Masi *et al. Agricultural and Food Economics* (2022) 10:27
https://doi.org/10.1186/s40100-022-00236-5

Agricultural and Food Economics

RESEARCH

Open Access

The long way to innovation adoption: insights from precision agriculture

Margherita Masi[1], Marcello De Rosa[2], Yari Vecchio[1*], Luca Bartoli[2] and Felice Adinolfi[1]

*Correspondence: yari.vecchio@unibo.it

[1] Department of Veterinary Medical Sciences, University of Bologna, 40064 Ozzano dell'Emilia, Bo, Italy
[2] Department of Economics and Law, University of Cassino and Southern Lazio, Cassino, Italy

Abstract

The adoption of innovations may boost the transition to sustainable agricultural models. Among these innovations, precision farming offers a fundamental contribution to sustainable soil management and the improvement in product quality. The work is set against this background and aims to analyse the rate of introducing precision farming tools and the variables that prevent/facilitate this adoption. Although adoption rates in Italy remain relatively low, it is vital to underline the obstacles that limit the broader use of precision agricultural technologies inside farms. To this end, the literature has highlighted various elements of complexity (farm characteristics, socio-economic and psychological), which can hinder or generate perceived complexity and significantly reduce the potential for technology adoption. In this context emerges the increasing importance of public and private activities related to knowledge transfer. The paper focuses on agricultural knowledge and innovation systems, which are also relevant in light of the recent proposal for the new regulation on rural development. The awareness–knowledge–adoption–product (AKAP) sequence was used to reveal the gap between the potential and actual adoption of innovation on Italian farms to comprehend the adoption process and identify relevant barriers and the role knowledge systems played. Empirical findings show that AKIS has a critical mediating function in promoting innovation uptake. Strengthening knowledge systems, acting on the different phases of the AKAP sequence, could allow a greater understanding of precision agriculture techniques and bottlenecks to adoption.

Keywords: Precision farming, AKAP model, AKIS, Innovation adoption

Introduction

Agri-food systems have been recently affected by numerous challenges like climate change, healthier and sustainable diets and transition towards circular agri-food systems. These challenges have stimulated the introduction of new technologies, which, in many cases, have become disruptive as digital technologies (Klerkx 2020). Against this background, the last SCAR report questions transition and resilience issues by assuming that *Technological innovations, particularly when coupled with scientific advances in social and organisational arrangements, can be game-changers* (EU SCAR 2020, p.6). Therefore, innovation adoption becomes a critical point to be investigated to better comprehend the subtle and complex mechanisms behind the farmer's decision-making process. A perfect example is precision farming, which has been shown in the literature to contribute to enhanced product quality and sustainable soil management. Precision farming is an information and technology-driven system leading to transformation and advancements in agriculture through *the advent of the Internet of Things, remote sensing, global positioning systems and aerial photography, allowing farmers to more easily monitor crop health and nutritional deficiencies* (Mishra 2022, p.1). Blackmore (1994. p.1) describes it as a *management practice that allows farmers to more accurately both understand and control what is happening on their farms*. It can be used in site-specific management to monitor the temporal and spatial variability of soil and crops ("Precision agriculture") (Pierce and Nowak 1999) or in livestock activities to screen physiological, reproductive and productive parameters of animals as well as the environmental impact of operations ("Precision livestock farming") (Cox 2003; Berckmans 2015). As posited by the US House of Representatives (1997), PA is "an integrated information- and production-based farming system that is designed to increase long term, site-specific and whole farm production efficiency, productivity and profitability while minimising unintended impacts on wildlife and the environment". Drawn on this definition, the EU Parliament identifies PA as a "whole-farm" management system which applies not only to cropping systems but to the entire farming sector, to reduce the environmental impacts through the use of information technology (European Parliament 2014).

These new technologies offer economic and environmental benefits as the need-based application allows input minimisation and improved crop or animal performance (Godwin et al. 2003; Banhazi et al. 2012). The use of big data collected from animals and soil to provide predictive analysis of on-farm concerns to support agricultural decision-making is becoming increasingly common (Wolfert et al. 2017).

Today, precision farming is growingly adopted across Europe. However, its incidence still remains relatively low, especially among small farms located in rural marginal areas, which may impede a faster transition towards more sustainable agricultural systems (Reichardt et al. 2009; Zarco-Tejada et al. 2014; Blasch et al. 2022). Scholars have highlighted various variables, like farmers' socio-economic characteristics (size, family composition and level of education), psychological and institutional variables, which can hinder or generate perceived complexity and, thus, influence the potential for technology adoption (Tey and Brindal 2012; Pierpaoli et al. 2013; Long et al. 2016; Barnes et al. 2019). The evolution of the theoretical framework explored the dynamic nature of adoption processes, increasingly emphasising the role of informational attributes and learning processes that occur from becoming aware of innovations onward (Klerkx et al. 2009). More precisely, best-fit approaches launched at the beginning of the 2000s posit the systematic replacement of linear models of innovation transfer with interactive models based on systemic perspectives (Birner et al. 2009). The establishment of new organisational arrangements able to stimulate knowledge transfer is the basis of systemic approaches grounded on the agricultural knowledge and innovation systems (AKIS). The recent regulation 2115/2021 on rural development[1] emphasises the role of AKIS, which cover a strategic role in knowledge transfer and innovation adoption.

[1] Regulation (EU) 2021/2115 of the European Parliament and of the Council of 2 December 2021 establishing rules on support for strategic plans to be drawn up by Member States under the common agricultural policy (CAP Strategic Plans) and financed by the European Agricultural Guarantee Fund (EAGF) and by the European Agricultural Fund for Rural Development (EAFRD) and repealing Regulations (EU) No 1305/2013 and (EU) No 1307/2013, https://eur-lex.europa.eu/eli/reg/2021/2115/oj

This paper is set against this background and aims to analyse the rate of introduction of precision agriculture tools (PATs) in Italy by focusing on the variables preventing/facilitating this adoption and assuming an innovation brokering role by the agricultural knowledge and innovation systems. More precisely, the paper explores the role of AKIS in fostering knowledge transfer and innovation adoption under the hypothesis that AKIS play a fundamental role in the complex adoption process. With this purpose, we provide an original contribution to the literature relying on the awareness–knowledge–adoption–product (AKAP) sequence.

The article is structured as follows: Sect. 2 provides a literature review on drivers and barriers to adoption, including the role of the AKIS model and focuses on the AKAP approach; Sect. 3 describes the method and results of the analysis. The discussion and conclusions with policy implications are followed in Sect. 4.

Knowledge transfer and innovation adoption: a complex process

Since the early studies of Ryan and Gross (1943) on the diffusion of hybrid maize seeds and Rogers' theory (2010) "Diffusion of innovations", the complex mechanisms behind the adoption of new technologies have been widely investigated in farming sector. More precisely, recent studies stress that "farmers are not on a unique S curve of adoption" (Schnebelin 2022, 8) and boost different perspectives on innovation adoption. In this context, systemic approaches to innovation provide a sound basis for facing complexity.

