Irrigation Atlas

Water Use in Irrigated Agriculture

2nd Edition

ANA

NACIONAL WATER AND
SANITATION AGENCY - BRAZIL

National Water and Sanitation Agency

MINISTRY OF INTEGRATION AND REGIONAL DEVELOPMENT

IRRIGATION ATLAS

WATER USE IN IRRIGATED AGRICULTURE

2nd edition

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CONTENT

Center pivot in the municipality of Igarassu (PE)

CONTENTS

PRESENTATION

Rice cultivation in the municipality of Cachoeira do Sul (RS) Bernardo Rudorff /ANA Image Bank

Irrigation dates to ancient civilizations, most notably by those that developed in dry regions such as Egypt and Mesopotamia. In territories with more favorable physical and climatic characteristics, agriculture initially developed in regions where the amount and spatial and temporal distribution of rainfall could supply the need of crops and as a result, irrigation emerged in more recent periods.

That is the case in Brazil, where irrigation began in the 1900s to produce rice in Rio Grande do Sul. The significant intensification of this activity in other regions began in the 1970s and 1980s. With strong and persistent growth, new hubs have emerged in recent decades.

Several factors contribute to the need for irrigation. In regions affected by the continuous shortage of water, as in the Brazilian Semiarid region, irrigation is fundamental, i.e., important part of agriculture is only made possible through the artificial application of water. In regions affected by scarcity in specific periods of the year, such as in the central region of the country (between May and September), several crops and the third harvest are only possible with the additional application of water in dry months, although production can be carried out (without or with little irrigation) in the rainy season (first and second harvests).

Although growth of the activity results, in general, in the increased use of water, several ***benefits*** can be observed, such as increased productivity, improved product quality, reduced unit costs, mitigation of climate variability impacts and the optimization of inputs and equipment. Irrigation is also fundamental to increase and stabilize food supply and the consequent increase in ***food and nutritional security*** of Brazilian population. Tomatoes, rice, peppers, onions, potatoes, garlic, fruits and vegetables are examples of foods produced using high levels of irrigation. From the point of view of rational water use, legal requirements and management instruments, such as granting the right to use water resources (water use permits) and charging for its use, seek to ensure the sustainability of the activity, increasing efficiency and the consequent reduction of waste.

Given the importance of irrigated agriculture in a country of continental dimensions and great geodiversity, the foundational knowledge and monitoring of the activity pose a significant challenge. In this context, the National Water and Sanitation Agency – ANA has promoted studies and partnerships whose results have assisted both in the planning and management of water resources within the National Water Resources Management System – SINGREH and in sectoral decision-making. Part of the results has been published in recent years in the Brazilian Water Resources Report and in specialized publications more recently, such as the ***Survey of***

Irrigated Agriculture using Center Pivots in Brazil, the ***Survey of Irrigated and Fertigated Sugarcane in Brazil*** and ***Irrigated Rice Mapping in Brazil***.

In the face of various initiatives aimed at addressing the lack of information about irrigated agriculture, as well as the availability of new secondary data, there was a need to integrate the available knowledge into a single product, configuring the technical foundation of irrigated agriculture in its interface with water resources at a national scale. It is in this context that ANA launched the first edition of ***Irrigation Atlas: Water Use in Irrigated Agriculture*** in 2017 – which, in this second edition, has its scope updated and expanded.

Advancements in the content of Irrigation Atlas were made possible through a broad network of ***partnerships***, including the Ministry of Integration and Regional Development (MIDR), the National Supply Company, the Brazilian Agricultural Research Company, Agrosatélite Geotecnologia Aplicada, the Federal University of Paraná and the University of São Paulo. ***Sectorial coordination***, with ANA's closer involvement in sectoral policy and participation in forums and events - such as river basin committees and technical chambers on irrigation in the MIDR and Ministry of Agriculture, Livestock and Food Supply (MAPA) - allowed the content and presentation of results in the Atlas.

This ***technical foundation*** built in recent years, and which will continue to be the subject of continuous improvement, is of fundamental importance for estimating water use and updating water balances, supporting decision-making and risk analysis with a focus on the ***water security*** of irrigated agriculture and ensuring the multiple water uses. The Atlas gains even more significance by becoming a common basis for both the ***National Irrigation Policy*** and the ***National Water Resources Policy***, considering the ongoing preparation of the ***2022-2040 National Water Resources Plan***.

The databases and other additional materials are available on the Website of the ***National Water Resources Information System - SNIRH*** (www.snirh.gov.br) and at http://atlasirrigacao.ana.gov.br/.

Plantations along the Pardo river on the border between Jaborandi (SP) and Morro Agudo (SP)

1 IRRIGATION AND THE ATLAS

Rural area with irrigation in the Paranapanema
Raylton Alves river basin/ANA Image Bank

Irrigation corresponds to agricultural practice using a set of equipment and techniques to supply total or partial water deficiency to plants. Irrigation is part of our daily lives, whether on the soccer fields and residential condominiums; or when we consume rice, beans, vegetables, fruits and leafy greens – foods largely produced using irrigation.

Irrigation is essential in arid and semi-arid regions, such as Brazilian Semiarid region, where productive security is significantly affected by the non-continuous water supply, minimized only in the wetter period between December and March, when some rainfed crops can still be cultivated.

In regions affected by water scarcity during specific periods of the year, like the Southeast and, especially, the Midwest, certain crops and harvests can only be made viable with the supplementary application of water during these periods. And although production can be carried out with lower climatic risks during rainy season, Indian summers (dry periods during the rainy season) have become more frequent, causing serious damage to rainfed crops in these regions.

While it may yield excellent results on its own, this practice is usually implemented alongside other improvements in the ***technological package*** of the rural producer. In other words, it tends to be accompanied or preceded by enhancements in other inputs, services, machinery and implements – improvements that, when combined, result in several benefits.

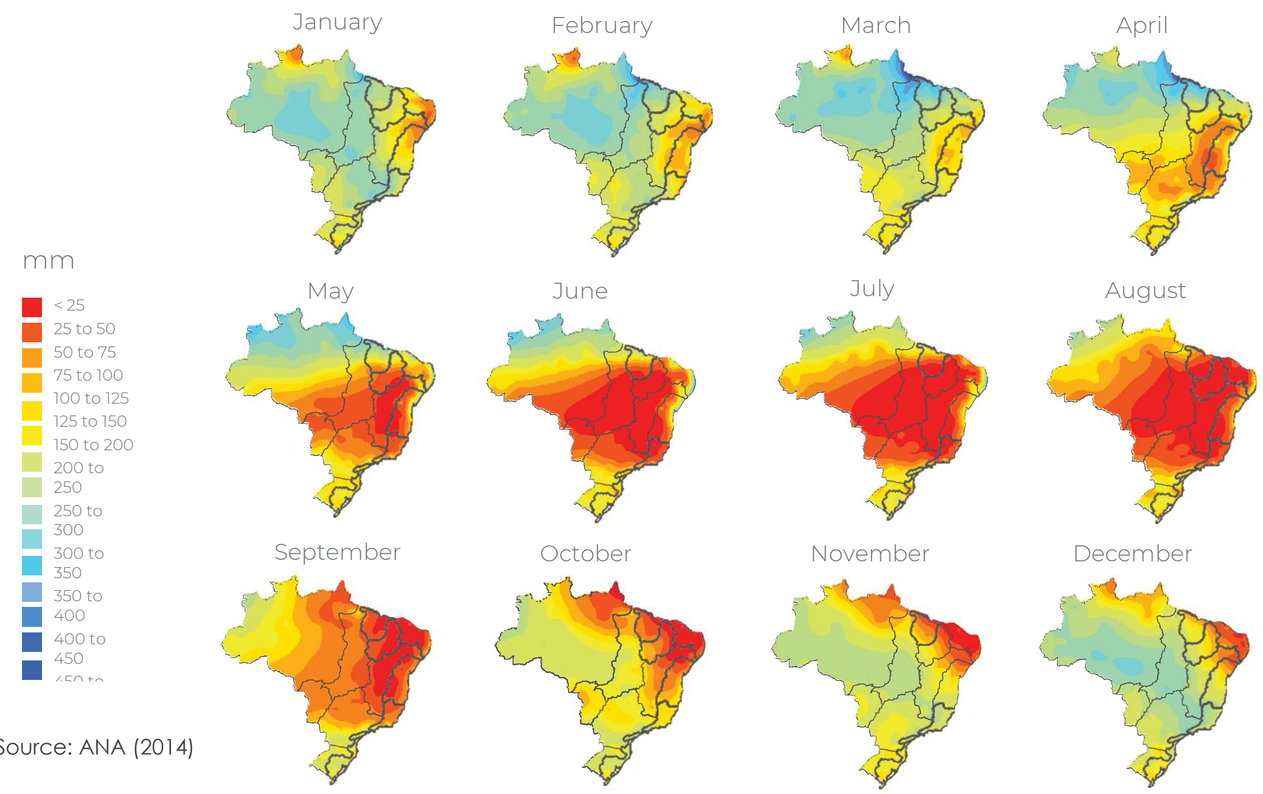
Irrigation methods can be grouped according to how water is applied, with four main methods standing out: surface, subsurface, sprinkler and localized irrigation. In the first method, water is placed on the soil surface and its level is controlled for plant use. In underground (or subsurface) method, water is applied below the soil surface, forming or controlling the water table in the region where it can be harnessed by plant roots. In sprinkler irrigation, water is applied using pressure above the ground, through sprinklers or spray holes, resembling artificial rain. The localized method (or micro-irrigation) involves applying water in a very limited area, using small volumes of water at a low pressure, with high frequency. There are different systems for each of these methods, such as the flood system in surface irrigation; the center pivot system in sprinkler irrigation; and the drip system that occurs in subsurface and localized methods.

There is no ideal irrigation method or system a priori. Surface irrigation requires less investment and involves less attached technology.

However, land with a high infiltration rate and higher slope is not favorable to this method, but may be suitable for sprinkler irrigation which, in turn, may not be suitable for regions with strong winds. Localized methods, despite their high efficiencies, are not ideal for temporary crops (corn, beans, rice, soybeans), as they require good water quality and have a high implementation and maintenance cost.

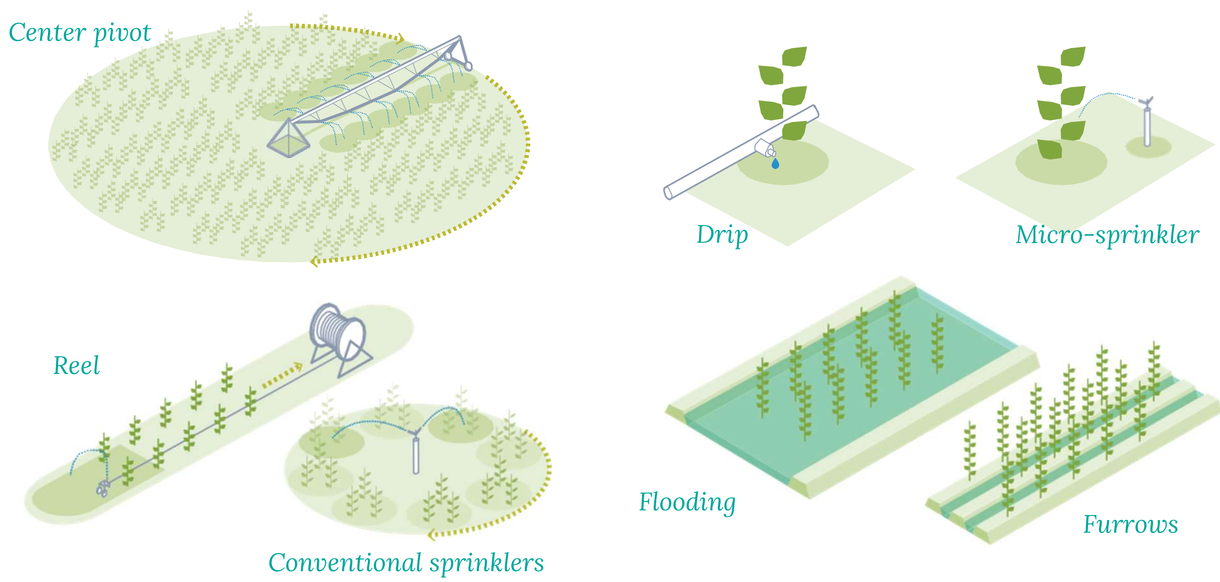
These examples highlight that the selection of the method and system for a particular location involves an integrated assessment of socioeconomic and environmental components, including water availability and quality. After the selection of the method and system, the qualitative and quantitative efficiency of water use becomes a function of crops management, equipment and environmental resources.

Average monthly rainfall in Brazil



Source: ANA (2014)

Representation of the main irrigation systems



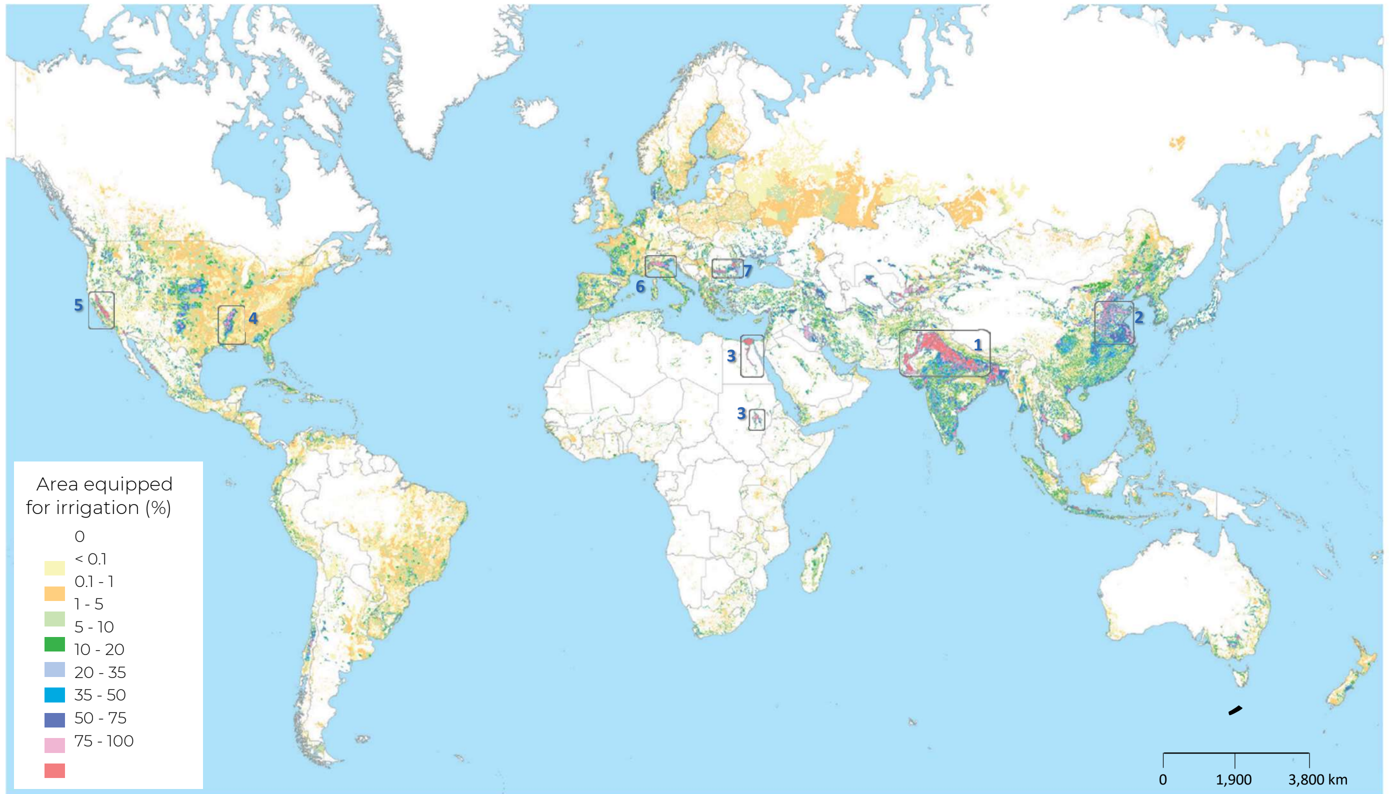
According to data from FAO (2020), Brazil is among the top ten countries with the largest equipped area for irrigation in the world. The global leaders are China and India, each with approximately 70 million hectares (Mha), followed by the USA (26.7 Mha), Pakistan (20.0 Mha) and Iran (8.7 Mha). Brazil ranks sixth with 8.2 Mha, followed by countries that have an area between 4 and 7 Mha, such as Thailand, Mexico, Indonesia, Turkey, Bangladesh, Vietnam, Uzbekistan, Egypt, Italy and Spain. The global map of areas equipped for irrigation provides an overview and the regions with major concentrations.

Despite its global prominence, ***irrigation in our country is considered modest*** compared to the estimated potential, the total agricultural area, the territorial extension and set of favorable physical-climatic factors, including good water availability. This scenario is opposite to what is observed in other leading irrigation countries, as they are generally closer to the exhaustion of their estimated potential.

On the other hand, historical data show that annual increases in irrigated area in Brazil have been strong and persistent in recent decades, intensifying in recent years, indicating that the potential has been increasingly harnessed.

This growing development of irrigated agriculture in Brazil is due to some key factors, especially the expansion of agriculture into regions with unfavo-

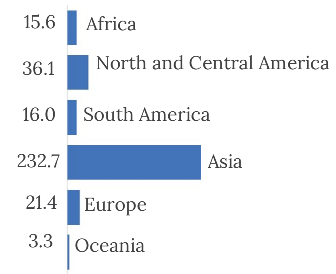
Global Map of Irrigated Areas



Larger contiguous irrigation areas

1. North India and Pakistan along the Ganges River and Indus
2. In China, in the basins of the Hal He, Yellow and Yangtze rivers
3. In Egypt and Sudan along the Nile River basin
4. In the Mississippi-Missouri river basin
5. In parts of the state of California (USA)
6. In Northern Italy, on the plain of the Po River
7. Along the lower course of the Danube River

Distribution of the area equipped for irrigation by continent (in millions of hectares)



Source: FAO (2013)

rable climate (in part of or throughout the entire year); government incentives for regional development; and benefits observed in practice with good availability of financing.

Among the potential ***benefits of irrigation***, one can highlight a 2 to 3 times increase in productivity compared to rainfed agriculture; a reduction in the unit cost of production; year-round land use with up to three crops per year; intensive use of machinery, implements and labor; application of agrochemicals and fertilizers through the same irrigation equipment (chemigation); increase supply and regularity of food and other agricultural products; mitigation of climatic seasonality factor and associated production risks; more favorable prices for the rural producer; greater quality and standardization of agricultural products; opening of new markets, including abroad; production of seeds and specialty crops; increase income for rural producers; regular employment opportunities; modernization of production systems, stimulating the introduction of new technologies; direct planting with selected seeds; and greater viability for the creation of agro-industrial hubs (ANA & Embrapa, 2019).

Like agriculture in general, Brazilian irrigated agriculture structure is highly ***dynamic and diversified***. In water use permits issued by ANA in rivers under Federal domain, for example, there are records of 70 different irrigated crops associated with different methods/systems, sizes, management and regions.

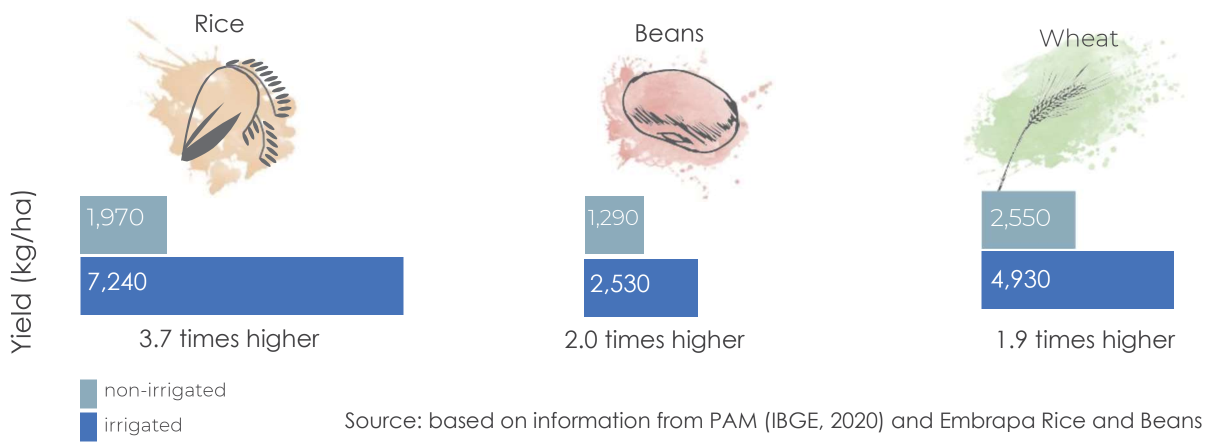
Despite the diversity, some ***large-scale patterns*** can be extracted among methods/systems and crops, such as: the strong correlation between flooding and rice; between drip and coffee and fruit-growing; between sprinkler irrigation with hose reels (hydro roll) and sugarcane; and between center pivots and cotton and grains production, especially beans, corn and soybeans.

Although all the benefits related to irrigation are recognized, there are still difficulties in assessing its importance over the total amount of food produced and its ***role in food and nutritional security*** of the Brazilian population due to the unavailability of data or the impossibility of disaggregation concerning agriculture in general (average data that include rainfed data).

Productivity indicators for rice, beans and wheat – important grains in the Brazilian diet – show that predominantly irrigated production yielded, respectively 3.7, 2.0 and 1.9 times higher than rainfed production (average 2010-2019).

The third bean harvest mostly occurs under irrigation, as its calendar coincides with dry periods in the producing regions, with the initial plantings starting in April and harvests extending until October (Conab, 2016). The harvest is concentrated in West of Bahia, in Mato Grosso and in the region of the Federal District and neighboring municipalities of Goiás and Minas Gerais (Cristalina/GO and Unaí/MG regions). With the high yields obtained through irrigation, the third bean harvest reached

Yield in predominantly irrigated and non-irrigated conditions - Brazil



Source: based on information from PAM (IBGE, 2020) and Embrapa Rice and Beans (2020)

reached 8.9% of the total harvested area of beans in Brazil in 2019 but accounted for 22.6% of the quantity produced (655.4 thousand tons in 245.6 thousand ha).

The amount of beans currently produced is very adjusted to consumption (Conab, 2016) - a concern that could be minimized with greater incentives for irrigated production.

Brazilian rice has shown a decreasing allocation of area in recent years, with a systematic decrease in rainfed areas but a constant increase in average productivity, especially due to the greater proportion of irrigated crops. Thus, there has been an improvement in the technological package used, as well as greater efficiency in water use, resulting in a production with relatively stable values, in a smaller planted area, reflecting better crop yield levels.

In 2018, rainfed areas reached a historical minimum with 482 thousand ha occupied, while irrigated areas remained stable in recent years between 1.3 and 1.4 million hectares. With improvements in soil, water and input management, irrigation provides rice with more than three times the productivity observed in rainfed areas.

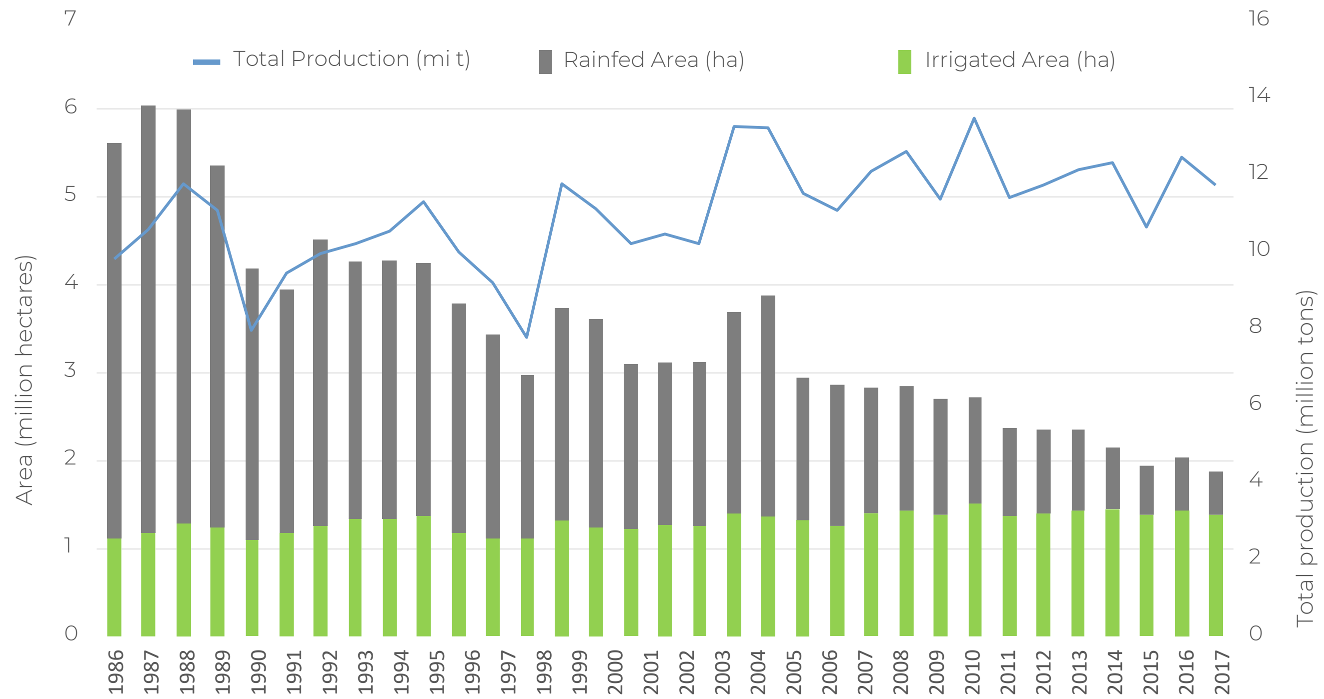
As a result, rainfed represents 25% of the area, but only 10% of the production, while irrigated rice concentrates 75% of the total area and 90% of the production.

Rice production that is currently focused on irrigation in Santa Catarina and mainly Rio Grande do Sul, has good prospects of increase in other states that use irrigated planting, as there are accumulated experiences and infrastructure (Conab, 2016), such as in Goiás, Mato Grosso do Sul, Tocantins, Maranhão, Piauí, Alagoas, and Sergipe.

Soybeans and corn tend to show similar additional yields under irrigation (2 to 3 times more than rainfed). Even in the 1st harvest period, corresponding to better climatic conditions for development, irrigation has demonstrated its economic viability due to the significant productivity gains and the minimization of climatic and meteorological risks, such as dry spells.

In addition to the examples highlighted earlier, it is worth mentioning the relevance of irrigated agriculture in supplying other foods for the domestic market, such as coffee, tomatoes, peppers, onions, potatoes, garlic, fruits and vegetables in general, i.e., its importance for food security and nutrition of the Brazilian population.

