# To plough or not to plough?

## An investigation into what influences farmer decision making regarding the adoption of conservation agriculture

*Alice Roberts*

Master Thesis Series in Environmental Studies and Sustainability Science,
No 2017:030

A thesis submitted in partial fulfillment of the requirements of Lund University International Master's Programme in Environmental Studies and Sustainability Science (30hp/credits)

LUCSUS
Lund University Centre for Sustainability Studies

# To plough or not to plough?

An investigation into what influences farmer decision making regarding the adoption of conservation agriculture

Alice Roberts

A thesis submitted in partial fulfillment of the requirements of Lund University International Master's Programme in Environmental Studies and Sustainability Science

Submitted May 16, 2017

Supervisor: Genesis Yengoh and Elina Andersson, LUCSUS, Lund University

## Abstract

Agriculture is necessary for providing nutrition to a growing global population. However, many unsustainable agricultural practices contribute to climate change, cause local pollution and disrupt natural biological and nutrient cycles. Conservation agriculture (CA) is one of the many practices that have been proposed to meet the challenge of sustainable agricultural production. CA aims to restore natural systems which help to reduce erosion, chemical reliance, pollution and agricultural emissions whilst improving long-term productivity. Despite CA's increasing world-wide use, England's adoption remains low. This study utilizes the theory of planned behaviour to understand what influences English farmers' decision to either adopt or not adopt CA. Thus, this provides policy makers and other relevant stakeholders with the tools necessary to increase the adoption of CA in English farming. The study combines data from farmer communication, mixed-stakeholder focus groups, engagement with knowledge exchange organizations and an online survey to thoroughly examine farmers' decisions concerning CA. Of the theory of planned behaviour's behavioural determinants, attitude was found to be the most important in influencing the adoption of CA. This was predominantly driven by the motivation to improve soil health. Perceived behavioural control was also important for the adoption of no-tillage and crop rotations or companion cropping. This was mainly due to expensive costs, incompatibility with physical conditions and inadequate information. Information on CA was found to lack relevance as most studies are abroad or do not cover a range of soil and climatic conditions, contributing to uncertainty of results. The corporate nature of some data and informal farmer produced information can reduce the unreliability of information. Also, information is not in accessible forms for farmers to easily understand and apply practically. Policy interventions should aim to improve knowledge generation and exchange as well as providing a financial incentive system to reduce fears of unknown productivity for farmers that want to adopt CA. However, stakeholder perceptions of the political environment revealed that policy makers seem to be unaware or uninterested in CA, thus change from the top-down may be unlikely.

**Keywords:** *conservation agriculture, decision making, theory of planned behaviour, sustainable agriculture, soil health, knowledge exchange*

**Word count:** 13998

## Acknowledgements

I am thankful to everyone that has helped me throughout my thesis process. Firstly, I would like to thank Rothamsted Research Centre for welcoming me as a visiting worker and allowing me to have access to your resources and join in with symposium days and RRA meetings that enriched my experience. I have long wanted to work with Rothamsted Research as I have always been interested in the science and kept up to date with the new trials and discoveries whilst growing up in the same town. Thank you to Professor Angela Karp for helping me to reach out to the researchers at Rothamsted and thank you Dr Ian Shield for having faith in my thesis idea enough that you decided to take me under your wing. I am extremely grateful to you for giving me the opportunity to work at Rothamsted Research.

During my research, I met so many farmers and agricultural specialists. I have been overwhelmed at the number of responses and enthusiasm you all show! Thank you to the farmers who invited me to your farms, sometimes even providing lunch and showing me round. Getting involved with the agricultural community, both online and in person, has been a fun and enriching experience. For example, being welcomed to kick-start a debate on conservation agriculture on twitter with #AgriChatUK. Without you all I would not have a thesis so I am extremely grateful.

Thank you to my university supervisors, Elina Andersson and Genesis Yengoh, for steering me on the right track and discussing with me every step of the way. Thank you to my parents who had to put up with me being back home for a few months. Thanks Oli Watson, you have been so supporting and motivating the whole way, whilst making sure we take breaks and have fun throughout the whole process.

## Table of contents

Acronyms:

AHDB: Agriculture and Horticulture Development Board
CA: Conservation agriculture
CAP: Common agricultural policy
DEFRA: Department of environment, food and rural affairs (Government department)
EFRAC: Environment, food and rural affairs committee
EU: European Union
GHG: Greenhouse gas
LEAF: Linking Environment and Farming (organisation)
PBC: Perceived Behavioural Control
RQ: Research question
RRA: Rothamsted Research Association
SN: Subjective Norms
ToPB: Theory of Planned Behaviour

## 1.0. Introduction

Agriculture has a significant global footprint; covering 37% of the terrestrial surface (Smith *et al.*, 2008), using 70% of fresh water (UNESCO, 2012), requiring more human capital than any other industry (Kiers *et al.*, 2008), and accounting for the largest share of anthropogenic greenhouse gas emissions (Pandey & Agrawal, 2014). Arable farming contributes considerably to this footprint. For example, 40% of all agricultural emissions are released due to soil management practices and land use, compared to 25% from methane emissions from livestock (McIntyre *et al.*, 2009). Kates *et al.* (2001) defined sustainability as "meeting the needs of present and future generations while substantially reducing poverty and conserving the planet's life support systems". It is fair to say that conventional arable agriculture is not meeting this definition. Arable farming contributes significantly to climate change, which threatens current and future societies (Smith *et al.*, 2008). Furthermore, soil ecosystems (Hobbs, Sayre, & Gupta, 2008), levels of available phosphorous (Steffen *et al.*, 2015), fresh water resources and biodiversity are depleting at agriculture's hand (McIntyre *et al.*, 2009).

The unsustainability of agriculture causes problems on global, regional and local scales. For example, conventionally ploughed fields erode 10 to 100 times faster than the rate of soil production (Montgomery, 2007), which is thought to be a key reason why UK wheat yields have been stagnating since 1996 (Knight *et al.*, 2012). Although England is considered food secure (EFRAC, 2015), Garnett *et al.* (2013) stated that a goal of developed countries is likely not to increase yields immediately, but to create the capacity to respond to future demand increases. Moreover, the more a country imports, the more local agricultural pollution is externalized overseas (O'Bannon *et al.*, 2014). The UK currently imports over half of its food and animal feed and is becoming increasingly reliant on imports, thus the environmental impacts of UK food is progressively displaced to other countries, with already 64% of GHG emission impacts externalized (de Ruiter *et al.*, 2016).

The unsustainability of conventional practices has called for the development of sustainable agricultural practices. Sustainable agriculture has been defined as "agriculture that will continue to conserve natural resources and protect the environment indefinitely, enhance the health and safety of the public, and produce adequate quantities of food at a profit for farmers" (Schaller, 1993, p. 89). Examples include organic farming, permaculture and conservation agriculture (CA) (Hobbs *et al.*, 2008; Pretty, 2008). Within this thesis, I will focus on the adoption of CA as an example of a sustainable agriculture. CA is a set of soil and farm management practices that could greatly improve the sustainability of arable agriculture (Hobbs *et al.*, 2008). CA provides the potential to help mitigate climate change impacts (McIntyre *et al.*, 2009), reduce soil erosion (Govaerts *et al.*, 2009), increase nutrient availability and improve long-term productivity (Hobbs, 2007).

The flexibility of CA has led to it being successfully adopted in large-scale American farms to smallholder farms across Africa (Friedrich, Karami, & Sayre, 2009; Van den Putte *et al.*, 2010). The percentage adoption of CA increased in every continent other than Europe between 1988 and 2008 (Kassam *et al.*, 2009). Since 2008 European adoption of CA has risen but remains low (Scopel *et al.*, 2012), especially in England (Powlson *et al.*, 2012). CA would help to improve the economic and environmental sustainability of English agriculture and alleviate local agricultural-driven problems, such as flooding. Reduced soil erosion and increased water storage of CA fields reduces flood likelihood and, in the event of a flood, prevents the inclusion of particulate matter to floodwater, which greatly reduces severity and damage cost (Nicholson *et al.*, 2012). UK's annual financial burden of soil degradation and its resulting contribution to flooding and water pollution is estimated at £200-300 million, excluding health impacts (Ockenden *et al.*, 2014). With England's risk of flooding projected to significantly increase as early as 2020 (Sayers *et al.*, 2016), an increased adoption rate of CA in England could help to alleviate these problems and improve economic sustainability.

Consequently, the research problem I investigate within this thesis is the low adoption of CA, as an example of a sustainable agriculture, on English arable farms. Sustainable transitions in agriculture are complex due to the interdependencies between the use of natural resources to produce private goods, whilst being embedded within specific local contexts and conditions (McIntyre *et al.*, 2009). Therefore, farmers must make informed management decisions by weighing up, potentially contesting economic goals and environmental preservation (Beedell & Rehman, 1999; Tilman *et al.*, 2002). I therefore focus on addressing the research problem by investigating farmers' decision-making regarding the adoption of CA.

## 1.3. Aim and research questions

Within this thesis, I aim to investigate what influences English arable farmers' decisions to adopt or not adopt conservation agriculture, in order to conclude what could encourage more farmers to adopt CA in the future. This will help to inform policy makers and other relevant stakeholders how to encourage the adoption of these sustainable agricultural practices. This is achieved by answering the following research questions (RQs):

1. How do English farmers' beliefs and perceptions influence their decision to adopt conservation agriculture or not?
2. Is information on conservation agriculture relevant, accessible and of a high quality for farmers?
3. Do relevant stakeholders perceive the political environment to be supportive or inhibiting of a transition to conservation agriculture?

RQ1 explores theoretically informed categories of prominent beliefs driving the behavioural choice to either adopt or not adopt CA, whilst delving further by analysing the main motivational and challenging factors that influence farmers' beliefs and perceptions. The analysis of challenging factors is further used to imply probable barriers to the adoption of CA. This leads me onto RQ2 and 3, which both examine external factors that influence English farmers' decisions concerning the adoption of CA.

The adoption of CA has been analysed globally (Knowler & Bradshaw, 2007) and on a Europe-wide scale (Lahmar, 2010). These conclude that there are "few if any universal variables that regularly explain the adoption of conservation agriculture across past analyses" (Knowler & Bradshaw, 2007, p. 25). This emphasises the need for case-specific analysis to understand the barriers and drivers of CA adoption. The factors influencing sustainable agricultural adoption (and non-adoption) in England have previously been explored in the literature for organic farming (Burton, Rigby, & Young, 1999), integrated pest management (Bailey *et al.*, 2009) and agri-environmental schemes (Morris & Potter, 1995). However, there has yet to be a study on what influences the adoption of CA in England.

I carried out this research in a very pivotal moment in time as there are likely to be relatively high numbers of policy reforms due to UK's imminent exit from the EU, such as the possible removal of the common agricultural policy (Helm, 2016). This provides an opportunity to inform policy makers of factors that may encourage increased adoption of CA, to be integrated into the new policies.

My thesis begins by outlining the three main principles of CA and its sustainable potential. Followed by a description and justification of the two theories I draw from before introducing the methods used to answer the RQs. The results and discussion are combined as one section, mirroring the structure of the research questions. This is followed by suggestions of how my results can be translated into interventions to encourage the adoption of CA in England. Finally, I conclude with a summary of the data and brief indication of how future research can build upon my thesis.

### 1.4. Contribution to sustainability science

This thesis is informed by the principles of sustainability science and contributes to the body of literature from within the field. Sustainability science is a transdisciplinary field of research that aims to gain understanding of complex interactions between natural and social systems to guide them along more sustainable trajectories (Kates *et al.*, 2001; Miller, 2013). I explore these interactions by uncovering the behavioural motivations behind a social choice that impacts the sustainability of natural soil, biological and atmospheric systems. I draw on a multitude of literature from natural and social science disciplines, overcoming the divide between social and natural sciences (Jerneck *et al.*, 2011). Moreover, characteristic of sustainability science, my research is driven by a problem-solving agenda to produce use-inspired research committed to translating knowledge into societal action that can improve natural and social wellbeing (Clark, 2007; Kates, 2011; Miller *et al.*, 2014). Namely, my findings help to decipher the problem that most English farmers are not using CA, to advise how farmers could be encouraged to adopt CA in the future so that environmental, economic and social sustainability is improved.

## 2.0. Conservation agriculture as a sustainable alternative?

*"We just need to work with nature rather than against it."* – Farmer (Interviewee 2)

### 2.1. The defining principles of conservation agriculture

Throughout this thesis, I define conservation agriculture (CA) as a sustainable agriculture production system comprising a set of farming and soil management techniques that aim to protect the soil from erosion and degradation, improve soil quality and biodiversity, and contribute to the preservation of natural resources, while optimizing yields (revised from ECAF, 2014). CA is characterised exclusively by three interlinked principles (Friedrich *et al.*, 2009):

1. **Continuous minimum mechanical soil disturbance.**
2. **Permanent organic soil cover.**
3. **Diversification of crop species.**

Principle 1 tends to include practices like conservation tillage and no-tillage, however for this thesis I am only including no-tillage in this category. This is to overcome the ambiguity with definitions and huge variety of practices under the umbrella term of "conservation tillage", which include practices that still disturb and erode the soil and thus cannot be considered conservation agriculture (Reicosky, 2015). I confirmed my decision when I asked interviewee 1 and 5 (table 1) if they consider conservation tillage a form of CA, to which they both strongly said they did not. No-tillage can be defined as a practice in which "seeds are placed into otherwise untilled soil by opening a narrow slot, trench, or hole of only sufficient width and depth to obtain proper seed placement and coverage. No other soil tillage is done"(Derpsch *et al.*, 2014, p. 18).

Principle 2 of CA is mainly achieved using cover cropping (figure 1), defined as "a temporary vegetative cover that is grown primarily to provide protection for the soil and the establishment of plants"(OECD, 2001, p. 399). So that nutrients are not removed from the field, cover crops are not harvested, instead they are killed and decomposed back into the soil to form organic matter. Another practice that can be used to achieve this principle is residue retention, which I define as maximising the biomass cover of the soil through leaving past crop stubble in the field or adding mulch.

Principle 3 includes the practice of crop rotation, defined as "the system of growing a sequence of different crops on the same ground so as to maintain or increase its fertility"(Crozier, 2006). This principle also includes the practice of companion cropping which is "a system of cultivation in which two or more different crops are grown together in close association"("Oxford English Dictionary," 2010).

**Figure 1:** photo of a conventionally ploughed field (left) compared to a CA farmed field (interviewee 2's farm), with a bean cover crop (right). Authors own photos (February 2017).

## 2.2. Conservation agriculture's sustainable potential

*"A nation that destroys its soil, destroys itself."* – Franklin D. Roosevelt

The combination of these principles creates a holistic system which is environmentally, economically, and thus socially, sustainable (Pieri *et al.*, 2002). More widespread adoption of CA would reap numerous benefits including a reduction of GHG emissions, increase in biodiversity, improved agricultural productivity, reduction in environmental pollution and reduced likelihood of flooding (figure 2)(McIntyre *et al.*, 2009).

Research has demonstrated the potential for soils under CA to sequester carbon from the atmosphere (Beheydt *et al.*, 2008), and thus CA has been discussed as a climate change mitigation strategy (McIntyre *et al.*, 2009). This can be achieved through the combination of CA principles one and two. No-tillage prevents the loss of soil carbon via erosion and reduces soil exposure to the air, thus decreasing the likelihood of carbon dioxide release through oxidation (Hobbs *et al.*, 2008; Lal, 2004). Soil holds an estimated carbon content double that of the atmosphere within the top 1m (Govaerts *et al.*, 2009). Therefore, the carbon dioxide lost from land use change and soil disturbance can be substantial (MacLeod et al., 2010). Smith et al. (2000) calculated that improving the management of UK agricultural land, through practices such as no-tillage, could lead to the potential carbon dioxide equivalent mitigation of 6.1MtCO2e per year. Crop residues are the precursors of organic matter, adding carbon to the soil (Smith et al., 2008). Moreover, the practice of no-tillage does not require a tractor to pass over the field to plough before passing again to plant the seeds, greatly reducing fossil fuel use (Hobbs et al., 2008). Lal (2004) found a 73% decrease in fuel consumption of no-tillage compared to conventional ploughing methods. He also found that conventional ploughing produced 35.3kg carbon emissions (CE)/ha, whereas no-tillage released only 5.8kg CE/ha.

The reduced number of tractor passes in no-tillage also improves soil structure by minimising compaction (Hobbs *et al.*, 2008). Soil structure and porosity is further improved as the soil is not ripped up by the plough (Lahmar, 2010), allowing larger soil aggregates that are more resistant to wind and water erosion (McIntyre *et al.*, 2009). This creates more pore spaces and increases water infiltration rates, reducing soil run-off (FAO, n.d.; McIntyre *et al.*, 2009), thus providing environmental benefits by reducing water pollution (Ockenden *et al.*, 2014). The lack of soil disturbance in no-tillage also means that soil organisms, such as earthworms, and beneficial mycorrhizal fungi remain unharmed and increase in numbers over time (Reicosky, 2015). Crop residues further stimulate soil organisms by providing more nutrients (Hobbs *et al.*, 2008). After soil organisms have become re-established, biological activity negates the need for tillage practices as earthworms and microorganisms mix the soil and create channels (Lahmar, 2010). Crop rotations and cover crops also contribute to biological tillage by introducing various rooting patterns to create an extensive network of channels in the soil (Hobbs *et al.*, 2008). These mechanisms all promote soil and plant health by increasing the nutrient content, developing larger stable soil aggregates and stabilizing organic matter (Beheydt *et al.*, 2008).

These soil improvements induced by CA have been shown to increase crop productivity (Varvel & Wilhelm, 2011). However this remains debated as the scientific community have not yet reached a consensus on whether yields are reduced in initial years and whether CA yields will ever exceed those of conventional farming (Knight *et al.*, 2012; Lahmar, 2010). This is likely due to differing soil and climatic conditions, as well as the state of soil health before the conversion to CA, which can lead to differences in outcomes and time-scales (Lahmar, 2010). In a global meta-analysis, Pittelkow *et al.* (2015) found wheat and maize yields decreased by 2.6% and 7.6% respectively in the first few years of no-tillage, yet after 3-10 years crops achieved higher yields than conventionally farmed fields. Productivity can be further improved due to increases in soil microbes associated with CA that can improve crop health by being antagonistic to soil pathogens and reducing the likelihood of plant diseases (Leake, 2003). The greater diversity from crop rotations also increases microbial diversity and prevents the establishment of pests, weeds and pathogenic outbreaks (Hobbs *et al.*, 2008). Cover crops further reduce weed infestations via direct competition for light and nutrients (Hobbs *et al.*, 2008). This all increases productivity as well as reducing the need for chemical inputs, further increasing profitability through reduced input costs (Govaerts *et al.*, 2009).

