What drives farmers to increase soil organic matter? Insights from the Netherlands

R. Hijbeek[1] (iD), A. A. Pronk[2], M. K. van Ittersum[1], H. F. M. tenBerge[2], J. Bijttebier[3] & A. Verhagen[2]

[1]*Plant Production Systems, Wageningen University & Research, Droevendaalsesteeg 1, 6708 PB Wageningen, the Netherlands,*

[2]*Agrosystems Research, Wageningen University & Research, Droevendaalsesteeg 1, 6708 PB Wageningen, the Netherlands, and*

[3]*Flanders Research Institute for Agriculture, Fisheries and Food, Burgemeester Van Gansberghelaan 92, 9820 Merelbeke, Belgium*

Abstract

Soil organic matter (SOM) is an important resource base for arable farming. For policies on SOM to be effective, insight is needed on why and under which conditions farmers are willing to increase SOM content. This study used the theory of planned behaviour to analyse what prevents or encourages Dutch farmers to increase the SOM content of their fields. In an online survey, 435 arable farmers were asked questions to understand their attitude (perceived benefits), subjective norm (social pressure) and perceived behavioural control (anticipated impediments and obstacles) related to management of SOM. Farmers' answers were related to their intention to increase SOM content, use of organic materials and perceived increase in SOM content. Our results showed that Dutch farmers are well aware of the possible benefits of SOM content for crop productivity. Farmers' attitude, subjective norm and perceived decrease in SOM content were significantly related to their intention to increase SOM content. In our farm survey, this intention was very strong: 90% of the farmers stated a high or very high intention to increase the SOM content of their fields. A higher intention to increase SOM content was correlated with the use of organic materials as expressed as total and effective C ($P = 0.003$ and $P = 0.002$, respectively), but this did not lead to a perceived increase in SOM content. From a farmer's point of view, this indicates that increasing SOM content is to a large degree beyond their direct influence. The Dutch Manure and Fertiliser Act, costs of organic inputs and the need to cultivate profitable crops (such as potatoes or sugar beet) were indicated as important impeding factors for increasing SOM content.

Keywords: soil organic matter, soil management, organic materials, theory of planned behaviour, farmers' intentions, farmers' behaviour, soil conservation

Introduction

Soil organic matter (SOM) content affects many soil properties including soil structure, nutrient availability and soil health (Johnston *et al.*, 2009). Increasing SOM content can therefore be seen as a strategic means to safeguard long-term farm productivity. As such, SOM management is an important farm objective for many Dutch arable farmers (Mandryk *et al.*, 2014).

Farmers can use different practices to increase the SOM content of their fields. They can use more organic materials (such as animal manures or compost) instead of mineral fertilizers, include more cereals (rather than root crops) in

their crop rotation or cultivate green manures (Magdoff & Weil, 2004). However, these practices might conflict with other farm objectives such as profit maximization, labour use efficiency or minimization of gross margin variation. Farmers need to balance these objectives, which can prevent implementation of practices to increase SOM content of their topsoil. This can become especially challenging when short-term profits outweigh long-term objectives (Ingram *et al.*, 2014; Mandryk, 2016).

In the Netherlands, organic materials are widely available for arable farmers due to the large livestock sector and related production of animal manures. Since the 1980s, however, restrictions on the use of organic manure have been implemented (Schröder & Neeteson, 2008), which has caused some concern for farmers' abilities to maintain or increase SOM contents. Using approximately 2 million soil samples,

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Reijneveld *et al.* (2009) showed that, between 1984 and 2004, average SOM content remained stable in agricultural soils in the Netherlands. Verloop *et al.* (2015) however found a decrease in SOM content for each nutrient management strategy assessed on a Dutch experimental farm. The latter might be explained due to the relatively high initial SOM content (4.8%) in combination with a sandy soil.

Maintenance of SOM is a policy target, as documented in European policy documents (EC, 2011a,b) and international food security and climate objectives (UNFCCC, 2015). Through maintenance of SOM, soil is being protected as a resource base for food production, soil life is conserved (Chang *et al.*, 2007) and carbon sequestered (Smith, 2016). For policies on SOM to be effective, insight is needed on why and under which conditions farmers are willing to increase SOM content.

Behavioural research approaches aim to identify what prevents or encourages individuals from displaying a certain type of behaviour. An important component in understanding human behaviour is the effect of social relationships (Coleman, 1990). Both the theory of reasoned action (Fishbein, 1979) and the theory of planned behaviour (Ajzen, 1991) include (i) people's own attitude and (ii) their subjective (social) norm when trying to understand motivational influences on human behaviour. An attitude is based on the degree to which a person expects a certain impact or outcome. Subjective norm refers to the social pressure people experience to perform a certain behaviour.

Unlike the theory of reasoned action, the theory of planned behaviour also includes beliefs on the possession of requisite resources and opportunities – (iii) the perceived behavioural control (Madden *et al.*, 1992). Perceived behavioural control refers to the perceived ease of performing a behaviour and reflects both past experiences and anticipated impediments and obstacles. These three constructs together lead to an intention, which might lead to a certain behaviour (Ajzen, 1991; Figure 1).

According to the theory of planned behaviour, attitudes, subjective norm and perceived behavioural control are formed by underlying beliefs. These can be beliefs on the outcomes of a certain behaviour, beliefs on the views of social referents or beliefs on the strength of control factors restricting a certain behaviour. In our study, we would like to understand what prevents or encourages Dutch arable farmers to increase SOM content. All three previously mentioned components seem relevant for SOM management (farmers' attitudes, subjective norm and perceived behavioural control), and therefore, we used the theory of planned behaviour for obtaining quantitative measures of their underlying beliefs, as done previously by Burton (2004) and Wauters & Mathijs (2014).

When recently asked for their concerns on the future of soil fertility, Dutch farmers placed SOM content at the top of the list (Reijneveld, 2013). It is however yet unknown how the different elements of the theory of planned behaviour play a role in farmers' intention to increase SOM content or use of organic materials. In this study, we used the theory of planned behaviour to analyse why and under which conditions Dutch arable farmers are willing to increase the percentage of SOM content of their fields. We addressed the following research questions:

1. Which beliefs form farmers' attitudes, subjective norms and perceived behavioural controls regarding SOM and its management?
2. How do these beliefs influence the intention of farmers to increase SOM content?
3. How does actual behaviour (use of organic material inputs) correspond to farmers' intentions to increase SOM content?

Materials and methods

A farm survey was conducted among 435 arable farmers in the Netherlands. Using this survey, we first studied the underlying beliefs of attitude, subjective norm and perceived behavioural control of Dutch farmers regarding SOM and its management. Second, we related these beliefs to farmers' intention to increase SOM content. Farmers' intention to
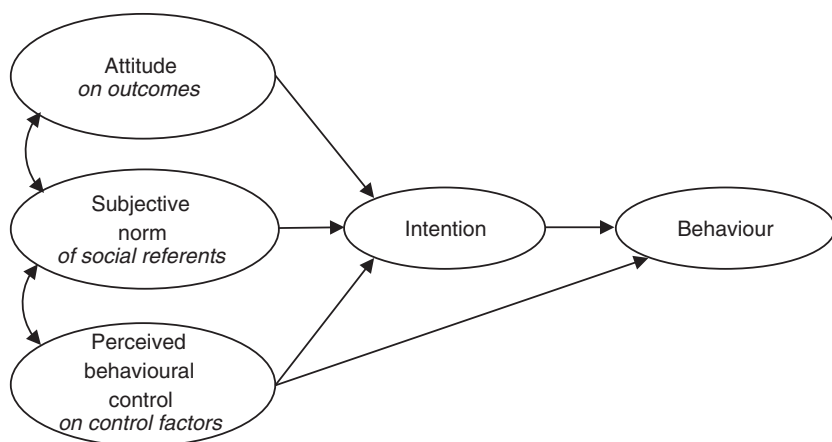

Figure 1 Illustration of the framework of the Theory of planned behaviour (Ajzen, 1991). When experiences are clear and risks are low, perceived behaviour control is directly linked to actual behaviour.

increase SOM content was then related to actual (as stated by respondent) use of organic materials. Finally, perceived change in SOM content was related to perceived behavioural control, intentions to increase SOM content and the use of organic materials.

