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The factors affecting the adoption of smart farming technologies: literature review and proposal of the conceptual model.

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Abstract

Agriculture is pivotal in fostering economic growth and societal advancement across numerous countries globally, especially in developing economies. However, this industry faces several challenges such as crop and soil quality, impacts of climate change, economic difficulties for farmers, and technological gaps. Improving food security while contributing to climate change mitigation and preserving natural resources requires a transition to more productive agricultural production systems. These systems need to optimize input use, ensure more stable agricultural production less prone to fluctuations, and enhance resilience to risks, shocks, and climate variability.

Smart agriculture explores opportunities offered by the Industry 4.0 revolution o accomplish these objectives. The key to this digital transformation lies in farmers' willingness to incorporate and leverage these advanced, interconnected technologies in their agricultural practices. The adoption of these innovations by farmers not only significantly improves yields and crop quality but also minimizes the ecological footprint of their activities and strengthens agricultural sustainability.

This article aims to identify the factors influencing Moroccan farmers' intention to adopt smart agriculture technologies based on the theoretical framework of the Unified Theory of Acceptance and Use of Technology (UTAUT 2) and existing literature.

Keywords : Climate change**;** smart farming ; Industry 4.0; Adoption of innovations, digital transformation.

Résumé

L'agriculture joue un rôle crucial dans la stimulation de la croissance économique et du progrès social dans de nombreux pays à travers le monde, particulièrement dans les économies en développement. Toutefois, cette industrie fait face à plusieurs défis tels que la qualité des cultures et des sols, les impacts du changement climatique, les difficultés économiques rencontrées par les agriculteurs et les lacunes technologiques. **L'amélioration de la sécurité alimentaire tout en contribuant à atténuer le changement climatique et à préserver les ressources naturelles nécessite une transition vers des systèmes de production agricole plus productifs. Ces systèmes doivent optimiser l'utilisation des intrants, garantir une production agricole plus stable et moins sujette aux variations, tout en renforçant la résilience face aux risques, aux chocs et à la variabilité climatique**. A cet effet, l'agriculture intelligente explore les opportunités offertes par la révolution de l'industrie 4.0 pour répondre à ces objectifs. La clé de cette transformation digitale réside dans la volonté des agriculteurs d'incorporer et de tirer parti de ces technologies avancées et interconnectées au sein de leurs pratiques agricoles,

L'adoption par les agriculteurs de ces innovations leurs permettent non seulement d'améliorer significativement les rendements et la qualité des cultures, mais aussi de minimiser l'empreinte écologique de leurs activités et renforcer la durabilité agricole

Ce présent article vise donc à identifier les facteurs influençant l'intention des agriculteurs marocains d'adopter les technologies de l'agriculture intelligente en se basant sur le cadre théorique de la théorie unifiée de l'acceptation et de l'utilisation de la technologie (UTAUT 2) et la littérature existante.

Mots clés : Changement climatique **;** Agriculture intelligente ; Industrie 4.0; Adoption des innovations, Transformation digitale.

Introduction

For over three decades, the Kingdom has been experiencing its most severe drought period, exacerbated by climate change and a drastic decrease in precipitation, down by 67% compared to the usual seasonal average. These phenomena have had profound repercussions on the national economy, particularly on agricultural activity.

Agriculture remains crucial for many nations around the world and is a vital sector for Morocco. Indeed, agriculture plays an essential role as a cornerstone of the economy, contributing up to 15% of the national GDP and ensuring both the livelihoods of local populations and the production of crucial agricultural exports for the country's economy. However, according to the report from the Royal Institute of Strategic Studies, Moroccan agriculture is currently facing an unprecedented critical situation. This situation is characterized by an advanced deterioration of its basic productive resources (water, soils, and biodiversity), as well as an increased dependence on imports to meet the growing deficits in basic food products.

Improving food security while mitigating climate change impacts and preserving natural resources requires a transition to more productive agricultural production systems. These systems must optimize input use, ensure more stable agricultural production less susceptible to fluctuations, and enhance long-term resilience against risks, shocks, and climate variability.

A more productive and resilient agriculture requires a major shift in land management practices, water and soil nutrient management, and genetic resource management to ensure these resources are handled more efficiently. It is in these efforts to promote agricultural growth that the Moroccan agricultural sector sees digital agriculture, also known as smart agriculture, as a potential response to these challenges. This innovative approach is a fundamental pillar of the new agricultural strategy "Génération Green 2020-2030". The key to the success of this digital transformation lies in farmers' willingness to incorporate and leverage advanced, interconnected technologies of smart agriculture (such as smart sensors, drones, Internet of Things, and artificial intelligence) within their farming practices.

Farmers' adoption of these innovations not only allows them to significantly improve yields and crop quality but also to minimize the ecological footprint of their activities. Smart sensors provide real-time data on soil, moisture, and nutrients, enabling precise management of agricultural inputs. Drones facilitate crop monitoring over large areas, allowing for rapid intervention in case of diseases or water stress. IoT connects agricultural equipment, optimizing their use and maintenance. AI analyzes massive volumes of data to provide personalized recommendations to farmers, such as optimal planting or fertilization schedules, thereby contributing to more efficient management of limited resources. By integrating these technologies, farmers are better equipped to tackle climate challenges while ensuring the long-term sustainability of agriculture.

