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Evolution and current scenario of irrigated area in Brazil: Systematic data analysis

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ABSTRACT: Water is an essential element to life and used in various human activities. However, because of the amount used in agriculture and the increase in irrigated area, the sustainable use of this resource has become a worldwide concern. In this study, data from the Censuses of Agriculture published by the Instituto Brasileiro de Geografia e Estatística (IBGE) from 1960 to 2017 were evaluated in relation to the regions and irrigation methods, performing a detailed analysis between the data from the 2006 and 2017 Censuses. There was an increase in irrigated area in Brazil in all geographic regions, reaching 6.9 million hectares in 2017. Sprinkler irrigation methods are the most used, with 48% of the irrigated area, followed by localized irrigation (24.4%) and surface irrigation (22.3%). Drip irrigation is the most used system in establishments up to 50 ha (617,423 ha), followed by conventional sprinkler (514,893 ha), while the center pivot stands out in areas larger than 50 ha (1,362,828 ha). The Southeast region (38.6%) and the states of Rio Grande do Sul (20.4%), Minas Gerais (16.6%) and São Paulo (16.0%) stand out as the ones with the largest irrigated area in the country. The State of Minas Gerais showed the highest growth of irrigated area in the 2006-2017 period (116.1%), due to the expansion of areas irrigated with center pivot.

Key words: census of agriculture, irrigation methods, irrigated area

Evolução e cenário atual da área irrigada no Brasil: Análise sistemática dos dados

RESUMO: A água é um elemento essencial à vida e empregada em diversas atividades humanas, todavia, em função do montante utilizado na agricultura e do aumento de área irrigada, o uso sustentável deste recurso tem se tornado uma preocupação mundial. Neste estudo foram avaliados os dados dos Censos Agropecuários publicados pelo Instituto Brasileiro de Geografia e Estatística (IBGE) de 1960 a 2017, com relação às regiões e aos métodos de irrigação, sendo realizada uma análise detalhada entre as informações dos Censos de 2006 e 2017. Houve aumento na área irrigada no Brasil em todas as regiões geográficas, atingindo 6,9 milhões de hectares em 2017. Os métodos de irrigação por aspersão são os mais utilizados, com 48% da área irrigada, seguido pela irrigação localizada (24,4%) e superfície (22,3%). O gotejamento é o sistema mais empregado em estabelecimentos de até 50 ha (617.423 ha), seguido da aspersão convencional (514.893 ha), enquanto o pivô central é o que se destaca em áreas acima de 50 ha (1.362.828 ha). A região Sudeste (38,6%) e os Estados do Rio Grande do Sul (20,4%), Minas Gerais (16,6%) e São Paulo (16,0%) se destacam como os de maior área irrigada do país. O Estado de Minas Gerais apresentou o maior crescimento de área irrigada no período 2006-2017 (116,1%), devido à expansão das áreas irrigadas com pivô central.

Palavras-chave: censo agropecuário, métodos de irrigação, área irrigada



INTRODUCTION

Water is an essential factor in the maintenance of agricultural and industrial activities (Ding & Ghosh, 2017) and its optimized use in food production is one of the main challenges, especially in the world scenario of climate change (Saccon, 2018). Although approximately 20% of the total cultivated area on the planet is irrigated, its participation reaches 40% of the production of food, fibers and bioenergy crops (FAO, 2017), demonstrating the importance of irrigation for the viability of agriculture, especially in arid and semi-arid regions with high insolation and low precipitation (Winter et al., 2017).

The world's irrigated agriculture occupies an estimated area of 310 Mha, 75% of which is located in Asia, where India (66 Mha) and China (62 Mha) are the countries with the largest area equipped for irrigation (FAO, 2017). The irrigated area in Brazil is more than 6.0 million ha (ANA, 2017), ranking it among the ten countries with the largest irrigated area in the world.

Globally, the irrigated area is expected to increase in the next decades and reach 402 Mha by 2030, with 40 Mha in developing countries (Darko et al., 2015). In Brazil, the potentially irrigable area is estimated at 61.4 Mha, of which 18.4 Mha is in regions with high suitability of soil and relief (Sparovek et al., 2015). On the other hand, the increase in irrigated area can cause reduction in water reserves and, therefore, the sustainable use of water has increasingly become a global concern (Velasco-Muñoz et al., 2018).

