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Agricultural advantages in soil management practices generated from the use of precision

agriculture techniques. Literature review

Vantagens agrícolas em práticas de manejo de solo geradas a partir do uso de técnicas de agricultura de precisão. Revisão de literatura

Ventajas agrícolas en las prácticas de manejo del suelo generadas mediante el uso de técnicas de agricultura de precisión. Una revisión bibliográfica

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Abstract

The growing demand for food production, the economic importance of agricultural activities, and the concern with preserving natural resources justify the use of new technologies intended to increase productivity per unit area, reduce production costs, and minimize environmental impacts. Given this, in recent decades, the use of technologies related to Precision Agriculture (AP) became a viable alternative, spreading frantically in the various agricultural activities, encompassing, above all, the great cultures of agribusiness crops such as sugar cane, soy, corn, and cotton highlighting the tools and input application techniques at variable rates on the ground. Therefore, this work aimed to carry out a literature review of the last ten years' main technical/scientific publications related to soil fertility management from application techniques of input at variable rates, emphasizing agronomic results from the use of AP tools.
KEYWORDS: site-specific management; agricultural technologies; variable rate application.

Resumo

A crescente demanda por produção de alimentos, a importância econômica das atividades agrícolas e a preocupação com a preservação dos recursos naturais, justifica o uso de novas tecnologias que visem aumentar à produtividade por unidade de área, tornou uma alternativa viável, se difundindo de maneira frenética nas diversas atividades agrícolas, englobando, sobretudo, as grandes culturas do agronegócio tais como a cana-de-açúcar, a soja, o milho e o algodão, com destaque para as ferramentas e técnicas de aplicação de insumos em taxas variáveis no solo. Objetivou-se com este trabalho realizar uma revisão bibliográfica sobre as principais publicações técnico/científicas dos últimos 10 anos, relacionadas ao manejo da fertilidade do solo a partir de técnicas de aplicação de insumos em taxas variáveis, enfatizando aos resultados agronômicos, econômicos e ambientais obtidos a partir do uso das ferramentas de AP.
PALAVRAS-CHAVE: manejo de sítio específico; tecnologias agrícolas; aplicação em taxas variáveis.

Resumen

La creciente demanda por la producción de alimentos, la importancia económica de las actividades agrícolas y la preocupación con la preservación de los recursos naturales justifican el uso de nuevas tecnologías destinadas a aumentar la productividad por unidad de área, reducir los costos de producción y minimizar los impactos ambientales. Teniendo en cuenta esto, en las últimas décadas, el uso de tecnologías relacionadas con la Agricultura de Precisión (AP) se convirtió en una alternativa viable, extendiéndose frenéticamente en las diversas actividades agrícolas, abarcando, sobre todo, las grandes culturas de cultivos agroindustriales como la caña de azúcar, soja, maíz y algodón destacando las herramientas y técnicas de aplicación de insumos a tasas variables sobre el terreno. Por lo tanto, este trabajo tuvo como objetivo realizar una revisión bibliográfica de las principales publicaciones técnico-científicas de los últimos diez años relacionadas con el manejo de la fertilidad del suelo a partir de técnicas de aplicación de insumos a tasas variables, enfatizando los resultados agronómicos a partir del uso de herramientas de AP.
PALABRAS CLAVE: manejo sitio-específico; tecnologías agrícolas; aplicación a tasa variable.

1. Introduction

The food security of current and future generations is a challenge increasingly imposed on the agricultural and livestock sector. Over the last two decades, the popularization of precision agriculture has been driving the emergence of new tools and agricultural techniques, providing the sector to reach productivity levels not reached before, in compliance with the precepts of environmental sustainability.

Precision agriculture is considered a new philosophy of agricultural management (Batista, 2016) and has its principal field of action in soil fertility management, from systematic procedures for inspection and diagnosis of the spatial variability of soil attributes (Haghverdi *et al*., 2015), allowing the improvement of intervention techniques from the application of inputs in the correct places and the exact amount (Manzatto *et al*., 1999) thus promoting greater economic, agronomic and environmental sustainability to agricultural production (Sátiro *et al*., 2019) and a new way of meeting the nutrition needs of crop plants, according to Liebig's Minimum Law (Molin *et al*., 2015).

