogation or not. The average value of the 47 derogation parcels was 145 ± 117 mg NO_3/l. On the 39 parcels without derogation, an average value of 176 ± 127 mg NO_3/l was determined. The nitrate concentration in the soil water of derogation and no derogation parcels with maize on sandy soils did not differ significantly ($p = 0.34$).

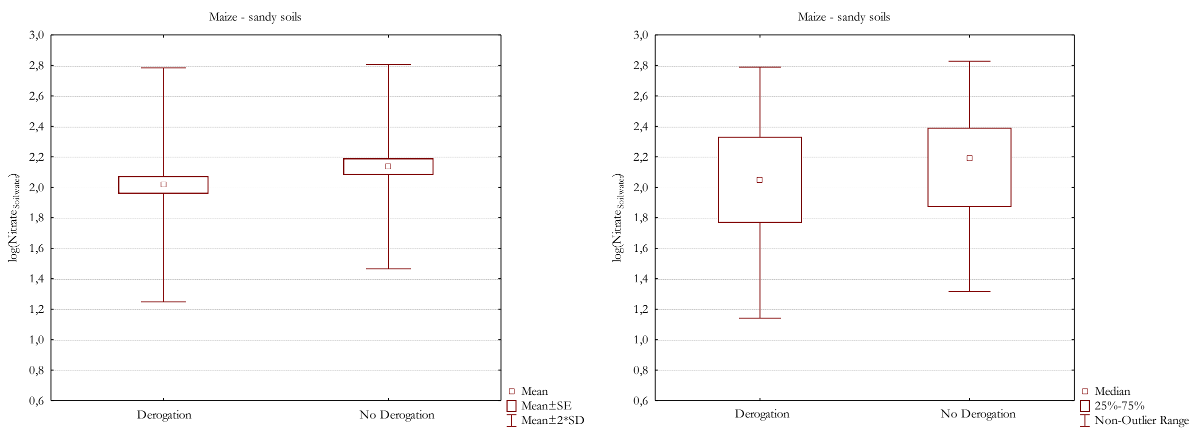


Figure 403: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with maize on sandy soils in the monitoring network in autumn 2019. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Two detected outliers were parcels cultivated with maize on sandy soils with and without derogation. Without those 2 outlying values, the average nitrate concentration in the soil water of sandy parcels cultivated with maize was 147 ± 98 mg NO_3/l, 134 ± 95 mg NO_3/l with derogation and 163 ± 99 mg NO_3/l without derogation.

All crops on sandy loam soils

In autumn 2019, the nitrate concentration in the soil water could be evaluated of 133 parcels on sandy loam soils. Regardless of crop and application of derogation, the average nitrate concentration in the soil water of the sandy loam parcels of the monitoring network was 98 ± 99 mg NO_3/l. Specified for parcels with and without derogation, the average nitrate concentration in the soil water was 100 ± 87 mg NO_3/l and 97 ± 113 mg NO_3/l, respectively. The nitrate concentration in the soil water of derogation and no derogation on sandy loam soils did not differ significantly (p = 0.62).

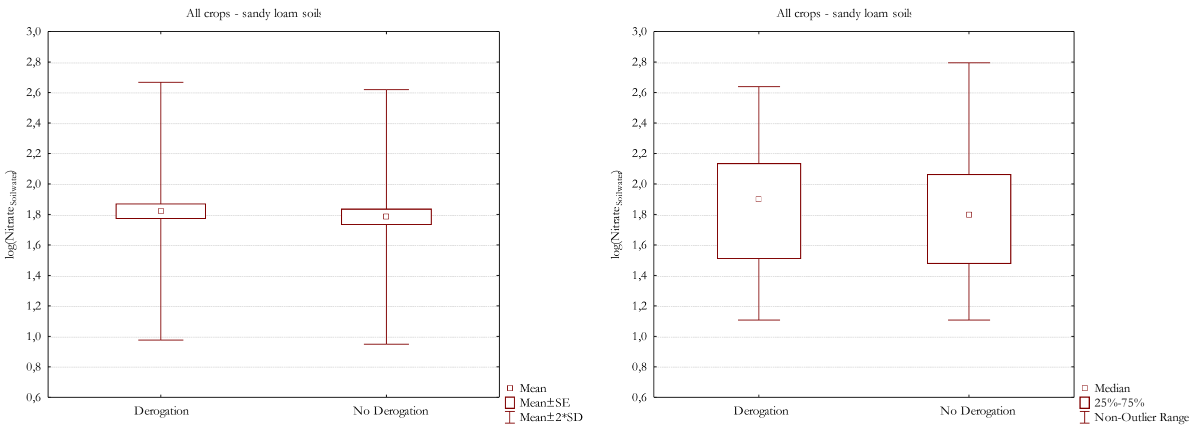


Figure 404: Boxplot of log($Nitrate_{soilwater}$) for derogation and no derogation parcels with all crops on sandy loam soils in the monitoring network in autumn 2019. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Grass on sandy loam soils

The evaluation of the nitrate concentration in the soil water of sandy loam parcels cultivated with grass was based on the results of 64 parcels in autumn 2019. The average nitrate concentration in the soil water of those parcels was 83 ± 86 mg NO_3/l. The request of derogation had no significant effect (p = 0.12) on the nitrate concentration of the soil water on sandy loam soils cultivated with grass in the monitoring network. The average value amounted 98 ± 97 mg NO_3/l in derogation conditions and 67 ± 72 mg NO_3/l without derogation conditions.

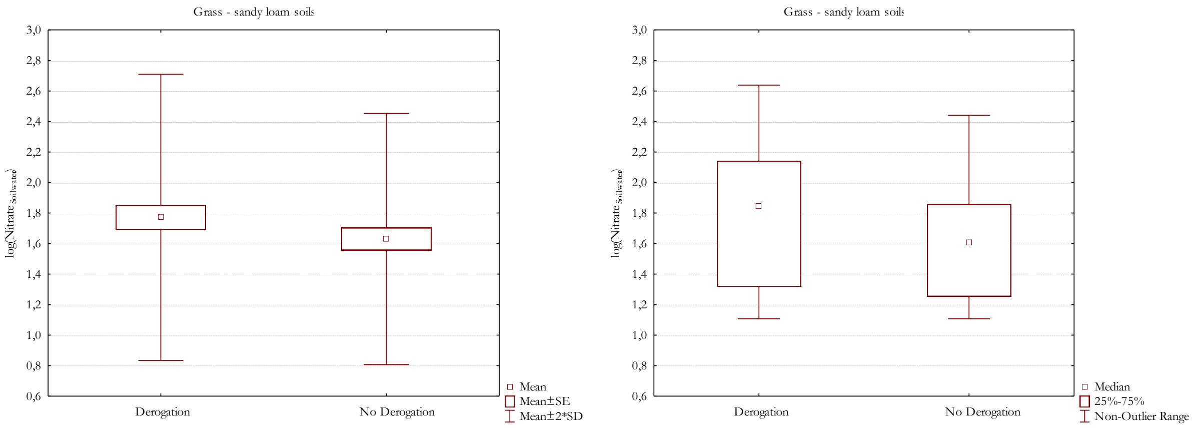


Figure 405: Boxplot of log(Nitrate$_{soilwater}$) for derogation and no derogation parcels with grass on sandy loam soils in the monitoring network in autumn 2019. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Maize on sandy loam soils

On sandy loam soils, the average nitrate concentration in the soil water was 112 ± 109 mg NO_3/l in autumn 2019, including the results of 69 parcels.

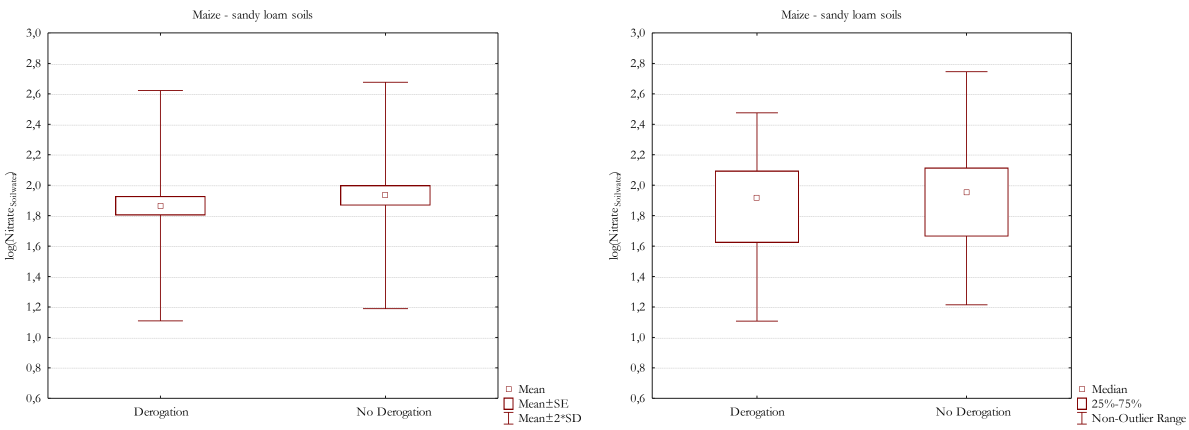


Figure 406: Boxplot of log(Nitrate$_{soilwater}$) for derogation and no derogation parcels with maize on sandy loam soils in the monitoring network in autumn 2019. Mean: left Median: right. SE: standard error of the mean. SD: Standard Deviation

Cultivating maize with derogation on sandy loam soils resulted in 2019 in the monitoring network in an average nitrate concentration in the soil water of 101 ± 78 mg NO_3/l. Without derogation, an average value of 125 ± 137 mg NO_3/l was measured. The difference between the average nitrate concentration in the soil water with and without derogation was not statistically significant (p = 0.37).

Among the detected outliers, two parcels were situated on sandy loam soils and were cultivated with maize. Both were parcels without derogation and nitrate concentrations in the soil water of 556 and 623 mg NO_3/l. The average nitrate concentration in the soil water was 94 ± 63 mg NO_3/l for the no derogation parcels without the outlying values.

3.3.2 Phosphorus & water

Phosphorus in the soil water was proposed not to be determined by analysing centrifuged soil water. Van der Zee et al. (1990) stated that the Phosphate Saturation Degree (PSD) is well correlated with P-leaching on non-calcareous sandy soils. This was confirmed in ongoing research regarding phosphorus "Environmentally and agriculturally sustainable P use", also instructed and monitored by VLM, for Flemish circumstances in laboratory leaching experiments (Amery *et al.* (2019)). An approximation of the possible P-loss to ground water and the possible P-concentration in ground water on long-term was achieved by use of the Phosphate Saturation Degree (PSD).

It was calculated that a PSD of 25 % limits the P concentration leaching to the ground water to 0,1 mg ortho-P/L, the average eutrophication limit of orthophosphate in surface water. Consequently a PSD of 25 % can be set as a threshold value. This threshold value for PSD was translated into a threshold value of P-AL (P extracted in ammonium-lactate) in the upper soil layer by Amery *et al.* (2019). The threshold value of P-AL in the upper soil layer regarding the risk of P-leaching was set at 16 mg P/100 g dry soil.

The comparison between derogation and no derogation circumstances regarding phosphorus in the water or the risk of possible P-leaching is performed 'on long term', by comparing parcels managed continuously with and without derogation conditions in the period 2008-2016.

On both long-term derogation and long-term no derogation parcels P-AL amounted on average 26 mg P/100 g dry soil in the soil layer of 0-30 cm. $P\text{-}AL_{0\text{-}30cm}$ of both types of parcels did not differ significantly (p = 0.78 - Mann-Whitney U; Table 81). The boxplot in Figure 407 confirms visually the lack of a statistical difference in P-AL in the upper soil layer of long-term derogation and long-term no derogation parcels.

Table 81: P-AL (mg P/100g dry soil) in the soil layer 0-30 cm ($P\text{-}AL_{0\text{-}30cm}$) for the long-term derogation and no derogation parcels. The number of parcels is indicated by 'n'.

	n	$P\text{-}AL_{0\text{-}30cm}$	Min-max
Long-term derogation	115	26	2-84
Long-term no derogation	115	26	2-72
p-value		0.78	

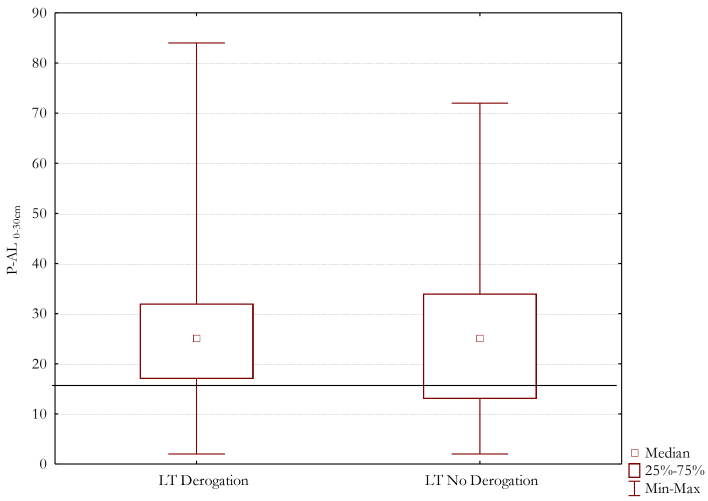


Figure 407: Boxplot of P-AL (mg P/100 g dry soil) in the soil layer 0-30 cm ($P\text{-}AL_{0\text{-}30cm}$) for the long term (LT) Derogation and No derogation parcels in the monitoring network. The horizontal line indicates P-AL 16 mg P/100 g dry soil.

According to Amery *et al.* (2019), P-AL measured in autumn 2016 on the long-term parcels was translated to PSD and the resulting PSD was translated in a concentration of P that can be leached out on long term, using Equation 1 or Equation 2 and Equation 3.

$$P-AL = 0{,}78442 * \text{FVG} + 12{,}795$$ if P-AL >36 mg P/100g **Equation 1**

$$P-AL = 1{,}1779 * \text{FVG} + 0{,}96635$$ if P-AL <36 mg P/100g **Equation 2**

$$FVG_{krit} = \frac{\gamma.K.c_{krit}}{1+\gamma.K.c_{krit}}$$ $\gamma = 0{,}5/0{,}167$, $K = 35$ **Equation 3**

Evidently nor PSD (p = 0.78), nor the P-concentration leachable on long term (p = 0.78) did differ significantly between the parcels managed continuously with or without derogation conditions, since those figures are based on P-AL which was not significantly different between both types of parcels.

Nevertheless, the boxplot in Figure 407 also shows that more than 25 % of the data of the long-term no derogation parcels are below the threshold value of 16 mg P/100 g dry soil, while of the long-term derogation parcels less than 25 % of the P-AL data are beneath the threshold. The cumulative spreading of P-AL on both long-term derogation and no derogation parcels is shown in Figure 408.

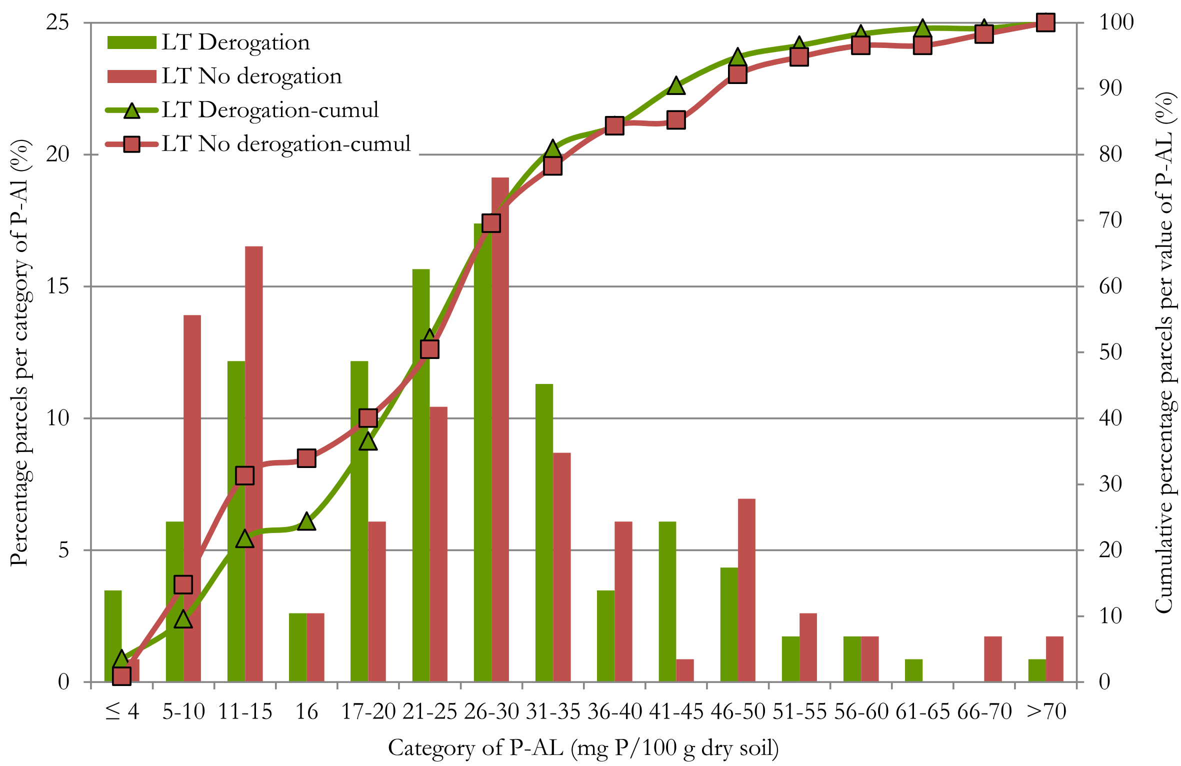


Figure 408: Percentage (columns; %) of long-term derogation (green) and long-term no derogation (red) parcels per category of P-AL and cumulative percentage (lines; %) of long-term derogation (green) and long-term no derogation (red) parcels that respect a certain value of P-AL.

The threshold value of 16 mg P/100 g was respected on 34 % of the parcels without derogation conditions on long term and on 24 % of the long-term derogation parcels of the monitoring network.

A **summary** of the results of the **water monitoring** in the period 2016-2019 shows that the nitrate concentration in the soil water increased each year. The average nitrate concentrations in the soil water amounted respectively 58, 70, 83 and 116 mg NO_3/l. In 2018 and 2019, not one statistically significant difference in nitrate concentration in the soil water was marked between derogation and no derogation parcels. In 2016 and 2017, the differences were generally not significant. The difference in nitrate concentration in the soil water between derogation and no derogation conditions was only statistically significant when focused on sandy soils cultivated with grass in 2016 and 2017.

The P-concentration leachable on long term did not differ significantly between the parcels managed continuously with or without derogation conditions. However, the proportion of long term derogation parcels that exceeds the threshold value of 16 mg P/100 g, according a PSD of 25 % that limits the P concentration leaching on long term to the ground water to 0,1 mg ortho-P/L, is larger than the proportion of parcels without derogation on long term.

4 Exploration environment and circumstances

In 3 'Monitoring' the monitoring results are reported as such with little explanation of the observations. However, it is important that the results are clarified and determinant factors are pointed out.

Besides the monitoring as such, the monitoring network offers the opportunity to relate the monitoring parameters to each other and to explore other parameters and evaluate them in relation to the nitrate-N residue.

Parameters suggested for exploration:

• Year	
• Rainfall	Climate parameters
• Temperature	Climate parameters
• Rainfall deficit	Climate parameters
• Standardized Precipitation Index spring	Climate parameters
• Standardized Precipitation Index summer	Climate parameters
• Agricultural region	Parcel parameters
• Soil texture	Parcel parameters
• Drainage	Parcel parameters
• pH (0-30cm)	Parcel parameters
• %C (0-30cm)	Parcel parameters
• Acreage parcel (ha)	Parcel parameters
• Converted meadow past 15 years (Y/N)	Parcel parameters
• Years after conversion	Parcel parameters
• Main crop	Crop parameters
• Second crop	Crop parameters
• Crop at sampling nitrate-N residue	Crop parameters
• Time between sowing second crop and sampling nitrate-N residue	Crop parameters

• Derogation request (Y/N) • Organic fertilisation (Y/N) • Mineral fertilisation (Y/N) • Total organic N-fertilisation (kg N/ha) • Mineral N-fertilisation (kg N/ha) • Total effective N-fertilisation (kg N/ha) • Type organic fertiliser • Grazing (Y/N) • Time between last day of grazing and sampling nitrate-N residue (days) • Time between last organic fertilisation and sampling nitrate-N residue (days) • Time between last mineral fertilisation and sampling nitrate-N residue (days) • N-export by harvest (kg N/ha)	N-fertilisation parameters of the parcel
• Fertilisation standard total effective N (kg N/ha) • Fertilisation standard total organic N (kg N/ha) • Respecting fertilisation standard total effective N (≤/>) • Respecting fertilisation standard total organic N (≤/>) • Nitrate-N residue standard	Fertilisation standards and nitrate-N residue standards
• Acreage (ha) • Proportion acreage with derogation (%) • Acreage grass-proportion • Acreage maize-proportion • Proportion grass under derogation conditions • Proportion maize under derogation conditions • Ratio acreage grass to acreage maize • Focus farm (Y/N)	Farm parameters
• Animal N-production • Use of organic N • Use of mineral N • Use of N from other fertilisers • Farm surplus of organic N • Farm surplus of effective N	Farm N-indicators

The first phase of the exploration is a descriptive statistical analysis.

4.1 Parameters

4.1.1 Year

Since the data are gathered in different years, a first variable or parameter to evaluate is the year of which the results originate. The year is considered as a categorical variable (Year). This variable has three categories:

- 2016
- 2017
- 2018

'Year' is a wide-ranging parameter. Most determining for this parameter will be the weather. Five parameters related to the meteorological circumstances were evaluated as 'climate parameters'.

4.1.2 Climate parameters

4.1.2.1 Rainfall

Rainfall can influence the nitrate-N residue in many ways. The amount of rainfall during the whole growing season is important for the production, the success of the crop, the N-uptake and the residual nitrate. For N-mineralisation or leaching in autumn, the rainfall in the last months before measuring the nitrate-N residue is important.

In the statistical analysis of the nitrate-N residue in the period 2011-2016, realised by VLM, rainfall on the day of sampling and rainfall during the week before sampling was evaluated (VLM, 2018). In this study rainfall during 30 days before sampling for the nitrate-N residue was opted.

Rainfall data were gathered from 106 Belgian weather stations, 36 stations of the Metagri network of the Royal Meteorological Institute of Belgium (RMI), 52 stations of the Flemish Environmental Agency (VMM) and 18 stations of the Hydrological Information Centre (HIC). Rainfall data of the nearest station were assigned to the parcels. If more than 3 values were missing, data of the next nearest station were used. For some parcels, the 3 nearest weather stations had less than 27 records in the respective period, which resulted in missing data.

	n	Average	median	min-max
Rain (mm)	1425	47 ± 23	43	3-149

The amount of rainfall during 30 days before sampling for the nitrate-N residue (Rain) is a continuous variable, expressed in mm.

The minimum and maximum values indicate large differences between parcels and years.

4.1.2.2 Temperature

Temperature is included in the analysis as the average temperature in the period July, August and September. Temperature data were gathered of 36 stations of the Metagri network of the RMI and 8 stations of the VMM. It was postulated to exclude the stations with more than 10 % missing values in the period July-September. In 2017 and 2018, however, none of the Metagri-stations achieved the threshold of 90 % records in the period July-September. A compromise between sufficient stations and the number of missing values was reached in a higher maximum of missing values. In 2017, a threshold of 70 % records was needed to include 9 Metagri-stations. A threshold of 75 % records resulted of inclusion of 23 Metagri-stations.

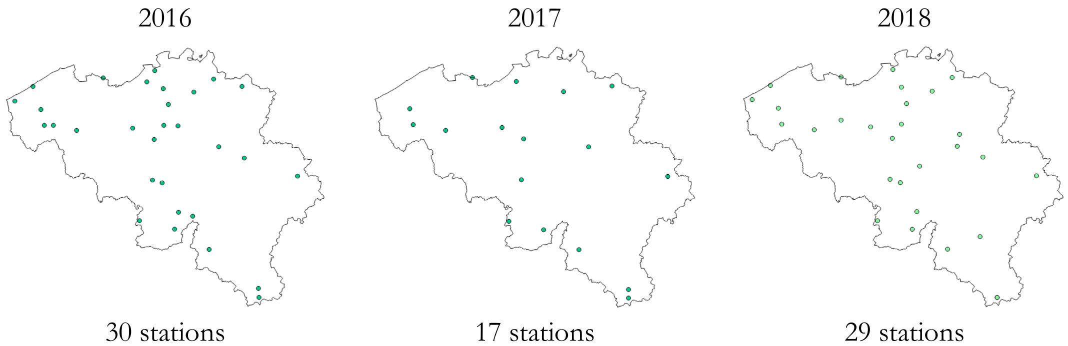


Figure 409: Geographical distribution of the temperature stations used for the temperature interpolation.

The values of the stations were interpolated by a reverse distance weighting (Figure 410). Each parcel is assigned a value based on the interpolation and the centre coordinate of the parcel.

The average temperature during the period July-September is a continuous variable (Temp) expressed in degrees Celsius (°C).

	n	Average	median	min-max
Temp (°C)	1440	18.1 ± 0.8	18.4	16.6-19.4

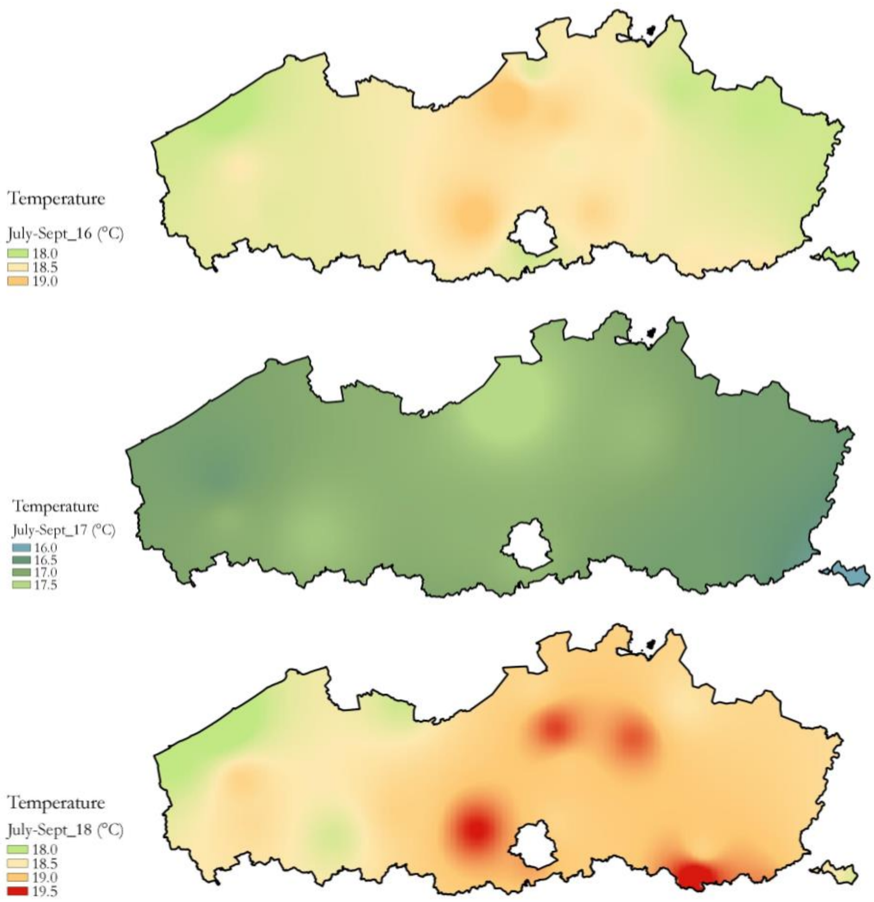


Figure 410: Mean temperature (°C) in the period July, August and September in 2016, 2017 and 2018.

