Chapter 11
How to Model the Adoption and Perception of Precision Agriculture Technologies

Giacomo Carli, Vilma Xhakollari, and Maria Rita Tagliaventi

Abstract The adoption of precision agriculture has shown to positively affect the performance of farms, even though its benefits vary according to the size of farms and their location. In light of the promising avenue that precision agriculture opens up, it is essential to understand which factors may facilitate its diffusion, and through which processes. This chapter focuses on the models proposed to explain technology adoption: Theory of Reasoned Action, Theory of Planned Behaviour, Motivational Model, Technology Acceptance Model, TAM2 and TAM3, Combined TAM and TPB, Model of PC Utilization, Innovation Diffusion Theory, Social Cognitive Theory and Unified Theory of Acceptance and Use of Technology. We analyse contributions targeting specifically the agricultural domain. Remarkably, most models and papers share the perspective that individual factors account for the willingness of individuals to engage in technology adoption, and there is a progressive commonality of factors between models based on different theories. In addition to individual-level features, some models analyse the relevance of environmental and social factors in prompting technology diffusion, thus depicting a more comprehensive framework to aid understanding of the dynamics linked to the adoption of precision agriculture. Eventually, some reflection on how to expand knowledge of precision agriculture along this line of reasoning aimed at integrating personal and social characteristics is offered. The importance of social network patterns and of social support in entrepreneurial initiatives that sustain adoption of precision agriculture is stressed in this chapter.

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11.1 Introduction

A recent survey in the USA shows that Precision Agriculture (PA) adopters can increase their profits by $66 per acre (Schimmelpfennig 2016). Nevertheless, this value is strongly affected by the size of the farms, with higher benefits for larger farms because of economies of scale. European farms are considerably smaller than USA farms with an average of 175 ha in the USA compared to just 16 ha in Europe (Census of Agriculture 2012; Eurostat Farm structure statistics 2013), and size is believed to be one of the causes of a low diffusion of PA technologies in Europe.

It is, however, important to observe that this structural difference not only affects the availability of financial resources for farmers to fund the adoption of site-specific solutions, but it might affect the whole process of adoption. The fact that European farmers are mainly smallholders effects the adoption of technology and makes the process based on adoption beyond purely rational evaluations. Moreover, while the 70–80% of new farm equipment is manufactured with some kind of PA technology embedded, the advantages stemming from PA in Europe remain limited and can be increased only by complementing different technologies in a more complex, yet expensive system (Zarco-Tejada et al. 2014). We argue that farmers' evaluations might not be based solely on the net benefits of the investment in technology, but also on perceptions related to innovation and social factors. Accordingly, it is important to improve our understanding of how and why farmers come to the decision to adopt PA technologies. To delve into this issue, we look at studies on how potential adopters decide on the use of new innovations. We conducted a careful review of the approaches and of the contributions in the so-called ex-ante studies (Pierpaoli et al. 2013; Pignatti et al. 2015). Our review depicts the state-of-art of the research on the adoption of agriculture-related technology to aid the design of new studies on the topic.

In the first section, we introduce the theoretical models that can be applied to evaluate the adoption of technological innovation in different fields. We reviewed nine models: Theory of Reasoned Action, the Theory of Planned Behaviour, the Motivational Model, the Technology Acceptance Model, the TAM2 and TAM3, the Combined TAM and TPB, the Model of PC Utilization, the Innovation Diffusion Theory, Social Cognitive Theory, and the Unified Theory of Acceptance and Use of Technology. In drawing our comparison, we depict which theoretical constructs are typically measured in the models to show areas of overlap across different models.

In the second paragraph, we focus on the domain of agriculture looking at how the models introduced in the previous paragraph have been applied in this field. We conduct a review on ex-ante evaluation of innovations in the broad agricultural domain. We delve into 16 papers and compare their findings to elucidate the current understanding of adoption of agriculture-related technology. The comparison of

models proposed in the 16 papers shows how different factors can be introduced to explain the decision to adopt. As models are oriented to overlap and merge progressively, the analysis depicts areas for further development of the models.

In the last paragraph, we discuss possible avenues of future development of the analysis of the ex-ante adoption models to account for the dual nature of this process—individual and social. The discussion entails the importance of evaluating the interrelation of individual and social aspects and the role of institutional actors as possible promoters of the adoption of agricultural technologies.

11.2 Theoretical Models

The aim of this section is to introduce the principal models used in the evaluation of technology adoption. We found nine models applied in the evaluation of technology adoption, and in this paragraph we present their rationale and the dimensions considered as affecting technology adoption.

The Theory of Reasoned Action (TRA) and the Theory of Planned Behaviour (TPB) are the earliest theories; they derive from social psychology and are used to explain the use of Information Systems (IS). At that stage, it was seen as relevant to understand first the generic underlying behaviour related to the adoption of new technologies, and then to proceed with specific models focused entirely on understanding and identifying the behavioural factors affecting IS usage.