The literature agrees on studying innovation processes through systemic approaches, culminating in the perspectives of agricultural knowledge and innovation systems (Klerkx et al. 2012). Systemic views replaced individual ones with networks and ambidexterity propensity to raise farmers' innovation capability (Turner et al. 2017). Systemic approaches design a more complex scenario, which has called for a new vision of innovation. As pointed out in the SCAR report (EU SCAR 2012, p.35): "Innovation not only involves a technical or technological dimension. It also, and increasingly, involves strategy, marketing, organisation, management and design. Farmers do not necessarily apply or develop 'new' technologies: their novelties emerge as the outcome of different ways of thinking and different ways of doing things and in recombining different pieces of knowledge in an innovative way. Innovation is both problem solving and opportunity taking as a response to internal and external drivers. Each innovation is characterised by a combination of technical, economic, organisational and social components".

Following this definition, innovation is more than a technical problem and involves a diversified set of features at the farmer's disposal. Recent research has pointed out several factors limiting farmers' response to new proposals. Vecchio et al. (2020) provide an original contribution to the comprehension of these complex mechanisms through a context-related analysis drawn on the theoretical framework proposed by Welter (2011), who categorises the variables within three main dimensions of "context": who, why and where. The hypothesis is that context may affect entrepreneurial behaviour through multiple dimensions, which Welter classifies in the three W: the "who context" includes the characteristics of the respondents and the farm's structural and financial characteristics. The "who context" can be extracted through a typological analysis of the farmer's characteristics. The "where context" concerns a diversified set of dimensions, including the spatial, institutional, business and social context with which the farm interfaces. Finally, the "why" dimension regards motivation for engaging in entrepreneurial activities, like adopting an innovation, which is the outcome of different capabilities of recognising and exploiting an opportunity on behalf of farmers. As far as precision farming is concerned, the literature has clearly classified these dimensions. Socio-demographic variables are frequently recalled, such as age, educational profile and farm experience. Young farmers are generally more motivated to innovate due to their higher educational profile (Kutter et al. 2011; Watcharaanantapong et al. 2014). Generally, older farmers compensate with a higher level of experience and informal knowledge (Guerin and Guerin 1994), but this prevents them from adopting cutting-edge technologies in many cases. However, in some empirical cases in the primary sector, it has been found that at more advanced levels of adoption, the older farmers support the increased use of technology (Wetengere 2011).

Scholars have also investigated the influence of farm characteristics, also named structural (Vecchio et al. 2022), and economic variables (such as initial investment costs and payback time, access to credit and farm size) on precision farming adoption. Larger farms are generally more inclined to innovate due to greater access to credit and higher labour costs to bear (Swinton and Lowenberg-Deboer 2001; Kassie et al. 2013; Paustian and Theuvsen 2017). The cost of access to new technologies and the need for dedicated training represent high barriers for smaller farms, especially those unable to foster forms of aggregation and cooperation (del Río Gonzalez 2005; Isgin et al. 2008). In addition, these technologies have long payback periods relative to the initial investment, often leading to late adoption (Long et al. 2016).

Another group of variables concerns behavioural factors. Farmers are generally more ready to adopt if they perceive benefits and familiarity in using new instruments or if they are well suited to everyday business management. Differently, farmers are less likely to adopt technologies if they perceive the use as more complex (Aubert et al. 2012; Antolini et al. 2015).

Studies have identified the organisational factors as explicative variables, such as the impact of everyday routines, organisational inertia and even cases of bouncing back to traditional practices (Faber and Hoppe 2013).

However, farmers' propensity depends also on social factors, such as exposure to information sources, as well as the mediating role of knowledge systems in boosting innovation adoption (Vollaro et al. 2020). Lack of skills and interest or communication and poor technical support is considered a significant barrier to adoption (Mcbride and Daberkow 2003; Antolini et al. 2015). Several papers have shed light on the role of extension services in innovation adoption (Kassem et al. 2021), while, more recently, the positive influence of trusted friends or involvement in farmer clusters is positive enablers for adoption in the primary sector (Edwards-Jones 2006; Joffre et al. 2020). Regarding the external environment, agroecosystem factors, which include topography, quality and variability in soil conditions, resource availability and climate aspects, also matter. Finally, institutional factors should be considered because some institutional environments are more attractive for innovation than others. Sauer and Vrolijk (2019, p. 4690) conclude that "the institutional context in which the farm operates is likely to be significant for its innovation behaviour in terms of access to finance, institutional support, cultural values, cooperation with research entities and knowledge producing institutions, etc.". Poor local policy interventions, institutional support or lack of coordination between public and private sectors, and the distance from markets/suppliers are also meaningful in the adoption process (Robertson et al. 2012; Kassie et al. 2013; Long et al. 2016).

The aforementioned barriers may add up to either a reduced rate of innovation and unfair distribution of knowledge access among potential beneficiaries, with the emergence of well-known phenomena of élite capture. To confirm this, the EU communication on the *Future of food and farming* underlines how access to both technology and knowledge is "very patchy around the Union", which may limit the potential of the Common agricultural policy (CAP) instruments, then reducing the future competitiveness and sustainability of the farming sector and rural areas. This scenario indirectly challenges the role of institutional arrangements in facilitating knowledge transfer and innovation adoption. Recent systemic approaches have been codified within the agricultural knowledge and innovation systems, identified as a "set of agricultural institutions, organisations, persons and their linkages and interactions, engaged in the generation, transformation, transmission, storage, retrieval, regulation, consolidation, dissemination, diffusion and utilisation of knowledge and information, to work synergically to support opinion formation, decision making, problem-solving and/or innovation in a given sector, branch, discipline or other domain" (Roling 1989: 1–2). According to the definition, AKIS is a multistakeholder institution, collecting actors from different worlds and contexts (scientific, institutional, entrepreneurial and civil society), whose purpose is to contribute to co-producing innovation within an interactive model of innovation (EU SCAR 2019). Consequently, a more comprehensive perspective, including technological, social and institutional innovations, should be able to shape future trajectories of farming and rural systems (Klerkx and Begemann 2020). The interactive model of innovation puts the farmer at the centre of the new mechanisms of knowledge transfer and innovation adoption, whose performance is conditioned by constraining variables at the micro- (farmer), meso- (territorial and regional contexts) and macro-level (national/European policy level).

The CAP has officially institutionalised the interactive model since the last programming period (2014–2020), strengthening the AKIS in the new regulation for the CAP 2023–2027. This relevance is clearly stated in the CAP's new regulation 2115/2021. It has been witnessed by numerous initiatives within the EIP-AGRI framework, underlying the importance of adopting precision farming tools. The success of the interactive model across Europe and the launch of the AKIS network as an expression of the systemic approaches to innovation should not hold back the risks mentioned above of result paradox in the distribution of knowledge and technology adoption rates.

How AKIS can fill this gap is an object of concern in the recent literature: this paper is set against this background and tries to provide an original contribution by putting forward a methodology for the analysis of the articulated steps of knowledge and innovation uptake, analysed through the lens of the AKAP sequence. The role of AKIS in the process will be particularly emphasised.

