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ADOPTION OF PRECISION FARMING TECHNOLOGIES: USA AND EU SITUATION

Review Article

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Abstract

Through this article, the author aims to identify the adoption rates and types of precision farming technologies embraced by farmers in the USA and the EU. Research papers in relation to the adoption of precision agriculture technologies were collected and divided into two groups, according to their geographic region: USA and EU. Books, scientific articles, reports and conference papers were reviewed and studied. Likewise, the material about the adoption of precision agriculture technologies was accumulated. The level of adoption in the USA differs from one state to another. The percentage rate of adoption is higher in the Southern States, and the overall adoption of precision agriculture technologies reaches to about 91%. United Kingdom, Denmark and Germany have higher rates of adoption compared with other countries in the EU. Similarly, the percentage rate of adoption is higher in the USA in comparison with EU countries. In the USA prevails a diversification of precision agriculture technologies adopted by US farmers. On the contrary, in the EU, the majority of research papers reported mainly some level of adoption of yield monitors/mapping and variable rate technologies for applying inputs.

INTRODUCTION

Precision agriculture was first defined in 1997 from US House of Representatives as: "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 minimizing unintended impacts on wildlife and the environment" (Whelan & Taylor, 2013). Correspondingly, the European Parliament has defined precision agriculture as "a whole-farm management approach using information technology, satellite positioning (GNSS) data, remote sensing and proximal data gathering" (European Parliament, 2014).

In 2016 the global market value of smart agriculture was approximately five billion dollars and it is expected to grow to 15 billion dollars by 2025 (Statista, 2018). Simultaneously, it has revealed progressive signs in the last decade in countries like United States, Germany, United Kingdom, France and other developed countries, which by utilizing the information technology and evolving precision farming techniques appropriate for their region and farm structure have overcome the encounters related with precision nutrition management (Khosla, 2010).

However, the adoption of these technologies is a challenging subject for policymakers, extension services, farmers and agri-businesses due to barriers that need to be addressed ranging from infrastructure in rural areas, heterogeneous farming types, significant investment costs, and its use requires the provision of advisers/consultants specialized in data creating competition among the current advisers/consultants as a result (Kritikos, 2017). Similarly, the diversity of agriculture around Europe concerning the farming practices, farm size, types of farming, employment and output presents a challenge for European policymakers, considering the fact that prospects and apprehensions vary from one member state to another (Schrijver, Poppe, & Daheim, 2016) From the management approach, precision agriculture is composed by four elements: geographical positioning (GPS), gathering information, decision support and variable rate treatment, and since the late 1980s, the combination of GPS (global positioning system) and GIS (geographical information systems) with yield monitors and maps advanced in several directions and its term has sheltered various technical resolutions (Pedersen & Lind, 2017). Precision farming is considered as the latest technological movement applied in agriculture. Similarly, it is a combination of technologies which current adoption level is partial, with 1,600 flotation fertilizer-application systems, map driven variable rate technology (most commonly used technology), and on-the-go sensor tractor based application systems sold (NAS, 1997). Presently, agriculture contributes to 3.5% of total world GDP (World Bank, 2017). It indicates an irrelevant role in the economies of EU member states, accounting for around 2% of GDP and only 5% of EU employment yet its impact on the environment is more substantial presenting 45% of EU total land use and up to 30% of total water use (Parris, 2001). Agriculture has faced prominently changes over the last years on a global foundation. The development of technology associated with new types of machinery, a high specialization of agriculture experts, and the government policies to encourage and expand the production has facilitated the operating process of farmers worldwide, resulting in high revenues and less cost. To survive in a highly competitive market, and become more profitable by using fewer sources, embracing agricultural technologies is seen as crucial. The size of the farm, age of farmers, household incomes and long work experience of farmers has a significant effect on the adoption of precision farming (Paustian & Theuvsen, 2017; Barnes, et al., 2018). Correspondingly, farmers in developing countries are facing challenges on adopting these technologies due to the high entry cost, thus those farms associated with high household incomes are more likely to adopt them (Barnes, et al., 2019). On the other hand, it cannot be said the same for developed countries where the adoption rate is higher. Similarly, Zhou et al. (2017) reported that in Southern US, 73.5% of farms used precision farming technologies, and from 1,811 survey responses, 1,331 respondents used at least one or more precision farming technologies. Moreover, in Asia Pacific countries, China, Japan, India and Australia are leading in the adoption of precision agriculture technologies (Mordor Intelligence, 2018). However, there were not found any research papers that report the adoption rates and trends of precision agriculture in China and Japan. The highest percentage rate of adoption is presented in Australia (POST, 2015), Canada (Mitchell, Weersink, & Erickson, 2018) and Brazil (Islam, Bagchi, & Hossain, 2007). Other countries such as: Argentina, India, Egypt, South Africa, Malawi and Ethiopia have some level of adoption.