Therefore, knowledge of the spatial variability of soil attributes is an essential tool for decision-making, allowing to increase in the precision of crop management from localized interventions in specific regions with application techniques in varying doses (Carneiro, 2016; Santos *et al*., 2017; Gelain *et al*., 2021; Santos Júnior *et al*., 2021). Hence, mediation of soil management using precision farming techniques has become a fundamental strategy to increase crop productivity and efficiency in using natural resources and reduce the impact of agriculture on the environment.

In another sense, conventional soil management practices can over or underestimate the need for tillage input application because they treat tillage as uniform, considering the average need of an area for fertilizers and correctives (Sanchez *et al*., 2012), not observing the spatial variability of soil attributes.

In the last years, the use of precision agriculture tools and techniques, especially the application of inputs at variable rates in the soil, has become an object of study in Brazil, promoting several technical and scientific publications on the subject, especially those that compare modern practices of soil management improvement with traditional practices of conventional agriculture, disseminating information relevant to knowledge, understanding, and comprehension, by the various sectors of society, about the economic, agronomic, and environmental benefits generated from the adoption of techniques for rational use of agricultural inputs, mediated by the tools of precision agriculture.

The work intends to present a compilation of 10 years (2012-2022) containing the main technical and scientific publications on soil fertility management from variable-rate input application techniques, emphasizing the agronomic, economic, and environmental results obtained from the use of precision agriculture tools in Brazil.

2. Literature review

2.1 History, concepts, and definitions of precision agriculture

Precision agriculture starts with exact and precise information to perform agricultural management with accurate decision-making since its technologies allow the producer to observe the productive field meter by meter, considering that each area of the rural property has different properties (Roza, 2000).

The context of precision agriculture emerged in the late 20th century because of the development and availability of technologies related to the global positioning system (GPS), yield sensors, remote sensing techniques, and variable-rate input application systems (Amado y Santi, 2007).

McBratney *et al*. (2005) stated that precision agriculture was constantly evolving, becoming popularized from different terms such as 'variable rate technologies', 'vehicle steering systems', 'crop and soil fertility mapping'," and 'site-specific management'.

Antuniassi *et al*. (2015) stated that the tools were diverse, including satellite mapping, autopilot, aerial photography, georeferenced soil sampling, variable rate application of correctives and fertilizers, crop mapping, and others.

All these technologies incorporated into the management and production process have

expanded the ability to understand the variability of agricultural production factors, allowing their characterization and management through interventions with greater agronomic precision (Bernardi *et al*., 2014), spreading and popularizing PA from the primary perspective of increasing agricultural productivity and reducing input costs, making its adoption frenetic in the various regions of Brazil (Batista, 2020), especially in the main crops of Brazilian agribusiness.

In another sense, precision agriculture can be implemented in rural properties of low technological level (Batista, 2020), considering that it presents several approaches and possibilities for the improvement of crop management without the need, many times, for significant investments for the acquisition of machinery and equipment embedded with high technology.

Therefore, precision agriculture can be applied to small, medium, and large farms as a management tool and improvement. Its techniques enable achieving positive results towards the reduction of territorial expansion, mitigation of environmental impacts, reduction in production costs, and increase in productivity and quality of crops (Machado *et al*., 2018).

2.2 Agricultural advantages gained from applying inputs at variable rates

Santos *et al*. (2012) conducted research in the municipality of São Mateus, ES, on a dystrophic Red-Yellow Latosol cultivated with black pepper (*Piper nigrum* L.) to analyze the spatial variability of soil and crop chemical attributes. The authors concluded that the spatial assessment was a relevant tool in understanding the behavior of nutrients in the soil and can be essential to assist in decision-making aimed at greater agricultural crop productivity.

