Spatial distribution and farm size variation of small, medium, and large holdings across the agrotechnological districts of the Semear Digital

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Abstract

This study analyzes the spatial distribution and size variation of small, medium, and large farms across ten Agrotechnological Districts (DATs) in Brazil. Using geospatial data and the fiscal module as classification metrics, we observed the predominance of small farms, despite significant variation in average size between regions. These findings reflect local economic and agricultural characteristics, underscoring the need for context-specific rural development strategies when implementing digital solutions through the Semear Digital "Center of Science for Development in Digital Agriculture."

Keywords: Farm size classification; Spatial analysis; Fiscal module.

1. Introduction

The categorization of farms by spatial scale (small, medium, or large) varies significantly between and even within countries and is not universally consistent. For example, in Mozambique, a small farm is defined as having less than 10 hectares of unirrigated land or less than 5 hectares of irrigated land. In contrast, in India, small farms have an area between 1 and 2 hectares, medium-sized farms have an area between 4 and 10 hectares, and large farms have an area above 10 hectares (HLPE, 2013).

In Brazil, farms are classified by spatial scale according to Special Instruction No. 5 (Brasil, 2022) of the National Institute for Colonization and Agrarian Reform (INCRA). This classification is based on the concept of the fiscal module (FM). The size of an FM can vary significantly, ranging from five to 110 hectares, depending on the municipality. An FM represents the minimum area necessary for a rural property to be considered

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economically viable. It is an agrarian measurement unit defined by factors such as types of farming activities, manner and conditions of economic use, and predominant income (Brasil, 2022; Landau et al., 2012).

According to this classification, small farms have up to four fiscal modules, medium-sized farms have more than four and fewer than 15, and large farms have more than 15 fiscal modules (Brasil, 2022).

The distribution of small, medium, and large farms significantly influences agricultural productivity, access to support programs and technological innovations, and policy design (Daberkow; McBride, 2003; Bekkerman et al., 2019; Rada; Fuglie, 2019). This study investigates the spatial distribution and variation in farm sizes (small, medium, and large holdings) across the Agrotechnological Districts (DATs) of the Semear Digital "Center of Science for Development in Digital Agriculture." The aim is to provide a comprehensive understanding of the diverse farm structures present within the DATs.

2. Methods

The DATs are municipalities where the demands of farmers for digital solutions are raised and then developed and validated by Semear Digital. They are geographically diverse and spread throughout Brazil. Currently, there are ten DATs: Breves in Pará (PA); Boa Vista do Tupim in Bahia (BA); Guia Lopes da Laguna in Mato Grosso do Sul (MS); Ingaí in Minas Gerais (MG); Vacaria in Rio Grande do Sul (RS); and five municipalities within the state of São Paulo (SP): Alto Alegre, Caconde, Jacupiranga, Lagoinha, and São Miguel Arcanjo (Figure 1).

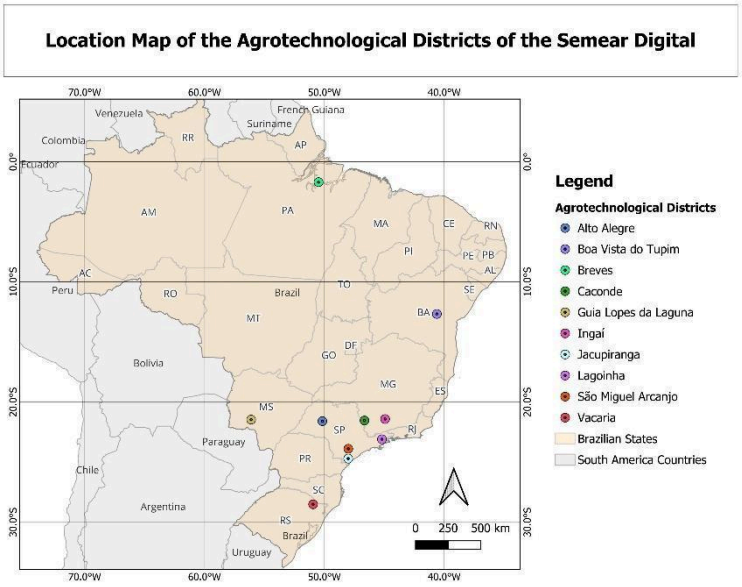

Figure 1. Location of the Agrotechnological Districts of the Semear Digital.

