Topics in Agricultural Entomology XIII

Joacir do Nascimento | Claudiane Martins da Rocha
Daniel Dalvan do Nascimento | Edimar Peterlini
Érica Ayumi Taguti | Joao Rafael Silva Soares
Matheus Cardoso de Castro | Sandy Sousa Fonsêca
Vinicius Ferraz Nascimento| Ricardo Antonio Polanczyk
(organizadores)

Atena Editora
Ano 2022

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PREFACE

The Graduate Program in Agronomy (Agricultural Entomology) at the UNESP Faculty of Agricultural and Veterinary Sciences in Jaboticabal has always been characterized by its focus on Integrated Pest Management (IPM). Since its foundation, the program has graduated 287 students with a master's degree and 148 Ph.D. students. They are now active in various areas of the public or private sector and contribute to agriculture's economic and environmental sustainability.

This e-book entitled "Topics in Agricultural Entomology - XIII" was made possible through the immense effort of the Organizing Committee, formed by MSc and Ph.D. students from all research areas of our Graduate Program. In its 14 chapters, readers will find information on the most diverse areas of IPM, with a richness of information on both the fundamental and applied aspects of IPM.

As coordinator of the 2022 edition of the Winter Workshop on Agricultural Entomology, it is my pleasure to provide event attendees with an e-book of excellent content, demonstrating the importance of our research to society.

Prof. Ricardo Antônio Polanczyk

FCAV/UNESP

PPG Entomologia Agrícola Coordinator

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LANDSCAPE STRUCTURE AND INSECT PEST MANAGEMENT

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1 I INTRODUCTION

Landscape, which refers to the spatial arrangement of natural, semi-natural, and anthropic elements, as well as their interactions, can provide a series of ecosystem services, such as soil nutrient cycling, plant pollination, water conservation, and natural control of pests (Metzger, 2001; Power, 2010). These services are essential for humans and the maintenance of biodiversity (Woltz; Isaacs & Landis, 2012; Duarte et al., 2018). However, the landscape configuration can influence the availability and interaction between these multiple services (Rieb & Bennett, 2020).

In the agricultural context, the arrangement of landscape elements highly influences the ecosystem services provided to the crops of interest, especially in the population dynamics of insect pests and their natural enemies (Jonsson et al., 2010; Zamberletti et al., 2021). With the expansion of agriculture, natural habitats have changed or even reduced (Figure 1). Therefore, the indiscriminate alteration of the environment can cause the loss of diversity of species that act in pest control (Bianchi; Booij & Tscharntke, 2006).

Figure 1 - Typical landscape of Central Brazil used for raising livestock with agricultural, natural, and semi-natural elements. Source: O.A. Fernandes

Natural habitats near crops are essential for providing shelter and food to maintain populations of predators and parasitoids (Cronin & Reeve, 2005; Bianchi; Booij & Tscharntke, 2006). Although beneficial to natural enemies, natural vegetation fragments can also benefit pest species in some contexts (Blitzer et al., 2012). As a result, several studies have evaluated how the proportions of different landscape elements can affect pest abundance and their biological control at various spatial and temporal scales (Veres et al., 2013; Haan; Zhang & Landis, 2020).

This chapter discusses the interactions between natural and agricultural habitats, the role and influence of landscapes on different types of insects, and how it is possible to manage the environment to keep the ecosystem services provided by the landscape.

2 I COMPOSITION AND CONFIGURATION OF NATURAL AND AGRICULTURAL LANDSCAPES

The concept of landscape has been discussed since the 19th century, when geography was established as a science (Schier, 2003; Silveira, 2009; Barbosa & Gonçalves, 2014). The discussion on this topic presented multiple divergent approaches influenced by social and philosophical trends that occurred at the time (Luchiari, 2001; Detoni, 2012). Landscape can be defined as a set formed by heterogeneous units that interact with each other or even a system of natural and semi-natural formations that produce services and natural resources (Metzger, 2001; Rodriguez; Silva & Cavalcanti, 2022).

The study of landscapes considers the relationships between the various components for their formation, as structural, functional, and dynamic-evolutionary processes. In general, the study of landscapes requires the evaluation of a set of physical or cultural elements, which are interconnected in space and time (Sauer, 1998). The most important features to consider in a landscape are its structure, composition, and function (Noss, 1983). Structure refers to the arrangement of units, the distribution of elements, and their relationships, while composition describes the variety of elements or species within a region. Finally, the function encompasses all processes, from cycling materials to defining the ecological role played by each species (Forman & Godron, 1986; Walz, 2011; Vidal & Mascarenhas, 2019).