Research developed by Caon & Genu (2013) in a 48-hectare soybean crop located in the region of Guarapuava, PR, to compare the efficiency of different sampling densities for both the characterization of spatial variability of soil fertility and the recommendation of soil amendments and fertilizers, indicated that a sampling grid of one (1) point per hectare allowed the preparation of reliable and representative maps of the crop area and that this density promotes the rational use of inputs when compared to conventional soil sampling methods.

Zonta *et al*. (2014) developed research in Cristalina, GO, to evaluate the spatial variability of soil fertility attributes in a Yellow Red Latosol under cotton cultivation in the no-tillage farming system with an area of 57.6 hectares. The authors highlighted that the spatial variations of soil attributes should be taken into account for planning and decision-making regarding management practices and concluded that, due to the conditions of the research area, it would be recommended to apply lime at variable rates since base saturation and pH presented reliable and representative spatial variability maps of the cultivation area.

In the city of Três Pontas, Minas Gerais, Brazil, in an area of red dystrophic clayey Latosol with 22 hectares of coffee plantations, Ferraz *et al*. (2015) conducted a study to compare fertilizer recommendations based on conventional soil sampling and square-mesh sampling. As a result, the authors observed a decrease of up to 25.7% in total fertilizer use from the precision agriculture technique. This result denotes, in addition to savings, the rational use of inputs, and less environmental impact.

A study published by Richart *et al*. (2016) was conducted in the municipality of Terra Roxa in Paraná to evaluate the spatial and temporal variability of productivity and chemical attributes of a Red Eutroferric Latosol in a commercial soybean area of 41.68 hectares cultivated in the no-till farming system (SPD) and with precision agriculture for ten years, concluded that the localized management and at variable rates homogenized and increased the average pH, K+, and V% contents over the years. The authors also pointed out that the management promoted the reduction of tillage spots, homogenizing, and increased productivity.

Almeida *et al*. (2016) evaluated two forms of soil sampling, the first following Conventional Agriculture (CA) characteristics and the second according to precision agriculture principles. The study was conducted in Bela Vista do Paraiso, PR, in an area of 8.34 hectares with acidic Red Latosol. The authors concluded that through PA, it is possible to generate maps showing the true variability in the

soil, indicating the areas of low and high fertility, resulting in the rational use of fertilizers.

In the municipality of Três Pontas, MG, in an area of clayey red dystrophic Latosol with 22 hectares of coffee plantation, Ferraz *et al*. (2016) compared soil fertility diagnosis from conventional and mesh sampling methods. According to the authors, unlike conventional sampling, georeferenced mesh sampling allowed the identification of the spatial variability of soil attributes, thus allowing the interpretation of the different fertility classes in the evaluated area. However, the authors also stated that conventional sampling could induce the rural producer to an error in the intervention phase when considering the average element contents for the recommendation of correctives and fertilizers.

Silva *et al*. (2015) compared the liming and fertilizer recommendations from the conventional and systematic sampling methods in a yellow-red Latosol under pasture in the municipality of Alegre, ES. The limestone recommendation by the conventional method provided unnecessary limestone additions in more than 80% of the area and insufficient additions in 15% of the area. In the recommendation of P_2O_5 by the systematic method, more than 90% of the area needed additions below the recommended by the conventional method. In contrast, the recommendations of K_2O by conventional sampling resulted in excessive doses in more than 90% of the area. The analysis of the data by the spatial method made it possible to identify zones of deficit and excess liming and fertilizer recommendations in the area, which could not be defined with the conventional tillage method.

Research conducted in Gilbués, Piauí, Carneiro *et al*. (2016) characterized the spatial variability of the chemical attributes of a dystrophic Red Latosol of clayey texture in an area of 24.31 hectares of conventional soybean (*Glycine max* (L.) Merrill) cultivation to recommend fertilizers and correctives at variable rates in the soil. The authors concluded that the management adopted allowed reduced costs with fertilizer and soil correction concerning the adoption of conventional techniques that standardize average values of soil fertility indicators by plots, mistakenly considered homogeneous.

