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EVOLUÇÃO E DISTRIBUIÇÃO DA IRRIGAÇÃO POR PIVÔ CENTRAL NO RIO GRANDE DO SUL

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1 RESUMO

A irrigação por pivô central tem se consolidado como uma das principais tecnologias para o aumento da produtividade e para a mitigação dos efeitos das instabilidades na ocorrência de chuvas. O presente estudo teve como objetivo mapear e analisar a distribuição espacial da área irrigada por pivôs centrais no estado do Rio Grande do Sul. Foram utilizadas imagens de satélite, sistemas de informação geográfica e dados complementares de instituições oficiais, consultores técnicos e empresas do setor. Identificaram-se 5.043 pivôs centrais, ocupando 275.736,60 ha em 161 municípios, com destaque para São Borja, Cruz Alta, São Luiz Gonzaga, Palmeira das Missões e Santa Bárbara do Sul. As bacias do Alto Jacuí (46,8 mil ha), Ijuí (46,7 mil ha) e Piratinim (46,4 mil ha) concentram as maiores áreas irrigadas, representando, em conjunto, 51% da área irrigada total do estado. A análise temporal revelou um incremento médio anual de 329 equipamentos e 16.464,07 ha, com tendência de duplicação da área irrigada no estado em aproximadamente 17 anos. Embora o ritmo de crescimento tenha desacelerado no último quinquênio, devido às limitações de investimento e aos elevados custos de implantação, o potencial hídrico e territorial do estado continua expressivo. Os resultados obtidos fornecem subsídios técnicos e espaciais para o planejamento da gestão dos recursos hídricos e para o fortalecimento de políticas públicas voltadas à irrigação no Rio Grande do Sul.

Palavras-chave: Área irrigada, Gestão de recursos hídricos, bacias hidrográficas, sistema de irrigação, irrigação pressurizada.

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EVOLUTION AND DISTRIBUTION OF CENTER-PIVOT IRRIGATION IN RIO GRANDE DO SUL

2 ABSTRACT

Center-pivot irrigation has become one of the main technologies for increasing agricultural productivity and mitigating the effects of variable rainfall. This study aimed to map and analyze the spatial distribution of areas irrigated by center pivots in Rio Grande do Sul, Brazil. Satellite imagery, geographic information systems, and complementary data from official institutions and producers were used. A total of 5,043 center pivots were identified, covering 275,736.60 ha across 161 municipalities, with major concentrations in São Borja, Cruz Alta, São Luiz Gonzaga, Palmeira das Missões, and Santa Bárbara do Sul. The largest irrigated areas are concentrated in the Alto Jacuí (46.8 thousand ha), Ijuí (46.7 thousand ha), and Piratinim (46.4 thousand ha) river basins, which represent 51% of the total irrigated area of the state. The temporal analysis revealed average annual increases of 329 center pivots and 16,464.07 ha, indicating that the irrigated area may double within approximately 17 years. Although the growth rate has slowed in the past five years because of investment constraints and implementation costs, the water and land potential of the state remains significant. The results provide technical and spatial support for water resource management planning and for strengthening public policies aimed at irrigation development in Rio Grande do Sul.

Keywords: Irrigated area, water resources management, watersheds, irrigation system, pressurized irrigation.

3 INTRODUCTION

Center pivot irrigation is a strategic tool for strengthening Brazilian agriculture and promoting greater productivity and production stability in regions with water deficits. In 2015, Brazil had approximately 6.95 million hectares irrigated, of which 1.39 million were equipped with center pivots, which were used mainly for soybean and corn cultivation. Between 2010 and 2022, the area irrigated by center pivots increased by approximately 225%, reaching 1.92 million hectares (ANA, 2023), while the total irrigated area in the country has shown average annual growth rates exceeding 4% since the 1960s, demonstrating the continuous expansion of irrigated agriculture in Brazil.