In this context, our research focuses on the adoption of innovations, particularly smart farming technologies. Therefore, we aim to address the following question: What are the determinants, from both theoretical and empirical perspectives, of the adoption of smart farming technologies by Moroccan farmers? Identifying these determinants is essential for formulating effective strategies to promote and support the integration of Industry 4.0 technologies in the Moroccan agricultural sector. This effort contributes to enhancing the resilience of agricultural communities and ensuring sustainable management of valuable natural resources.

In this article, we pursue two main objectives: first, to identify and understand the key factors influencing the decision to adopt smart farming technologies, drawing on existing literature and the Unified Theory of Acceptance and Use of Technology (UTAUT 2) framework. Second, we will propose a conceptual model illustrating the cause-and-effect relationship between these factors and the adoption of smart farming technologies.

To address our research question, our article is structured into three parts. Firstly, we introduce a conceptual framework that explores the key concepts of our study. Secondly, we conduct a literature review analyzing the factors influencing farmers' decisions to adopt smart farming technologies, with a particular emphasis on the theoretical framework of UTAUT2 (Unified Theory of Acceptance and Use of Technology 2) and its applications in this field. Finally, we conclude our work by proposing a conceptual research model that will be the focus of our empirical research.

1. Adoption of Smart Farming Technologies (SFT)

1.1. Clarification on the Concept of Adoption

The adoption of innovations is a fundamental concept in many fields, extensively studied by various authors both at the organizational and individual levels.

In the context of the Larousse French Dictionary, the definition seems to focus more on the individual aspect of adoption. This definition of adopting a new product emphasizes the idea of selecting something for regular and ongoing use.

In the innovation literature, the definition of adoption can vary depending on the context and field of study. Le Nagard-Assayag et al. (2005) discuss adoption within the context of consumer goods. According to them, for a product to be considered adopted, it is necessary for the individual to make repeated purchases of that product. In other words, adoption is not merely associated with the initial purchase but also with the ongoing repetition of purchases over time.

African Scientific Journal
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Vol : 03, Numéro 25, Août 2024

In the sector of a durable asset such as technological innovations, Rogers (1995) defines adoption as the process by which a decision-making unit, whether it be an individual or an organization, accepts and uses a new idea, product, or brand continuously and regularly. This definition emphasizes that adoption is not merely a one-time act but a continuous process that involves the ongoing acceptance and regular use of the innovation over time.

In the field of agricultural technologies, Van Den Ban et al. (1994) consider adoption as a process whereby farmers or agricultural stakeholders make the decision to implement new technical proposals into their production systems, while seeking to progressively improve their utilization over time.

Mabah et al. (2013), in their study on the adoption of agricultural innovations, affirm the definition provided by Van Den Ban et al. (1994). They focus on the process by which individuals or organizations decide to implement new technical proposals into their agricultural production systems. Adoption of innovations, as defined in this study, refers to a deliberate decision to implement new or modified practices or technologies aimed at improving the efficiency, sustainability, or profitability of agricultural operations.

1.2. The Concept of Smart Farming

Smart farming is a rapidly growing concept in the agricultural field, offering precise soil management, valuable data collection, and automated farming techniques.

In the agricultural sector, technological advancements have led to a plethora of terms describing various forms of agricultural digitization. These include smart agriculture (Blok and Gremmen, 2018; Wolfert et al., 2017), precision agriculture (Wolf and Buttel, 1996; Eastwood et al., 2017), digital agriculture (Keogh and Henry, 2016), and Agriculture 4.0 (Clasen, 2016), echoing the concept of Industry 4.0. However, there remains a lack of consensus regarding their definitions. Some consider these terms to be synonymous (C. Balaceanu et al., 2019; L. Klerkx et al., 2019), while others view precision agriculture as a component of smart agriculture (S. M. Pedersen, K. M. Lind, et al., 2017; M. Carolan, 2018). According to these authors, smart agriculture goes beyond precision agriculture, encompassing broader domains involving digitization, automation, and the use of the Internet of Things (A.-u. Rehman, 2015; DC Rose and J. Chilvers, 2018).Some argue that precision agriculture constitutes the foundational concept (H. El Bilali et al., 2020), while subsequent technological developments have given rise to new terms such as digital agriculture or Agriculture 4.0.

In our study, we use the term "smart farming" (SF) collectively to refer to various technological advancements in this field. Smart farming encompasses advancements such as precision

African Scientific Journal
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Vol : 03, Numéro 25, Août 2024

agriculture, agricultural management information systems, as well as smart or digital technologies like IoT, automation, and AI.

According to the FAO[1] definition, mart farming entails integrating various innovations aimed at enhancing agricultural production efficiency. These innovations encompass precision agriculture, IoT, and Big Data.

Wolfert et al. (2017) define smart agriculture as a practice that focuses on the application of information and communication technologiesin the cyber-physical management process of agriculture, enabling farmers to react appropriately to real-time events based on context and situation.

In the same vein, C. Balaceanu et al. (2019) consider smart afarming as a contemporary approach that integrates information and communication technologies to monitor all processes and activities associated with the agricultural sector.

In the white paper on digital agriculture, it is defined by the wide array of technologies involved: "data acquisition technologies (satellites, sensors, IoT devices, smartphones...), transfer and storage (3G/4G coverage, low-bandwidth terrestrial or satellite networks, clouds), and processing technologies (artificial intelligence, ...) (Bellon-Maurel et al., 2022).

Smart farming is therefore an agricultural production practice that involves adopting and using digital advancements to manage farms, aiming to optimize the quality and quantity of products while reducing long-term risks and costs, and enhancing the efficiency of human labor.

