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Relationship between soy productive chain, circular economy, precision agriculture, and no-tillage planting system

Karoline Arguelho Silva[1], Universidade de São Paulo
Anamari Viegas de Araújo Motomiya[2], Universidade Federal da Grande Dourados
Isotilia Costa Melo[3], Universidade de São Paulo
Diogo Ferraz[4], Universidade Federal Rural da Amazônia
Daisy Aparecida do Nascimento Rebelatto[5], Universidade de São Paulo

ABSTRACT

Despite the relevance of these themes for the soy production chain, No-Tillage System, Precision Agriculture, and Circular Economy (CE) are still little studied jointly in the Brazilian context. Less focus has been given to the relationship between the three concepts so far. For this reason, this paper aimed to analyze the contribution of Precision Agriculture and No-Tillage to the achievement of the CE, through the mapping of soy production. The method used was the literature review of the specialized references and the case study, to demonstrate the possibility of a more sustainable production system in a rural property in the state of Mato Grosso do Sul. The results showed that the application of the CE generated better use of the production residues, in addition to the reduction of agricultural inputs used in the rural property. Consequently, it was found that the application of these concepts made the business more profitable for the rural producer.

***Keywords**: Circular Economy, No-Tillage, Precision Agriculture, Soy, Brazil*

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1 Av. Prof. Luciano Gualberto, 1380 - Butantã, São Paulo - SP, 05508-010, karoline.arguelho@usp.br; 2. anamarimotomiya@ufgd.edu.br; 3. isotilia@gmail.com; 4. diogoferraz@alumni.usp.br; 5. daisy@usp.br
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1. INTRODUCTION

Since the 1980s, Brazil has stopped importing food and has become one of the largest agro-exporters in the world. For this reason, the Brazilian economy depends on two important factors, namely: agriculture and sustainability (PAULA; FAVERET FILHO, 1998). In this respect, the agricultural sector has a fundamental role in the country's economy. According to the Brazilian Institute of Geography and Statistics (IBGE, 2020), in 2017, agriculture represented 21% of Brazil's Gross Domestic Product (GDP), accounting for half of the exported total, which contributed to a national positive trade balance. Furthermore, the agricultural sector is also important from a social point of view (SILVA; FERNANDES, 2012), as it generates around 16.5 million direct or indirect jobs (CONAB, 2019).

Rural properties depend on inputs, i.e. essential technical information to aid planting and managing services, factors that are impacted by the globalization of the economy. For example, Brazilian agricultural productivity has grown due to technological advances in the field, which, joint with research to improve the use of inputs, optimized grain production and quality. Besides, the mechanization of the field contributed to the increase in productivity, as well as to the greater international competitiveness (VERGARA et al., 2017).

According to Mulla (2013) Precision Agriculture (PA) generally involves better management of farm inputs such as fertilisers, herbicides,seed, fuel (used during tillage, planting, spraying, etc.) by doing the right management practice at the right place and the right time. Gardemaier et al. (2012) considers that agricultural systems such PA are regenerative, designed to promote soil health. The PA regenerates the soil through practices such as composting, crop rotation, cover cultivation, and no-tillage. For example, No-Tillage System is widely used in PA, it consists of a practice in which agricultural residues are left in the soil, there is no mechanized soil preparation, and weeds are controlled by non-polluting herbicides.

The projection of a Circular Economy (CE) model represents an opportunity with several associated benefits. In this approach, the materials are returned to the production cycle, through reuse, recovery, and/or recycling. CE intends to design products intelligently, extending product life, changing the role of goods and services within the system. This is because, the CE provides multiple product life cycles, which is crucial to obtain effectiveness (BRESSANELLI; PERONA; SACCANI, 2019).

Given the previous context, this paper aimed to analyze the contribution of Precision Agriculture and No-Tillage System to the achievement of the Circular Economy, through the mapping of soy production, executed in a rural property in the state of Mato Grosso do Sul (MS). Thus, this paper addressed production activities, from soil preparation to soybean harvest. Also, it related, conceptually, precision agriculture, no-tillage system, and circular economy, in search of a more sustainable production system.

