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The Soybean Trap: Challenges and Risks for Brazilian Producers

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Since the 1970s, Brazilian soybean production has grown rapidly, driven by increasing national and international demand and rising prices. Consequently, soybean production has come to be perceived as an attractive opportunity, with the number of farms producing soybean across the country reaching around 240,000 in 2017. However, producers can become trapped by dependencies on moneylenders, traders and input supply companies, facing so-called' agricultural treadmills'. In this study we undertook interviews with individual soybean producers and representatives of trader companies, producers' associations, the processing industry, government and civil society, and used these data to analyze rural production operations related to the soybean supply chain and to interpret how agricultural treadmills persist in this sector. Based on literature review and fieldwork interviews, we found that producers have been able to add value to their products, but some strategies they use to cope with production costs lead them into high-risk situations. Our findings show that, sectoral (e.g., producers' associations) and collective actions (e.g., farmers' buying groups) are a useful strategy for producers to gain influence and bargaining power against transnational companies and input suppliers compared to acting as an individual within the soybean supply chain. Producers were emphatic that the current soybean business is now much more than just farming activities, and that education and training are highly valuable and important strategies to keep producers in the soybean business and out of traps. These findings are important given the neoliberal context in which individual producers find themselves and which presents challenges that alone they can do little to change. Policies that enable individual producers to make environmentally- and financially-sound agricultural decisions are vital to ensure a sustainable soybean system that does not trap producers in endless cycles of debt and investment.

Keywords: agricultural inputs, profit margins, agricultural risks, agricultural treadmill, food commodity

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INTRODUCTION

Many contemporary agrifood supply chains are global in extent—from pre-production through production, and then post-production including processing, trading and distribution to consumption—but individual producers experience only a fraction of this long chain (Matopoulos et al., 2007). The global soybean supply chain is a prime example. According to the *Observatory* *of Economic Complexity*[1], in 2016 soybeans were the 50th most-traded of 1,238 products globally, yielding US$51.7 billion of exports, with US and Brazil having the largest shares (US$22.8 billion and US$19.4 billion, respectively). In the global soybean supply chain, pre-production is related to inputs from supplying industries (e.g., seed, agrochemicals, and machinery companies) and financial institutions. The post-production stage is composed of warehousing (e.g., cooperatives and traders), processing industries (e.g., grain transformation, animal feed, and vegetal oil production), logistics (distribution to internal and external markets) and consumption (Roberti et al., 2014). Sitting between these pre-production and post-production stages, producers are often vulnerable due to high economic indebtedness (Pujari, 2011; Gerber, 2014) as they try to keep up with technological innovations in inputs and management and experience reduced bargaining power over both inputs and outputs in a globalized market. This situation can lead producers to become tied to an "agricultural treadmill," a set of structural conditions shaped by international political and economic processes that produce a negative feedback cycle of investment and debt driven by the need to incorporate technology and scientific advances into production processes (Ward, 1993). We demonstrate that Brazilian soybean producers may be currently tied to an agricultural treadmill given their limited power to change the broader political and economic context that reinforces the cycle of investment and debt.

Soybean production in Brazil has expanded since the 1970s and occupies an area of approximately 35 million hectares, comprising a third of the total area of global soybean cultivation (CONAB, 2018). Recent expansion during the twenty-first century has been driven by the global appetite for meat (soybeans is used as an animal feed source) and the increased purchasing power of consumers in emerging economies such as China (Pinazza, 2007; Silva et al., 2017). Economic and institutional players (e.g., traders, public research agencies) have also influenced expansion of the crop in Brazil, not only by stimulating the increase of soybean planted area but also investing in farm credit, subsidies, logistics and market chains (Steward, 2007; Wesz, 2016). As a result, Brazil has increased the number of soybean producers engaging in this global market, as observed by the exports to China and other countries since 2000s (Silva et al., 2017). Concomitantly, there has been consolidation of private companies developing and marketing seeds, agrochemicals (e.g., fertilizers, pesticides) and dominant in the commodities market (Oliveira, 2016; Wesz, 2016; Westengen et al., 2019).

Currently, there are almost 240,000 farms producing soybean in Brazil (IBGE, 2018) and in a survey conducted by the *Projeto Soja Brasil*[2], in 2016 82% of 1,065 soybean producers from different regions of the country declared difficulties in repaying loans acquired for the agricultural year of 2015/2016, in turn making it more difficult to acquire new credit to produce in the next season. This indebtedness in the Brazilian agricultural sector dates back to the 1990s, and from 2001 to 2014 the major factor driving indebtedness was the imbalance between production costs and product prices (Melo and Resende Filho, 2017).

In this study we examine the decision pathways Brazilian soybean producers take that can lead them into indebtedness and supply chain dependency, tying them to "agricultural treadmills" and forcing them to continue in the business. The study is conducted through semi-structured interviews with producers, traders, and producers' associations and supported by literature review, using Mato Grosso State, Brazil, as a case study region. We identify types of strategies that producers are taking at the farm-level in efforts to increase their competitive advantage and decrease risks. Our emphasis is on what producers can do within the scope of their own decision-making, given their limited control over broader international political economy factors. In section Treadmills: Coping Strategies and Risks we present ways producers are attempting to cope with the risks associated with soybean production or how they are trying to alleviate the bottlenecks imposed by the international system of flows of commodities, described by Silva et al. (2017) as "the telecoupled soybean system."

TREADMILLS IN AGRICULTURE AND THE SOYBEAN TRAP

The treadmill metaphor in this study represents the many management techniques, technologies (e.g., seeds, pesticides) and financing mechanisms to support soybean production and commercialization that continuously push producers to increase their reliance on debt to avoid bankruptcy. Once producers adopt mechanisms within the farm system to participate in this capital-intensive activity, through time the benefits obtained by such decisions become less economically advantageous or effective (e.g., weed or pest control; Ward, 1993). In turn, this pushes producers to invest in new mechanisms and strategies to boost profit margins and production standards. To facilitate this continuous cycle of innovation, soybean producers take loans from public and private sectors (e.g., traders and retailers) to cover production costs and improvements on the farm (e.g., construction of on-farm storage facilities, new machinery, additional land acquisitions) that tie them to the soybean supply chain treadmill and keep them in a financially exposed situation (Melo and Resende Filho, 2017).

