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1 Introduction

Organic matter is valued as an essential part of the soil quality concept in agricultural production systems. Soil quality or soil health can simple be defined as the 'fitness of soil for use' (Beare *et al.* 1999), where, in this study use is restricted to agricultural use. Soil organic matter influences a number of soil properties and nutrient cycling. Freshly applied organic matter stimulates microbial activity and can therefore enhance the disease suppressive capacity of the soil (Postma 2002a). Traditionally, agriculture depended strongly on organic matter and organic matter applications for crop production. Fertilizers and pesticides profoundly changed this and crop rotations were intensified. The attention to soil organic matter and organic matter applications decreased and the attention focused during the second half of the twentieth century on fertilization/nutrient use and chemical crop protection. As fertilizer/nutrient use and pesticide use are limited nowadays, to prevent unacceptable emissions to the environment, soil organic matter has regained interest. Soil organic matter and organic matter applications are valued for their contribution to the nutrient supply, their positive effects on physical soil properties, the effect on soil biodiversity and the expected positive effects associated with the increased soil biodiversity.

This regained interest in soil organic matter and organic matter applications initiated the study ahead.

The aim of this explorative study was to demonstrate the role of organic matter in agriculture and to some extent in soil biodiversity. The role of organic matter in agriculture in all its complex aspects is presented, the legislation on the applications of organic products and legislation on soil conservation are discussed. In addition, a case study shows the effects of legislation on organic matter applications and subsequently on the soil organic matter content as well as the effects of farm management on the soil organic matter content.

This explorative study is part of the research project 'Functional biodiversity in agricultural production systems: a synthesis of studies on linking above- and belowground multitrophic interactions and consequences for crop protection' initiated by the Netherlands Institute of Ecology (NIOO), Heteren and financed by the Dutch Science Foundation (NWO).

2 Legislation on organic matter applications

2.1 Background

As mentioned before, increasing the organic matter content of soils is considered beneficial for soil biodiversity (Moore & De Ruiter 2000). Application of organic matter can help to build up the organic matter content of soils. In the Netherlands main organic matter sources are animal manure and compost. Availability of both streams is abundant. However, current application is not without problems.

The number of livestock has gradually increased during the last three decades of the previous century (Table 1). This increase was accompanied by an increase in manure production, which eventually became a waste product in excess. In 1990 the annual nitrogen surplus (of artificial N-fertilizers, manure and deposition) of the Netherlands was estimated to be more than 850 10^6 kg N, which was about 400 kg N per ha of agricultural land (Goossensen & Meeuwissen 1990).

Table 1. Livestock numbers in The Netherlands.

	Numbers of animals (millions)					Manure production (million ton)				
Type of livestock	1970	1980	1990	2000	2005	1970	1980	1990	2000	2005
Cattle	4.3	5.2	4.9	4.1	3.8	57.1	68.5	65.4	56.7	54.1
Pigs	5.5	10.1	13.9	13.1	11.3	8.8	14.6	16.4	14.1	11.9
Chicken	57.3	82.6	94.9	106.8	95.5	1.1	1.7	2.4	2.1	1.5
Others	0.7	0.9	0.1	1.3	2.9	0.6	0.9	1.9	2.6	2.8
Total	67.8	98.9	113.9	125.3	113.4	67.6	85.7	86.1	75.6	70.1

Source: http://statline.cbs.nl/StatWeb.

The manure production within The Netherlands is not evenly distributed. Cattle manure is produced on farms with grassland but pig manure production is concentrated on farms with relatively small areas of land belonging to the farm. The majority of the pig manure production takes place in areas with sandy soils and low water tables. As the transport of manure is one of the most costly activities, the applications are usually close to the production. These areas evolved in the last 50 years from poor areas with low yields to wealthy areas with high yields. Increase in soil fertility by high inputs of manure have significantly contributed to this development. Other changes have taken place as well. Farm size increased over time and crop rotations were intensified. Understandably, high nitrate concentrations in the shallow groundwater are found in these areas (Bouwmans & Van Drecht 1998; Ondersteijn *et al.* 2002; Van den Berg & Pulleman 2003).

2.2 Nutrient application standards

European Directives

The EU Nitrate Directive (Council Directive 91/676/EEC 1991) protects waters against pollution by nitrate from agricultural sources (for more detail see De Clercq & Sinabell 2001). Over time, several systems have been implemented to regulate the use of animal manure and to meet the Nitrate Directive (Anonymous 1991; Neeteson *et al.* 2001; Schroder & Neeteson 2008). The implications of EU Nitrate Directive for agricultural practices of the Netherlands will be discussed below.

In 2000, an overall framework for the protection of inlands surface waters, transitional waters, coastal waters and groundwaters was developed and approved, 'the Water Framework Directive' (http://europa.eu/scadplus/leg/en/lvb/l28002b.htm). The Directive holds a framework for Community actions in the field of water policy (Anonymous 2000). The framework intends to prevent further deterioration and protects and enhances the status of aquatic ecosystems, promotes sustainable water use based on long term-protection of available water resources, aims at enhanced protection and improvement of aquatic environment, ensures the progressive reduction of pollution of groundwater and prevents its further pollution, and contributes to mitigating the effects of flooding and drought.

Other Community actions are for instance the EU Groundwater Directive (Anonymous 2006).

In October 2003 the European Court of Justice dismissed the Action Programme to reduce emissions of agricultural sources of N of the Netherlands at the time. It was, at least partly, considered to be in conflict with the EU Nitrate Directive. A new Action Programme was therefore introduced in 2006. This Action Programme reckons with the stated conflicting issues and defines application standards for nitrogen and phosphate (P_2O_5). In addition to application standards the system also regulates application periods. The application standards are based on applications per ha but registered at the farm level. The following will present parts of the new Action Programme but will not be complete as the regulations are very detailed for some aspects. The rules which regulate the application of organic materials are highlighted.

Application standards

Organic materials are categorized as either manure (animal origin) or compost (vegetable origin). Compost can be made from domestic waste (vegetable, fruit and garden compost) or urban waste (green compost). Mushroom compost is considered as a manure product. When products of both categories are mixed they automatically become manure products, also when the manure part is very small.

Three application standards are used to limit the application of nitrogen and phosphate. The most limiting application standard is applicable.

1. The first application standard is the use of phosphate. Phosphate use of manure (animal origin) is limited to 110 kg P_2O_5 ha^{-1} annually for grassland and is gradually reduced to 100 kg P_2O_5 ha^{-1} in 2008. For arable land phosphate application rates are limited to 85 kg ha^{-1} of manure (animal origin) and total phosphate use decreases from 95 kg P_2O_5 ha^{-1} in 2006 to 85 kg P_2O_5 ha^{-1} in 2008 (Table 2).

Table 2. Application standard for phosphate from manure (animal origin) and mineral fertilizer together (kg P_2O_5 ha^{-1}; source: www.minlnv.nl/loket).

	2006	2007	2008	2009	2015
Grassland	110	105	100	(95)[2]	(90)[2]
Arable land	85 (+10)[1]	85 (+5)	85	(80)[2]	(60)[2]

[1] *The supplements (in brackets) may only be given in the form of mineral fertilizer phosphate.*
[2] *Indicative values.*

The phosphate applied with compost products is not from manure and may therefore be applied in the same amounts as the mineral fertilizer phosphate. However, a certain amount of the phosphate application with compost products is levy free. This phosphate is considered to be in the soil fraction of the products and will therefore not enrich the land. The limit for the levy free phosphate application is set at 7 g kg^{-1} product: up to 7 g phosphate kg^{-1} product 50% of the phosphate is levy free. Above this limit all phosphate counts.