The **Theory of Reasoned Action (TRA)** was formulated in social psychology and was originally developed by Fishbein in 1967. It aims to explain human behaviour; the TRA maintains that behaviour is controlled by intention and the stronger the intention is, the harder the effort to perform the action will be (Fishbein 1967; Fishbein and Ajzen 1975; Ajzen and Fishbein 1980). According to Fishbein and Ajzen (1975), two factors determine the intention: the Attitude toward the Behaviour and the Subjective Norms. The former is affected by the beliefs on the outcome of the behaviour and by the individual evaluation of that outcome, either positive or negative. The latter is related to individual perceptions on what society thinks of the behaviour. Subsequent research has found that Experience and Voluntariness are two relevant factors in explaining a behaviour (Karahanna et al. 1999): with the increase in experience, Attitude towards the Behaviour becomes more important, while the relevance of Subjective Norms diminishes. However, Hartwick and Barki (1994) showed that when users are not forced to adopt technology, Subjective Norms become more important supporting the inclusion of Voluntariness in the model.

The **Theory of Planned Behaviour (TPB)** is an extension of the TRA (Ajzen and Fishbein 1980). According to Sheppard et al. (1988), the theory explains a broader range of behaviour in comparison to TRA. This is because TPB, besides attitudes and subjective norms, comprises a third factor: perceived behavioural control (PBC). This latter consists of "the perceived ease of use or difficulty of performing the behaviour" (Ajzen 1991).

The TPB has been applied successfully to analyse users' behaviour regarding different types of technologies (Harrison et al. 1997; Mathieson 1991). In this context, the Perceived Behavioural Control is related to the perceptions of internal and external constraints on behaviour (Davis et al. 1989; Taylor and Todd 1995b).

Similarly to TRA, in TPB Experience and Voluntariness were not included in the original model. As shown for TRA, however, research has found these two factors are important in explaining the behaviour *vis-à-vis* technology adoption (Venkatesh and Morris 2000; Karahanna et al. 1999).

Regarding gender, research has shown that Attitude was more relevant for men, whereas Subjective Norms and PBC were found to affect both men and women with limited experience (Venkatesh et al. 2000).

Finally, even though age was not included in the original model, Morris and Venkatesh (2000) concluded that Subjective Norms were more relevant to older women. On the other hand, Perceived Behavioural Control was more relevant for seasoned workers, whereas Attitude was more important for younger workers.

The **Motivational Model (MM)** ensued from the Motivational Theory (Davis et al. 1992). According to Deci and Ryan (1985), motivation is the most important factor that affects behaviour in different fields. Drawing on a wide variety of studies, research has grouped motivational factors into two main categories: intrinsic and extrinsic factors (Deci 1971; Deci and Ryan 1985): "*Intrinsic motivation refers to the pleasure and inherent satisfaction derived from a specific activity*" (Venkatesh and Speier 1999, p. 2; Deci 1975; Vallerand 1997). Examples of intrinsic motivation include Enjoyment and Playfulness. Conversely, *"extrinsic motivation emphasizes performing a behaviour because it is perceived to be instrumental in achieving valued outcomes that are distinct from the activity such as increased pay and improved job performance"* (Venkatesh and Speier 1999, p. 2; Lawler and Porter 1967; Vroom 1964). Perceived Usefulness, Perceived Ease of Use and Subjective Norms are examples of extrinsic motivation.

Davis et al. (1992) applied the theory to the domain of technology usage. They found that office workers' intention to use computers depends primarily on their perceptions of how computer-usage would improve their work performance (Usefulness), and secondly, by the enjoyment they experience while using the computers (Enjoyment). A particularly striking result was that when determining intentions, Usefulness is four to five times more influential than enjoyment.

Thus, considering the motivational theory and the findings from Davis et al. (1992), extrinsic motivations are far more important and influential when deciding about technology usage.

The **Technology Acceptance Model (TAM)** was adapted from the TRA (Ajzen and Fishbein 1980; Fishbein and Ajzen 1975) to depict the factors affecting technology usage. In the TAM, the intention to adopt technology is determined by two principal factors: Perceived Usefulness, i.e. "*the degree to which a person believes that using particular system would enhance his/her job*" (Davis 1989, p. 320); and Perceived Ease of Use, i.e. *"the degree to which a person believes that using a particular system would be free of effort"* (Davis 1989, p. 320).

Studies have concluded that TAM explains approximately 40% of the total variance of behaviour and intention to use technology (Venkatesh and Davis 2000).

TAM has been refined over the years and been later elaborated as **TAM2**. This extended version of TAM is derived from the TRA and the TPB described above. Additional factors related to social influence processes (Subjective Norm, Voluntariness, and Image[1]) and cognitive instrumental processes (Job Relevance, Output Quality, Result Demonstrability, and Perceived Ease of Use) are incorporated into the TAM2 (Venkatesh and Davis 2000).

