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MAPEAMENTO DA ÁREA IRRIGADA POR PIVÔ CENTRAL EM NÍVEL DE BACIA HIDROGRÁFICA NO EXTREMO SUL DO BRASIL

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1 RESUMO

O pivô central é um mecanismo de inovação na agricultura irrigada, por aliar eficiência de aplicação à automação e devido à menor demanda de energia quando comparado aos métodos tradicionais. Assim, este estudo teve como objetivo mensurar as áreas irrigadas por pivô central, em nível de município e bacias hidrográficas (BH), do estado do Rio Grande do Sul. Imagens de satélite de média e alta resolução e imagens derivadas do Google Earth-Pro foram utilizadas para mapear a área irrigada em cada BH e município. Cada área foi identificada visualmente, marcando-se o centroide e delineando os limites externos da área irrigada. Foram detectados 3.208 sistemas, o que resultou em uma área irrigada total acumulada de 190.550,30 ha, com média de 58,39 ha. Os pivôs centrais estão distribuídos em 20 BH e 152 municípios. Cerca de 87% da área dos pivôs centrais concentra-se em sete BH: Alto Jacuí, Ijuí, Piratinim, Turvo-Santa Rosa e Santo Cristo, Ibicuí, Butuí-Icamaquã e rios Várzea. A maior área irrigada está concentrada nas BH de Alto Jacuí (34.192,6 ha) e Ijuí (34.067,2 ha). Os municípios com maior área irrigada são Cruz Alta (12.992,6 ha), São Borja (10.336,2 ha) e São Luiz Gonzaga (10.061,7 ha).

Palavras-Chave: irrigação, sensoriamento remoto, recursos hídricos.

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2 ABSTRACT

The central pivot is an innovation mechanism in irrigated agriculture, by combining water application efficiency with automation and due to less energy demand when compared to traditional methods. Thus, this study measured the areas irrigated by the central pivot, at the municipality and watershed level, in the State of Rio Grande do Sul. Medium and high-resolution satellite images and images derived from Google Earth-Pro were used to map the irrigated area in each municipality inside the watershed. Each area was visually identified,

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marking the centroid and outlining the external boundaries of the irrigated area. 3,208 systems were detected and delineated, which resulted in a cumulative irrigated area of 190,550.30 ha, with an average of 58.39 ha. The center pivots are distributed in 20 watersheds and 152 municipalities. Around 87% of the central pivots area were concentrated in seven watersheds: Alto Jacuí, Ijuí, Piratinim, Turvo Santa Rosa and Santo Cristo, Ibicuí, Butuí-Icamaquã, and Várzea rivers. The largest irrigated area is concentrated in the Alto Jacuí (34,192.6 ha), and Ijuí (34,067.2 ha) watersheds. The municipalities with the largest irrigated area were Cruz Alta (12,992.6 ha), São Borja (10,336.2 ha), and São Luiz Gonzaga (10,061.7 ha).

Keywords: irrigation, remote sensing, water resources

3 INTRODUCTION

Irrigation uses 70% of the world's available water resources (UNESCO, 2018), reaching 90% in arid regions (MOLDEN, 2007), and is also responsible for approximately 30% of total energy demand (FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, 2014). Water and energy are important sources for the economic and social development of a community or region, while they are also the basis for irrigation (TARJUELLO et al., 2015), especially pressurized irrigation.

The implementation of irrigation systems is essential to ensure food security, stability, and production diversification (SILVA, 2020). However, knowledge of water demand and use in irrigated systems must be updated frequently to enable adequate monitoring and management of water resources. In this context, the combined use of remote sensing techniques can improve water resource management at different spatial and temporal scales, enabling the monitoring of large irrigated areas (SILVA; MANZIONE; ALBUQUERQUE FILHO, 2018).

