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Use of organic inputs by arable farmers in six agro-ecological zones across Europe: Drivers and barriers

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ABSTRACT

Soil organic matter (SOM) in agricultural soils builds up *via* – among others - the use of organic inputs such as straw, compost, farmyard manure or the cultivation of green manures or cover crops. SOM has benefits for long-term soil fertility and can provide ecosystem services. Farmer behaviour is however known to be motivated by a larger number of factors. Using the theory of planned behaviour, we aimed to disentangle these factors. We addressed the following research question: What are currently the main drivers and barriers for arable farmers in Europe to use organic inputs?

Our study focuses on six agro-ecological zones in four European countries (Austria, Flanders [Belgium], Italy and the Netherlands) and four practices (straw incorporation, green manure or cover crops, compost and farmyard manure). In a first step, relevant factors were identified for each practice with farmers using 5 to ten semi-structured interviews per agro-ecological zone. In a second step, the relevance of these factors was quantified and they were classified as either drivers or barriers in a large scale farm survey with 1263 farmers.

In the semi-structured interviews, 110 factors that influenced farmer decisions to use an organic input were identified. In the larger farm survey, 60% of the factors included were evaluated as drivers, while 40% were evaluated as barriers for the use of organic inputs. Major drivers to use organic inputs were related to the perceived effects on soil quality (such as improved soil structure or reduced erosion) and the positive influence from social referents (such as fellow farmers or agricultural advisors). Major barriers to use organic inputs were financial (increased costs or foregone income) and perceived effects on crop protection (such as increased weeds, pests and diseases, or increased pesticide use).

Our study shows that motivating farmers to use organic inputs requires specific guidance on how to adapt cultivation practices to reduce weeds, pests and diseases for specific soil types, weather conditions, and crops. In addition, more research is needed on the long-term financial consequences of using organic inputs.

1. Introduction

Using organic inputs, such as straw, green manures, compost or animal manure, contributes to the soil organic matter (SOM) content of a soil (Panagos et al., 2015). SOM is generally considered an important indicator for soil fertility (Christensen and Johnston, 1997; Reeves, 1997) as it is known to promote soil aggregation, stabilize soil structure, increase nutrient availability and improve water holding capacity (Johnston et al., 2009; Watts and Dexter, 1997). In addition, SOM content can have environmental benefits such as supporting soil biodiversity (Chang et al., 2007), sequestering carbon (Freibauer et al., 2004) or immobilizing toxic organic pollutants (Bollag et al., 1992).

Recently, a decline in SOM has been identified as a threat to soil quality on a European scale (Toth et al., 2008; Stolte et al., 2015). Precise magnitudes of decline are unknown because monitoring of SOM dynamics is currently rarely done (ten Berge et al., 2017) or gives

Abbreviations: AEZ, agro-ecological zone; FYM, farmyard manure; SOM, soil organic matter; CT, conservation tillage; GM, green manure; SI, Supporting Information

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contrasting results. For Great Britain, studies suggest either a decline or no changes in SOM content over the past decades (Bellamy et al., 2005; Chapman et al., 2013; Reynolds et al., 2013). For Austria and the Netherlands, positive changes in SOM content have been reported (Dersch, 2015; Reijneveld et al., 2009). In contrast, for Germany, Italy, Belgium, Finland and Denmark, a decline in SOM content of arable soils over the last decades has been reported (Capriel, 2013; Fantappiè et al., 2011; Goidts and van Wesemael, 2007; Heikkinen et al., 2013; Taghizadeh-Toosi et al., 2014).

Currently, maintenance of SOM content is included in the cross-compliance standards of Good Agricultural and Environmental Conditions proposed by the EU Council (GAEC; EC, 2013). Most member states have only agreed to a ban on burning of stubble, but a small number of countries has added additional measures including the use of solid manures or other solid organic inputs such as compost (Frelih-Larsen et al., 2016). Frelih-Larsen et al. (2016) recommend a strengthening of GAEC by adding a requirement to incorporate crop residues, either directly or following mulching by composting or use as animal bedding. This would be in line with the 4/1000 initiative to increase SOM as a climate change mitigation measure (UNFCCC, 2015), which would also require increasing the amount of organic inputs to agricultural soils. Before enforcing such a measure, it is important to first understand the current drivers and barriers experienced by European farmers with regards their use of organic inputs.

Van den Putte et al. (2010) argue that farmers in Europe often have few incentives to use soil conservation measures because the productive capacity of their farms is often not affected by soil degradation in the short term. Glenk et al. (2017) made an economic farm level analysis of SOM management in two areas of Scotland and Spain and found both negative and positive financial consequences, depending on input type and region. They did however note that farmer behaviour may be motivated by factors which are not directly economic such as perceived workability of the soil, or soil health for future generations. Simple cost-benefit models might hence not capture the complexity of farmer behaviour and attitudes (Lynne et al., 1988). Burton (2004) argues that understanding farmer willingness to adopt certain management practices improves when using the theory of planned behaviour (Ajzen, 1991) as a conceptual framework.

The theory of planned behaviour has recently been successfully applied in an agricultural context (see for example Werner et al., 2017; Bijttebier et al., 2018). In this study, the theory of planned behaviour is used to identify drivers and barriers for the use of organic inputs by farmers. The aim of this research is: 1) to understand which outcomes of using organic inputs are considered positive or negative by European farmers; 2) to investigate whether the subjective norm linked to using organic inputs is positive or negative across Europe; and 3) to identify which factors currently stimulate or prevent the utilization of organic inputs on European farms. We made the assumption that specific drivers and barriers might be context-specific, depending among other things on soil type, climate, farm type and the socio-economical context. Drivers and barriers were therefore assessed separately in six regions with different soil types and climates, hereafter called agro-ecological zones (AEZ).

2. Materials and methods

2.1. Study area

This study formed part of the European project CATCH-C in which AEZs in Europe were identified based on three environmental factors: climate, slope and soil texture. Each AEZ has more or less homogeneous conditions for each factor (Hijbeek et al., 2013). Six AEZs were studied in four countries (Austria, Belgium [Flanders], Italy and the Netherlands). Selection of AEZs in each country was mainly based on the area of the AEZ and the economic importance of agriculture in the AEZ. Six AEZs were selected (Fig. 1 and Table 1): Austria (AT1), Belgium (BE1), Italy (IT1, IT2) and the Netherlands (NL1, NL2). Within each AEZ, we focussed the data collection on arable farmers, because SOM contents in arable farms are often lower than in grasslands and therefore farmers are more likely to benefit from using organic inputs.

In Austria, AT1 has a relatively dry climate (mean aridity index of 0.51), level or gentle slopes and a medium soil texture (meaning > 15% sand and 18–35% clay or 15–65% sand and < 18% clay). In Belgium, BE1 has a relatively wet climate (mean aridity index 0.73), a medium fine soil texture (meaning < 15% sand, < 35% clay) and level to gently sloping lands.

In Italy, IT1 and IT2 both have a very dry climate. IT1 is mainly present in the Po plain and has more level land. IT2 is mostly located in the hills of centre and southern Italy and has steeper slopes. To differentiate this difference, in figures and tables IT1 is labelled IT1-level and IT2 is labelled IT2-sloping. To keep the text flowing, this adjective is not included in the text.

