Scientia Agraria Paranaensis – Sci. Agrar. Parana.
ISSN: 1983-1471 – Online
DOI: https://doi.org/10.18188/sap.v20i2.24946

PRECISION AGRICULTURE: SOYBEAN CULTURE IN SOUTH BRAZIL

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SAP 24946 Received: 16/05/2020 Accepted: 24/01/2021
Sci. Agrar. Parana., Marechal Cândido Rondon, v. 20, n. 2, apr./jun., p. 97-111, 2021

ABSTRACT - The objective of describing the scientific production on precision agriculture for soybean cultivation in southern Brazil. Integrative review developed in five stages: 1) to identify research problems: what is the scientific production on precision agriculture for the soybean economy in Brazil, 2) data collection, 3) data evaluation, 4) analysis and interpretation of data and 5) presentation of results. 19 articles appeared, published in the period from 2011 to 2019. All involve the study of soy, created in Latosol, Cambisolo and Argisolo; study areas ranging from 1.74 to 225 hectares; predominance of no-tillage carried out over ten years; crop rotation in summer and winter. As topics addressed: Physiological quality of soybean seeds; Sowing of soybeans; Chemical and physical attributes of the soil; Spectral indices during soybean growth; Weeds and pest control. There was greater emphasis on technologies: digital maps, machinery, tests, computer systems / programs, software, georeferencing, soil analysis, electronic meters, digital images, equipment and optical sensors. The tools used in precision agriculture are important for professional qualification, increased reduction, environmental impacts, sustainability, optimization of time and products and services, cost reduction.
Keywords: productivity, technology, grains.

AGRICULTURA DE PRECISÃO: CULTURA DE SOJA NO SUL DO BRASIL

RESUMO - O objetivo desta revisão foi descrever a produção científica sobre agricultura de precisão para eficiência na cultura da soja no sul do Brasil. A revisão integrativa foi desenvolvida em cinco etapas: 1) formulação do problema de pesquisa: qual é a produção científica sobre agricultura de precisão para eficiência na cultura da soja no sul do Brasil, 2) coleta de dados, 3) avaliação dos dados, 4) análise e interpretação dos dados e 5) apresentação dos resultados. Emergiram 19 artigos, publicados no período de 2011 a 2019. Todos envolveram a produtividade da soja, desenvolvidos em Latossolo, Cambissolo e Argisolo; áreas de estudo com variação de 1,74 a 225 ha; predominância do plantio direto realizado a mais de dez anos; rotação de culturas no verão e inverno. As temáticas abordadas foram: qualidade fisiológica das sementes de soja; semeadura da soja; atributos químicos e físicos do solo; índices espectrais durante o crescimento da soja; plantas daninhas e controle de pragas. Houve maior destaque nas tecnologias, como mapas digitais, maquinários, testes, sistemas/programas computacionais, softwares, georreferenciamento, análise de solo, medidores eletrônicos, imagens digitais, equipamentos e sensores ópticos. As ferramentas utilizadas na agricultura de precisão são relevantes para qualificação profissional, aumento da produtividade, diminuição de impactos ambientais, sustentabilidade, otimização do tempo e dos produtos e serviços, além da redução de custos.
Palavras-chave: produtividade, tecnologia, grãos.

INTRODUCTION

Increasing food production is a major concern in the 21st century. The projections of the United Nations (UN, 2013) point to a global population of 9.5 billion people in 2050, indicating an increase in the demand for food. Commercial production of soy in Brazil began in the 1960s, with expansion in the 1970s, motivated by the high price on the world market and the country's competitive advantage (MONTOYA, 2019), in addition to the constant need for increase of food, allied to population needs. In Brazil, research on soy cultivation indicated the profile of the expansion of the agricultural area with this legume, although with lesser intensity from 2009 on; it is one of the main crops of Brazilian agribusiness, occupying 49% of the country's grain area (MAPA, 2016).

In the 2020/21 harvest, the expectation is for continued growth in the planted area, with an estimated increase of 2.5%, compared to the previous harvest, reaching 37.9 million hectares. Good performance is expected to continue, supported by strong Chinese demand, favorable exchange rates and good soy prices, creating a scenario where producers can invest more in the technological package and better care in the management and management of crops. The estimated volume to be produced for the 2020/21 soybean crop is 133.67 million tons, with an expected area increase of 2.5%, that is, 37.88 million hectares to be planted. The adjustment made in the planted area is motivated by the high profitability obtained by the producer in 2020 and the expectation of sustaining prices in 2021 (CONAB, 2020).

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Brazil is the second largest producer of soybeans in the world, behind only the United States. The total production per year in the country exceeds 100 million tons. In the South region, a percentage increase in planted area of 1.5% is expected for 2020 compared to the previous year. The region should leave the level of 11,879.6 thousand hectares to 12,062.1 thousand hectares (CONAB, 2020). Thus, in this study, the southern region of the country (Paraná, Santa Catarina and Rio Grande do Sul) stands out due to the high production of soybeans, justified in part by the edaphoclimatic conditions of the region; a percentage change in the planted area of 0.3% is expected in relation to that observed in the previous year (12,085.1 thousand hectares to 12,123.6 thousand hectares) (CONAB, 2020; IPCC, 2013).

Regardless of the sowing date, the duration of the soybean cycle tends to decrease in the southern region of Brazil, due to its cooler location. A study indicates that in the future, soybean yield will increase by up to 0.330 ton ha^{-1} and 0.667 ton ha^{-1}, in the short and medium term, respectively. The projected rainfall in the short and medium term for southern Brazil will still be sufficient to meet the water needs of soybeans (MINUZZI et al., 2017).

Considering the growing world demand and the need to increase soy production, the technology becomes fundamental. In Brazil, the use of herbicides in areas cultivated with soy resistant to glyphosate is growing, with an increase of 55% in the use of herbicides complementary to glyphosate in soy cultivation in the year 2015/2016 to 2016/2017 (LAMAS, 2017). These data are worrying and may indicate that the technology is not being used properly, but it is emphasized that precision technology is an ally of man in agricultural production. There are currently seeds, inputs of greater significance, in addition to various types of equipment, including planters that are "self-propelled", georeferencing systems, among others (LAMAS, 2017).

The term precision agriculture (PA) is relatively new among Brazilian rural producers and has raised doubts in the use of its management techniques. There are several producers who associate PA as a package of methodologies that will be able to solve all the problems of national agriculture (MOLIN; RABELLO, 2011). The precision farming system involves the analysis of spatial variability, being characterized by the steps of data collection, information management, application of inputs at a varied rate and, finally, the economic and environmental assessment of the results (SOARES FILHO; CUNHA, 2015).

In this context, the PA gains notoriety, due to the better use of planted areas and greater grain cultivation. It can be defined as a systematic procedure to inspect and incorporate the spatial variability of the soil in field management (HAGHVERDI et al., 2015). This spatial variability can be caused by climatic, topographical and biological factors (CÓRDOBA et al., 2013).

Several technologies are currently available for agribusiness, so it is important to identify in the scientific literature aspects of PA for efficiency in soybean cultivation. Therefore, it is believed that these technologies can benefit soybean production, optimizing raw material and reducing costs. Thus, it is important to identify in the scientific literature the aspects of precision agriculture for efficiency in soybean cultivation. Therefore, the research question is: What is the scientific production on precision agriculture for efficiency in soybean cultivation in southern Brazil? This study aims to describe the scientific production on precision agriculture for efficiency in the soybean crop in southern Brazil.

MATERIAL AND METHODS

The Integrative Review (IR) makes it possible to synthesize completed research and obtain results based on a topic of interest. It offers quick access to research results that support the conduct and decision-making of professionals in different areas of expertise, thus providing critical knowledge (COOPER, 1989) and allows the simultaneous inclusion of experimental and non-experimental research with the objective of understand the phenomenon in question. The elaboration of this type of research can occur in five distinct stages: 1) formulation of the research problem; 2) data collection; 3) data evaluation; 4) analysis and interpretation of data; 5) presentation of results (COOPER, 1989), which were used in this study and will be presented below:

In this first stage, the theoretical deepening of the subject was carried out and the purpose of the review was formulated. The subject was defined in a clear and specific way, as the initial objectivity predisposes the entire process to a targeted and complete analysis, with conclusions that are easy to identify and apply. Thus, it was obtained as a research question: what is the scientific production on precision agriculture for efficiency in soybean culture in southern Brazil?