Online farm survey

An online survey was held among arable farmers in the Netherlands. We focused only on arable farmers because (compared to livestock farmers) arable farmers cultivate less grass and feedstocks and are therefore assumed to be more dependent on high soil fertility and related SOM content. Three groups of farmers were targeted as follows: farmers on sandy soils, farmers on loam soils and farmers on clay soils (Figure S1). Addresses were obtained from the national agricultural census 2012 (CBS, 2012). While selecting addresses, the following two criteria were used to exclude pensioners and hobby farmers: (i) year of birth after 1947 and (ii) spending more than 20 h labour per week to farming. In total, 4770 letters were sent to farmers with a personal link and password to the online questionnaire.

Before data analysis, two criteria were used to select only arable farmers from the respondents (following Andersen *et al.* (2007): (i) more than two-third of the monetary value of agricultural outputs from arable crops; and (ii) <50% of farmland was grassland (either temporary or permanent). In addition, farmers with <10 ha of land or having peat soils (either reporting peat soils or more than 12% SOM on average across all fields) were also excluded from data analysis.

Each farmer was asked to provide information on age, gender, farm size (ha), crop rotation, soil texture and average SOM content. To reduce errors, farmers could leave certain questions unanswered (for example, due to confidentiality of crop rotation or manure application). In those cases, only filled sections were used in the data analysis. Economic farm sizes (expressed as the monetary value of agricultural output at farm-gate price) were calculated using farm activities (e.g. crops cultivated, ha) and Standard Output (SO) coefficients for the Netherlands (Eurostat, 2013). Economic intensity of each farm was calculated by dividing economic farm size by farm ha (and thus expressed in €/ha). In addition, farmers were asked to indicate which type of organic materials they used and how much.

Finding underlying beliefs of attitude, subjective norm and perceived behavioural control regarding SOM and its management

Farmers' attitude. In the terminology of the theory of planned behaviour (which this study used as a methodology), expected or potential benefits are called 'outcomes'. For brevity and consistency, we therefore adopt the term 'outcome' in this text, in spite of its potential ambiguity.

A literature review revealed nine outcomes that SOM may have for soil properties, processes and functions in arable farming: improved soil structure, rooting, workability, water-holding capacity, soil life, nutrient release, nutrient binding capacity, soil fungi and productivity (Allison, 1973; Gregorich *et al.*, 1994; Johnston *et al.*, 2009; Murphy, 2014). For each outcome ($N = 9$), farmers were asked to rate its probability of occurrence on a Likert scale from not very likely (1) to very likely (5). For instance, farmers were asked to rate the likelihood that SOM improves workability of their soil. This is called the belief strength. Farmers were also asked to evaluate each outcome. In the same example, farmers were asked to evaluate workability from negative (1) to positive (5). This is called the outcome valuation. Outcome valuations were lowered by three points to give a negative to positive scaling (−2 to +2); see also Table S1.

For each farmer, an attitude on each outcome (i) was found by multiplying belief strength with outcome valuation (equation 1). Consequently, attitude values ranged between −10 and +10. Mean attitude values for each outcome were found by taking the average across all farmers. Usually, overall attitude of farmers is calculated as the sum of the attitude values for the separate outcomes. In this study, however, we aimed for consistency in scales between categories by keeping all scales between −10 and +10. Therefore, the mean attitude value of all outcomes was taken as a proxy for overall attitude (which had no further consequences in data analysis except for improving readability of tables).

$$\text{attitude}_i = \text{belief strength}_i * (\text{outcome valuation}_i - 3) \quad (1)$$

Farmers were not only asked to rate specific outcomes of SOM (such as improved water-holding capacity or nutrient binding capacity), but also to rate the overall effect of SOM on crop productivity as a more general term (thus bypassing any presumed mechanisms of contribution to crop yields). To assess how the perceived specific outcomes of SOM are related to perceived effect of SOM on productivity as a general term, a correlation analysis was performed using a Spearman correlation (Kendall, 1948).

Farmers' subjective norm. As part of the CATCH-C project (CATCH-C, 2017), a series of open interviews revealed five social referents to be most important for arable farmers in the Netherlands, as follows: advisors, research, magazines, study clubs and fellow farmers (Pronk *et al.*, 2014). These five referents were included in our questionnaire. For each referent ($N = 5$), farmers were asked if they thought the referent had a negative or positive view on increasing SOM. For example, farmers were asked if they thought agricultural advisors are positive towards increasing SOM (1–5). This is called the normative belief of farmers' referents on SOM. For each social referent, farmers were also asked how motivated they are to comply with the referents' view. For

example, farmers were asked how motivated they are to comply with the opinion of fellow farmers (1–5). This is called the farmers' motivation to comply.

For each farmer, the subjective norm for each social referent (k) was found by multiplying normative belief with the motivation to comply (equation 2). Normative beliefs were lowered by three points to give a negative to positive scaling (−2 to +2). This resulted in a subjective norm value for each referent for each farmer between −10 and +10. Mean values of the subjective norm for each referent were found by taking the average value of the farmers in the survey. Means of all subjective norm scores ($N = 5$) were taken as a proxy for overall subjective norm.

$$\text{subjective norm}_k = \text{motivation to comply}_k * (\text{normative belief}_k - 3)$$
(2)

Farmers' perceived behavioural control. Perceived behavioural control of farmers on increasing SOM content was assessed using five control factors: the long-term effect of SOM, costs of organic material inputs, availability of organic materials, cultivation of specialized crops and the Dutch Manure and Fertiliser Act. For each control factor ($N = 5$), farmers were asked how strongly they thought the factor was applicable to them. For example, farmers were asked if availability of organic material inputs was limited in their region on a scale from 1 to 5. This is called the control strength. For each control factor, farmers were also asked to what extent they thought the control factor hampers increasing SOM content. For example, farmers were asked if they thought limited availability prevents increasing SOM on a scale from 1 to 5. This is called the control power.

For each farmer, perceived behavioural control of each control factor (m) was found by multiplying control strength with control power (equation 3). Values for control power were lowered by three points to obtain a negative to positive scaling (−2 to +2). This resulted in a value for perceived behavioural control for each control factor for each farmer between −10 and +10. Mean values were found by taking the average score of all farmers in the survey. Means of all values for perceived behavioural control ($N = 5$) were taken as a proxy for overall perceived behavioural control.

$$\text{perceived behavioural control}_m = \text{control strength}_m * (\text{control power}_m - 3)$$
(3)

Dependency of farmers' beliefs on farm characteristics. Statistical tests were performed to assess whether beliefs of attitude, subjective norm and perceived behavioural control were dependent on certain farm characteristics such as soil texture, age, farm size or farm intensity. Farms and farmers were classified according to their age, soil texture, farm size and farm intensity. For soil texture, the dominant soil texture present on a farm (largest share of farmland being sand, loam or clay) was chosen as an indicator. When constructing classes based on continuous variables (such as age or farm intensity), farmers were divided into three equally sized groups ($N = 145$) where possible.

