DIMENSIONS OF AGRICULTURAL MODERNIZATION: A MULTIVARIATE APPROACH TO TECHNOLOGICAL LEVELS IN RONDÔNIA, BRAZILIAN AMAZON

DIMENSÕES DA MODERNIZAÇÃO AGROPECUÁRIA: UMA ABORDAGEM MULTIVARIADA SOBRE OS NÍVEIS TECNOLÓGICOS EM RONDÔNIA, AMAZÔNIA BRASILEIRA

DIMENSIONES DE LA MODERNIZACIÓN AGRÍCOLA: UN ENFOQUE MULTIVARIADO DE LOS NIVELES TECNOLÓGICOS EN RONDÔNIA, AMAZONÍA BRASILEÑA

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ABSTRACT
This study aimed to characterize rural establishments in the state of Rondônia based on records from the 2017 Agricultural Census, using multivariate statistical analysis methods to determine the municipal technological level based on factor scores. The methodological foundation consisted of applying Factor Analysis and Cluster Analysis techniques. Six latent factors were identified—named Plantation, Soil, Technical Instruction, Livestock, Dairy Production, and Rural Modernization—which, together, explained 82.5% of the total variability of the analyzed data. The cluster analysis, validated by K-means and hierarchical methods, revealed that the division into two distinct groups adequately represents the productive heterogeneity of the state. Regarding the technological level (ITEA), it was found that the municipalities are distributed only between the medium and low categories, with no localities at extreme levels (high or very low). The municipality of Pimenteiras do Oeste obtained the highest technological index, standing out as a reference for agricultural modernization in the region. It is concluded that multivariate modeling is a robust and suitable tool to support regional diagnoses and guide public policies aimed at sustainable rural development in Rondônia.

Keywords: Agriculture. Multivariate Statistics. Rural Properties. Technological Levels.

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RESUMO
Este trabalho objetivou caracterizar os estabelecimentos rurais do Estado de Rondônia a partir dos registros do Censo Agropecuário de 2017, utilizando métodos de análise estatística multivariada para determinar o nível tecnológico municipal com base em escores fatoriais. A fundamentação metodológica consistiu na aplicação das técnicas de Análise Fatorial e de Agrupamento (Cluster). Foram identificados seis fatores latentes — denominados Plantação, Solo, Instrução Técnica, Pecuária, Produção Leiteira e Modernização Rural — que, em conjunto, explicaram 82,5% da variabilidade total dos dados analisados. A análise de cluster, validada pelos métodos K-means e hierárquico, revelou que a divisão em dois agrupamentos distintos representa adequadamente a heterogeneidade produtiva do estado. No que tange ao nível tecnológico (ITEA), verificou-se que os municípios se distribuem apenas entre as categorias médio e baixo, com ausência de localidades em níveis extremos (alto ou muito baixo). O município de Pimenteiras do Oeste obteve o maior índice tecnológico, destacando-se como referência de modernização agropecuária na região. Conclui-se que a modelagem multivariada é uma ferramenta robusta e adequada para subsidiar diagnósticos regionais e nortear políticas públicas voltadas ao desenvolvimento rural sustentável em Rondônia.

Palavras-chave: Agropecuária. Estatística Multivariada. Propriedades Rurais. Níveis Tecnológicos.

RESUMEN
Este estudio tuvo como objetivo caracterizar los establecimientos rurales en el estado de Rondônia con base en los registros del Censo Agrícola de 2017, utilizando métodos de análisis estadístico multivariado para determinar el nivel tecnológico municipal con base en puntuaciones factoriales. La base metodológica consistió en la aplicación de técnicas de Análisis Factorial y Análisis de Conglomerados. Se identificaron seis factores latentes — denominados Plantación, Suelo, Instrucción Técnica, Ganadería, Producción Lechera y Modernización Rural— que, en conjunto, explicaron el 82,5% de la variabilidad total de los datos analizados. El análisis de conglomerados, validado por los métodos K-means y jerárquico, reveló que la división en dos grupos distintos representa adecuadamente la heterogeneidad productiva del estado. Con respecto al nivel tecnológico (ITEA), se encontró que los municipios se distribuyen solo entre las categorías media y baja, sin localidades en niveles extremos (alto o muy bajo). El municipio de Pimenteiras do Oeste obtuvo el índice tecnológico más alto, destacándose como referencia para la modernización agrícola en la región. Se concluye que el modelado multivariante es una herramienta robusta y adecuada para respaldar los diagnósticos regionales y orientar las políticas públicas dirigidas al desarrollo rural sostenible en Rondônia.

Palabras clave: Agricultura. Estadística Multivariante. Propiedades Rurales. Niveles Tecnológicos.

1 INTRODUCTION

The state of Rondônia, covering a territorial extension of 237,765.347 km² (IBGE, 2021), requires a broad livestock and agrarian program related to production and consumption itself, reinforcing the state economy, through the national and international export of its breeding and cultivation.

Seeking this production with high profitability, the agribusiness sector strives to demand innovations that contribute to the modernization of agricultural activity that result in greater productivity. Adequate use of technological tools, with a scientific and statistical basis, increases the productivity of the sector and reduces its production cost. In this sense, several scientific studies have been carried out (Sena, 2010; Santos *et al*., 2017; Simões *et al*., 2017).

Santos *et al*. (2017) evaluated the technological level of cattle production systems in the Brazilian Amazon. Using official data from the IBGE, they calculated 15 indicators of technology adoption for each of the municipalities of the legal Amazon, the state of Mato Grosso and the municipalities of the state of Maranhão located west of the 44° meridian, a total of 775 municipalities, which were submitted to factor analysis by principal components to estimate the technological index of cattle raising in these regions. The authors found that the state of Mato Grosso has the largest number of municipalities with cattle ranching with the highest technological level, followed by Rondônia, Tocantins and the state of Pará.

Simões *et al*. (2017) investigated the technological heterogeneity of dairy farming in Minas Gerais, through factor analysis of the data and cluster analysis. Based on 15 variables of technology and production scale, based on the Agricultural Census, they built a Dairy Livestock Modernization Index for the 66 micro-regions of Minas Gerais. They concluded that the factor analysis allowed the elaboration of three explanatory factors of the technological level and the scale of milk production and that the cluster analysis enabled the construction of four technology clusters, making it possible to infer that the grouping of micro-regions based on information from the Agricultural Census is coherent with the current reality and can be used to guide public policies.

Factor analysis is a multivariate statistical modeling, which is used to measure the common variability between a set of variables, seeking to reduce the number of these variables, through summarization with latent, unobservable factors (Corrar *et al*., 2017), while Cluster analysis (clustering) refers to a wide spectrum of methods that attempt to subdivide a set of data and/or variables into subsets (clusters) that are separated into pairs and not empty. The subsets reproduce via union (Bezdek, 1981). A cluster is usually formed by grouping similar data samples around a center, called a centroid or prototype cluster (Mota; Damasceno and Leite, 2018). In view of the above, the work aims to use multivariate factor and cluster analysis to characterize the records of the agricultural census of rural establishments in the State of Rondônia and to determine the technological level based on factor scores. XcX

2 THEORETICAL FRAMEWORK

2.1 CATTLE AND AGRARIAN PRODUCTION IN THE STATE OF RONDONIA

Rondônia exports almost all of its beef production, quarterly, on average, about 75 thousand to 90 thousand tons of beef, generating a positive effect of US$ 1.1 billion, from January to September 2025. The state received a declaration of a foot-and-mouth disease-free zone, achieving certification without vaccination since 2021 by the World Organization for Animal Health (WHOA), increasing the demand for beef (Idaron, 2025).

In this sense, we can also consider that the sanitary condition of the local herd is the result of an advantageous public-private partnership, appropriately certified by international systems, attracting more and more rigorous markets. The gross value of agricultural production in Rondônia for 2021 was estimated at 19.1 billion reais, a result 12.9% higher than that obtained in 2020 (Pfeifer *et al.*, 2021).

In relation to Agrarian Production, according to data from the National Supply Company – Conab, Rondônia showed a growth of 18.6% in the bulk of grain production in the 2022/2023 harvest. Rondônia stood out with above-average values, reaching a 16.5% increase. It produced 790.1 million tons in the previous harvest and the Conab study predicted an increase to 936.9 million at the end of the 2023/24 harvest. In the grain harvest in 2024, productivity levels were also grandiose, with an estimated increase of 19.2% compared to the figures of the previous period (Conab, 2024). In this new grain harvest (2025/2026), production levels in Rondônia continue to expand, with an estimate of reaching 5.6 million tons, an increase of 3.1% compared to the volume harvested in the previous period. (Conab, 2026).

2.2 TECHNOLOGICAL LEVELS OF AGRICULTURAL PRODUCTION

Technology is a permanent need around the world, and has also sensitized the agricultural field, being one of the important areas for the Brazilian economy, attracting innovations to ensure a high level of production and profits. Producers who invest in technology and innovation had a higher profitability, as productivity increased with technological optimization, where their efficiency indicators in the sector reached high rates (Carvalho, 2022).

The receptivity of rural producers has also been resisted regarding the implementation of innovative tools, until the moment that they get to know and orient themselves better on the subject. By discovering that production is facilitated, and often expanded, generating more income, more organized and better quality work, this blockage of the new is minimized (Carvalho, 2022).

Software, drones, applications, and other innovation systems developed for the livestock sector allow accurate measurements of results (Gasques *et al*., 2017). For example, maintaining the vaccination history of animals, cattle registration form, weighing records, coverage registration, batch movement, birth registration of new calves and other significant data, provide the breeder with full access to all information to manage his production. The administrative and functional control of cattle breeding benefits the producer in decision-making, regarding the management, sale and purchase of animals, resolving losses and automatically maximizing profits.

Consequently, in the agrarian sector, technological modernization leveraged agricultural production, with an increase in productivity, which in aggregate terms, in the time that production increased 4.5 times, the use of inputs advanced a little more than 15%, which can be explained by the evolution of total factor productivity (TFP), which grew almost four times between 1975 and 2015 (Gasques *et al*., 2017). Improving the quality of the final product, with stricter monitoring of agricultural practices and the use of advanced harvesting and processing techniques help ensure that products reach consumers with a high standard of quality and safety.

High profitability with environmental sustainability in the use of data intelligence such as precision agriculture tools timely in real time, monitoring the operation of farm machines, visualizing alerts, fuel level, speed and average productivity of machinery. In this way, the agricultural sector unifies a large-scale agriculture, while being sustainable, rotating crops, using biological insecticides and natural fertilizers. So that these actions contribute to a healthy soil, which is capable of meeting the demands of cultivation without compromising the next generations.

2.3 STATISTICAL MODELING – FACTOR ANALYSIS

Factor Analysis is a modeling that aims to expose a set of variables based on a smaller number of indices or factors and, during the procedure, obtain a broad understanding and/or comprehension of these variables (Manly and Alberto, 2019).$pX_1, X_2, X_3, \ldots, X_p$

In summary, Factor Analysis represents a multivariate random process through the creation of new variables, from the original variables and, usually in smaller numbers, which correspond to the commonalities of the process, leaving the hypothetical ones not to be described by the factorial model. To test the feasibility of using factor analysis in a data set, it is possible to perform, among others, the Bartlett Sphericity Test, the Sample Adequacy Measure (MAA) and the Kaiser-Meyer-Olkin (KMO) (Mingoti, 2005; Hair *et al*. 2009).