In 2015 the policy is to develop a balanced system for the use of phosphate which aims at a maximum application of 90 and 60 kg ha^{-1} annually for grassland respectively arable land (Table 2).

2. The second application standard is the use of (total) nitrogen from manure (animal origin). This is limited to 170 kg N ha^{-1} annually for arable land and for grassland. However, if the farm has grazing animals and the farm applies for an exemption, the limit for grassland is increased to 250 kg N ha^{-1}, the so called derogation.

3. The third application standard is the use of plant available nitrogen which is defined per crop. The plant available nitrogen application (kg N ha^{-1}) is the sum of all sources of N becoming available to the crop, including the release from manure or compost in the first growing season after application (i.e. the N-fertilizer replacement value (Table 3)) and/or of all mineral N-fertilizers which availability is 100%. The plant available nitrogen application standards (hereafter named nitrogen application standard) for some arable crops are presented in Table 4.

Table 3. The N-fertilizer replacement value for manure[1] and compost (kg N per 100 kg total N applied; source: www.minlnv.nl/loket).

Product	N-fertilizer replacement value
Liquid manure, liquid fraction after separation	80
Slurry	60
Solid manure (pigs, poultry)	55
Solid manures (others)	40
Mushroom compost	25
Compost	10
Sewage sludge	40
Peat	0

1 Only values of imported manures are given. On-farm produced manures have different N-fertilizer replacement values.

Table 4. Nitrogen application standards for some arable crops (kg ha^{-1}; source: www.minlnv.nl/loket).

	Clay			Sandy/loess		
Crop	2006	2008	2009	2006	2008	2009
Ware potatoes	250-300	240-285	225-275	240-290	225-275	220-270
Sugar beets	165	160	150	150	145	145
Winter wheat	245	230	220	190	160	160
Corn[1,2]	205	195	185	185	175	150
Broccoli	295	285	270	270	255	245
Non-leguminous green manure	65	65	60	60	60	60
Leguminous green manure	35	35	30	30	30	30

1 Application rate includes the application rate of the mandatory green manure sown after harvest.
2 Application rate of farms without derogation.

Application periods

The application of manure is prohibited during specified periods of the year, those periods most sensitive for leaching of mineral N. The majority of the limitations are for slurry, which may not be applied between 1 September and 31 January on sandy and loess soils on arable and on grassland (Table 5). On clay or peat soils, application is allowed until 15 September on grassland. On arable land, no manure application is allowed on peat soils later than 15 September. On clay soils applications are allowed until 15 October 2008 but in 2009 this date is moved to 15 September. A farm with a derogation request on clay soil however, may not apply manure after 15 September on arable land.

No application periods are defined for compost products.

Mineral fertilizers may not be applied between 15 September and 1 February except for field grown vegetables for which no limitations exist. In fruit bearing fruit crops mineral fertilizer products may be applied till 15 October and urea may be applied year round. In Hyacinths, mineral fertilizer may be applied between 15 January and 15 September.

Table 5. Overview on the application periods of manure on different soils with different crops (no means applications not allowed, yes means allowed)(source: www.minlnv.nl/loket).

	Sand/loess	Clay/peat	Clay/peat	Peat	Clay
	Grassland/arable	grassland	arable	arable	Arable
Month	Slurry/solid	Slurry/solid	solid	Slurry	Slurry
January	No	No	Yes	No	No
February-August	Yes	Yes	Yes	Yes	Yes
September	No	Until 15th	Yes	Until 15th	Yes
October	No	No	Yes	No	Until 15th [1]
November	No	No	Yes	No	No
December	No	No	Yes	No	No

[1] *In 2009 it will be 15th of September. For farms with a derogation request, applications after 15 September are not allowed.*

Grassland turnover

Grassland may only be turned over in predefined periods. Grassland on sandy and loess soils may be ploughed down in the period 1 February till 10 May whereas on clay and peat soils till 15 September. Because much N is released from the ploughed grass stubble only high N-demanding crops (a predefined list including grass) may be cultivated following grassland. On clay soils grassland turnover is also allowed between 1 November and 31 December, although no grass may be sown as the following crop.

Application rates of several products

The legislation limits the application of organic materials. The composition of the materials leads to a limitation by either the nitrogen or phosphate content of the product (Table 6). The liquids are in general limited by the N-content, at least in 2008. In 2015 however, the phosphate content limits the application of liquid cattle manure to 67 tons ha^{-1}. The organic matter applications applied with liquids are low. Slurry of fattening pigs is a major concern in some areas as production is high and applications are severely decreased by the regulations.

Table 6. Composition of various organic materials and the maximum application rate on arable land based on the 170 kg N ha^{-1}, the phosphate standard in 2008 (85 kg ha^{-1}) and the indicative standard in 2015 (60 kg ha^{-1}), followed by the accompanying organic matter applications.

Product		Content (kg per ton fresh product)				Maximum application (ton ha^{-1})			Organic matter application (kg ha^{-1})	
		DM	o.m.	N-total	P_2O_5-total	N	2008	2015	2008	2015
Liquid manure	Cattle	25	10	4	0.2	43	425	300	425	425
	Fattening pigs	20	5	6.5	0.9	26	94	67	131	131
	Sows	10	10	2	0.9	85	94	67	850	667
Slurry	Cattle	86	64	4.4	1.6	35	47	33	2473	2400
	Fattening pigs	90	60	7.2	4.2	24	20	14 [1]	1214	857
	Sows	55	35	4.2	3	40	28	20	992	700
	Poultry	145	93	10.2	7.8	17	11	8	1013	715
Solid manure	Cattle	265	182	8.5	5.2	25	22	16	2975	2100
	Poultry litter	640	423	19.1	24.2	9	4	2	1486	1049
	Broiler litter	605	508	30.5	17	6	5	4	2540	1793
Compost	Mushroom	350	220	5.8	3.6	n.a.[2]	24	17	5194	3667
	Domestic waste	650	190	8.5	3.7	n.a.	39	27	8730	6162
	Urban waste	623	200	1.8	3.6	n.a.	47	33	9444	6667
	Peat	700	200	4.1	0.5	n.a.	340	240	68000	48000

1 *Amounts of slurry below 17 ton ha^{-1} are in practice rarely applied due to technical limitations.*

2 *n.a. means not applicable.*

2.3 The Soil Protection Strategy

The Thematic Strategy for Soil Protection (http://ec.europa.eu/environment/soil/index.htm) consists of a Communication from the Commission to the other European Institutions (COM 2006a), a proposal for a framework Directive (COM 2006c), and an Impact Assessment (COM 2006b). The Communication sets the frame. It explains why further action is needed to ensure a high level of soil protection, sets the overall objective of the Strategy and explains what kind of measures must be taken. It establishes a ten-year work programme for the European Commission. The proposal for a framework Directive sets out common principles for protecting soils across the EU. Within this common framework, the EU Member States will be in a position to decide how to protect the soils in a sustainable way on their own territory. Finally, the Impact Assessment contains an analysis of the economic, social and environmental impacts of the different options that were considered in the preparatory phase of the strategy and of the measures finally retained by the Commission.

The framework Directive allows EU Member States to develop their own evaluation systems (based on common methodologies) for soil quality with specific criteria to indicate so called 'Risk Areas'. Risk Areas are areas were soil quality is insufficient or susceptible to degradation. At first, risk areas for erosion, organic matter decline, compaction, salinization and land slides should be identified. Second, Member States need to develop action plans to maintain or improve soil quality in order to preserve soil functions. The Directive should also contribute to halting desertification and loss of soil biodiversity.

