# Dutch energy crops

Parameters to calculate greenhouse gas emissions in 2011





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In this study, a set of parameters is presented, which enable NL Agency to calculate greenhouse gas emission values for four Dutch arable crops for the full production chain of biofuels. Emission values below the so-called RED-default values make the production of biofuels from such crops easier from a legal point of view.

In dit rapport worden parameterwaarden gepresenteerd, waarmee Agentschap NL broeikasgasemissies kan berekenen voor vier Nederlandse akkerbouwgewassen over de gehele keten van bio-energieproductie. Emissiewaarden onder de zogenaamde standaardwaarden uit de RED maken de productie van biobrandstoffen uit dergelijke gewassen wettelijk gezien gemakkelijker. This research has been carried out by commission of the Agentschap NL of the Ministry of Economic Affairs.

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# Preface

In the EU and globally, a transition from oil-based and other non-replaceable energy sources to more sustainable and bio-based sources of energy is high on the political agenda. Production of bio-diesel and bio-ethanol and adding certain percentages of these fuels to traditional diesel and ethanol is decided on in EU regulations, for example. Bio-energy production from such sources is good for the world's reserves of oil and gas but is also thought to contribute to a solution for greenhouse gas emission problems from traditional energy sources. However, this only appears to be true when the production of alternative bio-based energy complies with certain conditions. Therefore, the EU has set limits for greenhouse gas emission levels from the production processes involved.

This report focuses on the primary production part of the chain, i.e. the cultivation and harvest of four arable crops in the Netherlands, winter wheat, rapeseed, grain maize and sugar beet. The study was ordered by NL Agency, a Service of the Dutch Ministry of Economic Affairs (EZ) and part of a larger study to fulfil EU requirements from the Renewable Energy Directive (RED), for which the Dutch Ministry of Environment (VROM) is responsible.

The study was carried out by a research team from LEI-Wageningen UR, Agricultural Economics Research Institute in The Hague and PRI-Wageningen UR, Plant Research International in Wageningen, the Netherlands, in close cooperation with NL Agency and a board of relevant stakeholders in the field of bio-based energy production from arable crops: LTO-Nederland (Land- en Tuinbouw Organisatie Nederland; Dutch Farmers Association; Ben Hasselo), NAV (Nederlandse Akkerbouw Vakbond; Dutch Arable Association, Klaas Hoekstra), PA (Productschap Akkerbouw: Board for the Arable Production Chain, (Tiitse Bouwkamp), IRS (Instituut voor Rationele Suikerproductie; Dutch Institute of Sugar Beet Research, Frans Tijink), PRI (Plant Research International, Sjaak Conijn), PPO-agv (Praktijkonderzoek Plant & Omgeving akkerbouw en groenteteelt in de vollegrond; Applied Research Institute for Plant and Environment, arable and field vegetable farming, Marcel van der Voort) and ministerie van LNV; Dutch Ministry of Agriculture, Nature and Food Quality, Puck Bonnier). This board was involved in discussions with NL Agency and the research team on the working plan and procedures and the report. LEI wants to thank NL Agency and the board for their involvement in the project and their contribution to data collection and model runs.

The research team consisted of Bert Smit (project leader, report), Bas Janssens (co-project leader, data collection), Jakob Jager (data collection and processing), Henri Prins (data collection and processing) and Harry Luesink (Mambo simulations, data supply). Sjaak Conijn (PRI-Wageningen UR) provided  $N_2O$  calculations with the model 'E-CROP'.

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Managing Director LEI

# <u>Summary</u>

#### Introduction

The background of this report is the Renewable Energy Directive of the EU. Article 19.2 in the RED states that the EU member states have to compile a list of greenhouse gas (GHG) emissions from crop cultivation and harvest for bio-fuel purposes and submit it to the European Committee in 2010. The member states have to prove that the emissions from biofuel production are equal to or lower than the emissions in the regional values in Annex V part D of the RED. If this applies, then producers of bio-fuel can use the relevant default values in this annex. They can also use values measured and calculated by themselves.

In this study, the relevant parameter values are presented for the cultivation and harvest of four arable crops, which are already (rapeseed) or could potentially be used for biofuel production (winter wheat, sugar beet and grain maize). In compliance with the RED, the data are collected per province (the so-called NUTS2 region level). Two soil types are discerned in every region: clay and other soil types.

The collected parameters about cultivation are part of the input for calculations of the greenhouse emissions for each biofuel production chain of the crops studied. The calculations at chain level were carried out by NL Agency. This report focuses on the crop parameters concerning cultivation and harvest of the four crops listed.

#### Data sources, models and methods

During the research, the following parameters were collected per crop, region and soil type: crop areas, yields of main and by-product, seed quantity, N, P, K and CaO fertilisation rates, amount of pesticides (kg active ingredients), fuel use and N<sub>2</sub>O emissions from soil. The N<sub>2</sub>O emissions from the soil were calculated per crop and region with the model E-crop, including equations from IPCC (2006).

The parameters were assessed for 2011 in order to approach the current situation as optimally as possible. In particular, the crop yields of sugar beet and rapeseed and the fertilisation rates in the four crops have significantly changed compared with the years 2005-2008. Available CBS statistics over these years were the main data source. Where these data were missing, other data sources were used.

The yields of main product for 2011 were assessed through trend analysis on data from the years 1994-2009. An expert meeting was organised to optimally estimate the effects of the increasingly strict fertilisation regulations for the four crops; the experts invited were asked to estimate the current fertilisation situation per crop in 2011. Not only were historic (2005-2008) data on manure application, annually reported through model estimate with MAMBO, and legal regulations for 2011 taken into account. The availability and the application of relatively cheap manure were also taken into account in the estimates. Afterwards, the results of the expert meeting were attributed to regions.

#### Results

The parameter values were reported for each crop at provincial level, both per soil type and for the province as a whole and both per ha and per tonne of product (Table 3.9). Yields of main product and fertilisation level data vary mostly between regions. All parameters only concern crop cultivation and harvest. NL Agency uses the parameters to calculate greenhouse gas emissions of the bio fuel production chains concerned.

#### Discussion

A number of parameter values could change in future due to significant changes in crop yields, prices and areas, fertilisation levels and fuel use efficiency, for example. This suggests the need to re-calculate the parameter values on a regular basis (e.g. once in five years).

# Samenvatting

#### Inleiding

De achtergrond van dit rapport is de Renewable Energy Directive van de EU. Artikel 19.2 in de RED stelt dat de EU-lidstaten een lijst met broeikasgasemissies moeten samenstellen van gewassen die bestemd zijn voor de productie van bio-brandstoffen en deze lijst in 2010 aan de Europese Commissie moet overhandigen. De lidstaten moeten aantonen dat de emissies van biobrandstof lager zijn dan de standaardwaarden voor emissies die zijn opgenomen in Annex V deel D van de RED. Als dat het geval is, dan kunnen producenten van biobrandstoffen de standaardwaarden overnemen. Zij kunnen ook de door henzelf gemeten en berekende waarden gebruiken.

In dit onderzoek zijn de relevante parameterwaarden voor de teelt en oogst verzameld voor vier gewassen die in Nederland al geteeld worden voor de productie van biobrandstof (koolzaad) of daar in potentie voor in aanmerking komen (suikerbiet, wintertarwe en korrelmaïs). Conform de RED gaat het om een uitwerking per provincie (de zogenaamde NUTS2-regio). Binnen elke regio zijn twee grondsoorten onderscheiden: klei- en overige gronden.

De verzamelde parameters over de teelt zijn onderdeel van de input voor berekeningen van de broeikasgasemissies per biobrandstofketen van ieder gewas. Deze ketenberekeningen zijn uitgevoerd door Agentschap NL. Dit rapport beperkt zich tot de gewasparameters die betrekking hebben op de teelt en oogst van de vier genoemde gewassen.

#### Databronnen, modellen en methoden

Tijdens het onderzoek zijn per gewas, regio en grondsoort de volgende parameters verzameld: gewasarealen, opbrengsten hoofd- en bijproduct, hoeveelheid zaaizaad, bemestingsniveaus N, P, K en CaO, hoeveelheid gewasbeschermingsmiddelen (kg actieve stof), brandstofverbruik en N<sub>2</sub>O-emissie uit de grond.

De  $N_2$ O-emissies van de grond zijn per gewas en regio berekend met het model E-crop waarin formules van IPCC (2006) zijn opgenomen.

Om aan te sluiten bij de actuele situatie zijn parameters voor 2011 vastgesteld. Met name de gewasopbrengsten van suikerbiet en koolzaad en de bemestingsniveaus in de vier gewassen zijn aanzienlijk gewijzigd ten opzichte van de jaren 2005-2008. In principe is gebruik gemaakt van beschikbare CBS- statistieken 2005-2008. In geval deze ontbraken zijn andere databronnen geraadpleegd.

De opbrengsten hoofdproduct voor 2011 zijn vastgesteld via trendanalyse op data uit de jaren 1994-2009. Om de effecten van het steeds stringentere mestbeleid voor de vier gewassen goed in te schatten is een expert meeting georganiseerd waarbij experts gevraagd is een inschatting te maken van de bemestingssituatie per gewas in 2011. Daarbij is niet alleen gebruik gemaakt van mestgiften uit het verleden (2005-2008), zoals jaarlijks gerapporteerd worden via berekeningen met model MAMBO, en van de wettelijke voorschriften zoals die in 2011 gaan gelden. Ook de beschikbaarheid en het gebruik van relatief goedkope dierlijke mest is meegenomen in de schattingen. De resultaten van de expertmeeting zijn vervolgens via regio's toegewezen.

#### Resultaten

Voor ieder gewas zijn de parameterwaarden op provinciaal niveau zowel per grondsoort als voor de gehele provincie gerapporteerd en zowel per hectare als per ton product in tabelvorm weergegeven (tabel 3.9). Van regio tot regio variëren vooral de opbrengsten van het hoofdproduct en de bemestingcijfers. De parameters in dit rapport hebben uitsluitend betrekking op de teelt en oogst van de vier gewassen. Agentschap NL gebruikt deze waarden bij de berekening van de broeikasgasemissies voor de betreffende productketens voor biobrandstoffen.

#### Discussie

Een aantal parameterwaarden zouden in de toekomst kunnen veranderen door significante veranderingen in bijvoorbeeld gewasopbrengsten, -prijzen en -arealen, bemestingniveaus en efficiëntie in brandstofgebruik. Men zou eigenlijk regelmatig de parameterwaarden opnieuw moeten berekenen (bijvoorbeeld eens in de vijf jaar).

# 1 Introduction

#### 1.1 Background

The background for this report is the EU's Renewable Energy Directive (RED; EU, 2009). Article 19.2 in the RED states that the EU member states have to compile a list of greenhouse gas (GHG) emissions from crop cultivation and harvest for bio-fuel purposes and submit it to the European Committee in 2010. The member states have to prove per region (equivalent to a province in the Netherlands) that the emissions from biofuel production are equal to or lower than the disaggregated default values for cultivation in Annex V part D of the RED. If this applies, then producers of bio-fuel can use the relevant default values in this annex. They can also use values measured and calculated by themselves. It is still unclear whether regional average values can be used instead.

For the Netherlands, the Ministry of VROM (Housing, Regional Planning and Environment), with the help of NL Agency, will submit the list of parameter values to the European Committee. NL Agency will carry out calculations for GHG emissions and compile standard parameter values for four crops in the Netherlands that are used or could be used for bio-fuel production: winter wheat, grain maize, sugar beet and rapeseed. To make these calculations possible, the Agricultural Economics Research Institute LEI supplies NL Agency with a number of specific basic values (parameters) at province level (NUTS2 level) and within provinces divided over clay and other soil types (mainly sandy soils, peat and reclaimed peat soils). The parameter values required are area, yield, diesel use for agricultural machinery applied, nutrient, pesticide and seed use and  $N_2O$  emissions from soil for each of the four crops. In this report, the parameter values are listed as requested and the methods of data collection and processing are given.

#### 1.2 Crops studied, assumptions and restrictions

Rapeseed is the only one of the four crops studied that is currently grown in the Netherlands for bio-fuel production (biodiesel). In 2008, a relative small area of 2,467 ha of rapeseed was grown with an average yield of 3,800 kg per ha (CBS, 2008). This area almost fully consisted of winter rapeseed; therefore,

summer rapeseed is not taken into account in this study. The other three crops are currently almost exclusively grown for food and/or feed purposes and not for bio-fuel production. Maize is grown in the Netherlands mainly for feed and processed as silage. It is unlikely that silage maize will be used for bio-fuel production. Therefore, this study is limited to grain maize, which in other countries is used for bio-fuel production. Thus, grain maize is a potential crop in the Netherlands for bio-fuel production (ethanol). The same is true for wheat and sugar beet. In the case of wheat, this study is limited to winter wheat, which makes up about 90% of the wheat area in the Netherlands. The remaining 10% of the area consists of summer wheat, which has a shorter growing period and lower inputs; this wheat type may therefore have other parameter values than winter wheat.

The parameter values should include soil, climate and yield variation in the Netherlands. Soil variation is included through discerning (as far as possible) between clay and other soil types. Yield variation corresponds with soil, year/ climatic and crop effects.

In this study, it is assumed that the parameter values for maize, wheat, rapeseed and sugar beet are the same for bio-fuel as for food and feed purposes. This seems reasonable, since the crop types used for bio-fuel production are similar to those used for other purposes. The only exception is 'energy maize', but this crop is used for biogas production. However, this type of bio-fuel production is outside the scope of this study. The same applies to production and other processes outside crop cultivation and harvest, e.g. the bio-fuel production itself and the logistics of inputs to and outputs from the farms.

Since 2006, the Dutch nutrient regulations have become stricter every year. Because of these significant changes, it was decided that the study should focus on the year 2011, also connecting the most relevant data to the first year of RED.

### 1.3 Guide for readers

Besides this introductory chapter, this report describes methods of data collection and processing, including data sources (Chapter 2), results of the data collection and processing (Chapter 3) and discussion of both methods and data provided (Chapter 4). The study is completed with a list of references referred to and a set of appendices.

# 2 Data sources, models and methods

#### 2.1 Introduction

In this chapter, the data collection and processing is described per parameter, including data sources and models applied. A summary of the parameters required and data sources is given in Table 2.1.

The parameters listed in the table differ in variability over years. Some of the parameters were assumed to be more or less constant over the years. For those parameters, values were derived from the most recent datasets available. However, some parameters significantly change over time:

- On average, crop yields annually increase due to improvement of varieties and cultivation methods. Estimates of yields are assessed through trend analysis on available statistical data over 1994-2009.
- Nitrogen and phosphate application levels from manure and fertiliser in the Netherlands have been changed in recent years because of changes in the Dutch nutrient management regulations. Therefore, NL Agency and the advisory board decided that nutrient levels for the situation in 2011 should be estimated. This task was carried out through an expert meeting (see 2.5.2).

For the more or less stable parameters, separate and average values for the four years 2005-2008 were collected per crop, per province (NUTS2 level) and if possible for soil types (clay and other soil types) within provinces. Other soil types include all non-clay soils like sandy soils and peat. The area of organic soils used for growing of arable crops in this study is nil. If such was possible, the parameter values of single parameters were weighed at province level according to the respective areas of clay and other soil types. In all cases, outcomes were also weighed per tonne, assuming that processors prefer data on ton level and that farmers are more used to decide on a ha basis.

For sugar beet, a correction factor was applied on the CBS data. During determination of beet quality and quantity, the tops of the beets are removed, because they contain less extractable sugar. Farmers are paid for net amount of beets delivered, whereas the total beet yield is about 13% higher (CBS net sugar beet yield data were divided by a factor 0.93\*0.95, based on Corré and Langeveld (2008); Van Swaaij (IRS, pers. comm., 2009), which can also be used for ethanol production.

Table 2.1	Overview of parameters requested and data sources				
Parameter (per c	rop)	Data source			
Area (ha) and		CBS1			
Yield (kg/ha)		Estimated through trend analysis based on			
		CBS and IRS data <sup>2</sup>			
Yield by-product (kg	g/ha)	KWIN, <sup>3</sup> IRS			
Moisture contents of	of (by-products)	Literature, IRS			
Oil, starch and suga	ar contents (%)	Literature, IRS			
Diesel use of agricu	ultural machinery	KWIN method			
(MJ per ha)					
Nutrient use (kg/ha	<i>):</i>				
- N		LEI Information net, <sup>4</sup> expert meeting, <sup>5</sup>			
		IRS, LNV <sup>6</sup>			
- CaO		Nutrient supply advice <sup>7</sup>			
- P <sub>2</sub> O <sub>5</sub>		Nutrient supply advice, expert meeting, IRS			
- K <sub>2</sub> O		Nutrient supply advice			
Pesticide use (kg a	.i./ha) <sup>8</sup>	LEI Information net, KWIN, IRS			
Seed applied (kg/h	a)	KWIN, IRS			
N <sub>2</sub> O emissions from	n soil	Model simulations <sup>9</sup>			

Therefore, it is more logical to take total beet yield into account in the calculations instead of net beet yield, which is given in official statistics.

