DECISION-MAKING IN AGRICULTURE:
WHY DO FARMERS DECIDE TO ADOPT A NEW PRACTICE?

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“If we fail on food, we fail on everything”

Charles Godfray
ABSTRACT

Current rates of environmental degradation demand changes to the way in which food is produced. Transforming agricultural production requires both the development and the adoption of new practices that facilitate high yields at least environmental cost. Many beneficial practices have already been developed and their limited adoption now constrains their potential to deliver sustainable agriculture. Greater understanding is needed of why farmers decide to adopt or reject different practices. The Technology Acceptance Model (TAM) has been used in an agricultural context to examine adoption. The TAM posits that perceptions of a practice’s usefulness (PU) and its ease of use (PEOU) drive its adoption. In this thesis, the TAM was first revised such that adoption was considered as being composed of five stages to reflect the preparatory and trial phases that precede the full-scale adoption of agricultural practices. An empirical study was then conducted to investigate farmers’ attitudes in the Southern Ontario region towards agrominerals and cover cropping – two practices that show promise in maintaining soil health at low environmental cost. PU and PEOU were found to be significant drivers of the adoption of agrominerals. However, PEOU did not have a significant direct effect on farmers’ decisions to continue using cover crops. A longitudinal study that applies the revised TAM is needed to ascertain whether it is effective in explaining the adoption process, particularly in the latter stages of adoption when PEOU appears to be of less importance and PU alone appears to largely drive farmers’ decision-making. The concern participants showed for the potential environmental impacts of agriculture highly varied with those showing greater concern reporting greater intentions of adopting agrominerals. Socio-economic and agro-ecological factors were found not to be correlated to adoption. This study demonstrated the need to increase knowledge sharing between farmers and scientists to facilitate the transition towards sustainable agricultural production.

Keywords: Sustainable agriculture; technology adoption; soil health; agrominerals; cover cropping.
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Chapter 1

GENERAL INTRODUCTION

Current rates of environment degradation demand transformation of the practices used to produce food (Foley et al. 2011). Agriculture is a major driver of biodiversity loss – primarily through habitat loss and degradation – and the cause of 30% of greenhouse gas emissions annually (Dirzo and Raven, 2003; Bellarby et al. 2008). Yet whilst there is drastic need to reduce these environmental impacts, agricultural production must simultaneously increase to meet the needs of a population growing in both size and wealth (Foley et al. 2011; Godfray & Garnett 2014). To keep pace with growing demand, current production must increase by an estimated 25-70% (Hunter et al. 2017). Since unfarmed land has far greater levels of biodiversity than land farmed at any yield (Phalan et al. 2011; Williams et al. 2017), biodiversity would be best protected by farming land at high yields to minimise the area required to meet production targets. Therefore, the “sustainable intensification” discourse posits that, to avert irreversible damage of global ecosystems, production gains must come
from increases in yields on existing farmland and not by further expansion of agriculture into new lands (Foley et al. 2011; Godfray & Garnett 2014).

Historically, substantial yield gains have been achieved by using high-yielding varieties, synthetic fertilisers and pesticides (Burney, Davis & Lobell 2010). This intensification, known as the Green Revolution, is thought to have spared between 18 to 27 million hectares from being converted to agricultural land (Stevenson et al. 2013) and avoided the release of 161 gigatons of carbon between 1961-2004 (Burney, Davis & Lobell 2010). The addition of synthetic fertilisers alone can result in two to four-fold yield gains (Yadav, Dwivedi & Pandey 2000), and so it is unsurprising that global fertiliser application increased approximately 10-fold between 1950 and 2008 (Robertson & Vitousek 2009). If past trends are to continue to prevail, it is estimated that the demand of 2050’s population could be met with a 140% increase in fertiliser phosphorus (P) and a 170% increase in fertiliser nitrogen (N; Tilman et al. 2001).

However, the yield gains achieved by applying synthetic fertiliser are not without cost. The application of synthetic fertiliser is often highly inefficient: it is estimated that no more than 60% of fertiliser N and 30% of fertiliser P are actually taken up by the crop, and it can be much less (Withers et al. 2014). Periods of heavy rainfall can send the surplus into surrounding areas, leading to the pollution and eutrophication of both freshwaters (Edwards & Withers 2008) and oceans (Smith 2003; Rabalais et al. 2010). Repeated addition of synthetic fertiliser to the soil can lead to heavy metal contamination which has implications both for soil fertility and human health (Atafar et al. 2010). Synthetic fertiliser use results in vast greenhouse gas emissions, which arise both at production and on application (Garnett 2011; Vermeulen, Campbell & Ingram 2012). The need for alternatives is magnified by the rapid depletion of the world’s phosphorus reserves – the source of fertiliser P – which may be exhausted in the next 50-100 years (Cordell, Drangert & White 2009). Furthermore, despite
synthetic fertiliser addition, the annual yields of major crops (including rice, soybeans and wheat) have repeatedly shrunk since 1970 (Alston, Beddow & Pardey 2009; Grassini, Eskridge & Cassman 2013). Thus, it is clear that calls for production to increase must not, and possibly cannot, be met with additional synthetic fertiliser use without severe environmental consequences.

One method of mitigating environmental damage is to reduce the volume of synthetic fertiliser applied to crops by increasing the efficiency of its uptake. There are a number of under-utilised strategies for this, including careful timing of application, more accurate delivery using soil testing, application at the optimum soil depth and the use of slow or controlled-release products (i.e. precision agriculture techniques; Snyder et al. 2009). Indeed, there is evidence to suggest that fertiliser is commonly over-applied and application levels can be reduced – possibly by up to 50% – without corresponding losses in yield (Ju et al. 2009; Carberry et al. 2013). However, this is not universally true: some cropping systems are already operating close to the limits of efficiency, thus any reductions in synthetic fertiliser would lead to yield declines (Carberry et al. 2013).

Synthetic fertiliser, though the most mainstream, is only one possible strategy for increasing the availability of nutrients to stimulate crop growth. Agrominerals, or rock fertilisers, represent an alternative nutrient source to synthetic fertiliser (Van Straaten 2007). Agrominerals are mined rock minerals that are generally not processed or modified prior to their addition to soils – and therefore are distinctly different from the rock phosphates (which are commonly modified before use) that are widely used in agricultural systems (Van Straaten 2007). Whereas synthetic fertilisers are highly soluble leading to high run-off rates, agrominerals are applied in solid form and rely on natural weathering for their breakdown. By consequence, nutrients are released slowly throughout the growing season (Labib et al. 2012). When applied in combination with synthetic fertiliser, agrominerals can positively
impact yield (Sanz Scovino & Rowell 1988; Labib et al. 2012). Importantly, preliminary evidence indicates a positive yield effect of agrominerals without the addition of synthetic fertiliser (Jones 2016).

These yield benefits may be greatest when agrominerals are used in combination with the practice of using leguminous cover crops. The nitrogen-fixing capability of leguminous cover crops leads to increased soil nitrate content which is thought to underlie the corresponding observed increased rates of photosynthesis and crop yields (Blanco-Canqui, Claassen & Presley 2012; Mbuthia et al. 2015). The use of cover cropping brings additional benefits related to reduced rates of soil erosion, improved soil structure, and weed and pest control (Snapp et al. 2005). Therefore, the adoption of these such alternative strategies may provide an avenue for achieving high yields at less environmental cost than the use of synthetic fertiliser.

Despite knowledge of the damage afforded by synthetic fertiliser, possible strategies for its reduction are vastly under-exploited amongst farmers (Rodriguez et al. 2009; Stuart, Schewe & Mcdermott 2014). Indeed, throughout agricultural systems the lack of adoption of promising strategies is rife: Tilman et al. (2011) concluded that greater progress could be made towards sustainable production by increasing the uptake of already available technologies, compared to continued innovation at the current rate alone. Thus, a better understanding of why farmers decide to adopt or reject different practices may bolster attempts to realise the sustainable intensification of agriculture.

Whilst much information of the impacts of different agricultural practices can be found in the literature, the extent to which farmers are aware of these issues is questionable. In a group of farmers in the United States of America, Stuart et al. (2014) reported that most farmers claim to have had no prior exposure to information about the linkages between fertilisers, greenhouse gas production and climate change. However, in a study of grain
farmers in China, Ma et al. (2009) found excess fertiliser application to be the most frequently cited response to the question of why the environment is becoming degraded. Indeed, limited access to information is considered a significant barrier to climate change mitigation in agriculture (Smith et al. 2007).

The extent to which farmers’ concern for the environmental implications of agriculture drives changes in farming practices is unclear. Evidence suggests that farmers’ environmental behaviours are dictated to an extent by their awareness of the environmental impacts of agriculture (e.g. Bayard and Jolly, 2007). Stuart et al. (2014) found farmers who consider climate change to be an issue to society to be more willing to enrol in a fertiliser offsets program. However, financial motives prevail above environmental ones, even when farmers are aware of the environmental problem (Falconer & Hodge 2001; Hudson & Hite 2003; Amsalu & de Graaff 2007; Robertson et al. 2012). Therefore, an awareness of the environmental impacts of fertiliser use is unlikely to lead to changes in farming practices that are not financially beneficial.

An understanding of the factors that lead farmers to adopt specific strategies for soil amendment purposes is critical. Whilst profitability is thought to play a large role in technology adoption, models based purely on profitability have had relatively little success in explaining patterns of technology adoption in agriculture, particularly for technologies that are more complex to learn and use (Flett et al. 2004). In recent years, the relevance of the Technology Acceptance Model (TAM; Davis 1989), developed initially for studying the adoption of information technology, to an agricultural context has been recognised (Flett et al. 2004; Adrian, Norwood & Mask 2005; Rezaei-Moghaddam & Salehi 2010; Aubert, Schroeder & Grimaudo 2012; McDonald et al. 2016).

The TAM is based on Fishbein & Ajzen’s (1975) Theory of Reasoned Action, which aims to explain the relationship between attitudes and behaviours. The TAM proposes that
perceptions of two characteristics of a technology contribute to potential users’ intentions of adoption: the technology’s usefulness and its ease of use. The model posits that these intentions lead to actual adoption – a relationship that is somewhat problematic since intentions do not always translate into action (reviewed in Legris et al. 2003). The TAM has become one of the most widely used models to study the adoption of computer technology due to its understandability and simplicity (King & He 2006). Applied in a variety of circumstances, perceived usefulness (PU) and perceived ease of use (PEOU) have frequently been found to explain adoption tendencies (reviewed in King & He (2006)). Whilst several studies have applied the TAM to an agricultural context, discussion in the literature of the validity of such an approach is lacking.

1.1 Thesis Objectives

The overall goal of this research was to determine the major factors that influence a farmers’ decision-making regarding the adoption of new practices/technologies. To achieve this goal, there were three objectives:

1. To determine whether the TAM is suitable for application to study adoption in the context of agricultural practices.

2. To establish whether PU and PEOU drive the adoption of new practices and the continued use of existing practices.

3. To determine whether concern for the environment, socio-economic and agro-ecological factors are correlated to the adoption and continued use of different practices.

1.2 Thesis Structure
The thesis is structured according to the Integrated Article format so Chapters 2 and 3 are written as standalone manuscripts. Chapter 2 reviews the literature on the TAM and assesses its suitability for use in an agricultural context, thereby fulfilling the first objective. At the time of writing, this chapter is a manuscript ‘In Preparation’ and is referred to in subsequent chapters as ‘Collas & Vasseur (2018)’. The second and third objectives are addressed in Chapter 3 which investigates the attitudes of farmers in Southern Ontario to understand their intentions to use agrominerals and cover crops, based on the TAM. Chapter 4 outlines the extent to which the model was successful in explaining adoption and considers additional lines of research. Notwithstanding imperfect explanation of adoption, some recommendations are offered about the action required to make agriculture more sustainable.
1.3 References


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Smith, V.H. (2003). Eutrophication of freshwater and coastal marine ecosystems a global


Chapter 2

CAN THE TECHNOLOGY ACCEPTANCE MODEL BE USED TO STUDY THE ADOPTION OF AGRICULTURAL PRACTICES?