The AKAP sequence as a tool for analysing innovation adoption

The process of innovation adoption related to precision farming is explored through the AKAP sequence. Developed from the pioneering contribution of Evenson (1997), the sequence identifies the natural order of the steps leading to innovation adoption. The hypothesis here is that the mechanism of uptake is not "epidemic" as theorised by some theoretical approaches (Hagerstrand 1952) but instead follows a series of steps starting from the awareness of the existence of an innovation, which must be associated with adequate knowledge of it before proceeding to the adoption, from which the farm should derive certain expected benefits (product). This process is not fluid as Evenson (1997, p.39) posits: *Awareness is not knowledge. Knowledge requires awareness, experience, observation, and the critical ability to evaluate data and evidence. Knowledge leads to adoption, but adoption is not productivity. Productivity depends not only on adopting technically efficient practices but also on allocatively efficient practices. Productivity also depends on the infrastructure of the community and market institutions.*

The use of this conceptualisation allows mainly to:

Better understand the characteristics of the adoption process concerning specific innovations (Evenson 1998);
Better identify the "gaps" associated with each sequence phase (Evenson et al. 1994).

The AKAP approach has been mainly tested to explain the impacts of alternative extension approaches (De Rosa et al. 2014; De Rosa and Bartoli 2017; Gangappagouda 2015; Riawanti and Effendi 2017), measuring their ability to induce the sequence.

This multistage approach, on the one side, allows policy-makers to capture barriers to adoption at each stage; on the other side, it focuses on the post-adoption phase of the process, the "product", to whom less attention has been devoted in the literature. The uptake of innovation does not automatically translate into a gain in productivity or better performance (Amara et al. 1999). Its effectiveness is affected by the farmer's ability to combine technical and allocative efficiency (Dawson et al. 1991; Dillon and Anderson 1971). It is the case of PATs, whose introduction often calls for significant adaptations in the farming style (Aubert et al. 2012; Marra et al. 2003). Precision agriculture is a data-driven approach strongly connected to several data mining problems (McBratney et al. 2005; Ruß and Brenning 2010; Sassenrath et al. 2008). It offers many applications to support operations and decision-making processes but can also require cultural, organisational and technical changes (Marra et al. 2003). Radical technological innovation usually requires the departure from existing knowledge stock (Long et al. 2016) and reconfiguring of administrative, organisational and infrastructural capabilities (Bessant et al. 2014).

The empirical analyses testing the AKAP approach were mainly carried out in developing countries (Gandhi et al. 2009; Kyaruzi et al. 2010) and have indicated the changes in productivity as the measure of the effectiveness of innovation. In developed areas, where food security is not the only dimension guiding policy-makers' choices, farmers are involved in a more complex and multidimensional scenario (Aubert et al. 2012; Robertson et al. 2012; Tey and Brindal 2012) that cannot be overlooked and reveal the multidimensionality of innovation. Consequently, the "product" stage cannot simply coincide with an increase in yield. The few works that have used a different meaning of "product" have focused on changes in agricultural practices as a proxy of the effectiveness linked to introducing the innovation (De Rosa et al. 2014). Nonetheless, in this paper, we posit that benefits following the introduction of the innovation cannot be represented by the changes they induced (Aubert et al. 2012; Robertson et al. 2012).

An alternative and more holistic way to investigate the post-adoption phase is to call into question the perceived complexity of the potential adopter (Vecchio et al. 2022). The farmer's perception of complexity towards innovation results from the influence exerted by the multiple aforementioned context variables, which may be affected by the innovation brokers and, more generally, by the knowledge system to which he belongs. Studying the relationship between increased perceived complexity and contextual factors, particularly the role of knowledge systems, could be a key to understanding the entire process. This aspect deserves more attention, as the interdependencies between various stages of the sequence and the knowledge transfer and adoption system provided by AKIS assume a relevant role to explore.

This paper attempts to fill this gap and, unlike Evenson's proposal, presents an analysis in which the AKAP sequence is reviewed through:

a. The impact analysis of AKIS in each step of the sequence;
b. Considering the adoption not as a simple increase in productivity but as an expected benefit from introducing precision farming techniques. This perspective allows us to excavate the relevance of the AKIS in affecting the entire innovation adoption process and the perceived benefits the farmers gather in adopting PATs.

Methodology

Sample

Primary sources cover all aspects of our research. A questionnaire was administered through a CAWI tool[2]to a sample of farms registered with Coldiretti, Italy's most important farmers' association. Coldiretti has spread the questionnaire through an online platform (ilpunto-coldiretti.it). After ten days online, the survey was closed. We have collected 5045 questionnaires. After careful analysis of the data collected, 75 questionnaires were excluded, as they were not complete in every part of the questionnaire. In the end, therefore, the sample analysed was 4970 farmers.

The questionnaire is articulated into four parts:

Socio-demographic and business characteristics.
Sources of information:

o Related to ordinary business activity;
p Related to the introduction of innovations.

[2] The computer-assisted website interview (CAWI) is one of the most popular survey methods to collect a large number of questionnaires. It consists of filling in the questionnaire directly online through the use of dashboards or digital tools. The instrumentation is well suited to the collection of numerical data for quantitative analyses.

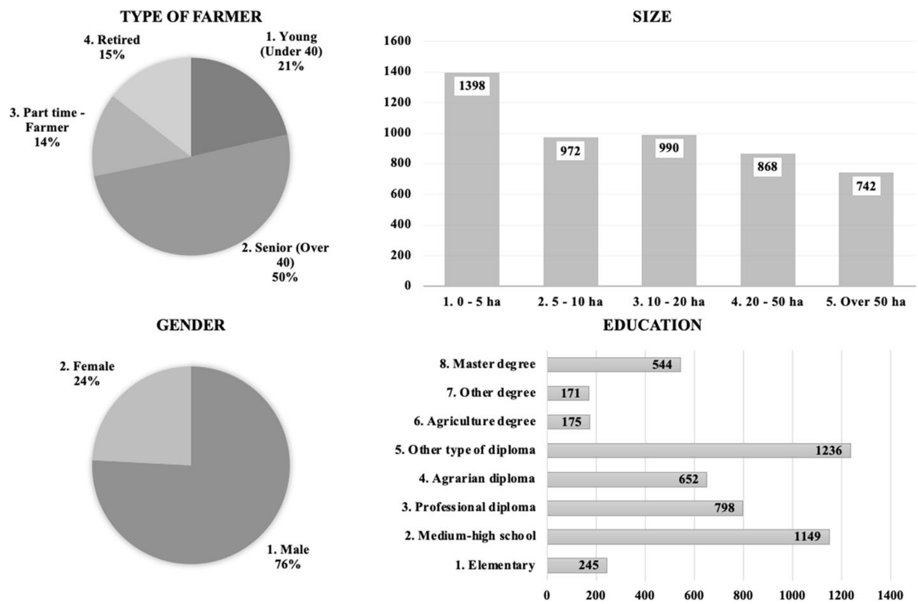

Fig. 1 Socio-structural characteristics of farmers

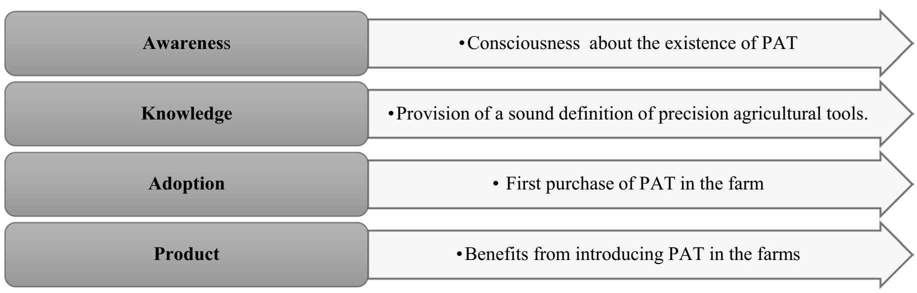

Fig. 2 AKAP sequence

Adoption of precision farming tools.
Role of AKIS in the adoption of precision agriculture.