The development of digital technologies in agriculture leads farmers to adopt a wide range of tools and methods. The adoption of these technologies and associated services necessarily brings changes in farmers' practices to the extent that some authors (Clasen, 2016) have introduced the term Agriculture 4.0 to characterize farmers' technical or strategic decisions based on information or data.

2. Unified theory of acceptance and use of technology (UTAUT)

2.1. Theoretical foundations of the UTAUT

Venkatesh et al. (2003) developed the Unified Theory of Acceptance and Use of Technology based on the conceptual and empirical similarities of eight theories and models used in the field of information systems to propose unified variables and provide a more comprehensive understanding of the acceptance process than previous individual models had achieved. These models include:

[1] FAO; IPA. *Pathways to Profit—Experimental Evidence on Agricultural Technology Adoption*; Investment Brief; FAO: Rome, Italy, 2023.

African Scientific Journal
ISSN : 2658-9311
Vol : 03, Numéro 25, Août 2024

- **Theory of Reasoned Action (TRA)**

Developed by M. Fishbein and I. Ajzen in 1975, the Theory of Reasoned Action is a psychosocial theory aimed at explaining and predicting human behaviors. According to these authors, an individual's behavior is directly shaped by their intention to adopt a specific behavior. This intention is influenced by the individual's attitude toward the behavior, defined as "the positive or negative feelings a person has about performing the behavior" (Fishbein and Ajzen, 1975), and by subjective norms regarding the behavior, which refer to "the perceived social pressure from significant others" (Fishbein and Ajzen, 1975).

- **Theory of Planned Behavior (TPB)**

As an enhancement of TRA, where authors assume that individuals have complete control over their behavior, neglecting other internal and external factors over which they have no mastery but which can influence an individual's intention to perform a certain behavior, Ajzen (1991) developed the Theory of Planned Behavior (TPB). This theory integrates a third explanatory variable of intention and behavior, namely: perceived behavioral control, which refers to perceptions and internal or external constraints of a behavior (Ajzen, 1991).

- **The Technology Acceptance Model (TAM)**

Developed in 1989 by Davis as an adaptation of TRA, which posits that beliefs influence attitudes, which in turn influence intentions, leading to observed behaviors, according to this author attitude is determined by two variables representing end users' beliefs about technology (Lokeswari, 2016): Firstly, Perceived usefulness refers to the degree to which an individual believes that using a particular system will enhance their job performance. Perceived ease of use indicates the extent to which an individual believes that using a specific system will require minimal effort. Additionally, perceived ease of use directly impacts perceived usefulness.

- **Combined TAM-TPB Model (C-TAM-TPB)**

Taylor and Todd (1995) introduced a more integrated approach by merging predictors from the TAM and TPB models into what they termed the Combined TAM-TPB Model (C-TAM-TPB). In this model, behavioral intention is posited as the key determinant of behavior, influenced by attitude, subjective norm, perceived behavioral control, perceived usefulness, and perceived ease of use. The C-TAM-TPB model also proposes that perceived behavioral control directly influences behavior, alongside its indirect influence through intentions. Perceived usefulness and perceived ease of use shape attitude, with perceived ease of use directly impacting perceived usefulness.

- **Model of Personal Computer Utilization (MPCU)**

Developed by Thompson, Higgins, and Howell (1991) to predict the usage behavior of personal computers as a dependent variable, these authors identified a set of determining factors: (1) Job Fit: "A person's perception of a technology's capability to increase their job effectiveness" (Thompson et al., 1991).(2) Complexity: "Perceived difficulty level in understanding and using an innovation" (Thompson et al., 1991). (3) Long-term Consequences: "Anticipated outcomes that have repercussions in the future" (Thompson et al., 1991). (4)Affect: "Emotions such as satisfaction, enthusiasm, or pleasure, as well as depression, disgust, or discontent associated with use" (Thompson et al., 1991). (5) Social Factors: "The internalization by an individual of the subjective culture of a reference group, as well as specific interpersonal agreements made with others in particular social contexts" (Thompson et al., 1991).(6) Facilitating Conditions: "Refer to objective factors in the environment that facilitate the accomplishment of an action." (Thompson et al., 1991).

- **The Motivation Model (MM)**

Developed by Davis, Bagozzi, and Warshaw (1992), their study showed that intentions to use computers in the workplace are primarily influenced by the perception of the computer's usefulness (extrinsic motivation) in enhancing job performance, and secondarily by the degree of enjoyment experienced while using it (intrinsic motivation).

- **The Social Cognitive Theory (SCT).**

Albert Bandura (1986) suggests that human behavior is shaped by the interaction among three key factors: (1) Personal Factors (cognition), (2) Behavior, and (3) Environment (external factors). Each factor influences and is influenced by the other two in a continuous cycle. Similar to the TPB (Theory of Planned Behavior), SCT encompasses other beliefs that can influence behavior, regardless of outcome perceptions (Compeau et al., 1999).

Bandura (1986) states that an individual's behavior is associated, on one hand, with (i) self-efficacy, defined as "beliefs in one's capabilities to organize and execute the courses of action required to produce given attainments" (Bandura, 2003), and on the other hand, (ii) outcome expectations, which are "judgments of the likely consequences of the behavior" (Bandura, 1986). The Social Cognitive Theory also includes two other constructs that directly or indirectly influence behavior: (a) behavioral goals or intentions, and (b) perceived environmental obstacles and facilitators (Bandura, 2004).