This paper has five sections, in addition to this Introduction. The second section discusses the literature review on Circular Economy, No-Tillage System, and Precision Agriculture. The third section presents the applied Method. The fourth section discusses the found results. Finally, the fifth section concludes.

2. LITERATURE REVIEW

2.1 Approach to the Soy Productive Chain

Soy is one of the most economically important crops for Brazilian agribusiness. This fact can be attributed to the development and structuring of the international market, to the consolidation of soy as a source of vegetable protein, and to the generation of new technologies that made possible the expansion of exploration in various regions of the world (HIRAKURI, 2014).

In Brazil, soy has consolidated itself as one of the main agricultural products, strengthening the country's position as one of the main players in the world agricultural trade. Also, the agricultural commodity has an important role in the country's economy, due to the participation of the soy complex in Brazil's total exports (GADERMAIER et al., 2012).

For example, exports from the soy agro-industrial complex reached an approximate value of US$ 25 billion in the year 2016, which represents about 35% of national agribusiness exports (Brazil, 2016). In terms of production, there was an increase in recent years, as Brazilian soybean production went from 26,160 thousand tons in the 1997 harvest, to 95,434.60 thousand tons in the 2016 harvest, which corresponds to an increase of 264.81%. Concerning the cultivated area, in the same period, there was an increase of 192.16%, going from 11,381.3 thousand hectares to 33,251.9 thousand hectares (CONAB, 2017).

2.2 Soy, Precision Agriculture and Circular Economy

Complexity is present in all the biological diversity that sustains life on Earth. Human beings experience the ability to adapt and intervene in systems, consolidating the development of advanced technologies focused on productivity gains (UNSCHOOL, 2019). However, this interference in natural processes may have consequences for the environment and has been a matter of concern worldwide since the 1980s (KAZAZIAN, 2005).

The No-Tillage System consolidates the greatest technological innovation in the agricultural sector (ARAÚJO, 2011). The improvement of no-tillage according to regional conditions creates regional identity, according to the environmental offer of growth factors. Much of the success of this system resides in the fact that the straw, left by cover crops on the soil surface, added to the residues of the commercial crops, creates an extremely favorable environment for plant growth and simultaneously contributes to the stabilization of production and the recovery or maintenance of soil quality (BROCH; PITOL; BORGES, 1997).

The search for soil cover plants that are more adapted to different environments is better suited to crop rotation systems, such as corn and soybeans. In this context, it fits the concepts of the Precision Agriculture system, which is the management of the spatial variability of production and the factors involved in this process, carried out through recent technologies adapted to the agricultural environment, to enable the reduction of the use of inputs and the environmental impacts (CIRANI; MORAES, 2010).

The application of large-scale regenerative agriculture could restore Brazil's great reserve of natural capital, increase biological diversity, close nutrient cycles, increase the nutritional content of food, and provide water savings - this occurs while increasing agricultural production and profitability. These practices could reduce the costs of the used resources and create financial advantages over conventional agricultural methods (ADL, IRON; KOLOKOLNIKOV, 2011).

Achieving scale will require expanding access to long-term financial resources, both in large operations and in small rural properties, through new financing vehicles and more information on long-term returns and risks of regenerative systems compared to those of conventional systems. It will also require the dissemination of knowledge to rural producers throughout the country about the benefits of regenerative approaches, in addition to detailed information on its implementation at the local level (ARAÚJO, 2011).

Another requirement is a strong link with urban centers, e.g. cities, in a way to recover urban organic waste and adopt strategies to value it. This process of capturing the value of reuse can close the cycle of nutrients by returning them to the soil (CIRANI; MORAES, 2010).

Given the concepts of Araújo (2011), No-Tillage System and Precision Agriculture increase efficiency in the use of agricultural inputs, taking advantage of the plantation residues, managing activities, saving resources, promoting greater sustainability, greater cost-benefit and less soil degradation, similar to the concepts of the Circular Economy that, in addition to waste management, applies in its theory reuse, recovery, and recycling.

The concept of the Circular Economy appears in opposition to the conventional perception that economic systems are linear. A linear system is converted into a circular system when it is made the connection between the use of resources and waste (Bilitewski, 2012). According to Abramovay (2014), this is a production standard with the objective of removing raw materials from nature, processing them, offering the results to consumption, and discarding their remnants. Also, according to this author, an increasing number of organizations and specialists use this concept.

