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RURAL DEVELOPMENT OF MUNICIPALITIES IN THE SUBMEDIUM SÃO FRANCISCO REGION: A MULTIDIMENSIONAL ANALYSIS

Desenvolvimento rural dos municípios da região do submédio São Francisco: uma análise multidimensional

Desarrollo rural de las ciudades de la Región del Submedio São Francisco: un análisis multidimensional

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ABSTRACT

Rural development it is a set of actions that promotes changes in rural areas to improve the social well-being and living conditions of the people who live there. Therefore, the present analyzes rural development in the municipalities of the São Francisco River Sub-Middle Region in a multidimensional. To this end, we seek to measure the Rural Development Index (RDI) for the municipalities in this region and group them into clusters using Factor Analysis and Cluster Analysis methods. The results found indicated the presence of three factors, which, together, explain 85.45% of the total variance of the original data, named, respectively, well-being and quality of life (F1), sustainable agricultural practice and environmental preservation (F2), and intergovernmental dependence and population dynamism (F3). The majority of the municipalities have low or very low RDI and the municipalities of Petrolina (PE) and Juazeiro (BA) have the best RDI's. Therefore, it is concluded that the study offers a comprehensive view of rural development in the region, highlighting its complexities and challenges, as well as identifying opportunities to leverage rural development in the municipalities under study. These discoveries are fundamental to guide decision-making and the implementation of policies that seek to improve the living conditions of the populations in this region.

Keywords: São Francisco River Sub-Middle Region; RDI; Factor Analysis; Cluster Analysis.

RESUMO

O desenvolvimento rural trata-se de um conjunto de ações que promove mudanças no meio rural para melhoria do bem-estar social e das condições de vida das pessoas que ali residem. Dessa forma, o presente estudo analisa o desenvolvimento rural nos municípios da Região do Submédio São Francisco em uma abordagem multidimensional. Para tanto, busca-se mensurar o Índice de Desenvolvimento Rural (IDR) para os municípios dessa região e agrupá-los em clusters por meio dos métodos de Análise Fatorial e Análise de Clusters. Os resultados encontrados indicaram a presença de três fatores, que, conjuntamente, explicaram 85,45% da variância total dos dados originais, nomeados, respectivamente, de bem-estar e qualidade de vida (F1), prática agrícola sustentável e preservação do meio ambiente (F2), e dependência intergovernamental e dinamismo populacional (F3). A maioria dos municípios apresenta baixo ou baixíssimo IDR e os municípios de Petrolina (PE) e Juazeiro (BA) possuem os melhores IDR’s. Portanto, conclui-se que o estudo oferece uma visão abrangente do desenvolvimento rural na região, destacando suas complexidades e desafios, bem como identificando oportunidades para alavancar o desenvolvimento rural nos municípios estudados. Essas descobertas são fundamentais para orientar a tomada de decisões e a implementação de políticas que buscam melhorar as condições de vida das populações dessa região.

Palavras-chave: Região do Submédio São Francisco; IDR; Análise Fatorial; Análise de Clusters.

RESUMEN

El desarrollo rural es un conjunto de acciones que promueven cambios en las zonas rurales para mejorar el bienestar social y las condiciones de vida de las personas que allí habitan. Por ello, el presente estudio analiza el desarrollo rural en las ciudades de la Región del Submedio São Francisco en un abordaje multidimensional. Para eso, se busca medir el Índice de Desarrollo Rural (IDR) para las ciudades de esa región y juntarlas en aglomerados por medio de los métodos de Análisis Factorial y Análisis de Aglomerados. Los resultados encontrados indicaron la presencia de tres factores, que, conjuntamente, explicaron 85,45% de la variedad total de los datos originales, nombrados, respectivamente, de bienestar y calidad de vida (F1), práctica agrícola sustentable y preservación del medio ambiente (F2), y dependencia intergubernamental y dinamismo de la población (F3). La mayoría de las ciudades presenta bajo o bajísimo IDR y las ciudades de Petrolina (PE) y Juazeiro (BA) poseen los mejores IDR’s. Por tanto, se concluye que el estudio ofrece una visión amplia del desarrollo rural en la región, destacando sus complejidades y retos, bien como identificando oportunidades para incrementar el desarrollo rural en las ciudades estudiadas. Esas descubiertas son fundamentales para guiar la toma de decisiones y la implementación de políticas que buscan mejorar las condiciones de vida de las poblaciones de esa región.

Palabras clave: Región del Submedio São Francisco; IDR; Análisis Factorial; Análisis de Aglomerados.

1 INTRODUCTION

The Brazilian agricultural sector underwent several changes starting in the 1960s, based on the principles of the so-called Green Revolution, which established a new pattern of agricultural production. This included the introduction of new production techniques, the use of fertilizers and pesticides, agricultural mechanization, genetically modified seeds

(Biotechnology), and genetic varieties of crops more adapted to different regions of Brazil, among other changes, all aimed at increasing production and productivity in the field (Batista et al., 2023; Melo; Parré, 2007).

These transformations in the Brazilian agricultural sector were not limited to the introduction of new machinery and technologies but also included the integration of agriculture with industry, which resulted in significant changes in rural activities. The increased access to and use of technological resources, especially in agriculture, created greater dynamism that attracted non-agricultural activities, contributing to rural development. According to Begnini and Almeida (2016), these transformations have impacted the very conceptual understanding of rural development.