4.1.2.3 Rainfall deficit

The rainfall deficit is the difference between the potential evapotranspiration (PET) and the amount of rainfall.

$$\text{Rainfall deficit} = \text{PET} - \text{Rainfall}$$

The potential evapotranspiration is the maximal evapotranspiration of a short green crop (grass), completely shading the ground, of uniform height and with adequate water status in the soil profile.

The rainfall deficit is an indicator for the amount of rainfall that the crops lack for an optimal growth and production. The rainfall deficit is considered for the period of April 1st-September 30th, the hydrological summer. The daily deficit is summed over this period. Negative values of the cumulative value are considered as zero.

Data of rainfall and evapotranspiration were available for 13 stations of the Metagri-network. Eight stations of the VMM provide data about the rainfall deficit. Only stations with minimal 90 % of records during the hydrological summer were withheld. The data of the stations resulted in a rainfall deficit map based on a reverse distance weighted interpolation (Figure 411). Each parcel of the monitoring network was assigned a value based on the centre coordinate of the parcel.

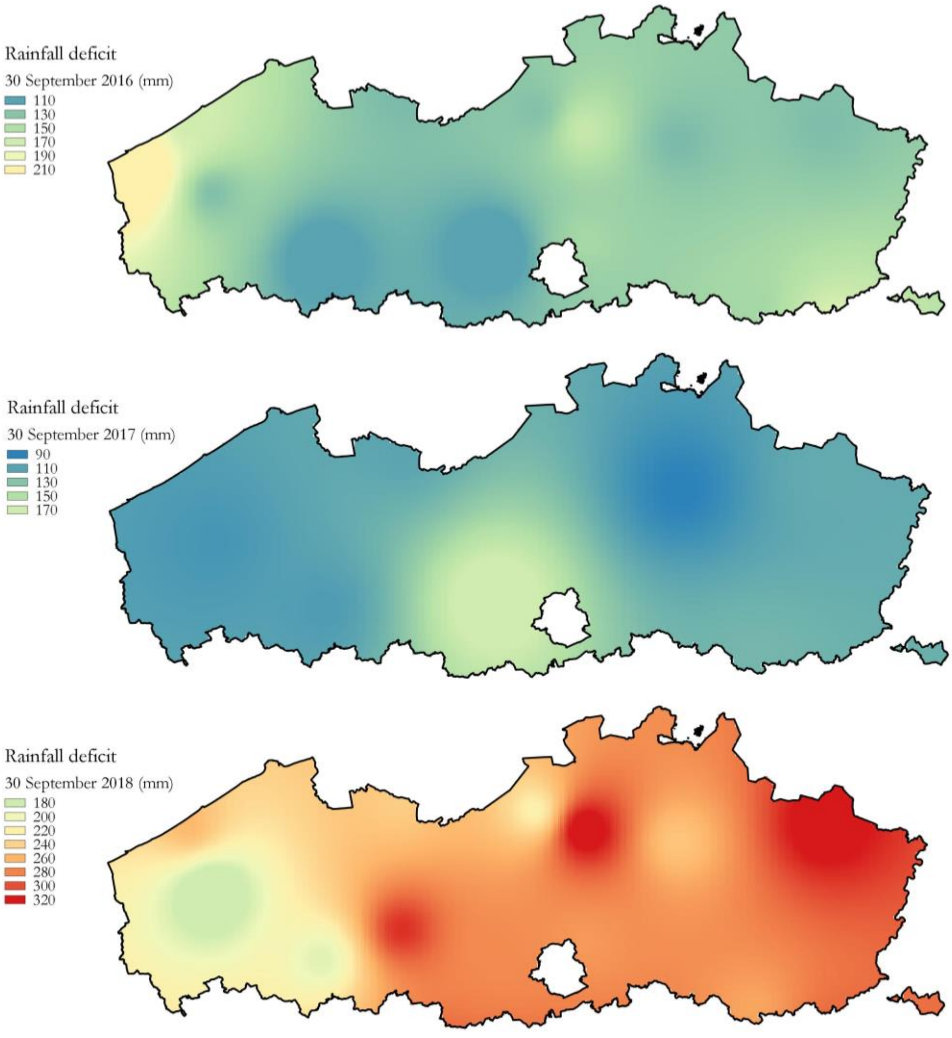


Figure 411: Rainfall deficit on September 30th (mm) in 2016, 2017 and 2018.

The rainfall deficit cumulated over the hydrological summer, is a continuous variable (RDef) expressed in mm.

	n	Average	median	min-max
RDef (mm)	1440	170 ± 69	138	91-332

4.1.2.4 Standardized Precipitation Index spring

As described in 2.1.3 'Climate 2018' the Standardized Precipitation Index is a parameter that uses rainfall data to indicate periods of drought. The index compares rainfall data of a period of 1 month (SPI-1) or 3 months (SPI-3) to the rainfall data of the same period of the reference period 1981-2010. SPI-3 describes how dry or how wet the last three months are, compared to the same months in the period 1981-2010. SPI-1 describes the situation on short term and SPI-3 describes the situation on a longer term or a season.

Regarding SPI, 7 categories are used:

- SPI >2 Extremely wet
- $1.5 < SPI \leq 2$ Very wet
- $1 < SPI \leq 1.5$ Moderately wet
- $-1 < SPI \leq 1$ Normal
- $-1.5 < SPI \leq -1$ Moderately dry
- $-2 < SPI \leq -1.5$ Very dry
- $SPI \leq -2$ Extremely dry

As in the statistical analysis of the nitrate-N residue realised by VLM (VLM; 2018) the parameters 'SPI-3 on July 1st' and 'SPI-3 on October 1st' are included in the analysis.

SPI-3 on July 1st compares the period of 1 April until 1 July to the reference period and is an indicator of the drought in the spring ($SPI3_{Spring}$).

Data about the Standard Precipitation Index were procured on waterinfo.be. SPI data are presented for 43 locations. Depending on the moment of evaluation data of 41 or 42 locations were available. The data of the stations were interpolated for Flanders by inverse distance weighting (Figure 412). Each parcel of the monitoring network was assigned a value based on the centre coordinate of the parcel.

SPI-3 on July 1st is evaluated as a categorical variable ($SPI3_{SpringCat}$). However to include the nuances inherent to the assigned values, **SPI-3 on July 1st is also evaluated as a continuous variable ($SPI3_{SpringCont}$).**

	n	Average	median	min-max
$SPI3_{SpringCont}$	1440	-0.6 ± 2.2	-1.6	-3.6-4.3

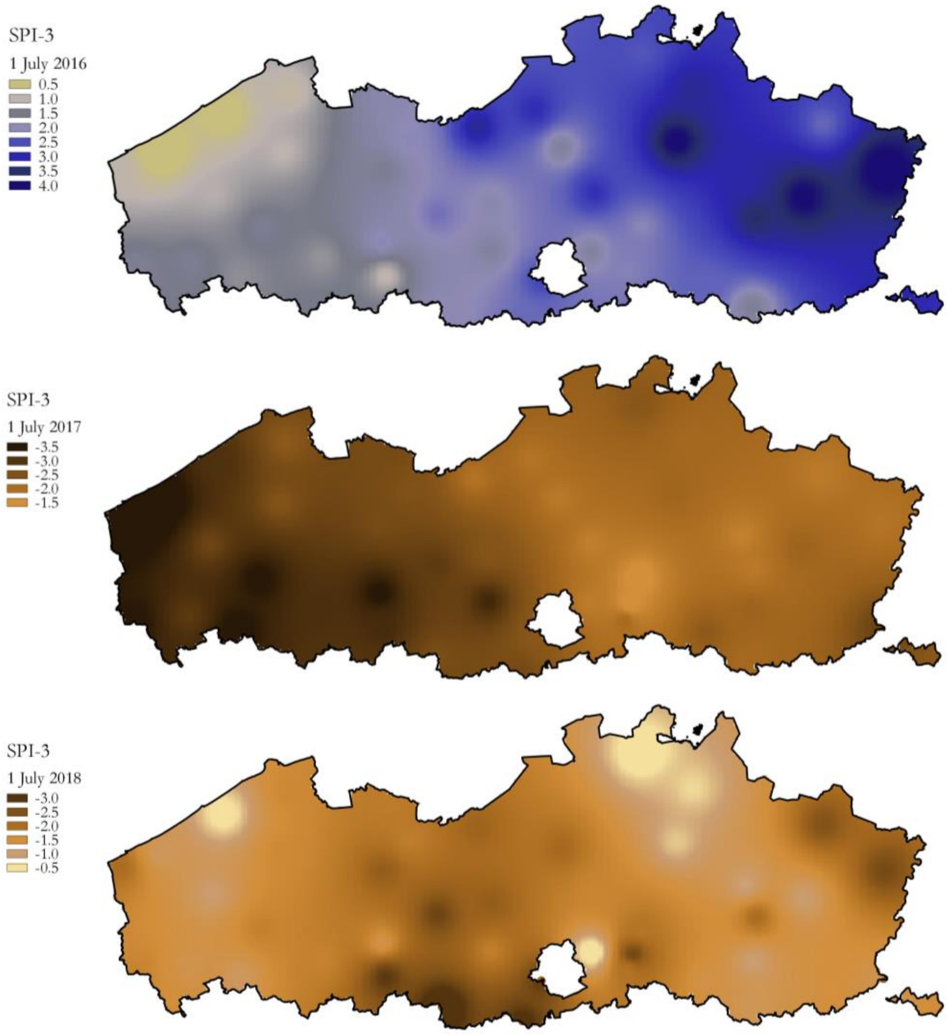


Figure 412: SPI-3 on July 1st in 2016, 2017 and 2018.

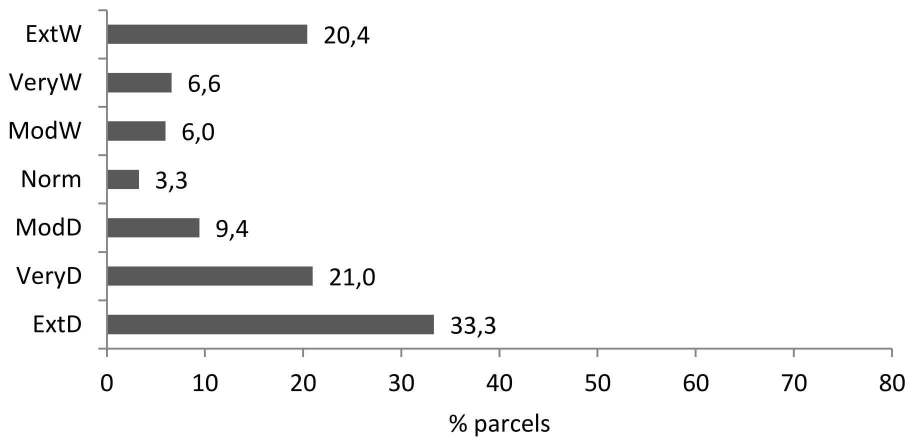


Figure 413: Frequency of the different categories of SPI-3 on July 1st ($SPI3_{SpringCat}$) in the monitoring network in 2016, 2017 and 2018.

4.1.2.5 Standard Precipitation Index summer

SPI-3 on October 1^{st} compares the period of 1 July until 1 October to the reference period and is an indicator of the drought in the summer ($SPI3_{Summer}$). Depending on the year of evaluation data of 40 or 41 locations were available. The data of the stations were interpolated for Flanders by inverse distance weighting (Figure 414). Each parcel of the monitoring network was assigned a value based on the centre coordinate of the parcel.

SPI-3 on October 1^{st} is both evaluated as a continuous and as a categorical variable ($SPI3_{SummerCont}$ - $SPI3_{SummerCat}$).

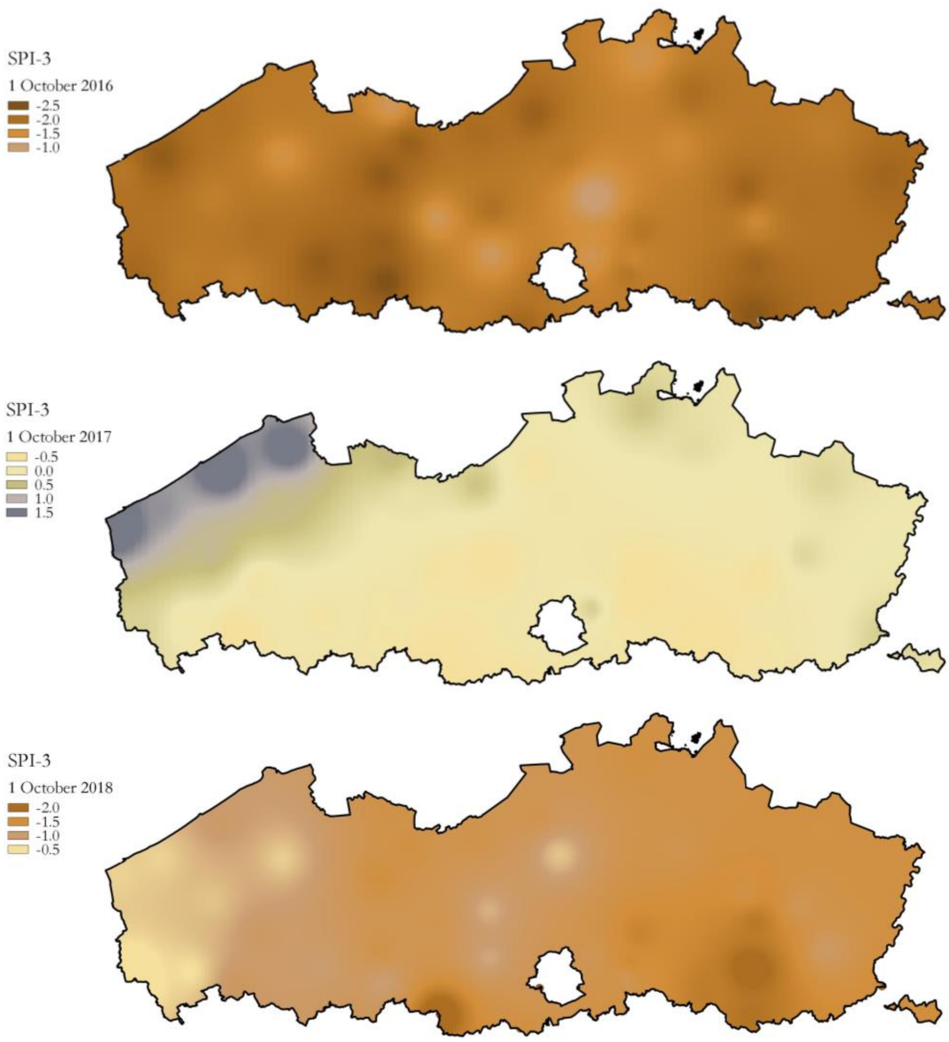


Figure 414: SPI-3 on October 1^{st} in 2016, 2017 and 2018.

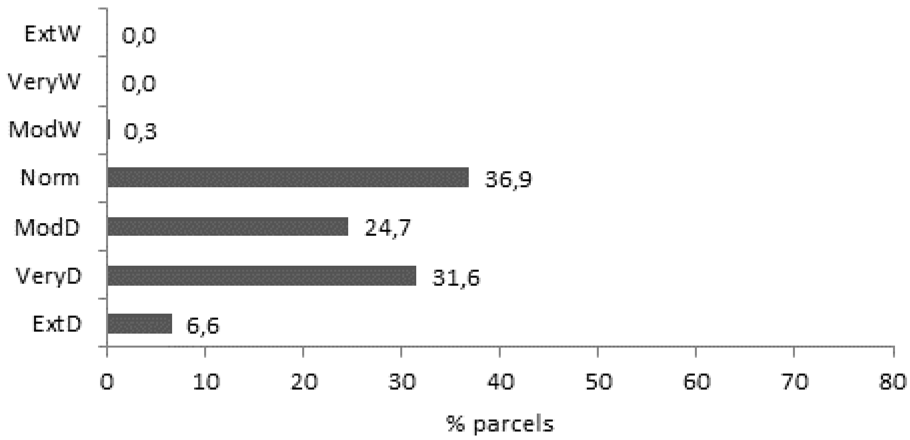


Figure 415: Frequency of the different categories of SPI-3 on October 1st ($SPI3_{SummerCat}$) in the monitoring network in 2016, 2017 and 2018.

	n	Average	median	min-max
$SPI3_{SummerCont}$	1440	-1.1 ± 0.8	-1.3	-2.3-1.4

4.1.3 Parcel parameters

Some properties of a parcel such as soil texture, draining properties, agricultural region, … are not determined by the farmer but are peculiar to a parcel. Other properties of the parcel more or less influenced by the farmer are pH, the percentage of organic carbon, the size of the parcel, being a converted meadow yes or no… .

Such parameters are referred to as 'parcel parameters'.

4.1.3.1 Agricultural region

The monitoring network was meant to be set up on sandy and sandy loam parcels. Therefore, farms with a considerable acreage in the agricultural regions 'Kempen', 'Vlaamse Zandstreek' and 'Zandleemstreek' were selected. The whole of parcels of a farm crosses the boundaries of the agricultural regions. Consequently, parcels of other agricultural regions than 'Kempen', 'Vlaamse Zandstreek' and 'Zandleemstreek' were to a lesser extent included in the monitoring network (Figure 416).

Agricultural region is a categorical variable (AgrReg), having 5 levels in the monitoring network in the period 2016-2018:

- Zandleemstreek
- Vlaamse-Zandstreek
- Kempen
- Leemstreek
- Polders

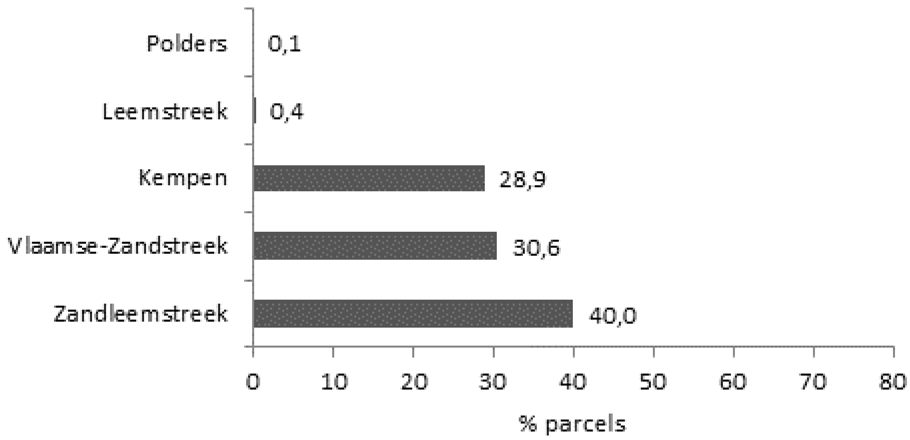


Figure 416: Frequency of agricultural region in the monitoring network in 2016, 2017 and 2018.

Agricultural region however, is not such an unambiguous parameter. It is rather a combination of different parameters a.o.:

Soil properties: texture, drainage, subsoil,….

Topography

Type of farm: acreage, cultivated crops, presence and amount of animals

Regional excess of organic manure

4.1.3.2 Soil texture

The monitoring network was meant to be set up on sandy and sandy loam parcels. From this perspective, farms and parcels were selected. A farm however, includes typically parcels of different soil texture. A first indication of soil texture was obtained based on the agricultural region and by the farmer. The soil texture of the parcels was formally determined by linking the coordinates of the parcels to the digital soil map of Belgium. Soil textures different from sand or sandy loam were included in the network because the indication of soil texture could deviate from the soil texture marked on the soil map of Belgium (Figure 417).

Soil texture is a categorical variable (Text) and has 5 levels in the monitoring network in the period 2016-2018:

- Sand
- Sandy-loam
- Clay
- Loam
- Anthropogenic

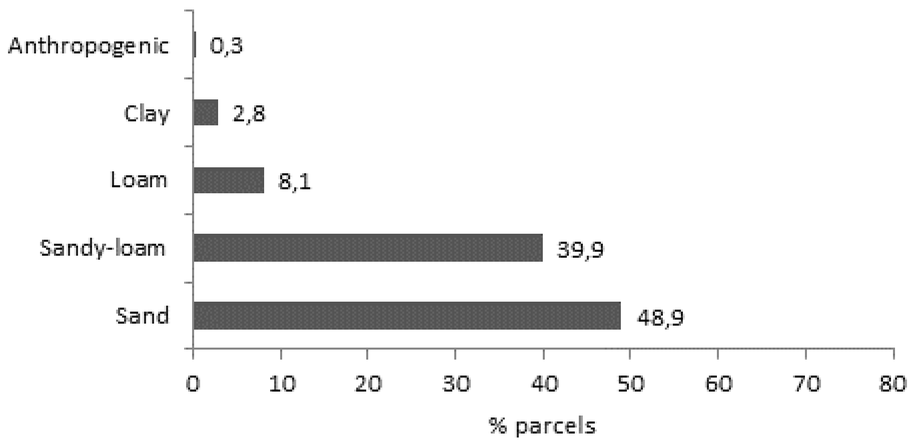


Figure 417: Frequency of soil texture in the monitoring network in 2016, 2017 and 2018.

4.1.3.3 Drainage

Linking the parcels of the monitoring network to the digital soil map of Belgium offers not only information about soil texture (4.1.3.2) but also information about the draining level of the soil.

For the statistical evaluation, the different draining levels were clustered in 3 groups:

- Dry
- Moist
- Wet

Three parcels were marked as 'Very wet', they were categorised as 'wet' because of the limited number.

The category 'Dry' involves the draining levels a and b. The category 'Moist' involves the draining levels c and d. The category 'Wet' involves the draining levels e, f and h.

Drainage is a categorical variable (Drain).

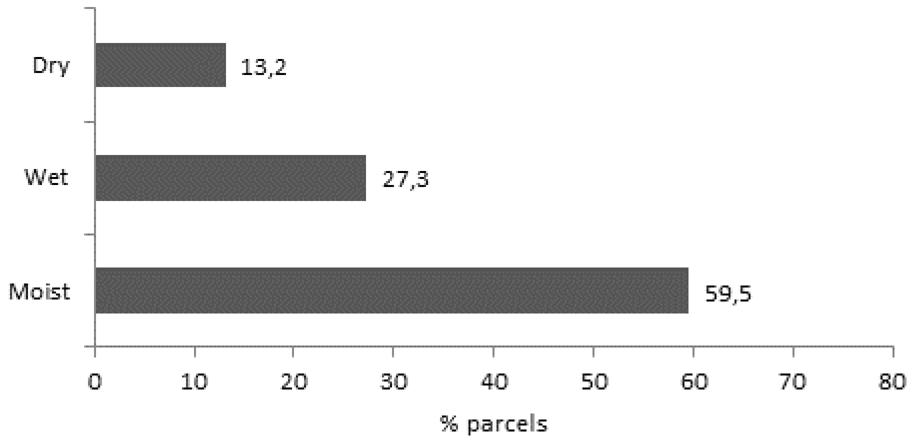


Figure 418: Frequency of drainage in the monitoring network in 2016, 2017 and 2018.

4.1.3.4 pH and organic carbon

The acidity (pH) and the percentage of organic carbon (%OC) are soil parameters that affect soil fertility. For evaluation of the soil fertility, these parameters need to be determined in the soil layer 0-6 cm for parcels with grass or 0-23 cm for arable land. These measurements were not planned in the monitoring assignment. However, after winter when the parcels were sampled to determine the difference in nitrate-N over winter, pH and %C were determined in the soil layer 0-30 cm. The results of pH and %C measured in the soil layer 0-30 cm cannot be compared with the target zone used in Belgium, but the results can be used in this set-up.

The percentage of organic carbon ($\%OC_{0\text{-}30cm}$) and pH ($pH_{0\text{-}30cm}$) are continuous variables.

	n	Average	median	min-max
$pH_{0\text{-}30cm}$	1435	5.7 ± 0.7	5.6	3.8-7.9
$\%OC_{0\text{-}30cm}$	1435	1.8 ± 0.9	1.6	0.4-8.7

4.1.3.5 Parcel acreage

The acreage of the parcels is obtained from the Flemish Land Agency (VLM). It's a **continuous variable shown in hectares** and referred to in the further analysis as **"AcrParc".**

	n	Average	median	min-max
AcrParc (ha)	1440	2.48 ± 1.91	1.88	0.29-17.18

4.1.3.6 Converted meadow

Farmers were asked if the parcels that were monitored had been a meadow and were converted during the last 15 years. This variable is a **categorical variable (ConvM)** with only 2 categories:

- N: the parcel is no converted meadow
- Y: the parcel is a converted meadow, conversion during past 15 years

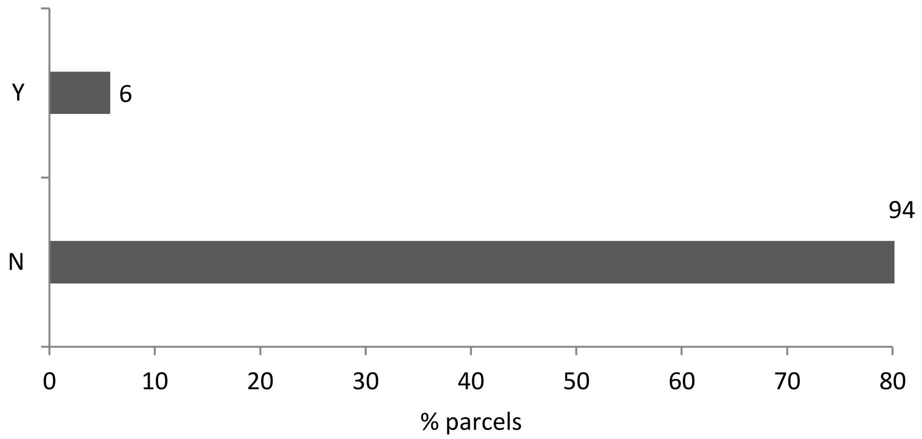


Figure 419: Frequency of converted meadows in the monitoring network in 2016, 2017 and 2018.