In São Carlos, São Paulo, Santos *et al*. (2017) developed an experiment to define Management Zones (MZ) in a yellow-red dystrophic Latosol in a 1.6-hectare pasture area of Tanzania grass. The authors concluded that the definition of the MZs provided knowledge about the productive potential of each region of the evaluated area. According to the authors, the definition of management zones in a crop area can increase the efficiency of using natural resources and agricultural inputs, reducing the impact of agriculture on the environment, and generating savings for the rural producer.

Dalchiavon *et al*. (2017), in research conducted in the city of Campo Novo do Parecis, Mato Grosso, in a typical dystrophic Red Latosol with an area of 5 hectares of soybean cultivation under no-till, evaluated the spatial variability of soil attributes and crop productivity and concluded that the study of the variability of soil attributes as well as the adoption of techniques that assist in soil management, such as geostatistics, is essential to proper plant development.

Bernardi *et al*. (2018) conducted, in the city of São Carlos, São Paulo, in an experimental area of EMBRAPA with dystrophic Red Yellow Latosol of medium texture, with 1.7 hectares of pasture milk production system research that aimed to map and evaluate the spatial variability of soil properties after liming and application of phosphate fertilizer at variable doses. The authors also evaluated the production cost of this pasture area. They concluded that the technology of applying limestone and simple superphosphate at variable rates contributed to the increase in pH, P, Ca2+, Mg2+, and V% values and homogenized these attributes in the evaluated area.

In the city of São Carlos, SP, Bernardi *et al*. (2019) conducted between the 2015/6 and 2018/9 crops in an area with Red-yellow Latosol research to evaluate the application of limestone and phosphate fertilizer at variable rates in an Integrated Crop-Livestock-Forestry system with 30 hectares of cultivation. The authors concluded, at the end of the four years of research, that the application of lime and phosphate fertilizer at variable rates was efficient in correcting, fertilizing, and homogenizing the chemical attributes of the soil, besides highlighting that the doses gradually

decreased over the years from the fertility building in the area evaluated.

Amorim *et al*. (2019) performed the economic and risk evaluation of fixed-rate by average and variable-rate fertilizer application systems in sugarcane culture in an area of 80 hectares in the municipality of Ribeirão Preto, SP. The results indicated that the average P_2O_5 application recommendation would result in the application of 12.800 kg of the input, while with variable rate application, 2282.50 kg of the product would be saved (17.83%). These results allow us to infer that there are savings using inputs from localized management and variable rates.

Matias *et al*. (2019) evaluated the efficiency of different sampling meshes in characterizing soil chemical attributes. They recommended the necessity for agricultural correction in a yellow Argissolo in an area intended for soybean cultivation in the Corrente municipality in Piauí. The authors concluded that diagnosing soil fertility from PA techniques and with a higher information density provided significant savings in using inputs compared to the fixed-rate application from conventional soil sampling techniques.

Batista (2020) characterized the spatial variability of the chemical attributes of a Quartz Neosol in the city of Vilhena, RO, and, with the help of Geostatistics, defined two homogeneous management zones in a 3.2-hectare crop of urucum (*Bixa orellana* L.). The author concluded that the soil management improvement technique of variable-rate liming between homogeneous zones promoted increased homogenization of the crop's seed yield.

3. Final consideration

Precision agriculture is underway in Brazil. In the last ten years, there has been great dissemination and popularization of the term and its main tools, especially those related to improving soil management.

The leading scientific publications in the last ten years related to soil management mediated by the techniques and tools of precision agriculture are unanimous in highlighting the savings in the use of inputs and natural resources, the increase and homogenization of productivity, and the minimization of environmental impacts as the main advantages arising from the adoption of PA.

Scientific studies that show agronomic, economic, and environmental results adjusted to the local realities of the different Brazilian regions are fundamental for the popularization and diffusion of the adoption of precision agriculture practices.

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