Identification of risk areas

A methodology to identify risk areas for organic matter was proposed in 2007 (Smit *et al.* 2007). The methodology focuses on the loss of organic matter in mineral soils due to degradation (loss of soil fertility) and on the loss of organic matter due to soil shrinkage and the emission of greenhouse gasses. Smit *et al*. (2007) present a list of possible criteria which may be used to identify risk areas. The trend of the organic matter content of mineral soils rather than an absolute value, may serve as an indicator for risk areas. The value of the organic matter content found in soils is unique for the combination of many different aspects like soil texture, land use and water table. A decreasing organic matter content may therefore not immediately put a soil at risk in terms of suitability for agricultural use. In general, an organic matter content of 2% is suggested to be the minimum value (Eckelmann *et al.* 2006; Loveland & Webb 2003; Römkens & Oenema 2004). The role of organic matter in soils is discussed in more detail in Chapter 3.

Loss of soil biodiversity

After the identification of risk areas Member States need to develop action plans to maintain or improve soil quality in order to preserve soil functions. One issue that is addressed is the prevention of loss of soil biodiversity. In the Netherlands, soil biology became of interest in the early 1980 when a research programme on Soil Biology was started (Veen 1997). More recent, research focuses on the relationship between soil biology, soil quality and sustainable soil use (Rutgers *et al.* 2005). Soil biodiversity may contribute to disease suppression (Garbeva *et al.* 2006) and sustainable land use (Brussaard *et al.* 2007).

3. The role of organic matter

3.1 Organic matter in the soil

The soil has three phases: solid, air and water (Locher & De Bakker 1990). The solid phase consists of two components: mineral particles and organic matter. To characterize soils, the composition of the mineral particles, the organic matter content and the presence of carbonates are the most commonly used aspects. The mineral particles are divided into size classes. Based on the size classes, the major mineral soils in the Netherlands are sandy, clay and loess soils.

The organic components can be distinguished into living and dead organic matter (Janssen 2002). The living part is about 15% of the total organic matter content. Of this living organic matter content approximately 57% are roots, 10% soil fauna and 33% microorganisms (Table 7). The dead organic matter is shortly called organic matter or humus.

Table 7. Composition of soil organic matter in mass percentages (Lebbink & Antonides 1990).

Soil	Mineral soil	94%						
	Organic matter	6%	Dead org. matter	85%				
			Living org. matter	15%	Living roots	8.5%		
					Edaphon	6.5%	Bacteria and actinomycetes	50%
							Fungi	25%
							Worms	14%
							Macrofauna	5%
							Mesofauna	2.5%
							Microfauna	3.5%

A fertile soil facilitates all demands of growing plants, for example easy for roots to grow in, enough available water and air, sufficient nutrients for crop growth and free of pests and diseases. Soil fertility is divided into physical, chemical and biological aspects and organic matter plays a key role in all these aspects. Also, these aspects of soil fertility (chemical, physical and biological) are highly interrelated.

The physical soil fertility is characterized by the ability of the soil to provide stability to crops by supporting the root system, water to crops so they can regulate their temperature by transpiration and air for root activity so nutrients can be taken up and the root system can grow. The ability to support these demands is highly associated with the structure of the soil and depends on the particle size distribution and on the arrangements of the particles, the soil aggregates but also on the organic matter in the soil. At field capacity (pF = 2) pores $<30\ \mu m$ are filled with water and pores $>30\ \mu m$ are filled with air. The pore volume filled with air at pF = 2 (aeration-index) is a measure for the quality of the soil structure and most crops show growth reduction if lower than 10%. The total pore volume of Dutch agricultural soils varies between 40 and 60% and the percentage of pores filled with water at field capacity between 7 (dune sand) and 49% (heavy clay) (Kuipers 1976). The aeration index varies between 23% for alluvial soils to over 50% for dune sand. Clay soils are most likely to have a low aeration index as at field capacity 49% of the pores can be filled with water and theoretically a maximum of only 11% remains to be filled with air. On sandy soils organic matter increases the amount of available water at field capacity but not at the wilting point and therefore the water holding capacity. Sandy soils have water holding capacities between 5% (dune sand) and 12% (alluvial sand) (Kuipers 1976). Every additional gram of organic matter increases the water holding capacity by 1 - 8 cm^3 (Janssen *et al.* 1991).

The chemical soil fertility is characterized by the ability of the soil to release and bind nutrients. Nutrient release is done by chemical processes like weathering but also by the decomposition of organic materials through soil fauna and soil flora. Organic matter is the substrate for microorganism and plays an important role by the retention of nutrients.

The biological soil fertility can be viewed from many different angels. One important angle is the absence of pests and diseases, meaning that no potential threat comes from soil organisms regarding crop production. The other most common angle is the contribution of soil organisms to the physical and chemical soil fertility which will be discussed under the paragraph 3.2 on organic matter dynamics.

3.2 Organic matter dynamics

Organic matter in soils decomposes by physical-mechanical, inorganic-chemical and biological processes (Janssen 2002). The biological processes (soil- fauna, micro flora) are of major importance to the decomposition of organic matter. The soil fauna is usually at the beginning of the process of turning organic materials into smaller pieces, followed by a variety of other soil organisms. At least 6 criterions are used to classify soil fauna, of which the nature of the food is the most functional one with respect to decomposition (Table 8).

Table 8. Classification of soil fauna after the nature of their food (after Janssen 2002).

Name	Subdivision	Nature of food
Microphytes		Fungus spores and -hyphae, bacteria, algae
Saprophytes	Coprophagous	Faeces, dead and rotting organic material
	Xylophagous	Wood
	Necrophagous	Cadavers
Phytophages		Living plant: • green aboveground • roots • wood
Carnivores	Predators	Meso- and macro-fauna
	Parasites	
Mixed		All that is available, plant or animal, dead or alive, green of woody

Soil micro flora is commonly classified by other classifications than the nature of the food. Only three major groups are distinguished, including aerobic and anaerobic bacteria (Table 9).

The biological processes contribute to the physical and chemical soil fertility of soils. For example, earthworms contribute to soil structure (physical soil fertility) by increasing the porosity due to the formation of burrows and manufacturing of aggregates in their digestive system. Periodical applications of organic matter stimulate earthworm activity and therefore soil structure (Janssen 2002). The effect of soil organisms on chemical soil fertility is most clear for nitrogen mineralization. When substrate (organic matter) is decomposed by microorganism 1/3 is assimilated by the microorganisms and 2/3 is released. The composition of organic matter is for instance 50% carbon, a C:N-ratio of 10 and a C:P (P=phosphorus) and C:S (S=sulpher) ratio of 1. When 600 mass units of organic matter are decomposed, 100 units of C, 10 units of N and 1 unit of P and S are used for assimilation and 200 units of C are respired and 20 units of N, 2 units of P and S are mineralized (Janssen *et al.* 1991).

The relationship between soil organisms is very complex as all types of organisms can be found. Environmental conditions like temperature, soil moisture content, oxygen supply, acidity, nutrients, salt, microstructure and complexity of the substrate, have a profound influence on both the rate of the reactions as well as on the composition of the soil fauna. These environmental conditions are transient or relatively easily to influence by management practices, for example liming to decrease the acidity.

Table 9. Classification of soil micro flora after the nature of their food (after Janssen 2002).