Although long-term fertilizer, herbicide and pesticide demand can be progressively reduced in CA (Knowler & Bradshaw, 2007), there are often increases in agrochemical demand in the initial few years and use of agrochemicals is rarely completely discarded (Pittelkow *et al.*, 2015). Moreover, England climates require the use of the broad-spectrum herbicide, glyphosate, to kill cover crops and any weeds that emerged over winter before planting the crop seed so that they do not outcompete the crop (Snapp & Borden, 2005). CA's reliance on agrochemicals sparks a debate regarding the practice's sustainability. However, it is debated whether a practice based on the exclusion of synthetic agrochemicals and soluble mineral inputs, such as organic farming (Trewavas, 2001), can compete with yields of other agricultural systems (Kirchmann *et al.*, 2009; Trewavas, 2001). For this reason, organic farming has been referred to as "extensive" as it requires more land than conventional methods to produce the same quantity of produce (Pretty, 2008, p. 5). CA provides a sustainable intensification method that makes better use of existing resources whilst having the potential to be high yielding (Garnett *et al.*, 2013). A farmer I interviewed (Interviewee 2 - table 2) commented that "we can't feed the world on organic farming. So, I see this [CA] as the best of both worlds between conventional and organic farming".

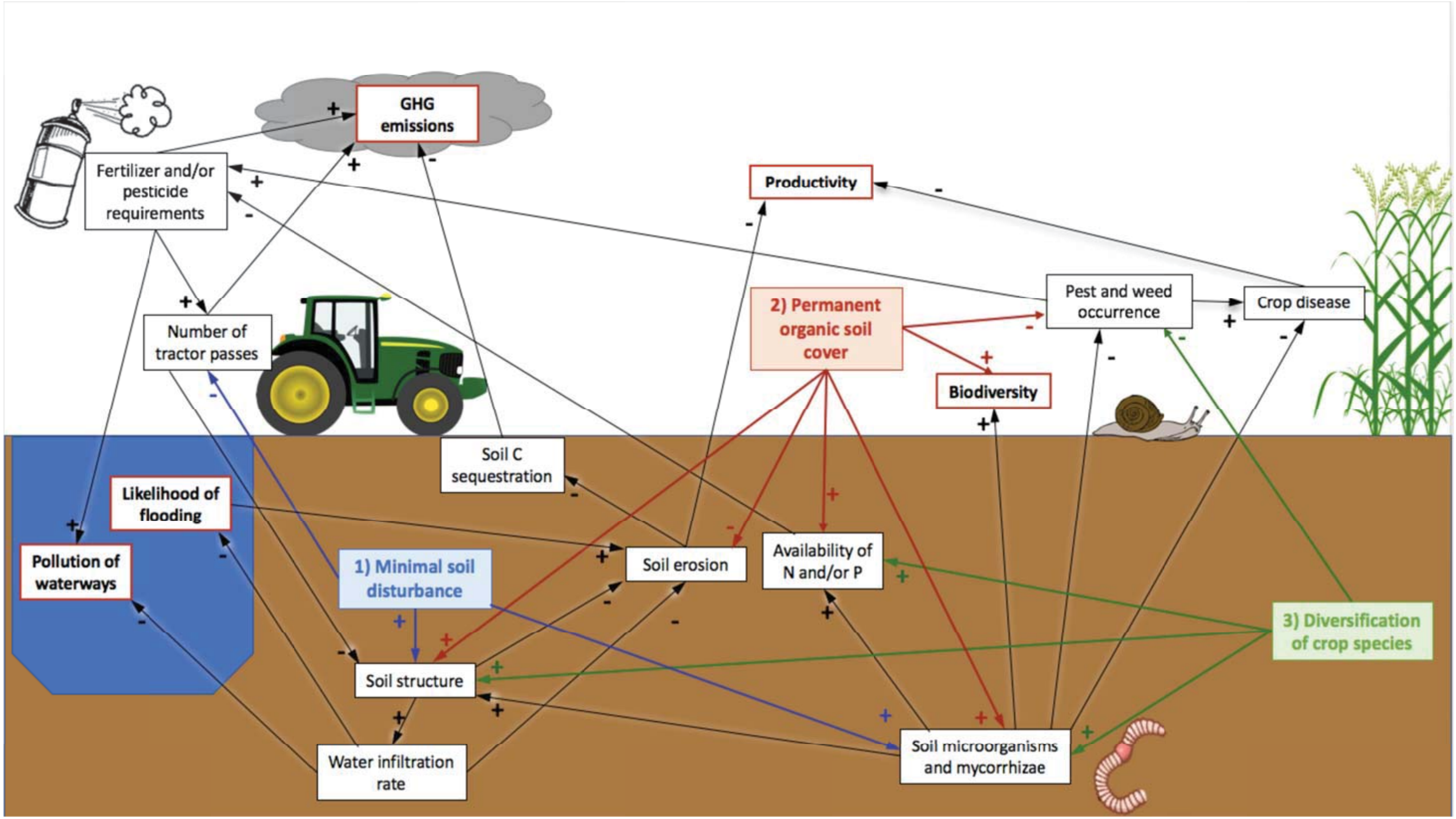


**Figure 2:** Causal loop diagram showing the effect that CA principle 1 (blue), principle 2 (red) and principle 3 (green) has on an agroecosystem and ultimately on the pollution of waterways, productivity, greenhouse gas emissions and biodiversity. (Authors own image, including non-copyright clip-art images)

## 3.0. Theoretical frameworks

I theoretically inform this thesis by combining the diffusions of innovations theory and the theory of planned behaviour. The diffusions of innovations theory is utilized to broadly conceptually frame the study and research problem and inform the individualist approach of my research. I apply the theory of planned behaviour as an analytical framework to more explicitly inform and design my data collection and analysis. The combination of these theories provide the "significant determinants of innovation adoption" (Weigel *et al.*, 2014, p. 619).

### 3.1. Conceptualizing the research with diffusions of innovations theory

Aspects of the diffusion of innovations theory are used to position English CA adoption as a disseminating agricultural system as well as theoretically informing my study as a conceptual framework. This theory fits my study well as it was originally designed to explain the spread of new agricultural practices amongst farmers (Greenhalgh *et al.*, 2004). The diffusions of innovations is an extensive theory and I will not be drawing on every aspect, rather drawing on parts that are relevant to this case. Rogers (2010) defines diffusion as the "process by which an innovation is communicated through certain channels over time among the members of a social system" (p.5), and innovation as an "idea, practice or object that is perceived as new by an individual or other unit of adoption" (p.11). Following this definition CA can be considered innovations (Borges, Foletto, & Xavier, 2015).

According to diffusion of innovations theory, the rate of adoption is the "relative speed with which an innovation is adopted by members of a social system", which is measured as the number of individuals who decide to adopt the innovation within a time period (Rogers, 2010, p. 206). The theory states that all innovations are adopted following a normative bell curve representing the frequency of new adopters (figure 3)(Rogers, 2010). This relates to a normative s-curve of cumulative frequency of adopters that shows the rate of adoption over time (figure 3)(Rogers, 2010). The frequency distribution is used to classifies five adopter categories; innovators (initial 2.5%), early adopters (13.5%), early majority (34%), late majority (34%), laggards (16%)(Rogers, 2010). CA has an estimated adoption of 8% of UK arable land (CA-UK, 2016), which I calculated to be relative to 8%-14.6% of farms (calculation explained in appendix 1). This is close to the critical mass, normally within the stage of early adopters or early majority, where the innovation becomes self-sustaining (Valente, 1995). This justifies the need to gain understanding at this moment in time, as

CA still requires work to sustain current numbers of adopters and move towards the critical point of adoption.

I draw on the theory's perspective that individuals drive the diffusion of an innovation as a central framing of this study by focusing on individual farmer decisions to gain an understanding of the low adoption of CA in England. The theory further clarifies that it is the actor's perceptions of the attributes of an innovation, rather than its true attributes or those defined by experts, that affect the individual's adoption and thus the diffusion rate of the innovation (Rogers, 2010). This conforms to the critical realist position of this thesis, which suggests people have differing and subjective snapshots of reality (Bryman, 2012), and supports my choice to use theory of planned behaviour as an analytical framework. However, Rogers (2010) also noted that, as well as individuals, a system influences diffusion via norms and other system-level qualities. Thus, this study has expanded to include external factors; namely the political environment and adequacy of information.

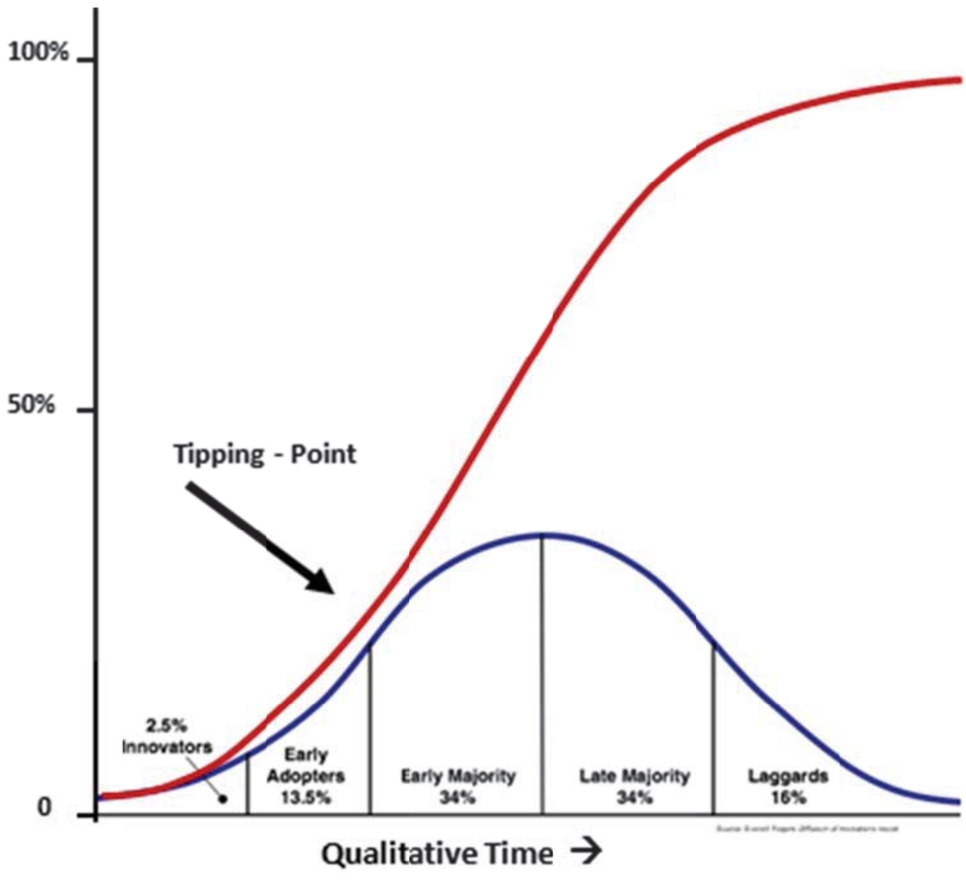


**Figure 3:** plot of normally distributed adopter frequency curve (blue) and cumulative frequency curve (red) (Gur-Arie, 2010)

### 3.2. The theory of planned behaviour as an analytical framework

The theory of planned behaviour (ToPB) is one of the most influential and widely cited frameworks for the prediction of human behaviour and has been applied to an array of disciplines (Ajzen, 2011). It has been used successfully in the past to assess sustainability choices (Tonglet, Phillips, & Read, 2004), farmer behaviour (Burton, 2004; Hansson, Ferguson, & Olofsson, 2012) and farmer conservation choices (Beedell & Rehman, 1999; Borges *et al.*, 2015; Lynne *et al.*, 1995). I apply the ToPB to this thesis as an analytical framework to decipher what influences English arable farmers' decisions to adopt CA or not. In utilizing the theory, I am in turn contributing to its debate by providing empirical evidence of the theory's ability to decipher the reasoning behind specific behavioural choices. Many sustainability challenges are linked to societal choices, such as the one I investigate via this thesis. Thus, producing behavioural research, which is informed by an empirically grounded and highly regarded theory (Ajzen, 2011), on sustainability decision-making provides an important contribution to sustainability science. Miller (2013, p. 285) commented on the need for more behavioural research in the sustainability science field; "Part of the mission of sustainability science is to determine what knowledge is needed. This is done based on a better understanding of decision-making and perceptions".

The ToPB is designed to predict and understand behavioural choices in specific contexts (Ajzen, 1991), with the behavioural choice in this study being farmers' choice to adopt CA or not in the context of arable English farms at the beginning of 2017. The theory states that the likelihood of an actor engaging in a behaviour strengthens as their intention increases (Ajzen, 1991), moderated by actual control to do so (Ajzen, 2011; Wauters *et al.*, 2010). The ToPB assumes that intentions capture the motivational factors that drive a behavioural choice, as intention represents the level of effort they are planning to apply in order to achieve the behaviour (Ajzen, 1991). Consequently, to further investigate RQ1, I identify English arable farmers' perceived motivations to choose to adopt CA. Following the logic of the ToPB, this can identify factors that trigger increased intentions, and thus increased likelihood of behavioural performance.

The ToPB suggests three independent determinants of intention (figure 4); attitude towards the behaviour, subjective norms (SN) and perceived behavioural control (PBC). The relative importance of these behavioural parameters varies from one case to another, depending on the behaviour in question, the population studied and the context (Wauters *et al.*, 2010). Thus, one of the objectives of this study is to discover the relative importance between attitude, SN and PBC to determine what is driving positive or negative intentions. This is one way that I utilize the ToPB to tackle the aim to understand what influences English arable farmers' decisions concerning CA. This also allows the identification of intervention points for encouraging more farmers to adopt CA in the future.

As well as a determinant for intention, PBC can be used as a proxy measure of "actual control" as it can predict the degree to which the behaviour is likely to be inhibited by external factors, such as resource availability and knowledge (figure 4)(Ajzen & Madden, 1986, p. 459). Drawing on this, I investigate the main challenging factors that farmers perceive to be inhibiting the choice to adopt CA. Following the ToPB's reasoning, this identifies the main actual barriers, along with some prerequisites of intentions, influencing CA adoption. This allows me to fully understand behavioural achievement.

The three behavioural parameters are determined by a person's salient beliefs (Ajzen, 1985). Behavioural beliefs, associated with attitude, relate the behaviour to outcomes, which are valued based on the estimated probability and evaluation of each outcome (Ajzen, 1985). Normative beliefs are the prerequisites for subjective norms, consisting of the social pressure from the actor's important others (Ajzen, 1991). Control beliefs are the salient believes that provide the foundation for PBC, made up of the perceived difficulty of performing the behaviour and the extent that the actor believes they can overcome expected obstacles (Ajzen, 1991). The ToPB clarifies that a person's beliefs represent their view on the world, which is shaped by the information they possess (Ajzen, 1985). Therefore, a person's behaviour is ultimately determined by their information of the world (Ajzen, 1985). Hence my emphasis on investigating the relevance, access and quality of CA information for farmers in RQ2.

The ToPB follows a few assumptions that must be considered while drawing conclusions from this study. Firstly, it assumes that people behave rationally and act in accordance with their beliefs (Beedell & Rehman, 1999). It also considers that the strength of salient beliefs are translated with directly proportionally to their general measures (Attitude, SN, PBC)(Beedell & Rehman, 1999). My research follows this as I use numerical measures of beliefs to calculate the three ToPB parameters.

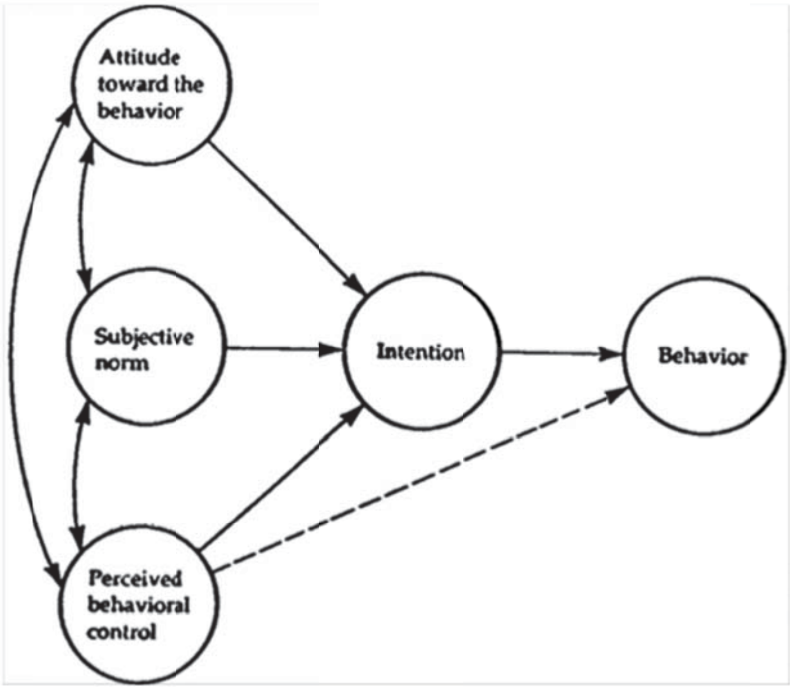


**Figure 4:** A representation of the ToPB. The dotted arrow represents PBC's ability to reflect actual behavioural control, which influences the behaviour directly. (Ajzen & Madden, 1986)

The ToPB fits the aim of my study well, due to the theory's actor-orientated nature that resonates with the farmer perspective approach of this research. The ToPB is designed only for context specific decisions (Ajzen, 1991), which I well suited to this study as it is positioned in spatially and temporally unique contexts and I do not aim to extrapolate the study's conclusions onto other scenarios. As this study is within agricultural context, which is subject to physical, economic and political fluctuations, it lacks volitional control and thus is well suited to the ToPB rather than the theory of reasoned action (Burton, 2004). The use of the ToPB enhances credibility by proving standardised, theoretically sound and empirically validated research (Beedell & Rehman, 1999), which is necessary for this thesis as it is designed to advise policy makers and relevant stakeholders (Wauters *et al.*, 2010). This theory also provides the flexibility necessary for this research, by endorsing the use of generalised "global measures" to assess the behavioural parameters (Ajzen, 1991, p. 191).

# 4.0. Research design

## 4.1. Methodology

I present a study characteristic of sustainability science as it consists of “research with a place-based focus on coupled human-natural systems from an interdisciplinary, problem-driven perspective” (Miller, 2013, p. 280). I have structured this research as a three-stage study, represented in table 1. The first stage used farmer interviews and mixed stakeholder focus groups in an exploratory approach to understand the context and identify the key issues required to for the development of stage two. Within the second stage I utilized a descriptive approach to characterise farmers’ decisions to adopt CA or not by using an online survey. The most important decision making factors were identified at this stage, which were explored further in stage 3 by using follow-up questions, and interviews with knowledge exchange organisation employees and a researcher (referred to as “knowledge exchange interviews”) and drawing again from the methods used in stage 1. Here I clarified confusions and explored the results of the second stage in more depth.