In the Netherlands, NL1 and NL2 both have a wet climate and level land. NL1 however has medium or medium fine soil textures and NL2 has only coarse soil textures (meaning > 65% sand and < 18% clay). To differentiate this variety in soil texture between the two AEZs in the Netherlands, NL1 was labelled NL1-clay and NL2 is labelled NL2-sand in figures and tables.

2.2. Study approach

To identify drivers and barriers, we used the theory of planned behaviour. According to the theory of planned behaviour (Ajzen, 1991), people base their behaviour on three main constructs: 1) their attitude, 2) their subjective (social) norms and 3) the degree of perceived behavioural control. In this framework, an attitude refers to the degree to which a person expects a certain outcome, together with the desirability of that outcome. An outcome is an expected result or impact of the practice, for example increased weed pressure or improved soil fertility. Subjective norm refers to the influence from social referents to perform a behaviour. Referents are a social influence, such as a fellow farmer or an agricultural advisor. Perceived behaviour control refers to perceived support or hindrance from control factors. A control factor is a specific, often local, condition that governs the impact of the practice, or facilitates or hampers its adoption. These three constructs together lead to an intention, which might lead to a certain behaviour (Ajzen, 1991).

Farmers were questioned about four types of inputs: incorporation of small grain cereal straw or grain maize straw; cultivation of green manures or cover crops; application of compost; and application of farmyard manure (FYM). Not all practices were included in the questionnaire of each AEZ. Incorporation of straw was included in five AEZs. Cultivation of green manures or cover crops was included in six AEZs. Application of compost was included in two AEZs. Application of FYM was included in one AEZ (Table 2).

Our study approach consisted of two steps: 1) a qualitative step to identify relevant outcomes, referents and control factors for each practice; 2) a quantitative step to quantify each relevant outcome, referent or control factor. For the first step, semi-structured interviews were conducted with a smaller number of farmers, whilst for the second step, a much larger farm survey was conducted. In this manner, we used a bottom-up approach by using farmer knowledge on their local farming conditions in each region.

2.3. Step 1: semi-structured interviews

In the first step, 5–10 farmers were interviewed in each AEZ in order to identify outcomes, referents and control factors for each practice. Farmers selected for the semi-structured interviews were located in the specific AEZ and had the desired slope and soil type (Fig. 1 and Table 1). The objective of these semi-structured interviews was to use farmer knowledge to identify relevant factors for each practice, based on the theory of planned behaviour. Farmers were asked five questions

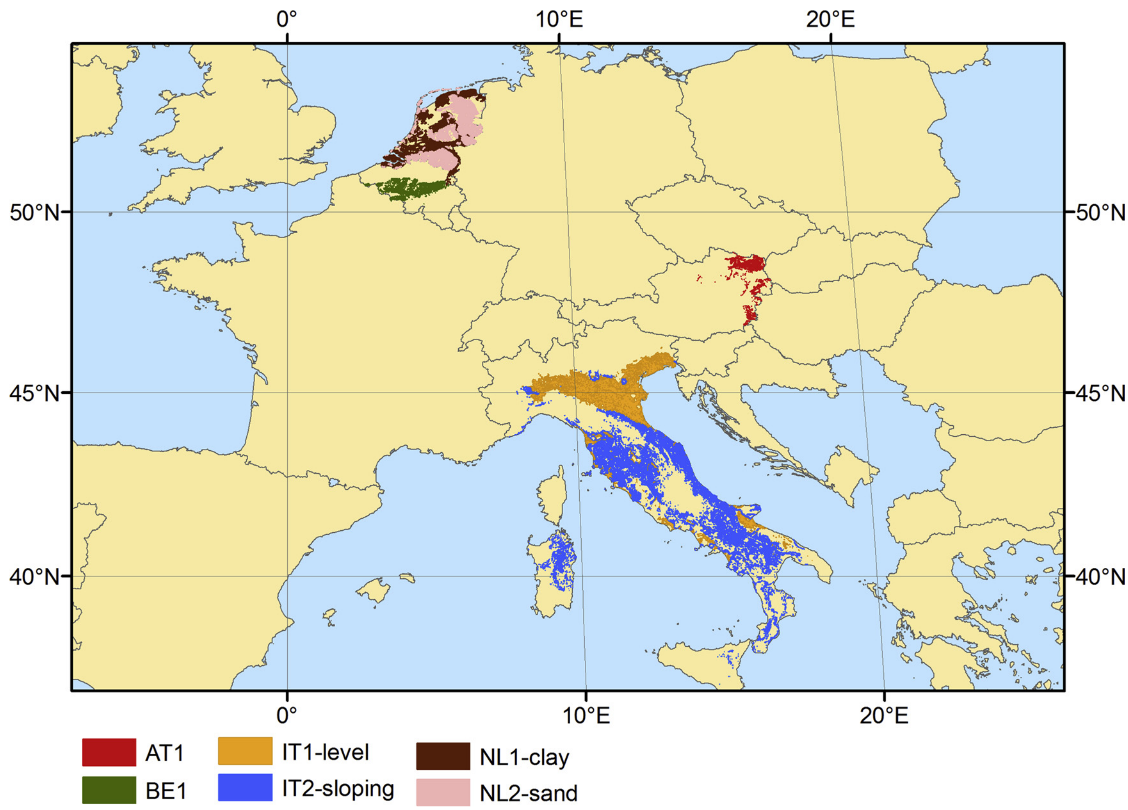

Fig. 1. Map of study area indicating the six agro-ecological zones in four European countries (the Netherlands, Belgium, Austria and Italy).

to identify outcomes of each practice, four questions to identify referents for each practice and three questions to identify control factors for each practice (see for a list the Supplementary Information [SI] Table 1).

The semi-structured interviews in the six AEZs resulted in 298 identified outcomes, referents and control factors. Each of these was related to a practice and an AEZ. As could be expected, a substantial number of these items were similar, or almost similar, between practices and AEZs. Therefore, mentioned outcomes, referents and control factors were clustered in 110 classes (40 outcome classes, 13 referent classes and 57 control factor classes). Following this, they were given shorthand labels (such as soil structure, or contract workers). The 110 classes were clustered into nine main categories (Table 3). The nine main categories were: soil type & climate, soil quality, crop protection, land use, technical, financial, environmental impact, legal and social. As such, the categories were based on insights provided by farmers.

2.4. Step 2: farm survey

The outcomes, referents and control factors for the use of organic inputs identified in the semi-structured interviews were quantified in a large farm survey. For each outcome, referent and control factor, two questions were asked, based on the theory of planned behaviour. In this manner, the attitude, subjective norm and perceived behavioural control on the use of organic inputs could be calculated. In addition, farmers were also asked to report on their current usage of each organic input. Farmers were asked whether they cultivate green manures or cover crops, incorporate straw and/or use FYM or compost, on at least one of their fields.

The sampling for the questionnaires depended on the availability of a valid sampling frame of arable farmers within each country (*i.e.* contact details of farmers). The most ideal sampling frame to obtain a

Table 2
Overview of agro-ecological zones and practices included in survey.

	Incorporation of straw	Cultivation of green manures/catch crops	Compost	FYM
AT1		X		
BE1	X	X	X	X
IT1 (level)	X	X		
IT2 (sloping)	X	X		
NL1 (clay)	X	X		
NL2 (sand)	X	X	X	

Table 1
Characteristics of each agro-ecological zone. Climate zones follow Metzger et al. (2005). Aridity index is calculated by dividing annual precipitation by potential evapotranspiration, using spatial climatic data for the period 1975-2009(Janssen et al., 2009). A lower aridity index indicates a drier climate. Soil texture classes follow classes used in the European soil database (EC and ESBN, 2004).