2.3.1 Cluster Modeling (Clustering)

Cluster analysis can be defined as the organization of a set of objects (usually represented by feature vectors, i.e., points in a multidimensional space into groups based on the similarity between them. In other words, it means that grouping objects is the method of partitioning a set of data into subsets (groups) so that the objects in each group (preferably) share common attributes, usually proximity in similarity to some measure of similarity or distance (Castro; Ferrari, 2016).

Intuitively, objects belonging to the same group are more similar to each other than objects belonging to different groups. In this way, a group can be determined as a function of internal cohesion (homogeneity) and external isolation (separation) of its objects (Castro; Ferrari, 2016).

In summary, cluster analysis is a set of multivariate techniques whose main purpose is to aggregate objects based on the characteristics they have, i.e., it does aggregation based on distance (proximity), the resulting clusters of objects should then exhibit high internal homogeneity, within the clusters, and high external heterogeneity, between the clusters (Hair *et al*., 2009).

2.3.2 Types of Cluster *Analysis*

Many algorithms have been proposed for cluster analysis, however, hierarchical and partition techniques are the most used, and will be briefly described in this work.

Hierarchical techniques, most of the time, are used in exploratory analyses of the data with the objective of identifying possible groupings and the probable value of the number of groups (Mingoti, 2005). This technique produces a dendrogram, starting with the calculation of the distances from each object to all other objects, groups are then formed by a process of agglomeration or division. With conglomeration, all objects start out on their own in groups of one, and the nearby groups are then gradually merged until finally all objects remain in the same group (Manly; Alberto, 2019).

The clustering technique, on the other hand, uses partitioning, with objects being able to move in and out of groups at different stages of the analysis. There are variations in the algorithms used, but the basic approach involves first choosing centers from more or less occasional groups, with objects then allocated to their nearest center, i.e., new centers are then calculated, and these reflect the means of the objects in the groups (Manly; Alberto, 2019). In this way, an object is moved to a new group as follows:

> Whether the object is closer to that group center than to the center of its present group. Any group that is close is merged, scattered groups are split, etc., following some set rules. The process continues iteratively until stability is achieved with a number of predetermined groups. Usually a domain of values is experimented with for a final number of groups (Manly; Alberto, 2019, p. 164).

Commonly used by scholars among non-hierarchical clustering (partition) schemes, the *K-means* clustering method relates objects within multiple groups, so that *intra-cluster* variation is minimized by the sum of squares of Euclidean distances between the elements and their centroids (Johnson; Wichern, 2002).

3 METHODOLOGY

3.1 DATA

The present study was carried out with data from the Brazilian Institute of Geography and Statistics (IBGE), in the state of Rondônia, covering its 52 municipalities, using information from the 2017 Agricultural Census, the most recent found in the database of this agency. The variables that were analyzed are adapted from Santos *et al. (2017)* and Simões *et al*. (2017) and the naming of the indicators are presented in Table 1.

Table 1

Definition of the variables used to characterize the technological level of agricultural establishments in the State of Rondônia

V1 - Pasture Areas	Proportion of pasture areas in relation to the total area of agricultural establishments (%)
V2 - Disease Control	Proportion of establishments that carry out disease control in relation to the total number of establishments with livestock (%)
V3 – Crops	Proportion of establishments with crops in relation to the total number of agricultural establishments (%)
V4 - Soil preparation	Proportion of establishments that carry out soil preparation in relation to agricultural establishments (%)
V5 – Livestock	Proportion of establishments with livestock in relation to the total of agricultural establishments (%)
V6 - Electrical Power	Proportion of establishments with electricity in relation to the total number of agricultural establishments (%)
V7 – QL	Locational Quotient (LL) of the municipality in relation to livestock in the state of Rondônia
V8 - Water resources	Proportion of establishments with water resources in relation to the total number of agricultural establishments (%)
9 - Milked cows	Number of cows milked annually in relation to the number of agricultural establishments with cattle.

V10 - Production trade	Proportion of establishments with commercialization of production in relation to the total number of agricultural establishments (%)
V11 - Soil Correction	Proportion of establishments that carry out soil correction in relation to the total number of agricultural establishments (%)
V12 - Animal Nutrition	Proportion of livestock establishments that supplement with feed, grains and agro-industrial by-products (%)
V13 – Mineral salt	Proportion of establishments with cattle rearing that supplement with mineral salt (%)
V14 – Technical Guidance	Proportion of establishments receiving technical assistance in relation to total agricultural establishments (%)
V15 – Fertilization	Proportion of establishments that carry out fertilization in relation to the total number of agricultural establishments (%)
V16 – Irrigation	Proportion of establishments that carry out irrigation in relation to the total number of agricultural establishments (%)
V17 - Milk production	Amount of cow's milk produced (Thousand liters) in relation to the number of establishments that produce cow's milk.
V18 – Internet	Proportion of establishments with internet in relation to the total number of agricultural establishments (%)
V19 - Tractors and agricultural implements	Proportion of establishments with tractors and agricultural implements in relation to the total number of agricultural establishments (%)
V20 - Email	Proportion of agricultural establishments that have e-mail in relation to the total number of agricultural establishments (%)

Source: Prepared by the authors (2026).

The variables called indicators were calculated as percentages, with the exception of V7, V9 and V17, with the variable V7, - Locational Quotient (QL) of the municipality in relation to cattle raising, which was calculated according to Santos *et al*. (2017) by:

$$Ql = \frac{\left(\frac{VBP_{ij}}{VBP_j}\right)}{\left(\frac{VBP_{iRO}}{VBP_{RO}}\right)}, \quad (1)$$

where: it is the gross value of the production of activity i, in the case of cattle, in municipality j;VBP_{ij}

VBP_j it is the total gross value of agricultural production;

VBP_{iRO} it is the gross value of cattle production in Rondônia;

VBP_{RO} is the gross value of agricultural production in Rondônia.

The variable V9 - Milked cows, was calculated by the ratio of the number of cows milked annually in relation to the number of establishments with cattle and the variable V17 - Milk production, was calculated by the ratio of the amount of cow's milk produced (Thousand liters) in relation to the number of agricultural establishments that produce cow's milk.

The technological index of agricultural establishments (ITEA) was calculated from the weighted average of the factors by the proportion of explanation of the total variance associated with each of them, adapted from Santana, 2007 and Santos *et.al*., 2017, according to Expression 9.

$$ITEA = \frac{\sum_{j=1}^{n} w_j * FP_{ij}}{\sum_{j=1}^{n} w_j} \quad (2)$$

where, ITEA is the index of the i-th municipality; is the proportion of variance explained by the j-th factor and is the value of the i-th standardized factorial score associated with the i-th municipality. The factorial score was standardized for the acquisition of positive values between and (Santos $W_j FP_{ij} 0100$*et.al*., 2017). The standardization of the scores and the calculation of the ITEA followed the parameters validated in previous studies in the area (Silva *et al*., 2026a). From the ITEA values, four technological levels were established:

i) ITEA ≥ 75 (high);
ii) 50 ≤ ITEA < 75 (medium);
iii) 25 ≤ ITEA < 50 (low);
iv) 0 < ITEA < 25 (very low).

The levels were defined in relation to the set of municipalities analyzed, thus, a municipality classified as high level does not imply agricultural establishments with high technological indexes, only that its level is higher in relation to the other municipalities in the sample.

3.2 DATA ANALYSIS

3.2.1 Descriptive Statistics

The data from the 2017 Census of Agriculture were initially analyzed through the procedures of descriptive statistical analysis, calculating the mean and the maximum and minimum values (Andrade; Ogliari, 2013).

3.2.2 Modeling

After the initial analyses, the Factor Analysis technique was applied to find the possible factors within the records of rural establishments in the state of Rondônia, using within the technique the resource of rotation of the factors to obtain the interpretability of each factor.

Factor analysis had its initial development based on the result of Charles Spearman's work, according to the factor analysis model, which establishes that:

$$X_i = a_{i1} F_1 + a_{i2} F_2 + \ldots + a_{im} F_m + e_i, \quad (3)$$

where:

X_i it is the ith test score with zero mean and unit variance;

a_{i1} a are loads of factors for the ith test;a_{im}

F_1 a $F_m$are $m$common uncorrelated factors, each with zero mean and unit variance;

e_i *It is* a specific factor only for the *i-th* test that is not correlated with any of the common factors and has a mean of zero.

With this model,

$$Var\ (X_i) = 1 = a_{i1}^2\ Var(F_1) + a_{i2}^2 Var(F_2) + \ldots + a_{im}^2\ Var\ (F_m) + Var(e_i)$$
$$= a_{i1}^2 + a_{i2}^2 + \cdots + a_{im}^2 + Var(e_i)\ , \quad (4)$$

where:

$a_{i1}^2 + a_{i2}^2 + \cdots + a_{im}^2$ they are called the commonality of (the part of their variance that is related to common factors), and $X_i Var(e_i)$it is called the specificity of X_i(the part of their variance that is not related to common factors) (Manly; Alberto, 2019).

It can also be shown that the correlation between and is $X_i X_j$

$$r_{ij} = a_{i1}\, a_{j1} + a_{12}\, a_{j2} + \ldots + a_{im}\, a_{jm.} \quad (5)$$

Therefore, two test scores can only be highly correlated if they have high loads on the same factors. Moreover, since commonality cannot exceed one, it is necessary that $-1 \leq a_{ij} \leq +1$(Manly; Alberto, 2019).

The criteria described in Mingoti (2005) were used to estimate the number of m factors. The choice of the number of factors is essential and aims to replace the set of original variables with factors, and it is natural that the number of factors is lower than the number of variables analyzed (Corrar *et al*., 2017). Thus, instead of working with 100% of the total variability of the data, only a total portion of the data explained by factors was analyzed.

To verify the rotation of these factors, the *Varimax method was applied*, which, according to Fávero *et al*. (2021) is the most widely used method and seeks to minimize the number of variables that have high loads on a factor, simplifying the interpretation of factors. Next, the Bartlett Sphericity Test, the Sample Adequacy Measure (MAA) and the Kaiser-Meyer-Olkin (KMO) tests were applied (Mingoti, 2005; Hair *et al*. 2009).

3.2.2.1 Bartlett Sphericity Test

Bartlett's sphericity test allows verifying, for this number of degrees of freedom and a given level of significance, whether the value of the statistic is greater than the critical value of the statistic.$\mathcal{X}^2_{Bartlett}$

We can affirm that Pearson's correlations between pairs of variables are statistically different from 0 and for this reason factors can be extracted from the original variables, thus being the appropriate analysis according to Fávero; Belfiore, (2021) is given by:

$$\mathcal{X}^2_{Bartlett} = -\left[(n-1)\left(\frac{2k+5}{6}\right)\right]\ln|D|, \quad (6)$$

with degree of freedom, where: $\frac{k.(k-1)}{2}$

n is the sample size;

k is the number of variables;

$|D|$ is the determinant of the correlation matrix, which has a chi-square distribution with degrees of freedom.