The best-known definition of Circular Economy was introduced by the Ellen MacArthur Foundation, as “an industrial economy that is restorative or regenerative by intention and design” (EMF, 2013). In this process, reuse happens when there is an appreciation of the products used in the production process, where the inputs are reused, which makes productivity efficient (FERREIRA et al., 2020; CAMPOLI et al., 2019).

2.3 Approach to the relationship between inputs and the environment

The cultivation of soy in Brazil is guided by an environmentally responsible standard, that is, with the use of sustainable agriculture practices, such as the integration-crop-livestock system and some planting techniques. These are practices that allow intensive land use and have a less environmental impact, which reduces the pressure for opening new areas and contributes to the preservation of the environment (CIRANI; MORAES, 2010). Branco et al. (2019) demonstrated, through a multi-criteria approach, that there is no necessity of production area expansion, whether there are a more efficient plating and logistics system.

The use of soil is the main element of agricultural production. The soil is a basic component, a substrate that has organic and mineral materials - essentials for survival and plant development (EMBRAPA, 2014). The degradation of this resource, because of its unregulated use, is one of the greatest environmental problems derived from agricultural practice, generating depletion of the natural fertility of the land (PUGLIESI, 2007).

According to Alves et al. (1997), Precision Agriculture can contribute to minimizing the impact of agriculture on the environment, through: a) the reduction in the application of fertilizers in areas whose capacity for supplying nutrients from the soil is already at sufficient levels for attending cultures’ nutritional requirements. This can have a short-term effect in areas where residual nitrate can be used by the crop, reducing leaching or, in the long run, in the case of phosphorus, which can take several years to reduce the high levels of this nutrient in the soil. Thus, with the application of variable doses of fertilizers, it is possible to achieve the best distribution in the area and minimize the impact on the environment; b) reduction in the use of agrochemicals (insecticides, fungicides, and herbicides), with the application of variable doses. This can be of great value whether most of the area does not require the application of agrochemicals; c) minimize or even eliminate the application of agrochemicals where there is a potential for large losses. This is possible by varying the application of agrochemicals in terms of type, dose, and formulation, according to soil conditions for leaching, erosion, and volatilization; d) reduction of water application, in areas subject to leaching, using a variable irrigation rate; e) to improve erosion control, with a reduction in surface runoff. Soils, in a given area, may present different degrees of susceptibility to erosion, making desirable the application of specific management of soils and crop residues.

2.4 Mapping of activities

According to Barbrow e Hartline (2015), any change in the production process impacts on costs and benefits, highlighting the importance of these factors in the process, as a subsidy for decision making. Regardless of the possible implications, an increase in productivity or a reduction in costs is expected as a return.

The cost analysis is related to the operations carried out on rural properties. Firstly, it is necessary to map all activities that are part of the production process, as well as the costs involved with each activity. It is also necessary to verify the fixed costs or those that do not depend on the produced quantity, as well as the variables that have a direct relationship with the volume of production, with inputs falling into this category (MARTINS, 2006).

In this sense, the mapping of processes meets the identification of the main steps and decisions in a routine workflow in a visual way. It also controls the flow of information, materials, and documents involved in the process and clarifies tasks, decisions, and actions that are necessary at certain points in time. Also, process maps represent the roles of a variety of stakeholders that impact or act during the process (BARBROW; HARTLINE, 2015).

The focus on the approach by process and activities consists of developing a horizontal view of the organizational system, understanding how the production process works and how all its activities are integrated, acting in a complementary way in obtaining the desired results, and finally, the focus on continuous improvement guidance that represents the perception that processes can and should always be improving (OROFINO, 2009).

3. METHODOLOGICAL PROCEDURES

3.1 Research typology

This paper is part of the area of cleaner production and eco-efficiency applied to a soybean farm, with a focus on the applicability of the circular economy and precision agriculture. This paper is relevant from an academic and scientific point of view as Brazilian agribusiness influences the economic development of several Brazilian regions.