- **The Theory of Diffusion of Innovations (IDT)**

Developed by Rogers for the first time in 1962 in his book "Diffusion of Innovations," this theory aims to predict and explain how a technological innovation progresses from the stage of

African Scientific Journal
ISSN : 2658-9311
Vol : 03, Numéro 25, Août 2024

invention to widespread use, both at the individual and organizational levels. Throughout different editions, Rogers identified five main characteristics of technology that influence the innovation adoption process: (1) Relative Advantage: Defined as "the extent to which an innovation is perceived to be superior to the technology it replaces" (Rogers, 2003).(2) Compatibility: Refers to "the extent to which an innovation is perceived to be consistent with existing values, past experiences, and the needs of potential adopters" (Rogers, 2003).(3) Trialability: Defined as "the extent to which an innovation can be experimented with on a limited basis" (Rogers, 2003). (4) Observability: Defined as "the degree to which the results of an innovation are visible to others." (Rogers 2003, p.229), (5) Complexity: Refers to "the perceived difficulty in understanding and using an innovation." (Thompson et al., 1991).

2.2. Key variables of the UTAUT Model derived from eight behavioral theories

By combining 8 theories and models of behavioral intention, UTAUT measures the effect of four key variables on users' intentions to adopt an information system and their subsequent behavior. These factors include Performance Expectancy (PE), Effort Expectancy (EE), Social Influence (SI), and Facilitating Conditions (FC).

- **Performance Expectancy:** Defined as "the degree to which an individual believes that using the system will help improve job performance" (Venkatesh et al., 2003), this variable is determined by the perception of usefulness (TAM1/TAM2), relative advantage (IDT), intrinsic motivation (MM), job-fit (MPCU), and outcome expectancy (SCT).
- **Effort Expectancy,** defined as "the perceived ease of using the system" (Venkatesh et al., 2003),expected effort is based on the concepts of perceived ease of use (TAM1/TAM2) and complexity (MPCU/IDT).
- **Social influence**, defined as "the extent to which an individual perceives that influential people believe they should use the new system" (Venkatesh et al., 2003) includes subjective norm (TRA, TPB, TAM1, TAM2, C-TAM-TPB), social factors (MPCU), and image (IDT). The effect of social influence is significant when technology use is mandatory (Venkatesh et al., 2003).
- **Facilitating conditions** Facilitating conditions are defined as "the extent to which an individual perceives the organizational and technical infrastructure to support system use" (Venkatesh et al., 2003). This construct is influenced by perceived behavioral control (TPB, C-TAM-TPB), facilitating conditions (MPCU), and compatibility (IDT).includes perceived behavioral control (TPB, C-TAM-TPB), facilitating conditions (MPCU), and compatibility (IDT). Facilitating conditions have a direct

positive effect on intention to use, but after initial use, the effect is no longer significant (Venkatesh et al., 2003).

The initial three factors directly impact both intention and usage behavior, whereas the fourth directly influences usage behavior. The impact of these predictors is moderated by gender, age, experience, and the voluntary nature of use, as depicted in Figure 1 (Venkatesh et al., 2003).

The extension of UTAUT, named UTAUT2, builds on the recommendations of Johns (2006), highlighting how specific environments can influence existing theories in diverse ways. According to the original UTAUT, only elements of extrinsic motivation are considered, focusing on the utility value of technology. This is represented by the concept of performance expectancy as perceived usefulness. Venkatesh et al. (2012) expand this extrinsic motivation component in UTAUT2 to include intrinsic motivation and hedonic motivation.

UTAUT2 posits that individuals' technology usage is influenced by three new constructs: hedonic motivation, price value, and habit, moderated by age, gender, and experience.

- **Hedonic motivation** refers to the pleasure or joy resulting from the use of technology (Venkatesh et al., 2012).
- **Price value** refers to users' cognitive assessment that represents a trade-off between perceived benefits of the technology and the monetary cost of its use (Venkatesh et al., 2012).
- **Habit** is defined as individuals' propensity to automatically adopt behaviors due to learning (Venkatesh et al., 2012). In other words, it is based on the principle that individuals tend to maintain familiar routines and exhibit resistance to change, which poses a barrier to adopting tools that cause too rapid and/or significant disruption of these habits.

Furthermore, 'UTAUT2' abandons the voluntary nature of use, which was previously moderated in 'UTAUT,' as the use of technologies in consumer contexts is entirely voluntary.