The leading obstacle in precision farming is to become an essential part of the farming daily operations and be managed in an accurate mean (Mcbratney, Whelan, Ancev, & Bouma, 2005). Consequently, various studies show that the adoption of precision farming technologies is affected by several factors such as:

a. *Farm size* – Larger farmers have a higher tendency to adopt these technologies due to the capacity to absorb costs and risks (Tey & Brindal, 2012).
b. *Socio-economic factors such as age, education, and experience* – Socio-economic factors can influence the use of precision agriculture

technologies. Old, less educated farmers with less years of farming experience are less likely to adopt precision agriculture technologies (Barnes, et al., 2019).

c. *Financial Status* – As the main limitations of the adoption of precision farming technologies, lack of finance and credit facilities have been acknowledged (Maheswari, Ashok, & Prahadeeswaran, 2008).
d. *Technological factors* - Producers that have a high level of mechanization technology and adoption of various technologies are more likely to adopt them (Antolini, Scare, & Dias, 2015).
e. *Information sources* – Likewise, Tey & Brindal (2012) showed that in the use of technologies, including irrigation facilities, PAT's, and computers technological factors may personalize a number of indicators

A similar research was done in 2017 with the purpose to review the adoption of precision agriculture technologies in developed and developing countries, and based on their findings, adoption of PAT is more present in developed countries specifically in US but also some developing countries have an increasing adoption rate in the last years (Say, Keskin, Sehri, & Sekerli, 2017).

The objective of this article is to review the research papers on the adoption of precision agriculture technologies and the main technologies embraced by farmers in the USA and EU, and discuss trends in recent years, in the adoption form.

MATERIALS AND METHODS

The study concentrates on the results of secondary data based on different literature sources such as books, journal articles, conference proceedings and reports. Secondary analysis is defined as" The reanalysis of existing data for exploratory, explanatory, or descriptive purposes" (Thyer, 2010). This article analyzes the adoption rates and types of precision agriculture technologies adopted by farmers in the USA and the EU. Research papers in relation to the adoption of precision agriculture technologies were collected and divided into three groups, according to their geographic region: USA and EU.

Books, scientific articles, reports and conference papers were reviewed and studied. Similarly, the material about the adoption of precision agriculture technologies was accumulated. Furthermore, there may be other countries that have adopted precision farming technologies, but are not mentioned in research papers. Consequently, this paper gives a general overview of the adoption of precision agriculture technologies in recent years in different countries, based on the data reported by authors worldwide.

RESULTS AND DISCUSSION

Adoption of precision farming technologies in the USA

In the US, GNSS accounts for 28% of the market (GNSS, 2019). Currently, North America is the largest market in precision farming technologies and the US is leading in the adoption of these technologies (Mordor Intelligence, 2018).

Adoption of precision agriculture technologies varied up to 22% until the 2000s, thus from 1998-2013, the US farms began to use precision farming technologies at different times and crops where the guidance systems had the highest adoption rate, adopted in half of the planted acres in main crops, GPS soil sampling is used more in planted acres such as corn, peanuts and soybeans, and VRT considered as having a high cost of installment and maintains has increased to about a fifth of planted acres of corn, peanuts, soybeans and rice (Schimmelpfennig, 2016).

The level of adoption and the main precision agriculture technologies used in the USA were summarized in (Table 1). The level of adoption in the USA differs from one state to another. The percentage rate of adoption is higher in the Southern States. The adoption rate of VRT for applying inputs reaches to about 80%, yield monitors/yield mapping reaches to about 68%, automated guidance reaches to about 68%, soil sampling with GPS reaches to about 86% and satellite/aerial imagery reaches to about 46.72%. Similarly, Pedersen, Fountas, Blackmore, Gylling & Pedersen (2006) reported that 20,000 US farmers have adopted Yield Monitors. Moreover, according to Lambert et al. (2014) the overall adoption of PA technologies reaches to about 91%.

