

Drivers of the adoption of organic farming in Brazil: a combinatorial analysis

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Abstract

The general objective of this study is to identify the combinations of eco-innovation drivers associated with Brazilian municipalities in which a large proportion of farms report that they engage in organic farming. To this end, a theoretical review identified 11 drivers, which were classified as internal and external to the farms. The data were obtained from the 2017 agricultural census, published by the Brazilian Institute of Geography and Statistics (IBGE). Qualitative comparative analysis was used to identify the combinations of drivers associated with organic farming. The results showed that no single driver can be considered necessary. Nonetheless, two combinations of internal drivers and three combinations of external drivers were found to be sufficient to explain the existence of a large proportion of properties engaged in organic farming. These findings contribute to the literature on eco-innovation in agriculture and to the monitoring of public policies.

Keywords

Agriculture, agricultural ecology, innovations, organic farming, agricultural production, rural development, Brazil

JEL classification

Q18, Q16, Q15

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I. Introduction

Brazil is considered one of the world's largest food producers, in terms of both diversity and the quantity and quality of its agricultural production (MAPA, 2022). Population growth projections, increasing per capita income in developing countries, and restrictions on land use for the expansion of cultivated area fuel expectations that Brazilian agriculture will meet the world's food demand (MAPA, 2022) and, at the same time, minimize the environmental and socioeconomic problems generated by conventional agriculture (Gerten and others, 2020).

Such problems include the following: (i) the artificial introduction of nitrogen (N), which has impaired water quality and biodiversity (Foley and others, 2005; Therond and others, 2017); (ii) climate changes resulting from the intensive use of nitrogenous nutrients, methane production in flooded soils and originating from the fermentative digestion processes of ruminant animals, production of manure, deforestation and the burning of agricultural waste, and conventional tillage systems (Shukla and others, 2008); (iii) poisoning of human beings and contamination of food by pesticides (Carneiro and others, 2015) and increased insect resistance, with negative effects on the ecosystem services of biological regulation (Therond and others, 2017); (iv) soil degradation, with an estimated 40% of agricultural soils potentially suffering from some degree of erosion and reduced fertility (Therond and others, 2017).

Given the numerous problems associated with conventional agriculture, there is a need to change the system as a whole, or at least in large part (Blazy, Carpentier and Thomas, 2011). Organic farming is an alternative for minimizing the problems related to the agricultural system based on chemical inputs (Antunes, Dias and Maehler, 2016). In Brazil, an organic system of farming is defined as

[...] one in which specific techniques are adopted, by optimizing the use of available natural and socioeconomic resources and respecting the cultural integrity of rural communities, in pursuit of economic and ecological sustainability; maximization of social benefits; minimization of reliance on non-renewable energy (employing biological and mechanical methods and practices, wherever possible, as opposed to using synthetic materials); elimination of the use of genetically modified organisms and ionizing radiation at all stages of the production, processing, storage, distribution and marketing process, and environmental protection (Brazil, 2003).

According to data from the 2017 agricultural census, just 1.3% of crop or livestock farming in Brazil is organic (IBGE, n.d.) —still a very small proportion. The problem of adopting new environmentally superior agricultural systems can be understood through the theoretical approach of eco-innovation (Yuan, 2016; Galliano and others 2018; Shih and others 2018; Kiefer, Del Rio Gonzalez and Carrillo-Hermosilla, 2019; Dudek and Wrzaszcz, 2020, Fernandes, Souza and Belarmino, 2020). An analysis of research on eco-innovation (Shih and others, 2018) reveals that most of the studies that have been conducted refer to the drivers of this process (Díaz-García, González-Moreno and Sáez-Martínez, 2015). Research on drivers seeks to identify the precursors of eco-innovation at different levels and focuses mainly on the motivations underlying the adoption, development or implementation of those innovations (Díaz-García, González-Moreno and Sáez-Martínez, 2015).

A review of studies on the drivers of eco-innovation shows that few have been conducted in the agriculture sector (Shih and others, 2018; Dudek and Wrzaszcz, 2020; Fernandes, Souza and Belarmino, 2020). Moreover, Blazy, Carpentier, and Thomas (2011) and Fernandes, Souza, and Belarmino (2020) state that, as much attention has been paid to the adoption of comprehensive and environmentally better agricultural systems and farming practices, the factors that foster the adoption of such systems and practices need to be identified. However, the authors of the studies on the drivers of eco-innovation were only concerned with describing these factors individually, and did not analyse their potential combination to encourage the adoption of integrated farming systems. The study by Dias and Braga (2022), which performs a combinatorial analysis of the drivers, is an exception.

After considering the environmental problems associated with conventional farming practices and the possibility of understanding the factors that influence the adoption of the organic system — on the basis of eco-innovation drivers—, the following research question was formulated: what combinations of eco-innovation drivers in agriculture foster the adoption of organic farming systems?