For each class, means of beliefs were calculated and a test of significant difference was performed using a Kruskal–Wallis rank sum test (McDonald, 2009). If a significant difference was found, pairwise comparisons were made using the Conover-Iman test (Holm, 1979) to find which group means actually differed (e.g. whether attitudes of farmers on the effect of SOM on water-holding capacity on clay soils differed from those farmers on loam soils or farmers on sandy soils or both).

Testing correlations between underlying beliefs and farmers' intention to increase SOM

Farmers were asked to indicate their intention to increase SOM content on a Likert scale from low (1) to high (5). Correlations were tested between intention to increase SOM content and stated beliefs on outcomes, referents and control factors. In addition, correlation tests were performed between farmers' intention to increase SOM content and calculated values of attitude, subjective norm and perceived behavioural control using Spearman's rank correlation test (Kendall, 1948).

Testing correlations between farmers' intention to increase SOM content and (stated) use of organic materials

Farmers were asked to report their use of organic material inputs, such as compost, slurry, farmyard manure (FYM) and the incorporation of straw. Fresh weight quantities as reported by farmers were converted to total carbon (C) and effective C content (see Table S2 for conversion factors). To calculate effective C, humification coefficients were used indicating the remaining fraction of C from organic material inputs which is still present in the soil after one year (Wolf & Janssen, 1991). This conversion allowed for the calculation of an annual input of organic materials expressed in total C and effective C per ha, which we refer to as 'actual organic materials'. Consequently, farmers' intentions to increase SOM were correlated with their annual organic material inputs.

Testing correlations between perceived change in SOM, perceived behavioural control, intentions to increase SOM and use of organic materials

Farmers were asked to state whether SOM content of their fields showed an increasing or decreasing trend, on a scale from 1 to 5. This perceived trend was correlated with actual organic material input (as defined above), farmers' intentions to increase SOM and the use of organic materials. All correlations were tested using Spearman's rank correlation test.

Results

Farm and farmers' characteristics and actual use of organic materials

Of the 4770 farmers who were sent an invitation, 542 farmers filled out the section of the survey that dealt with SOM management. Of these farmers, 501 were confirmed to be arable farmers, of which 10 were excluded from analysis because their farm size was smaller than 10 ha and 52 farmers were excluded because they either farmed peat soils or had an average SOM content above 12%. Four farmers were removed because their stated application of organic materials seemed unreasonably high (more than two times the legally permitted N application), which we interpreted as typographical error. As a result, 435 farmers were included in the analysis.
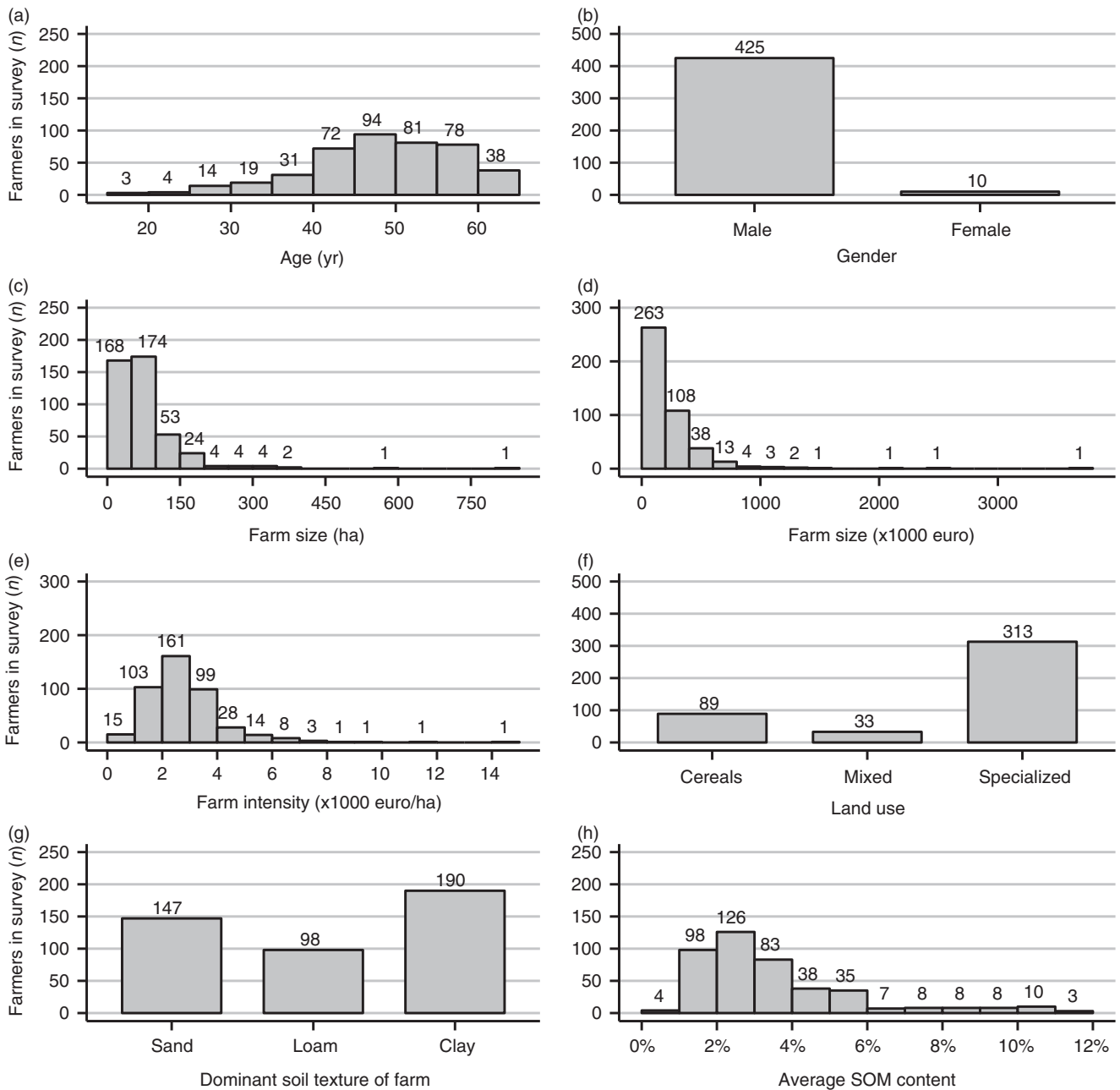

Figure 2 Characteristics of farmers in the farm survey ($N = 435$). Land use categories: cereals indicate >50% of farmland cultivated with cereals such as wheat, barley, rye, oat and triticale. Specialized land use indicates more than 50% of farmland cultivated with specialized crops such as potatoes, sugar beet, carrots and onions. Mixed land use means neither category is present on more than 50% of farmland.

The mean age of farmers included in analysis was 48.8 yrs old, with the median age exactly 50 yrs (Figure 2a). Farmers in our survey were some years younger compared to the entire population of Dutch farmers, for which the mean age was 55 yrs in 2012 (Voskuilen *et al.*, 2013). The difference in age can at least partly be attributed to our criteria used for

address selection (only farmers born after 1947 were included).