2.1 Introduction

Major transformation is needed in the agricultural industry for food production to become more sustainable (Tilman et al. 2001; Godfray & Garnett 2014). However, production must simultaneously increase to meet the growing demand of a larger, and richer, human population (Tilman et al. 2011). Recent evidence indicates that the latter challenge is being more readily met, while the associated environmental impacts of agriculture only continue to grow (Hunter et al. 2017). Innovation has long been recognised as a key component to fulfilling this dual mandate (Tilman et al. 2011). However, an innovation’s potential is limited by its uptake and promising strategies are often not adopted at a large scale. Indeed, greater gains could be achieved by increasing the uptake of existing
agricultural practices, as opposed to continued innovation at the current rate alone (Tilman et al. 2011). Therefore, understanding the reasons why farmers choose to adopt or reject a practice can prove fruitful in taking steps towards more sustainable agricultural production.

A number of models have been developed to study the adoption of new practices/technologies in many different industries (e.g. Rogers 2003; Scherer 1986; Lowry et al. 2013). The Technology Acceptance Model (TAM) was initially developed to study information and digital technologies (Davis 1989) but has been widely used to study the adoption of agricultural practices (e.g. Flett et al. 2004; Adrian, Norwood & Mask 2005; Rezaei-Moghaddam & Salehi 2010; Aubert, Schroeder & Grimaudo 2012). The TAM posits that two variables – a practice’s perceived usefulness (PU) and its perceived ease of use (PEOU) – underlie a potential user’s intention to adopt the practice (Fig. 2.1; Davis 1989). PU and PEOU are subjective variables, and hence not easily discerned by researchers seeking to investigate their effect of adoption. Intention to adopt is proposed to drive the actual adoption of the practice (termed “actual system use” in the TAM; Fig. 2.1; Davis 1989). In some cases, the TAM has been shown to explain a significant amount of variation in adoption with both PU and PEOU contributing to final adoption (Rezaei-Moghaddam & Salehi 2010). However, existing results are not totally consistent or clear: some studies have found either PU or PEOU to have an insignificant effect (Adrian, Norwood & Mask 2005; Naspetti et al. 2017). Furthermore, the relationship between one’s intentions of adopting a practice and actual adoption is imperfect due to individuals not always following through on their intended behaviour (reviewed in Legris et al. (2003)).
The Technology Acceptance Model was developed to explain the adoption of information technologies (Davis 1989). Though a number of studies have applied the TAM to an agricultural setting in recent years (e.g. Flett et al. 2004; Adrian, Norwood & Mask 2005; Rezaei-Moghaddam & Salehi 2010; Aubert, Schroeder & Grimaudo 2012), there has been little exploration of the validity of this approach. These existing studies have been inconsistent with respect to their interpretation of how to apply the TAM in this context. Therefore, general conclusions cannot be drawn regarding whether the TAM can be successfully used to explain adoption in agriculture.

This paper critically assesses the capacity of the TAM to explain the adoption of farming practices. Each aspect of the TAM is discussed in turn to establish how it can be interpreted to an agricultural context. In this way, this paper establishes how best to apply the TAM to explain patterns of adoption in agriculture.

2.2 The TAM

The TAM posits that adoption is driven by perceptions of both a practice’s usefulness (PU) and its ease of use (PEOU). PU and PEOU are latent constructs, and thus they cannot be measured directly (Davis 1989). Instead, PU and PEOU are considered to be comprised of a
number of representative variables that can be measured. Interpreting the TAM from the context in which it was originally designed into an agricultural context necessitates the review of the variables originally proposed to drive PU and PEOU. The TAM has been criticized for its lack of sound theory and method for identifying the variables that comprise PU and PEOU (Bagozzi 2007), and this has been reflected in the variability of interpretations of PU and PEOU in past studies that have investigated the adoption of agricultural practices. Here, we propose the key component variables of PU and PEOU for future studies to consider; some degree of variability in the selection of these variables may arise between studies depending on the particular practice under investigation.

2.3 Perceived usefulness

In Davis (1989), PU was defined as the degree to which a person believes that using a particular system would enhance one’s job performance. This was further broken down into three component elements: whether the technology (i) enhances job effectiveness, (ii) increases productivity and time savings, and (iii) is important to the job in question.

In an agricultural context, notions of increased productivity and time savings have often been retained (e.g., Adrian et al. 2005; Flett et al. 2004), while increased profits have also been incorporated (e.g., Flett et al. 2004). Some studies have widened the definition to include the extent to which the practice aids farm management (e.g., Adrian et al. 2005). General notions of whether the practice improves farm management (e.g., Adrian et al. 2005) and whether it is better than what it replaces, or is important to farming needs (e.g., Flett et al. 2004), have sometimes been included. Aubert et al. (2012) took a very different approach to assessing PU of asking whether the use of the practice in question is (i) insignificant to fundamental; (ii) not important to very important; (iii) uninteresting to interesting; (iv)
mundane to fascinating; (v) unattractive to attractive. Clearly, PU has been inconsistently measured in studies of adoption in agriculture.

The ultimate aims of the farmer must be considered when selecting the variables of PU to determine what would render a practice useful. Interpreting the PU construct in this way does invoke goal orientation (counteracting Bagozzi’s (2007) criticism of the TAM for its lack of a goal-orientated approach to studying adoption). Financial motivations are generally at the forefront of farmers’ decision-making (Turvey 1991). For most farmers, action to reduce the environmental impact of production will likely only be taken if it is economically viable in a given timeframe decided upon by the farmer (and perceptions of the length of this timeframe will vary between farmers; Falconer & Hodge 2001; Hudson & Hite 2003; Amsalu & de Graaff 2007; Robertson et al. 2012).

Therefore, we propose the PU construct to be composed of whether performing the practice increases farm profits (in line with Turvey (1991)) via three variables: whether the practice (i) increases productivity, (ii) increases the value of the product or (iii) improves produce quality (Table 2.1). Additionally, as a fourth component variable, whether a particular practice is cost effective should be included in PU to encourage farmers to consider how the costs of implementing and operating a practice compared to the associated benefits/losses. This consideration can substitute for two of the vaguer aspects of PU set out in Davis (1989) related to whether the practice either enhances job effectiveness or is important to the job.

Table 2.1. The variables which comprise PU and PEOU as described out in this paper. A practice that fulfils these statements would be expected to be considered highly useful and easy to use.

<table>
<thead>
<tr>
<th>Construct</th>
<th>Component</th>
</tr>
</thead>
<tbody>
<tr>
<td>PU</td>
<td>Practice increases productivity</td>
</tr>
</tbody>
</table>
Farmers’ perceptions of the usefulness of a practice may be impacted by external factors that affect profitability. Government policies incentivise some methods of food production via subsidies and discourage others with taxes (Robertson & Swinton 2005). Therefore, subsidies offer a potential mechanism to encourage the adoption of practices that may otherwise not be adopted due to associated profitability declines compared to using an alternative practice with greater environmental impact. Market forces may also impact the perceived profitability of using different technologies since the conditions under which goods are produced can impact their desirability to buyers (Long, Blok & Coninx 2016). Therefore, understanding farmers’ perceptions of a practice’s usefulness may require study of the role of government policies and market forces. Whether these external forces should be included in the model as an external driver of PU could be investigated.

2.4 Perceived ease of use

In combination with PU, the TAM proposes that adoption is driven by perceptions of the ease of using the practice (PEOU; Davis 1989). In the context of computer technology, Davis (1989) defined PEOU as the degree to which a person believes that using a particular system will be free from effort (Davis 1989). Davis (1989) proposed PEOU to be composed

<table>
<thead>
<tr>
<th>PU</th>
<th>Practice increases produce quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>PU</td>
<td>Practice is cost effective</td>
</tr>
<tr>
<td>PU</td>
<td>Practice increases product value</td>
</tr>
<tr>
<td>PEOU</td>
<td>Practice is easy to use</td>
</tr>
<tr>
<td>PEOU</td>
<td>Easy to understand how to use the practice</td>
</tr>
<tr>
<td>PEOU</td>
<td>Practice is compatible with other farm practices (can be broken down into compatibility with farm operations and compatibility with equipment that the farmer owns or is willing to acquire).</td>
</tr>
</tbody>
</table>
of three elements: the associated (i) physical effort; (ii) mental effort; and (iii) ease of learning (Davis 1989). In comparison with PU, previous studies in an agricultural context have been more consistent in their interpretation of PEOU and have generally retained these main elements of Davis’ (1989) definition.

Previous studies in an agricultural context have focused on whether the practice is easy to use, thereby combining Davis’ (1989) physical effort and mental effort elements (e.g. Adrian et al. 2005; Aubert et al. 2012; Flett et al. 2004). Studies have also included whether farmers understand how to use the practice, reflecting Davis’ (1989) ease of learning element (e.g. Aubert et al. 2012; Flett et al. 2004). In line with Davis (1989), we consider these two variables to be components of PEOU in the context of agricultural practices (Table 2.1). In addition, the extent to which a new practice is compatible with other farm operations should be considered as an additional variable in recognition of farms being complex operational systems (as in Aubert, Schroeder & Grimaudo 2012). Where practices require specific equipment, it may be useful to consider compatibility as being composed of two separate variables: firstly, the compatibility of the practice with existing farm equipment (or equipment that the farmer would be willing to acquire); and secondly, the compatibility of the practice with general farm operations (e.g. the timing and spacing of other practices).

Perceptions of the ease of using a practice are impacted both by characteristics of the practice itself and perceptions of self-efficacy. Self-efficacy is defined as the belief of an individual that they are capable of using the technology to perform a specific task/job (Compeau & Higgins 1995)). In previous studies of adoption in agriculture, notions of self-efficacy have sometimes been separated from PEOU (as in Adrian et al. (2005)). We advocate away from doing so as in following the Davis (1989) definition of PEOU (the degree to which a person believes that using a particular system would be free of effort),
notions of self-efficacy are inherently invoked. Therefore, defined in this way, perceptions of the ease of using the practice are expected to contribute to farmers’ intentions of adopting.

2.5 Relationship between PU and PEOU

The TAM posits that PU has a direct effect on users’ intentions to adopt the technology, whereas PEOU has both a direct and an indirect effect via PU (Davis 1989). This follows the logic that practices that are perceived to be easier to use will by consequence be perceived as more useful. Previous studies of adoption in agriculture have often found PEOU to have a significant effect on PU (Flett et al. 2004; Rezaei-Moghaddam & Salehi 2010), though this has not always been the case (Adrian, Norwood & Mask 2005; Aubert, Schroeder & Grimaudo 2012). These non-significant correlations may be explained by the interpretation of PU and PEOU in these studies (which do not follow the interpretation of PU and PEOU described in this paper). For example, in Adrian et al. (2005), self-efficacy was separated from PEOU, leaving PEOU largely devoid of meaning. Aubert et al. (2012) treated compatibility as a separate variable that impacts both PU and PEOU, and found the effect of PU on PEOU to be non-significant whilst compatibility had a significant effect on PU. Compatibility is here proposed a component of PEOU since a practice that can be easily implemented alongside existing operations is expected to be perceived as easier to use. When PEOU is interpreted to include notions of compatibility, we hypothesise that PEOU will have a significant effect both on PU and on intention of adoption.

2.6 Adoption intentions and actual adoption

Integral to the TAM is quantifying adoption of the technology in question – so-called “Actual system use” (Fig. 2.1; Davis 1989). In agriculture, this becomes immediately problematic given the non-discrete nature of adoption. Farmers will commonly trial a new
practice on a small portion of their farmland, before deciding whether to pursue it in future years and on what scale to do so (reviewed in Marra, Pannel & Ghadim 2003). This approach poses less risk compared to immediately adopting a new practice at a large scale (Ghadim, Pannell & Burton 2005). Consequently, treating adoption, or indeed farmers’ intention to adopt, as binary variables (i.e. yes/no) – as previous studies involving the TAM in agriculture have done – may fail to capture this complexity. The explanatory power of the TAM may be improved if a different approach was taken that better differentiates between these distinct stages of adoption.