Given the importance of irrigated agriculture in Brazil for food production and the significant increase in this area in the country in recent decades, this study was conducted to evaluate the evolution and current scenario of the irrigated area in Brazil, through a systematic analysis of the available data, taking as reference the Census of Agriculture 2017 (IBGE, 2017).

MATERIAL AND METHODS

This study was conducted using data of the Instituto Brasileiro de Geografia e Estatística (IBGE) available in the Automatic Recovery IBGE System (*Sistema IBGE de Recuperação Automática* - SIDRA), referring to the Censuses of Agriculture of 1960, 1970, 1975, 1980, 1985, 1995-1996, 2006 and 2017, the last-mentioned preliminarily released in June 2018. For the last Census specifically, the number of agricultural establishments using irrigation and the area of these establishments by irrigation method were evaluated, in addition to the groups of total area and groups of crop area.

Analyses were conducted for: evolution of irrigated area in Brazil by region from 1960 to 2017; comparison of the area by administrative region and of the irrigated area by irrigation system/method between 2006 and 2017; evaluation of the irrigated area by region and by area intended for crops of the agricultural establishment for the irrigation systems drip, micro-sprinkler + other localized systems, flood, furrow, self-propelled sprinkler, center pivot sprinkler, conventional

sprinkler, and subsurface + wetting and other methods based on the 2017 Census; and also variation of irrigated area in the ten States with the largest irrigated area in Brazil, comparing the years 2006 and 2017.

For better comparison with previous Censuses, some irrigation methods were grouped into the same classification, with the self-propelled and conventional sprinkler systems classified as sprinkler (without center pivot) and drip and micro-sprinkler systems classified as localized irrigation. The subsurface and wetting irrigation systems and other methods not contemplated in the previous ones formed a specific class, called "other methods".

According to the definition established by the Census of Agriculture, the crop area was considered as the fraction of the total area of the agricultural establishment under permanent or temporary crops on the reference date (30/09/2017) (IBGE, 2017). Thus, it was considered as "producer without crop area" (WCA) the one who, despite owning areas with agricultural exploitation (forestry, pasture, etc.), did not have areas intended for crops on the above-mentioned date, although he/she could have had irrigated areas in the reference period of the Census (01/10/2016 to 30/09/2017). Additionally, in situations in which the area irrigated by a given system referred to less than 3 informants, its value was taken into account, but not discriminated, in order to preserve the identity of the informant/producer. In these cases, the name "X" was used.

RESULTS AND DISCUSSION

Between 1960 and 2017, the irrigated area in Brazil increased in all geographic regions, reaching 6.99 Mha in 2017 (Figure 1). Compared to the previous Census, there was an increase of 2.36 Mha (51.9%), and this increase was higher than that observed in the Censuses of Agriculture of 1995-1996 and 2006, a period in which the irrigated area in Brazil increased from 3.1 to 4.45 Mha (45.6%) (Paulino et al., 2011).

The Southeast region of Brazil, which until the 1995-1996 Census was the second region of the country with the largest irrigated area, increased its irrigated area by 73.0% until 2006, surpassing the South region (13%), still considered a traditional center of irrigated agricultural production (Figure 1).

The increase in irrigated area in the Southeast and South regions continued in the following decade, with 65.8 and