Farm size can be expressed in ha or monetary values, for example, using the monetary value of agricultural output at farm-gate price (SO). The mean farm size of the farmers included in the analysis was 79.4 ha (Figure 2b), which was
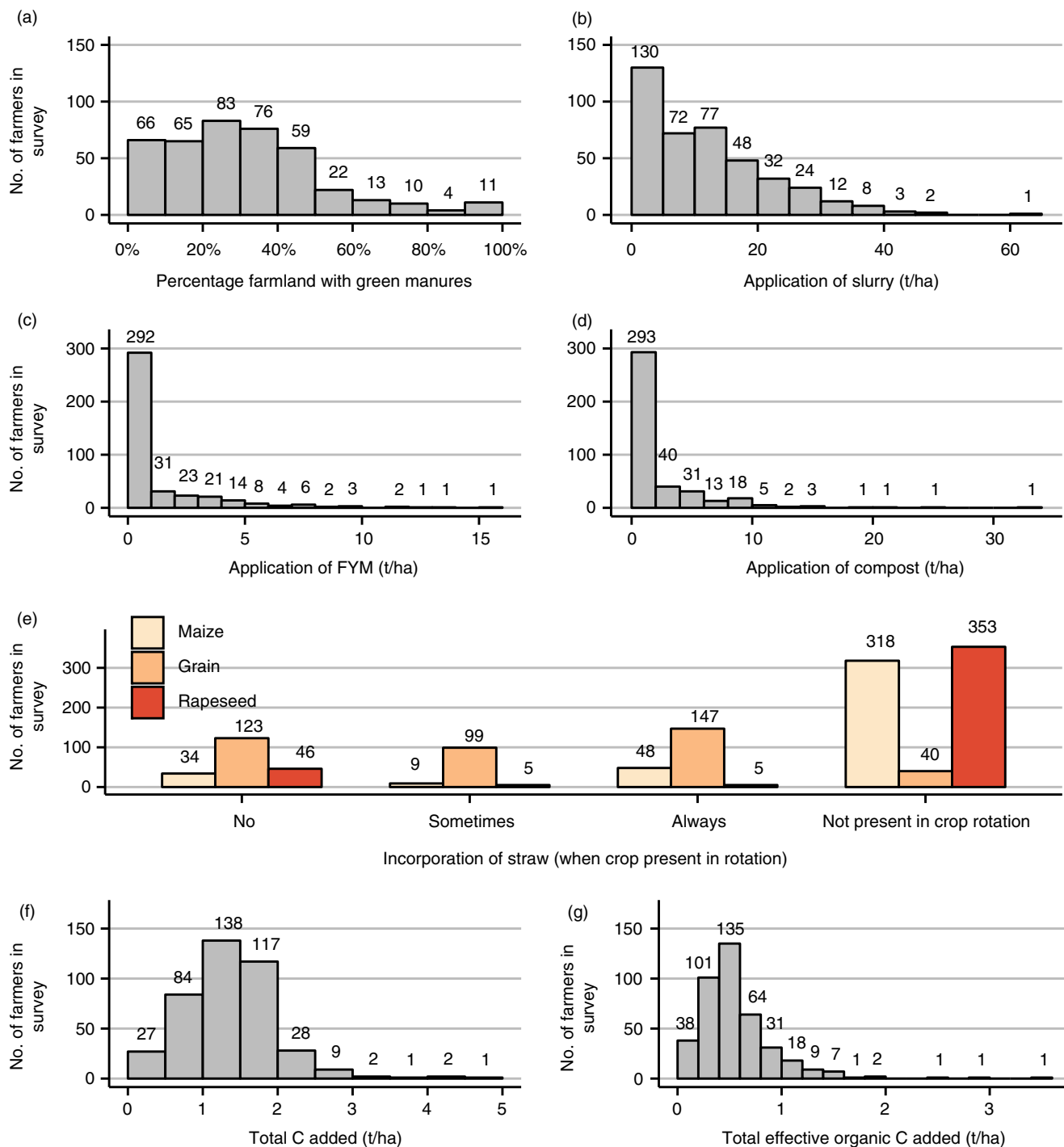

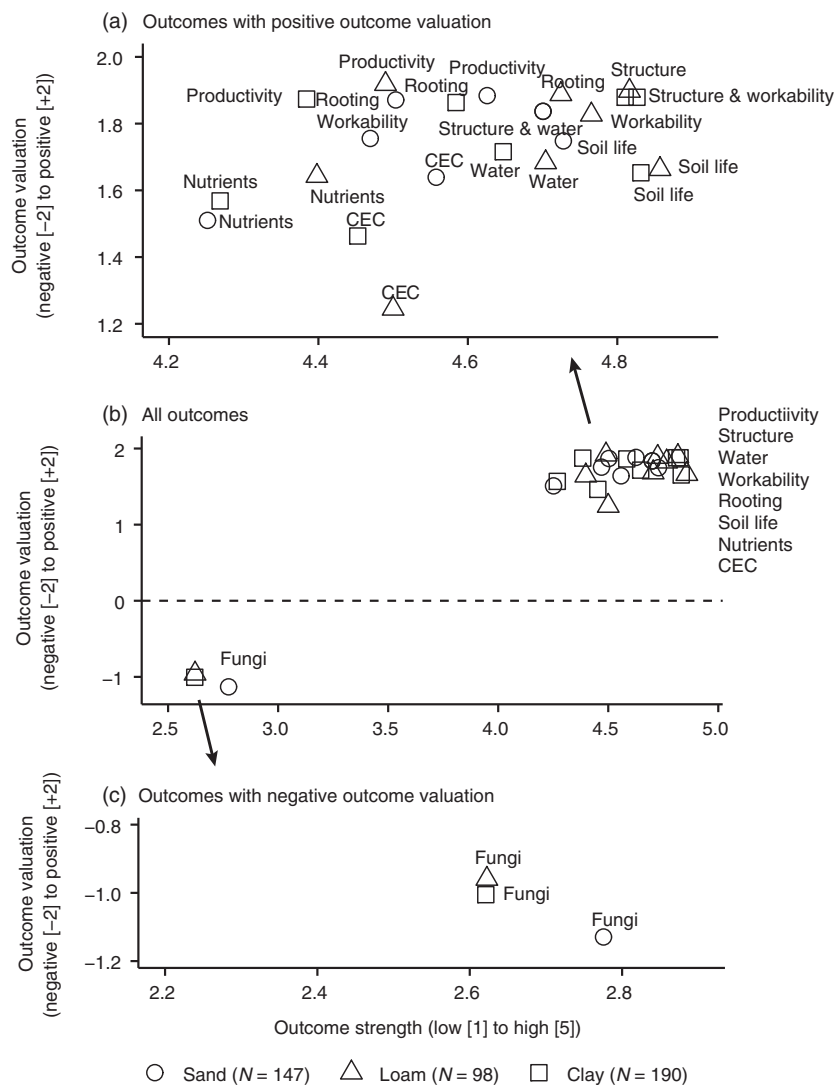Figure 3 Use of organic inputs by farmers in the farm survey (*N* = 435).

Figure 4 Mean values of outcome strengths related to mean outcome valuations. CEC = nutrient binding capacity; nutrients = nutrient release. Symbol shapes indicate dominant soil texture of the farms.

Table 1 Attitudes on SOM (calculated using equation 1). Farmers are grouped by the dominant soil texture of their farm

	Sand (N = 147)		Loam (N = 98)		Clay (N = 190)	
	Attitude (−10 to +10)	Rank	Attitude (−10 to +10)	Rank	Attitude (−10 to +10)	Rank
Improved soil structure	8.76[ab]	3	9.17[a]	1	9.12[a]	1
Easy rooting	8.54[bc]	4	8.92[ab]	2	8.61[b]	3
Improved workability	7.99[cd,*]	6	8.70[ab,*]	3	9.08[a,*]	2
Increased productivity	8.83[a,*]	1	8.62*	4	8.30*	4
Increased water-holding capacity	8.78[ab,*]	2	7.99*	6	8.04[b,*]	6
More soil life	8.44[abc]	5	8.10[bc]	5	8.07[bc]	5
Continuous nutrient release	6.64[e]	8	7.36[d]	7	6.87[d]	7
Increased binding capacity of nutrients	7.70[d,*]	7	5.87[e,*]	8	6.68[d,*]	8
Increase in soil fungi	−3.19[f,*]	9	−2.50[f,*]	9	−2.44[e,*]	9
Mean	6.94		6.91		6.93	

*A significant difference between at least two outcome scores within one row (using the *post hoc* Conover-Iman test). Letters indicate a significant difference within one column between outcome scores.

larger than the mean farm size of Dutch arable farmers in the same year (57.2 ha according to CBS (2017), excluding farms SO < € 25 000). Mean economic farm size was € 238 924 (Figure 2c), which was also larger than mean economic farm size of Dutch arable farmers in 2013 (€ 187 700 according to CBS (2017), excluding farms SO < € 25 000).