Later on, Venkatesh and Bala (2008) proposed another extended version of TAM2, which has been labelled as **TAM3**. This new evolution introduces experience as a moderating factor of the relation between three couples of factors: (1) Perceived Ease of Use and Perceived Usefulness; (2) Computer Anxiety and Perceived Ease of Use; (3) Perceived Ease of Use and Behavioural Intention to Adopt.

Gender and age were not included in either of the three versions of the TAM. Nevertheless, Venkatesh and Morris (2000) found that perceived usefulness was more relevant for men than women, whereas ease of use was more important for women than for men.

Taylor and Todd (1995a) introduced a new model, which consists of a combination of the two previous models, TAM and TPB, and has been called "The **Combined TAM and TPB (C-TAM-TPB)**". The new model comprises factors emerging from the two original models: Attitude toward Behaviour, Subjective Norm, Perceived Behavioural Control and Perceived Usefulness. Taylor and Todd (1995a) argued that this model can be applied to both experienced and inexperienced users. According to the same study, for both groups of individuals, all other determinants, except for Attitude, were significant. Thus, this model version might be used successfully to predict the behaviour prior to the implementation of a technology.

The **Model of PC Utilization (MPCU)** was elaborated by Triandis in 1980 to allow for a better understanding of the determinants of behaviour introduced in the TRA. According to this theory, *"behavioural intentions are determined by feelings people have toward the behaviour (affect), what they think they should do (social factors), and by the expected consequences of the behaviour"* (Thompson et al. 1991, p. 125). In other words, behaviour is affected by habits, intentions and facilitating conditions. Thompson et al. (1991) included this theory into the IS context to predict PC usage in the workplace. Venkatesh et al. (2003) have later considered the model in their research on the unification of technology acceptance models, but unlike Thompson et al. (1991) and in line with Triandis (1980), they focused on intention rather than on behaviour.

The following factors are considered in the model:

- Job Relevance – *"the extent to which an individual believes that using a technology can enhance the performance of his or her job"* (Thompson et al. 1991, p. 129).

[1] The degree to which an individual perceives that use of an innovation will enhance his or her status in his or her social system (Moore and Benbasat 1991, p. 195).

- Complexity – "*The degree to which an innovation is perceived as relatively difficult to understand and use"* (Rogers and Shoemaker 1971; p.154).
- Long term Consequences – *"Outcomes that have a pay-off in the future"* (Thompson et al. 1991, p. 129).
- Affect towards Use – Based on Triandis (1980), affect toward use is a *"feeling of joy, elation, or pleasure, or depression, disgust, displeasure, or hate associated by an individual with a particular act"* (Triandis 1980, p. 211).
- Social Factors – *"the individual's internalization of the reference group's subjective culture, and specific interpersonal agreements that the individual has made with others, in specific social situations"* (Triandis 1980, p. 210).
- Facilitating Conditions – *"objective factors, 'out there' in the environment that several judges or observers can agree make an act easy to do"* (Triandis 1980, p. 205. In the Information Systems context, "provision of support for users of PCs may be one type of facilitating condition that can influence system utilization*"* (Thompson et al. 1991).

Remarkably, the **Innovation Diffusion Theory (IDT)** has been used to study a broad range of innovations, from agricultural tools to industrial technologies (Tornatzky and Klein 1982). Moore and Benbasat (1991) have adapted the model to technology acceptance, modifying the characteristics defined by Rogers (1995) and refining a set of constructs. The factors that are taken into account in the model are as follows:

- Relative Advantage – *"the degree to which an innovation is perceived as being better than its precursor"* (Moore and Benbasat 1991, p. 195).
- Perceived Ease of Use – *"the degree to which an innovation is perceived as being difficult to use*" (Moore and Benbasat 1991, p. 195).
- Image – *"the degree to which use of innovation is perceived to enhance one's image or status in one's social system"* (Moore and Benbasat 1991, p. 195).
- Visibility – *"the degree to which one can see others using the system in the organization"* (Venkatesh et al. 2003, p. 431; Moore and Benbasat 1991).
- Compatibility – *"the degree to which an innovation is perceived as being consistent with the existing values, needs, and past experiences of potential adopters"* (Rogers 2003, p. 15; Moore and Benbasat 1991, p. 195).
- Results Demonstrability – *"the tangibility of the results of using the innovation, including their observability and communicability"* (Moore and Benbasat 1991, p. 203).
- Voluntariness of Use – *"the degree to which use of the innovation is perceived as being voluntary, or of free will"* (Moore and Benbasat 1991, p. 195).

A different view on models addressing technology adoption has been inspired by the **Social Cognitive Theory (SCT)**. This theory holds that individuals' knowledge

is related to the information they obtain by other subjects who perform a behaviour (Bandura 1986). Compeau and Higgins (1995) extended the original model to target the context of computer usage. Their formulation made possible application of the SCT model to the evaluation of technology acceptance.