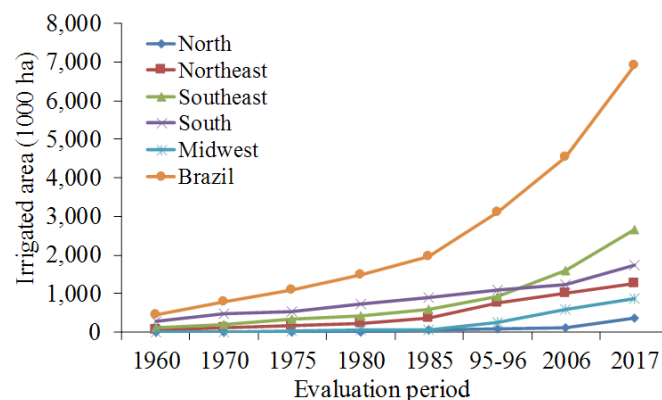


Figure 1. Evolution of irrigated area in Brazil by region from 1960 to 2017

39.8%, respectively, and in 2017, these regions represented 38.6 and 25.1% of the total irrigated area in the country (Figure 2A). Between 2006 and 2017, the lowest growth of irrigated area was observed in the Northeast region (25.9%), while the highest growth occurred in the North region (240%), due to agricultural expansion and investments in public and private irrigated perimeters, especially in the State of Tocantins (Testezlaf, 2017; ANA, 2017).

Despite the expansion observed, the North region still has the smallest irrigated area in the country (372,185 ha) due to its climatic characteristics, with a large area occupied by the Amazon Forest. In the 1995-1996 Census, the irrigated area in this region represented 2.7% of the irrigated area in the country (Loiola & Souza, 2001), increasing to 2.4% in 2006 and to 5.4% in 2017.

The Midwest increased its irrigated area by 280,047 ha (48.3%) in the 2006-2017 period (Figure 2A), standing out for concentrating 48.4% of areas with high suitability for irrigation and 33.4% of the areas with high-medium suitability (Sparovek et al., 2015).

With 131,145 recorded establishments using irrigation, the irrigation method covering the largest area in Brazil is sprinkler irrigation, which totaled 3.31 Mha in 2017, a 33.3% increase compared to 2006 (Figure 2B). In this period, the area irrigated only by center pivot increased by 60.7%, reaching 1.44 Mha. Next, the localized methods stood out with 1.68 Mha in 2017, a 409% increase compared to the previous survey (330,800 ha), and with 249,772 establishments recorded in 2017. Surface irrigation methods have the third largest irrigated area in the

country (1.54 Mha), with a 13.7% increase compared to 2006 (36,080 establishments). Despite this, the area under furrow irrigation decreased by 52.7% (Figure 2B), mainly due to its limitations when compared to other methods. Irrigation in areas with table tomato has been carried out using this method but, according to Testezlaf (2017), as it is not the most efficient method and because of the lack of information of farmers, its use tends to decrease in the next years.

According to the scenario of expansion in the irrigated area with projection for 2030 carried out by the National Water Agency (ANA, 2017), non-mechanized systems such as furrow and flood irrigation are expected to undergo a retraction, being either replaced by others or discontinued in some areas, with the exception of flooded rice, which has a trend of stabilization in the main centers of the country, mainly in Rio Grande do Sul, with an irrigated area of 1,113,500 ha in the 2013/2014 season (Köpp et al., 2016). Also, according to these projections, the net estimated growth of irrigation methods will be concentrated in drip irrigation and micro-sprinkler irrigation.

The area with localized irrigation showed higher values than those of center pivot in 2017 (Figure 2B), due to its demand in the Southeast region, mainly in coffee crops (Assis et al., 2014), which grew by 37% in the number of trees planted between 2006 and 2017, and citrus (Palaretti et al., 2011; Santos et al., 2016) (Figure 3B). In addition, the lower demand for water and inputs caused localized irrigation to expand to areas previously occupied by other irrigation systems (ABIMAQ, 2018).

In the Northeast region, the area under surface irrigation decreased by 64.5% from 2006 (Figure 3A) to 2017 (Figure 3B)