The mean reported SOM content of farms was 3.61% SOM (Figure 2e), which is very similar to mean SOM content of Dutch arable farms on mineral soils in the last decades (around 20 g C/kg soil in the upper 25 cm, or approximately 3.5% SOM, as reported by Reijneveld, 2013). Most farmers grew specialized crops (such as potatoes, sugar beet and/or onions) on more than half of their land (Figure 2h).

Most farmers ($N = 409$) also provided information on their use of organic materials (Figure 3). The majority of the farmers (around 87%) cultivated green manures on some parts of their land, but the exact percentages of farmland cultivated differed widely (Figure 3a). Slurry was the most often used animal manure, with 81% of the farmers using some amount of slurry (Figure 3b). Most farmers did not use FYM ($N = 271$), while 21 farmers used <1 tonne FYM per ha (together 292 farmers, Figure 3c). Most farmers did not use compost ($N = 258$), and 35 farmers used <2 tonnes compost per ha (together 293, Figure 3d). When grain maize or other cereals were cultivated, more than half of the farmers incorporated the straw, from at least sometimes up to always (Figure 3e). When converting organic material inputs into total C content, the mean application rate was 1.35 tonne C/ha/yr (±0.06, 95% confidence interval (CI), Figure 3f). When converting organic material inputs into effective C content, the mean application rate was 0.57 tonne effective C/ha/yr (±0.04, 95% CI, Figure 3g).

Beliefs of Dutch farmers on SOM

Farmers' attitude. Dutch farmers had a strong positive valuation of eight outcomes of SOM and a negative valuation of one outcome (the last being soil fungi, Figure 4b). Among the positive outcomes, nutrient release and nutrient binding capacity were considered the least strong outcomes of SOM content and were also evaluated least positively by Dutch arable farmers (Figure 4a). At the other end of the spectrum, soil structure was considered one of the strongest outcomes of SOM and was also evaluated most positively by Dutch arable farmers. For farmers on sandy soils, water-holding capacity takes exactly the same position as soil structure for both outcome strength and valuation. For farmers on clay soil, workability takes almost the exact same position as soil structure for outcome strength and valuation.

Reported SOM contents of farmers showed a strong skew to the right beyond 6% SOM (Figure 2h). Comparing farmers reporting more than 6% SOM and farmers reporting <6% SOM, no significant differences were found in attitudes on SOM. Both the outcome strengths of SOM on workability and on ease of rooting were however significantly higher for farmers reporting <6% SOM than those reporting more than 6% SOM ($P = 0.03$ and $P = 0.04$, respectively; Wilcoxon–Mann–Whitney test).

Farmers evaluated the general term 'soil life' positively, but when asked specifically about soil fungi, this was the only outcome of SOM which was evaluated negatively (Figure 4c). The perceived strength of SOM influencing soil fungi was however much weaker than the strength of the other perceived outcomes (2.6–2.8 and 4.3–4.9, respectively).

Combining outcome strengths and valuations into attitude scores, farmers with different soil textures had a significantly different attitude on a number of outcomes from SOM. These outcomes were: workability, productivity, water-holding capacity, nutrient binding capacity and soil fungi (Table 1).

Despite these differences in attitude for specific benefits of SOM, mean attitudes on the overall benefit of SOM did not vary significantly between soil textures (mean attitude scores varied non-significantly between 6.90 and 6.96). This shows that farmers on different soil textures appreciated the effects of SOM content equally, but for different reasons. On sandy soils, farmers most valued the effect of SOM content on productivity, water-holding capacity and soil structure. On loam and clay soils, farmers most valued the effect of SOM content on soil structure, ease of rooting and workability.

How are the specific effects of SOM related to perceived effects of SOM on productivity? On sandy and clay soils, correlations were highest overall (Figure 5). On sandy soils, perceived effects of SOM on continuous nutrient release and water-holding capacity were strongly correlated with how farmers perceived the effects of SOM on productivity (Spearman's rho > 0.5). On clay soils, perceived effects of SOM on ease of rooting and soil life were strongly correlated with perceived effects of SOM on productivity (Spearman's rho > 0.5). On loam soils, perceived effects of SOM on ease of rooting had the strongest correlation with perceived effects of SOM on productivity (Spearman's rho > 0.5).

Farmers' subjective norm. Considering the subjective norm of Dutch arable farmers, there were significant differences dependent on the age group. Younger farmers were less motivated to comply with views from the given referents (such as fellow farmers, research or advisors, Figure 6). Overall, advisors were thought to be most positive about increasing SOM content, while fellow farmers were thought to be least positive about increasing SOM content.

On average, the subjective norm of farmers to increase SOM content was positive (5.84 on a scale from −10 to +10). Age group had a significant effect on the subjective

Figure 5 Correlations between perceived effect of SOM on specific soil characteristics and perceived effects of SOM on productivity, using Spearman's rank correlation test. Numbers indicate Spearman's rho. Stars show confidence level of correlation coefficients (* means $P < 0.05$. ** means $P < 0.01$). Larger circle sizes indicate a higher correlation. Colours indicate correlation direction (negative or positive).
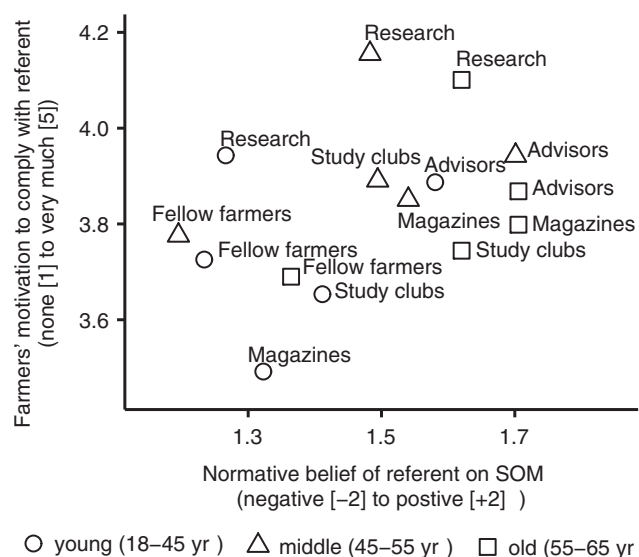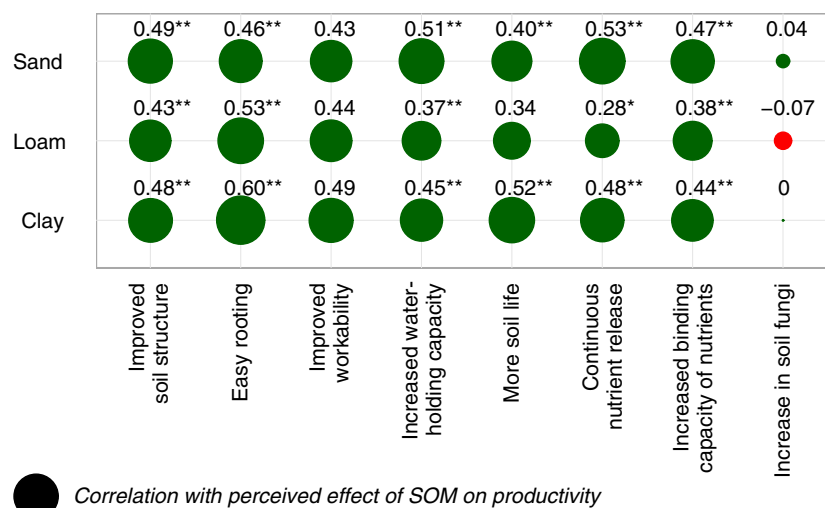

Figure 6 Mean values of normative belief related to mean motivation to comply with referents. Symbol shapes indicate age groups of farmers.

norm. Older farmers (55–65 yr) had a significantly more positive overall subjective norm on increasing SOM content than medium age (45–55 yr) or younger (18–45 yr) farmers (6.29 vs. 5.96 and 5.28, respectively, Table 2).