Factors included in the model are:

- Output Quality – "*performance expectations deal with job-related outcomes*" (Venkatesh et al. 2003, p. 432; Compeau and Higgins 1995).
- Outcome Expectations – personal – "*it deals with individuals' esteem and sense of accomplishment*" (Venkatesh et al. 2003, p. 432; Compeau and Higgins 1995).
- Self-Efficacy – "judgement of one's ability to use a technology" (Venkatesh et al. 2003, p. 432).
- Perceived Enjoyment – "an individual's liking for a particular behaviour" (Venkatesh et al. 2003, p. 432).
- Computer Anxiety – "*evoking anxious or emotional reactions when it comes to performing the behaviour*" (Venkatesh et al. 2003, p. 432).

Finally, the so-called **Unified Theory of Acceptance and Use of Technology (UTAUT)** is a model developed through the integration and further development of the eight models described above. Targeting users' intention to include IT systems in their daily work, Venkatesh et al. (2003) showed that the eight models accounted for between 17 and 53% of the variation. Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions are considered the main determinants of Behaviour, whereas Gender, Age, Experience and Voluntariness of use are considered as moderating factors (Venkatesh et al. 2003).

Table 11.1 reports the factors explaining the behaviour of all the above-mentioned models. As seen, TAM is the model that includes most of the factors that explain technology adoption behaviour.

Voluntariness and experience are considered the most relevant factors affecting the behaviour. This is because they emerge as explanatory variables in most of the models taken into consideration in this review.

It is important to stress that all the theories concerned in explaining the users' behaviour for IS usage are affected or based on the TRA and the TPB. Nevertheless, recent research has further developed and improved those theories, and the UTAUT is an example of the most recent theory regarding IS usage.

Table 11.1 represents a summary of the above mentioned behavioural models and the factors from which the behaviour of adopting a new technology depends. The TAM3 is the model that accounts for most of the factors. The TPB and IDT models depend on eight factors, which is half of the factors of TAM3.

The next paragraph will introduce some applications of these models and theories to the agricultural sector.

Table 11.1 Factors used in the models related to technology adoption behaviour

Factors	Models								
	Theory of Reasoned Action (TRA)	Theory of Planned behaviour (TPB)	Motivational Model (MM)	Technology Acceptance Model (TAM3)	Combined TAM and TPB (C-TAM. TPB)	Model of PC Utilization (MPCU)	Innovation Diffusion Theory (IDT)	Social Cognitive Theory (SCT)	Unified Theory of Acceptance and Use of Technology (UTAUT)
Attitude toward Behaviour (AB)	✓	✓			✓				
Subjective Norm (SN)	✓	✓		✓	✓				
Perceived Usefulness (PU)				✓	✓				
Perceived Ease of Use (PEOU)				✓			✓		✓
Computer Self-Efficacy (CSE)				✓					
Perceptions of Internal Control (PIC)		✓			✓				
Perceptions of External control (PEC)		✓		✓	✓				
Computer Playfulness (CPLAY)				✓					
Computer Anxiety (CANX)				✓				✓	

Perceived Enjoyment (ENJ)				✓				✓	
Voluntariness (VOL)	✓	✓		✓	✓		✓		
Image (IMG)				✓			✓		
Job Relevance (REL)				✓		✓			
Output Quality (OUT)				✓				✓	✓
Result Demonstrability (RES)				✓			✓		
USE (USE)				✓				✓	
Extrinsic Motivation (EM)			✓						
Intrinsic Motivation (IM)			✓						
Complexity (CPX)						✓			
Long Term Consequences (LTC)						✓			
Affect Towards Use (ATU)						✓			
Social Factors (SC)						✓			✓
Facilitating Conditions (FC)						✓			✓
Relative Advantage (RA)							✓		
Visibility (VIB)							✓		

(continued)

Table 11.1 (continued)

Factors	Models								
	Theory of Reasoned Action (TRA)	Theory of Planned behaviour (TPB)	Motivational Model (MM)	Technology Acceptance Model (TAM3)	Combined TAM and TPB (C-TAM. TPB)	Model of PC Utilization (MPCU)	Innovation Diffusion Theory (IDT)	Social Cognitive Theory (SCT)	Unified Theory of Acceptance and Use of Technology (UTAUT)
Compatibility (COB)							✓		
Outcome Expectations Personal (OEP)								✓	
Experience	✓	✓		✓		✓	✓		✓
Gender		✓		✓					✓
Age		✓							✓

11.3 Behavioural Models and Their Application in Agricultural Sciences

After introducing a detailed picture of behavioural models about technology adoption, this section shows how they have been applied to study the adoption of agriculture-oriented technologies.