Prochaska & Velicer’s (1997) Transtheoretical Model (TTM) presents a way to overcome the issues posed by the complex and gradual nature of the adoption process in agriculture. The TTM has previously been applied to an agricultural context (Lemken, Spiller & Von Meyer-Höfer 2017). Originally developed in the context of healthy-eating behaviours, the TTM proposes the adoption process to be composed of six stages which assess an individual’s readiness to change an established behaviour: Pre-contemplation, Contemplation, Preparation, Action, Maintenance and Termination (Table 2.2). Farmers are considered to be in the Pre-Contemplation stage when they are not currently thinking about implementing the practice on any scale in the future (and this may be due to not being aware of the practice’s existence). Farmers in the Contemplation stage are thinking about installing the practice. Farmers that are making arrangements to use a practice (but have not yet begun to use it) are in the Preparation stage. In the Action stage, farmers are undertaking preliminary trials of the practice having not yet decided whether to pursue it in future years.

Table 2.2. Description of the different stages of the TTM (adapted from Lemken et al. (2017)).

<table>
<thead>
<tr>
<th>Stage</th>
<th>Concept</th>
<th>Operationalisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-contemplation</td>
<td>No intention to change, lack of motivation or</td>
<td>“I am not willing to try x”</td>
</tr>
</tbody>
</table>

23
In line with Lemken et al. (2017), the Termination stage is here excluded since it does not bear relevance to an agricultural setting. (Termination would refer to where a farmer intends not to ever pursue any other practices for doing a particular task, other than the one in question). However, unlike Lemken et al. (2017), the Maintenance stage is included as an important stage given the need to provide an option for farmers that have fully-adopted a practice. The Maintenance stage may follow the successful trialling of a practice, leading farmers to adopt it at a wider-scale as an established practice. Alternatively, farmers may skip straight from the Preparation to the Maintenance phase by immediately adopting a practice at a large-scale with the intention of continuing to use it in future years. Farmers who have previously experimented with a new practice but have decided not to continue using it are considered to have regressed to one of the previous stages (as in Prochaska & Velicer (1997)) – the exact stage depending on their intentions to use it again in the future.

Here, we have integrated the TTM into the TAM such that the TAM’s “intention to adopt” variable is replaced by the Pre-contemplation and Contemplation stages of the TTM and the TAM’s “actual system use” is replaced by the Preparation, Action and Maintenance
stages of the TTM (Fig. 2.2). When cross-sectional studies are being conducted to understand the drivers of adoption, investigators must establish the stage that best describes the farmer’s current situation according to the TTM (i.e. either Pre-contemplation, Contemplation, Preparation, Action or Maintenance) before determining how this correlates to their perceptions of the practice’s usefulness and ease of use. Longitudinal studies would be highly valuable to examine the time and manner in which individuals go through these stages, while assessing how their perceptions of the practice’s usefulness and ease of use change throughout.

Figure 2.1. Revised version of the Technology Acceptance Model, which incorporates aspects of the Transtheoretical Model, for use in studies of adoption in agriculture.

2.7 Expected outcomes of using the revised model

Perceptions of PU and PEOU are expected to change as potential adopters progress and regress through the different stages of adoption. Douthwaite et al. (2009) identified
learning (either from one’s own actions or from others) as a critical process in adoption. Learning of a neighbour’s failure in adopting a particular practice can prevent others from making the same mistake. For beneficial practices, learning from others can prompt one to adopt and can provide insight into how to implement and use the practice (Douthwaite et al. 2009). Learning from one’s own efforts is expected to particularly affect PEOU since this construct includes notions of whether the adopter understands how to use the practice – knowledge that will accrue during its implementation (Venkatesh & Davis 1996).

One aspect of the TAM that has previously been highlighted as problematic is the link between intention of adoption and actual adoption, since intention does not always translate into actual adoption (Davis & Venkatesh 1996; Legris, Ingham & Collerette 2003). Whilst the revised model presented here does not completely overcome this problem, the inclusion of the Preparation and Action stages may shed light on why intentions do not always translate into adoption. For example, perhaps practices are trialled (the Action stage) but are then found to not be as useful or easy to use as expected and so are not fully adopted. Alternatively, individuals may not progress from the Preparation stage, which may suggest that implementing the practice requires complicated planning or large investment of financial capital or time. Where those thinking positively about adopting the practice do not progress from the Contemplation stage, this may be indication that more support is needed to provide guidance for preparing to trial the practice.

Demographic factors are not directly incorporated either into Davis’ (1989) original TAM or in the revised model presented here. Studies in agricultural have found demographic variables – including socio-economic, agro-ecological, institutional and informational factors – to have very inconsistent effects on adoption (reviewed in Tey & Brindal 2012; Knowler & Bradshaw 2007). Given the effects of demographic variables appear to be very specific to the practice in question (Knowler & Bradshaw 2007), they are not included in the revised model.
presented here which seeks to provide an overall view of the drivers of adoption in agriculture. However, there may still be value in studying the demographic factors that drive the adoption of a particular practice. Furthermore, investigating their impact of PU and PEOU may be particularly interesting since it is foreseeable that a demographic factor (e.g. the size of the land that is farmed) may indeed affect a farmer’s perceptions of a practice’s usefulness (e.g. because a practice may be more cost effective to perform at a wider scale) or ease of use (e.g. because a practice involves actions that can only be performed by hand).

2.8 Future directions

Future studies should seek to take a uniform approach to interpreting PU and PEOU when applying the TAM to an agricultural context. This would enable general conclusions to be drawn as to why farmers choose to either adopt or reject agricultural practices. Since the TAM in its initial form is not wholly suitable for this purpose, here a revised model is presented that incorporates aspects of the TTM as a means of better assessing adoption in an agricultural context. When using this model, it is vital that future studies carefully consider how to interpret PU and PEOU with respect to the practice in question. The variables discussed here as being the major determinants of PU and PEOU should allow a relatively consistent approach, though studies will likely need to tweak these variables depending on the practice under investigation. Future studies should seek to apply this model to investigate whether PU and PEOU, as defined by the variables presented here, drive the adoption and continued use of agricultural practices. This research is most urgently needed for practices that show promise in reducing the environmental impact of agriculture.
2.9 REFERENCES


http://doi.org/10.4278/0890-1171-12.1.38


http://doi.org/10.1073/pnas.1116437108


http://doi.org/ 10.1126/science.1057544

Chapter 3

UNDERSTANDING FARMERS’ INTENTIONS TO USE AGROMINERALS AND COVER CROPS TO MAINTAIN SOIL HEALTH

3.1 INTRODUCTION

Agriculture accounts for more than 30% of anthropogenic greenhouse gas emissions (Tubiello et al. 2013) and imperils 80% of all threatened bird and mammal species (primarily through habitat destruction, degradation and fragmentation; Tilman et al. 2017). Reforming the way in which food is produced requires both the development and the adoption of practices that facilitate high yields at least environmental cost (Foley et al. 2011; Miller et al. 2014; Tilman & Clark 2015). Now that many promising practices have been developed that could alleviate the environmental impact of agriculture, great progress could be made by increasing their uptake (Tilman & Clark 2014).
Understanding farmers’ goals is central to establishing why a practice is adopted or rejected. Purely economic models have generally failed to accurately predict adoption, suggesting that profit maximisation is not the sole driver of decision-making (Gartrell & Gartrell 1985; Turvey 1991). Davis (1989) proposed that the adoption of a new practice is predominantly driven by potential adopters perceptions’ of its usefulness (PU; the belief that using the practice will enhance performance; Davis 1989) and ease of use (PEOU; the belief that using the practice will be free of mental and physical effort; Davis 1989). This is the basis of Davis’ (1989) Technology Acceptance Model (TAM). Developed in the context of computer technology, the TAM proposes that PU and PEOU drive one’s intention of adopting the practice which, in turn, drives its actual adoption.

PU and PEOU are multi-faceted constructs and, to apply the TAM to an agricultural context, their key component variables must be established. PU relates to the effects of using the practice on crop productivity and produce quality, as well as whether it adds value to the products and is cost effective considering the necessary input costs (Collas & Vasseur 2018). PEOU encompasses the ease of performing the practice, the ease of understanding how to perform the practice and its compatibility with equipment and other farm operations (Collas & Vasseur 2018). Application of the TAM to agriculture has produced wide-ranging results. While some studies have found PU and PEOU to accurately predict adoption intentions (Rezaei-Moghaddam & Salehi 2010), others have found either PU or PEOU to have no significant effect (Adrian, Norwood & Mask 2005; Naspetti et al. 2017). Studies investigating adoption retrospectively (i.e. after a practice has been adopted) have reported that adopters tend to rate a practice more highly for both PU and PEOU compared to those that have not adopted the practice (Flett et al. 2004; Aubert, Schroeder & Grimaudo 2012). Whether PU and PEOU explain adopters’ intentions to continue using an agricultural practice following its initial adoption is yet to be investigated.
Having been developed to study the adoption of computer technology, the TAM is made more suitable for agriculture by taking an alternative approach to measuring adoption. The TAM considers adoption in an all-or-nothing manner. This does not account for the experimental approach that is sometimes taken by farmers of performing small-scale trials before deciding whether to adopt the practice at a larger scale. Collas & Vasseur (2018) proposed a model that combines the PU and PEOU aspects of the TAM with the way in which adoption is considered in the Transtheoretical Model (Prochaska & Velicer 1997; Fig. 3.1). The Transtheoretical Model proposes adoption to be composed of six stages: Pre-Contemplation, Contemplation, Preparation, Action, Maintenance and Termination (though the Termination stage was excluded by Collas & Vasseur (2018)).

![Diagram of Transtheoretical Model](image)

Figure 3.1. Collas & Vasseur’s (2018) Revised Technology Acceptance Model combines aspects of the Transtheoretical Model to better depict adoption in an agricultural context.

### 3.1.1 Socio-economic and agro-ecological factors

Demographic factors have been hypothesised to correlate to the adoption of new practices. There is discrepancy in the literature as to whether demographic factors influence
intentions directly (as suggested in Adrian, Norwood & Mask (2005)), or indirectly – i.e. by influencing one’s perceptions of usefulness and ease of use (Porter & Donthu 2006; Tarhini, Hone & Liu 2014).

A number of socio-economic factors may be linked to patterns of adoption. Due to their longer career horizon, younger farmers may be more likely to adopt new practices than older farmers (Larson et al. 2008). However, studies investigating this correlation have found mixed results (Mcbride & Daberkow 2003; Knowler & Bradshaw 2007; Isgin et al. 2008; Tey & Brindal 2012; Lemken, Spiller & Von Meyer-Höfer 2017). Education has also been hypothesised to promote adoption (Rogers 2003). Whilst this relationship has been confirmed in some studies of agricultural practices (Mcbride & Daberkow 2003; Adrian, Norwood & Mask 2005; Walton et al. 2008; Larson et al. 2008), others have reported non-significant effects (Tey & Brindal 2012; Lemken, Spiller & Von Meyer-Höfer 2017).

Characteristics relating to the farm, agro-ecological factors, may also be correlated to farmers’ intentions to adopt a new practice. Farm size may be associated with adoption, though the nature of this correlation may depend on the particular practice in question—studies have so far found positive, negative, and non-significant effects (Knowler & Bradshaw 2007; Lemken, Spiller & Von Meyer-Höfer 2017; Tey & Brindal 2012).

3.1.2 Potential practices for maintaining soil health

Maintaining soil health and providing the nutrients required to achieve high crop yields often presents a challenge to farmers of arable cropping systems. Realising the sustainable intensification of agriculture requires high yields to be realised at minimal environmental cost. Many different approaches are employed by farmers to improve crop yields which have varying implications for the environment.
The application of synthetic fertilisers in arable systems remains a widely used practice and, historically, this approach of adding nutrients to the soil in a soluble form has resulted in dramatic yield increases (Yadav, Dwivedi & Pandey 2000). However, alternative strategies may also maintain yields while reducing the environmental costs associated with synthetic fertiliser – such as water pollution, greenhouse gas emissions and contamination of the soil (Smith 2003; Edwards & Withers 2008; Rabalais et al. 2010; Atafar et al. 2010). Agrominerals (also known as rock fertilisers) are a potential alternative source of soil nutrients (Van Straaten 2007). Agrominerals have been found to boost crop yields when combined with synthetic fertiliser (Sanz Scovino & Rowell 1988; Labib et al. 2012). Preliminary evidence indicates a positive effect of agrominerals on crop growth in absence of synthetic fertiliser (Jones 2016), though this remains to be investigated in the field. No known studies have investigated farmers’ attitudes towards using agrominerals and thus understanding of whether they consider it a viable practice is lacking.