African Scientific Journal
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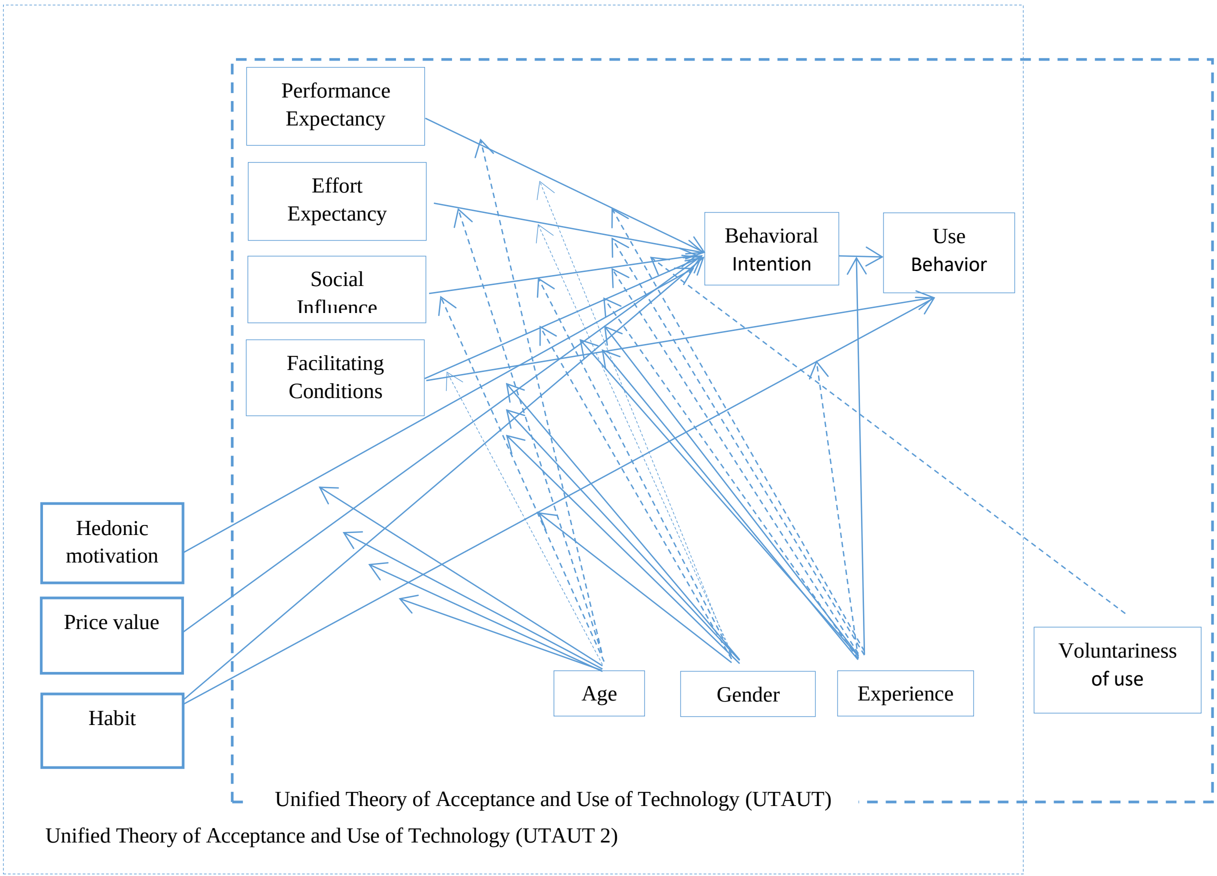
Vol : 03, Numéro 25, Août 2024

Figure N°1 : Unified theory of acceptance and use of technology (UTAUT2 vs UTAUT)



Source : (Boughzala.I ,2014)[2]

A review of the scientific literature on the Unified Theory of Acceptance and Use of Technology (UTAUT) highlights the robustness and flexibility of the variables considered in the enhanced UTAUT model. UTAUT 2 is often favored by researchers and practitioners because it provides a more comprehensive and updated perspective on the factors influencing technology adoption compared to the original UTAUT, which could be seen as a more basic or initial version of the model.

UTAUT 2 explains approximately 70% of the variance in behavioral intention, whereas the original UTAUT explained around 50% of this variance. Thus, UTAUT 2 represents a significant improvement over UTAUT in terms of explaining the variance in users' behavioral intentions toward new technologies (Venkatesh et al., 2012). Consequently, UTAUT 2 can serve as a preferred tool to identify factors influencing Moroccan farmers' intention to adopt smart agricultural technology.

[2] Boughzala.I (2014) .How Generation Y Perceives Social Networking Applications in Corporate Environments.?. Grenoble Ecole de Management (Post-Print) hal-01242865, HAL.

African Scientific Journal
ISSN : 2658-9311
Vol : 03, Numéro 25, Août 2024

3. The application of the UTAUT2 model in the field of smart farming

To predict the intention to adopt smart farming technologies (SFT), many researchers (M. Ronaghi and A. Forouharfar, 2020; Masukujjaman et al., 2022; Giua et al., 2022; E. Bezaa et al., 2018; Michels et al., 2020; Wee Wei En and Lim Siang Siew, 2022; W. Li et al., 2020; Schukat and Heise, 2021) have applied the UTAUT model in its original and developed versions, sometimes modifying it to fit their specific context by excluding certain variables and/or introducing new concepts.

E. Beza et al. (2018) applied the developed version of UTAUT to assess the acceptance of mobile SMS technology for collecting data from small-scale farmers in Ethiopia by adding three new constructs: "personal motivation," "trust," and "goal-directed mastery approach." In this research, 220 farmers participated. The study results revealed that factors positively influencing farmers' intention to adopt mobile SMS for agricultural data provision include performance expectancy, effort expectancy, price value, and trust. The three factors from the UTAUT2 model accounted for 32% of the variability, and the inclusion of the trust construct raised this percentage to 41% in farmers' intention to adopt mobile SMS.

M. Ronaghi and A. Forouharfar (2020) applied the UTAUT model to investigate farmers' intention to adopt Internet of Things (IoT) technology in smart agriculture within Iran's Fars province. Unlike the original model, they treated individual factors as independent variables rather than mere moderators of variables influencing ITU. Their study highlighted the positive influences of performance expectancy, effort expectancy, social influence, individual factors, and facilitating conditions on the intention to adopt IoT technology. However, age, experience, and income were found to negatively impact individuals' intentions to use smart agricultural technologies.

