Chapter N (please do not write anything in this line. Editors will annotate the chapter number)

Precision Agriculture technologies in the Italian agricultural context. A study on the rate of knowledge and diffusion among Italian farmers.

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**Abstract.** The agriculture of our century is facing rapid changes in economic, social and environmental scenarios due to the evolution of the global context. On the one hand, there is the pressing need to improve the yield of agricultural crops to meet future food needs given by the expected increase in the world population, on the other hand, the need to frame the entire agricultural management system from a perspective of environmental sustainability. Therefore, technological innovation linked to the sublimation of the Industry 4.0 paradigm in agriculture (called Precision Agriculture) is necessary to meet the aforementioned needs and allow companies to pursue a development strategy based on the use of integrated technologies in the agricultural production and processing. This work aims to identify the awareness rate and the adoption drivers of Precision Agriculture among Italian farmers. The research methodology is based on an online survey on a sample of 755 farmers (N = 755), in a period between July and November 2020. A regression analysis was subsequently carried out on the data collected. The results showed that Italian farmers do not have all the information necessary for the development of Precision Agriculture techniques (Informed Farmers: n = 366; 48.48%), while among the adoption drivers (Adopting Farmers: n = 155; 20.4%) the main ones seem to be: age, company size, gender and previous year's turnover. In light of the research results, it seems necessary to undertake training development paths linked to Industry 4.0 so that farmers can adequately adopt the technologies within their business models with an orientation towards sustainability. The present research aims to be a starting point for future studies that will have to investigate further why so many differences emerge in the rate of knowledge, in the adoption drivers and in the technological adoption models.

**Keywords.** Precision Agriculture, Industry 4.0, Adoption Drivers, Sustainability.

## Introduction

The adoption and development of new technologies have always been among the factors of great interest and have shaped all the most modern agricultural production systems. The mechanization of the various agricultural processes, developed mainly in the last 200 years, has led to a work that is far less tiring for man with great results in terms of productivity for almost all agricultural crops (Binswanger, 1986). The new paradigms of technological implementation in industry have made Industry 4.0 become pervasive in all sectors: in the agricultural sector it is identified as “Precision Agriculture” (PA). The term Industry 4.0 indicates a trend of industrial automation that integrates some new production technologies to improve working conditions, create new business models and increase the productivity and production quality of plants. This new paradigm of Industry 4.0 is based on the advanced digitalization of factories, the Internet, and future-oriented technologies bringing intelligence in devices, machines, and systems.

## Literature Review

The concept of PA emerged in the United States in the nineties, where the House of Representatives (1997) defines it as an application of technological principles and strategies to monitor and optimize agricultural production processes in order to manage agricultural production in relation to the real needs of the plot.

Starting from a literature review carried out on the Scopus database focused on the analysis of definitions of the concept of PA, it emerged that technology was the first central element of PA. However, over the years the attention of the scientific community has also focused on other elements, such as: General Benefits, Sustainability and Applications. This development path has been an evolution of the various provisions of the PA that have slowly allowed to establish the constitutive elements of the concept and its fields of application in order to intercept, among other things, the PA as a management tool alongside with concepts of economic and environmental sustainability. Furthermore, in the literature emerges that there is a gradual transition that has been starting from the management approach from considering PA as an application (Pierce and Nowak, 1999) to Kirchmann and Thorvaldsson (2000) which define it as a discipline to achieve a particular goal. Stafford (2000) describes it as an “information intense” while Zhang (2002) introduces it as a system approach, up to the definition of Tey and Brindal (2012) who frame it as a production system. In more recent years, starting from the studies of Pierpaoli et al., (2013) it is possible to notice a different approach to the PA paradigm that goes from being considered a mere application of agricultural practices to a “new concept of farm management”. This new approach can also be seen in the European study published by Schrijver et al. (2016) where it is presented as a “modern farming management concept” up to the more complete definition provided by ISPA (2019) where PA is defined as “a management strategy”.