3.2.2.2 Sample Adequacy Measure (MAA)

The Sample Adequacy Measure (MAA) serves to calculate the degree of intercorrelation between the variables and the adequacy of the factor analysis (Hair *et al*., 2009), a (MAA) is considered acceptable and essential when .$MAA > 0{,}5$

If the MAA result shows a low value, we can detect the variables responsible for this effect. The MAA analysis is comparable to the KMO, in which the variables found within the unacceptable domain must be excluded in order to later apply the factor analysis, that is, it is considered Good, acceptable and unacceptable to proceed with the factor analysis without the removal of this variable (Hair $MAA \geq 0{,}75 0{,}5 \leq MAA < 0{,}75 MAA < 0{,}5$*et al*. 2009).

3.2.2.3 Kaiser-Meyer-Olkin Test (KMO)

The KMO measure evaluates the adequacy of the factor analysis, being calculated as described in Fávero and Belfiore, (2021) by:

$$KMO = \frac{\sum_{l=1}^{k}\sum_{c=1}^{k}\rho_{lc}^2}{\sum_{l=1}^{K}\sum_{c=1}^{k}\rho_{lc}^2 + \sum_{l=1}^{K}\sum_{c=1}^{k}\varphi_{lc}^2}, l \neq c, \quad (7)$$

where:

l and represent, respectively, the rows and columns of the correlation matrix $c\ \rho,$ the terms represent the partial correlation coefficients between two variables. While Pearson's correlation coefficients are also called zero-order correlation coefficients, φ partial correlation coefficients$\varphi\ \rho$ are also known as higher-order correlation coefficients (Fávero; Belfiore, 2021).

With variation between and , where is the correlation coefficient between variables and the partial correlation coefficient, in which, the lower the partial correlations, the closer the index is to 1 (Johnson; Wichern, 2002). In the literature on the interpretation of KMO indices, authors report that it is considered Good, acceptable and unacceptable to perform factor analysis on the data sample (Kaiser, 1958; Castro and Mota, 2022). This index compares the amplitude of the correlations observed between the variables with the dimension of the partial correlations, since the latter shows the degree of relationship between two variables by suppressing the influence of the others. $01{R^2}_{ij}x_{ij}KMO \geq 0{,}750{,}5 \leq KMO < 0{,}75KMO < 0{,}5$

The values of the KMO index that indicate that Factor Analysis is appropriate vary from author to author. For Hair *et al*. (2009) are acceptable values between 0.5 and 1.0, so below 0.5 indicates that factor analysis is unacceptable.

3.2.2.4 Factor Retention

The Kaiser-Guttman factorial retention criterion, described in (Damásio, 2012), was used. This factor retention criterion is one of the most widely used, also called the eigenvalue criterion greater than 1. To verify the reliability of the factor analysis. This criterion proposes a quick, concrete measurement of the number of factors to be retained and each retained factor has an eigenvalue that refers to the total variance explained by this factor.

3.2.2.5 Hierarchical methods and *k-means algorithm*

The hierarchical cluster analysis methods were used for the elaboration of the dendrogram and the *k-means algorithm*. In k-means-generated partitioning, each object refers to the centroid group closest to it. The standard *k-means* algorithm acts through an iterative realignment technique as follows: the initial centroids of the groups are formed randomly or by randomly selecting certain objects from the database itself. Once this step is completed, the distance between the objects of the base and each centroid is calculated, which can generate a repositioning of the centroids and a new allocation of objects to groups (Castro; Ferrari, 2016).k

The data were analyzed using the following software: R *Development Core Team* (2024) and Jamovi (2024).

4 RESULTS AND DISCUSSIONS

4.1 GENERAL DESCRIPTIVE ANALYSIS OF THE STATE OF RONDÔNIA

The Agricultural Census carried out by the Brazilian Institute of Geography and Statistics (IBGE) in 2017 made it possible to assess the technological level of rural properties in the state of Rondônia. This characterization is relevant to understand the particularities of these agricultural establishments. The descriptive statistics of the 20 variables related to rural properties through qualitative modeling are described below.

For V1 - Pasture area, the agricultural establishments in the state had an average of 69%, with Vilhena being the municipality with the smallest pasture area, 36%, and Teixeirópolis with the largest pasture area, 90%. In item V11 - Soil correction, the average achieved was 11% and with the highest value was the municipality of Vilhena with and the lowest value with 3% was Governor Jorge Teixeira.

According to Rosa Neto (2021), Vilhena's GDP stands out in services, corresponding to 42.3% of the state total, since this municipality has agricultural production as its main economic aptitude, this value consumed in services is strongly related to agriculture, as is the case with soybeans and corn, as it encompasses the commercialization of machinery, implements, inputs and other related items. As for Teixeirópolis, having a large area of pastures, it is justified, as it is a dairy municipality with a daily production of 38 thousand liters (Emater-RO, 2017), with the main economic activity being cattle raising and dairy production.

Checking the variable number of milked cows - V9, the average was 7.83, with Ouro Preto do Oeste presenting the maximum value in relation to this variable 15.21, confirming that the municipality is a large dairy producer (IDARON, 2025). Pimenta Bueno, on the other hand, had the lowest value of 2.59 milked cows according to the 2017 census (IBGE, 2021). For the variable V17 - Milk production, the average value of production in the state was 22.63 thousand liters. The municipality of Ouro Preto do Oeste had the highest milk production, with 30.75 thousand liters and Nova Brasilândia D'Oeste the lowest with 14.29 thousand liters. In 2023, Rondônia saw a significant increase in milk production, consolidating itself as a leader in the North region (IBGE, 2024).

Analyzing the variable V6 - Electricity, the average value was 91%, where Teixeirópolis reached the highest volume 98% and Primavera de Rondônia the lowest 56%. When item V7 - Livestock Locational Quotient was evaluated, the average was 1.03, with emphasis on the municipality of Parecis with 1.31 and a low QL for Cabixi 0.41. The Locational Quotient according to Haddad (1989) and Santana (2007) is a measure frequently used in regional economic studies to assess whether a municipality has specialization in a specific activity or sector.

As for the variable Proportion of establishments with livestock in relation to the total of agricultural establishments in percentage, there was an average value for the state of RO of 93.27% in this item the municipality with the highest percentage of properties focused on livestock was Governador Jorge Teixeira, reaching 99.47% of the properties, while the municipality with the lowest livestock activity was Guajará-Mirim, reaching 64.95%. In theme V12 - Animal nutrition, the average achieved was 43% and the highest and lowest values were the municipalities of Pimenteiras do Oeste and Machadinho D'Oeste with 76% and 16%, respectively. In the use of mineral salt - V13, the average was 85%, with higher and lower values for the municipalities of Nova Mamoré, 96% and Vilhena, 54%.

For component V2 - Disease control, the average value was 89%, where the municipalities with the highest and lowest values were Parecis and Chupinguaia with 99% and 66%, respectively. In item V3 - Crops, the municipalities highlighted were Cerejeiras and Parecis with 34% and 0% respectively. In relation to Soil Tillage - V4, an average of 28% was verified, with maximum values of 73% for Primavera de Rondônia and minimum of 5% for Theobroma. On the other hand, the variable V8 - Water resources reached an average of 80% in the state, and Theobroma due to its fertile soils, concatenated to favorable climatic conditions and the abundance of river resources presented the highest value (94%), while Alto Alegre do Parecis the lowest value 47% in relation to the availability of this variable. According to the State Secretariat for Environmental Development (Sedam), Rondônia has increased the area dedicated to fish farming and currently has about 16 thousand hectares of water mirror.

Observing the variable V15 - Fertilization, an average of 17% was found for the state. Alto Alegre do Parecis with a maximum value of 61% and Governador Jorge Teixeira with a minimum value of 3% regarding fertilization in these municipalities. Regarding the variable V16 - Irrigation, the average reached was 9%. Nova Brasilândia D'Oeste 37% had the highest use of this resource, on the other hand, Pimenta Bueno obtained the lowest value of and 1% compared to the other municipalities.

The variable V10 - Trade of production obtained an average of 90%. Being the municipality of São Felipe do Oeste with the highest 100% commercialization of production in rural establishments and the lowest value for Chupinguaia 53%. In relation to the Receipt of Technical Guidance -V14, the average verified was 22%. The municipality of Pimenteiras 57% received the highest amount of guidance according to the census, while Campo Novo de Rondônia received the lowest technical guidance.

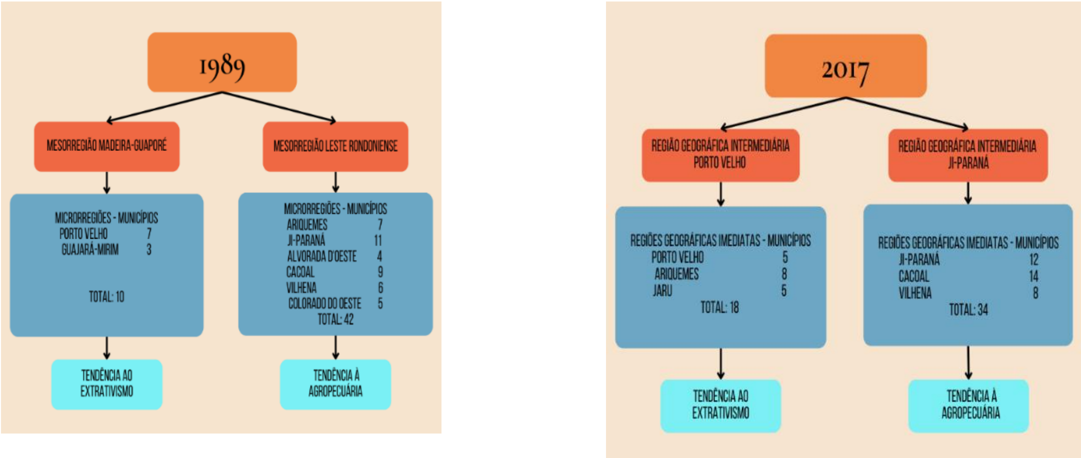
As a result of technological modernity, an average of 30% was observed for the variable Internet access - V18. The municipality of São Felipe do Oeste reached 54%, being considered the highest use and access to this technology, while Candeias do Jamari reached 11%, the lowest value observed. For variable V19 - Tractors and Implements, the average use in Rondônia was 16%, with Pimenteiras do Oeste with 76% and Urupá with 2%, the municipalities with the highest and lowest values, respectively. Regarding the possession of E-mail - V20, rural properties registered an average of 4%, a very low average value in line with the importance of using new technologies in the current scenario. The municipality of Pimenteiras do Oeste 15% was the one that most used this resource, while Vale do Anari presented a minimum value of 1% for the use of E-mail.

4.2 DESCRIPTIVE ANALYSIS BY INTERMEDIATE REGIONS OF THE STATE OF RONDÔNIA

The mesoregions and microregions of Brazil have constituted the regional geographic division of the country in force since 1989, according to the composition prepared by the Brazilian Institute of Geography and Statistics (IBGE). This division was replaced by the new regional division in 2017 (IBGE, 2017). As mentioned by Cavalcante (2011), in 1989, the State of Rondônia had mesoregions with extractive and agricultural characteristics (Figure 1). Today, these regions are known as intermediate and immediate regions and have undergone a slight change, with a decrease in extractivism and a small growth in the agricultural sector. The central part of the state has Ji-Paraná as its second largest city, while the southern cone stands out for its promising agricultural dominance.