This technology combines water efficiency, automation, and ease of operation and plays a fundamental role in food security and productive resilience in the face of climate variability, especially with respect to precipitation. However, the system requires continuous monitoring to mitigate environmental impacts and avoid overloading water resources. In Rio Grande do Sul, irrigation is historically associated with flooded rice cultivation; however, in recent decades, there has been a significant expansion of center pivot systems, especially in the northwestern region. In 2015, the state had 111,122.9 hectares irrigated by 1,753 pivots, concentrated in basins such as the Upper Jacuí and the Ijuí River (MARTINS *et al*., 2016). By 2020, this irrigated area had already reached 190,550.3 hectares (MARTINS *et al*., 2021).

In 2024, the area reached 205,620 hectares (GUIMARÃES; LANDAU, 2024).

Compared with rainfed areas, central pivot irrigation systems offer significant advantages, such as uniform water application, reduced labor, and increased productivity of up to 66.1% (IBGE, 2017). However, despite the significant progress of this irrigation system, there is still a lack of integrated, systematized, and up-to-date information on the spatial distribution of center pivots across the state, which limits the planning and efficient management of water and agricultural resources. The intensive expansion of this system may have exerted increasing pressure on water resources, especially in the Jacuí and Uruguay river basins, reinforcing the need for integrated and sustainable management. Projections indicate that center pivots will account for approximately 75% of irrigation growth by 2030 (ANA, 2016), highlighting the importance of public policies aimed at regulating water use and providing technical and financial support to producers.

The last harvests in Rio Grande do Sul, especially between 2020 and 2025, were marked by severe droughts associated with the La Niña phenomenon, which reduces rainfall due to the cooling of the Pacific Ocean. In the 2021/22 harvest, Emater-RS reported losses of 41.9% in grain production, with soybeans and corn decreasing by up to 50% in regions such as São Borja and Alegrete (RIO GRANDE DO SUL, 2022). By 2025, the decrease in soybean productivity will reach 28% throughout the state (RIO GRANDE DO SUL, 2025). Given the expansion of center pivot irrigation systems and the recurring impacts of drought on agricultural production, understanding the spatial distribution and dynamics of irrigated areas in Rio Grande do Sul is essential. Detailed mapping of these areas will provide support for water resource management, agricultural planning, and the formulation of public policies aimed at food security and sustainability. Thus, this study aims to map and analyze the evolution and distribution of areas irrigated by center pivot systems in the state, considering their relationships with municipalities and river basins, as well as their implications for the integrated management of irrigated agriculture.

4 MATERIALS AND METHODS

This study was developed using geoprocessing techniques and high-resolution satellite imagery and official cartographic databases for mapping and analyzing the area irrigated by center pivot irrigation systems in the state of Rio Grande do Sul, considering images available up to September 2025. The study covered the area between latitudes 27°03'42" S and 33°45'09" S and longitudes 49°42'41" W and 57°40'57" W in the state of Rio Grande do Sul. Satellite images available in Google Earth Pro software, covering the entire state territory, were analyzed, as well as the database from the center pivot irrigation survey conducted in 2019 by the National Water Agency (ANA) and Embrapa Maize and Sorghum (ANA; EMBRAPA, 2019).

Initially, the images were spatially overlaid with georeferenced maps of municipal boundaries (IBGE, 2019) and the state's hydrographic basins (SEMA-RS, 2025), both of which were imported into the Google Earth Pro environment. Considering that the state does not have a well-defined dry season, which makes it difficult to identify irrigated areas using satellite imagery, a visual interpretation methodology was adopted, following the approach proposed by Guimarães and Landau (2011). Additionally, complementary information obtained from rural producers, technical consultants, and companies supplying center pivot irrigation systems was used, especially regarding the location of recently installed equipment. This information was used to support the identification and validation of pivots in satellite images, guiding spatial analysis and reducing uncertainties in the delimitation of irrigated areas.