To conduct a careful review of the research studies available on the topic, we resorted to Scopus and Google Scholar to search for articles using keywords related to the specific sector, such as "agriculture", "farm", "food production", in combination with keywords related to technology adoption, for instance "technology adoption", "behavioural models" and "technology acceptance". The numerous results were then divided into two groups: the empirical studies related to the behavioural models introduced in Paragraph 1, and the studies with an ex-post approach regarding technology adoption. We focused on the contributions analysing farmers and specialists' behaviour prior to the choice of adoption.

We identified sixteen papers: eight studies are based on the technology acceptance model, six on the theory of planned behaviour, and the remaining two studies combine the Theory of Reasoned Action, the Model of PC Utilization and the Innovation Diffusion Theory.

We analysed each paper to identify its theoretical underpinnings, the method and the setting studied. We summarize the main findings of the sixteen papers in Table 11.2.

Articles included in this review gauge attitudes and intentions to adopt innovative technologies in farm activities. As previously mentioned, this review has taken an ex-ante approach, i.e. only papers that measured farmers' attitudes prior to the adoption of a new technology have been taken into account.

Table 11.3 reports on the factors used in the selected articles to explain the adoption behaviour. We also show their Cronbach alphas' coefficients to compare the quality of the measurement scales of the factors across the sixteen studies. All factors show good coefficients of Cronbach alpha, which means a high reliability.

The factors most used in explaining the adoption behaviour are Attitude toward the Behaviour, Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). Other factors, such as Intention to Use, Subjective Norms and Perceptions of Control (internal and external) also appear as relevant in explaining the behaviour. Even though TPB and TAM are the models that have been adopted mainly in these studies, Subjective Norms emerge as relevant in explaining the behaviour in only four studies. This is surprising, given the fact that this factor is considered as one of the most powerful in explaining the behaviour in theoretical models. Nevertheless, future research in the agricultural domain may deepen the study of the social factors (SC) in the technology adoption behaviour.

Table 11.2 Papers on the adoption of technology in agriculture and their main findings

Nr	Paper	Theoretical model	Method	Technologies	Setting	Sample size	Data source	Main findings
1.	Lynne et al. (1995)	Theory of Planned Behaviour and Theory of Derived Demand	Tobit Regression Model	Water saving technology	Crop growers (strawberry)	44	Florida, USA	Both Perceived and Actual External Control are important for explaining the Behaviour. Policy makers should apply a moderate control on farmer's decisions combining moral suasion and incentives in their policies.
2.	Herath (2013)	Theory of Planned Behaviour	Regression Model	New farm technology	Farmers	36	Southern Moravian region, Czech Republic	Intention, Attitude, Perceived Behavioural Control, Age and Education affects positively the Adoption of technology systems from part of farmers.
3.	Flett et al. (2004)	Technology Acceptance Model	Factor analysis and discriminant function analysis	Dairy farming technologies	Dairy Farms	985	North and South islands, New Zeeland	Farmers consider separately Perceived Ease of Use Perceived Usefulness.
								When deciding about the adoption of a new technology, Perceived Usefulness is more important than Perceived Ease of Use.
4.	Adrian et al. (2005)	Technology Adoption Model	Structural Equation Model	Seven PA technologies	Row crop Growers	85	Alabama, USA	Attitudes of Confidence toward using PA technologies, Perceptions of Net Benefit, Farm Size and Farmer Educational Levels positively influence the Intention to Adopt PA technologies. The Perception of Usefulness positively influences the Perception of Net Benefit.

5.	Rehman et al.(2007)	Theory of Reasoned Action	Principal Component Analysis	Oestrus detection, nitrogen supply management, and, inclusion of white clover	Dairy Farms	145	Cornwell, Devon and Dorset, England	Cost Effectiveness, Improved Detection and Conception Rates are the main drivers when adopting new technologies. Threat of demeaning the personal knowledge and skills of a farmer in 'knowing' their cows is a barrier.
6.	Folorunso and Ogunseye (2008)	Technology Acceptance Model and Model of PC Utilization	Structural Equation Model	Knowledge management system	Farmers, extension specialist and researchers	370	Abeokuta, Ogun state, Nigeria	All original TAM constructs affect computer usage. Social Factors and Facilitating Conditions (constructs from MPCU) are good predictors in the TAM.
7.	Pouratashi and Rezvanfar (2009)	Technology Acceptance Model	Descriptive and inferential analysis	Basic ICT: word processing, spreadsheets, internet access, etc.	Students	110	Teheran, Iran	Skills have direct and indirect effects on the application of Information Communication Technology (ICT). Support and facilities affect the application of ICT indirectly. When students' skills improve, they are more likely to use ICT.
8.	Zhang et al. (2009)	Technology Acceptance Model	Correlatio-nal Analysis	Information technology	Farmers	231	Different regions, China	Perceived Usefulness, Perceived Ease of Use, Learning Intention, Risk Preference, and Experience are considered important factors which positively affect farmers' Behaviour in adopting Market Information Systems. Income and Education may also affect the decision.