	Climate zone	Average aridity index of the climate zone	Slope	Soil texture
AT1	Pannonian	0.51 (dry)	level (0°) or gentle (2-3°)	Medium
BE1	Atlantic Central	0.73 (wet)	nearly level (1°)	Medium fine
IT1-level	Mediterranean North	0.38 (very dry)	level (0°) or gentle (2-3°)	Coarse to medium fine
IT2-sloping	Mediterranean North	0.38 (very dry)	gentle to moderate (2-7°)	Medium or medium fine
NL1-clay	Atlantic North and Central	0.76 (wet)	level (0°)	Medium or medium fine
NL2-sand	Atlantic Central	0.76 (wet)	level (0°)	Coarse

Table 3
Classification of identified outcomes, referents and control factors into nine categories.

Soil type & climate	Soil quality	Crop protection	Land use	Technical	Financial	Environmental impact	Legal	**Social**
Control factors	***Outcomes***	***Outcomes***	***Outcomes***	***Outcomes***	***Outcomes***	***Outcomes***	***Referents***	***Referents***
Clay soil	Long term quality	Attracting insects	Crop rotation	Heterogeneous spread of input	Costs	Landscape view	Government	Advisors
Weather	Reduced erosion	Diseases	Extensification	Machinery	Costs cultivation	Nitrogen leaching	***Control factors***	Agricultural education
Wet climate	Soil fauna	Fungal diseases	***Control factors***	Polluted compost	Crop yields	Soil carbon sequestration	Administrative demands	Contract workers
	Soil fertility	Herbicide use	Compatibility GM	Residue incorporation	Fertiliser use	***Control factors***	Burning not allowed	Family
	Soil health	Nematodes	Crop rotation	Sowing cover crops	Fuel use	Nitrogen leaching	Legal nutrient limits	Fellow farmers
	Soil nutrients	Pesticide use	Cultivation potatoes	Timing application	Income		Legal sowing restrictions	Government
	Soil organic matter	Weeds	Cultivation silage corn	***Control factors***	Labour/time		Subsidy	Land owners
	Soil structure	Weeds, pests, diseases	Cultivation winter wheat	# field operations	Protein content			Livestock farmers
	Soil water		Sod seeding	Adjacent agricultural land	Risk low biomass GM			Magazines
	Soil workability			Compatibility CT	***Control factors***			Study club
	Straw decomposition			Knowledge	Availability of FYM			Suppliers
	Uncertainty N release			Legislation on effective N	Availability of straw			***Control factors***
				Machinery	Av. of compost			Contract workers
				Night harvests	Costs			Cooperation livestock
				Ploughing straw	Costs chopping straw			Land exchange
				Residue incorporation	Costs fertilisers			Protein content contracts
				Seeding	Fertiliser use			
				Timing application (of input)	Fodder need			
				Variation in quality	High biomass straw			
					Income			
					Labour/time			
					Labour for incorporating			
					Labour for sowing			
					Land availability			
					Compatibility livestock			
					Loss of income			
					Market demands			
					(Availability of) other organic inputs			
					Seed costs			
					Storage facilities			
					Straw as crop cover			
					Straw prices			
					Subsidy			

Table 4
Numbers of farmers included in the semi-structured interviews (step 1) and the larger farm survey (step 2).

	Step 1 Semi-structured interviews	*Step 2* Questionnaires sent	Response	Response rate
AT1	8	*open online survey*	34	*NA*
BE1	7	1600	430	27%
IT1-level	8	211	124	59%
IT2-sloping	9	165	98	59%
NL1-clay	10	2700	336	12%
NL2-sand	5	2000	241	12%

completely random sample is a nation-wide database of farmer addresses. Such a database was available for Belgium (Flanders) and the Netherlands. In these countries farmers were invited by letter to participate in the farm survey. In Austria and Italy researchers depended on farmer associations, farmer extension services or other contacts to distribute the questionnaires. Questionnaires were filled online (Austria and the Netherlands) or as a paper questionnaire (Belgium and Italy). Response rates varied from 12 to 59% (Table 4).

To reduce the length of the questionnaires and increase the response rate, questionnaires in Belgium and the Netherlands were split into two or three parts allocated to different groups of farmers. As such, each group of farmers received a questionnaire with a common introduction section combined with in-depth questions for only one or a few specific types of organic input(s). In addition, to reduce errors in farmers' answers, respondents were not obliged to fill out every question. In the case of partly completed questionnaires, only the filled parts were used in the analysis. For these two reasons, numbers of farmers differed between analyses. Questionnaires were returned during the summer and autumn of 2013. Filled questionnaires were checked for irregularities (typing mistakes or extreme numbers) and if any were found these answers were removed from analysis.

Targeting farmers with similar conditions for slope and soil texture within one AEZ proved to be difficult as these characteristics differ on small geographical scales. Overall, reported soil textures and slopes of the respondents in each AEZ showed correspondence with the targeted AEZs (Table 1) but there was also considerable variation within each AEZ (Table 5).

In Austria, respondents to the farm survey had a very diverse range of slopes and soil textures. In Belgium, farmers had mainly loamy soils (91%) and mostly level to gently sloping lands. In Italy, IT1 farmers had mainly level land and in IT2 farmers had mainly gentle to steep sloping land. In the Netherlands, farmers in NL1 had mainly clay soils and famers in NL2 had mainly sandy soils.

2.4.1. Quantification of attitude, subjective norm and perceived behavioural control

In the semi-structured interviews, relevant outcomes, referents and control factors were identified for each combination of organic input and AEZ. In the larger farm survey (step 2), these were quantified on a scale of 1 to 10 by asking pairs of questions. For each identified outcome, two types of questions were asked in the farm survey: 1) To which degree a farmer expects a certain outcome (*i.e.*, result, effect) from the given practice ('belief strength') and 2) how is the outcome valued on a scale from 'bad' to 'good' ('outcome evaluation'), both on a Likert scale from 1 to 5. The Likert scale was proposed by Rensis Likert (Likert 1932) as a means to measure the level of agreement or disagreement with given statements in questionnaires and has been commonly used since then. For example: a possible outcome from the application of compost is improved soil structure. In the farm survey, farmers were first asked to which degree they expected compost to improve soil structure (1 = very little, 5 = very much) and second how they evaluated an improvement in soil structure (1 = very bad, 5 = very good).

For each identified referent, two types of questions were asked in the farm survey: 1) how motivated are they to comply with the referents' view ('motivation to comply') and 2) to which degree the referent is positive or negative towards a practice ('normative belief'), both on a Likert scale from 1 to 5.

For each identified control factor, two types of questions were asked in the farm survey: 1) to which degree that control factor is valid for the farm ('control strength') and 2) to which degree the control factor makes the practice attractive or difficult ('control power'), both on a Likert scale from 1 to 5.