We opted for the development of a descriptive and exploratory case study, because from the data collected it describes the reality of the rural enterprise and explores the soy culture. Regarding exploratory research, Diehl and Tatim (2006) describe that this type of research provides a deep relationship with the research problem, to make it more explicit or to build a hypothesis. The descriptive research, Gil (2002) reports that "the descriptive research has as its primary objective the description of the characteristics of a given population or phenomenon or else the establishment of relationships among variables".

Concerning technical procedures, the research is characterized by the following criteria: as bibliographic research, since at first it is necessary to use the theoretical basis, exploring books, national and international scientific articles, among other research sources; it is also characterized as documentary, due to the need to analyze original documents to formulate the base of the collected data; finally, it is characterized as a case study, because it uses a relevant case, which serves to interpret the analyzed phenomenon (YIN, 2001).

The research that addresses the deductive method is contemplated by Diehl and Tatim (2006), as being a method that starts from the analysis of the general to the particular, arriving in a conclusion. Empirical field research is used as a research environment, given that the researcher collected the data in loco and subsequently analyzed the data and presented conclusions about the object of study.

3.2 Data collection procedure

The research was carried out in a rural property, located in the region of the municipality of Maracaju (state of Mato Grosso do Sul), whose geographical coordinates of the agriculture area have latitude of 22º9'17.97'S and longitude of 54º29'40.91'O, using the precision farming system, with fertilization at a varied rate and circular economy at a fixed rate. The climate is of the humid mesothermal Cwa type, according to the classification of Köppen and Geiger (1948). The average annual precipitation is 1500 mm and the average temperature is 22º C and the type of soil in the region is classified as Dystrophic Red Latosol, with a very clayey textural class (EMBRAPA, 2014).

The data collected were provided by the rural owner of the property, which has an average of 200 hectares, the production of the 2016/2017 crop was monitored, from the analysis of the soil to the harvest of the grain.

The interviews were conducted from a structured questionnaire with questions that cover similarities between precision agriculture and the circular economy. As shown in Table 1, there was an analysis of how each productive activity occurred during the harvest.

The visits and interviews served to analyze the soybean crop yield in the diversified farming systems and to identify the main differences among systems.

The interviews took place in 5 informal meetings with the producer on June 4, June 5, June 19, 2017, August 5 and 18, 2018. The interviews lasted, on average, two hours, to collect the data accurately, avoiding the divergence of the results. In this way, it was necessary to know the various agricultural operations that existed in the analyzed property, the necessary phases for the production process, according to the type of soybean crop.

The soil preparation is done to improve its chemical, physical and biological properties, to increase its productive potential with the technique of liming and fertilization. The intensive use of the soil can lead to the formation of compacted layers, the reduction of aggregate stability and the appearance of micropores that lead to soil loss.

The inputs used were the same in both systems, what differed was the quantity and the place of application, and this results in the quality of the grains, due to a lack or excess of products.

With the use of good quality seeds and sowing carried out under ideal conditions, there is a greater probability of gain due to the greater survival of the inoculant bacteria without the use of seed fungicides (BROCH; RANNO, 2011).

Right after the planting of the seeds there is control of the manifestation of weeds throughout the plantation, which according to Procópio *et al.* (2000), the control is done in soybean crops to eliminate weeds, insects, pests, and plant diseases. The use of herbicides has become a mandatory practice in no-tillage systems, that is, chemical weed management. The decision to apply or not the herbicide varies according to the species of weeds present, the level of infestation, the climatic and edaphic conditions, and the type of crop to be sown in the area (SZNITOWSKI, 2012).

3.3 Data Analysis Procedures

The data were collected, followed by data adjustment to the chosen areas. The precision agriculture and circular economy were characterized according to the collected information of each production area. Finally, after the analysis, it was set up a table with the most relevant information.

4. RESULTS AND DISCUSSION

4. 1 System activities in soy production

The research results pointed out several questions regarding the activities of the soy production process, of each system, that of precision agriculture and the circular economy. Table 1 shows the activities that the two systems have in common, the particular activities of each, and the activities that are unrelated. These questions were raised through the researched literature, in order to identify their attributes and, from these, compare the two systems, highlighting the similarity or difference between the activities.