In the second stage, the criteria for inclusion and exclusion of studies/sampling and literature search were established. The database selected for this study was *Scientific Electronic Library Online (Scielo*), which was chosen because it is an electronic library that includes a selected collection of Brazilian scientific journals. The search strategies were assembled using the descriptors “precision agriculture” and “soybean”. Inclusion criteria were: full articles; available online; published in Portuguese or English in the last ten years (2010-2020), with studies carried out in the southern region of Brazil (Paraná, Santa Catarina and Rio Grande do Sul states).

In the third stage, the information to be extracted from the selected studies was defined, as well as its categorization using an instrument to gather and synthesize key information. The information was organized in a concise manner, forming a database that is easy to access and manage. The articles were fully read, for data organization, an instrument developed by the author will be used, which consists of a table with the following items: identification of the article, year and journal of publication, place (country, state and city) of performance, objectives, methodological attributes, precision agriculture technology, main results and conclusion. These elements allowed organizing and synthesizing the information contained in the articles.

In the fourth stage, based on the results of the critical evaluation of the included studies, comparing them with theoretical knowledge, the identification of conclusions and implications resulting from the integrative review (COOPER, 1989). The data (precision farming in the efficiency of soybean crop in southern Brazil) identified in the articles were synthesized and compared. After pooling evidence and identifying gaps, it was possible to point out pertinent suggestions for future research directed at this theme.

The characterization of the studies and thematic analysis were carried out, starting with a comprehensive and exhaustive reading of the texts, in order to obtain a view of the whole (MINAYO, 2012). Then, an interpretive reading was carried out, seeking convergences and contrasting subsets, which will result in varied units of meaning. As a last step, the units of meaning that represent connection points of dialogues elaborated on broader themes were grouped (MINAYO, 2012). In the last step, it was decided to present the results initially through a table with the characterization of the articles. The presentation of the themes was descriptive, carried out through a coding process. The reflection on the data took place in the light of the bibliography related to the theme. In Figure 1, the methodological scheme of the study is presented.

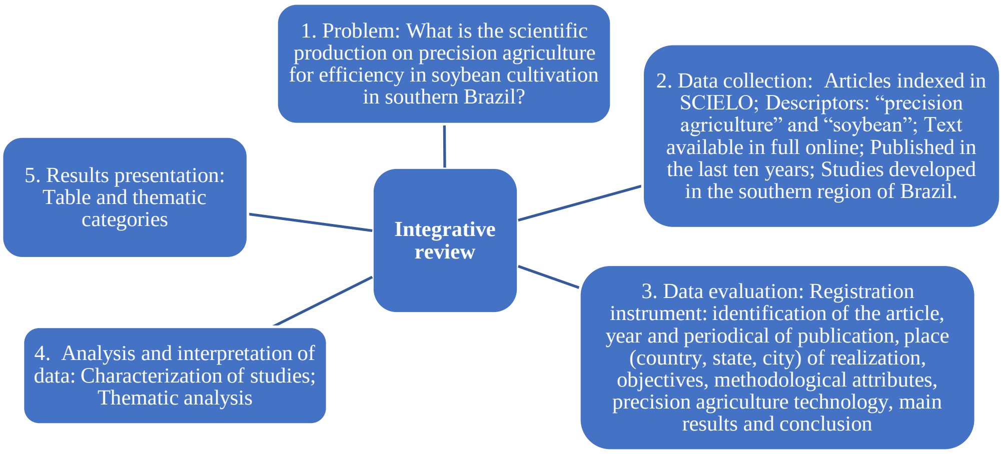

FIGURE 1 - Methodological scheme of the study. Source: Hammerschmidt et al. (2021).

RESULTS AND DISCUSSION

19 articles emerged, published in the period 2011 to 2019, three in 2011, three in 2012, two in 2013, two in 2014, two in 2015, three in 2016, one in 2017, two in 2018 and one in 2019. With Regarding the location of the studies, six were carried out in the state of Paraná (Céu Azul, Carambeí, Realeza, Guarapuava, Cascavel and Serranópolis do Iguaçu), two in Santa Catarina (Curitibanos and Brunópolis), and 11 in Rio Grande do Sul (three in São Gabriel, two in Boa Vista das Missões and Victor Graeff, one in Júlio de Castilhos, Palmeira das Missões, Sertão and Não-Me-Toque), as shown in Figure 2.

As for the objectives, all studies involved soybean productivity, being addressed: physiological quality of soybean seeds (three studies), soybean sowing (two studies), chemical and physical attributes of the soil (eight studies), spectral indices during the soybean growth (one study), weeds (four studies), pest control (one study). In relation to the type of soil, the researches were developed in: Oxisol, Cambissolo and Argisolo. As for the size of the study areas, there was a variation from 1.74 to 225 ha, with direct planting predominated (14 studies - 73.68%) carried out for more than ten years (maximum of 25 years), with crop rotation in the summer and winter: soy, wheat, white and black oats, corn, onion, garlic, turnip and blue lupine.

All articles were developed under the theme of precision agriculture, but highlighting the technologies: seeder machine cultivar TEC 5936 IPRO, germitest® agricultural system SR-Campeiro 7, seeder machine; STARA seeder machine, AF5 PRO 600 crop monitor, connected to a HARVESTER Case IH 2388, AFS Case 3 software; Axial-Flow 2399 combine harvester equipped with GPS system; GPS signal receiver; GPS receiver (GPSMap-Garmin®), Surfer program, version 10; seeder machine equipped with blade type guillotine and perforated disk system for seed distribution (Semeato® Sun T15). CR-Campeiro 7 agricultural system; SSM27 drag fertilizing seeder machine, Semeato® brand. New Holland® tractor, model TM150, Trimble Navigation Limited® brand AgGPS EZ-Guide 500 autopilot guided navigation system, GPS normal system and XP corrected signal; seeder machine cultivate TEC5936 IPRO; Garmin 76CSx GPS, Track Maquer PRO software, SDUM program, SURFER 8.0 software; Trimble Geo Explorer XT 2005 GPS and PathFinder software, electronic Facker PGL1020 gauge; GPS, AutoCAD® and Track Mecker Pro® program, TABCROSS tool from IDRISI TAIGA program, Surfer program; Portable navigation GPS brand Garmin®, model Legend, computer program CR-Campeiro 7; Massey Ferguson harvesting machine, model MF34, equipped with a FieldStar system, comprising a set of two-rod Micro-trak type yield sensor, PCMCIA data storage card and GPS antenna, CR-Campeiro 7 program; backpack sprayer equipped with DG 8002 spray nozzles, GreenSeeker™

equipment, Canon A460 digital photo imaging camera, Sigma Scan Pro 5 software, ImageJ software, GreenSeeker™ Handheld Sensor Unit tool, JMP IN version 4 program; Combine harvester MF 32 equipped with FieldStar system, Fox® equipment, CR-Campeiro 5 program; tests proposed by Anderson Darling and Kolmogorov-Smirnov; germitest® CR-Campeiro 6 farming system; site specific scarifier FOX®-Stara, equipment for treatment conventional scarifier JUMBO®, tractor with FALCON 3500 monitor and computer program with VRC files and DGPS receiving antenna (TRONICK), harvester MF 32 equipped with GPS system, FieldStar® and productivity sensor; GPS CR-Campeiro 7 software, FALKER MAP PLUS software.