The qualitative comparative analysis (QCA) method was used to identify the combinations. It uses combinatorial logic and applies logical operators to explain how the drivers that influence the adoption of agricultural systems combine to create specific outcomes (Dias and Braga, 2022).

The results indicate that two combinations of internal drivers and three combinations of external drivers are sufficient to explain greater adoption of organic farming in the Brazilian municipalities analysed. Drawing on these findings, this study aims to contribute to the literature on eco-innovation in agriculture by relating the drivers to the adoption of the organic farming system by Brazilian farmers. It also seeks to contribute to the dissemination of the QCA method, which has not yet been widely discussed in Latin America as in other developed countries. Lastly, the identification of combinations of eco-innovation drivers for agricultural systems is useful for monitoring public policies aimed at promoting, encouraging and improving the adoption of the organic system in developing countries.

II. Drivers of eco-innovation in agriculture

The concept of eco-innovation stems from two terms: the prefix “eco”, associated with the environmental dimension, and the word “innovation”. While the general definition of innovation is neutral in terms of the type of change involved, the concept of eco-innovation emphasizes innovation related to sustainable development, which reduces environmental damage (Rennings, 2000). Meanwhile, Kemp and Pearson (2007) defined eco-innovation as the production, application or exploitation of a good or service that is new to an organization or user.

According to Schiederig, Tietze and Herstatt (2012), the concept is referenced through various terms and definitions, such as eco-innovation, environmental innovation and green innovation. In their discussion, those authors argue that the various definitions are similar because they have several aspects in common. Eco-innovation can be understood as a special type of innovation (Schiederig, Tietze and Herstatt, 2012, p. 182). It should be noted that not all innovations are eco-innovations, but all eco-innovations are innovations, with certain key characteristics that distinguish them (Bossle, 2015, p. 32).

The Organisation for Economic Co-operation and Development (OECD) defines eco-innovation as the development or implementation of new or significantly improved products (goods and services), processes, marketing methods or organizational systems in business practices, workplace organization or external relations (OECD/Eurostat, 2005, p. 47, cited in OECD, 2009).

Hasler and others (2017) sought to determine the factors affecting eco-innovation in agriculture, which is the focus of this research. They identified 11 main drivers of eco-innovation: (i) participation in external or cooperative groups; (ii) information; (iii) access to credit; (iv) market access; (v) gender; (vi) age; (vii) education; (viii) farm size; (ix) land ownership; (x) quality of technical assistance; and (xi) expectations.

Participation in groups, cooperatives or advisory boards can stimulate process innovations and ensure good information exchange (Hasler and others, 2017). It can also stimulate the adoption of service innovations because these groups can provide professional support or establish contacts (Huang and others, 2015). Cooperation among rural producers is a social process based on associative relationships, through which people seek solutions to their common problems in a cooperative way (Thesing, 2015).

Access to agricultural information is the second driver of eco-innovation (Hasler and others, 2017). Watcharaanantapong and others (2014) noted that farmers who obtained agricultural information from crop consultants, university extension programmes, other farmers, trade fairs, Internet or the media

were more likely to adopt eco-innovations. While information can be seen as an important precursor to eco-innovation, capacity is required to obtain and process it. Information plays an important role in the process of distinguishing between potentially valuable opportunities and others of less value, and also in the ability to exploit them effectively. Access to certain types of information and the capacity to use it effectively determine whether a given individual is better able than another to recognize a good opportunity (Baron and Shane, 2007).

Access to credit is another eco-innovation driver. If a new process requires further investment, access to credit can motivate adoption of the innovation in question. The establishment of credit lines for small- and medium-scale producers advances the eco-innovation transition process (Hasler and others, 2017).

Market access can generate knowledge about the desired eco-innovation. It can also foster good information exchange, which is important for the adoption of process innovations (Hasler and others, 2017). Producers integrated into more structured marketing channels, which offer certain market guarantees for production, are those that adopt the most capital-intensive environmental technologies (Hasler and others, 2017).

With regard to gender, male farmers tend to adopt more radical innovations, such as a new farming system, sooner than female farmers. One reason may be that male farmers are more risk-tolerant. Gender differences are important in technology adoption and farming practices in many agricultural systems, mainly because access to resources and management of rural properties and natural resources are often determined by culturally defined and unequal gender roles (Ndiritu, Kassie and Shiferaw, 2014).

Age is another factor affecting eco-innovation, with younger people tending to be more positive towards its adoption. Younger farmers have longer planning horizons and, therefore, greater incentives to consider new investments in equipment or changes in management practices than older farmers. Younger farmers are more readily attracted to new ideas and are more likely to be early adopters (Anosike and Coughenour, 1990; D'Souza, Cyphers and Phipps, 1993; Rahm and Huffman, 1984). Greater experience, as measured by age or the number of years in farming, could also be considered a positive factor for the adoption of sustainable practices, by potentially indicating greater management capacity. However, older farmers may have less energy, be more change-averse, or have a shorter planning horizon (Hasler and others, 2017).