In Google Earth Pro, each pivot was identified, delimited, and associated with its respective municipality and watershed. In cases where the structure extended across more than one administrative or hydrographic unit, the one containing the largest fraction of the center pivot area was considered. To determine the effectively irrigated area of each pivot, vector delimitations were performed in Google Earth Pro using the “add path” tool for sector pivots or the “circle” tool for full-rotation center pivots, drawing polylines and polygons over the areas visible in the satellite images. After identification, detailed visual verification of the respective images was carried out, and the files were saved in KML format containing geographic and administrative identification information.

The vector data were processed using the Quantum GIS Geographic Information System (QGIS DEVELOPMENT TEAM, 2025), version 3.40.9 (Bratislava). Using the KML tools plugin, the KML file was imported, and the layer was converted to a shapefile. Afterward, the “lines to polygons” tool (vector menu, Geometry Tools) in QGIS was used to convert the polyline geometries into polygons. In the attribute table, a double column was created for the automatic calculation of feature areas, expressed in hectares, and another column was created for recording the central coordinates of each pivot. After processing, the data were exported in .xlsx format, enabling statistical and tabular analysis in Microsoft Excel.

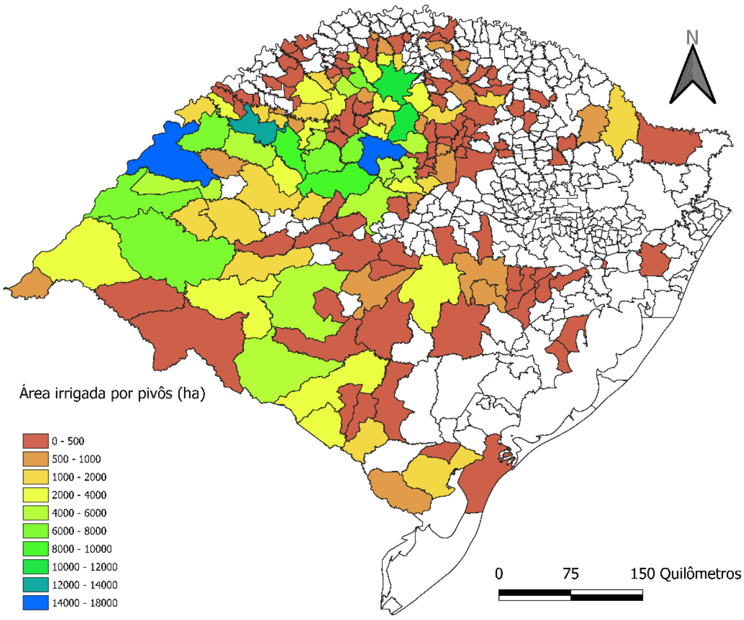
Finally, thematic maps were created in the QGIS environment using the SIRGAS 2000/UTM Zone 22S reference system to spatially represent the distribution of center pivot irrigation systems by municipalities and river basins. To verify the temporal evolution of irrigation in the state, the 2025 results were compared with those of previous surveys (MARTINS *et al*., 2016; MARTINS *et al*., 2021; GUIMARÃES; LANDAU, 2024). The percentage variation rate and absolute expansion (in hectares) were calculated for 5- and 10-year intervals, allowing inferences about growth trends and possible conditioning factors of the expansion or contraction of irrigated areas.

5 RESULTS AND DISCUSSION

A total of 5,043 center pivot irrigation systems were identified in the state of Rio Grande do Sul, totaling 275,736.60 hectares of irrigated land distributed across 161 municipalities. Furthermore, a reduction in the average area of center pivot systems was observed over the analyzed period, decreasing from approximately 63 ha in 2015 to approximately 54 ha in 2025, indicating a trend toward the implementation of smaller systems. The municipalities with the largest irrigated area, which together represent approximately one-quarter of the total irrigated area, were São Borja (267 pivots, 17,383.04 ha), Cruz Alta (257 pivots, 15,495.30 ha), São Luiz Gonzaga (260 pivots, 13,503.10 ha), Palmeira das Missões (201 pivots, 11,678.10 ha), and Santa Bárbara do Sul (185 pivots, 10,617.89 ha). The spatial distribution of irrigated area by municipality is shown in Figure 1, where the highest concentrations are represented in dark blue tones, indicating the municipalities with the highest density of equipment, especially highlighting the municipalities of São Borja and Cruz Alta. Spatial variation is represented by irrigated area classes, allowing the identification of municipalities with different concentrations of center pivot systems, while the white areas correspond to municipalities with no records of center pivot irrigation equipment.