Name	Nature of food	
Bacteria	Only inorganic nutrient salts + sugars	(10%)
	Ditto + one or more amino acids	(10%)
	Ditto + B vitamins	(10%)
	Ditto + one or more amino acids + B vitamins	(40%)
	Mixture of many growth factors	(30%)
Actinomycetes	Resistant materials, left by other micro-organisms	
Fungi	Decompose all organic molecules of plant origin	

During decomposition organic matter stabilizes and three processes are proposed to contribute to this process (Christiansen 1996; Stevenson 1994):
1. Chemical stabilization,
2. Physical protection,
3. Biochemical stabilization.

Chemical stabilization is understood to be the result of chemical or physiochemical binding between the organic matter and soil minerals, the clay and silt fraction. Many studies report a relationship between stabilization of organic C (and N) in soils and clay or silt plus clay (Feller & Beare 1997; Hassink 1997; Merckx *et al.* 1985; Sorensen 1972). The type of clay mineral also influences the stabilization of organic C (and N).

The physical protection of organic C by aggregates is indicated by a positive relationship between aggregation and soil organic matter (Elliott 1986; Tisdall & Oades 1982). The soil organic C is physically protected to microbes and enzymes within the soil aggregates. Cultivation disturbs the aggregate structures resulting in a release of C, a loss of C-rich macro-aggregates and an increase of C-depleted micro-aggregates (Elliott 1986; Six *et al.* 2000).

Biochemical stabilization is understood as the stabilization of organic matter due to its own chemical composition (residue quality) and through chemical complexing processes in the soil (Cadisch & Giller 1997).

The decomposition of organic matter depends among other factors, on temperature and soil water content. A temperature increase of 9°C doubles the relative decomposition rates of common plant residues (Jenkinson & Ayanaba 1977). As standard temperature for the Netherlands 9°C is used.

3.3 Effects of crop rotation, soil management and fertilization practices on organic matter dynamics

The organic matter content is a result of crop rotation, soil management, fertilization practices, type of soil (including soil forming processes) and climate. A steady state between input and decomposition will take a long period (hundreds of years) to establish, but little increase is found after 20 to 40 years (Kolenbrander 1970). Longer periods are more likely to be necessary when the controllable factors (e.g. crop rotation, soil management and fertilization practices) are significantly changed compared to the previous situation. In practice, crop rotations or soil management are usually changed before a steady state has established.

Controllable factors can be manipulated to serve specific goals whereas others are given (soil type and climate). Crop rotation, soil management and fertilization practices are to some point interrelated. Rotations with only grains have different soil management strategies (less intensive tillage) and larger amounts of crop residues than rotations with root crops like potatoes and sugar beets. Consequently, different steady state organic matter contents will be established. Crop rotations are mainly driven by economics and constraints due to the crop. Most crops suffer from yield reduction when grown continuously due to increased health problems so crops are alternated. The most profitable crop will be cropped as much as possible in the rotation and most likely all necessary inputs will be provided to this crop as much as possible.

In the beginning of 20th century grains were profitable and common crop rotations were oats, winter barley, beans, sugar beets, spring wheat followed by red clover as a soil improving crop for 1.5 years, fodder beets, spring wheat, potatoes, beans, poppy seeds and winter rye (Maschhaupt 1936). Roots and stubbles of this crop rotation presented by Masschaupt (1936) compensated the decomposition of the organic matter in the soil and the organic matter content stabilized around 1.8%. When no crop was grown and land was managed as bare soil, the organic matter content decreased over 22 years to 1.3%. The management of this trial was changed in 1947. First three years of alfalfa was grown on all fields. Thereafter the crop rotation included more root crops and the organic matter content decreased to 1.4% in 1961. The organic matter content of the treatment with an application of 15 tons ha^{-1} solid manure annually stabilized around 1.7% in 1961 whereas the bare field with the same solid manure applications stabilized around 1.5% (Kortleven 1963). As production methods evolved potatoes and sugar beets became profitable and rotations with potatoes, sugar beets, winter wheat and a fourth crop like carrots, onions (root crops) or cabbage became standard. Solid manure applications were more and more replaced by large slurry applications in the mid 80's containing less organic matter and more easy available nutrients. Especially on sandy soils slurry applications improved crop production (Smaling *et al.* 1999) but it also became clear that agriculture had become a significant source of ground- and surface water pollution and measures to control emissions were taken (Ondersteijn *et al.* 2002) (Chapter 2).

The overall minimum organic matter content for temperate zones is suggested to be 2% (see above). The question arises if organic matter contents will decrease due to recent changes in fertilizer use or other management factors. On the national scale no decrease of organic matter content is found (Ministerie VROM *et al.* 2006). Detailed investigations on measured organic matter contents of agricultural land supports these findings (Hanegraaf & André 2007; Van Wensem *et al.* 2006), although land use and land use changes have effects on organic matter contents. Most obviously is the change in land use between grassland and arable crop production. Grassland has a much higher organic matter content due to a large input of crop residues and little to no soil cultivation. When grassland is turned over to arable land organic matter content decreases rapidly in the first years.

3.4 Threats concerning organic matter

Manure

Traditionally, animal husbandry was practiced to supply nutrients to arable crop production for human consumption. The manure produced by the stock was used for crop production to maintain the soil fertility and the soil quality. As mineral (nitrogen) fertilizers were introduced, the dependence on manure decreased. Production systems intensified and arable crop production was uncoupled from husbandry. Arable crop production in the Netherlands was practiced more and more to produce animal feed for husbandry (grain and silage corn) and products for human consumption were imported from other countries. The economic benefits of husbandry increased, followed by an increased number of animals and increased availability of organic residues as manure, especially in some regions. Manure became a waste product instead of a valuable fertilizer and over applications occurred. Legislation was introduced to regulate applications, see Paragraph 2.2.

On arable land, the legislation limits the N application of manure to 170 kg ha^{-1} and the phosphate application to 85 kg ha^{-1} in 2008 to 60 kg ha^{-1} in 2015 (Table 2). A bottleneck in this approach is the regional production and distribution of manure. Transport costs of manure are very high compared to mineral fertilizers and other sales for manure are developed, which subsequently withdraws manure from agricultural use. For one, manure is dried and exported (subsidized by the Government). Manure is also digested for energy (Van Lent & Van Dooren 2001). The residues from the digestion of manure are relatively new products and they can be used as fertilizers in arable crop production (Wageningen 2008). However, during the digestion process organic matter is used by micro-organisms as an energy source to produce biogas. With the residue less organic matter is applied compared to the undigested product.

Crop residues

Especially vegetable crop production on sandy soils struggles to meet the Nitrate Directive (De Ruijter *et al.* 2006; Van den Berg & Pulleman 2003). Several solutions are suggested, of which the removal of crop residues is expected to reduce N emissions up to 25% (Zwart *et al.* 2004). However, the organic matter content is expected to reduce as well. When the vegetable crop residues are mixed in with other, more carbon containing residues (e.g. nursery stock crop residues) and composted, the valuable organic fertilizer can be used to improve soil fertility.

Composted vegetable, fruit and garden waste and urban compost

Compost can be made of either vegetable, fruit and garden waste (domestic waste) or of organic waste from parks or other public areas, so called green waste. The domestic waste is collected separately from the inorganic waste by households and has therefore relatively low levels of contaminants (heavy metals). The application rates are limited to the phosphate application or the plant available N released by the product. This product contains relatively large amounts of organic matter per kg phosphate or kg N (Table 6) and is mainly used in horticultural. Organic waste from gardens and parks is however, also considered to be a valuable source for the production of energy, for burning or as supplement in anaerobic digestion. When energy prices continue to increase compost will increasingly be deprived of agricultural use.