<sup>&</sup>lt;sup>1</sup> CBS: Central Bureau for Statistics, The Hague, responsible for the annual national survey on agricultural production (crop areas, livestock size, yields, etc).

<sup>&</sup>lt;sup>2</sup> IRS: Institute of Sugar Beet Research, Bergen op Zoom (Bietenstatistiek).

<sup>&</sup>lt;sup>3</sup> KWIN: Quantitative Information on Arable and Field Vegetable Farming (2009), a handbook with standard and normalised data on arable and field vegetable crops, produced by PPO-agv in Lelystad. <sup>4</sup> LEI Information-net: the Dutch version of the FADN (Farmers Accountancy Data Network) of the EU

<sup>(</sup>Poppe, 2003; Vrolijk et al., 2008a).

<sup>&</sup>lt;sup>5</sup> See 2.5.2.

<sup>&</sup>lt;sup>6</sup> LNV: The Dutch Ministry of Agriculture, Nature and Food Quality, which has set a number of regulations on maximum nutrient supply levels ('Gebruiksnormen').

<sup>&</sup>lt;sup>7</sup> Nutrient supply advice: Van Dijk and Van Geel, 2008.

<sup>&</sup>lt;sup>8</sup> A.i.: active ingredients, the effective part of pesticides that has an effect on weeds, plagues and diseases.

<sup>&</sup>lt;sup>9</sup> With E-CROP, explained in 2.8.

# 2.2 Crop area and yields of main and by-products

#### Crop area

From CBS data, crop areas per province and per soil type per province were derived. These data are based on the national CBS survey carried out annually among all farmers with a certain minimum farm size (threshold value). Therefore, this sample covers all relevant agricultural land use and can be regarded as a reliable source for area data per crop. The 2011 area was based on the average crop area data over 2005-2008. A check on changes in 2010 did not reveal any significant changes in area data of the four crops studied.

#### Yields

CBS also collects yield estimates based on observations throughout the harvest season, mainly by experts in the field<sup>1</sup>. The estimated yields of the four energy crops in 2011 were based on CBS yield data (1994-2009). Average national crop yields in 2011 were estimated through trend analysis. In recent years, more than average yield improvements were observed in some crops (like sugar beet). To incorporate such developments, a second estimate over a more recent, shorter period, 2003-2009, was additionally carried out. The average of both estimates was used as crop yield for 2011. Table 3.1 shows the estimated yields of the crops studied. More background information is given in Appendix 4.

#### **By-products**

In general, yields of by-products are not officially registered. Yields of straw of rapeseed and winter wheat were adopted from KWIN. They slightly differ for different regions. The yield of straw of grain maize was adopted from Groten (2003). For sugar beet, an average yield of 40 tonnes of leaf was assumed from Corré and Langeveld (2008) and Van Swaaij (IRS, pers. comm., 2009). These data were considered as standard for the Netherlands as a whole and listed in 3.1. The same applies for moisture contents of sugar beet.

<sup>&</sup>lt;sup>1</sup> The yield data of CBS refer to average values per province. Provinces generally have mixed soil types, although in many cases either clay soil or other types dominate. To correct for clay soils in provinces with predominantly other soil types and vice versa, data from other provinces were inserted in which clay and other soil types respectively dominate. The procedure is summarised in Appendix 1, Table A1.1.

# 2.3 Oil, starch, sugar and moisture contents

Oil contents of rapeseed and starch contents of winter wheat and grain maize are usually not measured and registered on a regular basis because there is no connection with the price paid to the farmer.<sup>1</sup> This connection is however present in the case of sugar beet growers, so that data on sugar content are available in IRS data sources. Sugar and dry matter contents of sugar beet are not registered in CBS statistics. Therefore, these parameters were estimated for 2011 by IRS. The moisture contents of the other crops (main and by-product) were derived from literature (CVB, 2004).

# 2.4 Energy use during field operations

Fuel (diesel) use of machinery involved in crop cultivation and harvest was calculated according to the method applied by PPO-agv in compiling KWIN. In this method, all operations including contract work are taken into account as applied in practice. The calculations are based on the fuel use expressed in litres diesel and the standard process time per operation applied. Energy use was calculated with a factor 37.1 MJ per litre diesel. Detailed information is given in Appendix 2. Fuel use per operation depends on the engine power (in kilowatt) of the machinery applied. Table 2.2 summarises the total energy use per crop and per soil type.

Table 2.2	Energy use of field operations including contract work per crop						
Crop		Energy use of field operations on soil type (MJ/ha)					
		Clay	Other				
Winter wheat		6,615	6,350				
Rapeseed		6,509	6,244				
Grain maize		6,120	6,350				
Sugar beet		5,761	5,673				
Source: PPO-agv, adapted by LEI after communication with PPO-agv.							

<sup>&</sup>lt;sup>1</sup> An exception is the rapeseed co-operative Colzaco in Overijssel/the Eastern part of the Netherlands, which pays the farmers according to oil content (on average 43.3% in 2008, www.colzaco.nl).

# 2.5 Fertilisation of the crop

#### 2.5.1 Introduction

This section describes the regulations on fertiliser and manure application on arable land in the Netherlands. It explains why an expert meeting was organised to assess current fertilisation rates in the four crops studied.

#### Regulation based on application norms

The nutrient management regulations in the Netherlands have been changed several times in recent years. At the end of 2005, a shift was made from the old nutrient management regulation system MINAS<sup>1</sup> to a set of application norms which have and will generally become increasingly strict over time. The international nitrate regulations were the basis for the shift to the new national regulation. The current application norms are based on the nutrient uptake of the crop plus a small loss of nutrients allowed to the environment.

The nutrient rates in the application norm regulation are not considered per crop but per farm. The maximum rates are defined per crop and soil type (Table 2.3 (A and B)), but farmers are allowed to apply more on one crop than the maximum rate allowed for in the regulation if they compensate that through lower application rates on other crops, so that the maximum rate (in the crop rotation) is not exceeded.

<sup>&</sup>lt;sup>1</sup> Including a bookkeeping system, making compensation of surpluses over years possible. In the new system, compensation between crops is still possible, but no longer over years (LNV, 2005).

Table 2.3 A	N ap	N application norms for crops on clay (kg N per ha)								
	2005	2006	2007	2008	2009	2010	2011	2012	2013	
Winter wheat	-	245	240	230	220	245	245	245	245	
Rapeseed	-	225	225	215	205	205	205	205	205	
Sugar beet	-	165	165	160	150	150	150	150	150	
Grain maize a)	-	205	205	195	185	185	185	185	185	

a) Grain maize: norms without derogation,<sup>1</sup> meaning that higher norms are valid in case 70% or more of the farm area consists of grassland.

Source: www.lnvloket.nl.

Table 2.3 B	N application norms for crops on other soils (kg N per ha)								
	2005	2006	2007	2008	2009	2010	2011	2012	2013
Winter wheat	-	190	160	160	160	160	160	160	160
Rapeseed	-	205	195	195	195	195	195	190	190
Sugar beet	-	150	145	145	145	145	145	145	145
Grain maize a)	-	185	175	175	150	150	150	150	150
a) Crain maizer norma without deregation 1 mapping that higher norma are valid in acces 70% or more of the form									

a) Grain maize: norms without derogation,<sup>1</sup> meaning that higher norms are valid in case 70% or more of the farm area consists of grassland.

Source: www.lnvloket.nl.

#### Manure application

In the Netherlands, there is a surplus of manure. Arable farmers can get this surplus manure for free or even with receiving payments. Besides, the use of manure is profitable because less fertiliser is required, saving costs.

Until 2009 application of manure in autumn was quite common, especially on farms with clay soils. An important recent change in the nutrient management regulations is the obligation to apply manure in spring or late summer instead of autumn (15 September-1 February). This means that application of manure in autumn has been forbidden since 2009. As a consequence, most arable farmers on clay soils will turn to spring applications of manure. On other soils, autumn application of manure had already been forbidden.

<sup>&</sup>lt;sup>1</sup> Farms with at least 70% (permanent) grassland and fodder crops are allowed to use more manure than other farms: 250 kg N instead of 170 kg N per ha (the so-called derogation). On that type of farm, more manure can be applied under the legal restrictions. Thus, higher nutrient rates are possible for arable crops on such farms. However, in the calculations, the maximum manure rate (170 or 250 kg N/ha) does not play a role. The maximum rates are expressed as average values per farm. Higher rates for a specific crop are no problem as long as the average rate at farm level does not exceed the limit, meaning that lower rates on certain crops can compensate for higher rates on the other crops at the farm.

At arable farm level, manure application is maximised to 170 kg N on average per ha in total; meanwhile the total P application (including fertiliser) is restricted to 70 kg per ha. The amounts of N and P that will become available for the crop are calculated by taking the efficiency into account, expressed as legal efficiency coefficients (see Table 2.4 for coefficients for slurry). Thus the maximum effective N rate from slurry applied in the spring of 2011 is 170\*60% = 102 kg/ha, taking the maximum effective N rate and the efficiency coefficient into account.

Table 2.4	Legal e arable f	egal efficiency coefficients for N from slurry applied in arable farming (%) a)							
Period and type			Legal e	efficienc	cy coeff	icients i	in year		
of application	2005	2006	2007	2008	2009	2010	2011	2012	2013
Autumn application	-	30	40	50	prohi-	prohi-	prohi-	prohi-	pro-
slurry on clay and					bition	bition	bition	bition	hibi-
other soils									tion
Slurry on clay	-	60	60	60	60	60	60	60	60
and peat soils		(60)	(60)	(60)	(60)	(60)	(60)	(60)	(60)
in spring b)									
Slurry on sandy	-	60	60	65	65	60	60	60	60
and loess soils b)		(60)	(60)	(65)	(65)	(70)	(70)	(70)	(70)
a) For stable and liquid manure, other coefficients apply; b) Between brackets: slurry from other animals than graz- ing livestock.									

As a summary, the main adaptations in the fertilisation regulations are:

- the fertilisation norms are more or less based on fertilisation rates advised;
- manure application in autumn (15 September-1 February) is forbidden on clay and other soils.

## 2.5.2 Expert meeting

The significant change in nutrient management regulation (from MINAS to a system with application norms) makes it rather difficult to estimate nutrient applications per crop in 2011 from trend analysis based on available data over 2005, until 2008. Alternatively, an expert meeting was organised to assess better estimates of nutrient management in 2011 in practice.

The aim of the expert meeting was to estimate N and  $P_2O_5$  application levels applied to the four crops studied in 2011, taking into account the increasing stringency of Dutch nutrient regulation. To this end, a relatively simple spreadsheet model was developed containing the fertilisation levels in the past years (MAMBO 2005-2008),<sup>1</sup> advised nutrients levels and the fertilisation regulations for 2011. The participants in the expert meeting (Appendix 5) could suggest appropriate fertilisation levels per crop and adapt them until the participants had reached consensus on a crop-specific fertilisation strategy; the results were calculated and compared with data from previous years.

During the meeting, the following procedure was followed:

- Firstly, a crop specific fertilisation strategy was formulated, closely relating to real life strategies, taking into account fertilisation at farm and rotation level and legal restrictions;
- Secondly, manure was applied in spring in crops with suitable crop stands and soil conditions. A crop specific manure dose was completed with doses of fertiliser, focusing on application norms and levels advised;
- Finally, consensus about the fertilisation strategy per crop was reached among the fertilisation specialists, both for clay and other soils.

After the workshop, the results were translated to regional results and shared with the experts for feedback. A further step was to translate the regional fertilisation levels for both soil types discerned to provinces (NUTS2 level, see Appendix 1, Table A1.2).

A difficult aspect during the expert meeting was the Dutch fertilisation regulation, which focuses on farm level, not on crop level. Consequently, farmers are allowed to apply higher fertilisation levels than the legal norm on one crop and lower levels on another as long as they comply with the application norm for their farm. In theory, fertilisation levels are calculated on the removal of nutrients through crop harvest; in practice, fertilisation levels are set considering the crop rotation.

The nutrient supply rates for 2005-2008 in the four crops had been assessed through the model MAMBO (Appendix 3). The input data for this model consist of:

1. The amount of fertiliser applied in the year(s) studied according to the annual statistics for fertilisers (see e.g. CBS Land- en tuinbouwcijfers 2009). The

LEI Information-net is the basis for the distribution of this amount of fertiliser over regions and the assessment of the fertiliser rates per crop group;

2. The amount of manure applied in the year(s) studied. These data are based on data on the production and delivery of manure (including exports) in those years and the transportation of manure to the regions, mainly the so-called 'VDMs' (Vervoersbewijzen Dierlijke Mest; Manure Transportation Certificates), reported by the Ministry of Agriculture (LNV) for the 31 Dutch regions for manure transportation. The distribution of the regional supply over the crops is based on registration in the LEI Information-net (Luesink et al., 2009).

In the case of nitrogen, the N level reported consists of an efficient part that is taken up by the plant in the first year after application and the remaining part, and a non-efficient part. The N rates reported consist of the total N rate, meaning the sum of the efficient and the non-efficient parts of the rate.

#### Manure application in autumn

Manure application is reported in the LEI Information-net. The attribution of the manure to crops takes into account the period in which the manure has been applied. When the manure is applied in autumn, after the harvest of the major crop in that year, then the manure is attributed to the crop cultivated on that specific field in the following year.

#### Example

In September 2006, pig manure was applied on a field after the harvest of winter wheat. In 2007, potatoes were cultivated on that field. The pig manure applied on that field is attributed to potato in 2007 and not to winter wheat in 2006.<sup>1</sup>

#### 2.5.3 Phosphate application

In this study, a small phosphate dose is assumed, based on data from MAMBO (2005-2008). It was assumed that the additional phosphate requirement is supplied with manure application in other crops in the rotation, a common practice, according to the experts.

<sup>&</sup>lt;sup>1</sup> This example mainly refers to the calculations with MAMBO (2005-2007); in 2011, only manure can be applied in autumn in rapeseed.

# 2.5.4 Potassium and lime

Potassium and lime are expressed in K<sub>2</sub>O and CaO, respectively.

The calculation of the potassium fertilisation rate is based on the discharge with the crop harvest (per province, soil type and year):

- 1. The discharge in harvested product is calculated by multiplying the average kg yield of the main product with the average potassium content of that crop (CVB, 2004). The same procedure was followed for by-products;
- 2. We assumed that the discharge of potassium with harvested product must be compensated with fertilisation. The loss of potassium to clay soils is assumed to be nil; for the other soil types, a loss of 50 kg potassium per ha was taken into account.

Lime is only supplied on sugar beet, not on the other three crops. Lime supply was based on registered data from the sugar industry (Table 2.5).

Table 2.5	Lime supply registered from farmers' data					
Region a)		Lime supply (neutralising value; kg/ha) b)				
South west clay		72				
Holland clay		54				
Flevoland clay		0				
Clay soils in the No	rth	195				
Other soil types in t	the North	212				
South east clay soi	ls	730				
South east other so	pil types	373				
a) The translation from regions for fertilisation to province level is explained in Appendix 1, Table A1.3; b) 1 kg neu-						
tralising value corresponds with 1 to 1.1 kg CaO.						
Source: Suiker Unie, 20	)07.					

# 2.6 Crop protection

Crop protection data for the four crops were derived from the Information net of LEI, given in 3.1.6. Data are given in a.i., i.e. active ingredients, not taking into account differences in impact on environmental and public health between pesticides.

# 2.7 Input of seed

Input of seed is derived from KWIN, combined with additional information on seed weight, for example. For sugar beet and grain maize, KWIN gives the seed amount in units, which had to be multiplied with unit size and seed weight. These data are considered to be uniform for the Netherlands as a whole and listed in 3.1.7 (General data per crop).

# 2.8 N<sub>2</sub>O emissions from the soil

# 2.8.1 Input data

In order to calculate  $N_2O$  emissions from the soil, the model E-CROP with formulas from IPCC (2006) was used. To make the calculations possible, the following input data were collected, if possible specifically for crop, region and soil type (between brackets, units and sources are given):

- N rate from fertiliser applied (kg/ha; based on application norms);
- Fraction NH<sub>3</sub> emissions from fertiliser (%; MAMBO);
- Total N rate from manure applied (kg/ha; expert meeting);
- Fraction NH<sub>3</sub> emissions from manure (%, MAMBO) a);
- Characteristics of crop parts at harvest time (A-C):
  - A Yield of product harvested (kg/ha; CBS);
  - A Dry matter contents of product harvested (%; CVB, 2004);
  - A N contents of product harvested (%; CVB, 2004);
  - B Yield of by-product (kg/ha; KWIN);
  - B Dry matter contents of by-product (%; CVB, 2004);
  - B N contents of by-product (%; CVB, 2004);
  - B Fraction outflow of by-product (% of crop area; estimation by LEI);
- N mineralisation due to a decrease of the organic N reserves (kg/ha) b);
- Area of 'organic soils' (ha) b).