In Brazil, the São Francisco Valley stands out with several initiatives promoting rural development, primarily supported by irrigation. CODEVASF (São Francisco and Parnaíba Valleys Development Company) is a state-owned enterprise responsible for the development of several river basins in Brazil. It highlights that the São Francisco River is 2,776 km long, the São Francisco Valley covers an area of 640,000 km² and had an estimated population of 23.5 million inhabitants in 2017. Several companies are being established in this valley, and new investments are constantly emerging, enabling CODEVASF to operate according to internationally recognized quality standards (CODEVASF, 2021).

In this context of regional and rural development, the Sub-Middle São Francisco Region, located along the banks of the São Francisco River, is included. According to the São Francisco River Basin Committee (CBHSF, 2021), the region encompasses 93 municipalities, 24 in Bahia and 69 in Pernambuco. Its notable characteristics include a semi-arid and arid climate, caatinga vegetation, with high temperatures, and irregular rainfall.

Thus, according to Lima and Sousa (2017), irrigated fruit farming has driven the dynamics of this region, as evidenced by the growth in virtually all sectors of the local economy, being the main determining factor of its new economic and social trajectories. This region influences various sectors and areas, with Petrolina/Juazeiro standing out as the most dynamic irrigated fruit farming hub in Brazil, supplying products to both national and international markets.

The municipalities under study, despite being located in the semi-arid northeastern region with irregular rainfall, stand out in Brazil's agricultural production, driven by irrigation systems with various fruit production and export hubs, promoting dynamism in the rural areas of the region (CODEVASF, 2021).

The need to construct the Rural Development Index (IDR) arises from the importance of rural development, a multidimensional process that encompasses various dimensions, such as socio-cultural, economic, political-institutional, demographic, and environmental. This index is crucial for analyzing the different aspects involved in this process, which result from the interactions between these dimensions (Martínez et al., 2020; Bezerra; Lima, 2022; Renzi; Piacenti; Santoyo, 2022; Moura; Campos, 2022).

Given the above and the relevance that this region plays at both national and international levels, it is justified to analyze the rural development process of the municipalities in this region from a multidimensional perspective, as well as to identify the factors associated with the degree of rural development in these municipalities, a topic that has not yet been specifically researched in the literature. The general objective of this study is to analyze the rural development of the municipalities in the Sub-Middle São Francisco region. Specifically, it aims to: create a Rural Development Index (IDR) for the municipalities in the region and identify the determining factors of rural development in these municipalities using factor analysis; as well as classify the municipalities according to their degree of rural development through cluster analysis.

In addition to this introductory section, this work is divided into four more sections, namely: the second addresses the theoretical framework; the third is dedicated to the methodology; the fourth presents and discusses the results; and finally, the last section is reserved for the study's final considerations.

2 THEORETICAL FRAMEWORK

The analysis and understanding of the term rural development have undergone many changes as various transformations have occurred in rural areas. According to Schneider (2004), in light of the economic and institutional restructuring transformations in recent years, several researchers have emphasized the need to rethink the approaches that were previously used as theoretical references to define rural development.

According to Schneider (2004), rural development may be understood as the articulation of actions that result in social, economic, and environmental transformations in the rural context, aiming to improve the social well-being, and, consequently, the life conditions of the rural population.

For Kageyama (2004), rural development must be characterized as a) multilevel, that is, it needs to be considered at the global level because of the agriculture-society relation; b) multi-actors, because it depends on the local relations and the relations between the localities and the global economy, involving, therefore, several actors; and c) multifaceted, involving needs like the organic agriculture, administration and conservation of natural landscapes, agritourism, and production of regional specialties.

Delgado et al. (2013) show the transformations in a Latin American and European context, highlighting the processes of industrialization, new rurality, modernization, agricultural expansion, multifunctionality of agriculture, credit policies, environmental issues, and rural development, among others.

Rural and territorial development requires the implementation of public policies that consider particularities and specificities, along with a wide range of institutional innovations. To better understand rural development, it is essential to take into account, especially, the composition of rural society and social categories, access to natural resources and citizenship goods and services; and the cultural values that specify their ways of life. The rural is not solely a result of the presence of agriculture. This highlights that: i) the current rural context has an increasing interdependence with cities; ii) the distinctive traits of rural spaces vary according to societies; iii) rural development is a societal project. The dilemmas and challenges of rural areas need to be included in governmental development policies and should be part of this debate: the social struggle against poverty, the fight against inequality, the structuring of productive chains, and the generation of wealth on new (territorial) platforms; the generation of social income; and the understanding of the strategic dimension of development (Leite, 2020).

Rural development from a new perspective is marked by considering the various changes that rural areas have undergone in recent decades and the need to shift from a sectoral approach to a more integrated approach, acknowledging the complexity of rural spaces and the necessity of establishing a new model of political intervention that addresses existing social relations and the space (Hentz; Hespanhol, 2020).

Rural development requires a holistic approach that opens up social, environmental, demographic, economic, and political dimensions to promote the quality of life of the rural population, thereby strengthening rural spaces. Promoting access to quality education, sustainable conservation and use of resources, ecological agricultural practices, preserving biodiversity, promoting efficient water resource management, and developing strategies to face the challenges of climate change and mitigate its impacts are some of the objectives of the rural development proposed here.