Farmers' perceived behavioural control. Considering the perceived behavioural control of Dutch arable farmers, the long-term effect of SOM was evaluated as the factor with the highest control strength and evaluated most positively (Figure 7). Availability and costs of organic materials were considered more or less neutral in control power, while Dutch law on manure and fertilizer use (The Dutch Manure and Fertiliser Act) and crop rotations were considered to have a negative influence on SOM management.

There were some significant differences in perceived behavioural control, depending on farm intensity (€/ha). Farmers with high-intensive farms were most positive about the long-term effect of SOM content. Farmers with medium-intensive farms were most negative about the costs of organic materials. Farmers with low-intensive farms were

Table 2 Subjective norm on SOM (calculated using equation 2). Farmers are classified according to their age

	Young 18–45 yr (N = 124)		Middle 45–55 yr (N = 176)		Old 55–65 yr (N = 131)	
	Subjective norm (−10 to +10)	Rank	Subjective norm (−10 to +10)	Rank	Subjective norm (−10 to +10)	Rank
Advisors	6.25[a]	1	6.80[a]	1	6.75[ab]	2
Research	5.06[b],*	3	6.27[ab],*	2	6.83[a],*	1
Study club	5.41[b],*	2	5.94[b],*	4	6.23[b],*	4
Magazines	4.85[b],*	4	6.03[b],*	3	6.55[ab],*	3
Fellow farmers	4.81[b]	5	4.74[c]	5	5.07[c]	5
Mean	5.28*		5.96*		6.29*	

*A significant difference between at least two referent scores within one row (using the *post hoc* Conover-Iman test). Letters indicate a significant difference within one column between referent scores.
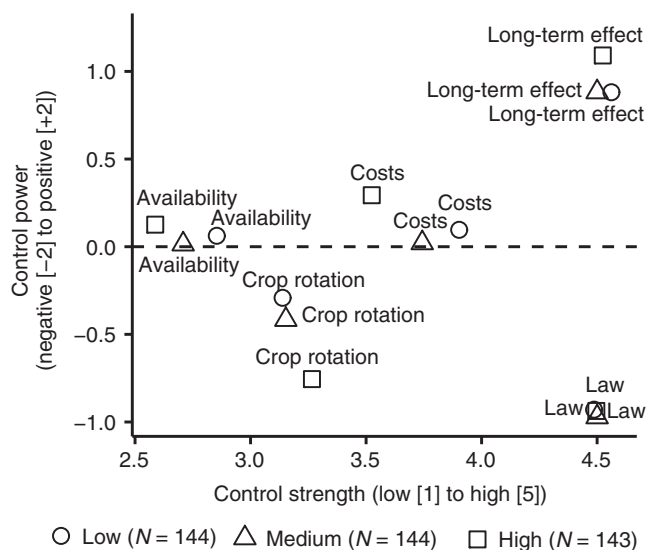
Figure 7 Mean values of control strength related to control power. Costs = costs of organic inputs. Availability = availability of organic inputs. Crop rotation = crop rotation with specialized crops. Law = Dutch Manure and Fertiliser Act. Symbol shapes indicate farm intensity.

least negative about the effects of specialized crops on the management of SOM. Overall perceived behavioural control was not significantly different across farm intensities (Table 3).

For low, medium and high-intensity farms, control factors had exactly the same ranking in order of relevance. For all farm intensities, the Dutch Manure and Fertiliser Act was considered the most hampering factor, followed by crop rotations with specialized crops.

Correlations between beliefs and farmers' intention to increase SOM

Most Dutch arable farmers who participated in the survey stated an intention to increase SOM content (90.1%). On a scale from 1 to 5, 71.9% gave a 5 and 18.2% a 4. Only 2.5% of the farmers did not want to increase the SOM content of their fields (indicating either 1 or 2 on a scale of 5), and 7.4% of the farmers were neutral (indicating a 3).

In the previous sections, underlying beliefs of Dutch arable farmers on SOM were assessed. How are these underlying beliefs related to farmers' intention to increase SOM content? Almost all beliefs on outcomes and social referents were significantly but weakly related to farmers' intentions to increase SOM content. Beliefs on control factors were much less related to farmers' intentions to increase SOM content (Table 4).

For outcomes, (Table 4a) belief strengths and outcome valuations were more or less equally related to farmers' intention to increase SOM content (significant Spearman rho's between 0.15 and 0.30). The strongest relation was found between perceived increase in crop productivity and intention to increase SOM content.

There was a stronger correlation between normative beliefs of referents and farmers' intentions to increase SOM content than between the motivations to comply with those referents and farmers' intentions to increase SOM content (Table 4b, 0.22–0.33 vs. 0.11–0.16). Subjective norms based on advisors and study clubs were slightly more strongly related with intentions to increase SOM content than the subjective norms of research, magazines and fellow farmers.

Table 3 Perceived behavioural control on SOM content by farmers (calculated using equation 3). Farmers are divided into equally sized groups according to their farm intensity. Low-intensity farms: <2273.40 €/ha. Medium-intensity farms: 2 273.40–3062.40 €/ha. High-intensity farms: >3062.40 €/ha. A different uppercase letter indicates a significant difference within one column between control factors

	Low-intensity farms (N = 144)		Medium-intensity farms (N = 144)		High-intensity farms (N = 143)	
	Perceived behavioural control (−10 to +10)	Rank	Perceived behavioural control (−10 to +10)	Rank	Perceived behavioural control (−10 to +10)	Rank
Effects of SOM are long term instead of short term	4.00[d]*	1	4.13[d]*	1	5.00[d]*	1
Costs of organic materials	0.35[c]*	2	−0.10[c]*	2	0.91[c]*	2
Availability of organic materials	−0.19[c]	3	−0.24[c]	3	0.16[c]	3
Crop rotations with specialized crops	−1.24[b]*	4	−1.90[b]*	4	−2.84[b]*	4
Dutch Manure and Fertiliser Act	−4.61[a]	5	−4.80[a]	5	−4.81[a]	5
Mean	−0.34		−0.58		−0.31	

*A significant difference between at least two values for perceived behavioural control within one row (using the *post hoc* Conover-Iman test).