The questionnaire was administered online, without stratified sampling, but randomly. Data collection stopped after 1 week of submission. The results of socio-demographic data are shown in Fig. 1.

The data distribution for the four variables analysed is in line with that of Italian farms, as indicated in the last analysis provided by Istat (2016).

Statistical analysis

All the data are processed through descriptive statistical techniques allowing for analysing farm composition in each step of the sequence, assuming that the share of farms in each step tends to decrease. The sequence that we analysed is the following (Fig. 2):

In a second step, we try to estimate the influence of the AKIS in adopting innovations through a probabilistic model in which the adoption of the technologies represents our dependent variable, while the independent variables express their degree of involvement

Table 1 Equations for the logit model

Formula	Equation	n
$\eta_i = \beta_0 + \sum_{j=1}^{k} x_{ij}\beta_j$	Predictive	(1)
$y_i \epsilon Y_i \sim \text{Bernoulli}(\pi_i)$	Stochastic	(2)
$\pi_i = \exp_{(}\eta_{i)}/(1+\exp_{(}\eta_{i)})$	Systematic	(3)

in the AKIS. In order to build the model, the dichotomous question (yes or no) "Have you purchased any of these precision agriculture technologies?" was used as the dependent variable. In contrast, the two questions on awareness and knowledge of AKIS were used as independent variables, both measured with a unipolar scale from 1, as no awareness/knowledge, to 5, as complete awareness/knowledge.

Most ex-post papers on the uptake of PATs use logit models to explore the adoption behaviour of farmers (Pierpaoli et al. 2013). Typically, logistic regression analysis is used to estimate the effects of at least one independent variable on a binary dependent. The analysis is based on looking for associations of the different probabilities at which the modes of the dependent variable occur, as the independent ones vary. This method consists of 3 equations: predictive, stochastic and systematic (Table 1).

In the first formula (1), we have to estimate the parameter η_i, where "i" corresponds to the N cases considered. β_0 is the value of η_i when regressors are 0, β_j measures the variation of η_i for each unit increased of the corresponding regressor x_j.

Looking at the second formula (2), in the case of binary option, the Y_i has a Bernoulli distribution, and the parameter π_i determines it, that is, the probability that a specific event will occur, (1-π_i), represents the opposite probability. In the end, third Eq. (3) binds the probability distribution of Y_i to independent variables and permits the link of the parameter to estimate π_i to the predictive equation, so the β coefficient, which produces a variation of π_i between 0 and 1, represents the parameter to be estimated and describes effects of the independent variables on the dependent one. Wald statistics are used to interpret the model (De Lillo 2007). This test equals the ratio between the logistic coefficient and its standard error, squared. To express whether the relationship between two categories varies as a function of another variable, the interpretation of β must be done in terms of the odd ratio, which is obtained through calculating a ratio between the odds. Odd is expressed by $\frac{\pi_i}{1-\pi_1}$. The standard outputs of the regression analysis model are represented by an odd ratio or exp (β). In the case of binomial logistic regression, the maximum likelihood algorithm is used to estimate the parameters (De Lillo 2007).

Results

Applying the AKAP model reveals the goodness of sequence in defining the mechanisms for adopting innovations. As a matter of fact, by looking at Fig. 3, a downward trend characterises the sequence, evidencing a divide between the consciousness and the effective adoption of PATs.

The introduction of explanatory variables, in particular socio-demographic and farm characteristics aspects, also makes it possible to specify the results of the analysis better, thus articulating them based on the dimensions mentioned above, such

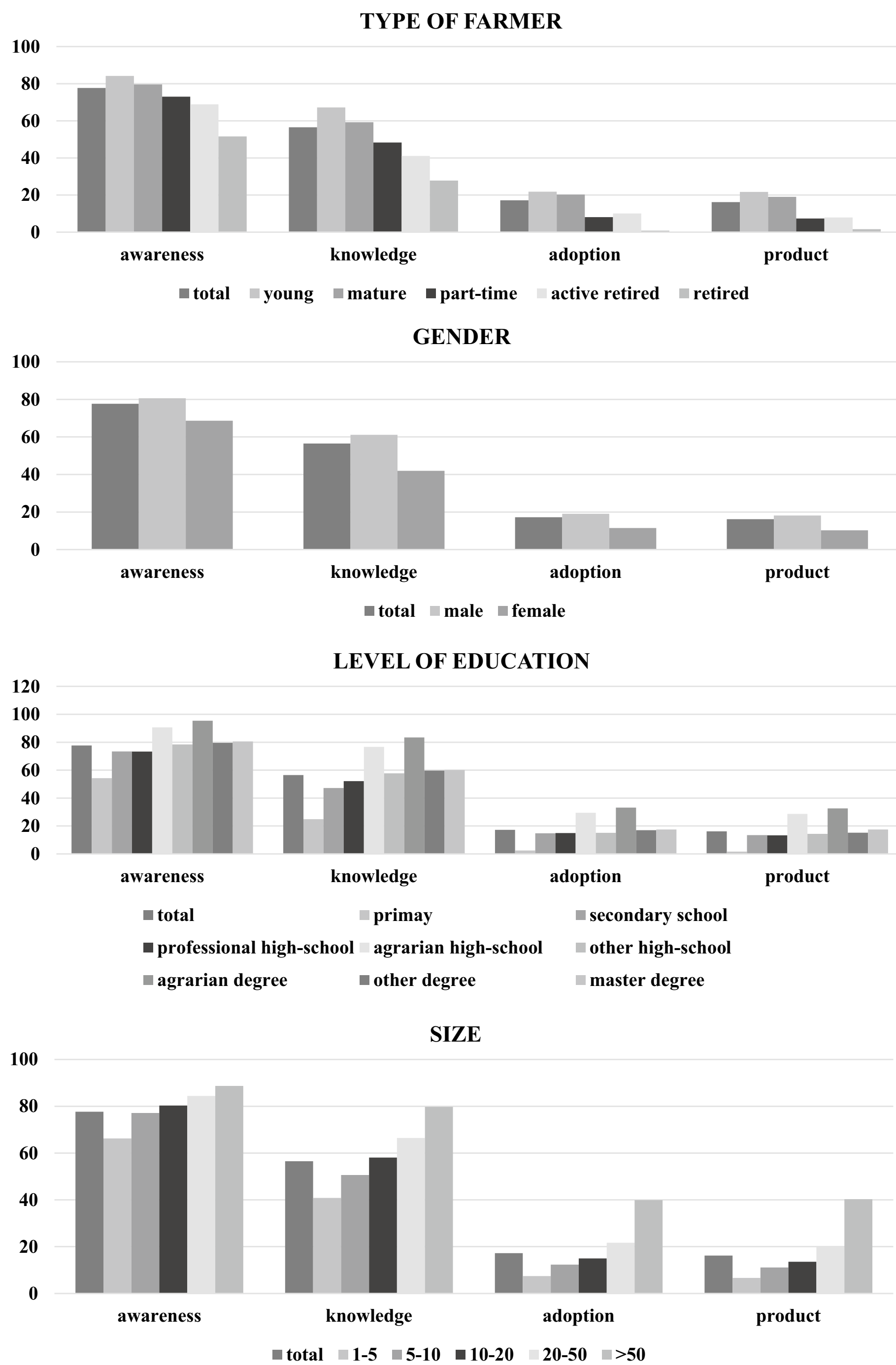

Fig. 3 AKAP sequence for the socio-structural factors

as age, gender and size of the farm (Fig. 3). In what follows, each phase is detailed, reporting the main results.