Spanish River Carbonatite (SRC) is an agromineral currently being mined in Spanish River (near Sudbury, Ontario). SRC is an alkaline rock primarily composed of calcite, apatite and biotite minerals (Sage 1987). The mechanism by which SRC affects crop growth is not entirely understood. Once applied, natural weathering gradually breaks down SRC, releasing nutrients throughout the growing season, which is thought to lead to increased growth for a prolonged period of time (Jones 2016). SRC addition may also benefit the soil microbial community which, in turn, increases the availability of nutrients to plants (Jones 2016).

The practice of cover cropping (the growth of other crops either adjacent to the main crop or during fallow periods) is another strategy used to improve soil health and crop growth. Cover cropping reduces erosion, alleviates soil compaction and can aid pest management (Snapp et al. 2005; Blanco-Canqui, Claassen & Presley 2012; Olson, Ebelhar & Lang 2014; Poeplau & Don 2015). Cover crops also increase the availability of phosphorus
and, where leguminous cover crops are used, the availability of nitrogen (via a symbiosis with *Rhizobia* bacteria; Mbuthia *et al.* 2015; Blanco-Canqui *et al.* 2015). SRC may improve the efficiency of this symbiosis (possibly due to SRC containing small quantities of rare metal ions; González-Guerrero *et al.* 2014; Jones 2016). Consequently, the benefits of SRC use may be greatest when combined with cover cropping.

### 3.1.3 Objectives

This study investigated whether the revised TAM proposed by Collas and Vasseur (2018) explains farmers’ intentions to adopt two practices for maintaining soil health – agrominerals and cover cropping. Where farmers have already adopted these practices, whether PU and PEOU explain their intentions to continue using the practice was investigated. To do so, questionnaires were distributed to farmers in the Southern Ontario region to ascertain their attitudes towards agrominerals and cover cropping. Also investigated were whether socioeconomic and agro-ecological factors are correlated to adoption, and finally whether concern for the environmental impacts of agriculture is a significant driver of farmer decision-making.

### 3.2 Methods

This study was completed in conjunction with an ongoing project investigating the effects of using SRC and cover cropping to maintain soil health in vineyards. To assess farmers’ attitudes towards these practices, two questionnaires were developed (which were approved by the Brock University Research Ethics Board (#REB16-300VASSEUR) and are included as Appendix A and B) and delivered at three workshops in Southern Ontario: two at Vineland Research Centre on the 23rd November 23rd and 6th December, 2017, and one at Wilfred
Laurier University on the 19th February, 2018. Attendees were recruited by circulating posters electronically (see Appendix C for a copy of the poster) amongst farmers known to the involved researchers and with local farming organisations that were identified through web-based research (see Appendix D). Therefore, the target population was farmers in the Southern Ontario region who produce goods for sale. The first session was attended by 25 people, the second by 22 people, and the third by 30 people.

These workshops followed the same format whereby, on entrance, attendees were greeted and asked to review the ethics consent form. To be eligible to complete the questionnaires, attendees had to be actively farming an area of land from which they produced goods for sale. (This rendered some attendees ineligible, including employees of the Ontario Ministry of Agriculture, Food and Rural affairs and other academics). Having signed the consent form, participants were given the first questionnaire to complete which gathered information on socio-economic and agro-ecological characteristics. The workshop included a 45-minute talk, given by a university professor (Liette Vasseur) who introduced both agrominerals and cover cropping as potential soil management strategies and presented the preliminary results from on-going greenhouse and field trials. This was followed by a period of questions and discussion of 20-35 minutes. After the question-and-answer period, participants were given the second questionnaire and a leaflet that summarised the information presented during the talk.

3.2.1 Applying the revised TAM to agrominerals and cover crops

To examine whether perceptions of a practice’s usefulness and ease of use drive its adoption, the revised TAM developed in Collas & Vasseur (2018) was deployed. As per the revised model, adoption was considered to be composed of five stages: Pre-Contemplation,
Contemplation, Preparation, Action and Maintenance. In the second questionnaire, participants stated the stage of adoption with which they identified, for both agrominerals and cover cropping, according to the following statements:

Pre-Contemplation: “I do not intend to try using agrominerals/cover cropping on the land that I farm”
Contemplation: “I am thinking about using agrominerals/cover cropping but I have not yet begun preparations for doing so”
Preparation: “I intend to try using agrominerals/cover cropping and I have begun to make preparations for doing so”
Action: “I work with agrominerals/cover cropping on a trial basis”
Maintenance: “I have successfully trialled the use of agrominerals/cover cropping on the land that I farm and plan to continue using agrominerals in coming years”

Participants’ intentions to progress to the next stage of adoption were assessed according to a seven-point Likert scale. Participants identifying with the Pre-Contemplation, Contemplation and Preparation stages (i.e. those that hadn’t actually begun using the practice) were asked for their agreement to the statement “I intend to try using agrominerals/cover cropping on the land that I farm in the next five years”. This statement reflected their intentions to move to the Action stage. Participants identifying with the Action and Maintenance categories (i.e. those who had already begun using the practice in question) were asked for their level of agreement with the statement “I intend to continue to use agrominerals/cover cropping on the land that I farm in the next five years”. For those in the Action phase, this assessed their intentions to progress to the Maintenance phase, and for those already using agrominerals/cover cropping as an established practice, this assessed their intentions to remain in the Maintenance phase.

In the second questionnaire, the PU and PEOU of both agrominerals and cover cropping were quantified. PU and PEOU are latent constructs (Davis 1989), and thus cannot be directly
quantified. Instead, a number of variables are employed to measure each construct. It is recommended that no more than six variables are used to measure PU and PEOU to minimise the number of questions that participants must answer (Compeau & Higgins 1995). Any less than three variables is considered problematic due to not providing flexibility for removing a variable to improve reliability (Compeau & Higgins 1995). In both the model for agrominerals and the model for cover cropping, four variables were used to assess PU and PEOU (Table 3.1), based on Collas & Vasseur (2018). As stated by Collas & Vasseur (2018), PU should centre on consideration of whether the practice increases yields. Cover cropping can indirectly lead to yield benefits by providing pest control (Snapp et al. 2005). Therefore, this study included whether farmers considered cover crops to decrease crop losses to pests in place of whether the practice benefited produce quality. Participants were asked to state their level of agreement, according to a seven-point Likert scale, to each variable listed in Table 3.1.

Table 3.1. The variables used to measure the latent constructs PU and PEOU. In the variable description column, “x” can be replaced with the practice in question which is indicated in the first column of the table.

<table>
<thead>
<tr>
<th>Practice</th>
<th>Latent construct</th>
<th>Variable label</th>
<th>Variable description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agrominerals</td>
<td>PU</td>
<td>Productivity</td>
<td>&quot;Using x would increase my crop productivity”.</td>
</tr>
<tr>
<td>Cover cropping</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agrominerals</td>
<td>PEOU</td>
<td>Easy</td>
<td>“It would be easy for me to use x”.</td>
</tr>
<tr>
<td>Cover cropping</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agrominerals</td>
<td>PEOU</td>
<td>Compatible</td>
<td>&quot;Using x would be compatible with my farm operations”.</td>
</tr>
<tr>
<td>Cover cropping</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agrominerals</td>
<td>PEOU</td>
<td>Understand</td>
<td>“I understand how to use x”.</td>
</tr>
<tr>
<td>Cover cropping</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agrominerals</td>
<td>PEOU</td>
<td>Equipment</td>
<td>&quot;Using x would be compatible with equipment that I currently own or would be willing to acquire”.</td>
</tr>
<tr>
<td>Cover cropping</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PU</td>
<td></td>
<td>Productivity</td>
<td>&quot;Using x would increase my crop productivity”.</td>
</tr>
<tr>
<td>Produce</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agrominerals</td>
<td>PEOU</td>
<td>Easy</td>
<td>“It would be easy for me to use x”.</td>
</tr>
<tr>
<td>Cover cropping</td>
<td></td>
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</tr>
<tr>
<td>Agrominerals</td>
<td>PEOU</td>
<td>Compatible</td>
<td>&quot;Using x would be compatible with my farm operations”.</td>
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<tr>
<td>Cover cropping</td>
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</tr>
<tr>
<td>Agrominerals</td>
<td>PEOU</td>
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<tr>
<td>Cover cropping</td>
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</tr>
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<td>Agrominerals</td>
<td>PEOU</td>
<td>Equipment</td>
<td>&quot;Using x would be compatible with equipment that I currently own or would be willing to acquire”.</td>
</tr>
<tr>
<td>Cover cropping</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Most participants in this study were not currently using agrominerals, whereas the majority were using cover crops. Therefore, the analysis focused on understanding participants’ intentions to adopt (rather than continue using) agrominerals (Fig. 3.2a), and so excluded the data of the twelve participants who were already using agrominerals. Conversely, the cover cropping model analysed participants’ intentions to continue cover cropping (Fig. 3.2b), thus excluding the data of the seven participants who were not already cover cropping. The sample sizes for (i) continued use of agrominerals and (ii) initial adoption of cover cropping were too small to analyse in this study.

To test for internal consistency amongst the variables used to measure both PU and PEOU, Cronbach’s alpha was calculated. A high inter-variable correlation — reflected by Cronbach’s alpha being >0.7 — indicates that the variables are measuring the same construct (Nunnally & Bernstein 1992). Discriminant validity — that each of the constructs tests are distinct — was calculated using the average variance extracted (AVE) for each construct. For discriminant validity, the square root of AVE for each construct should be greater than the correlation between constructs (Hulland 1999).

To examine the relationship between PU, PEOU, and intention to adopt/continue-using the practice, a path analysis (a form of Structural Equation Modelling (SEM)) was conducted using the ‘lavaan’ software package (version 0.5 - 23) in R (version 3.3.1). The path analysis is a multi-variate regression analysis that investigated whether participants’ intentions to
adopt agrominerals were driven by PU and PEOU (Fig. 3.2a), according to the variables used to measure these constructs (Table 3.1). A separate path analysis investigated whether participants’ intentions to continue using cover crops were driven by the PU and PEOU of cover cropping. In line with previous studies, the effect of PEOU on PU was included (Fig. 3.2b).

Figure 3.2. Under investigation is whether PU and PEOU influence (a) the intended adoption of agrominerals and, (b) the continued use of cover cropping. PEOU is proposed to have both a direct effect on adoption/continued use and an indirect effect via PU.

The path analysis runs iterations that seek to match as closely as possible the observed covariance matrix and the model-implied covariance matrix. The final parameter values are those that minimise the difference between what is observed in the data and what is implied by the model. Factor loadings were calculated to examine whether the variables used to measure the latent constructs (PU and PEOU) are representative of these constructs. In social science, factor loadings of >0.3 are considered significant (Norman & Streiner 2008).
3.2.2 Viability of agrominerals/cover crops as soil amendments

The mean scores of intention, PU and PEOU, and the associated standard deviations, were examined to provide an indication of participants’ general attitudes towards these practices (as in Flett et al. (2004)). Means were calculated for PU and PEOU by firstly finding the mean of the scores participants gave to the variables comprising PU and PEOU respectively, before finding the mean score of PU and PEOU across all participants.

To assess whether participants would be more likely to use agrominerals/cover crops with the provision of financial incentive, participants were asked whether they agree with the statement “I would implement agrominerals/ cover cropping if a financial incentive was provided,” again according to a seven-point Likert scale.

3.2.3 Other correlates to PU, PEOU, and adoption

Both the first and second questionnaires assessed farmers’ satisfaction with the practices they currently use to maintain soil health. The first questionnaire also quantified their tendency to experiment with new practices, how keen they are to trial different practices, and their concern for the environmental impacts of practices for maintaining soil health, all according to a seven-point Likert scale. Finally, the extent to which participants consider themselves capable of making decisions to change farming practices was assessed.