Notes:

a)  $NH_3$  contents of manure

The national agricultural survey in 2005 contained a question about methods of manure application. The results of this part of the survey were reported by Hoogeveen et al. (2008) and used in Mambo. These crop and region specific  $NH_3$  data from Mambo are used in this study.

A third of the manure on arable land is applied through injection. Thus, in total about 10% of the manure is injected, having an emission factor of 5%. The other application systems have much higher emission factors than injection, which can amount to more than 15% of the total N rate for manure shuffles.

The fraction  $NH_3$  emissions from fertiliser used in this study for all crops and regions amounted to 3.7%. The fraction  $NH_3$  emissions from manure used in this study is presented per crop and region in Appendix 6.

b) Organic soils

The area of organic soils used for growing of the arable crops in this study is nil.

#### 2.8.2 Description of E-CROP

The (in)direct  $N_2O$  emissions from the soil by cultivating biofuel crops have been calculated using the LCA tool for energy crops, developed in recent years (E-CROP; Corré & Conijn, 2008). In E-CROP, the calculation methodology of the IPCC with standard emission factors, last revised in 2006, is used (IPCC, 2006). This emission is defined as the enhanced emission, caused by agricultural activities; it does not include the (natural) background emission. The IPCC factors are estimated by very general default values and are discerned in direct and indirect emissions. Direct emission related to crop production is defined as the emission from soil processes (nitrification and denitrification) occurring in the field where the crop is produced. Indirect emissions, however, are caused by the same soil processes but occur in other locations after volatilisation or leaching of nitrogen compounds from the field of production. The IPCC emission factors are summarised in Table 2.6.

Table 2.6	Emissions of $N_2O$ , expressed as fraction of N inputs (kg $N_2O$ -N per kg N; default values)						
Source of N			Type of emis	ssion			
		direct	indirect, after	indirect, after			
			volatilisation	leaching a)			
Synthetic N fertilise	ers	0.01	0.001	0.00225			
Organic N applied as fertiliser			0.002	0.00225			
N in crop residues, left at harvest b)			0	0.00225			
N mineralisation from loss of SOM c)			0	0.00225			
Drainage/manager	nent of temperate organic soils	8 d)					
a) Only when rain and/or irrigation exceeds evapotranspiration plus soil water holding capacity; b) Above ground							

and below ground; c) SOM = soil organic matter; changes can result from change of land use or management of mineral soils; d) ln kg  $N_2O$  ha<sup>1</sup> yr<sup>1</sup>.

Source: IPCC, 2006.

LEI data on synthetic and organic N fertiliser inputs per crop/soil/region (tables in Chapter 3) were used in combination with the factors of Table 2.6. LEI also gathered information on the amount of N in above ground crop byproducts and the average percentage of this by-product removed from the fields in the Netherlands. This estimated removal of N in by-products was subtracted from the total N in crop residues left at harvest which was calculated by using default equations for determining the total amount of crop residues, as provided by IPCC. There are two exceptions in this calculation method because IPCC has no equations for sugar beet and winter rapeseed. For sugar beet, this omission has been solved by assuming that the number of roots of a potato crop (for which IPCC has an equation) is equal to that of a sugar beet crop. Total N in sugar beet crop residues is found by taking the sum of N in roots and N in leaves, the latter obtained from information from CVB (2004). For winter rapeseed we used the equation of winter wheat, but if this equation is used in combination with the generally much lower yields of winter rapeseed. the estimated N in crop residues is too low. The lower yield of winter rapeseed compared to winter wheat is largely caused by the accumulation of oil instead of starch. A correction was applied by calculating a wheat (starch) equivalent yield of the rapeseed yields and to use this 'virtually' (higher) yield in the equation which was developed for winter wheat to calculate the crop residues of winter rapeseed.

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# 3.1 General data per crop

# 3.1.1 Yields

Table 3.1 gives the estimated national yields of the crops studied.

Table 3.1	Crop yields estimated of four (potential) energy crops in 2011							
Year		Crop	yield estimated (	ton per l	na) of			
		winter	sugar beet net	rape-	grain			
		wheat	(gross) a)	seed	maize			
Average 2005-20	80(	8.6	67.6 (76.6)	3.6	11.9			
Estimate 2011 b	ased on 1994-2009 [A]	8.9	74.3	4.1	12.9			
Estimate 2011 b	ased on 2003-2009 [B]	8.7	80.6	4.1	11.7			
2011 (average [A	\] and [B])	8.8	77.4 (87.7)	4.1	12.3			
Increase in 2011	(%) b)	3.4	14.5	12.8	3.2			
a) Between brackets: sugar beet gross yield = net yield/ (93% * 95%) (see for a more detailed explanation, 2.1);								
b) Compared to 2005-2008.								
Source: CBS, adapte	d by LEI.							

# Regional yields

Regional yields per province in 2011 were estimated by multiplying the average regional yield 2005-2008 with the national trend estimation of the yield increase of the concerning crop.

# 3.1.2 Yields of by-products

Table 3.2 gives the yield of the by-products of the crops studied and their typical moisture contents (also for the main product).

Table 3.2	Yield and dry matter contents of the (by-)product of four crops							
Crop	Dry r	natter content (%) a)	Yield (kg/ha)					
	main product	by-product	by-product					
Winter wheat	87	90	4,000					
Sugar beet	26	11.50	40,000					
Rapeseed	92	90	2,500					
Grain maize	65	35	18,600					
a) Moisture content = 100% - dry matter content.								
Sources: KWIN, Corré and Langeveld (2008), Van Swaaij (IRS, pers. comm., 2009), Corré and Conijn (2008),								
Sources: KWIN, Corré and Langeveld (2008), Van Swaaij (IRS, pers. comm., 2009), Corré and Conijn (2008), De Visser et al. (2008), and Forbes and Watson (1999, typical moisture contents), Groten (2003).								

3.1.3 Oil, starch and sugar contents

Rapeseed has an oil content between 40 and 45% (www.kennisakker.nl; Bernelot Moens en Wolfert, 2003). In a Crop cultivation Guide from Belgium, an oil content of 42% is given, which was applied in this study.

Winter wheat has a starch content of 58.7% (or 86.8% of dry matter; CVB, 2004). Grain maize has 68% starch (87.2% of dry matter; CVB, 2004).

Sugar contents of sugar beet on a regional level in the years studied are given in Table 3.3.

Table 3.3	Average sugar contents in the Netherlands in 2005-2007						
Sugar content (%) in year							
2005	2006	2007	2005-2007				
16,8 16,2 17,3 16							
Source: CBS, different years.							

The parameters for 2011 for sugar beet were estimated by IRS:

- sugar content: 17.9%;
- dry matter: 26%.

# 3.1.4 Nutrients: results of the expert meeting

In this section, first a number of basic principles are given, followed by the results per soil type and crop.

# 3.1.4.1 Basic principles

- LEI data reveal that the arable sector in the Netherlands utilises about 2/3 of the room for manure application (Personal communication by Luesink).
- The arable sector mainly applies pig manure; poultry manure is mainly exported. The application of cattle manure is limited, but the experts expect that the availability will increase due to stricter regulations.
- Arable farmers on clay soils shift to spring application of manure. Similar developments are not to be expected on other soils: spring application is the normal procedure in such regions.
- On clay soils, less manure is applied than on other soil types. In 2008, the average manure level was about 60 kg phosphate per ha. On clay soils, a lower level was observed (circa 40 kg/ha), which corresponds with 10 tonnes of pig manure per ha. On sandy and other soils, a higher level (circa 80 kg phosphate) was applied, but his level is expected to decline in 2011 to circa 70 kg/ha. This level corresponds with 17.5 tonnes op pig manure per ha. Both levels were estimated on a rotation level.
- In the province of Zeeland, the general fertilisation level is higher than in the Northern provinces. The manure application level is regionally different, depending on the crop rotation and the supply of manure.
- On other soil types, manure is and will be mainly applied prior to the crops sugar beet and potato.
- In the estimation process of fertilisation levels, average conditions per crop were considered. The manure levels were estimated per crop and not per ha over the farm as a whole.
- The experts observed that the phosphate regulations will be more limiting in 2010 than the nitrogen regulations.

# 3.1.4.2 Clay soils

# General observations

Until 2010, manure application in autumn was common on clay soils prior to potato and sugar beet. On lighter clay soils, manure was applied on winter wheat

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as spring application. The modified nutrient regulations have forbidden autumn application of manure since 2011; so farmers must shift to spring application. On clay soils, manure application to winter wheat will increase. On light clay soils application on potato and sugar beet will be continued.

## Winter wheat

The stricter nutrient regulations will lead to an increase in manure application in cereals as winter wheat compared to the period 2005-2007; manure will be applied in March-April as the second of three doses. On average, 15 tonnes pig manure will be applied to winter wheat on clay soils; a supplementary dose of 170 kg N per ha is applied as fertiliser. In the central clay region, the application level will be somewhat less and in the southwest a bit more.

# Sugar beet

The obligatory shift from autumn to spring application of manure on clay soils will reduce the number of farm(er)s using manure on sugar beet because of the risk of soil damage during spring. As a consequence, manure will be applied to other crops on this soil type, e.g. cereals. To avoid damaging soil structure, spring application of manure in sugar beet is minimal and only possible on light clay soils. On average a small dose of 5 tonnes pig manure per ha is applied before sugar beet drilling.

## Rapeseed

This crop will receive a small start off application (circa 40 kg N per ha) in August, just before sowing/seed drilling. The experts estimated that 50% of the rapeseed growers apply manure as start application and the others use fertiliser.

## Grain maize

Due to the stricter nutrient regulations, the supply of cattle manure will increase further. This type of manure suits grain maize perfectly. Besides manure, a small application of fertiliser is common in grain maize.

## Overall

The overall picture from the expert meeting is given in Table 3.4. The figures are based on the estimates of the experts during the meeting and translated to regional fertilisation strategies. An example of the calculation method is given here.

# Example

The calculation procedure is illustrated with an example for winter wheat. First, the crop specific norms are gathered (Table 3.5). From Table 3.4, the following fertilisation levels are taken:

- 170 kg N fertiliser;
- 5 kg  $P_2O_5$  fertiliser; 1 tonne of pig manure contains: 7 kg N and 4 kg  $P_2O_5$ ;
- 15 tonnes of pig manure in spring application.

Table 3.4	Nutrient management strategies on clay soils				
Crop/region	Application form and amount (kg/ha)			Manure type:	Spring or
	N from	P <sub>2</sub> O <sub>5</sub> from	manure	pig, poultry	autumn
	fertiliser N	fertiliser	(tonne)	or cattle	
Winter wheat	170	5	15	Pig	Spring
North	170	5	15	Pig	Spring
Central	185	5	13	Pig	Spring
Southwest	155	5	18	Pig	Spring
Sugar beet	110	20	5	Pig	Spring
North	110	20	5	Pig	Spring
Central	120	20	5	Pig	Spring
Southwest	110	20	5	Pig	Spring
Rapeseed	175	20	5	Pig	Autumn
North	175	20	5	Pig	Autumn
Central	175	20	5	Pig	Autumn
Southwest	175	20	5	Pig	Autumn
Grain maize	55	10	40	Cattle	Spring
North	55	10	40	Cattle	Spring
Central	55	10	40	Cattle	Spring
Southwest	55	10	40	Cattle	Spring
Source: Expert meeting, as described.					

Table 3.5	Crop specific fertilisation norms for winter wheat 2011			
Legal norm		Level in 2011		
Legal total application norm N (kg/ha)		245		
Legal total applicat	75			
Maximum N level fr	170			
Practical advice N	220			
Legal Efficiency no	60			
Source: www.lnvloket.n	I			

The following fertilisation levels per ha are calculated for winter wheat in 2011:

- N application:
  - Manure: 15 tonnes \* 7 kg = 105 kg N of which 60% efficient = 63 kg
  - Total N: manure + fertiliser
  - Total application: 105 kg + 170 kg = 275 kg N, of which 63 kg + 170 kg = 233 kg N efficient
- P<sub>2</sub>O<sub>5</sub> application:
  - Manure: 15 tonnes \* 4 kg= 60 kg
  - Fertiliser: 5 kg
  - Total: 65 kg

#### 3.1.4.3 Other soils

#### General

Stricter legal application norms for phosphate will result in a decline in manure application levels on other soil types. All manure will be applied in spring, mainly prior to potato and sugar beet. Manure application in cereals on other soil types will be minimal.

#### Winter wheat

On other soil types, the winter wheat area is small. Only few winter wheat growers on these soil types apply manure in winter wheat. Manure is used more often in the southern regions of the Netherland than in the northern regions. Experts signalled the lowering of the legal nitrogen application norm (160 kg N/ha) and they expect that more nitrogen will be applied in winter wheat (190 kg N/ha) which is possible when green manure is grown afterwards.

### Sugar beet

Compared to clay soils, manure application is common in sugar beet on other soil types. On average, a dose of 20 tonnes pig manure per ha and a small amount of fertiliser is applied before sugar beet drilling.

#### Rapeseed

Rapeseed nutrient management on other soil types is similar to clay soils: a small start dose (circa 40 kg N) in August-September just before drilling; almost 50% of the rapeseed growers apply manure as start application and 50% use fertiliser (expert meeting). No differences between regions were indicated.

#### Grain maize

Nutrient management on grain maize on other soil types is fairly similar to clay soils. As a consequence of stricter nutrient regulations, the supply of cattle manure will increase further. This type of manure suits grain maize perfectly and is widely available in all regions. Besides manure, a small fertiliser application is common in grain maize.

#### Overall

The overall picture from the expert meeting is given in Table 3.6. The figures are based on the estimates of the experts during the meeting and translated to regional fertilisation strategies.

3.1.5 Energy use in field operations

See 2.4/Table 2.2.

## 3.1.6 Crop protection data on a national level

Table 3.7 gives a summary of the crop protection data per crop in 2005-2007. The input of pesticides, expressed in kg a.i., is not expected to decline much further in the coming years. The averages over the period 2005-2007 are used as parameters for 2011.

Table 3.6	Nutrient management strategies on other soil types				
Crop/region	Application form and amount (kg/ha)			Manure type:	Spring or
	N from	P <sub>2</sub> O <sub>5</sub> from	manure	pig, poultry	autumn
	fertiliser N	fertiliser	(tonne)	or cattle	
Winter wheat	165	0	5	Pig	Spring
North	165	0	5	Pig	Spring
South	140	0	10	Pig	Spring
Sugar beet	40	5	20	Pig	Spring
North	40	5	20	Pig	Spring
South	40	5	20	Pig	Spring
Rapeseed	175	5	5	Pig	Autumn
North	175	5	5	Pig	Autumn
South	175	5	5	Pig	Autumn
Grain maize	45	10	40	Cattle	Spring
North	45	10	40	Cattle	Spring
South	45	10	40	Cattle	Spring
Source: Expert meeting, as described					

Table 3.7	Summary of cro (Netherlands)	p protection dat	ta per crop and	per soil type		
Soil type/year	Crop protection input (kg a.i./ha)					
	sugar beet	winter wheat	rapeseed	grain maize		
Clay soils						
2005	4.1	4.3	0.1	1.0		
2006	4.8	4.2	0.9	2.1		
2007	5.0	3.5	0.4	3.1		
Average	4.6	4.0	0,5	2.0		
Other soils						
2005	4.1	3.7	0.1	0.9		
2006	4.7	3.6	0.9	1.5		
2007	4.9	4.0	0.4	2.6		
Average	4.6	3.7	0.5	1.7		
Source: LEI Information	n net, weighed averages o	f data over provinces.				
#### 3.1.7 Input of seed

Table 3.8 gives the amount of seed per crop studied.

Table 3.8	Input of seed for four crops		
Crop		Input of seed (kg/ha)	
Rapeseed		4	
Winter wheat		150	
Grain maize		27	
Sugar beet		2.75	
Sources: KWIN, J. Grot	en (PPO, pers. comm., 2009), IRS.		

The amounts of seed for rapeseed and winter wheat are based on regional specific standards (KWIN, 2009).

Grain maize seed is available in units of 50.000 seeds. The weight of one unit depends on the variety but is 14 to 15 kg on average. A successful crop holds 80,000 to 85,000 plants per ha for which 10% extra seeds are needed (J. Groten, PPO, pers. comm., 2009). The seed amount required is therefore: ((85,000 + 8,500)/50,000) \* 14.5 kg  $\approx$  27 kg per ha.