Evolution of the area of rice (irrigated and rainfed) and total production - Brazil



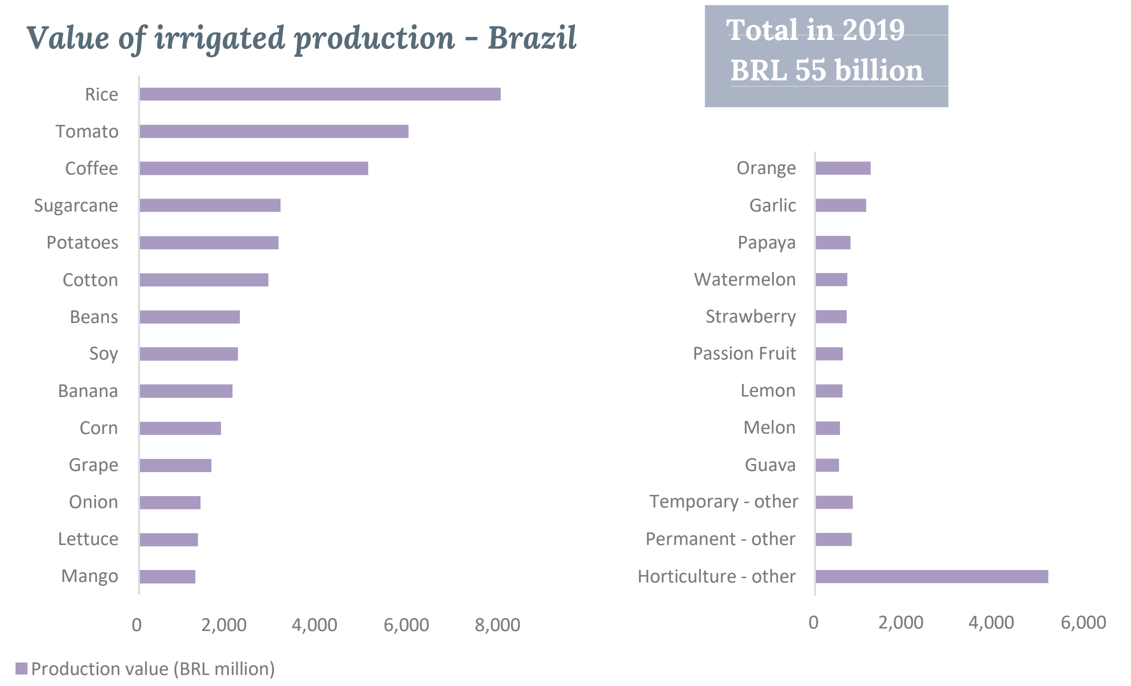
Source: Embrapa Rice and Beans (2020)

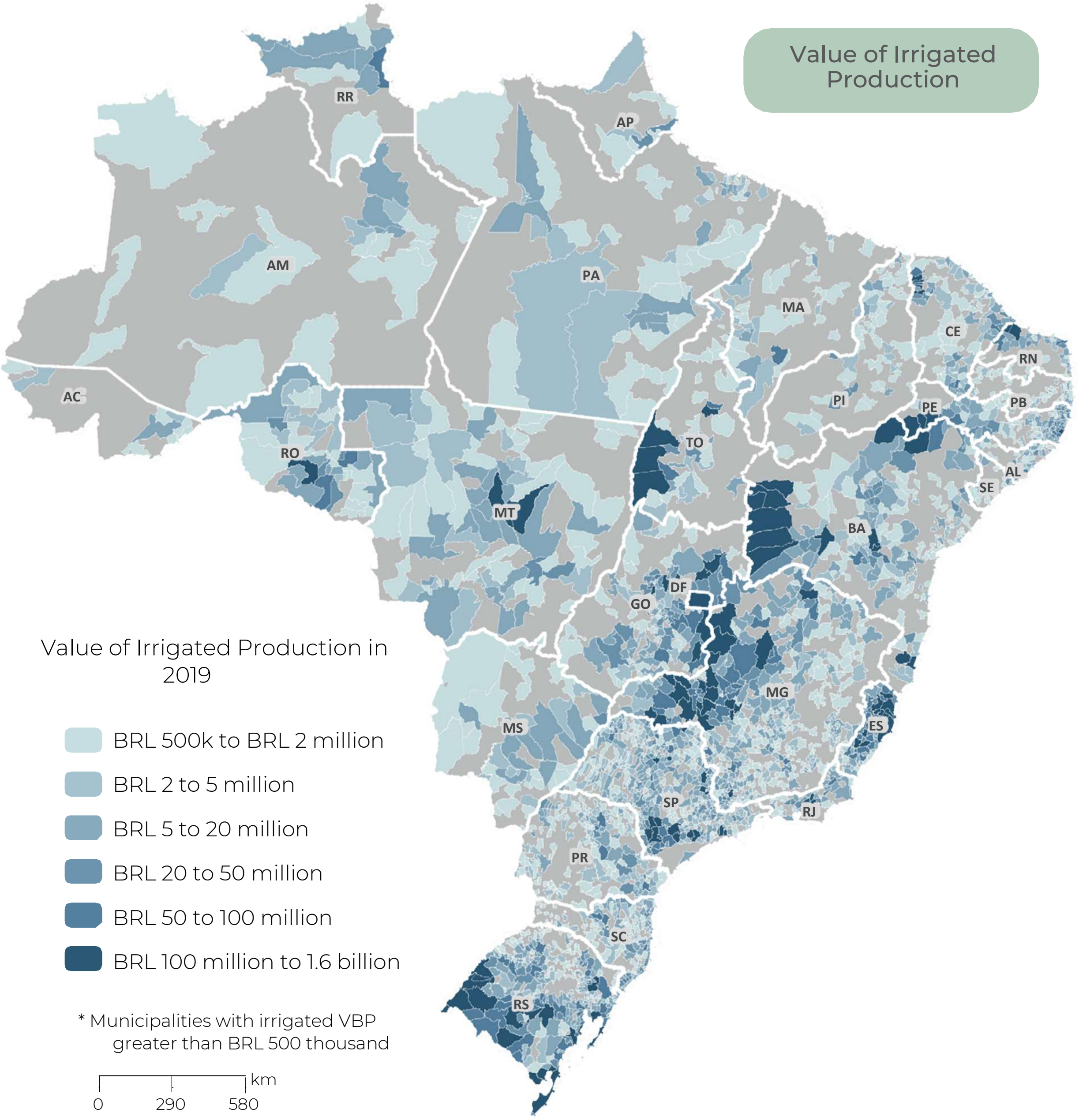
These other crops tend to add more value than irrigated grain production, which shows significant absolute values in the quantity produced and total value but add less value to the economy (BRL per ha or BRL per m³ of water) than irrigated products from horticulture and fruit-farming, for example.

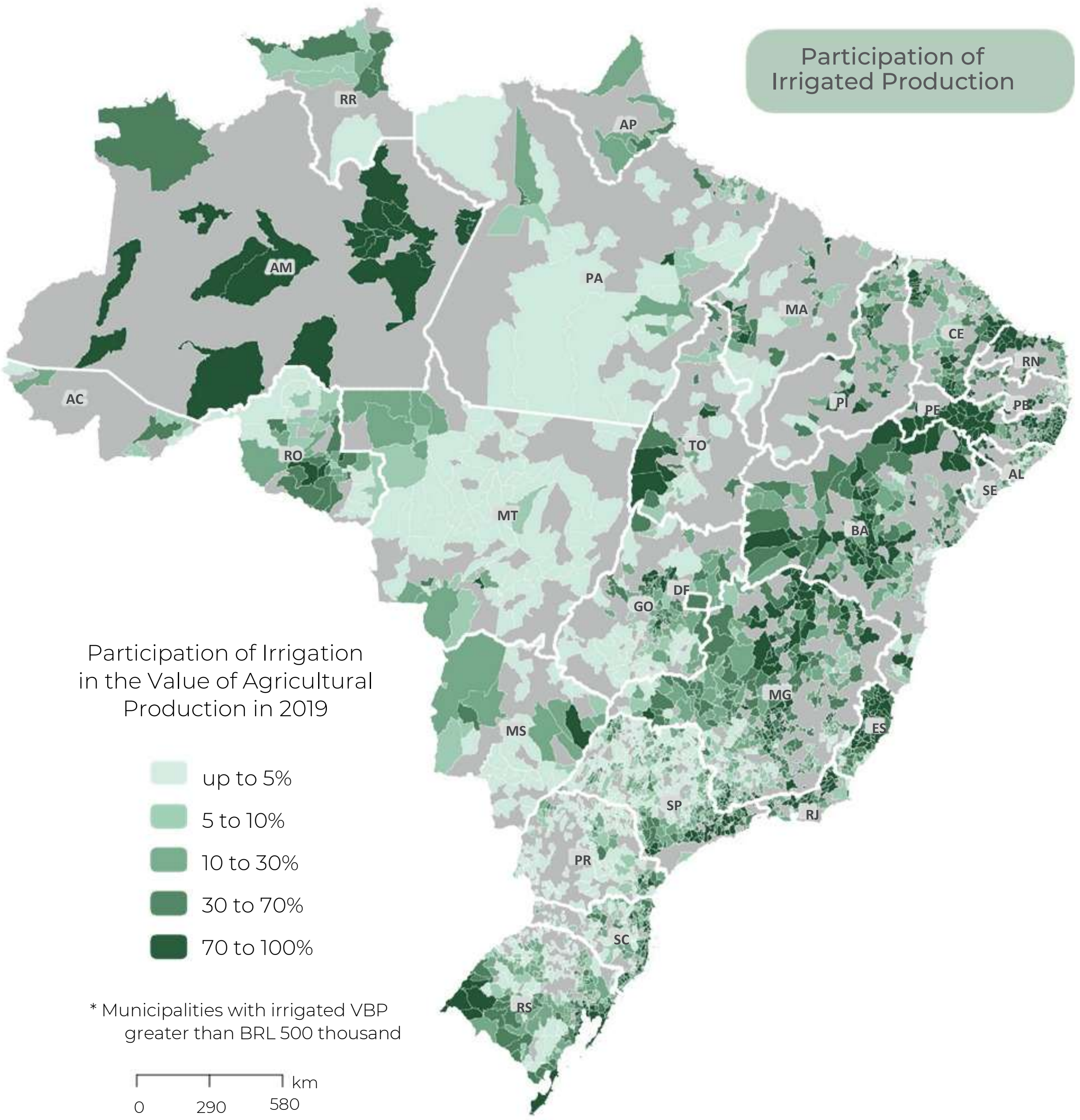
The ***Atlas*** estimated the ***value of irrigated production*** in Brazil based on microdata from agricultural surveys provided by IBGE (Census of Agriculture and Systematic Survey of Agricultural Production - LSPA).

It is estimated that between 7 and 9% of the physical production of agriculture occurs in irrigated areas, which account for 13 to 15% of the production value due to the possibility of producing more than one crop in the same location and crop year; and also because irrigated production has a higher added value (higher quality and more profitable crops). In 2019, the value of irrigated production was **BRL 55 billion** - 16 products had an annual value greater than BRL 1 billion.

Grains such as rice, beans, corn and soybeans, as well as sugarcane, stand out for physical production, but add less value to the economy per unit of area (between BRL 4 and 7 thousand per hectare irrigated). Coffee and cotton have significant areas but smaller than the crops mentioned earlier, adding







around BRL 11 to 13 thousand per hectare. Crops with a smaller occupied area emerge in the ranking of the irrigated production economy due to their higher proportional values: orange and watermelon (around BRL 17 to 19 thousand/ha); banana and mango (around BRL 25 thousand/ha); papaya, onion and potato (over BRL 40 thousand/ha); garlic, tomato and grape (over BRL 100 thousand/ ha).

Proportionally to the total value of agricultural production, irrigation is even more relevant in rice and coffee hubs; in municipalities surrounding large urban centers supplied with horticultural products; and in the Semi-arid region where the need for irrigation is high and there is good participation of higher unit value products (BRL/ha or BRL/kg).

This is an initial overview of the value of irrigated production. The estimate is conservative as it was not possible, with the available data, to fully capture the added value - for example, due to the possibility of more favorable sales during the off-season of rainfed agriculture or the superior quality of certain products.

Irrigation in Brazil requires further ***economic studies*** to reveal its importance more deeply as a sector of the economy (domestic and export) and in its interface with other sectors, such as agribusiness. It is important to include indicators related to water use that support management instruments and negotiated allocation in situations of scarcity (jobs, production value, revenue, and quantity produced per m³ of water, among others).

Atlas Development Process

The context of persistent relevance and development in recent decades has accelerated in the last 15 years in Brazil, even against unstable and negative periods in the Brazilian and global economy.

Monitoring and consolidation of a common technical foundation remain a major challenge for irrigated agriculture and public policies. The Irrigation Atlas seeks to fill these gaps by providing a retrospective and a current overview of Brazilian irrigated agriculture structure, as well as a vision of the future and pathways to strengthen water security.

The ***Irrigation Atlas*** was developed between 2018 and 2020 based on planning stages and execution strategies outlined in 2017. Activities and partnerships were defined and developed in parallel or integrated manner, depending on the nature of the theme. This preparation process can be summarized in the following macro activities, which will be detailed in methodology and results throughout the document: irrigated areas, water demand, expansion potential, and integrated analysis.

The mapping of ***irrigated areas*** guides the other analyses of the Atlas, and therefore, significant effort is applied in this macro activity. With the National Supply Company - **Conab** , irrigated rice and coffee areas were mapped in the main producing states. The Brazilian Agricultural Research Company - ***Embrapa***, published the historical series of center pivot irrigation (1985-2017, updated by ANA for 2019). With the support of ***Agrosatélite*** Geotecnologia Aplicada, irrigated and fertigated areas of sugarcane were identified and tools were created to support mapping out the other nonpoint irrigated areas in the Semi-arid region. **ANA** carried out additional mapping in public perimeters and other typologies that deviate from the aforementioned standards and that are focused in the Northeast and other specific hubs (especially fruit and horticulture). Supplementary data from the 2017 Agricultural Census of **IBGE** complemented the panorama of irrigated areas in Brazil.

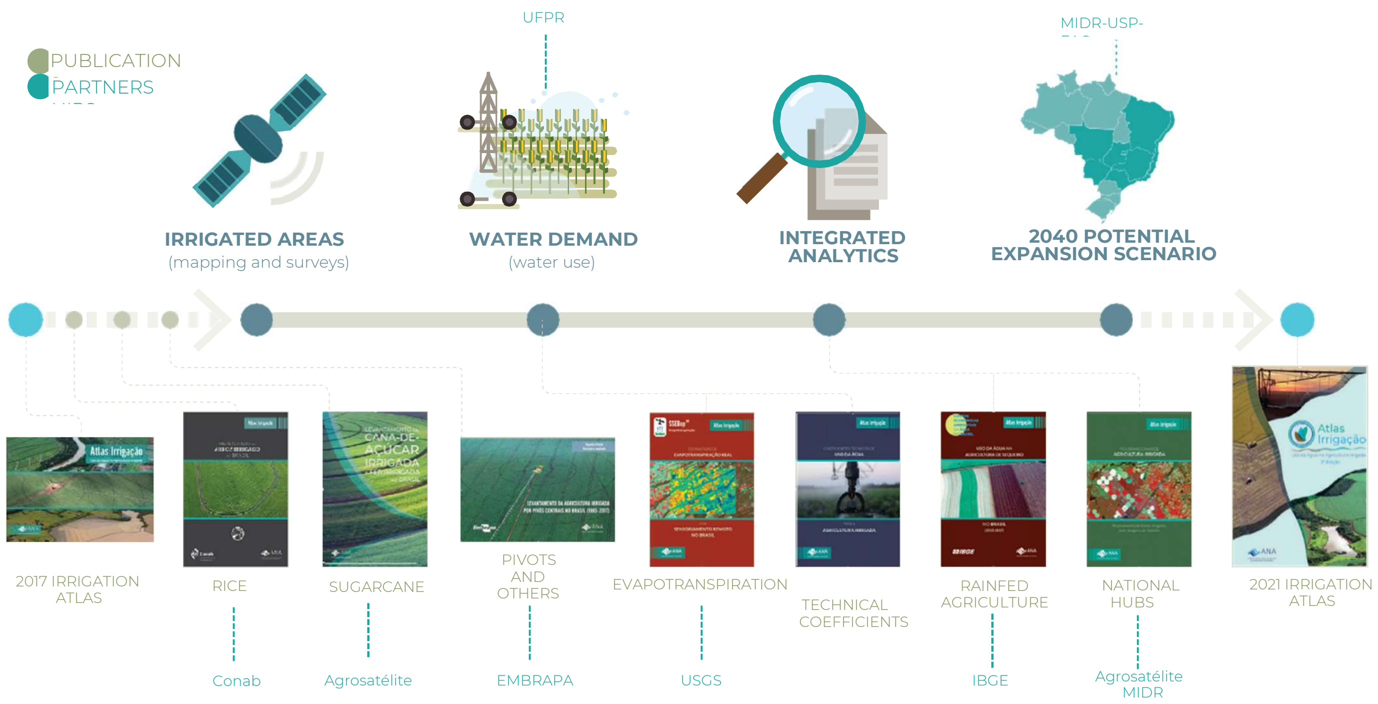
The conversion of irrigated areas into ***water demand*** is based on estimating the balance in irrigated areas – similar to what irrigators do on their properties. This calculation requires a set of additional information and parameters on planting/harvesting schedules, duration of cycles, crop coefficients and climatic data, among others. This step relied on the knowledge acquired and published by ANA in the Handbook of Consumptive Water Uses in Brazil and in the Technical Coefficients for Irrigated Water Use. It also involved the partnership of the Federal University of Paraná - **UFPR** in updating and ensuring the consistency of potential evapotranspiration and rainfall databases.

The ***potential for expansion*** of irrigated agriculture, in terms of both area and water use, constitutes another central component of the Atlas and the overall sector planning. In partnership with the **MIDR** and ***ESALQ/USP***, with support of **FAO**, estimates of additional irrigable area in Brazilian territory were updated, followed by an effort to convert areas into water demand and the projection of this potential development within the adopted planning horizon (2040).

In the ***integrated analysis***, the aim is to consolidate the previous steps in their most relevant indicators in order to aid planning and decision-making. This Activity also involves efforts in communication and providing additional information and interactive content in SNIRH, which makes the content of the Atlas more extensive than the publication itself.

The results of the Atlas and the ongoing dialogue with the sector in recent years have also allowed ***contributions to the planning and implementation of public policies***, notably the implementation of National Policies (Agriculture, Irrigation and Water Resources).

Macro activities and partnerships in the development of the Irrigation Atlas



Studies and Tools for Irrigated Agriculture

Initiatives aimed at expanding knowledge about irrigated agriculture in its interface with water resources, i.e., on irrigated areas and crops and their reflection in water demand and in the current and future water balance, have resulted in an updated technical foundation synthesized in the Atlas. The continuation of these efforts is expected to contribute to recognizing the importance of irrigation in the expansion and sustainability of agricultural production, as well as the specific and unique stimuli that the sector requires compared to other producers.

All pathways to water security in irrigation require up-to-date and systemized information that can be accessed by users and decision makers.

Given the complexity, continuous expansion, and the diffuse and dynamic nature of irrigation in Brazil, the search for data must occur on different work fronts, with different methodologies and frequencies. Systematic subjective surveys and geotechnology-based surveys (remote sensing) emerge as promising experiences that should be integrated and expanded.

In addition to these groups, the importance of ***field surveys*** is highlighted. Defining sample networks in irrigated agriculture hubs would provide significant gains in the quality of information and validation of data obtained through subjective surveys and geotechnologies. Water use efficiency (or irrigation efficiency), understood as the relationship between the volume of water needed for plants and the volume drawn from water bodies (losses), correlates with the adopted irrigation system but is highly influenced by local management practices and the use of water and soil. Therefore, it is an important parameter to be monitored in field surveys.

Systematic surveys related to Brazilian agriculture are crucial for understanding the current reality and the expansion trends, which are essential for general planning, credit promotion, and the forecast and monitoring of harvests. In general, these surveys use a network of informants to collect data (subjective methodology), although they may be supported by information obtained from direct methods, such as mappings. The Systematic Survey of Agricultural Production – LSPA, the Municipal Agricultural Production – PAM survey and the Census of Agriculture are examples of this type of survey.

In addition to these national surveys, it is worth noting the existence of administrative records in state agencies, farmers' associations, and institutions responsible for public projects (in particular DNOCS, Codevasf and the MIDR). Most of this information is used internally by institutions or made available in a dispersed or restricted manner. The same applies to numerous scientific researches and academic systematization surveys that do not reach levels of consolidation or dissemination applicable to management.

In this regard, to advance in producing data on Brazilian irrigation, priority should be given to incorporating or adapting existing surveys in institutions such as IBGE and Conab, as well as the consolidation of scattered data in other institutions, to expand the systematic data on irrigated agriculture. In this way, existing data collection networks and knowledge can be leveraged, optimizing resources application.

The frequency and level of detail of systematic subjective surveys should be improved, but it is much more aimed at a periodic snapshot of agriculture than at monitoring it with the necessary level of spatial and temporal detail.

Remote sensing, coupled with other ***geotechnologies***, allows a significant scale-up in surveys related to irrigated agriculture. Visual or automated interpretation of satellite images for identifying irrigated areas and direct estimates of water consumption by irrigation can be highlighted as those with the highest development potential for application in Brazilian irrigation hubs.

The visual interpretation of satellite images remains an important tool for gathering data on irrigated agriculture. With the large supply of images (historical and current), many of them free and pre-processed, it is possible to establish objective criteria for identifying irrigated areas and associated reservoirs. This method has been used by ANA and Embrapa to monitor center pivot irrigation in the national territory (ANA, 2019); and by ANA and Conab to map irrigated rice and coffee (ANA, 2020).

Visual interpretation is most feasible in regions where: (a) predominant irrigation systems have well-defined geometries, such as center pivots; (b) agriculture is only feasible through irrigation (total or in specific periods of the year), such as in the Brazilian Semiarid region; or (c) there is well-founded knowledge of the reality in the field or the possibility of on-site validation. The main effort consists of determining the best image types, the best image band compositions, the most suitable time of year, the necessary additional processing, and other auxiliary data (such as digital terrain models, census data and vegetation indices). Analyst training is also a key factor in the process.

Identifying certain types of irrigation requires a time series analysis of satellite images over large areas, which is only possible with the application of automated or semi-automated processes.

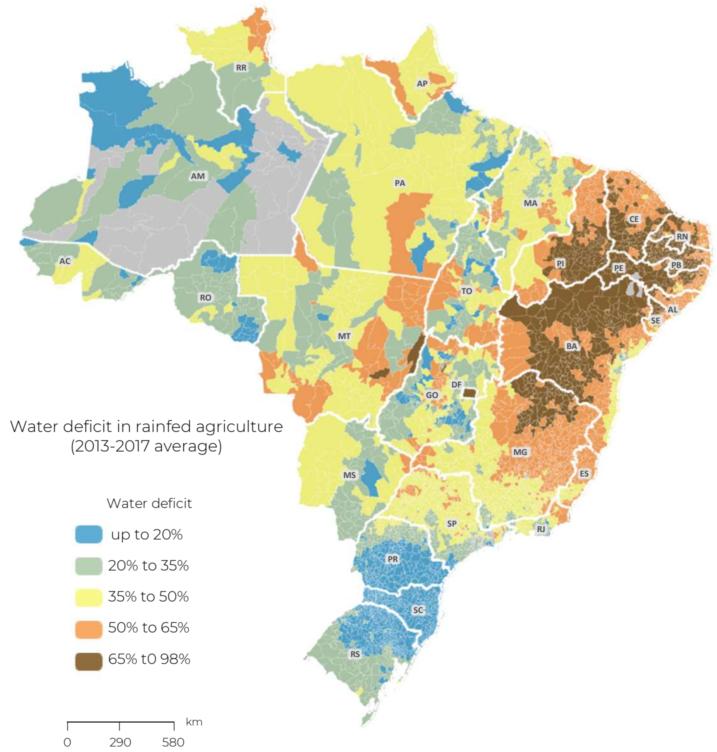
Time series of vegetation indices (IVs) – a type of product derived from satellite image processing – have been an important input for identifying agricultural crops and land use changes. The most well-known vegetation index is NDVI, which ranges from -1 to +1, with the lowest value indicating little or no biomass (vegetation), while the highest value indicates a greater presence of green biomass. Analyzing IVs over time allows extracting patterns that characterize a particular crop or group of crops, or even determined dynamics of land use (e.g., changing from one crop to another). By transforming the standards into programming and processing routines of a series of images, this type of mapping can be carried out on a large scale. This technique was applied in mapping the ***Irrigated and Fertigated Sugarcane in Brazil*** (ANA, 2020), which was an evolution of the Survey of Irrigated Sugarcane in the Central-South Region of Brazil (ANA, 2017). It was also applied in the evaluating mapping methodologies for other irrigated areas in irrigation hubs (ANA, 2020), with promising results especially in the Semiarid region.

Remote sensing data can also be used to directly estimate water consumed by irrigated agriculture. One way is through estimating real evapotranspiration (ETr), i.e., the amount of water that evaporates from the soil and is transpired by vegetation together. ETr is useful for estimating the water used by plants, not differentiating the proportional contributions of different sources. With measured or estimated data on what is supplemented by natural sources (rain, soil), it is possible to estimate the artificially applied plot (irrigation). Recently, ANA launched the ***SSEBop-BR app*** (Operational Simplified Surface Energy Balance), developed in partnership with USGS (United States Geological Survey), available on SNIRH and which allows the estimation of ETr anywhere in the national territory, from 1985 to the last available Landsat images period (generally a few days ago). The work is documented in the publication ***Real Evapotranspiration Estimates by Remote Sensing in Brazil*** (ANA, 2020).

Related to water use estimates, ANA launched in 2019 the ***Technical Coefficients for Irrigated Water Use***, which presents reference values with great relevance for the planning and management of irrigation, including as support for granting and sizing projects and studies. Water use indicators – monthly, by crop and municipality – are the result of millions of simulations with climatic data and detailed technical parameters throughout the study. The results can be accessed on an interactive indicator display on the SNIRH website.