4.1.3.7 Converted meadow-Years after conversion

Farmers were not only asked if the monitored parcels were a converted meadow, but also when they were converted. This variable is a **continuous variable (YrsConv) and expressed in years**.

Eighty-seven parcels could be pointed out as a converted meadow. Zero years between the year of monitoring and conversion means that conversion was realised in the year of monitoring, this could be in spring or shortly before sampling.

	n	Average	median	min-max
YrsConv	87	4.3 ± 4.0	3.0	0.0-15.0

4.1.4 Crop parameters

4.1.4.1 Main crop

The main crop is the crop cultivated on the parcel on May 31st. Because the monitoring network was focused on crops that are eligible for derogation, and more specific on grass, maize and grass with less than 50 % clover, only those 3 crops appeared in the monitoring network. The **main crop is a categorical variable (Crop)** with only 3 categories:

- Grass
- Grass and less than 50 % clover
- Maize

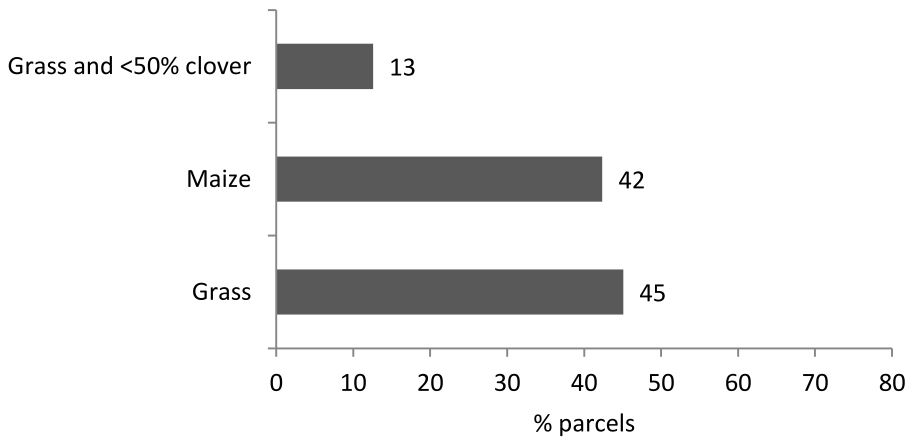


Figure 420: Frequency of the 3 types of main crop in the monitoring network in 2016, 2017 and 2018.

4.1.4.2 Second crop

The second crop is the crop that is sown or planted after harvest of the main crop. The second crop can be a catch crop or a crop sown to harvest the next year. Information is obtained from the farmers and from VLM. Since there are some months between the registration of the second crop and the sowing of the second crop, decisions can be changed in the crop planning. Therefore information about **the second crop** obtained from the farmer is used. This variable **is a categorical variable (SCrop).**

In the monitoring network 13 categories for this variable where distinguished:

- No second crop
- Grass
- Winter wheat
- Mixture of crops sown for ecological purpose (MixEP)
- Rye
- Barley
- White mustard (WhMust.)
- Spelt
- Triticale
- Grass and clover (GrCl)
- Mixture of non-leguminous plants (MNL)
- Rapeseed
- Black Oat

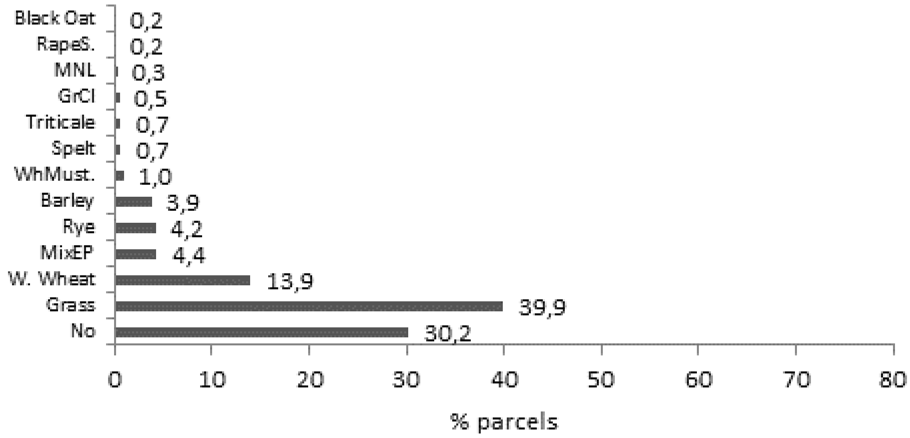


Figure 421: Frequency of the grown second crops in the monitoring network in 2016, 2017 and 2018.

4.1.4.3 Crop at sampling nitrate-N residue

Nor the main crop nor the second crop gives information about the crop growing at the time of sampling for the nitrate-N residue. Therefore the **crop sown and growing at the time of sampling the nitrate-N residue** is evaluated. This variable is a **categorical variable (CropNRes)** with 13 categories:

- No crop
- Grass
- Grass and clover (GrCl)
- Maize
- Winter wheat
- Mixture of crops sown for ecological purpose (MixEP)
- Barley
- Rye
- White mustard (WhMust.)
- Triticale
- Mixture of non-leguminous plants (MNL)
- Spelt
- Black Oat

‘No crop’ appears only on parcels cultivated with maize: maize was harvested but a second crop was not yet sown or growing. This categorical parameter will thus be correlated with the main crop.

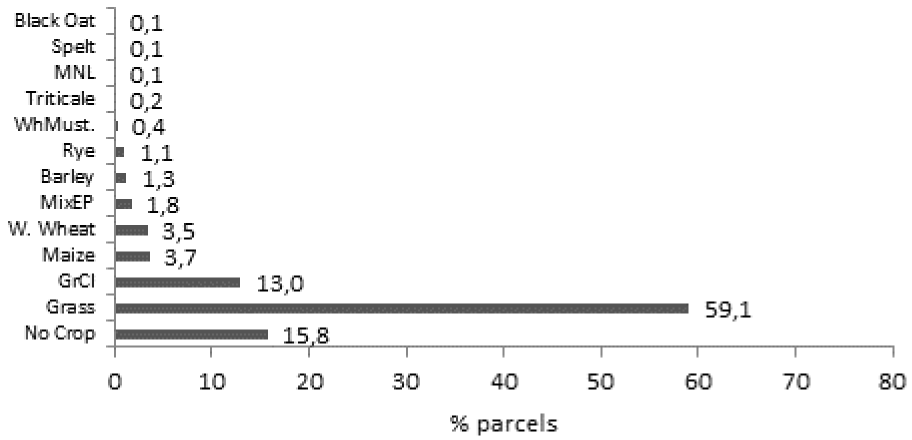


Figure 422: Frequency of crops sown/growing on the parcels at the time of sampling for the nitrate-N residue in the monitoring network in 2016, 2017 and 2018.

4.1.4.4 Interval between sowing second crop and sampling nitrate-N residue

Besides the second crop as such, the moment of tillage and sowing or even more the interval between tillage and/or sowing and sampling for the nitrate-N residue can be important. Dates of harvest, tillage after harvest and sowing the second crop were obtained from the farmers. **The interval between tillage and/or sowing and sampling for the nitrate-N residue is expressed in days** (Date sampling nitrate-N – Date tillage/sowing) and is a **continuous variable (IntSCrNRes)**.

On 98 parcels, tillage or sowing was realised after sampling for the nitrate-N residue. This occurred until 58 days after sampling. Only the positive figures which mean that tillage or sowing was x days before sampling for the nitrate-N residue, were used for further analysis since only they could be relevant for the nitrate-N residue.

	n	Average	median	min-max
IntSCrNRes (days)	343	26 ± 17	25	0 - 87

4.1.5 N-fertilisation parameters of the parcel

A range of fertilisation parameters of the parcel can be evaluated for their influence on eventual nutrient losses. Regarding the monitoring network the request of derogation, the application of organic and/ or mineral fertilisers are important parameters. An evident parameter is the dose of fertilisation as such.

The fertilisation dose however, can be approached in several ways:

as - the applied amount of effective nitrogen,

- the applied amount of mineral nitrogen,
- the applied amount of total organic nitrogen,
- the applied amount of effective nitrogen of organic origin,

4.1.5.1 Derogation request

Derogation request (Der) is a categorical variable, concerning two categories:

- Y: derogation was requested
- N: derogation was not requested

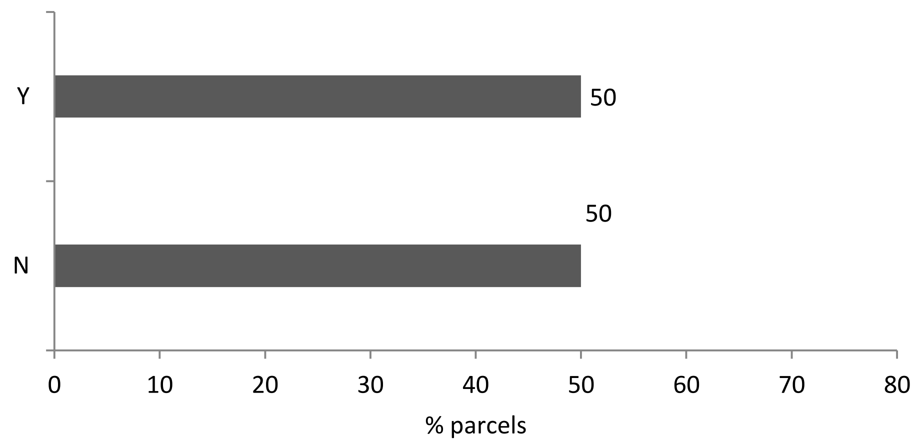


Figure 423: Frequency of derogation request in the monitoring network in 2016, 2017 and 2018.

The request of derogation determines the fertilisation standard of total organic N. Those variables cannot be evaluated separately.

4.1.5.2 Organic fertilisation

Besides the dose of a certain fertiliser, the application of a certain fertiliser, yes or no, can be an interesting variable to evaluate regarding the nitrate-N residue.

The application of organic fertilisation is a categorical variable (OrgF) with two categories:

- Y: organic fertilisers are applied
- N: organic fertilisers are not applied

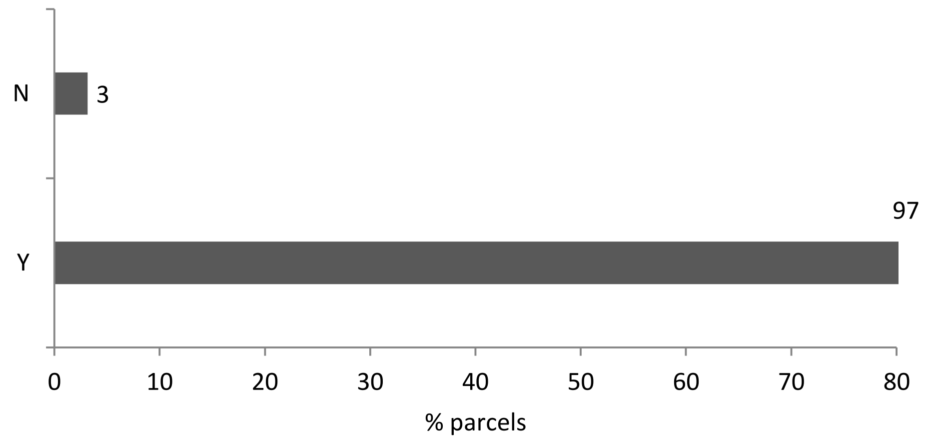


Figure 424: Frequency of parcels with and without application of organic fertilisers in the monitoring network in 2016, 2017 and 2018.

4.1.5.3 Mineral fertilisation

As for organic fertilisers, the application of a mineral fertiliser, yes or no, can be evaluated regarding the nitrate-N residue.

The application of mineral fertilisation is a categorical variable (MinF) with two categories:

- Y: mineral fertilisers are applied
- N: mineral fertilisers are not applied

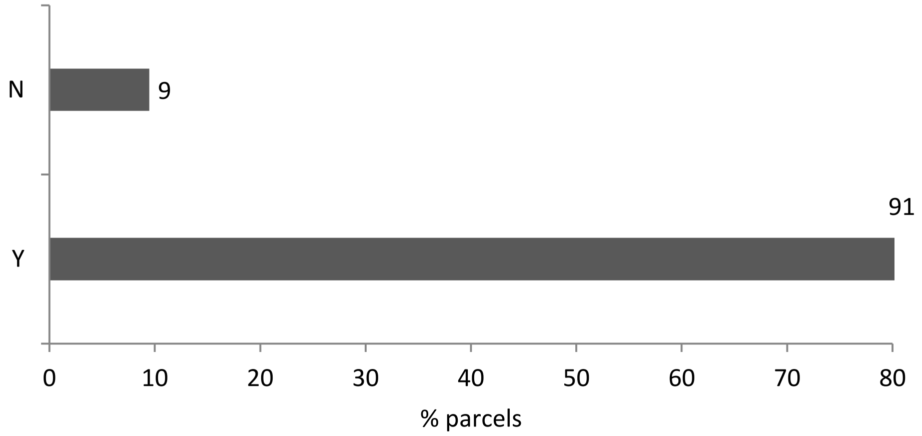


Figure 425: Frequency of parcels with and without application of mineral fertilisers in the monitoring network in 2016, 2017 and 2018.

4.1.5.4 Total organic N-fertilisation-dose

The applied amount of total organic nitrogen (kg N/ha) is the sum of the nitrogen applied by organic fertilisers and the nitrogen applied by possible grazing animals. This variable is a **continuous, numerical variable (N_{org_TOT}).**

Opposite to the monitoring assignment for which the fertilisation of the whole year was reported, only the fertilisation before sampling for the nitrate-N residue will be used in this explorative analysis. On 185 parcels organic N-fertilisation happened after sampling for the nitrate-N residue.

	n	Average	median	min-max
N_{org_TOT} (kg N/ha)	1387	209 ± 108	195	0 - 695

4.1.5.5 Mineral N-fertilisation-dose

The dose of mineral N-fertilisation is a continuous, numerical variable (N_{min}). Mineral fertilisers were never applied after sampling for the nitrate-N residue.

	n	Average	median	min-max
N_{min} (kg N/ha)	1387	136 ± 99	122	0 - 591

4.1.5.6 Total effective N-fertilisation-dose

The effective nitrogen is the nitrogen that will be available during the growing season. It includes all the nitrogen of mineral fertilisers and the effective nitrogen of organic origin. This was further specified in '2.2 Fertilisation'. **The total effective N-fertilisation is a continuous, numerical variable (N_{Eff}).**

	n	Average	median	min-max
N_{Eff} (kg N/ha)	1387	248 ± 124	237	0 - 812

4.1.5.7 Type organic fertiliser

Information about the fertilisers used on the monitored parcels was obtained from the farmers. **The type of organic fertiliser is a categorical variable (TypOrg).** Nine categories of organic fertiliser were distinguished:

- Cattle slurry
- Pig slurry
- Cattle slurry and cattle manure
- Cattle slurry and other organic fertilisers
- Cattle manure
- Pig slurry and cattle slurry
- Pig slurry and cattle manure
- Pig slurry and other organic fertilisers
- Other organic fertilisers

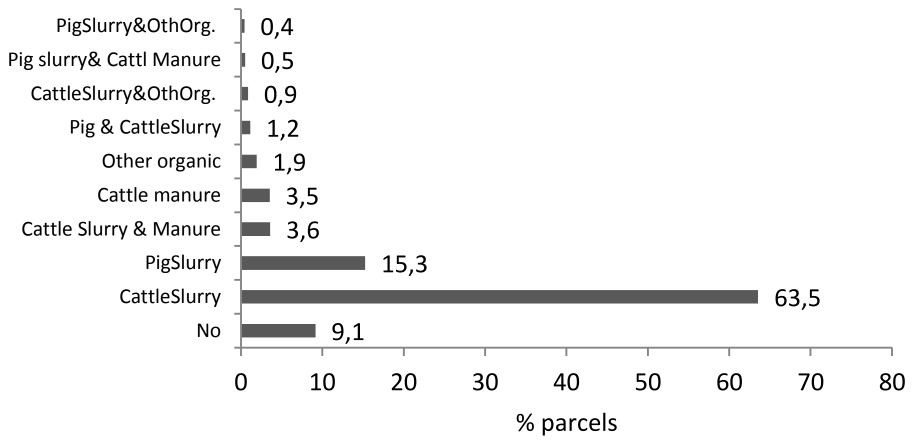


Figure 426: Frequency of type of used organic fertilisers in the monitoring network in 2016, 2017 and 2018.

4.1.5.8 Grazing

Because of the focus on parcels cultivated with grass, the effect of the parameter **"grazing"** is useful to evaluate. It **is a categorical parameter (Grazing)**, with only two categories:

- Y: Yes, the parcel was grazed
- N: No, the parcel was not grazed and only cut.

The parameter "Grazing" is obviously only evaluated on parcels cultivated with grass and grass with less than 50 % clover. This parameter was set as missing value for the parcels cultivated with maize.

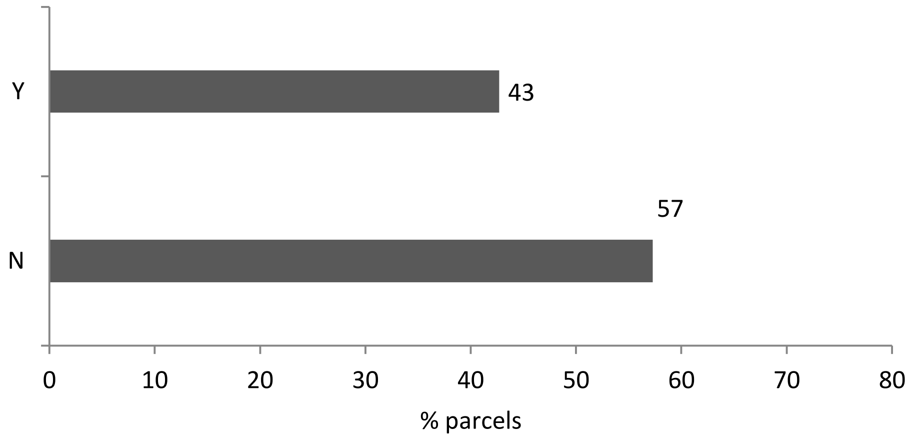


Figure 427: Frequency of grazed and not grazed parcels cultivated with grass or grass and less than 50 % clover in the monitoring network in 2016, 2017 and 2018.

4.1.5.9 Time between last day of grazing and sampling nitrate-N residue

The interval between the last moment of grazing and the time of sampling for the nitrate-N residue was evaluated for the grazed parcels. This interval between last grazing and sampling for the nitrate-N residue is expressed in days (Date sampling nitrate-N – Date last grazing) and **is a continuous variable (IntGrNRes)**.

	n	Average	median	min-max
IntGrNRes (days)	345	14 ± 25	0	0 - 164

Many parcels were still grazed after sampling for the nitrate-N residue. The last date of grazing was therefore limited to the sampling date. The variable ranges by consequence between 0 and x days. A zero means that the parcel was grazed at the time of sampling. The positive figures mean that grazing stopped x days before sampling for the nitrate-N residue.

4.1.5.10 Time between last organic fertiliser and sampling nitrate-N residue

The interval between the last moment of application of an organic fertiliser and the moment of sampling for the nitrate-N residue was also evaluated. The interval is expressed in days (**Date sampling nitrate-N – Date last organic fertiliser**) and **is a continuous variable (IntOrgFNRes)**. On some parcels organic fertilisers were applied after sampling for the nitrate-N residue. Only the date and interval of the last organic fertiliser before sampling for the nitrate-N residue is evaluated. The application of an organic fertiliser after sampling is not relevant for the measured nitrate-N residue.

	n	Average	median	min-max
IntOrgFNRes (days)	1259	151 ± 59	167	1 - 285

4.1.5.11 Time between last organic fertilisation and sampling nitrate-N residue

The last moment of organic fertilisation is the last application of an organic fertiliser or the last moment of grazing. The interval between this moment and the time of sampling for the nitrate-N residue was evaluated. The interval is expressed in days (**Date sampling nitrate-N – Date last organic fertilisation**) and **is a continuous variable (IntOrgNRes)**. As described before only the last moment before sampling is evaluated.

	n	Average	median	min-max
IntOrgNRes (days)	1342	116 ± 78	142	0 - 268

4.1.5.12 Time between last mineral fertilisation and sampling nitrate-N residue

The interval between the last moment of mineral fertilisation and the moment of sampling for the nitrate-N residue was also evaluated. The interval is expressed in days (**Date sampling nitrate-N – Date last mineral fertilisation**). It **is a continuous variable (IntMinNRes)**. Mineral fertilisers were not applied after sampling for the nitrate-N residue.

	n	Average	median	min-max
IntMinNRes (days)	1261	149 ± 51	159	22 - 254

4.1.5.13 N-export by harvest

Estimations of yield were obtained from the farmers. **The nitrogen export** by the harvested crops is expressed in kg N/ha. It **is a continuous variable (Nexp).**

	n	Average	median	min-max
Nexp (kg N/ha)	1392	254 ± 94	255	22 - 570

4.1.6 Fertilisation standards and nitrate-N residue standards

Since 2016 the manure policy evaluates the amount of total effective N and the amount of organic N. Concerning nitrogen, 2 fertilisation standards are imposed: a standard regarding the total amount of effective nitrogen and a standard regarding the amount of total organic nitrogen (Table 82).

The fertilisation standard regarding the total amount of effective nitrogen is differentiated for soil texture, crop and crop management. This standard is equal for derogation and no derogation parcels. The fertilisation standard regarding the amount of total organic nitrogen is different depending on the application of derogation and the cultivated crop.

Table 82: Overview of the nitrogen fertilisation standards of MAP V regarding effective and organic nitrogen on derogation and no derogation parcels cultivated with grass, grass and less than 50 % clover or maize.

		Effective nitrogen		Organic nitrogen	
		Derogation / no derogation		Derogation	No derogation
Crop	Combination/ regime	Sandy soils	No sandy soils	All soils	
Grass or grass and <50% clover	Cutting	300	310	250	170
	Cutting & grazing	235	245	250	170
Maize	No cut of grass	-/135	-/150	250	170
	Cut of grass	200	230	250	170

The average fertilisation data in Table 11, Table 13, Table 16 and Table 18 showed indeed that fertilisation standards are not always respected. Respecting the fertilisation standards could be an interesting parameter to evaluate regarding the nitrate-N residue. However, evaluation of exceeding the fertilisation standards at parcel level is not that clear. Within the framework of the farm-specific approach, it is postulated that the fertilisation standards at farm level need to be respected. At parcel level however, it is allowed to apply fertilisers until the double of the fertilisation standard of the respective parcel. For the following discussion and decision if fertilisation standards are respected or not, the 'single' fertilisation standard of the respective parcel is set as reference, not the 'double fertilisation' standard as it's allowed within the framework of the farm-specific approach.

4.1.6.1 Fertilisation standard total effective N

Regarding the set-up of the monitoring network, the standard for total effective nitrogen should range from 135 kg N/ha till 310 kg N/ha. However, on the farms without derogation some parcels appeared to be situated in 'vulnerable region-nature', more specific 'natural area'. Since it were parcels cultivated with grass, these parcels can only be grazed and the amount of effective N is restricted to 34 kg N/ha. **The standard for total effective nitrogen** is used as a **continuous variable** in the statistical analysis **(StandEffN).**

	n	Average	median	min-max
StandEffN (kg N/ha)	1436	224 ± 48	235	34 - 310

The number of fertilisation standards is rather limited and this fertilisation standard is correlated with soil, crop and crop management.

4.1.6.2 Fertilisation standard total organic N

Under derogation conditions, the standard for total organic N ranges from 200 to 250 kg N/ha. In the monitoring network, the standard for total organic nitrogen under derogation is 250 kg N/ha, since the involved derogation crops are only grass, grass and less than 50% clover and maize preceded by a cut of grass. Therefore, the fertilisation standard for total organic N has only 2 values in the monitoring network, being 170 kg N/ha when no derogation is requested and 250 kg N/ha when derogation is requested.

Like the fertilisation standard for total effective N also **the standard for total organic N is** used as **a continuous variable** in the statistical analysis **(StandOrgN).**

	n	Average	median	min-max
StandOrgN (kg N/ha)	1436	210 ± 40	210	170 - 250

This fertilisation standard is not correlated with crop but directly correlated with the application of derogation.

4.1.6.3 Respecting fertilisation standard total effective N

Respecting the fertilisation standard for total effective N is judged by comparing the applied amount of total effective N and the standards shown in Table 82. This variable **is a categorical variable (RespStandEffN)** with two categories:

- Y : The applied amount of total effective N was less than or equal to the standard for total effective N
- N : The applied amount of total effective N exceeded the standard for total effective N

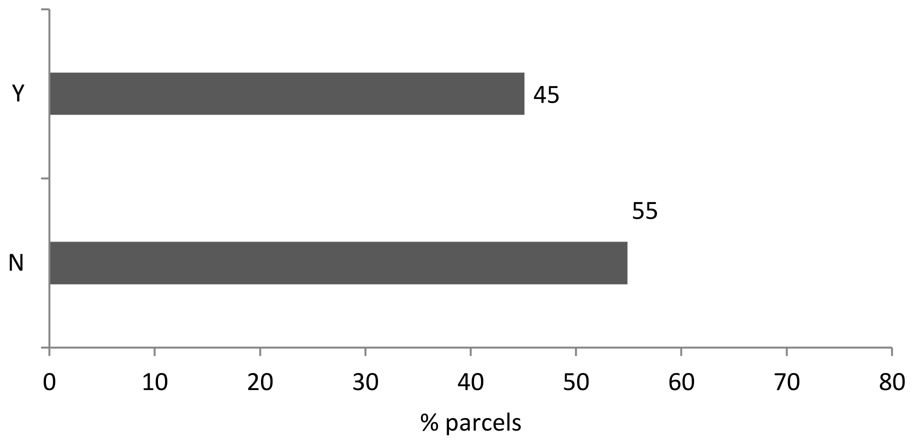


Figure 428: Frequency of respecting the fertilisation standard for total effective N in the monitoring network in 2016, 2017 and 2018.