To analyze the spatial distribution and variation in categorized farm sizes (small, medium, and large holdings), we first consulted the *Plataforma de Governança Territorial* to gather information on the size of the fiscal module for each Agrotechnological District (DAT). Subsequently, we accessed the INCRA website[260] to obtain shapefiles of rural properties from the *Sistema de Gestão Fundiária* for each relevant Brazilian state. Additionally, we retrieved shapefiles of rural properties from the *Cadastro Ambiental Rural* (CAR) platform[261], selecting the "rural properties perimeter" option for the states of Bahia, Mato Grosso do Sul, Minas Gerais, Pará, São Paulo, and Rio Grande do Sul.

The shapefiles corresponding to the DATs (municipalities) were obtained from the Brazilian Institute of Geography and Statistics (IBGE) website[262]. The INCRA and CAR farm shapefiles for the states and the IBGE shapefile were then imported into the geoprocessing software QGIS. Using the "Clip" geoprocessing tool, the farm shapefiles from INCRA and CAR were clipped according to the boundaries of each DAT. The resulting layers were merged using the "Merge Vector Layers" tool, and the "Delete Duplicate Geometries" tool was applied to remove overlapping features. The final output layers

[260] Available at: https://certificacao.incra.gov.br/csv_shp/export_shp.py.
[261] Available at: https://consultapublica.car.gov.br/publico/estados/downloads.
[262] Available at: https://www.ibge.gov.br/geociencias/organizacao-do-territorio/malhas-territoriais/15774-malhas.html.

were reprojected to the Universal Transverse Mercator (UTM) coordinate system to enable area calculation via the Field Calculator tool.

The resulting datasets containing the calculated farm areas were then used to classify rural properties into three categories: small (area ≤ 4 fiscal modules), medium (area > 4 and ≤ 15 fiscal modules), and large (area > 15 fiscal modules). This classification was automated using a Python script.

3. Results and Discussion

The largest fiscal modules were found in Breves and Boa Vista do Tupim, measuring 70 and 60 hectares (ha), respectively. Conversely, the smallest fiscal modules were found in Jacupiranga and São Miguel Arcanjo, both of which had fiscal modules measuring 16 ha. Caconde and Vacaria followed closely behind with fiscal module sizes of 22 and 25 ha, respectively (Figure 2).

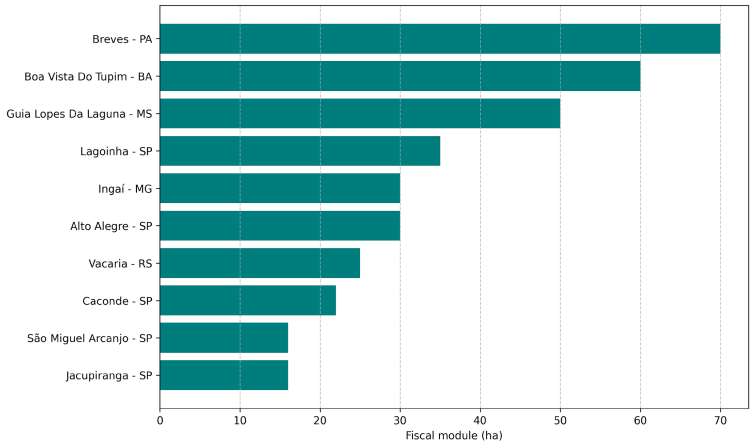

Figure 2. Fiscal module size, in hectares (ha), for each Agrotechnological District.

The differences observed in fiscal module sizes among the DATs reflect each municipality's economic and demographic characteristics, as well as the predominant types of rural farming activities (e.g., temporary and permanent crops, horticulture, forestry, and livestock) and the income generated from these activities. Together, these factors influence the minimum economically viable area for rural properties, as defined by INCRA (Brasil, 2022; Landau et al., 2012).

The small, medium, and large farms present spatial variation across the DATs of the Semear Digital (Figure 3).