In partnership with IBGE, the study on ***Rainfed Water Use in Brazil*** (2013-2017) (ANA & IBGE, 2020) quantified the use of green water (from the environment) by Brazilian agriculture and especially water deficits and consequent crop yield losses. The study also identified regions at risk to production that resulted both from more unfavorable weather in the analyzed period (in relation to historical averages) and from production itself in areas or calendars of higher production risk. Monitoring green water and its relationship with blue water (irrigation) proved to be important for agricultural planning by identifying areas where the productive potential has been systematically impaired and whe-

Deficit in Rainfed Agriculture

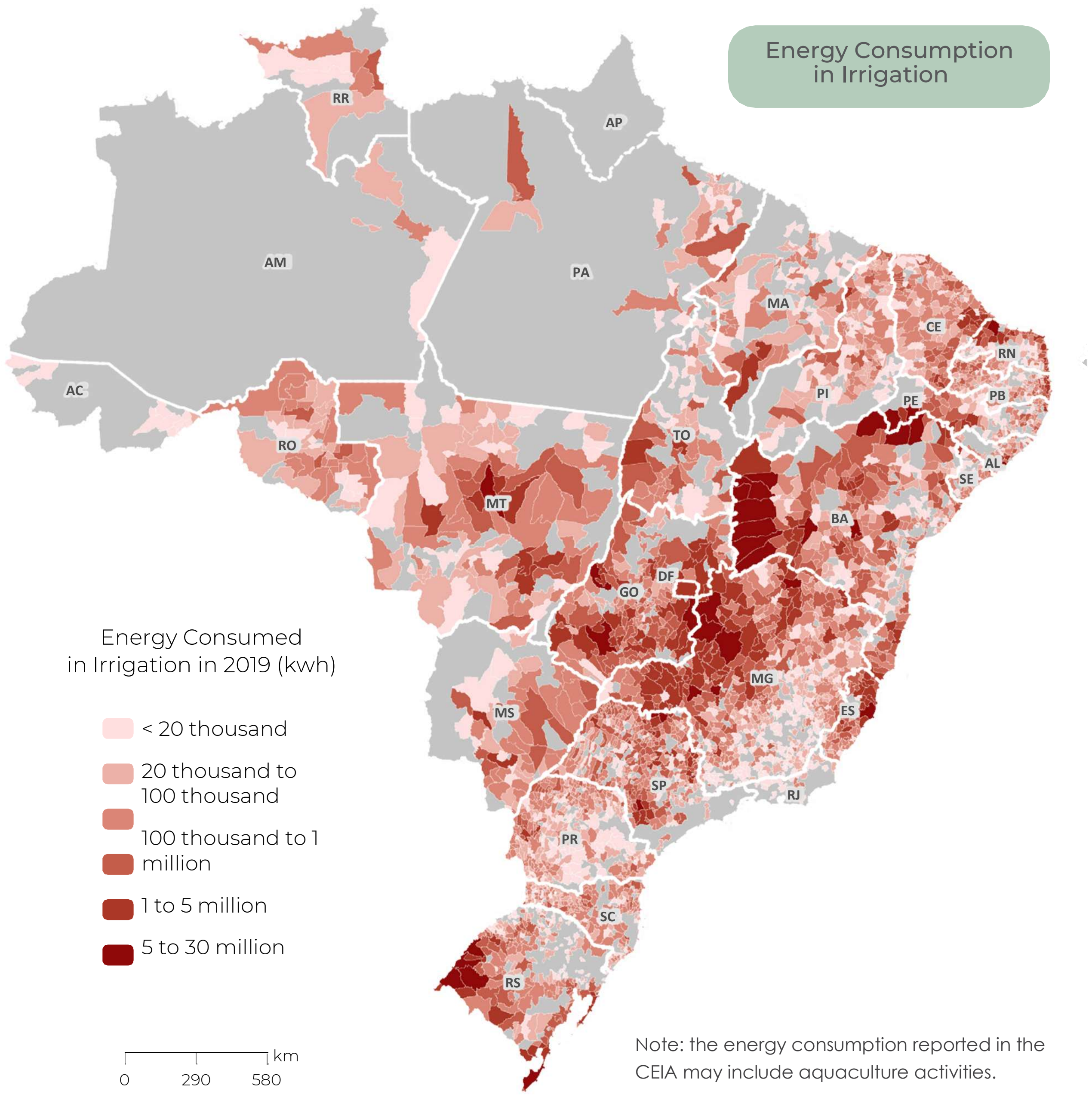


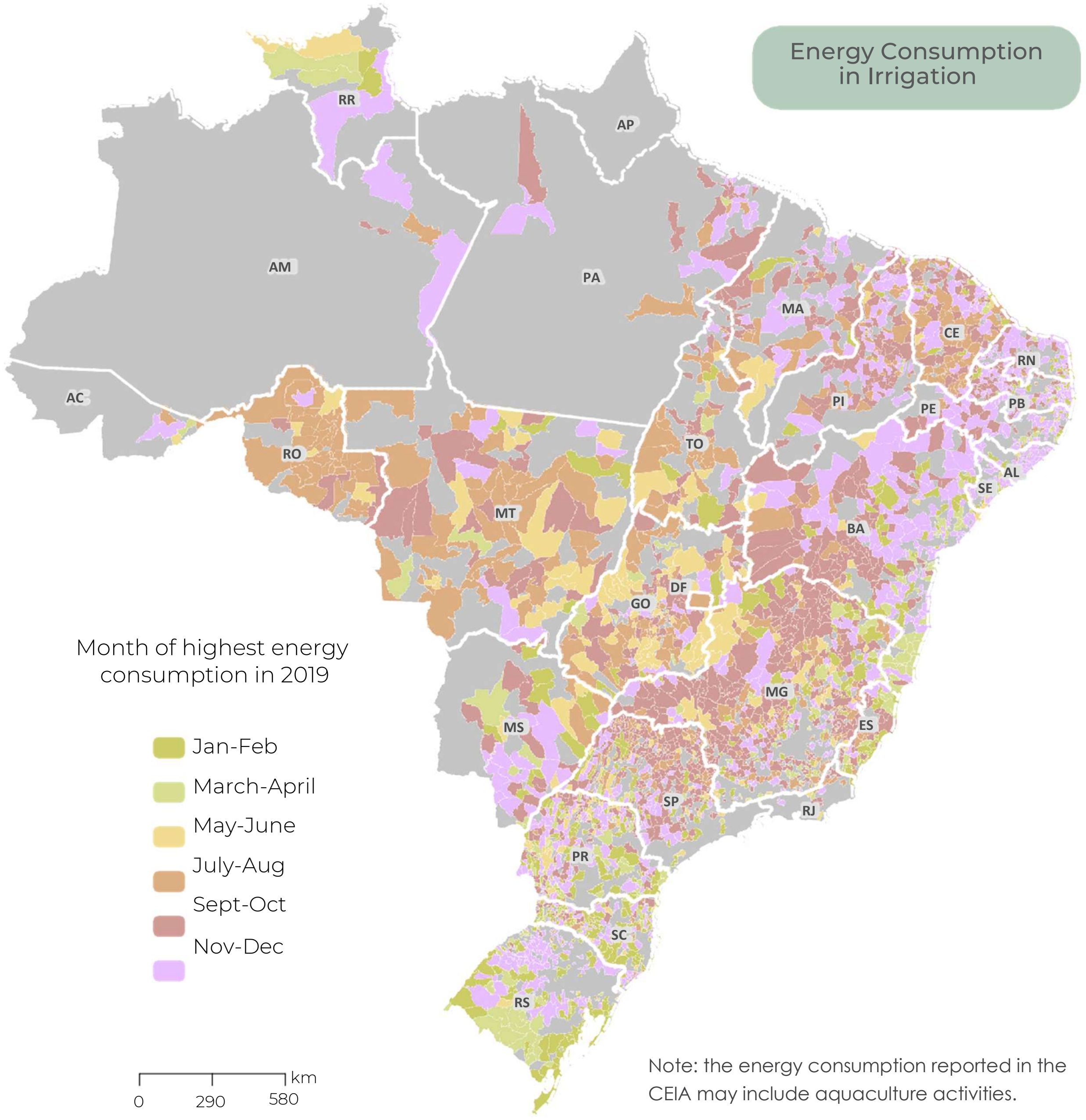
re irrigation could be encouraged, agricultural insurance reinforced, or agricultural credit discouraged.

ANA has also made efforts to monitor water use based on ***energy consumption***. Most of the water extracted for irrigation uses electricity, and current legislation grants irrigators involved in agricultural activities a special discount on the tariff (green tariff), ranging from 60% to 90%, applied during a continuous daily period of eight and a half hours, taking advantage of the nighttime period with lower demand on distribution systems.

Considering the strategic value of energy consumption information and its potential conversion into water consumption, ANA and ANEEL issued joint Resolution no. 05/2016 with the objective of improving both water and electricity regulations. The Resolution establishes conditions and procedures to be observed by the distributors in providing information on consumer units engaged irrigation or aquaculture activities. The data are restricted and must be used by ANA to exercise its functions, being of particular importance in in planning, regulation, and inspection activities. These consumption data were used to map or verifying irrigated areas in the Atlas.

Finally, it is worth noting that the ***Rural Environmental Registry*** (CAR) – created by Law no. 12,651/2012, within the scope of the National Environmental Information System (SINIMA) – is another important database. Mandatory for all rural properties in Brazil, it will consequently have a census character, storing georeferenced information about permanent preservation areas, legal reserves, remnants of native vegetation and consolidated areas (agricultural, for example).





2 HISTORY OF IRRIGATION IN BRAZIL

Sugarcane areas in the region of Indiaporã (SP), near the Grande Raylton Alves river /ANA Image Bank

Practiced since ancient civilizations that developed in dry regions, large-scale irrigation is, however, a recent practice in regions with more favorable physical and climatic characteristics for rainfed agriculture. These are areas where the quantity and spatial-temporal distribution of rainfall are capable of adequately meeting the water needs of crops.

In Brazil, irrigation began between the late 19th century and the early 20th century in the rice fields in Rio Grande do Sul, establishing itself as an important irrigation center since then. The beginning of the operation of the Cadro reservoir in 1903, whose construction began in 1881 (BRASIL, 2008), was an important milestone in this process. There were also occasional irrigation initiatives in the Semi-Arid region in this initial phase, especially with the construction of public reservoirs for multiple uses.

In 1960, Rio Grande do Sul still concentrated 57.2% of the irrigated area, totaling 462 thousand hectares, while new irrigation hubs were emerging and consolidated in São Paulo, Minas Gerais, Bahia, and Santa Catarina. These states accounted for 12.3%, 10.3%, 4.9% and 4.5% of the total area in 1960, respectively.

Driven by the expansion of the agricultural frontier to regions with less favorable physical and climatic characteristics (either total or seasonal), the greater economic viability of mechanized irrigation, and observed benefits, irrigation intensified in Brazil from the 1970s and 1980s.

Among the most important government initiatives, the following stands out: the creation of the Executive Group on Irrigation for Agricultural Development - GEIDA (1968); the Multiannual Irrigation Program (1969); the National Integration Program (1970); the National Program for the Rational Use of Irrigable Floodplains - **PROVÁRZEAS** (1981), the Irrigation Equipment Financing Program – **PROFIR** (1982), the National Irrigation Program – **PRONI** (1986) and the Northeast Irrigation Program – **PROINE** (1986). In the Midwest, one of the most important programs was **PRODECER** (Japan-Brazil Agricultural Development Cooperation Programs in the Cerrado biome), signed in 1974 and implemented from 1979 onwards.

The National Department Against Drought (**DNOCS**), created in 1945[1], the São Francisco and Paraíba Valleys Development Company (**CODEVASF**), created in 1975, and the Superintendency for the Development of the Northeast (**SUDENE**), created in 1959, were some of the main institutions responsible for implementing actions listed in government programs, despite the great relevance of financial institutions such as Banco do Nordeste, created in 1952, and resources from loan agreements with international organizations.

1 DNOCS originated from the Inspectorate of Works Against Drought (IOCS), created in 1909.

It is noteworthy that this development phase initiated in the 1980s with PRONI and PROINE, was marked by a **clearer division of roles** between government and private action in the development of irrigation programs (BRASIL, 2008). The government took the lead role in the execution of collective works for common use (as in public projects), basic infrastructure (power transmission and distribution, macro-drainage, logistics) and support (financing, research, extension). Private initiatives were responsible for supplementing government actions and other activities to implement irrigation on the property scale. This division, along with the establishment of clearer and more specific guidelines and standards, occurred with the regulation of the Irrigation Law in 1984 (Decree no. 89,496) – five years after its enactment (Law no. 6,662/1979).

Although government initiatives did not fully achieve the planned goals, several collective works of common use and basic infrastructure were executed, in addition to the provision of legal, institutional, technical, and financial support, which boosted the expansion of the activity, especially in stimulating the private sector through basic infrastructure and financing.

State institutions have also been very important in the development of irrigated agriculture, as seen in Rio Grande do Sul and São Paulo.

In Rio Grande do Sul, the role of the Rio Grande Rice Institute (IRGA), transformed into a state agency in 1940, is of recognized importance for the development of irrigated rice farming, in articulation with other state institutions. The operation of the Experimental Rice Station in the municipality of Cachoeirinha since 1939 is a symbol of performance in the expansion and modernization of the activity. Currently, IRGA also has other experimental stations and substations.

In São Paulo, the Water and Energy Department (DAEE) carried out a series of studies and surveys from 1972, with one of the products being the Basic Diagnosis for the State Irrigation Plan, which identified 4.5 million hectares (Mha) of economically irrigable land (São Paulo, 2000). The implementation program of Irrigation Demonstration Fields (CDI) was another DAEE initiative and was the first of the 13 CDIs implemented in Guaíra – still one of the largest irrigation hubs in Brazil.

Several factors contributed to the expansion of irrigation use in the state of São Paulo, which also became a hub for disseminating the practice to other regions, such as: the emergence of irrigation equipment manufacturing companies; improvement in the standard of agricultural products, especially fruits; high land value land requiring better utilization of it; feasibility of producing more noble crops with higher commercial value; early or late harvests, which enabled better prices; the stimulus given by the good results obtained by neighboring irrigating farmers; knowledge and dissemination of irrigation techniques; emergence of automated equipment for irrigation in large areas; and the possibility of maximizing the use of agricultural machinery and implements (São Paulo, 2000). Such factors are common in most Brazilian irrigation hubs.

The first ***National Irrigation Policy of 1979***, although successively amended directly or indirectly by later regulations[2] was in force until the current Policy was issued, which was processed for about two decades[3] until its enactment in January 2013 (Federal Law no. 12,787/2013). However, there has been little progress in regulating the provisions of the new policy so far.

The lack of a legal framework for the sector in the last decades can be pointed out as an important hindrance to its development, especially concerning long-term private investment, i.e., the role of the State as an inducer and not a centralizer of development.

[2] Decrees no.: 90,309/1984, 90,991/1985, 93,484/1984, and 2,178/1997; Federal Constitution of 1988; National Water Resources Policy (Law no. 9,433/1997) (Brasil, 2008).
[3] Bill no. 295/1995, later transformed into Bill no. 6,381/2005.

Historical milestones for the development of irrigated agriculture in Brazil

YEAR	MILESTONE
1903	Start of operation of the Cadro reservoir for rice irrigation in Rio Grande do Sul
1909	Creation of the Inspectorate Against Drought (IOCS), called the Federal Inspectorate of Works Against Drought (IFOCS) in 1919. Transformed into DNOCS in 1945
1926	Creation of the Rio Grande do Sul Rice Union. This gave way to **IRGA** in 1940
1934	Approval of the **Water Code** (Federal Decree no. 24,643/1934)
1940	Creation of the Rio Grande Rice Institute (**IRGA**)
1945	Creation of the National Department of Works Against Drought (**DNOCS**)
1948	Creation of the São Francisco Valley Commission, called the São Francisco Valley Superintendency in 1967. Transformed into **CODEVASF** in 1975
1952	Creation of Banco do Nordeste
1959	Creation of the Superintendency for the Development of the Northeast (**SUDENE**)
1968	Establishment of the Executive Group on Irrigation for Agricultural Development (GEIDA) at the Ministry of Internal Relations
1969	Creation of the Multiannual Irrigation Program (PPI)
1970	Creation of the National Integration Program (PIN)
1975	Creation of the São Francisco and Paraíba Valleys Development Company (**CODEVASF**[1])
1979	Approval of the first **National Irrigation Policy** (Federal Law no. 6,662/1979)
1979	Beginning of the implementation of the Japan-Brazil Agricultural Development Cooperation Programs in the Cerrado biome (**PRODECER**)
1981	Creation of the National Program for the Rational Use of Irrigable Floodplains (**PROVÁRZEAS**)
1982	The Irrigation Equipment Financing Program (**PROFIR**) was established
1986	The National Irrigation Program (**PRONI**) and the Northeast Irrigation Program (**PROINE**) were created
1988	The Constitution of the Federative Republic of Brazil was enacted, which addresses the use of water resources and irrigation in some articles
1997	Enactment of the Water Law (Federal Law no. 9,433/1997) – establishment of the **National Water Resources Policy**
2000	Creation of the National Water Agency (**ANA**) – Federal Law no. 9,984/2000
2001	CONAMA Resolution 284, of 08/30/01 was approved, which provides for the environmental licensing of irrigation projects
2008	The Permanent Forum for the Development of Irrigated Agriculture was created by Ordinance no. 1,869/2008, by the State Minister of National Integration
2013	The **new National Irrigation Policy** (Federal Law no. 12,787/2013) was enacted. Little progress in regulating the provisions

[1]Note: Currently, Codevasf operation area covers several river basins, the larger ones are the São Francisco, Parnaíba and Tocantins-Araguaia rivers. It fully includes all states in the Northeast, Amapá and Tocantins; and partially Pará, Mato Grosso, Goiás, Distrito Federal and Minas Gerais. Codevasf is the federal operator of the Integration Project of the São Francisco River with the Northeast Region (PISF).

Recently, as part of the implementation of the National Irrigation Policy and the incentive to regional development, the Ministry of Integration and Regional Development (MIDR) released the ***Irrigated Agriculture Hubs initiative*** (MIDR Ordinance no. 2,154/2020). The initiative is a leveraging strategy for the activity through collaborative efforts between organizations of irrigating rural producers and various levels of government, seeking integrated solutions to the main constraints of activity development in these regions.

Between the enactment of the Irrigation Policies (1979 and 2013), a notable event in 1997 was the establishment of the ***National Water Resources Policy*** – PNRH (Law no. 9,433/1997), known as the ***Water Law***. The PNRH aims, among other objectives, to ensure water in quantity and quality for current and future generations, as well as its rational and integrated use. Instruments of the PNRH include water resource plans, classification of water bodies into classes, fees for use, information systems, and the granting of water use rights. **ANA** is the federal entity responsible for implementing the PNRH.

The current National Irrigation Policy seeks compatibility with the PNRH in various aspects, such as the requirement for Irrigation Plans to be developed in harmony with Water Resource Plans.

Despite legal and institutional limitations, irrigation credit support has continued in recent years, notably through government programs for regional development or the Agricultural and Livestock Plans - PAPs. In 2019, the Central Bank recorded 28,870 credit contracts for irrigation, totaling BRL 806.6 million.

Investments in irrigation within the ***Agricultural and Livestock Plans*** – PAPs, released annually since the 2000/2001 harvest, were recently centralized as part of the Irrigation and Storage Incentive Program (Moderinfra). The program finances up to 100% of items, including all those related to irrigation systems, including electrical infrastructure, water conservation and soil moisture monitoring equipment.

Financing conditions for irrigation vary annually with the PAP, but show an increasing trend in resources allocation. Currently, interest rates are up to 6% per year, with a limit of BRL 3.3 million (individual credit) or BRL 9.9 million (collective credit) and a term of up to 10 years (with up to a three-year grace period). In Moderinfra 2020/2021, BRL 1.05 billion have been programmed. Operations are carried out through accredited financial institutions.

As executors of credit and agricultural insurance policies, it is worth highlighting the participation of public banks, especially the National Bank for Economic and Social Development - BNDES, which provides resources to financial institutions at subsidized interest rates; Banco do Brasil S/A – BB, the main credit line operator for investments and funding related to irrigated agriculture, in addition to rural security and the exclusive operation of resources from the Constitutional Financing Fund for the Midwest (FCO); Banco do Nordeste do Brasil – BNB, the main credit and agricultural insurance operator in the region, operating and managing the Constitutional Financing Fund for the Northeast - FNE; and Banco da Amazônia S/A – BASA, the main financial development institution in the Amazon and the exclusive operator of the Constitutional Financing Fund of the North (FNO), playing a crucial role in financing new irrigation projects in the states of Mato Grosso and Tocantins - important frontiers for the expansion of irrigated agriculture.

In regional development, BNB stands out as the exclusive administrator of the largest constitutional financing fund in the country (FNE[4]), created by the 1988 Constitution. The Complementary Infrastructure Financing Program - FNE Proinfra is extensive, providing resources for basic sanitation, transportation, and logistics, as well as for the generation and distribution of electric power and water supply projetcts for irrigation. The Irrigated Agriculture Financing Program – FNE Irrigation is even broader, financing everything from environmental studies and basic/executive irrigation projects to the project feasibility and technical assistance[4]. The projected financing for FNE Irrigation in 2020 is BRL 567 million – with a term of up to 20 years (and up to a five-year grace period).

[4] For more information, visit: https://www.bnb.gov.br/fne

Despite the programs and the involvement of various institutions, the demand from irrigators for agricultural financing and insurance lines that consider the specificities of irrigated agriculture have not been fully met yet. The advantages of irrigation (changes in and/or reduction of production seasonality and reduction of the negative impacts of climate variability) are still not fully considered for the release timing of financing for crop funding, nor in the calculation of agricultural insurance risks, which obey the calendar and criteria of rainfed crops.

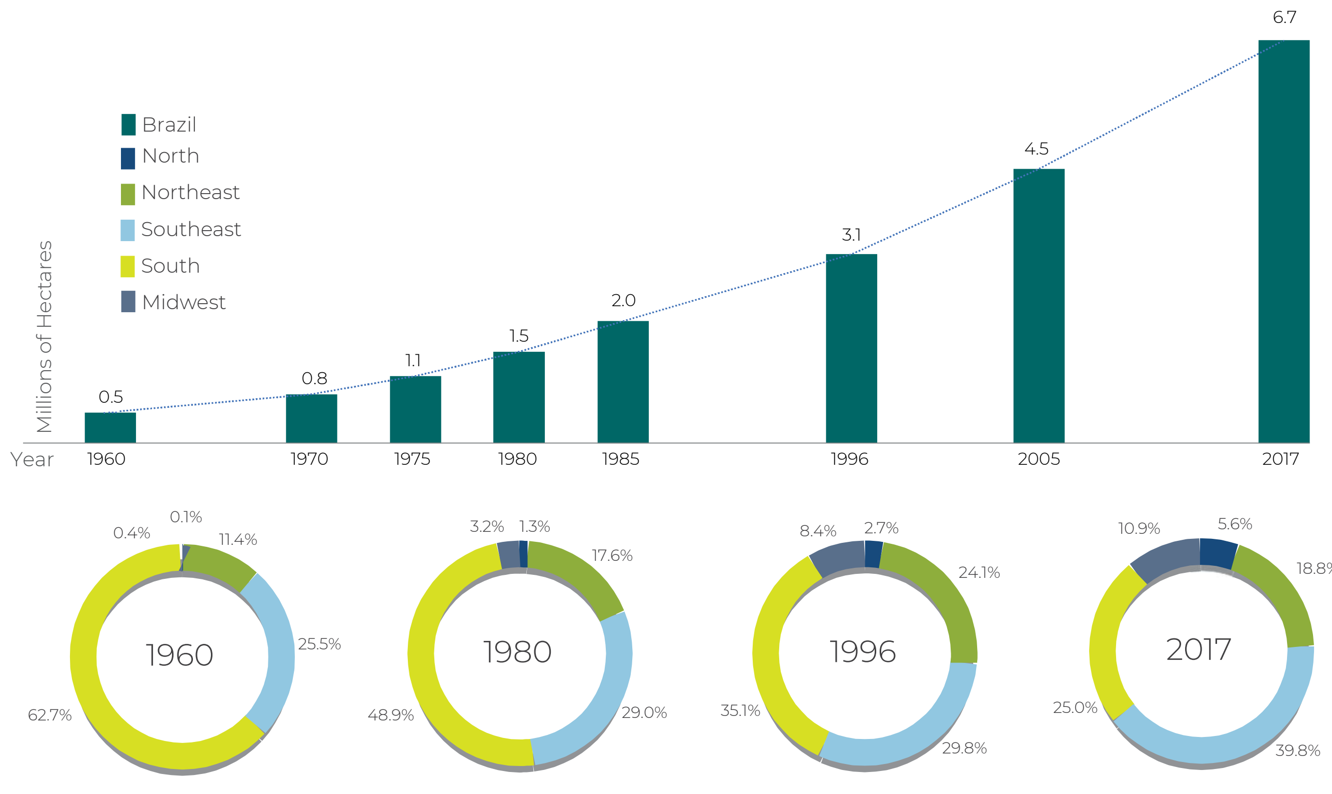
As a result of the historical water resources report summarized above, periodic data from Agricultural Censuses conducted by IBGE (1960-2017) record the robust growth of the activity. The irrigated area has been growing at average rates exceeding 4% per year since the 1960s. Starting at just 462 thousand hectares in 1960, the 1-million-hectare mark was surpassed in the 1970s. In the 1990s, the 3 million hectares were exceeded and equipped for irrigation. In 2017, IBGE registered 6.7 million hectares irrigated.

As previously pointed out, irrigation intensified in Brazil in the 1970s and 1980s due to the expansion of agriculture to regions with less favorable physical and climatic characteristics (total or seasonal), regional development policies and the benefits observed in practice. Before this period, the only large-scale irrigation hub was in Rio Grande do Sul for rice production.

Although all the States, and consequently all regions, have expanded their irrigated areas in recent decades, increases are more significant in São Paulo, Minas Gerais, Tocantins and Bahia, in addition to Rio Grande do Sul itself and, more recently, in Goiás.

The North region continues to be a region of low development of irrigated agriculture, with insignificant increases. Tocantins is the exception, since there were significant investments in public perimeters and private areas in the last 30 years, surpassing the 120 thousand hectares mark for irrigated land and increasing the region's share to 5.6% in 2017.

Evolution of the Irrigated Area in Brazil and participation of the Regions



Source: Census of Agriculture (IBGE, 1960-2017)

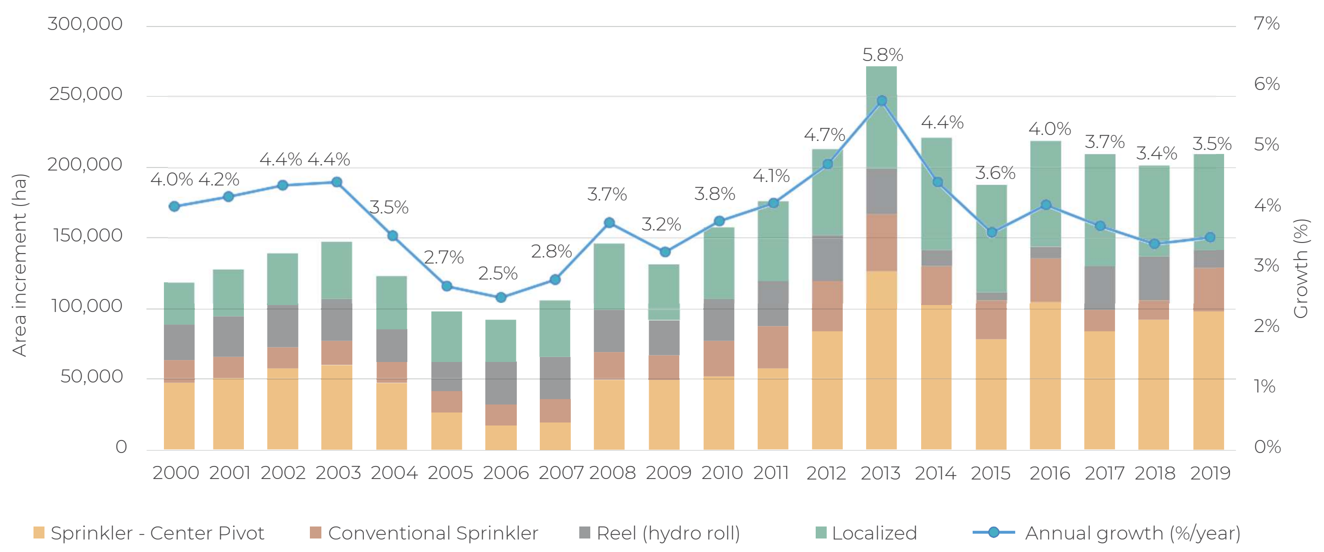
In the Northeast, there was a rapid incorporation of irrigated areas starting from the 1980s, a result of investments in public perimeters and other water infrastructure that boosted the private sector. In 2006, the region exceeded 1 Mha of irrigated land. In the last decade, except for Bahia, there is noticeable relative stability or a decline in areas, a consequence of the reduction of investments to expand the water infrastructure and the water crisis experienced in the recent years. Thus, the Northeast has reduced its share of the total area. Regarding the recent water crisis, it is estimated that many of the equipped areas between 2015 and 2019 were either idle or applying irrigation levels below the crop's needs (deficit irrigation). On the other hand, Bahia shows strong recent growth, especially in the Cerrado biome in the west (Barreiras region), with a significant adoption of center pivots.