Values for outcome evaluations, normative belief and control power were lowered by three points to give a negative to positive scaling (-2 to +2). Next, values for each pair of questions were multiplied to obtain a score for attitude, subjective norm and perceived behavioural control (scores ranging from -10 to +10), see equations 1 to 3.

$$attitude_i = belief\ strength_i * (outcome\ valuation_i - 3) \tag{1}$$

$$subjective\ norm_k = motivation\ to\ comply_k * (normative\ belief_k - 3) \tag{2}$$

$$perceived\ behavioural\ control_m = control\ strength_m * (control\ power_m - 3) \tag{3}$$

2.4.2. Classification as drivers or barriers

For each attitude, subjective norm and perceived behavioural control, the mean value across all respondents in an AEZ was calculated, together with the 95% confidence interval. The 95% confidence interval was calculated as $1.96 * \frac{sd}{\sqrt{N}}$ in which sd means standard deviation and N is the number of farmers who answered the question. Values were considered significantly different from zero when the 95% confidence interval did not include 0. Significant positive values were

Table 5
: Characteristics (slopes and soil texture) of the agro-ecological zones and their farms in the survey, averaged per agro-ecological zone. N indicates number of farmers on which the analysis is based; if a range is specified, this means that the number of farmers varied by practice.

	AT1 (N = 34)	BE1 (N = 371-395)	IT1-level (N = 102-114)	IT2-sloping (N = 82-85)	NL1-clay (N = 331-333)	NL2-sand (N = 217-219)
Slope (mean percentage farm area)						
Level (0°)	18%	39%	80%	8%	100%	100%
Nearly level (1°)	22%	31%	10%	8%	0%	0%
Gently sloping (2-3°)	32%	22%	5%	31%	0%	0%
Sloping (4-7°)	16%	7%	4%	39%	0%	0%
Steep (> 8°)	12%	2%	1%	14%	0%	0%
Soil texture (mean percentage farm area)						
Sand	26%	8%	12%	1%	1%	93%
Loam	40%	91%	72%	62%	7%	1%
Clay	32%	1%	16%	38%	91%	1%
Peat	0%	0%	0%	0%	0%	4%

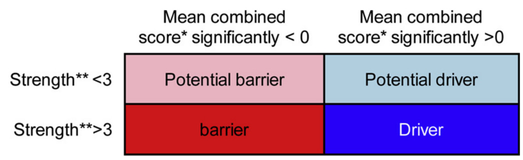

Fig. 2. Graphical illustration of the division on potential barriers, barriers, potential drivers and drivers, based on average scores on underlying questions. * combined score refers to the mean value for attitude, subjective norm or perceived behavioural control. ** strength refers to the mean value for the 'strength' questions (outcome strength, motivation to comply and control strength).

classified as drivers. Significant negative values were classified as barriers.

As described above, attitude, subjective norm and perceived behavioural control were based on two questions. The first question determines the 'strength' of a factor (from 1 to 5), while the second question illustrates how a farmer 'evaluates' a factor (from negative to positive). Whilst an outcome or a control factor can be evaluated very negatively, if the strength is very low (*e.g.* below 3), than the chance of this occurring is still considered very small. We therefore added a second dimension to the classification of drivers and barriers, denoting all drivers and barriers which had an average 'strength' score below 3 as 'potential'. These latter factors were perceived to have a positive or negative impact, but farmers considered the likelihood of this occurring less than average (Fig. 2).

Each factor belonged to one of the 110 classes and nine main categories (Table 3). If two identified factors for a practice and AEZ fell into the same class (*e.g.* soil fertility) and they were evaluated both positive (or both negative), the average was taken. When two identified factors for a practice and AEZ fell into the same sub category but the signs differed (the one being negative and the other positive), we wanted to keep this information visible in the results. Therefore, in these cases they were both kept separate in the analysis (meaning the specific class can act both positively or negatively for applying given practice).

3. Results

3.1. Current use of organic inputs

In all AEZs, farmers used organic inputs, but at varying quantities (Table 6). When cultivating cereals (including grain maize), most farmers incorporated straw, intermittently or consistently over the years, except for NL1. In BE1, fewer farmers incorporated straw (26%), probably due to the high use of FYM (straw is exported to livestock farm and imported as FYM).

A large difference in the cultivation of green manures or cover crops is observed between the six AEZs (Table 6). While in AT1, BE1, NL1 and NL2 most farmers (> 80%) cultivated green manures or cover crops on at least one of their fields, only a minority (10%) cultivated green manures or cover crops in IT1 and IT2.

A higher percentage of farmers in IT1 and IT2 (42 and 55%) used compost compared to farmers in AT1 and BE1 (17% and 8%), and with NL1 and NL2 in between (35% and 29%). The use of FYM varied widely, with the highest percentage of farmers using FYM in BE1 and IT2 (71% and 67%) and the lowest in NL2 (16%). In the Netherlands, farmers on sandy soils are often located near pig farms, which create a large availability of slurry, possibly explaining the low use of FYM.

3.2. Drivers and barriers for the incorporation of straw

Incorporation of straw was included in the farm survey of five AEZs (BE1, IT1, IT2, NL1 and NL2). The total number of outcomes, referents and control factors identified was 96 (summed over the five AEZ's, or on average 19.2 per AEZ). Out of these, 48 were evaluated positively as drivers, of which 6 potential drivers. 35 factors were evaluated significantly negatively as barriers, of which 16 potential (Fig. 3). Of the drivers, around 40% were related to soil quality (N = 19). Of the barriers, almost half were financial (N = 17), yet there were also some financial drivers (N = 6). All outcomes and control factors related to crop protection were evaluated as barriers (4 out of 4).

In all AEZs, effects on soil structure and SOM content were identified as outcomes and evaluated as drivers for straw incorporation (Fig. 3).

In almost all AEZs - besides BE1 – impacts on weeds, pests and diseases in general or specifically fungal diseases were evaluated as a barrier for straw incorporation. In addition, costs of straw incorporation and loss of income from selling were also evaluated as barriers for straw incorporation in all AEZs. In most AEZs, the subjective norms of referents were positive for straw incorporation. Only in BE1, a negative subjective norm exists from fellow farmers.

In BE1 (Fig. 3a), legal nutrient limits were seen as a driver as well as a barrier. Like the Netherlands, the region of Flanders in Belgium where the study was conducted, is a Nitrate Vulnerable Zone, which gives stricter limitations on nutrient inputs for farmer. Straw is however not counted within the legal nutrient limits, therefore it was seen by some farmers as an easy manner to increase SOM content. At the same time, other farmers prefer to add N to straw for decomposition, in which case the legal nutrient limits are a barrier. In addition, it is a legal obligation for farmers in Flanders (Belgium) to measure nitrate residues in autumn to prove that their fields will not cause excessive nitrate leaching. Some farmers also indicated that an advantage of incorporating straw is that it immobilises N and thus lowers the nitrate residue in autumn. The apparent contradictory results regarding straw incorporation and manure legislation due to the Nitrate Directive illustrates the complexity of the decision making process. As Belgian farmers often apply FYM – which also has a positive effect on SOM, this makes the incorporation of straw less attractive or necessary to maintain soil quality.

In Italy (both IT1 and IT2; Fig. 3bc), legal prohibition of burning straw was considered a driver for straw incorporation. In IT1 specifically, effects of straw incorporation on product quality (protein content) were considered a driver, while in IT2 availability of adequate machinery for chopping and incorporating residue was considered a driver.