The treadmill mechanism is propelled by the market, or induced by innovation, and consequently creates a system whereby the first producers to adopt an innovation have the best opportunity to increase profit margins while overall prices still reflect the state of the prevailing technology (Cochrane, 1958, 1979). Subsequently, technological diffusion of innovations drives over-production and decreases commodity prices, leading other producers to adopt the innovation, wiping out the initial financial benefits. Producers that cannot continue to realize profits to offset investments eventually fall off the treadmill (i.e., go bankrupt), opening opportunities for others (Röling, 2009; Chatalova et al., 2016). On the treadmill, producers

[1]https://atlas.media.mit.edu/en/

[2]http://www.projetosojabrasil.com.br/forum-soja-brasil-enquete-confirma-alto-indice-de-endividamento/; https://canalrural.uol.com.br/programas/soja-enquete-dos-participantes-dizem-estar-endividados-63206/.

are challenged to produce more and more to reduce their debt burdens. The ever-present need to increase production propels producers to keep looking for ways to improve yields, creating dependencies on chemical inputs. Pile (1991) argued that joining the technological treadmill is involuntary, as in order to survive farmers need to adopt new technologies to avoid marginalization in the production system. There are alternatives outside this production system (e.g., farm-to-table production; organic vegetable production of high value items) that involve different sorts of risks but allow greater autonomy. For decades, farmers in large-scale largely monocrop mechanized production have chosen to board the treadmill, whether consciously or not. For some, it is the only system they have known. Brazil began to encourage soybean production in the mid-1970's as a national objective during the military regime, and this model of economic development has not been questioned by any administration that has governed the country since. Innovations to improve production come every year in the form of attractive interest rates or less bureaucratic systems to obtain credit, political lobbying to help producers obtain debt forgiveness or renegotiation of debts with public (e.g., banks) and private financers (e.g., traders), seed varieties of higher productivity (e.g., kg per hectares), more effective pesticides, or technological tools (e.g., connection of mobile phones with machinery to provide producers with real-time field information; Chatalova et al., 2016; Oliveira, 2016; Wesz, 2016).

The treadmill metaphor has been used for many agricultural situations, including labor, technological improvements, finance, management (Pile, 1991), competitive innovation (Goodman and Redclift, 1991), and for entrepreneurial behavior of small-scale farmers (McKee, 2018). The treadmill in agriculture has also been observed for genetically modified (GMO) soybean producers in Argentina and Brazil (Binimelis et al., 2009; Cerdeira et al., 2011) and for cotton farmers in India due to reliance on biotechnological and insecticide inputs (Gutierrez et al., 2015). The agrifood system has changed since the introduction of the treadmill concept (Cochrane, 1958) and new contours have added greater importance to international contexts of the economy and politics (Ward, 1993). The soybean system reflects this; influenced by broader economic and political conditions the supply chain has evolved over recent decades to become a commodity controlled by few companies in pre- and post-production (Wesz, 2016). The control of the system by few multi-national corporations affects producers' decisions, severely limits control over inputs, reduces bargaining power in the market, hinders access to farm credit and other financial resources, and disrupts the ecological balance of the production system. Rising from the country's neoliberal model of the 1990s, the agribusiness model in Brazil has increased international capital, driven land holdings to continue growing by absorbing smaller properties, deepened rural poverty, and promoted the alliance of capitalist farmers with large transnational companies controlling pre- and post-production stages of the commodity sector (Navarro and Pedroso, 2018). These are the set of structural conditions that have led Brazilian soybean producers to become tied to an agricultural treadmill—what we term the "soybean trap."

The increased economic importance of the soybean sector to the country (Martinelli et al., 2017) would suggest that being a soybean producer in Brazil is a profitable and secure business. However, although the soybean price increased 72% between 2006 and 2017 (Cepea, ESALQ/USP, 2017), production costs in Mato Grosso State (the major producer in the country) increased by 95% (in Brazilian Real; CONAB, 2017a). Based on fieldwork in Mato Grosso State in 2017 and previous work in Tocantins and Goiás States during 2016 (Silva et al., 2017), we have noted that the challenges to making profits in the soybean business traps producers into endless debt (taking new loans to pay existing debts) and high risk of losing their farms. Additionally, potential bottlenecks exist due to global currency market fluctuations and the reliance on inputs priced in US dollars. For example, if the US dollar depreciates between the time of purchasing inputs and selling the products, this squeezes profit margins.

In summary, the "soybean trap" as we define it, is a broad set of situations that challenge the autonomy of soybean producers (i.e., the freedom to act in accordance with their own will; Markussen et al., 2018). Primarily, if a soybean producer fails to produce sufficient quantities, profit margins are compromised making the producer yet more dependent on other actors that tie them yet more tightly to the treadmill (e.g., private and public moneylenders, input supply companies).

STUDY AREA, FIELDWORK, AND DATA SOURCES

In Brazil prior to 1970s, soybeans were predominantly cultivated in the southern States of Rio Grande do Sul, Santa Catarina, and Paraná. Since the 1970s, given higher prices of the grain in international markets (Trostle, 2008) and internal demand for oil and animal feed, the National Center for Soybean Research (Embrapa Soybean, launched in 1975) led the development of soybean varieties for diverse environmental conditions across the country (Campos, 2010; **Figure 1**).

In this study, we focus on municipalities in the State of Mato Grosso (MT), the largest soybean producer in Brazil since 2000. In 2017, MT produced 27% of the national soybean production (30.479 million tons) in 9.287 million hectares (IBGE, 2017). We conducted fieldwork with soybean producers in eight MT municipalities between May and June 2017 (**Figure 2**). We collected data on producers, producers' associations, traders, retailers, government and civil society. Overall, we completed 31 semi-structured interviews (**Table 1**). The protocol used was based on fieldwork conducted in the States of Goiás (GO) and Tocantins (TO) in the previous year (Silva et al., 2017).