3 METHODOLOGY

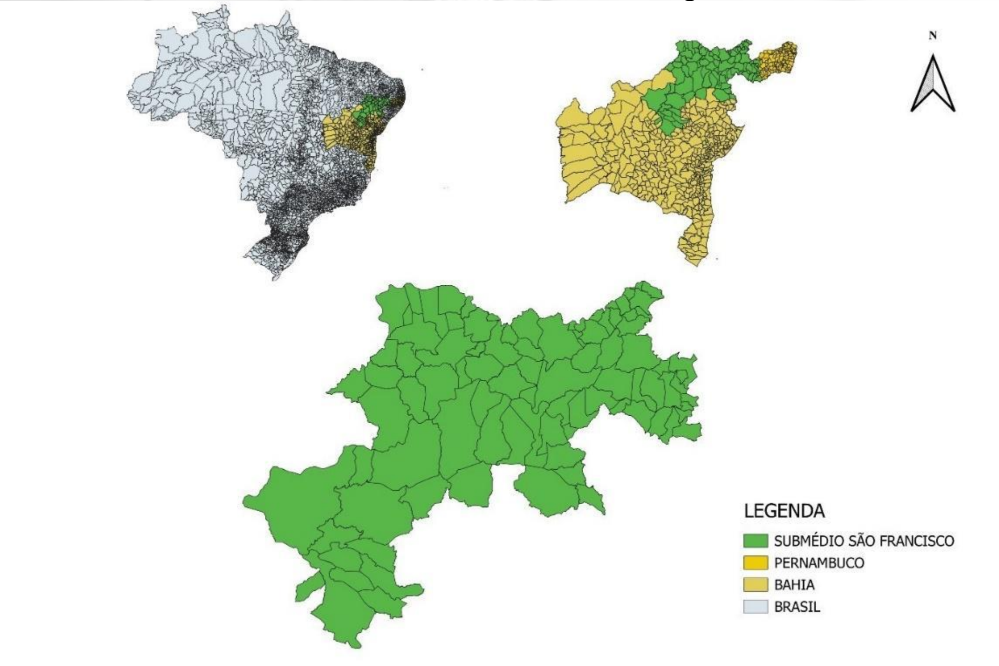
Due to the methodology employed to measure the level of rural development and the quantitative analyses that were conducted, the study can be classified as quantitative. The research can also be considered descriptive, as it analyzes observed facts without researcher manipulation (Rampazzo, 2013).

3.1 Study area

The study's territorial area analyzed is the Sub-Middle São Francisco Region, located along the banks of the São Francisco River, encompassing 93 municipalities across the states of Bahia and Pernambuco. This region includes the Integrated Development Region of the Petrolina-Juazeiro Pole.

In Figure 01, the Sub-Middle São Francisco Region is shown, allowing for its location to be identified both on the Brazilian map and between the states of Bahia and Pernambuco.

Figure 01 - Location of the Sub-Middle São Francisco Region, Bahia-Pernambuco, Brazil



Source: Designed by the authors using version 3.30.1 of QGIS Software (2023).

3.2 Factor analysis

For the calculation of the IDR, factor analysis was employed due to the multidimensional nature of rural development, taking into account a broad set of variables.

This technique is used to analyze models involving more than two variables, where all are random and interrelated in such a way that their different effects cannot be interpreted separately (Fávero; Belfiore, 2017; Hair Jr. et al., 2009).

According to Mingoti (2005) and Hair Jr. et al. (2009), a factor analysis model can be mathematically expressed by equation (1):

$$X_i = a_{i1}F_1 + a_{i1}F_1 + \cdots + a_{im}F_m + \varepsilon_1 \qquad (i = 1, \ldots, p) \qquad (1)$$

Where: $X_i = (X_1, X_2, \ldots, X_P)^t$ is a transposed vector of observable random variables; $a_{ij} =$ is a (*p x m*) matrix of fixed coefficients called factor loadings, which describe the linear relationship between X_i and F_j; $F_j = (F_1, F_2, \ldots, F_P)^t$ is a transposed vector (m < p) of latent variables that describe the unobservable elements of the sample, referred to as common random factors; $\varepsilon_i = (\varepsilon_1, \varepsilon_2, \ldots, \varepsilon_P)^t$ is a transposed vector of random errors corresponding to measurement errors and the variation of X_i that is not explained by the common factors F_j.

The components of the IDR are in different scales, so variable standardization is necessary (Lattin; Carroll; Green, 2011). The procedure for standardizing the variables is given by equation (2):

$$Z = \frac{(X_i - \underline{X})}{S}, \; i = 1, 2, 3, \ldots, n \qquad (2)$$

Where: Z = standardized variable; X_i = variable to be standardized; $\underline{X}$ = arithmetic mean of variable X; S = sample standard deviation of variable X.

After standardizing the observable variables X_i, these can be replaced by the vector of standardized variables Z_i, (Mingoti, 2005).

In the present study, the principal component method was used, which "consists of extracting factors in such a way as to maximize their contribution to the common variance (communality)" (Stege; Parré, 2011, p. 167). Principal Component Analysis (PCA) shows a linear combination of the observed variables, aiming to maximize the total explained variance. According to Fávero and Belfiore (2017), PCA takes into account the total variance of the data and allows the transformation of a set of quantitative variables into another set with a smaller number, reducing the complexity of data interpretation.

The selection of the appropriate number of factors for the model was made using a measure called *eigenvalue*, also known as the characteristic root, in which the number of factors was selected based on *eigenvalues* greater than one (1), which express the total variance explained by each factor (Mingoti, 2005). To facilitate the interpretation of factors, orthogonal rotation using the *Varimax* method was performed.

