Exploring the impact of innovation adoption in agriculture: how and where Precision Agriculture Technologies can be suitable for the Italian farm system?

G Bucci¹, D Bentivoglio*¹, A Finco¹ and M Belletti¹

¹ Department of Agricultural, Food and Environmental Sciences (D3A), Polytechnic University of Marche Region, Brecce Bianche 60131, Ancona, Italy
*email: d.bentivoglio@univpm.it

Abstract. Starting from the twenty-first century, the digital paradigm has brought with it a new way of thinking about innovation within the firms through the introduction of the Internet of Things (IoT) and the Information and Communications Technology (ICT), keys factors of digital transformation technologies. In addition, the use of Precision Agriculture (PA) has created a new approach to farming practices, allowing farmers to reduce the inputs, while protecting natural resources. Today, also in Italy PA is starting to be an effective technological innovation potentially capable to improve farms efficiency and sustainability. Given these considerations, the present paper aims, firstly, to review the factors more affect the adoption of precision agriculture technologies (PATs); secondly, to investigate where the PATs could be convenient to apply in Italy. A multi-Criteria Decision Analysis method is performed to achieve this goal. The analysis shows that the geographical area more likely to use PATs in Italy is the North East territory. However, in Italy, the adoption of these technologies in agriculture meets various obstacles: the cultural barrier to innovation and a limited awareness of benefits; the reduced average size of farms, with the difficulty of investing in and appreciating the benefits of PATs.

1. Introduction

In Europe innovation is a hot topic and for this reason it has been placed at the heart of the EU’s policies. In the interest of monitor the innovativeness of Members State, EU created a set of indices based on economic, demographic and social performance. According to European Innovation Scoreboard (ESI) 2018 [1], at worldwide level, the most innovative countries are South Korea, Canada and Australia, followed by Japan and United States (Figure 1).
Europe has lasted at 6th position, China lies in the 7th position, Brazil in 8th. At European level, Sweden remains the EU innovation leader, then Lithuania, the Netherlands, Malta, the UK, Latvia, and France are the fastest growing innovators. Finally, Italy still remains a moderate innovator. Within the agricultural scenario, in the last 100 years, innovation through technology has been one of the major factor changing agricultural sector [2, 3, 4]. The concept of innovation is a very broad concept and it has been studied extensively [5, 6, 7]. Thus, during the years, the literature on innovation has coined its own vocabulary and various classification. Focusing on agriculture and according to Sunding and Zilberman (2001) [8], the classification of innovation can be distinguished in three categories, based on:

- policy questions and the forces behind the generation and the adoption of innovation;
- form distinguished between process innovation and product innovation;
- their impact on economic agents and market.

Innovations can fall into one classification or fall into several of these categories. In addition, according to Rogers’ Theory (1962) [9], the adoption of an innovation follows an S curve when plotted over a length of time. The categories of adopters are: innovators, early adopters, early majority, late majority and laggards (Figure 2).

Figure 2. The model of diffusion of innovation by Rogers (1962)

According to Rogers, the causes of poor agricultural performance were essentially due to a low technological development and could be solved by developing and improving these lacks [10]. However, in general, innovation is a complex process and the adoption of new technologies in agriculture is not often immediate [11]. Indeed, the difficulty to apply innovative technologies is due to because farming operators go to meet complex decision-making problems. In order to optimize agricultural process/operations, farmers need to consider a variety of conditions and inputs (water, nutrients, fertilizers, weather, etc.) that can influence the entire agricultural system. Finally, the institutional setup is another important factor to be understanding to innovation activity. In particular, agricultural policy that supports the income of farmers could influence the innovation process. In fact, there is a strong connection between public support for innovation research and programs that support farm income. This could explain the investment in innovation in the agriculture sector.