Furthermore, Li et al. (2020) conducted a study to explore the factors determining the adoption of smart agriculture technologies among Chinese farmers in crop systems, based on the enhanced version of the UTAUT model. They integrated a new construct called "perceived need for technological features (PNTC)" in their research. With a sample of 456 farmers, the results showed that perceived need for technological features (PNTC), performance expectancy, perceived effectiveness of facilitating conditions, and perceived risks of adoption had significant impacts on farmers' intention to adopt smart agriculture technologies. Favorable conditions emerged as the strongest indicator of Chinese farmers' willingness to adopt these technologies.

Michels et al. (2020) applied the UTAUT model to examine the latent factors influencing farmers' decisions to adopt crop protection smartphone applications based on the Unified

Theory of Acceptance and Use of Technology framework. Their study, conducted with 207 German farmers, confirmed that performance expectancy, effort expectancy, social influence, and facilitating conditions have a positive impact on the intention to adopt these applications, explaining 73% of the variation in farmers' behavioral intention to use crop protection smartphone applications.

Schukat and Heise (2021) enriched the UTAUT model by integrating two new constructs, namely "trust" and "technological maturity," to understand and predict the intention to use smart agriculture technologies among German farmers. The results of their study demonstrated that performance expectancy, social influence, facilitating conditions, hedonic motivation, trust, and technological maturity have a significant positive influence on behavioral intention. Moreover, facilitating conditions, technological maturity, and behavioral intention have a significant positive direct influence on usage behavior. Thus, it was found that technological maturity, hedonic motivation, and social influence have the strongest influence on behavior.

Masukujjaman et al. (2022) investigated the factors influencing Bangladeshi farmers' adoption willingness and willingness to pay for Internet of Things (IoT) in smart agriculture, employing the Unified Theory of Acceptance and Use of Technology 2 (UTAUT 2) framework. Their findings revealed that performance expectancy (PE), effort expectancy (EE), social influence (SI), and facilitating conditions (FC) influenced behavioral intentions to adopt IoT. Particularly, social influence (SI) emerged as the most influential predictor of behavioral intention.

Giua et al. (2022) conducted an empirical analysis on a sample of 474 farmers to comprehensively examine the adoption of smart agriculture technology in Italy. The results showed that farmers' intention to use the technology primarily depends on performance expectancy, effort expectancy, and social influence, whereas facilitating conditions did not have a significant effect. Similar to M. Ronaghi and A. Forouharfar (2020), sociodemographic variables are considered direct determinants.

Wee Wei En and Lim Siang Siew (2022) applied the UTAUT model to examine the behavioral intention to use smart agriculture technologies from the perspective of Malaysian farmers in Sarawak. The study's results confirmed that performance expectancy (PE), effort expectancy (EE), social influence (SI), and facilitating conditions (FC) are antecedents of behavioral intention and directly influence the intention to adopt smart farming technology (SFT). Social influence (SI), having the strongest beta coefficient, emerged as the most powerful predictor of behavioral intention, indicating that farmers in Sarawak are easily influenced and guided by their peers.

African Scientific Journal
ISSN : 2658-9311
Vol : 03, Numéro 25, Août 2024

Given existing studies, Table 1 presents some applications of the UTAUT1 and UTAUT2 models in the field of smart agriculture technology adoption and the results obtained.

Table 1: Summary of Applications of the UTAUT Models and Results Obtained

Authors	Research Method / Sample Size / Country	Model	Factors	Results of Model Application
Beza and al (2018)	Empirical Study / 220 Farmers / Ethiopia	UTAUT2	performance expectancy, effort expectancy, social influence, facilitating conditions, price value, hedonic motivation, trust, personal motivation, mastery goal orientation	Performance expectancy, effort expectancy, and price value have a positive influence on the adoption intentions of mobile SMS. These three factors of the model explained only 32%, while the addition of the trust construct increased this figure to 41% of the variance in farmers' intentions to adopt mobile SMS.
Ronaghi et Forouharfar (2020)	Empirical Study /392Farmers /Iran	UTAUT	performance expectancy, effort expectancy, social influence, facilitating conditions, Age, Experience, agricultural income.	The study underscored the positive effects of performance expectancy, effort expectancy, social influence, individual factors, and facilitating conditions on the intention to adopt IoT technology. Conversely, age, experience, and income were found to negatively influence individuals' intentions to use smart agricultural technologies.

Li et al (2020)	Empirical Study / 456 Farmers / China	UTAUT 2	performance expectancy, effort expectancy, social influence, facilitating conditions, price value, hedonic motivation,the perceived need for technological features	Facilitating conditions were the strongest indicator of Chinese farmers' willingness to adopt smart agriculture technologies.
Michels et al (2020)	Empirical Study /207 Farmers / German	UTAUT	performance expectancy, effort expectancy, social influence, facilitating conditions.	Performance expectancy, effort expectancy, social influence, and facilitating conditions have a positive impact on the intention to adopt crop protection smartphone applications, explaining 73% of the variation in behavioral intention to use these applications.
Schukat et Heise (2021)	Empirical Study /523 Farmers / German	UTAUT2	performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation l’habitude,trust,	Technological maturity, hedonic motivation, and social influence have the strongest influence on behavior.