Sugar beet needs 1.1 unit of 100,000 per ha (KWIN, 2009). This corresponds with 2.75 kg seed per ha (IRS).

#### 3.2 NUTS2 and soil type specific data

The results of the calculations for the Netherlands are given in Tables 3.9A - 3.9C in different units per year. The results per region are presented in Appendix 7.

Table 3.9 A	Parameters to calcu	late annual	greenhou	se gas emi	ssions a)
Crop		Winter	Sugar	Rape-	Grain
		wheat	beet	seed	maize
Acreage (ha)		109,114	49,746	1,389	3,722
Yield (kg/ha)		8,909	89,855	4,145	12,620
Yield by-product (kg	g/ha)	4,472	40,000	2,500	18,600
N content (kg/ha)		180	95	131	166
P <sub>2</sub> O <sub>5</sub> content (kg/ha	a)	69	52	64	78
K <sub>2</sub> 0 content (kg/ha)	)	98	151	39	51
CaO content (kg/ha	a)	12	22	24	4
Parameter values p	per ha				
Fuel use (MJ/ha)		6,615	5,761	6,509	6,120
N applied total (kg/	'ha)	278	149	210	231
of which N applied	(kg/ha) from manure	110	35	35	176
P <sub>2</sub> O <sub>5</sub> used (kg/ha)		68	40	40	74
K <sub>2</sub> O used (kg/ha)		98	124	145	132
CaO used (kg/ha)		0	210	0	0
Pesticides used (kg	; a.i./ha)	4.0	4.6	0.5	2.1
Seed used (kg/ha)		164.2	2.8	4.0	27.0
N <sub>2</sub> O emissions fron	n the soil (kg/ha)	7.1	6.1	5.7	6.2
Parameter values p	per tonne				
Fuel use (MJ/tonne)	)	742.5	64.1	1570.3	484.9
N applied total (kg/	(tonne)	31.2	1.7	50.7	18.3
of which N (kg/tonr	ne) from manure	12.3	0.4	8.4	13.9
P <sub>2</sub> O <sub>5</sub> used (kg/tonn	e)	7.6	0.4	9.7	5.9
K <sub>2</sub> O used (kg/tonne	2)	11.0	1.4	35.1	10.5
CaO used (kg/tonne)		0	2.3	0	0
Pesticides used (kg a.i./tonne)		0.45	0.05	0.11	0.17
Seed used (kg/tonr	ne)	18.43	0.03	0.97	2.14
N <sub>2</sub> O emissions from	n the soil (kg/tonne)	0.80	0.07	1.37	0.49
a) Region: Netherlands	clay soils (2011).				

Table 3.9 B	Parameters to calcul	late annual	greenhous	se gas emi	ssions a)
Crop		Winter	Sugar	Rape-	Grain
		wheat	beet	seed	maize
Acreage (ha)		16,534	31,886	1,444	16,726
Yield (kg/ha)		8,095	84,972	4,044	12,377
Yield by-product (kg	/ha)	4,000	40,000	2,500	18,600
N content (kg/ha)		163	90	128	162
P <sub>2</sub> O <sub>5</sub> content (kg/ha	a)	63	49	62	77
K <sub>2</sub> 0 content (kg/ha)		89	143	38	50
CaO content (kg/ha	)	11	21	24	3
Parameter values p	er ha				
Fuel use (MJ/ha)		6,350	5,673	6,244	6,350
N applied total (kg/	ha)	205	180	210	221
of which N applied	kg/ha) from manure	52	140	35	176
P <sub>2</sub> O <sub>5</sub> used (kg/ha)		30	85	25	74
K <sub>2</sub> O used (kg/ha)		158	197	163	165
CaO used (kg/ha)		0	350	0	0
Pesticides used (kg	a.i./ha)	3.7	4.6	0.5	1.7
Seed used (kg/ha)		150.0	2.8	4.0	27.0
N <sub>2</sub> O emissions from	n the soil (kg/ha)	5.4	6.8	5.6	5.9
Parameter values p	er tonne				
Fuel use (MJ/tonne)		784.5	66.8	1,544.0	513.0
N applied total (kg/	tonne)	25.3	2.1	51.9	17.9
of which N (kg/tonr	e) from manure	6.5	1.6	8.7	14.2
P <sub>2</sub> O <sub>5</sub> used (kg/tonn	e)	3.7	1.0	6.2	6.0
K <sub>2</sub> O used (kg/tonne	)	19.6	2.3	40.3	13.3
CaO used (kg/tonne)		0	4.1	0	0
Pesticides used (kg a.i./tonne)		0.46	0.05	0.12	0.13
Seed used (kg/tonr	ie)	18.53	0.03	0.99	2.18
N <sub>2</sub> O emissions from	n the soil (kg/tonne)	0.67	0.08	1.40	0.48
a) Region: Netherlands	other soils (2011).				

Table 3.9 C	Parameters to calcul	ate annual	greenhous	se gas emi	ssions a)
Crop		Winter	Sugar	Rape-	Grain
		wheat	beet	seed	maize
Acreage (ha)		125,648	81,632	2,833	20,447
Yield (kg/ha)		8,802	87,948	4,094	12,422
Yield by-product (kg	/ha)	4,410	40,000	2,500	18,600
N content (kg/ha)		177	93	130	163
P <sub>2</sub> O <sub>5</sub> content (kg/ha	)	69	51	63	77
K <sub>2</sub> 0 content (kg/ha)		97	148	39	51
CaO content (kg/ha	)	12	22	24	3
Parameter values p	er ha				
Fuel use (MJ/ha)		6,580	5,727	6,374	6,308
N applied total (kg/l	ha)	268	161	210	223
of which N applied (	kg/ha) from manure	102	76	35	176
P <sub>2</sub> O <sub>5</sub> used (kg/ha)		63	58	32	74
K <sub>2</sub> O used (kg/ha)		106	153	154	159
CaO used (kg/ha)			265		
Pesticides used (kg	a.i./ha)	4.0	4.6	0.5	1.7
Seed used (kg/ha)		162.4	2.8	4.0	27.0
N <sub>2</sub> O emissions from	the soil (kg/ha)	6.9	6.4	5.7	5.9
Parameter values p	er tonne				
Fuel use (MJ/tonne)		747.6	65.1	1,557.1	507.8
N applied total (kg/t	tonne)	30.5	1.8	51.3	17.9
of which N (kg/tonn	e) from manure	11.6	0.9	8.6	14.2
P <sub>2</sub> O <sub>5</sub> used (kg/tonne	e)	7.1	0.7	7.9	6.0
K <sub>2</sub> O used (kg/tonne	)	12.0	1.7	37.7	12.8
CaO used (kg/tonne)		0	3.0	0	0
Pesticides used (kg a.i./tonne)		0.45	0.05	0.11	0.14
Seed used (kg/tonn	e)	18.44	0.03	0.98	2.17
N <sub>2</sub> O emissions from	the soil (kg/tonne)	0.78	0.07	1.38	0.48
a) Region: Netherlands a	III soils (2011).				

Yields of main product and fertilisation level data vary mostly between regions. All parameters only concern crop cultivation and harvest. NL Agency uses the parameters to calculate greenhouse gas emissions of the relevant biofuel production chains; the results of their calculations are published on their website www.senternovem.nl/gave. In this chapter, a number of assumptions in the study are discussed.

#### 4.1 Area data

Area data are based on the situation in 2005-2008. All crops except rapeseed have another cultivation purpose than to be raw material for the production of bio-fuels. Grain maize is mainly grown for pig feed, sugar beet for sugar production and Dutch winter wheat for feeding purposes. New application possibilities can lead to changes in the market, product prices and consequently to area shifts. In this study, no attention was paid to such dynamics.

To estimate crop yields in 2011, a trend analysis was applied on statistical yield data of the crops studied. It is possible that the yield of by-products is correlated to the yield of the crop itself. In that case, a trend analysis on yield data of by-products would be required, but lack of data was an obstacle to do so. Moreover, the nutrient contents of by-products of all crops except sugar beet are relatively low, as is their theoretical contribution to GHG emissions.

The method of trend analysis of yield data led to a single yield estimate per combination of crop and location. No attention was paid to the estimate errors of such estimation or to possible climatic changes. Allowing for variation in yield data would produce a number of scenarios, each resulting in different estimates of the greenhouse emission estimates for crop cultivation and harvest. Such a sensitivity analysis could increase insight into possible effects of yield variation. However, it is not clear how other variables change with climatic change, e.g. nutrient uptake and contents, emissions from the soil etc. Assessment of such effects would require a lot more data.

#### 4.2 Manure application

In this study, the present situation is considered as fixed, meaning that large amounts of manure are available for fertilisation of crops. Significant changes in the supply of manure or in the fertilisation regulations could lead to adaptation of fertilisation strategies: decrease of manure application and increase of fertil-

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iser levels. On the other hand, scarcity of fertiliser, mainly phosphate, could result in opposite changes. Such changes could affect different parameter values in this report. A renewed calculation, e.g. once in five years, could be suggested.

#### 4.3 Fuel use

Parameters for fuel use (MJ per ha) are based on KWIN calculations (Section 2.4). Estimated crop yields for 2011 are higher than for the period 2005-2008. However, higher yields could lead to higher fuel use per ha. On the other hand, new machinery will work more economically per kilowatt, thus the net energy saving effect is expected to be nil.

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### Attribution of regional data to provinces (NUTS2-level)

Table A1.1	Attributio	n of CBS yield data per province to soil type				
Target province	per provi	Source province per soil type				
		clay soil types	other soil types			
Groningen		Groningen	Drenthe			
Friesland		Friesland	Drenthe			
Drenthe		Groningen	Drenthe			
Overijssel		Overijssel	Overijssel			
Flevoland		Flevoland	Flevoland			
Gelderland		Gelderland	Drenthe			
Utrecht		Zuid-Holland	Utrecht			
Noord-Holland		Noord-Holland	Noord-Holland			
Zuid-Holland		Zuid-Holland	Zuid-Holland			
Zeeland		Zeeland	Zeeland			
Noord-Brabant		Zeeland	Noord-Brabant			
Limburg		Limburg	Limburg			

Table A1.2	Attribution of regional fertilisation strategies for clay and other soils to provinces				
Target province	Source region, per s	oil type			
	clay soil types	other soils types			
Groningen	Northern clay	Northern sand and reclaimed peat soils			
Friesland	Northern clay	Northern sand and reclaimed peat soils			
Drenthe	Northern clay	Northern sand and reclaimed peat soils			
Overijssel	Northern clay	Northern sand and reclaimed peat soils			
Flevoland	Central Clay	Northern sand and reclaimed peat soils			
Gelderland	Southern clay	Northern sand and reclaimed peat soils			
Utrecht	Southern clay	Northern sand and reclaimed peat soils			
Noord-Holland	Central Clay	Northern sand and reclaimed peat soils			
Zuid-Holland	Central Clay	Northern sand and reclaimed peat soils			
Zeeland	Southern clay	Southern sand			
Noord-Brabant	Southern clay	Southern sand			
Limburg	Southern clay	Southern sand			

Table A1.3	Attribution of IRS regions to province and soil type						
	(used for	data on lime fertilisation)					
Target province		Source region, per soil type					
		clay soil types	other soil types				
Groningen		Clay soils in the North	Other soil types in the North				
Friesland		Clay soils in the North	Other soil types in the North				
Drenthe		Clay soils in the North	Other soil types in the North				
Overijssel		South-east clay soils	Other soil types in the North				
Flevoland		Flevoland	Flevoland				
Gelderland		South-east clay soils	South-east sandy soils				
Utrecht		South-east clay soils	Other soil types in the North				
Noord-Holland		Holland	Holland				
Zuid-Holland		South west	South west				
Zeeland		South west	South west				
Noord-Brabant		South-east clay soils	South-east sandy soils				
Limburg		South-east clay soils	South-east sandy soils				

### Field operations and process time per crop

Field operations, process time (hours per ha) and power of machinery to carry out the field operations, per crop, in detail

Table A2.1	Winter wheat					
Field operation		Proces (hours	Process time (hours per ha)		Power (kW)	
		clay soils	other soil types	clay soils	other soil types	
Tillage: ploughing clay: reversible, sand: compaction roller		2.1	3.1	100	75	
Seedbed preparation		1.2	-	50	50	
Drilling 3 m		0.9	0.9	50	50	
Application of fertiliser		0.9	0.9	50	50	
Application of manure		0	0	50	50	
Spraying: weeds		0.6	0.6	50	50	
Spraying: diseases		0.9	0.9	50	50	
Harvest		1.1	1.1	210	210	
Transportation		1.1	1.1	50	50	
Harvest of straw (baling)		0.7	0.7	60	60	
Transportation of straw		2	2	50	50	
Calculation of fuel use according t - Tractors (ltr/ha) = power (kW)	o method PPC * 70/100 * (	)-agv (also in tab ).2727 * proces	les A2.2-A2.4): ss time;			

- Other self driven machinery (ltr/ha) = power (kW) \* 80/100 \* 0.312 \* process time.

Source: PPO-agv

Table A2.2 Rapeseed	Rapeseed					
Field operation	Proces (hours	ss time per ha)	Power (kW)			
	clay soils	other soil types	clay soils	other soil types		
Tillage: ploughing clay: reversible,	2.1	3.1	100	75		
sand: compaction roller						
Seedbed preparation	1.2	-	50	50		
Drilling 3 m	0.9	0.9	50	50		
Application of fertiliser	0.6	0.6	50	50		
Application of manure	0	0	50	50		
Spraying: weeds	0.6	0.6	50	50		
Spraying: diseases	0.9	0.9	50	50		
Harvest	1.1	1.1	210	210		
Transportation	1.1	1.1	50	50		
Harvest of straw (baling)	0.7	0.7	60	60		
Transportation of straw	2	2	50	50		
Source: PPO-agv						

Table A2.3	Grain maize					
Field operation		Proce	ess time	Power	Power (kW)	
		(hours	per ha)			
		clay soils	other soil	clay soils	other soil	
			types		types	
Tillage: ploughing	g clay: reversible,	2.1	3.1	100	75	
sand: compactio	n roller					
Seedbed prepara	ation	1.2	-	50	50	
Drilling 3 m		0.4	0.4	50	50	
Application of fer	tiliser	0.9	0	50	50	
Application of ma	anure (injection)	0	1.8	50	50	
Harrowing agains	st weeds	0	0.8	50	50	
Spraying: weeds		0.6	0.3	50	50	
Spraying: diseas	es	0	0	50	50	
Harvest		1.1	1.1	210	210	
Transportation		1.1	1.1	50	50	
Harvest of straw	(baling)	0.7	0.7	60	60	
Transportation of	f straw	2	2	50	50	
Source: PPO-agv						

Table A2.4 Sugar beet				
Field operation	Proces (hours	s time per ha)	Power (kW)	
	clay soils	other soil types	clay soils	other soil types
Tillage: ploughing clay: reversible, sand: compaction roller	2.1	3.1	100	75
Seedbed preparation	1.2	-	50	50
Precision drilling 12 m	0.7	0.7	50	50
Application of fertiliser	0.6	0.6	50	50
Application of manure (injection)	0	0	50	50
Harrowing against weeds	0	0.8	50	50
Spraying: weeds	0.6	0.3	50	50
Spraying: diseases	0	0	50	50
Harvest 6 row collector	1.1	1.1	220	220
Transportation	2.2	2.2	60	60
Harvest of straw (baling)	0	0	60	60
Transportation of straw	0	0	50	50
Source: PPO-agv				

### Description of MAMBO

See also: Kruseman et al., 2008.

# Calculation of N2O emission, fertiliser and manure application with MAMBO

#### A3.1 Basic assumptions model calculations

'Milieubalans' ('Environmental balance') calculations over the years 2005, 2006 and 2007 were used for the calculations of N<sub>2</sub>O emissions, fertiliser and manure applications of the different crops. The aim of the 'Milieubalans' calculations is to monitor ammonia emissions from the agricultural sector. The 'Emissie-Registratie' ('Emission Registration', ER) is responsible for the calculation of emission data, under the supervision of the 'Planbureau voor de Leefomgeving' (Netherlands Environmental Assessment Agency; PBL).

The reason for taking ER calculations as a basis is that the relevant data are available for all three years required and that the basic assumptions of the calculations are decided on through fixed protocols. The results of the PBL calculations are also used to calculate  $N_2O$ , methane and fine dust emissions for the Milieubalans.

The basic assumptions of the model calculations over the years 2005, 2006 and 2007 have not yet been published. It is expected that these assumptions will be published soon. In the working document 'Ammonia emission from the agricultural sector in 2006 and 2007' (Luesink et al., 2009) the basic assumptions are described in general terms. The calculations of  $N_2O$  emissions are carried out according to the study 'National emission ceilings 2020 (Vrolijk et al., 2008b).