**Table 1:** Representation of the methods used for each stage of the study

<table>
<tr><th>Research stage</th><th>Method</th><th>Data type</th><th>RQs Answered</th></tr>
<tr><td rowspan="2">Stage one: foundation</td><td>Farmer Interviews</td><td rowspan="2">Qualitative</td><td>All RQs</td></tr>
<tr><td>Mixed-stakeholder focus groups</td><td>RQ1</td></tr>
<tr><td>Stage two: body</td><td>Online survey</td><td>Quantitative</td><td>All RQs</td></tr>
<tr><td rowspan="4">Stage three: depth and clarification</td><td>Knowledge exchange interviews</td><td rowspan="4">Qualitative</td><td>RQ2</td></tr>
<tr><td>Farmer follow-up questions</td><td>RQ1, 2</td></tr>
<tr><td>Farmer interviews</td><td>All RQs</td></tr>
<tr><td>Mixed-stakeholder focus groups</td><td>RQ1</td></tr>
</table>

I utilized a mixed methods approach, combining quantitative data from the farmer survey and qualitative data from interviews, focus groups and follow-up questions. Increasing numbers of researchers are adopting this method and opposing criticisms by suggesting that there are commonalities and overlaps between the quantitative and qualitative research (Bryman, 2012). Burton (2004) suggests this balance between qualitative and quantitative data is essential for researched framed using the theory of planned behaviour (ToPB) to gain an informed understanding of decisions. I employed a mixed methods approach in four ways, identified by Bryman (2006). Firstly, is it used for “*instrument development”* as farmer interviews were used to develop a well-informed survey (p. 106). Stage three of the study used qualitative data as *"explanation"* for the survey data (p. 106). The higher number of participants and capacity to use numerical analysis in quantitative methods was combined with more in-depth exploration and detailed individual accounts from qualitative methods, utilizing the strengths and offsetting weaknesses of quantitative and qualitative methods (*"offset"*), allowing a more comprehensive study of farmer adoption of conservation agriculture ("*completeness"*)(p. 106). This mixed methods approach is grounded within a critical realist positioning (Zachariadis, 2013). Critical realism proposes that reality exists independently to our knowledge of it, yet through research we can begin to capture some understanding of it (Bryman, 2012; Sayer, 2000). Critical realism explains that this understanding is contextually defined and dependent on the type of knowledge the methods convey, thus a mixed-methods approach builds a greater understanding of reality via various mechanisms (Zachariadis, 2013).

Conforming to the critical realist perspective, my research strategy collected the majority of insights from farmers themselves to better understand their perspective of reality. This is advocated in the sustainability science field as knowledge to support future decision-making should be "coproduced through close collaboration between scholars and practitioners" (Clark & Dickson, 2003, p. 8059). Mixed-stakeholder focus groups and knowledge exchange interviews provide a broader array of perspectives to draw from. This helps to produce salient, legitimate and trustworthy information that can more appropriately assist society in a transition to sustainability (Miller, 2013). Lang *et al.* (2012) comment that sustainability science should incorporate knowledge from all relevant actor groups to enable constructive research on complex sustainability problems. Hence, policy makers were also contacted for interview, however all declined my invitation.

During my data generation, I collaborated with Rothamsted Research Centre, UK. This helped me to reach more participants via the use of the centre's network, for example to send farmers in the Rothamsted Research Association (RRA) emails asking for participation in the survey. I also attended their farming events and used this space to conduct focus groups and ask questions.

## 4.2. Data generation

### *4.2.1. Farmer interviews*

I conducted face-to-face interviews, combined with farm visits, with five farmers between 17th and 20th February. Purposive sampling was used to identify farmers within the East of England so that they were more comparable. This region's farmland has the highest percentage of arable agriculture (77%)(DEFRA, 2017). Participants were chosen with differing CA adoption statuses (Table 2).

All participants read and signed a consent form and indicated they give consent for the interview to be recorded (appendix 3). Interviewees agreed to be named, yet I kept them anonymous throughout this thesis to avoid any repercussions from the research. Furthermore, to avoid response bias I ensured there were no leading questions and only probed for further information when I felt it was necessary (appendix 2). Qualitative content analysis was used to identify sub-categories and broader categories from transcribed interviews for important question topics (Mayring, 2014). The sub-categories distinguished for motivational and challenging factors (appendix 8 and 9) were ranked by survey participants. These were also classified as being "behavioural beliefs", "normative beliefs" or "control beliefs", which are relative to attitude, SN and PBC respectively. This shows which factors are driving each ToPB parameter.

**Table 2:** list of farmers interviewed and the CA practices they are using

| **In text reference** | **Agricultural practices** | **CA Practices** |
|---|---|---|
| Interviewee 1 | 1 year CA | No-tillage,<br>Cover crops,<br>Crop rotations |
| Interviewee 2 | 2 years CA | No-tillage,<br>Cover crops,<br>Crop rotations,<br>Companion cropping |
| Interviewee 3 | Conventional practices | -- |
| Interviewee 4 | Conventional practices | -- |
| Interviewee 5 | 15 years CA | No-tillage,<br>Cover crops,<br>Residue retention,<br>Crop rotations, |

#### *4.2.2. Focus groups*

I conducted four focus groups to promote discussion between different stakeholders to provide an in-depth and realistic dialogue in a relatively natural environment for finding the challenging factors influencing farmers' perceptions of CA (Bryman, 2012). Each focus group lasted approximately 10-20 minutes (timings had to comply with rotating sessions in a RRA meeting) and had three or four participants, who were attending the RRA meeting. Stakeholders included: farmers who were and were not using CA; agronomists; a PhD student; an agricultural researcher; an agricultural accountant; and a knowledge exchange organisation employee.

I briefed each group on my project and the definition of conservation agriculture before asking them to "discuss why you think most UK farmers are not using CA practices". Participants verbally agreed to participate and were aware they would remain anonymous and could withdraw at any time. I made hand-written notes during the focus groups and none needed prompting. Qualitative content analysis was used to analyse these (Mayring, 2014).

#### *4.2.3. Online Survey*

The survey was designed online (surveymonkey.com), using information gathered from stage one. Following Pennings, Irwin, and Good (1999), the survey took approximately 15 minutes to complete to increase response rate and decrease response bias. It was open for 4 weeks (23rd Feb - 21st March) and distributed to members of RRA by email, posted to discussion threads on *The Farming Forum* and circulated on twitter, using mentions of popular farming users (figure 5). This online engagement sparked internet discussions on the topic between myself, farmers and agronomists, which provided greater understanding of the situation as well as expanding my online network. This may be subject to bias towards farmers whom are more active online. Yet the variety of methods I use throughout this study helps to alleviate the impact of a survey sampling bias, although this should be considered when drawing conclusions. There was a total of 147 responses. However, once responses from other countries, livestock farmers and responses incomplete before part 3 were deleted, 108 responses remained for analysis. A title page at the start of the survey ensured that participants were aware of their rights (appendix 4)


**Figure 5:** examples of tweets mentioning popular farmer profiles to encourage more farmers to fill out the survey

To avoid ambiguity among farmers, questions were worded regarding agricultural practices rather than CA principles. Principle 1 was referred to as "no-tillage", principle 2 as "cover cropping or residue retention" and principle 3 as "crop rotations or companion cropping". Practices were grouped as it is irrelevant for CA if, for example, a farmer chooses to use cover cropping, residue retention or both, as both practices contribute to the 2nd principle. This was made clear to respondents for each survey section this applied to. However, practices were separated in part 1 of the survey to identify the commonality of each practice.

***Analysing the relative importance of attitude, subjective norms and perceived behavioural control***

Part 3 of the survey was designed following the theory of planned behaviour (ToPB). Rather than evaluating the many perceived outcomes of the behaviour, the normative beliefs of all influencing individuals, and the perceived power and likelihood of each of the control beliefs (Ajzen, 1991), "global measures" were used (Ajzen, 1991, p. 191). These measures are directly proportional to those calculated from multiple criteria and reduce the number of repetitive questions that may lead to participants dropping out (Burton, 2004; Pennings *et al.*, 1999). For example, SN was assessed based on "important others" rather than separate referents (Ajzen, 1991; Burton, 2004).

The three ToPB parameters (attitude, subjective norms and perceived behavioural control) were analysed so that they could be numerically measured and compared to answer RQ1. These were measured in the survey using questions with 5-point Likert scales. Questions and respective Likert scales are presented in appendix 5. Attitude was calculated by measuring (a) likelihood of positive outcome, (b) likelihood of negative outcome, and (c) evaluation of overall impact of the outcomes. SN is made up of (d) normative expectations of others and (e) whether the participant is likely to comply with their opinion. PBC is made up of (f) perceived difficulty and (g) perceived control (Wauters *et al.*, 2010). Each question produced a numerical answer for each participant derived from Likert scale values. Scales for all questions, aside from (e), were numbered from -2 to 2, whilst (e)'s Likert scale valued from 0 to 4. I devised the following equations (1, 2 and 3) to calculate a value directly proportional ($\propto$) to the behavioural parameters:

$$Attitude \propto \frac{(a-b)}{2} + c \qquad (1)$$

$$SN \propto d + e - 2 \qquad (2)$$

$$PBC \propto f + g \qquad (3)$$

Letters represent numeric answers to the relative questions derived from Likert scale value. These equations result in each behavioural parameter being on a scale of -4 to 4, with positive values indicating that the parameter encourages the use of the agricultural practice, whereas negative values imply the parameter discourages the use of the practice (1 =slightly influential, 2 =somewhat influential, 3 =moderately influential, 4 =very influential). Individuals' values of the behavioural parameters were correlated (Pearson's rank) with the adoption of the CA practices. An average value of each ToPB parameter was calculate for adopters and non-adopters for each CA principle to be graphically presented.

***Analysing the main drivers behind the theory of planned behaviour parameters***

Part 4 was designed to explore the motivational and challenging factors that drive farmers' perceptions of CA. Survey respondents ranked the four most important factors from the motivating and challenging factors derived from the farmer interviews (appendix 8 and 9 sub-categories) that influence them to use each of the CA principles. Although challenging factors excluded "farmers dislike change" because a personal variant of this could be included in the factor "Don't see a need to change practices", and included "ineffective or inadequate agricultural policy", which emerged from the farmer focus groups. This allows further detail on the main drivers of behaviour that is missed when using general measures in part 3.

The relative importance of the factors (sub-categories that emerged from interview analysis) was analysed by calculating the average ranking of the survey responses (equation 5). **x** represents the response count for each rating choice and **w**, the weighted value of the ranked position. 1st ranks were given a weighting of 4, 2nd a weighting of 3, 3rd a weighting of 2, 4th a weighting of 1. The average ranking of motivational and challenging factors were graphed on a scale from 0 to 4, the closer to 4 the higher the relative importance the factor is in the decision to adopt CA or not.

$$Average\ ranking = \frac{x_1w_1+x_2w_2+x_3w_3+x_4w_4}{Total\ number\ of\ respondants} \qquad (4)$$

Sub-categories were also classified into broader categories (e.g. knowledge, economic, social, practical). The average rankings of sub-categories were averaged for each broader category. Using this, the relative importance (%) of each category was found using equation 5.

$$Relative\ importance\ of\ a\ category\ (\%) = \frac{mean\ ranking\ of\ category}{Sum\ of\ average\ rankings} \times 100 \qquad (5)$$

Part 4 also included questions regarding knowledge exchange and political environment as a way of answering RQ2 and 3.

### *4.2.4. Follow-up questions*

Follow-up questions were sent to survey respondents who provided an email address and agreed to be contacted for further questions. These were designed after identifying important factors and points of clarification from a preliminary review of the qualitative methods and preliminary data analysis of the first 88 survey responses. Questions are presented in appendix 6. 19 farmers responded, all of which were using at least one CA principle. Thus, themes emerging from this during qualitative content analysis will all be from the CA adopters' perspective.

### *4.2.5. Knowledge exchange interviews*

Drawing from the two theories informing this thesis and following preliminary analysis, I further explored knowledge exchange between researchers and farmers, often via a knowledge exchange manager. I interviewed a CA researcher and people working at knowledge exchange organisations (appendix 6), such as Agriculture and Horticulture Development Board (AHDB) and Linking Environment and Farming (LEAF)(Table 3). Qualitative content analysis was used to find themes and quotes were extracted for further explanation.

**Table 3:** Interview participants from knowledge exchange organisations or research institute

| In text reference | Organisation | Role | Interview date |
|---|---|---|---|
| KE1 | AHDB | Knowledge exchange manager for East Anglia cereals and oil seeds | 20.03.17 |
| KE2 | AHDB | Knowledge exchange manager for East Midlands cereals and oil seeds | 21.03.17 |
| KE3 | Rothamsted Research Centre | CA Researcher: Soil health, no-tillage, earthworms | 23.03.17 |
| KE4 | LEAF | LEAF Technical Assistant | 27.03.17 |

Face-to–face interviewees (KE1 and KE3) read and signed a consent form and I read the consent form to phone interviewees, whom gave verbal consent. It may be possible to identify participants through information provided, such as their role and organisation, however as they all agreed to be named in the publication I do not feel this is a breach of ethical practice.

### 4.4. Limitations

Ajzen (2011) warns that ToPB intentions and control perceptions should be assessed as close in time to the behavioural choice to avoid intervening variables from changing actor's decision process. This limitation is avoided during this research as the decision is considered at the time of assessment. However, as the behavioural measures and use of CA are self-reported, it is possible that values are vulnerable to social desirability and acquiescence bias (Beedell & Rehman, 1999). Furthermore, measuring the salient beliefs for the application of the ToPB can require high respondent concentration due to seemingly obtuse questions (Beedell & Rehman, 1999). The anonymity of most of the methods should help to remove social desirability and the ease of a 5-point rather than 7-point scale may help to reduce concentration requirement and acquiescence bias.

## 5.0. Results and Discussion

This chapter presents and discusses the results of the analysis. 5.1. answers RQ1 following the theory of planned behaviour (ToPB), which is explored in more detail within the sub-sections 5.1.1 and 5.1.2.. The answer to RQ2 is presented in section 5.2. and a discussion of the perceived political environment (RQ3) is presented in section 5.3.. However, before answering the RQs, it is important to note the differences in survey respondent adoption rates of the different CA practices. For example, less than half of respondents used no-tillage, whereas 90% of respondents used crop rotations (figure 6). (Goodwin, 2014) also demonstrates that only a few farmers have picked up no-tillage in England. From figure 6, it is possible to suggest that CA principle 3 (Diversification of crop species) is more commonly being met by the practice of crop rotation rather than companion cropping, while the cover cropping and residue retention (principle 2) seem to have similar adoption rates.

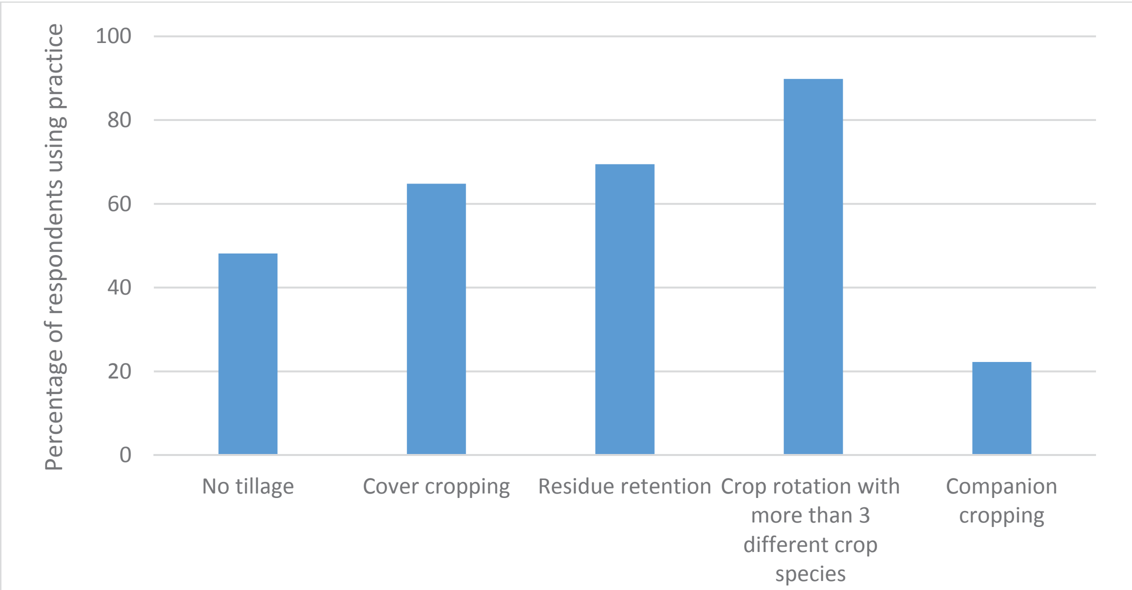


**Figure 6:** representation of the distribution of adoption of the different CA practices by survey respondents (N=108)

Although I focus on the decision making of each of the principles separately in order to account for differences between them, all three principles are required for a farmer to be using CA agriculture. An FAO report demonstrated the importance of combining principles in retaining an extensive soil biota and good soil structure compared to using no-tillage separately (Friedrich *et al.*, 2009). Nevertheless, I calculated from the survey respondents that adopted at least one CA principle, that 13% used only one of the three CA principles, 40% used two and 47% were currently using all the CA principles and thus fulfilling the definition of CA. It also seems that no-tillage is often considered in isolation of the other two principles (implied by interviewees 1 to 4), especially in research (Morris *et al.*, 2010; Triplett & Dick, 2008; Varvel & Wilhelm, 2011). Interviewee 1 commented on this, saying that "No-till is about saving money, CA is about maintaining soil health; it's a very different mind-set". One follow-up question response admitted they started no-tillage "from a time saving perspective", then used the money saved to buy cover crop seed, mentioning that "I don't believe there would have been the same degree of health benefits if we hadn't integrated cover crops".

Moreover, there was no correlation between personal variations (age, education level, gender, farm size, region, farming cooperative membership, percentage land ownership, soil type, information sources, if farming is the main source of income and if they received specialist agricultural training) and the adoption of each of the CA practices for survey respondents. This contradicts much of the literature, which find correlations with one or more personal factors (Drost, 1996; Rodriguez *et al.*, 2009).