To test the adequacy of the factor analysis model, the Kaiser-Meyer-Olkin (KMO) test and Bartlett's Test of Sphericity (BTS) were used. For interpreting KMO in terms of factor analysis adequacy to the data set, the following ranges are considered: [0.90-1.00]: very good; [0.80-0.90): good; [0.70-0.80): average; [0.60-0.70): reasonable; [0.50-0.60): poor; [0.00-0.50): unacceptable (Fávero et al., 2009). BTS tests the hypothesis that the correlation matrix is an identity matrix, meaning that there is no correlation between the variables. A visual inspection must show a significant number of correlations above 0.30. Another adequacy measure is the anti-image matrix, which reveals sample adequacy measure values (MSA – measure of sampling adequacy) for each variable on the diagonal. The higher these values, the more appropriate the factor analysis method is (Mingoti, 2005; Hair Jr. et al., 2009; Fávero; Belfiore, 2017).

According to Mingoti (2005), the factor scores for each observation are expressed by equation (3):

$$F_j = \sum_{j=1}^{k} b_i X_{ij}, i = 1,2,\ldots,p \tag{3}$$

Where: F_j are the factor scores; b_i are the regression coefficients representing the weighting of each variable X_{ij} in factor F_j; X_{ij} are the variable values for the k-th element of the sample. To operationalize the factor analysis, SPSS software version 20 was used.

Before constructing the IDR, the factor scores were standardized to vary on a scale from 0 to 1. This standardization was performed using equation (4):

$$FP_{ij} = \frac{F_{ij} - Min(F_j)}{Max(F_j) - Min(F_j)} \tag{4}$$

Where: FP_{ij} = new standardized score of the j-th factor for the i-th municipality; F_{ij} = score of the j-th factor for the i-th municipality; $Min(F_j)$ = lowest score among municipalities; $Max(F_j)$ = highest factor score.

For measuring the Rural Development Index (IDR) for the municipalities of the Sub-Middle São Francisco Region, this research was based on the works of Stege and Parré (2011); Pinto and Coronel (2016); and Moura and Sousa (2020). Algebraically, the IDR can be obtained by equation (5):

$$IDR = \sum(\lambda j \ k \ j\text{=}1 \sum \lambda j \ j\text{=}1)FPij \qquad (5)$$

Where: IDR = Rural Development Index; λ_j = percentage of variance explained by factor j; k = number of selected factors; FP_{ij} = standardized factor score for municipality i in factor j.

3.3 Cluster analysis

Cluster analysis is a statistical technique that enables the grouping of variables or cases into homogeneous groups based on the pattern of similarity among individuals, using pre-established variables (Fávero; Belfiore, 2017; Fávero et al., 2009).

According to Fávero et al. (2009), cluster analysis can be broadly divided into the following steps: a) analysis of the variables and objects to be clustered; b) selection of the distance or similarity measure between each pair of objects; c) selection of the clustering algorithm: hierarchical or non-hierarchical method; d) choice of the number of clusters formed; and e) interpretation and validation of the clusters.

The second step in performing a cluster analysis involves defining the measure of distance (dissimilarity) or similarity that serves as the basis for assigning each observation to a certain group. The Squared Euclidean Distance, used by Bezerra and Lima (2022), is defined as the distance between two observations (i and j) and is calculated by summing the squares of the differences between *i* and *j* for all *p* variables, as shown in equation (6) (Fávero; Belfiore, 2017; Fávero et al., 2009).

$$dij \ 2 = \sum(xik - xjk)2 \ k\text{=}1 \qquad (6)$$

Where: x_{ik} is the value of variable *k* for observation *i*, and x_{jk} represents variable *k* for observation *j*.

Once the dissimilarity measure has been chosen, the next step is to determine the clustering scheme. There are two basic clustering schemes: hierarchical and non-hierarchical. The hierarchical scheme forms a step-by-step hierarchical structure to create clusters, while the non-hierarchical scheme uses an algorithm to maximize homogeneity within each cluster without a hierarchical process. Among the non-hierarchical clustering methods, the most popular is the k-means procedure. This method was adopted in the study for the analysis and interpretation of the identified clusters. The procedure classified the municipalities into four groups, based on the values of the IDR: i) very low level of rural development (IDR ≤ 0.172); ii) low level of rural development (0.172 < IDR ≤ 0.337); iii) medium level of rural development (0.337 < IDR ≤ 0.810); and iv) high level of rural development (IDR > 0.810).

3.4 Database and Variable Description

Chart 01 provides the dimensions, the variables considered, based on the literature, and the respective data sources used in the composition of the Rural Development Index (IDR).

Chart 01 - Dimensions, Variables, Data Sources, and Year for the Rural Development Index (IDR) of the Sub-Middle São Francisco municipalities

(Chart continues...)