The following socio-economic and agro-ecological variables were measured: age, years farming experience, number of generations of farmers in the family, education, area of owned/rented land, and perceived soil quality (Table 3.2). Whether these factors correlate with PU, PEOU, intentions to adopt agrominerals and intentions to continue cover cropping was investigated.
Table 3.2. Description of the method used to measure the socio-economic and agro-ecological variables explored in this study.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Direction of effect on adoption found in previous research in agriculture</th>
<th>Method used to assess variable in this study</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Positive, negative and non-significant (reviewed in Knowler &amp; Bradshaw (2007) and Tey &amp; Brindal (2012)).</td>
<td>Six categories</td>
</tr>
<tr>
<td>Years farming experience</td>
<td>Positive and non-significant (reviewed in Tey &amp; Brindal 2012)</td>
<td>Six categories</td>
</tr>
<tr>
<td>Generations of family that have been farmers</td>
<td>No known studies in agriculture</td>
<td>Number of generations including self</td>
</tr>
<tr>
<td>Education</td>
<td>Positive (Mcbride &amp; Daberkow 2003; Adrian, Norwood &amp; Mask 2005; Walton et al. 2008; Larson et al. 2008) and non-significant (Tey &amp; Brindal 2012; Lemken, Spiller &amp; Von Meyer-Hofer)</td>
<td>High school/ College/ Bachelor’s /Master’s/ PhD</td>
</tr>
<tr>
<td>Area of owned/rented land farmed</td>
<td>Positive, negative and non-significant (reviewed in Knowler &amp; Bradshaw (2007) and Tey &amp; Brindal (2012)).</td>
<td>Area of owned land farmed, area of rented land farmed</td>
</tr>
<tr>
<td>Soil quality</td>
<td>Insignificant (Isgin et al. 2008; Kanna et al. 2001)</td>
<td>5-point scale of perception of soil quality ranging from poor to good</td>
</tr>
</tbody>
</table>

3.3 RESULTS

3.3.1 Summary of questionnaires returned

A total of 36 sets of questionnaires were returned, of which two were excluded on the basis of being incomplete. On average, questionnaire participants farmed a mean area of land of 229 ha. This is roughly in line with the mean area of land cultivated by farmers in Ontario which was estimated at 248 acres in 2016 (Statistics Canada 2016). Farmers that attended the workshops were far more likely to be growing fruit and vegetables compared to the average across Southern Ontario: 79% of participants reported that they grew fruit and/or vegetables, far lower than the average across Southern Ontario of 15% (Statistics Canada 2016). This
reflects the prevalence of grape-growing in the region surrounding where the workshops were held. It may also be a result of the field trials being conducted on a vineyard meaning that grape growers considered the workshops to be more applicable to them compared to farmers in different sectors and thus were more likely to attend.

1. **Is the adoption of agrominerals and cover cropping driven by perceptions of usefulness and ease of use?**

The 34 questionnaires that composed this study indicated that most participants were currently not using agrominerals on their land (22 participants out of 34; Table 3.3). Sixteen of these 22 participants were thinking about using agrominerals (the Contemplation stage). Of the participants not already using agrominerals, 55% reported being aware of the practice prior to the workshop.

Most participants were already using cover crops (27 out of 34; Table 3.3), with 25 participants identifying with the Maintenance stage where they intended to continue to use cover crops in the future. The other two participants identified with the Action stage where they were currently trialing the use of cover crops. Of the seven participants who are not already using cover cropping, six reported having knowledge of cover cropping prior to the workshop.

Table 3.3. The percentage of participants self-identifying as being in each stage of the adoption process.

<table>
<thead>
<tr>
<th></th>
<th>Pre-contemplation</th>
<th>Contemplation</th>
<th>Preparation</th>
<th>Action</th>
<th>Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agrominerals</td>
<td>8.82</td>
<td>47.06</td>
<td>8.82</td>
<td>14.71</td>
<td>20.59</td>
</tr>
<tr>
<td>Cover cropping</td>
<td>0.00</td>
<td>5.26</td>
<td>14.71</td>
<td>5.88</td>
<td>73.53</td>
</tr>
</tbody>
</table>
3.3.2 Testing for internal consistency and discriminant validity

Prior to completing the path analysis, internal consistency must be established to show that the variables used to measure the latent constructs are appropriate (Nunally & Bernstein 1992). Cronbach’s alpha provided strong evidence of internal consistency for agromineral PU, agromineral PEOU, cover cropping PU and cover cropping PEOU (all scores >0.7; internal consistency is implied by alpha > 0.7; Nunnally & Bernstein 1992; Table 3.4).

Table 3.4. Cronbach’s alpha, the mean and standard deviation associated with each variable (PEOU, PU and Intention). In the latter three columns, in bold are the square root of the average variance explained by each variable, and non-bolded are the correlations between constructs.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Cronbach’s alpha</th>
<th>Mean</th>
<th>SD</th>
<th>PEOU</th>
<th>PU</th>
<th>Intention</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agrominerals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEOU</td>
<td>0.80</td>
<td>4.75</td>
<td>1.11</td>
<td>0.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PU</td>
<td>0.87</td>
<td>4.49</td>
<td>0.81</td>
<td>0.45</td>
<td>0.74</td>
<td></td>
</tr>
<tr>
<td>Intention</td>
<td>N/A</td>
<td>4.83</td>
<td>1.61</td>
<td>0.60</td>
<td>0.69</td>
<td>0.86</td>
</tr>
<tr>
<td>Cover cropping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEOU</td>
<td>0.83</td>
<td>6.19</td>
<td>1.01</td>
<td>0.67</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PU</td>
<td>0.78</td>
<td>5.70</td>
<td>1.10</td>
<td>0.73</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td>Intention</td>
<td>N/A</td>
<td>6.58</td>
<td>1.30</td>
<td>-0.29</td>
<td>0.68</td>
<td>0.54</td>
</tr>
</tbody>
</table>

Calculating the AVE for each construct indicated that the agrominerals model showed discriminant validity. However, the cover cropping model did not display discriminant validity since the square root of the AVE was not always greater than the correlations between PEOU, PU and Intention (as described in Hulland 1999; Table 3.4).

3.3.3 Model fits

The SEM for the agrominerals model was well fitting according to the chi-squared index (x²=30.95, df =25, p=0.191; good fit is implied by a non-significant chi-squared value), the
Comparative Fit Index (0.942; good fit is indicated by scores >0.9), and the Tucker-Lewis Index (0.916; good fit is indicated by scores >0.9). The Root Mean Square of Approximation index implied a relatively good fit (0.109 (90% CL 0.0220); good fit is indicated by scores <0.1). The model confirmed the expected positive correlation between PU and PEOU ($\beta=0.45$, $p<0.05$; Fig. 3.3), indicating that perceptions of increased ease of use coincided with perceptions of increased usefulness. The model also confirmed positive correlations between PU and intention of adoption ($\beta=0.69$, $p<0.5$), and PEOU and intention of adoption ($\beta=0.59$, $p<0.05$).

![Diagram](image)

Figure 3.3. The SEM for agrominerals was well fitting, with intention being driven both by perceptions of the usefulness and ease of using agrominerals. Perceived ease of use was also found to have a significant effect on perceived usefulness.

When applied to the adoption of cover cropping, the SEM was poorly fitting. The chi-squared index showed that the estimated covariance matrix was significantly different from the actual covariance matrix ($\chi^2=64.27$, df=25, $p<0.05$). The Comparative Fit Index revealed similarly poor fit (0.622; good fit is indicated by scores >0.9), as did the Tucker-Lewis Index (0.455, good fit is indicated by scores >0.9), and the Root Mean Square of Approximation (0.256 (90% CL 0.180, 0.334); good fit is indicated by scores <0.1). The model implied significant
positive correlations between PU and PEOU ($\beta=0.73$, $p<0.05$; Fig. 3.4), and between PU and intention of continued use ($\beta=0.68$, $p<0.05$). However, there was no significant correlation between PEOU and intention of continued use ($\beta=-0.29$, $p>0.05$).

![Diagram showing correlations]

Figure 3.4. The SEM for continued use of cover crops was poorly fitting but implied a role of perceived usefulness in driving the intention of continued use. Perceived ease of use had a significant effect on perceived usefulness but not on intention.

### 3.3.4 Factor loadings

Factor loadings are a measure of the correlation between each variable used to measure PU and PEOU and the overall construct. Factor loadings of $>0.3$ are considered to indicate that variables are well correlated to the overall construct and are thus representative measures of that construct (Norman & Streiner 2008). In the agrominerals model, all variables had factor loadings of $>0.3$, aside from the cost variable which showed a non-significant factor loading onto the PU construct. All factor loadings for the variables used to measure PU and PEOU in the cover cropping model were $>0.3$, indicating that they were representative of the constructs (Norman & Streiner 2008; Table 3.5).
Table 3.5. The means and associated standard deviations of each variable. All factor loadings (‘Beta’) were significant apart from the ‘Cost’ variable in the Agrominerals model.

<table>
<thead>
<tr>
<th>Latent Variable</th>
<th>Measured Variable</th>
<th>Mean</th>
<th>SD</th>
<th>Beta</th>
<th>Standard Error</th>
<th>Z value</th>
<th>p value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agrominerals</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEOU</td>
<td>Easy</td>
<td>4.95</td>
<td>1.56</td>
<td>1.36</td>
<td>0.28</td>
<td>4.82</td>
<td>0.00</td>
</tr>
<tr>
<td>PEOU</td>
<td>Compatible</td>
<td>5.45</td>
<td>1.21</td>
<td>1.15</td>
<td>0.21</td>
<td>5.58</td>
<td>0.00</td>
</tr>
<tr>
<td>PEOU</td>
<td>Understand</td>
<td>4.20</td>
<td>1.77</td>
<td>0.92</td>
<td>0.34</td>
<td>2.74</td>
<td>0.01</td>
</tr>
<tr>
<td>PEOU</td>
<td>Equipment</td>
<td>4.42</td>
<td>1.43</td>
<td>0.61</td>
<td>0.31</td>
<td>2.01</td>
<td>0.04</td>
</tr>
<tr>
<td>PU</td>
<td>Productivity</td>
<td>4.85</td>
<td>1.02</td>
<td>0.64</td>
<td>0.14</td>
<td>4.59</td>
<td>0.00</td>
</tr>
<tr>
<td>PU</td>
<td>Produce</td>
<td>4.80</td>
<td>1.14</td>
<td>0.77</td>
<td>0.16</td>
<td>4.87</td>
<td>0.00</td>
</tr>
<tr>
<td>PU</td>
<td>Value</td>
<td>4.08</td>
<td>1.23</td>
<td>0.60</td>
<td>0.19</td>
<td>3.20</td>
<td>0.00</td>
</tr>
<tr>
<td>PU</td>
<td>Cost</td>
<td>4.24</td>
<td>1.25</td>
<td>0.15</td>
<td>0.20</td>
<td>0.72</td>
<td>0.47</td>
</tr>
<tr>
<td>Cover cropping</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PEOU</td>
<td>Easy</td>
<td>6.04</td>
<td>1.51</td>
<td>0.56</td>
<td>0.28</td>
<td>1.97</td>
<td>0.04</td>
</tr>
<tr>
<td>PEOU</td>
<td>Compatible</td>
<td>6.44</td>
<td>1.12</td>
<td>0.34</td>
<td>0.14</td>
<td>2.47</td>
<td>0.01</td>
</tr>
<tr>
<td>PEOU</td>
<td>Understand</td>
<td>6.00</td>
<td>1.30</td>
<td>1.17</td>
<td>0.21</td>
<td>5.55</td>
<td>0.00</td>
</tr>
<tr>
<td>PEOU</td>
<td>Equipment</td>
<td>6.30</td>
<td>1.07</td>
<td>0.63</td>
<td>0.19</td>
<td>3.26</td>
<td>0.00</td>
</tr>
<tr>
<td>PU</td>
<td>Productivity</td>
<td>6.19</td>
<td>1.04</td>
<td>0.64</td>
<td>0.16</td>
<td>3.96</td>
<td>0.00</td>
</tr>
<tr>
<td>PU</td>
<td>Value</td>
<td>5.37</td>
<td>1.50</td>
<td>0.97</td>
<td>0.23</td>
<td>4.20</td>
<td>0.00</td>
</tr>
<tr>
<td>PU</td>
<td>Cost</td>
<td>5.85</td>
<td>1.23</td>
<td>0.88</td>
<td>0.19</td>
<td>4.65</td>
<td>0.00</td>
</tr>
<tr>
<td>PU</td>
<td>Pest</td>
<td>5.32</td>
<td>1.68</td>
<td>0.67</td>
<td>0.28</td>
<td>2.41</td>
<td>0.00</td>
</tr>
</tbody>
</table>
2. Are agrominerals and cover crops considered to be viable soil amendments?