A comparison of the results obtained with the survey by Guimarães and Landau (2024), which revealed that 205,620 ha irrigated by center pivots in the state, an increase of 34.1% was observed in just one year. This increase, although significant, may be partially associated with methodological differences between the surveys, since the previous study considered images obtained between April and June 2024 a period of lower spectral contrast between irrigated and nonirrigated areas—which makes it difficult to precisely delineate irrigated perimeters. Thus, the greater temporal and spatial coverage adopted in this work allowed for a more complete and up-to-date identification of the equipment in operation.

Figure 1. Distribution of the area equipped with center pivot irrigation systems by municipality in the state of Rio Grande do Sul in 2025.



Source: Author (2025)

According to Guimarães and Landau (2020), automation techniques for recognizing irrigation equipment using remote sensing have not yet surpassed visual interpretation techniques because of the absence of uniform spectral patterns, as well as the existence of circular rainfed crops, which can lead to inaccuracies in automated classification. This limitation reinforces the importance of supervised manual mapping, such as that applied in this study.

When the irrigated area was related to the municipal agricultural area (IBGE, 2023), the municipalities with the greatest relative irrigated area were Chapada (18.1%), Santo Augusto (12.8%), Salto do Jacuí (11.8%), Boa Vista do Incra (10.8%), Boa Vista do Cadeado (10.7%), and Cruz Alta (10.5%) (Table 1). These values indicate that in certain regions of the state, center pivot irrigation already represents a significant fraction of the productive area, indicating a high level of agricultural mechanization. Table 1 presents the irrigated area; the number of pivots; and the average, minimum, and maximum dimensional characteristics per municipality, as well as the relative irrigated area. A significant range in the size of the equipment is observed, varying from 1.2 ha to 230.7 ha, which reflects the diversity of the production scale between small properties and large agricultural enterprises.

Table 1. Number of center pivots, total irrigated area (ha), average and maximum (max.) area of center pivots (ha) and relative area occupied by center pivots in the main municipalities of Rio Grande do Sul in 2025.

Municipalities	**Number of Pivots**	**Irrigated area**	**Average area**	**Max. area**	**Relative area occupied by pivots**
		(there is)	**(there is)**	**(there is)**	**(%)**
São Borja	267	17,383.04	65,105	193.7	10.1
Cruz Alta	257	15,495.30	60,293	198.5	10.5
São Luiz Gonzaga	260	13,503.10	51,935	157.5	9.9
Palmeira das Missões	201	11,678.10	58,101	150.2	6.4
Santa Bárbara do Sul	185	10,617.89	57,394	175.8	8.8
São Miguel das Missões	164	9,888.71	60,297	169.0	8.0
Tupanciretã	131	9,084.06	69,344	206.0	4.8
Jóia	115	7,800.22	67,828	161.7	6.6
Santo Augusto	123	7,020.84	57,080	152.3	12.8
Santo Antônio das Missões	118	6,661.69	56,455	161.3	7.2
Itaqui	80	6,603.44	82,543	176.7	4.9
Boa Vista do Cadeado	87	6,498.29	74,693	205.4	10.7
Alegrete	86	6,229.07	72,431	230.7	3.4
Dom Pedrito	69	5,010.78	72,620	185.3	2.4
Júlio de Castilhos	95	4,725.97	49,747	152.1	3.8
Boa Vista do Incra	76	4,698.85	61,827	161.2	10.8
Maçambara	57	4,609.36	80,866	188.9	4.5
Bossoroca	90	4,511.70	50,130	141.7	6.7
São Gabriel	57	4,404.96	77,280	245.5	2.6
Fortaleza dos Valos	108	4,174.74	38,655	163.3	8.3
Ibirubá	113	3,970.82	35,140	127.1	6.1
Chiapetta	67	3,967.61	59,218	172.4	6.3
Eugênio de Castro	75	3,846.45	51,286	171.5	7.6
Salto do Jacuí	92	3,837.60	41,713	105.9	11.8
Chapada	72	3,539.81	49,164	131.8	18.1
Entre-Ijuís	66	3,366.59	51,009	165.6	5.3
Cachoeira do Sul	68	3,339.07	49,110	163.3	2.2
Bagé	58	3,289.18	56,710	141.0	6.4
Coronel Bicaco	61	3,277.77	53,734	131.3	6.7
Pejuçara	61	3,092.70	50,700	151.4	5.9
Outros municípios (131)	1684	79,608.89	47,273	-	-
Grand total	5043	275,736.60	54.68		