### 5.1. Farmer beliefs and perceptions influence on adoption of conservation agriculture

Of the three ToPB parameters, attitude had the strongest correlation with adoption for all of the CA principles (table 4). Attitude was also found to be the most important factor for the adoption of soil conservation practices in Belgium (Wauters *et al.*, 2010). When the average values of the behavioural parameters for adopters and non-adopters were graphically presented, it is clear to see that positive attitudes of adopters is the main driver of this, rather than negative attitudes of non-adopters (figure 7). Yet, it should be noted that non-adopters of no-tillage had a weak negative attitude (figure 7a). This reflects the interviews as the non-adopters overall gave much less beneficial outcomes than those currently using CA practices. Interviewee 4 even commented that he could not see CA having any benefit to his farm at all.

Perceived behavioural control (PBC) had a strong relationship with adoption of CA principle 1 (continuous minimum mechanical soil disturbance), a weak correlation with principle 3 (diversification of crop species) and no correlation with principle 2 (permanent organic soil cover)(table 4). This suggests that farmers perceive the principles as having different levels of difficulty. It can further be assumed that the challenging factors associated with no-tillage are more important at hindering its adoption than the challenges of the other practices hindering their adoption (table 4). All ToPB parameters seem to be discouraging the use of no-tillage for non-adopters, yet the most dissuading factor seems to be PBC (figure 7a). However, the influence seems to remain moderate, not exceeding -1 (figure 7a). Past research has also demonstrated PBC importance for conservation tillage in Belgium (Wauters *et al.*, 2010) and conservation technology in Florida strawberry farms (Lynne *et al.*, 1995).

**Table 4:** Pearson correlation coefficients showing the relation between the ToPB parameters and adoption CA practices. Blue signifies a significant but weak correlation, red signifies a significant strong correlation. Values under 0.3 are considered as no correlations.

| | Attitude | Subjective Norms | Perceived behavioural control |
|---|---|---|---|
| **Principle 1: No-tillage** | **0.68** | **0.45** | **0.51** |
| **Principle 2: Cover cropping or residue retention** | **0.58** | 0.24 | 0.22 |
| **Principle 3: Crop rotation or companion cropping** | **0.47** | 0.28 | **0.36** |

Subjective norms (SNs) are the lowest for adopters for every practice (figure 7). This reflects the finding that SN is not very influential in respondent adoption of CA; it does not correlate with principle 2 or 3 and only has a weak correlation with the adoption of principle 1 (table 4). Past studies support this, for example a study in Belgium found that farmers do not perceive any social pressure to adopt soil conservation strategies or not (Wauters *et al.*, 2010). However, it is important not to ignore the influence SN has on the adoption of no-tillage as it may still represent the deciding factor preventing some farmers from adopting.

Adopters showed positive average values for all ToPB parameters for all CA practices and all were more positive than non-adopters (figure 7). However, it is not clear whether this is required for a farmer to be encouraged to adopt CA. In contrast to the adopters, non-adopters show differing influences of the ToPB parameters for each of the practices (figure 7). Crop rotation or companion cropping has a surprisingly high attitude value for the non-adopters, which implies farmers are not using the practices despite thinking it would be positive for their farm (figure 7c). Perhaps this could be explained by the negative value of PBC (figure 7c), namely that farmers have a positive attitude towards the practices but feel that they are not practically able to adopt it. Ajzen (1985) suggested that intention-behaviour correlations are stronger when intentions are held with increased confidence. Increasing PBC would increase a farmer's confidence in their ability to adopt crop rotation or companion cropping (Ajzen, 1991). It is also possible that the non-adopters have positive intentions, driven by attitude, yet the challenging factors associated with the practices prevent successful adoption due to low actual behavioural control, which is directly proportional to PBC (Ajzen & Madden, 1986).

Moreover, for cover crops or residue retention, all the ToPB parameters for non-adopters have positive values, other than SN with the value of 0 (figure 7b). This suggests farmers' beliefs and perceptions encourage the adoption of CA principle 2. It is important to consider that this may simply be due to the small sample size of non-adopting respondents; only eight farmers not using crop rotations or companion cropping responded. However, as not adopting is the default decision, whilst adoption of CA requires enough encouragement for a farmer to consider change, it is possible that there is a threshold level of encouragement that must be great enough to trigger a farmer to change.

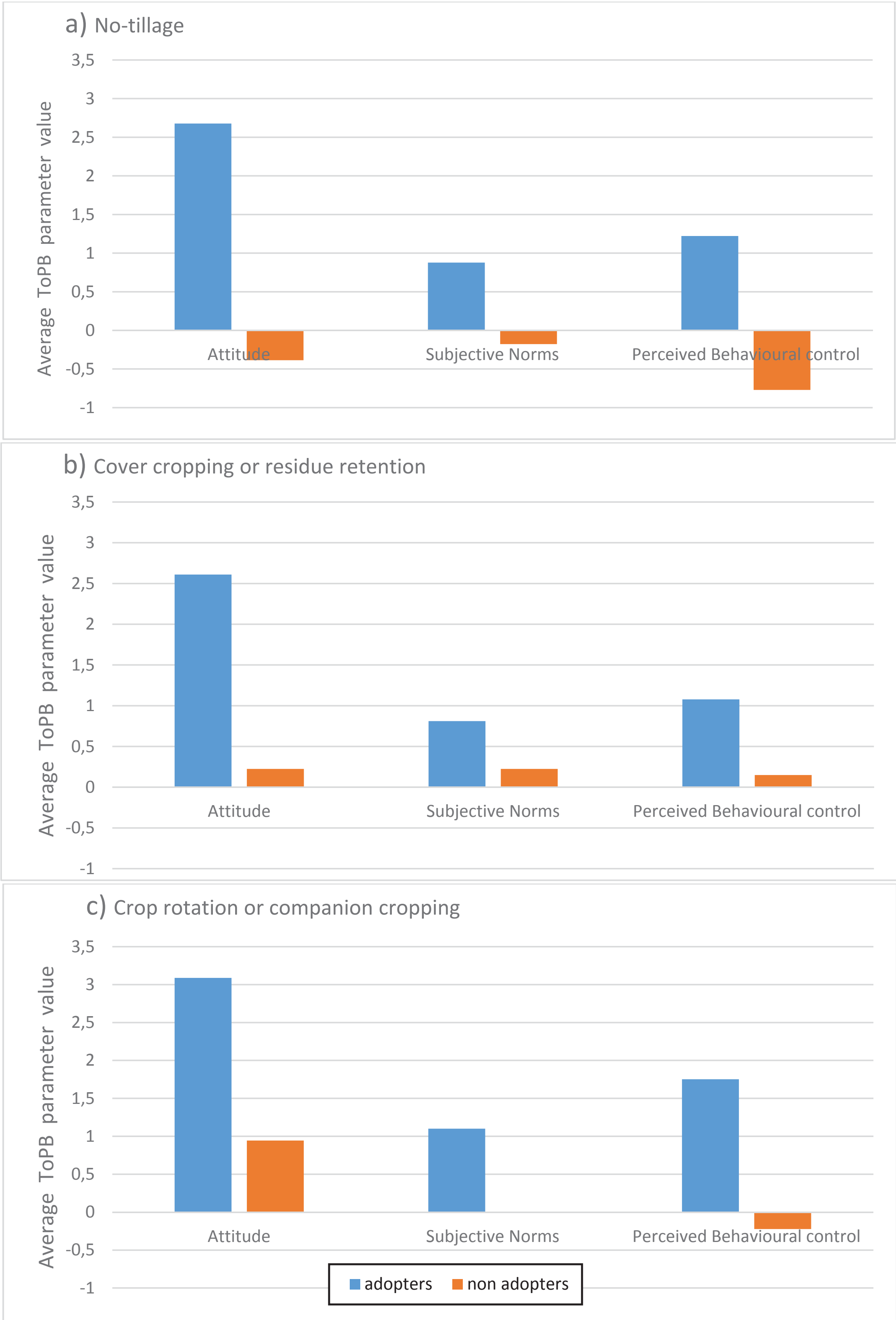


**Figure 7:** Theory of planned behaviour parameters on a scale of influence from -4 to 4 for a) no-tillage (N=46 adopters, 48 non-adopters), b) cover crops or residue retention (N=77 adopters, 20 non-adopters), and c) crop rotation or companion cropping (N=85 adopters, 8 non-adopters). Positive values signify the parameter encourages the adoption of the practice and negative values signify the parameter discourages the adoption of the practice. The further from zero, the stronger the influence on farmers' decision making.

### *5.1.1. Motivational factors of conservation agriculture adoption*

Farmer interviews identified motivational factors behind farmer intentions to adopt CA. These were split into 8 sub-categories (appendix 8). When the sub-categories were classified as either behavioural, normative or control beliefs, all represented behavioural beliefs as they represent positive outcomes of the behaviour (Ajzen, 1985). Therefore, all motivational factors identified influence behaviour via attitude (Ajzen, 1991). This conforms to the finding that attitude is the most important factor influencing the use of CA via by the positive beliefs of adopters (table 4, Figure 7).

The motivational factors ranked the most important by survey respondents for at least one adopter group for one or more CA practice included "cutting costs", "reduction of pests and weeds" and "improvement of soil health" (figure 8). "Improvement of soil health" was ranked highly by survey respondents for all practices; the most important factor for long-term adopters for all CA principles, new adopters (using practices for under 10 years) for the first and second CA principles, and non-adopters for CA principles 2 and 3 (figure 8). This factor could be categorised as either economic or environmental due to its positive effects on productivity, whilst encompassing reduced erosion, increasing soil microorganism biodiversity and reducing fertilizer requirements (Montgomery, 2007). Therefore, follow-up question three (appendix 6) asked farmers if they believe this motivational factor was driven by a moral responsibility to improve the soil ecosystem or the want to increase crop productivity. The majority (14/19) of respondents explicitly commented that economics were the driver of wanting to improve soil health. However, many identify that environmental benefits come hand-in-hand with economic improvements. For example, "soil health is a win-win" and "it will make my business more sustainable both financially and environmentally" (follow-up question responses). This relates to a Brazilian study that found increased productivity, increased soil fertility were the most important motivations behind the adoption of sustainable practices (Leite et al., 2014). Therefore, the most important motivating factors can all be related to economics.

Survey adopters and non-adopters identified similar motivational factors for CA principle 2 (figure 8b). There is some disparity between survey farmers' groups for the use of no-tillage; "cutting costs" was highly ranked for the new and non-adopters, whilst "long-term productivity" and "(long term) reductions in pesticide/fertilizer use" were more important for farmers who had used no-tillage for at least 10 years (figure 8a). It has been shown that people undervalue events in the future compared to benefits they can experience imminently (Soman *et al.*, 2005). Thus, the differences may be because long-term adopters may have started to experience these benefits and value them highly, whereas new and non-adopters discount the long-term outcomes' importance as they regard them future benefits.

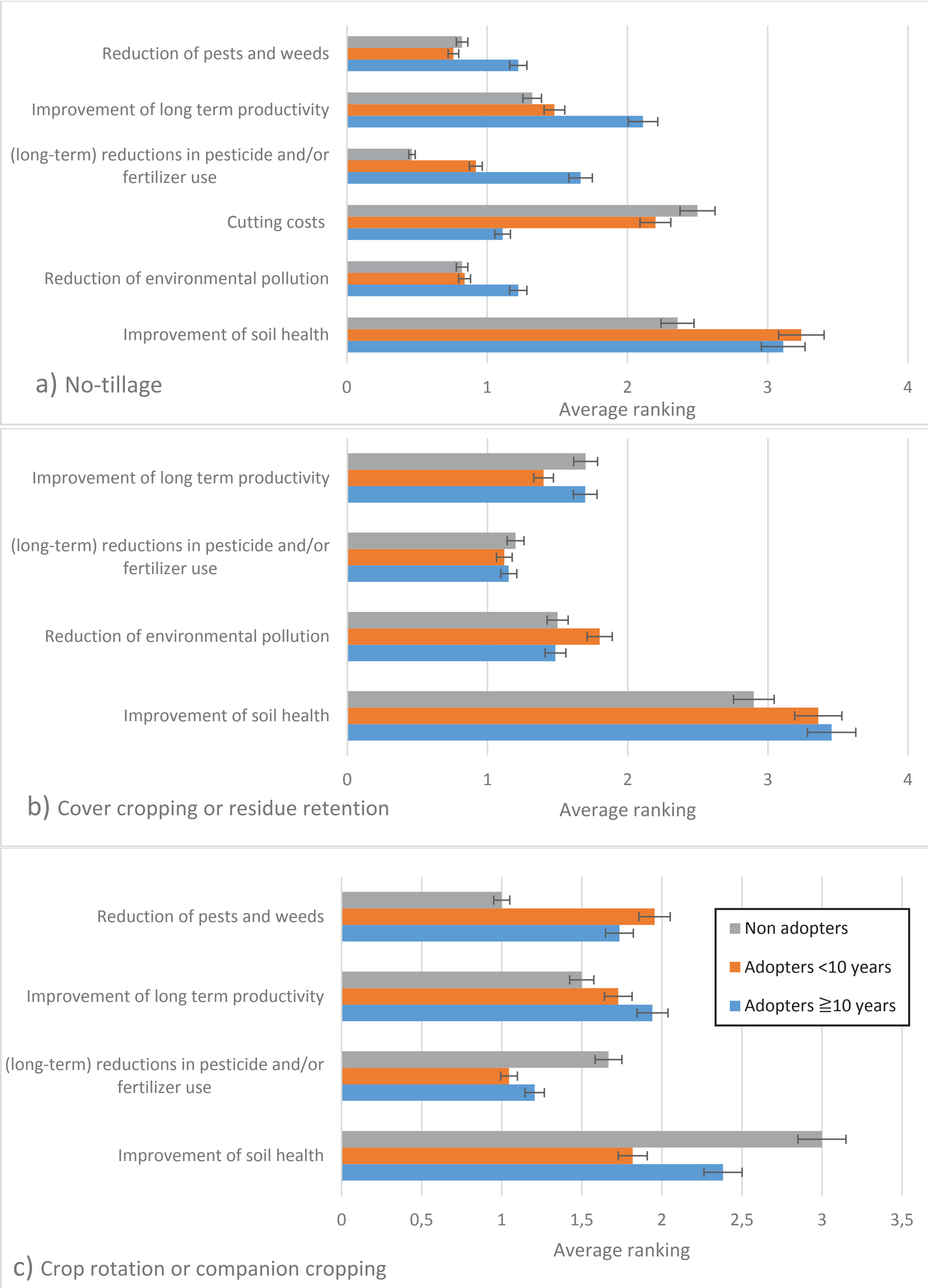


**Figure 8:** survey respondents' average ranking values of the three most important motivational factors for each adopter group. Ranked from 0 to 4. The higher the average ranking, the more it is perceived to relatively influence the decision to adopt a) no-tillage (N=25 new adopters, 9 long-term adopters, 28 non-adopters), b) cover cropping or residue retention (N=25 new adopters, 33 long-term adopters, 10 non-adopters), c) crop rotation or companion cropping (N=22 new adopters, 34 long-term adopters, 6 non-adopters). Error bars represent 5% error, if error bars overlap factors are assumed to be statistically the same

### *5.1.2. Challenging factors of conservation agriculture adoption*

Figure 9 presents the sub-categories of challenging factors that emerged from the focus group analysis, showing that “insufficient knowledge/research” and “expensive (initial) costs” were identified by all four groups (figure 9). Survey respondents also regarded “lack of adequate information/research” to be important, especially new adopters whom ranked it 2nd for principles 2 and 3, and 3rd for principle 1 (figure 10). “Expensive (initial) costs” was within the top four important factors for each of the practices by at least one adopter group (figure 10). A meta-analysis of USA management strategy adoption studies also demonstrated that the most important variables influencing adoption were the quality and accessibility of information and financial capacity (Baumgart-Getz, Prokopy, & Floress, 2012). There is some disparity between survey adopter groups; for crop rotations or companion cropping, “expensive (initial) costs” is the second most important factor for non-adopters and the sixth most important for the adopter groups (figure 10c). This suggests a knowledge-gap between adopters and non-adopters or a difference in priorities. Long-term adopters of no-tillage did not consider “expensive (initial) costs” as important, possibly because costs of no-tillage are mainly buying a new seed drill at the start, which was over 10 years ago for this group.

