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ACCEPTANCE AND ADOPTION OF TECHNOLOGIES IN AGRICULTURE

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ABSTRACT

There is a need for transition towards sustainability in agriculture and food systems. New technologies and innovations can play a central role in improving agriculture productivity and sustainability. However, there is still a gap in understanding the factors that determine the acceptance and adoption of technologies in agriculture. Therefore, this review provides an overview on the main models and theories on the acceptance, adoption, use and/or diffusion of technologies. The most prominent theories and models include the Theory of Reasoned Action, the Technology Acceptance Model, the Motivational Model, the Theory of Planned Behaviour, the Innovation Diffusion Theory, the Social Cognitive Theory, the Social Construction of Technology, and the Unified Theory of Acceptance and Use of Technology. Furthermore, different combinations of these models have been used in technology adoption studies. These conceptual approaches and models span across disciplines (e.g. sociology, psychology, innovation, management) and differ in terms of theoretical assumptions, goals, variables and assessment methods. Factors determining the acceptance and use of technologies in agriculture are related to the technology itself and the ease of its use as well as social (age, gender), emotional, attitudinal and cognitive factors. Technology adoption is also affected by the environment and context in which it takes place. Technology acceptance models make use of predictors that are cognitive or relating to attitude, beliefs or perceptions. Some of the models focus on internal factors, such as antecedents of behaviour (e.g. values, attitudes, intentions), while others also address external issues (e.g. social norms, economic incentives, institutional environment). The framing of technology adoption within the wider Agricultural Knowledge and Innovation System (AKIS) offers interesting opportunities for fostering transition towards sustainability in agriculture. Indeed, technologies are just one component of AKIS and innovation in agriculture also encompasses social, organizational, marketing and institutional fields.

Keywords: *agriculture, technology, technology acceptance, technology adoption, technology use, innovation.*

INTRODUCTION

Science, innovation and technology have a vital role to play in meeting the interweaved environmental, economic and social challenges facing humanity such as environmental sustainability, social justice, poverty reduction and climate change mitigation (STEPS Centre, 2010; United Nations, 2012). The International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD, 2009) highlights the important role of agricultural knowledge, science and technology (AKST) in addressing different sustainable development issues (e.g. poverty, food insecurity). The IAASTD (2009) points out that "*There is ample evidence available from the literature that AKST investments have contributed significantly to […] innovations in the form of methods, tools development, capacity strengthening […]*" (p. 516). The agri-food system is clearly associated to numerous sustainability challenges such as biodiversity loss, climate change, food insecurity, water scarcity (Bruinsma, 2011; FAO, 2014, 2016; Foley et al., 2011; IAASTD, 2009; Postel, 2000). Therefore, there have been many calls for sustainability transitions in agriculture and food systems (El Bilali, 2018b; FAO, 2017; UNEP, 2018). It is asserted that shifting towards sustainability in agri-food systems requires appropriate innovations and technologies (Bello & Aderbigbe, 2014; El Bilali, 2018; El Bilali & Allahyari, 2018; Singh et al., 2014).

New technologies that allow profitable and sustainable agricultural production are central for achieving food security (Loevinsohn et al., 2012). There are numerous promising new technologies and innovations in agri-food systems that can contribute to achieving food and nutrition security (HLPE, 2017; United Nations Conference on Trade and Development, 2017) such as precision agriculture technologies, ICT and nanotechnologies. Technologies that address the availability dimension of food security aims at improving agricultural productivity through, among others, enhancing soil management, breeding, irrigation (United Nations Conference on Trade and Development, 2017). Due to enhanced input/output ratios, new technologies are likely to increase output and decrease production costs, which leads, in turn, to a substantial increase in farm income (Challa, 2013). Low technology adoption rates cause low agricultural productivity and, consequently, food insecurity (Ngigi, 2003).