Source: Author (2025). *Relative area by municipality considering the percentage of irrigated area in relation to the area occupied by permanent and temporary crops, taking into account IBGE data (2023).

With respect to the analysis of hydrographic basins, Table 2 shows that the greatest concentrations of irrigated area are in the basins of Alto Jacuí (46,818.05 ha), Rio Ijuí (46,714.37 ha), Rio Piratinim (46,440.38 ha), Rio Ibicuí (29,232.2 ha), Rio

Turvo (27,159.33 ha) and Rio Butuí-Icamaquã (22,598.26 ha). These basins represent more than 80% of the area irrigated by center pivots in Rio Grande do Sul, the concentration of which can be seen in Figure 2.

However, although the Upper Jacuí Basin has the greatest number of installed systems, its total irrigated area is similar to that of the Piratini and Ijuí River Basins, indicating a smaller average area per pivot. This pattern is associated with the more undulating topography and land fragmentation of Upper Jacuí, which limit the installation of large-radius systems. In the Piratini and Ijuí Basins, the gently undulating relief and more extensive properties favor pivots with a larger irrigated radius and better use of the available water potential.

Table 2. Distribution of pivot irrigation in the hydrographic basins of Rio Grande do Sul, number of pieces of equipment, irrigated area (ha), average area (ha), and growth (%) and expansion (ha) of the irrigated area over the past five and ten years.

Bowl Hydrographic	No. Pivots	Irrigated area (there is)	Average area (ha)	Growth (%)		Expansion (there is)	
				10 years	5 years	10 * years	5 ** years
Rio Alto Jacuí	1.037	46,818.05	45,148	98	37	23,142.9	12,625.4
Rio Ijuí	861	46,714.37	54,256	120	37	25,436.5	12,647.2
Rio Piratinim	843	46,440.38	55,089	173	48	29,457.3	15,015.9
Rio Ibicuí	415	29,232.20	70,439	214	57	19,933.9	10,569.5
Rios Turvo	530	27,159.33	51,244	72	29	11,336.3	6,085.5
Rio Butuí-Icamaquã	331	22,598.26	68,273	243	74	16,005.7	9,627.6
Rio da Várzea	335	16,792.15	50,126	165	34	10,461.1	4,215.5
Rio Santa Maria	155	10,976.97	70,819	387	79	8,723.9	4,832.1
Rio Baixo Jacuí	120	6,175.39	51,462	91	11	2,935.4	636.9
Mirim - São Gonçalo	63	5,400.27	85,719	896	76	4,858.3	2,330.8
Rio Negro	77	4,495.65	58,385	619	85	3,870.7	2,061.8
Rio Passo Fundo	91	4,077.32	44,806	207	66	2,751.1	1,624.5
Rio Vacacaí	70	3,478.30	49,690	233	68	2,434.7	1,403.7
Rios Apauê-Inhandava	51	2,010.99	39,431	348	64	1,561.8	786.7
Rio Quaraí	16	1,165.48	72,842	105	4	597.4	41.1
Rios Taquari-Antas	27	985.25	36,491	61	49	371.6	325.8
Rio Camaquã	11	654.83	59,530		81	654.8	293.7
Rio Pardo	4	215.70	53,925	36	39	56.7	60.3
Rio Guaíba	2	193.90	96,952	0	0	0.0	0.0
Rio Gravatai	4	151.81	37,951	34	1	38.8	2.1
Grand total	**5.043**	**275,736.6**	**54.7**	**148**	**45**	**164,613**	**85.186**