Higher education levels can be a stimulating factor, because they may mean that farmers are more willing to engage in lifelong learning and cooperation. Higher levels of education appear to stimulate the adoption of new technologies (Hasler and others, 2017).

Larger farms can give farmers a better foundation for financial investments and thus encourage the adoption of eco-innovation (Hasler and others, 2017). Smallholder farmers are particularly susceptible and risk-averse, especially those whose immediate survival depends directly on the outcome of current production (Hasler and others, 2017). In Brazil, the vast majority of small-scale farmers, even those who are better capitalized, do not have institutional protection mechanisms to cushion the impact of negative production outcomes and are therefore more reticent about adopting technological and environmental innovations (Almeida and Buainain, 2005).

When the land belongs to the farmer who works it, the willingness to invest in new technologies to maintain soil fertility and quality is much greater (Hasler and others, 2017). Conversely, the terms of a lease or partnership contract may not create incentives to adopt certain eco-innovation practices. Tenants or partners may judge that they will not receive the benefits of land improvement. When a property is managed by the landowner, the likelihood of investing in technologies is greater (Nowak, 1987). Small-scale leasing in Brazil revealed that short-term and informal contracts do not provide tenant farmers with the conditions needed to invest in technology; and they further hinder access to credit and more stable marketing channels (Almeida and Buainain, 2005).

Quality technical assistance can stimulate farmers to trial a new product (Chianu, Chianu and Mairura, 2012). Ensuring quality technical assistance is easier when producers are grouped together, as there is an exchange of experiences among farmers that increases learning for all, including technical consultants in rural extension.

Lastly, Hasler and others (2017) also highlight the importance of expectations: farmers who have higher expectations for innovation outcomes are more inclined to adopt new technologies.

Drivers can also be classified in two categories: internal and external (Bossle and others, 2016). External drivers are those determined by circumstances outside the farm under analysis. On the basis of the literature review, the following drivers were classified in this group (see table 1): participation in external groups or cooperatives, information, access to credit, market access and quality of technical assistance. Internal drivers are those determined by circumstances prevailing within the farm (Bossle and others, 2016), such as farm size, ownership of the land, gender, age and education.

Table 1
Internal and external drivers of eco-innovation

Internal drivers	External drivers
Farm size	Participation in external groups or cooperatives
Ownership of the land	Information
Gender	Access to credit
Age	Market access
Education	Quality of technical assistance
Expectations	

Source: Prepared by the authors, on the basis of M. B. Bossle, "Drivers for adoption of eco-innovation and enhancement of food companies' environmental performance", PhD thesis, Federal University of Rio Grande do Sul, 2015; and K. Hasler and others "Drivers for the adoption of different eco-innovation types in the fertilizer sector: a review," *Sustainability*, vol. 9, No. 12, November 2017.

III. Methodological procedures

Qualitative comparative analysis was the research method used in this study (Ragin, 1987). The data were obtained from the 2017 agricultural census published by the Brazilian Institute of Geography and Statistics (IBGE, n.d.).

1. Cases, causal conditions and indicators

In qualitative comparative research, the cases are what is to be compared —in this study, the 120 Brazilian municipalities with the largest proportion of farms reporting organic farming and the 20 municipalities with the smallest proportion. This procedure aimed to obtain a sample with a gradient of municipalities that varied between those with a large proportion of organic farms and those with a small proportion of organic farms, as recommended by Schneider and Wagemann (2010).

Once the 140 municipalities had been selected, the drivers established in the literature (see table 1) were associated with the questions formulated by IBGE, and indicators were developed for each driver. Annex A1 describes the identification codes, the classification, the drivers, the 2017 agricultural census questions to which they refer, the reply alternatives, the formulas for calculating the indicator by municipality and the numbers of the tables referring to the census in the IBGE Automatic Retrieval System (SIDRA) platform. These associations were then used to create the database for the analysis.

2. Calibration of the indicators associated with the drivers

For each driver, descriptive statistics were calculated to identify the maximum (N1), median (N2) and minimum (N3) values, and thus support the definition of the three anchors needed for the calibration process (see annex A2).

These results were then used for the driver calibration process. The definition of the driver “purpose of production (subsistence or commercial sale)” is an exception, because it is a binary variable. For this reason, 50% was set between production for commercial purposes and subsistence, as a midpoint between the two classes. Calibration is the process of converting continuous data to an interval of 0 to 1. All drivers were calibrated with the fuzzy set qualitative comparative analysis (fsQCA) programme (Ragin and Davey, 2017). In the process of calibrating the outcome (proportion of organic farms in the municipality), the value 0.10 was chosen, because it was considered that this value could best distinguish municipalities that have a high proportion of organic farms from those that do not. Following calibration, the drivers and the result were designated with capital letters to differentiate them from the other uncalibrated drivers.