Interviews focused on the soybean production system and management strategies adopted by producers at the farm level, including production costs, commodity prices, decision-making on credit, and generational succession. Overall, we aimed to understand how producers can fail within this supply chain, but also the strategies that they are adopting to be successful as producers. The study used a "snowball" sampling approach, which started by contacting government

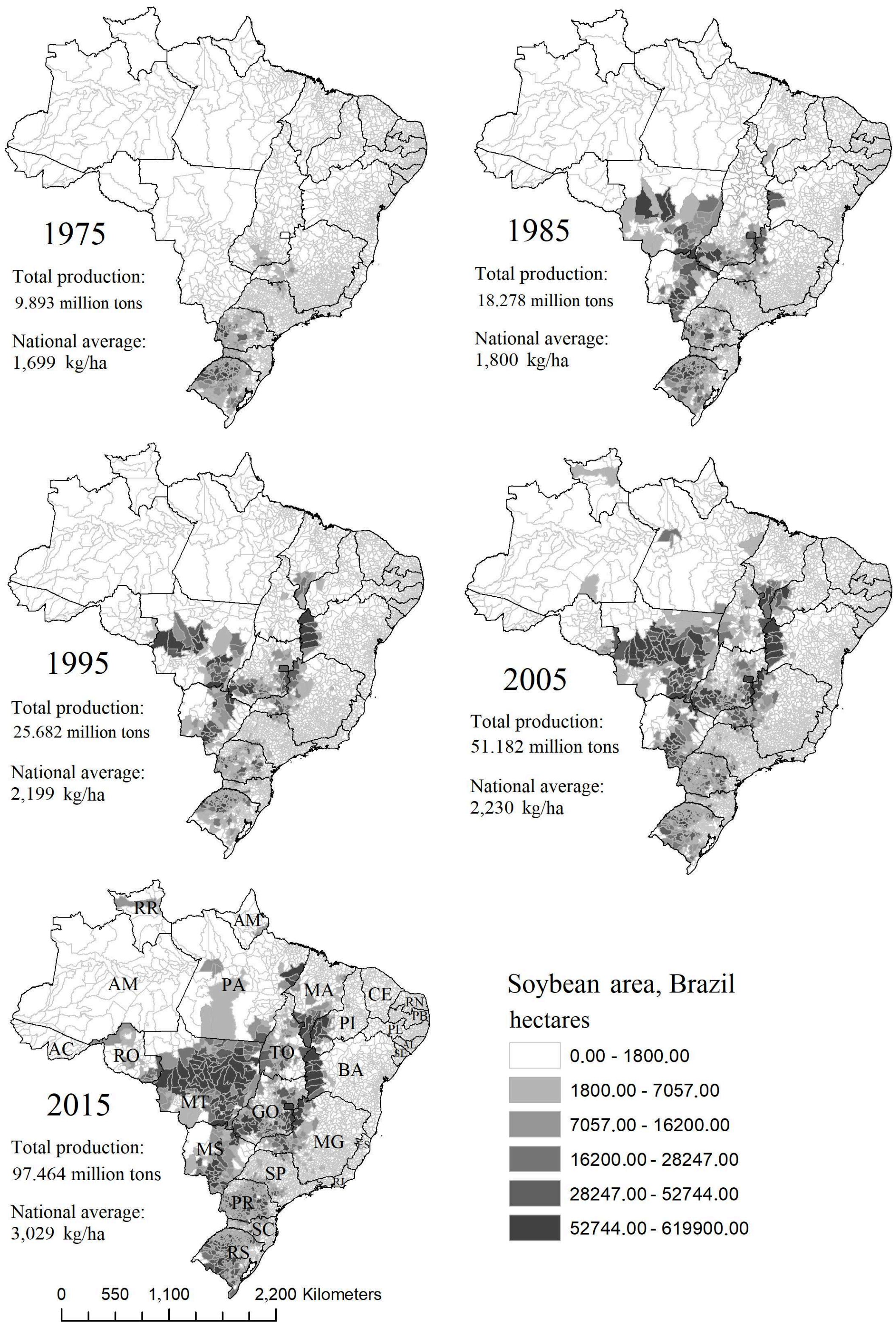

FIGURE 1 | Forty years of soybean area expansion in Brazilian municipalities, 1975–2015 (IBGE, 2017).

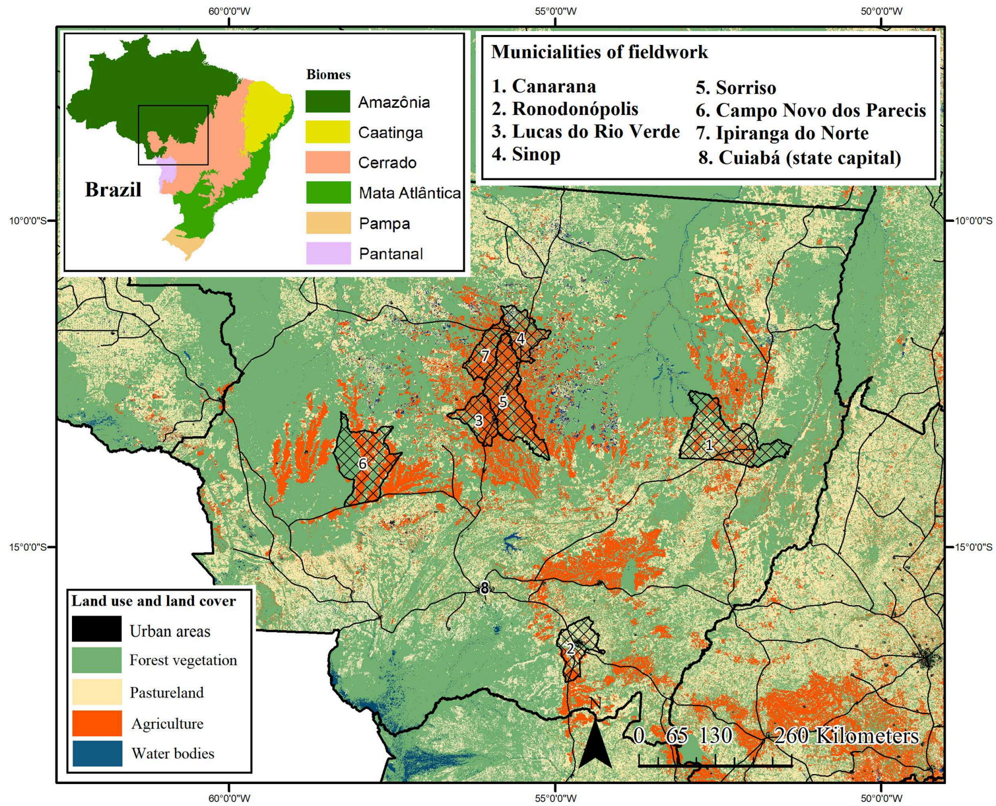

FIGURE 2 | Geographical distribution of the municipalities surveyed during the fieldwork of 2017, in Mato Grosso State, Brazil. Land use and land cover data source: Mapbiomas (http://mapbiomas.org/).