Figure 1

Institutional changes in the State of Rondônia according to information from the IBGE. (a) Geographical division of 1989. b) Geographical breakdown of 2017



a) b)

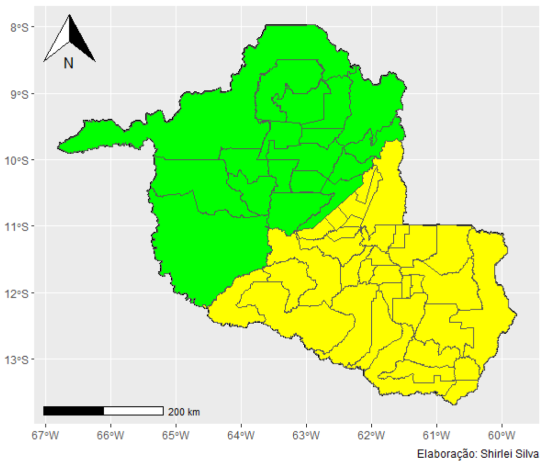
Source: Adapted from Cavalcante (2011).

The state of Rondônia is composed of 52 municipalities, grouped into two intermediate geographic regions: Porto Velho; and Ji-Paraná. These two regions were subdivided, each of them into three geographic regions immediate to the main municipalities belonging to them.

The cartographic representation of the two main regions of the state of Rondônia can be seen in Figure 2, in this cartogram it is also verified the subdivision of the state into its 52 municipalities.

Figure 2

State of Rondônia subdivided into two intermediate geographic regions: Porto Velho in green and Ji-Paraná in yellow



Source: Prepared by the authors (2026).

4.2.1 Intermediate Geographic Regions

The intermediate geographic region of Porto Velho houses 18 municipalities and that of Ji-Paraná 34. To perform the analyses, the intermediate geographic regions were classified by separating them into two colors for better visualization and characterization of the descriptive statistics. The municipalities housed in the intermediate geographic region of Porto Velho in green (Figure 2) are: Alto Paraíso, Ariquemes, Buritis, Cacaulândia, Campo Novo de Rondônia, Candeias do Jamari, Cujubim, Governador Jorge Teixeira, Guajará-Mirim, Itapuã do Oeste, Jaru, Machadinho D'Oeste, Monte Negro, Nova Mamoré, Porto Velho, Rio Crespo, Theobroma and Vale do Anari.

The intermediate region of Porto Velho, according to Table 2, has an average of 68% of pasture area -V1 in relation to the establishments in Rondônia, with Porto Velho being the municipality with the smallest pasture area, with 45% and Jaru with the largest pasture area 88%. The variable V2 - Disease control had an average of 89%, where the municipalities with the highest and lowest values were Nova Mamoré and Porto Velho with 96% and 77%, respectively.

In item V3 - Crops, with an average of 5%, the municipalities highlighted were Alto Paraíso and Cacaulândia, with 12% and 2%. In item V4 - Soil preparation, an average of 19% was reached, with a maximum of 41% for Candeias do Jamari and a minimum of 5% for Itapuã do Oeste. In V5 - Livestock, the average found was 93% and the municipalities were Governador Jorge Teixeira with 99% and with 65% for Guajará-Mirim.

Table 2

Average, maximum and minimum values observed for each variable of the agricultural establishments of Rondônia in the Intermediate Geographic Region of Porto Velho - RGIPV in data obtained from the agricultural census - IBGE 2017

		Municipalities	
Variables	**Average**	**With the highest average**	**With lower average**
V1- Pasture Areas	68%	88% -Jaru	45% - Porto Velho
V2- Disease control	89%	96% - Nova Mamoré	77% - Porto Velho
V3- Crops	5%	12% - Alto Paraíso	2% - Cocoa
V4- Soil preparation	19%	41% - Candeias do Jamari	5% - Itapuã do Oeste
V5- Livestock	93%	99% - Governor Jorge Teixeira	65% - Guajará-Mirim
V6- Electric power	90%	98% - Governor Jorge Teixeira	68% - Guajará - Mirim
V7- QL	1,05	1.28 – Nova Mamoré	0.60 – Cujubim
V8- Water resources	81%	94% - Theobroma	50% - Guajará- Mirim
V9-Milked cows	8,29	14.42 – Governor Jorge Teixeira	4.08 – Alto Paraíso
V10 - Production trade	91%	99% - Governor Jorge Teixeira	82% - Cocoa
V11- Soil Correction	9%	22% - Itapuã do Oeste	3% - Governor Jorge Teixeira

V12- Animal Nutrition	43%	67% - Cocoa	16% - Machadinho do Oeste
V13- Mineral salt	85%	96% - Nova Mamoré	69% - Porto Velho
V14- Technical guidance	19%	44% - Guajará-Mirim	6% - Campo Novo de Rondônia
V15- Fertilization	10%	18% - Rio Crespo	3% - Governor Jorge Teixeira
V16- Irrigation	4%	10% - Candeias do Jamari	1% - Cocoa
V17- Milk production	23,62	30.66 – Nova Mamoré	17.91 – Buritis
V18- Internet	21%	39% - Nova Mamoré	11% - Candeias do Jamari
V19- Tractors and implements	13%	33% - Rio Crespo	5% - Governor Jorge Teixeira
V20- Email	2%	7% - Candeias do Jamari	1% - Anari Valley

QL = Livestock locational quotient, V9 = Head/Establishments with cattle, V17 = Milk production in Thousand liters.
Source: Prepared by the authors (2026).

For the variable V6 - Electricity, the average value reached was 90%, where Governador Jorge Teixeira obtained 98%, while Guajará-Mirim presented a minimum value of 68%. However, for item V7 - Locational quotient, the average was 1.05, with highlights for the municipalities of Nova Mamoré with 1.28 and 0.60 for Cujubim. Now, in the variable V8 - Water resources, the average was 81% and highlights for Theobroma with 94% and the lowest value for Guajará-Mirim with 50%. In terms of the number of V9 - Cows milked annually, the average was 8.29, and the municipality of Governador Jorge Teixeira reached the highest value in relation to this variable: 14.42, on the other hand, Alto Paraíso had the lowest proportion of the number of cows milked during the year, with a value of 4.08.

The variable V10 - Production trade had an average of 91% and the municipalities with the highest value 99% and the lowest value 82% were Governador Jorge Teixeira and Cacaulândia, respectively. In the variable V11 - Soil correction, the average was 9% and values higher than 22% and lower than 3% were in the respective municipalities of Itapuã do Oeste and Governador Jorge Teixeira. For the variable V12 - Animal nutrition, the average measured was 43% and its highest and lowest values were in the municipalities of Cacaulândia and Machadinho do Oeste, with their respective values of 67% and 16%. In the use of mineral salt - V13, the average obtained was 85% and the municipalities with the highest and lowest values were Nova Mamoré with 96% and Porto Velho with 69%.

As for the municipality of Porto Velho, the items that contributed most to the GDP were services and industry, with a combined share of 73.4%. Agriculture had a share of only 3.6% in the municipality's GDP (Neto, Araujo and Silva, 2022), thus it is understood that the low agricultural participation in 2017 reflects the low use of mineral salt in agricultural establishments in Porto Velho.

In terms of Technical Guidance - V14, the average was 19% and the corresponding municipalities with the highest value of 44% was Guajará-Mirim and with the lowest value of

6% was Campo Novo de Rondônia. The variables V15 - Fertilization with an average of 10% and V16 - Irrigation with an average of 4%, denote in their results that agriculture in Rondônia is still in its infancy, however, in vigorous development, as it currently represents an expansion of 7.7% of the planted area, with an estimated production of 4.1 million tons, 8.7% higher than that of the last harvest.

The average productivity is estimated at four thousand kilograms per hectare, 0.9% higher than that obtained in the 2022/2023 harvest (EMBRAPA RONDÔNIA, 2024), with the municipalities with the highest value Rio Crespo 18% and the lowest Governador Jorge Teixeira 3% in fertilization and Candeias do Jamari with 10% and Cacaulândia with 1% for variable irrigation. In V17 - Milk production, the municipalities corresponding to the highest and lowest values were Nova Mamoré with 30.66 thousand liters and Buritis with 17.91 thousand liters respectively and presented an average production of 23.62 thousand liters.

Regarding the variable Internet access - V18, the average was 21%, with a value higher than 39% for Nova Mamoré and a lower value of 11% for Candeias do Jamari. In relation to the variable V19 - Tractors and agricultural implements reached an average of 13% and the municipalities with the highest value of 33% in Rio Crespo and the lowest value of 5% in Governador Jorge Teixeira. For variable V20 - E-mail, the average was 2%, with the highest value for Candeias do Jamari with 7% and the lowest in Vale do Anari with 1%.

The municipalities of the intermediate geographic region of Ji-Paraná in yellow (Figure 2) are: Alta Floresta D'Oeste, Alto Alegre do Parecis, Alvorada D'Oeste, Cabixi, Cacoal, Castanheiras, Cerejeiras, Chupinguaia, Colorado D'Oeste, Corumbiara, Costa marques, Espigão D'Oeste, Ji-Paraná, Ministro Andreazza, Mirante da Serra, Nova Brasilândia D'Oeste, Nova União, Novo Horizonte do Oeste, Ouro Preto do Oeste, Parecis, Pimenta Bueno, Pimenteiras do Oeste, Presidente Médici, Primavera de Rondônia, Rolim de Moura, Santa Luzia do Oeste, São Francisco do Guaporé, São Miguel do Guaporé, Seringueiras, Teixeirópolis, Urupá, Vale do Paraíso and Vilhena.

The intermediate region of Ji-Paraná, as shown in Table 3, presented an average of 70% of pasture area - V1, in the establishments of Rondônia, with Vilhena being the municipality with the smallest area of pastures, with 36% and Teixeirópolis with the largest area of pastures 90%. The variable V2 - Disease control had an average of 90%, where the municipalities with the highest and lowest values were Parecis and Chupinguaia with 99% and 66%, respectively. In item V3 - Crops, with an average of 9%, the municipalities highlighted were Cerejeiras, with 34% and Parecis, with 0%. For variable V4 - Soil tillage, the average observed was 32%, with maximum values of 73% for Primavera de Rondônia and minimum of 9% for Pimenta Bueno. For V5 - Livestock, the average found was 94%. The municipality of Vale do Paraíso reached a value of 99% for the Proportion of establishments with livestock in relation to the total of agricultural establishments, while Vale do Paraíso obtained 86%, being considered the lowest value in the State.