Given the complexity and continuous expansion of irrigation, geotechnology-based surveys are among the most promising recent experiences, in addition to offering significant opportunities for expansion (AGÊNCIA NACIONAL DE ÁGUAS, 2017a). The state of Rio Grande do Sul (RS) contributes approximately 11% of national grain production (IBGE, 2017). Its agricultural base is due to its geographic location and climatic conditions, which exhibit significant seasonal variation, characteristic of temperate, humid subtropical climates (ALVARES et al., 2013). In the 2019/20 harvest, with the exception of irrigated rice, other crops experienced reduced yields due to reduced rainfall between November and March (CARDOSO et al., 2020). The variability in the distribution of rainfall results in yield losses due to water deficiency, meaning that different management strategies (BATTISTI; SENTELHAS, 2017; MATZENAUER; RADIN; CARGNELUTTI FILHO, 2018) and the use of supplementary irrigation, especially in the most critical periods, are often needed (MONTOYA et al., 2017) to circumvent or avoid the risks inherent to productive activity.

Events such as the severe droughts of 2004/2005, 2011/12 (NOBRE et al., 2016) and 2019/20 were the causes of the reduction in agricultural production in many regions of the state, resulting in a significant increase in the area irrigated by central pivots after each of these events (MARTINS et al., 2016). One of the paradigms of irrigation use, which goes far beyond increased productivity, is the tolerance and/or reduction of uncertainties and risks associated with agricultural activity (ENGLISH; SOLOMON; HOFFMAN, 2002).

The central pivot has been adopted in irrigated areas because of its robustness, versatility, uniformity of application (CHAKRABORTY; KHOT; PETERS, 2020), energy efficiency (TARJUELLO et al., 2015), reduced need for labor (ROGERS et al., 2017) and possibility for the application of agrochemicals and fertilizers (KING; WALL; KARSKY, 2009).

The area irrigated by central pivots in the RS has increased significantly in the last decade, jumping from approximately 76,000 ha in 2013 (LANDAU; GUIMARÃES, 2014) to 111,000 ha in 2016 (MARTINS et al., 2016), generating an increase of 58.6% in just 5 years and an increase of 146% compared with the 2006 agricultural census (IBGE, 2017). Despite the intense work developed by the National Water Agency (ANA) and the Brazilian Agricultural Research Corporation (EMBRAPA) in mapping agriculture irrigated by central pivots in Brazil on the basis of high- and medium-resolution satellite images (AGÊNCIA NACIONAL DE ÁGUAS, 2019), there is still considerable uncertainty about the exact area irrigated in the RS by central pivots, as also documented by Martins et al. (2016). The discrepancies can be attributed to the difficulties in mapping the precise spatial distribution of irrigated areas due to the dynamics of the landscape in Rio Grande do Sul (without a characteristic dry period) and the characteristics of the supplementary irrigation carried out in these areas.

Remote sensing, combined with other geotechnologies, allows for significant gains in scale in surveys related to irrigated agriculture. Currently, geoprocessing techniques and tools, such as the identification and quantification of irrigated areas (SANTOS et al., 2015; FREITAS; ANDRADE 2017; RIBEIRO; GONÇALVES; PINHEIRO, 2019), the measurement of crop water demand (SCHIRMBECK et al., 2017; SILVEIRA et al., 2020), and the spatial analysis of agricultural production areas with irrigation systems (SILVEIRA et al., 2013; DEMARQUI; DEMARQUI, 2020), are applicable in agriculture.

Given this scenario, the objective of the study was to map and quantify, on the basis of satellite images, the area irrigated by central pivots at the level of river basins and municipalities in Rio Grande do Sul.

4 MATERIALS AND METHODS

The study focused on southern latitudes parallel to 27°03'42" and 33°45'09" and western longitudinal meridians 49°42'41" and 57°40'57" in the state of Rio Grande do Sul. Satellite images obtained by Google Earth Pro for the entire state were observed, specifically the Landsat 8 OLI/TIRS satellite image archives (UNITED STATES GEOLOGICAL SERVICE, 2020) and the database of the central pivot survey carried out in 2017 by EMBRAPA in partnership with ANA (AGÊNCIA NACIONAL DE ÁGUAS, 2017b).

Google Earth Pro images from the Landsat 8 OLI/TIRS satellite image archives (UNITED STATES GEOLOGICAL SERVICE, 2020) with a resolution of 30 m were used. Initially, spatial overlay was performed with a georeferenced digital map of the boundaries of each municipality (IBGE, 2007) and a georeferenced digital map of the state's hydrographic basins (RIO GRANDE DO SUL, 2020), which were imported into Google Earth Pro. Each irrigation system was identified by interpreting the images as described by Freitas and Andrade (2017), and band fusion was used to improve resolution. Since the study region does not have a characteristic dry season, which makes it difficult to identify irrigated areas, the methodology of cross-referencing data with surface observations, information from producers, technical consultants and companies supplying equipment for central pivots was also used, aiming at the effective identification of the equipment (GUIMARÃES; LANDAU, 2011).