4.1.6.4 Respecting fertilisation standard total organic nitrogen

The allowed amount of organic nitrogen per hectare is the key parameter/subject of derogation. In the monitoring network the fertilisation standard for total organic nitrogen amount 170 or 250 kg N/ha.

Respecting the fertilisation standard for total organic N is judged by comparing the applied amount of total organic N and these standards. This variable **is a categorical variable (RespStandOrgN)** with two categories:

- Y : The applied amount of total organic N was less than or equal to the standard for total organic N
- N : The applied amount of total organic N exceeded the standard for total organic N

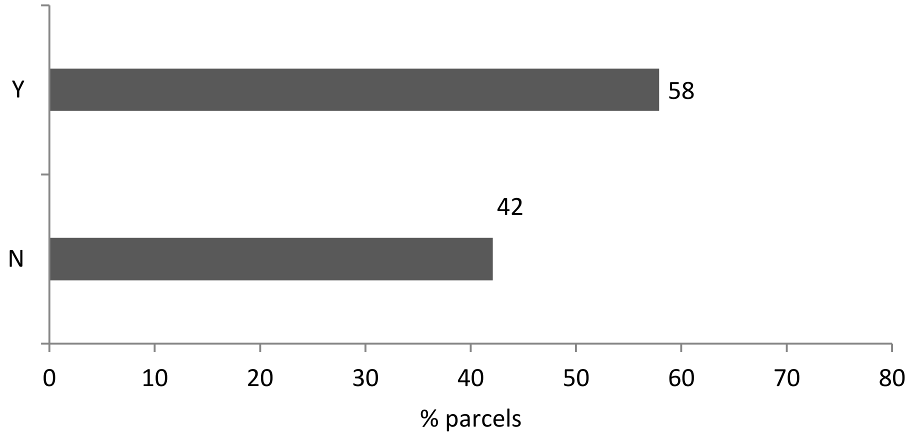


Figure 429: Frequency of respecting the fertilisation standard for total organic N in the monitoring network in 2016, 2017 and 2018.

4.1.6.5 Nitrate-N residue standard

The standard for the nitrate-N residue of a parcel depends on:

- Being part of a focus farm
- Crop
- Soil texture

The Flemish Land Agency (VLM) uses two standards or two levels for evaluation of the nitrate-N residue. Only the first nitrate-N standard, the lowest value, is considered in this statistical analysis.

Table 83: Overview of the first level nitrate-N residue standards of MAP V regarding parcels cultivated with grass, grass and less than 50% clover or maize.

Crop	Soil texture	No Focus farm	Focus farm
Grass or grass and <50% clover	Sandy soils	90	70
	No sandy soils	90	70
Maize	Sandy soils	90	70
	No sandy soils	90	80

Regarding the monitoring network the standard for the nitrate-N residue has only 3 values (Table 83). **The standard for the nitrate-N residue is** expressed in kg NO_3-N/ha and will be used as **a categorical variable (StandNres)** with 3 categories:

- 70 kg NO_3-N/ha
- 80 kg NO_3-N/ha
- 90 kg NO_3-N/ha

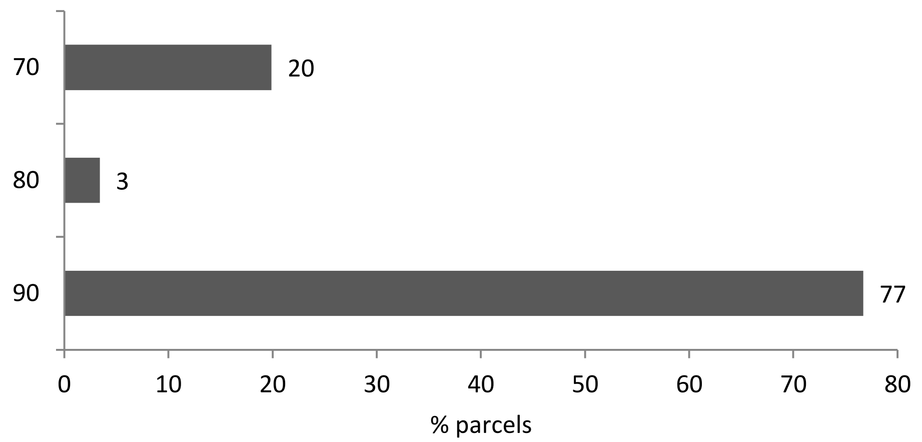


Figure 430: Frequency of the standards for the nitrate-N residue in force in the monitoring network in 2016, 2017 and 2018.

4.1.7 Farm parameters

Parameters as farm acreage, being a focus farm or not, a.o. could influence the crop and parcel management which could result in differences in nitrate-N residue. Therefore also a selection of farm parameters were evaluated.

4.1.7.1 Farm acreage

The total acreage of the farm is shown in hectares. It **is a continuous variable** and displayed in the further analysis as **"AcrFarm".**

	n	Average	median	min-max
AcrFarm (ha)	1440	66.4 ± 37.2	58.2	0.71 - 345

4.1.7.2 Proportion acreage with derogation

The proportion acreage with derogation is the share of the acreage of the farm that is cultivated under derogation conditions. This proportion is expressed in percentage. It **is a continuous variable (%Dero)**.

	n	Average	median	min-max
%Dero	1440	35.6 ± 37.8	23.4	0.0 – 100.0

4.1.7.3 Acreage grass-proportion

Since only 3 crops are involved in the monitoring network, the proportion of the acreage of these crops on farm level is included in the statistical evaluation. The proportions are shown in percentages.

The proportion acreage grass is a continuous variable (%AcrGrass).

	n	Average	median	min-max
%AcrGrass	1440	36.8 ± 18.2	37.6	0.0 – 100.0

4.1.7.4 Acreage grass and less than 50% clover-proportion

For each farm the proportion of the acreage of grass and less than 50% clover was determined. **The proportion of the acreage grass and less than 50% clover is a continuous variable (%AcrGrClov).**

	n	Average	median	min-max
%AcrGrClov	1440	5.8 ± 11.4	0.0	0.0 – 97.4

4.1.7.5 Acreage maize-proportion

For the acreage of maize no distinction was made between silage maize and grain maize in first instance. **The proportion of the acreage maize is a continuous variable (%AcrMaize).**

	n	Average	median	min-max
%AcrMaize	1440	37.0 ± 15.7	37.9	0.0 – 100.0

4.1.7.6 Proportion grass under derogation conditions

Because of the evaluation in the frame of the monitoring network, also the proportion of grass under derogation can be interesting. It is the ratio of the acreage grass under derogation to the total acreage of grass, multiplied by 100. **The proportion of grass under derogation is a continuous variable (%DeroGrass).** For parcels of farms without grass, this variable is set as missing value.

	n	Average	median	min-max
%DeroGrass	1413	44.4 ± 45.6	19.0	0.0 – 100.0

4.1.7.7 Proportion maize under derogation conditions

Also **the proportion of maize under derogation** is evaluated. It is the proportion of the acreage maize which is cultivated under derogation conditions.

	n	Average	median	min-max
%DeroMaize	1422	32.8 ± 38.5	0.0	0.0 – 100.0

This variable **(%DeroMaize) is** also **a continuous variable**. For parcels of farms without maize, this variable is set as missing value.

4.1.7.8 Ratio acreage grass to acreage maize

The ratio of the acreage grass to the acreage maize appeared to be an interesting parameter in a statistical analysis of the nitrate-N residue directed by the Flemish Land Agency (VLM, 2018). This parameter was therefore also evaluated in this statistical evaluation. The ratio **is a continuous variable (RatGrM).** On farms without maize, the denominator of the ratio would be zero. In that case, the result is referred to as a missing value.

	n	Average	median	min-max
RatGrM	1422	1.5 ± 4.7	1.0	0.0 – 89.7

Visualising the variation of this ratio in the monitoring network, showed two outlying values. One farm had in 2016 almost 48 times as much grass as maize on the farm. A second farm had in 2018 only 0.31 ha maize while 27.82 ha grass was cultivated, resulting in a grass/maize ratio of 89.7. For further statistical analysis in paragraphs 4.2 "Single effects and correlations" and further, this parameter will be set as a missing value for these farms.

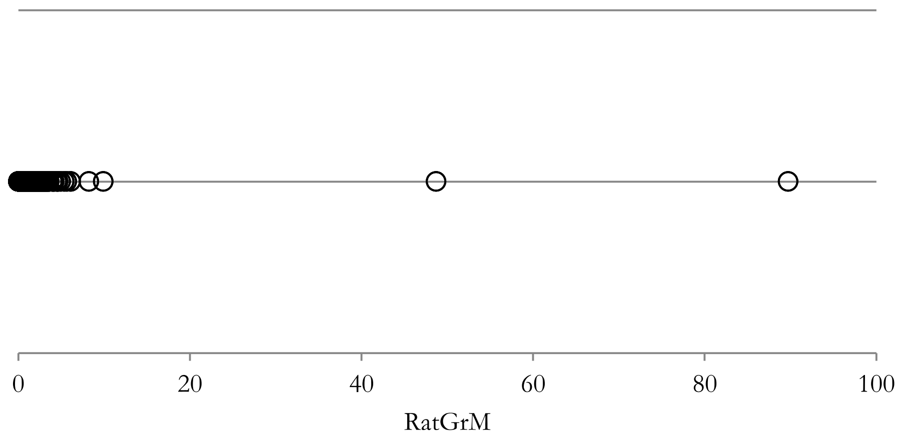


Figure 431: Spreading of the ratio of the acreage grass to the acreage maize in the monitoring network in 2016, 2017 and 2018.

4.1.7.9 Focus farm

Focus farms are minimally subjected to lower standards for the nitrate-N residue, a more stringent timing of fertilisation and the obligation to sow catch crops. A farm can be designated as a focus farm for several reasons. Exceedance of the nitrate-N residue standards can be a reason but even so is the location of the farm and it's parcels. Farms of which more than 50 % of the acreage is situated in focus area are designated as focus farms by location. Every year areas are marked as focus area or not by ministerial decree, based on water quality. Regions where the threshold value of 50 mg NO_3/l in surface water is exceeded or regions where the evolution of the nitrate concentration in the surface water is insufficient, are marked as focus area.

This variable (Focus) is categorical with only two categories:

- Y: Yes, the parcel is part of a focus farm
- N: No, the parcel is part of a farm which is <u>not</u> designated as focus farm

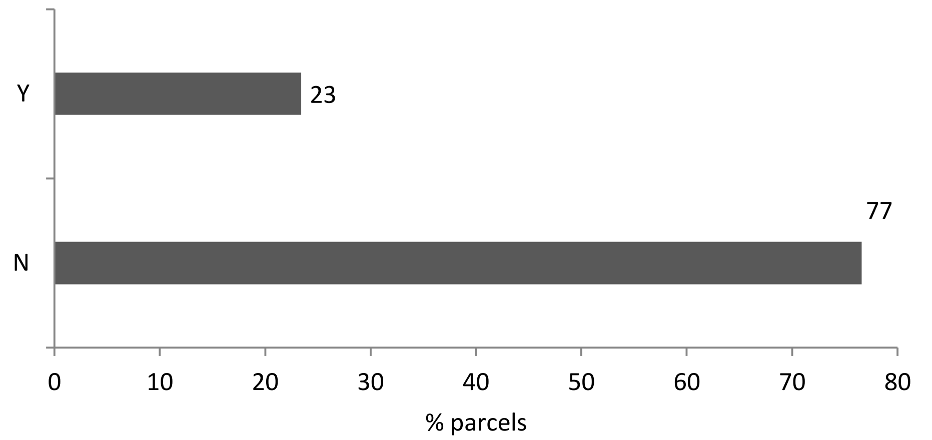


Figure 432: Frequency of parcels belonging to a focus farm or not in the monitoring network in 2016, 2017 and 2018.

4.1.8 Farm N-indicators

Parameters which are situated at the level of the farm and which are related to the N-fertilisation are grouped as 'Farm N-indicators'.

At the Flemish Land Agency (VLM), following data at farm level are available:

- Net organic nitrogen production
- N-fertilisation by organic fertilisers
- Reported N-fertilisation by mineral fertilisers
- Reported N-fertilisation by other fertilisers
- N-fertilisation as total effective N
- The surplus of organic N
- The surplus of effective N

These values are expressed as kg N/farm. For further analysis, these results were standardised by converting them in amounts of N per hectare. The values at farm level were divided by the total acreage of the farm.

4.1.8.1 Net organic nitrogen production

The net organic nitrogen production is the raw organic N production at farm level minus the N-losses by emission at the stables and at storage. **The net organic N production is a continuous variable (ProdNOrgFarm)**, expressed in kg N/ha.

	n	Average	median	min-max
ProdNOrgFarm (kg N/ha)	1440	226 ± 161	208	0.0 – 1640

Plotting of the values of the net organic nitrogen production reveals that one farm has an outlying net organic nitrogen production in 1 year. For further statistical analysis in paragraphs 4.2 ‘ Single effects’ and further, the balance data of this farm will not be used.

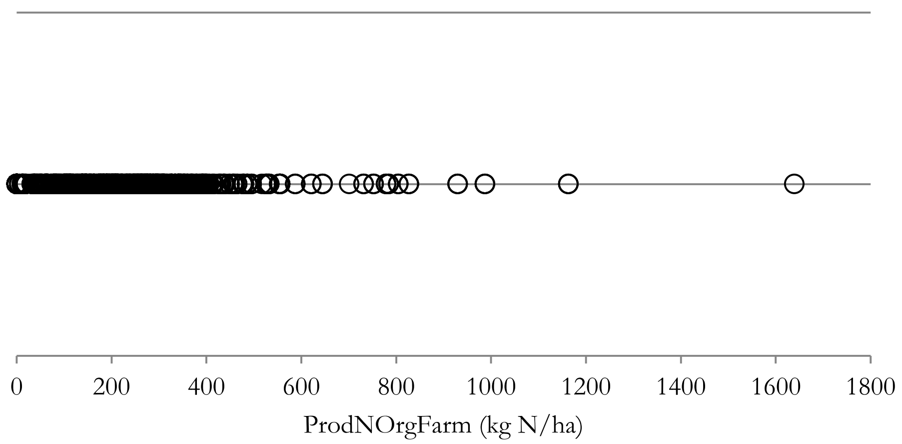


Figure 433: Spreading of the net organic nitrogen production at farm level (kg N/ha) in the monitoring network in 2016, 2017 and 2018.

4.1.8.2 Farm use organic N

The use of organic nitrogen is determined by VLM taking into account the net organic N-production, supply of organic nitrogen, disposal of organic nitrogen and the difference in storage of organic nitrogen between the beginning of the year x and the beginning of year x+1.

Farm use organic N = net organic N-production + supply of organic nitrogen – disposal of organic nitrogen + difference storage organic N ($storage_x$- $storage_{(x+1)}$)

This variable **is a numerical, continuous variable (UseNOrgFarm)** and expressed in kg N/ha.

	n	Average	median	min-max
UseNOrgFarm (kg N/ha)	1440	170 ± 115	166	0 – 2392

Plotting these values of the use of organic nitrogen at farm level showed that for one farm a clearly outlying use of organic nitrogen was calculated. For further statistical analysis in paragraphs 4.2 'Single effects and correlations' and further, the balance data of this farm will not be used.

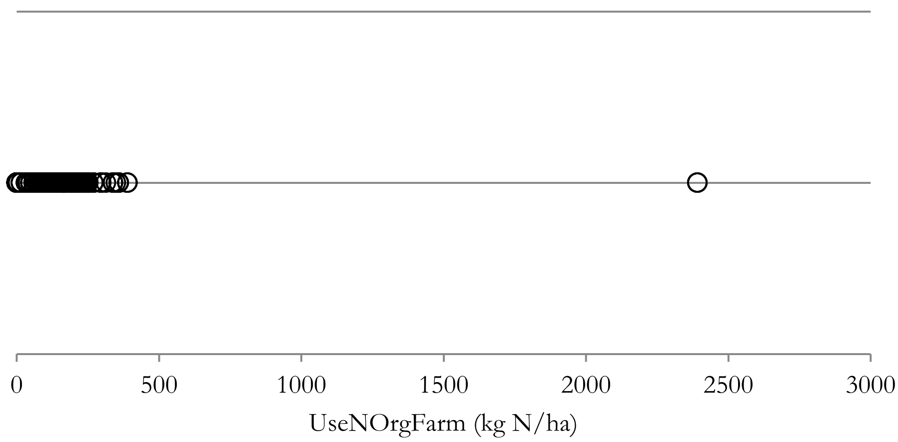


Figure 434: Spreading of the use of organic nitrogen at farm level (kg N/ha) in the monitoring network in 2016, 2017 and 2018.

4.1.8.3 Farm use mineral N

The **use of mineral N at farm level** is based on registration by the farmer at VLM. The standardised use of mineral N at farm level **is a numerical, continuous variable (UseNMinFarm)**, expressed in kg N/ha. The use of mineral N at farm level showed no remarkable values (Figure 435).

	n	Average	median	min-max
UseNMinFarm (kg N/ha)	1440	83 ± 37	89	0 – 160

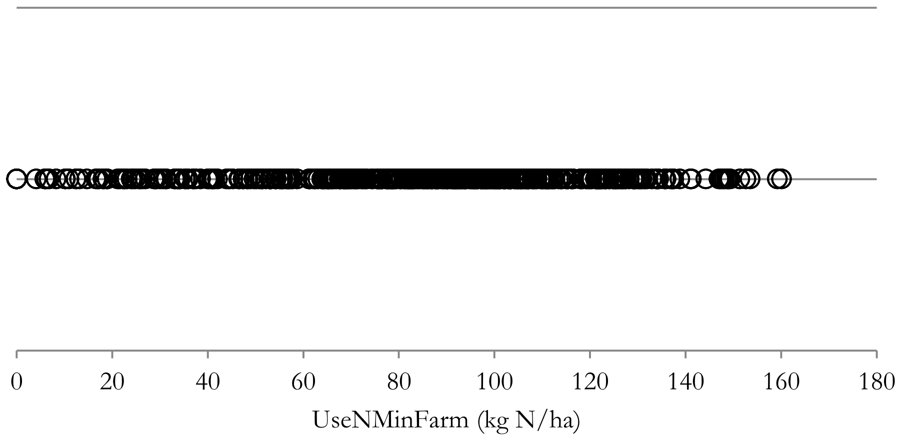


Figure 435: Spreading of the use of mineral nitrogen at farm level (kg N/ha) in the monitoring network in 2016, 2017 and 2018.

4.1.8.4 Farm use other N

The use of nitrogen of other fertilisers at farm level is determined by VLM. The standardised use of nitrogen of other fertilisers at farm level **is a numerical, continuous variable (UseNOthFarm)**, expressed in kg N/ha.

	n	Average	median	min-max
UseNOthFarm (kg N/ha)	1440	3 ± 12	0	0 – 137

Concerning the use of nitrogen of other fertilisers at farm level, two values stood out (Figure 436). It concerned 1 farm, but balance data of 3 years. These balance data will not be used in the further explorative statistical analysis.

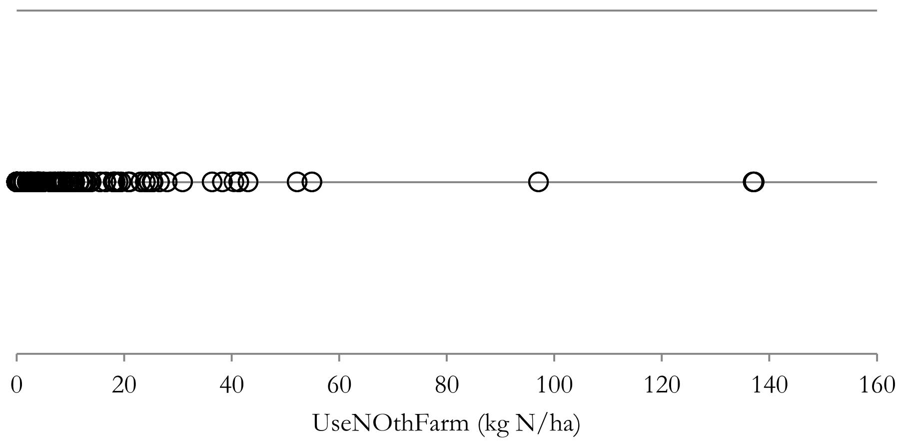


Figure 436: Spreading of the use of nitrogen of other fertilisers at farm level (kg N/ha) in the monitoring network in 2016, 2017 and 2018.

4.1.8.5 Farm use total N

The use of total nitrogen at farm level is determined by VLM by taking into account the amounts of organic, mineral and other nitrogen. The standardised use of total nitrogen at farm level **is a numerical, continuous variable (UseNTotFarm)**, expressed in kg N/ha.

	n	Average	median	min-max
UseNTotFarm (kg N/ha)	1440	256 ± 121	265	0 – 2392

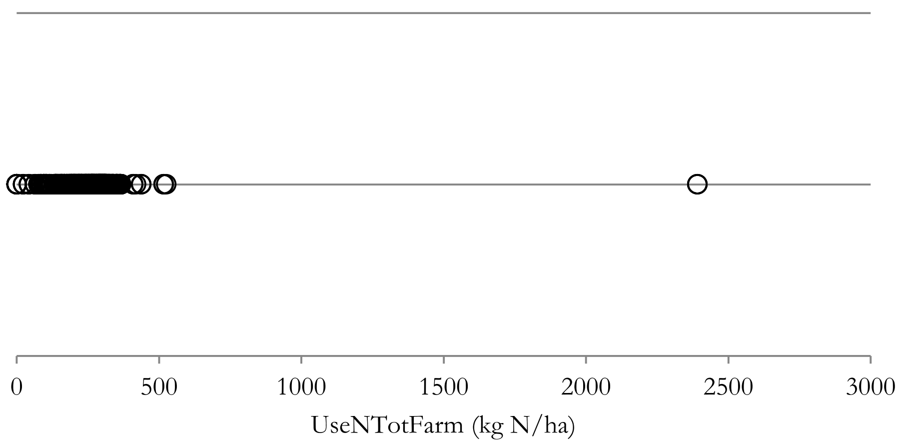


Figure 437: Spreading of the use of total nitrogen at farm level (kg N/ha) in the monitoring network in 2016, 2017 and 2018.

The outstanding value of total nitrogen use at farm level concerned the farm, which was already noticed at the level of organic nitrogen use at farm level.

4.1.8.6 Farm surplus of organic N

The farm surplus of organic N is determined by VLM. The margin to dispose organic nitrogen at the farm and the net organic N production at farm level are compared. The margin to dispose organic nitrogen at farm level is determined by summing the margins to dispose organic nitrogen of all parcels, which are on their turn determined by multiplying the acreage of the parcel with the imposed standard for organic nitrogen. The farm surplus of organic N is the difference between the net organic N production at farm and the margin to dispose organic nitrogen at the farm.

$$\text{Farm surplus of organic N} = \text{net organic N-production} - N_{org}\ \text{Disposal Margin}$$

The surplus is standardised by dividing through the farm acreage. **The farm surplus of organic nitrogen is a numerical, continuous variable (SurpOrgNFarm)**, expressed in kg N/ha. Positive values indicate that the farm produces more organic nitrogen than it can dispose on its own farmland. Negative figures indicate that the farm produces less organic nitrogen than it could dispose on its own farmland.

	n	Average	median	min-max
SurpOrgNFarm (kg N/ha)	1440	30 ± 149	11	-198 – 1469

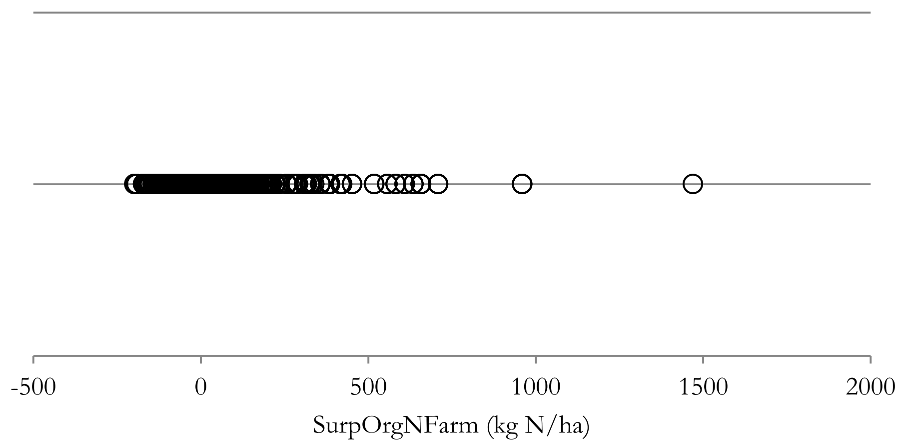


Figure 438: Spreading of the farm surplus of organic nitrogen (kg N/ha) in the monitoring network in 2016, 2017 and 2018.

Since the farm surplus of organic nitrogen involves the net organic nitrogen production, the outlying value (Figure 438) concerns the farm mentioned in 4.1.8.1.

4.1.8.7 Farm surplus of effective N

The farm surplus of effective N is determined by VLM. The margin to dispose effective nitrogen at farm level and the net production of effective N are compared.

$$\text{Farm surplus of effective N} = \text{net } N_{Eff}\text{-production} - N_{Eff} \text{ Disposal Margin}$$

The surplus is standardised by dividing through the farm acreage. **The farm surplus of effective nitrogen is a numerical, continuous variable (SurpEffNFarm)**, expressed in kg N/ha. Positive values indicate that the farm produces more effective nitrogen than it can dispose on its own farmland. Negative figures indicate that the margin to dispose effective N on own farmland is larger than the production of effective nitrogen at the farm.

	n	Average	median	min-max
SurpEffNFarm (kg N/ha)	1440	-93 ± 90	-110	-264 – 589

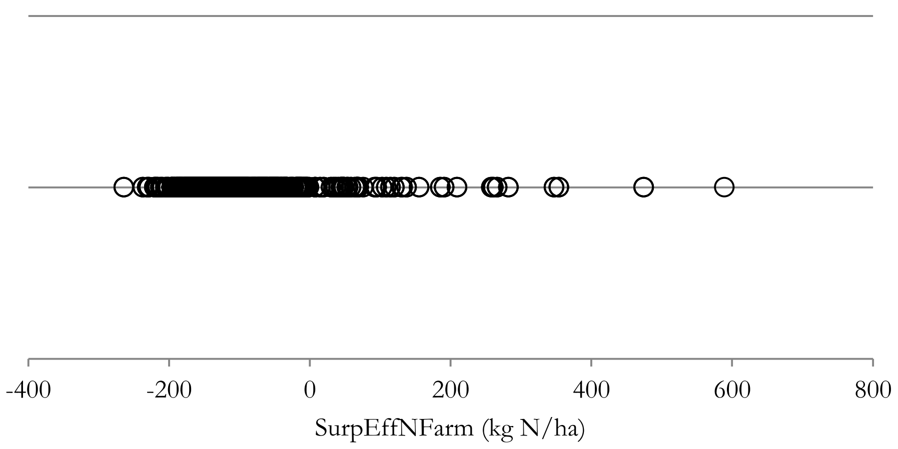


Figure 439: Spreading of the farm surplus of effective nitrogen (kg N/ha) in the monitoring network in 2016, 2017 and 2018.