As landscape comprises a heterogeneous set of interactive units, each unit will have a different structure and composition (Opdam et al., 1993). The landscape structure can be characterized by three types: horizontal, vertical, and functional. The horizontal structure is the organization and spatial distribution of individuals on the surface of a territory. The vertical structure is formed by the interrelation of the components considering their participation or function, such as dominant, intermediate, or dominated species. The functional structure is expressed by the sequence of permanent processes that are interrelated in the exchange of energy, matter, and information in which the landscape operates (Rodriguez; Silva & Cavalcanti, 2022). Therefore, the structure of a landscape is determined by its type of use, size, arrangement, shape, and the distribution of individual elements constituting it (Walz, 2011). Thus, a landscape structure can be defined by understanding its elements, parameters, and indices. These components change their composition due to natural biological processes, as well as modifications due to anthropic action. Such modifications alter the functioning of a landscape, affecting its structure and, consequently, the pattern distribution of species (Vidal & Silva, 2021).

It is also noteworthy that the changes in the natural environment resulting from human activities are not easily dissociated from studies of the ecology of natural landscapes, besides impacting ecological processes leading to the loss of biodiversity (Tannier et al., 2016). The natural landscape can be understood as a mosaic formed essentially by natural elements, and modified according to their processes, without human interference (Shafer; Hamilton & Schmidt, 1969). On the other hand, cultural, humanized, or semi-natural landscapes are those that relate biological and geographical elements to elements derived from human action (Tricart, 1982; Thomine et al., 2022).

To study the fragmented natural structures and their composition, the concepts of fragment, corridor, and matrix were created (Siqueira; Castro & Faria, 2013). Fragments can be defined as non-linear surfaces that differ in appearance from their surroundings (Forman; Godron, 1986 & Casimiro, 2009). The corridors, on the other hand, are the elements that promote the connection between other ecosystems in the landscape; however, they can also represent physical barriers that prevent the movement of species (Marsh, 2005). Finally, the matrix represents the type of ecosystem that occupies the largest area, thus being the most extensive and the most connected with the other elements (Casimiro, 2009).

One of the main changes in natural landscapes is due to agriculture (Tilman et al., 2011; Tanentzap et al., 2015). The traditional agroecosystem is characterized by growing a plant species on a large scale, with low genetic variability, and generally with a short life cycle (annual or semi perennial). Agricultural intensification and expansion reduce the number of natural habitats around crop fields and, consequently, the complexity of the ecosystem (Rieb & Bennett, 2020). Landscape simplification modifies the amount and diversity of land cover types (compositional heterogeneity), including natural and semi-natural habitats (Gagic; Paull & Schellhorn, 2018; Blassioli-Moraes et al., 2022).

Landscape homogeneity also alters the spatial arrangement of cultivated and uncultivated areas, resulting in low connectivity (Blitzer et al., 2012; Gámez-Virués et al., 2015). Habitat loss and fragmentation reduce the compositional and configurational heterogeneity of the landscape, leading to biotic homogenization, species loss, and reduction of ecosystem services (Tscharntke et al., 2012). These factors contribute to a concentration of resources, favoring herbivorous organisms.

The need for sustainable agricultural practices, especially the reduction of the use of pesticides, guided the search for agroecosystem management options that improve biodiversity and ecosystem services (Duru et al., 2015). Thus, the services provided by the landscape are a field of study that considers the spatial configuration and the influence of elements external to the ecosystem (Bastian et al., 2014). These biodiversity-based management options can be complex, as they require prior knowledge, the integration of agricultural practices, and ecological processes that can occur at different spatial and temporal scales (Turner, 2005; Médiène et al., 2011; Petit; Deytieux & Cordeau, 2021). Therefore, knowing the influence of these ecological processes on phytophagous or carnivorous arthropods is the first step towards the correct inclusion of landscape components in management programs, and maximum benefit from the services provided.

3 I INFLUENCE OF LANDSCAPE ON INSECT PESTS

Habitat structure has the potential to influence the number of a species in a location, as it can affect the reproduction, dispersal, and mortality of such a species, including its natural enemies (Veres et al., 2013). In agricultural fields, the presence of natural and semi-natural areas can affect the development and damage caused by insect pest species (Poveda et al., 2012; Rice et al., 2017). However, the influence of landscape structure on pests is often contradictory or taxon-specific (Jonsson et al., 2010; Karp et al., 2018). Thus, understanding the relationships between the source and sink of insects in fragments close to crops is of paramount importance to improve pest management, and predict the occurrence of insect infestations (Goethe et al., 2022).