Participants generally showed positive reactions to using both agrominerals and cover cropping. Of those yet to adopt agrominerals, participants showed a mean intention of adoption of 4.83, a mean PU of 4.49, and a mean PEOU of 4.75 (all measured on a seven-point Likert scale; Table 3.4). Those already using agrominerals showed a mean intention of 5.82 of continuing to do so, a mean PU of 4.85 and a mean PEOU of 5.56.

Of those yet to adopt cover cropping, participants showed a mean intention of adoption of 5.43, a mean PU of 4.74 and a mean PEOU of 5.25 (Table 3.4). Those who have already adopted cover cropping indicated a high likelihood of continuing to use the practice with a mean score of 6.58, with relatively lower perceptions of the practice’s usefulness (mean=5.70) and ease of use (mean=6.19). The mean scores attributed to each of the variables used to measure PU and PEOU are provided in Table 3.5.

Participants were no more likely to adopt agrominerals should financial incentive be provided (paired Wilcoxon two-tailed test: V=71.5, P=0.875,). Somewhat counterintuitively, the proposition of financial incentive saw participants significantly less likely to want to continue cover cropping (V=86, P=0.008).

3. Are farmers generally satisfied with their current practices for maintaining soil health?

*In this section, only significant correlations to PU and PEOU are reported; complete results can be found in Table 3.6.*
Participants were asked to rate their satisfaction with current practices for maintaining soil health on a seven-point scale in both questionnaires. On average, participants were somewhat satisfied with their current practices (Questionnaire 1: mean score of 4.87; Questionnaire 2: mean score of 4.56; Table 3.6). The difference between the satisfaction scores in the questionnaires was not significant (paired Wilcoxon rank sum two-tailed test: $V=74, P=0.142$).

There was no significant correlation between intention of adopting agrominerals and satisfaction with current practices, measured in both the first questionnaire (Spearman’s rank correlation: $r_s=-0.193, P=0.376$; Table 3.6) and second questionnaire ($r_s=-0.216, P=0.321$). Those that indicated a desire to adopt some new practices for maintaining soil health showed significantly stronger intentions of adopting agrominerals than those who did not wish to adopt new practices for maintaining soil health ($r_s=0.420, P=0.046$). This desire to adopt new practices was significantly correlated to increased confidence of the PEOU, but not the PU, of agrominerals (PEOU: $r_s=0.504, P=0.020$; PU: $r_s=0.376, P=0.093$).

Of the participants already practicing cover cropping, their intentions to continue were positively correlated to their satisfaction with current practices used to maintain soil health in the second questionnaire ($r_s=0.398, P=0.044$; Table 3.6), but not in the first questionnaire ($r_s=0.272, P=0.179$). There was no significant correlation between these participants' intentions to continue cover cropping and their desire to adopt new practices for maintaining soil health ($r_s=0.034=5, P=0.866$).

Participants’ intentions to adopt agrominerals were significantly positively correlated with their concern for the impact that practices for maintaining soil health can have on the
environment ($r_s=0.515$, $P=0.012$; Table 3.6). Those that showed a greater level of concern also perceived agrominerals to be more useful ($r_s=0.578$, $P=0.006$). Contrastingly, there was no significant correlation between participants’ intentions of continuing to cover crop and their concern for the impact that soil health practices can have on the environment ($r_s=0.057$, $P=0.784$).

Participants’ tendency to experiment with new practices was not significantly correlated to their intentions of adopting agrominerals ($r_s=0.346$, $P=0.106$; Table 3.6). No correlation was found between participants’ tendency to experiment with new practices and their intentions to continue cover cropping ($r=0.188$, $P=0.358$). Those that reported being more experimental rated cover cropping as being significantly more useful ($r_s=0.588$, $P=0.002$).

No significant correlation existed between participants’ ability to implement changes in the way land is farmed and their intentions of adopting agrominerals ($r_s=0.190$, $P=0.385$; Table 3.6). The ability to implement changes showed a positive, though non-significant, correlation to participants’ intentions to continue cover cropping ($r_s=0.355$, $P=0.075$), and a significant positive correlation to the PEOU of cover cropping ($r_s=0.417$, $P=0.034$).
Table 3.6. Means, standard deviations and correlations to intention of a number of variables investigating participants’ attitudes towards practices for maintaining soil health (** = correlation coefficient significant at p<0.01; * = correlation coefficient significant at p<0.05).

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Mean</th>
<th>SD</th>
<th>Intention of adopting agrominerals Correlation coefficient</th>
<th>Intention of continuing cover cropping Correlation coefficient</th>
<th>PU of agrominerals Correlation coefficient</th>
<th>PEOU of agrominerals Correlation coefficient</th>
<th>PU of cover cropping Correlation coefficient</th>
<th>PEOU of cover cropping Correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satisfaction 1</td>
<td>Satisfaction with current practices used to maintain soil health (measured in first questionnaire).</td>
<td>4.87</td>
<td>1.48</td>
<td>-0.19</td>
<td>0.27</td>
<td>-0.30</td>
<td>-0.35</td>
<td>0.29</td>
<td>-0.34</td>
</tr>
<tr>
<td>Satisfaction 2</td>
<td>Satisfaction with current practices used to maintain soil health (measured in second questionnaire).</td>
<td>4.56</td>
<td>1.31</td>
<td>-0.22</td>
<td>0.40 *</td>
<td>-0.04</td>
<td>-0.03</td>
<td>0.25</td>
<td>-0.19</td>
</tr>
<tr>
<td>Desire new practices</td>
<td>Desire to adopt some new practices for maintaining soil health.</td>
<td>5.40</td>
<td>1.25</td>
<td>0.42 *</td>
<td>0.04</td>
<td>0.38</td>
<td>0.50 *</td>
<td>0.05</td>
<td>-0.23</td>
</tr>
<tr>
<td>Concern</td>
<td>Concern for the impact practices used to maintain soil health can have on the environment.</td>
<td>4.31</td>
<td>2.08</td>
<td>0.52 *</td>
<td>0.06</td>
<td>0.58 **</td>
<td>0.40</td>
<td>-0.10</td>
<td>-0.19</td>
</tr>
<tr>
<td>Experiment</td>
<td>Tendency to experiment with new practices.</td>
<td>6.14</td>
<td>0.91</td>
<td>0.35</td>
<td>0.19</td>
<td>0.17</td>
<td>0.38</td>
<td>0.59 **</td>
<td>0.17</td>
</tr>
<tr>
<td>Decisions</td>
<td>Capacity to make decisions to change farm practices.</td>
<td>6.34</td>
<td>0.94</td>
<td>0.19</td>
<td>0.36</td>
<td>0.15</td>
<td>0.24</td>
<td>0.38</td>
<td>0.42 *</td>
</tr>
</tbody>
</table>
4. Can socio-economic and agro-ecological factors predict adoption?

The amount of owned land did not impact participants’ intentions to adopt agrominerals ($r_s=-0.178$, $P=0.428$; Table 3.7) or continue to use cover crops ($r_s=-0.159$, $P=0.449$). Agrominerals were considered to be marginally significantly easier to use by participants farming smaller plots of land compared to those farming larger areas ($r_s=0.435$, $P=0.055$).

Participants’ age showed no significant correlation to either their intentions of adopting agrominerals ($r_s=0.321$, $P=0.135$; Table 3.7) or continuing cover cropping ($r_s=0.135$, $P=0.511$). Furthermore, the time participants had been farming showed no correlation to either adopting agrominerals ($r_s=0.049$, $P=0.823$) or continuing cover cropping ($r_s=0.248$, $P=0.221$). Education did not correlate with intentions to adopt agrominerals (Kruskal-Wallis One Way Anova: $x^2=1.355$, $P=0.508$; Table 3.6) or to continue cover cropping ($x^2=1.418$, $P=0.841$).

When asked to state how many generations of the participants’ family had been farmers, some were not entirely sure and thus gave answers such as “3+”. These non-numerical answers were removed from the analysis since it was impossible to know the actual number of generations of the participants’ family that had been farmers. No significant correlation was found between the numbers of previous generations of farmers in the participant’s family and their intention to adopt agrominerals ($r_s=-0.002$, $P=0.993$; Table 3.7) or continue to cover crop ($r_s=-0.016$, $P=0.945$). Participants’ perceptions of the soil quality on the land that they farmed was not significantly correlated to their intentions of adopting agrominerals ($r_s=0.044$, $P=0.844$; Table 3.6) or continuing to cover crop ($r_s=-0.026$, $P=0.901$).
Table 3.7. Means, standard deviations and correlations to intention, PU and PEOU for socio-economic and agro-ecological variables. Where data was non-numerical the mode is listed (in brackets) in place of the mean. †Values listed for ‘Education’ are Kruskal-Wallis test statistics, not correlation coefficients.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Mean (mode)</th>
<th>SD</th>
<th>Intention of adopting agrominerals</th>
<th>Intention of continuing cover cropping</th>
<th>PU of agrominerals</th>
<th>PEOU of agrominerals</th>
<th>PU of cover cropping</th>
<th>PEOU of cover cropping</th>
<th>Correlation coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owned area (ha)</td>
<td>Area of owned land farmed by participant.</td>
<td>229.58</td>
<td>390.16</td>
<td>-0.18</td>
<td>-0.16</td>
<td>-0.16</td>
<td>-0.43</td>
<td>-0.04</td>
<td>0.05</td>
<td></td>
</tr>
<tr>
<td>Age (years)</td>
<td>Age of participant (measured as six categories).</td>
<td>(55-64)</td>
<td></td>
<td>0.32</td>
<td>0.14</td>
<td>0.12</td>
<td>0.40</td>
<td>-0.04</td>
<td>-0.20</td>
<td></td>
</tr>
<tr>
<td>Time farming (years)</td>
<td>Number of years participants have been farming (measured as six categories).</td>
<td>(&gt;30)</td>
<td></td>
<td>0.05</td>
<td>0.25</td>
<td>-0.03</td>
<td>0.06</td>
<td>0.18</td>
<td>-0.11</td>
<td></td>
</tr>
<tr>
<td>Generations</td>
<td>Number of generations of the participants’ family who were farmers.</td>
<td>2.83</td>
<td>2.33</td>
<td>-0.00</td>
<td>-0.02</td>
<td>0.39</td>
<td>-0.04</td>
<td>0.00</td>
<td>0.04</td>
<td></td>
</tr>
<tr>
<td>Education</td>
<td>Highest level of education reached (Bachelor’s degree)</td>
<td>1.36†</td>
<td></td>
<td></td>
<td></td>
<td>1.42†</td>
<td>2.66†</td>
<td>2.18†</td>
<td>5.08†</td>
<td>1.85†</td>
</tr>
<tr>
<td>Soil quality</td>
<td>Perceived quality of soil on farmland (1-5 scale).</td>
<td>3.87</td>
<td>0.80</td>
<td>0.04</td>
<td>-0.03</td>
<td>0.06</td>
<td>0.01</td>
<td>0.06</td>
<td>0.12</td>
<td></td>
</tr>
</tbody>
</table>
### 3.4 Discussion

In this study, potential users’ intentions to adopt agrominerals to maintain soil health were well explained by their perceptions of the usefulness and ease of using agrominerals. In contrast, the model applied to understand farmers’ intentions to continue cover cropping showed poor fit since PEOU did not contribute to participants’ intentions to continue using cover crops. Participants showed positive reactions towards the use of agrominerals and cover cropping, indicating that both practices are considered viable methods for maintaining soil health. Participants’ concern for the environmental impacts of agriculture was positively correlated to their intentions of adopting agrominerals and their perceptions of agrominerals’ usefulness. Participants’ that showed a desire to adopt new practices for maintaining soil health also showed greater intentions of adopting agrominerals and considered the practice easier to use. Cover crops were considered more useful by those that regularly experiment with different practices and easier to use by those that have the capacity to make decisions on the land that they farm. Socio-economic and agro-ecological factors had no significant effects on driving either the adoption of agrominerals or the continued use of cover cropping.