4.2 Single effects and correlations

The effect of the former described parameters, categorical and continuous, on the nitrate-N residue is evaluated for each parameter separately by means of an analysis of variance or a regression analysis. An analysis of variance is used if the investigated parameter or variable is categorical. For continuous or numerical variables a regression analysis is used.

The number of cases on which these analyses, being an analysis of variance or a single regression analysis, are based, can differ from the numbers mentioned in the former paragraph. The number of cases could decrease because of missing values when the parameters were linked to the log-transformed nitrate-N residue.

Afterwards interactions between parameters will be investigated by Pearson correlation tests.

To meet the conditions for these parametric analyses, more specific normality of data and homogeneity of variances, the nitrate-N residue was log-transformed. The statistical analyses are performed on the transformed data; however for comprehensiveness the mean values and standard deviations of the untransformed data are presented. Even so for the single linear regression: the functions and coefficients (intercept and slope) were calculated based on the log-transformed data. The intercept and slope are thus indicative. More important are the statistical key figures ‘p’ and ‘R^2’. They indicate respectively the significance of the model and the percentage of the variation in the dataset explained by the model. The regression analyses are restricted to a single linear regression analysis. As for the categorical variables, a significant effect is indicated by the p-value and significant different values are indicated based on the post-hoc Unequal HSD test by different letters. The Unequal HSD test is, like the variance analysis, performed on the log-transformed data. This may sometimes result in a less logic indication of significant different values, since the shown values are not log-transformed.

4.2.1 Single effects

An overview of the single effects of the evaluated independent variables on the nitrate-N residue is given in Table 84. The p- and R^2-values permit to compare the significance and importance of the independent variables for the nitrate-N residue.

Based on the single effects 39 parameters appeared to have a significant effect on the nitrate-N residue. Each variable separately could declare 0.3 to 17 % of the variation. The variables that appeared to have a significant effect on the nitrate-N residue are further discussed and commented in descending order of significance and 'R^2'.

It is appropriate to mention at the start that the terms 'positive effect' and 'negative effect' could be confusing. They are meant to be interpreted pure mathematically. A positive effect means that a higher value of the independent variable results in a higher nitrate-N residue. A negative effect means that the nitrate-N residue decreases when the independent variable increases. A positive or negative effect has nothing to see with a better or worse nitrate-N residue.

Table 84: Overview of the evaluated variables: concise description, indication of type, effect. P-value and R² as result of the one-way ANOVA or single regression analysis.

Variable		Type of variable	Effect	p-value	R²
Year	Year of monitoring	categorical	2018>2017>2016	0,00	0,076
Rain	Rainfall during 30 days before sampling for the nitrate-N residue (mm)	continuous	(+)	0,09	0,002
Temp	Average temperature during the period July-September (°C)	continuous	(+)	0,14	0,002
Rdef	Rainfall deficit cumulated over period of April 1st–Sept. 30th (mm)	continuous	+	0,00	0,038
$SPI3_{SpringCat}$	SPI-3 on July 1st	categorical	ExtW≤VeryW=ModW≤Norm=VeryD=ExtD≤ModD	0,00	0,065
$SPI3_{SpringCont}$	SPI-3 on July 1st	continuous	-	0,00	0,052
$SPI3_{SummerCat}$	SPI-3 on October 1st	categorical	VeryD≤extD=ModW≤Norm<ModD	0,00	0,060
$SPI3_{SummerCont}$	SPI-3 on October 1st	continuous	+	0,00	0,009
AgrReg	Agricultural region	categorical		0,56	0,002
Text	Soil texture	categorical		0,46	0,003
Drain	Draining level	categorical		0,08	0,005
$pH_{0\text{-}30cm}$	pH of soil layer 0-30cm	continuous	+	0,00	0,009
$\%OC_{0\text{-}30cm}$	Percentage organic carbon of soil layer 0-30cm	continuous	+	0,00	0,006
AcrParc	Acreage of the parcel (ha)	continuous		0,91	0,000
ConvM	Being a meadow converted during past 15 years: yes or no	categorical		0,44	0,000
YrsConv	Years after conversion	continuous		0,39	0,010
Crop	Main crop	categorical	GrassClover=Grass<Maize	0,00	0,171
SCrop	Second crop	categorical	MNL=BlOat=RS=MixEP=WhMust=Wwheat=Spelt=NoCrop=Grass=Barley=Rye=Trit<GrCl	0,01	0,044
CropNRes	Crop sown/growing at sampling nitrate-N residue	categorical	GrCL≤Grass≤MixEP=Barley=Rye=WHMust=Trit.=MNL=Spelt=BlOat ≤Maize=WWheat≤NoCrop	0,00	0,073
IntSCrNRes	Interval between tillage and/or sowing and sampling for the nitrate-N residue	continuous		0,93	0,000
Der	Request of derogation	categorical	N<Y	0,00	0,006
OrgF	Application of organic fertilisation	categorical		0,46	0,000
MinF	Application of mineral fertilisation	categorical	N<Y	0,00	0,012
N_{org_TOT}	Applied amount of total organic nitrogen	continuous		0,23	0,001
N_{min}	Applied amount of mineral nitrogen	continuous	-	0,04	0,003
N_{Eff}	Applied amount of effective nitrogen	continuous		0,35	0,001
TypOrg	Type of used organic fertiliser	categorical		0,00	0,063
Grazing	Parcel being grazed or not	categorical	N<Y	0,04	0,005

Variable		Type of variable	Effect	p-value	R^2
IntGrNRes	Interval last moment of grazing-moment of sampling nitrate-N residue	continuous	-	0,00	0,024
IntOrgFNRes	Interval last moment of organic fertiliser-moment of sampling nitrate-N residue	continuous	+	0,00	0,020
IntOrgNRes	Interval last moment of organic fertiliser/grazing-moment of sampling nitrate-N residue	continuous	+	0,00	0,047
IntMinNRes	Interval last moment of mineral fertiliser-moment of sampling nitrate-N residue	continuous	+	0,00	0,034
Nexp	Nitrogen export by harvest	continuous	-	0,00	0,006
StandEffN	Fertilisation standard for total amount of effective N	continuous	-	0,00	0,082
StandOrgN	Fertilisation standard for amount of total organic N	continuous	+	0,00	0,006
RespStandEffN	Respect of the fertilisation standard for total effective N	categorical	Y<N	0,00	0,009
RespStandOrgN	Respect of the fertilisation standard for total organic N	categorical		0,12	0,002
StandNres	Standard for the nitrate-N residue	categorical	70<90=80	0,00	0,021
AcrFarm	Total farm acreage (ha)	continuous		0,55	0,000
%Dero	Proportion of farm acreage cultivated under derogation conditions	continuous	+	0,00	0,006
%AcrGrass	Proportion of farm acreage cultivated with grass	continuous	-	0,00	0,020
%AcrGrClov	Proportion of farm acreage cultivated with grass and less than 50% clover	continuous	-	0,00	0,007
%AcrMaize	Proportion of farm acreage cultivated with maize	continuous	+	0,00	0,032
%DeroGrass	Proportion of acreage grass cultivated under derogation conditions	continuous		0,06	0,003
%DeroMaize	Proportion of acreage maize cultivated under derogation conditions	continuous	+	0,00	0,010
RatGrM	Ratio of acreage grass to acreage maize	continuous	-	0,00	0,037
Focus	Parcel belongs to a focus farm or not	categorical	Y < N	0,01	0,006
ProdNOrgFarm	Net organic N-production at farm level/farm acreage	continuous	+	0,00	0,013
UseNOrgFarm	Use of organic nitrogen at farm level/farm acreage	continuous	+	0,05	0,003
UseNMinFarm	Use of mineral nitrogen at farm level/farm acreage	continuous	+	0,00	0,010
UseNOthFarm	Use of nitrogen of other fertilisers at farm level/farm acreage	continuous	+	0,01	0,004
UseNTotFarm	Use of total nitrogen at farm level/farm acreage	continuous	+	0,00	0,011
SurpOrgNFarm	Surplus of organic nitrogen at farm level	continuous	+	0,00	0,010
SurpEffNFarm	Surplus of effective nitrogen at farm level	continuous	+	0,00	0,012

4.2.1.1 Main crop

The main crop (Crop) appears to be the most determining parameter for the nitrate-N residue in the monitoring network in the period 2016-2018.

Table 85: Overview of the number of cases and the average, median, minimum and maximum value of the nitrate-N residue (kg NO_3-N/ha) regarding the main crop. Results of the one-way ANOVA.

	n	Average*	median	min-max
Grass	613	56 ± 55 a	36	3-344
Grass <50% clover	172	54 ± 60 a	35	7-450
Maize	591	95 ± 63 b	79	8-384
p-value		0.00		
R^2		0.17		

*Different letters indicate a significant difference based on the Unequal N HSD-test on the log transformed data.

Between grass or grass and less than 50 % clover no distinction has to be made regarding the nitrate-N residue.

4.2.1.2 Fertilisation standard total effective N

The standard for total effective nitrogen (StandEffN) ranges between 34 and 310 kg N/ha. Used in a single linear model this variable appeared to have a significant effect on the nitrate-N residue ($p = 0.00$).

$$\log(Nres) = 2.21 - 0.0023 * StandEffN \qquad p = 0.00 \qquad R^2 = 0.08$$

The effect is negative, a higher fertilisation standard for total effective nitrogen leads to a lower nitrate-N residue (Figure 440).

The fertilisation standard for total effective N is correlated with the main crop and its management.

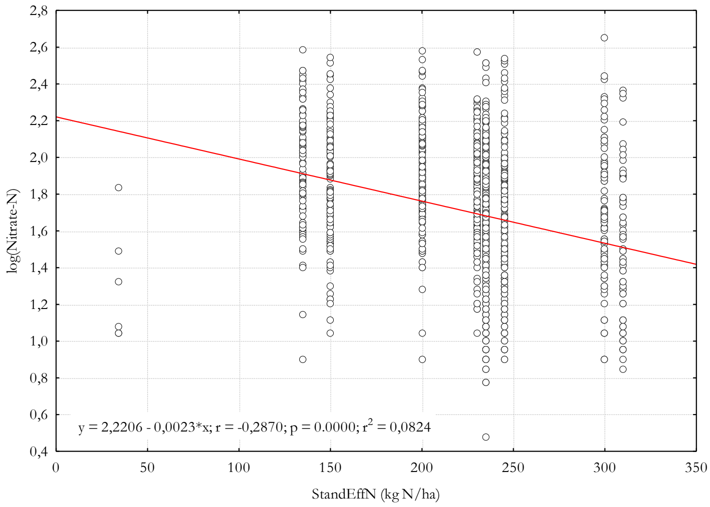


Figure 440: Log transformed nitrate-N residue regarding the standard for total effective nitrogen (StandEffN). Linear fit through the data (red line).

4.2.1.3 Year

'Year', which is a wide-ranging parameter, had a significant effect on the nitrate-N residue (p = 0.00).

Table 86: Overview of the number of cases and the average, median, minimum and maximum value of the nitrate-N residue (kg NO_3-N/ha) regarding the year of production. Results of the one-way ANOVA.

	n	Average*	median	min-max
2016	462	50 ± 41 a	40	6-379
2017	458	73 ± 59 b	58	7-328
2018	456	95 ± 75 c	78	3-450
p-value		0.00		
R^2		0.08		

*Different letters indicate a significant difference based on the Unequal N HSD-test on the log transformed data.

This parameter includes mostly climate elements, which are further specified by 5 parameters.

4.2.1.4 Standardized Precipitation Index spring-categorical

The standardized precipitation index evaluated on July 1st appeared to have a significant effect on the nitrate-N residue in a single parameter analysis. The index was evaluated both as a continuous and as a categorical parameter. In both situations the effect on the nitrate-N residue was significant ($p = 0.00$). As categorical variable ($SPI3_{SpringCat}$) explains 6 % of the variation and as continuous variable ($SPI3_{SpringCont}$) the index explains 5 % of the variation.

Table 87: Overview of the number of cases and the average, median, minimum and maximum value of the nitrate-N residue (kg NO_3-N/ha) regarding $SPI3_{Spring-Cat}$. Results of the one-way ANOVA.

	n	Average*		median	min-max
Extremely wet	279	48 ± 45	a	36	6-379
Very wet	92	53 ± 30	ab	46	9-163
Moderately wet	86	54 ± 38	ab	43	8-184
Normal	46	86 ± 69	bc	60	10-292
Moderately dry	125	90 ± 74	c	70	3-450
Very dry	287	82 ± 72	bc	58	7-374
Extremely dry	461	82 ± 64	bc	69	8-339
p-value		0.00			
R^2		0.06			

*Different letters indicate a significant difference based on the Unequal N HSD-test on the log transformed data.

4.2.1.5 Standardized Precipitation Index summer-categorical

Also the standardized precipitation index evaluated on October 1st appeared to have a significant effect ($p = 0.00$) on the nitrate-N residue.

Table 88: Overview of the number of cases and the average, median, minimum and maximum value of the nitrate-N residue (kg NO_3-N/ha) regarding $SPI3_{Summer-Cat}$. Results of the one-way ANOVA.

	n	Average*		median	min-max
Extremely wet					
Very wet					
Moderately wet	3	79 ± 18	abc	80	61-96
Normal	505	74 ± 59	b	58	7-328
Moderately dry	340	94 ± 73	c	77	3-450
Very dry	434	54 ± 50	a	40	7-379
Extremely dry	94	73 ± 62	abc	55	6-335
p-value		0.00			
R^2		0.06			

*Different letters indicate a significant difference based on the Unequal N HSD-test on the log transformed data.

4.2.1.6 Standardized Precipitation Index spring-continuous

The standardized precipitation index evaluated on July 1st and included as a continuous parameter ($SPI3_{SpringCont}$) in a single parameter analysis had also a significant effect on the nitrate-N residue (p= 0.00).

$$\log(Nres) = 1.6847 - 0.0403 * SPI3_{SpringCont} \qquad p = 0.00 \qquad R^2 = 0.05$$

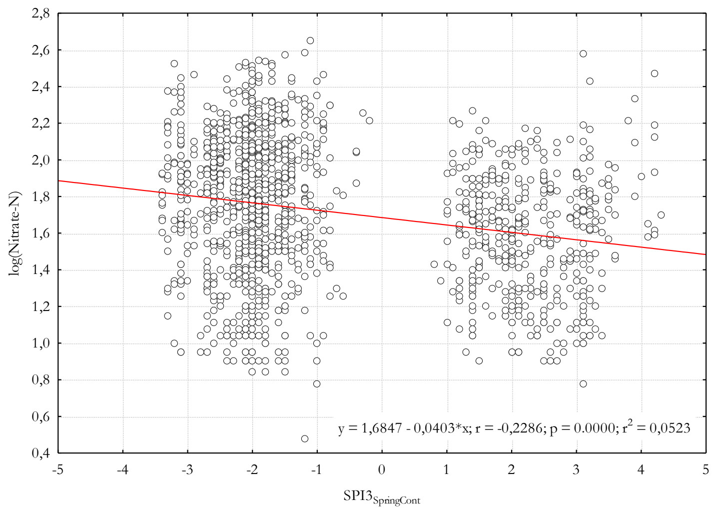


Figure 441: Log transformed nitrate-N residue regarding the standardized precipitation index evaluated on July 1st ($SPI3_{SpringCont}$). Linear fit through the data (red line).

This parameter is obviously correlated with the categorical variant of SPI_{Spring}. This continuous variant will not be picked up at the start to a multivariate model (see also 4.3 Multivariate effects).

4.2.1.7 Crop at sampling nitrate-N residue

The crop sown or growing at the time of sampling the nitrate-N residue is evidently correlated with the second crop. This parameter however should have a more direct effect on the nitrate-N residue. The one-way ANOVA showed that the crop at the time of sampling for the nitrate-N residue had a significant effect on the nitrate-N residue.

Table 89: Overview of the number of cases and the average, median, minimum and maximum value of the nitrate-N residue (kg NO_3-N/ha) regarding the crop at sampling for the nitrate-N residue. Results of the one-way ANOVA.

	n	Average*		median	min-max
No crop	219	91 ± 65	c	74	8-384
Grass	799	66 ± 58	ab	49	3-374
GrCl	175	57 ± 63	a	39	7-450
Maize	50	103 ± 95	bc	62	13-379
Winter wheat	48	92 ± 50	bc	89	19-207
MixEP	25	73 ± 47	abc	52	11-162
Barley	17	114 ± 69	abc	86	47-297
Rye	15	80 ± 47	abc	53	32-172
WhMust	5	94 ± 27	abc	96	54-123
Triticale	3	138 ± 119	abc	110	36-269
MNL	1	29 ± /	abc	29	
Spelt	1	103 ± /	abc	103	
Black Oat	1	35 ± /	abc	35	
p-value		0.00			
R^2		0.07			

*Different letters indicate a significant difference based on the Unequal N HSD-test on the log transformed data.

4.2.1.8 Time between last organic fertilisation and sampling nitrate-N residue

The interval between the last organic fertilisation (whether organic fertiliser whether grazing) and the moment of sampling for the nitrate-N residue (IntOrgNRes) was evaluated in a single linear regression. The interval, expressed in days, had a significant positive effect on the nitrate-N residue.

$$\log(Nres) = 1.5899 + 0.0010 * IntOrgNRes \qquad p = 0.00 \qquad R^2 = 0.05$$

This interval can be suspected of being correlated with the main crop. On parcels cultivated with grass, fertilisation in late summer is still possible and parcels can be grazed until winter. On parcels cultivated with maize this possibility is limited. Late grazing is impossible and fertilisation on parcels cultivated with maize is only possible for some types of organic fertiliser or in case of very early harvest.

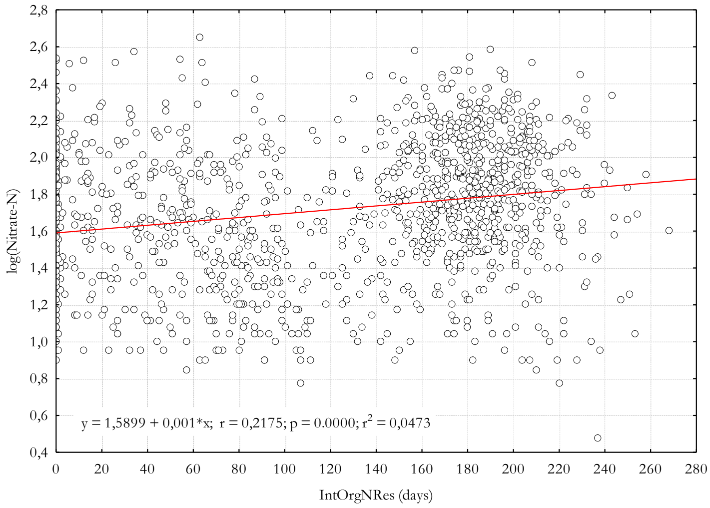


Figure 442: Log transformed nitrate-N residue regarding the interval between the last organic fertilisation (whether organic fertiliser whether grazing) and the moment of sampling for the nitrate-N residue (IntOrgNRes). Linear fit through the data (red line).

4.2.1.9 Type organic fertiliser

The type of organic fertiliser (TypOrg) used in a one-way ANOVA had a significant effect on the nitrate-N residue.

Table 90: Overview of the number of cases and the average, median, minimum and maximum value of the nitrate-N residue (kg NO_3-N/ha) regarding the used type of organic fertiliser. Results of the one-way ANOVA.

	n	Average*		median	min-max
None	120	63 ± 70	a	32	7-344
Cattle slurry	856	65 ± 56	ab	49	3-450
Pig slurry	206	84 ± 67	c	66	8-350
Cattle slurry & cattle manure	49	107 ± 65	c	103	14-339
Cattle slurry & other organic fert.	11	86 ± 60	abc	78	12-195
Cattle manure	48	95 ± 58	bc	85	8-297
Pig slurry & cattle slurry	16	79 ± 73	abc	70	9-327
Pig slurry & cattle manure	7	108 ± 53	abc	110	32-192
Pig slurry & other organic fert.	6	78 ± 48	abc	75	16-160
Other organic fertilisers	24	146 ± 102	c	121	17-379
p-value		0.00			
R^2		0.06			

*Different letters indicate a significant difference based on the Unequal N HSD-test on the log transformed data.

Other organic fertilisers comprised in the monitoring network chicken manure, goat manure and digestate.

The type of organic fertiliser is supposed to be correlated with the request of derogation since not all types of slurry and manure or allowed to apply under derogation conditions.

4.2.1.10 Rainfall deficit

The rainfall deficit during the hydrological summer (RDef) appeared to have a positive significant effect on the nitrate-N residue in a single linear regression model (p = 0.00).

$$\log(Nres) = 1.5259 + 0.0011 * RDef \qquad p = 0.00 \qquad R^2 = 0.04$$

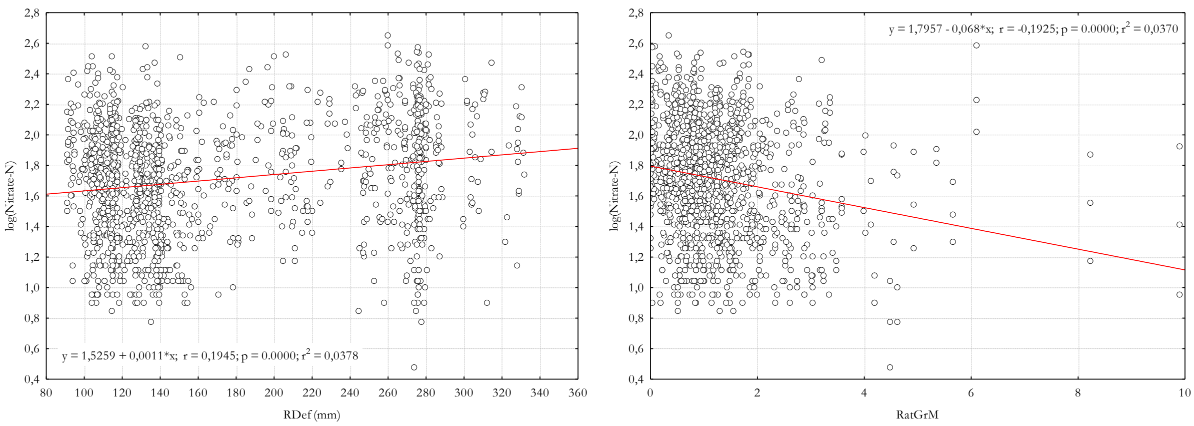


Figure 443: Log transformed nitrate-N residue regarding the rainfall deficit during the hydrological summer (RDef) (left) or against the ratio of the acreage grass to the acreage maize (RatGrM) (right). Linear fit through the data (red line).

4.2.1.11 Ratio acreage grass to acreage maize

The ratio of the acreage grass to the acreage maize (RatGrM) could be related to the nitrate-N residue for 1353 parcels. Based on a single linear regression this ratio appeared to be significantly related with the nitrate-N residue.

$$\log(Nres) = 1.7957 - 0.068 * RatGrM \qquad p = 0.00 \qquad R^2 = 0.04$$

The effect on the nitrate-N residue was negative. If the ratio increases (more grass, less maize), the nitrate-N residue decreases. This corresponds with the negative effect of the variable %AcrGrass and the positive effect of the variable %AcrMaize. The ratio RatGrM will most probably related with those parameters.

4.2.1.12 Acreage maize-proportion

The proportion of the acreage maize (%AcrMaize) evaluated against the nitrate-N residue in a single linear regression showed a significant effect of the parameter. The effect of the proportion of the acreage maize was positive (Figure 444).

$$\log(\text{Nres}) = 1.547 + 0.004 * \%\text{AcrMaize} \qquad p = 0.00 \qquad R^2 = 0.03$$

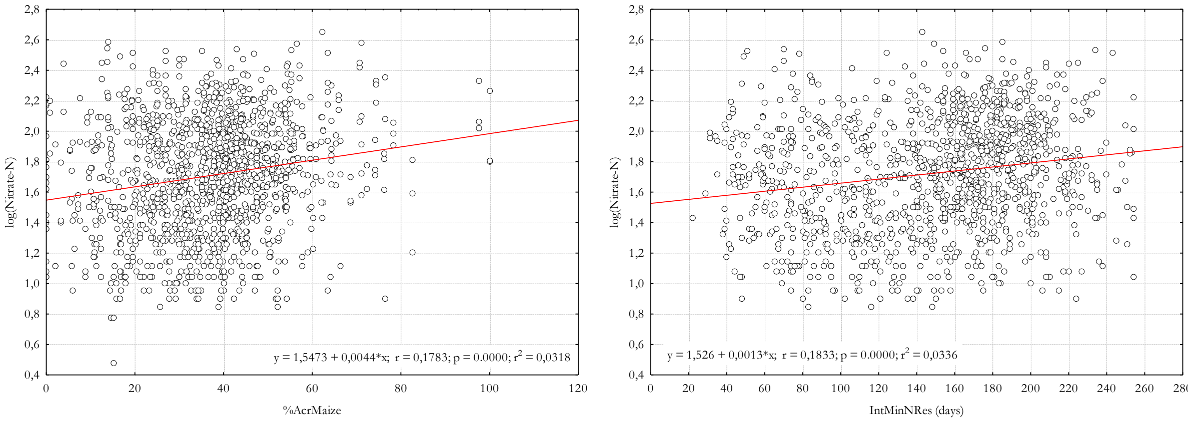


Figure 444: Log transformed nitrate-N residue regarding the proportion of the acreage maize (%AcrMaize) (left) and the interval between the last moment of mineral fertilisation and the moment of sampling for the nitrate-N residue (IntMinNRes) (right). Linear fit through the data (red line).

4.2.1.13 Time between last mineral fertilisation and sampling nitrate-N residue

The interval between the last moment of mineral fertilisation and the moment of sampling for the nitrate-N residue (IntMinNRes) was used in a single linear regression. This period appeared to have a positive and significant effect on the residual nitrate-N.

$$\log(Nres) = 1.5260 + 0.0013 * IntMinNRes \qquad p = 0.00 \qquad R^2 = 0.03$$

Also this interval can be expected to be related with the main crop. Mineral fertilisation on parcels cultivated with maize is generally restricted to spring. On parcels cultivated with grass however, mineral fertilisation is possible during the whole year.