TABLE 1 | List of stakeholders interviewed during fieldwork in Mato Grosso State, Brazil, in 2017.

Municipality	Stakeholder category	Year of arrival in MT	Min. to max. planted area (ha)	
			Soybean	Maize
Sinop	Producers: 6	1980–2003	1,000–7,500	500–5,250
	University (UFMT): 2	–	–	–
	Government (Embrapa): 2	–	–	–
	Agribusiness (trader): 1	–	–	–
	Agribusiness (Retailer): 1	–	–	–
	Producer's association (Rural Union): 1	–	–	–
Ipiranga do Norte	Producers: 1	1999	860	500
Sorriso	Producers: 2	1977	840–1,335	840–1,290
	Civil society (CAT): 1	–	–	–
Lucas do Rio Verde	Producers: 1	1982	1,200	600
Campo N. dos Parecis	Producers: 2	1981–1985	500–8,000	500–4,000
Canarana	Producers: 3	1977–2008	1,200–7,000	400–4,000
	Government (SMA): 1	–	–	–
Rondonópolis	Producers: 3	1980–1982	150–7,000	150–4,000
Cuiabá (State capital)	Government (IMEA, SENAR): 2	–	–	–
	Producer's association (Aprosoja): 1	–	–	–
	Agribusiness (trader and producers): 1	1980	155,550	66,245

authorities from local- to State-level agencies related to agricultural affairs, representatives from producers' associations (i.e., Aprosoja/MT—Soybean and Maize producers Association of Mato Grosso State, and Rural Unions at municipality level), and faculty members of local Universities [i.e., Federal University of Mato Grosso (UFMT), campus of Sinop] who in turn suggested other potential interviewees. The interviews took place mostly at producers' offices in the urban areas of the municipalities of Sinop, Sorriso, Canarana, Campo Novo dos Parecis, Cuiabá, Rondonópolis, Ipiranga do Norte, and Lucas do Rio Verde (**Figure 2**). Some farmers hosted the research team at their farm. To ensure as representative a sample as possible, we conducted interviews with producers and representatives of agribusiness in the four major soybean production regions of Mato Grosso State. Hence, the municipalities surveyed (**Figure 2**) produced 21% of the total soybean of MT in 2017 (IBGE, 2017). In MT, but also observed in other agricultural frontiers such as in Goiás and Tocantins States (Silva et al., 2017), it is not feasible to randomly select farmers for interview. This is because farmers are not easily found on their farms (they often work in office in nearby towns) and are often cautious about whom they discuss their business with. Furthermore, farmers' concerns about crime (theft of inputs and machinery) means visiting farms without previous consent is inadvisable. Therefore, as identified by other studies in soybean production areas typical of large producers (Silva et al., 2017), the "snowball" sampling approach represents the most suitable technique.

Aprosoja/MT is the largest soybean producers' association in Brazil, representing approximately 5,500 soybean producers (around 80% of the State) spread across 50 municipalities of Mato Grosso (Aprosoja/MT, 2019). Thus, Aprosoja/MT represents an important pool of information about the state of soybean agribusiness in Brazil and the State. The State-level agencies interviewed during the fieldwork—SENAR/MT and IMEA—have a systemic view of the State's agribusiness. SENAR/MT study producers' management strategies, helping with education and training but also fostering intergenerational succession within the farm. IMEA work in a similar way but focus on the economic dimension of agribusiness. Both SENAR/MT and IMEA are representative institutions of the soybean sector in Mato Grosso, conducting systematic surveys and qualitative data collection to subsidize State level policies for the sector. UFMT, campus of Sinop, runs the largest undergraduate education program in agronomic sciences in the major soybean production region in the State (i.e., Region North). Consequently, the faculty members interviewed during the fieldwork were able to provide key information about the soybean sector in MT (e.g., management techniques, trade, logistics, and technological packages), but also enabled our research group the opportunity to visit farms involved with the University's research. In order to understand key actors of the soybean business in MT, we interviewed the largest local agribusiness company in the State that produces over 155,000 hectares of soybean and trades with international organizations.

Additionally, we conducted a literature review on reports from specialized media groups on agribusiness (e.g., Notícias Agrícolas, Successful Farming), and from official governmental agencies such as the Brazilian Institute of Geography and Statistics (IBGE), National Company of Food and Supply (Conab), Brazilian Ministry of Agriculture (MAPA).

It is important to highlight that many data sources cited come from professional associations and may be subject to conflict of interests and biases. However, very often, there are no alternatives nor better sources for these data in Brazil. This issue makes our qualitative fieldwork data collection particularly important for appropriately understanding farmers' situations within the soybean supply chain.

Thus, our study integrates a systematic review on literature to highlight the many treadmills and bottlenecks for producers within the soybean chain, and with fieldwork information to present the many strategies they are taking to cope with treadmills and avoid being caught in traps. The interviews during the fieldwork in Mato Grosso were not intended to produce quantitative data (for inferential statistics) because, as pointed out, is difficult to obtain a sufficient sample size from large soybean producers. Further studies are necessary to overcome this challenge in order to produce larger samples.

TREADMILLS: COPING STRATEGIES AND RISKS

The risk of producers being trapped by the soybean supply chain pushes them to take actions to find tangible solutions to increase their resilience within that supply chain. Producers seek strategies to negotiate sales of their grains at the greatest price possible, to reduce production costs and risks of production losses, and to increase profit margins. Focusing on the farm level, we describe the strategies producers told us they have adopted to increase the competitive advantage of their farm and keep up with the many treadmills of the soybean supply chain while making it more profitable and less risky. These competitive advantages represent the set of measures that an organization may take to increase its capacity to make profits, stay in business and eventually surpass its competitors (Porter, 1985).