In Google Earth Pro, each pivot was identified with the municipality and watershed in which it was located. Since the central pivot could be located in more than one watershed or municipality, the watershed and municipality where the largest fraction of the central pivot area was located were considered. To determine the effectively irrigated area of each pivot, the pivots were marked in Google Earth Pro via the *add path tool for sector pivots or the circle* tool for full-turn central pivots, drawing a polyline over each irrigated area. After the respective identifications, a thorough analysis of the respective images and the files saved in the KML extension was performed.

The ArcMap toolbox of ArcGIS 10.1.2 software was used, and the files generated in Google Earth Pro were converted to *shapefiles* via the *KML tool. Layer.* Later, this *shapefile* was converted from the GCS-WGS 1984 coordinate system to SIRGAS2000 via the *ArcToolBox > Data Management Tools > Projections function and ArcMap 's Transformations > Project*. A data management tool was then used to manipulate and convert the *shapefile containing the* pivot polyline geometry into polygons. To determine the area of each irrigated polygon and the coordinates of each pivot center, *two* fields in hectares and the latitude and longitude coordinates of the centroid were inserted into the *shapefile* attribute table, and these fields were determined via the Calculate Geometry function.

Data processing and map production were performed via ArcGIS 10.2.1, a software package that includes geostatistical tools and the interpolator chosen for this study. In ArcMAP, the information was geoprocessed, and thematic maps of the distribution, concentration, and location of pivot-irrigated areas were generated to describe the spatial distribution of irrigated areas in the different basins.

5 RESULTS AND DISCUSSION

In this survey, 3,208 central pivots were identified, irrigating an area of 190,055.3 ha. The pivots are distributed among 156 municipalities, which corresponds to 31% of the municipalities in the state. The municipalities with the largest irrigated area are Cruz Alta (198 pivots, 12,992.6 ha), São Borja (157 pivots, 10,366.2 ha), São Luiz Gonzaga (178 pivots, 10,061.7 ha), Palmeira das Missões (144 pivots, 9,076.4 ha), São Miguel das Missões (96 pivots, 6,454.2 ha), Tupanciretã (85 pivots, 6,302.0 ha) and Santo Augusto (104 pivots, 6,218.9 ha).

