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Adoption of Precision Farming Tools: a context-related analysis

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Abstract
This paper deals with precision farming tools (PFTs), a way of farming which relies on specialized equipment, software and **information technologies services**, whose importance is underlined in recent documents of the European Union. Precision farming is an integrated and sustainable **farm** management system making use of modern technologies to increase farm's profitability, by reducing environmental impact. **In this paper we explore the complex mechanisms that affect PFT's adoption by Italian farmers**. More precisely, we try to analyse the context-related factors affecting adoption of PFTs in the Italian farms.

Little research has been carried out in Italy on this **topic**, therefore our paper tries to fill a gap in literature. In order to investigate the process of technology adoption related to precision agriculture, a questionnaire **was** submitted to a sample of Italian farms. The questionnaire has been structured in order to apply the AKAP (Awareness, Knowledge, Adoption, Product) sequence. Our analysis underlines that context-related factors are fundamental dimensions to be explored in order to specify uptake of PFTs. Therefore, the paper has relevant policy implications, within the context of a new participatory approach to agricultural innovation characterized by bottom-up processes boosted by farmers, which has informed the recent policies of agricultural innovation at the EU level.

Keywords: precision agriculture; AKAP sequence; entrepreneurial profile; complexity.

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1. Introduction

This paper deals with precision farming tools (PFTs), with the aim of exploring factors affecting farmers' adoption of precision agriculture (PA) in rural enterprises of Italy. PA is a way of sustainable farming relying on specialized equipment, software and IT services to 'apply the right treatment in the right place at the right time' (Gebbers and Adamchuk, 2010). It has recently gained ground in European Union (European Parliament, 2016) as a 'farming management concept based upon observing, measuring and responding to inter and intra-field variability in crops or in aspects of animal rearing' (European Parliament, 2014, 11). Precision agriculture brings about a change in the land use, by fostering 'whole-farm management strategies using information technology, highlighting the potential improvements on production while reducing environmental impacts' (European Parliament, 2014, 11). Moreover, literature has emphasised multiple benefits from PFTs, under both economic and environmental perspectives (Zhang et al., 2002; Finger et al., 2019).

There are various levels of PFTs currently available on the market (Robertson et al., 2012) classified in the literature mainly on the basis of their focus (use of fertilizer and pesticide, tillage regime, water saving etc.) and/or on their applied technologies (GIS, remote sensor, smart tractors). PFTs adoption is supported by policy for its ability to pursue on-farm economic efficiency (Takacs-Gyorgy, 2008), through either minimizing input, or maximizing yields (Arnò et al., 2012) and strengthening the provision of environmental public goods by farmers (Hudson and Hite, 2003; Silva et al., 2007; Takacs-Gyorgy, 2008). Moreover, PFTs may have a positive impact on climate crisis, as pointed out in recent studies (Balafoutis et al., 2017).

The increasing number of studies on factors and barriers affecting the adoption of PFTs has highlighted how the farmers' view of such instruments and technologies is influenced by several variables, then rendering the process more problematic. In our paper, we point out that complexity of PFTs adoption is affected by context-related factors. Therefore, the aim of the paper is to look into the relevant dimensions of context affecting the uptake of PFTs. Research questions are the following:

- **what are the mechanisms of adoption of PFTs?**
- **How do various dimensions of context influence the adoption of these tools?**

In order to explore these factors, the paper is articulated as follows: next part deals with theoretical background, with the purpose not to provide a full literature review, but to emphasize key drivers and barriers to the introduction of precision agriculture (section 2). The empirical analysis will be explained in the methodological note (section 3), while the results will be illustrated in part 4. The discussion and conclusion will end the paper.

2. Theoretical background

2.1 The complexity of PFT adoption process

Rogers (2003, 15) defines the complexity as "the degree to which an innovation is perceived as relatively difficult to understand and use". An extensive literature has analysed factors affecting the adoption of PFTs, highlighting the high number of variables involved and the complexity of their relationships. Recent studies analyse the impact on the cost/opportunity of access to innovation (Barnes et al. 2019) and on farm's profitability (Pedersen et al. 2001). Others have highlighted the role played by the characteristics of both farmer and family farms (Daberkow and McBride 2003; Edwards-Jones 2006). More recently, an increasing number of papers examined the role played by socio-cultural factors, as the social milieu (Edwards-Jones 2006). Finally, great attention has been paid to compatibility and complexity inherent to technology (Aubert et al. 2012).

Despite elements of complexity are systematically recalled, we point out that these elements need to be framed in a context-sensitive analysis, under the hypothesis that "contextualization is about recognizing differences" (Welter et al. 2016, 1). Against this background, the following dimensions of context emerge (Welter 2011).

The first one is related to *who* context, which includes sociodemographic variables, such as age, level of education, years of farm experience and off-farm activity participation (Daberkow and McBride 1998; Fernandez-Cornejo 1994; Kassie et al. 2013; Griffin, 2000; Popp and Griffin 2000). As far as age of farmer is concerned, young farmers have a greater capability to decode new information and to search the suitable tool to support production (Barnes et al., 2019; Larson et al. 2008; Paxton et al. 2011). Furthermore, Larson et al. (2008) and Paxton et al. (2011) report how both the young age and the high level of education among cotton farmers of the USA are good predictors to adopt information-gathering technologies (i.e. remote sensing). This is the reason why the profile of adopter has been represented in several studies as a better-educated farmer, who is well geared to receive new information providing PFT and accept technical support from crop consultants (Tey and Bridal 2012; Daberkow and McBride 1998; Larson et al. 2008; McBride and Daberkow 2003a; Pierpaoli et al. 2013; Popp and Griffin 2000).