Nevertheless, it seems that the real challenge in agriculture is not only to have appropriate technologies and innovations but also to make sure that farmers/producers (as well as other value chain actors and rural populations in general) effectively access and use them (Wyckoff, 2016). Indeed, innovation diffusion and technology adoption are central themes in the agro-food sector (Avolio et al., 2014; Feder & Umali, 1993; Ugochukwu & Phillips, 2018). Loevinsohn et al. (2012) consider technology adoption as "*the integration of a new* *technology into existing practice and is usually proceeded by a period of 'trying' and some degree of adaptation*" (p. 3). Webster (1969) defines a five-stage process of innovation adoption that starts with awareness about the existence of an innovation/new technology, through interest in the innovation, evaluation of the innovation using gathered information, testing and experimentation in real-world context, and ends with adoption. There is a host of literature on factors that affect technology adoption in agriculture (Antolini et al., 2015; Melesse, 2018; Mwangi & Kariuki, 2015; Ugochukwu & Phillips, 2018). Moreover, integration and adoption of new technologies is affected by technology acceptance, which is analysed by various models (Lai, 2017; Nejadrezaei et al., 2018; Sovacool & Hess, 2017; Taherdoost, 2018). The decision of farmers on whether to adopt a new technology is affected by the dynamic interaction between technology features and a host of conditions (social, economic, institutional, bio-physical) (Loevinsohn et al., 2012). Teklewold et al. (2013) and Melesse (2018) put that factors affecting technology adoption in agriculture can be grouped under (i) producer and farm characteristics (e.g. education level, experience, age, gender, level of wealth, farm size, labour availability, resource endowment, risk aversion); (iii) technology features (e.g. complexity, performance, cost, period of recovery of investment, susceptibility to environmental hazards); and (iii) institutional environment (e.g. availability of credit, access to information on the technology, infrastructure, extension support). This makes the technology adoption process quite complex and far from being straightforward.

Therefore, this review provides an overview on the main models and theories on the acceptance, adoption, use or diffusion of technologies. The paper comprehensively reviews the concepts, strengths and weaknesses of technology adoption theories and models. The most prominent theories and models include the Theory of Reasoned Action (TRA) (Fishbein & Ajzen, 1975), Technology Acceptance Model (TAM, and its variants TAM2 and TAM3) (Davis, 1985; Davis et al., 1989; Venkatesh & Bala, 2008; Venkatesh & Davis, 2000), Motivational Model, Theory of Planned Behaviour (TPB) (Ajzen, 1985; Ajzen, 1991b), Decomposed Theory of Planned Behaviour (DTPB) (Taylor & Todd, 1995), Innovation Diffusion Theory (IDT) (Rogers, 1995), Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003). Further theories, which are not reviewed in the present paper, comprise Domestication Theory (Silverstone, 2006), Large Technical Systems (Hughes, 1987), Social Construction of Technology (Bijker et al., 2012), Social Cognitive Theory (SCT) (Bandura, 1986), Perceived Characteristics of Innovating Theory (PCIT) (Hameed et al., 2012). There are also different combinations of the above-mentioned models; for instance, hybrid TPB-TAM model suggested by Taylor and Todd (1995).

TECHNOLOGY ADOPTION MODELS AND THEORIES

Innovation Diffusion Theory (IDT)

The Innovation Diffusion Theory (IDT) or the Theory of Diffusion of Innovations (DIT), by Everett Rogers (1995), seeks to explain why, how and at what rate new technologies and innovations spread. For Rogers (2003), adoption refers to the decision of “full use of an innovation as the best course of action available”, while diffusion is “the process in which an innovation is communicated through certain channels over time among the members of a social system” (p. 5). As the above-mentioned definitions shows, innovation, communication channels, time and social system are the four key components of the innovation diffusion model. In this context, research on innovation diffusion attempts to explain the variables affecting the adoption of new technologies by users. IDT integrates three main components that are innovation characteristics, adopter characteristics and the process of innovation decision (Taherdoost, 2018). As for innovation decision process, five steps (viz. understanding, persuasion, decision, implementation, confirmation) take place, thanks to various communication channels, over a period of time (Rogers, 2003). Regarding innovation characteristics component, five main constructs have been proposed (viz. relative advantage, compatibility, complexity, trialability, and observability/results demonstrability) (Sila, 2015). As for adopter characteristics, Rogers (1995, 2003) indicates five groups of adopters: innovators, early adopters, early majority, late majority and laggards. The Perceived Characteristics of Innovating Theory (PCIT) (Hameed et al., 2012) expands IDT by adding three features viz. image, voluntariness and behaviour.

Since the 1960s, IDT has been used to study a wide variety of technologies and innovations, varying from agricultural machines to organizational innovations (Tornatzky & Klein, 1982).