The Midwest, which has experienced an accelerated agricultural expansion process since the 1970s, began to incorporate more significant irrigated areas starting in the 1990s. It has been the region with the greatest expansion in the last 20 years, driven by Goiás and, more recently, by Mato Grosso, largely due to the expansion of center pivots for grain production and of sprinkler systems for sugarcane. Consequently, there is a significant increase in the in the region's share of the national total.

The Southeast has been showing successive and significant increases since the 1970s, counting on most diverse range of irrigation methods and types among Brazilian regions. The region totals 39.8% of the irrigated area - São Paulo and Minas Gerais concentrate in absolute terms, but Espírito Santo has the highest share of irrigated crops in the total agricultural area.

Finally, the South – a traditional irrigated production hub - has also seen significant gains in area in the recent decades. However, with the development of other regions at higher rates, the relative share of the region has been decreasing, reaching 25% in 2017.Nevertheless, it remains as the second-largest region and includes the state with the largest area in the country – Rio Grande do Sul (responsible for 80% of the South's area and 20% of the national area). In recent years, there has been relative stability in the irrigated area of rice, with short-term positive and negative variations. Production continues to increase due to productivity gains. Rio Grande do Sul also stands out for having one of the main hubs of recent irrigation expansion using center pivots, mainly for grain production, located in the Northwest of the state, in the Uruguay and Jacuí river basins.

Mechanized Irrigated Area - Annual Increment - Brazil



Source: Sector Chamber for Irrigation Equipment - CSEI/Abimaq (ABID, 2020)

Among mechanized irrigation methods and systems (i.e., excluding surface methods), it is observed that the most water-efficient groups - localized irrigation (drip and micro-sprinkler) and center pivot sprinklers - represented about 70% of the increase in irrigated area between 2006 and 2019, according to CSEI/Abimaq (ABID, 2020). Among other systems, reel sprinkler irrigation (hydro roll) stands out, accounting for about 15% of the increase in equipped area during the period.

The data also reaffirm the strong and persistent expansion of irrigation, which continues to grow above 200 thousand hectares per year despite the unfavorable economic conditions in recent years.

Between 2000 and 2011, the average annual growth was 130 thousand hectares; between 2012 and 2019 there was annual rate of 216 thousand hectares (66% higher). The growth in the share of irrigated agriculture in physical production and the value of food production is even more important, considering the higher yield and the higher quality of the product compared to rainfed agriculture, as well as enabling higher-value crops and positive synergies with agribusiness.

Irrigated rice crop in Santa Vitória do Palmar (RS) Rafaela dos Santos Souza /ANA Image Bank

3 ÁREAS DE RIEGO

Área de producción de semillas en el municipio de Lucas do Rio Verde (MT)
Joel Risso /Banco de imágenes ANA

Las áreas de riego son parámetros clave en las otras etapas del análisis de la agricultura irrigada. El concepto aquí utilizado corresponde a la superficie equipada para el riego. Con la fuerte expansión observada y el alto potencial de crecimiento, el monitoreo se convierte en un desafío para una actividad que ya carece de datos e información de referencia.

Los datos del censo, de gran valor para varias aplicaciones, presentan limitaciones para la aplicación en la gestión sectorial y de los recursos hídricos, como la metodología subjetiva (aplicación de cuestionarios), la temporalidad (Censos cada 10 años), el nivel de agregación de datos (municipios o UF) y la confidencialidad (lo que resulta en un gran número de desidentificaciones, es decir, datos no disponibles).

Consciente de este reto, la ANA intensificó en 2014 una estrategia de levantamiento de información, resultando en un área de riego equipada estimada de 6,1 Mha en 2014 (ANA, 2016). Este diagnóstico reveló en su momento no solo la continuidad de la fuerte expansión del sector en relación con la encuesta agrícola del IBGE de 2006, sino también diferentes patrones de concentración espacial en las cuencas hidrográficas y subcuencas. Es decir, aunque en la media nacional el crecimiento del 36% entre 2006 y 2014 no fue sorprendente a la vista de la historia observada, en regiones importantes para la gestión de los recursos hídricos las áreas superaron la encuesta censal hasta en tres veces. Cabe señalar que las diferencias entre los datos no se refieren necesariamente a la dinámica del riego en el período, sino a las diferencias metodológicas y conceptuales vinculadas a los levantamientos.

El Atlas 2017 incorporó actualizaciones de productos anteriores y datos más recientes en el momento, especialmente del Levantamiento de Caña de Azúcar de Riego en la Región Centro-Sur de Brasil (ANA, 2017), la actualización del mapeo de pivotes centrales y mapeos regionales realizados en los planes de recursos hídricos, además de una reevaluación de las proyecciones censales que incluyeron nuevos criterios para la proyección y cumplimiento de las desidentificaciones.

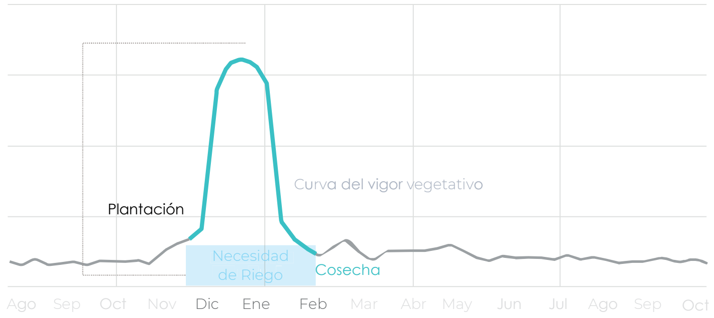
Para la elaboración del Atlas 2017, se identificaron los principales ***grupos de áreas de riego*** a gran escala que, por sus características específicas, requerirían diferentes estrategias y metodologías de levantamiento. Así, se identificó el riego de arroz, caña de azúcar y otros cultivos por pivotes centrales como los grupos más expresivos a escala nacional, totalizando el 70% del área total y ocurriendo de manera concentrada en el territorio en polos nacionales y regionales.

Riego de otros cultivos fuera de los pivotes centrales - asociados con los sistemas localizados (microaspersión y goteo) y pulverización convencional - son los principales grupos de otros cultivos irrigados por otros métodos o sistemas. Este grupo también tiende a ocurrir más difusamente en el territorio, con la excepción de los perímetros públicos y otros polos regionales.

Perfiles representativos de la dinámica agrícola en zonas de regadío en Brasil

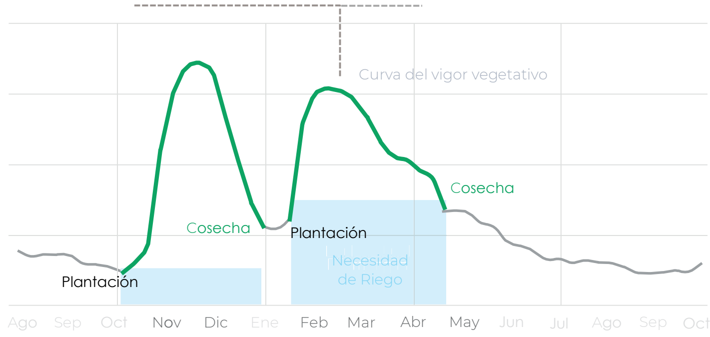
PERFIL DE CULTIVO ÚNICO (VERANO)

En este caso, la transmisión es suplementaria, **cuando hay sequía inusual**, por lo tanto, consume poca agua. Es un perfil poco observado, más común en las tierras secas, ya que el riego permite más de un cultivo, pero puede ocurrir debido a varios factores.



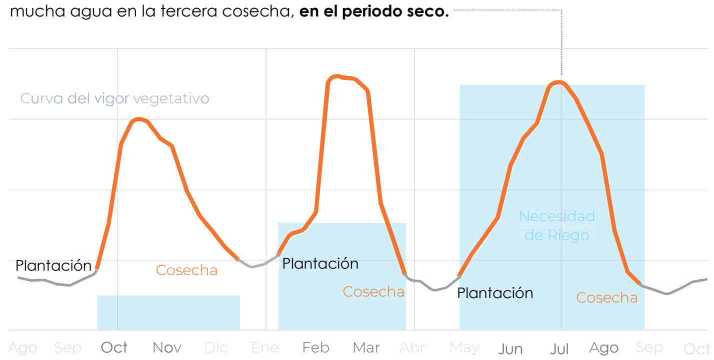
PERFIL CULTIVO DOBLE (COSECHA-«SAFRINHA»)

Perfil más común en pivotes, en verano usando poca agua, y con aumento del riego en la «safrinha» **porque la lluvia comienza a disminuir.**



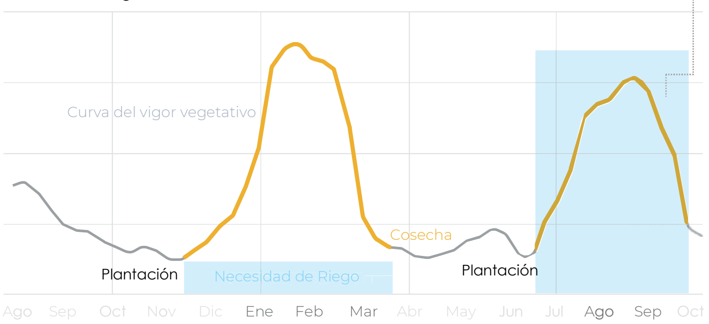
PERFIL COSECHA TRIPLE

Utiliza poca agua enel verano, agua media en la «safrinha» y mucha agua en la tercera cosecha, **en el periodo seco.**



PERFIL COSECHA DOBLE (COSECHA Y COSECHA DE INVIERNO)

En este perfil de sucesión de cultivos, se utiliza poca agua en verano, pero la **segunda cosecha se produce en el pico de la estación seca** y utiliza una gran cantidad de agua casi nada proveniente de la lluvia. El segundo cultivo puede ser un cultivo de ciclo más corto o más largo.



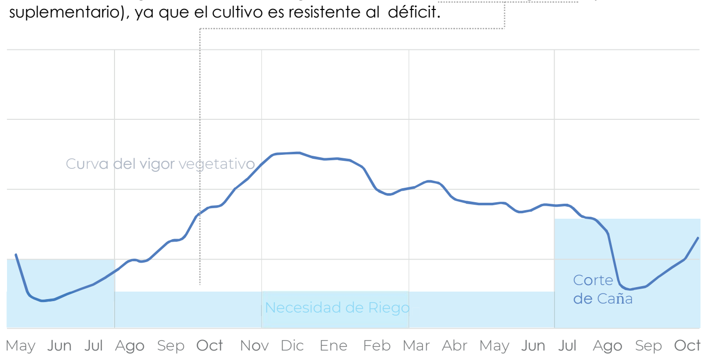
El Atlas 2017 llevó a cabo la primera gran sistematización de estos levantamientos por tipología, resultado de los propios estudios de la ANA y asociaciones, complementados con proyecciones censales y datos secundarios. Con los avances realizados, se redujo la incertidumbre sobre las áreas de riego, su ubicación y el consumo de agua asociado.

En la edición actual, Atlas actualiza y amplía los análisis realizado con anterioridad, con profundización en el uso de geotecnologías y fortalecimiento de la red de socios en los levantamientos. Además de las tipologías anteriormente trabajadas (arroz, caña de azúcar y pivotes), se pudo detallar la ocurrencia de café irrigado (principal cultivo de riego permanente), además de la subdivisión de la caña de azúcar en irrigada y fertirrigada. Los otros cultivos irrigados por otros sistemas -pasturas, flores, verduras, legumbres, frutas, bosques plantados, etc.- permanecen como tipología agregada.

El mapa municipal destaca la tipología de cultivo(s) predominante entre las zonas de riego de los municipios. Se observa la concentración de arroz en polos en el Sur y en Tocantins; de caña irrigada en el litoral nordestino y en otros polos del Centro-Sur y Nordeste; de la caña de azúcar fertirrigada en el Centro-Sur (São Paulo, suroeste de Goiás, triángulo mineiro y suroeste de Mato Grosso); del café en los polos de Espírito Santo, Minas Gerais, Bahía y Rondônia; de otros cultivos temporales cultivados bajo pivotes centrales en la meseta central (especialmente Goiás, Minas Gerais y Bahía); y de los otros cultivos y sistemas en el Norte y Semiárido.

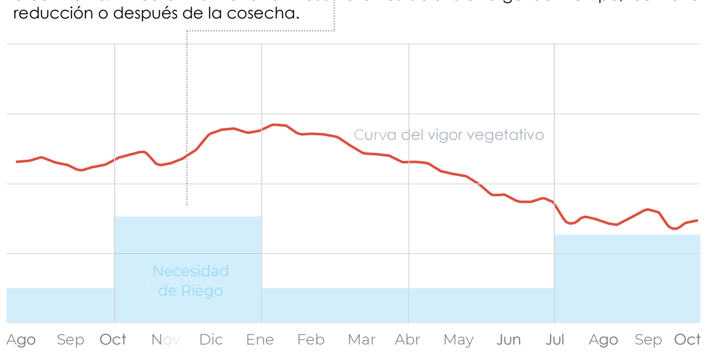
PERFIL CULTIVO SEMIPERENE

La caña de azúcar pertenece aeste perfil de cultivo y generalmente es regada por asperisón por carrete. Un corte anual ocurre cuando el riego es más necesario. El consumo de agua depende en gran medida del **tipo de gestión** (salvamento o suplementario), ya que el cultivo es resistente al déficit.

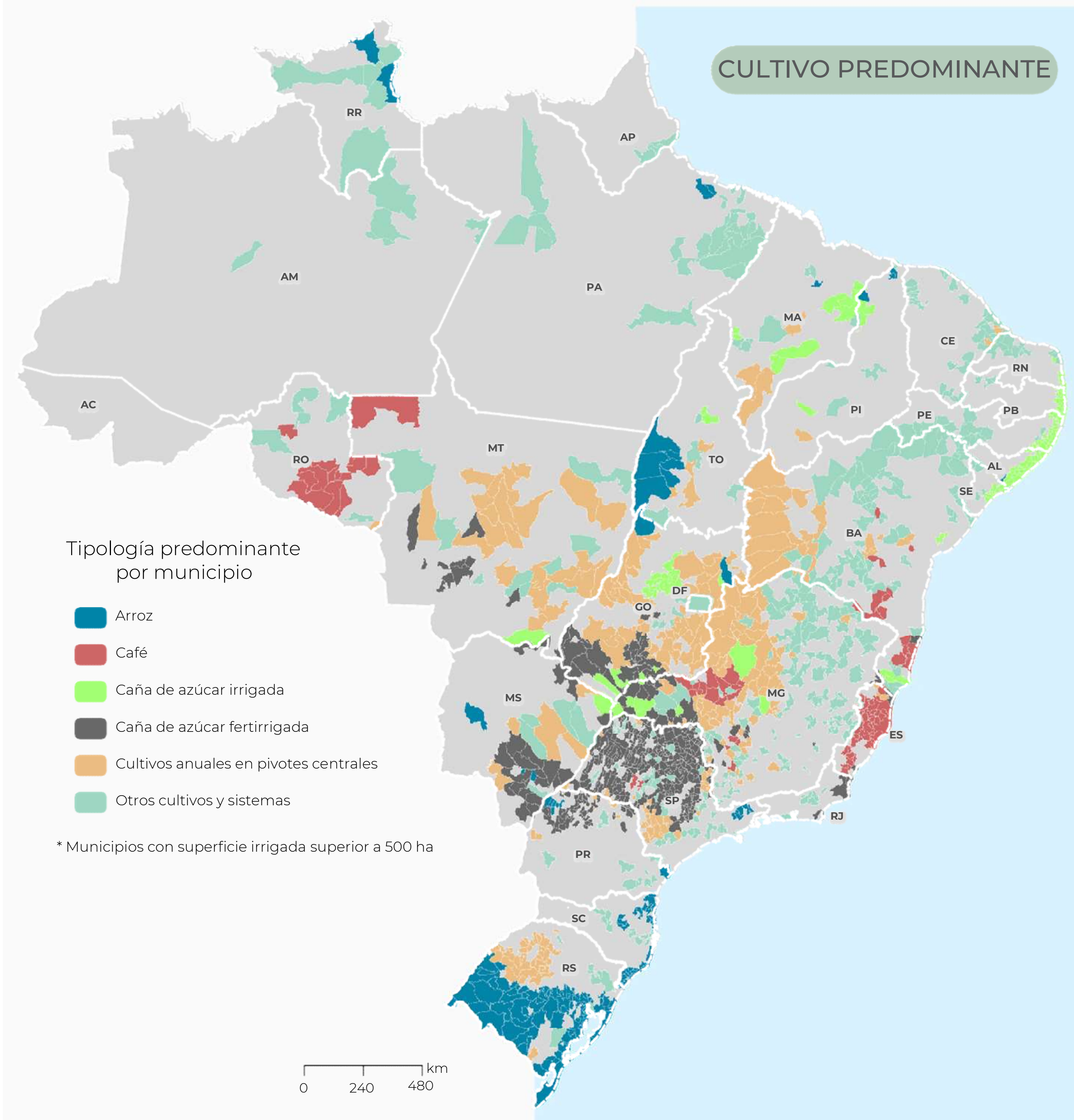


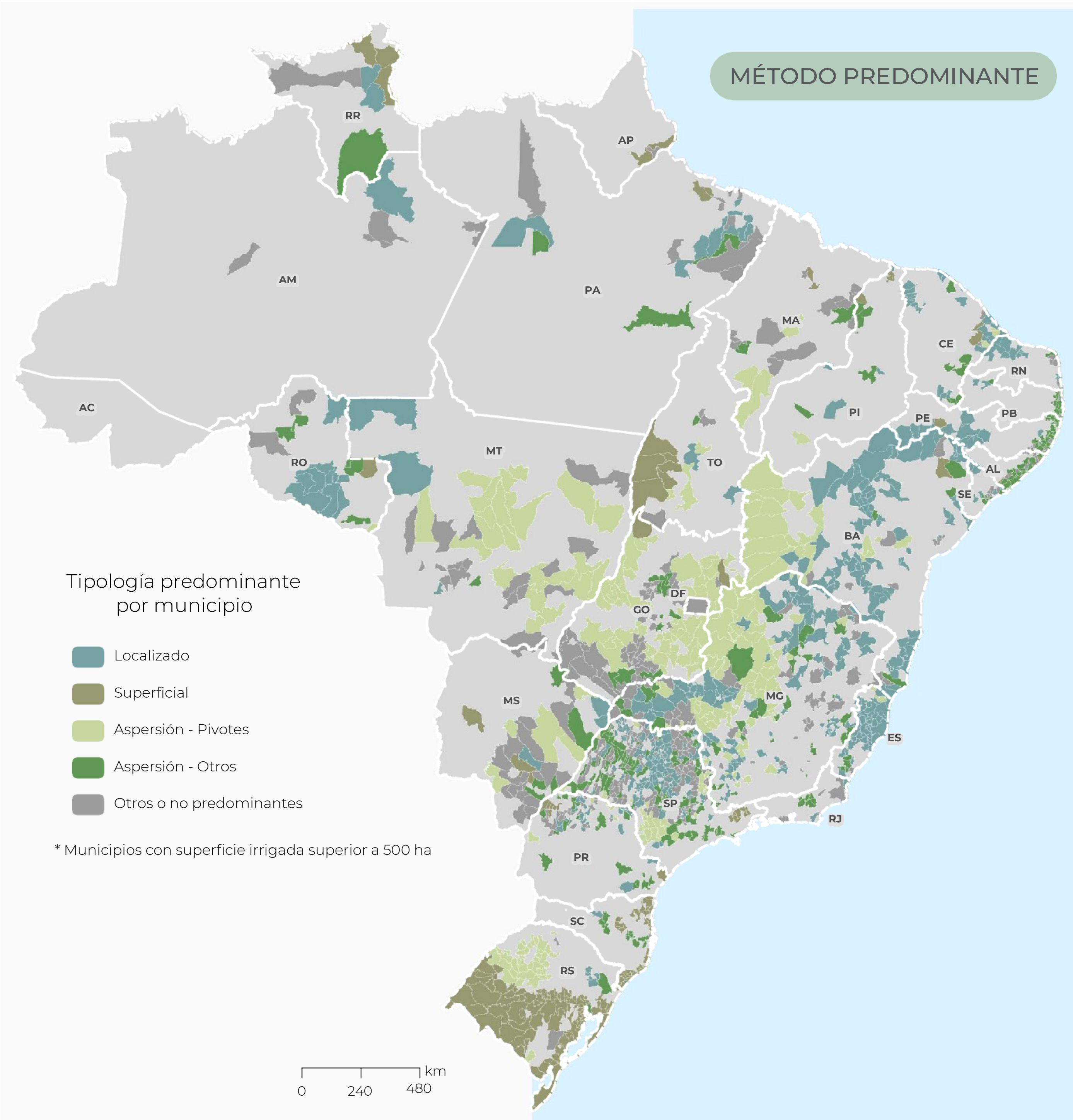
PERFIL CULTIVO PERENNE

El café y algunas frutas son cultivos perennes. Demandan constancia de agua a lo largo del año y el periodo de mayor **riego depende del clima local y de las etapas de crecimiento.** El café mantiene la masa foliar estable alo largo del tiempo, con una reducción o después de la cosecha.



Los métodos de riego predominantes demostraron la correlación del arroz con el método superficial (inundación), de la aspersión por pivotes con cultivos anuales, de la aspersión por otros sistemas con caña de azúcar y riego localizado con café y con los polos frutícolas del Nordeste. El mapa muestra la consolidación de métodos más eficientes en el Semiárido, con predominio de métodos localizados, resultado de inversiones en reemplazo de sistemas.





Plantación de naranjas cerca de São Carlos (SP)
Zig Koch /Banco de Imágenes ANA

El siguiente es un resumen de la metodología y los resultados de los estudios de las principales tipologías de áreas de regadío adoptadas en el Atlas.

La ***rizicultura*** brasileña ha mostrado una menor asignación de área en los últimos años, con una caída sistemática de las áreas de secano, sin embargo, con un aumento constante en la productividad promedio, especialmente debido a la mayor proporción de cultivos de regadío – actualmente responsable del 90% de la producción y 75% de la superficie cosechada. El arroz representa alrededor de 25% del área de riego en Brasil y el 40% del volumen de agua captada - el manejo del cultivo por inundación requiere más agua por unidad de área que en otros sistemas. Además, el arroz se concentra tanto en el territorio como en el calendario agrícola (un cultivo anual de 100 a 140 días, concentrado entre octubre y abril), lo que facilita su identificación.

El mapeo del arroz de regadío fue realizado por la ANA y por la Conab en asociación con instituciones públicas y el sector privado (cooperativas, consultorías y productores rurales) en los principales estados productores. Se utilizaron imágenes satelitales y verificaciones de campo – la metodología y los resultados se detallan en el ***Mapeo de Arroz Irrigado en Brasil*** (ANA & Conab, 2020).

Los resultados indican ***1,298 Mha*** (millones de hectáreas) de arroz irrigado en Brasil - 92,8% de la superficie en los tres mayores productores: Tocantins (8,4%), Santa Catarina (11,5%) y, principalmente, Rio Grande do Sul (72,9%). La superficie actualmente identificada en la cosecha 2019/20 representa una reducción del 16% en relación a los datos consolidados por el Atlas Riego para el año 2015 (1,544 Mha). Esta diferencia se debe principalmente a la reducción de 255 mil hectáreas de área de riego en Rio Grande do Sul.

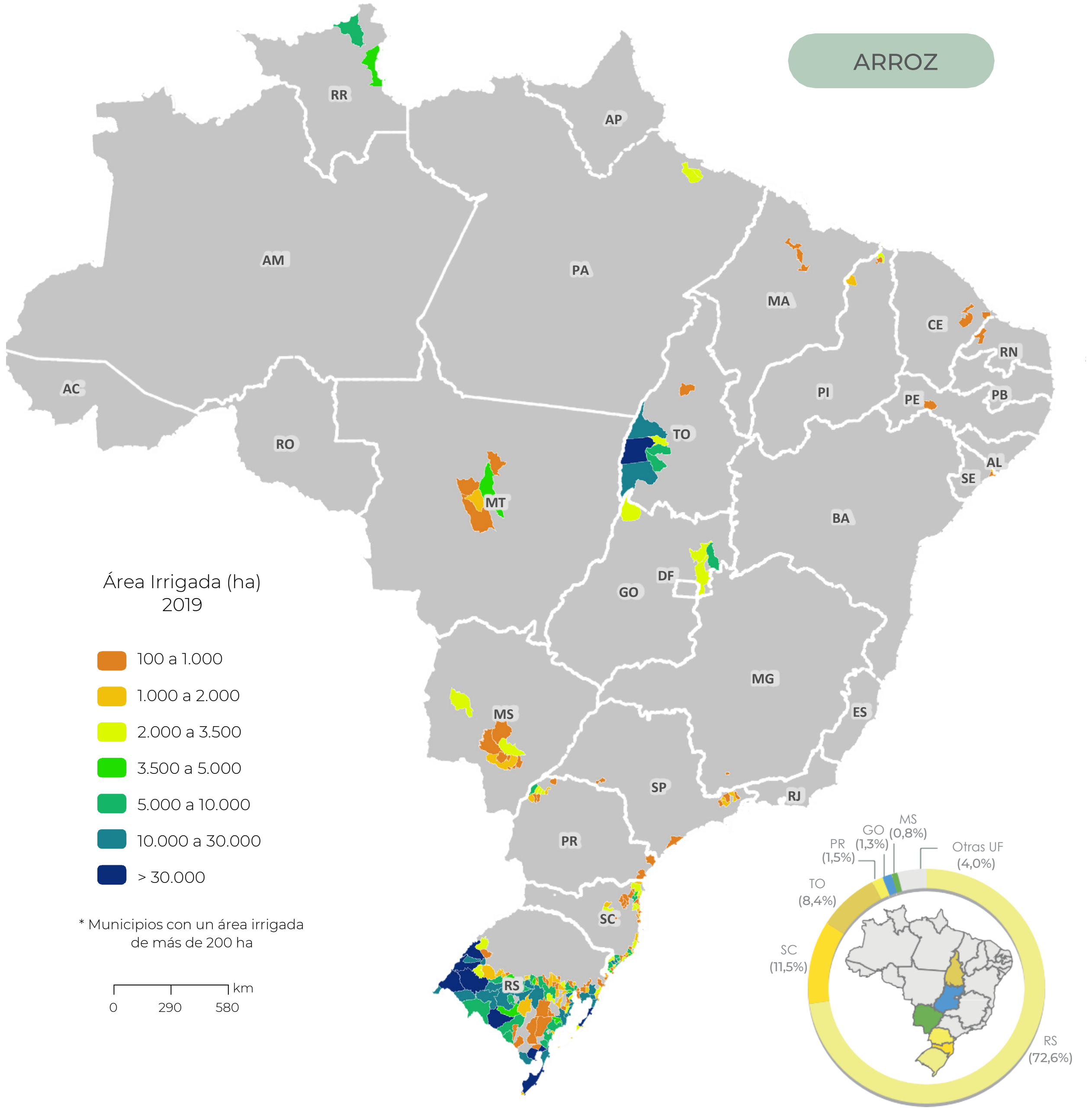
La caña de azúcar tiene características peculiares del manejo del riego. La mayoría de las regiones de caña de azúcar en Brasil tienen condiciones climáticas favorables para el desarrollo de cultivos sin riego. Sin embargo, se han observado grandes expansiones en áreas con mayor déficit hídrico, lo que lleva a una mayor necesidad de riego suplementario. En las zonas de menor deficiencia hídrica, también se ha intensificado el uso del riego con el objetivo de productividad o para la dispersión de los efluentes de los procesos industriales (especialmente la vinaza) en línea con las normas ambientales más recientes, que no permiten la dispersión directa en los cuerpos hídricos.