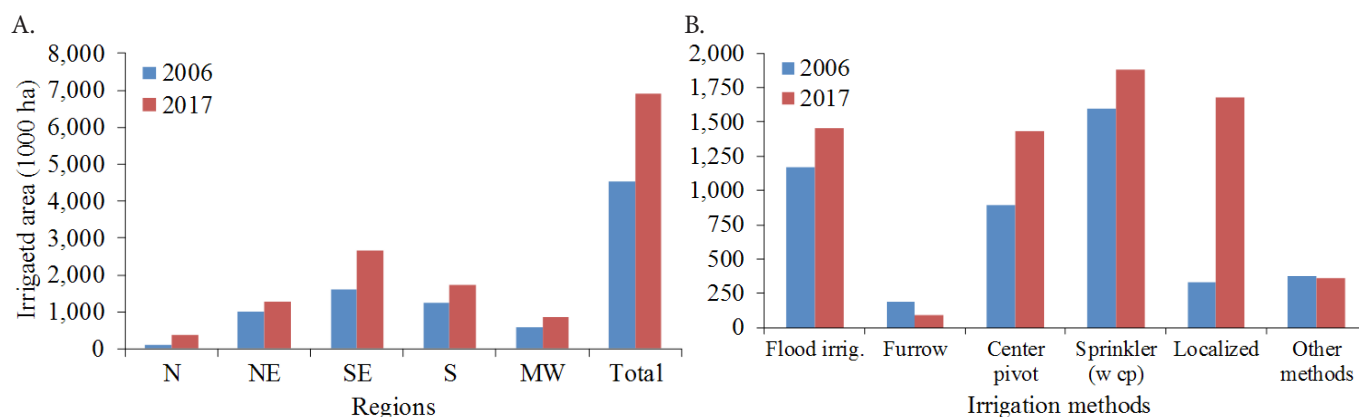


Figure 2. Comparison of irrigated area by administrative region (A) and irrigation system/method (B) in 2006 and 2017

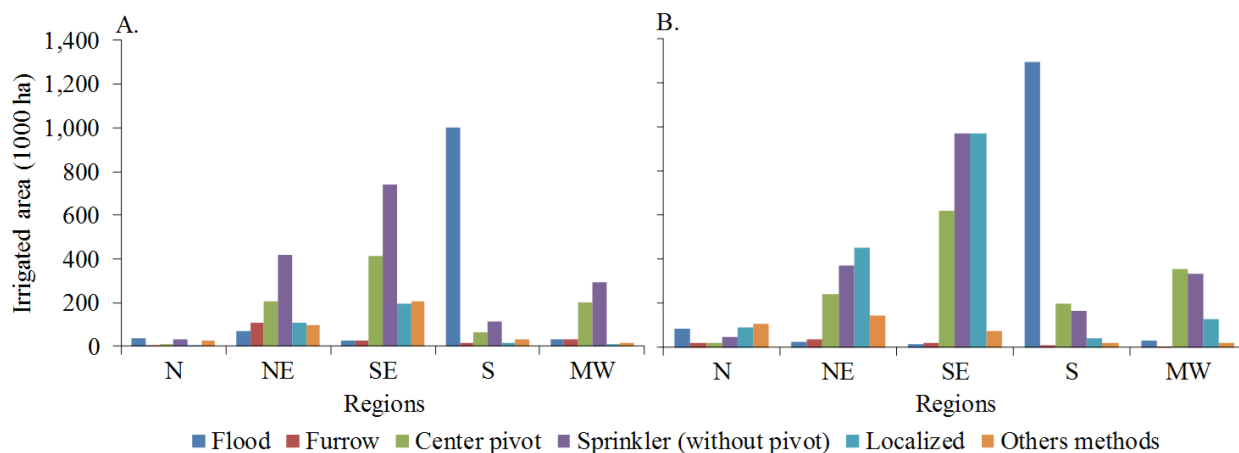


Figure 3. Irrigated area by system/method and by region of Brazil, in 2006 (A) and 2017 (B)

and one of the reasons for such reduction is the conversion to the localized method (drip and micro-sprinkler), which increased by 328.1%, mainly in the irrigated perimeters, such as Mandacaru in Juazeiro, BA, Brazil, state with the largest irrigated area in the Northeast region. According to CODEVASF (2018), the furrow irrigation system has been used in this region for many years, but since 2010 it has been replaced with drip and micro-sprinkler systems, resulting in saving of 50% of the total water used in perimeter irrigation.

Also with regard to localized irrigation, there was also a significant increase in the North (1,731.3%), Southeast (402.7%) and Midwest (1,234.9%) regions (Figure 3). Additionally, there was an increase of areas under sprinkler irrigation (without pivot) in the South (49.1%) and Southeast (31.1%) regions and under center pivot irrigation in the South (220.5%) and Midwest (76.7%) regions.