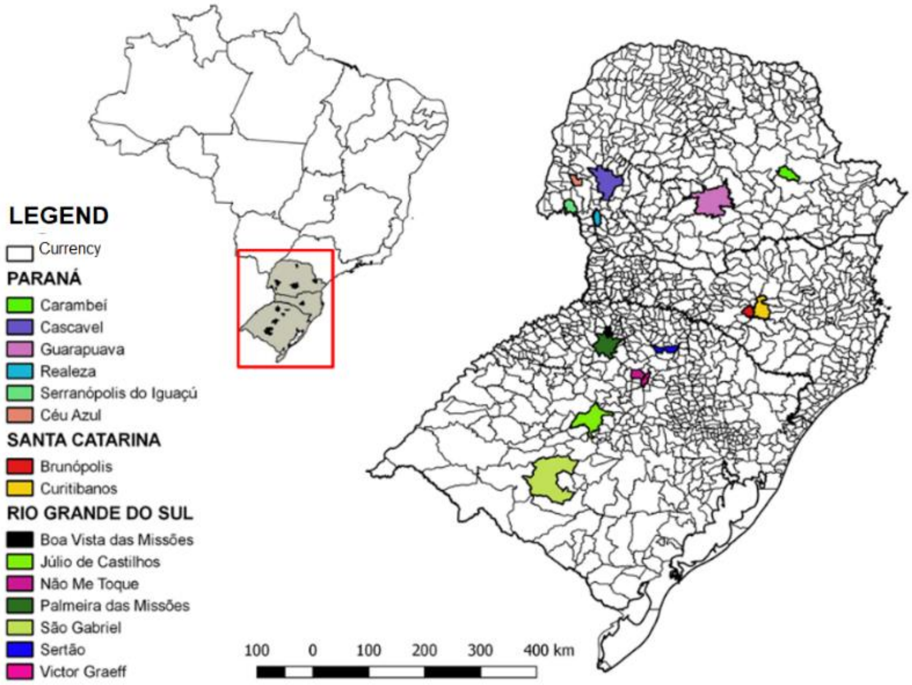

FIGURE 2 - Spatial geographic distribution of studies emerging from the integrative literature review. Source: Hammerschmidt et al. (2021).

Themes about precision agriculture for efficiency in the soybean crop in southern Brazil

The articles that emerged from the corpus of analysis involved the following themes:

1) Physiological quality of soybean seeds,
2) Soybean sowing,
3) Chemical and physical attributes of the soil,
4) Spectral indices during soybean growth,
5) Weeds and
6) Pest control.

1) Physiological quality of soybean seeds:

In soybean productivity, seed quality plays a fundamental role, higher quality seeds tend to generate more productive fields, in this area one of the problems is the storage with deterioration of seeds. A study developed in São Gabriel (RS) identified the spatial distribution of the physiological quality of soybean seeds during storage. The average values of germination on paper and seedling emergence in sand were above 90%, with a coefficient of variation below 2.5%. The average accelerated aging in 48 h was 94% and in 72 h, 91.51%, indicating that soybean seeds were of high physiological quality (VERGARA et al., 2019). In the study by the same authors, the degree of spatial dependence of the variables was moderate with 43.76 for germination at 180 days and 63.85 for germination at zero days. The analysis of the results obtained for germination, first germination count, protein, emergence and accelerated aging over 48 and 72 h demonstrated that the point spacing used in the sampling grid, with one point per hectare, was effective to obtain representative samples and to estimate seed quality and productivity.

The evaluation of the physiological potential of the seeds by interpolation of the variables of the spatial distribution map counted first germination, protein content, emergence, accelerated aging for 48 h and germination during storage, showing marked differentiation in the production area. The behavior of the germination variable at 120 and 180 days of storage was similar to that observed for the initial quality variable. The regions of the production area that had the lowest germination rates had the lowest seed quality during storage (VERGARA et al., 2019).

The incidence of seed damage caused by stink bugs showed a positive and significant correlation with the occurrence of damage due to moisture. This fact is related to the perforation caused by the insertion of the insect's mouthparts, which can leave the seed with greater exposure to the elements. The occurrence of damage by bugs showed a significant and negative correlation with the variables of seed quality during storage. It is noteworthy that the vigor analyzed through accelerated aging showed a negative correlation with the level of damage caused by bed bugs, and the vigor of seedlings after storage showed a negative correlation with the level of damage caused by bed bug attacks. Higher incidences of damage caused by bed bugs tend to coincide with a decrease in the initial strength and in the seedling emergence level after storage (VERGARA et al., 2019).

Other research also carried out in São Gabriel, Rio Grande do Sul, Brazil, identified and determined the spatial distribution of the physiological quality of soybean seeds in a production field using precision farming techniques. The seeder machine cultivar TEC 5936 IPRO completed the cycle in 115 days, between emergence and physiological maturity and 123 days between emergence and harvest, with seeds harvested with an average moisture of 17% (GAZOLLA-NETO et al., 2015).

The average values of germination, viability and field emergence were above 90%, with a coefficient of variation below 1.74%. The degree of spatial dependence of the variables showed moderate spatial dependence, with values between 48.98 for viability by the tetrazolium test and 59.97 for emergence, except for the emergence speed, which reached 28.03. The physiological potential of seeds by the interpolation of spatial distribution maps for the variables, germination, seedling emergence, emergence speed, viability and vigor by the tetrazolium test and accelerated aging showed differentiation within the production area, showing unevenness in the physiological quality of seeds (GAZOLLA-NETO et al., 2015). The same authors point out that the spatial variability of the variables associated with georeferenced mapping provided the mapping of regions with seeds of high and low vigor within the production field. Seeds with low vigor cause a reduction in emergence speed, uniformity, total emergence, initial seedling size and establishment of adequate stands. These factors can reduce dry matter accumulation and consequently productivity.

Soil pH presented a coefficient of variation of 5.97%, with a range of values between 4 and 5.2 and an average of 4.67, pH condition below the recommended range for soybean crops. The recommended pH values for soybeans are between 5.5 and 6, as these conditions lead to the neutralization of toxic aluminum, elimination of manganese toxicity, better use of soil nutrients, and adequate conditions for natural processes, such as the release of nutrients contained in organic matter and the fixation of atmospheric nitrogen. In the study there was a correlation between chemical attributes of the soil and physiological potential of seeds. Germination, emergence and viability by the tetrazolium test showed a negative correlation with soil pH. The use of precision farming techniques can determine the spatial distribution of the physiological quality of seeds in the production area, facilitating decision-making on areas to be harvested (GAZOLLA-NETO et al., 2015).

Research carried out in Não-Me-Toque (RS), evaluated the spatial variability of productivity and quality of soybean seeds in the production field, using precision agriculture tools. The soybean crop cycle was 111 days between emergence and physiological maturity and 115 days between emergence and harvest of seeds, which were harvested with an average moisture content of 15.5%. The development and production showed spatial variability according to the behavior of the physical or chemical properties of the soil (MATTIONE et al, 2011). For the same authors, the productivity map is an important tool for decision making and agricultural performance analysis, in addition to being a more complete and modern alternative to manage the spatial variability of crops, guiding management practices. There was spatial variability of the percentage of seeds in each sieve evaluated, with a high coefficient of variation for the 5.5 and 7.5 mm sieves and low for the 6.5 mm sieve. In this way, there was a greater production of seeds classified in the 6.5 sieve (79.2%), with, however, zones producing 54% and other 85%.

Seeds produced in the area of this study showed an average germination of 80% (range between 61% and 93%). The tests of first count and accelerated aging indicated coefficients of variation of 13.24% and 19.01%, respectively, showing that vigor is more sensitive to environmental variations, when compared to seed viability. Mattione et al. (2011) verified that the vigor tests presented minimum values of 37% and 30%, maximum values of 75% and 89% and averages of 57% and 62% for the first count and accelerated aging tests, respectively. Vigor tests allow for a better diagnosis of the physiological quality of seeds, as there is greater sensitivity in diagnosing their deterioration. The study of spatial variability and mapping makes it possible to distinguish with greater precision the regions of the production field that have superior quality seeds.

2) Soybean sowing:

Camicia et al. (2018), researched in the city of Céu Azul, in the west of the state of Paraná, the yield of the soybean crop with application of densities 171,200, 214,000 and 257,000 plants ha^{-1}, spaced between rows of 0.70 m, in management zones pre-established in an agricultural area. It was verified comparatively, in the agricultural years 2011/2012 and 2012/2013, when applied on average 257,000 ha^{-1} of plants in this area, a productivity of 2.44 and 3.93 t ha^{-1}.

The same authors mentioned above point out that the soybean yield values (2015/2016) in management zone 1 were 3.39 t ha^{-1}, with 3.43 and 3.36 t ha^{-1} for plants of 15 and 18 m^{-1}. In the 2017/2018 crop, yield in management zone 1 was 3.18 t ha^{-1}, 3.14 and 3.21 t ha^{-1}, for 12 and 15 plants m^{-1}, with a difference of approximately 0.07 t ha^{-1}. The average of management zone 2 was 3.30 and 3.11 t ha^{-1} of soybean for 2016 and 2018, respectively. In this region there was higher production with a density of 18 plants m^{-1} (average of 3.31 t ha^{-1}), while the density of 15 plants m^{-1} had a productivity of 3.30 t ha^{-1} in the first year of the study. And in the second year, 3.20 t ha^{-1} (15 plants m^{-1}), and 3.03

t ha^{-1} (12 plants m^{-1}) were produced. Thus, the plots with the highest productivity for soybeans were 12.11 and 3 with 3.51 (17/18), 3.50 (15/16) and 3.48 (15/16) t ha^{-1}, respectively, followed from plots 1, 4, 8 and 13, with 3.45, 3.41 and 3.40 t ha^{-1} (related to 15/16).