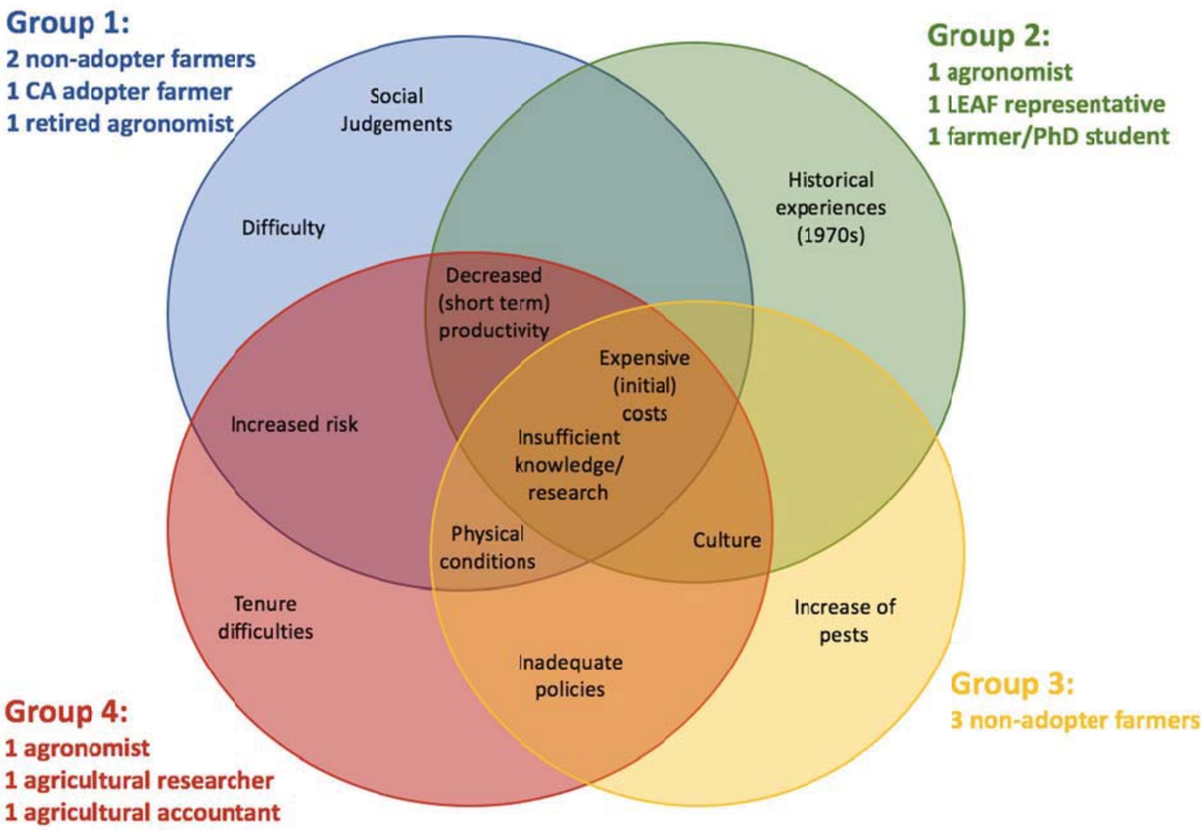


**Figure 9:** Venn diagram representing the categories that emerged from the focus groups

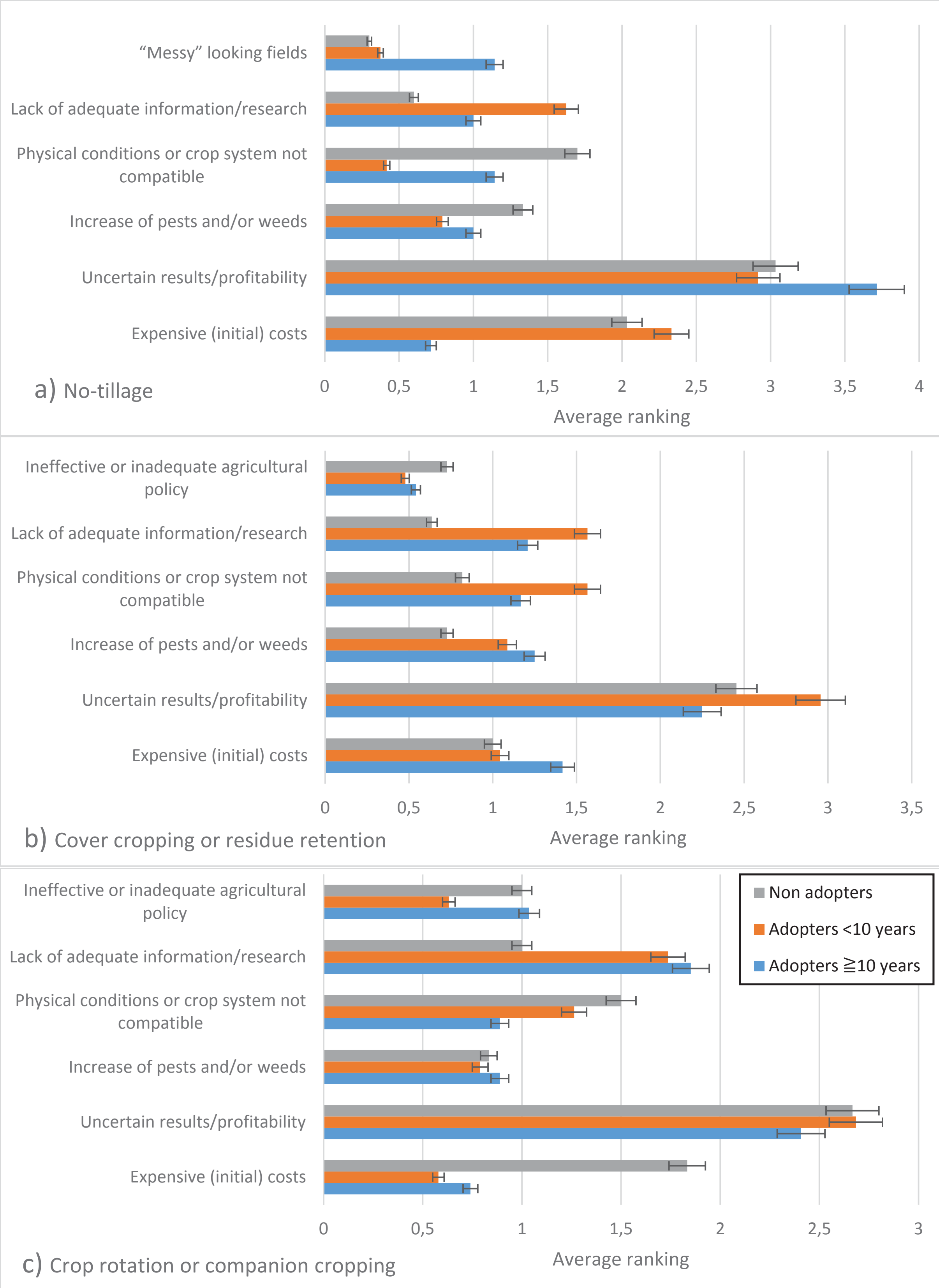


**Figure 10:** survey respondents' average ranking values of the four most important challenging factors for each adopter group. Ranked from 0 to 4. The higher the average ranking, the more it is perceived to relatively influence the decision to adopt a) no-tillage (N=24 new adopters, 7 long-term adopters, 30 non-adopters) , b) cover cropping or residue retention (N=23 new adopters, 24 long-term adopters, 11 non-adopters) c) crop rotation or companion cropping (N=19 new adopters, 27 long-term adopters, 6 non-adopters). Error bars represent 5% error, if error bars overlap factors are assumed to be statistically the same.

Three of the focus groups identified that culture was an important barrier, which included quotes such as “for the older generation ploughing was the norm and the only known way” (group 2). This relates to how agricultural sustainability had not been a priority in the past, especially in the case of soil sustainability (Ingram, 2008). In the 1970s-80s, the EU Common Agricultural Policy even encouraged increased cultivation with heavier machinery, less crop rotations and the ploughing up of pasture in the name of intensification and economic growth (Ingram, 2008). Focus group 2 mentioned historical experiences as a barrier as many farmers tried no-tillage and minimum tillage in the 1970s, only to experience unforeseen problems with weeds and yield declines (Lahmar, 2010). Rather than incorporating no-tillage in parallel with cover cropping or residue retention and having diverse crop rotations, farmers burned straw stubble on the fields to kill weeds, which led to nutrient reduction, nitrogen lock-up and pollution (Knight *et al.*, 2012; Lahmar, 2010). When straw burning was banned farmers reverted to the plough to avoid weed problems (Knight *et al.*, 2012); thus demonstrating the importance of incorporating all three CA principles to create a balanced system.

The focus group factors were divided into the broad categories “economic”, “practical”, “knowledge”, “political” and “social”. These categories, aside from “political”, also arose from the interview data (appendix 9). Excluding “social” as it was not used in survey rankings, “knowledge” had a relative importance of 45%, “economics” 31%, “political” 14% and “practical” 10% for survey respondents. This is similar to a Brazilian study that found a combination of lack of knowledge, lack of technical support and lack of adequate information were barriers to CA adoption (Leite *et al.*, 2014).

The sub-categories of challenges that emerged from the interview data analysis were also classified as behavioural, normative or control beliefs to assign the factors that correspondent ToPB parameters. No normative beliefs were classified, which corresponds to the relative unimportance of SN demonstrated in table 4. Five factors were classified as behavioural beliefs, associated with attitude (table 5). However, “uncertain results/profitability”, “(short term) increase in fertilizer use” and “increase of pests/weeds” could also be related to PBC as they have economic and practical implications that could make the adoption of CA more difficult. Figure 10 demonstrates that “uncertain results/productivity” is the most important challenging factor for all survey adopter groups for all three CA principles. Triangulating this with the interview data, it seems that this may predominantly be due to worries concerning yield; identified by interviewees 1, 2, and 4. KE2 said “There is a perception that you will suffer three years yield deficit from getting into non-plough situations. That's a big fear; that effects the farmers bottom line". Perhaps this is why CA adopters interviewed all identified a trigger point when they realised their previous farming system had problems that ultimately impacted their long-term yields. For example, Interviewee 1 had problems with resistant grass weeds and interviewee 5 had seen a significant decline in soil structure. Whilst, Interviewee 2 had experienced seven years of stagnating yields and was using increased volumes of fertilizer each year to achieve the same output.

**Table 5:** Classifications of the challenging factors from farmer interviews into behavioural or control beliefs. Bold demonstrates the most important factors shown in figure 10.

| Behavioural beliefs | Control beliefs |
|---|---|
| **Messy looking fields** | **Ineffective/inadequate agricultural policy** |
| Don't see a need to change practices | Changes in labour requirements |
| **Uncertain results/profitability** | Lack of control/security in tenure agreements |
| (Short term) increase in fertilizer use | **Incompatibility with physical conditions** |
| **Increase of pests/weeds** | **Lack of adequate information** |
| | **Expensive (initial) costs** |

From the control beliefs (table 5), which represent factors driving PBC, "incompatibility with physical conditions", "lack of adequate information" and "expensive (initial) costs" were considered within the top four important challenging factors by survey respondents (figure 10). Inadequate policy was also identified as 3rd most important by long-term adopters for crop rotations or companion cropping (figure 10). As PBC can correspond to actual behavioural control (Ajzen & Madden, 1986), it can be assumed that costs, inadequate information and physical conditions are barriers to CA adoption even if farmers had the intention to adopt. A challenging physical condition, readily identified by interviewees and the focus-group, was heavy clay soils. Interviewee 5 discussed that his light soil fields had not suffered any yield loss, whereas his heavy clay fields required an average of 10% more fertilizer in the first five years to keep yields as standard. A Brazilian study similarly found that farms with better soil conditions were more likely to adopt sustainable agriculture technologies (De Souza Filho, Young, & Burton, 1999). However, it is interesting to note that I found no significant correlation between soil type and adoption of CA practices from the survey analysis. Therefore, despite it being considered a challenge, heavy clay soils are not enough of a barrier to prevent the adoption of CA.

## 5.2. Quality, accessibility and relevance of conservation agriculture information

This section aims to answer RQ2 by identifying the relevance, reliability and quality of information on CA. Insufficient information was distinguished as a crucial challenging factor for farmers; this was identified by all focus groups, recognised as important by survey respondents, and survey analysis presented "knowledge" as having the highest relative importance of broader categories. Moreover, the most influential challenging factor for all adopter groups and all CA practices was "uncertain results/profitability" (figure 10). This relates to the diffusion of innovations theory, which states that the slow initial adoption rate is due to lack of information and high levels of uncertainty, which is reduced as more actors adopt the innovation, thus producing more practical experiential information on it (Rogers, 2010). This relates to Interviewee 1 and 5's comments on the self-taught trial and error period where farmers need to test how best to use CA with their specific soil and climate types. This may explain the large difference in PBC between adopters and non-adopters, especially for principles 1 and 3 (figure 7). The smaller difference in PBC for cover cropping or residue retention reflects past research showing similar PBC values between adopters and non-adopters for cover crops (Wauters *et al.*, 2010). Moreover, different conservation behaviours (e.g. hedge management and tree planting) that are more homogeneous in their ability to be implemented across differing soil and climate types, are affiliated with similar PBC values for adopters and non-adopters (Beedell & Rehman, 1999; Wauters *et al.*, 2010). The difference in attitude between adopters and non-adopters is also likely partially due to this, as non-adopters are not fully aware of the outcomes the practices will have on their farm. This is supported by Ingram (2008), whom found that English farmers using sustainable soil management practices, such as reduced tillage, understood the health of their soil better than non-adopters. This knowledge-gap, demonstrated by farmer uncertainty of results and between adopters and non-adopters, is likely exacerbated by the main challenges identified from analysis of answers from follow-up question 2 (appendix 6). These are: lack of relevant research; poor accessibility of information; and unreliable information.

The accessibility of research for farmers was identified by famer interviewee 2, whom commented that "I don't understand a lot of the research and don't want to spend time going into lots of detail" and "research doesn't filter through to farmers". This was identified during the knowledge exchange interviews, which stressed the importance of "getting the scientific document to some alive" (KE2), "making research meaningful and practical" (KE1). This reflects Goodwin (2014), who stresses the need for practical demonstrations of no-tillage in England.

Unreliability of information also emerged from farmer interview and follow-up question analysis. There seemed to be a worry that new adopters will fall prey to corporate companies that do not prepare them for the challenges and sell products that are not suited to their farm's conditions. For example, "my worry is a new convert get sold unsuitable products by a hungry supply industry", "quality of that info may be compromised due to commercial interest" and "most research and trials are funded by chemical and machinery companies"(follow-up question responses). KE3 mentioned that many agronomy days have salesmen presenting experiments that are not statistically verified, "but the farmers are often quite enthusiastic because having a silver bullet is always a nice thing". This is likely to cause a farmer to have unforeseen difficulties, which can give CA a "bad reputation because a couple of farmers had a bad experience as they've been sold the wrong product"(KE2). This may dissuade other famers from adopting CA as the analysis showed there to be a lot of farmer-farmer knowledge exchange. Interviewees 1 to 4 all described this: "if your neighbours got something you keep an eye on it" (interviewee 4), "there is not a great deal of people doing CA so anyone who is doing it in their area is being looked at as sharp as a hawk" (interviewee 2).

Perhaps farmers rely on watching and talking to other farmers due to the lack of relevant research that would help farmers understand the likely results CA would have on their farm. Interviewees 1 and 5 both commented how there is "no effective research on CA in the UK" (interviewee 5), so they often rely on research from America and Australasia. CA researcher, KE3, confirmed that there are no "zero till research resources around the UK at all". KE2 said "researchers have a habit of wanting funds to research things that they'd like but they haven't been out to a farmer group to ask what they'd like to be researched", whilst KE3 explained that it is very difficult to get CA funding as "in terms of the big research funding councils, agriculture falls between remits" and DEFRA funding was "cut in 2007 for applied agriculture". Answers to follow-up question 2 (appendix 6) further expressed that there is "not being enough information covering different regions/soil types/rainfall patterns to encourage people to see how it could work for them". A study on the adoption of CA in Nepal showed that researchers portraying formalized general information were not as accurate in predicting CA outcomes than local farmers, whom understood the implications of local conditions through experiential learning (Halbrendt *et al.*, 2014). This suggests that informal, but locally relevant, information can provide farmers with less uncertainty of the results CA will reap on their farm in comparison to more professional, but less locally applicable, research. This is likely due to the heterogeneous conditions of different farms (Knight et al., 2012), which can alter the outcomes of CA practices. During the interview, KE1 commented that "Research has to be replicated and at a certain level that it takes time.” “With our monitor farms, […] farmers can see one on the same soil type and how they’ve got on” and “there is a role for both”. Govaerts *et al.* (2009) suggests that traditional modes of research and extension will not work for the complex, multicomponent nature of CA, instead recommending systems that can adapt the technologies to local conditions.

A lot of locally relevant information on the benefits and challenges of CA is farmer driven. For example, interviewee 5 gives many talks, holds visits and even founded the organisation CA-UK. Interviewee 1 also commented that “there are more and more trusted networks about CA” and how the use of social media has allowed more rapid knowledge sharing. However, my research found that there is also a great deal of competition between farmers, which may reduce successful adoption of others. Interviewee 2 admitted that “I won’t tell people something that will commercially benefit me” and a follow-up question response said “Farmers will adopt CA if they can see it being done well. I hope they don't, I hope they fail, this will allow me to make more money farming more acres!”.

Overall 32% of survey respondents ranked the effectiveness of farmer-to-farmer knowledge exchange concerning CA as very good or excellent, compared to just 6% for knowledge exchange between farmers and researchers (figure 11). Survey respondents that adopted all three CA principles believed there to be better knowledge exchange. Whereas all survey respondents that did not adopt any of the CA principles did not rank knowledge exchange higher than “good” for either category. This indicates that adopters and non-adopters may have access to differing knowledge channels concerning CA. Baumgart-Getz *et al.* (2012) demonstrated that being part of a local network of farmers or a farming agency greatly increase the adoption of sustainable management practices in North America. Follow-up responses indicated that farmers must actively search for information on CA, for example being committed enough to pay to become a member of an organisation (e.g. BASE UK) to receive CA information.

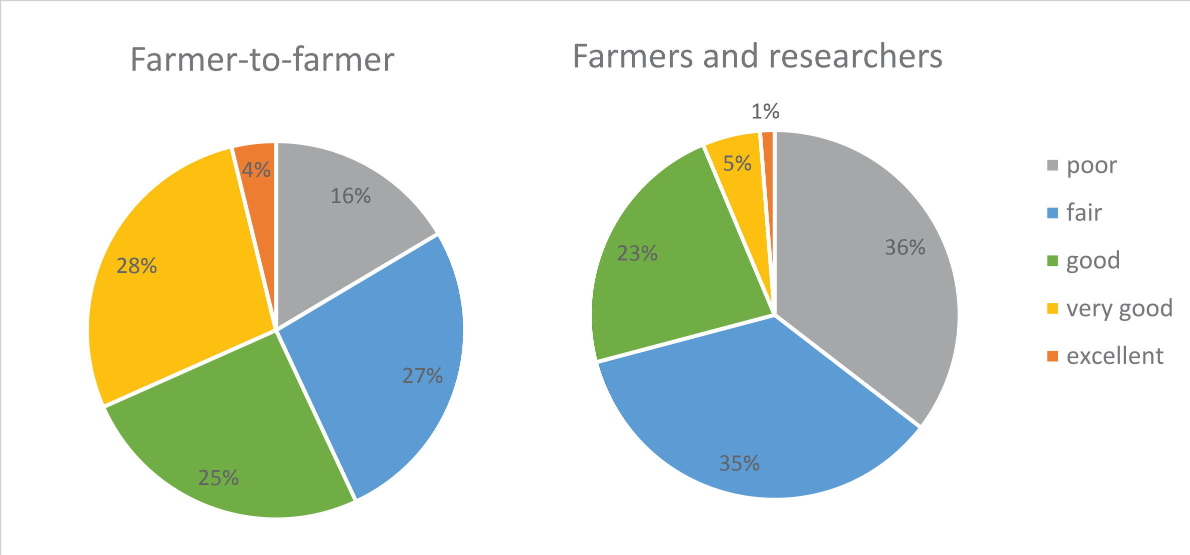


**Figure 11:** percentage of survey responses when asked how effective knowledge exchange was concerning CA. (N=79)

It became evident when interviewee 3 defined CA as "maintaining numbers of wildlife", that the use of the word "conservation" can confuse CA practices with wildlife conservation techniques, such as hedge rows and grass margins. The broad use of the term "conservation" and the pre-existence of unrelated agricultural conservation strategies means that the name "conservation agriculture" can be ambiguous. Yet, it is unclear whether this affects the generation, dissemination and understanding of information on CA. It was also apparent that non-adopters seem to regularly confuse no-tillage with minimum tillage. Minimum tillage (a form of conservation tillage) still degrades the soil and can increase weed outbreaks (Reicosky, 2015), as explained in part 2.1. This may explain negative behavioural beliefs and the increased importance given to "increase of pests/weeds" for no-tillage from non-adopters. However, this is unsurprising seeing as even peer-reviewed literature is seen to confuse conservation tillage with no-tillage, such as D'Emden, Llewellyn, and Burton (2006) reviewing and relating the outcomes of conservation tillage to the study of no-tillage adoption.