Farm-Scale Operations to Increase Bargaining Power and to Ensure Credit Access

Farmers interviewed during fieldwork shared a preference to obtain financial support for production costs from public farm credit over the private sector (e.g., traders, retailers). This preference comes from their experience that public farm credit provides financial support with lower interest rates, allowing producers to trade with several preferred traders and providing flexibility to negotiate debts. Thus, farmers who acquire public farm credit or use their own money to cover production costs have greater freedom to negotiate the price of their grain. However, producers agreed that the public credit limit per producer is commonly insufficient to cover total production costs in large-scale farms. This scenario creates a market opportunity for private companies such as traders and retailers to finance soybean production in the region. In 2016−2017, 38% of soybean production costs were covered by retailers (14%) and private transnational companies (24%), increasing to 52% in 2017–2018 (17% from retailers and 35% from transnational companies; IMEA, 2017). Producers noted during interviews that acting individually, especially when they operate large-farms, means they have limited bargain capacity to negotiate with input suppliers which can create a bottleneck squeezing the positive cost-benefit situations and lowering production costs.

According to producers in Mato Grosso, large-scale farms demand large amounts of inputs to ensure greater grain production. This rule influences producers to find ways to increase their bargaining capacity in trading their grains and purchasing inputs. As described during the interviews, in Mato Grosso producers may adopt the strategy of creating a family group of producers. In this situation, instead of many siblings dividing the family farm when the head of the family dies, they keep it together to remain large or at least to not reduce the scale of production. This decision allows the family group to keep the business as a larger player with stronger bargaining power to negotiate better cost-opportunities of supplies and investment than if they split into smaller entities. This strategy, as observed from interviews, is also adopted by producers with non-family partners (e.g., farmers' buying groups), with the aim of increasing the scale of operations, thereby avoiding the soybean trap. Other studies (Wesz, 2016) has noted that in some cases, large groups of producers can export directly to international buyers without the support of the largest international trader companies. In those cases, the large-scale operations reach a volume of production that allows producers to become traders themselves, as noted during interviews, passing over the post-production stage controlled by larger traders, and reaching the market directly through their own resources. The producers also noted that being larger operators they seek to pay for purchased inputs up-front (the pre-planting season) to negotiate lower prices and to decrease exposure to currency fluctuations (i.e., US Dollar against Brazilian Real) later in the season.

Storage to Cope With Logistics, Trade, and Grain Quality

Logistics and Trade

It was highlighted in the interviews that on-farm storage provides opportunities to increase profit margins by alleviating the commercialization bottleneck. Therefore, storage allows producers to negotiate sales when soybean prices are higher by keeping the grain on their farm after harvest, a key strategic point highlighted by Aprosoja/MT and IMEA. Furthermore, during the harvest period commercial storage facilities may face congestion due to high volumes of grain being delivered as noted by the producers and from site inspections in Sinop municipality where the fieldwork researchers observed long lines of loaded trucks (during harvest period of maize second-crop) waiting to liberate the grains in large private-company storage facilities within the urban area. According to interviews with producers, Aprosoja/MT, SENAR/MT, and IMEA, these delays trouble producers by making them wait for trucks to return from commercial facilities and compromising grain quality. The interviewed producers affirmed that on-farm storage reduces their need for trucks and allows them to harvest exactly as planned to guarantee grain quality and with lower harvest operation costs (e.g., gas, trucks, and workers).

During fieldwork, we observed that the need for on-farm storage facilities is greater in the areas of Sinop, Ipiranga do Norte, Sorriso, Campo Novo dos Parecis, and Lucas do Rio Verde, while in Canarana we found that producers prefer trading with independent storage facilities. This situation, according to the interviewees in Canarana is mainly due to the fact that trading companies offer storage facilities that do not require the producer to sell their grain to them (so the grain, even within the company's storage still belongs to the producer). Another factor is that storage facilities require qualified labor that is scarce. According to producers in Canarana, where this situation is acute, workers able to manage storage facilities are already hired by the trading companies, which makes it difficult for producers relying in their own skills. Based on this information from interviews it was noted that on-farm grain storage is a key strategy to improve profit margins but the risk of investing in such expensive equipment which demands specialized laborers (and which are scarce in some regions), means that producers decide against this approach (such as in Canarana).

Grain Quality

As a commodity, soybean grain quality must reach the standards of the Brazilian Ministry of Agriculture (Normative Instruction[3] 11/2007; MAPA, 2007). Producers reported that the *ardido* (i.e., a grain completely fermented with a dark-brown color) is one of the major factors associated with problematic climate conditions during harvest and storage. According to the Normative Instruction, the *ardido* is a critical problem affecting quality as it is classified as "damaged" (up to 8% damaged grain is allowed in a soybean cargo, with maximum of 4% total allowed for *ardido*). Other metrics of damage include water content (up to 14% of cargo), green color (up to 10%), foreign materials or non-grain material (up to 1%), and broken grain (up to 30%).

Therefore, the grain classification practices adopted by traders are considered unfair by producers given the rigid classification procedures that differ from the Normative Instruction in some cases. Thus, as according the producers and producers' representatives (e.g., Aprosoja/MT), grain quality is a sensitive component of the production system that makes them vulnerable to the agricultural treadmill.

As a solution to ensure high grain quality, the on-farm storage provides flexibility to manage this issue and avoid losses with damaged grains. Thus, producers with storage can blend grains of different qualities to ensure that the production will fit the standards established by the Normative Instruction. This practice allows producers to pass the inspection procedures of traders and commercial storage facilities, receiving a full payment per load without penalties. Based on producers' answers, an important strategy to avoid losses and increase profitability. Here the bottleneck lies on the dependency of high skilled professionals to properly manage the storage facility in order to keep grain quality, which may demand additional hired laborers (increasing

[3]Normative Instruction is an administrative act that regulates some aspect of a law.

total production costs). If producers decide to manage by their own, the risks are greater if they are not trained to cover this additional farm operation.