The values of higher and lower sowing density varied, with a difference in productivity on the map (55% of the area had negative values, indicating higher productivity when using the sowing density of 15 plants m^{-1}), the production increased by 45% of the area with the highest seeding density. Regarding the economic analysis, there was no significant difference between the management zones, indicating sowing at a constant rate for the entire area. In the case of soybeans, a population of 171,200 plants ha^{-1} would require 505 kg of legume, at a cost of R$188,311 ha^{-1}. 630 kg of soybean would be needed for a population of 214,000 ha^{-1} of plants, costing BRL 223.90 ha^{-1} (2015/2016) and BRL 235.16 ha^{-1} (2017/2018), a population of 257,000 plants ha^{-1} would need 758 kg of soybean seeds at a cost of R$ 268.97 ha^{-1}. The study showed a decrease in productivity with an increase in the density of soybean seeds in the 2015/2016 harvest (equivalent to a loss of R$ 20.00 ha^{-1}) and an increase of 12% in the acquisition of seeds for the implantation of a population of 18 plants^{-1} in the entire planting area (R$ 45.07 ha^{-1}). The application of 12 to 15 plants m^{-1} generated a cost of R$ 47.03 for the application of the highest density and caused an increase in the final income of R$ 115.50 ha^{-1}, resulting in a substantial increase in population (CAMICIA et al., 2018). The decrease in productivity is related to soil quality as an interference factor.

Another research developed by Garcia et al (2016), in Carambeí (PR), evaluated the maneuvering time during soybean sowing with and without autopilot. The turnaround time with autopilot was significantly shorter than the conventional turnaround time. This finding is due to the fact that the tractor needs to travel a shorter distance to perform the entire maneuver and start another pass (autopilot). The average time to maneuver in the system with the aid of GPS and autopilot was 27.1 sec., in the conventional system (without the aid of the navigation system), the average time was 52.9 sec/maneuver. Thus, the average economy per maneuver was 48.7% when using the aid of the navigation and piloting system. These data show the efficiency of the autopilot in aiding maneuvers and delimiting sowing lanes.

In areas with a longer seeding line, the maneuvering time at the ends has a reduced influence, however in the 800 meter seeding range there is a time savings of 7.6%. The relative savings of time and costs in sowing are based on an estimate of the operational capacity of the machine sowing 2.5 ha h^{-1}, obtained by the sowing range of 4.95 m; with a speed of 5.0 km h^{-1}. It is stated, based on these data, that the larger the stride length, the smaller the economy generated by the navigation system, because the greater the distance, the less representative the time spent during the maneuver at the edge of the area becomes. In the 50 m stride, the machine takes 25 sec. to cover the distance, with an average speed of 5.0 km h^{-1}. However only the conventional maneuvering time (without the help of the navigation device) is approximately 50 sec. In the case of the 800 m pass, the machine takes 400 sec. to travel the distance, with the conventional maneuvering time still being 50 sec. Thus, even adopting the 800 m stride length, the result is positive with the navigation system, generating savings of 7.6%, approximately R$ 4.15 ha^{-1}. The adoption of autopilot is economically viable even in areas with reduced maneuvering time (GARCIA et al., 2016).

3) Chemical and physical attributes of the soil:

A study carried out in the municipality of Boa Vista das Missões (RS), identified the chemical and physical attributes of the soil restricting grain yield in an Oxisol under the no-tillage system, using directed soil sampling, which showed a significant simple effect for the zones and soil depths for most attributes evaluated. In field I, the hydrogen ion potential (pH), magnesium (Mg), aluminum (Al) and vanadium (V) differed significantly between the three zones and yield. Considering the eight depths analyzed, the average pH values were 5.7, 5.7 and 5.3, for the low, medium and high productivity zones, respectively. The highest Mg contents were found in the medium yield, followed by the low zone and high yield. Due to the higher Al content in the high yield, the mean V at 0.0-0.40 m also differed significantly between the three zones and yield, being higher in the medium and low zone than in the high yield. In field II, pH, potassium (K), calcium (Ca) and Mg were the attributes that varied between the three zones and yield. The highest mean pH was observed in medium productivity, while K was higher in low productivity (CORASSA et al., 2018).

The same authors mentioned above identified that all attributes, except pH, varied significantly according to the soil depths assessed in field I. In field II, pH, Al and V were not affected by the different depths. The three zones and yield significantly interacted with soil depths for some soil attributes. In field I, the soil organic matter was higher for high productivity, in all evaluated strata, but presented similar vertical distributions for medium and low productivity. Also found high values for the potential cation exchange capacity, for high productivity, compared to low productivity zones, which increased with increasing soil depth. Considering the intermediate layers of 0.00-0.05, 0.20-0.25 and 0.35-0.40 m, the organic matter of the soil was 20, 19 and 34% higher in the high productivity than in the low productivity, respectively. In field II, the mean values of soil organic matter were similar between the three zones and yield, up to a depth of 0.15 m. However, below this depth, these values were higher in high productivity. These results highlight the importance of considering deeper soil layers for chemical analysis in the no-till system.

It can be seen in Figure 3, the production of the 2010/2011 soybean crop, in the study by Corassa et al. (2018), with information on the soil sampling points for each production zone (LY - low yield, MY - medium yield and HY - high yield), in field II. It is noticed that low crop yield is associated with low potential cation exchange capacity, low phosphorus and organic matter content and high clay content in the Oxisol under no-tillage system. Soil organic matter at greater depths is an indicator of high yield zones. Soil sampling, considering historical production data, allows the identification of chemical attributes that restrict grain production and can guide more specific interventions in the location, in addition to a high level of detail, it allows identifying the factors responsible for boosting the performance of harvesting in the fields. Considering the attributes evaluated in this study, site-specific interventions, using cover crops with an aggressive root system and increased straw production, are an alternative to low yield and can be used in conjunction with chemical interventions. Furthermore, the adoption of intelligent planning of crop rotation considering the zones should be investigated in future studies.

Another research carried out in the municipality of São Gabriel, Rio Grande do Sul, Brazil, evaluated the spatial dependence between the chemical properties of the soil and the components of soybean seed production using precision agriculture techniques. Descriptive measures were determined for the chemical properties of the soil (organic matter, pH, phosphorus, potassium, calcium, magnesium, boron, manganese and zinc) and for the yield components (productivity, weight of 1000 seeds and number of seeds). Among the chemical properties of the soil, the coefficient of variation (CV) presented values for the studied variables from 5.96 to 102% for soil pH and available phosphorus, and from 15.93 and 72.65% for organic matter and potassium, respectively (GAZOLLA NETO et al., 2016).

FIGURE 3. Soybean production at the soil sampling points for each production zone in field II. Source: Corassa et al. (2018).

In the characterization of soil chemical properties, the lowest range was identified for soil pH, classified as very low, with a minimum value of 4.00, a maximum of 5.10, an average of 4.67 and a pH coefficient, with variation of 5.96%. The recommended values for this variable in the soybean harvest are in the range of 5.50 to 6.00 and, when under these conditions, it should occur:

a) the neutralization of toxic aluminum,

b) the elimination of manganese toxicity,

c) better use of soil nutrients,

d) conditions suitable for natural processes, such as the release of nutrients present in organic matter and atmospheric nitrogen fixation.

The average yield in the production area was 2,964.6 kg ha^{-1}, ranging from 2006 to 3,456 kg ha^{-1}, with a magnitude of 1,450 kg ha^{-1}, but with a low coefficient of variation (9.86%). The spatial distribution of soil chemical properties and production components was established by analyzing the semivariograms and their components, thus significant variations were found in the spatial dependence interval for all variables, with values ranging from 200 to 700 m. The range indicates the limit of spatial dependence of a variable, so that determinations made at distances greater than this value will have random spatial distribution and, therefore, are independent and can be applied to classical statistics. In addition, the determinations made at shorter distances will be correlated, allowing interpolations at distances smaller than those sampled (GAZOLLA NETO et al., 2016).