The drip irrigation system has the largest area in establishments of up to 50 ha (617,423 ha) (Table 1), followed by conventional sprinkler (514,893 ha) (Table 2), mainly in the Southeast region. The establishments with these systems totalize 119,233 and 95,587, respectively, in which 39,119 and 38,849 are located in the Southeast region. Drip irrigation stands out in the Northeast region (157,353 ha, in 55,860 establishments) and micro-sprinkler is more widely used in the Southeast (239,380 ha) and Northeast (148,247 ha). Flood irrigation has a larger irrigated area in the South of the country and furrow irrigation has a larger area in the Northeast region. In general, the localized irrigation method is the most present in areas up to 50 ha.

For establishments larger than 50 ha, the center pivot is the one with the largest irrigated area (1,362,828 ha) (Table 2), followed by flood irrigation (1,282,084 ha) and self-propelled sprinkler (748,504 ha). In addition to the methods mentioned, conventional sprinkler irrigation and drip irrigation also stand out in establishments with areas larger than 50 ha, mainly in the Southeast and Northeast regions, respectively, totaling 7,012 and 7,472 establishments (conventional sprinkler irrigation) and 6,259 and 10,323 establishments (drip irrigation).

The other irrigation methods (subsurface, wetting and others) are used in more than 360,000 ha, and prevail in establishments up to 5 ha (78,863 ha) (Table 2).

Producers without crop area (WCA) are present throughout the national territory and irrigate approximately 300,000 ha in 3,238 establishments, especially the conventional sprinkler method (63,299 ha) in the Southeast region (Table 2), and other methods in the North region (42,466 ha). It is worth pointing out that the producers without crop area are those who produced on leased land, but who were no longer using the land on the reference date of the survey (30/09/2017).

The states of Rio Grande do Sul, Minas Gerais and São Paulo are the ones with the largest irrigated area in Brazil according to the 2017 Census (Figure 4). Rio Grande do Sul is the largest producer of irrigated rice, representing about 78% of the country's total production. However, in recent years, there has been a relative stability of the area cultivated with rice, with a trend of slight increase in the medium term (ANA, 2017). However, other crops such as corn, wheat and soybean have been gaining prominence in the Northwest Region of Rio

Table 1. Irrigated area (ha) by region and by groups of crop area of the agricultural establishments for irrigation systems drip irrigation, micro-sprinkler irrigation and other localized systems, flood irrigation and furrow irrigation, in 2017

Region/Brazil	Crop area of the agricultural establishments (ha)						WCA	Total
	0 - 5	5 - 10	10 - 50	50 - 100	100 - 500	> 500		
Drip								
North	7,923	4,782	6,359	3,457	3,542	6,399	2,073	34,535
Northeast	86,225	25,664	45,464	14,265	33,024	34,630	6,453	245,725
Southeast	99,615	66,579	238,653	40,351	94,185	120,825	14,009	674,217
South	8,059	4,903	9,695	1,769	3,241	1,586	1,074	30,327
MidWest	6,233	2,678	4,591	1,858	5,477	22,987	10,091	53,915
Brazil	208,055	104,606	304,762	61,700	139,469	186,427	33,700	1,038,719
Micro-sprinkler and others								
North	7,425	4,167	35,202	1,093	2,367	4,239	2,865	57,358
Northeast	64,203	44,787	39,257	12,579	23,620	12,217	9,067	205,730
Southeast	107,907	54,627	76,846	18,164	25,684	9,485	4,425	297,138
South	2,629	1,776	3,041	422	703	693	344	9,608
MidWest	2,320	1,000	2,315	924	60,516	338	4,556	71,969
Brazil	184,484	106,357	156,661	33,182	112,890	26,972	21,257	641,803
Flood irrigation								
North	335	45	386	1,279	13,554	65,882	5,985	87,466
Northeast	9,888	2,939	4,015	809	929	X	3,328	25,910
Southeast	2,882	1,165	1,694	1,721	2,305	X	1,078	13,455
South	3,745	10,368	102,503	90,882	416,726	655,833	15,488	1,295,545
MidWest	148	256	289	541	4,315	20,696	2,945	29,190
Brazil	16,998	14,773	108,887	95,232	437,829	749,023	28,824	1,451,566
Furrows								
North	1,376	129	206	X	159	15,461	X	19,246
Northeast	15,857	3,716	3,132	665	295	X	1,494	37,739
Southeast	438	300	439	260	X	12,198	4,651	20,193
South	98	92	439	532	4,021	X	X	11,351
MidWest	359	146	295	X	X	X	X	1,211
Brazil	18,128	4,383	4,511	1,600	7,256	44,555	9,307	89,740