Technology-Driven Decision-Making

It has been observed that food commodity markets provide a growing niche of investments for the private sector, reflecting recent shifts from public spending on food and agricultural R&D to the private sector (Pardey et al., 2016).

According to the producers interviewed, the need for constant change in seed cultivars increased during the 2010s, requiring additional effort to allocate time and capital in the search for best cultivars. Producers wanting to use old seed varieties or non-GMO are challenged by the dominance of the seed market by a few companies. As some producers mentioned, several months before the planting season each year sellers from different companies come to visit producers to convince them to purchase new technological packages, to allocate some hectares of the farm for seed testing, or to visit sampling plots of the new breakthrough cultivars.

Until the late 1990s, the soybean seed technology domain was dominated by Embrapa and other public organizations (e.g., Agronomic Institute of Campinas), as observed by the number of registered cultivars (**Figure 3**). Since the 2000s, there has been an increased number of new cultivars of soybean and a sharp switch from the public domain to the private sector, observed by the share of new cultivars registered by private companies in the 2010s. As highlighted to us by producers during the fieldwork and from the Brazilian Ministry of Agriculture data, the public sector largely abandoned the business of producing new soybean seed varieties and ceded that role to the private sector. For producers of our sample, new technologies such as the INTACTA technology for GMO soybean seeds launched in 2013, has dramatically increased soybean production costs, as a response to the price paid for seeds without offsets in the cost of agrochemicals.

Seed Production and Alternative Markets

In this scenario of higher private domain on seed developments emerged along the 2000s with increases in seed prices (a major factor for increased production costs in the last decade according to the interviewed producers in Mato Groso); to decrease production costs associated with technology (i.e., associated to seed and its associated technological packages as fertilizers and pesticides), the issue of "pirate seeds" has arisen. In Brazil, there are soybean producers that produce their own seeds (which is legally viable), reducing the need to purchase new seeds every year from companies—a practice known as "saving seeds." However, sometimes creating an opportunity to make extra money by trading the surplus saved seeds with other producers (an illegal trade system). This practice, according the producers interviewed, is a strategy to purchase seeds at lower prices and to relieve the need to purchase technological packages associated with soybean cultivars, such as specific agrochemicals, thus conferring lower costs by enabling purchase of alternative packages. This practice of purchase seeds from non-authorized

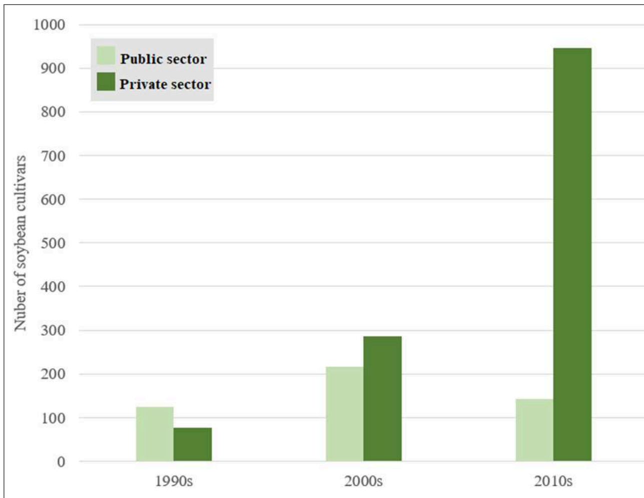

FIGURE 3 | Share of soybean cultivars registered by the Brazilian Ministry of Agriculture (CULTIVARWEB: http://sistemas.agricultura.gov.br/snpc/cultivarweb/cultivares_registradas.php?).

seed producers, a strategy to reduce costs, is what producers and stakeholder name as "pirate seed."

During interviews, producers highlighted the favorable cost-benefit situation in producing their own seeds, but at the risk of having lower germination rates or sanitary issues. Regarding the use or trade of pirate seeds they were critical and denied any participation in this market. To the interviewed Aprosoja/MT representatives, this is a high-risk strategy that is being coped through campaigns at the State level. However, in Brazil, the estimates of soybean planted area to produce pirate seeds in 2016 reached around 4 million hectares (ABRASEM, 2016), and according to the Brazilian Association of Soybean Seed Producers, around 30% of the seeds used for production are pirated (ABRASS, 2016). This illegal practice (According to the Law of Cultivars Protection, number 9456 of 1997) may be reflected in lower production costs while becoming a potential threat for producers. These threats include less productivity, lower plant vigor and phytosanitary vulnerabilities as pointed by the interviewed group, but also highlighted by previous studies (Lima and Bueno, 2001; Ternus, 2013; Tonello, 2017), making the use of pirate seeds a risky decision. Pirate seeds have no guarantees of productivity standards, minimum germination rates or resistance to diseases and pests. Furthermore, there is the risk of incurring fines and legal sanctions if caught by legal authorities. Producers willing to use pirate seeds of soybean accept higher risks to decrease production costs. Thus, the use of pirate seeds in the soybean business reflects the ways producers are looking to prevail on the technological treadmill, which otherwise cyclically increases seed prices by the appeal of delivering new and necessary advances.

Sectorial Actions to Cope With Grain Quality and Technological Challenges

From interviews with Aprosoja/MT and SENAR/MT representatives we found that the concerns of producers about inspections of grain quality has become a pillar of new programs supporting producers in Mato Grosso. In 2015, Aprosoja/MT launched the "Grain Classification" program to stimulate an increase in qualified personnel in the State and provide second evaluations on producers' loads when a producer disagrees with the assessment of a trader company. This is an important action to support producers with and without their own storage, increasing trust on the producers' side.

To SENAR/MT informant, the soybean business has become a highly technical and complex system, and producers are in an ever-growing need of a qualified workforce to manage their production systems. During day-to-day operations producers tend to use family labor and some hired workers. These workers and family members need to be trained in machinery management, seed and soil preparation, and crop management. These practices require training, which producers and their workforce can acquire through organizations like the National Service for Rural Learning (SENAR/MT) and Aprosoja/MT, to adopt new technologies and responsible practices, such as fire management, hazardous chemical management, and other key components of the soybean production chain.