In this context, thinking about the need of new innovative technologies in agriculture, precision agriculture (PA), is recognized as a major contribution to farm sustainability and innovativeness [12]. PA is a relatively new concept and many definitions of this agriculture exist in literature. In addition, many people have different ideas of what PA should encompass. PA is a “management strategy that uses information technologies to bring data from multiple sources to bear on decisions associated with crop production, designed to increase long term, efficiency, productivity and profitability while minimizing unintended impacts on wildlife and the environment” [13]. The goal of PA research is to “define a decision support system (DSS) for whole farm management with the goal of optimizing returns on inputs while preserving resources” [14]. It is a site-specific management which allows to do the right practice at “the right location and time at the right intensity” [15]. As Auernhammer and Demmel (2015) [16] highlighted, PA can be considered one of the different types of precision land management, which also includes precision forestry and aquaculture. Since 1980s, PA has developed from the use of the first
GPS system and yield maps to the latest applications with controlled traffic farming with RTK systems and UAVs (Unmanned Aerial Vehicles). Nowadays, more advanced technological systems are being developed, such as drones, agricultural robots and Decision Support Systems, so that precision agriculture technologies (PATs) became almost commonplace in America and Australia, compared to Europe and Italy, in which their application is still limited. Nevertheless, the percentage of PA adoption has also increased in Europe, with a rate of 15-20%, and today, also in Italy PA is starting to be an effective technological innovation potentially capable to improve efficiency and sustainability. Given these considerations, the present paper aims to collect the variables that affecting PATs adoption in agriculture and also to investigate where the PATs could be convenient to apply in Italy.

2. Data and Methods

The need for a smarter, more technological agriculture is rapidly spreading among farmers, however several studies came to the conclusion that the adoption of PA is limited both in the USA and in Europe [17,18,19,20,21,22]. Based on the available literature, several factors are found to be significant in affecting the adoption of technological innovations in the agriculture system. These factors are mainly related to the characteristics of the farms and the characteristics of the farm owner. The first factor to consider in determining farmers’ propensity to adopt PATs is the computerization of farms, understood as the computerized management of business processes, which in Italy concerns only 4% of farms. Land size is the second factor to be taken into account: a large land size is usually associated with a higher propensity to adopt Smart Farming Technologies [23, 24]. In fact, larger farms have a higher need for efficiency and this usually induces them to adopt PATs but they also have the possibility to better amortize technology investment costs [25]. This is especially true in USA where the average farm occupies an area of 180 hectares, compared to Europe, where the average stands only on 16 hectares. In parallel, even the presence of Agricultural contractors is relevant in the process of PATs adoption: this is because agricultural contractors have a general knowledge of farming methods and the types of farm machinery used in these operations and generally are used to work in large size farms, so they represent an interesting market segment to catch by technology providers [26]. In fact, contractor services will be used to share new technologies in agriculture, especially in Italy in which are contractors more widespread and in 2017 they arrived to manage the 1/3 of the total Italian farms and the 40% of the Utilised Agricultural Area. Finally, considering the farmer owner’s characteristics, in accordance with Rogers’ Theory, age and education are the most influential factors in the innovation process: younger farmers, the Innovators, show a more innovative attitude, compared to the oldest, the Laggards [27]. In Italy the rate of aging in agriculture is very high compared to other countries: farmers over 65 years represent 40% of the total, in France over 65 are 12%, while in Germany they are only 5%. This demographic structure is obviously reflected on the generational turnover index (the relationship between entrepreneurs aged under 35 and entrepreneurs over 65), which sees Italy in a position of relative weakness compared to the main European countries. Similarly, also the Educational level may influence the probability of investing in PA, because of a higher education may be helpful in enhancing the perceived benefit and usefulness of Smart technologies. In fact, the farmer’s education positively influences even the number of precision technologies adopted. In particular, as Paxton et al., (2010) [28] highlighted, just one additional year of schooling, may correspond to an 8 percent increase in the number of precision technologies adopted. A higher educational level may correspond with higher abilities to utilize these new technologies, with higher willingness to pay for them. Farmers with a higher level of education will be able to correctly interpret information from Big Data and to more understand the same technology language. However, one of the major limitations in the Agrifood sector is the lack of information and therefore, the low awareness of the availability of new farm innovation and of their potential benefits. In this sense, education could provide the right incentive to challenge agriculture practice, by inducing farmers to adopt PATs and raising their willingness to pay for these technologies. It is important to highlight that there are other important factors that could influence the adoption of innovation technology. A significant role is given by the policy that can support the innovation adoption through different measures and programs. In addition, the diffusion of innovation technology could be
influenced by aggregate adoption. The aggregation is seen as one way to increase the chances to compete by generating synergies and play an important role in innovation processes [29]. Precision agriculture management is thus by definition a multi-objective decision-making process that must take into account of different criteria, opinion, data, preference and objective [30, 31]. Considering this definition, it is important to assume that a considerable amount of aspects will be required to understand the feasibility and the possibility to apply this new technology in the agricultural sector. To date, Multi-Criteria Decision Analysis (MCDA) methods are incorporated between the examination and evaluation techniques considered useful by the EU and it is seen as a methodology to identify and support choices aimed at obtaining a sustainable development process [32, 33, 34, 35]. In general, the MCDA is organized in two steps [36]. The first phase includes the construction and compilation of the evaluation matrix, according to the established objective/problem. This matrix consists of the different alternatives, various criteria and different weightings. The second phase regards the processing of the data in the evaluation matrix used to assess the alternatives via a variety of different procedures. In details, the MCDA method described in this study has been used, in conjunction with factors (Criteria) collected by literature relating to the main variables influencing the adoptions of PATs, for identification of geographical areas (alternatives) more likely to use these technologies in Italy.