The low diversity of agricultural habitats is usually considered to benefit the population increase of insect pests and a disadvantage to natural enemies. Trophic interaction (intraguild predation), agricultural practices, crop susceptibility, or abiotic conditions are some reasons for such a scenario (Tscharntke et al., 2016). However, increasing landscape diversity can be detrimental to pest populations (Karp et al., 2018; Paredes et al., 2021). The predation intensity of the soybean aphid, *Aphis glycines* (Hemiptera: Aphididae), increases with a greater diversity of the landscape and/or soil cover (Gardiner et al., 2009; Noma et al., 2010; Mitchell et al., 2022). Similarly, populations of tobacco thrips, *Thrips tabaci* (Thysanoptera: Thripidae), are also influenced by habitat in leek crops, where lower populations of this insect are found when there is greater habitat diversity surrounding these crops (Den Belder et al., 2002).

Although there are positive examples of pest reduction with the presence of semi-natural habitats in the cultivation area, there are also cases in which these environments may be suitable for the development of insect pests and, consequently, the growth of their populations (Landis; Wratten & Gurr, 2000; Blitzer et al., 2012; Tscharntke et al., 2016). Five hypotheses can explain this situation: (1) there are more important resources in crops than in non-agricultural habitats for natural enemies; (2) there are no effective natural enemies in the region; (3) natural/semi-natural areas are more suitable for pests than natural enemies; (4) absence of configuration, composition, or proximity in uncultivated habitats to supply the demand of natural enemies in biological control, and (5) agriculture neutralizes the installation of natural enemies (Tscharntke et al., 2016). As an example, more abundant populations of *Oulema* spp. (Coleoptera: Chrysomelidae) and *Sitobion avenae* (Hemiptera: Aphididae) were found in landscapes with greater amounts of semi-natural habitat (Redlich; Martin; & Steffan-Dewenter, 2021). Non-agricultural habitats were positively correlated with aphid populations in wheat crops, as they assist in the life cycle, serving as a source of alternative host plants and shelter for aphid colonization (Yang et al., 2019).

However, it is important to note that different pest groups and species within the same cropping system show varying responses to landscape composition (Perez-Alvarez; Nault & Poveda, 2018). Landscape simplification in maize, for example, favors the Asian corn borer, *Ostrinia furnacalis* (Lepidoptera: Crambidae), a specialist pest, but negatively affects the small corn borer, *Conogethes punctiferalis* (Lepidoptera: Crambidae), a polyphagous pest in the crop (Dong et al., 2020). The abundance of some thrips species (Thysanoptera: Thripidae) was positively related to the proportion of forest in alfalfa crops, while other species of the same family were negatively affected (Madeira et al., 2022). It has been found that polyphagous leafhoppers (Hemiptera: Cicadellidae) can move more between patches because they are more likely to have long wings, while many specialist leafhoppers species have limited dispersal abilities due to their short wings. Furthermore, species richness of polyphagous leafhoppers is affected by connectivity, landscape composition, and fragment size, while specialist leafhoppers are not affected by this influence (Rösch et al., 2013).

Another issue to be considered is that the landscape structure can affect the movement and dispersion of pests (Goodwin & Fahrig, 2002). The presence of more diversified vegetation increases the complexity of the habitat and can negatively affect the location and use of the insect pest host plant (Mazzi & Dorn, 2012; Togni et al., 2021). Finding and choosing a host in environments with many plant species can be a difficult task, especially for polyphagous insects (Silva & Clarke, 2020). Semi-natural vegetation can limit the migration and diffusion of volatiles (pheromones and allelochemicals), which reduces, for example, the possibility of finding mates at low population densities, and recolonization of the cultivation area (Ricci et al., 2009; Blassioli-Moraes et al., 2022). In addition, the increase in time spent on dispersal results in costs, such as increased mortality from predation, and decreased resources for fecundity and survival (Mazzi & Dorn, 2012). Therefore, pest responses to landscape change must be linked to the ability of the species to disperse, and to changes in landscape structure (Goodwin & Fahrig, 2002).