In this scenario, according to the interviewed SENAR/MT representative, the role of educational and agricultural representative institutions is key to enabling soybean producers to deal with new technologies, climate change, market and business management and to empower them to become more active agents within the supply chain, similarly observed by other studies (Zamora et al., 2017; Magrini et al., 2018; Pincus et al., 2018). Thus, as observed during fieldwork, the professionalization and entrepreneurship required by producers to survive in a competitive market sometimes drains the producer's resources and time away from the land. A quote from an interviewed soybean producer illustrates this trend: "*If the farmer stays on the tractor, he is not a producer, he is an employee*."

In 2017, as noted by the interviewed Aprosoja/MT representatives, the institution moved an action against Monsanto to release producers from the need to pay royalties for the INTACTA technology (INTACTA RR2), claiming that the seed did not bring the benefits advertised by the company and given patent inconsistencies with the Law of Industrial Property (Law number 9279 of 1996). In this action, Aprosoja/MT represents the many producers of the State against the top-down technologies imposed by seed development companies, revealing the institutional possibilities of producers grouping together as agents within the soybean supply chain rather than remaining individual passive producers subject to any top-down change. This example strengthens the argument that producers acting individually have little to no influence or power against transnational companies and the prevailing international political economy situation, pushing them to become organized in representative groups able to act more like bigger players in the global market. In this way producers can avoiding or escape the soybean trap. During fieldwork the researchers attended the "*Circuito Aprosoja*" meeting in Lucas do Rio Verde organized by Aprosoja/MT with over a hundred producers (*Circuito Aprosoja* is an Aprosoja/MT program that organizes systematic meetings every year in all production regions of Mato Grosso—attending over 20 municipalities). There, the Aprosoja/MT directors and representatives presented statistics about the soybean/maize sector in the State, and the programs and strategies for the following years to help producers to increase profits and overcome challenges. By the time of the meeting they explained strategies to avoid robberies of agricultural inputs (e.g., fertilizers) in farms, a major concern among producers, and highlighted the partnership (firmed in 2016) between Aprosoja/MT and the State Secretariat of Public Safety to cope with this issue. These many situations observed during the fieldwork were supported by the producers interviewed, who identified the key role Aprosoja/MT play in representing their interests.

Productivity vs. Land Expansion: Strategies to Cope With Productivity Loss

Good productivity (kg/ha) was identified by the interviewed producers as the most important strategy to stay in business, particularly in a scenario where buying more land is becoming an expensive solution. To obtain expected (or greater than expected) productivity, producers are raising awareness about decision-making processes related to planted areas. As mentioned in section Farm-Scale Operations to Increase Bargaining Power and to Ensure Credit Access, all farms are divided into multiple plots with different conditions (e.g., soil and precipitation) that affect productivity. After years of soybean production and experience in Mato Grosso (see **Table 1**), the producers in our sample demonstrate the ability to identify the best plot areas on their farms (i.e., areas with the best history of productivity results). In those areas, they are willing to keep high levels of investments of capital and technology (e.g., best seed varieties) to reach greater productivity. Nevertheless, they also recognize the areas with lower productivity, which they corresponded to sandy soils.

Thus, from our sample, producers are taking the decision of not planting soybean every year on the entire land available for use. Two producers interviewed have used this practice for many years and others have tried it in the last crop year or are preparing to adopt it in the next seasons. Producers from our sample are sparing areas of lower productivity for recovery and preparation for longer rotation plans, such as planting soybean only every 2–3 years. Others are avoiding the use of maize after soybean in those areas to diminish the land use pressure. In these cases, as a second-crop, some producers adopt other plants only to provide green cover to protect the soil. These management decisions observed from the fieldwork data are justified by perceptions of productivity loss (or stagnation) during the last decade. This situation, noted by informants from the University (UFMT) and producers in our sample, but also corroborated by the National Company of Food and Supply (CONAB, 2017b) is because, among other reasons, of the increasing trend in maize production as a second crop which has pushed producers to plant short-season soybean varieties (affecting productivity standards) to enable two crops in the same agricultural year.

To expand soybean fields in new areas, according the interviewed producers, they must cultivate the grain for 2 or 3 years with low productivity, resulting in uncultivated lands

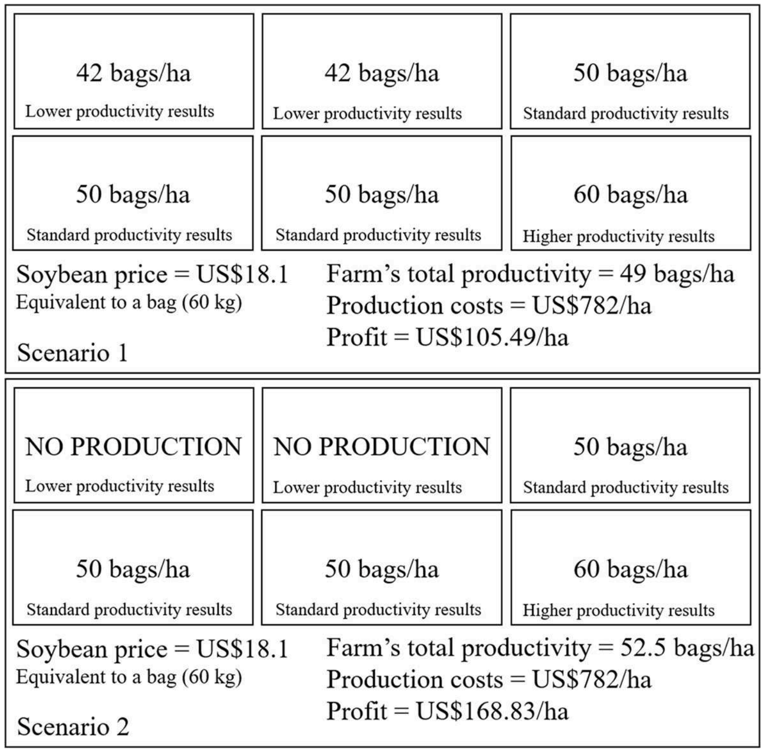

FIGURE 4 | Simulation of a producer's decision-making process at the farm level to produce soybean in the total area available or only in areas according to historical productivity results. Each bag represents 60 kg of soybean—Brazilian measure.