### 5.3. A helping or hindering political environment?

The perceptions of how the political environment influences the adoption of CA is discussed in this section in answer to RQ3. A "political" category emerged from focus groups in response to why most farmers are not using CA, which included quotes such as "blanket regulation doesn't match the variability of farms" and "a fundamental reform of agricultural support is required". This was not brought up as a significant challenging factor by farmer interviewees. Yet, when explicitly discussed in the "political environment" section of the interview, farmer interviewees revealed that farmers believe that the political environment is not necessarily hindering CA, but is not helping its adoption either. This is due to the lack of policies encouraging CA (interviewee 5), while farm subsidies "stifle innovation and inflate land and machinery prices" (interviewee 2) and "erode the business acumen of the farm" (KE2).

There appears to be frustration amongst farmers that politicians seem unaware about farming practices despite having such an important role in shaping agriculture. A survey respondent suggested that "politicians haven't got a clue what goes on on farm" and another even said that "we had a DEFRA policy maker come to one of our cover crop days, he said he wished he had visited before writing the EFA cover crop policy". Farmers interviewed commented on this regarding CA: "policy makers don't really know what CA is" (interviewee 2), "they refuse to believe CA even exists" (interviewee 5), and "if the policy makers have their heads screwed on a little bit, I think they'll see CA as a good thing for the environment" (interviewee 1). This is reflected in quantitative survey analysis, as over 80% of farmers classified knowledge exchange on CA between farmers and policy makers as "poor" and the remaining classified it as only "fair" or "good". Of course, capturing policy maker perspectives would have allowed a more rounded understanding on this issue, however all policy makers that I contacted politely declined an interview. This in itself provides an example of how politicians seem more out the loop and less likely to get involved in the common dialogue, despite them being major stakeholders that influence the adoption of CA greatly.

A barrier that may be preventing policy makers to take a stronger stance for the transition to more sustainable agriculture is the involvement of private corporations. For example, a follow-up question response mentioned that CA "results in less fertiliser, chemical and diesel use plus tractors do far fewer hours and are needed less. So, none of the big farming companies want it to succeed". In North America, the private sector influence is described as "possibly the most severe barrier" for sustainable agricultural practices, due to their economic power in the food industry, giving weight behind their government lobbying to limit pro-sustainable policy (Rodriguez *et al.*, 2009, p. 67).

### *5.3.1. Glyphosate ban as the biggest threat to conservation agriculture*

Via farmer interviews, it became evident that a major political inhibiting factor to the adoption of CA was the potential ban of the herbicide, Glyphosate. Despite multiple studies confirming the evidence that glyphosate is non-carcinogenic for humans (Environmental Protection Agency, 2016), a re-evaluation of a study on mice in 1985, other (un-named) animal studies and an inclusive human DNA study were used by the International Agency for Research on Cancer (IARC) branch of the World Health Organisation (WHO) to classify glyphosate as "*probably carcinogenic to humans" (IARC, 2015).* Since then a different subdivision of the WHO opposed this, concluding that glyphosate is unlikely to pose a carcinogenic risk to humans (Environmental Protection Agency, 2016). Many stakeholders believe that the evidence against glyphosate is overly represented due to environmental organisations and the media pushing it; "NGOs like 'friends of the earth' or 'Greenpeace' or 'bug life' carry a disproportionate amount of weight to some of their evidence than from the science side" (interviewee 1) and "the BBC are behind them and they can share this fake data" (interviewee 2).

Farmer interviewees strongly protested that "if glyphosate gets banned, CA gets killed" (interviewee 1) as it "would make CA impossible in this country" (interviewee 2). This became a remerging theme throughout the research; identified by all qualitative research methods. Due to the emergence of this inhibiting factor, survey participants were asked how much a ban of glyphosate would impact their ability to use CA (no, slight, moderate, considerable, or total impact). 46% responded that it would cause considerable impact and 47% selected total impact in that it would be impossible to use CA. Not only was it indicated that it would be more difficult if glyphosate was banned, but many farmers mentioned how it would lead to environmentally worse practices. For example, interviewee 5 said "instead of using glyphosate, we'd have to use a cocktail of two or maybe three chemicals, so we'd have to put three times as much on". A survey respondent left a comment that "losing glyphosate would result in a huge disaster for our soil health, and that of the environment". Essentially, not only would a glyphosate ban prevent more farmers from adopting CA, it could revert those currently using CA back to unsustainable conventional practices. This again raises the debate of the sustainability of CA as, although it uses less agrochemicals in the long-term and has many environmental benefits, it remains reliant on a single agrochemical for its use in England. KE2 explains that "farmers do accept that being beholden to one active ingredient for their farming system is also undesirable because at some point we don't know what will happen with glyphosate; we might get resistance to it in a few years".

## 6.0. Implications of the research for encouraging future adoption of conservation agriculture in England

Here I present suggestions of ways to increase farmers' adoption of CA, at least so that it reaches a critical point in which the sustainable agricultural system becomes self-sustaining in accordance to the diffusions of innovations theory (Rogers, 2010). As attitude was the most significant predictor of adoption for all CA practices (table 4), it is important to increase non-adopters' attitudes to more strongly encourage them to adopt CA. Nevertheless, perceived behavioural control (PBC) was shown to be the main dissuading factor of CA principle 1 and 3 use for non-adopters (figure 7), thus it is also important to address perceived difficulty, perceived control and actual control of these practices to encourage the adoption of CA.

It was evident from the analysis that improvement of the relevance, reliability and accessibility of knowledge regarding CA could help encourage more farmers to adopt CA as well as enabling more successful use of it. Improving knowledge of positive outcomes is a potential way to increase non-adopters' attitudes to CA. This especially important as the benefits are often not visible, such as increases in soil microorganisms or improved nutrient availability (Carolan, 2006). To improve information generation and distribution, I firstly suggest that funding needs to become more available for CA studies in English conditions. Perhaps previous governmental funding though DEFRA could be re-established? Secondly, Studies should be designed after a dialogue with farmers to tailor towards practical and useful information for farmers. As KE2 explains, it should be a "two-way flow of farmer requirements at one meeting and in 12 months time the researcher delivers what they've done and get another steer again from the farmer coming back". An increase in reliable relevant data would add to the available information and reduce the reliance on information generated from corporations. Once research is available, it is important for it to be accessible and applicable for the farmers. KE2 suggested presenting a scientific paper "in the form of a webinar, roadshow presentations, YouTube video or demonstrations, […] it's just got to be better than 100 pages of text". Farmer and knowledge exchange interviews suggested that accessibility is improving, as knowledge exchange organisations are actively working to make data more accessible and practical. Rodriguez et al. (2009) described American change agents as unprepared for helping farmers transition to sustainable agricultural practices and blame farmer's reluctance to change for non-adoption. Contrary to this, I suggest that knowledge exchange organisations in England, such as those I interviewed, have a good understanding of farmer requirements and can guide effective knowledge exchange between researchers and farmers. Also, "scientists are getting more switched on about making useful, tailored things" (KE3). I further suggest that information should be presented in one place, making it easier for farmers to search for data and reducing the number of memberships a farmer needs to commit to. KE4 commented that if "you're getting lots of information from one or two different channels then you're much more likely to trust them".

I conduct this thesis via an individual agency perspective; assuming the agricultural sector can be changed by many individuals deciding to adopt CA. This provokes the structural-agency debate that has long been disputed within the social sciences (Carlsnaes, 1992). One position in this debate is that society is one entity, responsible for shaping human behaviour through norms and rules (structure)(Tan, 2011). This is opposed to society being shaped by a collection of individuals whom all possess the agency to plan, understand and execute their actions (agency)(Tan, 2011). It is now widely agreed that human agents and social structures are interrelated (Carlsnaes, 1992). For instance, CA adoption from increasing numbers of individuals will start to change the social structures such as norms and industrial structures. For example, a farmer in focus group one mentioned "now cover crops have become trendy" and interviewee 1 commented that the "enormous industry of cultivation equipment […] are having to change what they design". Social structure also influence individual actions as "structure is not external to individuals"(Giddens, 1984, p. 25). This is also discussed within the diffusion of innovations theory as norms and other system-level qualities can influence the spread of an innovation (Rogers, 2010).

A dramatic change to England's political, institutional and social structure will happen within the next few years as the UK leaves the EU, which will likely influence the adoption of CA. When farmers interviewed were asked how they believe Brexit will impact adoption of CA, many had mixed views. On the one hand, CA in England would lose the support that it currently has as a sustainable agricultural practice from the EU. Interviewee 1 said "CA would be driven forward faster and more effectively within the EU than out of it; there are a lot of people in Europe that really see the merits of it". Moreover, a loss of free trade within the EU could mean that English agriculture could be "competing with Brazil and America" (interviewee 5) in the European market, so farmers will "need to get more efficient" (interviewee 4). AHDB (2016, p. 5) states that "reduced access to the single market is one of the biggest risks facing the UK arable industry". Lahmar (2010), on the topic of globalization, mentioned that increased global competition could increase CA adoption as European farmers seek reduced costs and increased productivity. Similarly, if "subsidies go people will have to be a lot cleverer about the way they farm because they're going to have to cut costs" (interviewee 2) and "look at where they can lower their cost of production" (KE2). The political decision on the potential glyphosate ban would also greatly influence CA adoption rates, as outlined in the previous section. This demonstrates the importance of political changes in changing behavioural intentions and outcomes, thus political interventions can be important in shaping individuals to encourage further CA adoption (Coburn, 2016).

An important component of sustainability science is “finding out what decision-makers need” (Miller, 2013, p. 287). Thus, I provide political suggestions that could increase the adoption of CA in England. When farmer interviewees were asked what they thought could encourage more farmers to adopt CA, four believed that economics was most important. For example, interviewee 2 said “if farmers think they can get more money from it they’ll do it” and even interviewee 4, who is against CA, admitted that “if you had somebody offering you a lot of money to grow something different you would have to consider it”. Therefore, an effective political intervention could be to provide subsidies for farmers that use CA. This follows the result that the most important motivational factors relate to economics and a financial safety net could help to reduce fears of uncertain profitability and help to alleviate the challenge of “expensive (initial) costs”. This policy change would not require any radical reforms as it could fit into the existing common agricultural policy (CAP) structure. CAP payment schemes are divided into two pillars; pillar one for income support and pillar two for environmental subsidies to decrease land pollution and degradation (Helm, 2016). Interviewee 1 explained how CAP could “include CA as a way to access the pillar 2 subsidies”. Subsidy systems have been successful before in England for conservation techniques. For example, the countryside stewardship scheme, designed to preserve wildlife and the landscape though the adoption of techniques including grass margins and hedgerows, has shown potential to change farmer attitudes to be more conservation-orientated (Wilson & Hart, 2001). Subsidies can provide a financial safety net to help reduce farmer fears of uncertainty or decreased yields in the first few years and help with initial expensive costs, which were indicated as challenges for all three CA principles.

## 7.0. Conclusion

I believe I have successfully captured an understanding of what influences English arable farmers' decisions to adopt CA or not. My main findings are that attitude is the most influential ToPB parameter for the decision to adopt CA or not. This is mainly driven by the positive attitudes of adopters, which is predominantly motivated by the economic-related factors to improve soil health, reducing pests and/or weeds and cut costs. Attitude was reduced by the behavioural beliefs that CA causes messy fields, increases pests and/or weeds and, more importantly, reaps uncertain results and/or profitability. PBC was most important in dissuading non-adopters for CA principles 1 and 3, which was due mainly to financial costs, incompatibility with physical conditions and inadequate information. Information was described as inadequate due to its lack of relevance, unreliability and poor accessibility.

I follow my results with suggestions as to how this can be improved, for example through policy changes. Nevertheless, I am not optimistic that these policy changes will be enforced as policy makers were perceived to be removed from farmers and CA. KE3 had a similar view, saying that "Brexit does provide opportunities, but […] I think they [DEFRA] will just copy and paste what was done previously". Despite this, there seems to be movement in a positive direction without the help of policy, as farmers seems to "care more about the environment" (interviewee 2), are "more aware of soil" (KE4), whilst "scientists are getting more switched on" (KE3) and CA is "becoming more and more accepted" (interviewee 5).

As my study is based on perceptions, future research should aim to back up my findings by researching barriers using observational or experimental methods, rather than via behavioural analysis. It would further be important to understand why there is a high level of uncertainty, what types of information farmers are lacking and further understandings of agrochemical use within CA. As previous studies have noted that farmers can begin to adopt CA practices but later stop or not commit to them continuously (Hobbs, 2007; Lahmar, 2010), it would be interesting to see if the drivers of this correlate to my results.

## 8.0. References


AHDB. (2016). *What might Brexit mean for UK trade in cereal and oilseed products?* Retrieved from: http://www.ahdb.org.uk/brexit/documents/CO_bitesize.pdf

Ajzen, I. (1985). From intentions to actions: A theory of planned behavior *Action-control: From cognition to behavior* (pp. 11-39): Springer Berlin Heidelberg.

Ajzen, I. (1991). The theory of planned behavior. *Organizational behavior and human decision processes, 50*(2), 179-211.

Ajzen, I. (2011). The theory of planned behaviour: reactions and reflections. *Psychol Health, 26*(9), 1113-1127. doi:10.1080/08870446.2011.613995

Ajzen, I., & Madden, T. J. (1986). Prediction of goal-directed behavior: Attitudes, intentions, and perceived behavioral control. *Journal of Experimental Social Psychology, 22*(5), 453-474.

Bailey, A. S., Bertaglia, M., Fraser, I. M., Sharma, A., & Douarin, E. (2009). Integrated pest management portfolios in UK arable farming: results of a farmer survey. *Pest management science, 65*(9), 1030-1039.

Baumgart-Getz, A., Prokopy, L. S., & Floress, K. (2012). Why farmers adopt best management practice in the United States: a meta-analysis of the adoption literature. *J Environ Manage, 96*(1), 17-25. doi:10.1016/j.jenvman.2011.10.006

Beedell, J. D. C., & Rehman, T. (1999). Explaining farmers' conservation behaviour: Why do farmers behave the way they do? *Journal of Environmental management, 57*(3), 165-176.

Beheydt, D., Boeckx, P., Ahmed, H. P., & Van Cleemput, O. (2008). N2O emission from conventional and minimum-tilled soils. *Biology and Fertility of Soils, 44*(6), 863-873. doi:10.1007/s00374-008-0271-9

Borges, J. A. R., Foletto, L., & Xavier, V. T. (2015). An interdisciplinary framework to study farmers decisions on adoption of innovation: Insights from Expected Utility Theory and Theory of Planned Behavior. *African Journal of Agricultural Research, 10*(29), 2814-2825.

Bryman, A. (2006). Integrating quantitative and qualitative research: how is it done? *Qualitative research, 6*(1), 97-113.

Bryman, A. (2012). *Social Research Methods* (4th ed.). Oxford: Oxford University Press.

Burton, M., Rigby, D., & Young, T. (1999). Analysis of the determinants of adoption of organic horticultural techniques in the UK. *Journal of Agricultural Economics, 50*(1), 47-63.

Burton, R. J. F. (2004). Reconceptualising the 'behavioural approach' in agricultural studies: a socio-psychological perspective. *Journal of Rural Studies, 20*(3), 359-371. doi:10.1016/j.jrurstud.2003.12.001

CA-UK. (2016). Why conservation Agriculture? *Making Sustainable Agriculture Real.* Retrieved from http://www.conservation-agriculture.co.uk/our-story/why-conservation-agriculture/

Carlsnaes, W. (1992). The agency-structure problem in foreign policy analysis. *International Studies Quarterly, 36*(3), 245-270.

Carolan, M. S. (2006). Do You See What I See? Examining the Epistemic Barriers to Sustainable Agriculture. *Rural Sociology, 71*(2), 232-260. doi:10.1526/003601106777789756

Clark, W. C. (2007). Sustainability Science: A room of its own. . *Proceedings of the National Academy of Sciences, 104*(6), 1737. doi:0.1073/pnas.0611291104

Clark, W. C., & Dickson, N. M. (2003). Sustainability science: the emerging research program. *Proc Natl Acad Sci U S A, 100*(14), 8059-8061. doi:10.1073/pnas.1231333100

Coburn, C. E. (2016). What's policy got to do with it? How the structure-agency debate can illuminate policy implementation. . *American Journal of Education, 122*(3), 465-475.

Crozier, J. (Ed.) (2006). HarperCollins Publishers.