3. Analysis of the drivers

The calibration process was followed by the two-step QCA (fsQCA): analysis of necessity and analysis of sufficiency (Schneider and Wagemann, 2012).

Firstly, the necessity of individual drivers was assessed. Necessary conditions are essential to management theory and practice, because if the factors in question are not present, the outcome will not occur. Moreover, other causal conditions cannot make up for their absence (Dul, 2016). A consistency threshold of 0.9 was established to infer a necessary causal condition (Schneider and Wagemann, 2012). The consistency criterion assesses the degree to which cases sharing a given condition agree in displaying the outcome in question (Ragin, 2008, p. 44). For Ragin (2000, cited in Bol and Luppi, 2013), a necessary condition is calculated as the sum of the minimum values of a condition associated with an outcome, divided by the sum of the values of that outcome in all cases.

A second criterion for defining whether or not a driver can be considered necessary is coverage, which is measured as the proportion of cases manifesting the driver and the outcome being investigated (Schneider and Wagemann, 2012). Coverage can thus be understood as an indicator of relevance or trivialness. A low level of coverage implies trivialness (Schneider and Wagemann, 2012).

Once completed, the analysis of necessity gave way to the second stage: the analysis of sufficiency. A driver can be considered sufficient if it is present in all cases of the subset, and the outcome being analysed is also present in that subset (Schneider and Wagemann, 2012, p. 57). Sufficiency was analysed using the truth table algorithm (fsQCA programme) and comprised the following stages (Rihoux and De Meur, 2009): (i) truth table analysis; (ii) decision on contradictory configurations; (iii) Boolean minimization procedure; (iv) consideration or otherwise of logical remainders, which are defined as sets of logically possible drivers that were not observed in the cases investigated.

For the first and second stage, all existing configurations of the observed drivers were listed. To exclude contradictory configurations (solutions for products that were both negative and positive for the outcome), a consistency rule of 80% was used, as well as the minimum proportional reduction in inconsistency indicator of 0.5 (Schneider and Wagemann, 2012). The Boolean minimization stage was performed with the standard analysis, since it is a very useful strategy for managing limited diversity (Schneider and Wagemann, 2012).

The standard analysis can produce three solutions: (i) a complex solution, which does not consider the logical remainders; (ii) a parsimonious solution, which does consider the logical remainders; and (iii) an intermediate solution, which selects logical remainders on the basis of theoretical guidelines or directional expectations.

In terms of directional expectations, necessary drivers are those that must be present in the solutions. Eco-innovation drivers that were not necessary were considered possibly present or absent (Schneider and Wagemann, 2012). Lastly, the intermediate solution, in which the use of logical remainders is controlled by the researcher, is presented and analysed (Schneider and Wagemann, 2012).

IV. Results

1. Analysis of necessity of the drivers of Brazilian organic crop and livestock farming

An analysis was made of whether the presence or absence of a given driver is always, or nearly always, associated with a municipality in which a large proportion of farms report organic farming (see table 2).

Table 2
Analysis of necessity of drivers of organic farming in Brazil

Driver	Midpoint – median of data distribution ^a	Consistency	Coverage
Higher education level	Average schooling greater than 7.6 years	0.816678	0.790529
Lower education level	Average schooling less than 7.6 years	0.743155	0.814223
Greater external participation	External participation in more than 31.96% of farms	0.693259	0.840580
Less external participation	External participation in less than 31.96% of farms	0.824322	0.735309
Greater diversity of assistance	Origin of technical assistance more than 0.60 sources	0.827936	0.825069
Less diversity of assistance	Origin of technical assistance less than 0.60 sources	0.782071	0.829941
Larger proportion of farms with own land	Proportion of farms with own land greater than 83.42%	0.729534	0.832514
Smaller proportion of farms with own land	Proportion of farms with own land less than 83.42%	0.847394	0.792333
Greater male predominance	Proportion of farms run by men greater than 84.64%	0.723419	0.760854
Lesser male predominance	Proportion of farms run by men less than 84.64%	0.764420	0.768264
Older age	Average age older than 54.34 years	0.862266	0.763946
Younger age	Average age younger than 54.34 years	0.672133	0.822589
Greater diversity of access to information	Average number of information sources greater than 1.60	0.684225	0.850113
Less diversity of access to information	Average number of information sources less than 1.60	0.837526	0.734073
Greater access to credit	Average number of credit sources greater than 0.09303	0.643641	0.756082
Less access to credit	Average number of credit sources less than 0.09303	0.809173	0.739302
Larger average farm size	Average farm size larger than 48.6 hectares	0.622376	0.811526
Smaller average farm size	Average farm size smaller than 48.6 hectares	0.842807	0.714926
Commercial farming	Subsistence as a production purpose in fewer than 50% of the farms	0.782487	0.694976
Subsistence farming	Subsistence as the purpose of production in more than 50% of the farms	0.534398	0.651806

Source: Prepared by the authors, on the basis of the fsQCA programme.