4.2.1.14 Acreage grass-proportion

The proportion acreage grass (%AcrGrass) had a significant and negative effect on the nitrate-N residue. A higher proportion of grass on farm level results in lower nitrate-N residues.

$$\log(Nres) = 1.8174 - 0.0030 * \%AcrGrass \qquad p = 0.00 \qquad R^2 = 0.02$$

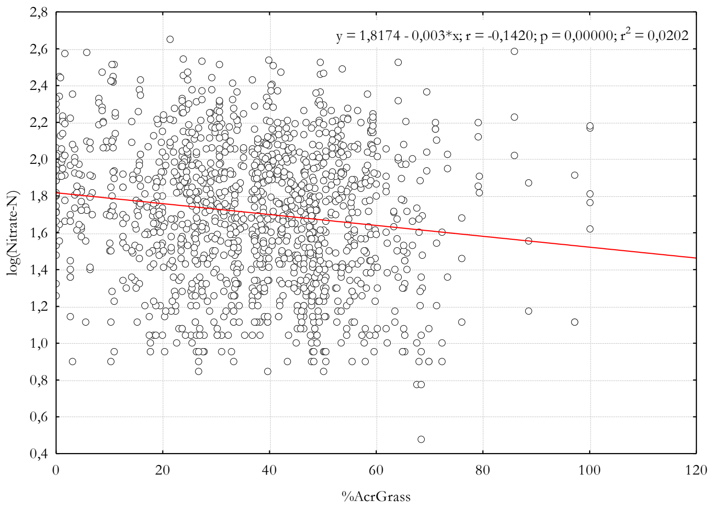


Figure 445: Log transformed nitrate-N residue regarding the proportion acreage grass (%AcrGrass). Linear fit through the data (red line).

4.2.1.15 Nitrate-N residue standard

The standard for the nitrate-N residue (StandNres) was evaluated against the nitrate-N residue in a one-way ANOVA.

The nitrate-N residue standard is differentiated regarding focus farms and regarding crop on focus farms. This parameter will therefore be correlated with the main crop and the variable 'Focus'.

Table 91: Overview of the number of cases and the average, median, minimum and maximum value of the nitrate-N residue (kg NO_3-N/ha) regarding the nitrate-N residue standard. Results of the one-way ANOVA.

	n	Average		median	min-max
70	276	59 ± 52	a	40	7-297
80	42	93 ± 48	b	84	16-239
90	1058	75 ± 65	b	56	3-450
p-value		0.00			
R^2		0.02			

*Different letters indicate a significant difference based on the Unequal N HSD-test on the log transformed data.

4.2.1.16 Time between last organic fertiliser and sampling nitrate-N residue

The interval between the last moment of application of an organic fertiliser and the moment of sampling for the nitrate-N residue (IntOrgFNRes) was evaluated in a single linear regression. The interval is expressed in days (Date sampling nitrate-N – Date last organic fertiliser). This interval had a significant, positive effect on the nitrate-N residue. It is very likely that this parameter will be correlated with the interval between the last organic fertilisation and the nitrate-N residue (IntOrgNRes - 4.2.1.8).

$$\log(Nres) = 1.5866 + 0.0009 * IntOrgFNRes \qquad p = 0.00 \qquad R^2 = 0.02$$

As stated for the variable 'IntOrgNRes' (4.2.1.8) also this interval (IntOrgFNRes) can be suspected of being correlated with the main crop. On parcels cultivated with grass, fertilisation in late summer is still possible. On parcels cultivated with maize, late fertilisation is only possible for some types of organic fertiliser or in case of very early harvest.

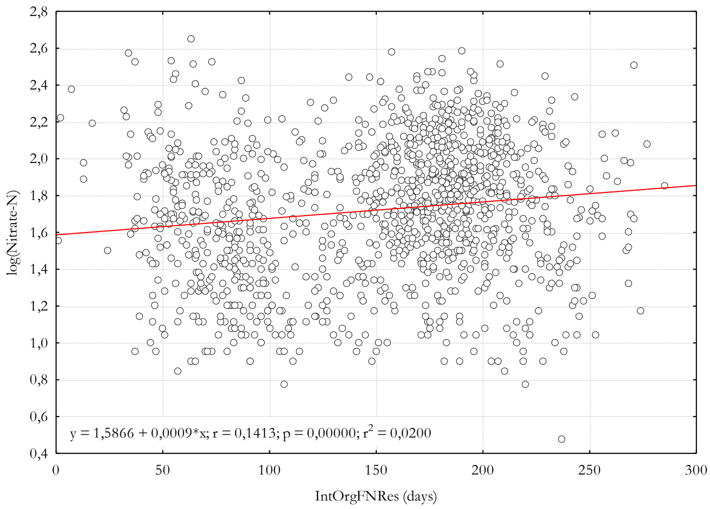


Figure 446: Log transformed nitrate-N residue regarding the interval between the last moment of application of an organic fertiliser and the moment of sampling for the nitrate-N residue (IntOrgFNRes). Linear fit through the data (red line).

4.2.1.17 Net organic nitrogen production

The net organic N production (ProdNOrgFarm) showed a significant and positive effect on the nitrate-N residue. A higher net production of organic nitrogen results in a higher nitrate-N residue.

$$\log(Nres) = 1.6462 + 0.0003 * ProdNOrgFarm \quad p = 0.00 \qquad R^2 = 0.01$$

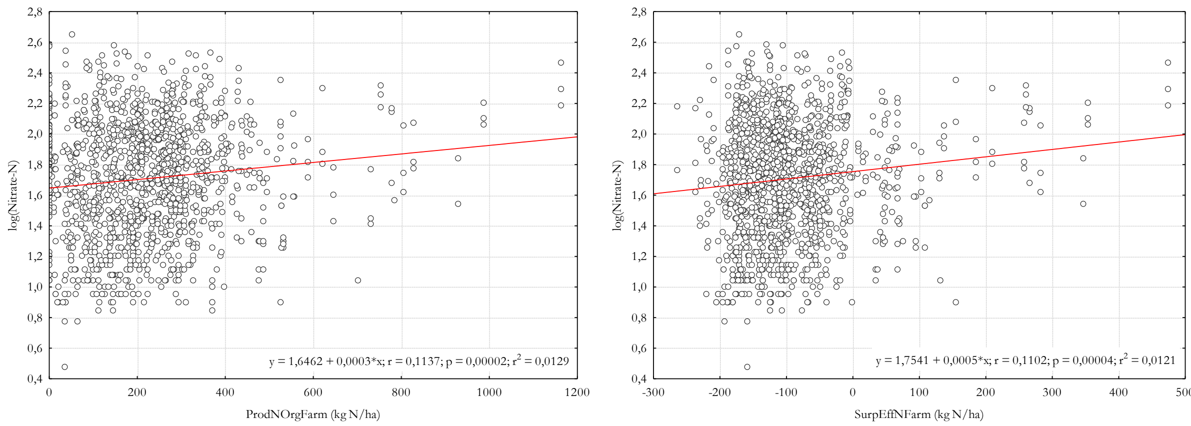


Figure 447: Log transformed nitrate-N residue regarding the net organic N production (ProdNOrgFarm) (left) or against the standardised farm surplus of effective N (SurpEffNFarm) (right). Linear fit through the data (red line).

4.2.1.18 Farm surplus of effective N

The farm surplus of effective N, standardised for the farm acreage (SurpEffNFarm), was related to the nitrate-N residue in a single linear regression. A larger surplus of effective N at farm level appeared to be related with higher nitrate-N residues measured in the monitoring network.

$$\log(Nres) = 1.7541 + 0.0005 * SurpEffNFarm \qquad p = 0.00 \qquad R^2 = 0.01$$

It can be assumed that this parameter is correlated with other farm parameters regarding N-fertilisation such as the net organic N production (4.2.1.17), the use of total nitrogen at farm level (4.2.1.20) and the use of mineral N at farm level (4.2.1.23). Variables as the proportion of farm acreage grass or maize could also be correlated since the fertilisation standards determine the disposal margin and by consequence the farm surplus.

4.2.1.19 Mineral fertilisation

The application of a mineral fertiliser (MinF) had a significant effect on the nitrate-N residue in the period 2016-2018 in the derogation monitoring network.

Table 92: Overview of the number of cases and the average, median, minimum and maximum value of the nitrate-N residue (kg NO_3-N/ha) regarding the application of mineral fertilisers. Results of the one-way ANOVA.

	n	Average*	median	min-max
N	123	60 ± 63 a	40	3-379
Y	1224	74 ± 62 b	55	7-450
p-value		0.00		
R^2		0.01		

*Different letters indicate a significant difference based on the Unequal N HSD-test on the log transformed data.

4.2.1.20 Farm use total N

The use of total nitrogen at farm level, determined by VLM and standardised per ha, (UseNTotFarm) had a significant and positive effect on the nitrate-N residue. The more total nitrogen is used per hectare on farm level, the higher the nitrate-N residue measured in the monitoring network (Figure 448).

$$\log(Nres) = 1.5625 + 0.0006 * UseNTotFarm \qquad p = 0.00 \qquad R^2 = 0.01$$

The use of total nitrogen at farm level could be related with the net organic N production (ProdNOrgFarm - 4.2.1.17).

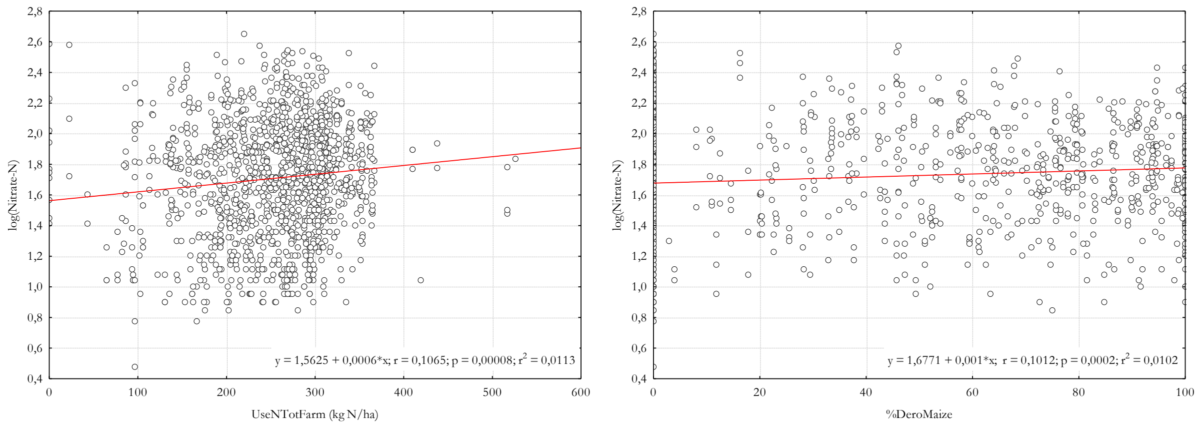


Figure 448: Log transformed nitrate-N residue regarding the standardised use of total nitrogen at farm level (UseNTotFarm) (left) or against the proportion of maize under derogation (%DeroMaize) (right). Linear fit through the data (red line).

4.2.1.21 Proportion maize under derogation conditions

The proportion of the acreage maize which is cultivated under derogation conditions (%DeroMaize) had a significant effect on the nitrate-N residue, based on the linear regression. When a larger proportion of the maize is cultivated under derogation conditions, a higher nitrate-N residue is observed (Figure 448).

$$\log(Nres) = 1.6771 + 0.0010 * \%DeroMaize \qquad p = 0.00 \qquad R^2 = 0.01$$

4.2.1.22 Farm surplus of organic N

The farm surplus of organic N, standardised by dividing through the farm acreage, (SurpOrgNFarm) had a significant effect on the nitrate-N residue in the monitoring network in the period 2016-2018. The effect on the nitrate-N residue determined in the single linear regression, was a positive effect. A higher surplus of organic N resulted in a higher nitrate-N residue which is not incomprehensible.

This variable however could be correlated with other N-indicators at farm level such as the net organic nitrogen production at farm level (ProdNOrgFarm, 4.2.1.17), the use of total nitrogen at farm level (UseNTotFarm, 4.2.1.20) and the surplus of effective nitrogen at farm level (SurpEffNFarm, 4.2.1.18).

$$\log(Nres) = 1.7012 + 0.0003 * SurpOrgNFarm \quad p = 0.00 \qquad R^2 = 0.01$$

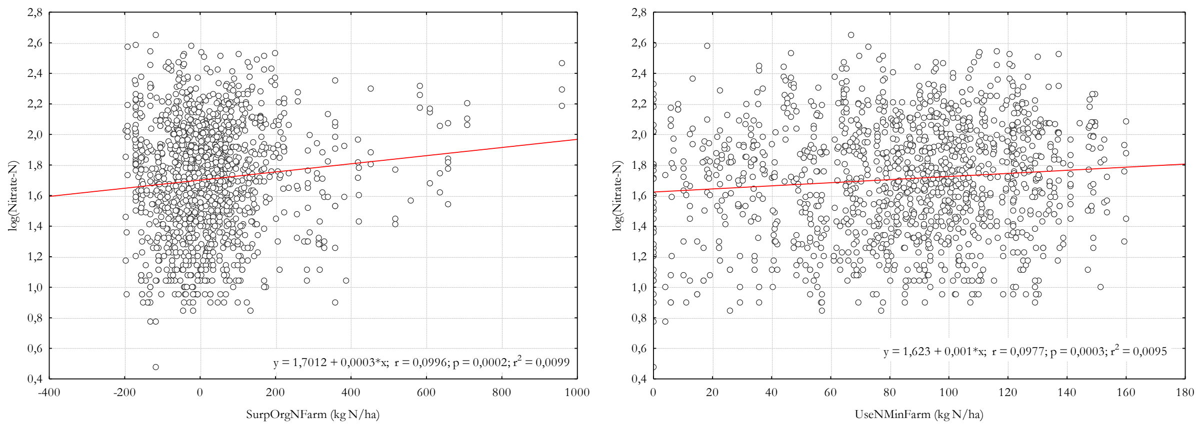


Figure 449: Log transformed nitrate-N residue regarding the standardised farm surplus of organic N (SurpOrgNFarm) (left) or against the standardised use of mineral N (UseNMinFarm) (right). Linear fit through the data (red line).

4.2.1.23 Farm use mineral N

The use of mineral N at farm level, standardised for the farm acreage, (UseNMinFarm), appeared to be positive related with the nitrate-N residue (Figure 449).

$$\log(Nres) = 1.6230 + 0.0010 * UseNMinFarm \quad p = 0.00 \qquad R^2 = 0.01$$

4.2.1.24 pH

pH, determined on the soil layer 0-30 cm in the derogation monitoring network, ($pH_{0\text{-}30cm}$) has a statistically significant effect on the nitrate-N residue (Nres).

$$\log(Nres) = 1.3966 + 0.0547 * pH_{0\text{-}30cm} \qquad p = 0.01 \qquad R^2 = 0.01$$

The effect on the nitrate-N residue is a positive effect. Not unexpected: a higher pH results in a higher mineralisation. This parameter could interact with $\%OC_{0\text{-}30cm}$ and soil texture.

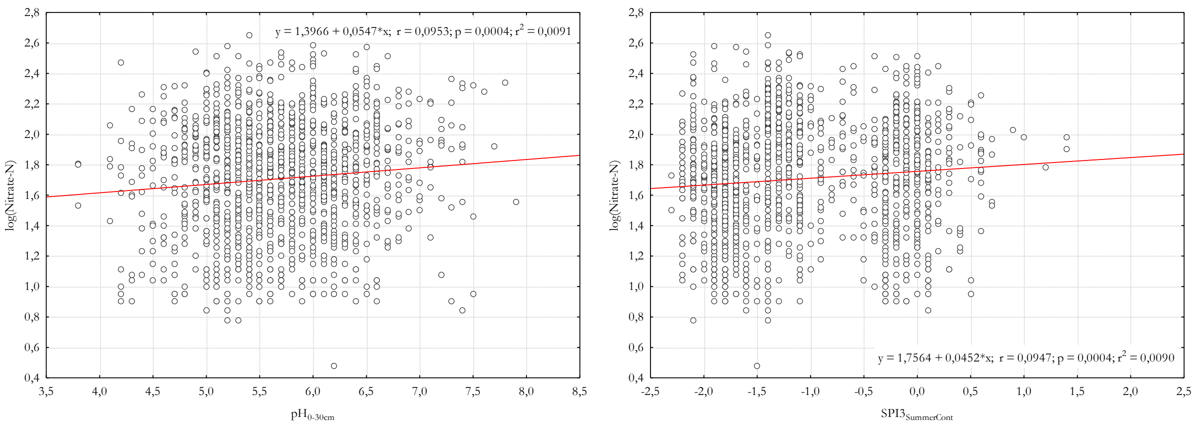


Figure 450: Log transformed nitrate-N residue regarding the pH ($pH_{0\text{-}30cm}$) (left) or against the standardized precipitation index evaluated on October 1st ($SPI3_{SummerCont}$) (right). Linear fit through the data (red line).

4.2.1.25 Standardized Precipitation Index summer-continuous

Also when the standardized precipitation index evaluated on October 1st was included as a continuous parameter ($SPI3_{SummerCont}$) in a single parameter analysis, it appeared to have a significant effect on the nitrate-N residue (p= 0.00).

$$\log(Nres) = 1.7564 - 0.0452 * SPI3_{SummerCont} \qquad p = 0.00 \qquad R^2 = 0.01$$

This parameter is obviously correlated with the categorical variant of SPI_{Summer}. Since this continuous variable has a lower R^2, it offers less explanation of the variation and it will not be picked up at the start to a multivariate model (see also 4.3 Multivariate effects).

4.2.1.26 Respecting fertilisation standard total effective N

Respecting the fertilisation standard for total effective N (RespStandEffN), evaluated against the nitrate-N residue in a one-way ANOVA, had a significant effect on the nitrate-N residue ($p = 0.00$).

In the period 2016-2018 the fertilisation standard of the total effective N was respected on 605 parcels. On these parcels the average nitrate-N residue amounted 66 ± 57 kg NO_3-N/ha. On 743 parcels the fertilisation standard of the total effective N was not respected and the average nitrate-N residue amounted 78 ± 66 kg NO_3-N/ha.

Table 93: Overview of the number of cases and the average, median, minimum and maximum value of the nitrate-N residue (kg NO_3-N/ha) regarding exceedance of the fertilisation standard for total effective nitrogen on all parcels of the monitoring network in the period 2016-2017. Results of the one-way ANOVA.

	n	Average*	median	min-max
Y, ≤standard	605	66 ± 57 a	48	3-384
N, >standard	743	78 ± 66 b	59	7-450
$p_{normEffN}$		0.00		
R^2		0.01		

*Different letters indicate a significant difference based on the Unequal N HSD-test on the log transformed data.

4.2.1.27 Acreage grass and less than 50% clover-proportion

The proportion of the farm acreage cultivated with grass and less than 50% clover (%AcrGrClov) appeared to have a significant negative effect ($p = 0.00$) on the nitrate-N residue in a single linear regression model. A higher proportion of grass and less than 50% clover on farm level resulted in lower nitrate-N residues.

$$\log(Nres) = 1.7241 - 0.0027 * \%\ AcrGrClov \qquad p = 0.00 \qquad R^2 = 0.01$$

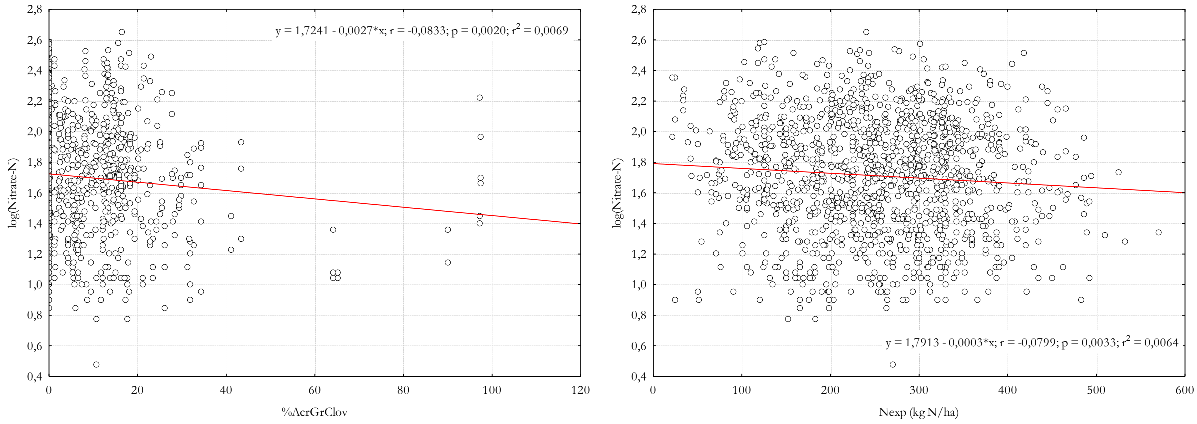


Figure 451: Log transformed nitrate-N residue regarding the proportion acreage grass and less than 50% clover (%AcrGrClov) (left) or against the nitrogen export by the harvested crops (Nexp) (right). Linear fit through the data (red line).

4.2.1.28 N-export by harvest

The nitrogen export by the harvested crops (Nexp), quantified based on the estimations of yield obtained from the farmers, was negatively related to the nitrate-N residue. This means that a higher export leads to lower nitrate-N residues. This is not surprising. One expects a lower nitrate-N residue after a successful crop and an accordingly higher nitrogen export.

$$\log(Nres) = 1.7913 + 0.0003 * Nexp \qquad p = 0.00 \qquad R^2 = 0.01$$

4.2.1.29 Organic carbon

The percentage of organic carbon (%OC), determined on the soil layer 0-30 cm in the derogation monitoring network ($\%OC_{0\text{-}30cm}$), has a statistically significant effect on the nitrate-N residue (Nres).

$$\log(Nres) = 1.6452 + 0.0346 * \%OC_{0\text{-}30cm} \qquad p = 0.00 \qquad R^2 = 0.01$$

It has a positive effect on the nitrate-N residue. Not unexpected: a higher percentage organic carbon means more mineralisation. The percentage of organic carbon is supposed to be related with soil texture and could have an interaction effect with pH.

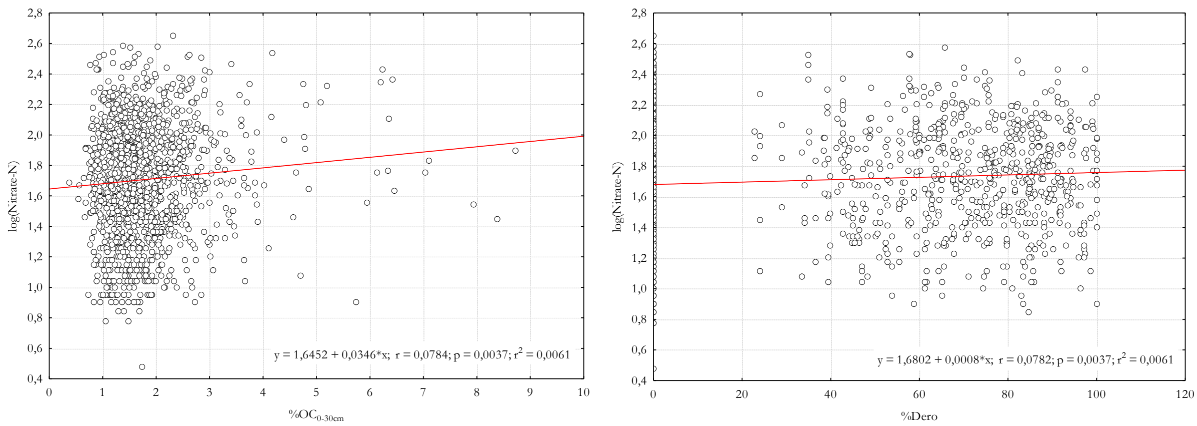


Figure 452: Log transformed nitrate-N residue regarding the percentage of organic carbon (%$OC_{0\text{-}30cm}$) (left) or regarding the proportion of the acreage of the farm cultivated under derogation conditions (%Dero) (right). Linear fit through the data (red line).

4.2.1.30 Proportion acreage with derogation

The share of the acreage of the farm which is cultivated under derogation conditions (%Dero) was evaluated regarding the nitrate-N residue using a single linear regression. A higher percentage cultivated under derogation resulted in higher nitrate-N residues, based on this linear regression.

$$\log(Nres) = 1.6802 + 0.0008 * \%Dero \qquad p = 0.00 \qquad R^2 = 0.01$$

This parameter can be suspected to be correlated with the percentage grass (%DeroGrass) and/or maize (%DeroMaize) cultivated under derogation conditions.

4.2.1.31 Derogation request

"Derogation request" (Der) is a 'multilateral' variable. The request of derogation can be inspired by several elements and will on its turn determine several elements. A higher application of organic manure is the attempt of the request of derogation. This is expected to be correlated with a higher use of organic nitrogen at farm level (farm-owned production or not), the use of organic fertilisers as such, the dose of organic fertilisation, ...

The request of derogation determines the fertilisation standard of total organic N, the main crop and second crop, the applied organic fertilisers, ….. Those variables will be correlated.

The request of derogation had a significant effect on the nitrate-N residue ($p = 0.00$). The numerical difference however was very modest.

Table 94: Overview of the number of cases and the average, median, minimum and maximum value of the nitrate-N residue (kg NO_3-N/ha) regarding the request of derogation. Results of the one-way ANOVA.

	n	Average*	median	min-max
N	686	72 ± 68 a	50	3-450
Y	690	73 ± 56 b	57	7-374
p-value		0.00		
R^2		0.01		

*Different letters indicate a significant difference based on the Unequal N HSD-test on the log transformed data.

4.2.1.32 Fertilisation standard total organic N

The standard for total organic nitrogen (StandOrgN) used in a single linear model resulted in a significant relation.

$$\log(Nres) = 1.5543 + 0.0007 * StandOrgN \qquad p = 0.00 \qquad R^2 = 0.01$$

The fertilisation standard for total organic nitrogen is determined by the granting of derogation or not. This variable is clearly related with the parameter "derogation request" (Der) (4.2.1.31).

4.2.1.33 Time between last day of grazing and sampling nitrate-N residue

The interval between the last moment of grazing and the moment of sampling for the nitrate-N residue was evaluated for the grazed parcels (IntGrNRes). This parameter is only useful for grazed parcels.

$$\log(Nres) = 1.6378 - 0.0023 * IntGrNRes \qquad p = 0.00 \qquad R^2 = 0.02$$

The interval had a significant effect on the nitrate-N residue. The regression function was the result of 335 cases. The observed effect was negative: a longer period between the last grazing and the sampling for the nitrate-N residue, results in a lower nitrate-N residue, which is logic. Sampling while a parcel is still being grazed often results in high nitrate-N residues.