A second group of variables affecting PFTs' adoption is related to *where* context, more precisely to business and institutional context (Welter, 2011): business context includes both farm's economic and structural variables. Not surprisingly, farm's size may be considered as one of the most important factors bringing about technology adoption. Indeed, there is large evidence that larger farms, with a good capacity to absorb costs and risks, are more inclined to use PFTs (Feder et al. 1985; Lambert et al. 2015; Watcharaanantapong et al. 2014; Tey and Bridal 2012; Daberkow and Bride 2000). Moreover, PFTs fit the model of an intensive capital technology: they required high entry costs, large fixed transaction ones and others "hidden costs" such as educational and informational ones. Furthermore, del Río Gonzalez (2005) states that the "switching cost" to a new technology, leading to changes in the production process and in the farm organization, might be costly especially for small farms (Feder et al. 1985; McBride and Daberkow 2003b; Long et al. 2016).

As far as institutional context is concerned, it includes social, cognitive, cultural, more generally, behavioural variables affecting farmers' conduct (Archer et al., 2008). We will synthesize these factors with the term “perceived complexity”. Complexity itself can be considered a real barrier to adoption of PFTs. Actually, adoption is rarely an immediate activity, and there is a span of time between the introduction of new technologies on the market and their wide use among farmers (Aubert et al. 2012; Pierpaoli et al. 2013; Tey and Bridal 2012; Winsten et al., 2011). This is particularly true for more complex, expensive and not too much profitable agricultural practices, characterized by a slower adoption process (Kuehne et al. 2017). Complexity leads the firm to either an “organizational inertia” and to revert to familiar routines, innovating only along already explored technological trajectories (del Río Gonzalez, 2005).

Jointly with *who* and *where* dimensions, a further element to be taken into account is the *why*, which let emerge the “polymotivation” in the adoption of PFTs (Lioutas et al., 2019). More precisely, some universal characteristics of farmers' motivation may be pointed out, as their willingness to follow the social streams of innovation (see, Lioutas, Charatsari, 2017), or their intrinsic motivation (see, for instance, Payne et al., 2019; Charatsari et al., 2017).

In order to take into account this high complexity, Evenson (1997) puts forwards the AKAP (awareness-knowledge-adoption-product) sequence, with the purpose of discriminating the cognitive step (cognitive sphere) from the decision of adopting (action sphere). Each step of the sequence may be affected by a set of variables contributing to raise the level of complexity in technology adoption. The aforementioned literature designs a clear picture of high complexity surrounding technology adoption, by stressing ex ante mechanisms and variables acting as barriers/drivers. Nonetheless, attention should be paid also in *ex post* analyses of complexity, emphasizing emergent constraints in post-adoption phases. Under this perspective, a gap in literature emerges we would like to fill. Next section deals with this aspect, bringing about our original methodological approach.

2.2 The results of PFT adoption: replacing linear processes with more holistic views of innovation

Despite an abundant literature has analysed the multiple dimensions of innovation adoption, with reference to precision agriculture, conversely, less empirical efforts have been developed to explore the results of adoption.

The literature on the impacts related to the introduction of PFTs, developed since the end of the seventies, has mainly focused on the use of input-output ratios (Adamchuck et al. 2004; Colvin and Arslan 2000; Godwin and Miller 2003), revealing a lack of whole-farm focus that has not yet been covered. Farms are part of a more complex and multidimensional scenario (Aubert et al. 2012; Robertson et al. 2012; Tey and Bridal 2012) whose performance cannot be simply measured in terms of yield variation (Adrian et al 2005; Mishra et al. 2009).

In this paper, we point out that result of innovation is the end stage of an articulated process of technology adoption, which investigates multi-faceted dimensions affecting farmers' decision to adopt PFTs. In order to synthesise these dimensions, it is possible to make reference to **both, personal characteristics of the farmers and characteristics of the farm enterprise** (Mcelwee, Smith, 2012). The assumption of a renewed perspective of innovation adoption brings about shifting the focus from linear to multi-dimensional approaches to innovation adoption (Knickel et al., 2009). It is possible to explore this "not linear" process, by applying the AKAP model. The awareness-knowledge-adoption-productivity sequence (AKAP) is developed from the pioneering contribution of Evenson (1997) and defines the natural order of the steps leading to the adoption of innovation, including its implementation. The use of this conceptualization allows to understand the characteristics of the adoption process in relation to specific innovations (Evenson et al. 1998; Kassem 2013) and helps to identify the “gaps” associated with each phase of the AKAP sequence (Evenson 1994).

The AKAP approach has been used mainly to explain the impacts of alternative extension approaches (De Rosa et al. 2014; Gangappagouda et al. 2015; Riawanti and Kurnia 2017), measuring their ability to induce the sequence. However, to look at the introduction of innovation by farmers as it proceeds through the AKAP sequence, could be a useful tool of analysis, in particular to help the policy makers to capture, and then to fill, the gaps associated to each stage of the sequence. The empirical works that have tested the AKAP approach, have focused mainly within the context of developing countries (Gandhi et al. 2009; Kyaruzi et al. 2010) identifying the performance of the “*P-stage*” with the associated productivity gains. The few works that have used a different meaning of “product” have focused on changes in agricultural practices, involving various potential innovation (strategic, normative, technical, marketing, organizational, management, etc.), linking them to eventual benefits from adoption (De Rosa et al. 2014).

Following this direction, in our work we suggest an adaptation of the AKAP with the purpose of approaching the phase of implementation with different metrics from traditional ones. The adaptation consists in replacing the concept of “*product*” with that of “*perceived complexity*” with the purpose of exploring innovation adoption as the result of a complex dynamic process, involving multiple factors and processes.