^a A value of 0.5 was used to classify production purpose.

The analysis of necessity of the drivers found that none attained the 0.9 consistency limit, which is usually applied to define a causal condition as necessary.

2. Analysis of sufficiency of the drivers of Brazilian organic farming

This section analyses the results of the combinations of drivers internal and external to the farm that are positively associated with a large proportion of organic farming properties in a given municipality.

(a) Internal drivers

The results of the fsQCA programme for the internal drivers indicate that the sample can be described by a total of two highly consistent configurations (above 90%), as described in table 3. These two configurations identify the combinations of drivers that are positively associated with a municipality in which a large proportion of farms are organic.

Table 3
Configurations of internal drivers of organic farming in Brazil

Configurations	Gross coverage	Unique coverage	Consistency
Older AND less male dominated AND larger average farm size AND smaller proportion of farms with own land	0.481862	0.0433634	0.920850
Older AND less male-dominated AND larger average farm size AND lower education level	0.449757	0.0112578	0.928284
Frequency threshold: 2			
Consistency threshold: 0.920077			
Solution coverage: 0.49312			
Consistency of the solution: 0.915613			

Source: Prepared by the authors, on the basis of the fsQCA programme.

The results show that the two configurations have high consistency measures of 92.08% and 92.82%, respectively. This means that 9 out of 10 municipalities thus configured reported a high proportion of organic farms. The consistency of the overall solution indicates that, when the two configurations are present, there is a 92.00% probability that the municipality in question has a large proportion of organic farms (Rihoux and De Meur, 2009).

The results also show that the two configurations have high coverage rates (gross coverage between 48.18% and 44.97% and unique coverage between 4.33% and 1.12%). For example, for the first configuration, the gross coverage measure indicates that 48.18% of municipalities in which more than 10% of farms are organic contain the first subset of cases. The solution coverage means that 49.31% of the municipalities with a large proportion of organic farms are covered by one of these two configurations.

Unique coverage ranged from 1.1% to 4.3%. This is drawn from the subsets that have the same configuration and indicates the proportion of those configurations that can produce the outcome variable without the addition of any other causal condition (Rihoux and De Meur, 2009).

(b) External drivers

The results obtained with the fsQCA programme for the external drivers indicate that the sample can be described by three highly consistent configurations (above 90%), as described in table 4.

Table 4
Configurations of external drivers of organic farming in Brazil

Configurations	Gross coverage	Unique coverage	Consistency
Commercially run AND less access to credit AND less external participation	0.613203	0.0924253	0.881518
Commercially run AND greater diversity of assistance AND less external involvement	0.545517	0.0229326	0.923530
Marketing AND greater diversity of assistance AND greater diversity of access to information	0.558721	0.0118138	0.938595
Frequency threshold: 2			
Consistency threshold: 0.928415			
Solution coverage: 0.723974			
Consistency of the solution: 0.869616			

Source: Prepared by the authors, on the basis of the fsQCA programme.

The results show that the three configurations are highly consistent with a large proportion of organic farms in a municipality, reporting values of 88.15%, 92.35% and 93.85%, respectively. This means that 9 out of 10 municipalities so configured displayed a positive outcome. The consistency of the overall solution indicates that, when the three configurations are present in a municipality, there is an 86.96% likelihood that a large proportion of its farms are organic (Rihoux and De Meur, 2009).

The results also show that the three configurations have high coverage (gross coverage rates of 61.32%, 54.55% and 55.87%, respectively, and unique coverage rates of 9.24%, 2.29% and 1.18%, respectively). Gross coverage indicates that 61.32% of municipalities in which more than 10% of agricultural properties engage in organic farming contain the first subset of configurations, 54.55% of municipalities contain the second subset, and 55.87% contain the third. The coverage of the solution means that 72.39% of the municipalities with a high proportion of organic farms are covered by one of these three configurations (Rihoux and De Meur, 2009).

Unique coverage ranged from 1.1% to 9.2%. This is drawn from the subsets that have the same configuration and indicates the proportion of those configurations that can produce the outcome variable without the addition of any other causal condition (Rihoux and De Meur, 2009).

V. Analysis of results

The QCA method makes it possible to identify configurations of drivers that explain the large proportion of properties reporting organic farming in a municipality.

Firstly, all drivers were analysed in isolation (see table 2). The results indicate that none of the drivers, individually, can be defined as necessary for the presence of a high proportion of properties reporting organic farming in the municipality. In other words, none of the drivers analysed in isolation is always associated with a large proportion of organic farms.

Secondly, combinations of internal and external drivers were analysed for sufficiency. In the case of internal drivers (see table 1), two explanatory configurations were found for the large proportion of properties reporting organic farming in a municipality. These two configurations identify internal drivers common to municipalities with a large proportion of organic farms, namely older age and lesser male predominance and larger average farm size.