It was used, inter alia, to investigate the adoption of land, soil and water conservation practices (Mango et al., 2017). IDT explains the adoption process and predicts the adoption rates (Askarany et al., 2012; Hameed et al., 2012), but does not consider how attitude and intention affect innovation adoption (Karahanna et al., 1999; Muchena et al., 2005). It focuses on the technology characteristics, personal attributes and environmental aspects but has less explanatory power when it comes to predicting adoption outcomes (Taherdoost, 2018).

Motivational Model (MM)

Since 1940’s, various theories stemmed from motivation research. One of these is the Self-Determination Theory (SDT) developed by Deci and Ryan (1985). SDT posits that self-determination is a human quality involving choice experience, having choices and making choices (Deci & Ryan, 1985). Deci et al. (1991) point out that choice is the regulatory process when behaviour is self-determined, but compliance or defiance when it is controlled. Motivation theory supported the psychology research in explaining behaviour. According to Davis et al. (1992) the core constructs of the Motivational Model (MM), and SDT, are intrinsic motivation (cf. process of performing the activity) and extrinsic motivation (cf. outcomes distinct from the activity itself). For instance, Davis et al. (1992) suggest perceived enjoyment as an extrinsic motivation and perceived usefulness as an intrinsic motivation. Besides intrinsic motivation and extrinsic motivation, SDT also considers how the social environment affects motivated behaviours (Deci & Ryan, 1985). MM has been used in many motivational studies (e.g. learning, health care) (Gagné & Deci, 2005; Parijat & Bagga, 2014) but its application in technology acceptance and use is limited (Deci & Ryan, 2008).

Theory of Reasoned Action (TRA)

The Theory of Reasoned Action (TRA) is one of the first technology acceptance theories. It was developed by Ajzen and Fishbein in 1975 (Fishbein & Ajzen, 1975) and has become one of the most fundamental human behaviour theories. The model of Ajzen and Fishbein (1980) aims to predict and explain any human behaviour. According to Ajzen and Fishbein (Ajzen & Fishbein, 1980), the core constructs of TRA are attitude toward behaviour, subjective norms (cf. social influence) and intention (i.e. behavioural intention). TRA represents the beginning of studies on behaviour focusing on the impact of attitude. Attitude is either one-dimensional or multidimensional factor and has direct or indirect effects on behaviour. Fishbein and Ajzen (1975) consider ‘attitude’ as the individual’s evaluation of a technology, ‘belief’ as link between technology and some attribute, and ‘behaviour’ as an intention result (cf. use). Attitude is affective and influenced by a set of beliefs about the new technology. Subjective norms refer to the person’s perception about the attitude of their immediate community towards a certain behaviour (e.g. use of a technology). TRA is a general model that was not designed to study any specific behaviour or technology (Davis et al., 1989). The theory does not consider other variables that effect intention like experience, fear and mood. Taherdoost (2018) puts that the main disadvantages of TRA are that it doesn’t address the role of habit, cognitive deliberation and moral factors.

Technology Acceptance Model (TAM)

Unlike TRA, the final conceptualization of the Technology Acceptance Model (TAM) excludes the core construct of ‘attitude’ in explaining intention. TAM, which was first proposed by Davis (1985), includes fundamental user motivation variables (i.e. perceived usefulness, perceived ease of use) and outcome variables (i.e. behavioural intention, technology use) (Davis, 1989). Perceived Ease of Use (PEU) and Perceived Usefulness (PU) are considered the main variables/beliefs that explain intention and, consequently, behaviour (Marangunić & Granić, 2015). Generally, PEU refers to the effort relating to the use of a technology while PU considers the outcomes and advantages of using a technology especially in terms of performance. PEU and PU are accompanied by external variables explaining their variation; among others, self-efficacy (CSE), subjective norms (SN) and facilitating conditions (FC) (Schepers & Wetzels, 2007). External variables refer to contextual factors and personal capabilities. In the basic TAM model (Davis, 1985; Venkatesh & Davis, 1996), intention predictors included only two specific beliefs viz. PU and PEU. TAM2 extends TAM by including subjective norms as a further intention predictor (Venkatesh & Davis, 2000). The integrated technology acceptance model, TAM3 (Venkatesh & Bala, 2008), is the result of the combination of TAM2 (Venkatesh & Davis, 2000) and the model of the perceived ease of use determinants (Venkatesh, 2000).