#### A3.2 Basic assumptions $N_2O$ emission

#### A3.2.1 Direct emissions

The direct  $N_2O$  emissions were calculated according to protocol '8132 Agricultural soil direct' (VROM, 2008b). The following equation is applied:

 $N2Oemissie(kgN2O) = \sum E_{ij} * EFi_j * 44/28$ 

- Eij quantity of N for defined input source (i) on soil type (j) (kg N)
- EFij emission factor for the defined input source (i) and soil type (j) in kg  $N_2$ O-N in input source
- 44/28 calculation factor from N<sub>2</sub>O-N to N<sub>2</sub>O

The following input sources are discerned:

- 1. Net application of nitrogen from fertiliser (excluding ammonia emission);
- 2. Net application of nitrogen from manure (excluding ammonia emission);
- 3. Net N to soil through grazing of livestock (excluding ammonia emission);
- 4. Nitrogen fixation;
- 5. Crop remainings;
- 6. Agricultural use of histosoles.
- A3.2.2 Indirect emissions

The indirect  $N_2O$  emissions are calculated according to protocol 8131 Agriculture soil indirect (VROM, 2008a). The following equation is applied:

$$N2Oemissie(kgN2O) = \sum E_i * EFi * 44/28$$

- Ei quantity of N for defined input source (i) (kg N)
- EFi emission factor for the defined input source (i) in kg  $N_2$ O-N in input source
- 44/28 calculation factor from  $N_2$ O-N to  $N_2$ O

The following input sources are discerned:

1. Deposition of ammonia from manure production and storage and from application of fertiliser and manure; 2. Leaching and run-off of N applied to agricultural land.

#### A3.3 Calculation of N<sub>2</sub>O emissions (not applied in this study)

#### N<sub>2</sub>O from application

The amount of nitrogen per crop group and per soil type is calculated with the model MAMBO. This amount is the gross application of nitrogen from manure. The net application of nitrogen is derived by subtracting the application (ammonia) emission from the gross nitrogen application. The next step is to multiply the net nitrogen application by the emission factor of the application of manure.

#### N<sub>2</sub>O from fertiliser

MAMBO calculates the gross nitrogen application from fertiliser. The ammonia emissions from the application of fertiliser is subtracted from the gross nitrogen application. The next step is to multiply the net nitrogen application from fertiliser by a weighted average emission factor for soil types.

#### N<sub>2</sub>O from histosoles

The area of histosoles is multiplied by the emission factor for agricultural use of hustles, only referring to the area of peaty soils.

#### N<sub>2</sub>O from crop remainders and fixation

The  $N_2O$  emission is calculated from crop remainders and fixation with a fixed factor for the Netherlands.

#### N<sub>2</sub>O from ammonia deposition

The total ammonia emission (from manure as well as fertiliser) is multiplied by the  $N_2O$  emission factor.

#### N₂O from leaching

Leaching is calculated from the gross amount of nitrogen applied through manure and fertiliser. This factor is corrected for the exports of manure. The gross amount of N applied is multiplied by a leaching fraction of 30% and subsequently multiplied by the emission factor of leaching.

#### A3.4 Calculation of fertiliser rates

New data on total fertiliser rate and the fertiliser rate per ha crop are annually derived for the formulation of basic assumptions (Luesink et al, 2009) from the 'Kunstmeststatistiek' (Statistics on fertilisers; CBS, 2008) and from the LEI Information-net. All data in the Information net of farms with fertiliser rates allocated to crops are collected to formulate the assumptions for the fertiliser rates. Farms are analysed for suitability; if they are unsuitable, they are not included in the calculations.

Robust average values are calculated through aggregation to crop groups; the minimum number of observations is 15. The aggregation continues until this minimum number is reached.

The next step is to validate the fertiliser rates from the LEI Information-net with the annual statistics of fertilisers (CBS, 2008). Before validation, the fertiliser rates from the annual statistics are corrected for fertiliser use outside the field farming sector (greenhouse horticulture, hobby farms).

#### A3.5 Calculation of manure rates

The calculation of manure rates is carried out with the MAMBO model (Vrolijk et al., 2008c). In MAMBO, five important processes are discerned, being:

- 1. The production of manure by animals (manure production);
- 2. The space for manure use (manure space);
- 3. The difference between production and space (manure surplus);
- The transportation of manure for use or storage elsewhere (manure transportation);
- 5. The nutrient load of the soil (soil load).

The processes are calculated on three aggregation levels. The themes manure production, manure space and manure surplus take place at farm level. Manure transportation is based on 31 manure regions (regions). Soil load is calculated on community level.

Figure A3.1 shows the relationships between the processes. The processes are categorised through lines. In the following, each process is described in more detail. The entities in this description are printed in italic and underlined. The places where ammonia emission takes place are indicated with a flag with a figure.

#### Manure production

Manure producing *farms*, holding *livestock*, form the basis for the calculation of the manure production. The manure is discerned in different manure types. The *manure types* produced are discerned after livestock species, e.g. the excretions depend on the *species type* and feeding regime.

Besides grazing of grassland by dairy cattle, different stable systems are discerned (e.g. tied up or not, deep pit stable). In all these *stable* and *grazing* systems, *ammonia* (1.2) is emitted due to manure production. *Manure types* are defined through the combination of *livestock species*, stable system and *feeding system*.

#### Manure space

The manure produced can be applied fully or partly on the farm itself. The available farmland, application norms and the crops grown on the area available determine the quantity of manure that can be applied on the farm itself. The application norms describe the maximum amounts of nutrients (e.g. phosphate and nitrogen) per *crop*, soil type and manure region that can be applied per ha.

#### Manure surplus or manure space for manure from outside the farm

A comparison of the manure production on a farm and the quantity of manure that can be used on the farm itself, determines whether a farm had a *manure surplus* or application space of manure from outside the farm. If there is a manure surplus, the manure quantity that has to be transported to other farms, is minimised through assessment of the manure types that can best be applied on the farm itself. When the manure space is not fully occupied, then manure (and/or manure products) from other farms can be applied, the so-called *manure space* for manure from other farms. The quantity of manure from outside that is actually accepted depends on the acceptance level. The acceptance level is determined per crop and per region, based on the manure transports, registered by the Ministry of Agriculture (Dienst Regelingen; Service for Regulations), and the fertilisation per *crop* from the LEI Information-net.

#### Manure transportation

The *maximum manure space* which can be used for the application of surplus manure from other farms is calculated from the acceptance level. Another application of *surplus manure* is exports. The quantity of manure from outside the farm actually applied depends on the quantity of surplus manure and the quantity of manure applied outside the Dutch agricultural sector in processed and un-

processed form. The quantity of manure which is exported is based on statistical data from Dienst Regelingen and CBS.

#### Soil load

The total application rate of manure is calculated from the application of manure on the farm itself and the application of manure from outside the farm.



### Crop yields

Table A4.1	Average crop yields (ton per ha)					
	Winter wheat	Grain maize	Rapeseed	Sugar beet		
1994	8.5	11.5	3.0	54		
1995	8.8	10.9	3.0	56		
1996	9.1	12.3	3.6	55		
1997	7.8	19.2	3.4	58		
1998	7.8	n.a.	3.1	50		
1999	8.9	10.8	3.5	61.1		
2000	8.6	16.9	3.4	61.3		
2001	8.3	13.7	3.4	55.4		
2002	8.1	14.8	3.0	58.2		
2003	9.1	12.9	3.5	60.7		
2004	9.3	13.1	4.6	64.6		
2005	9.0	13.5	3.7	65.3		
2006	8.8	10.2	3.5	66.0		
2007	7.4	12.6	3.5	67.1		
2008	9.0	11.4	3.8	72.2		
2009 a)	9.6	13.0	4.5	78.9		
a) Preliminary data. Source: CBS statline.						

#### Additional remarks:

#### Grain maize

Due to extreme yield deviations, data for grain maize yield in 1997 and 1998 have not been incorporated in the trend analysis.

#### Sugar beet

CBS yields of sugar beet have been compared with IRS data. IRS net yields deviate slightly from CBS data but the estimates for 2011 from CBS and IRS sources hardly differ.

#### Graphs showing crop yields

N.B. In all figures,  $\Delta$  expresses the 2011 estimate based on the years 2003-2009.









List of participating experts in the expert meeting on fertilisation levels in 2011, Utrecht, 7 May 2010

Participant	Organisation
S. te Buck	Agentschap NL
S. Conijn	PRI
W. van Dijk	PPO-agv
B. Hasselo	LTO
K. Hoekstra	NAV
T. Huijbregst	IRS
H. Luesink	LEI
F. Tijink	IRS
H. Verkerk	Cumela
M. van der Voort	PPO-agv
P. Wilting	IRS

### Fraction NH<sub>3</sub> emissions from manure (%)

Crop/soil type	Groningen	Friesland	Drenthe	Overijssel	Flevoland	Gelderland
Winter wheat						
Clay soils	15.7	14.6	12.4	13.7	14.7	17.0
Other soils	15.3	11.4	12.8	15.7	11.7	15.8
All soils	15.7	14.4	12.8	15.1	14.6	16.8
Sugar beet						
Clay soils	16.2	15.5	12.0	11.9	15.4	17.2
Other soils	15.6	13.1	12.2	11.1	14.1	14.4
All soils	15.9	15.4	12.2	11.2	15.3	16.2
Rapeseed						
Clay soils	14.0	13.7	12.1	12.1	16.2	16.7
Other soils	13.6	12.9	11.2	10.9	14.0	14.7
All soils	13.9	13.3	11.2	11.0	16.1	15.4
Grain maize						
Clay soils	14.4	13.0	13.1	12.5	9.6	16.9
Other soils	13.2	9.5	12.8	11.8	14.4	14.9
All soils	13.3	10.2	12.8	11.8	10.3	15.5

Region	Utrecht	Noord- Holland	Zuid- Holland	Zeeland	Noord- Brabant	Limburg			
Winter wheat									
Clay soils	19.6	15.9	14.8	16.2	14.1	11.7			
Other soils	18.2	15.7	14.7	15.4	13.8	10.2			
All soils	19.4	15.9	14.8	16.2	14.0	10.6			
Sugar beet									
Clay soils	16.1	13.7	14.5	16.2	13.2	11.9			
Other soils	14.5	7.9	13.2	16.3	11.9	11.4			
All soils	15.7	13.2	14.5	16.2	12.5	11.5			
Rapeseed									
Clay soils	12.9	14.8	11.8	14.8	13.4	11.7			
Other soils	8.0	13.8	13.1	15.9	13.4	11.9			
All soils	9.2	14.7	12.0	14.9	13.4	11.9			
Grain maize									
Clay soils	17.6	17.7	15.3	15.6	13.7	12.1			
Other soils	15.8	17.2	12.9	16.6	12.9	12.1			
All soils	16.8	17.5	14.4	15.9	13.0	12.1			

# Full set of parameters to calculate annual greenhouse gas emissions in 2011

Winter wheat on clay soils									
Region	Groningen	Friesland	Drenthe	Overijssel	Flevoland	Gelderland			
Acreage (ha)	25,730	4,895	120	369	11,534	6,120			
Yield (kg/ha)	8,560	8,560	8,560	7,700	9,410	8,530			
Yield by-product (kg/ha)	4,400	4,400	4,400	4,500	4,500	4,500			
N content (kg/ha)	173	173	173	158	189	173			
$P_2O_5$ content (kg/ha)	67	67	67	61	73	67			
K <sub>2</sub> 0 content (kg/ha)	96	96	96	93	101	97			
CaO content (kg/ha)	11	11	11	11	12	12			
Parameter values per ha									
Fuel use (MJ/ha)	6,615	6,615	6,615	6,615	6,615	6,615			
N applied total (kg/ha)	275	275	275	275	276	281			
of which N applied (kg/ha) from manure	105	105	105	105	91	126			
$P_2O_5$ used (kg/ha)	65	65	65	65	57	77			
K <sub>2</sub> O used (kg/ha)	166	96	166	139	91	139			
CaO used (kg/ha)									
Pesticides used (kg a.i./ha)	3.8	3.6	3.8	4.1	4.1	4.1			
Seed used (kg/ha)	175.0	175.0	175.0	160.0	160.0	160.0			
$N_2O$ emissions from the soil (kg/ha)	7.0	7.0	6.9	6.8	7.1	7.1			
Parameter values per tonne									
Fuel use (MJ/tonne)	772.8	772.8	772.8	859.1	703.0	775.5			
N applied total (kg/tonne)	32.1	32.1	32.1	35.7	29.3	32.9			
of which N (kg/tonne) from manure	12.3	12.3	12.3	13.6	9.7	14.8			
$P_2O_5$ used (kg/tonne)	7.6	7.6	7.6	8.4	6.1	9.0			
K <sub>2</sub> O used (kg/tonne)	19.4	11.2	19.4	18.0	9.6	16.3			
CaO used (kg/tonne)									
Pesticides used (kg a.i./tonne)	0.44	0.42	0.44	0.54	0.43	0.48			
Seed used (kg/tonne)	20.44	20.44	20.44	20.78	17.00	18.76			
N <sub>2</sub> O emissions from the soil (kg/tonne)	0.81	0.81	0.81	0.88	0.76	0.84			

Winter wheat on clay soils								
Region								
	Utrecht	Noord- Holland	Zuid- Holland	Zeeland	Noord- Brabant	Limburg		
Acreage (ha)	404	7,862	12,741	27,582	9,972	1,786		
Yield (kg/ha)	8,970	8,710	8,970	9,150	9,150	8,610		
Yield by-product (kg/ha)	4,500	4,500	4,500	4,500	4,500	4,500		
N content (kg/ha)	181	176	181	184	184	175		
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	70	68	70	71	71	67		
K <sub>2</sub> 0 content (kg/ha)	99	98	99	100	100	97		
CaO content (kg/ha)	12	12	12	12	12	12		
Parameter values per ha								
Fuel use (MJ/ha)	6,615	6,615	6,615	6,615	6,615	6,615		
N applied total (kg/ha)	281	276	276	281	281	281		
of which N applied (kg/ha) from manure	126	91	91	126	126	126		
$P_2O_5$ used (kg/ha)	77	57	57	77	77	77		
K <sub>2</sub> O used (kg/ha)	128	74	58	52	85	178		
CaO used (kg/ha)								
Pesticides used (kg a.i./ha)	4.1	4.1	4.1	4.1	4.1	4.1		
Seed used (kg/ha)	160.0	160.0	160.0	160.0	160.0	160.0		
$N_2O$ emissions from the soil (kg/ha)	7.3	7.0	7.0	7.2	7.2	7.1		
Parameter values per tonne								
Fuel use (MJ/tonne)	737.5	759.5	737.5	723.0	723.0	768.3		
N applied total (kg/tonne)	31.3	31.7	30.8	30.7	30.7	32.6		
of which N (kg/tonne) from manure	14.0	10.4	10.1	13.8	13.8	14.6		
$P_2O_5$ used (kg/tonne)	8.6	6.5	6.4	8.4	8.4	8.9		
K <sub>2</sub> O used (kg/tonne)	14.2	8.5	6.5	5.7	9.2	20.6		
CaO used (kg/tonne)								
Pesticides used (kg a.i./tonne)	0.46	0.47	0.46	0.45	0.45	0.48		
Seed used (kg/tonne)	17.84	18.37	17.84	17.49	17.49	18.58		
N <sub>2</sub> O emissions from the soil (kg/tonne)	0.81	0.80	0.78	0.79	0.79	0.82		

Winter wheat on other soils									
Region	Groningen	Friesland	Drenthe	Overijssel	Flevoland	Gelderland			
Acreage (ha)	3,262	246	2,427	883	177	937			
Yield (kg/ha)	7,390	7,390	7,390	7,700	9,410	7,390			
Yield by-product (kg/ha)	4,000	4,000	4,000	4,000	4,000	4,000			
N content (kg/ha)	150	150	150	156	186	150			
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	58	58	58	60	72	58			
K <sub>2</sub> 0 content (kg/ha)	85	85	85	87	95	85			
CaO content (kg/ha)	10	10	10	10	11	10			
Parameter values per ha									
Fuel use (MJ/ha)	6,350	6,350	6,350	6,350	6,350	6,350			
N applied total (kg/ha)	200	200	200	200	200	200			
of which N applied (kg/ha) from manure	35	35	35	35	35	35			
P <sub>2</sub> O <sub>5</sub> used (kg/ha)	20	20	20	20	20	20			
K <sub>2</sub> O used (kg/ha)	163	163	163	144	133	144			
CaO used (kg/ha)									
Pesticides used (kg a.i./ha)	4.1	3.6	4.1	3.6	3.6	3.6			
Seed used (kg/ha)	150.0	150.0	150.0	150.0	150.0	150.0			
N <sub>2</sub> O emissions from the soil (kg/ha)	5.2	5.1	5.1	5.2	5.5	5.2			
Parameter values per tonne									
Fuel use (MJ/tonne)	859.3	859.3	859.3	824.7	674.8	859.3			
N applied total (kg/tonne)	27.1	27.1	27.1	26.0	21.3	27.1			
of which N (kg/tonne) from manure	4.7	4.7	4.7	4.5	3.7	4.7			
$P_2O_5$ used (kg/tonne)	2.7	2.7	2.7	2.6	2.1	2.7			
K <sub>2</sub> O used (kg/tonne)	22.0	22.0	22.0	18.6	14.1	19.4			
CaO used (kg/tonne)									
Pesticides used (kg a.i./tonne)	0.58	0.51	0.58	0.50	0.40	0.51			
Seed used (kg/tonne)	20.30	20.30	20.30	19.48	15.94	20.30			
N <sub>2</sub> O emissions from the soil (kg/tonne)	0.78	0.78	0.78	0.76	0.64	0.78			