In the Netherlands (NL1 and NL2; Fig. 3de), reduced labour or time

Table 6
Use of organic inputs in each agro-ecological zone. Bold numbers indicate combinations of AEZ and input type for which further questions on outcomes, referents and control factors are included in the survey. For straw incorporation, percentages are calculated as share of the farmers who cultivate the specified crop.

	AT1	BE1	IT1-level	IT2-sloping	NL1-clay	NL2-sand
Straw incorporation (% farmers incorporating straw sometimes to always)[a]						
small grain cereal straw	71%	**26%**	–	–	**68%**	**60%**
maize straw	88%	**94%**	–	–	**38%**	**65%**
cereals, maize or sunflower	–	–	**93%**	**69%**	–	–
Green *manure or cover crops (% farms cultivating GM or CC)*						
GM or CC	**93%**	**87%**	**10%**	**10%**	**84%**	**83%**
Application FYM or compost (% farmers applying compost or FYM on at least some part of the land)						
Compost	17%	**8%**	42%	55%	35%	**29%**
FYM	46%	**71%**	57%	67%	39%	16%

[a] Only farmers are included when specific crop (maize, cereal) was present in crop rotation of farm. In Italy, sunflower was also included in the question on straw incorporation.

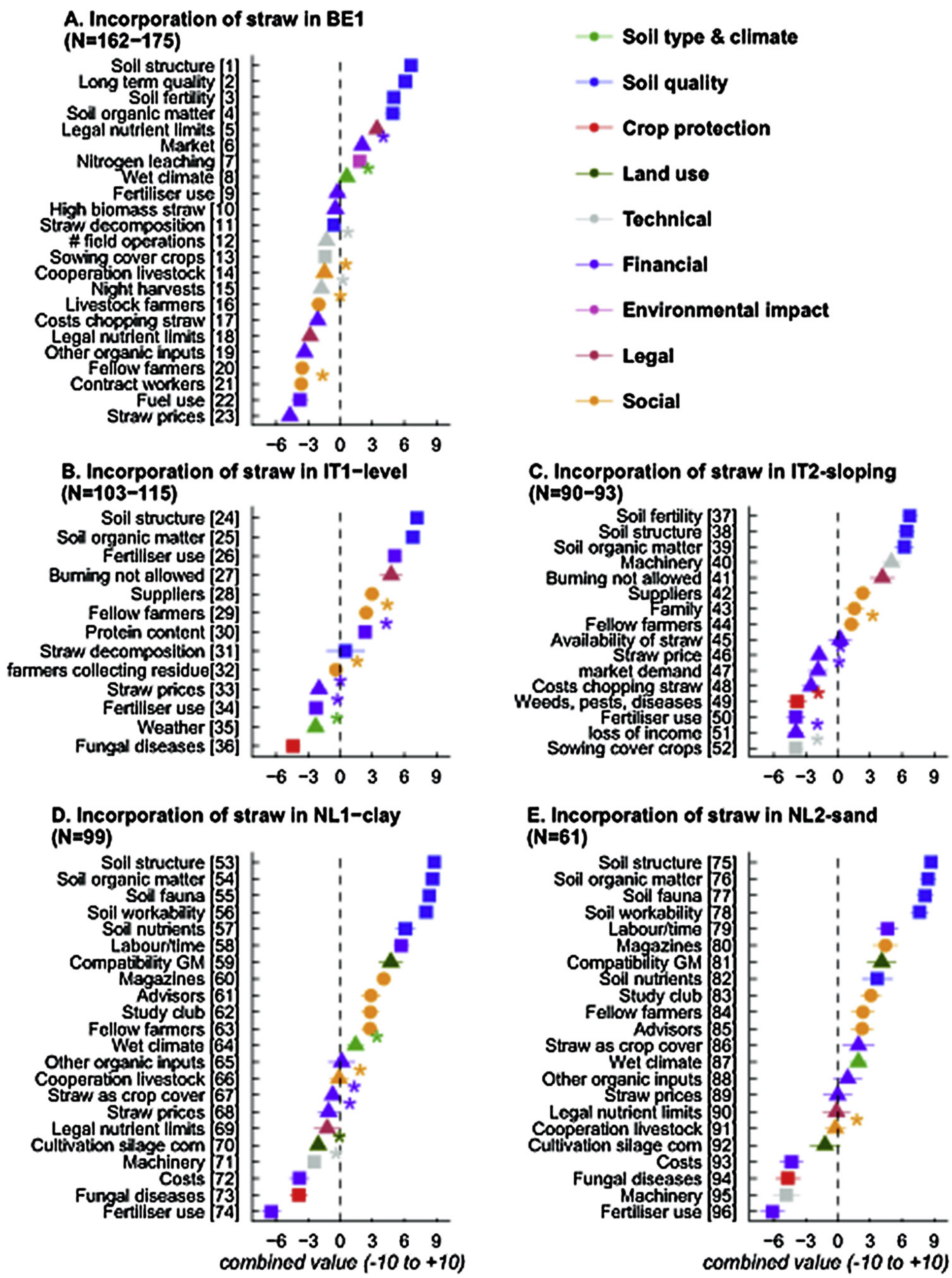

Fig. 3. Drivers and barriers for incorporation of straw per agro-ecological zone. ■ = mean attitude score on outcome; ● = mean subjective norm of referent ▲= mean perceived behavioural control on control factor. Lines indicate 95% confidence interval. * indicates an underlying strength score < 3. N = numbers of farmers included in analysis. Numbers in [] link to farmers' descriptions in SI Table 2. GM = green manure. Colours indicate main categories. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

requirements for straw incorporation (compared to removing it from the land) and positive effects on workability of the soil were considered important drivers. Fertiliser use was a strong barrier, because farmers believe additional fertiliser is needed for the decomposition of straw.

3.3. Drivers and barriers for the cultivation of green manures or cover crops

Cultivation of green manures or cover crops was evaluated in the farm survey of all six AEZs. The total number of outcomes, referents and control factors identified for the cultivation of green manures or cover crops was 144 (summed over the six AEZs, or on average 24 per AEZ). Out of these, 81 were evaluated positively as drivers and 44 were evaluated negatively as barriers. Of the drivers, 35% were related to soil quality (N = 28). One third of the barriers was financial (N = 14), yet there were also some financial drivers (N = 10). All outcomes and control factors for green manures related to environmental impact were evaluated as drivers (6 out of 6).

As for straw incorporation, effects on soil structure and SOM content were identified and evaluated as drivers in each AEZ for the cultivation of green manures or cover crops (Fig. 4). The effect of green manures or cover crops on soil erosion was also identified and evaluated as a driver in all AEZs except IT1 (this factor was not included in survey because it was not mentioned in the interviews). In the Netherlands (NL1 and NL2) subjective norms of all referents were positive, unlike for example Italy (IT1 and IT2) where especially fellow farmers and family were perceived to have a negative view on the cultivation of green manures or cover crops.