As far as the first phase of the sequence is concerned, we found that variables affecting *Awareness* are:

(a) *Type of farmer* as the age of the subject increases, awareness about PATs decreases (awareness is inversely correlated with the age of the entrepreneur): actually, very high values are found in young people (84.2), while in the mature and elderly age groups the share tends to decrease;
(b) Gender, men show higher values than women by more than 10 points at each stage
(c) Level of education, in that higher levels of education, brings about a higher level of awareness. More precisely, specialised education is associated with high awareness percentages (such as a diploma or degree in agriculture: 90.6% and 95.4%). Moving from technical diplomas (78.4) to specialised degrees (80.5), an increasing value emerges, even though the gap with the previous ones remains clearly visible (by at least 10 points). Therefore, the more outstanding and more sectoral the education, the greater the degree of awareness;
(d) Farm size, as the results confirm that this variable is positively correlated with awareness, so this tends to decrease in small companies.

The second step of the sequence is *knowledge*; at this stage, the farmer has to provide evidence of knowledge of PATs, specifically:

Monitoring (GPS, GIS, data processing, GSM);
Internet of Things (Wireless Sensor Network, RFID, Bluetooth, Zigbee, Wi-fi, Microcontroller, Arduino);
Automation (Autonomous Vehicle, Assisted Driving, Mobile Robot, Unmanned Aerial Vehicle, Agricultural Robot, Computer Vision, Data Management);
Decision Support (Artificial Intelligence, Data Mining, Forecasting, Machine Learning);
Hardware (Embedded Systems, Cybernetic Systems, CMOS, FPGA);
Laser (Sensors);
Other.

The results of our analysis show a remarkable contraction concerning the previous phase. As a matter of fact, despite the interpretative hypothesis being confirmed (inverse correlation with age and farm size and direct correlation with educational qualification), a gap of 20% points emerges. This trend becomes even more evident in the phase of *adoption* of PATs. In this case, there is an even more significant decrease than between the first and second phases. Most respondents did not answer or did not adopt any techniques: thus, we have 17.2% users. From a demographic standpoint, young and mature farmers get similar results (just over 20%). Regarding the level of education, the professional diploma and degree confirm their relevance, with a substantial gap compared to all other items. However, the gap between the two has considerably narrowed.

Finally, the *product* step shows similar percentages to adoption, i.e. most users show good satisfaction levels.

In the second step of the analysis, a logit model has been carried out to test the hypothesis that AKIS acts as a facilitator for the introduction of innovations (Table 2). This aspect is investigated in two steps: the first one concerns the awareness of the

Table 2 Results of logit model

	B	SE	Wald	Sig.	Exp (*B*)
Awareness of AKIS	0.502	0.107	21.99	0.0000	1.652
Willingness to use advisory services	0.357	0.048	54.708	0.0000	1.429
Constant	− 2.127	0.181	137.577	0.0000	0.119

AKIS role in stimulating innovation adoption; the second one implies the willingness to make use of advisors to introduce innovations at farm level.

The results show that awareness of AKIS is highly significant in determining the adoption of new technologies. In addition, a second variable, willingness to use consulting services, was added in a second step, and again both were significant and positively influenced the likelihood of adopting new technologies.

Discussion and conclusions

The analysis confirms the validity of the AKAP model in defining the process of deciding whether or not to adopt an innovation, highlighting socio-structural constraints. Therefore, adopting innovation is a complex process where many variables may interfere either in the final decision (to adopt or not) or in each step of the sequence. The paper confirms the idea of innovation as a networked process (Turner et al. 2017), where "co-resourcing" is at stake (Lioutas et al. 2021; Paschen et al. 2021). In this co-resourcing process, the role of agricultural knowledge and innovation systems has been explored as of paramount importance. As a matter of fact, our data evidence the relevance of the AKIS in performing higher levels of adoption, confirming the validity of the systemic approach to innovation.

A limitation of the study emerged. PA is regarded as a single entity in the paper, but there is a wealth of information that adoption rates vary for different types of PF technology (Robertson e al. 2012; Lowenberg-DeBoer and Erickson 2019). However, the current study should be viewed as a preliminary assessment of PF adoption on Italian farms. In this regard, it serves as a starting point for future research that replicates the study focusing on specific PAT.

Beyond limitation, relevant results emerged. Starting from socio-structural variables, as far as age is concerned, it is precisely the youngest who show higher values of awareness, knowledge and adoption, in line with what is confirmed by most of the studies conducted in the literature (Khanna 2021; Blasch et al. 2022). Actually, the adoption of PAT is the exit of an entrepreneurial decision-making process aiming at exploiting an opportunity. However, the potential long-term payoffs of the investment discourage elderly farmers from engaging in a cutting-edge innovation whose results may be uncertain. In addition, the study reports that men have the highest scores. Although the literature is still discordant on the influence of the gender variable for adoption, some scholars (Zheng et al. 2019; Michels et al. 2020) show a higher propensity of men to use PATs, while other researchers evidence multiple paths of innovation in women farms, characterised by heterogeneity and by special attention towards multifunctional agriculture (Seuneke Bock 2015). Regarding education, the results highlight, in line with the literature (Marescotti et al. 2021), how higher values correspond to more excellent knowledge and propensity to adopt: in particular, those with a university degree or diploma in an agricultural specialisation are more likely to uptake PATs (Balafoutis et al. 2017).

Undoubtedly, larger farms record the highest rates along the sequence, consistent with the literature (Shang et al. 2021; Giua et al. 2022). Therefore, our findings confirm the abundant literature on adopting precision farming tools dependent on structural and socio-economic characteristics. Nonetheless, we gathered further explicative information, which can be considered explicative of the complex innovation adoption process, by analysing the impact of agricultural knowledge and information systems. The second part of the empirical analysis excavated the role of innovation brokerage in affecting the sequence through the study of the AKIS. The empirical results evidence the mediating role of AKIS in boosting innovation adoption (Klerkx et al. 2012; Knierim et al. 2019). The correlation of both awareness of AKIS and the cheerful willingness to adopt advisory services as a means to uptake innovations confirm the effectiveness of the systemic approach grounded on a bottom-up perspective, where needs for innovation are expressed by farmers and satisfied by a collective of actors making up the AKIS. The role of advisory services is therefore deployed in all phases, confirming that innovation brokers develop a competence portfolio able to affect the various steps of the AKAP sequence, starting from the awareness and knowledge to the adoption. Consequently, AKIS may develop an integrative learning system involving personal, social, disciplinary and interdisciplinary competencies (Mulder 2017).