3. Methodology

In order to investigate the process of technology adoption related to precision agriculture, a questionnaire has been submitted to a non-random sample of 200 Italian farms from various regions of Italy. Questionnaires have been administered in March 2018, however, out of 200, 174 have been considered valid for empirical analysis (87%). Questionnaires have been submitted during national fairies devoted to precision agriculture. Non-random sampling is commonly used to collect data for the purpose of implementing an exploratory work (Kelley et al. 2003). It is often associated with qualitative research. These studies tend to focus on small samples and aim to examine a real phenomenon, not to make statistical inference in relation to the larger population (Yin, 2003). Following the purposive sampling approach (Maxwell, 1996), only those who knew precision agriculture were included so as to have no disinterested answers. This approach presents some limitations, in terms of subjectivity; moreover, it allows generalization (Taherdoost, 2016).

Interviewed participants were all aware about the meaning and the main tools of precision agriculture. This has permitted to join the first two steps of the AKAP sequence, awareness and knowledge.

The sequence distinguishes cognitive and action steps, being cognitive synthesized by the awareness and knowledge about precision farming, while action phase implies decision of adopting precision agricultural tools. Finally, as we explained above, products phase concerns perceived complexity of innovation adoption. The steps have been investigated as follows:

- *awareness:* questionnaires have been submitted during a congress on the theme of precision agricultural tools, where all participants were conscious about these tools. Therefore, everyone is aware by the concept of "heard of" (Coleman et al., 1955);
- *knowledge*: the cognitive variables have been synthesized through exposure to information, for example through magazines, journals, training course, etc. The index is calculated as amount of hours/day of exposure;
- *adoption* implies uptake and use of any PFTs; farmers are asked to specify if they have recently adopted one or more PFTs;

- *products*: the product step is synthesized through the index of perceived complexity in the use of PFT. This is a composite indicator, made up of 5 variables (whose answers are numbered from 1 - totally disagree - to 5 - fully agree):

$$\frac{\sum_{i=1}^{5} x_i}{25} \quad (1)$$

  - *efficiency effects*: introduction of PFT lets efficiency gains at farm level;
  - *complexity effects in the management of PFT*: introduction of PFT makes farm's management more complex;
  - *organizational effects*: introduction of PFT requires difficult to implement organizational and structural adjustments;
  - *effects on agricultural practices*: PFT requires radical change in agricultural practices;
  - *financial exposure effects*: introduction of PFT requires long term investments to be recovered in the long term.

As it is evident from table 1, the robustness of the index is demonstrated by the fact that the five variables are interrelated with significant Pearson correlation factors (<0.01).

Table 1 – correlation indexes between the variables

Correlations					
	Efficiency effects	Complexity effects in the management of **PFT**	Organizational effects	Effects on agricultural practices	Financial exposure effects
Efficiency effects	1	.435**	.393**	.477**	.441**
Complexity effects in the management of **PFT**	.435**	1	.596**	.434**	.488**
Organizational effects	.393**	.596**	1	.523**	.515**
Effects on agricultural practices	.477**	.434**	.523**	1	.457**
Financial exposure effects	.441**	.488**	.515**	.457**	1
** Correlation is significant at the 0.01 level (2-tailed).					

For this reason, internal consistency has been tested through the Cronbach's alpha[1], as showed in table 2. The unidimensionality of the scales was tested through an exploratory factorial analysis, which extracted only one factor. Subsequently, Cronbach's alpha showed good results of consistency (over 0,8), which added to the result of factorial analysis, allow us to affirm that the realization of the index has a robust justification.

Table 2 - Reliability Statistics

Cronbach's alpha	Cronbach's alpha Based on Standardized Items
0,81	0,82

Farm's entrepreneurial profile is drawn on a segmentation framework (McElwee and Smith 2012; McElwee 2008), which considers business characteristics and personal characteristics of farmers. More precisely, as far as business characteristics are concerned, size of farms has been taken into account, as well as the worker's contribution in terms of days per year per farm; personal characteristics take into account the age of the manager and the level of education.

After descriptive statistics, a multivariate analysis has been carried out, with the purpose of aggregating homogeneous farms in relation to the AKAP sequence.

The *Two Step Cluster Analysis* procedure is used to classify the groups.

The distance measure is the Log-likelihood and the automatic clustering criterion is the Akaike Information Criterion (AIC). This Information Criterion measures the deviation of the model by the probability distribution *f* from the true distribution *g*. It is defined by the formula:

[1] Cronbach's alpha is a measure of reliability of the test, that is, how is related a set of items are as a group. A high value of this index doesn't necessarily ensure that the scale is unidimensional, but we could test this with an exploratory factor analysis. The function of standardized Cronbach's alpha is:

$$\alpha = \frac{N \cdot c}{\overline{v} + (N+1) \cdot \overline{c}}$$

Where N is the number of the items, c is the average inter-item covariance among the item and v is the the average of variance.

$$AIC = 2k - 2\ln(L) \qquad (2)$$

Where k is the number of the parameters of the statistical model and L is the maximum value of the likelihood function of the estimate model. Clustering variables are the following: index of exposure, perceived complexity, intensity of daily work, farm's size, age, level of education, uptake of PFTs. The cluster analysis run with SPSS v25.