4. A case study on long term effects of organic matter applications

4.1 Introduction

The arable farm on a sandy soil

To study the long term effects of an arable crop rotation on the soil organic matter content, a standard farming practice was defined. The simulated arable farm is located on a sandy soil and has an acreage of 60 ha^{-1}. The crop rotation resembles current crop rotations on sandy soils in the southern part of the Netherlands and consist of 15 ha of ware potatoes, 15 ha of sugar beets, 10 ha of silage corn, 5 ha of broccoli and 15 ha of winter wheat (Table 10). After silage corn a mandatory green manure is cropped. However, corn in general is harvested late in the growing season, starting in the third week of September. A green manure does not contributes significantly to the organic matter balance and is therefore mentioned but not included in the calculations.

Table 10. One cycle of the basic crop rotation of the arable farm on sandy soil of 60 ha^{-1}.

	Field 1			Field 2			Field 3			Field 4		
Year	5 ha	5 ha	5 ha	5 ha	5 ha	5 ha	5 ha	5 ha	5 ha	5 ha	5 ha	5 ha
1	WP [1]	WP	WP	SB	SB	SB	SC/GM	SC/GM	Bro	WW	WW	WW
2	SB	SB	SB	SC/GM	SC/GM	Bro	WW	WW	WW	WP	WP	WP
3	SC/GM	SC/GM	Bro	WW	WW	WW	WP	WP	WP	SB	SB	SB
4	WW	WW	WW	WP	WP	WP	SB	SB	SB	SC/GM	Bro	SC/GM
5	WP	WP	WP	SB	SB	SB	SC/GM	Bro	SC/GM	WW	WW	WW
6	SB	SB	SB	SC/GM	Bro	SC/GM	WW	WW	WW	WP	WP	WP
7	SC/GM	Bro	SC/GM	WW	WW	WW	WP	WP	WP	SB	SB	SB
8	WW	WW	WW	WP	WP	WP	SB	SB	SB	Bro	SC/GM	SC/GM
9	WP	WP	WP	SB	SB	SB	Bro	SC/GM	SC/GM	WW	WW	WW
10	SB	SB	SB	bro	SC/GM	SC/GM	WW	WW	WW	WP	WP	WP
11	Bro	SC/GM	SC/GM	WW	WW	WW	WP	WP	WP	SB	SB	SB
12	WW	WW	WW	WP	WP	WP	SB	SB	SB	SC/GM	SC/GM	Bro

[1] *WP = ware potatoes; SB = sugar beets; SC/GM = silage corn followed by a mandatory green manure; Bro = broccoli; WW = winter wheat.*

The initial soil organic matter content was 3% of an 0.25 m deep plough layer with a dry bulk density of 1.5 kg L^{-1}. The bulk density depends on the organic matter content (Locher & Broekhuizen 1990) but is kept constant for this case study.

Model description and application

The mixed integer linear programming model Nutmatch is used to calculate fertilization schemes under predefined restrictions. Nutmatch is a mathematical calculation procedure with which fertilization strategies are optimized towards economically best results, given these predefined restrictions (Bos *et al.* 2007). Restrictions are for instance, the amount of phosphate that may be applied with manure (legislation of 2008 or 2015), the total N applied with manure or that several manure products need to be used. Nutmach is developed to optimize the fertilization strategies at the crop rotation level. Results involve a fertilization strategy that meets the restrictions and which provides the best income for the farmer.

The identified fertilization strategy is than used to estimate the effect on the soil fertility after 20 or 50 years in terms of soil organic matter content, see organic matter calculations below.

As this case study concentrates on the organic matter content under changing input conditions, prices of organic inputs have a large impact on the results. As presented in the previous chapters animal manure is available in surplus in the southern part of the Netherlands and in some cases sold for free or with benefits (Van Dijk *et al.* 2007b). In this study several manures have therefore no price although other products need to be bought (Table 11). Benefits for accepting manure as presented by Van Dijk *et al* (2007b) are not included in this study as this does not present a sustainable situation. The model will naturally select manure products which have no price up to the given restrictions because the N mineralized from the manure is for free and mineral fertilizers have a price.

Another aspect of economical optimization is the financial yield of the crop (appendix 1). The model will not identify fertilization strategies which apply too few fertilizers to profitable crops because profits will be decreased immediately. The model will only do so to meet the restrictions or when the application cost are higher than the financial benefits due to increased yields.

Yields are reduced as N-fertilization becomes lower than the standard advisory levels, the N-target (Van Dijk 2003), according to the reduction functions of Van Dijk *et. al* (2007a). The N-applications to a crop are reduced when N is released from the crop residues of the preceding crop: 30 kg N ha^{-1} is released from the crop residues of sugar beets and green manures.

The minimum application rate of liquid manure and slurries used in the model is 17 tons ha^{-1} because smaller amounts are rarely applied due to technical difficulties. The minimum application rate of compost products is set at 12 tons ha^{-1} and the minimum application rate of mineral N fertilizers is set at 27 kg N ha^{-1}, for the same reason as mentioned above.

Table 11. Prices (€/ton product), the nutrient content of the organic products and the decomposition parameters.

Product	€/ton product[2]	Total N	P_2O_5	K_2O	Organic matter	R_9[1]	S
		kg per ton product				(t^{S-1})	(-)
Cattle slurry	0	4.4	1.6	6.2	48	0.82	0.69
Fattening pig slurry	0	7.2	4.2	7.2	60	1.34	0.75
Chicken slurry	0	10.2	7.8	6.4	93	1.00	0.55
Domestic compost	17	8.5	3.7	6.4	200	0.37	0.60
Mushroom compost	7	5.8	3.6	8.7	173	0.37	0.60
Urban compost[3]	12	6.5	2.5	5.4	153	1.00	0.97
Solid poultry manure	10	30.5	17	22.5	508	1.00	0.57
Solid cattle manure	34	6.4	4.1	8.8	150	0.84	0.69
Broiler litter	10	24.1	24.2	13.3	423	1.00	0.57

1 *Source: deducted from (Van Dijk 2003) by Ten Berge.*
2 *Prices include transport and application costs (after Van Dijk2007b).*
3 *Product content taken from http://www.bvor.nl/bindex.htm.*

Detailed parameters used as input in the model are presented in appendix 1.

Organic matter calculations

The decomposition of the organic matter content is calculated according to the mono-component model of Yang (Janssen 2002; Yang 1996; Yang & Janssen 1997; 2000) which describes the decomposition of organic matter Y at time t (year) by:

$$Y_t = Y_0 * \exp^{-R_9 * t^{(1-S)}} \quad (1)$$

In this equation the parameter R_9 (t^{S-1}) represents the initial average mineralization of organic matter between t = 0 and t = 1 at the reference temperature 9 °C. The parameter S ($1 \geq S \geq 0$, no dimension) represents the decomposition of organic matter after one year. Mono-component models demonstrate, from a scientific point of view, a very simplistic approach, but also provide a practical method for a very complex dynamic system (Andrén & Kätterer 1997).

Note that Y_t approaches zero if time equals infinitely. For long term calculations decomposition may be overestimated as in reality the organic matter content never approaches zero in agricultural land.

Standard values of R_9 and S for the calculation of the decomposition of the soil organic matter are used (Table 12). Each organic application is assumed to decompose according to this exponential curve using product specific decomposition parameters (Table 11).To calculate the actual organic matter content, only the amount of organic matter of one year and older are included, the so called 'effective organic matter'. To reach a steady state condition for the organic matter content, the effective organic matter application should equal the decomposed amount of initial soil organic matter plus the applied organic matter.