TAM was used to analyse the adoption of, among others, biological control on rice in Iran (Bagheri et al., 2016), mobile phones in Sub-Saharan Africa (Kabbiri et al., 2018), precision agriculture in Iran (Tohidyan Far & Rezaei-Moghaddam, 2017) and pasture-based grazing system in Ireland (McDonald et al., 2016).

The main limitations of TAM are that it ignores the social influence (cf. subjective norms) on technology adoption. Furthermore, factors relating to extrinsic motivations are not addressed in TAM, which makes the model inappropriate where technology use is not only to achieve specific tasks but also to meet certain emotional needs (Taherdoost, 2018). In order to address these limitations, in TAM2 social influence (image, voluntariness and subjective norms) and cognitive (e.g. result demonstrability, output quality) groups of constructs were added to TAM (Venkatesh & Davis, 2000).

Theory of Planned Behaviour (TPB)

The Theory of Planned Behaviour (TPB), first described in 1985 (Ajzen, 1985), is today one of the most influential socio-psychological models used in understanding human behaviour. TPB suggests that behaviours are already planned and extends TRA by adding the core construct of ‘perceived behavioural control’ (Ajzen, 1991b; Sheppard et al., 1988). Indeed, the core constructs of TPB are besides ‘Attitude toward behaviour’ (or ‘behavioural attitude’) and ‘Subjective norms’ (cf. TRA), also ‘Perceived behavioural control’ (Ajzen, 1985). Perceived behavioural control is determined by the availability of skills and resources as well as the perceived significance of those skills and resources to achieve outcomes. However, both TRA and TPB assume that an individual’s behavioural intention (BI) affects their behaviour. TPB (Ajzen, 1985, 2005, 2012; Ajzen, 1991b) considers the behaviour of a specific consumer/user and provides a framework for analysing the determinants of such a behaviour. Briefly, ‘intention’ is the immediate antecedent of behaviour in the TPB. Intention, in turn, is assumed to be determined by three types of constructs or beliefs (viz. behavioural beliefs, normative beliefs, control beliefs). Behavioural beliefs refer to the perceived consequences of performing the behaviour and the subjective evaluations of these consequences. Behavioural beliefs lead to forming a positive or negative ‘attitude toward the behaviour’. Normative beliefs relate to the perceived expectations of referent individuals or groups and they combine to create a perceived social pressure (cf. subjective norms) with respect to behaviour performance. Control beliefs regard the perceived presence of facilitating or hindering factors that affect person’s ability to performing a behaviour. Researchers in different fields have added constructs to TPB to promote its behaviour prediction power (Burton, 2004). These include moral norms (Arvola et al., 2008; Kaiser & Scheuthle, 2003; Sandoghi & Raheli, 2017) and environmental concerns (de Leeuw et al., 2015; Sobhani et al., 2018; Yadav & Pathak, 2016). The Decomposed Theory of Planned Behaviour (DTPB) (Taylor & Todd, 1995) is a variant of TPB. It is identical to TPB in terms of intention prediction, but – similarly to TAM – it decomposes the core constructs (viz. attitude, subjective norms, perceived behavioural control) into their underlying belief structure within the contexts of technology adoption.

TPB was used, among others, to analyse the adoption of soil conservation practices (Wauters et al., 2010), water conservation practices (Chaudhary et al., 2017; Yazdanpanah et al., 2014) as well as pesticides use (Bond et al., 2007). It was also utilised in different fields such as purchase of organic products (Arvola et al., 2008; Sobhani et al., 2018), dairy farming (Bergevoet et al., 2004; Rehman et al., 2007), forestry (Karppinen, 2005; Pouta & Rekola, 2001). Furthermore, different types of behaviours of producers were analysed thanks to TPB such as entrepreneurial behaviour (Bergevoet et al., 2004), conservation behaviour (Beedell & Rehman, 2000) and environmentally-oriented behaviour (Willock et al., 1999).

As for model limitations, TPB does not consider other factors that may affect behavioural intention to perform a behaviour such as experience. Furthermore, it does not take into consideration economic and environmental variables (Truong, 2009).