WCA - Producer without crop area; X - Not informed

Table 2. Irrigated area (ha) by region and by groups of crop area of the agricultural establishments for the irrigation systems self-propelled sprinkler, center pivot sprinkler, conventional sprinkler and other methods, in 2017

Region/Brazil	Crop area of the agricultural establishments (ha)						WCA	Total
	0 - 5	5 - 10	10 - 50	50 - 100	100 - 500	> 500		
Self-propelled sprinkler								
North	458	171	373	X	X	16,909	1,455	19,851
Northeast	750	510	795	796	3,977	74,798	1,364	82,990
Southeast	1,789	1,504	7,911	4,956	24,838	290,004	2,503	333,505
South	866	1,183	4,133	1,890	6,200	79,468	1,665	95,405
MidWest	404	253	864	X	X	238,629	2,913	248,617
Brazil	4,267	3,621	14,076	8,715	39,981	699,808	9,900	780,368
Center pivot sprinkler								
North	533	380	549	X	1,817	16,475	1,412	21,640
Northeast	1,573	941	13,291	X	12,075	202,809	4,171	243,223
Southeast	2,438	1,860	16,767	23,350	178,700	387,202	7,683	618,000
South	1,293	879	2,123	3,204	41,347	142,502	5,730	197,078
MidWest	633	275	3,218	5,547	63,258	275,705	6,460	355,096
Brazil	6,470	4,335	35,948	40,938	297,197	1,024,693	25,456	1,435,037
Conventional sprinkler								
North	5,133	2,776	3,865	1,282	2,915	5,645	3,764	25,380
Northeast	42,932	31,241	24,415	8,378	23,522	138,060	17,041	285,589
Southeast	209,353	31,630	70,489	14,259	21,389	224,557	63,299	634,976
South	13,029	13,609	19,302	3,957	8,744	6,233	4,479	69,353
MidWest	40,274	2,693	4,152	1,205	4,203	22,854	7,704	83,085
Brazil	310,721	81,949	122,223	29,081	60,773	397,349	96,287	1,098,383
Subsurface + wetting + others methods								
North	13,171	4,125	9,580	1,764	X	1,507	42,466	106,709
Northeast	35,082	56,677	36,353	3,634	1,668	X	5,463	141,702
Southeast	21,895	5,831	8,736	1,801	X	11,260	17,069	73,964
South	4,628	1,596	3,814	929	2,477	X	613	22,645
MidWest	4,093	789	1,022	626	X	286	8,048	18,764
Brazil	78,863	69,018	59,503	9,251	44,951	26,749	75,449	363,784

WCA - Producer without crop area; X - Not informed

Grande do Sul (Manke et al., 2017), forming one of the main centers of recent expansion of center pivot irrigation (ANA, 2017), thus justifying the increase in irrigated area in the State compared to the 2006 Census (Figure 4).

Minas Gerais was the State with highest growth rate of irrigated area in the 2006-2017 period (116.1%), changing from 530,042 to 1,145,628 ha, and surpassing the State of São Paulo, which irrigated 786,051 ha until 2006 (Figure 4). The state has gained notoriety mainly due to the expansion of the area irrigated with center pivot (ANA, 2017), which already has about 29% of the total area of the country irrigated by this system. This expansion of the center pivot stands out in the *Triângulo Mineiro* region, with 134,700 ha irrigated (Ferreira et al., 2018) and in the municipalities of Unaí and

Paracatu (Ferreira et al., 2011), located in the Northwest region of the State, mainly for the cultivation of cereals (soybean, corn and beans) and sugarcane, especially in the municipality of Paracatu (ANA, 2017). The Northern region of the State also has important irrigated areas, mainly in the projects Gorutuba (Reis et al., 2012) and Jaíba (Duarte & Tavares, 2001). Besides Minas Gerais, the sprinkler irrigation system with center pivot is the reason for the increment in the irrigated areas of the States of São Paulo (40.8%), Goiás (68.5%) and Bahia (32.8%).