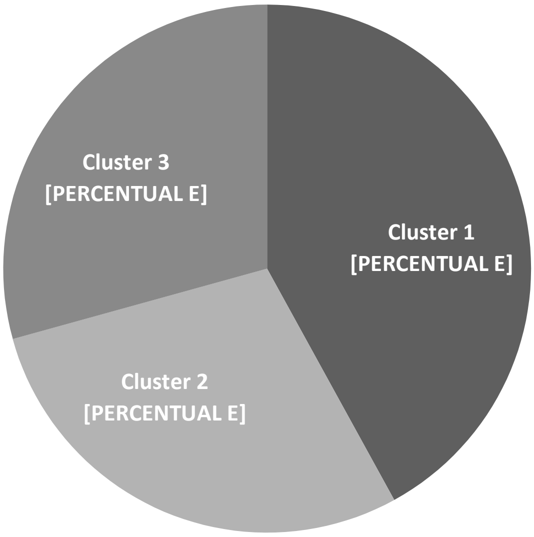
4. Results

Interviewed farmers have an average age of 46 years, ranging from a minimum of 24 to a maximum of 72. Size of the farm also varies from a minimum of 10 ha to a maximum of 475 ha, with an average dimension of 64 ha. Consequently, we are dealing with relatively big farms, if compared with the average dimension of Italian farms which is systematically below 10 ha. The following cluster analysis has permitted to classify homogeneous farms according to the previously illustrated methodology.

Cluster analysis

On the basis of cluster analysis, three homogeneous groups of farms have been extracted, which present strong intra-cluster similarities and strong differences among groups. Figure 1 illustrates the percentage relevance of each group, being the first cluster the biggest one.

Figure 1 – The three clusters extracted



The first cluster includes 73 farms absorbing 42% of the total sample. On the other side, the second one represents 29% with 50 farms, while 51 farms typify the third cluster.

In order to characterise each cluster, table 3 points out the AKAP sequence, from which clear differences emerge between the farmers of the various clusters, also typified by different entrepreneurial profiles.

Table 3 – Characteristics of the three clusters

		Cluster 1: *(42% - 73 farms)*	*Cluster 2* *(28.7% - 50 farms)*	*Cluster 3* *(29.1% - 51 farms)*
Awareness - knowledge	*Index of exposure*	0 - 8 h / day	> 8 h / day	4 – 8 h / day
Adoption	*Adoption of **PFTs***	*Not adopters*	*Adopters*	*Propense*
Product	*Perceived complexity*	0.86	0.61	0.75
Farm's characteristics				
Business characteristics	Work	0 - 25 days/ha	> 50 days/ha	25 - 50 days/ha
	Farm's size (hectares)	average 26.73	average 143.46	average 42.92
Personal characteristics	Age	average 50.27	average 42.42	average 45.12
	Education	Diploma	Post-graduate specialisation studies	Graduation and post-graduate studies

Cluster 1: not adopters

Cluster 1 is the broadest one, with 73 farms, characterised by a relatively small size (26.73 hectares). These farms have both a low exposure index (in terms of hours/day devoted to the acquisition of information from various sources) and a low intensity of work with the lowest daily work per hectare (0-25). In terms of PFTs, these farmers are not adopters: a possible explanation of this is the perceived complexity index, which reaches 0.86 of value, the highest value among the interviewed farmers. As far as personal farmers' characteristics are concerned, farmers are in the mature phase of the life cycle (50 years old) and hold an average level of education (diploma).

Cluster 2: adopters

Second cluster includes 50 farmers with the maximum level of exposure (> 8 hours/day), making these farmers as highly aware about PFTs potentialities. This brings about high rates of adoption, which is supported by the lowest index of perceived complexity revealed in the "product" step of the AKAP sequence. By observing the entrepreneurial profile, this group is marked by the presence of the biggest farms (average dimension equal to 143 hectares) and by young managers, with the highest level of education (post-graduate and specialization studies).

Cluster 3: inclined to adopt

The last cluster is typified by the presence of farms with average indexes of exposure (4-8 hours/day), togheter with the propensity to adopt PFTs in the next future. This group of farms is intermediate between the previous two clusters, with an average index of perceived complexity (0.75) and average intensity of daily work (25-50 days/ha). Entrepreneurs are in the young/mature phase of life cycle, with an average age of almost 43 and with a good level of education (graduation and post-graduate studies).

In order to deepen P-step, that is perceived complexity, the following scatterplot (Figure 2) shows the distribution of the farms on the basis of the complexity index. It is evident from the figure that the adopters are in lowest part of the graph while the Not Adopters are in the highest part.

Moreover, index of "perceived complexity", as previously explained in formula (1), may be split into 5 variables (figure 3): “efficiency effects”, “complexity effects in the management of PFTs”, “organizational effects”, “effects on agricultural practices”, “financial exposure effects”. From figure 3 we can see how the answers to the 5 questions are strongly differentiated according to whether the farmer is an adopter or not.

