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Economic, Agronomic, and Environmental Benefits From the Adoption of Precision Agriculture Technologies:

A Systematic Review

Thomas Koutsos, School of Agriculture, Faculty of Agriculture, Forestry, and Natural Environment, Aristotle University of Thessaloniki, Thessaloniki, Greece

Georgios Menexes, School of Agriculture, Faculty of Agriculture, Forestry, and Natural Environment, Aristotle University of Thessaloniki, Thessaloniki, Greece

ABSTRACT

Precision agriculture (PA) as an integrated information- and production-based farming system is designed to delivery high-end technology solutions to increase farm production efficiency and profitability while minimizing environmental impacts on the ecosystems and the environment. PA technologies are technology innovations that incorporate recent advances in modern agriculture providing evidence for lower production costs, increased farming efficiency and reduced impacts. However, the adoption of the precision agriculture technologies has encountered difficulties such as additional application or management costs and investment on new equipment and trained employees. Some of these PA technologies were proven efficient, providing tangible benefits with lower costs and as a result they quickly gained scientific interest. To investigate further the economic, agronomic, and environmental benefits from the adoption of PA technologies a systematic review was conducted, based on the systematic search and evaluation of related eligible articles.

KEYWORDS

Environmental Protection, Farming Efficiency, Innovations in Agriculture, Precision Agriculture

INTRODUCTION

The world's growing demand for food in the long term (Baudron & Giller, 2004) has raised the concern of our ability to meet this need without putting enormous pressure on the world's natural resources and causing environmental damage. Climate change will also greatly impact food supply and demand and tougher environmental conditions, while anticipated resource limitations and increased production costs are putting constantly pressure on crop production systems. The challenge of the adoption of precision agriculture technologies seems to be a 'One-way road' to increase farming efficiency while minimizing environmental impacts (Awan, 2016; Foley et al., 2011).

For the last two decades, technological innovations have been tested to improve farming efficiency and reduce environmental impact (Daberkow & McBride 2003; Robertson et al. 2012; Tey & Brindal

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2012). However, in the beginning, increased implementation costs had limited or uncertain benefits that lead more farmers to be unwilling to adopt available PA technologies on their farms (Castle et al., 2016). Recent studies (Liu et al., 2017; Nawar et al., 2017) on PA technologies indicated that the adoption of this technology can offer increased yields and productivity and also economic returns from reduced agricultural inputs limiting the excessive use of agro-chemicals in accordance with the latest environmental legislation. Individual studies (Calegari et al., 2013; Jayakumar et al., 2017; West and Kovacs, 2017) also focused and demonstrated the economic (monetary), agronomic (yield increase) and environmental benefits (reduction of negative impacts) of adopting PA technologies. These research findings on how data derived from soil characteristics, plant populations and environment can be organized to deliver targeted input applications to crop production systems encourage farmers to step into the new era of digital agriculture (Panagopoulos et al., 2014; West and Kovacs, 2017; Nawar et al., 2017).

In the traditional farm management model each field is treated as a homogeneous area (Srinivasan, 2006), where soil, topographic and environmental conditions are considered to be similar and the inputs are applied uniformly regardless any potential variability or heterogeneity. This approach leads to unwanted explicit economic costs due to inefficient application of inputs, causing also environmental damage due to the surplus of the unused nutrients (up to 30% of total N) that end up to ecosystems and the environment through leaching of water-soluble nitrates (Meisinger & Delgado, 2002), or runoff and gaseous emissions that increase the contamination risk (Follett & Delgado 2002; Hyytiainen et al., 2011; Rodriguez et al., 2011). In this case, the adoption of PA technologies can deliver a more efficient application of inputs under different conditions (Pierpaoli et al., 2013) or apply a single rate of a specific crop input to attain maximum efficiency (Vrindts et al., 2015) to sub-regions of broad similarity, defined as management zones, which regularly provide low or high yields (Fleming et al., 2004).

Criticism of the adoption of precision agriculture technologies has encompassed numerous arguments regarding the measurable benefits of adopting these new technologies (Basso et al. 2011; Stafford 2000,). In many cases, agronomic, economic and environmental benefits from the adoption of PA technologies indeed cannot be certain and they depend on several other factors, such as the farm size (bigger agricultural area income provides higher margin for new technology investments) or more dynamic variables, such the climate or soil conditions. However, many studies have successfully shown tangible benefits from the adoption of PA technologies (Basso et al., 2011; Boyer et al., 2011; Panagopoulos et al., 2014; West & Kovacs, 2017).

To investigate the economic, agronomic and environmental benefits from the adoption of PA technologies a systematic review was conducted to analyze the last decade literature and provide useful insights and reveal trends. The main aim of this study was to highlight the PA technologies that provide the most measurable benefits and be can easily adopted to improve farm productivity and profitability, while minimizing environmental impacts.

MATERIALS AND METHODS

Study Design

For this systematic review a comprehensive protocol was developed and approved by all the authors. All steps for performing atypical systematic review were followed (Prisma, 2009): (1) scoping (development of a review protocol); (2) planning (development of the search strategy, selection of digital data sources); (3) identification/Searching (executing the search and check the resulted articles); (4) screening (management of citations and remove duplicates); (5) eligibility/Assessment (inclusion/exclusion criteria, quality assessment of the included articles and assessment of bias); and (5) presentation/interpretation (synopsis of findings, discussion and presentation of the results).

Introducing Activity-Based Costing in Farm Management: The Design of the FarmBO System

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