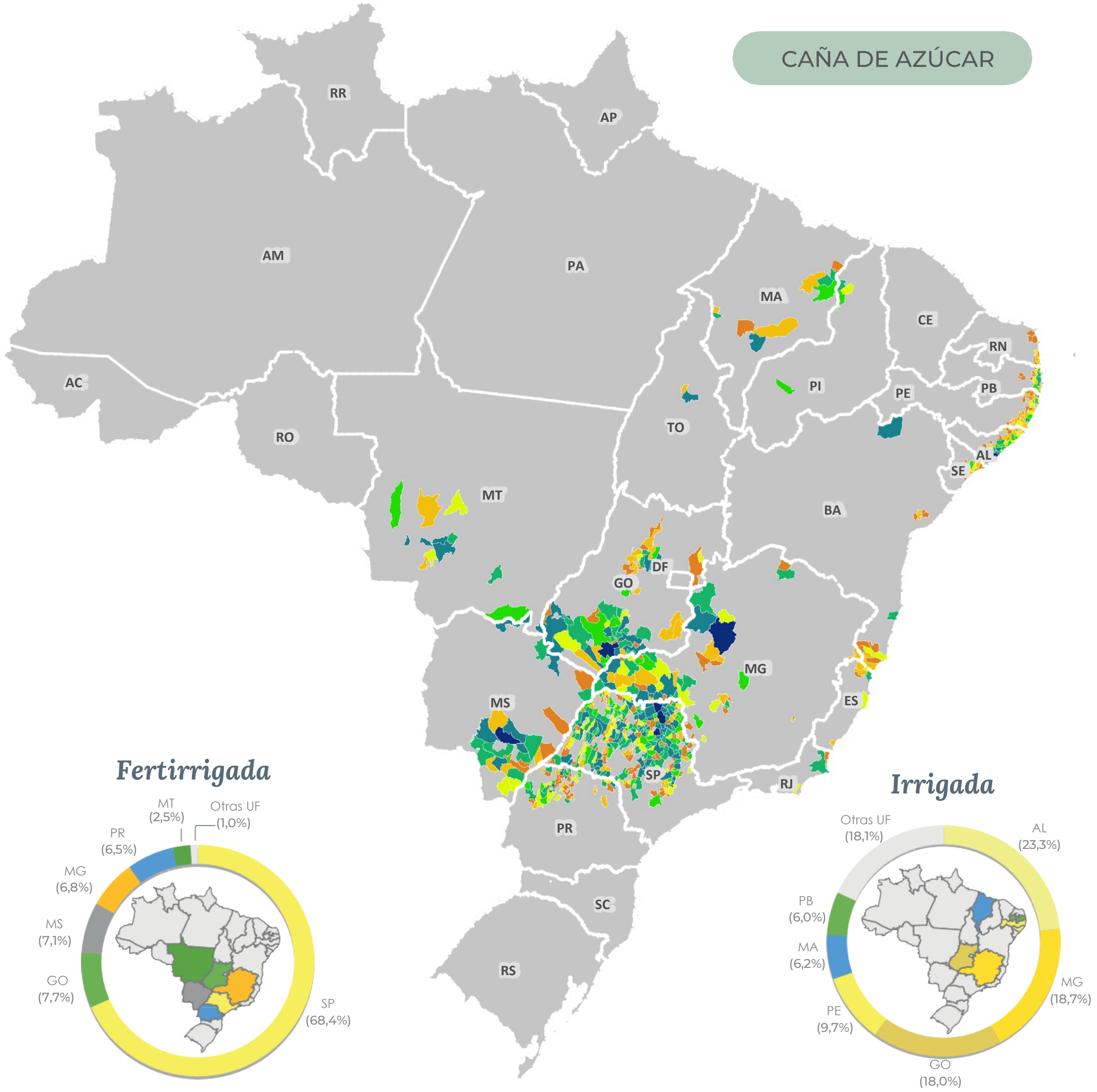
El cultivo tiene una alta resiliencia al estrés hídrico, es decir, la productividad se reduce, pero no económicamente inviable. La práctica del riego puede mitigar los impactos negativos resultantes de sequías prolongadas además de aumentar la longevidad de la plantación de caña de azúcar, es decir, el tiempo de retiro planificado de 5 o 6 años puede incluso duplicarse.

La adopción del riego presenta restricciones de naturaleza económica y medioambiental. Sin embargo, todas las plantas del país cuentan con equipos de riego (carretes enrolladores, principalmente) para su aplicación en cultivos de caña de azúcar, vinaza y aguas residuales de procesos de producción de etanol y azúcar, un proceso conocido como fertiirrigación. En las regiones con mayor déficit hídrico, esta reutilización procedente del proceso industrial se consorcia con el agua de los manantiales, proporcionando mayores aplicaciones de agua (riego de salvamento). En regiones aún más deficitarias, la producción solo es factible con un riego más integral (suplementario o plena), también utilizado en plantas que deciden realizar este tipo de inversiones con el objetivo de obtener ganancias en productividad y calidad.

Por lo tanto, la caña de azúcar tiene diferentes manejos de riego: La ***fertiirrigación***, que consiste esencialmente en la reutilización agronómica de efluentes del proceso agroindustrial (vinaza y aguas residuales), predominante en áreas con una deficiencia de agua de hasta 800 mm por año en la región Centro-Sur; riego de ***salvamento*** donde se produce la fertiirrigación mezclada o intercalada con bajos volúmenes de agua extraída de fuentes de agua, predominante en áreas con una deficiencia de más de 800 mm/año en la Zona de la Mata nordestina; y riegos ***suplementario y pleno***, que ocurren en áreas de alto déficit hídrico, como en el Semiárido, o en plantas que deciden esta inversión.

Actualmente, la caña de azúcar tiene ***3,66 millones de hectáreas (Mha)*** equipadas para el riego - la mayoría (***2,9 Mha o 79,5%***) realiza solo fertiirrigación. Otros ***749 mil hectáreas (20,5%)*** son regadas con agua de manantiales. En el riego en sí,





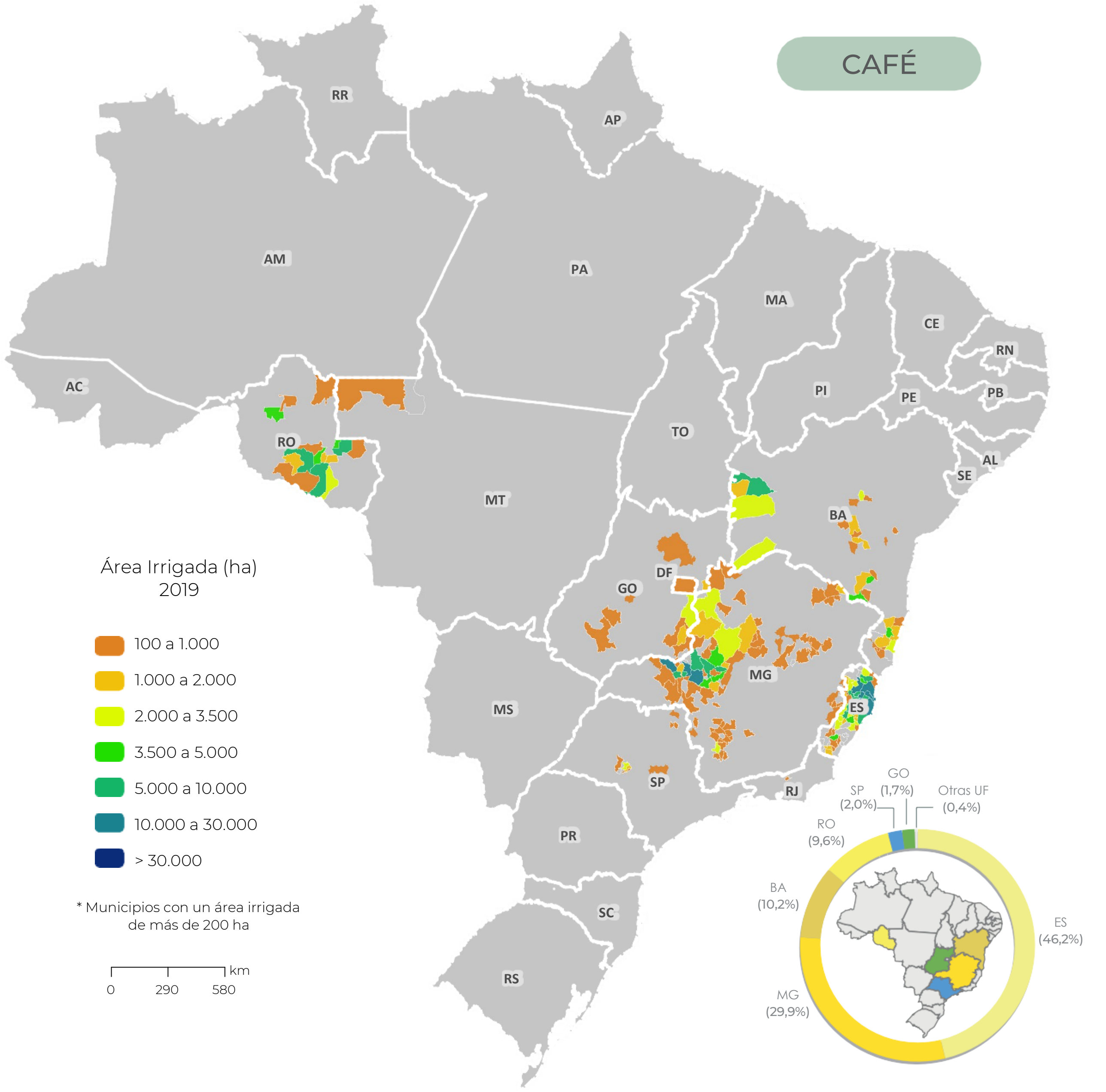
el salvamento representa el 76% de la superficie y las superficies completas y suplementarias el 24%. Con diferentes intenciones en el uso del agua, el volumen de agua utilizado durante un año en una hectárea de déficit/riego completo es, en promedio, equivalente al aplicado en 25 hectáreas de fertiirrigación/salvamento. El método y los resultados del mapeo se detallan en el ***Levantamiento de la Caña de Azúcar Irrigadas y Fertirrigada en Brasil*** (ANA, 2019).

Entre los Estados, el área fertirrigada predomina en São Paulo (68,5%), Goiás (7,7%), Mato Grosso do Sul (7,0%), Minas Gerais (6,8%) y Paraná (6,5%). El área riego con agua de manantiales (749 mil ha) es más relevante en Alagoas (23,3%), Minas Gerais (18,7%), Goiás (18%), Pernambuco (9,7%), Maranhão (6,2%) y Paraíba (6,0%).

El ***cultivo de café*** irrigado ha ido creciendo y ganando importancia en el escenario nacional en los últimos años. Brasil cultivó 1,825 Mha en la cosecha de 2019 (IBGE, 2020), una parte significativa de las pequeñas propiedades, lo que coloca al producto como el principal cultivo permanente del país. Con cerca del 25% de esta superficie bajo riego, es también el principal cultivo permanente irrigado. Es muy cierto que históricamente el café se cultiva y se sigue cultivando sobre un régimen de secano en las regiones más húmedas de la zona de la mata mineira en el al sudeste de Minas Gerais y en el centro-norte de São Paulo, pero el cultivo de café irrigado se ha expandido y ha ganado importancia socioeconómica en otras regiones.

En la región centro-norte de Espírito Santo, centro-este de Rondônia y al sur de Bahía, *Coffea canéfora* irrigada (variedades *Robusta* y *Conilon*) en sistema de goteo y microaspersión ya es una realidad entre el 50 y el 70% de los cultivos. En Minas Gerais, el cultivo de café irrigado está más densificado en la región sudoeste, cerca del triángulo de Minas Gerais, pero también ocurre en los estados del sur y del centro-norte, en sistemas diversificados de riego. Ya en Goiás y en el Distrito Federal, lugares de clima seco entre los meses de mayo y septiembre, el cultivo de café se produce en un sistema de riego de pivote central con predominio de la especie *Coffea arabica*.

En Rondônia, el cultivo de café ha demostrado bastante dinámica: en los últimos cinco años, los cultivos de secano han sido reemplazados en gran medida por el café clonal irrigado, un paquete tecnológico que ha aumentado significativamente la productividad y movido la economía agrícola del estado, donde el café se encuentra principalmente en pequeñas propiedades familiares.



La diferenciación del café irrigado del no irrigado no es trivial y se realizó combinando técnicas de teledetección y contactos técnicos con agencias que trabajan en investigación, asistencia técnica y levantamiento de cultivos de café, como Embra-pa, Emater y Conab; así como con departamentos estatales y municipales de agricultura, medio ambiente y recursos hídricos.

En Espírito Santo, la identificación de los cultivos irrigados se realizó a nivel municipal, a partir de la clasificación del mapeado de uso del suelo y cobertura del Instituto Estatal de Medio Ambiente y Recursos Hídricos – IEMA (IEMA, 2015), y su proximidad a los puntos de adjudicación emitidos por la Agencia Estatal de los Recursos Hídricos - AGERH.

En Goiás, Distrito Federal y Oeste de Bahía, donde el cultivo del café se produce casi en su totalidad bajo pivotes centrales, el riego del café se identifica fácilmente, ya que mantiene un vigor vegetativo relativamente estable que permite diferenciarlos en las imágenes de otros cultivos anuales bajo pivotes, que tiene ciclos de vida cortos y respuesta espectral a lo largo del año bastante distinta del café. En otras regiones de Bahía, la identificación de cultivos fue realizada por Conab con la interpretación visual de imágenes del satélite Sentinel 2A y 2B, con posterior clasificación en cultivos irrigados y no irrigados que combinan presencia de infraestructura hídrica y vigor vegetativo.

En Minas Gerais, el mapeo fue realizado por la Emater/MG en asociación con la ANA y Conab, también mediante interpretación visual de las imágenes de los satélites Landsat 8, RapidEye y Sentinel, seguida de una extensa validación de campo por parte de técnicos del propio Emater/MG. En los demás estados, se adoptaron estimaciones derivadas de el Levantamiento Sistemático de Producción Agrícola (LSPA/IBGE), la Producción Agrícola Municipal (PAM/IBGE) y el Censo Agropecuario. En Rondônia, hubo una evaluación cualitativa con profesionales de Emater, Embrapa y Conab involucrados en la asistencia técnica, investigación y promoción del cultivo de café en el estado.

El levantamiento consolidada por Atlas identificó ***449,3 mil hectáreas*** irrigadas de café en Brasil (0,449 Mha) – 25% del área destinada a cultivo. En términos relativos, Espírito Santo lidera con el 46,2% del área irrigada, seguido de Minas Gerais (29,9%), Bahia (10,2%), Rondônia (9,6%), São Paulo (2,0%) y Goiás (1,7%). Proporcionalmente a la superficie total (de secano + de riego), Goiás es más dependiente del riego (casi el 100% de las plantaciones de café), seguido por Espírito Santo y Rondônia (60 a 70% de las plantaciones de café son de riego) y Bahia (40%). Minas Gerais, responsable del 50% de la producción nacional, cuenta con el 14% de sus plantaciones de café irrigados; y São Paulo solo 4%.

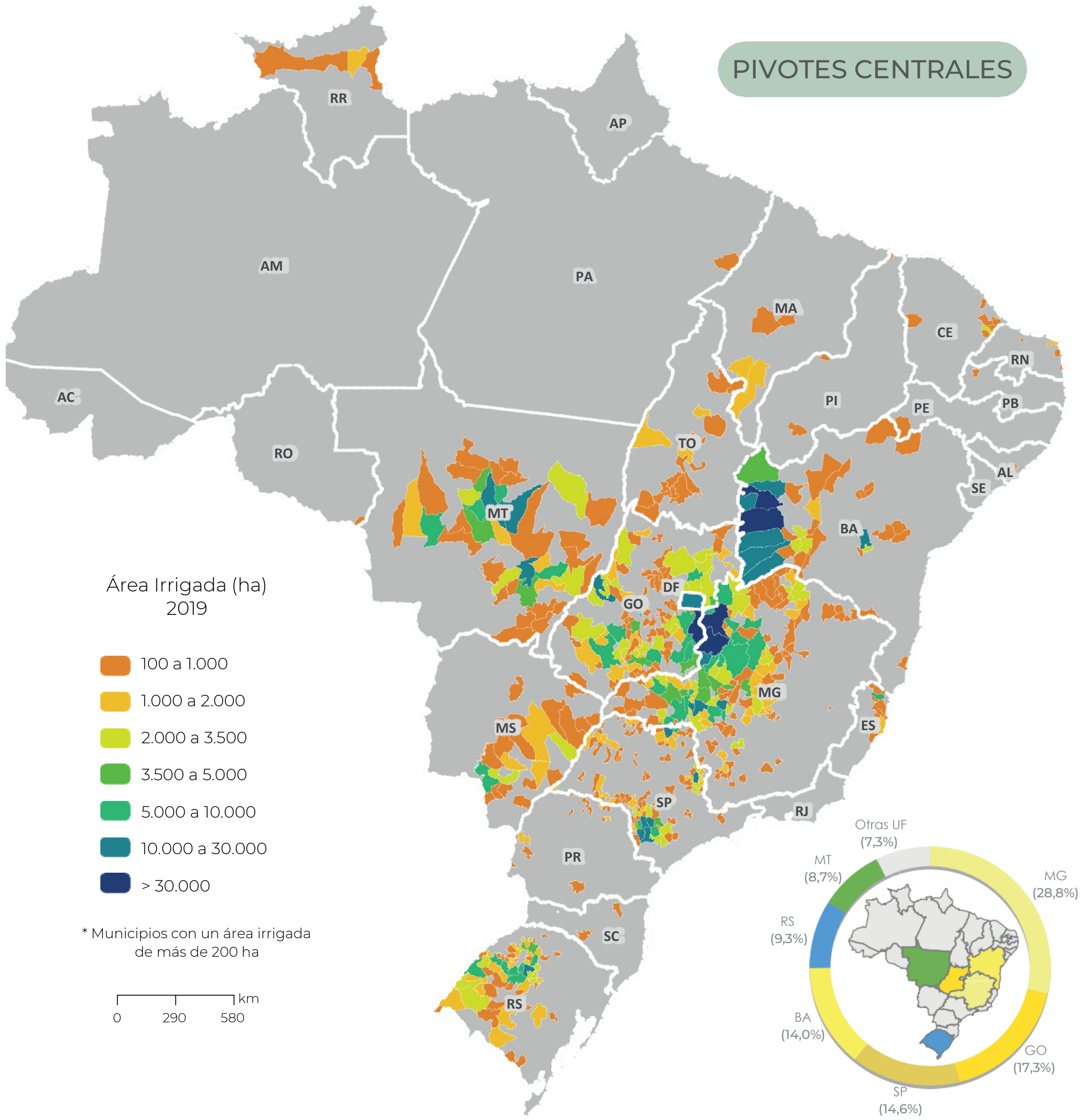
Los ***pivotes centrales*** riegan una gran diversidad de cultivos, pero hay una concentración de su uso para la producción de frijoles, maíz, soja, algodón y, en menor medida, trigo y papas. El mismo pivote puede realizar hasta tres cosechas en el mismo año (soja seguida de maíz y frijoles, por ejemplo). La realización de dos cosechas es más frecuente (cosecha y fuera de temporada; o cosecha y segunda cosecha de larga duración o invierno). También hay ejemplos de diferentes cultivos simultáneamente cultivados en el mismo pivote. Por lo tanto, no depende de los pivotes asignar cultivos específicos porque es un consorcio, que varía intra e interanualmente dependiendo de las condiciones del mercado, la disponibilidad hídrica y las diferentes decisiones de los productores.

Tipología que lidera el crecimiento del riego en los últimos años, los pivotes han sido mapeados regularmente por Ana y Embrapa. La segunda edición, revisada y ampliada del ***Levantamiento de la Agricultura Irrigada por Pivotes Centrales en Brasil*** (ANA & Embrapa, 2019) presenta una serie histórica de mapeo de 1985 a 2017. Para la segunda edición de Atlas Riego, este levantamiento se actualizó para el año de 2019, siguiendo la metodología publicada y con nuevas mejoras (incorporación del análisis de series de índices de vegetación dentro de la máscara pivotante central).

En 2019 se identificaron ***1,556 Mha*** irrigados por pivotes centrales, 111,1 mil hectáreas en caña de azúcar (67,7 mil ha) o café (43,4 mil ha). Por lo tanto, 1,445 Mha están ocupados con cultivos temporales que varían intra e interanualmente. Se presentan en polos muy limitados, especialmente en Minas Gerais (28,8%), Goiás (17,3%), São Paulo (14,6%), Bahia (14,0%), Rio Grande do Sul (9,3%) y Mato Grosso (8,7%). El área actual es 50 veces mayor que el área mapeada en 1985 y todos estos estados muestran un crecimiento significativo en el mediano y corto plazo – Mato Grosso y Rio Grande do Sul crecen a un ritmo mayor que los otros, lo que resulta en la aparición de polos de riego nacionales y la mayor participación de estos dos estados en el total nacional (7% en 2000, 11% en 2010 y 18% en 2019).

Los ***otros cultivos*** irrigados por otros métodos/sistemas también son diversos. Los cultivos regados predominantemente por pivotes centrales también son regados por otros sistemas (soja, maíz, frijol, algodón) en pequeñas propiedades y están incluidos en esta tipología. Entre los principales destacan el riego de cítricos (naranja, limón y mandarina) que ocupan cerca de 85 mil ha; banana (85 mil ha); tomate (45 mil ha); mango (44 mil ha); y melón y sandía (62 mil ha). El coco, la maracuyá, la papaya, la uva, la guayaba y la pimienta negra ocupan en conjunto unas 100 mil hectáreas irrigadas. Es decir, predominan en esta tipología los productos de la ***fruticultura*** y de la ***horticultura***, que son proporcionalmente más irrigados (70 a 90% de la superficie cultivada es regada) que los principales cultivos irrigados en cifras absolutas (granos).

Brasil es uno de los principales exportadores de frutas y el riego contribuye a la seguridad productiva y la calidad de los productos. Según el Anuario Brasileño de Horti&Fruti 2020 (Carvalho et. al., 2019), en 2019 se enviaron más de 980 mil toneladas de frutas (+16% respecto a 2018) – el

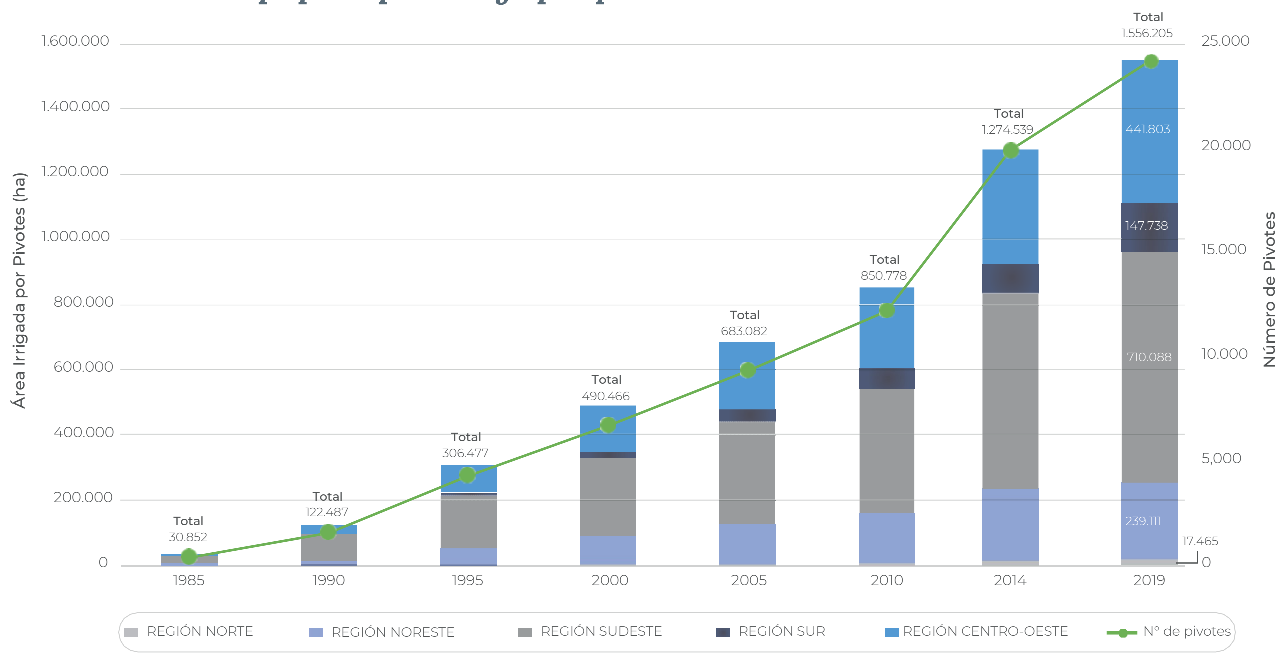


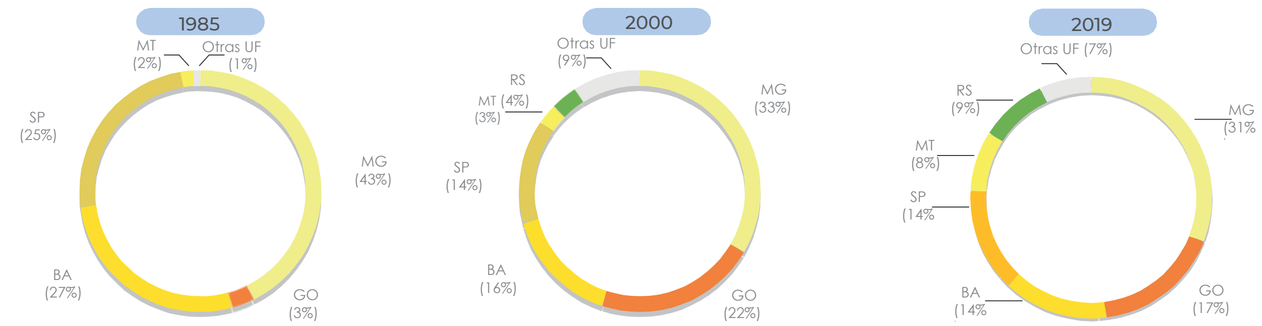
melón es el más exportado en volumen y el mango en valor.
En las exportaciones también destacan uvas, limones, lima, papaya, sandía, manzanas, plátanos y aguacate. Destacamos la producción irrigada en el valle de São Francisco (polo más grande, en la región entre Petrolina/PE y Juazeiro/BA), Ceará y Río Grande do Norte – pero otros estados también tienen riego importante, como São Paulo en riego de cítricos y Espírito Santo en papaya.