Figure 2 – Scatterplot: distribution of the farmers

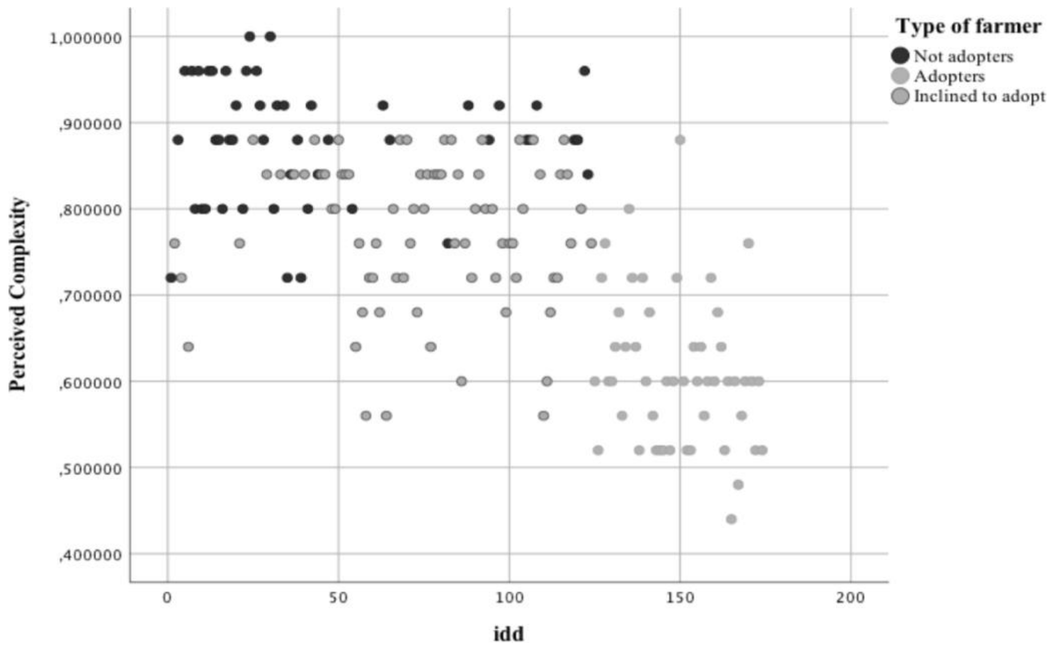


Figure 3 – Mean of the 5 effects for each type of farmers

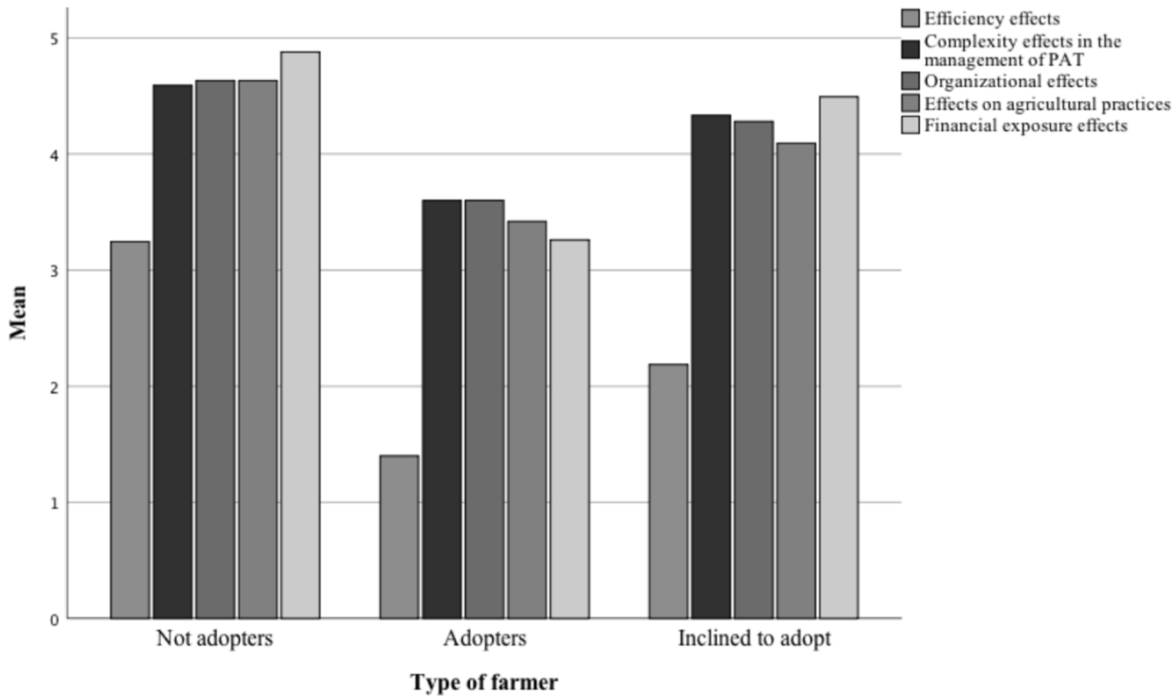


Figure 3 clearly shows a different perception of not inclined farmers about the effects of these tools compared to their adopters. The degree of difficulty in understanding these effects limits the acceptance of innovation as well explained in previous studies (Wheeler 2008). In table 4 we show the statistical measures of each single variable divided by the three farmer groups.

Table 4 – Statistical measures of 5 variables

Type of farm		*Efficiency effects*	*Complexity effects in the management of **PFT***	*Organizational effects*	*Effects on agricultural practices*	*Financial exposure effects*
Adopters	*Mean*	1.4	3.6	3.6	3.4	3.2
	Median	1	4	4	3	3
	Mode	1	3	3	3	3
Not Adopters	*Mean*	3.2	4.6	4.6	4.6	4.9
	Median	3	5	5	5	5
	Mode	3	5	5	5	5
Inclined to adopt	*Mean*	2.2	4.3	4.3	4.1	4.5
	Median	2	4	4	4	5
	Mode	2	5	4	4	5

The components of the variable take on different results for each type of farmer.

- The variable “*Efficiency effects*" increases in value from an average of 1.4 for adopters to 3.2 for non-adopters (cluster 1). This is probably due to the fact that the adopters have tried over time the effects of these tools and therefore they have a clearer view of the efficiency improvement that precision agriculture may provide to the farm.
- The variable "*Complexity effects in the management of PFTs*" assumes an average value for adopters of 3.6, while for non-adopters it rises to 4.6.
- The variable "*Organizational effects*" has an average value of 3.6 for adopters and 4.6 for non-adopters. As expected, precision agriculture has a deep impact on organizational variables, being it considered as a radical innovation.
- The variable "*Effects on agricultural practices*" it has a mean value of 3,4 for the adopters and 4,6 for the non-adopters. This confirm that changing the framework of action may be also influence the adoption process.
- The variable "*Financial exposure effect*" it has a mean value of 3,2 for the adopters (cluster 2) and of 4,9 for non-adopters (cluster 1), then confirming financial constraints as a barrier for adopting precision agriculture tools.