Dimensions	Code	Variables	Source	Foundational studies
Social	X1	Number of rural households supplied with water from a general supply network (units).	DATASUS (2010)	Melo and Parré (2007); Stege (2011); Lisbinski *et al.* (2020); Bezerra and Lima (2022)
	X2	Number of rural households with waste collected by a public or private service/company (units).	DATASUS (2010)	Conterato (2008); Stege (2011); Oliveira *et al*. (2020); Moura and Sousa (2020)
	X3	Number of literate people aged 10 or older in rural areas with income.	Demographic census (2010)	Conterato, Schneider, Waquil (2007); Souza (2019)

	X4	Number of rural households with electricity	Demographic census (2010)	Lobão and Staduto (2020); Bezerra and Lima (2022); Moura and Campos (2022)
	X5	Number of students enrolled in preschool, elementary, and high school in rural areas	INEP (2017)	Pinto and Coronel (2016); Muniz and Pereira (2018).
	X6	Number of family health teams in December 2017	DATASUS (2017)	Begnini e Almeida (2016); Muniz and Pereira (2018)
Economic	X7	Value of production of agricultural establishments	Agricultural census (2017)	Stege and Parré (2011); Renzi, Piacenti and Santoyo (2022).
	X8	Value of financing granted to agricultural producers and cooperatives for costs, investments, and marketing	BCB (2017)	Melo and Parré (2007); Begnini and Almeida (2016).
Political-institutional	X9	Intergovernmental transfers from the Union to the total municipal revenues	Siconfi - National Treasury (2017)	Stege and Parré (2011); Lisbinski *et al*. (2020);
Demographics	X10	Population density	Demographic census (2010)	Kageyama (2004); Lobão and Staduto (2020); López-Penabad, Iglesias-Casal, Rey-Ares (2022).
	X11	The proportion of the population that has not always lived in the municipality relative to its total population	Demographic census (2010)	Melo and Parré (2007); Paixão *et al*. (2020)
Environmental	X12	Number of agricultural establishments that used soil preparation systems	Agricultural census (2017)	Paixão *et al*. (2020); Moura and Sousa (2020); Moura and Campos (2022)

	X13	Number of agricultural establishments that did not use pesticides (units)	Agricultural census (2017)	Lobão and Staduto (2020); Moura and Sousa (2020); Bezerra and Lima (2022)

Source: Designed by the authors (2023).

The characteristics of rural households have a direct impact on the level of rural development. These observations are supported by empirical studies (Conterato, 2008; Stege; Parré, 2011). Economic performance indicators directly affect rural development. According to Pinto and Coronel (2016), the gross value of agricultural production and the amount of credit granted are variables that positively influence development.

The political-institutional dimension, characterized by the proportion of federal intergovernmental transfers relative to the total municipal revenues, has a negative effect on development. If a municipality is more dependent on federal resources, the lower the degree of development in the region (Pinto; Coronel, 2016).

Indicators related to the population play a favorable role in the progress of rural areas. This occurs because a higher population density is associated with less isolation, which in turn creates more opportunities for the formation of social networks and community interactions (Melo; Parré, 2007; Kageyama, 2008).

Environmental variables are relevant to rural development, as they address issues related to environmental preservation (Kageyama, 2004; Araujo; Theóphilo, 2021).

4 RESULTS and DISCUSSION

This section presents and discusses the results obtained in this study, which are divided into three parts. The first part analyzes the descriptive statistics of the variables used in the IDR measurement. The second part is dedicated to the presentation and discussion of the factor analysis. The last part includes the cluster analysis for the IDR.

4.1 Descriptive Statistics of the Variables that Comprise the IDR

From Table 01, it can be observed that most of the variables showed highly heterogeneous results, with high coefficients of variation and values far from the mean. The highest dispersion is found in the value of agricultural establishments' production (X7). While the municipality of Calumbi (PE) presented the lowest value for variable X7 (1.577 thousand reais), the municipality of Petrolina (PE) had the highest value for this variable (780,313 thousand reais). According to Lima and Sousa (2017), the municipality of Petrolina (PE) is characterized by strong irrigated fruit farming, with dynamic agricultural and commercial activities and market flows directed towards international trade, boosting job and income generation in rural areas. The lowest discrepancies are in the proportion of the population that has not always lived in the municipality relative to its total population (X11). The lowest proportion is found in the municipality of Manari (PE), while the highest proportion is in Sobradinho (BA). This variable indicates the municipality's attractiveness. According to Rego (2022), when the migratory process occurs more intensely, economic activities are more developed, promoting a strong urbanization process.

Table 01 - Descriptive Statistics of the Variables Used in the Measurement of the IDR for the Municipalities of the Sub-middle São Francisco Region

Variables	Minimum	Mean	Median	Maximum	Standard Deviation	CV*
X1	17,00	953,20	502,00	13.722,00	1.668,92	175,08
X2	1,00	524,98	226,00	11.452,00	1.333,52	254,01
X3	197,00	3.154,17	2.562,00	24.167,00	2.995,40	94,97
X4	126,00	2.980,59	2.426,00	18.735,00	2.469,48	82,85
X5	123,00	2.417,30	1.758,00	25.884,00	3.089,14	127,79
X6	1,00	12,14	9,00	105,00	12,79	105,36
X7	1.577,00	38.277,66	16.639,00	780.313,00	102.725,36	268,37
X8	84,50	1.780,18	788,89	36.797,78	4.155,77	233,45
X9	0,23	0,41	0,40	0,59	0,06	15,81
X10	2,85	31,48	23,65	196,05	28,96	91,99
X11	0,12	0,29	0,27	0,61	0,10	33,99
X12	111,00	1.427,03	1.108,00	6.779,00	1.093,67	76,64
X13	187,00	1.817,14	1.634,00	5.542,00	1.134,23	62,42

Source: Prepared by the authors (2023)
Note: * Represents the coefficient of variation (%). Variables X7 and X8 are in thousand reais.