Table 12. The composition and decomposition parameters of the soil organic matter and the used crop residues.

Product	Amount (kg o.s. ha^{-1})	R_9	S	Source
Soil organic matter	-	0.046	0.315	(Janssen 2002)
Crop residue WP[1]: roots + stubble	1950	0.80	0.67	(Yang 1996)
Crop residue SB: roots	835	0.80	0.67	(Yang 1996)
Crop residue SB: leaves	3850	1.39	0.64	(Yang 1996)
Crop residue SC: roots + stubble	2050	0.80	0.67	(Yang 1996)
Crop residue SC: leaves	6500	1.39	0.64	(Yang 1996)
Crop residue Bro: roots	650	0.80	0.67	(Yang 1996)
Crop residue Bro: leaves	3600	1.39	0.64	(Yang 1996)
Crop residue Bro: peat pots	1330	0.15	0.49	Deducted from (Kolenbrander 1969)
Crop residue WW: roots + stubble	3650	1.39	0.64	(Yang 1996)
Crop residue WW: straw	3333	1.12	0.67	(Ten Berge *et al.* 2007)
Crop residue green manure	3400	1.20	0.63	(Ten Berge *et al.* 2007)

[1] *WP = ware potatoes; SB = sugar beets; SC = silage corn; Bro = broccoli; WW = winter wheat.*

The organic matter decomposition of the present organic matter in the first year of the calculations is approximately 4.5% according to the input parameters in Table 12. Because a time step of 1 year is used, all organic inputs are supplied at the same time and this is at the end of the time step. In the first year of the calculations no organic matter applications are included and this will always show as a decrease in organic matter content. To overcome this initial decrease a preliminary run of 12 years, one crop rotation, was made. The initial conditions, e.g. at the start of the preliminary run, were fit to deliver an organic matter content of 3% after the preliminary run, which results in 100*100*0.25 *1.5 *3/100 * 1000 = 112500 kg organic matter ha^{-1} plough layer.

4.2 Organic matter application strategies and model scenarios

Strategies on organic applications and crop residue management.

The two major sources of organic matter applications in an arable crop rotation are the application of organic products (manure, composts) and crop residue/green manure management. Therefore, two strategies of organic matter applications are selected:
1. a strategy low on organic matter inputs (LOW) and
2. a strategy that maximizes the organic matter inputs (HIGH).

The differences between the two strategies are given in Table 13. Some of the differences in the strategies are defined as differences in model input, like cover crops in the rotation or seed corn instead of silage corn. The model handles these differences as 'given' and they are not changed in the optimization. Other differences are included as restrictions, for example that a compost product must be applied to at least one crop in strategy HIGH (Table 13). The model selects the crop to which the compost is applied. Because the application of compost cost money, it is obvious that it is broccoli to which the compost will be applied as this crop is cropped on the smallest area. In addition, the model will select the cheapest compost product, in this study urban compost (Table 13).

Table 13. Differences in the strategies on organic matter applications.

	Strategy	
	LOW	HIGH
Crop	Silage corn	Seed corn
Cover crops	No	After ware potatoes (15 ha), broccoli (5 ha) and winter wheat (15 ha)
Straw management	Removed	Incorporated
Type of organic application	Free[1]	A compost product in at least one crop

[1] *Free means that the model selects when an organic application will be used, and if so, which type of organic application.*

The amounts of roots + stubbles, the leafy green biomass and straw that are treated as crop residues are listed in Table 12. No slurries are applied to winter wheat as this would be a fall application and that is not allowed (Table 5).

Model scenarios

The impact of both strategies on the organic matter content of the soil are calculated for the years 2008 (basic scenario) and 2015 (second scenario). The basic scenario includes the presented crop rotations (LOW and HIGH) with the application standards for total N applied with manure or composts, the total phosphate application and the N application standard for this rotation of 2008 on a sandy soil (Table 4). This resembles a maximum application for this farm of 10200 kg of total N applied by manure and a total allowed phosphate application of 5100 kg. Based on the N-application standard 11350 kg N can be applied in strategy LOW and somewhat more, 13450 kg N, in strategy HIGH as green manures have a N-standard (see Table 4).
The second scenario entails the reduced application of P_2O_5 to the expected standard of 60 kg ha^{-1} in 2015. In this scenario the maximum total amount for this farm equals 3600 kg of P_2O_5.

Table 14. Maximum allowed application of nitrogen with manure, total phosphate and the total allowed nitrogen applied according to the application standards for the arable farm for the two scenarios, 2008 and 2015 (all values in kg for the entire farm area).

			Nitrogen application standard per strategy	
Scenario	Nitrogen with manure	Total phosphate	LOW	HIGH
2008	10200	5100	11350	13450
2015	10200	3600	11350 [1]	13450 [1]

[1] *Because no definite N-application standards for 2015 are known, this amount is used in the model calculations.*

The application of manure is confined to a maximum of 75% of the needed mineral N-amount calculated with the N-fertilizer replacement value (Table 3). The N-target values for the involved crops according to the Adviesbasis voor de Bemesting van Akkerbouw- en vollegrondsgroentegewassen (BAB, Van Dijk 2003) are listed in appendix 1. The application of manure is confined because farmers need to be able to correct nitrate levels in the plough layer as levels can be reduced by high precipitation rates during the growing season. For ware potatoes the N-target value is 264 kg N ha^{-1} (appendix 1) and manure can be applied up to a fertilizer N-replacement value of 198 kg N ha^{-1}, or approximately 73 tons ha^{-1} of cattle slurry or 37 tons ha^{-1} of fattening pigs slurry. This application rate of cattle slurry is nowadays relatively high compared to the current practice.

4.3 Results

4.3.1 The basic scenario (2008)

The optimized applications of organic manure in tons ha^{-1} are in general higher than presented as maximum allowed application rates of Table 6. Differences occur because winter wheat does not receive manure but does have application rights. The legislation is based on applications per ha but evaluated on the farm level. As Nutmach optimizes at the farm level, the unused amount of P_2O_5 of manure of winter wheat is distributed among the other crops within the restrictions.

The application of organic products in the basic scenario (restricted by the standards of 2008) to strategy LOW, was found to be pig slurry to ware potatoes and silage corn, and cattle slurry to sugar beets and broccoli (Table 15). Cattle slurry was applied to ware potatoes in the same scenario to strategy HIGH. There is no distinct reason why the model shifts from fattening pigs slurry on ware potatoes to cattle slurry. With both application rates, the maximum amount of 198 kg N ha^{-1} is applied (appendix II). In strategy LOW, an additional application of mineral fertilizer of 66 kg ha^{-1} is given to cover the maximum yield whereas only 36 kg ha^{-1} is needed in the strategy HIGH (appendix II). This difference is due to the additional mineralization of N from the green manure sown after ware potatoes in strategy HIGH. The crop demand for phosphate and the demand for potassium are met with both manure application rates.

The application of 80 tons ha^{-1} of cattle slurry to broccoli in strategy LOW is high and not likely to be practiced. However, the N from manure applications is for free and the model will apply manure as much as possible when an economic optimization is carried out.
The N-target values of strategy LOW are met except for silage corn (appendix II). In corn, the application of N is reduced to 90% of the N-target value. Apparently, the N application standard at the farm level is not completely used so N is available to be applied, but the application costs are higher than the economic return by the yield increase.