Las aspersión convencional y, sobre todo, los sistemas localizados (microaspersión y goteo) son los principales métodos/sistemas asociados con esta tipología. En menor medida y con tendencia a seguir sustituyendo por otros métodos más eficientes, también se engloban métodos superficiales (surcos e inundación).

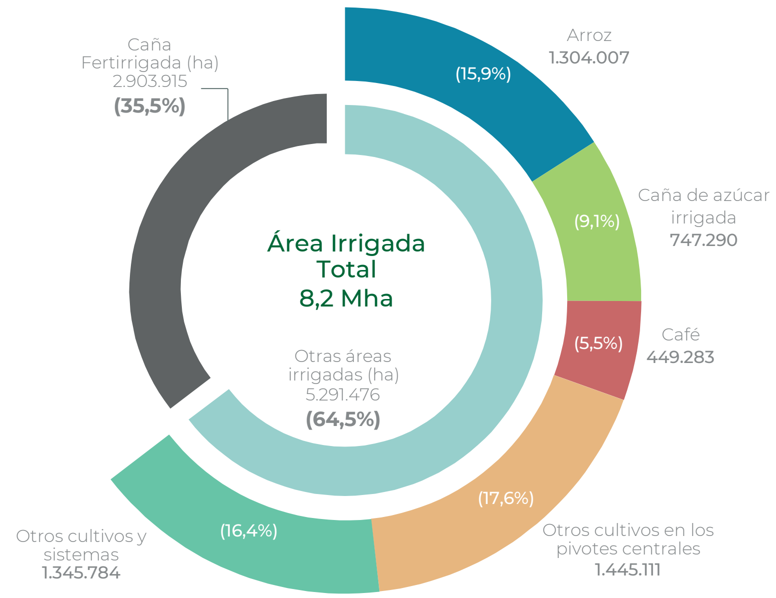
Se estimó el área de tipología ***otros cultivos y sistemas*** con: resultados del estudio Polos Nacionales de Agricultura Irrigada (ANA, 2020), mapeos complementarios realizados por ANA para Atlas (esfuerzo concentrado en el Semiárido), mapeo realizado por ADASA para el Distrito Federal (ADASA, 2020) e información del Censo Agropecuario del IBGE. En las regiones con divergencias entre las fuentes de datos, también se consultó a los municipios y entidades estatales (EMATER, Secretarías, etc.) en busca de información cualitativa y cuantitativa que ayudara a definir el área de riego municipal.

Área equipada para riego por pivotes centrales - 1985-2019





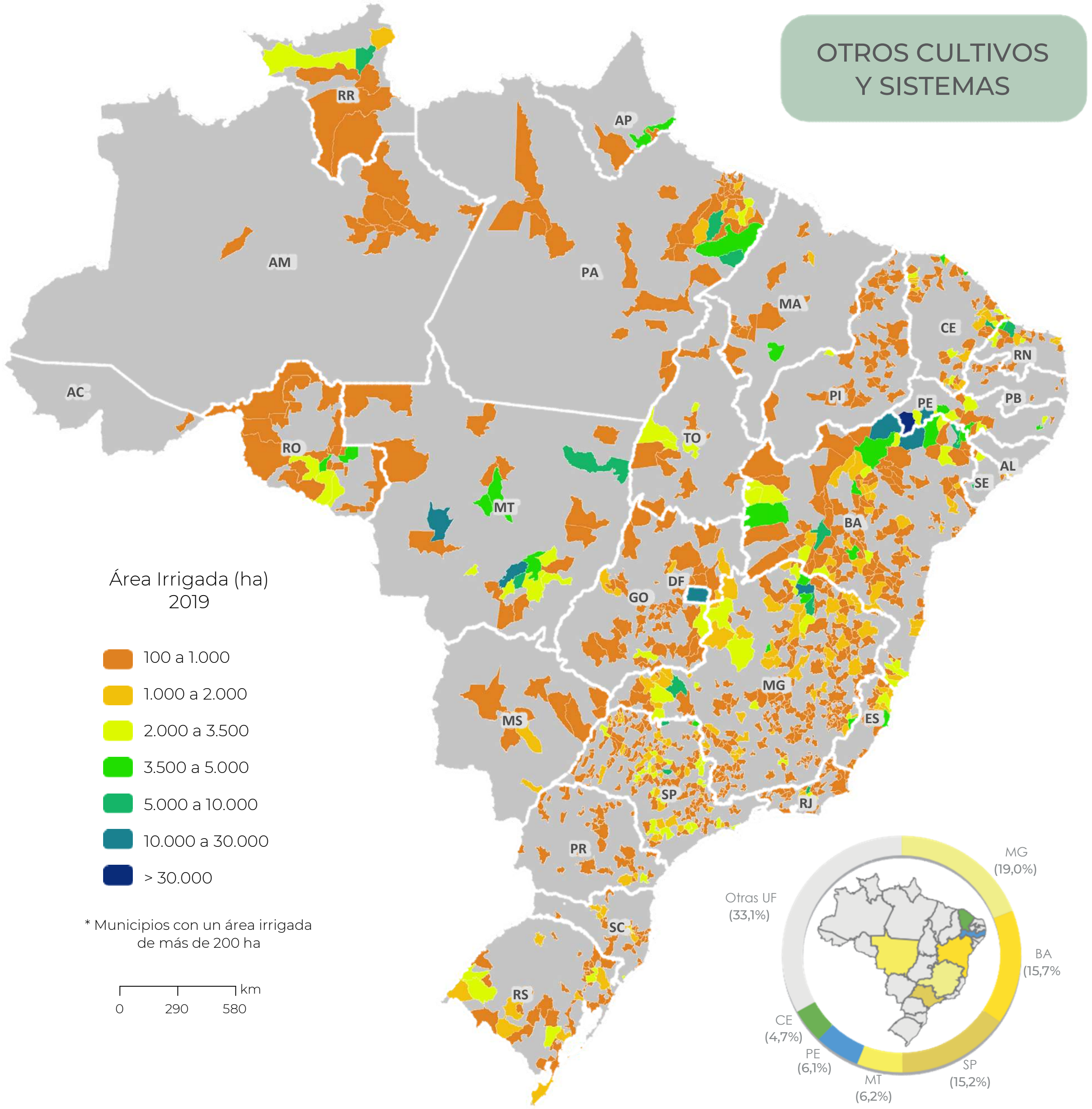
Área equipada para riego en Brasil - 2019



Con esto, se identificaron **1,346 Mha**, irrigados concentrados en el Norte-Nordeste y en el norte de Minas Gerais; y también pulverizados alrededor de los mercados de consumo (aglomeraciones urbanas). Entre los estados, Minas Gerais (19,0% del área irrigada por esta tipología), Bahia (15,7%), São Paulo (15,2%), Mato Grosso (6.2%), Pernambuco (6,1%) y Ceará (4,7%).

Agrupando las tipologías detalladas anteriormente Brasil suma ***8,2 millones de hectáreas equipados para el riego*** - 35,5% (2,9 Mha) con fertirrigación con agua de reutilización y 64,5% (5,3 Mha) con riego con agua de manantiales.

OTROS CULTIVOS Y SISTEMAS

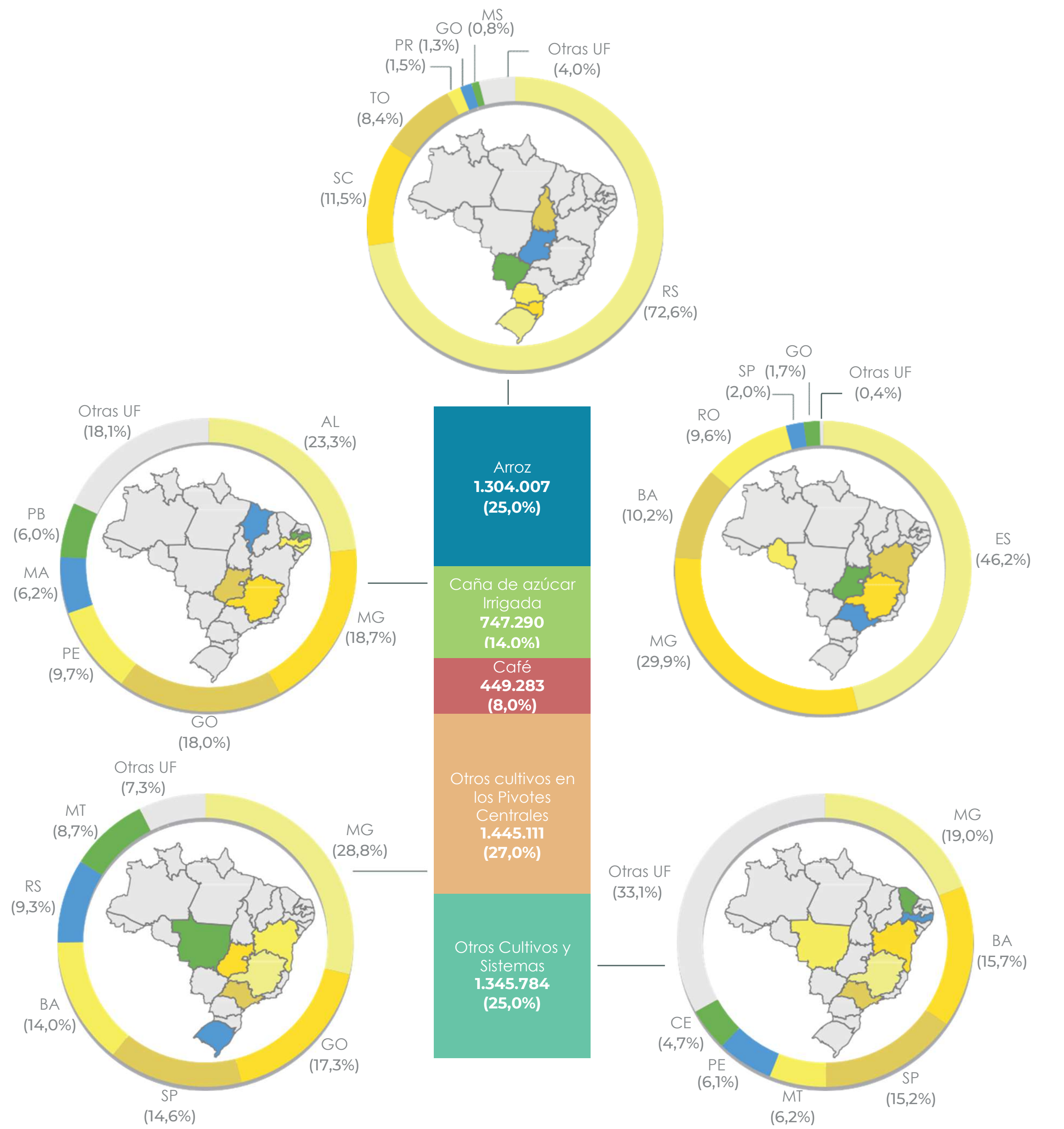


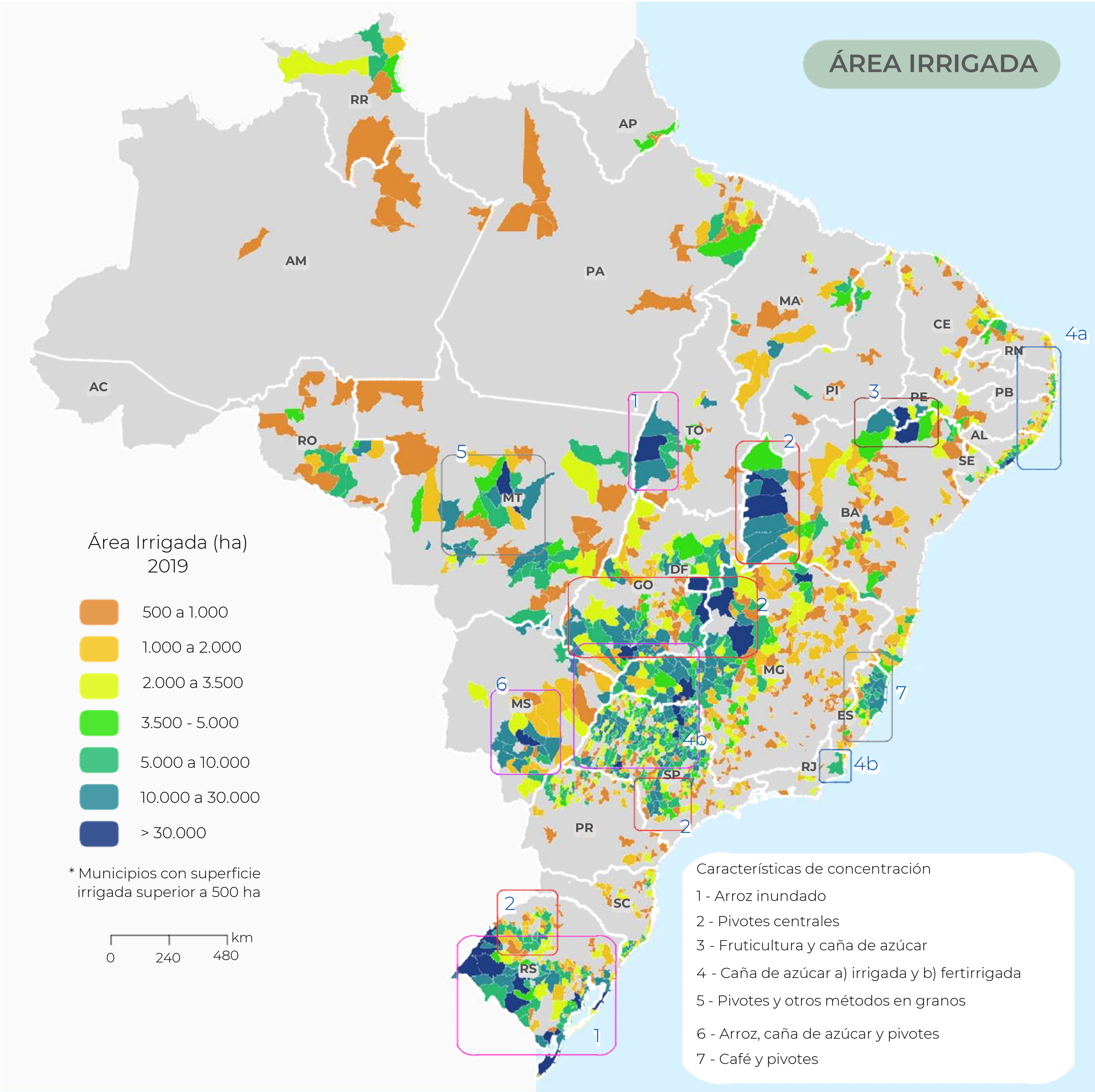
Pivote central y su reservorio en la región de Itaberá (SP)
Raylton Alves /Banco de Imágenes ANA

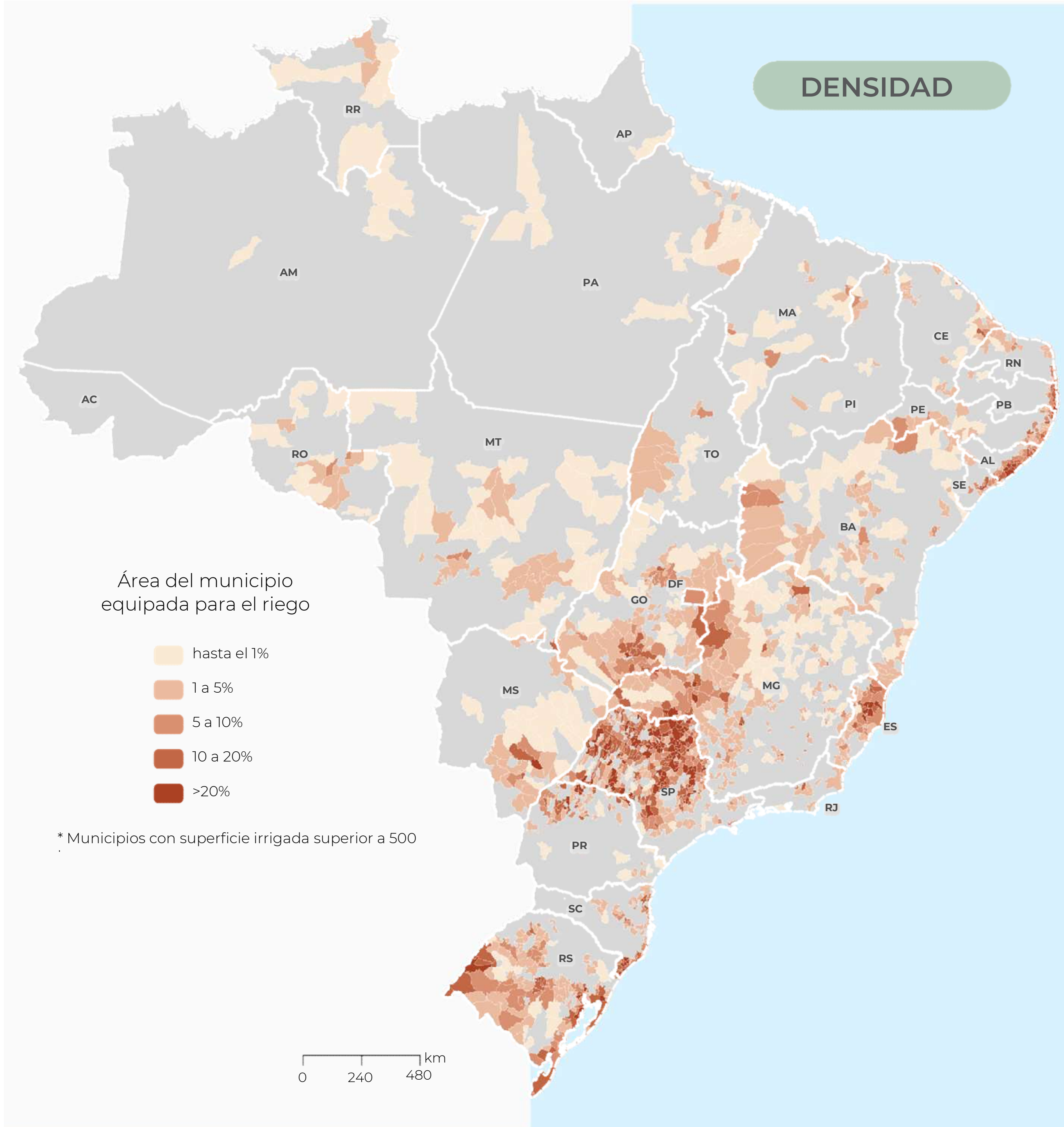
Los mapas de área irrigada total y de densidad de ocupación destacan las principales características de concentración en municipios y polos nacionales de riego.

Consideración de la distribución de las áreas irrigadas propiamente dicho (excluyendo fertirrigado), Brasil suma ***5,3 millones de hectáreas equipadas para riego*** - el arroz ocupa el 25% del total; la caña el 15%; el café el 8%; los cultivos anuales en los pivotes centrales el 27%; y otros cultivos y sistemas el 25%. La geografía de la distribución entre las unidades de la federación es diferente y debería cambiar en el futuro en la medida en que se estime un crecimiento diferenciado entre estas tipologías y diferentes potencialidades de expansión de la actividad en el territorio nacional.

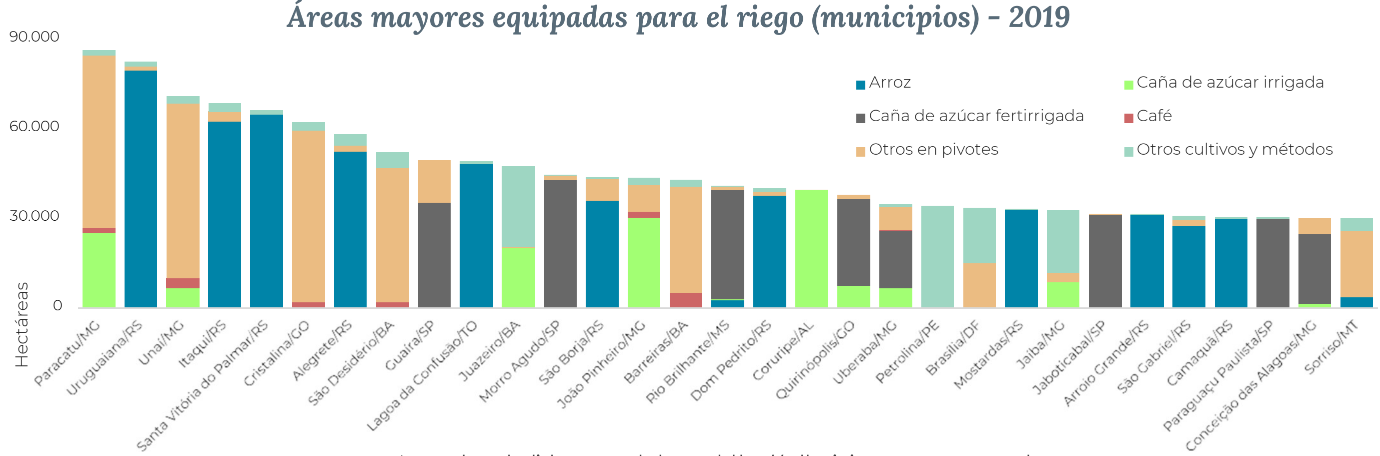
Área equipada para riego en Brasil, excepto fertirrigación - 2019





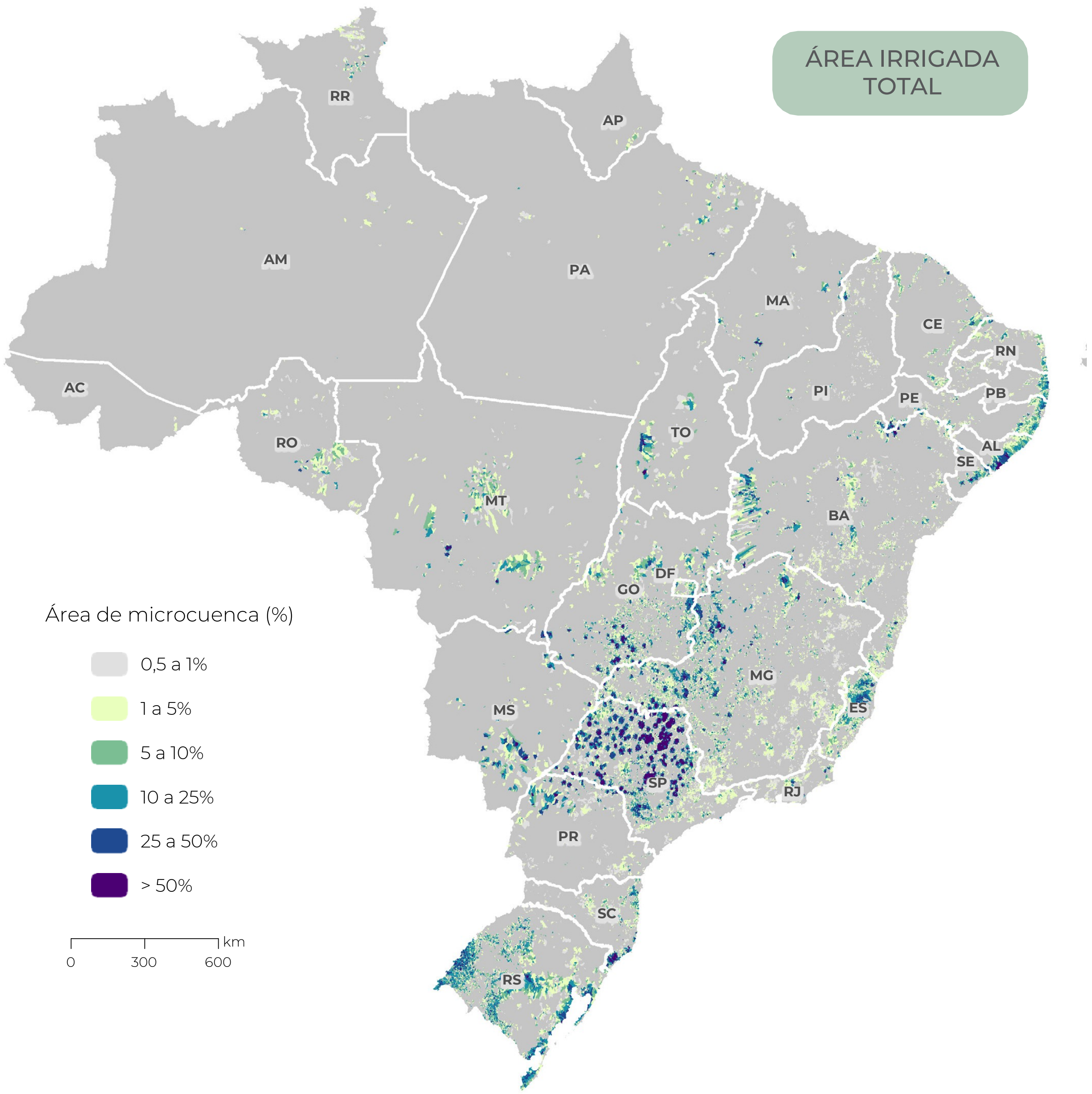


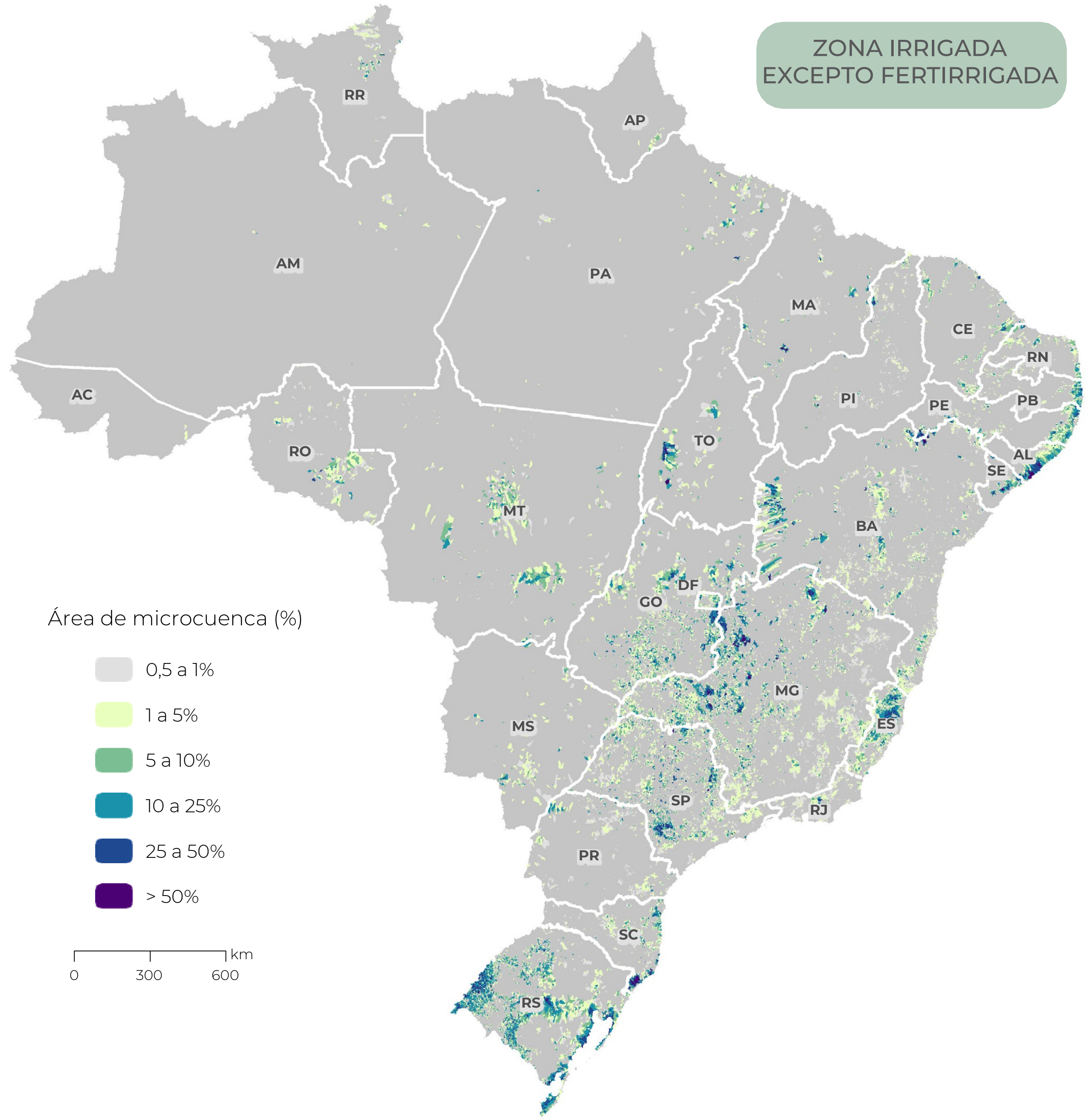
Áreas mayores equipadas para el riego (municipios) - 2019



Acceda a la lista completa en http://atlasirrigacao.ana.gov.br

Central azucarera-energética y riego en caña de azúcar, en São Francisco de Sales (MG)
Raylton Alves /Banco de Imágenes ANA





Además de estimaciones por municipio y tipología presentado anteriormente, Atlas buscó modelar, de una manera sin precedentes, la presencia de áreas regadas y fertirrigada en las cuencas hidrográficas, una escala que es más apropiada para las estimaciones del balance hídrico en los manantiales (oferta x demanda).