The level of adoption of VRT exceeds 50%, known as one of the first adopted technologies by farmers, however, farmers are not convinced by its value, thus considered as one of the reasons for the slow adoption of precision agriculture technologies as a result (Lowenberg-DeBoera & Erickson, 2019).

Adoption of precision farming technologies in the EU

In the EU, GNSS accounts for 27% in the market (GNSS, 2019). The level of adoption in EU and the type of PA technologies were summarized in (Table 2). The level of adoption differs from one country to another in Europe. The majority of research papers reported some level of adoption of yield monitors/mapping and variable rate technologies for applying inputs. Machine guidance and GPS steering and for soil sampling are also adopted. However, yield monitors are being adopted rapidly in Denmark, Sweden and Germany but less in France, Belgium and Holland.

According to Mordor Intelligence Report, Germany, France and the United Kingdom are leading in the adoption of PA technologies in the EU (Mordor Intelligence, 2018). This is also shown in (Table 2), where the United Kingdom, Denmark and Germany have higher rates of adoption compared with other countries in the EU. Likewise, Paustian & Theuvsen (2017) reported that 30% of German farmers use precision agriculture technologies and 200 farmers have applied yield monitors on their farm. Similarly, among United Kingdom countries, the highest rate of adoption was in Scotland with an 83% adoption rate, followed by Ireland with 63% adoption rate. Toma et al. (2016) also reported that 43% of Scottish farmers use one technology, 33% of farmers use two technologies, 10% of farmers use three technologies, 9% of farmers use four technologies and 4% of farmers use five technologies precision farming technologies. On the other hand, in Irish farms, the adoption was most detected in dairy farming, and amongst farmers who use mixed farms as well (Das, Sharma, & Kaushik, 2019).

In Hungary, Sweden, Belgium, Holland and France have some degree of adoption of precision agriculture technologies. Although France is considered one of the leaders in the adoption of precision agriculture technologies in the EU, there were not found research studies that report the adoption trends in France. At the same time, 8.9% of Hungarian farmers have applied precision agriculture technologies in their farm. Denmark has had a relatively high adoption rate of yield mapping due to the presence of a pioneering manufacturer of yield monitors (Fountas & Blackmore, 2005). Moreover, Danish farmers who first started to use precision agriculture technologies have principally tried to practice precision farming technologies with wheat and barley crops (80%) and about 30%-40% of the farmers have also tried to use with oilseed rape and grass seed (Pedersen et al., 2006).

In overall, yield monitoring and VRA fertilization has exceeded five percent only in the US and Canada, and adoption rates between one - five percent range may be applicable to Australia, Brazil, Denmark, United Kingdom, and Germany meanwhile only a few yield monitors in South Africa and some VRA fertilization in isolated plantation agriculture reserves, adoption of PA technologies is almost unfamiliar in Africa and Asia (Swinton & Lowenberg-Deboer, 2001).

CONCLUSIONS

Precision farming is considered as the latest technological movement applied in agriculture. Various studies show that the adoption of precision farming technologies is affected by several factors such as: socio-economic factors, farm size, financial status, technological factors and information sources. In this article, the author aims to identify the adoption rates and types of precision agriculture technologies used by farmers in the USA and the EU. Research papers in relation to the adoption of precision agriculture technologies were collected and divided into three groups: USA and EU. Books, scientific articles, reports and conference papers were reviewed and studied. Similarly, the material about the adoption of precision agriculture technologies was accumulated.

The level of adoption in the USA differs from one state to another. The percentage rate of adoption is higher in the Southern States. The adoption rate of VRT for applying inputs reaches to about 80%, yield monitors/yield mapping reaches to about 68%, automated guidance reaches to about 68%, soil sampling with GPS reaches to about 86% and satellite/aerial imagery reaches to about 46.72%. Consequently, the overall adoption of PA technologies reaches to about 91%.

Meanwhile, United Kingdom, Germany and Denmark have higher rates of adoption compared with other countries in Europe. In the USA prevails a diversification of precision agriculture technologies adopted by US farmers. On the contrary, in the EU, the majority of research papers reported some level of adoption of yield monitors/mapping and variable rate technologies for applying inputs.