If this parameter is included in the modelling of the nitrate-N residue, it should be in combination with a categorical parameter grazing, being 1 if the parcel is grazed and 0 if the parcel is not grazed. A '1' makes sure that the parameter 'IntGrNRes' is used, a '0' makes sure that the parameter is not included.

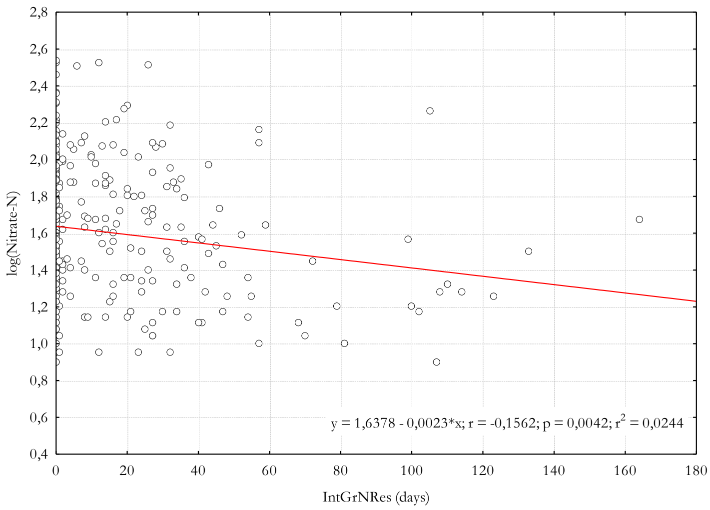


Figure 453: Log transformed nitrate-N residue regarding the interval between the last moment of grazing and the moment of sampling for the nitrate-N residue (IntGrNRes). Linear fit through the data (red line).

4.2.1.34 Focus farm

Belonging to a focus farm or not, picked up in the variable 'Focus', had a significant effect on the nitrate-N residue in the monitoring network. Parcels that do not belong to a focus farm appeared to have higher nitrate-N residue.

Table 95: Overview of the number of cases and the average, median, minimum and maximum value of the nitrate-N residue (kg NO_3-N/ha) regarding the fact of belonging to a focus farm. Results of the one-way ANOVA.

	n	Average*	median	min-max
N	1058	75 ± 65 b	56	3-450
Y	318	63 ± 53 a	47	7-297
p-value		0.01		
R^2		0.01		

*Different letters indicate a significant difference based on the Unequal N HSD-test on the log transformed data.

This variable is because of legislation correlated with the nitrate-N residue standard (StandNres). Parcels belonging to a focus farm are characterised by a nitrate-N residue standard lower than 90 kg NO_3-N/ha.

4.2.1.35 Second crop

The second crop (SCrop), although not necessarily sown or growing at the time of sampling for the nitrate-N residue, had a significant effect on the nitrate-N residue ($p = 0.01$).

Table 96: Overview of the number of cases and the average, median, minimum and maximum value of the nitrate-N residue (kg NO_3-N/ha) regarding the second crop. Results of the one-way ANOVA.

	n	Average*		median	min-max
No second crop	175	94 ± 72	a	69	8-384
Grass	234	97 ± 55	a	83	8-374
Winter wheat	82	90 ± 56	a	82	13-279
MixEP	26	72 ± 46	a	52	11-162
Rye	25	114 ± 91	a	94	19-379
Barley	22	108 ± 72	a	85	20-297
WhMust	6	88 ± 28	a	89	54-123
Spelt	4	90 ± 45	a	82	48-147
Triticale	4	129 ± 99	a	105	36-269
GrCl	3	169 ± 115	a	153	63-292
MNL	2	22 ± 10	a	22	15-29
Rapeseed	1	37	a	37	
Black Oat	1	35	a	35	
p-value		0.01			
R^2		0.04			

*Different letters indicate a significant difference based on the Unequal N HSD-test on the log transformed data.

The post-hoc Unequal N HSD-test however, did not mark significant differences in nitrate-N residue regarding the second crop. Evaluation of the effect of the second crop on the nitrate-N residue was also realised by a non-parametric test. The Kruskal-Wallis test and the Median test had p-values of respectively 0.04 and 0.30. The Kruskal-Wallis test however did not indicate significantly different crops. These results confirm the outcome of the Unequal N HSD-test.

The parameter second crop will no longer be included as a significant parameter for the nitrate-N residue. It is comprehensible that this parameter is less determinant for the nitrate-N residue since, as mentioned before, the parameter guarantees nothing regarding the second crop in the period before sampling and at sampling for the nitrate-N residue.

4.2.1.36 Farm use other N

The use of nitrogen of other fertilisers at farm level (UseNOthFarm) showed a significant positive effect on the nitrate-N residue in a single linear regression model. The more nitrogen of other fertilisers is used, the higher the nitrate-N residue.

$$\log(Nres) = 1.6986 + 0.0036 * UseNOthFarm \qquad p = 0.01 \qquad R^2 = 0.004$$

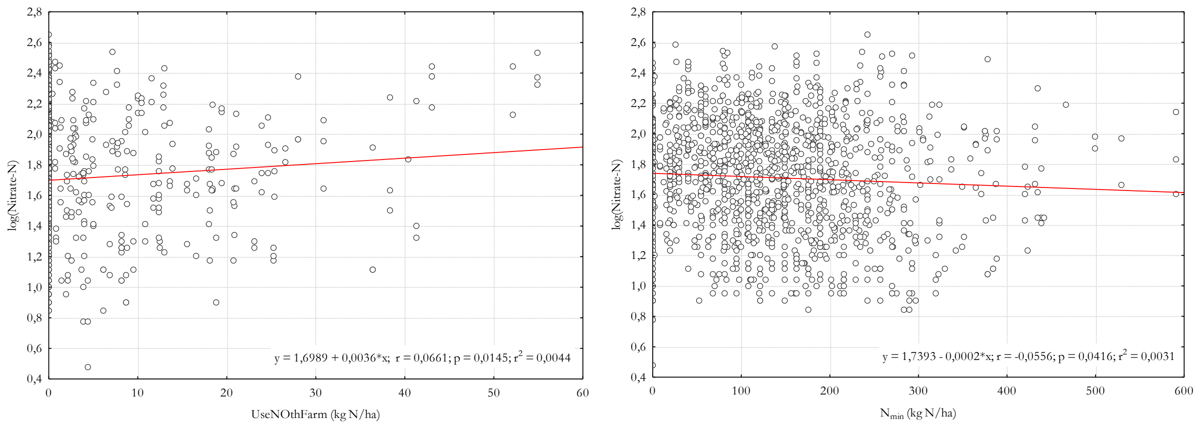


Figure 454: Log transformed nitrate-N residue regarding the standardised use of nitrogen of other fertilisers (UseNOthFarm) (left) or regarding the dose of mineral nitrogen (N_{min}) (right). Linear fit through the data (red line).

4.2.1.37 Mineral N-fertilisation-dose

The parcel specific applied nitrogen amount of mineral fertilisers (N_{min}) valuated in a single regression regarding the nitrate-N residue, appeared to have a significant effect.

The effect however, was negative. It was not expected that a higher dose of mineral nitrogen would lead to a lower nitrate-N residue.

$$\log(Nres) = 1.7393 - 0.0002 * N_{min} \qquad p = 0.04 \qquad R^2 = 0.003$$

4.2.1.38 Grazing

The categorical parameter "Grazing", which indicates if a parcel is grazed or not, was evaluated in a one-way ANOVA. The parameter had a significant effect (p = 0.0.4) on the nitrate-N residue.

Table 97: Overview of the number of cases and the average, median, minimum and maximum value of the nitrate-N residue (kg NO_3-N/ha) regarding grazing. Results of the one-way ANOVA.

	n	Average*	median	min-max
N	436	54 ± 55 a	35	3-450
Y	332	58 ± 57 a	39	8-344
p-value		0.04		
R^2		0.01		

*Different letters indicate a significant difference based on the Unequal N HSD-test on the log transformed data.

The post-hoc Unequal N HSD-test however did not mark significant differences in nitrate-N residue between grazed and non-grazed parcels. The non-parametric Kruskal-Wallis test (p = 0.0495) indicated a significant difference.

The parameter "Grazing" is obviously only evaluated on parcels cultivated with grass and grass with less than 50 % clover.

4.2.1.39 Farm use organic N

Just like other parameters of the farm nutrient balance, the use of organic nitrogen at farm level (UseNOrgFarm), standardised for the farm acreage, has a significant effect on the nitrate-N residue when it was related with the nitrate-N residue as only parameter.

$$\log(Nres) = 1.6434 + 0.0004 * UseNOrgFarm \quad p = 0.047 \quad R^2 = 0.003$$

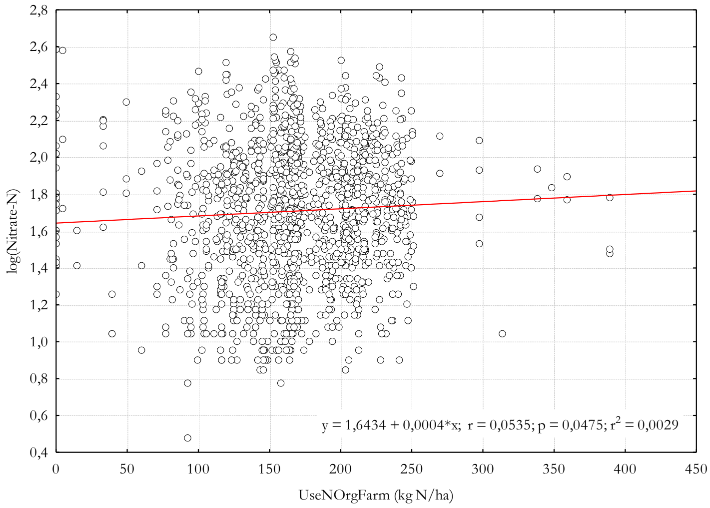


Figure 455: Log transformed nitrate-N residue regarding the standardised use of organic nitrogen at farm level (UseNOrgFarm). Linear fit through the data (red line).

4.2.2 Correlations

As indicated on the sideline when discussing the single effects, some of the independent variables will be more or less correlated. Both continuous and categorical variables can be correlated. Correlations were only evaluated for the parameters that were marked as significant parameter for the nitrate-N in the single effects analysis.

The interactions between the continuous variables are evaluated by the Pearson correlation test. The correlation coefficient indicates the strength and the direction of the correlation. The Pearson correlation coefficients are given in Table 98. Significant correlations are indicated in red. The parameters "$SPI3_{SpringCont}$" and $SPI3_{SummerCont}$" were no longer evaluated in the correlation test. The standardized precipitation index is further on only evaluated as categorical variable.

The interactions between the categorical variables are evaluated by the Pearson's chi-squared test ($\chi 2$). The p-values resulting of the Pearson's chi-squared test are given in Table 99.

Significant correlations are indicated in red. P-values smaller than 0.05 indicate that the null hypothesis can be rejected: the categorical variables are not independent.

The found correlations between the predictors are more or less logic.

Table 98: Pearson correlation coefficients of the significant continuous variables. Significant correlations are indicated in red.

N=1120 (Casewise deletion of missing data) - Marked correlations are significant at p < 0,05000

	$pH_{0\text{-}30cm}$	$\%OC_{0\text{-}30cm}$	IntMin NRes	Stand EffN	Stand OrgN	% Dero	%Dero Maize	Rat GrM	%Acr Grass	%Acr GrCl	%Acr Maize	ProdN Org Farm	UseN Min Farm	UseN Oth Farm	UseN Org Farm	UseN Tot Farm	Surp EffN Farm	Surp OrgN Farm	N_{min}	Int OrgF NRes	Int Org NRes	Nexp	Rdef
$pH_{0\text{-}30cm}$	1	-0,172	0,155	-0,032	0,032	-0,007	-0,012	-0,019	-0,199	-0,118	-0,138	0,002	0,175	0,017	-0,110	-0,002	-0,039	0,002	-0,074	0,089	0,222	-0,030	0,028
$\%OC_{0\text{-}30cm}$	-0,172	1	-0,182	0,247	0,105	0,143	0,158	0,001	0,105	0,246	0,100	0,104	-0,024	0,042	0,160	0,113	0,063	0,084	0,162	-0,240	-0,286	0,127	0,088
IntMinNRes	0,155	-0,182	1	-0,410	-0,030	0,006	0,044	-0,008	-0,045	-0,217	-0,026	-0,049	-0,044	0,098	-0,006	-0,010	-0,043	-0,061	-0,589	0,357	0,482	-0,271	0,115
StandEffN	-0,032	0,247	-0,410	1	0,371	0,298	0,210	0,042	0,139	0,278	0,052	0,159	0,161	-0,003	0,213	0,233	0,018	0,111	0,534	-0,455	-0,491	0,494	-0,014
StandOrgN	0,032	0,105	-0,030	0,371	1	0,930	0,811	-0,033	0,222	0,102	0,179	0,378	0,130	-0,038	0,544	0,473	0,198	0,210	0,165	-0,214	-0,186	0,394	-0,004
%Dero	-0,007	0,143	0,006	0,298	0,930	1	0,920	-0,012	0,258	0,135	0,183	0,396	0,121	-0,040	0,593	0,507	0,197	0,212	0,115	-0,186	-0,157	0,341	-0,016
%DeroMaize	-0,012	0,158	0,044	0,210	0,811	0,920	1	-0,069	0,186	0,095	0,200	0,363	0,100	-0,025	0,575	0,485	0,179	0,188	0,045	-0,160	-0,109	0,283	-0,027
RatGrM	-0,019	0,001	-0,008	0,042	-0,033	-0,012	-0,069	1	0,753	-0,055	-0,709	-0,167	-0,015	-0,045	-0,014	-0,018	-0,261	-0,176	-0,083	0,044	-0,091	0,018	-0,005
%AcrGrass	-0,199	0,105	-0,045	0,139	0,222	0,258	0,186	0,753	1	-0,215	-0,364	-0,003	0,033	-0,103	0,247	0,201	-0,173	-0,061	0,001	-0,004	-0,211	0,161	0,015
%AcrGrCl	-0,118	0,246	-0,217	0,278	0,102	0,135	0,095	-0,055	-0,215	1	0,084	0,098	-0,115	0,069	0,103	0,028	0,092	0,080	0,154	-0,215	-0,093	0,149	0,057
%AcrMaize	-0,138	0,100	-0,026	0,052	0,179	0,183	0,200	-0,709	-0,364	0,084	1	0,293	-0,161	0,009	0,132	0,020	0,356	0,277	0,089	-0,127	-0,024	0,071	0,027
ProdNOrgFarm	0,002	0,104	-0,049	0,159	0,378	0,396	0,363	-0,167	-0,003	0,098	0,293	1	0,103	0,051	0,142	0,139	0,914	0,976	0,125	-0,107	-0,040	0,148	-0,037
UseNMinFarm	0,175	-0,024	-0,044	0,161	0,130	0,121	0,100	-0,015	0,033	-0,115	-0,161	0,103	1	-0,133	0,146	0,602	-0,086	0,082	0,255	-0,027	-0,088	0,191	-0,084
UseNOthFarm	0,017	0,042	0,098	-0,003	-0,038	-0,040	-0,025	-0,045	-0,103	0,069	0,009	0,051	-0,133	1	0,009	0,039	0,034	0,047	-0,097	0,013	0,048	-0,066	0,017
UseNOrgFarm	-0,110	0,160	-0,006	0,213	0,544	0,593	0,575	-0,014	0,247	0,103	0,132	0,142	0,146	0,009	1	0,867	-0,010	0,001	0,085	-0,143	-0,164	0,293	-0,045
UseNTotFarm	-0,002	0,113	-0,010	0,233	0,473	0,507	0,485	-0,018	0,201	0,028	0,020	0,139	0,602	0,039	0,867	1	-0,067	0,019	0,171	-0,121	-0,168	0,311	-0,075
SurpEffNFarm	-0,039	0,063	-0,043	0,018	0,198	0,197	0,179	-0,261	-0,173	0,092	0,356	0,914	-0,086	0,034	-0,010	-0,067	1	0,935	0,058	-0,078	0,014	0,035	-0,030
SurpOrgNFarm	0,002	0,084	-0,061	0,111	0,210	0,212	0,188	-0,176	-0,061	0,080	0,277	0,976	0,082	0,047	0,001	0,019	0,935	1	0,115	-0,078	-0,016	0,087	-0,028
N_{min}	-0,074	0,162	-0,589	0,534	0,165	0,115	0,045	-0,083	0,001	0,154	0,089	0,125	0,255	-0,097	0,085	0,171	0,058	0,115	1	-0,424	-0,374	0,503	-0,074
IntOrgFNRes	0,089	-0,240	0,357	-0,455	-0,214	-0,186	-0,160	0,044	-0,004	-0,215	-0,127	-0,107	-0,027	0,013	-0,143	-0,121	-0,078	-0,078	-0,424	1	0,549	-0,361	0,010
IntOrgNRes	0,222	-0,286	0,482	-0,491	-0,186	-0,157	-0,109	-0,091	-0,211	-0,093	-0,024	-0,040	-0,088	0,048	-0,164	-0,168	0,014	-0,016	-0,374	0,549	1	-0,280	0,040
Nexp	-0,030	0,127	-0,271	0,494	0,394	0,341	0,283	0,018	0,161	0,149	0,071	0,148	0,191	-0,066	0,293	0,311	0,035	0,087	0,503	-0,361	-0,280	1	-0,204
Rdef	0,028	0,088	0,115	-0,014	-0,004	-0,016	-0,027	-0,005	0,015	0,057	0,027	-0,037	-0,084	0,017	-0,045	-0,075	-0,030	-0,028	-0,074	0,010	0,040	-0,204	1

The Pearson correlation test included 23 parameters. The least correlated continuous variables are UseNOtherFarm, RDef and the ratio grass-maize (RatGrM). They were significantly correlated to 6 or 8 other parameters. The ratio grass-maize is logically correlated with %AcrGrass and %AcrMaize. The rain deficit during hydrological summer was not unexpectedly negatively correlated with the nitrogen export by harvest. A larger rain deficit enhances the risk for a failed harvest and a smaller nitrogen export. The correlation was significant but rather weak. The significant correlations of the variable "UseNOtherFarm" were also rather weak.

Very strong correlations were found between the net organic nitrogen production (ProdNOrgFarm) and the farm surplus of organic N (SurpOrgNFarm) (r = 0.976), the farm surplus of organic N and the farm surplus of effective N (SurpEffNFarm) (r = 0.935), the net organic nitrogen production and the farm surplus of effective N (r = 0.914), the proportion of the acreage under derogation (%Dero) and the fertilisation standard for total organic nitrogen (StandOrgN) (r = 0.930), the proportion of the acreage under derogation and the percentage of maize under derogation conditions (r = 0.920), the percentage of maize under derogation conditions and the fertilisation standard for total organic nitrogen (r = 0.811), the use of organic and total nitrogen at farm level (r = 0.867). These correlations are evident.

The net organic nitrogen production is almost one on one related to the farm surpluses of organic N and effective N. The more organic nitrogen is produced the higher the risk that production exceeds the disposal margin to a greater extent. A higher use of organic nitrogen goes along with a higher use of total nitrogen, not surprisingly since the use of organic nitrogen is a part of the estimated total nitrogen.

Other strongly correlated parameters were the use of organic nitrogen and the fertilisation standard for total organic nitrogen (r = 0.544). Logically, the use of organic nitrogen is correlated in a positive way to the fertilisation standard for total organic nitrogen. A higher standard and a higher use on farm level go hand in hand. A higher use of organic nitrogen is correlated to a higher proportion of maize under derogation (r = 0.575). Using more organic nitrogen also correlates with a higher proportion of grass and maize on the farm (r = 0.27 and r = 0.132), irrespective of the application of derogation.

Not surprisingly: Higher net organic production compels often to derogation (r = 0.396), derogation can be applied on maize and grass, and the more derogation needs to be requested the larger the part of grass and maize (r= 0.363) will be cultivated under derogation conditions.

Both the interval between nitrate sampling and the latest organic fertiliser (IntOrgFNRes) or organic fertilisation (IntOrgNRes) are related to each other (r = 0.549). Grazing is experienced as the latest organic fertilisation, so IntOrgNRes guarantees the shortest interval.

Thirteen categorical variables appeared to be significant for the nitrate-N residue. Their interactions were tested by the Pearson's chi-squared test.

"Year" was logically correlated with the climate parameters "$SPI3_{SpringCat}$" and "$SPI3_{SummerCat}$". The weather conditions depend from year to year. Other categorical parameters were reasonably not correlated with "Year". The correlation of crop with the crop at sampling (CropNRes), type of organic fertiliser (TypOrg) and the following crop (SCrop) are not surprising. The main crop has an influence on the second crop and the crop at sampling. A parcel cultivated with grass has no second crop but will (in normal conditions) still be covered with grass when sampling. On a parcel cultivated with maize, a second crop can be grown or not and it can already be growing or sown at sampling for the nitrate-N residue yes or no.

Other expected correlations that are confirmed in Table 99:

- Derogation & type of organic fertiliser that is used
- Crop & nitrate-N residue standard
- Focus & nitrate-N residue standard

Unexpected correlations which in addition cannot be declared, are:

- Standardized precipitation index (spring and summer) & Focus
- Standardized precipitation index (spring and summer) & nitrate-N residue standard

Table 99: Pearson Chi-square p-values for correlation of the significant categorical variables. Significant correlations ($p < 0.05$) are indicated in red.

Pearson Chi-square; p-value													
	Crop	Year	$SPI3_{SpringCat}$	$SPI3_{SummerCat}$	CropNRes	TypOrg	StandNres	MinF	RespStandEffN	Der	Focus	SCrop	Grazing
Crop													
Year	1,00												
$SPI3_{SpringCat}$	0,07	0,00											
$SPI3_{SummerCat}$	0,14	0,00	0,00										
CropNRes	0,00	0,10	0,06	0,12									
TypOrg	0,00	0,48	0,03	0,00	0,00								
StandNres	0,00	0,15	0,00	0,00	0,00	0,00							
MinF	0,83	0,07	0,08	0,31	0,31	0,00	0,00						
RespStandEffN	0,00	0,09	0,00	0,03	0,00	0,00	0,01	0,00					
Der	1,00	1,00	0,00	0,13	0,00	0,00	0,02	0,00	0,00				
Focus	0,01	0,43	0,02	0,00	0,00	0,14	0,00	0,00	0,00	0,05			
~~SCrop~~	~~0,00~~	~~0,17~~	~~0,00~~	~~0,02~~	~~0,00~~	~~0,00~~	~~0,00~~	~~0,00~~	~~0,00~~	~~0,00~~	~~0,00~~		
Grazing	0,00	0,71	0,11	0,62	0,00	0,00	0,32	0,58	0,00	0,13	0,96	~~1,00~~	

4.3 Multivariate effects

Combination of the discussed significant parameters should give more explanation of the variation observed in the measured nitrate-N residues.

Although it is not opportune to pick up correlated parameters, the correlated nitrogen indicators at farm level such as net organic nitrogen production, farm use of total nitrogen, …. were all picked up initially to be evaluated in a multivariate model. In the further analysis it will be determined which parameters remain or should be excluded at the end.

On the other hand, some correlated parameters were no longer picked up when initiating a multivariate model. In the monitoring network, derogation on a parcel or not (Der) and the fertilisation standard for total organic nitrogen (StandOrgN) mean the same. Only StandOrgN is taken in the search for a multivariate model since it is the most unambiguous parameter of both.

Since grazing regularly happens later than the last application of organic fertilisers and the parameter "IntOrgNRes" takes both grazing and organic fertilisers into account, it includes the last organic fertilisation. Therefore, only this parameter and not IntOrgFNRes is used at the start of the multivariate analysis.

Because of the inconclusive results for the parameter "Grazing" (4.2.1.38) this parameter discarded. IntGrNRes (4.2.1.33) was highly correlated (r = 0.960) with IntOrgNRes. Since IntOrgNRes was the most comprehensive parameter of both, IntGrNRes was also left out when initiating a multivariate model.

'Year' was from the start described as a wide-ranging parameter. Most determining for this parameter will be the weather, which is confirmed by its significant correlations with the standardized precipitation index of spring and summer mentioned in Table 99. Therefore, the parameter 'year' was not included in the multivariate analysis.

As mentioned before SCrop (4.2.1.35) was not picked up to build a multivariate model.

Thirty one variables remained to start the multivariate analysis.

To be able to compare the obtained model coefficients and the relevance or contribution of the predictors, the predictors and the responsive variable were rescaled to values between 0 and 1. For the rescaling of the continuous predictors and the responsive variable Equation 4 was used.

$$x_{new} = \frac{x - x_{min}}{x_{max} - x_{min}}$$

Equation 4: Rescaling predictors to values between 0 and 1.

In first instance, the thirty one parameters were added manually one by one in a **general regression model** in descending order of significance and 'R^2' as they were discussed in 4.2.1.

If the added parameter had no significant effect ($p>0.05$), it was no longer withheld. If the added parameter had a significant effect ($p<0.05$), it was withheld. In that case: when the former withheld parameters remained significant, those parameters were withheld; when the former withheld parameters became insignificant, the former withheld parameter was rejected at that moment. A summary of these actions is given in Table 100.

The result of this procedure, the selected (rescaled) predictors and their related coefficient for the (rescaled) log transformed nitrate-N residue, is shown in Table 101.

In the framework of the monitoring network 2016-2018, the multivariate analysis indicated that the following parameters were the main significant predictors:

- The main crop (Crop)
- The standardized precipitation index evaluated on July 1st ($SPI3_{SpringCat}$)
- The standardized precipitation index evaluated on October 1st ($SPI3_{SummerCat}$)
- The interval between organic fertilisation (IntOrgNRes)
- The type of organic fertiliser (TypOrg)
- The percentage of organic carbon ($\%OC_{0\text{-}30cm}$)
- The use of nitrogen of other fertilisers at farm level (UseNOthFarm)
- The dose of mineral N-fertilisation is a continuous, numerical variable (N_{min}).

Table 100: Overview manual build-up of the general regression model. P-values of entering parameters, resulting R²- and R-value and MSE (Mean Square Error) of the resulting model. Side effect at entering a parameter and action after entering a parameter.