The demand for phosphate is met for all crops by the application of the organic products and no mineral P_2O_5 fertilizer is applied. The total effective organic matter application with this crop rotation and fertilization strategy is approximately 2000 kg ha^{-1} (Table 15). The organic matter content of 3%, which was chosen as the initial condition, will slowly decrease over time by about 0.5 (absolute) %-points in 50 years (Figure 1).

Table 15. Optimized applications of the various organic products (ton ha^{-1}) and the total applied effective organic matter by crop residues and organic products (kg ha^{-1}).

	LOW				HIGH			
	2008		2015		2008		2015	
Crop[1]	Product	Rate	Product	Rate	Product	Rate	Product	Rate
WP	Pig slurry	37	Pig slurry	25	Cattle slurry	73	Cattle slurry	73
GM					-[2]	-	-	-
SB	Cattle slurry	39	Cattle slurry	39	Cattle slurry	39	Cattle slurry	39
SC	Pig slurry	26	Cattle slurry	47	Pig slurry	26	Pig slurry	19
Bro	Cattle slurry	80	Cattle slurry	44	Urban compost	12	Urban compost	12
GM					-	-	-	-
WW	-		-		-	-	-	-
GM					-	-	-	-
Applications of 'effective organic matter'								
Crop residues		1081		1074		2153		2144
Organic products[3]		917		932		1257		1235
Total		1998		2006		3410		3379

1 WP = ware potatoes; SB = sugar beets; SC = silage corn; Bro = broccoli; WW = winter wheat.
2 No organic products applied.
3 Including peat pots.

The applications of organic products in strategy HIGH include urban compost on broccoli (Table 15). Because half of the phosphate applied with compost is levy free, the application rate of cattle slurry to ware potatoes is increased to 73 tons ha^{-1}. As in strategy LOW and for the same reasons, the application of N to corn is reduced by 10% compared to the N-target value (appendix 1). In addition, the application of N to sugar beets is reduced by 5% compared to the N-target value and no N is applied to green manures, 100% reduced. In case of the sugar beets, the needed mineral N fertilizer application is very small, only 7 kg ha^{-1}. When the model decides to apply this 7 kg N ha^{-1}, the actual application will be 27 kg N ha^{-1}, as smaller application rates are not feasible in practice. However, the costs to apply 27kg N ha^{-1} are higher than the benefits due to the yield increase and the model will decide not to apply the N. In the case of the green manures, all activities cost money and will be avoided unless they are needed to meet the restrictions.

The demand for phosphate is met for all crops by the application of the organic products. The total effective organic matter application with this crop rotation and fertilization strategy is approximately 3400 kg ha^{-1} (Table 15). The organic matter content of 3%, which was chosen as the initial condition, will hardly decrease over time, only 0.13%–points in 50 years (Figure 1). This decrease can hardly be measured with the current techniques to determine organic matter contents in soils, as the variability is larger than the decrease.

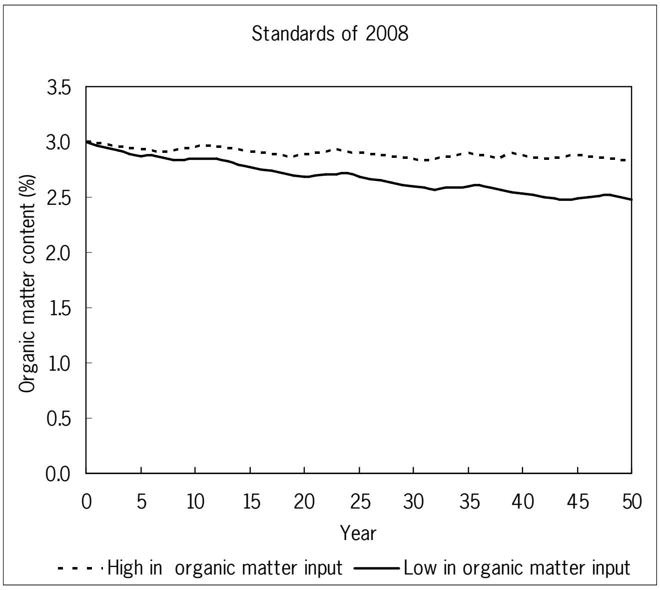

Figure 1. Results on the calculated organic matter content of the scenario with standards of 2008 with low or high organic matter inputs for 50 years.

4.3.2 The second scenario (2015)

The application of organic products, limited by the proposed phosphate standard of 2015, is comparable to the basic scenario but the application rates are reduced (Table 15). In strategy LOW, fattening pig slurry on corn is replaced by cattle slurry.

For the same reason as described above, the application rate of N to corn is reduced in this scenario: 15% for strategy LOW and 30% for strategy HIGH (appendix II). Further more, the application of N to winter wheat is reduced with 10% in strategy LOW but not in strategy HIGH and the needed 7 kg N ha^{-1} to sugar beets is not applied in strategy HIGH. As in the basic scenario, no N is applied to green manures.

The total effective organic matter application is approximately 2000 kg ha^{-1} in strategy LOW and 3400 kg ha^{-1} in strategy HIGH (Table 15). The effects of these effective organic matter applications are comparable with the results of the basic scenario (Figure 2).

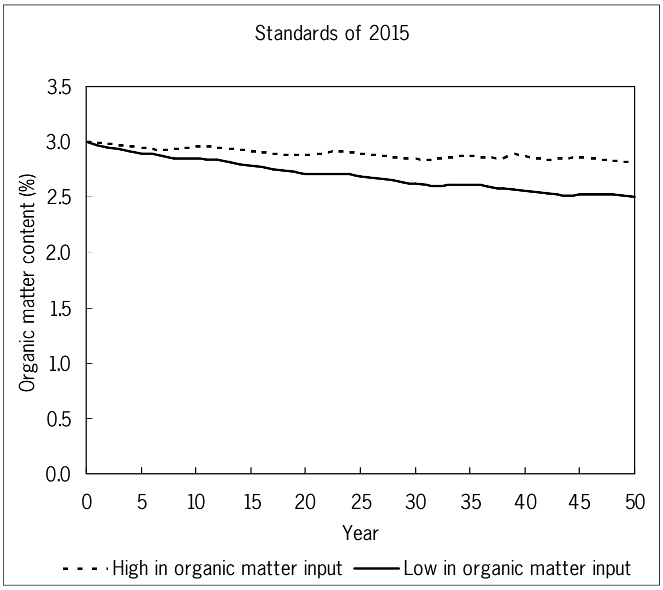

Figure 2. Results on the calculated organic matter content of the scenario with standards of 2015 with LOW or HIGH organic matter inputs for 50 years.

4.4 Conclusions and discussion on the case study

The organic matter content can be maintained at approximately 3% on a sandy soil if all crop residues stay on the field, green manures are included as much as possible and compost of domestic waste is applied on at least 8% of the cropped area (5 of the 60 ha). However, differences related to the input of effective organic matter by organic products are small, only ±300 kg ha^{-1}. The contribution of effective organic matter of crop residues and green manures is approximately 4 times higher, ±1200 kg ha^{-1}.