When analyzing the parameters of the semivariograms, the same authors mentioned above verified that all variables fit into the spherical model. Among the chemical properties of the soil, the coefficient of determination (R2) was between 0.728 for phosphorus and 0.997 for pH. For the production components, the variation observed was from 0.988 for number of seeds to 0.994 for productivity. Values greater than 0.728 for soil properties and 0.988 for yield components show, respectively, that 72.8% and 98.8% of the variability found in the values for estimated semi-variance can be explained by the adjusted models. The values for the nugget (C0) and sill (C0 + Cj) effect showed a remarkable destruction range, from 0.006 to 33,549.24 and 0.012 to 89,313.37, respectively. The nugget effect, an important semivariogram parameter, is an indication of unexplained variability, considering the sampling distance used. The greater the difference between the nugget effect and the sill of the semivariogram, the greater the continuity of the phenomenon, and the smaller the variation in the estimate or the greater the confidence to have in this estimate. The nugget effect coefficient (E%) had minimum and maximum values of 30.79% and 52.37%.

Research carried out in Serranópolis do Iguaçu, Paraná, Brazil, enabled the use of precision agriculture technology and evaluated aspects that can influence the soy nutrition process. The attributes P, K and Zinc (Zn) were classified as heterocedastic (CV>30%) and Fe, resistance to soil penetration from 0 to 10 cm (SPR1010) and sand as high CV. For other attributes, only pH can be classified as homoskedastic. Ca, Carbon (C), Copper (Cu), Hydrogen (H) + Al, Mg, Mn, productivity, resistance to soil penetration from 10 to 20 cm (SPR1020), from 20 to 30 cm (SPR2030) and average resistance to soil penetration (SPRAVG030) (MPa), moisture, silt and clay were classified as moderate CV. Cu, P, K and Zn showed positive asymmetry, negative silt asymmetry and other attributes, symmetrical distribution. Only the medium C and RPS presented kurtosis classified as platykurtic and Cu, P, K and Zn were classified as leptokurtic. Only the P attribute did not show normal distribution. For soil chemistry, the attributes Ca, Cu, Mg and Mn showed high availability throughout the area. C and Iron (Fe) had low availability at the sampling point, but at most sampling points (93% and 96.5%, respectively) they can be classified as medium availability. Zn also presented an average level in 84.2% of the samples (BAZZI et al., 2013).

A study carried out in the municipality of Guarapuava, Paraná, Brazil, established a sampling density for accuracy in the maps of chemical attributes generated on different sampling densities, at two depths, and its practical implication in the recommendation of fertilizer and liming for the soybean crop. For all attributes, the higher sample densities had a greater number of classes and as the sample density decreased, the more extreme classes lost representation or disappeared. Detailed knowledge of the property, which prevails in precision agriculture, suffers depreciation with the reduction of values and classes that represent the portions of the land. In the maps, classes that occupy smaller portions of the land are surrounded by more abundant classes and cease to exist, losing representation when the sample density decreases, a behavior identified for pH (CAON, GENÚ, 2013).

The decrease in overall accuracy as the sample density reduces is verified at a depth of 0-10 cm (overall average accuracy for the density of a sample every ½ ha is 82.1%, ranging from 75.4 to 88.3%, going to an average of 69.8% in the density of one sample per hectare and 62.6% for a sample of 2 ha, reaching an average of 56.2% in the lowest density equivalent to one sample every 4 ha, with variation from 47.3 to 65.8%). At a depth of 0-20 cm, the indices are similar to those at a depth of 0-10 cm and present mean global accuracy values close to and slightly higher (CAON, GENÚ, 2013). The same authors identified that in the sample density of 1 ha, the attributes presented good quality of accuracy in relation to maps generated with higher sample density. The 2 and 4 ha samples showed fair to poor quality, being inefficient for use in precision agriculture. Since it is bound by the quality of representation of the field's features. The higher sample density corresponds more strongly to the reality found in the field, and data maps with good accuracy quality are necessary for its use. It is possible to link the sampling density of one sample per hectare, and the sufficiency of quality for use in precision agriculture. Thus, the density and one sample per hectare is recommended in the elaboration of maps of chemical attributes of the soil.

At the two depths (0-10 and 0-20 cm) when comparing the liming requirements using precision agriculture and the conventional method based on the average, the differences in liming requirements in the first method did not include areas with base saturation greater than 70% and areas with lower saturation received proportionally their reduction. When performing the total average based on the calculation (conventional method), samples greater than 70% would reduce the need for liming, resulting in a decrease in the amount of correctives. The increased need for liming in precision agriculture is a result of the high fertility of the soil, with a large part of the results obtained by detailing with georeferenced sampling. Precision agriculture uses more efficiently the amount of limestone and fertilizers than conventional agriculture (CAON, GENÚ, 2013).

Study carried out by Santi et al. (2012), in the municipality of Palmeira das Missões (RS), with the objective of evaluating, through the analysis of the main components, the reduction in the dimensionality of chemical and physical soil attributes to understand the spatial and temporal variability of crop productivity of grain. The yield history involved six grain crop harvest events. For the soybean crop, 2000/2001 harvest, the total number of points stored and considered in the elaboration of the thematic map was 22,871. The high real grain yield was 4,860 kg ha^{-1}, the average real grain yield was 3,180 kg ha^{-1} and the low real grain yield was 1,980 kg ha^{-1}, with a standard deviation of 480 kg and CV of 16.20%. In the 2002/2003 harvest, 9,250 points were considered, the real high grain yield was 4,980 kg ha^{-1}, the average real grain yield was 3,240 kg ha^{-1} and the real low grain yield was 1,800 kg ha^{-1}. with standard deviation of 1800 kg ha^{-1} and CV of 20.62%. In the 2003/2004 harvest, 8,943 points were considered, and the high real grain yield was 3,780 kg ha^{-1}, the average real grain yield was 2,220 kg ha^{-1} and the low real grain yield was 720 kg ha^{-1}, with a standard deviation of 600 kg ha^{-1} and CV of 18.73%. These results indicate that there was spatial variation in grain yield in the experimental area, but with CV below 30%.

The studied area presented soil with high fertility, with the exception of P, which presented limiting levels for plant development, especially in the deeper layer (0.10-0.20 m); the contents of Ca, Mg, and K showed high levels in the superficial layers, affecting the crop productivity. Regarding physical attributes, it presented clayey texture, with values of density and resistance to penetration, in the deeper layers, likely to limit water infiltration and root development of crops (SANTI et al., 2012). The same authors argue that the chemical attributes of the soil (32 variables) were grouped into five factors, and the model adjustment was able to explain 99.24% of the variances with high values greater than 1. As for physical indicators, macroporosity in the 0 layer .05-0.10 m, soil water infiltration, soil density in the 0.10-0.20 m layer, aggregates in the >4.76mm class, and soil penetration resistance in the layers of 0.25-0.30, 0.30-0.35, 0.35-0.40, 0.40-0.45 and 0.45-0.50 m explained 88.71% of the first principal component. Water infiltration was the most important individual character.

The analysis of principal components of chemical and physical soil attributes is an efficient strategy to explain the spatial and temporal variability of grain crop yield in cultivated areas under site-specific soil management. Among the chemical and physical variables of the soil, the unbalance of bases and the limitation of water infiltration, respectively, are the ones that most limit productivity. In precision agriculture, hardly a single variable will be able to explain, in isolation, the spatial variability of soybean grain yield. The crossing of chemical and physical variables is important, the use of the variable reduction technique can select the main components, to identify and interpret the distribution of the most relevant variables (SANTI et al., 2012).

The authors of a study developed in Victor Graeff (RS), evaluated the efficiency of site-specific and conventional scarifications regarding the improvement of physical attributes for maintenance of soil cover and soybean yield. The characterization of the physical attributes of the soil was carried out in yield zones established from three superimposed harvest maps. Soil density, with the exception of the 0.15-0.20 m layer, was similar between yield zones. Total porosity was a more sensitive attribute to yield zones, with low yield zones being inferior to high yield zones in most layers investigated, with the exception of the first and the depth of 0-20 cm (GIRARDELLO et al., 2011). As for macroporosity, the yield zones did not differ, in part due to the high coefficient of variation and experimental imprecision for this attribute. Except for the first layer sampled, all the others presented macroporosity values below those established as critical (<0.10 m^3 m^{-3}). The observed macroporosity values are considered to limit water infiltration and adequate oxygen supply to the roots. With regard to microporosity, it was found, at depths of 0.10-0.15 and 0.15-0.20 m, that the values of the medium yield zone and high yield zone were higher than those of the low profit.