In four AEZs (AT1, BE1, NL1 and NL2) weeds, pests and diseases (as a general term) or more specifically increases in weeds, nematodes, herbicide use or pesticide use (as specific terms) were evaluated negatively as barriers for the cultivation of green manures or cover crops. In BE1 however, perceived negative effects on weeds and herbicide use were only potential (having a lower strength). In IT1 and IT2 issues with crop protection were not mentioned in the semi-structured interviews with the farmers and therefore not included in the farm survey. In all AEZs, costs and effects on income were barriers for the cultivation of

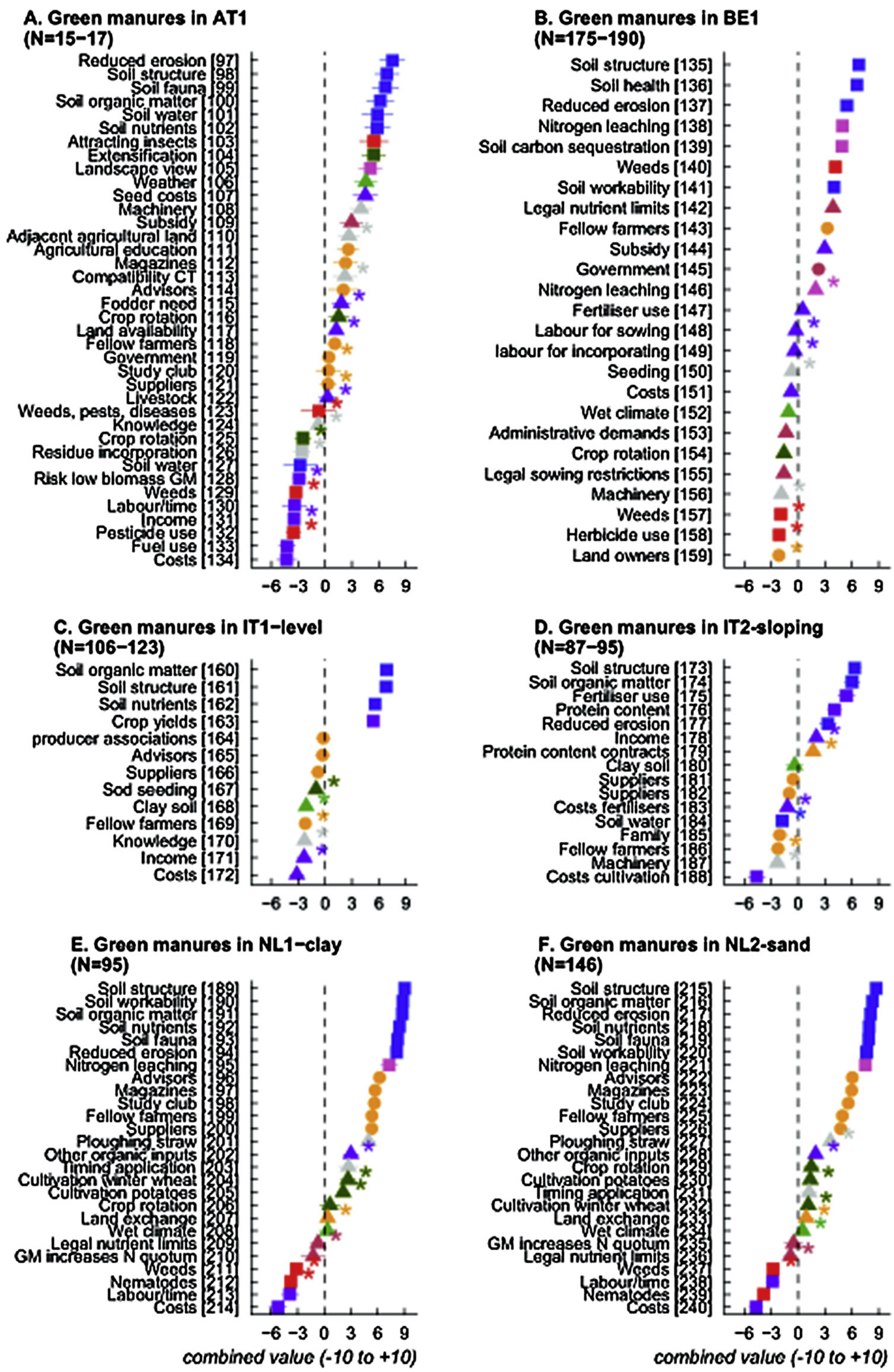

Fig. 4. Drivers and barriers for cultivation of green manures or cover crops per agro-ecological zone. ■ = mean attitude score on outcome; ● = mean subjective norm of referent ▲= mean perceived behavioural control on control factor. Lines indicate 95% confidence intervals. * indicates an underlying strength score < 3. N = numbers of farmers included in analysis. Numbers in [ ] link to farmers' descriptions in SI Table 3. GM = green manure. CT = conservation tillage. For legend of colours see Fig. 6 or 8 (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

green manures or cover crops.

In AT1 (Fig. 4a), effects of cultivating green manures or cover crops on the water holding capacity of the soil was evaluated as a driver as well as a barrier, consistent with previous experimental findings (Bodner et al., 2011; Bodner, 2013). Austrian farmers can receive a subsidy for the cultivation of green manures or cover crops if they follow a training, which was evaluated as a driver.

In Flanders (BE1; Fig. 4b), farmers could also receive a subsidy for cultivating green manures or cover crops at the time the survey was conducted. To be eligible for subsidy, farmers in Flanders have to sow the green manure before a certain date (before the 1st of September or the 15th of October, depending on their location). As the time period between harvest of some crops and legal sowing date is perceived as too short, this preconditions was considered a barrier. Crops harvested late in autumn were alsoconsidered a barrier for sowing cover crops. One of the most important perceived drivers for farmers for sowing cover crops in Flanders was that they result in uptake of remaining mineral N in the soil profile and thus prevent N leaching.

In Italy (IT1 and IT2; Fig. 4cd), costs were a major barrier for the cultivation of green manures or cover crops. Additional costs include production factors such as seeds, but also mechanical operations such as tillage or sowing. Interestingly, farmers perceived a positive effect of green manure or cover crops on fertiliser use in IT2, with savings of fertiliser in the following cash crop. In IT1, having clay soils was seen as a barrier for the cultivation of green manure or cover crops. On clay soils, seedbed preparation for green manures might be more complicated due to excessive soil water content.

In the Netherlands (NL1 and NL2; Fig. 4ef), improved workability of the soil was evaluated as an important driver. This relates to perceived reductions in fuel costs and perceived reductions in the loss of soil during harvest. In the Netherlands (NL1 and NL2), requirements in labour and time to cultivate green manures or cover crops was considered a barrier. This relates specifically to the small time frame available at the end of summer after harvesting the main crop for the sowing of the green manure.

3.4. Drivers and barriers for the application of compost or FYM

Application of compost was included as a practice in two AEZs (BE1 and NL2-sand), while the use of FYM was included in one AEZ (BE1). As both types of input are often imported on arable farms, we present the results of these two input types together. The total number of outcomes, referents and control factors identified for the application of compost or FYM was 58 (summed over the six AEZs, or on average 19.3 per AEZ). Out of these, 20 were evaluated positively as drivers and 28 were evaluated negatively as barriers. Of the drivers, more than half were related to soil quality (N = 13). Almost half of the barriers were financial (N = 13) and a quarter of the barriers were technical (N = 7). There were no financial drivers for the use of compost or FYM, nor was any driver related to crop protection or environmental impact.