The State of Ceará had the second highest growth rate of irrigated area in the period (89.5%), changing from 117,381 to 222,478 ha and surpassing the states of Pernambuco and Santa Catarina, which irrigated 152,917 and 136,249 ha in 2006 and 192,806 and 167,473 ha in 2017, respectively. This expansion is mainly due to the significant participation in fruit agribusiness, which during the 2010 - 2013 period enabled an expansion in the volume of production and commercialization of irrigated fruit crops, in response to the development of technologies applied in the abstraction, damming and channeling of water reservoirs (Ferreira et al., 2016). According to Rigotto et al. (2016), the organization of the State in agricultural centers made it possible to identify regions with greater potential for irrigation, enabling the creation of a master plan, aiming at improvements in the organization of irrigated perimeters cultivated with fruits and flowers and in financing lines such as those of the Growth Acceleration Project. In addition, the States of Ceará and Rio Grande do Norte have the most important irrigated perimeters of the Northeast region (Vidal

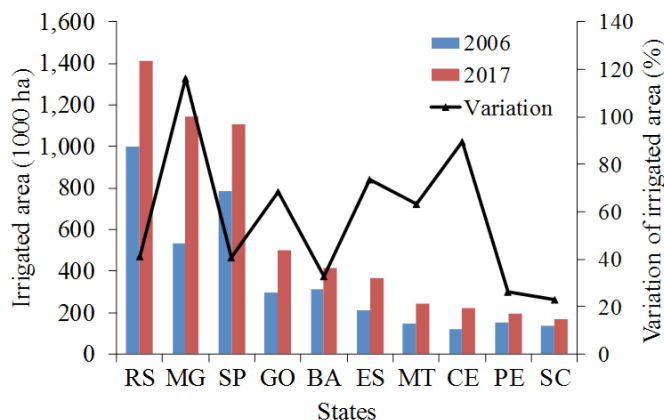


Figure 4. Variation of the irrigated area from 2006 to 2017 in the 10 main irrigating States in Brazil

& Ximenes, 2016), especially *Baixo Acaraú* and *Santa Cruz do Apodi*, respectively.

Espírito Santo also showed a significant growth rate of irrigated area (73.7%). Due to the reduction in water availability in recent years, there has been a change in irrigation methods and the localized system has become the most used (302,533 ha) (Dadalto et al., 2016). The State is a reference in coffee cultivation, with about 80% of the national production of Conilon coffee, predominantly grown under irrigation (Bonomo et al., 2013).

Favored by the support from public banks, as executors of credit and agricultural insurance policies, the State of Mato Grosso had the fourth highest growth rate of irrigated area in the period from 2006 to 2017 (63.2%). This State is one of the centers of agriculture irrigated by center pivot, with 6% of the area of the country (ANA, 2017), irrigating mainly plantations of common bean, corn, soybean and cotton. These numbers tend to grow in the next years, since the State has 15.5% of the additional irrigable area in Brazil (9.5 Mha), with 4.63 Mha located in areas with high suitability of soil and relief (Sparovek et al, 2015).

CONCLUSIONS

1. The total irrigated area in Brazil was 6,902,960 ha in 2017, increasing by 51.9% compared to the 2006 survey.

2. The most representative irrigation systems in the country are: sprinkler (without center pivot) (27.2%), localized irrigation (24.4%), flood irrigation (21%) and center pivot (20.8%).

3. The Southeast is the main irrigating region in the country, followed by the South, Northeast, Midwest and North regions, with the largest irrigated area in the States of Rio Grande do Sul, Minas Gerais and São Paulo, representing, respectively, 20.4, 16.6 and 16.0% of the country's total irrigated area.

4. The State of Minas Gerais showed the largest increase in irrigated area, followed by Rio Grande do Sul and São Paulo, mainly due to the expansion of areas irrigated with center pivot, especially under cereal production.

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