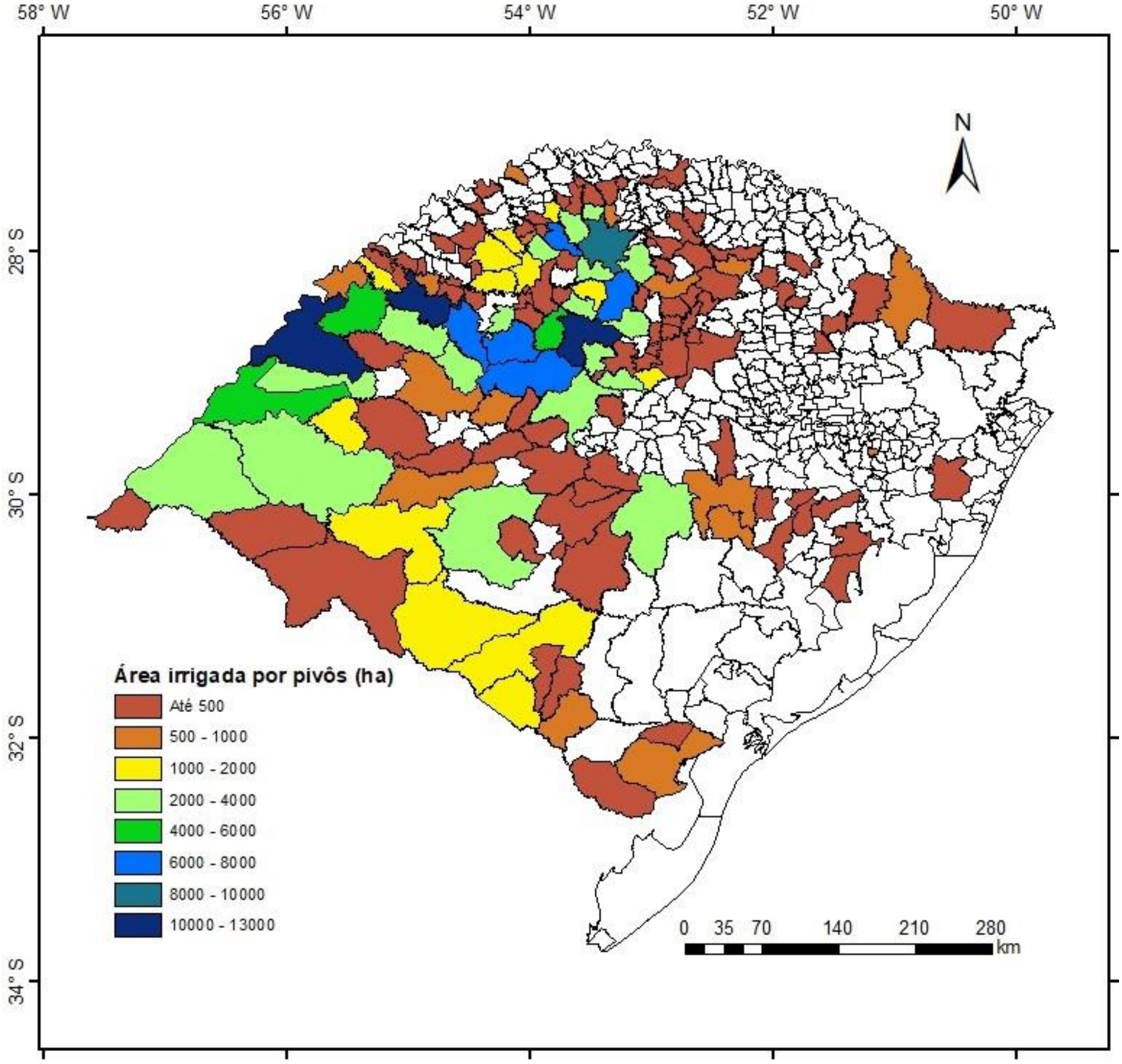
Table 1 presents the twenty municipalities with the largest irrigated areas in the state of Rio Grande do Sul. These totals cover 109,750 ha, representing 57.7% of the total area irrigated by central pivots in the state. The breakdown of the irrigated area in the different municipalities, with areas ranging from ≤500 to ≥10,000 hectares, is presented in Figure 1. Among the municipalities with pivot irrigation in the state of Rio Grande do Sul, 46 have irrigated areas exceeding 1,000 hectares.

With respect to the distribution of areas across Belo Horizonte, the municipalities with the greatest spatial distribution of central pivot irrigation are concentrated in the physiographic regions of Planalto Médio, Alto Uruguai, and Missões, which are located in the Northwest, Southwest, and Central-Western mesoregions. Currently, soybeans, rice, corn, and wheat are the main crops cultivated in this region, both in rainfed and irrigated areas, and are the regions with the largest cultivated areas and production volumes (FEIX; LEUSIN JÚNIOR, 2019). In contrast, rice crops are fully irrigated, although almost entirely by flood irrigation systems and, occasionally, by sprinkler irrigation systems in initial studies aimed at saving water and labor in lowland areas (STRECK et al., 2019). Currently, the projected area cultivated with rice for the 2020–2021 harvest is 970 thousand ha (INSTITUTO RIO GRANDENSE DE ARROZ, 2020).

Table 1. Irrigated area (ha), number of pivots and average, maximum and minimum areas of pivots (ha) in the main municipalities that use pivot irrigation systems in the state of Rio Grande do Sul.