It can still be inferred that the highest population density is found in the municipality of Arcoverde (PE), and the highest number of establishments that did not use pesticides is in the municipality of Buíque (PE). On average, 29% of the population in the municipalities have not always lived in the municipality. Boosting rural development is essential so that people do not migrate to other municipalities, states, or regions, thereby fostering the local economy to promote further development (Lisbinski et al., 2020).

4.2 Analysis of the Determinant Factors of Rural Development for the Municipalities of the Sub-middle São Francisco Region

Before conducting the factor analysis, some tests were carried out to verify the suitability of the variables for the chosen multivariate technique. Based on the correlation matrix, high correlation coefficients were observed for most variable pairs. The anti-image matrix was also analyzed, showing significant values, low coefficients, and main diagonal values above 0.6, except for variable X10. Similar results can be found in the literature by Moura and Campos (2022). Bartlett's sphericity test was significant at 1% probability, with a value of 1755.78, rejecting the null hypothesis that the correlation matrix is an identity matrix.

The KMO test used to verify the suitability of this analytical tool showed a value of 0.886. Thus, according to Fávero et al. (2009), the data present good [0.80-0.90) suitability for the use of this method. Moura and Campos (2022) found a KMO of 0.84 when analyzing rural development in the MATOPIBA region of Brazil. After confirming the model's suitability, factor analysis was performed using the principal components method and orthogonal rotation through the Varimax method.

From the factor analysis, it was possible to extract three determinant factors (Table 02) for the IDR in the Sub-middle São Francisco region. Thus, the socioeconomic, environmental, political-institutional, and demographic dimensions were able to explain 85.45% of the total variance.

Table 02 – Eigenvalues and Percentage of Total Variance Explained by Factor Analysis

Factor	Eigenvalue	Variance Explained by Factor (%)	Cumulative Variance (%)
1	7,815	60,113	60,113
2	1,932	14,865	74,978
3	1,361	10,468	85,447

Source: Prepared by the authors (2023)

Table 03 presents the factor loadings after orthogonal rotation and the communalities for the three factors considered. For interpretation purposes, factor loadings with absolute values greater than 0.5 were considered, which are highlighted in bold to indicate the variables most closely associated with a given factor.

Table 03 – Factor Loadings and Communalities after Orthogonal Rotation of Factors, Obtained through Factor Analysis

Variables	Factor Loadings			Communalities
	F1	F2	F3	
X1	**0,963**	0,043	0,046	0,931
X2	**0,942**	0,033	0,090	0,897
X3	**0,901**	0,378	0,080	0,961
X4	**0,821**	0,529	0,096	0,963
X5	**0,936**	0,274	0,077	0,957
X6	**0,878**	0,236	0,333	0,937
X7	**0,919**	0,055	0,138	0,867
X8	**0,915**	0,110	0,102	0,861
X9	-0,299	-0,149	**-0,770**	0,704
X10	-0,086	0,022	**0,804**	0,654
X11	0,296	-0,484	**0,560**	0,636
X12	0,196	**0,888**	0,139	0,847
X13	0,310	**0,892**	-0,047	0,894

Source: Prepared by the authors (2023)

The first factor (F1), designated as the well-being and quality of life factor, explains over 60% of the total variance of the data and has a strong positive correlation with variables X1, X2, X3, X4, X5, X6, X7, and X8. These variables reflect social and economic dimensions. Analyzing this set of variables, the positive signs and high values indicate higher economic and social performance, which translates into better living conditions and quality of life, and consequently, a higher level of rural development. The signs are consistent with the literature and can be supported by the findings of Melo and Parré (2007), Moura and Sousa (2020), and Moura and Campos (2022).

As shown in Table 02, around 14.87% of the total variance of the data is explained by Factor 2 (F2), named the sustainable agricultural practice and environmental preservation factor. According to Table 03, the variables included in this factor are X12 and X13. These variables are related to the environmental dimension and are positively associated with rural development. The lower the use of pesticides and the more soil preparation is conducted, the better the conditions for environmental preservation. These findings are corroborated by Pinto and Coronel (2016) and by Moura and Campos (2022), who analyzed rural development in Rio Grande do Sul and the MATOPIBA region, respectively.

The third and last factor (F3) is responsible for explaining 10.47% of the total variance of the data. According to Table 03, this factor includes variable X9 (Intergovernmental transfers from the Union relative to the sum of total municipal revenues) from the political-institutional dimension, and variables X10 (Population density) and X11 (Proportion of the population that has not always lived in the municipality relative to its total population) from the demographic dimension. This factor was designated as intergovernmental dependence and population dynamism.

Variable X9 has a negative relationship with rural development; the higher the municipalities' dependence on intergovernmental transfers, the lower their capacity to promote development (Conterato, 2008). Population dynamism factors are positively associated with rural development. Highly isolated areas reduce opportunities for social interconnections, which constitutes a barrier to development. On the other hand, areas with higher population densities are more interconnected, facilitating a greater establishment of social networks and enabling new development possibilities (Melo & Parré, 2007; Kageyama, 2008; Bezerra & Lima, 2022). Regarding variable X11, this measures the attractiveness of municipalities. The higher the proportion of residents who have not always lived in the municipality, the greater the municipality’s capacity to attract people within the region, potentially enabling higher levels of development (Lima & Sousa, 2017; Moura & Sousa, 2020).