The older average age of organic farmers (over 54.34 years) corroborates the earlier finding of Lourenço and Schneider (2022) that organic farmers are predominantly more than 55 years old. It is also consistent with what is happening in family farming, where an ageing process can be discerned

among those responsible for the farms — a phenomenon that is well documented in the literature on the rural world and has intensified in recent decades (Camarano and Abramovay, 1999)— since most organic farmers are also family farmers (Lourenço and Schneider, 2022). Another likely feature that can be inferred is that the greater experience of these farmers —who have often already confronted problems related to conventional farming (such as pesticide poisoning, high production costs and indebtedness)— makes them switch to organic farming later in life.

The lesser predominance of men running organic farms in the municipalities (less than 84.64%) may be explained by several studies that highlight the important role played by women in processes of transition to organic farming (Karam, 2004). Alternatively, it may suggest that the organic farming system involves the family to a greater extent (Shultz, de Souza and Jandrey, 2017), or even enable a greater role for women farmers in these farms (Schmitt and others, 2020). However, this is not entirely clear from the results obtained from the 2017 Agricultural Census (Lourenço and Schneider, 2022).

Larger average farm size (greater than 48.6 hectares) was another driver associated with a high proportion of properties reporting organic farming in a municipality. The literature did not suggest an explanation for this result. Nonetheless, in municipalities with larger average farm size, a possible complementarity with the adoption of organic farming is inferred as larger farms are generally associated with the production of commodities, while organic farming tends to be associated with growing vegetables and legumes (Valarini and others, 2005). Complementarity may arise from the demand for organic food from the larger farms to sustain the rural families working on them, or else for the subsistence of the organic farms.

These three internal drivers (older age, less male predominance and larger average farm size) are combined with two others: (i) smaller proportion of farms with owned land (less than 83.42%), which made it possible to infer the category of farms run by older men, with the participation of women and less owned land, representing 48.18% of municipalities with a high proportion of organic farms; or (ii) lower level of education (less than 7.6 years of schooling), which made it possible to infer the category of establishments headed by older men, with the participation of women and low levels of education, which represents 44.97% of the municipalities with a large proportion of organic farms.

These two internal drivers (smaller proportion of farms with their own land and lower education levels) stem from the origins of organic farming, associated with producers who were involved in various social movements in rural areas, especially those who were excluded from the “green revolution”, which occurred between the 1960s and 1980s. The green revolution involved increased concentration of properties, the exclusion of some producers from the modernization process, and worsening inequalities. Thus, an alternative to the effects of that process was diversification of production or the transition to ecologically based farming systems (Lourenço and Schneider, 2022).

In the case of external drivers, three configurations were identified: (i) commercially run, less external participation and less access to credit; (ii) commercially run, less external participation and greater diversity of assistance; (iii) commercially run, greater diversity of assistance and greater diversity of access to information. All of these are associated with a high proportion of organic farms in a municipality.

These three configurations indicate a common external driver, namely commercial sale as the production purpose. The result regarding the commercial purpose of production (more than 50% of farms) corroborates the proposal, made by Hasler and others (2017), that the market can foster knowledge about the desired eco-innovation; and it also supports the results reported by Mier y Terán and others (2021), who state that commercial purpose is a condition for the adoption and adaptation of agroecological systems by farmers.

In addition to the driver related to the purpose of production (commercial sale or subsistence), the following three pairs of drivers were associated:

- (i) Less external participation (less than 31.96% of the farms) and less diversity of access to credit (less than 0.09303 sources), which made it possible to infer the category of farms that are commercially run, isolated and without credit, which represented 61.32% of the municipalities with a large proportion of organic farms.
- (ii) Greater external participation (over 31.96% of the farms) and greater diversity of assistance (over 0.60 sources), which made it possible to infer the category of farms that are commercially run, technically assisted and non-participatory, which represented 54.55% of the municipalities with a high proportion of organic farms.
- (iii) Greater diversity of assistance (more than 0.60 sources) and greater diversity of access to information (more than 1.60 sources), which made it possible to infer the category of farms that are commercially run, technically assisted and informed, which represented 55.87% of the municipalities with a high proportion of establishments engaged in organic farming.

Less external participation can hinder the adoption of a constructivist teaching and learning practice that encourages active inclusion of traditional, local and contemporary knowledge, as well as the development of autonomy. Predominantly horizontal pedagogies can ensure collective participation, horizontal learning, diverse discussions and joint creation of knowledge and dialogues on different knowledge sources (Mier y Terán and others, 2021). When a family is engaged in organic farming but does not participate in a cooperative or class entity, their learning from new experiences and from other families is limited. Otherwise, learning can occur more easily and have a multiplier effect (Mier y Terán and others, 2021).