(mainly on previous degraded pastures) before reaching higher yields. These first years of soybean cultivation in new areas require some land preparation, such as improving soil fertility, to reach the necessary conditions to produce soybean with high productivity. During this period, they invest in production while reducing the farm's total productivity (i.e., the sum of the productivity of each plot divided by the total number of plots), increasing the likelihood of squeezing profit margins. Thus, beyond the productivity of each specific plot or the potential production increase by area expansion, producers seem to be switching focus to the farm's total productivity. As an example, **Figure 4** shows the rationale brought about by interviewees of how a producer can increase the farm's total productivity without expanding area or increasing productivity within a specific plot, by not planting in the less productive areas. In this example, a hypothetical production cost average of a farm at US$782 per hectare and the soybean price at US$18.1, the producer's profit margin would be 17% or US$168.83 of profit per hectare in Scenario 2. In the same conditions, the results of Scenario 1 would be 11% of profit margins or US$105.49 of profit per hectare.

This example, developed based on the producers' rationale evidenced during the interviews, simplifies a very complex decision-making process at the farm level. However, it illustrates how producers can avoid unnecessary losses in average productivity not by increasing productivity in some areas to offset others (which may increase production costs), but by avoiding planting in lower productivity areas. These areas are usually left fallow, rotated (e.g., not planting the soybean every year but rotating with maize) or used for less demanding crops in terms of soil fertility, such as pastures or planted forests (e.g., with eucalyptus). The example in **Figure 4** illustrates the need to overcome the narrow view of ever larger scales of production (typical from the economies of scale perspective) as the only means to achieve the best possible economic results. Thus, using the described strategy, producers from our sample are aiming to avoid being trapped by the logic of "expansion" and "large scales," which may jeopardize productivity results and profit margins.

Education and Training to Improve Producers' Resilience

During interviews, we found that all producers recognized the need to become educated at least to the undergraduate level, to keep up with the changes in their business. This understanding about the need for education reflects their view of agricultural production as a business that requires the use of technology and the knowledge provided by agronomists, business managers, and other consultants. Producers from our sample, but also representatives from SENAR/MT, Aprosoja/MT, IMEA and University (UFMT), were emphatic that the current soybean/maize business is now much more than just farming activities. It requires management strategy and a deep understanding of agricultural technology to enable, as they argued, a reliable way to take decisions in order to succeed as producers and avoid the many traps within the soybean supply chain.

In Mato Grosso the researchers attended a *"Dia de Campo"* (a typical transfer-technology program develop by Embrapa) activity promoted by Embrapa (i.e., Sinop Research Center), where the institution invited many producers to teach management techniques to produce soybean and maize with lower dependency on chemical pesticides and fertilizers, and highlighting the importance in varying the cover crop after soybean, not adopting maize only. Another example of the training stations used during the *"Dia de Campo"* was the presentation of integrated pest management, a strategy with potential to decrease the use of pesticides by 50%, benefitting both the environment and producers' profit margins (Conte et al., 2016).

CONCLUSIONS

In this study, based on literature review and qualitative fieldwork, we found that the soybean producers of our sample (18 in total, but in a situation we expect to be similar to many of the State's producers) recognize traps and bottlenecks, which may lead them to decreasing profit margins and increasing dependency on large agribusiness players (e.g., inputs sellers and traders). These producers have found no apparent way to get off the treadmills, but they do take actions to attempt to avoid being trapped within the soybean supply chain. This brings some valuable lessons to reflect on with regards to the currently dominant large-scale capital-intensive activities.

Lesson 1: Sectoral actions (e.g., producers' associations, institutions dedicated to rural training and learning) have capacity to increase producers' ability to defend their rights and therefore to become more resilient and able to overcome the challenges related to production and trade within the supply chain (sections Sectorial Actions to Cope with Grain Quality and Technological Challenges and Education and Training to Improve Producers' Resilience). In this regard, the role of educational and agricultural associations is key to enabling soybean producers to deal with business management challenges and to empower them to become more active agents. Additionally, soybean producers are finding useful the strategy of acting as group (e.g., through farmers' buying groups or family group of producers), which is enabling bargaining capacity to negotiate soybean production inputs with supplier companies and traders, therefore lowering production costs (section Farm-Scale Operations to Increase Bargaining Power and to Ensure Credit Access).

Lesson 2: Producers have found that to achieve satisfactory productivity results they must carefully consider variation between multiple land plots of their farms in order to take decisions on where best to plant soybean according to historic results and natural conditions (e.g., soil types; section Productivity vs. Land Expansion: Strategies to Cope with Productivity Loss). This strategy has proved a feasible way to increase total soybean productivity, leading to higher profit margins without the need of expanding planted area.

Lesson 3: The increased share of private companies in the seed development market through the 2010s was an important driver of increases in production costs, according to interviewees (section Technology-Driven Decision-Making). This increased cost also associated with technological packages (seeds and with their related agrochemical inputs) is driving producers to search for alternative seed markets (sometimes with high legal and agronomical risks, as in the case of the "pirate seeds"), and consider' seed saving' strategies (i.e., enabling them to supply their own seed demand at lower cost).

Lesson 4: On-farm storage provides opportunities for producers to increase their profit margins by enabling decisions about the best time to trade the grain (e.g., usually when prices are high), but also by avoiding commercial storage facilities during harvest season that may face congestion due to high volumes of grain being delivered (section Storage to Cope with Logistics, Trade, and Grain Quality). This congestion delays producers' harvest plans, potentially compromises grain quality, and increases reliance on trucks, gas and workers, all of which can lower their profits.

DATA AVAILABILITY STATEMENT

The datasets generated for this study are available on request to the corresponding author.

ETHICS STATEMENT

The project was submitted to Michigan State University's IRB Committee, IRB#15-514 May 13, 2015, and it was deemed EXEMPT. The investigators working in the project obtained informed consent from any person interviewed, and the information has been treated as confidential, with access only available to the principal investigators.

AUTHOR CONTRIBUTIONS

RB, MB, and EM contributed conception and design of the paper. RB wrote the first draft of the manuscript. All the other authors wrote several contributions in different sections of the manuscript. All authors contributed to manuscript revision, read and approved the submitted version.

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