Table 3

Average, maximum and minimum values observed for each variable of the agricultural establishments of Rondônia in the Intermediate Geographic Region of Ji-Paraná - RGIJP in data obtained from the agricultural census - IBGE 2017

Variables	Average	Municipalities With the highest average	With lower average
V1- Pasture Areas	70%	90% -Teixeirópolis	36% - Vilhena
V2- Disease control	90%	99% - Parecis	66% - Chupinguaia
V3- Crops	9%	34% - Cherry Trees	0% - Parecis
V4- Soil preparation	32%	73% - Rondônia Spring	9% - Bueno Pepper
V5- Livestock	94%	99% - Paradise Valley	86% - Nova Brasilândia D'Oeste
V6- Electric power	91%	98% - Teixeirópolis	56% - Rondônia Spring
V7- QL	1,01	1.31 – Parecis	0.41 – Cabixi
V8- Water resources	79%	94% - Parecis	47% - Alto Alegre dos Parecis
V9-Milked cows	7,58	15.21 - Ouro Preto do Oeste	2.59- Bueno Pepper
V10 - Production trade	90%	100% - São Felipe do oeste	53% - Chupinguaia
V11- Soil Correction	12%	31% - Vilhena	4% - Urupá
V12- Animal Nutrition	44%	76% - Vilhena	20% - Brazil nut trees
V13- Mineral salt	85%	95% - Parecis	54% - Vilhena
V14- Technical guidance	24%	57% - Pimenteiras do Oeste	9% - Rubber trees
V15- Fertilization	21%	61% - Alto Alegre dos Parecis	5% - Urupá
V16- Irrigation	11%	37% - Nova Brasilândia D'Oeste	1% - Corumbiara
V17- Milk production	22,10	30,75 - Ouro Preto do Oeste	14,29 - Nova Brasilândia D'Oeste
V18- Internet	34%	54% - São Felipe do Oeste	20% - Chupinguaia
V19- Tractors and implements	17%	76% - Pimenteiras do Oeste	2% - Urupá
V20- Email	5%	15% - Pimenteiras do Oeste	1% - Parecis

QL = Livestock locational quotient, V9 = Head/Establishments with cattle, V17 = Milk production in Thousand liters.
Source: Prepared by the authors (2026).

Analyzing the variable V6 - Electricity, it was found that the average was 91%, where Teixeirópolis had the highest volume with 98% and Primavera de Rondônia 56% the lowest. Regarding item V7 - Livestock locational quotient, the average was 1.01, with highlights for the municipalities of Parecis with 1.31 and the municipality of Cabixi with 41%. Now for variable V8 - Water resources, the average observed was 79%, with the municipality of Parecis having the highest availability of this resource in the state with 94% and Alto Alegre do Parecis the lowest with 47%.

In terms of the quantity of V9 - Milked cows, the average was 7.58, with the municipality of Ouro Preto do Oeste having the highest amount of this variable: 15.21, on the other hand, Pimenta Bueno obtained only 2.59. For variable V10 - Production trade, the average value obtained was 90% and the municipalities with the highest and lowest value were in São Felipe do Oeste 100% and Chupinguaia 53%, respectively.

Studying the variable V11 - Soil correction, an average of 12% was observed. The municipality with the highest value was Vilhena 31%, which uses the highest soil correction in its establishments analyzed and the lowest use was in Urupá with 4%. In the variable - V12 Animal nutrition with an average of 44%, it can be seen that the municipality with a high value, a total of 76%, was Vilhena and a low Castanheiras 20%. For the use of mineral salt - V13, the average was 85% and the municipalities with the highest and lowest values were Parecis with 95% and Vilhena with 54%.

Having received Technical Guidance - V14 reached the general average of 24% and the municipalities with the highest value were Pimenteiras do Oeste 57% again and the lowest value Seringueiras 9%. In the use of fertilization -V15, the average was 21%, and the municipalities with the highest value 61% in Alto Alegre do Parecis and the lowest value 5% in Urupá. In the use of Irrigation - V16, the average value was 11% and the municipalities with the highest value 37% were perceived in Nova Brasilândia D'Oeste and with the lowest value 1% in Corumbiara. It is worth noting that the municipality of Pimenteiras do Oeste stood out with higher values in two more variables; V19 - Tractors and implements with 76% and E-mail records - V20, with a value of 15% compared to the other municipalities.

In item V17 - Milk production (thousand liters), the general average of the geographic region of Ji-Paraná was 22.10 and with a lower value of 14.29 it was for the municipality of Nova Brasilândia do Oeste and the highest value for Ouro Preto do Oeste with 30.75 thousand liters of milk production. For the variable Internet access - V18, the average was 34% and the municipality of Chupinguaia had the lowest result 20%, with the highest access for São Felipe do Oeste with 54%. In item V19 - Tractors and agricultural implements, the average value was 17% and Urupá was the municipality that showed the lowest quantities of these implements, 2%. In the E-mail -V20 record, the average and accesses are still low, with a result of 5% and the municipality of Parecis had the worst record with 1%.

After the data were treated with descriptive statistics, factor analysis was initiated by applying the univariate and multivariate normality tests. For the univariate normality test, the Shapiro-Wilk test (Degroot; Schervish, 2002; Lopes *et al.,* 2021, Castro; Mota, 2022) and verified by the test that the factorial model can be adjusted.

4.3 FACTOR ANALYSIS OF THE TECHNOLOGICAL LEVEL OF RURAL PROPERTIES IN THE STATE OF RONDÔNIA

The factor analysis was applied twice to the database of agricultural establishments in Rondônia, in view of the results, the estimation of the orthogonal factor model was analyzed by the principal component method (Castro; Mota, 2022). However, only the second factor analysis was interpreted due to the low indices generated by the KMO (*Kaiser-Meyer-Olkin*) and MAA (Sample Adequacy Measure) tests in the first analysis. Following the cut-off criterion in which MAA < 0.5 is unacceptable to proceed with the factor analysis, it was necessary to remove the following variables, PROCESSING FACILITY, CATTLE HERD, TELEPHONE, VEHICLES, STORAGE UNITS and ORGANIC PRODUCTION. After cutting the variables, the statistics of the Bartlett sphericity test , KMO test and MAA were checked again. The overall value of the MAA was 0.704 and the variables are shown in Table 4.

Table 4

Result of the Sample Adequacy Measure - MAA

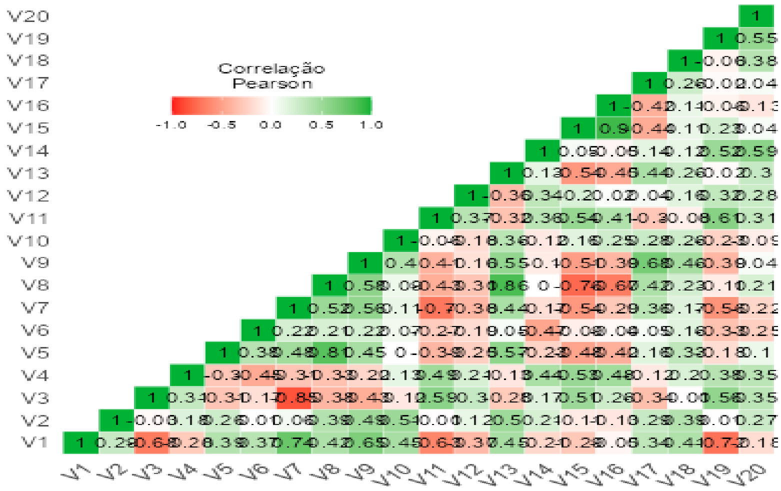
Variables	MAA	Variables	MAA
V1- Pasture Areas	0,783	V11- Soil Correction	0,734
V2- Disease control	0,638	V12- Animal Nutrition	0,595
V3- Farming	0,798	V13- Mineral salt	0,730
V4- Soil preparation	0,863	V14- Technical guidance	0,713
V5- Livestock	0,645	V15- Fertilization	0,689
V6- Electric power	0,730	V16- Irrigation	0,646
V7- QL	0,803	V17- Milk production	0,567
V8- Water resources	0.682	V18- Internet	0,675
V9-Milked cows	0,695	V19- Tractors and implements	0,629
V10 - Production trade	0,757	V20- Email	0,695

Source: Prepared by the authors (2026).

The new correlation matrix met the necessary assumptions to affirm that the data set is suitable for the use of the technique, as can be seen in Figure (3) of the numerical correlation matrix.

Figure 3

Graphical representation of Pearson's correlation matrix of data from agricultural establishments in Rondônia'



Source: Prepared by the authors (2026).

Pearson's correlation matrix is fundamental in factor analysis because it reveals the pattern of linear relationships between variables, indicating the direction and strength of these associations. High correlations suggest that the variables can be explained by the same underlying factor, while very low correlations indicate inadequacy for factor analysis, since the factors would not sufficiently explain the observed variables (Field, 2013).

As the objective of factor analysis is to reduce dimensionality, grouping correlated variables, Pearson's matrix serves as a basis to identify which of them move together. Methods such as Exploratory Factor Analysis (EFA) and Principal Component Analysis (PCA) use this matrix to extract factors that represent common variance. The reliability of the factors can be verified by the residual correlation matrix, in which low correlations indicate a good explanation of the data (Hair, 2009; Field, 2013).

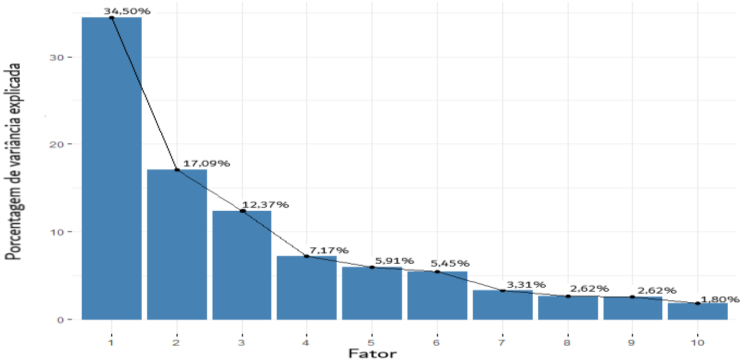
After checking the assumptions of minimum correlation between the variables, Bartlett test, KMO and MAA, exploratory factor analysis was initiated using the minimum residue and *varimax rotation method*. Rotation was applied to highlight the most relevant variables, increasing their charges (positive or negative) and reducing the less significant ones, bringing them closer to zero. The Bartlett test was significant at 1% probability, and the KMO test presented a value of 0.7921, indicating that the data sample is adequate for factor analysis.

According to the Kaiser-Guttman criterion, only the first 6 factors have eigenvalues greater than 1 in the confirmation of the number of adequate factors, the *screeplot* graph (Figure (4) was generated.

It is worth noting that determining the number of factors in a Factor Analysis (FA) is a crucial step, as it directly affects the interpretation and validity of the results (Hair, 2009). These six factors explain 82.50% of the total variability of the data.

Figure 4

Screeplot with proportional distribution of eigenvalues from the factor analysis of data from agricultural establishments in Rondônia



Source: Prepared by the authors (2026).