Increasing the organic matter content to above 3% seems very difficult given the used conditions of this case study and the used input parameters to calculate the organic matter decomposition. Increasing the organic matter content becomes increasingly difficult within the manure legislation (Pronk & Van Reuler 2007b). This requires other, more drastic changes in the management, like in the crop rotation and/or the application of compost products. Crop rotations with 50% root crops have generally lower organic matter contents than crop rotations with less root crops (Kortleven 1970). The results found in this case study are in line with results of long term field experiments where organic matter contents are measured (Christensen 1990; Christensen & Johnston 1997; Jenkinson & Rayner 1977; Kirchmann *et al.* 1994). In general, organic matter contents of these trials decreased when little to no organic matter was applied (amendments as well as crop residues) whereas in general organic matter contents only reduced over long periods of time when crop residues stayed on the field and organic amendments were applied. Only in trails were grass was included for 50% or more, an increase of organic matter content was measured (Uhlen 1991).

The farm management is based on many different aspects but is always closely related to economic yield. In horticulture, where profits nowadays tend to be higher than in regular arable farming, compost is used more frequently (Pronk *et al.* 2006) and growers are stimulated to use compost effectively (Pronk & Smit 2003). In studies on long term effects of organic matter contents, it is always difficult to predict farm management changes due to economic developments. It may even be questionable if the rotation of strategy HIGH is realistic from an economical point of view, with respect to all the green manures. The decrease in organic matter content will most likely be noticed after at least 15 years, when the organic matter content in the strategy LOW is reduced by 0.23%-points. The investment of cropping green manures to maintain the organic matter content over such a long period may need very determined farmers who look after their soils with great care and can afford the costs.
Cropping green manures has, beside costs, other possible disadvantages. It may not always fit into the crop rotation due to pest and disease problems. Nematodes are multiplied by several green manures (Timmer *et al.* 2003) and that constrains the use of some green manures.

5. Discussion and conclusions

To meet the EU Water Quality Standards, legislation on organic inputs like manure and composts for agricultural use, is extensive and this legislation strongly limits applications of these products. The regulations are established from an environmental point of view, the emissions from agriculture to groundwaters and surface waters need to be in agreement with the Water Quality Standards. These standards are suggested to eventually meet the Water Quality Standards, provide sustainable land use and therefore guarantee a future for the coming generations. The Dutch government has to provide results on the water quality periodical to the European Union to confirm progress as at this moment the Water Quality Standards are not met throughout the country (De Klijne *et al.* 2007; Fraters *et al.* 2004). Farming Systems Research on the experimental farm Vredepeel on a sandy soil, was originally designed to optimize yields with very low environmental impact: integrated management (Langeveld *et al.* 2004). Later, when the EU Water Quality Standards became clear, the system was redesigned to meet the standard of 50 mg nitrate L^{-1} (Smit *et al.* 2004). However, up to now this standard was not met at the farm level and much more measures need to be taken to achieve that (Van Geel *et al.* 2008). The line of thinking was to reduce organic matter inputs as much as possible as organic matter mineralizes at times that no crop is available to use the N and therefore N is leached and lost. Organic matter contents on different fields in the crop rotation decreased from 3.7-4.8% in 1994 to 2.9-3.8 in 2004 (Van Geel & De Haan 2007) but NO_3-concentrations in the shallow groundwater are still higher than the standard.

On the other hand, the Soil Strategy (http://ec.europa.eu/environment/soil/index.htm) is developed and aims to protect degradation of soils by, for instance agricultural use. Although the Soil Strategy is not mandatory, it is clear that legislation to meet the Water Quality Standards has a profound impact on the targets and issues of the Soil Strategy. From an agricultural point of view organic matter is a valuable production tool. However, two aspects complicate strategies to increase the organic matter content of soils.

First, management induced changes in organic matter will manifest only over an extended period of time (Christensen & Johnston 1997), unless very high applications of very effective organic products are applied (Stolwijk & Aendekerk 1993a; b). When a decrease is noticed, it is rather difficult to repair. It is also not clear if and how production, yield, suffers from a decrease of organic matter. The critical level of organic matter in agricultural soils of temperate regions is suggested to be approximately 2% (Loveland & Webb 2003). Production areas in the Western part of the Netherlands immediately prove this statement is not general applicable to all soil types as on dune sands horticulture is cropped with great success on soils with only 1% organic matter (Pronk 2007; Pronk & Van Reuler 2007a). This demonstrates how difficult the issue of organic matter is.

Second, organic products low on organic matter per ton are at the moment for free and organic products with more organic matter per ton have a price. This does not stimulate organic applications high on organic matter. Only very profitable corps, like vegetables, bulbs and ornamental crops invest in the expensive products with high organic matter contents (Pronk 2008). It should also be noticed that not all arable land can swift towards the use of products with more organic matter because the required quantities are simple not available.

Third, it is a challenging task to maintain organic matter content of soils after 2015 with the regulations as they are proposed so far, as demonstrated in the scenario calculations. However, studies are done (Chardon *et al.* 2007) in which the phosphate applications are banned completely if the soil phosphate levels are found adequate for crop production according to the BAB (Van Dijk 2003). That includes the applications of phosphate with organic products and that will complicate the difficulties to maintain organic matter contents in the soil.

Besides a valuable production tool for crop production, organic matter is also considered important for soil biodiversity. The activity of soil organisms is stimulated by annual organic matter applications which then improved soil health (Postma 2002b) and sustainable land use (Brussaard *et al.* 2007) as well as all other profitable functions related to organic matter (Loveland & Webb 2003).

In general can be said that changes in organic matter content of soils take a long time to show and changes are difficult to undo if noticed. This study suggests that under the present legislation, financial conditions and availability of the organic products, crop residues and green manures contribute more to the equilibrium between decomposition of organic matter and addition of organic matter, than the application of organic products do.

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Appendix I.
Detailed parameters used in the case study

Crop	N-target value	Financial yield € ha^{-1}
Ware potatoes	264	3850
Sugar beets	149	2268
Corn	185	963
Broccoli	250	7200
Winter wheat	190	980
Green manure	60	0

Appendix II.
Detailed results on scenario calculations

The N-target value (column 4) is met by the N-mineralized from organic products, applied by mineral fertilizers and mineralized from crop residues from the previous year either crop residues from the marketable crop or the green manure (columns 5 to 7). The shortage is calculated as the N-target value minus the applied amount of mineral N (column 8) and the percentage reduction as the shortage divided by the N-target value x 100 (column 9).

Strategy	Scenario	Crop	N-target value kg ha^{-1}	Available N-source (kg ha^{-1}) organic products	mineral fertilizers	N-mineralized	Shortage	Reduction (%)
LOW	2008	ware potatoes	264	198	66	0	0	0
		sugar beets	149	112	37	0	0	0
		silage corn/green manure	185	139	0	30	18	10
		Broccoli	250	188	32	0	0	0
		winter wheat	190	0	190	0	0	0
	2015	ware potatoes	264	135	129	0	0	0
		sugar beets	149	112	37	0	0	0
		silage corn/green manure	185	127	0	30	28	15
		Broccoli	250	104	116	0	0	0
		winter wheat	190	0	171	0	19	10
HIGH	2008	ware potatoes	264	198	36	30	0	0
		green manure	30	0	0	0	30	100
		sugar beets	149	112	0	30	7	5
		silage corn/green manure	185	137	0	30	18	10
		Broccoli	250	6	214	30	0	0
		green manure	30	0	0	0	30	100
		winter wheat	190	0	160	30	0	0
		green manure	30	0	0	0	30	100
	2015	ware potatoes	264	198	0	30	36	0
		green manure	30	0	30	0	0	100
		sugar beets	149	112	7	30	0	5
		silage corn/green manure	185	101	55	30	0	30
		Broccoli	250	6	0	30	214	0
		green manure	30	0	30	0	0	100
		winter wheat	190	0	0	30	160	0
		green manure	30	0	30	0	0	100