(continued)

Table 11.2 (continued)

Nr	Paper	Theoretical model	Method	Technologies	Setting	Sample size	Data source	Main findings
9.	Moghaddam and Salehi (2010)	Technology Adoption Model	Structural Equation Model	Yield monitoring, grid soil sampling and the variable rate technologies irrigation, fertilizer, tillage, spraying and seeding	Agricultural Specialists	249	Fars and Khuze-stan, Iran	Trialability has a significant effect on Perceived Ease of Use, Attitude and Intention.
								Observability has direct effect on Perceived Ease of Use, Perceived Usefulness, Attitude and Intention to Use.
								Among all the independent variables, Attitude to Use is the variable that affect the adoption of agriculture technologies mostly.
								Producers who declared confidence about using and learning PA technologies have greater propensity to adopt them.
10.	Yueh and Liu (2010)	Technology Adoption Model	Linear and Multiple Regression Analysis	Farm management information system (FMIS)	Farmers	23	Taiwan	Farmers' skills in Farm Management Information System (FMIS) improved after the training.
								In the future, perceived usefulness could positively affect farmers' motivation to use FMIS.
11.	Aubert et al. (2012)	Technology Adoption Model	Partial Least Square (PLS)	Six PA technologies	Crop Growers (cereal and oleaginous)	438	Quebec, Canada	PA technology adoption is determined by: Perceived Ease of Use and Usefulness, Resource Availability, Trialability, and Voluntariness (negatively), as well as personal characteristics of the farmer (Innovativeness, and Level of Education).
								Farmer's Age and Farm Size do not influence the Adoption.

12.	Sharifzadeh et al. (2012)	Theory of Planned Behaviour	Structural Equation Model	Climate information technology	Crop Growers (wheat)	314	Fars, Iran	Greater Attitude (Instrumental and Affective) toward Use of information in farming decisions was associated with stronger Intention to engage in behaviour. The Modified Theory of Planned Behaviour provides a significant improvement on the model fit by adding a direct causal path from Attitude to Behaviour.
13.	Tey et al. (2014)	Theory of Interpersonal Behaviour and the Theory of Diffusion of Innovation	Logistic Regression Model	Sustainable agricultural practices	Crop Growers (vegetables)	1168	Five regions of Malaysia	Adoption depends on a range of socio-economic, agro-ecological, institutional, informational, and psychological factors, as well as the perceived attributes of sustainable agricultural practices.
14.	Niles et al. (2016)	Theory of Planned Behaviour	Multiple Regression Model	Climate change practices	Farmers	490	Marlborough and Hawke's Bay, New Zealand	Attitudes towards climate change are not significantly associated with change of behaviour. Persisting in stating facts about climate change in hopes to change people's behaviours is not necessarily impactful.
15.	Lu et al. (2015)	Technology Acceptance Model	Partial Least Squares regression	Government-sponsored agricultural information systems	Farmers	1504	Jiangxi, China	Government's role is relevant as it positively affect intention to use new technologies. Perceived Enjoyment and Perceived Usefulness are considered important elements for male farmers. Female farmers consider as important only Perceived Usefulness.

(continued)

Table 11.2 (continued)

Nr	Paper	Theoretical model	Method	Technologies	Setting	Sample size	Data source	Main findings
16.	Alavion et al. (2016)	Theory of Planned Behaviour	Multiple Regression Model	E-marketing of agricultural commodities	Agricultural professionals (public and private sectors)	146	Guilan, Iran	Public and private sector professionals consider e-marketing as an important tool for farmers. The three factors of the Theory of Planned Behaviour are confirmed as predictors of the intention to adopt e-marketing. Subjective Norms and Perceived Behavioural Control show higher impact on public professionals, than personal Attitude.

Table 11.3 The constructs measured in each paper and their coefficients of Cronbach Alpha*

Factors	Papers															
	Lynne et al. (1995)	Herath (2013)	Flett et al. (2004)	Adrian et al. (2005)	Rehman et al. (2007)	Folorunso and Ogunseye (2008)	Zhang et al. (2009)	Pouratashi and Rezvanfar (2009)	Yueh and Liu (2010)	Moghaddam and Salehi (2010)	Aubert et al. (2012)	Sharifzadeh et al. (2012)	Tey et al. (2014)	Niles et al. (2016)	Lu et al. (2015)	Alavion et al. (2016)
Adopt/Not adopt (DND)	✓					.82										
Affect Towards Use (ATU)														.65		
Attitude toward Behaviour (AB)	✓	.71			.82	.74		.86		.83		.75	.96		.93	>.70
Biophysical Concern														.87		
Coercive Power (COE)															.95	
Compatibility (COB)											.86		.86			
Complexity (CPX)													.89			
Computer Anxiety (CANX)												.75				
Computer Self-Efficacy (CSE)				.87						.57						
Contact Scale														.65		

(continued)

Table 11.3 (continued)