Municipality	**Area (there is)**	**N. Pivots**	**Average area (there is)**	**Max area (there is)**	**Min. area (there is)**
Cruz Alta	12992.6	198	65.6	198.6	6.0
Saint Borja	10366.2	157	66.0	193.9	3.5
Saint Louis Gonzaga	10061.7	178	56.5	157.9	5.4
Palm Tree of the Missions	9076.4	144	63.0	150.3	9.0
Saint Michael of the Missions	6454.2	96	67.2	169.3	13.8
Tupanciretã	6302.0	85	74.1	206.4	12.3
Saint Augustus	6218.9	104	59.8	152.4	11.8
Jewel	6070.1	76	79.9	162.0	12.7
Boa Vista do Cadeado	4923.7	61	80.7	205.6	26.9
Santa Barbara do Sul	4749.0	73	65.1	175.9	11.0
Itaqui	4410.9	55	80.2	163.7	11.9
Boa Vista do Incra	3561.6	47	75.8	161.3	12.3
Saint Anthony of the Missions	3382.4	54	62.6	161.9	7.6
Saint Gabriel	3136.7	35	89.6	246.0	10.5
Chiapetta	3126.7	50	62.5	172.6	10.2
Santa Barbara do Sul	3109.8	54	57.6	128.9	19.0
Southern Waterfall	3106.3	59	52.6	163.3	8.9
Jacuí Falls	3049.0	66	46.2	105.9	11.6
Valos Fortress	2829.9	60	47.2	163.4	2.0
Plateau	2822.7	56	50.4	131.9	8.0

Figure 1. Distribution of areas equipped with central pivots by municipalities in the state of Rio Grande do Sul in 2020.



Considering the survey by Martins et al. (2016), a significant increase was observed between 2015 and 2020 for the municipalities of São Borja, São Luiz Gonzaga (in dark blue in Figure 1), and Palmeira das Missões (in turquoise blue in Figure 1), with increases in the irrigated area of 127%, 135%, and 134%, respectively. This is due mainly to the increase in technologies used to achieve high productivity and modernization of agricultural activity in these regions (GELATTI et al., 2020). A considerable increase in the number of municipalities with areas irrigated by pivots was also observed in the southwest region of the state (Fronteira Oeste and Campanha), whose region is traditionally rice growing, representing 45% of the area cultivated with rice in the state (INSTITUTO RIO GRANDENSE DE ARROZ, 2020). This expansion occurred primarily due to a change in land use in these regions, with the incorporation of crop rotation with soybeans, particularly to control difficult-to-manage weeds in rice (GIACOMELI et al., 2017). The region is well equipped with reservoirs, as well as infrastructure for capturing and transporting water used in rice cultivation, and is therefore a region with the potential for significant expansion of mechanized irrigation.