Table 4 Correlations between beliefs on expected outcomes, referents and control factors and farmers' intentions to increase SOM content. Tests of significance were performed using Spearman's rank correlation test. Numbers indicate Spearman's rho

	Correlation with intention to increase SOM	*P* value	Correlation with intention to increase SOM	*P* value	Correlation with intention to increase SOM	*P* value
A. Outcomes	Belief strength		Outcome valuation		Attitude	
Improved soil structure	0.21	0.000	0.29	0.000	0.28	0.000
Easy rooting	0.16	0.001	0.26	0.000	0.24	0.000
Increased productivity	0.30	0.000	0.26	0.000	0.32	0.000
Improved workability	0.22	0.000	0.15	0.002	0.18	0.000
Increased water-holding capacity	0.18	0.000	0.29	0.000	0.27	0.000
More soil life	0.18	0.000	0.26	0.000	0.24	0.000
Continuous nutrient release	0.17	0.000	0.16	0.001	0.18	0.000
Increased binding capacity of nutrients	0.21	0.000	0.27	0.000	0.26	0.000
Increase in soil fungi	−0.07	0.127	0.07	0.143	0.12	0.013
B. Referents	Normative belief		Motivation to comply		Subjective norm	
Advisors	0.33	0.000	0.13	0.006	0.29	0.000
Research	0.25	0.000	0.08	0.084	0.21	0.000
Magazines	0.25	0.000	0.16	0.001	0.24	0.000
Study clubs	0.33	0.000	0.09	0.053	0.29	0.000
Fellow farmers	0.22	0.000	0.11	0.027	0.21	0.000
C. Control factors	Control strength		Control power		Perceived behavioural control	
Effects of SOM are long term instead of short term	0.05	0.291	0.12	0.010	0.11	0.018
Costs of organic materials	0.10	0.043	0.15	0.002	0.13	0.007
Availability of organic materials	0.07	0.177	−0.03	0.591	−0.05	0.267
Crop rotation with specialized crops	0.15	0.002	−0.11	0.021	−0.13	0.008
Dutch Manure and Fertiliser Act	0.19	0.000	−0.08	0.091	−0.06	0.212

Control factors were not or only weakly related to farmers' intention to increase SOM content (Table 4c, significant numbers ranging between −0.11 to 0.19). Significant relations between perceived behavioural control and intentions to increase SOM content were only found for costs of organic materials, long-term effects of SOM and crop rotations with specialized crops. This indicates that, despite low availability of organic materials or the restrictions of the Dutch Manure and Fertiliser Act, farmers still have the intention to increase SOM content. Whether they succeed in doing so is a different question.

Correlations between farmers' intention to increase SOM and the actual use of organic materials

Comparing farmers' intention to increase SOM content with their use of organic materials, a positive correlation was found with the use of slurry and compost ($P = 0.044$ and $P = 0.035$, respectively, Table 5). When converting all organic materials into total C added or total effective C

added, in both cases application amounts increased with higher intentions to increase SOM content ($P = 0.003$ and $P = 0.002$, respectively).

Correlations between perceived change in SOM, perceived behavioural control, intentions to increase SOM and use of organic materials

Farmers also indicated whether SOM contents on their farm increased or decreased. Asked if SOM content was decreasing on their farms, on a scale from 1 to 5, only 1% indicated a 5 (meaning large decrease in SOM content). In addition, 11% of the farmers perceived some decrease (4). Around one-third (33.6%) of the farmers gave a neutral indication, while the majority (55% of the farmers) indicated a 1 or a 2, meaning that the SOM content of their fields was perceived to be stable or increasing.

Perceived change in SOM content was significantly related to the perceived behavioural control of farmers (Table 6, significant numbers ranging between −0.22 and 0.25).

Table 5 Actual use of organic materials by farmers with different intentions to increase SOM content. For incorporation of straw, only farmers for which the mentioned cereal is included in their crop rotation are shown

| | Intention to increase SOM (1 = low, 5 = high) | | | | | |
	1 (*N* = 2)	2 (*N* = 7)	3 (*N* = 31)	4 (*N* = 75)	5 (*N* = 290)	*P*
Green manures						
Percentage farmland with green manures	24%	34%	20%	33%	33%	0.079
Straw						
Grain maize (never/sometimes/always) *N* = 99	0/1/0	0/1/0	4/6/0	6/9/3	40/23/6	0.11
Other cereals (no/sometimes/yes) *N* = 390	0/1/1	3/0/5	17/5/8	28/20/25	82/81/114	0.06
Rapeseed (no/sometimes/yes) *N* = 63	0/1/0	0/1/0	1/10/1	0/9/2	4/32/2	0.81
Off-farm						
Slurry application (t/ha)	3.00	6.70	10.71	11.86	12.56	**0.044**
FYM application (t/ha)	3.41	0.73	1.52	1.06	1.15	0.555
Compost application (t/ha)	0.00	0.00	1.39	1.80	2.09	**0.035**
Total						
Total C added (t/ha)	1.16	1.09	1.04	1.33	1.40	**0.003**
effective C added (t/ha)	0.43	0.35	0.45	0.55	0.60	**0.002**

P values below 0.05 (written in bold) indicate a significant positive trend between a intention to increase SOM and the use of an organic input (straw – Spearman rank correlation test, all others – Jonckheere–Terpstra trend test).

Table 6 Correlations between farmers' beliefs on control factors and perceived increase in SOM content. Tests of significance were performed using Spearman's rank correlation test. Numbers indicate Spearman's rho

	Correlation with perceived increase in SOM	*P* value	Correlation with perceived increase in SOM	*P* value	Correlation with perceived increase in SOM	*P* value
Control factors	Control strength		Control power		Perceived behavioural control	
Effects of SOM are long term instead of short term	0.04	0.392	0.21	0.000	0.17	0.000
Costs of organic materials	−0.11	0.021	0.11	0.024	0.11	0.024
Availability of organic materials	−0.22	0.000	0.09	0.059	0.05	0.310
Crop rotation with specialized crops	−0.16	0.001	0.12	0.013	0.13	0.008
Dutch Manure and Fertiliser Act	−0.19	0.000	0.25	0.000	0.24	0.000

Among the different control factors, perceiving the Dutch Manure and Fertiliser Act as a strong obstacle was most closely related to perceived trends in SOM content.

No correlation was found between the use of organic materials and perceived increase in SOM (Figure 8). This might be due to the time it takes before organic materials have an effect on SOM content and thus before any change will be perceived by the farmers (for example through soil analyses) – this can take decades. At the same time, the lack of correlation also illustrates how difficult it can be for farmers to increase SOM content.

There was a weak but significant negative correlation between perceived increase in SOM and the intention to increase SOM content (Spearman's rho −0.16). The more SOM content was perceived to decrease, the higher was farmers' intention to increase SOM content. Thus, a perceived decrease in SOM content can lead to a higher intention to increase SOM content, which again can lead to an increase in the use of organic materials (Figure 8). In addition, a significant correlation was found between perceived behavioural control and perceived increase (or decrease) of SOM content, highlighting the apparent importance of control factors on the long term.