Winter wheat on other soils								
Region								
	Utrecht	Noord- Holland	Zuid- Holland	Zeeland	Noord- Brabant	Limburg		
Acreage (ha)	45	217	102	605	2,112	5,523		
Yield (kg/ha)	7,880	8,710	8,970	9,150	8,690	8,610		
Yield by-product (kg/ha)	4,000	4,000	4,000	4,000	4,000	4,000		
N content (kg/ha)	159	174	179	182	174	172		
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	61	67	69	70	67	67		
K <sub>2</sub> 0 content (kg/ha)	87	92	93	94	92	91		
CaO content (kg/ha)	10	11	11	11	11	11		
Parameter values per ha								
Fuel use (MJ/ha)	6,350	6,350	6,350	6,350	6,350	6,350		
N applied total (kg/ha)	200	200	200	210	210	210		
of which N applied (kg/ha) from manure	35	35	35	70	70	70		
P <sub>2</sub> O <sub>5</sub> used (kg/ha)	20	20	20	40	40	40		
K <sub>2</sub> O used (kg/ha)	133	133	133	160	160	160		
CaO used (kg/ha)								
Pesticides used (kg a.i./ha)	3.6	3.6	3.6	3.6	3.6	3.6		
Seed used (kg/ha)	150.0	150.0	150.0	150.0	150.0	150.0		
$N_2O$ emissions from the soil (kg/ha)	5.3	5.4	5.5	5.8	5.7	5.6		
Parameter values per tonne								
Fuel use (MJ/tonne)	805.8	729.0	707.9	694.0	730.7	737.5		
N-applied total (kg/tonne)	25.4	23.0	22.3	23.0	24.2	24.4		
of which N (kg/tonne) from manure	4.4	4.0	3.9	7.7	8.1	8.1		
$P_2O_5$ used (kg/tonne)	2.5	2.3	2.2	4.4	4.6	4.6		
K <sub>2</sub> O used (kg/tonne)	16.8	15.3	14.8	17.5	18.5	18.6		
CaO used (kg/tonne)								
Pesticides used (kg a.i./tonne)	0.52	0.44	0.43	0.41	0.45	0.44		
Seed used (kg/tonne)	19.04	17.22	16.72	16.39	17.26	17.42		
N <sub>2</sub> O emissions from the soil (kg/tonne)	0.78	0.68	0.68	0.67	0.72	0.72		

Winter wheat on all soils									
Region	Groningen	Friesland	Drenthe	Overijssel	Flevoland	Gelderland			
Acreage (ha)	28,992	5,140	2,547	1,251	11,711	7,057			
Yield (kg/ha)	8,428	8,504	7,445	7,700	9,410	8,379			
Yield by-product (kg/ha)	4,355	4,381	4,019	4,147	4,492	4,434			
N content (kg/ha)	171	172	152	157	189	170			
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	66	66	58	60	73	66			
K <sub>2</sub> 0 content (kg/ha)	94	95	86	88	101	95			
CaO content (kg/ha)	11	11	10	11	12	11			
Parameter values per ha									
Fuel use (MJ/ha)	6,585	6,602	6,362	6,428	6,611	6,580			
N applied total (kg/ha)	267	271	204	222	275	270			
of which N applied (kg/ha) from manure	97	102	38	56	90	114			
$P_2O_5$ used (kg/ha)	60	63	22	33	56	69			
K <sub>2</sub> O used (kg/ha)	165	99	163	142	91	139			
CaO used (kg/ha)									
Pesticides used (kg a.i./ha)	3.8	3.6	4.1	3.7	4.1	4.1			
Seed used (kg/ha)	172.2	173.8	151.2	152.9	159.8	158.7			
$N_2O$ emissions from the soil (kg/ha)	6.8	6.9	5.2	5.7	7.1	6.9			
Parameter values per tonne									
Fuel use (MJ/tonne)	781.3	776.4	854.6	834.8	702.5	785.3			
N applied total (kg/tonne)	31.6	31.9	27.3	28.8	29.2	32.3			
of which N (kg/tonne) from manure	11.5	12.0	5.1	7.2	9.6	13.6			
P <sub>2</sub> O <sub>5</sub> used (kg/tonne)	7.1	7.4	3.0	4.3	6.0	8.3			
K <sub>2</sub> O used (kg/tonne)	19.6	11.6	21.9	18.5	9.7	16.6			
CaO used (kg/tonne)									
Pesticides used (kg a.i./tonne)	0.45	0.42	0.54	0.48	0.43	0.48			
Seed used (kg/tonne)	20.43	20.44	20.31	19.86	16.99	18.94			
N <sub>2</sub> O emissions from the soil (kg/tonne)	0.80	0.81	0.70	0.74	0.75	0.82			

Winter wheat on all soils							
Region							
	Utrecht	Noord- Holland	Zuid- Holland	Zeeland	Noord- Brabant	Limburg	
Acreage (ha)	449	8,079	12,843	28,188	12,084	7,309	
Yield (kg/ha)	8,861	8,710	8,970	9,150	9,070	8,610	
Yield by-product (kg/ha)	4,450	4,487	4,496	4,489	4,413	4,122	
N content (kg/ha)	179	176	181	184	182	173	
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	69	68	70	71	70	67	
K <sub>2</sub> 0 content (kg/ha)	98	97	99	100	98	93	
CaO content (kg/ha)	12	12	12	12	12	11	
Parameter values per ha							
Fuel use (MJ/ha)	6,589	6,608	6,613	6,609	6,569	6,415	
N applied total (kg/ha)	273	274	275	279	269	227	
of which N applied (kg/ha) from manure	117	89	91	125	116	84	
P <sub>2</sub> O <sub>5</sub> used (kg/ha)	71	56	57	76	71	49	
K <sub>2</sub> O used (kg/ha)	128	76	59	54	98	165	
CaO used (kg/ha)							
Pesticides used (kg a.i./ha)	4.1	4.1	4.1	4.1	4.0	3.7	
Seed used (kg/ha)	159.0	159.7	159.9	159.8	158.3	152.4	
N <sub>2</sub> O emissions from the soil (kg/ha)	7.1	6.9	7.0	7.2	6.9	6.0	
Parameter values per tonne							
Fuel use (MJ/tonne)	743.5	758.7	737.2	722.3	724.3	745.0	
N applied total (kg/tonne)	30.8	31.5	30.7	30.5	29.6	26.4	
of which N (kg/tonne) from manure	13.2	10.3	10.1	13.6	12.8	9.7	
P <sub>2</sub> O <sub>5</sub> used (kg/tonne)	8.0	6.4	6.3	8.3	7.8	5.7	
K <sub>2</sub> O used (kg/tonne)	14.5	8.7	6.6	5.9	10.8	19.1	
CaO used (kg/tonne)							
Pesticides used (kg a.i./tonne)	0.46	0.47	0.46	0.45	0.44	0.43	
Seed used (kg/tonne)	17.94	18.34	17.83	17.46	17.45	17.71	
$N_2O$ emissions from the soil (kg/tonne)	0.80	0.80	0.78	0.79	0.76	0.69	

Sugar beet on clay soils									
Region	Groningen	Friesland	Drenthe	Overijssel	Flevoland	Gelderland			
Acreage (ha)	5,459	2,965	121	167	10,612	2,073			
Yield (kg/ha)	85,990	86,050	85,990	85,150	99,170	80,060			
Yield by-product (kg/ha)	40,000	40,000	40,000	40,000	40,000	40,000			
N content (kg/ha)	91	91	91	90	105	85			
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	49	49	49	49	57	46			
K <sub>2</sub> 0 content (kg/ha)	144	145	144	143	167	135			
CaO content (kg/ha)	21	21	21	21	24	20			
Parameter values per ha									
Fuel use (MJ/ha)	5,761	5,761	5,761	5,761	5,761	5,761			
N applied total (kg/ha)	145	145	145	145	155	145			
of which N applied (kg/ha)	35	35	35	35	35	35			
from manure									
P <sub>2</sub> O <sub>5</sub> used (kg/ha)	40	40	40	40	40	40			
K <sub>2</sub> O used (kg/ha)	236	166	205	178	118	178			
CaO used (kg/ha)	262	262	262	656	0	656			
Pesticides used (kg a.i./ha)	4.2	5.2	4.2	4.8	4.4	4.8			
Seed used (kg/ha)	2.8	2.8	2.8	2.8	2.8	2.8			
N <sub>2</sub> O emissionsfrom the soil (kg/ha)	6.0	6.0	6.0	6.0	6.1	6.0			
Parameter values per tonne									
Fuel use (MJ/tonne)	67.0	66.9	67.0	67.7	58.1	72.0			
N applied total (kg/tonne)	1.7	1.7	1.7	1.7	1.6	1.8			
of which N (kg/tonne) from manure	0.4	0.4	0.4	0.4	0.4	0.4			
$P_2O_5$ used (kg/tonne)	0.5	0.5	0.5	0.5	0.4	0.5			
K <sub>2</sub> O used (kg/tonne)	2.7	1.9	2.4	2.1	1.2	2.2			
CaO used (kg/tonne)	3.0	3.0	3.0	7.7	0	8.2			
Pesticides used (kg a.i./tonne)	0.05	0.06	0.05	0.06	0.04	0.06			
Seed used (kg/tonne)	0.03	0.03	0.03	0.03	0.03	0.03			
N <sub>2</sub> O emissions from the soil (kg/tonne)	0.07	0.07	0.07	0.07	0.06	0.08			

Sugar beet on clay soils								
Region	ť	. ס	p	q	. t	<u>ლ</u>		
	Utrech	Noord Hollan	Zuid- Hollan	Zeelan	Noord Brabai	Limbu		
Acreage (ha)	112	4,921	5,571	11,391	4,768	1,589		
Yield (kg/ha)	89,260	89,260	89,260	88,030	88,030	84,110		
Yield by-product (kg/ha)	40,000	40,000	40,000	40,000	40,000	40,000		
N content (kg/ha)	94	94	94	93	93	89		
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	51	51	51	51	51	48		
K <sub>2</sub> 0 content (kg/ha)	150	150	150	148	148	141		
CaO content (kg/ha)	22	22	22	22	22	21		
Parameter values per ha								
Fuel use (MJ/ha)	5,761	5,761	5,761	5,761	5,761	5,761		
N applied total (kg/ha)	145	155	155	145	145	145		
of which N applied (kg/ha)	35	35	35	35	35	35		
from manure								
P <sub>2</sub> O <sub>5</sub> used (kg/ha)	40	40	40	40	40	40		
K <sub>2</sub> O used (kg/ha)	156	102	86	80	106	200		
CaO used (kg/ha)	656	119	113	113	656	656		
Pesticides used (kg a.i./ha)	4.8	4.4	4.8	4.8	4.8	4.8		
Seed used (kg/ha)	2.8	2.8	2.8	2.8	2.8	2.8		
$N_2O$ emissions from the soil (kg/ha)	6.0	6.0	6.2	6.2	6.0	6.1		
Parameter values per tonne								
Fuel use (MJ/tonne)	64.5	64.5	64.5	65.4	65.4	68.5		
N applied total (kg/tonne)	1.6	1.7	1.7	1.6	1.6	1.7		
of which N (kg/tonne) from manure	0.4	0.4	0.4	0.4	0.4	0.4		
$P_2O_5$ used (kg/tonne)	0.4	0.4	0.4	0.5	0.5	0.5		
K <sub>2</sub> O used (kg/tonne)	1.7	1.1	1.0	0.9	1.2	2.4		
CaO used (kg/tonne)	7.3	1.3	1.3	1.3	7.5	7.8		
Pesticides used (kg a.i./tonne)	0.05	0.05	0.05	0.05	0.05	0.06		
Seed used (kg/tonne)	0.03	0.03	0.03	0.03	0.03	0.03		
$N_2O$ emissions from the soil	0.07	0.07	0.07	0.07	0.07	0.07		
(kg/tonne)								
Sugar beet on other soils								
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Region	Groningen	Friesland	Drenthe	Overijssel	Flevoland	Gelderland		
Acreage (ha)	5,218	110	10,755	1,265	173	1,166		
Yield (kg/ha)	85,050	85,050	85,050	85,150	99,170	85,050		
Yield by-product (kg/ha)	40,000	40,000	40,000	40,000	40,000	40,000		
N content (kg/ha)	90	90	90	90	105	90		
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	49	49	49	49	57	49		
K <sub>2</sub> 0 content (kg/ha)	143	143	143	143	167	143		
CaO content (kg/ha)	21	21	21	21	24	21		
Parameter values per ha								
Fuel use (MJ/ha)	5,673	5,673	5,673	5,673	5,673	5,673		
N applied total (kg/ha)	180	180	180	180	180	180		
of which N applied (kg/ha)	140	140	140	140	140	140		
from manure								
$P_2O_5$ used (kg/ha)	85	85	85	85	85	85		
K <sub>2</sub> O used (kg/ha)	233	233	202	183	161	183		
CaO used (kg/ha)	196	196	196	196	0	571		
Pesticides used (kg a.i./ha)	5.2	4.4	4.4	4.4	4.4	4.4		
Seed used (kg/ha)	2.8	2.8	2.8	2.8	2.8	2.8		
$N_2O$ emissions from the soil	6.9	6.8	6.8	6.8	6.9	6.9		
(kg/ha)								
Parameter values per tonne								
Fuel use (MJ/tonne)	66.7	66.7	66.7	66.6	57.2	66.7		
N applied total (kg/tonne)	2.1	2.1	2.1	2.1	1.8	2.1		
of which N (kg/tonne) from manure	1.6	1.6	1.6	1.6	1.4	1.6		
P <sub>2</sub> O <sub>5</sub> used (kg/tonne)	1.0	1.0	1.0	1.0	0.9	1.0		
K <sub>2</sub> O used (kg/tonne)	2.7	2.7	2.4	2.1	1.6	2.1		
CaO used (kg/tonne)	2.3	2.3	2.3	2.3	0	6.7		
Pesticides used (kg a.i./tonne)	0.07	0.06	0.06	0.06	0.05	0.06		
Seed used (kg/tonne)	0.03	0.03	0.03	0.03	0.03	0.03		
$N_2O$ emissions from the soil	0.10	0.10	0.11	0.11	0.08	0.10		
(kg/tonne)								

Sugar beet on other soils								
Region								
	Utrecht	Noord- Holland	Zuid- Holland	Zeeland	Noord- Brabant	Limburg		
Acreage (ha)	46	496	85	311	5,499	6,762		
Yield (kg/ha)	83,330	89,260	89,260	88,030	84,690	84,110		
Yield by-product (kg/ha)	40,000	40,000	40,000	40,000	40,000	40,000		
N content (kg/ha)	88	94	94	93	89	89		
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	48	51	51	51	49	48		
K <sub>2</sub> 0 content (kg/ha)	140	150	150	148	142	141		
CaO content (kg/ha)	21	22	22	22	21	21		
Parameter values per ha								
Fuel use (MJ/ha)	5,673	5,673	5,673	5,673	5,673	5,673		
N applied total (kg/ha)	180	180	180	180	180	180		
of which N applied (kg/ha)	140	140	140	140	140	140		
from manure								
P <sub>2</sub> O <sub>5</sub> used (kg/ha)	85	85	85	85	85	85		
K <sub>2</sub> O used (kg/ha)	161	161	161	188	182	182		
CaO used (kg/ha)	196	119	113	113	571	571		
Pesticides used (kg a.i./ha)	4.4	4.4	4.4	4.8	4.8	4.2		
Seed used (kg/ha)	2.8	2.8	2.8	2.8	2.8	2.8		
$N_2O$ emissions from the soil	6.9	6.7	6.9	6.9	6.9	6.9		
(kg/ha)								
Parameter values per tonne								
Fuel use (MJ/tonne)	68.1	63.6	63.6	64.4	67.0	67.4		
N applied total (kg/tonne)	2.2	2.0	2.0	2.0	2.1	2.1		
of which N (kg/tonne) from manure	1.7	1.6	1.6	1.6	1.7	1.7		
P <sub>2</sub> O <sub>5</sub> used (kg/tonne)	1.0	1.0	1.0	1.0	1.0	1.0		
K <sub>2</sub> O used (kg/tonne)	1.9	1.8	1.8	2.1	2.2	2.2		
CaO used (kg/tonne)	2.3	1.3	1.3	1.3	6.7	6.8		
Pesticides used (kg a.i./tonne)	0.06	0.06	0.06	0.06	0.07	0.06		
Seed used (kg/tonne)	0.03	0.03	0.03	0.03	0.03	0.03		
$N_2O$ emissionss from the soil	0.10	0.09	0.09	0.09	0.11	0.11		
(kg/tonne)								