## Precision Agriculture diffusion

The growing trend of PA adoption has attracted the attention of academic research (Trivelli et al., 2019) as well as being an increasingly common paradigm among farmers (Fountas et al., 2015). Among others, the spread of modern agricultural techniques can be reflected in the evaluation of the PA market. Europe appears to be a relevant context for investigating the adoption and diffusion of modern PA techniques. In particular, Italy is the second largest agricultural producer within the European context, generating 55.2 billion euros, with an increase of over 7 billion compared to 2010 data, and representing 13.4% of the total European output, preceded only by France (Eurostat, 2016). The Italian PA market is continuously growing: its value reached 450 million euros in 2019, with an increase of 22% compared to 2018 (Osservatorio Smart Agrifood, 2020). Although there are no official data on the rate of adoption of PA technologies in Italy, it has been observed that, in general, technological innovations spread slowly among Italian farmers (Long et al., 2016), partially in line with their European colleagues (Lowenberg-DeBoer and Erickson, 2019). The last Italian agricultural census carried out by ISTAT in 2010 found out that only 61,000 farms out of the total of 1.6 million adopted Information and Communications Technology (ISTAT, 2014). In this regard, the Italian Ministry of Agricultural, Food and Forestry Policies in 2017 developed a series of guidelines modelled on European agricultural policy with the aim of increasing the adoption rate of PA technologies among Italian farmers to bring the rate from an estimate of 1% to 10% by 2021 (Ministero delle politiche agricole alimentari e forestali, 2017).

## Objective and Method

The general objective of this research is to investigate what are the rates of awareness and adoption of the PA by Italian farmers. In this regard, an online survey was carried out, using the Snowball sampling method, among the largest number of reachable farmers and involving the main Italian trade associations (Confagricoltura, Coldiretti, Confederazione Italiana Agricoltori). For the drafting of the questionnaire, a survey based on mostly closed questions was developed. Questionnaire setup followed general scientific standards for online questionnaires as suggested by Baruch and Holtom (2008), Cook et al., (2000), Couper (2000), Couper et al. (2001), Hooker and Zuniga (2017). Snowball sampling was chosen, considering the large number of Italian farmers and their reluctance to release information. In this respect, Snowball Sampling appears to be the most effective method to get the maximum number of answers and increase the spreading of the survey (Goodman, 1961; Sadler et al., 2010; Wayman et al., 2019). The main objective of the survey is to identify the Italian PA adoption models in order to better focus on the major innovation drivers and on the general prerequisites useful to improve knowledge, adoption rate and future trends.

## Data

The data were collected from the end of July 2020 to the beginning of November of the same year. The online questionnaire was spread through the Google Form platform; its link was initially sent to the regional and provincial sections of the main Italian farmers associations and subsequently distributed via social networks (Facebook groups specifically committed to agriculture) and then directly to farmers. Overall, data from 755 farmers were collected through the questionnaire and used in the analysis. The data was analysed using the SPSS Statistics 27 software package based on the conceptual framework of factors potentially influencing the adoption of PA. The questionnaire was built in blocks with key questions, in any case the respondents had access to 2 minimum blocks of questions.

## Results and discussion

Although the total interviewees are 755, the different groups have different distribution. Uninformed farmers, those who are unfamiliar with PA, are 389, while those who claim to know it are 366. Of the latter, those who use at least one of the techniques in their companies are 154. On the other hand, those who have knowledge of PA techniques but do not use any of them are 211.

*Regression analysis on Knowledge of PA*

In order to test whether the likelihood of knowing of PA was predicted by the selected variables a logistic binary regression with enter method was performed. All the independent variables were recoded as dummy as indicated before. The dependent variable was the Knowledge PA coded as a dummy variable (1=Yes;0=No). In the final model (-2LL=763.561, Nagelkerke Rsquare=0.240; Hosmer and Lemeshow Test=0.085) the selected predictors were Gender, Education, Turnover, Size and Age as reported in Table 1.

Table 1. Results of binary logistic regression on knowledge of PA

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| --- |
| **Classification Tablea** |
|  | Observed | Predicted |
|  | Knowledge PA | Percentage Correct (%) |
|  | No (N) | Yes (N) |
| Step 1 | Knowledge PA | No | 225 | 102 | 68.8 |
| Yes | 97 | 219 | 69.3 |
| Overall Percentage |  |  | 69.1 |
| a. The cut value is .500 |

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| **Variables in the Equation** |
|  | B | S.E. | Wald | df | Α | Exp(B) |
| Step 1a | Gender | .964 | .210 | 21.027 | 1 | .000 | 2.623 |
| Education | .895 | .183 | 23.856 | 1 | .000 | 2.446 |
| Geography | .150 | .178 | .708 | 1 | .400 | 1.161 |
| Years Activity | -.236 | .207 | 1.297 | 1 | .255 | .790 |
| Turnover | .604 | .196 | 9.450 | 1 | .002 | 1.829 |
| Size | .901 | .191 | 22.320 | 1 | .000 | 2.462 |
| Qualification | .291 | .196 | 2.204 | 1 | .138 | 1.338 |
| Age | -.601 | .186 | 10.424 | 1 | .001 | .548 |
| Constant | -1.673 | .300 | 31.014 | 1 | .000 | .188 |
| a. Variable(s) entered on step 1: Gender. Education. Geography. Years Activity. Turnover. Size. Qualification. Age. |