African Scientific Journal
ISSN : 2658-9311
Vol : 03, Numéro 25, Août 2024

			technological maturity	
Masukujjaman et al (2022)	Empirical Study / 381 Farmers / Bangladesh	UTAUT 2	performance expectancy, effort expectancy, social influence, facilitating conditions, price value, hedonic motivation	Social influence (SI) has been found to be the most significant predictor of behavioral intention.
Giua et al (2022)	Empirical Study / 474 Farmers /Italy	UTAUT	performance expectancy, effort expectancy, social influence, facilitating conditions, price value, hedonic motivation, Age, l'expérience,…	The results show that farmers' intention to use relies primarily on technology performance expectancy, effort expectancy, and social influence exerted on farmers, while facilitating conditions do not have a significant effect.
Wee Wei En et Lim Siang Siew (2022)	Empirical Study / 381 Farmers / Malaysia	UTAUT	performance expectancy, effort expectancy, social influence, facilitating conditions.	Performance expectancy (PE), effort expectancy (EE), social influence (SI), and facilitating conditions (FC) are antecedents of behavioral intention and directly influence the behavioral intention to adopt SFT (Smart Farming Technology). Social influence (SI), with the strongest Beta, has been found to be the most powerful predictor of behavioral intention

<u>Source</u> : Designed by us

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4. Conceptual model proposal and reformulation of research hypotheses

4.1 Variables of the conceptual model

The conceptual research model draws on various theoretical and empirical contributions. Our approach to developing the conceptual model of adoption of smart agricultural technologies is primarily based on the enhanced version of UTAUT as the theoretical foundation, supplemented by previous applications in the field of smart agricultural technologies.

Indeed, our research extends the UTAUT2 model by retaining its key variables: "performance expectancy, effort expectancy, social influence, facilitating conditions, hedonic motivation, and price value." However, to adapt this model to the specific context of our study, we first decided to exclude the "habit" variable. This decision stems from the fact that smart agricultural technologies are recently integrated into the agricultural process in Morocco, where most farmers lack prior experience in using these innovations. Secondly, we found it relevant to enrich our model with two new constructs based on previous research: "trust attitude" and "existence of a secondary activity".

Furthermore, in the UTAUT2 model, individual factors such as "age, gender, and experience" were assumed to be moderating variables. In our study, however, these individual factors are considered independent variables due to their significance.

4.2 The research hypotheses

Performance expectancy (EP) is defined as "the extent to which an individual believes that using the system will improve job performance" (Venkatesh et al., 2003).EP is identified as one of the influential factors on behavioral intention (Ronaghi and Forouharfar, 2020; Michels et al., 2020). Therefore, we can propose the following hypothesis:

H1. Performance expectancy has a positive influence on the intention to adopt SFT.

Effort expectancy (EE) is "the degree of ease associated with the use of the system" (Venkatesh et al., 2003). Several studies have suggested that EE influences the behavioral intention to use technology (Giua et al., 2022; Ronaghi and Forouharfar, 2020; Michels et al., 2020). Therefore, the second hypothesis could be stated as follows:

H2. Effort expectancy has a positive influence on the intention to adopt SFT.

Social influence (SI) measures how much an individual perceives others' opinions regarding the use of technology and the system. Several studies have shown a statistically significant relationship between SI and behavioral intention.with SI being identified as the strongest predictor of behavioral intention to adopt SFT (Schukat and Heise, 2021; Masukujjaman et al., 2022; Wee Wei En and Lim Siang Siew, 2022). Therefore, the third research hypothesis is proposed as follows:

African Scientific Journal
ISSN : 2658-9311
Vol : 03, Numéro 25, Août 2024

H3. Social influence has a positive influence on the intention to adopt SFT.

Furthermore, facilitating conditions (FC) refer to "the degree to which an individual believes that there is an organizational and technical infrastructure to support the use of the system" (Venkatesh et al., 2003). In the UTAUT model and according to previous research, the relationship between FC and technology use is assumed to be positive. Moreover, according to Li et al. (2020), facilitating conditions were the strongest indicator of Chinese farmers' willingness to adopt smart agricultural technologies. Therefore, the fourth hypothesis could be proposed as follows:

H4: Facilitating conditions have a positive influence on the intention to adopt SFT.

Hedonic motivation refers to the pleasure or joy resulting from the use of technology (Venkatesh et al., 2012). It describes the intrinsic motivation of a farmer to use technology. In the context of smart agriculture, for example, the economic benefits of reducing agricultural inputs and improving farm management efficiency can serve as motivations for adopting new technologies (Schukat et Heise, 2021; Beza et al., 2018). Therefore, the fifth hypothesis could be proposed as follows:

H5: Hedonic motivation has a positive influence on the intention to adopt SFT.

The price value refers to the users' cognitive value, representing a compromise between the perceived benefits of technology and its monetary cost (Venkatesh et al., 2012). When farmers perceive that the benefits of using the system outweigh the monetary costs, they are more inclined to adopt it (Schukat and Heise, 2021). In this context, the perceived value of price positively influences the intention to use smart agriculture technologies. Therefore, the sixth hypothesis can be formulated as follows:

H6: Price value has a significant influence on the intention to adopt SFT.

Confidence, which according to some authors, has a significant impact on the intention to use SFT (Beza et al., 2018; Schukat and Heise, 2021). In our study, "confidence attitude" refers to farmers' perceptions of the reliability and accuracy of data provided by smart agricultural technologies in their specific context. Some empirical studies have shown that technology adoption rates are often more influenced by a lack of confidence than by costs. Even when farmers are informed about the potential benefits of a technology, some remain skeptical about its proper functioning (Edit et al., 2012). Thus, the seventh hypothesis proposed for our study is as follows:

H7: Confidence attitude has a significant influence on the intention to adopt SFT.