Sugar beet on all soils								
Region	Groningen	Friesland	Drenthe	Overijssel	Flevoland	Gelderland		
Acreage (ha)	10,677	3,075	10,876	1,432	10,785	3,239		
Yield (kg/ha)	85,531	86,014	85,060	85,150	99,170	81,857		
Yield by-product (kg/ha)	40,000	40,000	40,000	40,000	40,000	40,000		
N content (kg/ha)	90	91	90	90	105	86		
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	49	49	49	49	57	47		
K <sub>2</sub> 0 content (kg/ha)	144	145	143	143	167	138		
CaO content (kg/ha)	21	21	21	21	24	20		
Parameter values per ha								
Fuel use (MJ/ha)	5,718	5,758	5,674	5,683	5,760	5,729		
N applied total (kg/ha)	162	146	180	176	155	158		
of which N applied (kg/ha)	86	39	139	128	37	73		
from manure								
$P_2O_5$ used (kg/ha)	62	42	85	80	41	56		
K <sub>2</sub> O used (kg/ha)	234	168	202	182	119	180		
CaO used (kg/ha)	229	259	196	249	0	625		
Pesticides used (kg a.i./ha)	4.7	5.2	4.4	4.4	4.4	4.7		
Seed used (kg/ha)	2.8	2.8	2.8	2.8	2.8	2.8		
$N_2O$ emissions from the soil	6.4	6.0	6.8	6.7	6.1	6.3		
(kg/ha)								
Parameter values per tonne								
Fuel use (MJ/tonne)	66.9	66.9	66.7	66.7	58.1	70.0		
N applied total (kg/tonne)	1.9	1.7	2.1	2.1	1.6	1.9		
of which N (kg/tonne) from manure	1.0	0.5	1.6	1.5	0.4	0.9		
P <sub>2</sub> O <sub>5</sub> used (kg/tonne)	0.7	0.5	1.0	0.9	0.4	0.7		
K <sub>2</sub> O used (kg/tonne)	2.7	2.0	2.4	2.1	1.2	2.2		
CaO used (kg/tonne)	2.7	3.0	2.3	2.9	0	7.6		
Pesticides used (kg a.i./tonne)	0.05	0.06	0.05	0.05	0.04	0.06		
Seed used (kg/tonne)	0.03	0.03	0.03	0.03	0.03	0.03		
$N_2O$ emissions from the soil	0.08	0.07	0.08	0.08	0.06	0.08		
(kg/tonne)								

Sugar beet on all soils								
Region								
	Jtrecht	Voord- Holland	Luid- Holland	Ceeland	Voord- 3rabant	-imburg		
Acreage (ha)	158	5,417	5,655	11,702	10,267	8,351		
Yield (kg/ha)	87,527	89,260	89,260	88,030	86,241	84,110		
Yield by-product (kg/ha)	40,000	40,000	40,000	40,000	40,000	40,000		
N content (kg/ha)	92	94	94	93	91	89		
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	50	51	51	51	50	48		
K <sub>2</sub> 0 content (kg/ha)	147	150	150	148	145	141		
CaO content (kg/ha)	22	22	22	22	21	21		
Parameter values per ha								
Fuel use (MJ/ha)	5,735	5,753	5,760	5,759	5,714	5,690		
N applied total (kg/ha)	155	157	155	146	164	173		
of which N applied (kg/ha)	66	45	37	38	91	120		
from manure								
P <sub>2</sub> O <sub>5</sub> used (kg/ha)	53	44	41	41	64	76		
K <sub>2</sub> O used (kg/ha)	157	107	87	83	147	185		
CaO used (kg/ha)	521	119	113	113	610	587		
Pesticides used (kg a.i./ha)	4.7	4.4	4.8	4.8	4.8	4.3		
Seed used (kg/ha)	2.8	2.8	2.8	2.8	2.8	2.8		
$N_2O$ emissions from the soil (kg/ha)	6.3	6.1	6.2	6.2	6.5	6.7		
Parameter values per tonne								
Fuel use (MJ/tonne)	65.5	64.5	64.5	65.4	66.3	67.6		
N-applied total (kg/tonne)	1.8	1.8	1.7	1.7	1.9	2.1		
of which N (kg/tonne) from manure	0.8	0.5	0.4	0.4	1.1	1.4		
$P_2O_5$ used (kg/tonne)	0.6	0.5	0.5	0.5	0.7	0.9		
K <sub>2</sub> O used (kg/tonne)	1.8	1.2	1.0	0.9	1.7	2.2		
CaO used (kg/tonne)	6.0	1.3	1.3	1.3	7.1	7.0		
Pesticides used (kg a.i./tonne)	0.05	0.05	0.05	0.05	0.06	0.05		
Seed used (kg/tonne)	0.03	0.03	0.03	0.03	0.03	0.03		
N <sub>2</sub> O emissions from the soil (kg/tonne)	0.07	0.07	0.07	0.07	0.08	0.08		

Rapeseed on clay soils								
Region	Groningen	Friesland	Drenthe	Overijssel	Flevoland	Gelderland		
Acreage (ha)	842	29	1	17	65	110		
Yield (kg/ha)	4,200	4,230	4,200	3,890	3,810	3,980		
Yield by-product (kg/ha)	2,500	2,500	2,500	2,500	2,500	2,500		
N content (kg/ha)	133	134	133	123	121	126		
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	65	65	65	60	59	61		
K <sub>2</sub> 0 content (kg/ha)	40	40	40	37	36	38		
CaO content (kg/ha)	25	25	25	23	22	23		
Parameter values per ha								
Fuel use (MJ/ha)	6,509	6,509	6,509	6,509	6,509	6,509		
N applied total (kg/ha)	210	210	210	210	210	210		
of which N applied (kg/ha)	35	35	35	35	35	35		
from manure								
P <sub>2</sub> O <sub>5</sub> used (kg/ha)	40	40	40	40	40	40		
K <sub>2</sub> O used (kg/ha)	174	104	191	143	108	143		
CaO used (kg/ha)								
Pesticides used (kg a.i./ha)	0.5	0.5	0.5	0.5	0.5	0.5		
Seed used (kg/ha)	4.0	4.0	4.0	4.0	4.0	4.0		
N2O emissions from the soil (kg/ha)	5.7	5.7	5.7	5.6	5.6	5.6		
Parameter values per tonne								
Fuel use (MJ/tonne)	1,549.8	1,538.8	1,549.8	1,673.3	1,708.4	1,635.4		
N applied total (kg/tonne)	50.0	49.6	50.0	54.0	55.1	52.8		
of which N (kg/tonne) from manure	8.3	8.3	8.3	9.0	9.2	8.8		
P₂O₅ used (kg/tonne)	9.5	9.5	9.5	10.3	10.5	10.1		
$K_2O$ used (kg/tonne)	41.3	24.5	45.4	36.9	28.2	36.0		
CaO used (kg/tonne)								
Pesticides used (kg a.i./tonne)	0.11	0.11	0.11	0.12	0.12	0.12		
Seed used (kg/tonne)	0.95	0.95	0.95	1.03	1.05	1.01		
N <sub>2</sub> O emissions from the soil	1.36	1.35	1.36	1.44	1.47	1.42		

Rapeseed on clay soils								
Region								
	Jtrecht	Voord- Holland	Zuid- Holland	Zeeland	Voord- 3rabant	-imburg		
Acreage (ha)	1	73	66	112	53	21		
Yield (kg/ha)	4.060	3.860	4.060	4.260	4.260	4.290		
Yield by-product (kg/ha)	2.500	2.500	2,500	2,500	2.500	2,500		
N content (kg/ha)	129	122	129	135	135	136		
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	63	59	63	66	66	66		
K <sub>2</sub> 0 content (kg/ha)	38	37	38	40	40	41		
CaO content (kg/ha)	24	23	24	25	25	25		
Parameter values per ha								
Fuel use (MJ/ha)	6,509	6,509	6,509	6,509	6,509	6,509		
N applied total (kg/ha)	210	210	210	210	210	210		
of which N applied (kg/ha)	35	35	35	35	35	35		
from manure								
P <sub>2</sub> O <sub>5</sub> used (kg/ha)	40	40	40	40	40	40		
K <sub>2</sub> O used (kg/ha)	143	89	73	67	90	185		
CaO used (kg/ha)								
Pesticides used (kg a.i./ha)	0.5	0.5	0.5	0.5	0.5	0.5		
Seed used (kg/ha)	4.0	4.0	4.0	4.0	4.0	4.0		
$N_2O$ emissions from the soil	5.7	5.6	5.6	5.7	5.7	5.7		
(kg/ha)								
Parameter values per tonne								
Fuel use (MJ/tonne)	1,603.2	1,686.3	1,603.2	1,527.9	1,527.9	1,517.2		
N applied total (kg/tonne)	51.7	54.4	51.7	49.3	49.3	49.0		
of which N (kg/tonne)	8.6	9.1	8.6	8.2	8.2	8.2		
from manure								
P <sub>2</sub> O <sub>5</sub> used (kg/tonne)	9.9	10.4	9.9	9.4	9.4	9.3		
K <sub>2</sub> O used (kg/tonne)	35.1	22.9	18.0	15.7	21.1	43.1		
CaO used (kg/tonne)								
Pesticides used (kg a.i./tonne)	0.11	0.12	0.11	0.11	0.11	0.11		
Seed used (kg/tonne)	0.99	1.04	0.99	0.94	0.94	0.93		
$N_{2}\mathrm{O}$ emissions from the soil	1.39	1.45	1.39	1.34	1.34	1.33		
(kg/tonne)								

Rapeseed on other soils								
Region	Groningen	Friesland	Drenthe	Overijssel	Flevoland	Gelderland		
Acreage (ha)	477	26	95	248	5	202		
Yield (kg/ha)	4,000	4,000	4,000	3,890	3,810	4,000		
Yield by-product (kg/ha)	2,500	2,500	2,500	2,500	2,500	2,500		
N content (kg/ha)	127	127	127	123	121	127		
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	62	62	62	60	59	62		
K <sub>2</sub> 0 content (kg/ha)	38	38	38	37	36	38		
CaO content (kg/ha)	24	24	24	23	22	24		
Parameter values per ha								
Fuel use (MJ/ha)	6,244	6,244	6,244	6,244	6,244	6,244		
N applied total (kg/ha)	210	210	210	210	210	210		
of which N applied (kg/ha)	35	35	35	35	35	35		
from manure								
P <sub>2</sub> O <sub>5</sub> used (kg/ha)	25	25	25	25	25	25		
K <sub>2</sub> O used (kg/ha)	170	170	187	148	150	148		
CaO used (kg/ha)								
Pesticides used (kg a.i./ha)	0.5	0.5	0.5	0.5	0.5	0.5		
Seed used (kg/ha)	4.0	4.0	4.0	4.0	4.0	4.0		
N <sub>2</sub> O emissions from the soil (kg/ha)	5.6	5.6	5.6	5.6	5.6	5.6		
Parameter values per tonne								
Fuel use (MJ/tonne)	1,561.0	1,561.0	1,561.0	1,605.1	1,638.8	1,561.0		
N applied total (kg/tonne)	52.5	52.5	52.5	54.0	55.1	52.5		
of which N (kg/tonne) from manure	8.8	8.8	8.8	9.0	9.2	8.8		
P <sub>2</sub> O <sub>5</sub> used (kg/tonne)	6.3	6.3	6.3	6.4	6.6	6.3		
K <sub>2</sub> O used (kg/tonne)	42.6	42.6	46.8	38.1	39.4	37.1		
CaO used (kg/tonne)								
Pesticides used (kg a.i./tonne)	0.13	0.13	0.13	0.13	0.13	0.13		
Seed used (kg/tonne)	1.00	1.00	1.00	1.03	1.05	1.00		
N <sub>2</sub> O emissions from the soil (kg/tonne)	1.96	1.96	2.03	2.15	1.94	2.14		

Rapeseed on other soils								
Region								
	Utrecht	Noord- Holland	Zuid- Holland	Zeeland	Noord- Brabant	Limburg		
Acreage (ha)	3	12	12	6	202	156		
Yield (kg/ha)	3,810	3,860	4,060	4,260	4,230	4,290		
Yield by-product (kg/ha)	2,500	2,500	2,500	2,500	2,500	2,500		
N content (kg/ha)	121	122	129	135	134	136		
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	59	59	63	66	65	66		
K <sub>2</sub> 0 content (kg/ha)	36	37	38	40	40	41		
CaO content (kg/ha)	22	23	24	25	25	25		
Parameter values per ha								
Fuel use (MJ/ha)	6,244	6,244	6,244	6,244	6,244	6,244		
N applied total (kg/ha)	210	210	210	210	210	210		
of which N applied (kg/ha)	35	35	35	35	35	35		
from manure								
$P_2O_5$ used (kg/ha)	25	25	25	25	25	25		
K <sub>2</sub> O used (kg/ha)	148	148	148	175	166	168		
CaO used (kg/ha)								
Pesticides used (kg a.i./ha)	0.5	0.5	0.5	0.5	0.5	0.5		
Seed used (kg/ha)	4.0	4.0	4.0	4.0	4.0	4.0		
N <sub>2</sub> O emissions from the soil (kg/ha)	5.5	5.6	5.7	5.7	5.7	5.7		
Parameter values per tonne								
Fuel use (MJ/tonne)	1,638.8	1,617.6	1,537.9	1,465.7	1,476.1	1,455.5		
N applied total (kg/tonne)	55.1	54.4	51.7	49.3	49.6	49.0		
of which N (kg/tonne)	9.2	9.1	8.6	8.2	8.3	8.2		
from manure								
$P_2O_5$ used (kg/tonne)	6.6	6.5	6.2	5.9	5.9	5.8		
K <sub>2</sub> O used (kg/tonne)	38.7	38.2	36.4	41.1	39.2	39.1		
CaO used (kg/tonne)								
Pesticides used (kg a.i./tonne)	0.15	0.13	0.13	0.13	0.14	0.14		
Seed used (kg/tonne)	1.05	1.04	0.99	0.94	0.95	0.93		
$N_2O$ emissions from the soil	2.12	1.91	1.91	2.01	2.36	2.35		
(kg/tonne)								

Rapeseed on all soils								
Region	Groningen	Friesland	Drenthe	Overijssel	Flevoland	Gelderland		
Acreage (ha)	1,319	55	96	265	70	312		
Yield (kg/ha)	4,128	4,122	4,003	3,890	3,810	3,993		
Yield by-product (kg/ha)	2,500	2,500	2,500	2,500	2,500	2,500		
N content (kg/ha)	131	131	127	123	121	126		
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	64	64	62	60	59	62		
K <sub>2</sub> 0 content (kg/ha)	39	39	38	37	36	38		
CaO content (kg/ha)	24	24	24	23	22	23		
Parameter values per ha								
Fuel use (MJ/ha)	6,413	6,384	6,247	6,261	6,489	6,337		
N applied total (kg/ha)	210	210	210	210	210	210		
of which N applied (kg/ha)	35	35	35	35	35	35		
from manure								
$P_2O_5$ used (kg/ha)	35	33	25	26	39	30		
K <sub>2</sub> O used (kg/ha)	172	135	187	148	111	147		
CaO used (kg/ha)								
Pesticides used (kg a.i./ha)	0.5	0.5	0.5	0.5	0.5	0.5		
Seed used (kg/ha)	4.0	4.0	4.0	4.0	4.0	4.0		
N <sub>2</sub> O emissions from the soil (kg/ha)	5.7	5.7	5.6	5.6	5.6	5.6		
Parameter values per tonne								
Fuel use (MJ/tonne)	1,553.7	1,548.9	1,560.8	1,609.5	1,703.2	1,587.2		
N applied total (kg/tonne)	50.9	50.9	52.5	54.0	55.1	52.6		
of which N (kg/tonne)	8.5	8.5	8.7	9.0	9.2	8.8		
from manure								
P <sub>2</sub> O <sub>5</sub> used (kg/tonne)	8.4	8.0	6.3	6.7	10.2	7.6		
K <sub>2</sub> O used (kg/tonne)	41.8	32.7	46.8	38.1	29.1	36.7		
CaO used (kg/tonne)								
Pesticides used (kg a.i./tonne)	0.11	0.11	0.12	0.12	0.12	0.12		
Seed used (kg/tonne)	0.97	0.97	1.00	1.03	1.05	1.00		
N <sub>2</sub> O emissions from the soil (kg/tonne)	1.38	1.38	1.40	1.43	1.47	1.41		