Variable	p-value	R^2	R	MSE	Side effects	Action
Crop	0,000	0,171	0,413	0,025		
StandEffN	0,528					Out
$SPI3_{SpringCat}$	0,000	0,230	0,480	0,023		Withheld
$SPI3_{SummerCat}$	0,000	0,247	0,497	0,023		Withheld
CropNRes	0,103					Out
IntOrgNRes	0.000	0,268	0,517	0,022		Withheld
TypOrg	0,003	0,283	0,532	0,022		Withheld
Rdef	0,116					Out
RatGrM	0,000	0,289	0,538	0,021		Withheld
%AcrMaize	0,199				RatGrM: p=0.06	Out; RatGrM: Withheld
IntMinNRes	0,007	0,290	0,539	0,020		Withheld
%AcrGrass	0,204					Out
StandNres	0,921					Out
ProdNOrgFarm	0,021	0,292	0,540	0,020	RatGrM: p=0.11	Withheld; RatGrM: out
SurpEffNFarm	0,683				ProdNOrgFarm: p=0.18	Out; ProdNOrgFarm: Withheld
MinF	0,988					Out
UseNTotFarm	0,011	0,297	0,545	0,020		Withheld
%DeroMaize	0,209				ProdNOrgFarm: p=0.06; UseNTotFarm: p=0.06	Out; ProdNOrgFarm-UseNTotFarm: Withheld
SurpOrgNFarm	0,304				ProdNOrgFarm: p=0.15; UseNTotFarm: p=0.06	Out; ProdNOrgFarm-UseNTotFarm: Withheld
UseNMinFarm	0,327					Out
pH_{0-30cm}	0,033	0,299	0,547	0,020		Withheld
RespStandEffN	0.091					Out
%AcrGrClov	0.523					Out
Nexp	0.519					Out
$\%OC_{0-30cm}$	0.000	0.332	0.576	0.019	ProdNOrgFarm: p=0.10; pH_{0-30cm}: p=0.09	Withheld; ProdNOrgFarm-pH_{0-30cm}: Out
%Dero	0.334				UseNTotFarm: p=0.10	Out; UseNTotFarm: Withheld
StandOrgN	0.103				UseNTotFarm: p=0.13	Out; UseNTotFarm: Withheld
Focus	0.880					Out
UseNOthFarm	0.011	0.335	0.579	0.019		Withheld
N_{min}	0.026	0.342	0.585	0.020	IntMinNRes: p=0.08; UseNTotFarm: p=0.09	Withheld; IntMinNRes-UseNTotFarm: Out
UseNOrgFarm	0,100					Out

Table 101: Overview of the selected parameters and the related coefficient based on the data of the monitoring network of 2016, 2017 and 2018. (Rescaled) Log(nitrate-N residue)= intercept + Σ (coefficient * (rescaled) parameter)

Parameter	Coefficient
Intercept	0,536
Crop-grass <50% clover	-0,069
Crop-grass	-0,084
$SPI3_{SpringCat}$-ExtW	-0,069
$SPI3_{SpringCat}$-ModW	-0,059
$SPI3_{SpringCat}$-VeryW	-0,055
$SPI3_{SpringCat}$-ExtD	0,060
$SPI3_{SpringCat}$-VeryD	0,039
$SPI3_{SummerCat}$-Normal	-0,060
IntOrgNRes	-0,135
TypOrg-Cattle slurry	-0,040
TypOrg-None	-0,057
TypOrg-Other organic	0,119
$\%OC_{0\text{-}30cm}$	0,364
UseNOthFarm	0,085
N_{min}	0,181

Grass and grass with less than 50 % clover will result in lower nitrate-N residues. A standardized precipitation index for spring (evaluated on July 1[st]) which is categorised as extremely wet, moderately wet or very wet will result in a lower nitrate-N residue. The effect of very and moderately wet conditions is comparable while the effect of extreme wet conditions is larger. SPI_{Spring} categorised as very or extremely dry will result in a higher nitrate-N residue and the impact of extreme dry conditions is larger than this of very dry conditions.

A longer period between organic fertilisation (grazing or organic fertiliser) results in a lower nitrate-N residue.

Using no organic fertiliser or using cattle slurry as organic fertiliser reduces the nitrate-N residue. The use of other organic fertilisers will lead to higher nitrate-N residues. The same does a higher level of organic carbon.

A greater use of other fertilisers at farm level leads to higher nitrate-N residues, as does a higher dose of mineral nitrogen.

When these parameters and these coefficients are used, 34.2 % of the variation of the nitrate-N residue in the monitoring network in in the period 2016-2018 is explained.

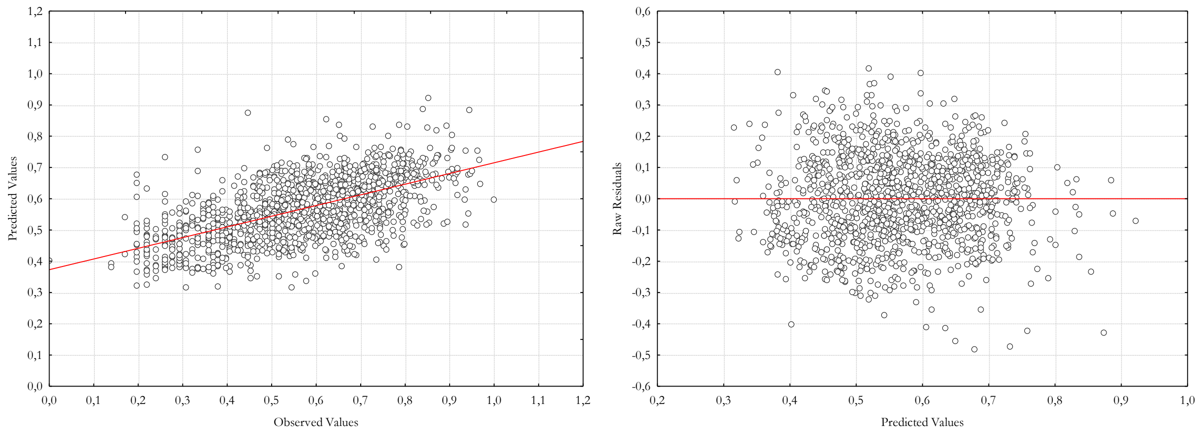


Figure 456: Predicted values versus the observed values (left) and residual values versus the predicted values (right).

The same objective was pursued by using a **forward stepwise** and a backward stepwise **approach**.

The forward stepwise solution revealed almost the same parameters. The standardized precipitation index evaluated on October 1st ($SPI3_{SummerCat}$) appeared not relevant in the forward stepwise solution. The standard for total effective nitrogen (StandEffN) and the standard for total organic N (StandOrgN) however were indicated as significant predictors for the nitrate-N residue in the monitoring network.

A higher standard for total effective nitrogen would result in a lower nitrate-N residue and the higher standard for total organic N would result in a higher nitrate-N residue. The impact of the standard for total organic N however, is modest compared to the impact of the standard for total effective nitrogen.

This combination of parameters and coefficients (Table 102) could explain 34.6 % of the variation of the nitrate-N residue in the monitoring network 2016-2018.

Table 102: Overview of the selected parameters by the forward stepwise model building and the related coefficient based on the data of the monitoring network of 2016, 2017 and 2018. (Rescaled) Log(nitrate-N residue)= intercept + Σ (coefficient * (rescaled) parameter)

Parameter	Coefficient
Intercept	0,625
Crop-grass <50% clover	-0,048
Crop-grass	-0,068
StandEffN	-0,142
$SPI3_{SpringCat}$-ExtW	-0,074
$SPI3_{SpringCat}$-ModW	-0,059
$SPI3_{SpringCat}$-VeryW	-0,056
$SPI3_{SpringCat}$-ExtD	0,059
$SPI3_{SpringCat}$-VeryD	0,046
IntOrgNRes	-0,109
TypOrg-Cattle slurry	-0,040
TypOrg-None	-0,056
TypOrg-Other organic	0,121
$\%OC_{0\text{-}30cm}$	0,338
StandOrgN	0,029
UseNOthFarm	0,121
N_{min}	0,142

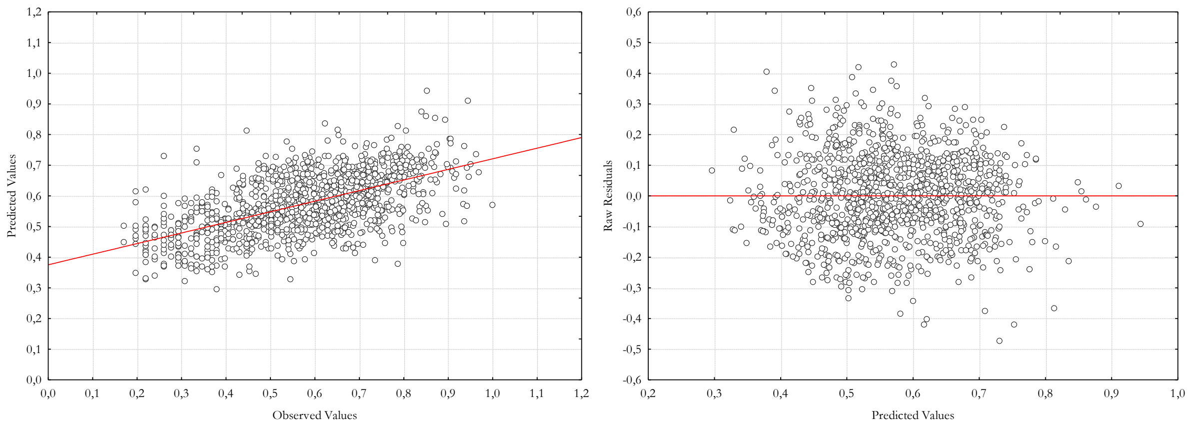


Figure 457: Predicted values via the forward stepwise modelling versus the observed values (left) and residual values versus the predicted values via the forward stepwise modelling (right).

The **backward stepwise modelling** picked up the same parameters as the forward stepwise modelling and assigned the same coefficients (Table 102).

A summary of the indicated parameters and their coefficients in the manual and forward stepwise approach is presented in Figure 458.

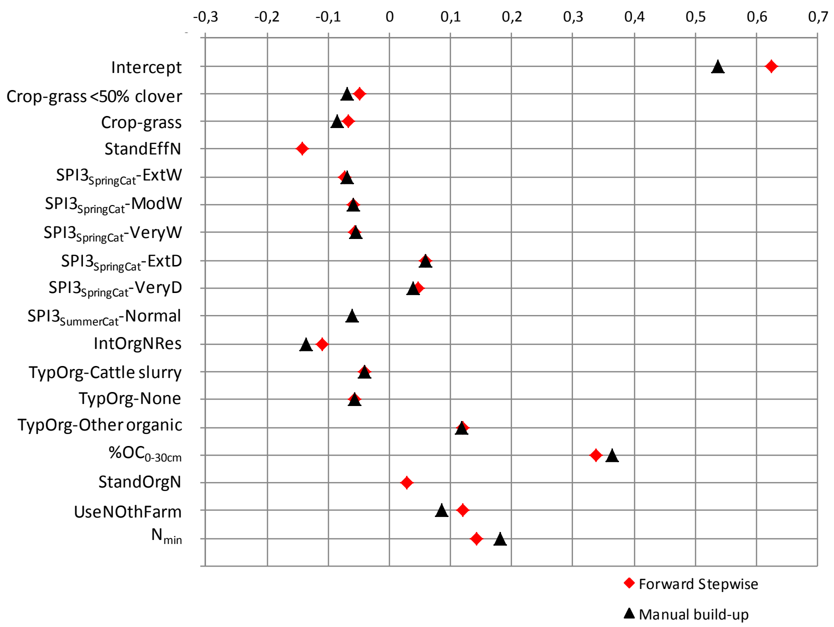


Figure 458: Summary of the coefficients of the predictors for the nitrate-N residue in the monitoring network 2016-2018, predictors marked by the manual and forward stepwise approach.

The more comprehensive statistical analysis of the nitrate-N residue in the monitoring network in the period 2016-2018 pointed out as determinant parameters a.o. the main crop, the Standardized Precipitation Index in spring, the interval between the last organic fertilisation and sampling the nitrate-N residue and the amount of organic carbon in the upper soil layer.

Although the statistical analysis of the nitrate-N residues in Flanders of the period 2011-2016 directed by the Flemish Land Agency (VLM, 2018) was conducted on more and other data, the conclusions of this study were basically confirmed by the statistical analysis of the nitrate-N residue in the monitoring network 2016-2018. The Flemish study stated that the most important parameters influencing the nitrate-N residue were related to: the main crop, the agricultural area, precipitation in spring (SPI-index) and N-deposition.

Conclusion

The monitoring network for the period 2016-2019 could be set-up according to the requirements. Seventy-five farms of former monitoring networks could be withheld. Former research projects and a network of partners appeared to be very valuable for the selection of the remaining farms. During the 4 years of monitoring the network proved to be robust. At each moment of comparison, enough parcels or farms could be compared.

In 2016, generally for none of the monitoring parameters so far (nitrate-N residue, nitrate in soil water, difference of nitrate-N between winter and spring) derogation led to statistically significant differences compared to no derogation practices, with a few exceptions at certain levels of comparison. When significant differences appeared between derogation and non-derogation conditions, the average values of both scenarios were always low. The practical relevance of these minimal differences are therefore not so important. Moreover, the significance of these numerical small differences needs to be approached with a certain caution because of the substantial standard deviations. In 2017, the nitrate-N residue, the nitrate-N difference over winter and the nitrate concentration in the soil water were all at a higher level as the year before. This was even worse in 2018. The nitrate-N residues of 2019 were assessable as in between values. The nitrate concentration in the soil water was the highest in autumn 2019. Significant differences were not often identified.

Fertilisation is higher when derogation is requested. In 2018 and 2019, the average N-fertilisation on parcels cultivated with grass or grass and less than 50 % clover indicated the adaptation to the drought. Mostly on parcels which were only cut, the fertilisation was reduced in summer. The reduction was most pronounced on derogation parcels.

Yield was at the lowest level in 2018. On derogation parcels however, the estimated yield was still higher than on parcels without derogation.

All 4 years of monitoring can be remembered by its climate. 2016 was characterised by a very wet spring and lots of rain in May and June and a very dry August and warm September. In 2017, farmers had to deal with a long period of drought. The drought got even more extreme in 2018. Throughout the network, farmers tried to adapt where possible, as can be seen in the fertilisation data on grass in 2018. A lot of events however cannot be foreseen and some parameters cannot be controlled by the farmers.

A statistical multivariate analysis of the data of 2016-2018 shows that derogation parameters indeed are not determinant for nutrient losses. The most important parameters are the main crop, the type of organic fertiliser that is used, climate parameters and the amount of organic carbon.

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Annex 1 – Nitrogen fertilisation standards

Table 103: Overview of the nitrogen fertilisation standards regarding effective and organic nitrogen on derogation and no derogation parcels cultivated with grass, grass and less than 50% clover or maize. 2016-2018

		Effective nitrogen		Organic nitrogen	
		Derogation / no derogation		Derogation	No derogation
Crop	Combination/ regime	Sandy soils	No sandy soils	All soils	
Grass or grass and <50% clover	Cutting	300	310	250	170
	Cutting & grazing	235	245	250	170
Maize	No cut of grass	-/135	-/150	250	170
	Cut of grass	200	230	250	170

Table 104: Overview of the nitrogen fertilisation standards regarding effective and organic nitrogen on derogation and no derogation parcels cultivated with grass, grass and less than 50% clover or maize in Zone Type 0, 1 and 2 - 2019

		Effective nitrogen		Organic nitrogen	
		Derogation / no derogation		Derogation	No derogation
Crop	Combination/ regime	Sandy soils	No sandy soils	All soils	
Grass or grass and <50% clover	Cutting	375	385	250	170
	Cutting & grazing	235	245	250	170
Maize	No cut of grass	-/135	-/150	250	170
	Cut of grass	200	230	250	170

Table 105: Overview of the nitrogen fertilisation standards regarding effective and organic nitrogen on derogation and no derogation parcels cultivated with grass, grass and less than 50% clover or maize in Zone Type 3 - 2019

		Effective nitrogen		Organic nitrogen	
		Derogation / no derogation		Derogation	No derogation
Crop	Combination/ regime	Sandy soils	No sandy soils	All soils	
Grass or grass and <50% clover	Cutting	356	366	250	170
	Cutting & grazing	223	233	250	170
Maize	No cut of grass	-/128	-/143	250	170
	Cut of grass	190	219	250	170

Annex 2 – Nitrate in soil water

Regarding the possibilities in the monitoring network it was decided to monitor water quality in the soil water. Also in the Netherlands soil water is monitored to understand the relation between ground water quality and agricultural activities (Ros, 2014). In the province of Limburg 3 networks are involved. In the networks the nitrate concentration in the soil water is determined because the concentration in the soil water indicates the nitrate concentration of the water leaving the root zone. Each network however uses another protocol. All three protocols are substantiated and realize an accurate estimation of the nitrate concentration in the soil water. Some protocols are based on centrifugation while others are based on extraction.

A comparative study mentioned some discrepancy between the nitrate concentration in the different networks and protocols but pointed out that the discrepancy was due partly to territorial factors. However all three protocols give a good indication of the possible N-losses by leaching and they are able to detect identical trends and evolutions when used in the same region (Figure 459 and Figure 460).

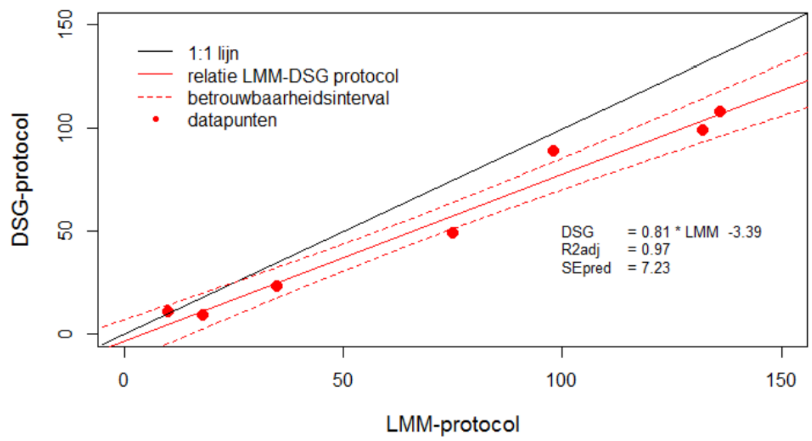

Figure 459: Indicative comparison of the nitrate concentration in the soil water according to the DSG- and LMM-protocol (Ros, 2014).

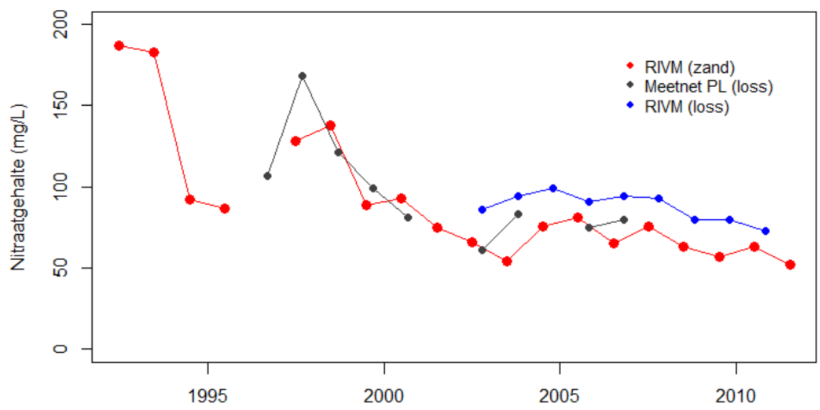

Figure 460: Comparison of regional average nitrate concentrations according to the LMM-protocol and the BVM-protocol (Baumann et al., 2012).

These conclusions supported the decision to realize the water monitoring by an extraction.

To determine the nitrate concentration in the soil water a water extraction was the most obvious choice. Based on the experience and knowledge of experts in nutrient management in soils, which evaluate the derogation monitoring in Flanders and some of which take an advisory role for the VLM, an extraction with potassium chloride was judged to be as efficient as an extraction with water. Both extraction methods were applied on a range of Flemish soil samples and the results of both methods were compared.

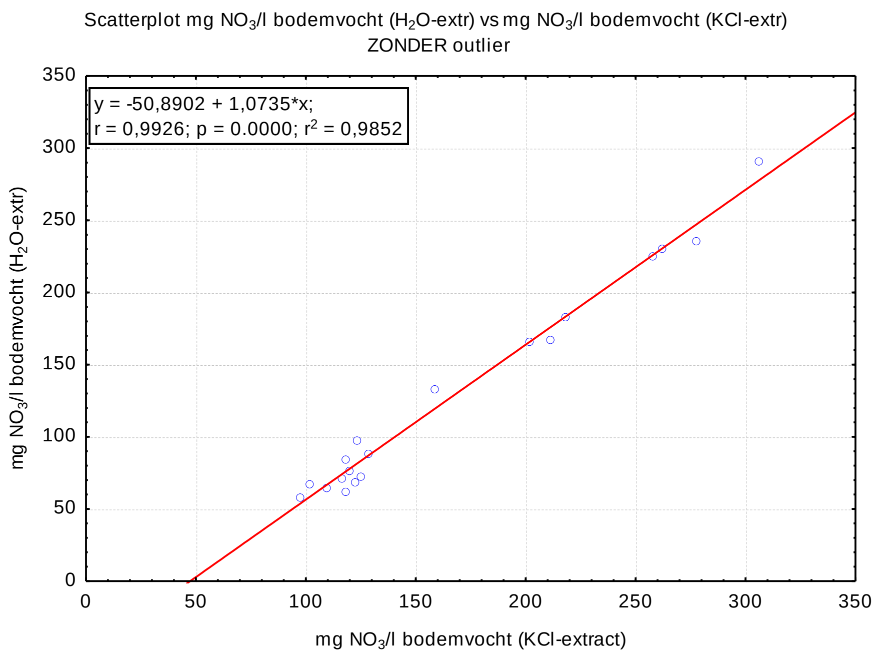

Figure 461: Scatterplot of the nitrate concentration in the soil water determined by extraction in water (mg NO_3/l H_2O-extr) versus the nitrate concentration in the soil water determined by extraction in potassium chloride (mg NO_3/l- KCl-extract). (samples under limit of quantification not withheld)

Both a linear as a quadratic relation between the results of both extraction methods were statistically significant. The results seemed to be significantly correlated.

A linear relation through the origin could explain 92 % of the variation (Table 106). The linear relation fitted through the origin was described by following function (Table 107):

"NO_3 concentration soilwater (mg NO_3/l) in H_2O-extraction= 0,81 x NO_3 concentration (mg NO_3/l) in KCl-extraction"

Table 106: Basic statistics of the linear relation mg NO_3/l (H_2O-extraction) cfr mg NO_3/l (KCl-extraction) fitted through the origin

Test of Whole Model, Adjusted for the Mean (Y=Mean)											
	Multiple - R	Multiple - R^2	Adjusted - R^2	SS - Model	df - Model	MS - Model	SS - Residual	df - Residual	MS - Residual	F	p
mg NO_3/l H_2O	0,957	0,917	0,917	89767,54	1	89767,54	8160,86	18	453,38	198,00	0,00

Table 107: Estimation of parameters of the linear relation between mg NO_3/l (H_2O-extraction) vs mg NO_3/l (KCl-extraction) fitted through the origin

Parameter Estimates Sigma-restricted parameterization		
	mg NO_3/l H_2O - Param.	mg NO_3/l H_2O - p
mg NO_3/l KCl	0,81	0,00

A quadratic function forced through the origin could declare 98 % of the variation (Table 108). This quadratic relation was described by the function: (Table 109 and):

"NO_3 concentration soilwater (mg NO_3/l) in H_2O-extraction = 0,0015 x (NO_3 concentration soilwater (mg NO_3/l) in KCl-extraction)^2 + 0.4773 x NO_3 concentration soilwater (mg NO_3/l) in KCl-extraction"

Table 108: Basic statistics of the quadratic function between mg NO_3/l (H_2O-extraction) vs mg NO_3/l (KCl-extraction) fitted through the origin

Test of Whole Model, Adjusted for the Mean (Y=Mean)											
	Multiple - R	Multiple - R^2	Adjusted - R^2	SS - Model	df - Model	MS - Model	SS - Residual	df - Residual	MS - Residual	F	p
mg NO_3/l H_2O	0,992	0,984	0,983	96339,14	2	48169,57	1589,26	17	93,486	515,26	0,00

Table 109: Estimation of parameters of the quadratic function between mg NO_3/l (H_2O-extraction) vs mg NO_3/l (KCl-extraction) fitted through the origin

Parameter Estimates Sigma-restricted parameterization		
	mg NO_3/l H_2O Z<BG - Param.	mg NO_3/l H_2O Z<BG - p
mg NO_3/l KCl Z<BG	0,4773	0,00
mg NO_3/l KCl Z<BG^2	0,0015	0,00

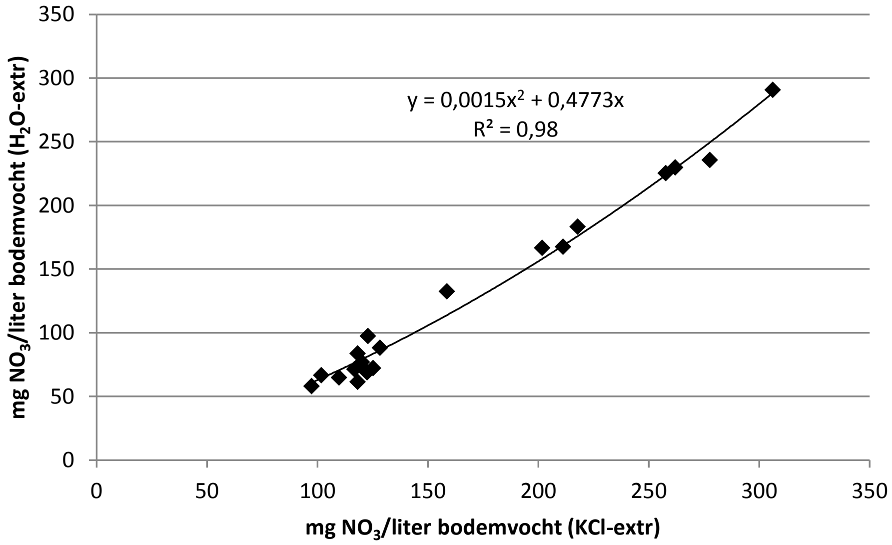

Figure 462: Quadratic relation of the nitrate concentration in the soil water determined with a water extraction versus the nitrate concentration in the soil water determined with a potassium chloride extraction.

These correlations were judged to be sufficient regarding to the statistical significance and the R^3-values.

With the agreement of the team of experts it was decided to monitor the nitrate concentration in the soil water by an extraction in potassium chloride of the soil layer 60-90 cm.