Factors	Papers															
	Lynne et al. (1995)	Herath (2013)	Flett et al. (2004)	Adrian et al. (2005)	Rehman et al. (2007)	Folorunso and Ogunseye (2008)	Zhang et al. (2009)	Pouratashi and Rezvanfar (2009)	Yueh and Liu (2010)	Moghaddam and Salehi (2010)	Aubert et al. (2012)	Sharifzadeh et al. (2012)	Tey et al. (2014)	Niles et al. (2016)	Lu et al. (2015)	Alavion et al. (2016)
Control Beliefs of New Technology Adoption		.63														
Education Level				✓			✓									
Environmental Policy														.69		
Experience							✓									
Expert Power (EXP)															.89	
Extrinsic Motivation (EM)																
Facilitating Conditions (FC)						.63					.81					
Farm Size				✓												
Income							✓									
Information											.80					
Innovativeness											.83					
Intention to use					✓	.69				.88		.96			.91	
Knowledge (employee)											.84					
Knowledge (farmers)											.72					

Learning Intention							✓								
Legitimate Power (LEG)														.89	
Motivation to comply												.64			
Motivation to comply with others		.84													
Normative beliefs												.74			
Outcome Expectations Personal (OEP)												.75			
Output Quality (OUT)													.65		
Perceived Ease of Use (PEOU)			.64	.88		.83	✓	.86	.92	.89	.84	.70		.92	
Perceived Enjoyment (ENJ)														.90	
Perceived Usefulness (PU)			.82	.93		.77	✓	.86	.92	.58	.89	.82		.92	

(continued)

Table 11.3 (continued)

Factors	Papers															
	Lynne et al. (1995)	Herath (2013)	Flett et al. (2004)	Adrian et al. (2005)	Rehman et al. (2007)	Folorunso and Ogunseye (2008)	Zhang et al. (2009)	Pouratashi and Rezvanfar (2009)	Yueh and Liu (2010)	Moghaddam and Salehi (2010)	Aubert et al. (2012)	Sharifzadeh et al. (2012)	Tey et al. (2014)	Niles et al. (2016)	Lu et al. (2015)	Alavion et al. (2016)
Perceptions of External control (PEC)	✓	.73										.65				>.70
Perceptions of Internal Control (PIC)	✓	.85										.65				>.70
Potential adaptation adoption														.78		
Potential mitigation adoption														.76		
Quality of support											.79					
Referent Power (REF)															.88	
Relative Advantage (RA)				.86							.81		.87			
Result Demonstrability (RES)										.87	.56					
Reward Power (REW)															.88	

Risk preference							✓									
Social Factors (SC)						.57								.75		
Subjective Norm (SN)	✓	.85			✓											>.70
Trialability										.87	.86		.85			
Use (USE)						.82										
Visibility (VIB)										.87						
Voluntariness (VOL)											.60					

The '✓' Indicates the factor has been measured in the paper but, given the particular methodology applied in the research, the Cronbach alpha was not reported

*Cronbach alphas ≥0.70 are considered acceptable (Hair et al. 2010, p. 124)

11.4 Discussions and Conclusion

In general, in the application to agricultural practices, all the reviewed theoretical models find good support. For instance, Folorunso and Ogunseye (2008), in their study of users' acceptance of AGROWIT, a knowledge management information system, found that all the constructs of the TAM were good predictors of the behaviour of participants. This might not be surprising given that TAM was initially developed using data on the evaluation of office technologies. In addition to factors taken from TAM, Folorunso and Ogunseye (2008) included Social factors (SC) and Facilitating Conditions (FC) in their model from the Model of PC Utilization (MPCU) and found a positive effect on the Intention to Adopt PA technologies. In line with this, Adrian et al. (2005) and Moghaddam and Salehi (2010) noticed that Farm Size, Perceptions of Net Benefit, Gender and Technology Awareness were good predictors of Technology Adoption. Aubert et al. (2012) reported that Age and Farm Size did not have any effect on Adoption, whereas other factors such as Perceived Ease of Use, Perceived Usefulness and Resource Availability are good predictors of the Intention to engage in PA.

Regarding the Theory of Planned Behaviour, almost all the theoretical constructs are supported by the studies included in this review. According to Lynne et al. (1995) and Herath (2013), the Intention to Adopt technology practices is related to the Attitude towards the Behaviour, Subjective Norms, Perceptions on Control and other sociodemographic characteristics such as Age and Gender. Despite the fact that Education is not included in the original theory, Herath (2013) revealed that it is a good predictor of Behaviour. Moreover, Sharifzadeh et al. (2012) showed that, among wheat growers, the ones with a positive attitude to use information in their farming decision were more predisposed to implement new and innovative technologies in their farming activity. Finally, in their study about climate change issues, Niles et al. (2016) showed that even though farmers were continuously exposed to possible threats of climate change, it did not have any effect on their behaviour.