Making a farmer aware and letting him know and trained about the real potentialities of innovation is the first task an AKIS operator can develop (Fieldsend et al. 2021) by providing the farmer with the necessary skills to evaluate the future impact of innovation, cost benefits in the long term and eventually new business models to be carried out to adopt the innovation effectively. This suggestion means the advisor must be aware of the “styles of consumption” of the advisory services by farmers to better target information and transfer learning and knowledge to boost innovation adoption. Consequently, the AKIS can affect the farmer’s relational configuration by empowering their social capital to widen the relational assets and empower the farmer through more complete and inclusive support networks (Horton et al. 2022; Charatsari et al. 2020).

The role of advisory services is therefore crucial for developing efficient AKIS. This role is confirmed in the recent regulation 2115/2021 on rural development, which underlines the strategic role of AKIS and strengthens the actions aimed at empowering farmers with updated information, knowledge and skills. More generally, the overall design of the new CAP and national strategic plans will move towards a more articulated vision of the agricultural sector, aimed at enhancing the possible new development paths of connections with other sectors of the rural economy. Moreover, the strategic vision of innovation in the policy document reveals, first, the strategic importance of the needs revealed at the bottom-up level, that is, by both farms and rural areas, in order to better target innovation; second, the systemic approach enlarges the range of actors involved in the uptake of innovation, by including (both private and public) decision support systems in the collective process of knowledge and innovation co-creation (Vagnozzi 2019).

Innovation is difficult to achieve without the development of a system that encourages the adoption of innovative tools, from technological ones, such as in-field or in-store technologies, to digital ones, such as big data platforms or apps. Therefore, sustainable development of the agricultural sector depends on innovation on the one hand and the role of training and advising services accompanying the development process (van Ooste Vagnozzi 2020). As demonstrated by the results of our preliminary work, strengthening knowledge systems, acting on the different phases of the AKAP sequence, could allow, on the one hand, more excellent knowledge of the techniques of precision agriculture and, on the other hand, to break down the constraints of adoption often linked to aspects of a perceptive nature (complexity and familiarity).

Abbreviations

AKAP	Awareness–knowledge–adoption–product
AKIS	Agricultural knowledge and innovation systems
CAP	Common agricultural policy
PAT	Precision agricultural tool

Acknowledgements
The research leading to these results has been conceived under the International PhD Program "Innovative Technologies and Sustainable Use of Mediterranean Sea Fishery and Biological Resources (www.FishMed-PhD.org).

Author contributions
All the authors have collaborated in the design and writing of the entire article. All authors read and approved the final manuscript

Funding
The author(s) declare(s) that they have not obtained any funding to write the work.

Availability of data and materials
The primary data that support the findings of this study are available from the corresponding author, upon reasonable request.

Declarations

Competing interests
The author(s) declare(s) that they have no competing interests.

Received: 10 March 2022 Revised: 16 August 2022 Accepted: 18 October 2022
Published online: 23 October 2022

References

Amara N, Traoré N, Landry R, Romain R (1999) Technical efficiency and farmers' attitudes toward technological innovation: the case of the potato farmers in Quebec. Can J Agric Econ 47:31–43

Antolini LS, Scare RF, Dias A (2015) Adoption of precision agriculture technologies by farmers: a systematic literature review and proposition of an integrated conceptual framework. In: IFAMA world conference June, pp 14–17

Aubert BA, Schroeder A, Grimaudo J (2012) IT as enabler of sustainable farming: an empirical analysis of farmers' adoption decision of precision agriculture technology Decis. Support Syst 54:510–520. https://doi.org/10.1016/j.dss.2012.07.002

Balafoutis A, Beck B, Fountas S, Vangeyte J, van der Wal T, Soto-Embodas I, Gómez-Barbero M, Barnes AP, Eory V (2017) Precision agriculture technologies positively contributing to GHG emissions mitigation, farm productivity and economics. Sustainability 9:1339

Banhazi TM, Babinszky L, Halas V, Tscharke M (2012) Precision livestock farming: precision feeding technologies and sustainable livestock production. Int J Agric Biol Eng 5(4):54–61

Barnes AP, Soto I, Eory V, Beck B, Balafoutis A, Sánchez B, Vangeyte J, Fountas S, van der Wal T, Gómez-Barbero M (2019) Exploring the adoption of precision agricultural technologies: a cross regional study of EU farmers. Land Use Policy 80:163–174. https://doi.org/10.1016/j.landusepol.2018.10.004

Berckmans D (2015) Smart farming for Europe: value creation through precision livestock farming. In Precision livestock farming applications: Making sense of sensors to support farm management). Wageningen Academic Publishers, pp 139–147. https://doi.org/10.3920/978-90-8686-815-5_1.2

Bessant J, Oberg C, Trifilova A (2014) Framing problems in radical innovation. Ind Mark Manag 43(8):1284–1292. https://doi.org/10.1016/j.indmarman.2014.09.003