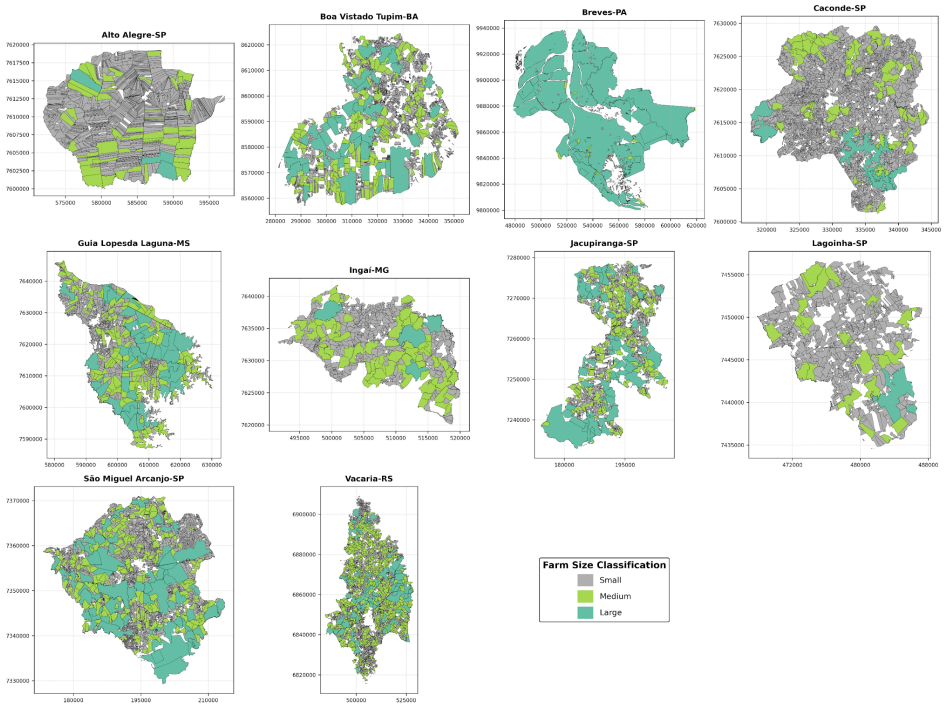

Figure 3. Small, medium, and large farm spatial distribution.

The predominant farm size classification across all DATs was small farms, accounting for between 76.7% (Vacaria) and 97.3% (Lagoinha) of total rural properties. The average size of small farms varied considerably among municipalities: It ranged from 11.4 ha in São Miguel Arcanjo to 46.1 ha in Guia Lopes da Laguna (Table 1).

Table 1. Mean area, in hectares, and percentage of occurrence of small, medium, and large farm sizes

Agrotechnological District	% Small Farms	Mean Area (Small)	% Medium Farms	Mean Area (Medium)	% Large Farms	Mean Area (Large)
Alto Alegre	95.0	21.1	4.7	201.2	0.4	523.4
Boa Vista do Tupim	90.5	28.7	7.2	454.6	2.2	2,014.1
Breves	93.7	31.6	1.4	643.1	4.9	16,477.9
Caconde	96.9	12.9	2.8	141.0	0.3	693.0
Guia Lopes da Laguna	81.1	46.1	13.9	355.7	5.0	1,297.6
Ingaí	87.9	24.9	11.3	200.8	0.8	771.9
Jacupiranga	84.1	14.7	12.0	115.4	4.0	653.0
Lagoinha	97.3	20.0	2.6	245.3	0.1	1,453.4
São Miguel Arcanjo	89.5	11.4	7.8	123.1	2.7	689.9
Vacaria	76.7	29.3	19.4	185.5	3.9	712.4

The mean area of medium-sized farms ranged from 115.4 ha in Jacupiranga to 643.1 ha in Breves, representing 1.4% to 19.4% of the total number of properties, respectively. In contrast, the mean area of large farms ranged from 523.4 ha in Alto Alegre to 16,477.9 ha in Breves. Large farms accounted for as little as 0.1% of properties in Lagoinha and up to 5.0% in Guia Lopes da Laguna.

4. Conclusion

Despite regional differences in fiscal module size, which are shaped by local economic, demographic, and agricultural characteristics, small farms are the most common classification across all DATs. However, the average size of small farms varies significantly between DATs, reflecting different land use and rural organization patterns.

Although medium and large farms are less numerous, they exhibit differences in average area, particularly in municipalities such as Breves and Guia Lopes da Laguna. These findings underscore the structural diversity of rural areas within DATs and emphasize the importance of considering local circumstances when designing digital solutions and agricultural policies.

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