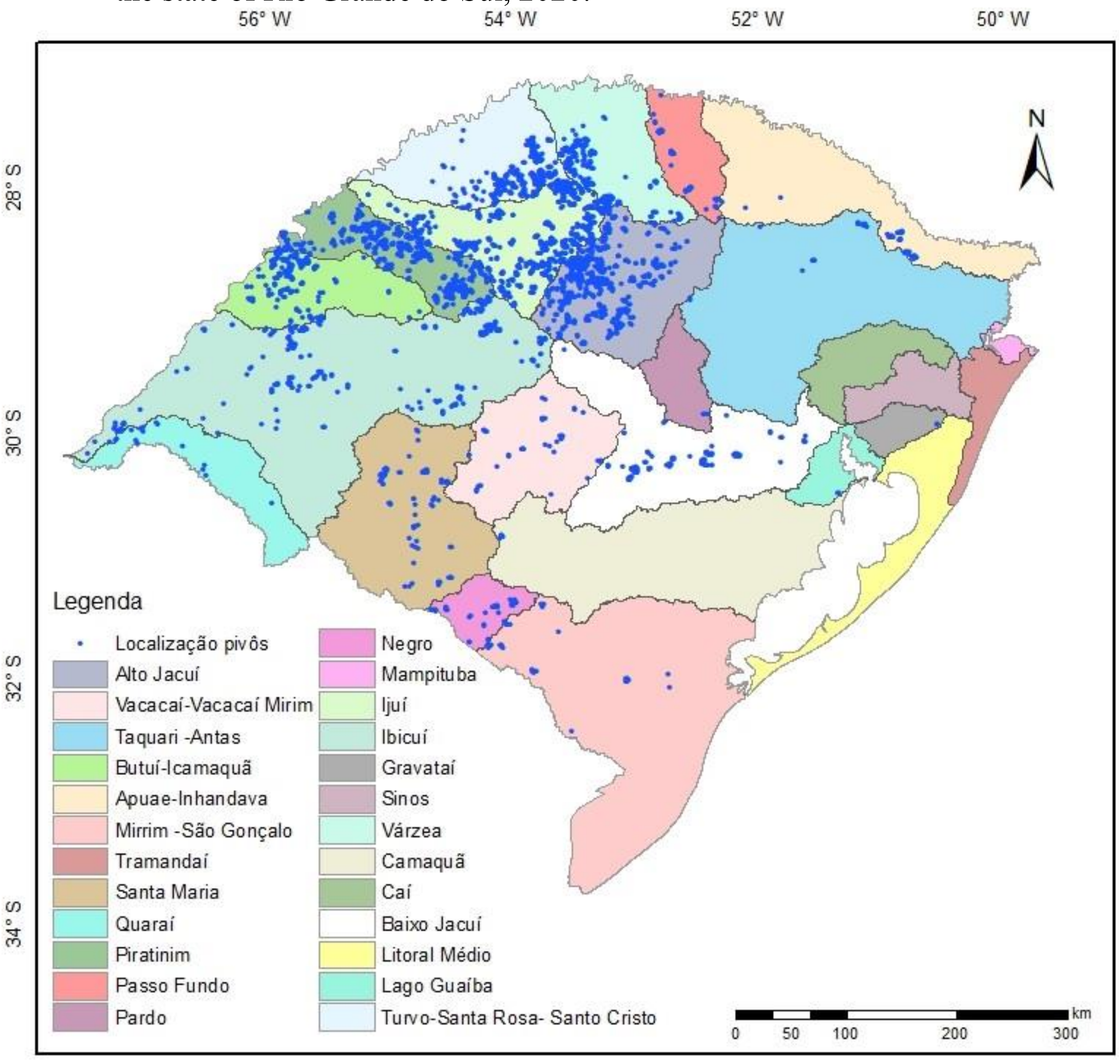
A high concentration of central pivots was observed in the physiographic regions of the middle plateau, upper Uruguay, and Missões (northwest in Figure 1), given that the local relief favors the installation of this irrigation system. The predominance of flat or slightly undulating areas favors the implementation of central pivots, which explains the high concentration of central pivots in the Brazilian Cerrado (SARAIVA et al., 2020). In the study on the concentration of central pivots in Brazil carried out by Landau et al. (2013), the authors reported a relatively high concentration of pivots in regions where the relief varies from flat to moderately undulating.

The pivots are distributed in 20 hydrographic basins of the state (Figure 2). However, approximately 87% of the areas irrigated by central pivots were concentrated in seven hydrographic basins, corresponding to the irrigated area and the percentage in relation to the total irrigated area: the Alto Jacuí River (34,192.6 ha and 17.9%), the Ijuí River (34,067.2 ha and 17.9%), the Piratinim River (31,424.5 ha and 16.5%), the Turvo-Santa Rosa-Santo Cristo River (21,073.8 ha and 11.1%), the Ibicuí River (18,662.7 ha and 9.8%), the Butuí-Icamaquã River (12,970.7 ha and 6.8%) and the Várzea River (12,576.7 ha and 6.6%) (Figure 2).

The size of the pivots varied considerably, with areas ranging from 1.0 to 246 ha observed. The size and number of towers and their length are lower than the national average (NATIONAL WATER AGENCY, 2019). These differences can be attributed to terrain characteristics and the presence of obstacles (buildings, legal reserves, and/or distance from the water source, as well as the difference in elevation between the center of the pivot and the intake). The average size of the central pivots found in this study was 59.4 ha, which was slightly smaller than that reported in other regions of the country. As observed by Guimarães and Landau (2011), in 2010, the average size of pivots was 68 ha (Minas Gerais), 73.37 ha (Goiás) (GUIMARÃES; LANDAU, 2014) and 68.65 for Bahia (LANDAU; GUIMARÃES; SOUZA, 2014).

The pivots with the largest average irrigated area were identified in the Guaíba Lake watersheds, with an average of 96.8 ha, and the Mirim System, with an average of 82.95 ha. However, they have a low number of pivots (2 and 37 pivots, respectively). Higher average areas irrigated by pivots were found in the Ibicuí River (73.8 ha) and Butuí-Icamaquã (70.5 ha) watersheds, which are watersheds with a greater number of pivots. In these locations, the flatter relief and the land structure, with larger properties, allow the installation of larger pivots. Approximately 47% of pivots in the RS have an irrigated area between 20 and 60 ha, while the highest frequency of area irrigated by pivots occurs in the range of 20--30 ha and 30--40 ha, with 12% and 12.2%, respectively.