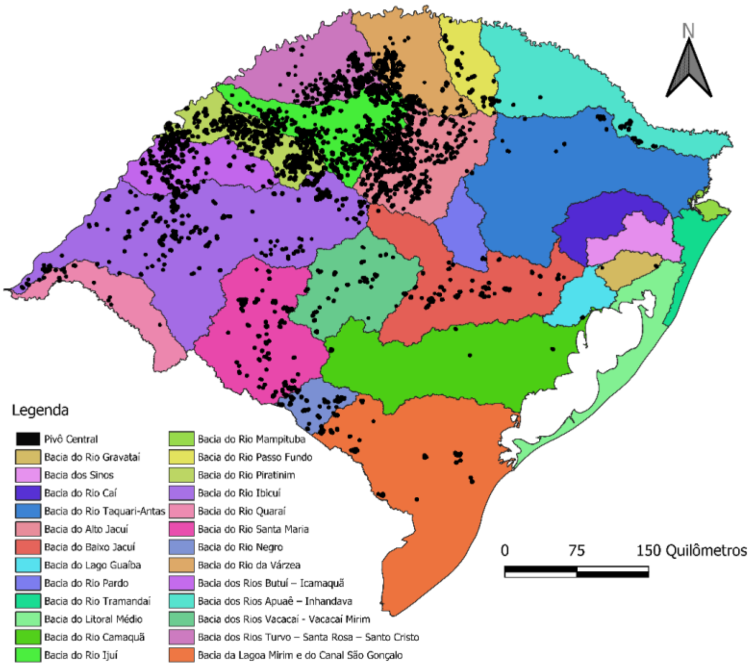
Source: Author (2025) *Adapted from Martins *et al.* (2016) **Adapted from Martins *et al.* (2021)

The river basin that experienced the greatest expansion of effective irrigated area was that of the Piratinim River, with an increase of almost 30,000 ha in the last 10 years. This growth may be directly linked to the use of preexisting reservoirs previously used for irrigated rice cultivation by flooding. This process is particularly evident in the municipalities of São Borja and Dom Pedrito, which are among those with the largest areas irrigated by center pivots and flooded rice (RIO GRANDE DO SUL, 2025).

In the state as a whole, an average annual increase of 329 irrigation systems and 16,464.07 hectares was observed between 2015 and 2025 in Rio Grande do Sul, corresponding to a cumulative expansion of 148% in ten years. If this expansion trend continues in the coming years, Rio Grande do Sul could double its current area irrigated by center pivots by approximately 17 years. Although this rate is lower than that observed in regions such as western Bahia, which showed an increase of almost 50,000 hectares annually between 2022 and 2024 (GUIMARÃES; LANDAU, 2024), the scenario in Rio Grande do Sul demonstrates a consistent and sustained growth trend, which is conditioned mainly by water availability and overcoming structural limitations, especially those related to the supply of electricity in rural areas. In this context, the National Water and Basic Sanitation Agency (ANA, 2021) estimates that the state still has approximately 1.9 million hectares available, considering different irrigation methods, which demonstrates ample room for sustainable expansion.