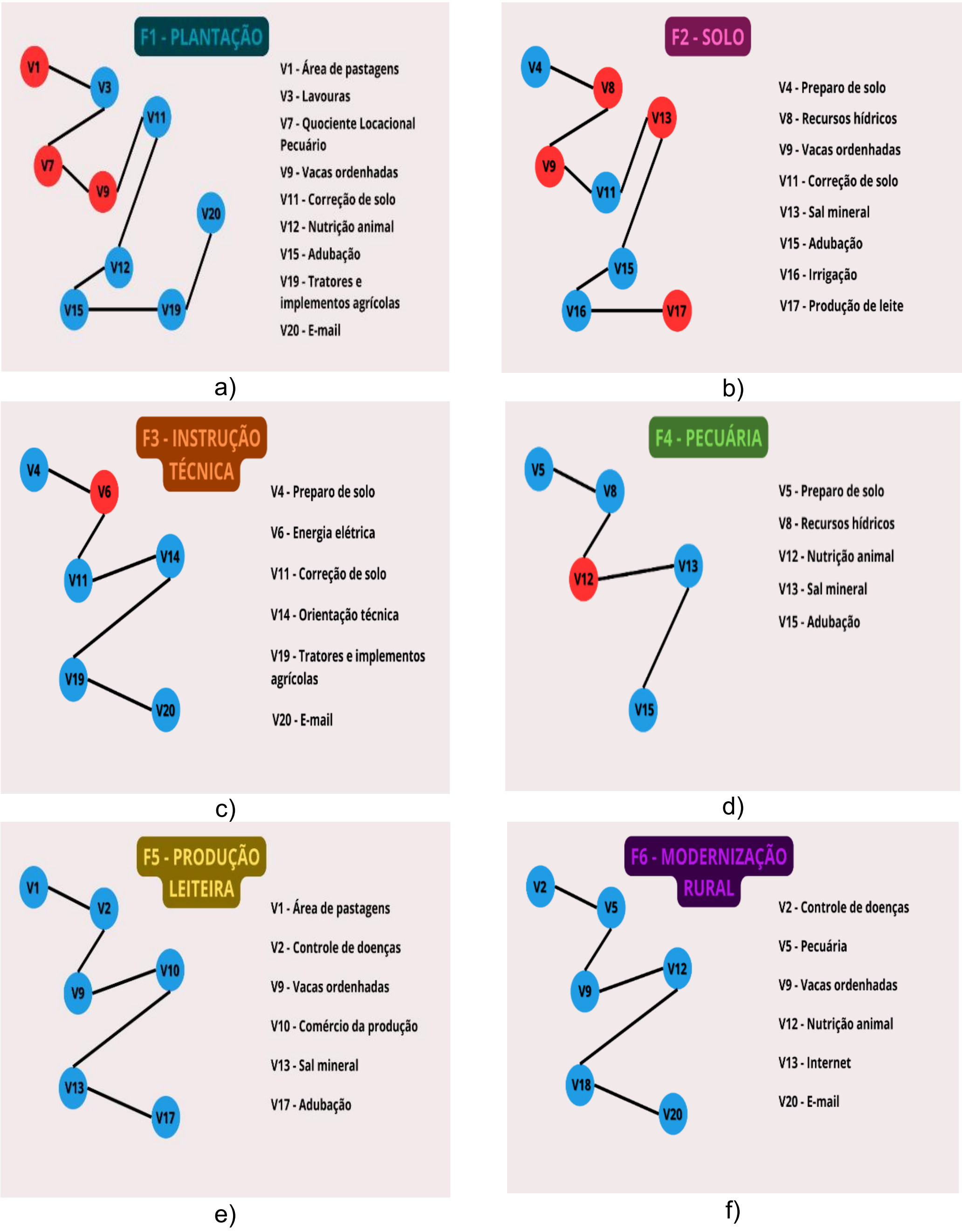
The distribution of variables in their respective factors in the study in question are 6 factors, namely: Factor 1 PLANTATION, Factor 2 SOIL, Factor 3 TECHNICAL INSTRUCTION, Factor 4 LIVESTOCK, Factor 5 MILK PRODUCTION and Factor 6 RURAL MODERNIZATION.

Analyzing the demonstrations of the distributions of factor loadings of the variables in their own factors, it is possible to notice positive and negative loadings that are represented in Figures (5) in red and blue respectively.

The factor loadings together with the commonality of each variable are presented in Table (5). Factor 1, because it has characteristics linked to the agricultural sector, was named PLANTATION (Figure 5a), which refers to the percentage of pasture area, crops, locational quotient, milked cows, soil correction, animal nutrition, irrigation, tractors and agricultural implements and e-mail. This factor tends to be a general factor with significantly high loads on these variables, explaining most of the variance.

Figure 5

Detail of the factors with their respective factor loadings. a) Factor 1 – Plantation. b) Factor 2 – Soil. c) Technical instruction. d) Livestock. e) Milk production. f) Rural modernization



Source: Prepared by the authors (2026).

Factor 2, because it has characteristics linked to the soil preparation sector, was denoted SOLO, attested to 17.09% of the total variability of the data (Figure 5b). Presenting technical characteristics, Factor 3 compiled the variables presented in Figure 5c) receiving the attribution of TECHNICAL INSTRUCTION, explained 12.37% of variance of the data.

With particularities in animal husbandry, factor 4 – LIVESTOCK, explained 7.17% of the total variance (Figure 5d). In Rondônia, the feeding of the herds occurs strictly based on pastures (natural and/or planted) that establish the main form of land occupation for livestock purposes. In the municipalities of Rondônia, according to our study, on average 69.30% of the total area of livestock farms is occupied by pastures.

Table 5

Factor loadings after orthogonal rotation and the respective communalities

Variables	Factor						Commonality
	1	2	3	4	5	6	
V1	-0,771				0,372		0,898
V2					0,598	0,303	0,535
V3	0,825						0,755
V4		0,463	0,568				0,616
V5				0,684		0,326	0,761
V6			-0,619				0,458
V7	-0,884						0,911
V8		-0,532		0,783			0,998
V9	-0,406	-0,425			0,545	0,359	0,809
V10					0,872		0,842
V11	0,627	0,320	0,332				0,636
V12	0,340			-0.419		0,345	0,487
V13		-0,321		0,745	0,450		0,926
V14			0,811				0,713
V15	0,335	0,851		-0,308			0,946
V16		0,937					0,948
V17		-0,511			0,433		0,565
V18						0,807	0,771
V19	0,668		0,516				0,734
V20	0,334		0,552			0,429	0,687

Source: Prepared by the authors (2026).

On the other hand, Factor 5, which has productive aspects, being categorized as MILK PRODUCTION, explained 5.91% of data variability and integrates the variables shown in Figure 5e). Among the 52 municipalities analyzed, it was found that 15.6% have more than 70% of their surface area occupied by pasture. These pastures are used by most rural properties, as only 4 out of 10 agricultural establishments use their areas with crops.

Comprising the technologies of mechanized milking, access to the internet with the use of e-mail, computing in tables and spreadsheets the livestock treatment of disease control and food record of the animals, Factor 6 with peculiarities of technological modernity, explained 5.45 of the variation of the data and was assigned RURAL MODERNIZATION (Figure 5f).

Specifically, in the results of the rotational factor analysis, factor 1 explains 34.50% of the total variance, followed by factors 2 and 3 that together explain 29.46% and 18.53% explained by the total of factors 4, 5 and 6 remaining, as shown in Table (6), with the exception of factor 1, the others explain progressively smaller portions of variance. These factors are based on the residual amount of variance. The objective of rotating the factorial matrix was to redistribute the variance from the first factors to the others, in order to make the interpretation simpler and more meaningful.

Explained variance indicates the proportion of total variability in the data that is illustrated by each factor and by the model as a whole (Lattin *et.al*., 2011). Through factor analysis and with the use of *varimax rotation*, the six factors that best represented the information of the agricultural establishments in Rondônia were characterized. Subsequently, the factor and standardized scores from 0 to 100 were calculated to compose the technological index of agricultural establishments (ITEA), the weighted average of the factors was used by the proportion of explanation of the total variance associated with each of the standardized factors (Santos *et al*., 2017). Thus, the standardized factor scores were processed in each of the six factors within the 52 municipalities. Based on the NETA values, the municipalities were classified into technological levels. They were classified only in two levels, medium (50 ≤ ITEA < 75) and low (25 ≤ ITEA < 50). No municipality with a high ITEA above 75 was verified and none was classified as very low (< 25).

Table 6

Explained variability of data from agricultural establishments in Rondônia

Factors	Eigenvalues	Variance explained (%)	Variance accumulated (%)
1 - Planting	6,9002	34,50%	34,50%
2 – Solo	3,4171	17,09%	51,59%
3 - Technical instruction	2,4749	12,37%	63,96%
4 - Livestock	1,4341	7,17%	71,13%
5 – Milk production	1,1828	5,91%	77,05%
6 – Rural modernization	1,0909	5,45%	82,50%

Source: Prepared by the authors (2026).

Pimenteiras do Oeste had the highest technological level with ITEA 70.45, followed by Cerejeiras 63.44, Alto Alegre do Parecis 58.68, Cabixi 57.01 and Nova Brasilândia do Oeste 51.01. The strong association between these indicators is due to the fact that they represent technologies with a higher level of adoption by regional producers in crop and pasture cultivation systems. In these municipalities, the cattle herd is concentrated in family farming establishments. It is composed of production units with an average size of 36.91 hectares, with a predominance of temporary and permanent crop areas (44.35%) and pastures occupying an average of 16.17% of the total area of the establishments. It is a system that combines agriculture and livestock as a strategy for income diversification in the production unit, involving the production of milk for self-consumption and the sale of the surplus to dairy products.

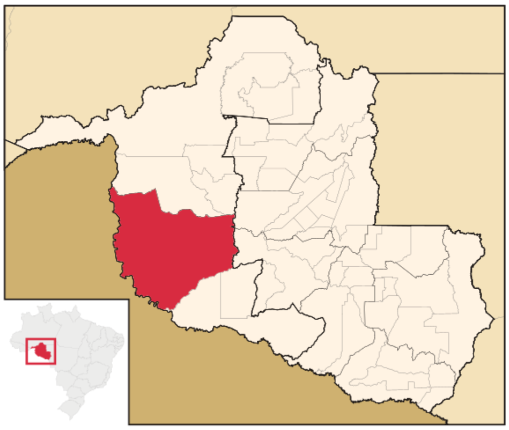
It is worth mentioning that Pimenteiras do Oeste (Figure 6a) is the first municipality in terms of GDP per capita in the state with a value of R$ 115,753.94. In comparison with other municipalities, it occupies the position of 149 among the 5570 municipalities in the country. The percentage of foreign revenues in 2023 was 90.68%, which placed it in fifth position among the 52 municipalities in the State of Rondônia, with an area of 6,014.733 km², which places it in twelfth position in the State. Located on the banks of the Guaporé River, it was created on December 27, 1995 by State Law No. 645. In a territorial division dated 1988, the district of Pimenteiras was in the municipality of Cerejeiras. Thus, it remained in a territorial division dating from 1993, dismembered from Cerejeiras and Cabixi in 1995, changing its name to Pimenteiras do Oeste (IBGE, 2021).

The 304 agricultural establishments analyzed occupy 207,432 hectares and generate work for 1,281 people. In total, they have 257 tractors, 91 seeders, 78 harvesters and 34 limestone fertilizers/distributors, representing 151.32% of machines in relation to the number of properties (IBGE, 2021).

Figure 6

Details of the Municipalities of Rondônia: a) Pimenteiras do Oeste b) Guajará-Mirim

a)



b)

Source: IBGE (2021).