The low-yield zone showed lower soil physical quality, expressed by soil density and upper and lower total porosity, respectively, at the critical values at a depth of 0.15-0.20 m, conditioning low water infiltration into the soil. In treatments with conventional and site-specific scarifier at varied rate, the increase in water infiltration into the soil was four times higher than in the control. However, this positive effect of mechanical scarification was temporary, being canceled seven months after the soil operation. Under high rainfall during the crop cycle and moderate state of soil compaction, the change in physical quality provided by mechanical scarification did not influence soybean yield in relation to the control. When comparing the scarifiers, the site-specific at the varied rate stood out for presenting 40% more cover of the remaining soil and providing 12% increase in soybean yield, compared to the conventional one. These results support that the site-specific scarifier can be an efficient alternative to the conventional scarifier for the no-till system (GIRARDELLO et al., 2014).

Research developed in Cascavel (PR), analyzed two techniques to define management zones based on soybean yield maps in a managed production area with localized chemical fertilization and another with conventional chemical fertilization. The soybean yield variation coefficients with localized and conventional fertilization showed a minimum of 12% and 13% and a maximum of 24% and 36%. Variability was lower in plots with localized fertilization (SUSZEK et al., 2011).

Problems with low productivity may be related to dry periods during the flowering and grain filling phases. Another factor can be the control of diseases in the vegetative growth phase and late disease, which, despite being carried out, can result in a decrease in photosynthetic capacity. For both fertilization systems and standardization methods, the fitted models for semivariogram were spherical and exponential. The two methods of defining management zones, using equivalent normalized and standardized productivity, proved to be effective, with similar data arrangements. Conformity of the maps for management zones with plots under conventional fertilization is reasonable, being considered good for management zones with plots under localized fertilization (SUSZEK et al., 2011).

In the experiment by Giardello et al. (2014), developed in Rio Grande do Sul, Brazil, the authors characterized the spatial variability of penetration resistance in long-term no-till areas, investigating the relationship between penetration resistance and soybean yield, as well as evaluating the efficiency of mechanical scarifiers. The use of thematic maps of penetration resistance and soybean yield, through the geographic information system, was an efficient strategy to determine the spatialization of areas with high resistance to penetration, subsidizing the localized intervention. The critical value of penetration resistance of the Red Latosol was 3.0 MPa, inducing a 10% decrease in soybean yield. From the critical value on, small increases in penetration resistance caused a sharp decrease in soybean yield, reaching a reduction of 38% at 5.0 MPa. Mechanical scarification did not increase soybean yield, compared to treatment without scarification, in soil managed under no-tillage system with resistance to penetration classified as low/moderate and under conditions of high precipitation.

4) Spectral indices during soybean growth:

Research carried out in the city of Curitibanos, Santa Catarina, Brazil, studied the spatial variability of the spectral response of the canopy as a function of the stage of development of the soybean crop, as well as evaluating the spatial correlation between vegetation indices and soybean yield and delineating zones of management stratified by soil attributes from spectral indices of canopy values and soybean altimetry. The three stages of crop growth showed similar behavior, diverging in reflectance peaks, mainly at 550 nm (green) and 750 nm (near infrared) wavelengths. The reflectance in the green band is influenced by the chlorophyll content in the plant, which strongly absorbs radiation in the blue and red region for photosynthesis, reflecting and transmitting the remaining green light. The infrared band is influenced by electromagnetic radiation from the cellular structure of the mesophile and canopy (KUIAWSKI et al., 2017).

Reflectance values were used to calculate the vegetation indices, which simplifies the variations of different regions of the electromagnetic spectrum into single values. The highest coefficient of variation was 25.16 for the simple ratio index (soybeans in stage V6), while the lowest was 1.28 for the vegetation index with normalized difference (soybeans in stage R5). The coefficient of variation values were low to moderate, indicating low data dispersion. The value of the vegetation index with normalized difference varied according to the stage of crop growth (KUIAWSKI et al., 2017).

The terrain altimetry improved the spatial organization of the harvest, as its variation is closely related to the soil, conditioning its physicochemical properties. Altitude can affect the accumulation of water and particles. The spatial variability of the soil can also influence part of the variations estimated by spectral indices and yield, contrasting the chemical and granulometric attributes between the management zones. Although the management areas have different clay contents, the discrepancy between them is not enough to modify the physicochemical properties, nutrient dynamics and, consequently, soybean yield. These differences may occur due to the detachment, transport and sedimentation of soil particles (silt and clay) during erosive events, as the second zone had the lowest portions of the terrain (KUIAWSKI et al., 2017).

5) Weeds:

A study developed in the municipality of Brunópolis, Santa Catarina, Brazil, used geostatistical techniques to map the weed species of common thistle (*Sonchus oleraceus*), lemon balm (*Conyza spp.*) and maria-mole (*Senecio brasiliensis*), in order to study their dependence in a no-tillage area during two agricultural seasons. In the 2013/2014 harvest there was spatial dependence only for weeds, the other weed species did not show spatial dependence, although it was present in the study area. The weed with the highest population density was horseweed (*Conyza Bonariensis*), with an average of 6.59 plants m-2. This species also had a higher coefficient of variation, 53.73%, indicating localized groups (clusters) (BOTTEGA et al., 2016).

The model that best described the spatial variability of weed plants was the exponential. The spherical model showed a better fit to empirical semivariance for spatial distribution in area under no-tillage. The 2013/2014 mapping detected an area of 13.2 ha with infestation of weeds, values above the recommended level for control (58.7% of the total area). Simulating the application of herbicide and considering only the delimited areas, there would be savings of 41.3%, equivalent to the percentage of the area where the control would not be carried out. The indicative maps of the samples for common thistle and mole mare in the 2013/2014 season did not show spatial dependence, making it possible to build an indicative map to visualize the localized occurrence of these weeds. The larger grouping of common thistle plants are strong indications of future infestation and dispersed occurrences of molluscs, do not characterize the formation of clusters (BOTTEGA et al., 2016).

In the 2014/2015 season, none of the studied species showed spatial dependence and no weeds were identified in the area. This fact can be explained by the management adopted in the area during the off-season. Instead of keeping the soil fallow during the winter, white oats were sown as a weed management strategy, using 60 kg of seeds per hectare, which favored dense and uniform planting. The aleopathic action of some oat genotypes is attributed to the ability to exude scopoletin, a secondary product capable of delaying the growth of other plants, so the association between forms of cultivation and chemical control is an efficient way to reduce weed infestation. Winter ground cover, without grazing, promotes weed control, contributing to summer culture (BOTTEGA et al., 2016).

Another study, carried out in the city of Realeza (PR), verified the spatial distribution of spontaneous monocotyledonous and dicotyledonous plants in different sampling networks in commercial agricultural areas, comparing the loss of quality of weed maps with reduced sampling points and existence of spatial correction between the physical and chemical attributes of soil and weeds. The average of broad leaves for the area in 2012 was 5.35 plants m^{-2}, in 2013 it was 1.98 plant m^{-2}. There was an average reduction in broadleaf plants, probably due to the use of efficient herbicides to control broadleaf plants, such as 2,4-D and metsulfuron-methyl. For attributes of narrow leaves, the values were 5.92 and 1.62 plants m^{-2}, in the years 2012 and 2013, respectively. In 2012, a large amount of emerging weeds was found in the three areas studied, originating from the previous crop installed, the reduction in the average of narrow-leaf plants is due to the use of an efficient herbicide for control, such as glyphosate and also to the fact that in 2012 there was frost in the region, during the reproductive phase of wheat. Maps representing three levels of infestation from the years 2012 and 2013 of the study area for broad-leaf and narrow-leaf plants were applied, for grids of 10, 30 and 50 m (CAMICIA et al., 2015).