4.3 Rural Development Index (IDR) and Cluster Analysis for the Municipalities of the Sub-middle São Francisco Region

Based on the standardized factor scores, it is possible to use Equation 05 to measure the IDR for all the municipalities in the Sub-middle São Francisco Region. The results showed that the minimum IDR was 0.093 (Rodelas-BA), the maximum was 0.811 (Petrolina-PE), and the average was 0.164, with a standard deviation of 0.087 and a coefficient of variation of 52.95%, demonstrating the heterogeneity of the IDR in the region. Table 04 presents the five highest and five lowest IDRs in the Sub-middle São Francisco, along with their respective municipalities.

Table 04 – Five Municipalities with the Highest and Lowest IDR in the Sub-middle São Francisco Region

Position	Municipality	IDR
1º	Petrolina-PE	0,811
2º	Juazeiro-BA	0,491
3º	Campo Formoso-BA	0,337
4º	Araripina-PE	0,285
5º	Jacobina-BA	0,262
89º	Calumbi-PE	0,102
90º	Itacuruba-PE	0,099
91º	Ingazeira-PE	0,098
92º	Macururé-BA	0,097
93º	Rodelas -BA	0,093

Source: Prepared by the authors (2023)

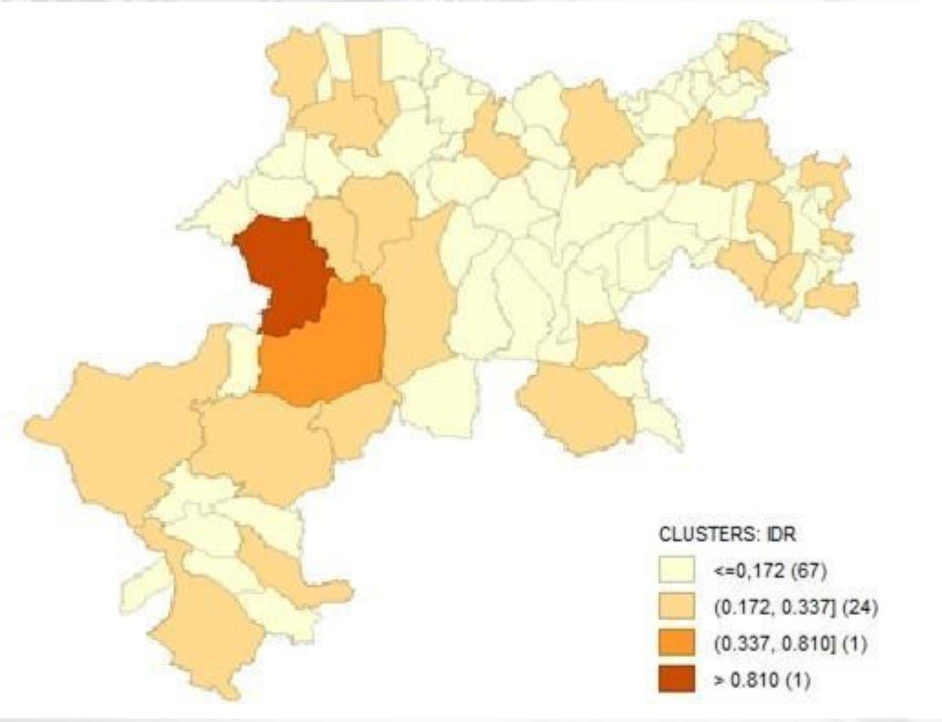
The municipality with the highest IDR is Petrolina-PE, which achieved the highest values in all variables of the social and economic dimensions. Juazeiro-BA obtained the second-highest IDR (0.491). These results are supported by Lima and Sousa (2017), who analyzed the IDR in the 8 municipalities of the Integrated Region of Petrolina (PE) – Juazeiro (BA). The Petrolina-Juazeiro hub is the most dynamic fruit-growing hub in Brazil, integrated into the international market, making the state of Pernambuco the largest exporter of fresh grapes in Brazil and Bahia the largest exporter of mangoes. The irrigated perimeters boosted agriculture, attracting new investments and people from other cities and regions seeking new opportunities. Furthermore, the Sub-middle São Francisco region has favorable climatic conditions for fruit production, which further accelerated the development of activities in the region (Oliveira & Lima, 2021).

In third place is the municipality of Campo Formoso-BA with an IDR of 0.337. Following are the municipalities of Araripina-PE (0.285) and Jacobina-BA (0.262). Although Campo Formoso-BA did not achieve the highest value in any variable, its results are well above average in all variables. Jacobina-BA has values well above average in the variables of the social and economic dimensions. The municipality of Araripina stood out in the environmental dimension, having the highest number of agricultural establishments using soil preparation systems and the second highest number of establishments that did not use pesticides.

The municipality of Rodelas-BA was identified as having the lowest IDR in the region. This municipality has the lowest population density among all the municipalities in the region, indicating low population dynamism. According to Melo and Parré (2007), population dynamism is a crucial factor for development. Moreover, it was found that the municipality has the lowest number of establishments that did not use pesticides. According to Moura and Sousa (2020), practices associated with the use of pesticides and soil correctives are issues related to environmental degradation, which are factors that hinder development. The other municipalities that presented very low rural development indices were: Macururé (0.097), Ingazeira (0.098), Itacuruba (0.099), and Calumbi (0.102).