The existence of a secondary activity can be defined as having another non-agricultural source of income that increases the likelihood of adopting new agricultural technologies (Ng'ang'a et al., 2019). Furthermore, smart farming technologies (SFT) offer several advantages to multi-active farmers who are not constantly in their fields, including remote crop monitoring, task automation, and improved time management. Digital platforms also provide valuable information on best agricultural practices and market trends, facilitating decision-making even from a distance. Therefore, we presume that "existence of a secondary activity" is positively correlated with the adoption of these technologies. Thus, the eighth hypothesis proposed is as follows:

H8: Existence of a secondary activity has a positive influence on the intention to adopt SFT.

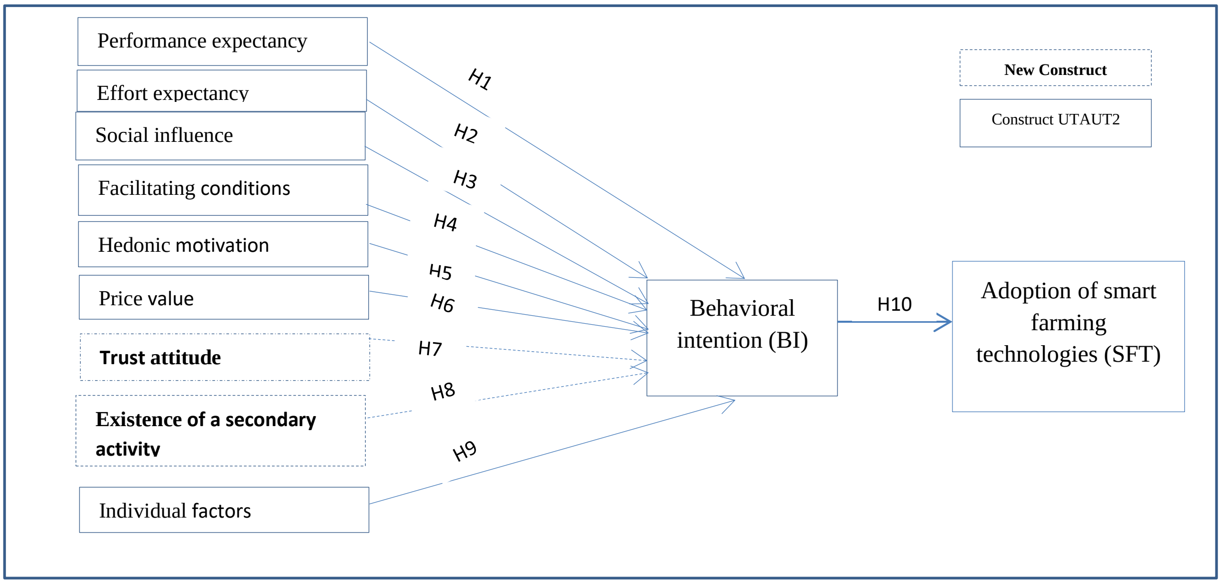
In the UTAUT2 model, individual factors (IF) were assumed to be moderators. In our research, we assume that individual factors are independent variables due to their importance. Therefore, the ninth hypothesis is as follows:

H9: Individual factors have a significant influence on the intention to adopt SFT.

Finally, behavioral intention (BI), defined as "the individual's mental willingness to use technology" (Venkatesh et al., 2003), is itself influenced by numerous factors, as mentioned earlier. In several studies, the effect of BI on actual technology use has been confirmed (Ronaghi and Forouharfar, 2020; Schukat and Heise, 2021). Therefore, the tenth hypothesis could be stated as follows:

H10. Behavioral intention positively impacts actual use of SFT.

Figure 2 : The research conceptual model



Source : prepared by us based on the literature review

African Scientific Journal
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Vol : 03, Numéro 25, Août 2024

Conclusion

The digitization of the agricultural sector poses a major challenge affecting farms across the country. Recognizing the stakes of this digital transformation, this article proposes a preliminary conceptual model specifically tailored to the integration of smart agriculture technologies by Moroccan farmers. This framework builds upon the UTAUT2 model (Venkatesh et al., 2012), adjusted to address the research topic and specific context. The aim of this study is to identify key factors influencing the adoption of smart agriculture technologies. By understanding these factors, it becomes possible to assess the prospects for digitalization success and comprehend the reasons for acceptance and adoption. This understanding enables proactive measures such as implementing training and awareness programs, as well as seeking governmental support, to overcome potential resistance among farmers toward adopting new technologies. The findings of this research will not only contribute to enriching existing knowledge on the digitalization of farms but also provide practical recommendations to farmers. By identifying factors influencing digitalization adoption, farmers can anticipate potential obstacles and leverage opportunities to successfully implement new technologies.

However, it is crucial to acknowledge the limitations of this study. While our preliminary conceptual model is informed by established theories and prior research, it has not yet been empirically validated in the field. Therefore, an empirical study would complement this theoretical work, allowing us to confirm or refute the determinants identified in our conceptual model. Additionally, relying on the UTAUT2 model and its applications to predict farmers' intention to adopt smart agriculture technologies, we were constrained by a primarily socio-psychological approach that overlooks the economic and institutional factors necessary for a comprehensive understanding of the barriers to adoption of these technologies, This limitation lays the groundwork for future research projects.

In conclusion, the success of the digital transformation of agricultural operations requires a comprehensive understanding of the determinants influencing adoption. By recognizing these factors, public authorities can formulate effective strategies aimed at promoting and supporting the integration of Industry 4.0 technologies in the Moroccan agricultural sector, thereby enhancing the resilience of agricultural communities and ensuring sustainable management of valuable natural resources.

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