Rapeseed on all soils								
Region								
	Utrecht	Noord- Holland	Zuid- Holland	Zeeland	Noord- Brabant	Limburg		
Acreage (ha)	4	85	78	118	255	177		
Yield (kg/ha)	3,869	3,860	4,060	4,260	4,236	4,290		
Yield by-product (kg/ha)	2,500	2,500	2,500	2,500	2,500	2,500		
N content (kg/ha)	123	122	129	135	134	136		
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	60	59	63	66	65	66		
K <sub>2</sub> 0 content (kg/ha)	37	37	38	40	40	41		
CaO content (kg/ha)	23	23	24	25	25	25		
Parameter values per ha								
Fuel use (MJ/ha)	6,306	6,471	6,468	6,495	6,299	6,275		
N applied total (kg/ha)	210	210	210	210	210	210		
of which N applied (kg/ha)	35	35	35	35	35	35		
from manure								
$P_2O_5$ used (kg/ha)	29	38	38	39	28	27		
K <sub>2</sub> O used (kg/ha)	146	97	85	72	150	170		
CaO used (kg/ha)								
Pesticides used (kg a.i./ha)	0.5	0.5	0.5	0.5	0.5	0.5		
Seed used (kg/ha)	4.0	4.0	4.0	4.0	4.0	4.0		
N <sub>2</sub> O emissions from the soil (kg/ha)	5.6	5.6	5.6	5.7	5.7	5.7		
Parameter values per tonne								
Fuel use (MJ/tonne)	1,630.0	1,676.4	1,593.1	1,524.6	1,486.9	1,462.6		
N applied total (kg/tonne)	54.3	54.4	51.7	49.3	49.6	49.0		
of which N (kg/tonne)	9.0	9.1	8.6	8.2	8.3	8.2		
from manure								
P <sub>2</sub> O <sub>5</sub> used (kg/tonne)	7.4	9.8	9.3	9.2	6.6	6.2		
K <sub>2</sub> O used (kg/tonne)	37.9	25.1	20.9	17.0	35.4	39.6		
CaO used (kg/tonne)								
Pesticides used (kg a.i./tonne)	0.12	0.12	0.11	0.11	0.11	0.11		
Seed used (kg/tonne)	1.03	1.04	0.99	0.94	0.94	0.93		
N <sub>2</sub> O emissions from the soil (kg/tonne)	1.44	1.45	1.39	1.34	1.35	1.33		

Grain maize on clay soils								
Region	Groningen	Friesland	Drenthe	Overijssel	Flevoland	Gelderland		
Acreage (ha)	45	62	31	33	40	847		
Yield (kg/ha)	12,620	12,620	12,620	12,620	12,620	12,620		
Yield by-product (kg/ha)	18,600	18,600	18,600	18,600	18,600	18,600		
N content (kg/ha)	166	166	166	166	166	166		
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	78	78	78	78	78	78		
K <sub>2</sub> 0 content (kg/ha)	51	51	51	51	51	51		
CaO content (kg/ha)	4	4	4	4	4	4		
Parameter values per ha								
Fuel use (MJ/ha)	6,120	6,120	6,120	6,120	6,120	6,120		
N applied total (kg/ha)	231	231	231	231	231	231		
of which N applied (kg/ha)	176	176	176	176	176	176		
from manure								
$P_2O_5$ used (kg/ha)	74	74	74	74	74	74		
K <sub>2</sub> O used (kg/ha)	174	104	191	143	108	143		
CaO used (kg/ha)								
Pesticides used (kg a.i./ha)	4.0	4.0	4.0	4.0	4.0	4.0		
Seed used (kg/ha)	27.0	27.0	27.0	27.0	27.0	27.0		
N <sub>2</sub> O emissions from the soil (kg/ha)	6.2	6.1	6.1	6.1	6.0	6.2		
Parameter values per tonne								
Fuel use (MJ/tonne)	484.9	484.9	484.9	484.9	484.9	484.9		
N applied total (kg/tonne)	18.3	18.3	18.3	18.3	18.3	18.3		
of which N (kg/tonne)	13.9	13.9	13.9	13.9	13.9	13.9		
from manure								
P <sub>2</sub> O <sub>5</sub> used (kg/tonne)	5.9	5.9	5.9	5.9	5.9	5.9		
K <sub>2</sub> O used (kg/tonne)	13.8	8.2	15.1	11.4	8.5	11.4		
CaO used (kg/tonne)								
Pesticides used (kg a.i./tonne)	0.32	0.32	0.32	0.32	0.32	0.32		
Seed used (kg/tonne)	2.14	2.14	2.14	2.14	2.14	2.14		
N <sub>2</sub> O emissions from the soil (kg/tonne)	0.49	0.49	0.49	0.48	0.48	0.49		

Grain maize on clay soils							
Region							
	Utrecht	Noord- Holland	Zuid- Holland	Zeeland	Noord- Brabant	Limburg	
Acreage (ha)	36	37	81	400	942	1,169	
Yield (kg/ha)	12,620	12,620	12,620	12,620	12,620	12,620	
Yield by-product (kg/ha)	18,600	18,600	18,600	18,600	18,600	18,600	
N content (kg/ha)	166	166	166	166	166	166	
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	78	78	78	78	78	78	
K <sub>2</sub> 0 content (kg/ha)	51	51	51	51	51	51	
CaO content (kg/ha)	4	4	4	4	4	4	
Parameter values per ha							
Fuel use (MJ/ha)	6,120	6,120	6,120	6,120	6,120	6,120	
N applied total (kg/ha)	231	231	231	231	231	231	
of which N applied (kg/ha)	176	176	176	176	176	176	
from manure							
P <sub>2</sub> O <sub>5</sub> used (kg/ha)	74	74	74	74	74	74	
K <sub>2</sub> O used (kg/ha)	143	89	73	67	90	185	
CaO used (kg/ha)							
Pesticides used (kg a.i./ha)	4.0	4.0	4.0	4.0	0.7	0.7	
Seed used (kg/ha)	27.0	27.0	27.0	27.0	27.0	27.0	
N <sub>2</sub> O emissions from the soil (kg/ha)	6.3	6.3	6.2	6.2	6.1	6.1	
Parameter values per tonne							
Fuel use (MJ/tonne)	484.9	484.9	484.9	484.9	484.9	484.9	
N applied total (kg/tonne)	18.3	18.3	18.3	18.3	18.3	18.3	
of which N (kg/tonne)	13.9	13.9	13.9	13.9	13.9	13.9	
from manure							
P <sub>2</sub> O <sub>5</sub> used (kg/tonne)	5.9	5.9	5.9	5.9	5.9	5.9	
K <sub>2</sub> O used (kg/tonne)	11.3	7.0	5.8	5.3	7.1	14.7	
CaO used (kg/tonne)							
Pesticides used (kg a.i./tonne)	0.32	0.32	0.32	0.32	0.05	0.05	
Seed used (kg/tonne)	2.14	2.14	2.14	2.14	2.14	2.14	
$N_2O$ emissions from the soil	0.50	0.50	0.49	0.49	0.49	0.48	
(kg/tonne)							

Grain maize on other soils									
Region	Groningen	Friesland	Drenthe	Overijssel	Flevoland	Gelderland			
Acreage (ha)	304	246	1,055	1,221	7	1,810			
Yield (kg/ha)	12,620	12,620	12,620	11,890	12,410	12,620			
Yield by-product (kg/ha)	18,600	18,600	18,600	18,600	18,600	18,600			
N content (kg/ha)	166	166	166	156	163	166			
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	78	78	78	74	77	78			
K <sub>2</sub> 0 content (kg/ha)	51	51	51	49	51	51			
CaO content (kg/ha)	4	4	4	3	3	4			
Parameter values per ha									
Fuel use (MJ/ha)	6,350	6,350	6,350	6,350	6,350	6,350			
N applied total (kg/ha)	221	221	221	221	221	221			
of which N applied (kg/ha)	176	176	176	176	176	176			
from manure									
$P_2O_5$ used (kg/ha)	74	74	74	74	74	74			
K <sub>2</sub> O used (kg/ha)	170	170	187	148	150	148			
CaO used (kg/ha)									
Pesticides used (kg a.i./ha)	4.0	4.0	4.0	4.0	4.0	4.0			
Seed used (kg/ha)	27.0	27.0	27.0	27.0	27.0	27.0			
$N_2O$ emissions from the soil (kg/ha)	5.9	5.8	5.9	5.8	5.9	6.0			
Parameter values per tonne									
Fuel use (MJ/tonne)	503.2	503.2	503.2	534.1	511.7	503.2			
N applied total (kg/tonne)	17.5	17.5	17.5	18.6	17.8	17.5			
of which N (kg/tonne)	13.9	13.9	13.9	14.8	14.2	13.9			
from manure									
P <sub>2</sub> O <sub>5</sub> used (kg/tonne)	5.9	5.9	5.9	6.2	6.0	5.9			
K <sub>2</sub> O used (kg/tonne)	13.5	13.5	14.8	12.5	12.1	11.8			
CaO used (kg/tonne)									
Pesticides used (kg a.i./tonne)	0.35	0.35	0.35	0.35	0.35	0.35			
Seed used (kg/tonne)	2.14	2.14	2.14	2.27	2.18	2.14			
N <sub>2</sub> O emissions from the soil (kg/tonne)	0.58	0.58	0.60	0.63	0.56	0.63			

Grain maize on other soils								
Region								
	Utrecht	Noord- Holland	Zuid- Holland	Zeeland	Noord- Brabant	Limburg		
Acreage (ha)	30	21	50	168	7,216	4,599		
Yield (kg/ha)	12,150	11,840	12,180	12,130	12,200	12,620		
Yield by-product (kg/ha)	18,600	18,600	18,600	18,600	18,600	18,600		
N content (kg/ha)	159	155	160	159	160	166		
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	75	74	76	75	76	78		
K <sub>2</sub> 0 content (kg/ha)	50	48	50	49	50	51		
CaO content (kg/ha)	3	3	3	3	3	4		
Parameter values per ha								
Fuel use (MJ/ha)	6,350	6,350	6,350	6,350	6,350	6,350		
N applied total (kg/ha)	221	221	221	221	221	221		
of which N applied (kg/ha)	176	176	176	176	176	176		
from manure								
P <sub>2</sub> O <sub>5</sub> used (kg/ha)	74	74	74	74	74	74		
K <sub>2</sub> O used (kg/ha)	148	148	148	175	166	168		
CaO used (kg/ha)								
Pesticides used (kg a.i./ha)	4.0	4.0	4.0	4.0	0.7	0.7		
Seed used (kg/ha)	27.0	27.0	27.0	27.0	27.0	27.0		
N <sub>2</sub> O emissions from the soil (kg/ha)	6.0	6.0	5.9	6.0	5.9	5.9		
Parameter values per tonne								
Fuel use (MJ/tonne)	522.6	536.3	521.3	523.5	520.5	503.2		
N applied total (kg/tonne)	18.2	18.7	18.1	18.2	18.1	17.5		
of which N (kg/tonne)	14.5	14.9	14.4	14.5	14.4	13.9		
from manure								
P <sub>2</sub> O <sub>5</sub> used (kg/tonne)	6.1	6.3	6.1	6.1	6.1	5.9		
K <sub>2</sub> O used (kg/tonne)	12.1	12.5	12.1	14.4	13.6	13.3		
CaO used (kg/tonne)								
Pesticides used (kg a.i./tonne)	0.35	0.35	0.35	0.35	0.06	0.06		
Seed used (kg/tonne)	2.22	2.28	2.22	2.23	2.21	2.14		
$N_2O$ emissions from the soil	0.56	0.56	0.56	0.56	0.62	0.64		
(kg/tonne)								

Grain maize on all soils									
Region	Groningen	Friesland	Drenthe	Overijssel	Flevoland	Gelderland			
Acreage (ha)	349	308	1,086	1,254	47	2,657			
Yield (kg/ha)	12,620	12,620	12,620	11,909	12,590	12,620			
Yield by-product (kg/ha)	18,600	18,600	18,600	18,600	18,600	18,600			
N content (kg/ha)	166	166	166	156	165	166			
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	78	78	78	74	78	78			
K <sub>2</sub> 0 content (kg/ha)	51	51	51	49	51	51			
CaO content (kg/ha)	4	4	4	3	4	4			
Parameter values per ha									
Fuel use (MJ/ha)	6,320	6,304	6,343	6,344	6,153	6,277			
N applied total (kg/ha)	222	223	221	221	230	224			
of which N applied (kg/ha)	176	176	176	176	176	176			
from manure									
$P_2O_5$ used (kg/ha)	74	74	74	74	74	74			
K <sub>2</sub> O used (kg/ha)	171	157	187	148	114	147			
CaO used (kg/ha)									
Pesticides used (kg a.i./ha)	4.0	4.0	4.0	4.0	4.0	4.0			
Seed used (kg/ha)	27.0	27.0	27.0	27.0	27.0	27.0			
N <sub>2</sub> O emissions from the soil (kg/ha)	6.0	5.9	5.9	5.8	6.0	6.1			
Parameter values per tonne									
Fuel use (MJ/tonne)	500.8	499.5	502.6	532.7	488.8	497.4			
N applied total (kg/tonne)	17.6	17.7	17.5	18.6	18.2	17.8			
of which N (kg/tonne)	13.9	13.9	13.9	14.8	14.0	13.9			
from manure									
$P_2O_5$ used (kg/tonne)	5.9	5.9	5.9	6.2	5.9	5.9			
K <sub>2</sub> O used (kg/tonne)	13.5	12.4	14.9	12.4	9.0	11.6			
CaO used (kg/tonne)									
Pesticides used (kg a.i./tonne)	0.32	0.32	0.32	0.34	0.32	0.32			
Seed used (kg/tonne)	2.14	2.14	2.14	2.27	2.14	2.14			
N <sub>2</sub> Oemissions from the soil (kg/tonne)	0.47	0.47	0.47	0.49	0.48	0.48			

Grain maize on all soils							
Region	Utrecht	Noord- Holland	Zuid- Holland	Zeeland	Noord- Brabant	Limburg	Nederland
Acreage (ha)	66	58	131	568	8,158	5,767	20,447
Yield (kg/ha)	12,405	12,343	12,452	12,475	12,249	12,620	12,422
Yield by-product (kg/ha)	18,600	18,600	18,600	18,600	18,600	18,600	18,600
N content (kg/ha)	163	162	163	164	161	166	163
P <sub>2</sub> O <sub>5</sub> content (kg/ha)	77	77	77	77	76	78	77
K <sub>2</sub> 0 content (kg/ha)	51	50	51	51	50	51	51
CaO content (kg/ha)	3	3	3	3	3	4	3
Parameter values per ha							
Fuel use (MJ/ha)	6,225	6,202	6,208	6,188	6,323	6,303	6,308
N applied total (kg/ha)	226	227	227	228	222	223	223
of which N applied (kg/ha)	176	176	176	176	176	176	176
from manure							
P <sub>2</sub> O <sub>5</sub> used (kg/ha)	74	74	74	74	74	74	74
K <sub>2</sub> O used (kg/ha)	145	109	102	99	157	171	159
CaO used (kg/ha)							
Pesticides used (kg a.i./ha)	4.0	4.0	4.0	4.0	0.7	0.7	1.7
Seed used (kg/ha)	27.0	27.0	27.0	27.0	27.0	27.0	27.0
$N_2 O$ emissions from the soil (kg/ha)	6.1	6.2	6.1	6.1	5.9	5.9	5.9
Parameter values per tonne							
Fuel use (MJ/tonne)	501.8	502.4	498.6	496.0	516.3	499.5	507.8
N applied total (kg/tonne)	18.3	18.4	18.2	18.3	18.1	17.7	17.9
of which N (kg/tonne)	14.2	14.3	14.1	14.1	14.4	13.9	14.2
from manure							
P <sub>2</sub> O <sub>5</sub> used (kg/tonne)	6.0	6.0	5.9	5.9	6.0	5.9	6.0
K <sub>2</sub> O used (kg/tonne)	11.7	8.9	8.2	7.9	12.8	13.6	12.8
CaO used (kg/tonne)							
Pesticides used (kg a.i./tonne)	0.33	0.33	0.32	0.32	0.05	0.05	0.14
Seed used (kg/tonne)	2.18	2.19	2.17	2.16	2.20	2.14	2.17
N <sub>2</sub> O emissions from the soil (kg/tonne)	0.49	0.50	0.49	0.49	0.48	0.47	0.48

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