While it was expected that agricultural credit would also be associated with a large proportion of properties reporting organic farming in a municipality, this was not detected in the results. Hasler and others (2017) note that credit can motivate the start of the process of transition to eco-innovation. However, the absence of credit as a driver of organic farming is also consistent with Aquino, Gazolla and Schneider (2021), who found that credit policies for Brazilian organic farming occupy a marginal place in the national credit programme, owing to problems in its regulatory design and the persistence of implementation obstacles.

Notwithstanding the arguments presented thus far, and the advantages of greater external participation and credit, it is impossible to claim that a lesser presence of these drivers means there are no municipalities with a high proportion of properties reporting organic farming, as shown by the municipalities included in the configuration “commercial purpose, less external participation and less access to credit”, characterized as farms that are commercially run, isolated and without credit and farms that are commercially run, technically assisted and non-participatory.

Technical assistance and access to information can facilitate the learning of simple and effective agroecological practices related to proper soil, water and invasive plant management, crop rotation and soil correction with organic matter. In the case of soil and plant management, knowledge of cultivation techniques such as crop rotation and mulching is necessary (Souza, Gomes and Gazzola, 2021; Mier y Terán and others, 2021).

Lastly, it is possible to associate some of the configurations found in the results with the characteristics of low-income farmers. Aquino, Gazolla and Schneider (2016) characterized this group of farmers through five types of asset: natural, physical, human, social and financial.

In relation to assets that are internal to the farm, Aquino, Gazolla and Schneider (2016) characterized low-income producers as those with less, or even, no land of their own (natural assets), of older age and low education levels (human assets). These characteristics are present in the two categories determined by combining the internal drivers, which jointly represent 49.31% of the municipalities

with a high proportion of organic farms, namely: (i) farms run by older men, with the participation of women and less land of their own; (ii) farms run by older men, with the participation of women and low education levels.

In relation to assets external to the farm, Aquino, Gazolla and Schneider (2016) characterized low-income farmers as those that lack technical support (human asset), have little social participation (social asset) and did not generate economic surpluses (financial asset).

The characteristic of low social participation was found in the category of farms that are commercially run, isolated and without credit (commercial purpose, less external participation and less diversity of access to credit). This is the most important category, since it represents 61.32% of the municipalities with a high proportion of organic farms.

The characteristic of low social participation was also found in the category of farms that are commercially run, technically assisted and non-participatory (commercial purpose, greater diversity of assistance, less external participation). This is the third most important category, representing 54.55% of the municipalities with a high proportion of organic farms.

Lastly, the characteristics related to assets external to the farm that Aquino, Gazolla and Schneider (2016) associate with low-income producers are not present in the category of farms that are commercially run, technically assisted and informed, represented by the following configuration: commercial purpose, greater diversity of assistance and greater diversity of access to information. This is the second most important category, representing 55.87% of the municipalities with a high proportion of organic farms.

VI. Final thoughts

The general objective of this research was to identify the combinations of drivers of agricultural eco-innovation that foster the adoption of organic farming. The results showed that no single driver can be defined as necessary; but combinations of internal and external drivers were found to be sufficiently explanatory of a high proportion of properties reporting organic farming in a municipality.

The two configurations of internal drivers that were identified involved municipalities with older farm operators, a lesser predominance of men and larger average farm size. These three characteristics were combined with a smaller proportion of farms with their own land in the municipality, or a lower level of education among the operators of these farms. The two configurations were characterized as: (i) farms run by older men, with the participation of women and less owned land; and (ii) farms run by older men, with the participation of women and low education levels.

The three configurations of external drivers encountered were characterized as: (i) commercial purpose, isolated and without credit facilities; (ii) commercial purpose, technically assisted and non-participatory and (iii) commercial purpose, technically assisted and informed.

Farms run by older men, with female participation and less owned land; farms run by older men, with female participation and low levels of education; farms that are commercially run, isolated and without credit; and farms that are commercially run, technically assisted and non-participatory have drivers associated with multiple productivity shortcomings, characteristic of poor farmers.

The study's main shortcoming was the fact that it was impossible to work with microdata — that is, data collected from the farms directly — owing to confidentiality agreements between IBGE and the respondents. Access to the microdata would have enabled direct inferences to be made about the farms. Given this constraint, aggregate data (averages) were used to represent the set of farms in each municipality. This may have restricted the diversity of the results, because the averages may conceal the diversity of farm characteristics. Nonetheless, it was possible to draw inferences on the drivers of organic farming in the Brazilian municipalities, even working with aggregate data.

It is also worth noting that organic farming is found to be associated with municipalities in which the average farm size is larger. No possible explanation for this result was found in the literature. Although a potential complementarity is inferred between larger and smaller properties, this explanation is recognized as insufficient. Accordingly, this is an issue that would merit future research.