D'Emden, F. H., Llewellyn, R. S., & Burton, M. P. (2006). Adoption of conservation tillage in Australian cropping regions: An application of duration analysis. *Technological Forecasting and Social Change, 73*(6), 630-647. doi:10.1016/j.techfore.2005.07.003

de Ruiter, H., Macdiarmid, J. I., Matthews, R. B., Kastner, T., & Smith, P. (2016). Global cropland and greenhouse gas impacts of UK food supply are increasingly located overseas. *J R Soc Interface, 13*(114), 20151001. doi:10.1098/rsif.2015.1001
De Souza Filho, H. M., Young, T., & Burton, M. P. (1999). Factors influencing the adoption of sustainable agricultural technologies: evidence from the State of Espírito Santo, Brazil. . *Technological Forecasting and Social Change, 60*(2), 97-112.
DEFRA. (2017). *Agricultural facts. England Regional Profiles.* . Retrieved from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/583682/regionalstatistics_overview_170117.pdf
Derpsch, R., Franzluebbers, A. J., Duiker, S. W., Reicosky, D. C., Koeller, K., Friedrich, T., . . . Weiss, K. (2014). Why do we need to standardize no-tillage research? *Soil and Tillage Research, 137*, 16-22. doi:10.1016/j.still.2013.10.002
Drost, D. (1996). Barriers to Adopting Sustainable Agricultural Practices. *Journal of Extension, 34*(6), n6.
EFRAC. (2015). *Food security: demand, consumption and waste*. Retrieved from London
Environmental Protection Agency, U. S. (2016). *Glyphosate Issue Paper: Evaluation of Carcinogenic Potential*. Retrieved from https://www.epa.gov/sites/production/files/2016-09/documents/glyphosate_issue_paper_evaluation_of_carcincogenic_potential.pdf
FAO. (n.d.). *Conservation agriculture: conserving resources above and below the ground*. Retrieved from http://www.fao.org/ag/ca/doc/2NRCEconservationAG.pdf
Federation, E. C. A. (2014). What is Conservation Agriculture? *Conservation agriculture.* Retrieved from http://www.ecaf.org/ca-in-europe/what-is-ca
Friedrich, T., Karami, E., & Sayre, K. (2009). *Conservation Agriculture*. Retrieved from
Garnett, T., Appleby, M. C., Balmford, A., Bateman, I. J., Benton, T. G., Bloomer, P., . . . Fraser, D. (2013). Sustainable Intensification in Agriculture: Premises and Policies. *Science, 341*(6141), 33-34.
Giddens, A. (1984). *The constitution of society: Outline of the theory of structuration*: University of California Press.
Goodwin, R. J. (2014). *Potential of "No-till" Systems for Arable Farming*. Harper Adams University, London
Govaerts, B., Verhulst, N., Castellanos-Navarrete, A., Sayre, K. D., Dixon, J., & Dendooven, L. (2009). Conservation Agriculture and Soil Carbon Sequestration: Between Myth and Farmer Reality. *Critical Reviews in Plant Sciences, 28*(3), 97-122. doi:10.1080/07352680902776358
Greenhalgh, T., Robert, G., Macfarlane, F., Bate, P.,, & Kyriakidou, O. (2004). Diffusion of innovations in service organizations: systematic review and recommendations. *Milbank Quarterly,, 82*(4), 581-629.
Gur-Arie, M. (2010). Diffusion of EHR Innovation. *On Hearlth Care Technology.* Retrieved from http://onhealthtech.blogspot.se/2010/09/diffusion-of-ehr-innovation.html
Halbrendt, J., Gray, S. A., Crow, S., Radovich, T., Kimura, A. H., & Tamang, B. B. (2014). Differences in farmer and expert beliefs and the perceived impacts of conservation agriculture. *Global Environmental Change, 28*, 50-62. doi:10.1016/j.gloenvcha.2014.05.001
Hansson, H., Ferguson, R., & Olofsson, C. (2012). Psychological constructs underlying farmers' decisions to diversify or specialise their businesses–An application of theory of planned behaviour. *Journal of Agricultural Economics, 63*(2), 465-482.
Helm, D. (2016). *British Agricultural Policy after BREXIT*. Retrieved from http://www.dieterhelm.co.uk/assets/secure/documents/British-Agricultural-Policy-after-BREXIT.pdf
Hobbs, P. R. (2007). Conservation agriculture: what is it and why is it important for future sustainable food production? *The Journal of Agricultural Science, 145*(02), 127. doi:10.1017/s0021859607006892

Hobbs, P. R., Sayre, K., & Gupta, R. (2008). The role of conservation agriculture in sustainable agriculture. *Philos Trans R Soc Lond B Biol Sci, 363*(1491), 543-555. doi:10.1098/rstb.2007.2169

IARC. (2015). *IARC Monographs Volume 112: evaluation of five organophosphate insecticides and herbicides*. Retrieved from: https://www.iarc.fr/en/media-centre/iarcnews/pdf/MonographVolume112.pdf

Ingram, J. (2008). Are farmers in England equipped to meet the knowledge challenge of sustainable soil management? An analysis of farmer and advisor views. *J Environ Manage, 86*(1), 214-228. doi:10.1016/j.jenvman.2006.12.036

Jerneck, A., Olsson, L., Ness, B,, Anderberg, S., Baier, M., Clark, E., . . . Persson, J. (2011). Structuring sustainability science. *Sustainability Science, 6*(1), 69-82. doi:0.1007/s11625-010-0117-x

Kassam, A., Friedrich, T., Shaxson, F., & Pretty, J. (2009). The spread of Conservation Agriculture: justification, sustainability and uptake. *International Journal of Agricultural Sustainability, 7*(4), 292-320. doi:10.3763/ijas.2009.0477

Kates, R. W. (2011). What kind of a science is sustainability science? *Proc Natl Acad Sci U S A, 108*(49), 19449-19450. doi:10.1073/pnas.1116097108

Kates, R. W., Clark, W. C., Corell, R., Hall, J. M., Jaeger, C. C., Lowe, I., . . . Faucheux, S. (2001). Sustainability science. *Science, 292*(5517), 641-642.

Kiers, E. T., Leakey, R. R., Izac, A. M., Heinemann, J. A., Rosenthal, E., Nathan, D., & Jiggins, J. (2008). Agriculture at a crossroads. *Science, 320*(5874).

Kirchmann, H., Bergström, L., Kätterer, T., Andrén, O., & Andersson, R. (2009). Can organic crop production feed the world? *Organic crop production–Ambitions and limitations* (pp. 39-72). Netherlands: Springer

Knight, S., Kightley, S., Bingham, I., Hoad, S., Lang, B., Philpott, H., . . . Ball, B. (2012). *Desk study to evaluate contributory causes of the current 'yield plateau' in wheat and oilseed rape*. Retrieved from

Knowler, D., & Bradshaw, B. (2007). Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy, 32*(1), 25-48. doi:10.1016/j.foodpol.2006.01.003

Lahmar, R. (2010). Adoption of Conservation Agriculture in Europe. Lessons of the KASSA project. *Land use policy, 27*(1), 4-10.

Lal, R. (2004). Carbon emission from farm operations. *Environ International, 30*(7), 981-990. doi:10.1016/j.envint.2004.03.005

Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., . . . Thomas, C. J. (2012). Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustainability Science, 7*(S1), 25-43. doi:10.1007/s11625-011-0149-x

Leake, A. R. (2003). Integrated pest managemnet for conservation agriculture. In L. García-Torres, J. Benites, A. Martínez-Vilela, & A. Holgado-Cabrera (Eds.), *Conservation agriculture: environment, farmers experiences, innovations, socio-economy, policy*: Springer Netherlands.

Leite, A. E., De Castro, R., Jabbour, C. J. C., Batalha, M. O., & Govindan, K. (2014). Agricultural production and sustainable development in a Brazilian region (Southwest, São Paulo State): motivations and barriers to adopting sustainable and ecologically friendly practices. *International Journal of Sustainable Development & World Ecology, 21*(5), 422-429.

Lynne, G. D., Casey, C. F., Hodges, A., & Rahmani, M. (1995). Conservation technology adoption decisions and the theory of planned behavior. *Journal of economic psychology, 16*(4), 581-598.

MacLeod, M., Moran, D., Eory, V., Rees, R. M., Barnes, A., Topp, C. F. E., . . . Moxey, A. (2010). Developing greenhouse gas marginal abatement cost curves for agricultural emissions from crops and soils in the UK. *Agricultural Systems, 103*(4), 198-209. doi:10.1016/j.agsy.2010.01.002

Mayring, P. (2014). *Qualitative content analysis: theoretical foundation, basic procedures and software solution.* Klagenfurt, Austria: SSOAR.

McIntyre, B. D., Herren, H. R., Wakhungu, J., & Watson, R. T. (2009). *Agriculture at a Crossroads: International Assessment of Agricultural Science and Technology for Development Global Report.* Retrieved from Washington, DC: IAASTD: http://www.fao.org/fileadmin/templates/est/Investment/Agriculture_at_a_Crossroads_Global_Report_IAASTD.pdf

Miller, T. R. (2013). Constructing sustainability science: emerging perspectives and research trajectories. *Sustainability Science, 8*(2), 279-293. doi:0.1007/s11625-012-0180-6)

Miller, T. R., Wiek, A., Sarewitz, D., Robinson, J., Olsson, L., Kriebel, D., & Loorbach, D. (2014). The future of sustainability science: a solutions-oriented research agenda. *Sustainability Science, 9*(2), 239-246.

Montgomery, D. R. (2007). Soil erosion and agricultural sustainability. *Proc Natl Acad Sci U S A, 104*(33), 13268-13272. doi:10.1073/pnas.0611508104

Morris, C., & Potter, C. (1995). Recruiting the new conservationists: farmers' adoption of agri-environmental schemes in the UK. *Journal of Rural Studies, 11*(1), 51-63.

Morris, N. L., Miller, P. C. H., J.H.Orson, & Froud-Williams, R. J. (2010). The adoption of non-inversion tillage systems in the United Kingdom and the agronomic impact on soil, crops and the environment—A review. *Soil and Tillage Research, 108*(1-2), 1-15. doi:10.1016/j.still.2010.03.004

Nicholson, A. R., Wilkinson, M. E., O'Donnell, G. M., & Quinn, P. F. (2012). Runoff attenuation features: a sustainable flood mitigation strategy in the Belford catchment, UK. *Area, 44*(4), 463-469.

O'Bannon, C., Carr, J., Seekell, D. A., & D'Odorico, P. (2014). Globalization of agricultural pollution due to international trade. *Hydrology and Earth System Sciences, 18*(2), 503-510. doi:10.5194/hess-18-503-2014

Ockenden, M. C., Deasy, C., Quinton, J. N., Surridge, B., & Stoate, C. (2014). Keeping agricultural soil out of rivers: evidence of sediment and nutrient accumulation within field wetlands in the UK. *Journal of Environmental management, 135*, 54-62.

OECD. (2001). *Environmental Indicators for Agriculture: Methods and Results*. Retrieved from https://www.oecd.org/tad/sustainable-agriculture/40680869.pdf

Oxford English Dictionary. (2010). Oxford University Press.

Pandey, D., & Agrawal, M. (2014). Carbon footprint estimation in the agriculture sector. *Assessment of Carbon Footprint in Different Industrial Sectors* (Vol. 1, pp. 25-47). Singapore.

Pennings, J. M., Irwin, S. H., & Good, D. L. (1999). *Surveying Farmers: A Research Note*. Retrieved from https://www.researchgate.net/profile/Joost_M_E_Pennings/publication/23517450_Surveying_Farmers_A_Research_Note/links/0912f50aa428739d29000000.pdf

Pieri, C., Evers, G., Landers, J., O'Connell, P., & Terry, E. (2002). *No-till farming for sustainable rural development*. Washington, DC: International Bank for Reconstruction and Development, Rural Development Department.

Pittelkow, C. M., Linquist, B. A., Lundy, M. E., Liang, X., Van Groenigen, K. J., Lee, J., . . . Van Kessel, C. (2015). When does no-till yield more? A global meta-analysis. . *Field Crops Research., 183*, 156-168.

Powlson, D. S., Bhogal, A., Chambers, B. J., Coleman, K., Macdonald, A. J., Goulding, K. W. T., & Whitmore, A. P. (2012). The potential to increase soil carbon stocks through reduced tillage or organic material additions in England and Wales: A case study. *Agriculture, Ecosystems & Environment, 146*(1), 23-33. doi:10.1016/j.agee.2011.10.004

Pretty, J. (2008). Agricultural sustainability: concepts, principles and evidence. *Philos Trans R Soc Lond B Biol Sci, 363*(1491), 447-465. doi:10.1098/rstb.2007.2163

Reicosky, D. C. (2015). Conservation tillage is not conservation agriculture. *Journal of Soil and Water Conservation, 70*(5), 103A-108A. doi:10.2489/jswc.70.5.103A

Rodriguez, J. M., Molnar, J. J., Fazio, R. A., Sydnor, E., & Lowe, M. J. (2009). Barriers to adoption of sustainable agriculture practices: Change agent perspectives. *Renewable Agriculture and Food Systems, 24*(1), 60-71.
Rogers, E. M. (2010). *Diffusion of innovations* (fourth ed.). New York, NY: Simon and Schuster.
Sayer, A. (2000). *Realism and social science*. Wiltshire, UK: SAGE Publications.
Sayers, P., Horritt, M., Penning-Rowsell, E., McKenzie, A., Thompson, D., Klijn, F., & Samuels, P. (2016). *The analysis of future flood risk in the UK using the Future Flood Explorer.* . Paper presented at the 3rd European Conference on Flood Risk Management, E3S Web of Conferences 7.
Schaller, N. (1993). Sustainable agriculture and the environment: the concept of agricultural sustainability. . *Agriculture, Ecosystems and Environment 46*, 89-97.
Scopel, E., Triomphe, B., Affholder, F., Da Silva, F. A. M., Corbeels, M., Xavier, J. H. V., . . . De Tourdonnet, S. (2012). Conservation agriculture cropping systems in temperate and tropical conditions, performances and impacts. A review. *Agronomy for Sustainable Development, 33*(1), 113-130. doi:10.1007/s13593-012-0106-9
Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., . . . Smith, J. (2008). Greenhouse gas mitigation in agriculture. *Philos Trans R Soc Lond B Biol Sci, 363*(1492), 789-813. doi:10.1098/rstb.2007.2184
Smith, P., Milne, R., Powlson, D. S., Smith, J. U., Falloon, P., & Coleman, K. (2000). Revised estimates of the carbon mitigation potential of UK agricultural land. *Soil Use and Management, 16*(4), 293-295.
Snapp, S. S., & Borden, H. (2005). Enhanced nitrogen mineralization in mowed or glyphosate treated cover crops compared to direct incorporation. *Plant and Soil, 270*(1), 101-112.
Soman, D., Ainslie, G., Frederick, S., Li, X., Lynch, J., Moreau, P., . . . Wertenbroch, K. (2005). The psychology of intertemporal discounting: Why are distant events valued differently from proximal ones? *Marketing Letters, 16*(3), 347-360.
Steffen, W., Richardson, K., Rockström, J., Cornell, S. E., Fetzer, I., Bennett, E. M., . . . Folke, C. (2015). Planetary boundaries: Guiding human development on a changing planet. *Science, 347*(6223), 1259855.
Tan, S. (2011). Understanding the “Structure” and the “Agency” Debate in the Social Sciences. *Habitus, 1*, 37-50.
Tilman, D., Cassman, K. G., Matson, P. A., Naylor, R., & Polasky, S. (2002). Agricultural sustainability and intensive production practices. *Nature, 418*(6898), 671-677.
Tonglet, M., Phillips, P. S., & Read, A. D. (2004). Using the Theory of Planned Behaviour to investigate the determinants of recycling behaviour: a case study from Brixworth, UK. . *Resources, conservation and recycling,, 41*(3), 191-214.
Trewavas. (2001). Urban myths of organic farming. *Nature, 410*(409-410).
Triplett, G. B., & Dick, W. A. (2008). No-Tillage Crop Production: A Revolution in Agriculture! *Agronomy Journal, 100*(Supplement_3), S-153. doi:10.2134/agronj2007.0005c
UNESCO. (2012). *Managing Water under Uncertainty and Risk. The United Nations World Water development report.* Retrieved from http://unesdoc.unesco.org/images/0021/002156/215644e.pdf
Valente, T. W. (1995). *Network models of the diffusion of innovations.* (Second ed.). New Jersey: Hampton Press.
Van den Putte, A., Govers, G., Diels, J., Gillijns, K., & Demuzere, M. (2010). Assessing the effect of soil tillage on crop growth: A meta-regression analysis on European crop yields under conservation agriculture. *European Journal of Agronomy, 33*(3), 231-241. doi:10.1016/j.eja.2010.05.008
Varvel, G. E., & Wilhelm, W. W. (2011). No-tillage increases soil profile carbon and nitrogen under long-term rainfed cropping systems. *Soil and Tillage Research, 114*(1), 28-36. doi:10.1016/j.still.2011.03.005

Wauters, E., Bielders, C., Poesen, J., Govers, G., & Mathijs, E. (2010). Adoption of soil conservation practices in Belgium: An examination of the theory of planned behaviour in the agri-environmental domain. *Land use policy, 27*(1), 86-94. doi:10.1016/j.landusepol.2009.02.009
Weigel, F. K., Hazen, B. T., Cegielski, C. G., & Hall, D. J. (2014). Diffusion of innovations and the theory of planned behavior in information systems research: a metaanalysis. *Communications of the Association for Information Systems, 34*(1), 619-635.
Wilson, G. A., & Hart, K. (2001). Farmer Participation in Agri-Environmental Schemes: Towards Conservation-Oriented Thinking? *Sociologia ruralis, 41*(2), 254-274.
Zachariadis, M., Scott, S. V., & Barrett, M. I. (2013). Methodological Implications of Critical Realism for Mixed-Methods Research. *MIS quarterly, 37*(3), 855-879.

# Appendix 1: Calculation of percentage of farms using CA

The estimation that 8% of total arable farm land translates to approximately 8% to 14.6% of farms was calculated using the following:

From the total utilized arable agricultural area in 2010 (6,393,300ha[1]), 8% of that was calculated (511464ha). The proportional distribution of agricultural holdings by size was calculated (in %) using raw data[2]. From this, I distributed the number of ha of CA agriculture into each farm size group. Yet, at this stage I assumed there would be no farms using CA that were under the size of 10ha; this is backed up as approximately 99% of farms using conservation tillage or no-tillage were large enough to present an agricultural output exceeding €25000/ha[3] and the smallest CA adopter farm from the survey was 40.5ha. Thus, the number of ha of CA agriculture in the groups under 10ha ("0", "<2", "2-<5", "5-<10ha") were treated as part of the "10-<20" size group. A max and min number of farms in each size group was found by calculating how many farms the ha of CA would represent at each end of the range for the size group (i.e. for the "20-<30"ha group, the number of ha for that group was divided by 20 to get the max number of farms and divided by 30 to get the min number of farms within that group). All min values and all max values were added up separately and divided by the total number of UK holdings (186,800)[2] and multiplied by 100 to achieve a percentage value. This produced the values 8% (min) and 14,6% (max).

As the smallest CA adopter farm from the survey was 40.5ha, I could have also chosen to calculate this with the smallest farm size group being "20-<30"ha or "30-<50"ha. These represent the percentages of UK farms using CA as: 6.2%-9.4% ("20-<30"ha) and 4.9%-6.7% ("30-<50"ha). Even using these different calculations, the framing of my thesis would remain the same as these all fall within the "early adopters" group in the diffusions of innovations theory. I chose to choose the calculation for "10-<20"ha as the smallest farm group to keep it closest to the UK proportional distribution.

---

[1] Eurostat (2013, September 3) *Table Utilised Agricultural Area by land use UK 2000 and 2010.* Retrieved from: http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Table_Utilised_Agricultural_Area_by_land_use_UK_2000_and_2010.PNG

[2] Eurostat (2013, October 28) *Agricultural holdings, by size of holding, 2010 (number of holdings)* Retrieved from: http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Agricultural_holdings,_by_size_of_holding,_2010_(number_of_holdings)_AgriPB13.png

[3] Eurostat (2013, July 9) Arable land *on which conservation and zero-tillage is practised by size of holding in SO.* Retrieved from: http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Arable_land_on_which_conservation_and_zero-tillage_is_practised_by_size_of_holding_in_SO,_EU-27,_NO,_IS,_CH,_HR_and_ME,_2010.png

## Appendix 2 - Letter of consent for interviews

**Letter of consent**

**Description and procedure**

You are invited to participate in a study conducted by Alice Roberts for her master's Thesis at Lund University. This study aims to research the factors that influence farmers' decision to adopt conservation agriculture or not and whether it is likely for conservation agriculture to become more widely adopted.

The interview will likely take approximately one hour to complete, however this may differ depending on the flow of the interview.

Unfortunately, I do not receive any funding for this research and so am unable to compensate you financially for your time, however you can receive a copy of the finished thesis if you would like.

**Rights**

With your consent, the interview will be recorded and transcribed at a later date. Once transcribed the original recording will be deleted. The raw data (recorded and transcribed interview) will only be accessible to Alice Roberts, her thesis supervisors and selected peers at Lund University and Rothamsted Research. The raw data will not be published or shared with secondary users (e.g. other researchers). Analysed data, short quotations and results will be public. Primarily via Lund University publishing Alice Roberts' master's thesis online and in print, and also possibly published later in a scientific journal and presented during presentations.