En este proceso, fue adoptada la Base Hidrográfica Ottocodificada Multiescalas 2017 5k (BHO5k), producido por la ANA, que subdivide el territorio brasileño en unas 400 mil microcuencas (u ottocuencas), que son las áreas de contribución de cada tramo de drenaje de la red hidrográfica.

Estos resultados se detallan de una manera más localizada la presencia de la agricultura de regadío dentro de los municipios y sus subcuencas hidrográficas, permiten mayores avances en las estimaciones del potencial de expansión de las áreas irrigadas y el uso del agua asociada - temas que se explorarán en detalle en los próximos capítulos.


Áreas irrigadas en Conceição das Alagoas (MG)
Raylton Alves /Banco de Imágenes ANA

Proyectos Públicos

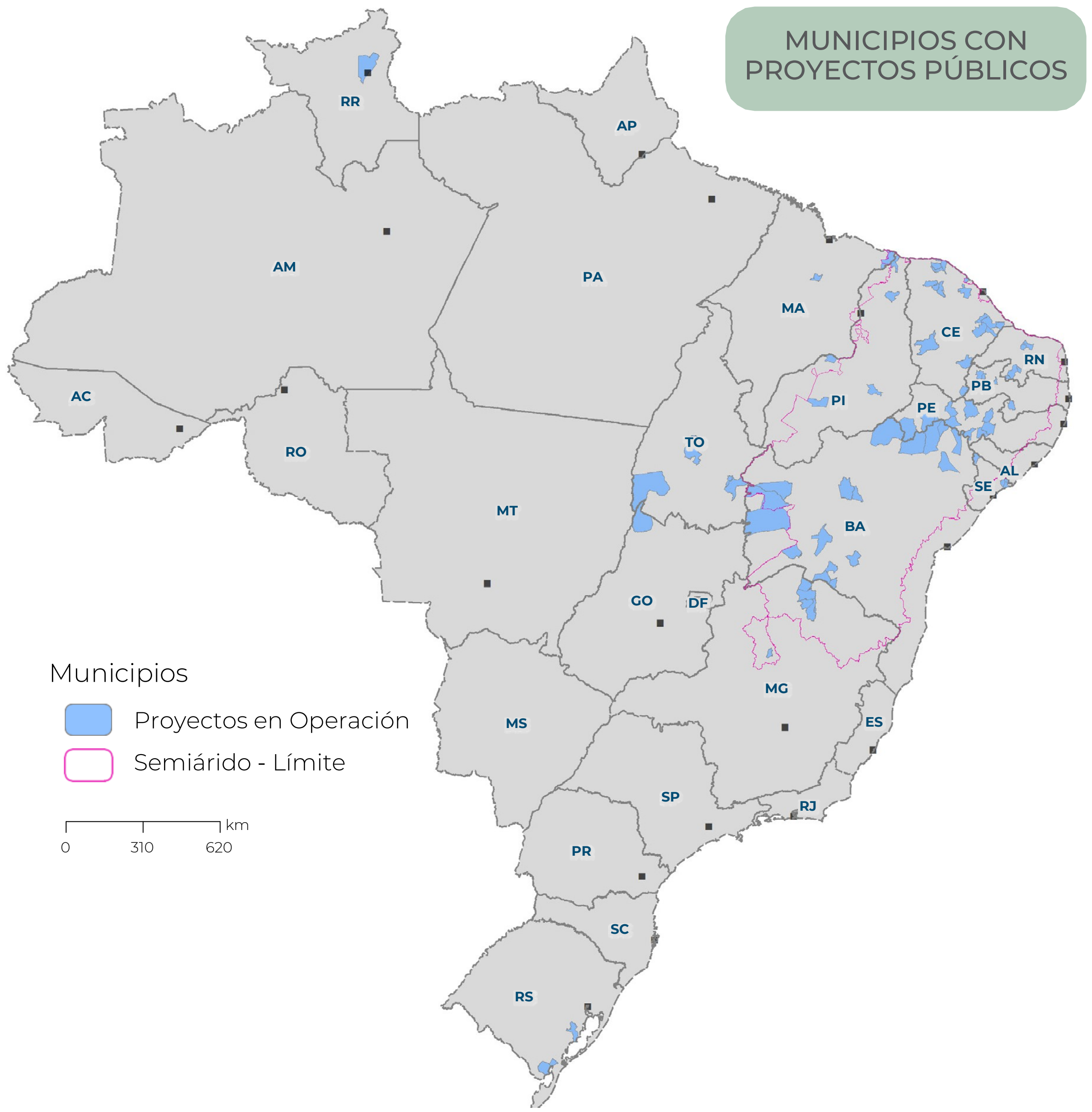
Importantes expresiones de iniciativas de desarrollo regional, especialmente en el Semiárido brasileño, los proyectos públicos siguen siendo importantes centros de riego locales y regionales, centrándose principalmente en el Semiárido (región de baja disponibilidad hídrica).

Actualmente, los proyectos riegan alrededor de ***200.000 hectáreas en 79 proyectos y 88 municipios***. La mayor parte de los perímetros es responsabilidad del DNOCS o Codevasf.

En 2003/2004, el área irrigada en los perímetros públicos fue de 162,1 mil hectáreas (SRH/MMA, 2006), aumentando a 173 mil hectáreas en 2007. El resultado en 2019 indica, por lo tanto, que la expansión de las áreas en operación ha sido inferior a 3 mil hectáreas por año, en promedio, en la última década. El ritmo es muy inferior al registrado por el sector privado, a pesar de las elevadas inversiones realizadas en los últimos años para la modernización de los proyectos, especialmente en la sustitución de métodos y sistemas de riego por otros más eficientes, en particular el riego de superficie por la presurizada (por lo general microaspersión y localizados). En función de este panorama, los perímetros públicos de riego redujeron su participación en el área irrigada del País de 4,7% en 2003/04 (SRH/MMA, 2006) a 2,4% en 2019.

Todavía quedan cerca de 100 mil hectáreas de áreas implantadas en proyectos públicos, pero que no presentó producción en 2019. El área implantada representa el área irrigable ya contemplada con todas las obras de infraestructura de riego de uso común que son necesarias para el inicio de la operación, pero que se enfrentan a varias dificultades para su ocupación efectiva.

MUNICIPIOS CON PROYECTOS PÚBLICOS



Entre los 79 proyectos con producción en 2019, los 34 que produjeron más de mil hectáreas sumaron 176 mil hectáreas (90% del área total). En las siguientes tablas se presentan los principales datos del proyecto, como ubicación, área ocupada y entidad responsable; cultivos principales, sistemas de riego e infraestructura asociada.

Se observa que, debido a la relación entre el área implantada y área cultivada, muchos perímetros también tienen una gran capacidad de expansión a corto plazo, como los de Jaíba/MG, Formoso/BA, Tabuleiros de Russas/CE y Baixo Acaraú/CE. Otros perímetros, por otro lado, ya tienen mayor uso de su área de cultivo implantada, como los de Senador Nilo Coelho/PE-BA, Luiz Alves do Araguaia/GO y Platôs de Neópolis/SE.

Basado en los datos del perímetro bajo responsabilidad de Codevasf, se estima que por cada 100 hectáreas irrigadas en producción se generan 116 empleos directos y 172 indirectos. Por lo tanto, se estima que los perímetros son responsables de alrededor de ***580.000 empleos*** (40% directos y 60% indirectos).

La ***emancipación*** de los proyectos, es decir, la transferencia de la gestión a los productores con sostenibilidad económica, política y social, ha sido un desafío para los productores y las instituciones responsables. Muchos proyectos se concibieron sin el arreglo productivo local completo y el arreglo institucional necesario para la sostenibilidad a largo plazo. En la gestión moderna, la infraestructura del tipo *Supply Driven*, es decir, principalmente diseñada para inducir el desarrollo del suministro de agua, debe estar precedida por un plan de desarrollo regional completo, según lo recomendado por el ***Plan Nacional de Seguridad Hídrica*** (ANA & MIDR, 2019), seguido de una estrategia para implementar el acuerdo productivo local con los otros eslabones de la cadena de producción (desde insumos hasta consumidores).

Riego en Batatais (SP)
Raylton Alves / Banco de Imágenes

Proyectos públicos: ubicación, área ocupada, valor de producción y responsable

Proyecto público	Inicio de Operación	Municipio(s)	UF	Área total (ha)	Área implantada (ha)	Área en producción	VBP (millones R$)	Responsable
Arroio Duro	1967	Camaquã	RS	58.623	20.406	20.406	R$ 181	MIDR
Río Formoso	1980	Formoso do Araguaia	TO	27.787	23.000	20.000	R$ 250	Estado de Tocantins
Senador Nilo Coelho	1984	Casa Nova, Petrolina	BA/ PE	55.525	23.486	21.797	R$ 1.555	Codevasf
Tourão	1979	Juazeiro	BA	14.567	14.677	14.677	R$ 134	Codevasf
Jaíba - Etapa I	1975	Jaíba, Matias Cardo-so, Verdelândia	MG	32.754	21.889	13.348	R$ 248	Codevasf
Formoso (BA)	1989	Bom Jesus da Lapa	BA	15.505	11.772	8.337	R$ 246	Codevasf
Chasqueiro	1985	Arroio Grande	RS	25.738	19.619	7.314	R$ 14	MIDR
Platô de Neópolis	1995	Neópolis; Japoatã; Pacatuba; Santana do São Francisco	SE	10.432	7.230	6.860	-	Estado de Sergipe
Jaguaribe Apodi	1989	Limoeiro do Norte	CE	9.606	5.658	5.658	R$ 31	DNOCS
Baixo Acaraú	2001	Bela Cruz; Acaraú; Marco	CE	13.909	8.439	5.277	R$ 65	DNOCS
Caribe/ Fulgêncio	1998	Santa Maria da Boa Vista, Orocó	PE	33.437	4.728	4.728	-	Codevasf
Curaçá	1980	Juazeiro	BA	15.234	4.708	4.708	R$ 160	Codevasf
Betume	1978	Propriá, Cedro do São João, Telha	SE	8.481	4.671	4.671	R$ 9	Codevasf
Maniçoba	1980	Juazeiro	BA	11.786	4.847	3.913	R$ 156	Codevasf
Salitre	1998	Juazeiro	BA	67.400	5.099	3.601	R$ 79	Codevasf
Luiz Alves do Araguaia	2000	São Miguel do Araguaia	GO	8.148	2.742	2.742	R$ 24	Estado de Goiás
Curu-Paraipaba	1974	Paraipaba	CE	6.913	3.357	2.733	R$ 16	DNOCS
Boacica	1984	Igreja Nova	AL	5.484	2.762	2.299	R$ 14	Codevasf
Icó-Mandantes	1994	Petrolândia	PE	26.097	2.187	2.187	-	Codevasf
Baixo Açu	1994	Ipanguaçu; Afonso Bezerra; Alto do Rodrigues	RN	6.000	5.168	2.099	-	DNOCS
Platôs de Gua-dalupe	1993	Guadalupe	PI	16.879	3.196	2.080	R$ 36	DNOCS
Tabuleiros de Russas	2004	Russas; Limoeiro do Norte; Morada Norte	CE	18.915	10.766	2.055	R$ 42	DNOCS
São Desidério/ Barreiras Sul	1978	São Desidério, Bar-reiras	BA	4.322	1.934	1.934	R$ 5	Codevasf
Bebedouro	1968	Petrolina	PE	7.484	2.418	1.892	R$ 49	Codevasf
Cotinguiba/Pin-doba	1982	Neópolis, Japoatã, Propriá	SE	3.086	2.232	1.708	R$ 6	Codevasf
Mirorós	1996	Gentio do Ouro, Ibipeba	BA	4.870	1.772	1.701	R$ 20	Codevasf
Gorutuba	1978	Nova Porteirinha	MG	8.487	4.800	1.683	R$ 34	Codevasf
Varzeas de	2006	Sousa; Aparecida	PB	6.336	4.404	1.600	R$ 5	Estado da Paraíba

Continua

Continuació

Proyecto público	Inicio de Operación	Municipio(s)	UF	Área total (ha)	Área implantada (ha)	Área en producción	VBP (millones R$)	Responsable
Brumado	1986	Livramento de Nossa Senhora	BA	8.302	4.313	1.509	R$ 12	DNOCS
Vaza Barris	1973	Canudos	BA	11.677	1.487	1.487	R$ 23	DNOCS
Brígida	1994	Santa Maria da Boa Vista, Orocó	PE	8.685	1.436	1.436	-	Codevasf
Morada Nova	1970	Morada Nova; Limoeiro do Norte	CE	11.166	4.474	1.268	R$ 1	DNOCS
Itiúba	1978	Porto Real do Colégio	AL	1.296	900	1.198	R$ 7	Codevasf
São João	2010	Porto Nacional	TO	5.139	3.027	1.048	R$ 7	Estado de Tocantins

Fuentes: Compilación a partir de datos MIDR, SISPPI/MI, Distrito de Riego Nilo Coelho (DINC), Codevasf y DNOCS.

Notas: Año de referencia de la información: 2018/2019

VBP: Valor del producto de la producción (anual), en millones de reales.

Superficie total: incluye áreas de preservación permanente - APPs, reserva legal e infraestructura de uso común, además del área irrigable y de secano;

Área Irrigada Implantada: área donde se realizan todas las obras de infraestructura (sistemas comunes de riego y drenaje de parcelas, en el caso de lotes para el pequeño riego) necesarias para el inicio de la operación del proyecto y se completa la producción agrícola de los lotes;

Área en Producción: área irrigable desplegada que está siendo efectivamente utilizada para la explotación agrícola.

Plantación de regadío cerca de Parnaíba (PI)
Zig Koch /Banco de Imágenes ANA

Proyectos públicos: cultivos, sistemas de riego e infraestructura

Proyecto público	Cultivos principales	Sistemas principales	Infraestructura
Arroio Duro	Arroz	Inundación	-
Río Formoso	Arroz	Inundación y superficial	-
Senador Nilo Coelho	Mango (40%), uva (24%), coco (11%), banana (8%), guayaba (7%) y acerola (5%)	Microaspersión, aspersión y goteo	976 km de canales; 818 km de tuberías, 711 km de carreteras; 263 km de drenajes; 39 estaciones de bombeo
Tourão	Caña de azúcar (96%) y menor producción de frutíferas	Superficie, goteo, microaspersión y aspersión.	65 km de canales; 45 km de drenajes, 42 km de carreteras; 5 estaciones de bombeo
Jaíba - Etapa I	Los cultivos permanentes ocupan el 79% del área. Más del 50% es fruticultura, destacando limón, mango y banana.	Microaspersión y aspersión.	548 km de canales; 385 km de tuberías; 533 km de carreteras; 3 km de drenajes; 11 estaciones de bombeo
Formoso (BA)	91% banana	Microaspersión y aspersión	286 km de canales; 175 km de tuberías; 148 km de carreteras; 120 km de drenajes; 23 estaciones de bombeo
Chasqueiro	Arroz	Inundación	-
Platô de Neópolis	Caña de azúcar (~50%) y frutas, especialmente coco (~25%)	Microaspersión	-
Jaguaribe Apodi	Ocupación permanente 23% (banana 17%). Temporales ocupan 77% (maíz 51% y soja 18%)	Pivote central (predominante), microaspersión y goteo	-
Baixo Acaraú	Permanentes ocupan 64% (coco 26%, banana 11% y naranja 10%). Temporales ocupan 36% (sandía 8%, yuca 12% y frijoles 6%)	Microaspersión y goteo	-
Caribe/Ful-gêncio	Permanentes ocupan el 71%, con predominio de la fruticultura. Banana ocupó el 56% del área.	Aspersión	39 km de canales; 200 km de carreteras; 1206 km de drenajes
Curaçá	Manga 57%, coco (20%) y uva (13%)	Microaspersión y aspersión	165 km de canales; 167 km de drenajes, 172 km de carreteras; 11 estaciones de bombeo
Betume	Arroz (100%)	Superficie 100%	148 km de red de riego; 134 km de drenajes, 88 km de carreteras; 24,8 km de diques, 9 estaciones de bombeo (sólo 4 para riego)
Maniçoba	Predominio de mango (59%), uva (5%) y caña de azúcar (20%)	Superficie, aspersión, microaspersión y, en menor escala, goteo	156 km de canales; 8 km de tuberías; 97 km de drenajes; 223 km de carreteras; 3 estaciones de bombeo.
Salitre	Banana, cebolla, caña de azúcar, mango, guayaba y coco	Goteo, superficie y microaspersión.	41,57 km de canales; 159,5 km de drenajes; 116,3 km de carreteras; 6,38 km de tuberías; 6 estaciones de bombeo (EB); y 8 reservorios
Brumado	Mango (90%)	Aspersor convencional, microaspersión	7 km de canales de aducción, 7,6 km de canales primarios; 31,5 km de drenajes y 8,4 km de carreteras principales
Curu-Paraipaba	Permanentes ocupan el 91%, con predominio de coco (82%).	Aspersión (principal), microaspersión, goteo y pivote central	8 estaciones de bombeo, 845 m de canales de aducción, 7 km de canal de drenaje principal; 17,09 km de carretera principal
Luiz Alves do Araguaia	Arroz, melón, calabaza, sandía, maíz y soja	Inundación y superficial	-

Continua

Continuació

Proyecto público	Cultivos principales	Sistemas principales	Infraestructura
Boacica	Caña de azúcar (51%), arroz (45%) y banana (4%)	Superficie y aspersión	150 km de canales; 146 km de drenajes, 122 km de carreteras; 46,6 km de diques, 3 estaciones de bombeo
Icó-Mandantes	Fruticultura, en particular calabaza (24%), sandía (23%) y coco (19%). Temporales ocupan el 72% del área	Aspersión convencional	90 km de carreteras; 610 km de drenajes
Baixo Açu	Permanentes ocupan 45% (banana 34%). Temporales ocupan el 55% (semilla de maíz (21%) y frijol (14%).	Aspersor convencional y pivote central	-
Platôs de Guadalupe	Permanentes ocupan el 87% (banana 70%) y guayaba el 13%). La sandía (temporal) ocupa el 13% del área	Pivote central, aspersor convencional, microaspersión y goteo	-
Tabuleiros de Russas	Predomina la fruticultura, en especial la sandía y el melón. Entre los temporales, destacan los frijoles	Microaspersión y goteo	-
São Desidério/ Barreiras Sul	Pastos, maíz verde, yuka, banana, coco y frijoles	Superficie	99 km de canales; 95 km de drenajes superficiales, 6 ha de drenajes subterráneos, 155 km de red de carreteras
Bebedouro	Predomina la fruticultura (uva 74% y mango 16%)	Superficie, microaspersión y goteo.	31 km de canales; 45 km de carreteras; 64 km de drenajes; 5 estaciones de bombeo
Cotinguiba/ Pindoba	Arroz (68%) y maíz (16%)	Superficie y aspersión.	96 km de red de riego (57 km en canales y 39 km en tuberías); 63 km de drenajes, 48 km de carreteras; 13 km diques, 16 estaciones de bombeo
Mirorós	Banana (89% do VBP e 72% da área)	Microaspersión y goteo	31 km de canales; 116 km de tuberías; 35 km de drenajes; 112 km de carreteras; 6 estaciones de bombeo
Gorutuba	Predomina la fruticultura (banana 74%). Los cultivos permanentes ocupan el 99% del área cultivada	Microaspersión, aspersión convencional y de superficie	134 km de canales; 320 km de carreteras; 136 km de drenajes
Varzeas de Sousa	Coco (40%) y banana (26%).	Aspersión (42%) y localizada (58%)	-
Vaza Barris	Permanentes ocupan el 84%, con predominio de la banana (82%). Las temporales ocupan el 16%.	Superficie/surcos	-
Brígida	Banana (35%) y yuka (55%). Temporales ocupan el 51% del área	Aspersión convencional	6 km de canales; 85 km de carreteras; 610 km de drenajes
Morada Nova	Arroz, frijoles, banana, acerola, coco, guayaba, graviola, hierba y sorgo	-	-
Itiúba	Arroz, caña de azúcar	-	-
São João	Piña	-	-

Fuentes: Compilación a partir de datos MIDR, SISPPI/MI, Distrito de Riego Nilo Coelho (DINC), Codevasf y DNOCS.

Notas: Año de referencia de la información: 2018/2019

En los proyectos Codevasf, los porcentajes de los cultivos principales se refieren al valor bruto de la producción, excepto cuando se expresan como porcentaje de la superficie ocupada.

4 ADDITIONAL IRRIGABLE AREA

Irrigation with center pivot on the banks of the Mogi-Guaçu River, between Descalvado/SP and Santa Rita do Passa Quatro/SP
Raylton Alves / ANA Image Bank

The analysis of the ***potential for expansion and intensification*** of irrigated agriculture combines explanatory variables in an attempt to point out areas that can be used in irrigated agriculture. They tend to focus on physical and environmental aspects and lack the application of robust economic models, as well as field research, but provide perspectives and direction for both the private sector and public policies.

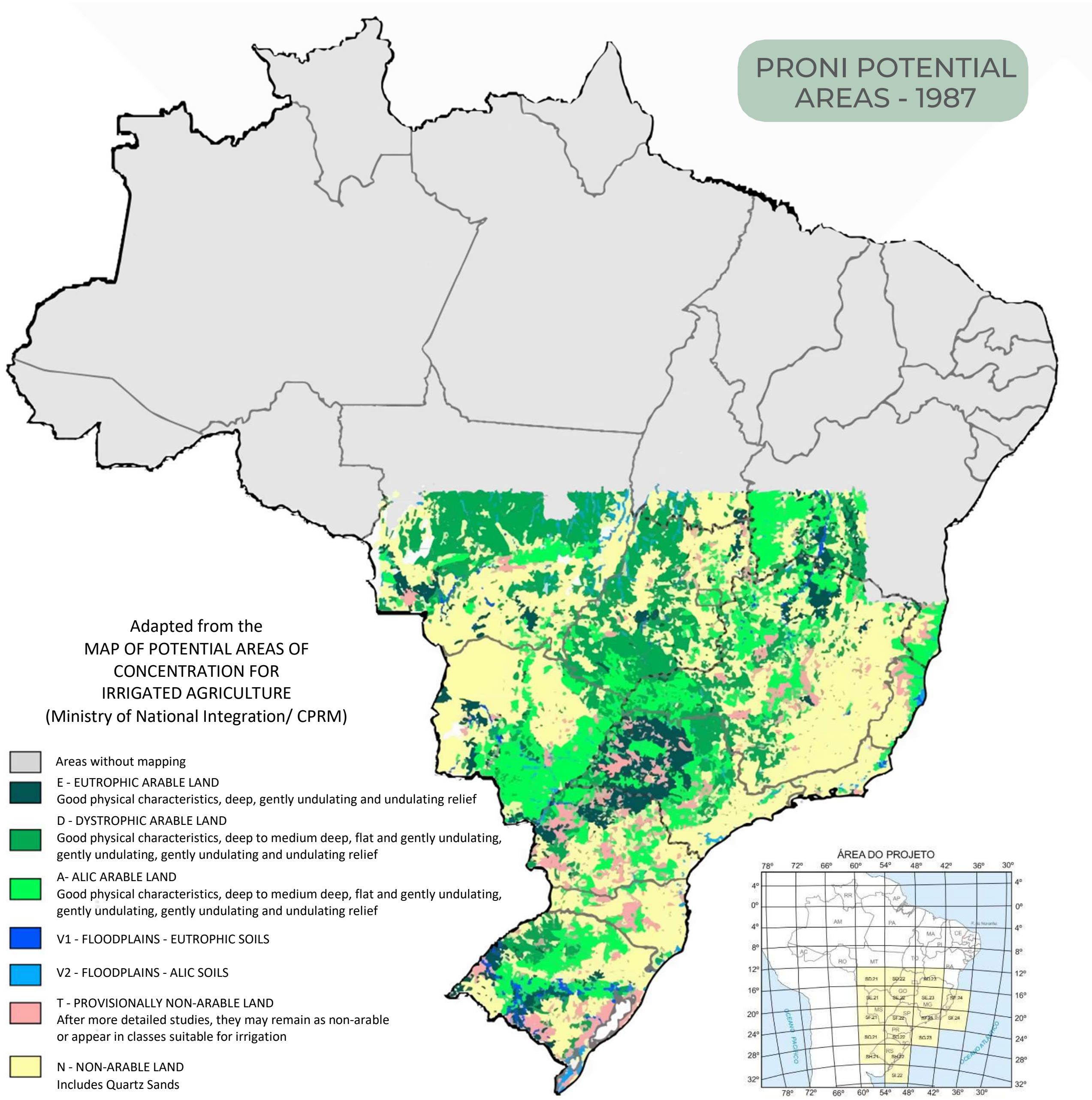
Within the scope of the National Irrigation Program – **PRONI**, the mapping of Potential Concentration Areas for Irrigated Agriculture was published in 1987, carried out by the National Institute for Space Research (INPE) and the Foundation for Space Science, Technology and Applications (FUNCATE) and in 2009, recovered and digitized in partnership with the Ministry of Integration with the Geological Survey of Brazil. The original work comprised the Central-South region and involved an analysis of satellite images, consolidation of cartographic bases, fieldwork and overflight surveys.

The survey established a classification of arable land and its classification into categories of greater or lesser potential for irrigated agriculture, however, it does not provide spatially explicit information on water availability for irrigation, it is instead more focused on the quality of land for agriculture in general (BRASIL, 2014).