Birner R, Davis K, Pender J, Nkonya E, Anandajayasekeram P, Ekboir J, Mbabu A, Spielman DJ, Horna D, Benin S, Cohen M (2009) From best practice to best fit: a framework for designing and analyzing pluralistic agricultural advisory services worldwide. J Agric Educ Ext 15(4):341–355. https://doi.org/10.1080/13892240903309595
Blackmore S (1994) Precision farming: an introduction. Outlook Agric 23(4):275–280. https://doi.org/10.1177/003072709402300407
Blasch J, van der Kroon B, van Beukering P, Munster R, Fabiani S, Nino P, Vanino S (2022) Farmer preferences for adopting precision farming technologies: a case study from Italy. Eur Rev Agric Econ 49(1):33–81. https://doi.org/10.1093/erae/jbaa031
Charatsari C, Lioutas ED, Koutsouris A (2020) Farmer field schools and the co-creation of knowledge and innovation: the mediating role of social capital. Agric Hum Values 37:1139–1154. https://doi.org/10.1007/s10460-020-10115-8
Cox S (Ed) (2003) Precision livestock farming. Wageningen Academic Publishers.
Dawson PJ, Lingard J, Woodford CH (1991) A generalised measure of farm-specific technical efficiency. Am J Agr Econ 73:1098–1104
De Lillo A, Argentin G, Lucchini M, Sarti S, Terraneo M (2007) Analisi Multivariata per le Scienze Sociali. Ed. Pearson Education, pp 197–245
De Rosa M, Bartoli L (2017) Do farm advisory services improve adoption of rural development policies? An empirical analysis in GI areas. J Agric Educ Ext 23(5):461–474. https://doi.org/10.1080/1389224X.2017.1347099
De Rosa M, Bartoli L, La Rocca G (2014) Testing extension services through AKAP models. J Agric Educ Ext 20(5):513–535. https://doi.org/10.1080/1389224X.2013.872044
del Río GP (2005) Analysing the factors influencing clean technology adoption: a study of the Spanish pulp and paper industry. Bus Strateg Environ 14(1):20–37. https://doi.org/10.1002/bse.426
Dillon J, Anderson J (1971) Allocative efficiency in traditional agriculture and risk. Amer J Agr Econ 53:26–32
Edwards-Jones G (2006) Modelling farmer decision-making: concepts, progress and challenges. Anim Sci 82(6):783–790. https://doi.org/10.1017/ASC2006112
Evenson R (1994) Analyzing the transfer of agricultural technology. In: Anderson JR (ed) Agricultural Technology policy issues for tile international community. CAB, Wallingford
Evenson R (1997) The economic contributions of agricultural extension to agricultural and rural development. In: Swanson BE, Bentz RP, Sofranko A (eds) Improving agricultural extension. A reference manual. FAO, Rome
Evenson RE, Pray C, Rosegrant MW (1998) Agricultural research and productivity growth in India, Intl Food Policy Res Inst 109
Faber A, Hoppe T (2013) Co-constructing a sustainable built environment in the Netherlands dynamics and opportunities in an environmental sectoral innovation system. Energy Policy 52:628–638. https://doi.org/10.1016/j.enpol.2012.10.022
Fieldsend AF, Cronin E, Varga E, Biró S, Rogge E (2021) 'Sharing the space' in the agricultural knowledge and innovation system: multi-actor innovation partnerships with farmers and foresters in Europe. J Agric Educ Ext 27(4):423–442. https://doi.org/10.1080/1389224X.2021.1873156
Gandhi R, Veeraraghavan R, Toyama K (2009) Digital green: participatory video and mediated instruction for agricultural extension. Inf Technol Int Dev 5(1):1–15. https://doi.org/10.1109/ICTD.2007.4937388
Gangappagouda SB (2015) Economic contribution of agricultural extension services provided by Karnataka watershed development Project to beneficiaries of Bijapur district doctoral dissertation. University of agricultural sciences gkvk, Bengaluru
Giua C, Materia VC, Camanzi L (2022) Smart farming technologies adoption: which factors play a role in the digital transition? Technol Soc. https://doi.org/10.1016/j.techsoc.2022.101869
Godwin RJ, Wood GA, Taylor JC, Knight SM, Welsh JP (2003) Precision farming of cereal crops: a review of a 6 year experiment to develop management guidelines. Biosys Eng 84(4):375–391. https://doi.org/10.1016/S1537-5110(03)00031-X
Guerin LJ, Guerin TF (1994) Constraints to the adoption of innovations in agricultural research and environmental management: a review. Aust J Exp Agric 34(4):549–571
Hagerstrand T (1952) The propagation of innovation waves. Lund Stud Geogr Human Geogr 4:3–19
Horton D, Devaux A, Bernet T, Mayanja S, Ordinola M, Thiele G (2022) Inclusive innovation in agricultural value chains: lessons from use of a systems approach in diverse settings. Innov Dev. https://doi.org/10.1080/2157930X.2022.2070587
Isgin T, Bilgic A, Forster DL, Batte MT (2008) Using count data models to determine the factors affecting farmers' quantity decisions of precision farming technology adoption. Comput Electron Agric 62(2):231–242. https://doi.org/10.1016/j.compag.2008.01.004
Istat (2016) Indagine sulla struttura e produzioni delle aziende agricole. https://www.istat.it/it/archivio/8366
Joffre OM, De Vries JR, Klerkx L, Poortvliet PM (2020) Why are cluster farmers adopting more aquaculture technologies and practices? The role of trust and interaction within shrimp farmers' networks in the Mekong delta Vietnam. Aquaculture 523:735181
Kassem HS, Alotaibi BA, Muddassir M, Herab A (2021) Factors influencing farmers' satisfaction with the quality of agricultural extension services. Eval Program Plann 85:101912
Kassie M, Jaleta M, Shiferaw B, Mmbando F, Mekuria M (2013) Adoption of interrelated sustainable agricultural practices in smallholder systems: evidence from rural Tanzania. Technol Forecast Soc Chang 80:525–540
Khanna M (2021) Digital transformation of the agricultural sector: pathways, drivers and policy implications. Appl Econ Perspect Policy. https://doi.org/10.1002/aepp.13103
Klerkx L (2020) Advisory services and transformation, plurality and disruption of agriculture and food systems: towards a new research agenda for agricultural education and extension studies. J Agric Educ Ext 26(2):131–140. https://doi.org/10.1080/1389224X.2020.1738046
Klerkx L, Begemann S (2020) Supporting food systems transformation: the what, why, who, where and how of mission-oriented agricultural innovation systems. Agric Syst 184:102901