#### 3.4.1 Is the revised TAM useful for studying adoption in agriculture?

*Initial adoption phase.* This study found that for potential adopters (those in the Pre-Contemplation, Contemplation and Preparation stages) to intend to adopt agrominerals, the practice must be perceived as both useful and easy to use (as previously found in studies of adoption in an agricultural context e.g. Rezaei-Moghaddam & Salehi (2010); though see Adrian, Norwood & Mask (2005)). PEOU had a significant effect on PU, confirming that practices considered easier to use are, by consequence, considered more useful (as first laid out by Davis (1989). This finding had been unconfirmed by prior studies in an agricultural context (Adrian, Norwood & Mask 2005; Aubert, Schroeder & Grimaudo 2012)).
Maintenance phase. Contrastingly, the model applied to understand participants’ intentions to continue cover cropping (that was either being performed on a trial basis or as an established practice – the Action and Maintenance stages of adoption) was poorly fitting. The cover cropping model showed poor discriminant validity, indicating that PU and PEOU may not be separate constructs in this case. The direct effect of PEOU on intention was non-significant, implying that whether the practice was considered easy to use had no direct impact on participants’ intentions to continue cover cropping. However, the effect of PEOU on PU was significant, and thus PEOU had an indirect effect on intention. PU emerged as the single direct driving factor of participants’ intentions to continue cover cropping.

This was the first study to examine whether PU and PEOU explain individuals’ intentions to continue using a practice. Some studies have reported that participants are more likely to be using a practice when they consider it more useful, as well as easier to use, than non-adopters (Flett et al. 2004; Aubert, Schroeder & Grimaudo 2012). However, these studies did not include participants’ intentions to continue using the practice. Other factors, such as observability (i.e. that the consequences of the practice are visible and understandable), or processes such as imitation within the farmer group, may become more influential once practices have become widespread (Rogers 2003; Sneddon, Soutar & Mazzarol 2011). Therefore, it is possible that this study did not adequately capture the driving forces of participants’ decisions to continue cover cropping. Therefore, Collas & Vasseur (2018)’s revised TAM in its current form may not accurately explain the latter stages of the adoption process.

The use of self-reporting in this study may have impacted the model fits. Self-reporting can lead to biased results due to participants stating the answer that they think is wanted, or that is socially desirable, rather than what they actually think (Van Ittersum & Feinberg 2010). Additionally, the cover cropping model may have been affected by the
choice-supportive bias whereby participants may have rated the practice more highly as justification for why they were using it (Gordon, Franklin & Beck 2005).

In both models, all variables used to measure PU and PEOU were relevant (as indicated by the significant factor loadings), except for the cost effectiveness variable in the agrominerals model. This supports Collas & Vasseur’s (2018) interpretation of PU and PEOU in an agricultural context. Uncertainty surrounding the cost of using agrominerals (the company has recently changed ownership and prices are in flux) may explain the non-significance of the cost effectiveness variable which was expected to be a key component of PU.

3.4.2 Reactions to agrominerals and cover cropping

Agrominerals. In this study, participants generally showed positive reactions towards agrominerals (participants reported a mean intention of adoption of 4.83 on a 7-point scale), particularly when they showed a prior desire to adopt new practices to maintain soil health. The limited scientific evidence currently available regarding the effects of using agrominerals was expected to be a barrier to adoption (in line with Long, Blok & Coninx (2016)). Participants’ perceptions of agrominerals may have been positively influenced during the question-and-answer session where those already using agrominerals shared their positive experiences. Neighbours are considered an important knowledge source (Odongo 2013) and imitation behaviour can result in so-called ‘faddish’ patterns of adoption (Sneddon, Soutar & Mazzarol 2011). Further study is needed to investigate the extent to which this affected participants’ responses and of how representative these attitudes are of other farmers in the region that did not choose to attend the workshops. Participants may have decided to attend the workshops due to a prior interest in alternative practices for maintaining soil health. This self-selection bias may mean that these results are not fully representative (Daberkow &
McBride 2003), and, on the whole, the farming population in Southern Ontario may not show such positive reactions towards using agrominerals.

**Cover cropping.** Participants showed a high level of awareness of cover cropping prior to the workshop. In reflection of cover-cropping being a more widely-known practice, a greater proportion of participants were already using cover crops compared to agrominerals. With most farmers at the workshops already using cover cropping, the relatively high scores given to PEOU were perhaps to be expected (Sneddon, Soutar & Mazzarol 2011; Aubert, Schroeder & Grimaudo 2012). Over time, it is logical to expect PEOU scores to increase in this way, e.g. for “I understand how to do cover cropping” due to adopters learning how to use the practice. Additionally, agreement to the statement “Cover cropping is compatible with equipment that I currently own or would be willing to acquire” would also be expected to increase as adopters accrue the resources required to perform the practice. The high scores given to PU is in keeping with the plethora of benefits associated with cover cropping which have been well documented (reviewed in Blanco-Canqui, Claassen & Presley (2012)) and which these farmers appeared to be realising.

### 3.4.3 Other correlates to PU, PEOU and intention

It is promising that participants’ concern for the impacts of practices used to maintain soil health was positively correlated to their intentions of adopting agrominerals. This concern was also significantly correlated to participants’ perceptions of the usefulness of agrominerals. This indicates that beliefs and values may act via PU and PEOU, rather than acting directly on intention of adoption as has previously been considered in an agricultural context (e.g. Adrian, Norwood & Mask 2005).

Existing literature indicates that environmental concern can translate into farmers taking action to address the environmental impact of their activities. For example, awareness
of the problems associated with maintaining soil health was frequently found to be associated with the adoption of no-till agriculture (Knowler & Bradshaw 2007). However, practices without economic benefits are unlikely to be adopted, regardless of their environmental benefits (Cullen, Forbes & Grout 2013; McDonald et al. 2016). Government subsidies can be powerful mechanisms for increasing adoption rates of practices that are environmentally beneficial without being cost effective to the farmer (Cullen, Forbes & Grout 2013). However, this study found that the provision of financial incentives made farmers no more likely to adopt agrominerals and less likely to adopt cover cropping. Both practices were viewed as relatively – though not extremely – cost effective. The unattractiveness of government subsidies found in this study may be due to the high transaction costs perceived to be associated with claiming compensation (Christensen et al. 2011).

Some participants were not aware of the ongoing environmental degradation associated with practices used to maintain soil health. When asked to state their level of concern, some ratings were as low as one on a seven-point scale (with a mean of 4.31, but a relatively high standard deviation of 2.08). This adds to an established and growing evidence base which necessitates urgent action to educate those producing food on the detrimental effects that different strategies can have on the environment (Long, Blok & Coninx 2016; Toma et al. 2016). Farmers may suffer from what is known as ‘over-discounting’, whereby perceptions of the future being better than what can be realistically expected reduces intentions to change behaviour now to avert an environmental crisis in the future (Hoffman & Henn 2008).

3.4.4 The role of socio-economic and agro-ecological factors

In line with existing evidence, demographic factors were not particularly useful for predicting whether participants intend to adopt/continue using a practice (reviewed in Tey &
Brindal (2012)). The marginally significant finding that agrominerals are perceived to be easier to use on smaller areas of land may be related to issues of spreading SRC at a larger scale. At a small scale, it is possible to spread SRC by hand, but at larger scales, farmers would have to invest in buying or adapting equipment for spreading which would translate to a lower PEOU score. This would indicate that the link between demographic factors and adoption is strongly dependent on the practice in question.

3.4.5 Knowledge exchange events

Information availability has previously been evidenced to limit adoption (Knowler & Bradshaw 2007; Aubert, Schroeder & Grimaudo 2012) and so events where information is exchanged between farmers and scientists are important. The workshops held as part of this study proved to be highly effective in achieving this knowledge transfer: despite only 55% of participants having heard of agrominerals beforehand, only three participants reported that they were not thinking about adopting agrominerals after the workshop. In addition to providing education to introduce farmers to alternative strategies, adoption rates may be higher where support is provided during the installation of the practice (Aubert, Schroeder & Grimaudo 2012). Other studies have pointed to the importance of so-called “co-creation” in maximising adoption rates, whereby joint interactions between a range of stakeholders guide the development of a new practice (Wever, Van Kuijk & Boks 2008).

3.5 CONCLUSION

This study provides a positive outlook of farmers’ intentions to use practices that achieve high yields at low environmental cost. Participants’ intentions of adopting agrominerals were found to be well explained by PU and PEOU. In light of the poorly-fitting model for cover crops, further study is needed to understand whether PU does indeed become
the sole direct predictor of the continued use of a practice – as indicated in this study – or whether PEOU continues to have a direct effect. Participants’ positive reactions towards agrominerals, despite their low initial awareness, indicate that improved communication between scientists, farmers and other stakeholders is vital for reforming agricultural production. Continued development of strategies that enable high-yield farming at least environmental cost must go hand-in-hand with outreach to inform and support farmers implementing these strategies if we are to reconcile agricultural production with environmental conservation on Earth.
3.6 REFERENCES


new insights into the role of metals in nodulation and symbiotic nitrogen fixation.

*Frontiers in Plant Science, 5.*


threats to biodiversity and pathways to their prevention. *Nature*, 546, 73–81.


Chapter 4

GENERAL DISCUSSION

4.1. Implications of this study for the revised TAM

This thesis sought to understand why farmers decide to adopt different practices, particularly for the maintenance of soil health. Chapter 2 saw the development of a model for studying adoption in agriculture, before an empirical investigation was undertaken in Chapter 3. The study in Chapter 3 examined two parts of this model separately: (i) the initial adoption of agrominerals (Pre-Contemplation, Contemplation and Preparation stages) and (ii) the continued use of cover cropping (Action and Maintenance stages). Due to insufficient data, it was not possible to examine participants’ intentions to continue using agrominerals or to initially adopt cover crops, and so the model could not be applied in full. Nonetheless, the conclusions derived from this study can be used to postulate whether the model would be capable of accurately explaining farmer behaviour across all stages of the adoption process.
This study found that the key elements of the TAM – PU and PEOU – were significant drivers of the initial adoption of agrominerals. However, the model was poorly fitting when applied to explain participants’ intentions to continue cover cropping – a practice that had already been widely adopted by the study participants. This study indicated that the effect of PEOU becomes less important once a practice has been adopted and its effect on decision-making is indirect, via PU. Other factors may become important in driving the continued use of a practice, such as whether the effects of using the practice are easily observed and understood (so-called observability; Rogers 2003). Therefore, the model developed in Chapter 2 may not sufficiently explain farmers’ behaviour when deciding whether to continue using a practice following the Action stage. Adoption may also be limited where farmers lack the financial capital to invest in implementing a practice. PU did include consideration of cost effectiveness, but it is possible that this did not adequately capture the effect on adoption of the initial costs of investing in a practice.

The results of this study may have been influenced by a self-selection bias whereby those attending the workshops had an existing interest in alternative soil management practices (Daberkow & McBride 2003). Therefore, they may have shown more favourable attitudes towards agrominerals and cover cropping compared to what would be found across the entire population of farmers in Southern Ontario. This self-selection bias could be overcome by selecting a geographical region to study and recording the attitudes of all farmers within that area.

The conclusions obtained from this study can only be considered correlational. To prove causation (i.e. that perceptions of the PU and PEOU of a practice actually cause it to be adopted or rejected), a longitudinal study spanning multiple years is needed. This method of inquiry is required to understand the extent to which intentions to adopt a practice translate into its actual adoption – a relationship known to be imperfect (Legris et al. 2003). The
model developed in Chapter 2 could be deployed to study how potential adopters progress and regress through the five stages of adoption and assess whether this behaviour is in function of PU and PEOU. Further research should also seek to further assess the impact of learning and beliefs (e.g. concern for the potential environmental impacts of agriculture) on PU and PEOU.

4.2 Potential for agrominerals and cover cropping to maintain soil health

This study found relatively positive attitudes towards the use of agrominerals with the majority of participants reporting positive intentions towards adopting and using the practice. Furthermore, many of these farmers were already using cover crops, with high intentions of continuing to do so. Therefore, in theory, these results indicate that synthetic fertiliser use in the study region could decline as it is replaced on many farms with the use of alternative practices to stimulate crop growth. However, since the sample studied may have more positive attitudes to agrominerals and cover-cropping compared to the entire farming population in the Southern Ontario region, the uptake of these practices may be more limited than what would be expected based on extrapolation of these results.