Figure 2. Geographic location of central pivots in relation to the main hydrographic basins of the state of Rio Grande do Sul, 2020.



Compared with data from previous mapping studies, the current survey revealed a significant and persistent increase in the irrigated area. In a study by Martins et al. (2016), considering data up to March 2015, 1,753 pivots and an area of 111,122.0 ha were identified, an area slightly larger than the ANA/EMBRAPA survey for the period up to 2017 (110,859.0 ha) (NATIONAL WATER AGENCY, 2019). These differences are due to the methodology adopted by ANA (2019), in which the interpretation of the images was performed by human experts, using satellite images from periods that were characteristically drier in each region. However, this methodology, while reliable, is flawed because it fails to differentiate between central pivot and rainfed crops, especially in seasons where there is little or no water stress, as was the case in Rio Grande do Sul between 2015 and 2019. Thus, accurate identification of the irrigated (or partially irrigated) circle will still depend on manual identification, which is based on the interpolation of high-resolution satellite imagery combined with knowledge of the regions under study. According to Guimarães and Landau (2011), pivot identification via Google Earth is possible because it is a combination of products generated by the American Space Agency

(NASA), which is constantly updated with high-resolution imagery.

Compared with data from Martins et al. (2016), which used the same methodology used in this study, there was an increase of approximately 50% in the number of pivots installed in the state in the last 5 years (Table 2), resulting in a 70% increase in the irrigated area, with the incorporation of 291 pivots and approximately 15,885.0 ha per year, between 2015 and 2020.

Table 2. Number of pivots, total area, average area of pivots and growth of the irrigated area from 2015--2020 in the river basins of the state of Rio Grande do Sul.

Hydrographic basin	N. Pivots	Pivot area (ha)				Increase 2015 * /20 (%)
		Total	Average	Bigger	Minor	
Alto Jacuí	662	34192.6	51.7	198.6	1,2	44.4
Ijuí River	554	34067.2	61.5	205.6	1.5	60.1
Piratinim River	511	31424.5	61.5	171.4	5.4	86.8
Turvo-Sta . Rosa-Sto . Cristo	372	21073.8	56.7	172.6	3.8	33.2
Ibicuí River	253	18662.7	73.8	206.4	9.7	100.7
Butuí-Icamaquã River	184	12970.7	70.5	193.9	3.5	96.7
Floodplain River	236	12576.7	53.3	154.7	4.9	98.6
Santa Maria River	83	6144.9	74.0	246.0	6.3	172.7
Lower Jacuí	100	5538.5	55.4	163.4	8.9	70.9
Children's System - São Gonçalo	37	3069.5	83.0	206.4	22.5	466.3
Passo Fundo River	44	2452.8	55.7	134.9	5.8	85.0
Black River	42	2433.9	58.0	144.5	11.7	289.4
Vacacaí River - Vacacaí Mirim	47	2074.6	44.1	115.2	1.0	98.9
Apauê-Inhandava Rivers	35	1224.3	35.0	101.0	9.9	172.5
Quaraí River	15	1124.4	75.0	134.7	31.6	97.9
Taquari-Antas Rivers	19	659.4	34.7	121.8	9.8	7.5
Camaquã River	6	361.1	60.2	99.9	31.2	
Guaíba River	2	193.8	96.9	98.7	95.1	0.0
Rio Pardo	3	155.4	51.8	64.4	37.7	0.0
Gravataí River	3	149.7	49.9	71.6	34.2	32.5
Total	3208	190550.3				71.5

* **Source**: Martins et al. (2016)

The significant expansion of the state's irrigated area began in 2012, driven by the impacts of the drought that occurred that year (NOBRE et al., 2016). This was driven by the approval of the State Irrigation Law in 2013 and the establishment of the Rio Grande do Sul State Irrigation Policy, the Irrigation Master Plan in the Context of Multiple Water Uses, the State Irrigation Policy Management Council, and the State Irrigation Fund. Furthermore, the State Program for the Expansion of Irrigated Agriculture aimed to encourage the expansion of irrigated areas as a way to increase the sustainability of primary production in the state (RIO GRANDE DO SUL, 2017).