In 2013, an increase was observed in areas of low infestation compared to 2012 for broad leaves (32.3%), comparing the 2012-10-BL and 2013-10-BL maps and for narrow leaves (43.8%), comparing the 2012-10-NL and 2013-10-NL maps. There was low infestation (less than 5 plants m^{-2}) in 57.6%, medium infestation (5 to 10 plants m^{-2}) in 29.8% and high infestation (above 10 plants m^{-2}) in 12.6%, in relation to the total area, representing, respectively, 4.58, 2.37 and 1.0 ha, in terms of area. This map is visually similar to 2012-30-BL, with low, medium and high infestation of 55.1% (4.38 ha), 38.5% (3.06 ha) and 6.4% (0.51 ha), respectively. As for the 2012-50-BL map, there was low infestation levels of 44.1% (3.51 ha); average 38.7% (3.07 ha); and 17.2% high (1.37 ha). The 2012-10-BL and 2012-30-BL maps are visually similar, but a *kappa* coefficient of 0.32 classifies as partial compliance. The comparison of the 2012-10-BL and 2012-50-BL maps does not show good visual compliance, which was confirmed by the *kappa* coefficient value of 0.30, classifying it as partial compliance, in which the overall accuracy was 55.7% (only 55.7% of the 2012-10-BL map classification was repeated in the 2012-50-BL map, due to reduced sampling density) (CAMICIA et al., 2015).

In 2013, the best comparison for maps was observed for the 10 and 30 m grids on broadleaf plants (maps 2013-10-BL and 2013-30-BL), which obtained an overall accuracy of 90.0%, with a *kappa* coefficient of 0.52 (moderate compliance). In area A comparisons, the *kappa* coefficient ranged from 0.30 to 0.95 and the overall precision from 55.7% to 99.6%. In the comparisons of the narrow-leaf maps, the *kappa* coefficient ranged from 0.55 to 0.95, showing moderate to complete compliance between them. In broadleaf comparisons, the *kappa* coefficient ranged from 0.30 to 0.52, showing partial to complete compliance between maps; thus, maps generated with 50 x 50 m grids were adequate to describe the occurrence of narrow-leaf weeds. The 30 x 30 m grid was the most suitable for the analysis of broadleaf data, according to the *kappa* coefficient, when compared to the maps generated in the 10 x 10 m grids (CAMICIA et al. 2015).

In the study area in the years 2012 and 2013, a reduction in the amount of detail in the maps generated with different grids was observed, proportional to the increase in the size of the sampling grid, due to the lower density of the samples and also the fact that weeds are distributed in an aggregated way, allowing its mapping. The maps obtained in this study show the aggregated pattern of spatial distribution of weeds. It was possible to define management zones with differences in infestation of five to ten times the total number of weeds, confirming the hypothesis that geostatistical analysis can be used as an auxiliary tool in management. In 2013, there was an increase in areas of low infestation compared to 2012 for the two factors studied (narrow leaves and broad leaves), which is due to the more efficient use of herbicides in the control of weeds, such as glyphosate for narrow leaves and 2,4-D and metsulfuron-methyl for broad leaves, these factors together reduced the mean levels of infestation over the two-year study in the area (CAMICIA et al., 2015).

The results of this study indicate that the use of larger grids to describe broad and narrow leaves is possible. According to data from the years 2012 and 2013, the broadleaf parameter showed no correlation with soil attributes for the study area. In relation to narrow leaves, in the two years there was a significant correlation for six soil attributes (clay, copper, iron, manganese, pH and potassium). The repetitions of the significance of the correlations for the two years are due to the fact that the soil and invasive plant samples were collected at the same sampling points established in the two years and also because there is no application of agricultural lime in the study area, the which confirms the existence of spatial dependence on weeds. It was confirmed in the research that the adequate and viable mapping for the aggregated distribution structure of the weeds uses grids that better described the information of the reduction of the sampling points, using 50 x 50 m for the monocots and 30 x 30 m for the dicots. Only monocots showed correlations with soil attributes, due to possible variations in the data found in studies of weeds, it is suggested that, for each sampling area studied, the behavior of infestation data in relation to the distribution of these plants be evaluated , determining feasible technical and economic characteristics to apply in all situations Invasive plants should not be disregarded, as this would neglect the process of preparing maps (CAMICIA et al., 2015).

Another survey carried out in 2012 evaluated the relationship between weed reflectance indices obtained by the GreenSeeker™ sensor and conventional parameters for quantifying weed inferences, in addition to indicating this real-time quantification through light sensors, facilitating the adoption of weed thresholds in precision agriculture for weed control. The correlation of weed leaf cover measured by digital photography with normalized difference vegetation indices (NDVI) and red to near infrared (red/NIR) ratio obtained by the GreenSeeker™ equipment in the soybean experiment was 0.711 and -0.693, respectively (MEROTTO et al., 2012).

Soybean grain yield showed increasing association with visual weed control performed at 15, 29 and 45 DAT. The analysis of the main components of the variables analyzed in the soybean experiment indicated that the first two main components accounted for 83.6% of the total variance, with 51.0 and 32.6% for the first and second main components, respectively, indicating the validity of the analysis with the data obtained. Component analysis indicated that the normalized difference vegetation index (NDVI) and weed leaf cover and weeds varied and were highly related to the variability of treatments. These variables showed opposite behavior to the Red/NIR index. Furthermore, principal component analysis indicated that visual weed control was highly associated with grain yield, and that these parameters showed opposite behavior to weed dry matter (MEROTTO et al., 2012).

The use of the GreenSeeker™ tool to quantify weeds in soybean and corn presented satisfactory performance. This tool has been used to determine the amount of canopy-related vegetation cover of crops without distinguishing their location. In the soybean experiment, row spacing was identified as a limiting factor for evaluating the presence of weeds with the GreenSeeker™ tool. For corn, the greater spacing between rows may result in better conditions to estimate weed reflectance and its relationship with other methods of quantifying interspecific competition. The use of the tool to obtain digital photography was optimized in relation to the weed canopy, mainly regarding the horizontal location of the reading, walking speed and number of readings per sample area. Data analysis and manipulation in the corn experiment were similar to those performed in the soybean experiment (MEROTTO et al., 2012).

However, more details were obtained regarding the NDVI index. In addition to obtaining these indexes for the entire plot, specific measurements were also carried out in the same area used for digital photography and samples were collected to determine the dry matter of the weeds. In addition, data manipulation was performed by eliminating NDVI readings less than 0.5. These readings are related to bare ground or straw and may confound the effect of one or a few small NDVI readings related to weeds when considering data for the entire plot. This information was used to obtain the frequency and average reading of the NDVI. The NDVI obtained at 1 m was associated with dry matter and leaf cover and the regression analysis of leaf cover and NDVI indicated that both have a positive association. In addition, the NDVI value for bare soil obtained by the linear regression intercept coefficient value was 0.42 and 0.36 for the soybean and corn experiments, respectively (MEROTTO et al., 2012).

The close association of reflectance indices with leaf cover and weed dry matter indicates the possibility of using the GreenSeeker™ tool for weed quantification. Making it possible to provide information for the composition of the infestation map or be used as a tool for a combined diagnostic, decision-making and control system in real-time operation. The effectiveness of the GreenSeeker™ tool in obtaining accurate reflectance indices for weed quantification can be assessed by correlating the NDVI index and weed leaf cover, as well as comparing the values of each NDVI reading at the distance of approximately 2.5 cm and the corresponding actual presence of weeds based on digital photography. It was found that the NDVI values are approximately 0.3 for straw and increase to 0.73 in the reading that corresponds to the location of the central part of the *Urochloa plantaginea* plant. Indicating that the NDVI index is also discriminatory for *U. plantaginea* plants at different stages of development, in which the NDVIs for plants with lower and upper leaf areas were approximately 0.50 and 0.73, respectively (MEROTTO et al., 2012).

Considering the relationships with grain yield, the NDVI measured in the entire portion of the study showed a better association with grain yield than measurements performed only in the sample area of 1 m, illustrating that, as the cover of the leaves of the weed increases, the index increases and the crop grain yield decreases. This relationship was closer when the NDVI was obtained in the entire plot, which was the same sampled area for grain yield. In addition, the analysis of the principal components shows an association between grain production and weed control measured by the visual method, in relation to the effect of herbicides applied in the post-emergence period. This association was closer, as the evaluations were carried out later, representing a greater correspondence with the effect of the intensity of weed competition with the growth and development of the crop. Digital images with a resolution of approximately 0.048 mm^2 per pixel were accurate, however, the main purpose of using digital photographs in this research was not the means of decision making for a specific method of weed control. The evaluation of weed infestation by digital imaging was used as a method to quantify weeds to be compared with the reflectance indices provided by the GreenSeeker™ equipment (MEROTTO et al., 2012).