For a better visualization of the spatial distribution of the IDR in the municipalities of the Sub-middle São Francisco Region, a distribution via cluster analysis was conducted. It is noteworthy that the non-hierarchical K-means method was used, which allocates each observation into one of the pre-defined *k* clusters. The significance of the method was confirmed with the aid of the ANOVA table, which showed a global F value of 294.474 and a significance of 0.000 (1%). The results were distributed into 4 clusters (Figure 02) and the following nomenclature was considered for the IDR: i) Very Low (IDR ≤ 0.172); ii) Low (0.172 < IDR ≤ 0.337); iii) Medium (0.337 < IDR ≤ 0.810); and iv) High (IDR > 0.810).

Figure 02 – Rural Development Index (IDR) for the Municipalities of the Sub-middle São Francisco Region through Cluster Analysis



Source: Prepared by the authors using GeoDa software, version 1.20 (2023).

From Figure 02, a significant heterogeneity can be observed among the municipalities regarding the level of rural development. Only the municipality of Petrolina-PE is in Cluster 1, representing the highest level of rural development in the region. The municipality of Juazeiro-BA was classified in Cluster 2, with a medium IDR. These findings are supported by Lima and Sousa (2017), who, studying the IDR in eight municipalities of the Integrated Development Region of the Petrolina (PE)-Juazeiro (BA) hub, found these municipalities to have the highest IDRs in the region. It is noteworthy that the majority (72.04%) of the municipalities in the Sub-middle São Francisco have a very low IDR (Cluster 4). Another 25.81% of the municipalities are in Cluster 3 (low IDR). Begnini and Almeida (2016) also found a predominance of low and very low IDR in the municipalities of Santa Catarina.

Moura and Sousa (2020) highlighted that out of the 330 municipalities analyzed in Pernambuco and Ceará, 56.36% obtained low or very low IDR, and only 4.24% reached a very high IDR. Moura and Campos (2022) found that 52.13% and 38.03% of the municipalities in MATOPIBA were classified, respectively, at very low and low IDR levels. The authors observed that, for Bahia and Piauí, low and very low levels of development stand out, reinforcing the significant rural poverty in the Brazilian Northeast.

It is evident, therefore, that regional imbalances and inequalities are present in the Sub-middle São Francisco. There is an intense concentration in the municipalities with the highest IDRs, to the detriment of neighboring municipalities that lack the social, productive, and economic infrastructure of these areas. These differences were already expected, as noted by Souza (2019, p. 110): “They stem, above all, from the social, economic, environmental, institutional, and demographic changes that define the rural development processes in each state of the federation or even within them.”

It can be inferred that the low levels of rural development in these municipalities are likely a reflection of low-income levels, poor educational attainment, low proportion of establishments that have secured financing, low population, and economic dynamism, among other factors. The municipalities with the highest IDR rankings have better infrastructure, access to basic hygiene and health services, strategic geographical location, access to production financing, and other indicators that have favored rural development.

5 FINAL CONSIDERATIONS

Studying the rural development of a region is not an easy task, as it involves a multidimensional analysis. It requires examining a set of variables or indicators that encapsulate the multidimensionality of rural development. Thus, the objective of this study was to measure rural development in the Sub-middle São Francisco Region through the IDR, identifying its main conditioning factors using factor analysis. Additionally, a comparative analysis of the IDR was conducted using clusters.

As a result, three specific factors related to the dynamics of rural development in the region were obtained. Factor 1 (F1) was designated as well-being and quality of life, the second factor (F2) as sustainable agricultural practices and environmental preservation, and the third and last factor, named intergovernmental dependence and population dynamism. Factor 1 explains the largest variance (60.113%) of the data and refers to the socioeconomic dimension. Factor 2, in turn, showed the second-largest variance (14.865%) and relates to environmental aspects, while factor 3 explains 10.468% of the total variance of the data and captures indicators from the political-institutional and demographic dimensions. These three factors synthesize the 13 variables used to calculate the IDR and jointly explain 85.447% of the total variance of the data.

Based on the IDR analysis, it was found that the municipalities of Petrolina-PE (0.811) and Juazeiro-BA (0.491) had the highest IDRs in the region. These municipalities benefit from a network of public and private investments surrounding the irrigated perimeters, which promote chain growth in other areas. In contrast, the Bahian municipalities of Rodelas (0.093) and Macururé (0.097) have the lowest levels of rural development in the region. These municipalities likely have economic, social, and environmental vulnerabilities that are hindering their IDR performance. These data reveal the imbalances present in the region and point to the need for more effective action in areas such as health, education, the economy, and environmental preservation.

These results highlight the challenges faced by public managers in improving rural development indices in the region, such as the concentration of development in the municipalities of Petrolina and Juazeiro, and the need to reduce the disparities present in the region. Additionally, these findings can serve as a basis for creating and implementing public policies that promote and propagate rural development. Government managers can develop specific mechanisms to improve IDR indicators, especially in municipalities where these levels are significantly below those of the more developed municipalities, considering the particular characteristics of each territory.

It is suggested that future studies expand the sample of municipalities or compare it with other subdivisions of the São Francisco Valley, as well as with different regions of the Northeast and Brazil. Furthermore, it is essential to conduct new studies that address a broader range of variables, including socioeconomic, political-institutional, and demographic aspects of the municipalities in the Sub-middle São Francisco. Conducting comparative analyses over time is also crucial to observe the evolution of rural development indicators in the region.

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