Thus, it is possible to verify that natural habitats can simultaneously benefit or even disadvantage nearby crops depending on cropping systems and geographic regions (Thies; Roschewitz & Tscharntke, 2005; Tscharntke et al., 2016; Karp et al., 2018). However, it should be noted that there are a limited number of studies on the influence of landscape structure on pests. Furthermore, the existing studies on insect pests encompass mainly the orders Lepidoptera, Coleoptera, and Hemiptera (Worner & Gevrey, 2006; Letourneau et al., 2011).

Although there are divergences among existing studies, evidence suggests that landscapes with sufficient levels of non-agricultural vegetation are more diverse and have a greater provision of ecosystem services (Haan et al., 2021). However, the influence of semi-natural habitats cannot be generalized, as arthropods can be affected in different ways (Kheirodin; Carcamo & Costamagna, 2020).

4 I INFLUENCE OF LANDSCAPE ON NATURAL ENEMIES

Cultivated areas with little vegetation diversity and disturbed frequently are usually unsuitable for some beneficial insects (Landis; Wratten & Gurr, 2000; Haan; Zhang & Landis, 2020). Therefore, the presence of more stable non-agricultural areas (natural or semi-natural) near cultivated areas may favor the presence of these individuals (Bianchi; Booij & Tscharntke, 2006; Haan; Zhang & Landis, 2020). As for phytophagous insects, natural and semi-natural habitats can provide different resources, such as alternative foods (nectar, pollen, prey, and hosts), shelter, or a microclimate in which natural enemies can hibernate or seek refuge (Landis; Wratten & Gurr, 2000; Bianchi; Booij & Tscharntke, 2006; Haan; Zhang & Landis, 2020). In addition, organisms that require resources from various types of land cover can benefit from landscape complementation and move between different types of habitats (Veres et al., 2013; Haan; Zhang & Landis, 2020). Therefore, the interaction between natural and semi-natural habitats with agricultural fields can benefit the presence of natural enemies and lead to more effective pest control (Tscharntke et al., 2007; Woltz; Isaacs & Landis, 2012; Rusch et al., 2016).

Several studies demonstrate the benefits of the presence of uncultivated areas on natural enemies. The increase in landscape complexity can augment the response of natural enemies (abundance, richness, diversity, and direct effects on pest reduction) by about 25% (Duarte et al., 2018). Egg predation rates of the cabbage moth, *Mamestra brassicae* (Lepidoptera: Noctuidae), are reported to be positively correlated with structurally complex landscapes, and negatively correlated with a horticultural area (Bianchi et al., 2005). The abundance of nymphs of *Lygus lineolaris* (Hemiptera: Miridae), an important strawberry pest in the USA, was negatively associated with increasing proportions of semi-natural habitats in the landscape, resulting from increased parasitism rates (Grab et al., 2018).

In tropical and subtropical regions, forest fragments can also be important sources of natural enemies. The forest fragments of the Atlantic Forest (Brazil) are important habitats for predatory and omnivorous ant species that are involved in the regulation of herbivores in sugarcane cultivation (Santos; Bischoff & Fernandes, 2018). In the Chaco Serrano region (Argentina), it was found that as the forest cover in the landscape decreases, fewer species of natural enemies are found moving between native forest fragments and soybean plantations. In addition, natural enemies (especially the orders Coleoptera and Hymenoptera) move more frequently from the forest to the crop field (González et al., 2016). More species and specimens of natural enemies were also found, as well as a higher rate of biological control of green belly stink bug eggs, *Diceraeuss furcatus* (Hemiptera: Pentatomidae), in places with high forest cover. In these locations, biological control by predators and parasitoids was 20% higher (González; Salvo & Valladares, 2017).

Although there is evidence that the responses of natural enemies (abundance, diversity, predation, parasitism) to landscape complexity are positive, these effects may vary between different insect groups and species (Thies; Steffan-Dewenter & Tscharntke, 2003; Woltz; Isaacs & Landis, 2012; Medeiros et al., 2019). In soybean crops in Canada, aphid regulation has increased as the landscape has been simplified (in other words, landscape complexity has decreased). In addition, there was a trend of reduction in the regulation of aphids with the abundance and diversity of their predators (Mitchell; Bennett & Gonzalez, 2014). Therefore, it is observed that even if the landscape complexity in agroecosystems is more important for natural enemies than for pests, the positive response of natural enemies does not necessarily translate into pest control (Chaplin-Kramer et al., 2011). Landscapes heavily disturbed by agricultural practices and insecticide applications can become unsuitable for their specialized organisms, and do not allow the establishment of pest enemy populations. In addition, intraguild predation and greater predation of alternative prey that may not be considered pests may occur (Veres et al., 2013).