The NDVI reflectance index was correlated with leaf area cover and weed dry matter in soybean and corn. The GreenSeeker™ tool was able to accurately obtain the NDVI of the weeds present in these crops. These results indicate that GreenSeeker™, originally used to determine nitrogen topdressing rates in row crops, can also be used to obtain weed reflectance indices between soybean and corn rows and can be used in the decision procedures related to weed control (MEROTTO et al., 2012). Another research carried out in Boa Vista das Missões (RS), characterized the spatial and phytosociological variability of weeds in a soybean preparation area, managed with precision agricultural tools. The phytosociological survey identified 1,739 individuals belonging to 19 species (15 Magnoliopisidas and 4 Liliopisidas) from 13 families, with Poaceae (4), Asteraceae (3) and Solanaceae (2) being those with the highest number of species in the area. The sampling mapping method in regular sampling networks was able to capture the spatial variability of the sampled points, increasing the precision as it thickened the samples, having as a limitation the farmer, the time and work required for denser collections (SANTI et al., 2014).

The weed *Raphanus raphanistrum* was the one with the highest frequencies and relative frequencies, equivalent to 0.214 and 21.83%, respectively. Its spatial distribution presented a more uniform behavior when compared to the other species, presenting the third largest IVI (41.00). This uniformity may be associated with its use as a green cover in winter before soybean cultivation. At the time, the desiccation of R. *raphanistrum* was delayed and, consequently, many plants closed the cycle in the area, increasing the seed bank of the species. The importance of performing an efficient *burndown* application is highlighted, avoiding the occurrence of cover species such as weeds in the crop in succession and/or rotation (SANTI et al., 2014).

The total density of weed infestation was approximately 20 plants m^{-2}, meaning a significant decrease in productivity when no control method is adopted. The species *Euphorbia heterophylla* showed low density, 0.98 plant m^{-2}; however, it is necessary to observe its relative frequency (FR%), which represented approximately 62% of the IVI, reaching a value of 13.86%, demonstrating the presence of species in most of the area, but with low density. Although this has occurred, the infestation community composed mainly of *E. heterophylla* and *U. plantaginea* requires attention in monitoring, due to the high competitive capacity of these species in soybean cultivation. In the Brazilian state of Rio Grande do Sul, where soybean cultivation is almost entirely carried out with glyphosate-resistant transgenic cultivars, the species E. *heterophylla* has glyphosate-tolerant biotypes (SANTI et al., 2014).

The *Liliopsida* plants showed a tendency to behave in the area as a spot, and this characteristic was observed for the species U. *plantaginea* and *Digitaria horizontalis*, due to the relative density (DR%) and relative abundance (AR%) rates, which were more expressive for these species. The species *Ipomoea grandifolia* and *Sida rhombifolia* presented very similar phytosociological rates FR%, DR% and AR%. For *I. triloba*, they were 6.49, 3.91 and 5.81, and for *S. rhombifolia*, 7.37, 3.86 and 5.04, as well as the IVI of 16.21 and 16.27, respectively. The main weed species observed in the study are called rudal strategists, established in the area and adapting to the system used (currently, direct seeding on straw) (SANTI et al., 2014).

The localized management of weeds is justified if performed based on the species class, Liliopsidas or Magnoliopsidas, as it would establish the infestation zones. In this sense, to characterize the spatial variability based on species families, thematic maps based on cumulative species belonging to the same class are relevant. Maps reveal that there is greater infestation of plants classified as Magnoliopsidas. Based on the interpolated maps, 68.91% of the area would have no need for herbicide to control weeds of the Liliopsida class and, in 28.68%, there was no need to control the species of the Magnoliopsida class, which can generate savings on herbicides and minimize the environmental impact. As the localized application was not performed, studies that can really prove the technical and economic efficiency of this weed control method are suggested (SANTI et al., 2014).

The sampling method was able to characterize the occurrence and spatial variability of weeds in soybean cultivation. The species *Cardiospermum halicacabum*, *Digitaria horizontalis*), *U. plantaginea*, *R. raphanistrum* showed the greatest variation in population in the region; however, only *C. halicacabum*, *U. plantaginea* and *R. raphanistrum* considerably taller. Localized management strategies, considering the spatial variability of weed species grouped in the Magnoliopsida and Liliopsida classes, have a high potential for use in soybean cultivation. With the evolution of cases of herbicide-resistant weed biotypes, sample studies - such as this one - should be carried out more frequently, in order to monitor the population dynamics of weeds occurring in crops and thus assist in decision making for its control (SANTI et al., 2014).

6) Pest control:

Research carried out in the municipality of Júlio de Castilhos (RS), evaluated the influence of sample density applied to georeferenced monitoring of defoliating caterpillars in the soybean crop. It was verified, regardless of the sample grids, high relative dispersion in relation to the average (high coefficient of variation), revealing non-homogeneity. This finding is justified by the minimum and maximum number of caterpillars, which vary the crop cycle starting from zero in the first evaluation, until reaching 20.3 caterpillars per whipping cloth in the fifth evaluation. The increase in defoliating caterpillars at the end of the cycle may be related to the non-application of insecticides, as the control level of 20 caterpillars was not reached (RIFFEL et al., 2012).

As the number of caterpillars increased (fifth evaluation), the coefficient of variation values were reduced, demonstrating homogeneity in the distribution of caterpillars in the area. The smaller the sampling grid (closer sampling points), the more accurate the evaluations performed. Allowing greater levels of success in the distribution of caterpillars in the area. The best-fitted semivariogram model was the spherical one, applied with parameters related to entomology, indicating that insects form aggregations in the field and attack occurs in reboleiras (RIFFEL et al., 2012).

The results of spatial dependence represent the influence of sampling points in relation to neighboring points. When the spatial dependence between the sampled points, the spatial distribution of insects is characterized as aggregated, in this case geostatistics is the most suitable tool for the study of insects. As for range, the values range from 176 to 352 m (50 x 50 m mesh), 124 to 372 (71 x 71 m mesh) and 350 to 370 m (100 x 100 m mesh), thus located sampling points at greater distances they are randomly distributed, being independent of each other. The range data are important for choosing the sampling grid, allowing the maximum distance between the points to provide reliable data of insect pest infestation in the cultivated areas. It was found that the three sample meshes studied were efficient to characterize the distribution of *A. gemmatalis* and *P. includens* caterpillars in the soybean crop (RIFFEL et al., 2012).

By approaching sample points, there is greater detailing of the spatial distribution of the caterpillar, generating accurate thematic maps. On the other hand, the measure of sample density increases, more time is needed to carry out the monitoring and higher costs to develop activities. Therefore, it is necessary to choose the use of a larger or smaller mesh considering: area size, availability of labor, phenological stage of the crop, infestation levels, time and costs. The spatialization of values obtained at the time of greater presence of caterpillars in the area, through thematic maps, allows identifying the sub-regions of the area with the greatest propensity to suffer damage from pests, regardless of the sampling grid used. Although the level of accuracy in the definition of these sub-regions depends directly on the sampling network, unlike what was found in the evaluation using the traditional method, which does not allow obtaining such information and elaborating specific management strategies in the area (RIFFEL et al., 2012).

Knowing the space-time dynamics of the pest can provide decision-making based on the greater amount of information, enabling control of infested areas. The use of precision farming tools, such as site-specific application, can reduce the amount of insecticide used. Thus, the use of precision agriculture tools, such as sampling and georeferenced monitoring of caterpillars in soybean crops, allows the development of control strategies, aiming at the rational use of insecticide and generating lower environmental impacts (RIFFEL et al., 2012).

CONCLUSIONS

The results of this integrative review demonstrate several aspects related to the soybean crop, including characteristics related to the physiological quality of the seeds, the sowing efficiency of the soybean, the chemical and physical attributes of the soil, the spectral indices of the soybean growth stages, evaluation of weed and pest control.

The articles cited in this review show the possibilities of precision agriculture as a tool for improving soybean crop productivity. Among the items highlighted as technologies for precision agriculture were maps and digital images, machinery, tests, computer systems/programs, software, georeferencing, soil analysis, electronic meters, equipment and optical sensors.

This research proved that the tools used in precision agriculture are relevant for professional qualification, increased productivity, reduced environmental impacts, sustainability, optimization of time and products and services, and cost reduction.

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