Table 01 - Comparison of system activities

ACTIVITIES	PRECISION AGRICULTURE	CIRCULAR ECONOMY
Environment	○	○
Reuse of Waste	○	○
Resource Income	○	○
Maintenance	○	○
Reuse and Redistribution	-	●
Remanufacturing	-	●
Recycling	-	●
Production Quality	○	○
Technology	○	○
Remote system	●	-
Sensors	●	-
Global Positioning System - GPS	●	-
Mapping of fertility and productivity of activities	●	-

*○ It is common for both concepts, ● It's exclusive for one of the systems, - The system does not have this attribute.

Source: Prepared by the Authors.

Analyzing the data presented in Table 1, it is observed that similar activities (○) in the two systems are environment, waste reuse, resource yield, maintenance, production quality, and technologies. The particular activities (●) of the precision agriculture system are remote control, sensors, GPS, mapping of fertility, and productivity of activities. And the exclusive features of the circular economy (●) are reuse and distribution, remanufacturing, and recycling. The benefits can be applied in the soy production process, precision agriculture, with necessary inputs without waste, and the circular economy with no-tillage, reusing the straw from the harvest as part of fertilizers.

It is important to emphasize that higher return is expected as a consequence of an increase of productive and/or a cost reduction. Both are expected benefits of the decision for changing the soy production system.

4.2 Analyzing the systems

In the soy production process, precision agriculture is composed of three main phases: data collection for mapping, map interpretation, and localized application. Figure 1 is composed of three phases: the data collection phase consists of production monitor, GPS, GIS analysis and production map; the phase of data interpretation, crop and soil data, GIS model, application map; and the application phase that constitute sowing, fertilizing and spraying.

In the circular economy, the soy production process involves data collection, raw material/biochemistry, regeneration, waste utilization, and then minimal losses.

The processes are fed from beginning to end, due to the effect of circularity, and in this case, it is analyzed by the biological cycle of the circular economy, generating management of the flow of renewable inputs, which in this case of the circular economy is direct planting.

4.3 Mapping activities

The activities that constitute the mapping will be shown in Figure 1, as a consequence of all the total resources used in the 2016/2017 harvest period, in the precision agriculture system.

The analyzes were separated into 11 activities: leveling harrow, heavy harrow, soil analysis, application of fertilizers and correctives, application of corrective rates, planting and variable rates, monitoring of crops to map pests and diseases, localized application of pesticides, harvesting with a machine and with productivity sensors, generation of productivity maps, storage, and freight. The activities of analysis and preparation of the soil are carried out in several stages, according to the needs of the soil and/or pest controls. Therefore, it was decided to segregate these activities for better detailing of the information. The following steps are represented in Figure 1.

In this precision farming system, the process from the beginning starts with the leveling harrow and the heavy harrow.

● Leveling grid and heavy grid: the leveling grid is used once and the heavy grid twice. It is the implement intended for soil preparation, which performs plowing and harrowing in the same operation.

● Soil analysis: removal of a sample from the area for chemical analysis, to find out the soil deficiencies for possible corrections.

● Application of fertilizers and correctives: this activity involves the application of insecticides, fungicides, and foliar fertilization, making it necessary to hire third-party services.

● Corrective rate application: the correction of the soil with correctives aims to standardize fertility, allowing all plants to express their maximum productive potential, achieving greater productivity per area.

● Planting and variable rates: application at a variable rate in precision agriculture considers the spatial variability of soil attributes and prescribes the rate of inputs according to the specific needs of each sub-area.

● Monitoring of crops to map pests and diseases: this technology can be applied to support the management and control of plant diseases, phenomena such as pests, diseases, and weed infestations must be monitored, though direct methods must be developed.