In some cases crop damage does not decrease with an increasing diversity of natural enemies, and even with increased pest control, actual crop damage is not necessarily smaller (Bianchi; Booij & Tscharntke, 2006; Chaplin-Kramer et al., 2011). Instead, the diversity of enemies increases due to the abundance of pests in the environment (Martin et al., 2016; Madeira et al., 2022). Thus, to demonstrate benefits to farmers, it is necessary to consider pest control, as well as crop yield, and reduction of insecticide spraying (Macfadyen et al., 2015; Gagic; Paull & Schellhorn, 2018).

It is important to consider that different species of natural enemies generally respond differently to landscape variables (Pfister et al., 2017; Karp et al., 2018; Jowett et al., 2019). The response of generalist natural enemies occurs on larger spatial scales than for specialist individuals (Chaplin-Kramer et al., 2011). Furthermore, for natural enemies that depend only on resources within agricultural fields, proximity to semi-natural habitats may be irrelevant or even harmful (Haan; Zhang & Landis, 2020).

It is also worth noting that natural enemies must present a rapid numerical response to herbivore density to contribute to pest control. For this, they must be present in the area, act easily nearby, or colonize at a greater distance (Tscharntke et al., 2007). Initially, the influence of landscape structure on pest suppression by natural enemies focused on the effects of landscape composition (number of different habitats). However, more recent studies demonstrate that landscape configuration (habitat size and shape, amount of shared edge, and connectivity) is an important factor for pest suppression (Haan; Zhang & Landis, 2020).

In general, pest suppression is expected to be greater in fine-grained agricultural landscapes (small patches and higher edge density) because, in smaller fields, enemies that emerge from the edges of fields or nearby semi-natural habitats can reach the edges and the interiors of crop fields more easily (Haan; Zhang & Landis, 2020). Martin et al. (2016) demonstrated that landscape configuration (edge density) positively influences the abundance and species richness of natural enemies such as parasitoids (Hymenoptera), hoverflies (Diptera: Syrphidae), predatory wasps (Hymenoptera: Vespidae), and rove beetles (Coleoptera: Staphylinidae). However, different landscape parameters also influence different groups of natural enemies in different ways. Fragmentation in rice fields negatively influences the richness and abundance of parasitoids but favors the abundance of the ladybird *Micraspis* spp. (Coleoptera: Coccinellidae) (Dominik et al., 2018). In coffee-growing areas, species richness, and abundance of wasps (Hymenoptera: Vespidae) increased with the expansion of the forest cover in multiple spatial extents, while richness and abundance of hoverflies (Diptera: Syrphidae) were not affected (Medeiros et al., 2019). However, even with these variations between the different groups, of the parameters tested, the landscape configuration had the most stable and consistently positive effects on natural enemies and reaffirms the importance of fine-grained landscapes that facilitate the movement of insects between habitats (Martin et al., 2016).

When considering the agricultural context, landscape management seeks to ensure sustainable biological control that can reorganize itself after disturbances (Tscharntke et al., 2007). Keeping non-agricultural vegetation in cultivated areas contributes to promoting biodiversity and favoring pest suppressive landscapes that can reduce the need for insecticides (Veres et al., 2013). It can be noted that the complexity of the landscape affects natural enemies positively as non-agricultural habitats act as reservoirs for biodiversity in agricultural landscapes (Bianchi; Booij & Tscharntke, 2006; Chaplin-Kramer et al., 2011; Rusch et al., 2016; Garratt et al., 2017). However, the size of the natural fragment, its shape, composition, amount of shared edge, the distance between habitats, characteristics of the area, and the organism in question are characteristics that influence the results of this interaction (Holland et al., 2016; Tscharntke et al., 2016; Haan; Zhang & Landis, 2020). Thus, landscape management strategies to improve natural pest control should differ depending on their specificities (Chaplin-Kramer et al., 2011).

5 I CONCLUSIONS AND FUTURE PERSPECTIVES

Knowledge about the influence of the landscape on insect pests and natural enemies has advanced, but mainly in temperate regions. It was found that this response is variable so the landscape may or may not favor pest populations. In a recent review, Pinto et al. (2022) compiled studies involving mortality factors in both temperate and tropical regions. This assessment indicated that abiotic factors are important in causing mortality of herbivorous insects, but that predators exert greater mortality in tropical than temperate environments. As predators are usually generalists, there is a need to improve the understanding of landscape influence in tropical regions, as predators can benefit from the landscape structure. Although most research on the ecology of landscapes and agroecosystems has been carried out in temperate areas (Veres et al., 2013), information regarding tropical regions is also emerging (Gagic; Paull & Schellhorn, 2018; Togni et al., 2021).