5. Discussion and conclusions

This paper investigates the variables affecting the attitude towards adoption of precision farming tools.

With this purpose, we put forward an AKAP model, with the purpose of detailing the complex process of technology adoption. Two main limitations mark the paper: first one concerns the representativeness of the sample: farmers were selected during fairies devoted to PFTs; therefore, self-selection bias in the sample may emerge. This approach impedes the generalization of our results. Secondly, PFT is treated as one entity throughout the manuscript, but there is good evidence that adoption rates vary widely among different kinds of PF technologies (Lowenberg-DeBoer and Erickson, 2019). It is likely that the factors influencing adoption differ from one PF technology to the other. Nonetheless, the paper has to be considered as a first attempt to evaluate PFTs adoption in Italian farms. Under this perspective, we have considered precision farming tools as a unique.

Therefore, despite previous limitations, on the basis of our analysis, some interesting insights emerge. *Who* and *where* context variables reveal their utility in explaining the complex mechanisms of innovation adoption in cases of radical innovation. Moreover, McElwee's segmentation framework lets homogeneous farms to emerge, in terms of PFTs adoption. Indeed, empirical analysis reveal three distinct groups of farmers with different inclination towards PFTs. Entrepreneurial profile seems a relevant variable in describing mechanisms of adoption: "classic" variables are evident in depicting differences, such as level of education (Becker, 1966; Lucas, 1988). As pointed out in literature, farmers that are more educated reveal higher propensity to adopt this new technology compared to not educated farmers (Daberkow and McBride 1998; Larson et al. 2008; McBride and Daberkow 2003a). However, what seems remarkable in explaining differences is the relevance of opportunity skills (Rudmann et al. 2008), which refer to a kirznerian perspective of entrepreneurship (Kirzner, 1997). We have tried to synthesize this variable through an index of exposure to information. This index has to be considered as an explanatory variable of entrepreneurial alertness (De Rosa et al., 2019). Therefore, as evident from the empirical analysis, the more "exposed/alert" is the farmer-entrepreneur, the more he/she is in favour of adopting the PFTs. Our empirical analysis demonstrates how not adopters show the lowest exposure index, in terms of hours/day devoted to the acquisition of information from various sources. On the contrary, higher alertness of adopters is synthesized by higher numbers of hours "spent" to acquire information from various external (both formal and informal) sources. This aspect has relevant consequences in addressing issues of knowledge transfer, about that it emphasises the role of innovation support systems to address adequate and coherent knowledge to a diversified range of exposed/not exposed farmers (Lioutas et al., 2019).

The outcome of PFTs introduction, the last step of the AKAP sequence here adopted ("product"), is synthesized by a diversified set of effects. PFTs adoption shows an increase in the farm's efficiency, which is also confirmed by Watcharaanantapong (2012) who demonstrated in his study that precision farming tools help farmers increase business efficiency.

As far as complexity effects are concerned, complexity seems to rise moving from adopters to not-adopters. The entrepreneur is more inclined to adopt if he perceives the new technology as better than the current one in terms of advantages in the firm and time savings ("relative advantage"), or if the new tools are easy to use and to integrate into the daily routines ("easy to use") (Rogers, 2003; Aubert et al., 2012; Davis 1989). Furthermore, complexity effects in not adopters may also depend on lack of knowledge: some studies, such as del Río Gonzalez (2005) and Montalvo (2008) affirm that the lack of knowledge and, therefore, the perceived complexity in the management of such tools, can become a barrier to adoption. This is confirmed in our study.

Not surprisingly, introduction of PFTs has also organizational effects, so linking both process and organizational innovation, already underlined in literature. Bessant et al. (2014) state that the development of radical technological innovations requires organizational and infrastructural changes, which may be difficult for specific firms. On the other side, del Rio Gonzalez (2005) affirms that farmers suffer from "organizational inertia", in that they fail to change organizational asset that would allow the introduction of the tools. This is confirmed by the results of our study, being non-adopters characterized by an average significantly higher value than the adopters.

Potential effects on agricultural practices are also relevant in stimulating adoption/not adoption. Aubert et al. (2012) affirm that the compatibility of the technologies of precision agriculture with the existing technologies and with the agricultural practical routine has a very strong effect on farmers perception in the decisional trial to adopt. In our study this is confirmed, in fact the non-adopters perceive this as a very strong barrier.

Economic and financial barriers are mostly analyzed among the researchers (Bogdanski 2012; Brunke et al. 2014; Cullen et al. 2013; del Río Gonzalez 2005; Faber and Hoppe 2013; Hoffman and Henn 2008; Luken and Van Rompaey 2008; Luthra et al. 2014; McCarthy et al. 2011; Montalvo 2008). The economic variable engraves on the initial decision of investments; in fact, many tools ask for a high initial investment to be recovered in a long span of time. This makes it impossible to access innovation, above all in cases of small-medium farms, marked by problems of credit crunch. Further economic barriers are the costs for the training and the costs for of adaptation to the new technologies.