However, 47 municipalities are categorized with low ITEA. Guajará-Mirim (Figure 6b) had the lowest technological index of 28.55. Located on the border with Bolivia, divided by the Mamoré River, it has a vast green area, composed practically of native vegetation and natural reserves, it has a GDP per capita of R$ 22,462.79. The municipality has 602 agricultural establishments, which occupy 70,487 hectares and employ 2,780 people, but has only 91 tractors, equivalent to 15.12% of the properties and practically no other agricultural implements, which contributed to its low technological performance in the ITEA

The indicators make visible two important aspects regarding local rural properties. The first is the hegemony of extensive grazing and agricultural cultivation systems, the results of which are the average stocking rate of pastures of only 1.58 AU/ha in 2012 with a projection of 1.95 AU/ha in 2031 and that of agricultural cultivation with a projection of an occupation of 620 thousand hectares of planted area, data from Idaron and the Association of Soybean and Corn Producers of Rondônia (Aprosoja) (Idaron, 2024). The second aspect is of an environmental nature, as the need for environmental regularization is evident, in order to comply with the provisions of Federal Decree No. 11,015, which addresses the environmental regularization of rural establishments (Brasil, 2022).

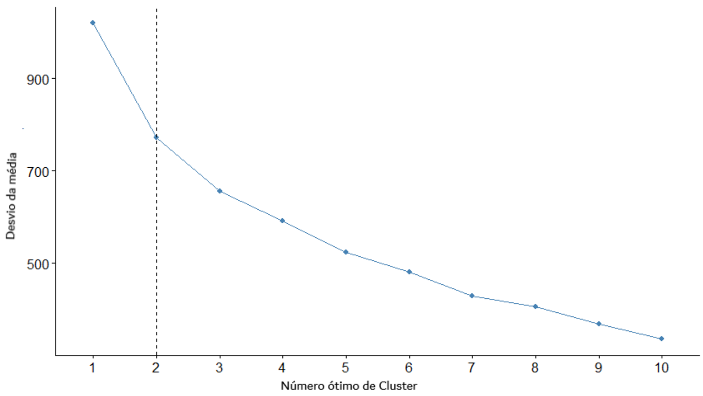
The production systems of rural establishments in Rondônia consist of a heterogeneous technology, this sign is due to the fact that at the same time we find properties with production strategies with very different levels of technology adherence. Among the 52 municipalities studied, 5 were classified as having a medium technological index. All municipalities with the highest levels belong to the intermediate geographic region of Ji-Paraná, composed of 34 municipalities, reaching 14.71% of representativeness with medium level in the total of municipalities in the state.

4.4 CLUSTER ANALYSIS OF AGRICULTURAL ESTABLISHMENTS IN THE STATE OF RONDÔNIA

As for the number of clusters, the solution with two *clusters* proved to be better in all processing. This statement is based on the *Mclust* command () that graphically presents the optimal cluster number (Figure 7) and also validated by means of the *Elbow* method , with the demonstration of the position of a curve (elbow) in the graph, considered as an indicator of the appropriate number of *clusters*. Checking the *screeplot* we can observe a deceleration in the slope, so the ideal number of clusters according to the *Elbow* method is 2 (two).

Figure 7

Detail of the optimal number of clusters through the Scree plot



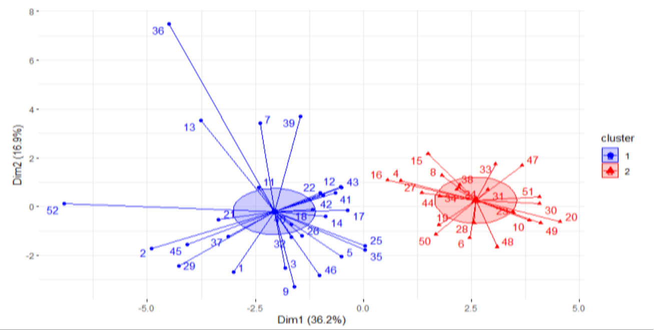
Source: Prepared by the authors (2026).

The cluster analysis indicates that the division into two clusters represents well the differences between the municipalities, with cluster 2 showing greater distinction in relation to the others. Figure 8 confirms this separation, demonstrating a consistent formation of the groups based on Euclidean distance.

In cluster 1, the *K-means algorithm* grouped 29 municipalities, including Alta Floresta D'Oeste, Alto Alegre do Parecis, Ariquemes, Cabixi, Cacoal, Cerejeiras, Guajará-Mirim, Machadinho D'Oeste, Nova Brasilândia D'Oeste, Pimenteiras do Oeste, Porto Velho, Rolim de Moura, Vilhena and others, as illustrated in Figures 8 and 9a.

Figure 8

Detail of the frequency of municipalities in each cluster

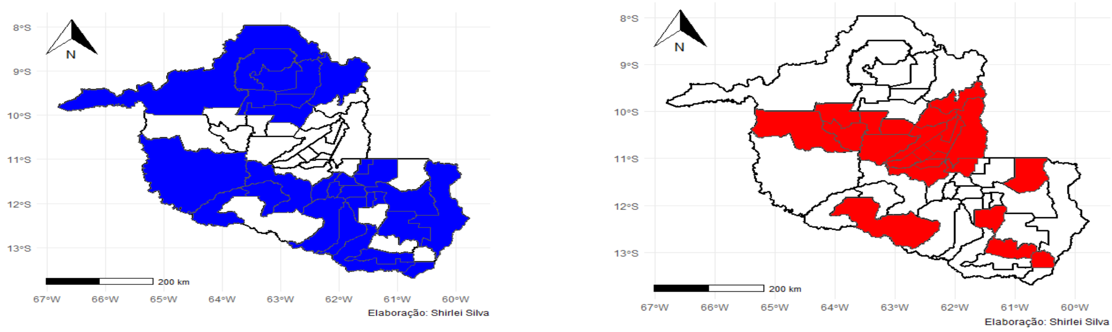


Source: Prepared by the authors (2026).

However, *cluster* 2 allocated 23 municipalities: Alvorada do Oeste (4), Buritis (6), Cacaulândia (8), Campo Novo de Rondônia (10), Colorado D'Oeste (15), Corumbiara (16), Espigão D'Oeste (19), Governador Jorge Teixeira (20), Jaru (23), Ji-Paraná (24), Mirante da Serra (27), Monte Negro (28), Nova Mamoré (30), Nova União (31), Ouro Preto do Oeste (33), Parecis (34), Presidente Médice (38), São Franciso do Guaporé (44), Teixeirópolis (47), Theobroma (48), Urupá (49), Vale do Anari (50) and Vale do Paraíso (51), as shown in Figures (8 and 9b).

Figure 9

Cluster positioning detail a) Spatial image of the municipalities belonging to cluster 1.b) Spatial image of the municipalities belonging to cluster 2



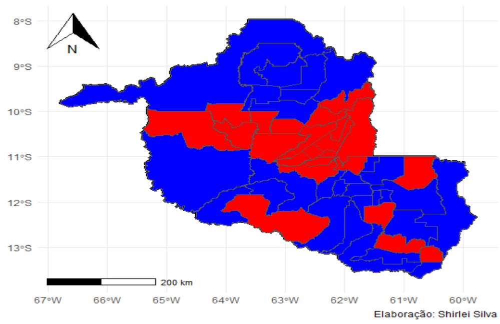
a) b)

Source: Prepared by the authors (2026).

We can observe through Figure (10) that *cluster* 2 was concentrated in one location of the state practically covering the central region, with only 5 dispersed municipalities, but maintaining the similarities of the other 18, however *cluster* 1 with extractive characteristics was gathered at the extremities of the state. This analysis was carried out in order to make a survey on some important characteristics of the municipalities of Rondônia and to verify their location in relation to the classification of technological levels.

Figure 10

Spatial image of the subdivision of Rondônia into 2 clusters

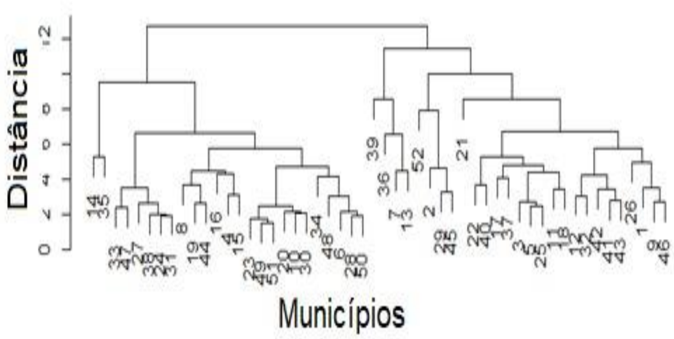


Source: Silva *et al.*(2026).

The measure of dissimilarity used was the Euclidean distance, and the complete linkage method was used to compose the clusters . The cut made in the axis of the dissimilarity of the dendrogram was at height 1.5, which demonstrated the composition of 2 probable groups and based on the dendrogram observed in Figure (11), it was verified, through the agglomerative grouping with complete linkage, considering the dissimilarity between the closest pair of objects, although the complete linkage tends to produce convenient and homogeneous groupings, these are not necessarily taken by the natural modality of the data. The complete linkage can be highly sensitive to discrepancy in the data (Lattin *et.al.*, 2011). Considering 27 municipalities with a representation of 51.92% of the total of 52 municipalities for cluster 1 obtained by hierarchical analysis. In the second Cluster, 25 municipalities were indicated, with a representativeness of 48.08% of the total, showing a small change after the use of a hierarchical method of grouping.

Figure 11

Rondônia dendrogram of 2 clusters



Source: Prepared by the authors (2026).

The 5 municipalities that presented the highest technological level are distributed as follows, Pimenteiras do Oeste, Cerejeiras, Alto Alegre dos Parecis, Cabixi and Nova Brasilândia do Oeste, are located in cluster 1, using the K-means *Algorithm* and hierarchical grouping method. Thus, it is understood that they retain greater similarity among themselves in terms of the performance of the technological level indicators for the agricultural establishments of Rondônia, observing distinct peculiarities from the others. When observing the results of the clusters, the distributions showed similarities in the two analyses, where only two municipalities changed, Chupinguaia (14) and Pimenta Bueno (35) that were in cluster 1 by *K-means* and in the hierarchical were for cluster 2.

It should be added that cluster analysis is an important tool for pattern recognition and data mining, with *K-means* being advantageous for its simplicity and scalability, while hierarchical clustering provides detailed insights through dendrograms, but can be computationally expensive for large datasets" (Tan; Steinbach; Kumar, 2018).

It was found that both cluster analyses can be used due to the small amount of data referring to the agricultural census of rural establishments in the State of Rondônia, in future works it is intended to test this analysis for different measures of distance between the *clusters*, to verify if there is a change in the location of the municipalities, because for this analysis only the Euclidean distance was used.

The spatial distribution of the clusters in Rondônia corroborates the findings of Silva *et al*. (2026b). The formation of Cluster 1, which brought together 29 municipalities, reveals an interesting spatial dynamic at the extremities of the state of Rondônia. Although this group brings together municipalities with extractive characteristics, it is in it that the five localities with the highest Technological Indexes of Agricultural Establishments (ITEA) are found: Pimenteiras do Oeste, Cerejeiras, Alto Alegre dos Parecis, Cabixi and Nova Brasilândia do Oeste.