For future studies, it would also be worth evaluating drivers not envisaged in the IBGE questionnaire that could improve understanding of the factors that might foster organic farming. These include expectations (Hasler and others, 2017), the perception of crises that challenge conventional systems, constructivist teaching and learning processes, the presence of a mobilizing discourse and favourable public policies, and political opportunities (Mier y Terán and others, 2021).

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Annex A1

Table A1.1
Drivers of Brazilian organic crop and livestock farming and corresponding questions

Identification code	Internal or external driver	Drivers	Questions from the 2017 agricultural census	Response options	Indicator calculation procedure	IBGE Automatic retrieval system (SIDRA) charts
AssocEnvExt	EXTERNAL	Participation in external groups or cooperatives	5.1 Is the farmer a member of a cooperative or class entity?	(1) No; (2) Yes. If yes: (3) Cooperative; (4) Class entity - trade union; (5) Producer associations or movements; (6) Resident associations	Option Yes (question 5.1)/ number of crop and livestock farms in the municipality	6846
Inform	EXTERNAL	Information	5.5 How does the farmer obtain technical information?	(1) Television; (2) Radio; (3) Internet; (4) Magazines; (5) Newspapers; (6) Non-governmental organizations (NGOs); (7) System S; (8) Other	Σ options 1–8 (question 5.5)/ number of farms in the municipality	6846
AcCred	EXTERNAL	Access to credit	38.4 From which agents did the farmer obtain financing or loans?	(1) Banks; (2) Credit unions; (3) Governments; (4) Commodity traders; (5) Suppliers; (6) Integrator firms; (7) Other financial institutions; (8) NGOs; (9) Family and friends; (10) Others	Σ options 1–10 (question 38.4)/ number of farms in the municipality	6895
FinalProd	EXTERNAL	Market access	2.14 What is the purpose of the farming?	(1) Consumption by the farmer and family; (2) Commercial sale, barter or exchange	Option 1 (question 2.14)/ number of farms in the municipality	6762
TerrasTam	INTERNAL	Farm size	1.18 What is the total area of the farm on the reference date?	0<0,1; 0,1<0,2; 0,2<0,5; 0,5<1; 1<2; 2<3; 3<4; 4<5; 5<10; 10<20; 20<50; 50<100; 100<200; 200<500; 500<1000; 1000<2500; 2500<10.000; x>10.000	Σ (class frequency X class mean)/number of farms	6906
Propr	INTERNAL	Land ownership	3.2 Own land area	(1) Total; (2) Owned; (3) Awarded; (4) Leased; (5) In partnership; (6) On loan (<i>comodato</i>); (7) Occupied	Option 2 (question 1.18)/ Option 1 (question 1.18)/ Option 2 (question 1.18)	6845
GEn	INTERNAL	Gender	2.4 Gender	(1) Male; (2) Female	Option 1 (question 2.4)/ Σ options 1 and 2	6779
Idade	INTERNAL	Age	2.5 Age	()	-	6779
Educ	INTERNAL	Education	2.8 What is the highest-level course the farmer has attended?	(1) Never attended school; (2) Basic literacy class (CA); (3) Youth and adult literacy (AJA); (4) Former primary education (elementary); (5) Former basic secondary education (lower secondary); (6) Regulated primary education or first grade; (7) Youth and adult education (EJA) of primary school or supplementary first grade; (8) Former scientific, classical or other baccalaureate (upper secondary); (9) Regular secondary education or second grade; (10) Secondary education or second grade technician; (11) Youth and adult education (YAE) of secondary education or supplementary second grade; (12) Higher education degree; (13) Master's degree or PhD	(A) Definition of the number of years studied at each school level investigated in question 2.8 (B) Determination of the number of farms in each response option for question 2.8 - AXB/ Σ B calculation	6779
QualSup	EXTERNAL	Quality of assistance	5.4 What is the origin of the technical assistance?	(1) Government; (2) Self or farmer; (3) Cooperative; (4) Integrator firm; (5) Private planning firm; (6) NGO; (7) System S; (8) Other	Σ options 1-8 (question 5.4)/ number of farms in the municipality	6846

Source: Prepared by the authors.

Annex A2

Calibration process

compute: PRODORG = calibrate(PropOrg,1,0.1,0)

compute: EDUC = calibrate(Educ,12.88,7.63,0.35)

compute: FINALPROD = calibrate(FinalProd,0.93272,0.5,0)

compute: ASSOCEVENTEXT = calibrate(AssocEnvExt,1.56552,0.31961,0)

compute: QUALSUP = calibrate(QualSup,6.0,0.6,0)

compute: TERRASPROP = calibrate(Propr,1;0.83,0.07)

compute: GEN = calibrate(GEn,1,0.84644,0.64679)

compute: IDADE = calibrate(Idade,60.5,54.34,27.57)

compute: INFORM = calibrate(Inform,8.93,1.60,0.36)

compute: ACCRED = calibrate(AcCred,0.48,0.09,0)