Despite the divergence of results, the preservation and restoration of semi-natural habitats in agricultural areas increase the abundance and richness of natural enemies, in addition to improving pest control services. Thus, landscape management can be important to maintain or even expand ecosystem services. The simple preservation of biodiversity could already be considered an important condition, even if biological control does not drastically reduce the populations of pest arthropods. However, this requires the cooperation of many stakeholders, who often have different interests.

Decision-making in Integrated Pest Management programs is mainly based on the monitoring and adoption of pest control products, or genetically modified plants that express insecticidal proteins as control tools. Thus, only pest dynamics are considered, while natural enemies are neglected. Therefore, a better understanding of the contribution of ecosystem services, including natural biological control, could be crucial to improving such pest management programs. In Brazilian conditions, these studies are already being carried out (Togni et al., 2021), and there is an increase in the number of researchers interested in this topic. Such concern is an important step forward for the sustainable production of food, fiber, and bioenergy, besides contributing to achieving the goals established within the United Nations (UN) Sustainable Development Goals.

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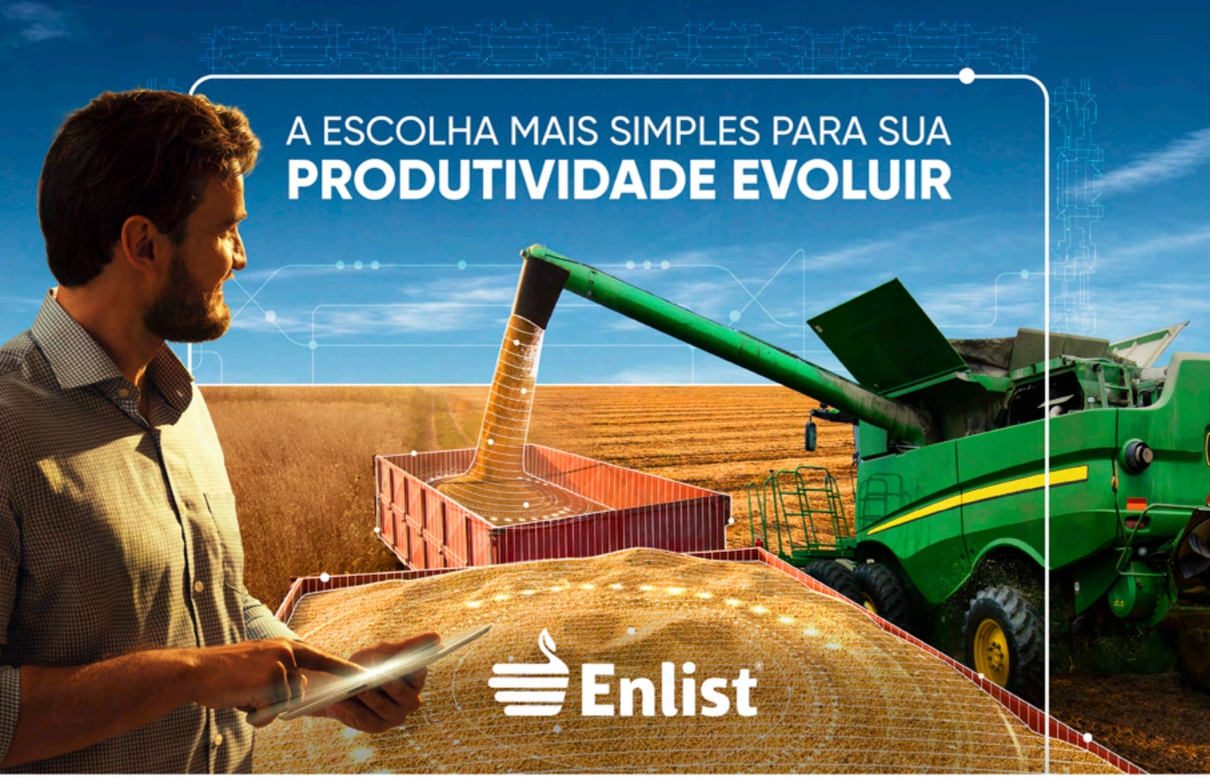

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