The MCDA in our study, was carried out using the software ‘Definite 3.1’ [37]. In details, the aim was to identify among the different geographical area of Italy (North East, North West, Central, South and Islands) the best alternative in which apply innovation technologies. The alternatives considered were identified on the basis of the different precursory criteria for the adoption of PATs that are: the farms size (>20 ha), the use of contractors, the computerization of the farm (digitalization/digital farms), the age (between 18-40) and the degree of education (qualifications). All the data were obtained from ISTAT census 2010. Therefore, a summary table (Table 1) was created to represent our evaluation matrix, which shows the average values for each criterion chosen for the different alternatives.

| CRITERIA       | Farms (>20 ha) | Contractors | Digital farms | Age 18-40 | Qualifications |
|----------------|----------------|-------------|---------------|-----------|----------------|
| North East     | 18             | 2           | 9             | 13        | 26             |
| North West     | 14             | 3           | 11            | 11        | 20             |
| Central        | 13             | 1           | 4             | 8         | 28             |
| South          | 7              | 1           | 1             | 9         | 24             |
| Islands        | 18             | 1           | 2             | 13        | 23             |

3. Result and Discussion

After the design and quantification of the evaluation matrix, the data entered in the matrix were standardized per column. The method used for the all criteria is defined as ‘maximum standardization’. In this context, an equal weight was given to the farms size (>20 ha), the use of contractors, the age (between 18-40) and the degree of education (Qualifications) because they were considered of equal importance. On the contrary, a different weight is given to the computerization (Digital farms) because this factor has been identified by the literature as the main precursor factor for the adoption of PATs. According the studies of Daberkw and McBride (2003) and Isgin et al. (2008) [38, 39], the use of the computer use is a predictor for the adoption of PATs, because it is supposed that a farmer who already uses a computer to manage company data will be more inclined to adopt a more developed technology in the near future. The results from our MCDA are shown in a graphic form (Figure 3). The analysis shows that the geographical area more likely to use PATs in Italy is the North East territory.
This area, in fact, recorded the best performance for two criteria including computerization that assumes a much higher value than the other criteria. However, also the North West register a good performance, followed by Islands and central territory that show similar performance. These results are confirmed by the various applications of PA in Northern Italy [40, 41], which mainly concern rice cultivation and fruit trees. Relating to the Islands, these territories have good potential to apply these new technologies. Indeed, Islands recorded the best performance for two criteria that are big land size and younger farmers. Nevertheless, the presence of digital farms is low, even if different projects with PATs are already being applied [42]. For these reasons, the digital providers could decide to invest in these geographical areas. Finally, the South is positioned at the last place because of it register the lowest level of computerization.