The increase in the area irrigated by center pivot systems in Rio Grande do Sul reflects not only technological advancement but also structural changes in the regional production base. The growing adoption of this form of irrigation has allowed for greater stability in grain production, especially for soybeans and corn, which are highly sensitive to water deficit. In 2025, soybean productivity in irrigated areas was approximately 80% higher than that in rainfed areas; in the case of grain corn, the average gain was 63%, according to official data (RIO GRANDE DO SUL, 2025).

Figure 2. Geographic location of center pivot irrigation systems in relation to the main hydrographic basins of the state of Rio Grande do Sul in 2025.



Source: Author (2025)

On the other hand, the annual expansion rate of irrigated areas slowed in the last cycle, influenced by financial limitations and adverse climatic events associated with the La Niña phenomenon and rainfall instabilities. Although severe droughts increase the demand for irrigation, highlighting the importance of water supplementation, their effects on agricultural productivity result in significant economic losses, compromising producers' cash flow. Successive crop failures in the 19/20, 21/22 and 22/23 seasons limited the capacity for investments in water and electricity infrastructure. In response, the National Monetary Council authorized, in 2025, the exceptional expansion of the limits for renegotiating rural debt in Rio Grande do Sul, recognizing that the scarcity of financial resources and production losses compromised the continuity of investments in agricultural infrastructure, such as irrigation (BRASIL, 2025). These losses have significantly reduced the purchasing power of the agricultural sector, limiting investments in infrastructure, including the acquisition of center pivot irrigation systems, whose high initial cost and financing requirements hinder widespread adoption. Even with the low returns obtained in recent harvests, state incentive/economic subsidy programs aimed at sprinkler irrigation have helped producers invest in the technology (RIO GRANDE DO SUL, 2024).

In addition to irrigation-focused programs, Rio Grande do Sul faces another significant challenge in enabling the expansion of center-pivot irrigation: the supply of electricity in sufficient quantity and quality in rural areas. Among the electrified rural properties, only 37% have three-phase power, representing a significant obstacle to the installation of larger irrigation systems. In many cases, the financial investment required from producers by electrification cooperatives for the expansion of the three-phase network exceeds their financial limits, making the investment project unfeasible. In this regard, the state government created the “Energia Forte no Campo” (Strong Energy in the Countryside) program, which aims to promote investments with energy cooperatives to bring three-phase power networks to vital points in rural areas through analysis of the best submitted projects (RIO GRANDE DO SUL, 2022).

Given these findings, the need for further studies on the state's effective irrigable potential becomes evident. Taking into account scenarios of climate variability, water availability, and electrical infrastructure. The integration of public policies on irrigation, energy, and rural credit, coordinated at the state level, is fundamental to promoting the planned and sustainable expansion of center-pivot irrigation and ensuring productive resilience and agricultural competitiveness in the face of extreme climate events affecting Rio Grande do Sul.

6 CONCLUSION

The survey identified 5,043 center pivot irrigation systems distributed across 161 municipalities in Rio Grande do Sul, totaling 275,700 hectares of irrigated land. The highest concentrations were observed in the northwestern and southwestern regions, particularly in the municipalities of São Borja, Cruz Alta, São Luiz Gonzaga, Palmeira das Missões, and Santa Bárbara do Sul, which together account for approximately one-quarter of the total irrigated area. Approximately 80% of the area irrigated by center pivot systems is concentrated in five river basins, especially the Upper Jacuí (46,800 ha) and the Ijuí River (46,700 ha) basins.

The results indicate a slowdown in the rate of expansion of irrigated areas, which is attributed mainly to the financial and energy constraints faced by producers and intensified by successive droughts. Despite these obstacles, the state still has great potential for the sustainable expansion of irrigation, provided that public policies aimed at water and energy planning, access to rural credit, and modernization of electrical infrastructure are strengthened. The integration of these actions is essential for ensuring the efficient use of water, reducing climate vulnerabilities, and consolidating irrigation as an instrument for productive stability and regional economic development.

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