Based on previous considerations, the analysis has relevant policy implications: first, implications for future agricultural land use in Italy should be emphasised when dealing with structural characteristics of farms. Currently, Italian agriculture is made up of small family farms and PFTs may offer a good support to minimize inefficiencies and, consequently, raise farm's competitiveness. Furthermore, positive environmental benefits should encourage policy action also to support small-scale farmers to adopt PFTs (Finger et al., 2019). Therefore, it is necessary to follow up the need to "boost investments and uptake of new technologies and digital-based opportunities such as precision agriculture" underlined in the recent EU documents (EC, 2017, 16). Secondly, the extracted clusters feed different circuits of knowledge transfer: EU rural policies for the period post-2020 underline the importance of knowledge in performing more competitive and sustainable agricultural systems. Furthermore, EU document on the Future of Food and agriculture points out how "Not only technology but also access to sound, relevant and new knowledge is very patchy around the Union" (EC, 2017, 12). Against this background, anchoring mechanisms of knowledge should recognize differences in the socioeconomic characteristics of the farms, with the purpose of addressing "coherent" stock of knowledge (Crevoisier, 2014; Lioutas et al., 2019).

However, in order to better target knowledge transfer, entrepreneurial orientation matters. The possibility to link innovation adoption to entrepreneurial profile address specific policy goals with the purpose of targeting rural development policy on the basis of both entrepreneurial aptitude and entrepreneurial skills of farmers. Policies targeted towards the who/where variables are relevant. As far as *who* context is concerned, reducing transaction costs for gaining access to rural policy become fundamental, with the aim of (financially) stimulating adoption of precision agriculture. Information and knowledge circulation are key channels to promote the new frontiers of agriculture based on sustainable innovations. Collective action should also be supported, by insisting on the same lines traced by the EIP-AGRI partnership for innovation, launched within the actual programming period 2014-2020. As far as *where* context is concerned, not only spatial, but also institutional contexts may affect technology adoption. Therefore, in order to realize enabling contexts, agricultural knowledge and innovation systems are fundamental and, more specifically, the farm advisor may play a role in the circulation of sound knowledge, with the purpose of better performing the AKAP sequence:

- in the awareness/knowledge phase, by in delivering significant information and knowledge and, consequently, their adoption;
- in the product phase, by reducing the perceived complexity through expanding the farmer's familiarity about PFTs (Gow et al. 2002).

However, recent trend in farm advisory services cast some doubts, in account of new farming paradigm that may create situations of uncertainty linked to the new professional needs for advisors (Cerf et al. 2011; Nettle et al. 2018). Next programming period for rural development 2021-2027 puts both information and knowledge at the centre of the new strategy. It could be a good occasion to accelerate the rate of adoption of technologies, which may address farming activities towards more sustainable methods of production. It could also open new directions for future researches in order to better specify complex mechanisms of PFTs adoption.

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Figure 1 – The three clusters extracted