It is important to understand the reasons why research focuses on these models and how other models might be applied especially to the field of agriculture. Our review shows that among the theoretical models mentioned in the previous paragraph, TPB and TAM have a greater capability for explaining behaviour. Some final remarks are noteworthy. Despite the variety of factors that the different models on technology adoption consider, all of them share the view that the decision to engage in technology adoption is largely affected by individual perceptions (e.g. Perceived Ease of Use, Attitudes and Perceived Usefulness). When comparing factors in the theoretical models, Experience was found as relevant in explaining the behaviour in six models. Nevertheless, in the literature focused on the adoption of farm technology a central role of experience was not found because studies focused mainly on non-users of technology.

Aubert et al. (2012) found that Voluntariness negatively affects the Intention to Use PA technologies. This suggests that adopters are more influenced by external pressures, considering the use of PA technologies as a legal requirement or a

recommendation of their cooperative. Therefore, Aubert et al. (2012) suggest that PA technology adoption could be enhanced by reducing the level of voluntariness. For instance, the introduction of specific regulations (e.g. norms on the use of pesticides and fertilizers) would raise the issue of compulsory reporting required of farmers. Since PA technologies can provide more accurate information for reporting, new regulations could negatively affect voluntariness and increase PA adoption. This conclusion suggests that Voluntariness can be a relevant factor for the adoption of models, but it has not emerged prominently from studies investigating the agricultural domain yet. While Aubert et al. (2012) used voluntariness to explain adoption, their findings might be affected by a reduced level of reliability (Cronbach alpha: 0.60) and the reduction of two items in a factorial scale of five. Other studies might take into consideration voluntariness investigating differences between users and non-users of PA technologies. The example on Voluntariness is particularly interesting because it suggests that other individual attitudes such as Visibility and Motivation to Comply with Others could also have a similar effect on technology adoption. These factors have scarcely been included in the models on PA technology adoption so far, and they could be explored as possible mediators between contextual factors and the intention to adopt or the perceptions on usefulness or on the ease of use. For instance, Aubert et al. (2012) suggested that the relation between environmental policy and adoption was mediated by Voluntariness. Similarly, other individual attitudes could play the role of mediators between the availability and quality of support, environmental policy or other facilitating conditions and PA adoption or to the Perceived Ease of Use or the Perceived Usefulness of technology.

Since TAM has been used mainly to study the intention to adopt information technologies, its application in the evaluation of technologies with a significant orientation on information processing seems worthy. Nevertheless, the Model of PC Utilization and the Unified Theory of Acceptance and Use of Technology may go beyond the individual level considered in the TAM to take into account social and environmental features as facilitators in the approach to technology adoption. In fact, what remains surprisingly overlooked is the effect that the others may exert on individuals' stance towards technology. Studies on social networks and innovation have long underlined the role that interactions with peers may play in the adoption and diffusion of technology (e.g. Burt 1980; Tucker 2008). The opinions and experience concerning the technology of those with whom one interacts are able to affect the orientation in technology use. We can follow the example of individuals who are similar to us in terms of relations or, alternatively, we can imitate peers to whom we are strongly linked.

Studies addressing technology adoption in agriculture do not so far allow us to understand how individuals who have different access to network resources may react when appraising technology adoption. Independent farmers might act differently from farmers operating within an integrated value chain and supply network. Similarly, farmers who cooperate with large distributors may select courses of action, when gauging technological opportunities, which differ from those available to farmers cooperating with micro-companies to serve local markets. An integration

of the models with a social network perspective could enrich the understanding of the processes through which adoption is evaluated, chosen and implemented in an industry characterized by heterogeneous patterns of social ties.

In addition, in the development of a scale for the evaluation of entrepreneurship in agriculture and food production, in addition to the financial, human-related and technological factors, it was found that infrastructure and network elements are constituents of the measurement instrument (Bolzani et al. 2016). The infrastructure factor refers to the availability of tangible and intangible resources for knowledge development and sharing. They can range from R&D facilities to mentoring and counselling organizations (e.g. Knudson et al. 2005). The presence of an infrastructural layer in the innovation system might favour the overcoming of some factors that hinder the diffusion of innovative PA technologies. Agricultural innovation is often capital intensive and requires a good level of training on the farmer's side. In the European context, made of smallholders, the existence of social ties between farmers could improve their bargaining power and their influence on the development of infrastructural entities. These latter may be able to create the necessary economies of scale and scope to close the knowledge gap faced by farmers. Specialized support could in fact become accessible where a consistent level of demand sustains its development.

Finally, our review focused on ex-ante approaches to appraise how an innovation can be perceived in the agricultural domain and raise the interest of farmers. As a future research direction, we shall devise an investigation on how different public policies could foster the introduction of innovation in agriculture. In many countries, local, national and transnational institutions enact initiatives to support the introduction of PA. These policies can be evaluated in terms of their efficacy in favouring the diffusion of the innovations and efficiency in the use of public funds. We suggest that both in their design and assessment, the complex process of adoption that we described in this chapter should be taken into consideration.

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