*Regression analysis on Adoption of PA*

In order to test whether the likelihood of adoption of PA was predicted by the independent variables (Gender, Education, Geography, Years of activity, Size of cultivated area, Qualification, Age, Turnover for 2019) a logistic binary regression with enter method was performed. All the independent variables were recoded as dummy as indicated in Table 2. The dependent variable was the Adoption PA coded as a dummy variable (1=Yes;0=No). In the final model (-2LL=394.754, Nagelkerke Rsquare=0.142; Hosmer and Lemeshow Test=0.993) the selected predictors were Gender, Turnover and Size.

Table 2. Results of binary logistic regression on adoption of PA

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| --- |
| **Classification Tablea** |
|  | Observed | Predicted |
|  | Adoption PA | Percentage Correct (%) |
|  | No (N) | Yes (N) |
| Step 1 | Adoption PA | No | 129 | 54 | 70.5 |
| Yes | 58 | 75 | 56.4 |
| Overall Percentage |  |  | 64.6 |
| a. The cut value is .500 |

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| --- |
| **Variables in the Equation** |
|  | B | S.E. | Wald | df | Α | Exp(B) |
|
| Step 1a | Gender | .707 | .340 | 4.329 | 1 | .037 | 2.029 |
| Education | .067 | .254 | .070 | 1 | .791 | 1.069 |
| Geography | .104 | .246 | .180 | 1 | .672 | 1.110 |
| Years Activity | .355 | .290 | 1.500 | 1 | .221 | 1.426 |
| Turnover | .885 | .286 | 9.599 | 1 | .002 | 2.422 |
| Size | .559 | .272 | 4.211 | 1 | .040 | 1.748 |
| Qualification | -.197 | .293 | .454 | 1 | .501 | .821 |
| Age | -.283 | .267 | 1.128 | 1 | .288 | .753 |
| Constant | -1.891 | .482 | 15.391 | 1 | .000 | .151 |
| a. Variable(s) entered on step 1: Gender. Education. Geography. Years Activity. Turnover. Size. Qualification. Age. |

## Conclusion

This paper aimed to detect the Italian farmers’ rate of knowledge and adoption of modern farming techniques. The analysis identified various business and socio-demographic characteristics of farmers as significantly relevant which, consequently, influence the rate of knowledge and adoption of PA techniques among Italian farmers. The results of the analysis show a great relevance of the size of the farm as reported several times in the literature (Daberkow and McBride, 2003; Pierpaoli et al., 2013; Tey and Brindal; 2012). Specifically, farmers owning farms with a size above the Italian average in terms of cultivable hectares, are more aware of PA technologies and more likely to use them. Gender is also a factor of strong influence for the knowledge and adoption of PA, with men more likely to know and adopt PA. Another factor of strong influence for the knowledge and adoption of PA technologies is the turnover of the company referring to the year 2019. In fact, those who declared to have a turnover exceeding € 50,000 for the year 2019 are more likely both to know and to use PA technologies in the company. Regarding age, the results show that generally farmers younger than 50 years old are more likely to know PA but there is no specific effect on use. This data can be explained as younger farmers are on average more educated and more accustomed to the use of new technologies even outside the workplace but, generally, having fewer financial resources find the adoption more difficult. Empirical findings on predictors exerting a positive influence on PA adoption have multiple managerial implications for industry, consulting and farmers. As far as the industries and research and development laboratories of PA technologies are concerned, this study can be of help for in-depth analysis on the composition and characteristics of their reference group. However, several limitations of the research must be mentioned. First, the sample cannot be considered representative of the entire population of Italian farmers. Furthermore, the use of wording for the first “Precision Agriculture” key question could be interpreted slightly differently among farmers. The research aims to be a starting point for any future work in order to better understand the composition of the sample of Italian adopters as there are no updated census data on the use of technologies. Future research will need to explore more deeply why so many farmers have never heard of PA. Furthermore, for policy makers there are still very large margins of intervention to spread knowledge and educate farmers to know the advantages of adopting PA technologies, highlighting their merits in terms of economic profitability for the company, increase in productivity and in terms of environmental sustainability. In this way the PA will be able to constitute a fundamental element for the development of a more resilient agri-food sector.

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