For compost, the effect on SOM content was evaluated positively by farmers as a driver in both AEZs (Fig. 5ab). In BE1, effects of compost on various aspects related to soil quality were also evaluated as drivers (*e.g.* soil life, soil health, soil fertility and soil structure). In the Netherlands compost may be applied throughout the year - in contrast to animal manures - making it a more attractive option compared to other organic inputs. Therefore, the legally allowed timing of application was also evaluated as a driver for compost in NL2. Availability of alternative organic inputs such as animal manure, pollution of compost and required labour and time for spreading were considered barriers for using compost in both BE1 and NL2. In addition a range of other issues were evaluated as barriers in BE1, such as availability, costs, little knowledge on the composition, variation in quality, lack of experience and a risk for high nitrate residue in autumn (see also above), increases in weeds, pests and diseases, and legal nutrient restrictions. A more thorough discussion of the data for compost can be found in Viaene et al. (2016).

For the application of FYM, a similar range of positive effects were found on soil quality as from compost (*e.g.* soil life, soil organic matter, reduced erosion, soil fertility and soil structure). An important barrier here is the need for appropriate storage facilities for FYM in Flanders during winter. Many farmers stated that they do not have adequate storage place and that if they must have such a place it makes the use of farmyard manure unattractive. Another perceived barrier was the alternative availability of slurry, which has lower costs.

3.5. Drivers and barriers aggregated per category

Of all the 298 identified outcomes, referents and control factors in the semi-structured interviews, 149 were evaluated positively as drivers, of which 21 had a mean strength score below 3 and were therefore

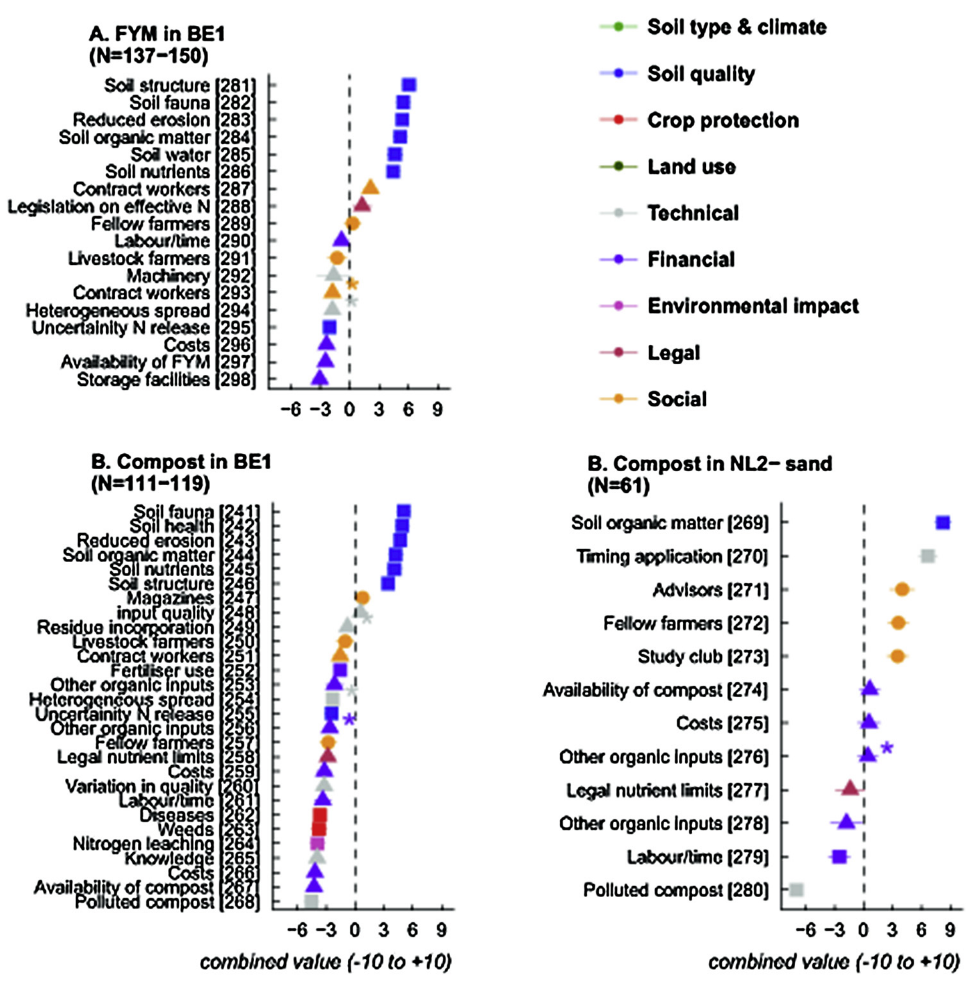

Fig. 5. Drivers and barriers for application of compost or FYM per agro-ecological zone. ■ = mean attitude score on outcome; ● = mean subjective norm of referent ▲= mean perceived behavioural control on control factor. Lines indicate 95% confidence intervals. * indicates an underlying strength score < 3. N = numbers of farmers included in analysis. Numbers in [ ] link to farmers' descriptions in SI Tables 4 and 5. FYM = farmyard manure. N = nitrogen. Colours indicate main categories.

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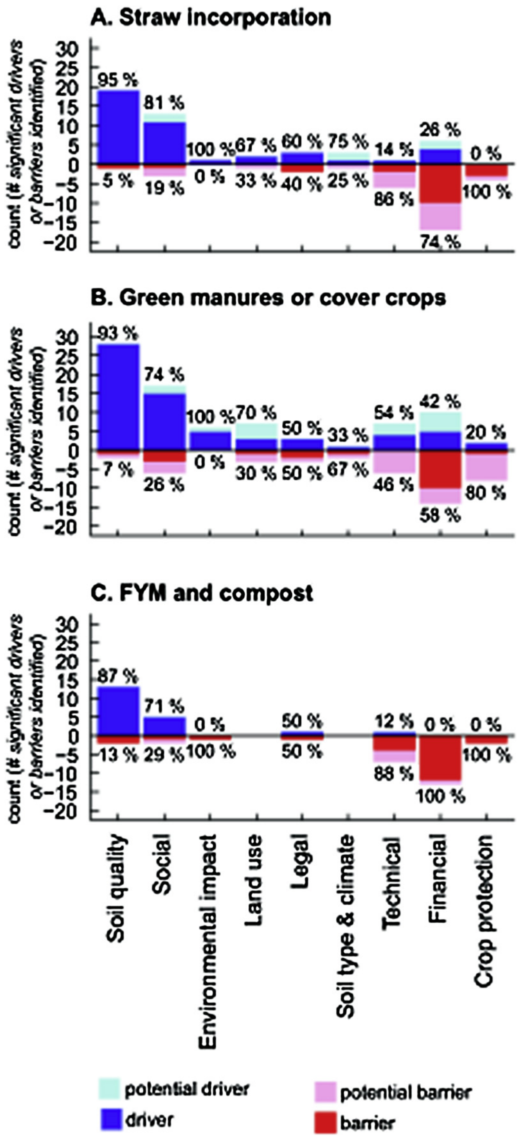

Fig. 6. Counts and percentages of drivers, potential drivers, barriers and potential barriers per practice and category.

considered as ‘potential’ drivers (Fig. 6). Out of all factors, 107 were evaluated negatively as a barrier, of which 46 were considered as ‘potential’ barriers.

Aggregating drivers across AEZs, a positive impact on soil quality stands out as the most important driver for using organic inputs. For all types of organic input, soil quality consistently has the highest count and percentage of cases in which it is evaluated as a driver (except environmental impact of green manures or cover crops, Fig. 6b).