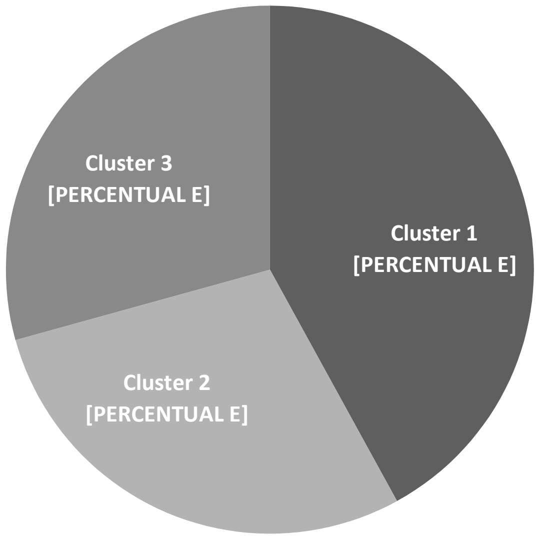


Figure 2 – Scatterplot: distribution of the farmers

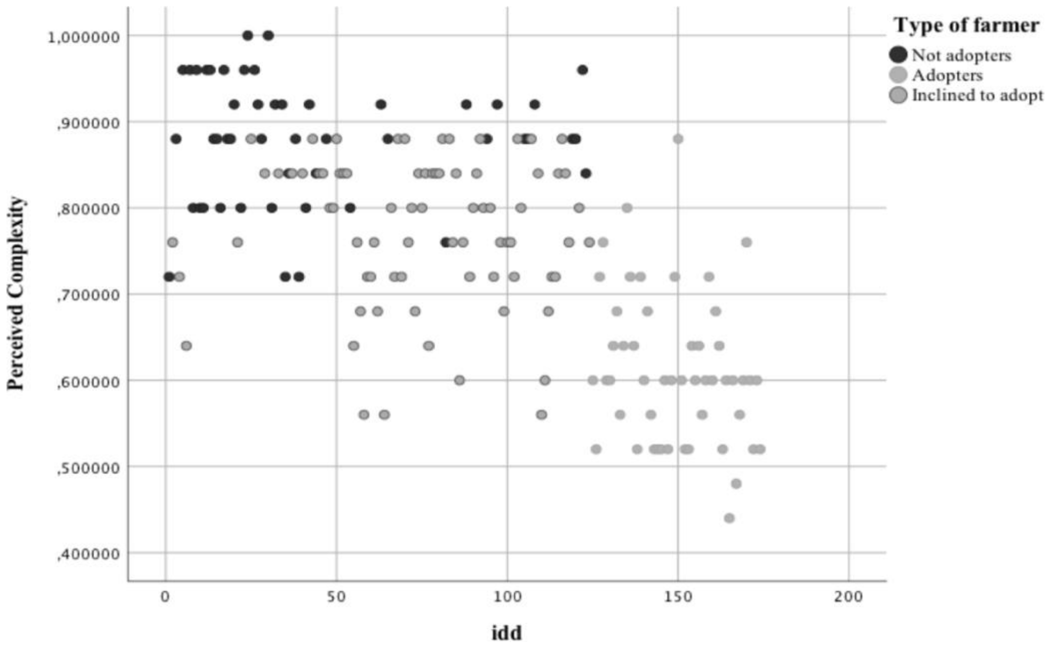
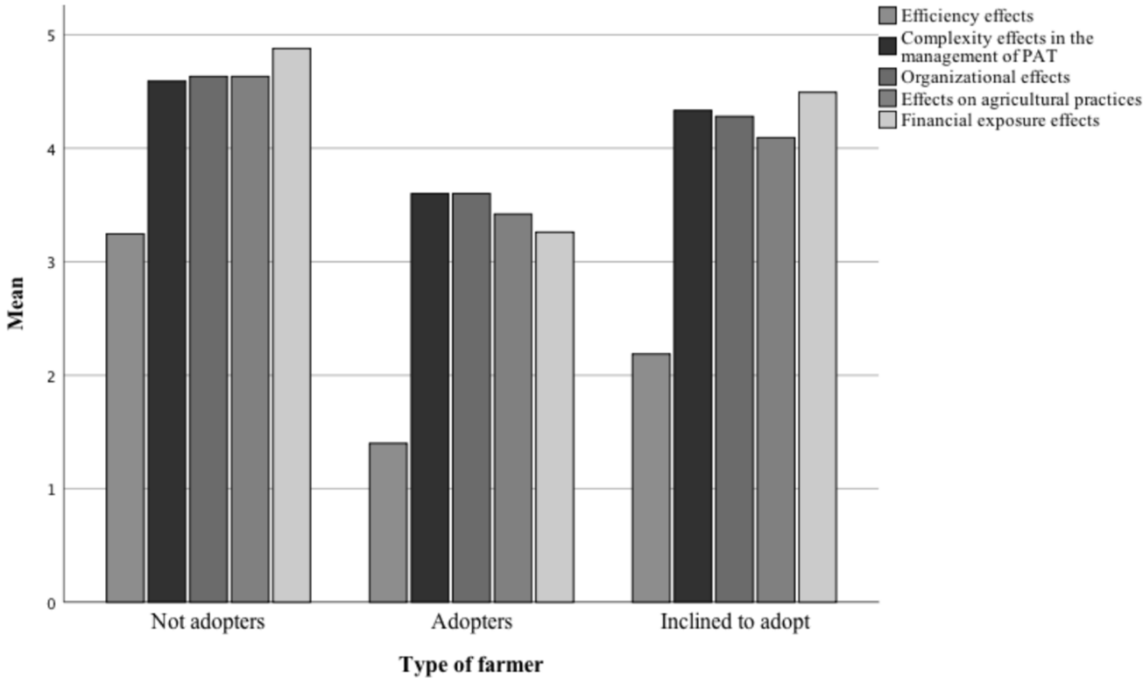


Figure 3 – Mean of the 5 effects for each type of farmers



Efficiency effects
Complexity effects in the management of PAT
Organizational effects
Effects on agricultural practices
Financial exposure effects
Mean
5
4
3
2
1
0
Not adopters
Adopters
Inclined to adopt
Type of farmer

Table 1 – correlation indexes between the variables

Correlations					
	Efficiency effects	Complexity effects in the management of PFT	Organizational effects	Effects on agricultural practices	Financial exposure effects
Efficiency effects	1	.435**	.393**	.477**	.441**
Complexity effects in the management of PAT	.435**	1	.596**	.434**	.488**
Organizational effects	.393**	.596**	1	.523**	.515**
Effects on agricultural practices	.477**	.434**	.523**	1	.457**
Financial exposure effects	.441**	.488**	.515**	.457**	1
** Correlation is significant at the 0.01 level (2-tailed).					

Table 2 - Reliability Statistics

Cronbach's Alpha	Cronbach's Alpha Based on Standardized Items
0,81	0,82

Table 3 – Characteristics of the three clusters

		Cluster 1: (42% - 73 farms)	*Cluster 2 (28.7% - 50 farms)*	*Cluster 3 (29.1% - 51 farms)*
Awareness - knowledge	*Index of exposure*	0 - 8 h / day	> 8 h / day	4 – 8 h / day
Adoption	*Adoption of PFTs*	*Not adopters*	*Adopters*	*Propense*
Product	*Perceived complexity*	0.86	0.61	0.75
Farm's characteristics				
Business characteristics	Work	0 - 25 days/ha	> 50 days/ha	25 - 50 days/ha
	Farm's size (hectares)	average 26.73	average 143.46	average 42.92
Personal characteristics	Age	average 50.27	average 42.42	average 45.12
	Education	Diploma	Post-graduate specialisation studies	Graduation and post-graduate studies

Table 4 – Statistical measures of 5 variables

Type of farm		*Efficiency effects*	*Complexity effects in the management of PFT*	*Organizational effects*	*Effects on agricultural practices*	*Financial exposure effects*
Adopters	*Mean*	1.4	3.6	3.6	3.4	3.2
	Median	1	4	4	3	3
	Mode	1	3	3	3	3
Non	*Mean*	3.2	4.6	4.6	4.6	4.9

Adopters	*Median*	3	5	5	5	5
	Mode	3	5	5	5	5
Inclined to adopt	*Mean*	2.2	4.3	4.3	4.1	4.5
	Median	2	4	4	4	5
	Mode	2	5	4	4	5

Authors' statement

All Authors have
shared:
Conceptualization
Methodology
Software
Validation
Formal
analysis
Investigation
Resources
Data curation
Writing - Original draft
Writing - Review & Editing
Visualization
Supervision