Unified Theory of Acceptance and Use of Technology (UTAUT)

The Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) is one of the most prominent models in technology acceptance and adoption field. The UTAUT integrates various models on technology acceptance and adoption (Williams et al., 2015) such as Motivational Model (Deci & Ryan, 1985), Technology Acceptance Model (Davis, 1985), Innovation Diffusion Theory (Rogers, 1995) and Theory of Planned Behaviour (Fishbein & Ajzen, 1975). In its initial form, the UTAUT suggests that four main elements/core constructs – ‘effort expectancy’ (cf. perceived ease of use), ‘performance expectancy’ (cf. perceived usefulness), ‘social influence’ (cf. subjective norms) and ‘facilitating conditions’ – determine ‘behavioural intention’ to use/adopt a new technology and that these constructs are moderated by different variables (e.g. age, gender, experience, voluntariness of use) (Venkatesh et al., 2003). More recently, the UTAUT has been augmented with additional three core constructs viz. hedonic motivation (from consumer behaviour research), price value (from economics) and habit (from sociology), while ‘voluntariness of use’ was removed (Venkatesh et al., 2012).

Since its introduction, UTAUT has been widely used in innovation diffusion and technology adoption research. It has been utilised to study a variety of technologies with various moderators (e.g. gender, age, experience, education, income) and users (e.g. professionals, students, farmers). UTAUT was praised for its power to elucidate the factors determining the acceptance and use of a new technology. One key benefit of UTAUT is that it represents an encompassing and integrative model that synthesizes eight theories and models and counter their deficiencies and limitations. For that, despite being new, UTAUT is increasingly popular among technology adoption models (Al-Hakim, 2007). Furthermore, its validity, stability and viability in technology adoption surveys have been confirmed within numerous contexts. Unlike other models (e.g. TAM, TRA, TPB), UTAUT model explains

high percentage of behavioural intention to use a technology as well as effective technology use (Brown & Venkatesh, 2005). Therefore, Taiwo and Downe (2013) put that UTAUT "*is believed to be more robust than other technology acceptance models in evaluating and predicting technology acceptance*".
Although UTAUT is a robust model, it has some shortcomings. The limitations of the composing models affect the ultimate viability of UTAUT. These shortcomings relate, among others to the conceptualisation of the relation between intention (cf. behavioural intention) and use (cf. use behaviour). One further shortcoming of UTAUT is that it relies on a relatively narrow conception of the user (e.g. purchaser). Moreover, it does not specify the relative significance and weight of its different core constructs/constituent elements, nor does it capture qualitative aspects of technology acceptance (e.g. informal learning, interpersonal social networks) (Sovacool & Hess, 2017).

CONCLUSIONS

Adoption of innovations and new technologies in agriculture can not only have a central contribution to the achievement of food security and the improvement of the sustainability of agri-food systems worldwide but is also vital in achieving the targets of the second Sustainable Development Goal (SDG 2: Zero Hunger) in the framework of the 2030 Agenda for Sustainable Development. Moreover, deployment of appropriate technologies is crucial to address the pressing challenge of climate change. However, impacts depend on the level of acceptance by farmers/producers and the types of technologies adopted. For that, it is of paramount importance to understand the factors that affect the adoption of technologies in agriculture worldwide and to fine-tune the acquired knowledge to the specific context of each country. Therefore, this review provides an overview on the main models and theories on the acceptance, adoption and use of technologies. These conceptual approaches and models span across disciplines and differ in terms of theoretical assumptions, variables/constructs and assessment methods. Each model has its strengths as well as shortcomings and limitations. Factors determining the acceptance and use of technologies in agriculture are related to the technology itself and the ease of its use as well as social (age, gender), emotional, attitudinal and cognitive factors. Adoption of technologies is also affected by the environment and context in which it takes place. Nevertheless, it is important to highlight that technologies alone are not enough and that they represent only one of the components of the wide AKIS. Indeed, innovation in agriculture concerns many areas affecting the technological field (cf. technology adoption) as well as broader organizational, marketing and institutional areas. Furthermore, evidence shows that, besides technical innovations (e.g. new technologies), also social innovation significantly affects agriculture productivity and sustainability. Moreover, it is of paramount importance to pay attention to the environmental, economic and social sustainability of technologies used in agriculture, especially in the era of high-tech, precision and smart agriculture. It is also crucial to involve end-users (e.g. farmers, herders, fisher folk) in technology development and validation to make sure that it is context-relevant, appropriate and accessible and to move towards more participatory models of 'technology transfer' in agriculture.

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