For each type of organic input, financial consequences are most often mentioned as a barrier, but ‘negative impacts on crop protection’ has the highest percentage of cases in which it is evaluated as a barrier compared to the total sum of barriers and drivers in that category. Both financial consequences and crop protection are therefore important barriers for the types of organic input considered in this study.

4. Discussion

4.1. Identified drivers and barriers

In this study, a large number of outcomes, referents and control factors (298) were identified as relevant to farmers in their use of organic inputs.

For all types of organic inputs, important drivers were ‘perceived effects on soil quality’ and a positive influence from social referents. Farmers in our survey showed a great interest in maintaining long-term soil fertility and SOM contents. This seems in contradiction to the assumption that farmers in Europe have too few incentives to use soil conservation measures because productive capacities are not affected by soil degradation in the short-term (Van den Putte et al., 2010). Effects on SOM content and soil fertility were consistently amongst the top drivers for each type of organic input (Fig. 3, 4 and 5). We confirmed the notion that farmer behaviour is motivated by a wide array of factors which are not all directly economic (Glenk et al., 2017) as financial aspects were only a selected part of the total listed drivers and barriers. Identified drivers more often had a higher mean strength (> 3) than identified barriers, indicating a larger likelihood of occurrence. If mentioned, financial consequences of using organic inputs were more often evaluated as negative than positive.

In our farm survey, farmers consistently evaluated the effects of organic inputs on crop protection negatively. Cereal straw may spread an important fungal disease causing grain contamination (Fusarium head blight, FHB) to subsequent cereals in crop rotations (Maiorano et al., 2008), although some measures to relieve this pressure are also known. The spread of FHB can be reduced when crop residues are incorporated into the soil (Blandino et al., 2012). Organic inputs have been observed to reduce soil-borne diseases, but only if they are rich in nitrogen (Bailey and Lazarovits, 2003). In a recent literature review on the role of compost on soil-borne plant diseases, Mehta et al. (2014) found a large variation in effects, but mainly positive effects on disease suppression when composts were enriched with beneficial soil microbes. As indicated by Bailey and Lazarovits (2003), the effect on disease suppression in soils might manifest itself only after long-term continuous application of organic inputs. If farmers experiencenegative effects on crop protection in the first year of using a specific type of organic input, they might however not be willing –without convincing evidence - to wait and see if this changes in the future.

4.2. Variation in drivers and barriers and the use of organic inputs between AEZs

When considering the use of organic inputs in each AEZ (Table 6), the most striking is the difference in cultivation of green manures. In both IT1 and IT2, only 10% of farmers cultivated green manures or cover crops, whilst in the other AEZs this percentage was above 83%. In IT1 and IT2 specifically, fellow farmers and family were perceived as having a negative view on the cultivation of green manures whilst suppliers and advisors were somewhat neutral. (Fig. 3b,c). Therefore, the community surrounding farmers does not promote the adoption of green manures. More generally, from personal experience it is known that, because green manure is still a relatively new practice for Italian farmers, communication and learning from peers are very important factors in increasing its adoption. From the experience of farmers who are already successful with green manures, other farmers could learn what are the best species or mixes, seed rate, seeding date, seeding technique, and termination technique in a given soil and climate. Currently the adoption of green manures is, however, low, so farmers have little exposure to these practices.

4.3. Straw incorporation and N requirements

For the incorporation of straw, legal nutrient limits were mentioned to be relevant in BE1, NL1 and NL2. Flanders (Belgium) and the Netherlands are designated Nitrate Vulnerable Zones (EEC, 1991). In these cases, farmers are restricted by legal nutrient limits when using mineral fertilisers and/or organic inputs. In BE1, legal nutrient limits were perceived both a driver and a barrier for the incorporation of straw. This corresponds with the observation that fertiliser use is both a driver and a barrier in IT1. In certain cases, incorporation of straw can supply N to crops, whilst in others, it can induce temporary N immobilization and needs N for decomposition (Hijbeek et al., 2018a; Silgram and Chambers, 2002).

Moreover, straw returns phosphorus (P) and potassium (K) to soil (which explains the driver 'expected reduced fertiliser use'). It seems that both in BE1 and IT1, farmers value the positive effects of straw incorporation in the long-term (build-up of SOM content; return of P and K), but have a negative view on the short-term needs of mineral N fertiliser for the decomposition of straw. In Italy, farmers preferred burning (despite the loss of organic matter and risk of fire), selling or even giving away the residues. Burning is now forbidden, which then acts as a driver for incorporating straw in both IT1 and IT2.

4.4. Limitations of the study

This study has used a sociological methodology to improve our understanding of agronomic practices. This resulted in a number of interesting insights, but also involved a number of limitations. Below we discuss the most relevant limitations.

First, slope and soil texture varied greatly within each agro-ecological zone. Second, means of the combined scores of attitude, subjective norm and perceived behavioural control were assessed. These concepts are based on underlying farmer beliefs. To account for this, we divided drivers and barriers into 'potential' drivers and barriers when their underlying 'strength' was below 3 on average. When zooming in on one specific practice in one region, one can also look in more details for the variation in the underlying beliefs, such as was for example done by Bechini et al. (2015) for straw incorporation in Italy and by Viaene et al. (2016) for compost in Flanders.

Thirdly, drivers and barriers were analysed separately for the use of each type of organic input. Farmers, however, indicated that the use of one type of organic input might depend on the use of another. For example, if they use FYM, they might not incorporate straw and if a farmer already uses slurry this might be a reason not to use FYM. Both the Netherlands and Belgium have a large supply of animal manure due to the presence of a relatively large livestock sector (Oenema and Berentsen, 2004; Viaene et al., 2016). Sometimes, animal slurry is even offered for free to arable farmers. In these cases, this cheap alternative organic input is a barrier for the use of for example compost (BE1 and NL2; Fig. 5ab). If all the amounts of organic inputs used by a farmers are known, one can also express the total sum in an aggregated measure (for example as total C or effective C, see Hijbeek et al., 2018b). This information was, however, not available for all our regions. In addition, aggregating all organic inputs may ignore robust drivers and barriers for a specific practice, which was the focus of this study.

5. Conclusion

Farmers across all six AEZs considered improvements in soil quality (*e.g.* soil structure, soil fertility, soil health) as drivers and in most cases there was a positive influence from social referents. Many perceived barriers related to crop protection (*e.g.* effects on the incidence of weeds, pests and diseases or effects on herbicide or pesticide requirements) and financial consequences (higher costs; income forgone). Other barriers were more context-specific such as manure legislation or a large and free availability of slurry.

Our findings show that farmers perceive a trade-off between positive effects on soil quality but negative ones on soil born parasites or plant diseases while using organic inputs. Farmers, therefore, require specific guidance on how best to reduce the pressure of weeds, pests and diseases with site- or farming-specific advice. These are relevant insights if agricultural and environmental policies aim to include the use of organic inputs to maintain or increase SOM contents.

Currently from a farmers' perspective, financial consequences of using organic inputs cannot be assumed to be neutral in the short-term. This highlights the need for more research into the long-term financial consequences of using organic inputs. In the meantime, when promoting societal benefits of using organic inputs beyond the farm-gate (*e.g.* biodiversity conservation or soil carbon sequestration), financial consequences should be accounted for.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.agee.2019.01.008.

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