Based on the findings of Swinton & Lowenberg-Deboer (2001), in overall, yield monitoring and VRA fertilization has exceeded five percent only in the US and Canada, and adoption rates between one and five percent range may be applicable to Australia, Brazil, Denmark, United Kingdom, and Germany meanwhile only a few yield monitors in South Africa and some VRA fertilization in isolated plantation agriculture reserves, adoption of PA technologies is almost unfamiliar in Africa and Asia as a result.

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Tables

Table 1
Adoption level of precision farming technologies in the USA

Country/Region	Adoption level and type of technology	Source
Alabama	Lightbar Guidance (60%); Automated Guidance (27%); VRT(37%); GIS mapping software (1/4 of farmers).	Winstead, et al., (2019)
Kansas	Lightbar guidance (85%); Section Control (70%); Variable Rate Fertility (63%); Variable Rate Seeding (42%); Automated Guidance (68%).	Griffin & Yeager, (2018)
US	Grid sampling (2%); Variable rate Fertilizer Application (2%); Yield Monitors (1%); Yield mapping (1%); Variable rate seed, pesticide application and remote sensing technologies (less than 1%).	Daberkow & McBride, (2000)
US	Applied inputs at a variable rate (22%).	Kotsiri, et al., (2011)
Florida	Lightbar Guidance (40%); Automated Guidance (40%); RTK (80%); VRT (80%); Yield Monitor (60%); GIS mapping software (1/5 of farmers).	Winstead, et al., (2019)
Ohio	38.7% of surveyed farmers have adopted precision farming technologies.	Diekmann & Batte, (2010)
US/Eastern Corn Belt	19% of American farmers own equipment for VR fertilizer applications; 18% of farmers own equipment for VR lime; Yield mapping (67%); Soil sampling with GPS(86%);	Fountas & Blackmore, (2005)
US/14 Southern States	73.5% of farms have adopted precision farming technologies. IG (40.9%); GPSG (67%); VRA (25.3%); ASC(29.3%).	Zhou, et al., (2017)
US	VRT fertilizer single nutrient (70.73%); VRT fertilizer multiple nutrient (64.52%); VRT Lime (62.99%); VRT Pesticide (29.17%); Satellite/aerial imagery (46.72%); Soil Sampling with GPS (71.32%).	Erickson, et al., (2013)
US	GPS Steering is operated on 68% of suitable land.	POST, (2015)
US	70-80% of large corn farms use mapping; 80% of large corn farms use guidance systems; 30-40% use VRT;	Schimmelpfennig, (2016)
US / 12 States	91% have adopted precision agriculture technologies; Precision soil sampling (28.1%-40.5%); Precision Soil Testing (20%).	Lambert, et al., (2014)

Source: Author's own affiliation

Table 2
Adoption level of precision farming technologies in the EU

Country/Region	Adoption level and type of technology	Source
Germany	30% of farms have adopted precision farming technologies.	Paustian & Theuvsen, (2017)
Germany	200 Yield monitors.	Pedersen, et al., (2006)
Sweden	300 Yield monitors; 24 custom operators applying VRA nitrogen using the Norsk Hydro greenness sensor.	Lowenberg-DeBoer, (2003); Pedersen, et al., (2006)
France	50 Yield monitors.	Lowenberg-DeBoer, (2003)
Holland	6 Yield monitors.	Lowenberg-DeBoer, (2003)
Hungary	6.9% of farms use precision farming technologies.	Katalin, et al., (2018)
Belgium	5 Yield monitors	Lowenberg-DeBoer, (2003)
Denmark	37% of Danish farmers own equipment for VR fertilizer; 29% of Danish farmers own equipment for VR lime; Yield Mapping (92%); Soil sampling with GPS(75%)	Fountas & Blackmore, (2005)
Denmark	400 Yield monitors.	Lowenberg-DeBoer, (2003)
Denmark	400 Danish farmers have adopted	Pedersen, et al., (2006)
UK/England	GPS steering (22%); Soil mapping (20%); Variable Rate (16%); Yield mapping (11%).	POST, (2015)
UK/Scotland	83% of farmers have adopted precision agriculture technologies.	Toma, et al., (2018)
UK/Scotland	52% of wheat farms have adopted VRNT; 28% of wheat farms have adopted Machine Guidance; 27% of potato farms have adopted VRNT; 34% of potato farms have adopted Machine Guidance.	Barnes & Eory, (2018)
UK/Ireland	62% of Irish farms have adopted information technologies	V., et al., (2019)

Source: Author's own affiliation.