Your participation in this study is voluntary and you have to right to refrain from answering any of the questions and can terminate the interview at any time. You may also withdraw from this study at any time before 12th May 2017 and your responses will be deleted and not included in the study.

You will be kept anonymous unless otherwise stated, however the county you farm in and other information you provide may be published so it may be possible for you to be identified through these parameters.

**Questions**

If you have any questions regarding the research, please feel free to contact me via phone (*contact details removed for publication*) or email (*contact details removed for publication*). Your contact details will not be shared.

--------------------------------------------------------------------------------------------------------

I give consent for myself to be recorded during the interview: Yes: ☐ No: ☐

I give consent for myself to be named in the publication: Yes: ☐ No: ☐

I understand the information provided above and consent to participate in this interview.

-----------------------------------------------------------

Participant's Name *(in Print)*

-----------------------------------------------------------   ------------------

Participant's Signature   Date

# Appendix 3 – Farmer interview questions

## Part 1 – Household and farm characteristics

1) What is your farm size in acres?
2) What is your farming system?
3) How long have you been farming for?
4) How old are you?
5) Do you own or rent the land you farm on?
    a. If Rent – do you feel like this restricts your decision making?
6) To what extent would you say you are involved in the decision making on your farm?
    a. Who else is involved in decision making?
    b. What is your role?
7) How many people work at your farm?
    a. Do you employ people to work at your farm?
    b. Is farming your main source of income?

## Part 2 – Sources of information

1. What are the main sources you use for information on farming practices?
    a. Has this changed in the last 5-10 years?
    b. Do you help to produce any information for other farmers on farming practices?
2) What is your highest education level?
    a. Have you received any specialist agricultural training (e.g. agricultural collage) or apprenticeship?
3) Would you say that you are part of a strong social network of farmers?
    a. Are you part of a farmers' association or cooperative?
    b. Do you think lots of farmers interact with each other and learn from each other?
        i. Do you think some farmers are less involved or harder to reach?
4) How good would you say the knowledge transfer regarding conservation agricultural practices is between…?
    a. Farmers
    b. Farmers and researchers
    c. Farmers and policy makers

## Part 3 – Conservation agriculture

1) How would you define Conservation Agriculture?
    a. Can you suggest some practices you associate with conservation agriculture?
    b. Do you think most farmers would define it the same as you?
    c. Prompt: Do you agree that it can be defined as:

    Conservation Agriculture (CA) = sustainable agricultural production system which protects the soil from erosion and degradation while enhancing the resource base and the environment.

    It can be characterized by three linked principles, namely:

    1. Continuous **minimum mechanical soil disturbance**.
    2. Permanent **organic soil cover**.
    3. **Diversification of crop species** grown in sequences and/or associations.

2) Which practices do you currently use that you would consider to be conservation agriculture?
    a. Detail (e.g. conservation tillage, zero till or min till or reduced till?)
    b. No-tillage, cover crops, crop rotations. If not, have you used them in the past?
    c. Do you consider conservation tillage to be conservation agriculture?

*Adopters:*

## Part 4 – Your opinion of conservation agriculture on your farm

1) What is your general opinion of conservation agriculture?
2) What are the main factors that have motivated you to use conservation agricultural practices?
    a. Cover crops?
    b. No-tillage?
    c. Crop rotations?
    d. Prompt: soil steward, long term investment, economics, trying something new?
3) What are the main benefits you consider when using conservation agriculture?
    a. Are you seeing any benefits yet?
    b. Do you still think it was a good decision to start using conservation agricultural practices?
4) What are the main factors that have made using conservation agriculture more challenging?
    a. Political, economic, technical, social etc. barriers?
    b. Have you found any negative impacts it has had on your farm?
5) Why do you think some other farmers have not yet started to use conservation agriculture?

## Part 5 – Transition to Conservation Agriculture?

1) Do you think increasingly more farmers are starting to use conservation agriculture?
    a. Why do you think that is?
2) Do you consider conservation agriculture to be part of a larger long-term vision?
    a. Prompt: sustainability? Soil protection? Protecting yields?
3) Do you think current political, economic and technical conditions are helping or inhibiting the adoption of conservation agriculture?
4) Do you think it is possible in the future that most farmers could be using conservation agricultural practices?
    a. Why?

## Part 6 – Political environment

1) Do you think the government support a widespread adoption of conservation agriculture?
    a. Do you think policies and subsidies reflect this?
2) Are you part of a scheme or receiving any subsidies other than the Basic Payments Scheme?
    a. What do you receive?
3) How do you expect Brexit to change the political environment or values on conservation agriculture?
    a. Do/did you get any support from the EU?
    b. Would the loss of Common Agricultural Policy affect you/conservation agricultural practices?
    c. Are you concerned about any changes?
    d. Does Brexit change your opinion or intensions regarding conservation agriculture?
4) How would a ban of glyphosate impact your ability to use CA?
5) Do you think a policy change could encourage more farmers to use conservation agriculture?
    a. How?
    **b.** Do you have any other ideas of what would encourage farmers to adopt conservation agriculture?
        **i.** Prompt: market conditions, pricing, eco labels etc.

*Non-adopters:*

## Part 4 – Your opinion

6) What is your general opinion of conservation agriculture?
    a. No-tillage
    b. Cover crops
    c. Crop rotations
7) What are the main factors that influence your decision not to use conservation agricultural practices?
    a. Prompt: economic? Physical? Technical? Lack of knowledge? Political? Legal? Historical?
    b. Would there be negative impacts to your farm if you used them?
8) What are the main factors, if any, that would motivate you to consider conservation agricultural practices?

## Part 5 – Transition to Conservation Agriculture?

9) Do you think increasingly more farmers are starting to use conservation agriculture?
    a. Why do you think that is?
10) Do you consider conservation agriculture to be part of a larger long-term vision?
    a. Prompt: sustainability? Soil protection? Protecting yields?
11) Do you think current political, economic and technical conditions are helping or inhibiting the adoption of conservation agriculture?
12) Do you think in the future most farmers could be using conservation agricultural practices?
    a. Why?

## Part 6 – Political environment

13) Do you think the government support a widespread adoption of conservation agriculture?
    a. Do you think policies and subsidies reflect this?
14) Are you part of a scheme or receiving any subsidies other than the Basic Payments Scheme?
    a. What do you receive?
15) How do you expect Brexit to change the political environment/values on different agricultural techniques?
    a. Do/did you get any support from the EU?
    b. Would the loss of Common Agricultural Policy affect you/your agricultural practices?
    c. Are you concerned about any changes?
    d. Does Brexit change your opinion or intensions regarding conservation agriculture?
16) How would a ban of glyphosate impact your ability to use CA?
17) Do you think a policy change would encourage you to use conservation agriculture?
    a. How?
    b. Do you have any other ideas of what would encourage you to adopt conservation agriculture?
        i. Prompt: market conditions, pricing, eco labels etc

# Appendix 4 - Survey title page

LUND UNIVERSITY

To plough or not to plough? An investigation into the factors influencing farmer decision making

Farmer decision making survey

You are invited to participate in a study conducted by Alice Roberts for her master's thesis at Lund University.

This study aims to research the factors that influence farmers' decision to adopt conservation agriculture or not and whether it is likely for conservation agriculture to become more widely adopted.

The survey will take roughly **15 minutes** to complete and is structured into four sections: 1) household and farm characteristics; 2) agricultural practices; 3) conservation agricultural practices; 4) your opinion of conservation agriculture on your farm. **All UK arable and mixed farmers** are invited to participate in this survey no matter which agricultural practices they use. Surveys will be closed at **5pm 21st March 2017.**

Unfortunately, I do not receive any funding for this research and so am unable to compensate you financially for your time, however if you would like to receive a copy of the finished thesis please write your email at the end of the survey. This email will not be associated with your responses.

Your participation in this study is voluntary, you have the **right to refrain** from answering any of the questions and can terminate the survey at any time. Your answers will remain **anonymous**, however the county you farm in and other information you provide may be published so there is a slight possibility you may be identified through these parameters. You may also withdraw from this study at any time before 12th May 2017 and your responses will be deleted and not included in the study, however as responses are anonymous, this will only be possible by providing the exact date and time you completed the survey.

The raw data collected from this survey will only be accessible to Alice Roberts, her thesis supervisors and selected peers at Lund University and Rothamsted Research. The raw data will not be published or shared with secondary users (e.g. other researchers). Analysed data, selected short quotations and results will be public, primarily via Lund University publishing Alice Roberts' master's thesis online and in print, and also possibly published later in a scientific journal and presented during presentations.

By completing this survey you are agreeing to these conditions.

If you have any questions regarding the research, please feel free to contact me via email (emails have been removed for publication). Your contact details will not be shared

.

## Appendix 5 – Survey questions for part three used to find values directly proportional to the ToPB parameter importance

**Attitude:**

Likelihood of a positive outcome:

*(a) "How likely would it be for at least one of the outcomes of each of the practices to be positive if you used it on your farm?"*

- very unlikely – Somewhat Unlikely – Undecided – Somewhat likely - very likely

Likelihood of a negative or positive outcome:

(b) "*How likely would it be for at least one of the outcomes of each of the practices to be negative if you used it on your farm*?"

- very unlikely – Somewhat Unlikely – Undecided – Somewhat likely - very likely

Evaluation of the total outcomes:

(c) "*Would the overall impact of all the outcomes (positive + negative) of each of the practices be positive or negative on your farm*?"

- very negative – Moderately negative - Neutral – Moderately positive - very positive

**Subjective norms:**

Normative expectations of others:

(d) "*Would most people who are important to you disapprove or approve if you used each of these practices*?"

- Strongly approve – Moderately disapprove – neutral – moderately approve - strongly disapprove

Whether the participant is likely to comply with their opinion:

(e) "*How much do/would those who are important to you influence your decisions to use each of the practices or not?*"

- Never – very little – somewhat – quite a lot - to a great extent

**Perceived behavioural control:**

Perceived difficulty:

(f) "Please indicate how difficult you would consider the implementation of each of the practices to be on your farm"

- very difficult – somewhat difficult – neutral – somewhat easy - very easy

Perceived control:

(g) “How true is this statement regarding yourself: Whether I use each of the practices or not depends entirely on myself, not on factors that facilitate or inhibit the performance or implication of each of the practices”

- Totally not true – usually not true – occasionally true – usually true - totally true

## Appendix 6 - farmer follow-up questions

Follow up email sent to farmers who gave their email and agreed to be contacted for follow-up questions:

Hello,

Thank you for completing my survey about farmer decisions to use conservation agriculture or not. I really appreciate your responses and there already looks like there could be some promising results! As you provided your email at the end of the survey I will make sure to send you the finished thesis and a summary results document.

As you also indicated that it would be alright for me to contact you for follow up questions, I was hoping you could help me by answering the following questions in reply to this email. Please give as much information as you would like. You do not have to answer all the questions, but any information you can provide will give valuable depth to the study.

1) Do you think better knowledge would encourage more farmers to use conservation agriculture?
2) Do you think there are challenges regarding the quality, relevance and/or accessibility of information about conservation agriculture? Why?
3) Many farmers indicated that “improvement of soil health” is a motivating factor to use conservation agriculture. Do you think this is driven by a moral responsibility to improve the soil ecosystem, the want to increase crop productivity/profitability, or another reason/combination of reasons?

Thank you, I really appreciate all your help!

Best wishes,

Alice Roberts

## Appendix 7 - researcher and knowledge exchange interview questions

**Part 1: Factors influencing use of conservation agriculture**

How would you define conservation agriculture?

This study will define Conservation Agriculture (CA) as: a sustainable agricultural production system which protects the soil from erosion and degradation while enhancing the resource base and the environment.
It can be characterized by three linked principles, namely:

1. Continuous **minimum mechanical soil disturbance**.
2. Permanent **organic soil cover**.
3. **Diversification of crop species** grown in sequences and/or associations.

What do you consider to be the main benefits of using these CA practices?

Why do you think many farmers still aren't using CA?

- Main barriers/challenges?

What do you think motivates farmers to use conservation agriculture?

Do you think CA is likely to become more widespread?

**Part 2: Political environment**

Do you think the current political environment supports or inhibits the use of CA?

How do you expect this to change in the coming years?

- Brexit?

How do you think a ban of glyphosate would impact the use of CA?

How effective do you think the knowledge exchange is between policy makers and researchers?

**Part 3: Knowledge exchange**

How effective do you think the knowledge exchange is between farmers and researchers/those who produce information?

How would you consider the quality, relevance and accessibility of the information on conservation agriculture for farmers?

- Do you think this is changing? (e.g. internet communication)

What do you think the main barriers are for knowledge exchange between farmers and researchers/those who produce information?

- What are the main challenges for you to provide farmers with information on CA?
- Is there enough soil specific data?
- Do many farmers learn as they are trying a practice?

How do you think funding infrastructure impacts the production and dispersal of information on CA?

How do you think knowledge exchange regarding CA can be improved?

# Appendix 8 – Farmer interview content analysis. Motivating factors

| Codes (interviewee) | Sub-categories | Categories |
|---|---|---|
| improve water holding capacity of your soil. less runoff, less diffuse pollution. (1) | Reduction of environmental pollution | Environment |
| less oxidization so less volatilization of fertilizer to the atmosphere (1) | | |
| Reduce harm to insects when reduce pesticides (1) | | |
| More environmentally friendly (2) | | |
| We were told we have to stop polluting the river (5) | | |
| big problem with wind erosion and dust blowing into the roads (5) | | |
| Prevent brown water with residue or cover crop (5) | | |
| main benefits will be reducing pesticides, reducing nitrogen use (1) | reduction of pesticide and/or fertilizer use | Economic/environment |
| Using less P, K or Lime for 10 years (5) | | |
| exciting as a farmer to do something where you're seeing your soil improve (1) | Improvement of soil health | |
| Improve soil health (1) | | |
| More worms in the soil (2) | | |
| More worms with no-till (3) | | |
| soil fertility has massively improved (5) | | |
| couldn't continue doing what we were doing so we needed to make some radical changes (1) | Problems with existing cropping system | Economic |
| yields were sat still for about 7 years. spending more on chemicals and manufactured fertilizer to get the same yield (2) | | |
| saw a decline in our soil (5) | | |
| savings in terms of labour and machinery costs (1) | Cutting costs | |
| getting machinery costs down is important (2) | | |
| less time at the machine (2) | | |
| No-till saves time (3) | | |
| Farmers no-till to save money (4) | | |
| reduced the cost of growing crops (5) | | |
| fuel and the other savings (5) | | |
| market opportunities with our education business and planting crops using CA on other farms(1) | Market opportunities | |
| I want to be making money off the farm in 20-25 years. it's quite a long term thing. In 10-20 years I'm going to be streaks ahead of my neighbours if I get it right. (2) | Improvement of long-term productivity | |
| people want to hand their farm over to their children in a better state than they've received it (2) | | |
| Now we are out-yielding (5) | | |
| reducing problems with grass weeds (1) | Reduction of pests and/or weeds | |

# Appendix 9 – Farmer interview content analysis. Challenging factors

| Codes (interviewee) | Smaller sub-categories | Sub-categories | Categories |
|---|---|---|---|
| cover crops: You have to pay for the seeds and you have to plant twice (1) | Expensive costs | Expensive (initial) costs | Economic |
| Cover crop seeds have royalties (more expensive) which they shouldn’t do as they are not used for profit. (2) | | | |
| cover crop seed is so expensive (4) | | | |
| Invested in an expensive new drill (1) | Expensive initial costs | | |
| buy different machinery (3) | | | |
| more hares in the field = hare coursing (1) | Increase of pests | Increase of pests and/or weeds | |
| Badgers churn up the soil (2) | | | |
| Slugs (2) | | | |
| badgers dig up the worms (5) | | | |
| Slugs were a problem early on but not now: Worms and ground beetles graze on slug eggs, so as we are getting more beetles and more worms they are beginning to balance it out. (5) | | | |
| Perennial weeds that are not controlled by glyphosate (5) | Increase of weeds | | |
| If people can’t control black grass they have to go back to conventional farming. (3) | | | |
| Minimum cultivation = increased black grass (4) | | | |
| We had to increase nitrogen fertilizer in the first few years (5) | (short-term) increase in fertilizer use | (short-term) increase in fertilizer use | |
| Hard to get seeds to regenerate year on year with cover crops (1) | Uncertain results | Uncertain results/productivity | Economic/ knowledge |
| Possible nutrient lock up from the cover crop (2) | | | |
| Yield losses - four or five years down the line have lots of black grass. So, will not increase profits (4) | Reduction in profits | | |
| beans direct drilled into cover crop yielded 2tonne/ha less but other types of beans yielded more (2) | Reduction in yields | | |
| In the 70s and 80s started direct drilling but went wrong as they weren’t understanding the need for green covers and the soil biology (1) | Outdated information | Lack of adequate information/research | Knowledge |
| tried no-till in the 70s and it didn’t work So they say “it didn’t work then, it won’t work now” even though we know far more about cover crops, rotation, everything. (2) | | | |
| very little research (5) | Lack of research | | |
| There’s research on the continent, global, and in America is massive. Here it is non-existent. (5) | Lack of information | | |
| Some farmers don't understand CA (2) | | | |

| | | | |
|---|---|---|---|
| Small farm size (3) | Not compatible with cropping pattern | Physical conditions or crop system not compatible | Practical |
| The more clay in the soil the harder it is to use CA (1) | Physical conditions | | |
| heavy soil is harder (2) | | | |
| Heavy clay soils (4) | | | |
| Takes a lot longer to see the impact on heavy clay soils (5) | | | |
| Cost of rent means we can't afford to make mistakes and loose profit (2) | Lack of control or security in tenure agreements | Lack of control or security in tenure agreements | |
| Rented means we won't have it for generations (3) | | | |
| Now all tenancies operate on an FBT (Farm business tenancy) normally between 3 and 5 years. CA is a long game. (1) | | | |
| Can't risk yield failures on contract farms because still need to make profit (2) | | | |
| People, as in people we farm for getting them to really understand it properly what we’re trying to achieve. (2) | | | |
| Short term (<10yr) rents pointless as need to decide if invest or not in the last 3 years. You won't see the benefits. (5) | | | |
| CA requires more management time. (2) | Changes in labour requirements | Changes in labour requirements | |
| hates to see fields that look untidy (5) | Messy looking fields | Messy looking fields | |
| Some farmers just don’t want to know anything different (5) | Don’t see a need to change practices | Don’t see a need to change practices | |
| At the minute the pressure (economic) isn’t necessarily on the farmer to make the change. (crop prices are good, fuel price isn't too high) (1) | | | |
| Farmers don’t like change (1) | Farmers dislike change | Farmers dislike change | Social |
| Farmers are very conservative (5) | | | |