Discussion

The 435 farmers who were included in analysis were somewhat younger and had larger farms (both in total land

Figure 8 Correlations between farmers' attitude, subjective norm, perceived behavioural control, intention to increase SOM and perceived increase in SOM using Spearman's rank correlation test. Numbers in circles indicate mean values. Numbers besides arrows give correlation coefficients (Spearman's rho). Numbers at top of figure indicate potential ranges. Dotted lines indicate relations with no significant correlation. Stars show confidence level of correlation coefficients (* means $P < 0.05$. ** means $P < 0.01$; *** means $P < 0.001$).
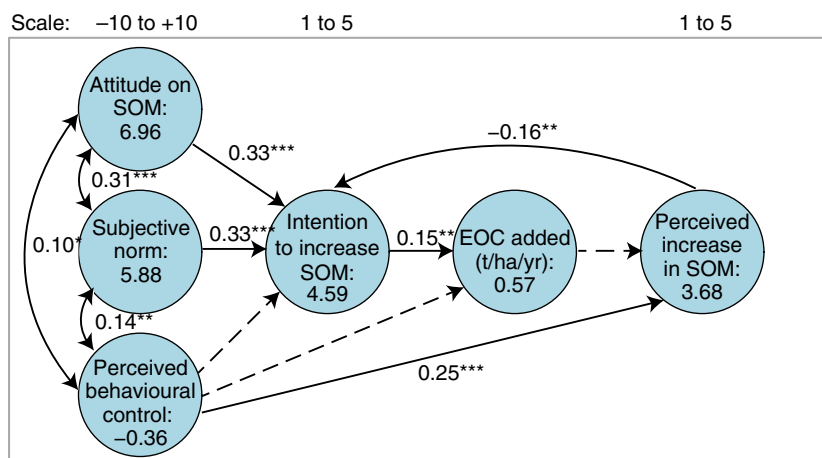
area cultivated and economic size) than average Dutch arable farms. The differences were however small and the SOM contents of farmers' soils corresponded very well with the average for the Netherlands (3.6 vs. 3.5% SOM). The outcomes of this study could therefore be considered reasonably representative for the larger population ($N = 20\ 260$ in 2013; CBS 2017) of Dutch arable farmers.

Farmers' beliefs on SOM

In the Netherlands, farmers usually have sufficient access to mineral fertilizers (Potter *et al.*, 2010; Eurostat, 2012). It is therefore not surprising that Dutch farmers value nutrient release and nutrient binding capacity of SOM the least (Table 1 and Figure 4): they do not primarily rely on these functions of SOM for productive capacity. Dutch farmers value the effect of SOM content on soil structure more, especially where it improves workability on clay soils and water-holding capacity on sandy soils (Figure 4). In addition, farmers with lower SOM contents (<6%) have a greater appreciation of the effect of SOM on workability, which builds further confidence in the practical benefits of this relationship. In this respect, farmers' views also align well with findings from field experiments (Soane, 1990; Watts & Dexter, 1997; Barzegar *et al.*, 2002; Rawls *et al.*, 2003; Hamza & Anderson, 2005).

One can question how far farmers' attitudes on SOM are primarily based on their own practical (empirical) experience or on lessons taught in agricultural college, by parents or on messages received from agricultural advisors. Figure 8 shows a significant correlation between farmers' attitudes on SOM and their subjective norm. Most likely, farmers' attitude is therefore based on a combination of the two (i.e. on practical experience and information received from social referents). Ideally, farmers are not only at the receiving end, but also return their knowledge and

experience to advisors and researchers, making this an iterative process, something which we aimed to facilitate with this study.

Younger farmers were less motivated to comply with referents than older farmers, especially when it comes to messages received from research, farmers' magazines and study clubs (Figure 6). The reason for this difference between young and older farmers remains unclear. Younger farmers in the Netherlands often have a higher education level, which might make them more critical of statements from social referents. At the same time, younger farmers probably have access to a wider range of information sources (through e.g. wider use of Internet, IT and social media) than older farmers. Another relevant factor might be the trend in privatization of both agricultural extension services and research in the Netherlands during the last decades (Roseboom & Rutten, 1998; Kierkels, 2006). This trend might affect younger farmers' confidence in the objectivity of extension services and research (the latter was specifically mentioned as an issue for Dutch farmers in a series of semistructured interviews conducted by the authors; Pronk *et al.*, 2014).

Farmers with high-intensity farms (with the highest economic output per ha) value the long-term effect of SOM more than medium or low-intensity farms and see the costs of organic materials as less of a constraint (Table 3). At the same time, farmers with more intensive farms cultivate more specialized crops (mostly root and tuber crops), which makes it more difficult for them to increase SOM content. This can be an additional challenge as root and tuber crops depend more on a good soil structure for successful crop growth than cereals (Verheijen, 2005; Hijbeek *et al.*, 2017). Over the past decades, the ratio of gross margins between specialized crops and cereals has gone up (KWIN, 2015), thereby making crop rotations with higher shares of cereals economically challenging.

Farmers' intentions to increase SOM and actual use of organic materials

Farmers with a higher intention to increase SOM content used significantly more compost and slurry ($P = 0.035$ and $P = 0.044$, respectively) and applied more total C and effective C to their soils ($P = 0.003$ and $P = 0.002$, respectively). We, however, found that the use of organic materials was not directly related to a perceived increase in SOM content. Increasing SOM using organic materials often takes many years or even decades (Körschens *et al.*, 2013), which could be one explanation for this lack of correlation.

Previously, it was observed that land ownership (or land tenure arrangements) affects the degree of soil conservation on farmland (Fraser, 2004). In our study, we did not find a significant relation between land ownership and farmers' intentions to increase SOM content (data not shown), but this seems a subject worth exploring further.

Currently, Dutch and European manure laws mainly focus on reducing nutrient leaching to ground and surface waters, which could discourage organic matter applications. Within this legal context, there is, however, potential to reuse organic wastes with low nutrient contents to arable land (van der Kolk & Zwart, 2013). Meyer-Kohlstock *et al.* (2015) recently found that only one-third of biowaste is used as compost in Europe. International policies to increase SOM content could therefore start by investigating how the availability of organic materials can be increased by facilitating the use of organic wastes. Meyer-Kohlstock *et al.* (2015) recommend setting recycling targets and implementation of collection systems. In addition, incentives are needed for farmers in the Netherlands to cultivate crops in a more balanced crop rotation by including a higher share of cereals or other crops which are beneficial for SOM content.

Broader relevance of the findings

This study looked specifically at farmers' beliefs regarding SOM content in the Netherlands. There is a large supply of animal manure in the Netherlands due to the presence of a relatively large livestock sector (Oenema & Berentsen, 2004), making it a relatively cheap source of nutrients. In addition, costs of mineral fertilizers are low relative to land prices in the Netherlands, and Dutch farmers cultivate relatively a high share of their land with root and tuber crops. In other countries, farmers might consider the role of SOM less important (due to lower share of root and tuber crops), but nutrient supply and costs of organic materials might play a larger role. The differences in attitude between farmers on different soil textures, the differences in subjective norm with farmers' age and the differences in perceived behavioural

control between farm intensities might be more general patterns. To find out whether and how farmers' beliefs on SOM exactly differ across regions will however require further research.

Conclusions

Using the theory of planned behaviour, this study has gained insight into the underlying beliefs of farmers on increasing SOM content. We found that Dutch arable farmers are well aware of the benefits of SOM. Most Dutch farmers also have a positive subjective norm on SOM (rating 5.84 on a scale from -10 to $+10$). Advisors seem most positive on increasing SOM content, while farmers are most motivated to comply with findings from research.

Farmers' attitude, subjective norm and perceived decrease in SOM content were significantly related to their intention to increase SOM content (Figure 8). In our farm survey, this intention was very strong: 90.1% of the farmers stated a high or very high intention to increase the SOM content of their fields.

Even though a higher intention of farmers to increase SOM led to an increased use of organic materials, it did not lead to a perceived increase in the SOM content of farmers' fields. In contrast, perceived behavioural control did have a significant effect on perceived increases in SOM content. From a farmer's point of view, this indicates that increasing SOM content is to a large degree beyond their direct influence. Despite their best intentions, costs of organic materials, (economic) needs to cultivate specialized crops and the Dutch Manure and Fertiliser Act have a larger effect on perceived increases or decreases of SOM.

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Supporting Information

Additional Supporting Information may be found in the online version of this article:

Figure S1. Soil texture map of The Netherlands.

Table S1. Expected outcomes of increasing SOM content, farmers' referents and control factors included in the farm survey.

Table S2. Conversion coefficients for calculating total and effective C content of organic inputs.