Klerkx L, Leeuwis C (2009) Shaping collective functions in privatized agricultural knowledge and information systems: the positioning and embedding of a network broker in the Dutch dairy sector. J Agric Educ Ext 15(1):81–105. https://doi.org/10.1080/13892240802617445
Klerkx L, van Mierlo B, Leeuwis C (2012) Evolution of systems approaches to agricultural innovation: concepts, analysis and interventions. In: Darnhofer I, Gibbon D, Dedieu B (eds) Farming systems research into the 21st century: the new dynamic. Springer, Dordrecht, pp 457–483
Knierim A, Kernecker M, Erdle K, Kraus T, Borges F, Wurbs A (2019) Smart farming technology innovations–Insights and reflections from the German smart-AKIS hub. NJAS-Wagening J Life Sci 90:100314. https://doi.org/10.1016/j.njas.2019.100314
Kutter T, Tiemann S, Siebert R, Fountas S (2011) The role of communication and co-operation in the adoption of precision farming. Precis Agric 12(1):2–17. https://doi.org/10.1007/s11119-009-9150-0
Kyaruzi AAM, Mlozi MRS, Busindi IM (2010) Gender based effectiveness of agricultural extension agents' contacts with smallholder farmers in extension services delivery: a case of kilosa District Tanzania. In: Towards improving agricultural extension service delivery in the SADC region, Proceedings of the workshop on information sharing among extension players in the SADC Region, pp 26–28
Lioutas ED, Charatsari C, De Rosa M, La Rocca G, Černič Istenič M (2021) Co-resourcing and actors' practices as catalysts for agricultural innovation. J Agric Educ Ext. https://doi.org/10.1080/1389224X.2021.1953547
Long TB, Blok V, Coninx I (2016) Barriers to the adoption and diffusion of technological innovations for climate-smart agriculture in Europe: evidence from the Netherlands, France, Switzerland and Italy. J Clean Prod 112(1):9–21. https://doi.org/10.1016/j.jclepro.2015.06.044
Lowenberg-DeBoer J, Erickson B (2019) Setting the record straight on precision agriculture adoption. Agron J 111(4):1552–1569
Marescotti ME, Demartini E, Filippini R, Gaviglio A (2021) Smart farming in mountain areas: investigating livestock farmers' technophobia and technophilia and their perception of innovation. J Rural Stud 86:463–472. https://doi.org/10.1016/j.jrurstud.2021.07.015
Marra M, Pannell DJ, Abadi Ghadim A (2003) The economics of risk, uncertainty and learning in the adoption of new agricultural technologies: where are we on the learning curve? Agric Syst 75:215–234. https://doi.org/10.1016/S0308-521X(02)00066-5
McBratney A, Whelan B, Ancev T (2005) Future directions of precision agriculture. Precis Agric 6:7–23
McBride WD, Daberkow SG (2003) Information and the adoption of precision farming technologies. J Agribus 21(345-2016–15210):21–38
Michels M, vonHobe CF, Musshoff O (2020) A trans theoretical model for the adoption of drones by large-scale German farmers. J Rural Stud 75:80–88
Mishra S (2022) Emerging Technologies: principles and applications in precision agriculture. In: data science in agriculture and natural resource management. Springer, Singapore, pp 31–53. https://doi.org/10.1007/978-981-16-5847-1_2
Mulder M (2017) A five-component future competence (5CFC) model. J Agric Educ Ext 23(2):99–102. https://doi.org/10.1080/1389224X.2017.1296533
European Parliament (2014) Precision agriculture: an opportunity for the EU farmers—Potential support with the CAP 2014-2020, Brussels
Paschen JA, Ayre M, King B, Reichelt N, Nettle R (2021) Shaking it up: the realities of 'doing' co-innovation in a privatised agricultural advisory and extension system. J Rural Stud 87:338–351. https://doi.org/10.1016/j.jrurstud.2021.09.003
Paustian M, Theuvsen L (2017) Adoption of precision agriculture technologies by German crop farmers. Precis Agric 18(5):701–716. https://doi.org/10.1007/s11119-016-9482-5
Pierce FJ, Nowak P (1999) Aspects of precision agriculture. In: Advances in agronomy, Academic Press, vol. 67, pp 1–85
Pierpaoli E, Carli G, Pignatti E, Canavari M (2013) Drivers of precision agriculture technologies adoption: a literature review. Proc Technol 8:61–69. https://doi.org/10.1016/j.protcy.2013.11.010
Reichardt M, Jürgens C, Klöble U, Hüter J, Moser K (2009) Dissemination of precision farming in Germany: acceptance, adoption, obstacles, knowledge transfer and training activities. Precis Agric 10(6):525–545. https://doi.org/10.1007/s11119-008-9101-1
Riawanti W, Effendi KC (2017) Public administration at a crossroad: policy on agricultural extension within digital society. Policy Govern Rev 1(1):1–11. https://doi.org/10.30589/pgr.v1i1.16
Robertson MJ, Llewellyn RS, Mandel R, Lawes R, Bramley RGV, Swift L, Metz N, O'Callaghan C (2012) Adoption of variable rate fertiliser application in the Australian grains industry: status, issues and prospects. Precis Agric 13:181–199. https://doi.org/10.1007/s11119-011-9236-3
Rogers EM (2010), Diffusion of innovations, 4th ed. Simon and Schuster
Roling N (1989) The research/extension interface: a knowledge system perspective. ISNAR Staff Notes, No. 89–48
Ruß G, Brenning A (2010) Data mining in precision agriculture: management of spatial information Lect. Notes Comput Sci 6178:350–359. https://doi.org/10.1007/978-3-642-14049-5_36
Ryan B, Gross NC (1943) The diffusion of hybrid seed corn in two Iowa communities. Rural Sociol 8(1):15
Sassenrath GF, Heilman P, Luschei E, Bennett GL, Fitzgerald G, Klesius P, Tracy W, Williford JR, Zimba PV (2008) Technology, complexity and change in agricultural production systems. Renew Agric Food Syst 23:285–295
Sauer J, Vrolijk H (2019) Innovation and performance–evidence at micro level. Appl Econ 51(43):4673–4699. https://doi.org/10.1080/00036846.2019.1597252
Scar EU (2019) Preparing for future AKIS in Europe. European Commission, Brussels
EU SCAR (2012) Agricultural knowledge and innovation systems in transition—a reflection paper, Brussels
EU SCAR (2020) Resilience and transformation, Report of the 5th SCAR Foresight Exercise Expert Group: Natural resources and food systems: Transitions towards a 'safe and just' operating space
Schnebelin E (2022) Linking the diversity of ecologisation models to farmers' digital use profiles. Ecol Econ 196:107422. https://doi.org/10.1016/j.ecolecon.2022.107422

Seuneke P, Bock BB (2015) Exploring the roles of women in the development of multifunctional entrepreneurship on family farms: an entrepreneurial learning approach. NJAS Wagening: J Life Sci 74–75:41–50. https://doi.org/10.1016/j.njas.2015.07.001
Shang L, Heckelei T, Gerullis MK, Borner J, Rasch S (2021) Adoption and diffusion of digital farming technologies: integrating farm-level evidence and system interaction. Agric Syst 190:103074. https://doi.org/10.1016/j.agsy.2021.103074
Swinton SM, Lowenberg-Deboer J (2001) Global adoption of precision agriculture technologies: who, when and why. In: Proceedings of the 3rd European conference on precision agriculture. June 2001, Citeseer 2, pp 557–562
Tey YS, Brindal M (2012) Factors influencing the adoption of precision agricultural technologies: a review for policy implications. Precis Agric 13:713–730. https://doi.org/10.1007/s11119-012-9273-6
Turner A, Klerkx L, White T, Nelson T, Everett-Hincks J, Mackay A, Botha N (2017) Unpacking systemic innovation capacity as strategic ambidexterity: how projects dynamically configure capabilities for agricultural innovation. Land Use Policy 68:503–523. https://doi.org/10.1016/j.landusepol.2017.07.054
Vagnozzi A (2019) Quali prospettive per il sistema della conoscenza e dell'innovazione nelle politiche 2014–2020? *Agriregionieuropa* 56.
Van Ooste I, Vagnozzi A (2020) Knowledge and innovation, privileged tools of the agro-food system transition towards full sustainability. Ital Rev Agric Econ 75(3):33–37. https://doi.org/10.13128/rea-12707
Vecchio Y, De Rosa M, Adinolfi F, Bartoli L, Masi M (2020) Adoption of precision farming tools: a context-related analysis. Land Use Pol 94:104481. https://doi.org/10.1016/j.landusepol.2020.104481
Vecchio Y, De Rosa M, Pauselli G, Masi M, Adinolfi F (2022) The leading role of perception: the FACOPA model to comprehend innovation adoption. Agric Food Econ 10(1):1–19
Vollaro M, Raggi M, Viaggi D (2020) Innovation adoption and farm profitability: what role for research and information sources? Bio-Based Appl Econ 8(2):179
Watcharaanantapong P, Roberts RK, Lambert DM, Larson JA, Velandia M, English BC, Rejesus RM, Wang C (2014) Timing of precision agriculture technology adoption in US cotton production. Precis Agric 15(4):427–446. https://doi.org/10.1007/s11119-013-9338-1
Welter F (2011) Contextualizing entrepreneurship: conceptual challenges and ways forward, entrepreneurship. Theory Pract 35(1):165–184. https://doi.org/10.1111/j.1540-6520.2010.00427.x
Wetengere K (2011) Socio-economic factors critical for intensification of fish farming technology. A case of selected villages in Morogoro and Dar es Salaam regions Tanzania. Aquac Int 19(1):33–49. https://doi.org/10.1007/s10499-010-9339-2
Wolfert S, Ge L, Verdouw C, Bogaardt MJ (2017) Big data in smart farming: a review. Agric Syst 153:69–80. https://doi.org/10.1016/j.agsy.2017.01.023
Zarco-Tejada PJ, Hubbard N, Loudjani P (2014) Precision agriculture: an opportunity for Eu farmers-potential support with the cap 2014–2020. Joint Research Centre (JRC) of the European Commission; Monitoring Agriculture ResourceS (MARS) Unit H04
Zheng S, Wang Z, Wachenheim CJ (2019) Technology adoption among farmers in Jilin Province China. China Agric Econ Rev 11:206–216

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.