Whilst the two practices studied here – agrominerals and cover cropping – hold potential to facilitate high yields at low environmental cost, they are only part of what must be a much larger solution. Agrominerals are a finite resource, and whilst there are many agrominerals deposits across the world, the rocks vary in their composition and are not always suitable for agriculture (Van Straaten 2007; Jones 2016). Some agrominerals cannot be used in agriculture due to a prevalence of toxic heavy metals (Sam et al. 1999; Heim et al. 2012). Furthermore, the long-term effects of agrominerals are unknown, and thus whether their addition results in sustained high yields across a long-term period remains to be understood.
Cover cropping does confer significant benefits for soil health and pest management, but the practice is not universally beneficial (Blanco-Canqui et al. 2015). In regions with limited water availability, increased competition for water as a result of planting cover crops may result in yield declines in the main crop (Blanco-Canqui et al. 2015). With on-going climate change, periods of drought are expected to both become more frequent, including in areas that were previously unaffected by drought (Vermeulen, Campbell & Ingram 2012). Therefore, the proportion of farmed land suitable for using cover crops may shrink. Nonetheless, in regions where water is not limiting, cover crops confer substantial benefits and – given the positive reactions to cover crops shown by the participants of this study – farmers appear to be realising these benefits.

Many other practices also hold promise in achieving sustainable agriculture. Each must be studied to better understand farmers’ attitudes to identify and address any barriers to their adoption. The use of higher-yielding varieties, integrated pest management, early-maturing varieties, precision agriculture technology, and intensive silvo-pastoral systems to farm livestock are just some of the approaches that show promise in making agriculture more sustainable (Foley et al. 2011; Tilman et al. 2011; Godfray & Garnett 2014; Williams et al. 2017). Where these practices require substantial investment on behalf of the farmer, it cannot be expected that they bare this cost alone. Support from the government, though found to be undesirable in the study in this research, is generally thought to be an effective tool for encouraging the adoption of certain practices (Cullen, Forbes & Grout 2013). Therefore, further study is needed to understand why participants in this study were generally unwilling to attain financial incentives and to understand how such a system could be better designed to encourage the implementation of beneficial practices.

4.3 Conclusion
With accelerating rates of climate change and biodiversity loss rivalling that of a mass extinction, there is an urgent need to transform agriculture (Tubiello et al. 2013; Tilman et al. 2017). This transformation requires behavioural change across all levels of the food system. This thesis provides a model for understanding farmers’ decision-making behaviour with respect to adopting new practices. When applied, the model found perceptions of both the usefulness and ease of using a practice to be influential to their intention of adopting the practice. Where farmers are already using a practice, the direct effect of perceived ease of use was non-significant and their intentions of continuing to use the practice were directly driven by perceptions of its usefulness alone.

Identifying the barriers that farmers perceive to be associated with adopting a new practice is crucial to better understand their attitudes towards beneficial practices. This knowledge must, in turn, translate into efforts to remedy these barriers such that practices that facilitate high yields at low environmental cost become widespread. This thesis showed that knowledge of both the potential environmental impacts of farming practices and of alternative practices was, at times, greatly lacking amongst farmers. However, once farmers attained this knowledge, they reported positive intentions towards changing their behaviour. This finding should give us great optimism that, with the right strategies in place, agricultural production can be transformed to feed the world’s growing human population without catastrophic environmental harm.
4.4 REFERENCES


APPENDICES

Appendix A: Questionnaire 1

Please state your 3-digit identifier number: 

1. What is your age?
   a. 18-24
   b. 25-34
   c. 35-44
   d. 45-54
   e. 55-64
   f. 65 & over

2. For how long have you been a farmer?
   a. Less than 2 years
   b. 2-5 years
   c. 6-10 years
   d. 11-20 years
   e. 21-30 years
   f. More than 30 years

3. How many generations of your family have been farmers (including yourself)?
   _____ generations

4. What is the highest level of education that you have achieved?
   a. High school
   b. College
   c. Bachelor’s degree
   d. Master’s degree
   e. PhD

5. Gender: _________

6. Is the land that you farm:
a. Owned: ___ acres
b. Rented: ___ acres

7. What crops do you grow on your farm?
_____________________________________________________________________
_____________________________________________________________________

8. Farm sales
a. < $10,000
b. $10,000 – $25,000
c. $25,000 – $50,000
d. $50,000 – $100,000
e. > $100,000

9. Indicate the quality, on average, of the soil on the land that you farm (circle one option):

<table>
<thead>
<tr>
<th>Poor</th>
<th>Good</th>
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10. Indicate the practices that you currently use to maintain your soil:

a. Chemical fertilizer
b. Manure addition
c. Cover cropping
   i. What plants do you use?

_____________________________________________________________________

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<th>d. Other: please specify</th>
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11. State any farming organizations in which you are a member:
_____________________________________________________________________

12. Who do you consider to be a knowledge source?

a. Neighbours
Please indicate your agreement with the following statements (circle one option).

13. I have the capacity to make the decision to implement new practices on the land that I farm.
   Strongly disagree  Strongly agree
   1  2  3  4  5  6  7

14. I am satisfied with the practices that I currently use to maintain soil health on my farm.
   Strongly disagree  Strongly agree
   1  2  3  4  5  6  7

15. I am concerned that some practices used to maintain soil health can have a negative impact on the environment.
   Strongly disagree  Strongly agree
   1  2  3  4  5  6  7

16. I like to experiment with new ways of doing things on my farm.
   Strongly disagree  Strongly agree
   1  2  3  4  5  6  7

17. I wait for financial incentives from the government to change my farming practices.
   Strongly disagree  Strongly agree
   1  2  3  4  5  6  7
Appendix B: Questionnaire 2

Please state your 3-digit identifier number:

Having listened to the presentation about the use of an agromineral soil amendment in combination with cover cropping, please consider the following questions. Unless otherwise indicated, you are asked to indicate the extent to which you agree with the statements on a scale of 1 (strongly disagree) to 7 (strongly agree) by circling one option.

1. I am satisfied with the practices that I currently use to maintain my soil.
   Strongly disagree
   1 2 3 4 5 6 7
   Strongly agree
2. I would like to adopt some different practices/techniques for maintaining my soil.
   Strongly disagree
   1 2 3 4 5 6 7
   Strongly agree

AGROMINERALS

The following questions are about using an agromineral as a soil amendment.

3. Before today, were you aware of the potential use of agrominerals as a soil amendment?
   Yes
   No

4. Which of the following statements best describes you position with respect to adopting agrominerals as a soil amendment?
   a) “I do not intend to try using agrominerals on the land that I farm”
   b) “I am thinking about using agrominerals but I have not yet begun preparations for doing so”
   c) “I intend to try using agrominerals and I have begun to make preparations for doing so”
   d) “I work with agrominerals on a small-scale trial basis”
   e) “I have successfully trialled the use of agrominerals on the land that I farm and plan to continue using agrominerals in coming years”

5. Answer this question only if you answered either a), b) or c) to Question 4
   To what extent do you agree with the following statement:
   I intend to try using agrominerals on the land that I farm in the next five years.
   Strongly disagree
   1 2 3 4 5 6 7
   Strongly agree

6. **Answer this question only if you answered either d) or e) to Question 4**

To what extent do you agree with the following statement:

I intend to continue to use agrominerals on my farm in the next five years.

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7. I would implement an agromineral soil amendment if a financial incentive was provided.

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8. Using an agromineral soil amendment would increase my crop productivity.

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10. Using an agromineral soil amendment would improve my produce quality.

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11. Using an agromineral soil amendment would be cost effective.

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12. Using an agromineral soil amendment would add value to my products.

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13. It would be easy for me to use an agromineral soil amendment.

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14. Using an agromineral soil amendment would be compatible with my farm operations.

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15. Using an agromineral soil amendment would **not** take too much of my time.

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16. I understand how to use an agromineral as a soil amendment.

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17. Using an agromineral soil amendment would be compatible with equipment that I currently own or would be willing to acquire.

Strongly disagree                                             Strongly agree
1 2 3 4 5 6 7

COVER CROPPING

The following questions are about cover cropping.

18. Before today, were you aware of the use of cover cropping to improve soil?
   Yes                                             No

19. Which of the following statements best describes your position with respect to adopting cover cropping?
   a) “I do not intend to try using cover crops on the land that I farm”
   b) “I am thinking about using cover cropping but have not yet begun preparations for doing so”
   c) “I intend to try cover cropping and I have begun to make preparations for doing so”
   d) “I work with cover crops on a trial basis”
   e) “I have trialled using cover crops and plan to continue to cover crop in coming years”.

20. Answer this question only if you answered either a), b) or c) to Question 19
    To what extent do you agree with the following statement:
    I intend to try cover cropping on the land that I farm in the next five years.

Strongly disagree                                             Strongly agree
1 2 3 4 5 6 7

21. Answer this question only if you answered d) or e) to Question 19
    To what extent do you agree with the following statement:
    I intend to continue to use cover cropping on my farm in the next five years.

Strongly disagree                                             Strongly agree
1 2 3 4 5 6 7

22. I would implement cover cropping if a financial incentive was provided.

Strongly disagree                                             Strongly agree
1 2 3 4 5 6 7

23. The use of cover crops would decrease crop losses due to pests.

Strongly disagree                                             Strongly agree
24. Using cover crops would increase my crop productivity.

Strongly disagree  Strongly agree

1 2 3 4 5 6 7

25. Cover cropping would improve my soil quality.

Strongly disagree  Strongly agree

1 2 3 4 5 6 7

26. Cover cropping would be cost effective.

Strongly disagree  Strongly agree

1 2 3 4 5 6 7

27. Cover cropping would add value to my products.

Strongly disagree  Strongly agree

1 2 3 4 5 6 7

28. It would be easy for me to implement cover cropping on the land that I farm.

Strongly disagree  Strongly agree

1 2 3 4 5 6 7

29. Cover cropping would be compatible with my farm operations.

Strongly disagree  Strongly agree

1 2 3 4 5 6 7

30. Cover cropping would not take too much of my time.

Strongly disagree  Strongly agree

1 2 3 4 5 6 7

31. Cover cropping would be compatible with equipment that I currently own or would be willing to acquire.

Strongly disagree  Strongly agree

1 2 3 4 5 6 7

32. I understand how to do cover cropping.

Strongly disagree  Strongly agree

1 2 3 4 5 6 7
Appendix C: Poster circulated to advertise the workshops held as part of this research

WORKSHOP: USING AGROMINERALS FOR SOIL AMENDMENT
Are you a farmer interested in different practices for maintaining soil health?

We are holding two workshops which will host talks from Brock University researchers and farmers involved in an ongoing project investigating the use of agrominerals for soil amendment. This is an opportunity to hear about the latest results from field trials, and a Q&A session will follow to allow for further discussion.

Everyone is welcome to attend one, or both, of the below workshops (free of charge):

November 23rd, 8.30am - 11am
December 6th, 8.30am - 11am

At the Rittenhouse Hall, Vineland Research & Innovation Centre, 4890 Victoria Avenue North, ON L0R 2E0

Please RSVP to lc15nl@brocku.ca
Appendix D: Farming organisations to which the poster advertising the workshops was circulated

Canadian Association of Farm Advisors, Niagara Region
Christian Farmers Federation of Ontario
Cool Climate Oenology & Viticulture Institute, Brock University
Junior Farmers’ Association of Ontario
Golden Horseshoe Food and Farming Alliance
Grain Farmers of Ontario
Grape Growers Ontario
Innovative Farmers Association Ontario
Niagara Falls Farmers Market
Niagara North Federation of Agriculture
Niagara South Federation of Agriculture
Niagara Sustainability Initiative
Ontario Ministry of Agriculture, Food & Rural Affairs
Ontario Apple Growers
Ontario Association of Agricultural Studies
Ontario Fruit and Vegetable Growers’ Association
Ontario Soil and Crop Improvement Association
Ontario Tender Fruits
Port Colborne Farmers Market
St Catharines Farmers Market
Vineland Growers
West Niagara Agricultural Society
Winery of Niagara-on-the-Lake