The expansion of the area irrigated by central pivots in Rio Grande do Sul will also function as a type of agricultural insurance against climate risks, especially prolonged dry spells. The high degree of automation of these systems and the uniformity in irrigation water distribution combine with reduced operating costs related to labor (increasingly scarce and expensive) and energy (PEREIRA et al., 2015). The current sprinkler packages used in pivots and the continuous tower alignment system, which allows adjustments between energy consumption and demand as the pivot moves, are largely responsible for optimizing the efficiency of water and energy use. According to Tarjuelo et al. (2015), the use of continuous alignment can reduce electricity consumption by up to 35%, although this depends on the pivot brand/model, pumping system, terrain characteristics, and other factors.

Brazil has experienced significant growth in the area irrigated by central pivots in recent decades, especially since 2010 (NATIONAL WATER AGENCY, 2019). In 1985, there were 363 identified points irrigating an area of 31,000 hectares. In 2000, 490,500 hectares were equipped for irrigation at 6,680 points, tripling to 1,476,000 hectares at 23,181 points. in 2017. The current area irrigated by this irrigation system is 47 times larger than the area mapped in 1985 (NATIONAL WATER AGENCY, 2019). Similar growth was also reported by Demarqui and Demarqui (2020) for the state of Mato Grosso, where they reported an annual variation of 8.07% in the area irrigated by pivots. In this state, the growth was on the order of 231.25% for the period from 2004--2015, a value much higher than the Brazilian average, which was 59.09% for the same period.

Another factor directly related to the significant expansion in the installation of irrigation systems is the financing lines for costs and investments offered by development banks, since the agricultural sector requires large financial investments, according to Demarqui and Demarqui (2020), in addition to easy access to credit. For Guimarães and Landau (2011), the increase in the area irrigated by central pivots can be attributed to the country's growing agricultural production, driven by the high prices of agricultural commodities on the international market and increased demand in the domestic market.

According to the National Water Agency (2017a), central pivot sprinkler systems are expected to account for the majority of the increase in irrigated area. Projections from this agency indicate that pivots will increase from 19.9% to 28.6% by 2030, becoming the primary irrigation system in Brazil (overcoming flooding).

With the growing interest in increasing agricultural production, it is also likely that the number of central pivots has increased considerably in recent years (GUIMARÃES; LANDAU 2014), making it important to periodically update this survey to identify the geographic location and the area irrigated by central pivots, aiming to better understand the situation of irrigated agriculture and improve the sectoral planning and management of water resources.

The growth of irrigated areas results in increased water withdrawals, generating considerable demand for technologies that optimize water use, reduce energy consumption, and improve production quality. Therefore, more efficient water use involves the use of irrigation by irrigators through the contracting of irrigation monitoring service providers. In addition, new technologies have emerged, such as data acquisition and irrigation scheduling control systems (HEDLEY; YULE, 2009; SUI et al., 2020), variable-rate irrigation (BARKER et al., 2019), variable-rate irrigation based on remote sensing (BARKER et al., 2018; SHI et al., 2019), and the use of the Internet of Things (IoT) for intelligent water management in irrigation systems (KAMIENSKI et al., 2019).

6 CONCLUSION

Rio Grande do Sul currently has 3,208 pivots, irrigating an area of 190,055.3 ha. The largest concentration of central pivots is in the Northwest and Southwest Regions, in the municipalities of Cruz Alta, São Borja, São Luiz Gonzaga, Palmeira das Missões, and São Miguel das Missões. Approximately 87% of the areas irrigated by central pivots are concentrated in seven river basins. The largest irrigated area is concentrated in the Alto Jacuí (34,192.6 ha) and Ijuí (34,067.2 ha) river basins.

An annual increase of approximately 291 pieces of equipment and 15,885.0 ha was observed between 2015 and 2020. If this growth trend continues over the next few years, the projection is that the RS will double its current area irrigated by a central pivot within a 12-year period.

Difficulties in identifying irrigated areas via satellite imagery are observed in the RS, as the state does not experience characteristically dry periods or harvests with little or no water shortages. However, accurate identification of irrigated areas still relies on manual identification from high-resolution imagery.

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