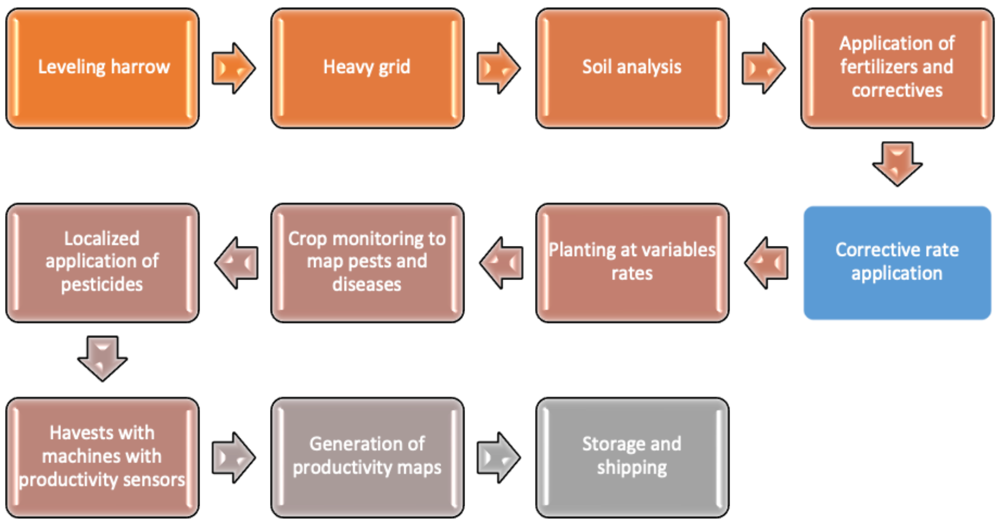
● Localized application of pesticides: this makes it possible for pesticides to be used only in the necessary quantities and locations.

● Harvesting with a machine with productivity sensors: this activity involves contracting third parties and harvesting the grains.

● Generation of productivity maps: provide a visualization of the crop's performance in each part of the planting area.

● Storage and freight: the property does not have grain storage and has outsourced freight, at R$ 1.20 per bag.

Figure 1 - shows the process flow chart. Flowchart of the Precision Agriculture Process



Source: Elaborated by the authors.

In the circular economy system, straw is reused, and no-tilage is used. The importance of this layer of straw on the soil surface is highlighted by Heckler, Hernani and Pitol (1998, p.73) as it works as an attenuator or dissipator of energy, protects the soil against the direct impact of raindrops, acts as an obstacle to the movement of excess water that has not infiltrated the soil evaporation, increasing the infiltration, and storage of water in the soil, promoting milder temperatures in the topmost layer to the development of plants and organisms. With its slow and gradual incorporation into the soil, it promotes an increase in organic matter, which is a source of energy for microorganisms. There is also an increase in microbial activity that, together with mineralization, makes nutrients available to plants, inducing improved productivity. Its protective presence promotes weed control, a decisive factor for the success of the no-tillage system. The straw is fundamental for permanent soil coverage, as it maintains or improves physical, chemical and biological attributes, and, therefore, the soil quality.

Figure 2 - Flowchart of the Circular Economy Process

Source: Elaborated by the authors.

The production process analyzed by the circular economy has five activities: crop planning, purchase of inputs, preparation and planting, management, and harvesting (Figure 2). Planting is carried out directly without interventions, the seed is injected into the soil under the straw. Some advantages of this system can be cited as erosion control, an increase of soil organic matter contents, improvement of soil structure, reduction of soil water losses, reduction of soil temperature variation, an increase of soil biological activity, lower number of operations with machinery among others.

5. CONCLUSIONS

This paper brought a bibliographic review on the concepts of the soy production chain, no-tillage, circular economy, precision agriculture, and the importance of mapping activities. Thus, this article correlates the theoretical concepts of precision agriculture, no-tillage, and circular economy. Besides, in order to give greater practicality, this paper used a case study on a 200-hectare property based on the literature used.

It was verified that, through the joint application of the circular economy and precision agriculture, it was possible to use residues generated by the production, which resulted in a significant decrease in demand for productive inputs. This impacting change was financially feasible for rural producer.

For future studies, it is recommended to study in-depth the costs of applying the new technologies available. It is also recommended to explore the concept of digital farm and related technologies such as, for example, the use of drones in agriculture. Finally, it argues the need to consolidate the theoretical and practical concepts between precision agriculture and circular economy, in order to incorporate scientific advances and generate benefits for the economic agents of the soy production chain.

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