4. Conclusion

Today, also in Italy PA is starting to be an effective technological innovation potentially capable to improve efficiency and sustainability of agriculture. However, Italy continues to suffer a considerable delay in the use of PATs compared to most European Union countries (Currently, only 1% of Italian utilized agricultural areas are managed through PA technologies). Despite the lack of propensity for the use of technologies in farms, the times seem ripe for a technological change in the Italian agricultural context; and this is evidenced by the fact that, according to the Smart AgriFood Observatory, among the 480 new firms supplying technologies for agriculture born since 2011 to date worldwide, 15% are Italian firms providing technological solutions to improve efficiency and sustainability for agricultural production. It is clear that on the market the increasing offer of technology for agriculture does not match the demand for ICT from farmers. Italy is at the top for available technology, but the farms are, not “smart”. This study highlights that the adoption of PATs depends on different factors, especially the computerization. In addition, the limited average size of farms, with the difficulty of investing in and appreciating the benefits of precision technologies represent a barrier to innovation. Finally, most of the
farmers already using this technology face many difficulties in managing such a large amount of data collected by PATs and in using technologies efficiently. The main problem is how to decode the data since there exist many interpretations. In the next years, it will be meaningful to develop more simple practical technologies in order to support the farmer in making decisions and educate farms to innovate. Of course, this would not be possible without the support of policies that enable innovations to materialize.

References
[1] Hollanders H and Es-Sadki N 2018. European Innovation Scoreboard 2018 Publications Office of the European Union, Luxembourg
[2] Schultz T W 1964 Economics 37 (1): 47-61.
[3] Cochrane W W 1979 The development of American agriculture: A historical analysis U of Minnesota Press.
[4] Reardon T, Echeverría R, Berdegué J, Minten B, Liverpool-Tasie S, Tscharley D and Zilberman, D 2018 Agricultural Systems. (In Press)
[5] Touzard J M, Temple L, Faure G and Triomphe B 2015 Journal of Innovation Economics Management 2: 117-142.
[6] Marotta G, Nazzaro C and Stanco M 2017 Journal of Globalisation and Small Business 9 (2-3): 144-167.
[7] Blanc S, Accastello C, Girgenti V, Brun F and Mosso A 2018 Calitatea 19 (165): 139-142.
[8] Sunding D and Zilberman D 2001 Handbook of agricultural economics 1: 207-261.
[9] Rogers E M 1962 Diffusion of innovations (1st ed.) New York Free Press.
[10] Guerin L J and Guerin T F 1994 Australian Journal of Experimental Agriculture 34 (4): 549-571.
[11] Pierpaoli E, Carli G, Pignatti E and Canavari M 2013 Procedia Technology 8: 61-69.
[12] Aubert B A, Schroeder A and Grimaudo J 2012 Decision Support Systems 54: 510–520.
[13] National Research Council 1997 Precision Agriculture in the 21st Century: Geospatial and Information Technologies in Crop Management. Washington, D.C., USA: National Academy Press.
[14] McBratney A, Whelan B, Ancev T and Bouma J 2005 Precision agriculture 6 (1): 7-23.
[15] Gebbers R and Adamchuk V I 2010 Science 327 (5967): 828-831.
[16] Auernhammer H and Demmel M 2015 State of the Art and Future Requirements. In Qin Zhang (Ed) Precision Agriculture Technology for Crop Farming CRC Press USA.
[17] Daberkow S G and McBride W D 2003 Precision agriculture 4 (2): 163-177.
[18] Fountas S, Blackmore S, Ess D, Hawkins S, Blumhoff G, Lowenberg-Deboer J and Sorensen C G 2005 Precision Agriculture 6 (2): 121-141.
[19] Pedersen S M and Lind K M 2017 Precision Agriculture: Technology and Economic Perspectives Springer International Publishing.
[20] Bucco G, Bentivoglio D and Finco A 2018 Calitatea, 19 (S1): 114-121.
[21] Barnes A, De Soto I, Eovy V, Beck B, Balafoutis A, Sánchez B and Gómez-Barbero M 2019 Environmental Science & Policy 93: 66-74.
[22] Barnes A P, Soto I, Eovy V, Beck B, Balafoutis A, Sánchez B and Gómez-Barbero M 2019 Land Use Policy 80: 163-174.
[23] Walton J C, Lambert D M, Roberts R K, Larson J A, English B, Larkin S L and Reeves J M 2008 Journal of Agricultural and Resource Economics 33(3): 428-448.
[24] Lambert D M, Paudel K P and Larson J A 2015 Journal of agricultural and resource economics 40 (2): 325-345.
[25] Castle M H, Lubben B D and Luck J D 2016 Factors influencing the adoption of precision agriculture technologies by Nebraska producers. University of Nebraska-Lincoln Digital Commons Presentations Working Papers and Gray Literature Agricultural Economics 49
[26] Taylor J A, McBratney A B, Viscarra Rossel R A, Minasny B, Taylor H J, Whelan B M and Short
M 2006 Development of a multi-sensor platform for proximal soil sensing. In *18th World Congress of Soil Science July* (pp. 9-15).