The highlight of Pimenteiras do Oeste, with an ITEA of 70.45, is not an isolated data from its financial reality. The municipality has the highest GDP per capita in the state (R$ 115,753.94), occupying a position of national prestige (149th place among the 5,570 Brazilian municipalities). The correlation between wealth and technology is evidenced by the ownership of machinery; the municipality has 151.32% of machines in relation to the number of properties, which indicates that many establishments have more than one essential implement (tractors, seeders or harvesters). This level of investment is reflected in Factor 6 (Rural Modernization), where the use of e-mail and the internet becomes a management tool, and not just a leisure tool.

In direct opposition, Guajará-Mirim (also in Cluster 1, but at the lower end of the scale) has the lowest technological index (28.55). Despite having 602 establishments, it has only 91 tractors (15.12% of the properties), evidencing subsistence agriculture or low added value, contrasting with the greatness of Pimenteiras.

Cluster 2, which covers the central region of Rondônia, demonstrates homogeneity at medium/low levels, suggesting that, despite the proximity to hubs such as Ji-Paraná, technological dissemination still faces structural or rural extension barriers.

This technological heterogeneity confirms that agribusiness in Rondônia operates at two speeds. On the one hand, municipalities that have integrated farming with livestock as a strategy for income diversification; on the other hand, regions that maintain extensive grazing with a low stocking rate (average of 1.58 AU/ha in 2012). The transition to the "High Technological Level" level (ITEA > 75), which has not been reached by any municipality, depends on the conversion of Factor 3 (Technical Instruction) into ubiquitous practices in the field

5 CONCLUSION

The application of multivariate statistical modeling on the records of the Agricultural Census allowed the rigorous identification of the heterogeneity and technological duality that characterize the 52 municipalities of Rondônia. The rotational factor analysis (*varimax*) proved to be robust and sufficient, condensing the original variables into six fundamental factors. Plantation, Soil, Technical Instruction, Livestock, Dairy Production and Rural Modernization, which together explain 82.50% of the accumulated variance of the sector. The results reveal a scenario of selective modernization. Spatially, the intermediate geographic region of Ji-Paraná presents levels of technification higher than those of the Porto Velho region, corroborating trends of productive consolidation already observed in the Eastern Amazon. The validation of the *cluster* analysis using the *K-means* and hierarchical methods confirmed the formation of two main clusters, evidencing patterns of similarities that can guide personalized regional interventions

It was verified with the study that all the municipalities of Rondônia were classified only in the medium and low levels of technological development. Although the municipality of Pimenteiras do Oeste stood out with the highest ITEA (70.45), no municipality reached the "high level" level (ITEA ≥ 75). This predominance of intermediate and reduced indices should not be seen only as a productive limit, but as a clear window of opportunity for the intensification of investments in rural extension, technological diffusion and credit policies aimed at innovation.

In summary, the use of multivariate analysis proved to be adequate and essential to manage the complexity of rural establishments in the state. The transition to higher technological levels will require a coordinated effort to convert the factors of Technical Instruction and Rural Modernization into accessible practices, especially for family farming, ensuring that Rondônia's economic growth is accompanied by productive efficiency and environmental sustainability. It is concluded that multivariate modeling is a robust and adequate tool to support regional diagnoses and guide public policies aimed at sustainable rural development in Rondônia.

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REFERENCES

Andrade, D. F., & Ogliari, P. J. (2013). Estatística para ciências agrárias e biológicas: Com noções de experimentação (3ª ed.). Editora da UFSC.

Bezdek, J. C. (1981). Pattern recognition with fuzzy objective function algorithms. Springer.

Castro, L. N., & Ferrari, D. G. (2016). Introdução à mineração de dados: Conceitos básicos, algoritmos e aplicações. Saraiva.

Castro, E. H. A., & Mota, V. C. (2022). Aplicação da análise fatorial na caracterização dos acidentes de trânsito na BR-364 em Rondônia. Conjecturas, 22(2), 87–106.

Carvalho, A. (2022). Tecnologia na pecuária e seus benefícios. AGRON – Agronegócios Online. https://agron.com.br/noticias/colunistas/2022/02/04/os-beneficios-da-tecnologia-na-producao-pecuaria/

Cavalcante, C. R. F., & Góes, B. S. (2011). O desafio da gestão ambiental em Rondônia: Um estudo sobre a pressão agropecuária nos municípios com e sem unidades de conservação da natureza. In Congresso Brasileiro de Gestão Ambiental (Vol. 2).

Companhia Nacional de Abastecimento. (2024). Produção de grãos é estimada em 320,1 milhões de toneladas com ganhos de área e produtividade. https://www.conab.gov.br/ultimas-noticias/5116-producao-de-graos-e-estimada-em-320-1-milhoes-de-toneladas-com-ganhos-de-area-e-produtividade

Companhia Nacional de Abastecimento. (2026). Rondônia projeta recuperação no café e crescimento na produção de grãos. https://ac24agro.com/2026/03/26/rondonia-projeta-recuperacao-no-cafe-e-crescimento-na-producao-de-graos

Corrar, L. J., Paulo, E., & Dias Filho, J. M. (2017). Análise multivariada: Para os cursos de administração, ciências contábeis e economia. Atlas.

Damásio, B. F. (2012). Uso da análise fatorial exploratória em psicologia. Avaliação Psicológica, 11(2), 213–228.

DeGroot, M. H., & Schervish, M. J. (2002). Probability and statistics (3rd ed.). Addison Wesley.

Empresa Brasileira de Pesquisa Agropecuária. (2024). Produção de grãos em Rondônia na safra 2023/2024 está estimada em mais de quatro milhões de toneladas. https://www.embrapa.br/busca-de-noticias/-/noticia/90053472/producao-de-graos-em-rondonia-na-safra-20232024-esta-estimada-em-mais-de-quatro-milhoes-de-toneladas

Fávero, L. P., & Belfiore, P. (2021). Manual de análise de dados.

Field, A. (2013). Discovering statistics using IBM SPSS statistics (4th ed.). Sage.

Gasques, J. G., Bacchi, M. R. P., & Bastos, E. T. (2017). Impactos do crédito rural sobre variáveis do agronegócio. Instituto de Pesquisa Econômica Aplicada.

Haddad, P. R. (1989). Medidas de localização e de especialização. In P. R. Haddad et al. (Orgs.), Economia regional: Teorias e métodos de análise. BNB-ETENE.

Hair, J. F., Jr., et al. (2009). Análise multivariada de dados (8ª ed.).

Instituto Brasileiro de Geografia e Estatística. (2017). Base de dados por municípios das regiões geográficas imediatas e intermediárias do Brasil. https://www.ibge.gov.br/geociencias/cartas-e-mapas/redes-geograficas/15778-divisoes-regionais-do-brasil.html

Agência de Defesa Sanitária Agrosilvopastoril do Estado de Rondônia. (2024). Rondônia mantém produtividade dentro da média nacional mesmo com reflexos do El Niño afetando o desenvolvimento da soja. https://rondonia.ro.gov.br/rondonia-mantem-produtividade-dentro-da-media-nacional-mesmo-com-reflexos-do-el-nino-afetando-o-desenvolvimento-da-soja/

Agência de Defesa Sanitária Agrosilvopastoril do Estado de Rondônia. (2025). Atuação do governo de RO fortalece a pecuária; estado é líder em exportação de carne na região norte. https://rondonia.ro.gov.br/atuacao-do-governo-de-ro-fortalece-a-pecuaria-estado-e-lider-em-exportacao-de-carne-na-regiao-norte/

Instituto Brasileiro de Geografia e Estatística. (2021). Cidades e estados. https://ibge.gov.br/cidades-e-estados/ro.html

Instituto Brasileiro de Geografia e Estatística. (2024). PIB fecha 2023 em 2,9%. https://agenciadenoticias.ibge.gov.br

Jamovi project. (2024). Jamovi (Version 2.3.21). https://www.jamovi.org

Johnson, R. A., & Wichern, D. W. (2002). Applied multivariate statistical analysis (3rd ed.). Prentice Hall.

Kaiser, H. F. (1958). The varimax criterion for factor rotation in factor analysis. Psychometrika, 23(3), 187–204.

Lattin, J., Carroll, J. D., & Green, P. E. (2011). Análise de dados multivariados. Cengage Learning.

Lopes, K. L. M., Mota, V. C., Silva, A. N., & Silva, R. J. S. (2021). Estatística experimental aplicada em ensaio de competição de variedades de feijoeiro comum. Brazilian Journal of Development, 7(3), 30442–30459.

Manly, B. F. J., & Alberto, J. A. N. (2019). Métodos estatísticos multivariados: Uma introdução (4ª ed.). Bookman.

Mingoti, S. A. (2005). Análise de dados através de métodos de estatística multivariada: Uma abordagem aplicada. UFMG.

Mota, V. C., Damasceno, F. A., & Leite, D. F. (2018). Fuzzy clustering and fuzzy validity measures for knowledge discovery and decision making in agricultural engineering. Computers and Electronics in Agriculture, 150, 118–124.

Neto, R. C., Araújo, L. V., & Silva, F. A. C. (2022). Valor da produção agrícola, PIB per capita e PIB agropecuário relacionados às principais culturas agrícolas de Rondônia. Embrapa Rondônia.

Pfeifer, et al. (2024). Caracterização da pecuária em Rondônia. https://www.alice.cnptia.embrapa.br/alice/bitstream/doc/1136523/1/cpafro-18627.pdf

R Core Team. (2020). R: A language and environment for statistical computing. R Foundation. http://www.r-project.org

Rosa Neto, C., Silva, F., & Araujo, L. V. (2021). Correlação entre valor da produção agrícola e produto interno bruto per capita: O caso de Rondônia. In Congresso da Sociedade Brasileira de Economia, Administração e Sociologia Rural (59.).

Santana, A. C. (2007). Índice de desempenho competitivo das empresas de polpa de frutas do estado do Pará. Revista de Economia e Sociologia Rural, 45(3), 749–775.

Santos, M. A. S., et al. (2017). Caracterização do nível tecnológico da pecuária bovina na Amazônia brasileira. Revista de Ciências Agrárias, 60(1), 103–111.

Sena, A. D. S., et al. (2010). Concentração espacial e caracterização da pecuária leiteira no estado do Pará. In Congresso da Sociedade Brasileira de Economia, Administração e Sociologia Rural (48.).

Silva, S. S., et al. (2026a). Uso da análise fatorial e de cluster na caracterização dos estabelecimentos agropecuários em Rondônia. Contribuciones a las Ciencias Sociales, 19(1), 1–27.

Silva, S. S., et al. (2026b). Elaboration and statistical analysis of the technological index of agricultural establishments (ITEA) in Rondônia. Artefactum, 25(1), e2488. https://doi.org/10.23900/artefactum.v25i1.2488

Simões, A. R. P., Reis, J. D., & Avelar, P. S. (2017). A heterogeneidade tecnológica da pecuária leiteira em Minas Gerais. Agrarian, 10(37), 261–269.

Tan, P. N., Steinbach, M., & Kumar, V. (2018). Introduction to data mining (2nd ed.). Pearson.