[27] Botsiou M G, Koutsou S and Dagdilelis V 2014. *Scientific Bulletin–Economic Sciences* **13**: 2-12.

[28] Paxton K W, Mishra A K, Chintawar S, Roberts R K, Larson J A, English B C and Martin S W 2011 *Agricultural and Resource Economics Review* **40**(1):133-144.

[29] Bentivoglio D, Giampietri E and Finco A 2016-*Quality-Access to Success* **17**(1): 57-63.

[30] Jones D and Barnes E M 2000 *Agricultural Systems* **65**(3): 137-158.

[31] Finco A, Bentivoglio D and Bucci G 2018 *Economia Agro-Alimentare/Food Economy* **20**(2):181-192.

[32] Nijkamp P and van Delft A 1977 *Multi-criteria analysis and regional decision-making* Springer Science & Business Media Volume **8**.

[33] Rehman T and Romero C 1993 *Agricultural systems* **41**(3): 239-255.

[34] Kiker G A, Bridges T S, Varghese A and Seager T P, Linkov I 2005 *Integrated environmental assessment and management* **1**(2): 95-108.

[35] Finco A, Bentivoglio D and Nijkamp P 2012 *International Journal of Foresight and Innovation Policy* **8**(2/3): 173-188.

[36] Janssen R 1992 *Multiobjective Decision Support for Environmental Management*, Environment and Management Kluwer Academic Publishers Dordrecht Netherlands.

[37] Daberkow S G and McBride W D 2003 *Precision Agriculture* **4**(2): 163-177.

[38] Isgin T, Bilgic A, Forster D L and Batte M 2008 *Computers and Electronics in Agriculture* **62**: 231-242.

[39] Stroppiana D, Migliazzi M, Chiarabini V, Crema A, Musanti M, Franchino C and Villa P 2015 Rice yield estimation using multispectral data from UAV: A preliminary experiment in northern Italy. In *2015 IEEE International Geoscience and Remote Sensing Symposium (IGARSS)* (pp. 4664-4667). IEEE.

[40] Nutini F, Confalonieri R, Crema A, Movedi E, Paleari L, Stavrakoudis D and Boschetti M 2018 *Computers and Electronics in Agriculture* **154**: 80-92.

[41] Zambon I, Delfanti L, Marucci A, Bedini R, Bessone W, Cecchini M and Monarca D 2017 *Agriculture* **7**(7): 56.