Also in the scope of PRONI, in 1989, studies were carried out to prioritize areas for private irrigation in the Northeast region. Based on information on soil and water potential, and agricultural and socioeconomic factors, a potential 362 thousand ha were identified to develop private irrigation in the region (BRASIL, 2006) - concentrated in the Parnaíba river valley (PI/MA – 113 thousand ha) and its tributary Balsas river (MA – 54 thousand ha); and in the upper-middle São Francisco river valley (MG/BA – 75 thousand ha).

Later, in the late 1990s, studies conducted by the Water Resources Department of the Ministry of Environment estimated 29.56 million hectares with potential soil for irrigation development, of which about 50% would be in the North. This assessment considered the suitability of the soils (classes 1 to 4), the availability of water and compliance with the environmental legislation at the time.

In 2014, the Ministry of National Integration, currently MIDR, published the study ***Territorial Analysis for the Development of Irrigated Agriculture in Brazil*** (BRASIL, 2014) in partnership with USP/ESALQ, which assessed the additional irrigable area of the country using ottobasins (micro-basins) as a territorial unit of analysis. The procedure for calculating the irrigable area was similar to that used in the sizing of irrigation projects in the field, taking into consideration: (i) the water demand of the reference crops (corn and beans); (ii) the quantitative balance between water uses and surface water availability; (iii) and the area available for agricultural activities. To define the territorial classes, other aspects were also analyzed, such as land dynamics, logistical quality and environmental importance.



Source: INPE/FUNCATE/MI/CPRM (apud. Brasil, 2014).

This 2014 study was adapted and used as a reference in the first edition of the Irrigation Atlas. The total potential was estimated at 76.19 million hectares (Mha), distributed in soil-relief suitability classes: 21.80 Mha of additional irrigable land with high suitability; 25.86 Mha with medium suitability; and 28.53 Mha with low suitability. The Midwest stood out for its concentration of 43.1% of additional irrigable areas with high suitability in Brazil.

Based on the modified study database, an indicator of effective expansion potential was prepared for the 2017 Atlas, only considering areas with high or medium soil suitability; high relief suitability; high logistic quality (existence of production flow and electric power); exclusion of other environmental protection areas; and territorial classes that indicate irrigation expansion, i.e., combinations in which there is both the potential for additional expansion and already established irrigated agriculture (referring to the presence of infrastructure, support services, technology, and technical assistance). This potential was estimated at 11.12 Mha, concentrated in the Central-South of Brazil, explaining more precisely the potential for expansion in the short and medium term.

Soil potential for irrigation – 1999 survey

Region / State	POTENTIAL AREA (1,000 ha)	POTENTIAL AREA (%)
NORTH	14,598	49.4%
AC	615	2.1%
AM	2,852	9.6%
AP	1,136	3.8%
PA	2,453	8.3%
RO	995	3.4%
RR	2,110	7.1%
TO	4,437	15.0%
NORTHEAST	1,304	4.4%
AL	20	0.1%
BA	440	1.5%
CE	136	0.5%
MA	244	0.8%
PB	36	0.1%
PE	235	0.8%
PI	126	0.4%
RN	39	0.1%
SE	28	0.1%
SOUTHEAST	4,229	14.3%
ES	165	0.6%
MG	2,345	7.9%
RJ	207	0.7%
SP	1,512	5.1%
SOUTH	4,507	15.2%
PR	1,348	4.6%
RS	2,165	7.3%
SC	994	3.4%
MIDWEST	4,926	16.7%
DF	18	0.10%
GO	1,297	4.4%
MS	1,222	4.1%
MT	2,390	8.1%
BRAZIL	29,564	-

Source: MMA/SRH/DDH (1999). Revised by Christofidis (2002) (apud. Brasil, 2006).

The ***Territorial Analysis for the Development of Irrigated Agriculture in Brazil*** was updated between 2019 and 2020 in a new joint effort by ANA along with the MIDR and USP/ESALQ (Public Policy Group - GPP). More updated databases, more refined technical criteria and more explicit water balance simulations of water from surface and underground springs were adopted. The update is part of, simultaneously, the Immediate Action Plan of Irrigated Agribusiness in Brazil (in preparation by the MDR) and the new edition of the Irrigation Atlas.

The current methodology is based on the consolidation of ***land use maps,*** and only consolidated agricultural uses are considered eligible for irrigation, i.e., without considering the opening of new areas, even if they meet current legislation. This assumption is justified both by sustainability (not predicting new use conversions) and by water availability limits – local springs sustainably support the irrigation of only part of the current agricultural area of 248.6 million hectares (73.9 Mha of agriculture and 174.7 Mha of pastures).

The adoption of surface water irrigation on rainfed agricultural areas was named ***intensification***; the potential conversion of pastures to irrigated agriculture was named ***expansion***. In addition, in order to support the regions with the greatest surface water limitation, the remaining agricultural areas (rainfed + pastures) that could expand with groundwater were estimated.

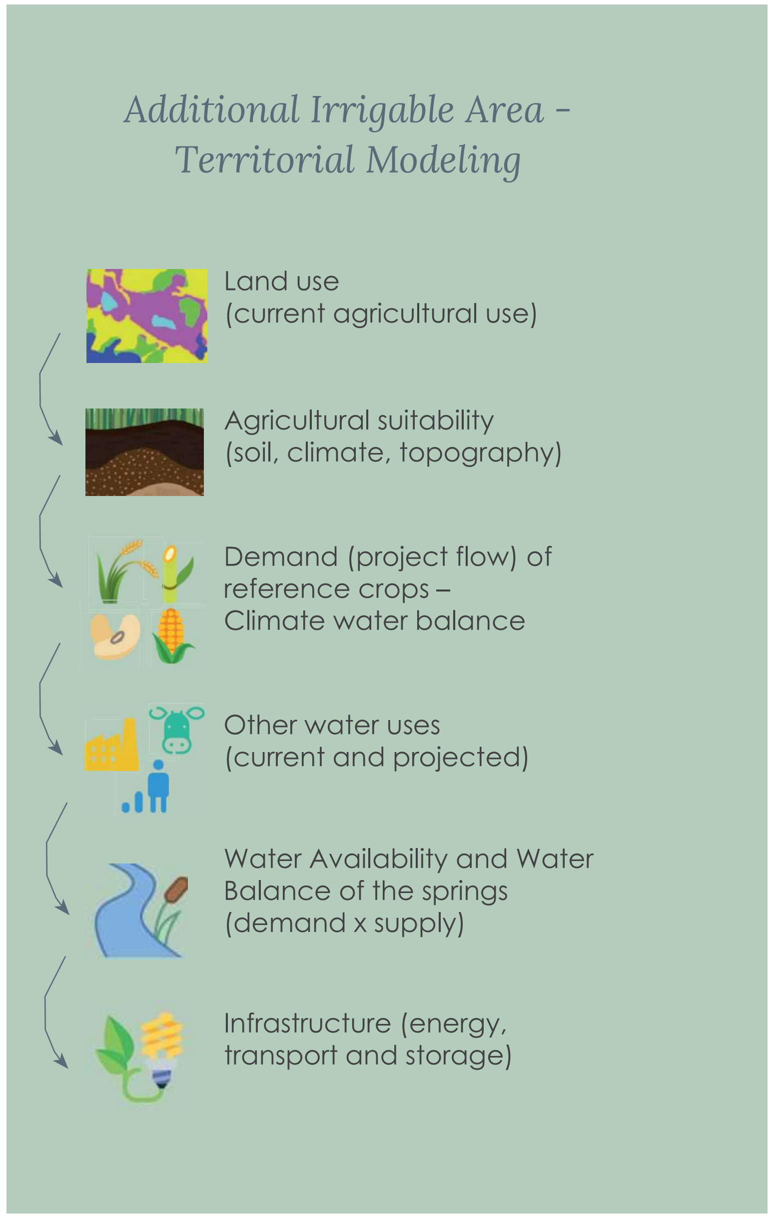
The second component of the methodology refers to the ***water demand of reference crops*** (rice, sugarcane, beans and corn), estimated in the micro-basins based on the consolidated use, the climatological water balance and technical criteria for conversion into the project flow rate. The water demand was simulated for the 36 periods in the year (every 10 days), adopting the most critical period as the reference, i.e., the period of lowest water satisfaction and maximum Kc (blooming period, in the case of annual crops). These criteria are capable of guiding the sizing of the irrigation system with greater certainty - a similar procedure is adopted in the assessment of projects for the purpose of granting water use for irrigation.

The third block of the methodology consolidates the previous steps (flow rate needed to irrigate the entire agricultural and pasture area available in the micro-basin). The already irrigated areas are subtracted, but the areas that have only been fertigated are not excluded from the potential, and can be intensified with irrigation itself.

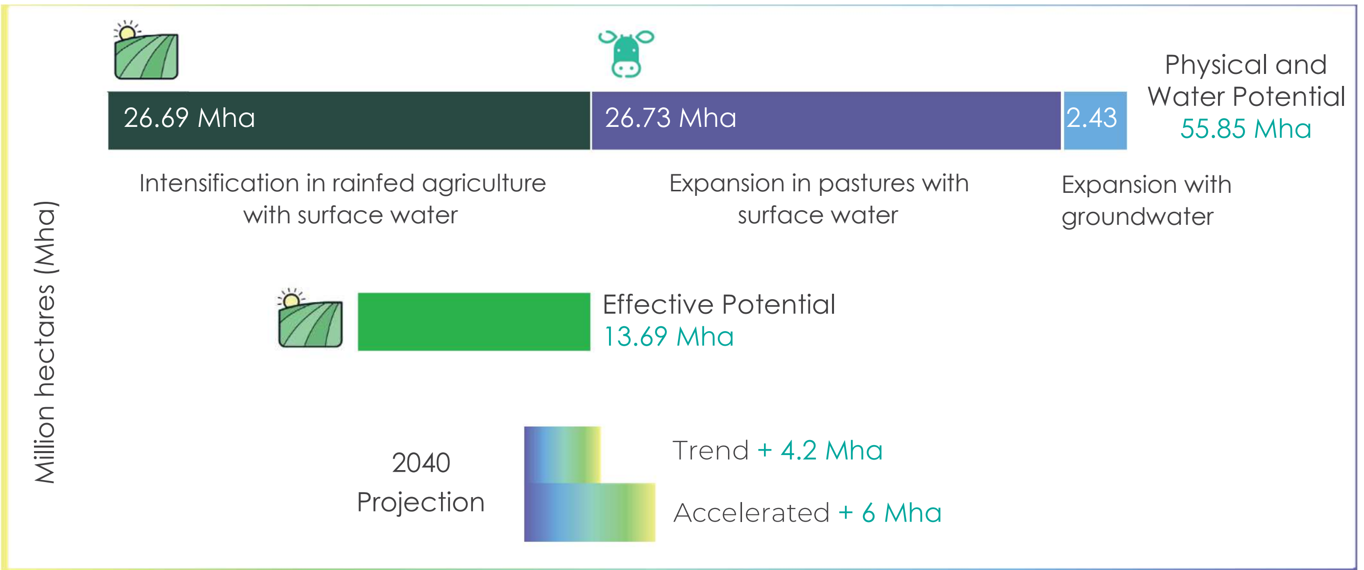
Next, the ***water balance in the springs*** is simulated (potential demand x water supply ratio in the rivers). The supply is characterized by the reference flow with 95% guarantee ($Q_{95\%}$) obtained from series of daily flows observed in flow stations or series of flows modeled in specific places. Before the simulation, the already installed demand for irrigation and the current and projected demands of the other water uses (urban and rural human use, animal supply, industry, mining and thermoelectricity) are subtracted.

Additionally, the study produced other indicators that guide complementary analyses of effective potential, such as ***soil-relief suitability*** and ***infrastructure*** (energy, road and rail transport and storage capacity of agricultural products).

As a result, an additional irrigable area in Brazil of **55.85 Mha**, 26.69 Mha on areas with rainfed agriculture (36% of the consolidated agriculture area). Another 26.73 Mha can be irrigated over pasture areas (15% of the consolidated pasture area).



Additional Irrigable Area over agricultural uses in Brazil



Additional irrigable area (total and effective potential) – by Region and State

Region / State	ADDITIONAL IRRIGABLE AREA - TOTAL (1,000 ha)					EFFECTIVE POTENTIAL	
	Surface water		Groundwater	Total	Total (%)		
	Intensification in agriculture	Expansion in pasture				(1,000 ha)	(%)
NORTH	797	10,142	347	11,287	20.2%	294	2.1%
AC	0	691	0	691	1.2%	-	-
AM	7	1,420	7	1,434	2.6%	-	-
AP	26	70	4	99	0.2%	-	-
PA	230	4,267	181	4,678	8.4%	84	0.6%
RO	159	2,240	99	2,497	4.5%	-	-
RR	14	207	2	224	0.4%	-	-
TO	361	1,248	54	1,663	3.0%	210	1.5%
NORTHEAST	1,112	2,104	105	3,321	5.9%	279	2.0%
AL	22	21	2	46	0.1%	18	0.1%
BA	633	879	49	1,560	2.8%	129	0.9%
CE	78	92	1	171	0.3%	25	0.2%
MA	197	944	23	1,164	2.1%	72	0.5%
PB	13	23	0	36	0.1%	4	0.03%
PE	32	63	0	95	0.2%	9	0.1%
PI	97	52	27	176	0.3%	19	0.1%
RN	32	13	2	47	0.1%	3	0.02%
SE	9	16	0	26	0.0%	1	0.01%
SOUTHEAST	8,150	4,116	672	12,938	23.2%	2,593	18.9%
ES	329	40	20	389	0.7%	88	0.6%
MG	3,407	3,241	385	7,033	12.6%	1,181	8.6%
RJ	326	265	27	618	1.1%	26	0.2%
SP	4,088	570	239	4,898	8.8%	1,299	9.5%
SOUTH	7,706	540	353	8,599	15.4%	4,293	31.4%
PR	3,587	275	219	4,082	7.3%	2,030	14.8%
RS	2,904	42	65	3,011	5.4%	1,896	13.9%
SC	1,215	223	69	1,507	2.7%	366	2.7%
MIDWEST	8,929	9,824	954	19,707	35.3%	6,227	45.5%
DF	30	19	3	53	0.1%	30	0.2%
GO	1,988	2,397	183	4,567	8.2%	1,415	10.3%
MS	1,670	2,867	189	4,725	8.5%	848	6.2%
MT	5,241	4,541	579	10,362	18.6%	3,934	28.7%
BRAZIL	26,694	26,726	2,431	55,851	-	13,687	-

Note: cells highlighted in green indicate the states with the highest participation in the total or effective potential.

The additional area over agricultural areas without surface availability, but with underground availability, is 2.43 Mha.

With this, it is concluded that although the area is expressed in absolute numbers, only ***22% of the area currently occupied with agriculture and pastures in Brazil can be irrigated*** due to limitations in the water availability of local springs.

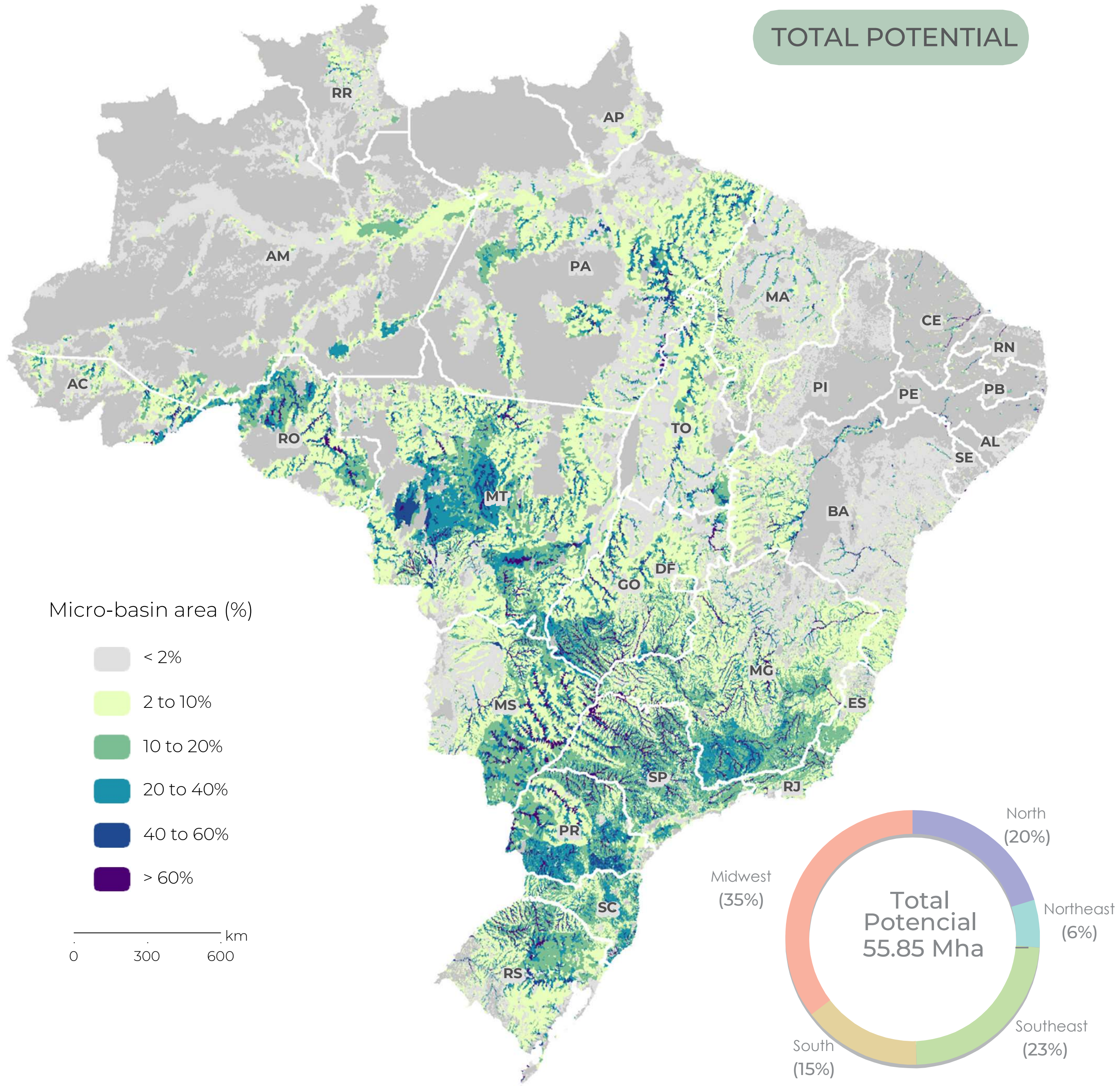
As effective potential, which more explicitly specifies the short and medium term potential in the Brazilian territory, the areas of intensification on rainfed agriculture that have medium or high soil-relief suitability are considered; and the most favorable indicator of infrastructure (high class). In addition, current sugarcane areas with a climatic water deficit of less than 400 mm per year are excluded from the effective potential.

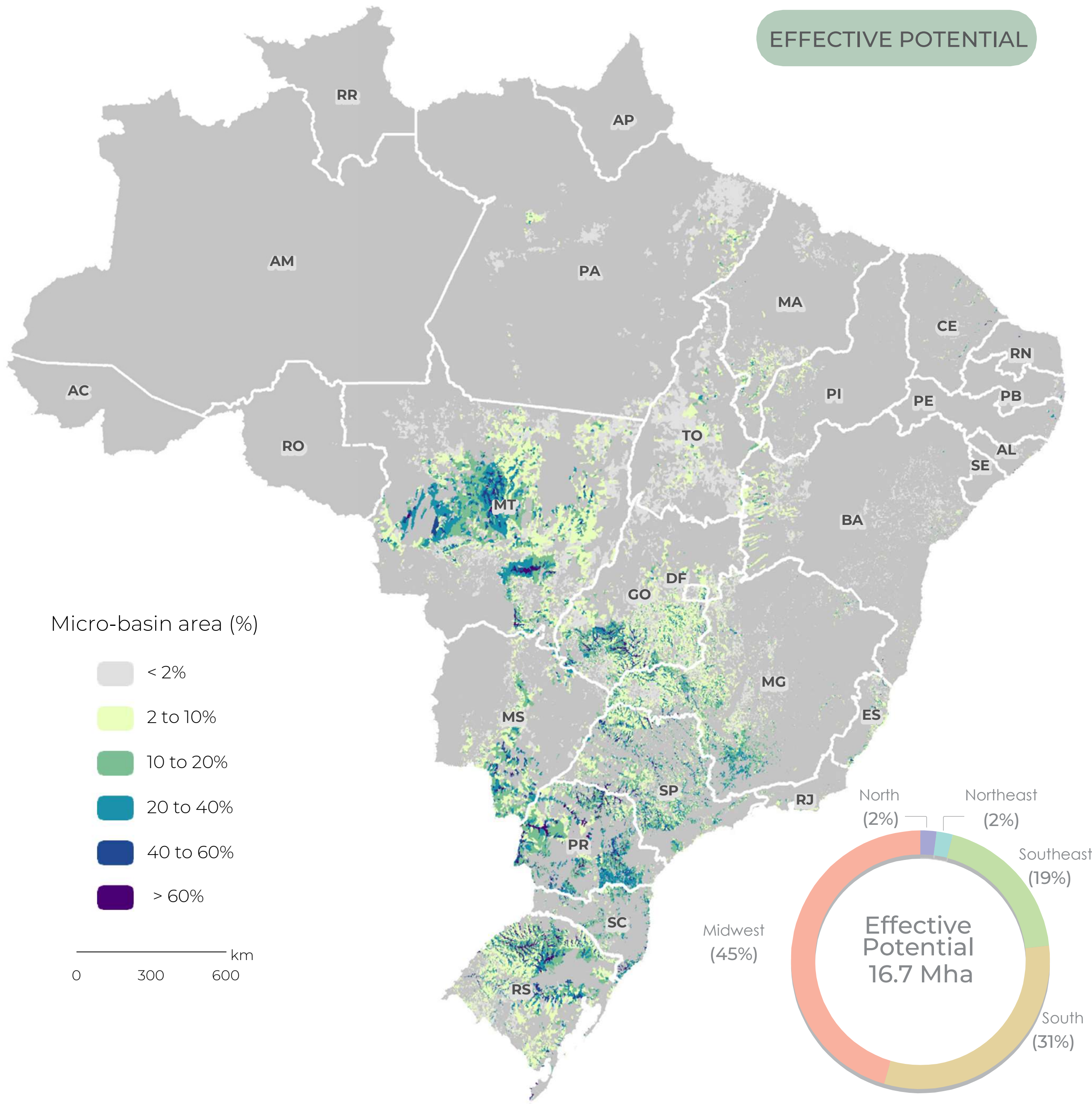
The ***effective potential is 13.7 Mha*** and is concentrated in the Midwest (45%), South (31%) and Southeast (19%). Among the states, Bahia, Goiás, Mato Grosso, Mato Grosso do Sul, Minas Gerais, São Paulo, Rio Grande do Sul and Santa Catarina have the greatest potential to increase irrigated areas. These regions already stand out for the strong growth of the area in recent years, especially Goiás, Bahia, Mato Grosso and Rio Grande do Sul.

The potential for irrigation (total and effective) ***must be observed with caution*** and is useful for the general planning, zoning and monitoring of the sector. Local particularities, infrastructure expansion and water infrastructure works can change the estimated additional irrigable area, especially when the water supply is increased through transfers from other basins. In addition, territorial modeling should be improved, in particular regarding water balance tools in springs and information on other current and projected water uses.

In addition to the expansion potential of irrigated areas, in order to estimate the priority regions and it is important to observe the medium-term trends, the prospects of harnessing this potential in the coming years. There are few indicators that point to trends in irrigation expansion in Brazil – indicators related to agriculture are usually aggregated with rainfed areas. As these areas are generally much higher than irrigated areas, the indicators do not characterize the dynamics of irrigated agriculture.

In order to make up for the lack of projections, the trend scenario for the growth of irrigated areas in the **2040** horizon is presented below. It is estimated that public policies and the conditions for financing and promoting irrigated agriculture





will not change significantly in the medium term; or even that any more significant changes will not produce large-scale effects on the horizon considered. Thus, the trends observed in the recent past and the analysis of the current situation can be used for projections in the next 20 years. The same trends observed in the 2017 Atlas continue today, but the data presented in this edition allow the estimates to be refined.

A scenario of increasing fertigated areas was not considered, both because water is not directly abstracted from springs and because of the trend towards increasingly efficient agronomic reuse, through increased industrial efficiency (generating less effluent) and more optimized application techniques (such as vinasse concentration). It is estimated, therefore, that there will be changes in the geography of fertigation through the territory, but the total area will suffer little change, remaining close to 2.9 Mha in 2040.

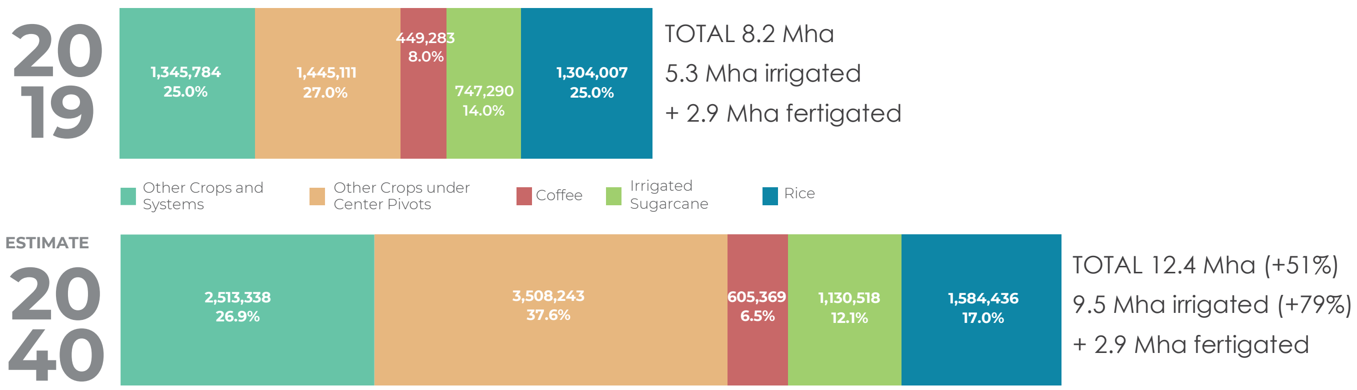
The projections indicate the ***incorporation of 4.2 million hectares irrigated by 2040*** – an average of ***200 thousand hectares per year –***, bringing the country closer to the total area of 12.4 million irrigated hectares. This increase corresponds to an increase of 51% over the current area (irrigated + fertigated) or 79% considering irrigated areas except fertigation. This increase also corresponds to the approval of 30% of the effective potential and only 7% of the total potential.

The most efficient methods of water use – localized irrigation (drip and micro-sprinklers) and center pivot sprinklers - should be responsible for about 75% of this growth. Conventional sprinklers and the reel (hydro roll) should also remain important in this expansion scenario. Surface irrigation methods (furrow, strip and flood) should continue in a downward trend, except for flooded rice, which shows a tendency to stabilize in the short term, but a tendency to increase in the long term in the main producing areas, especially with the recovery of areas in the South where rice suffered a retraction of 250 thousand ha in recent years.

Temporary crops grown under pivots will continue to lead the expansion of irrigation with about 100 thousand additional ha per year on average (50% of the growth). Rice, sugarcane and coffee should contribute an average of 40 thousand ha per year. Other crops, especially fruit-growing, should add up to between 50 and 60 thousand ha per year of expansion.

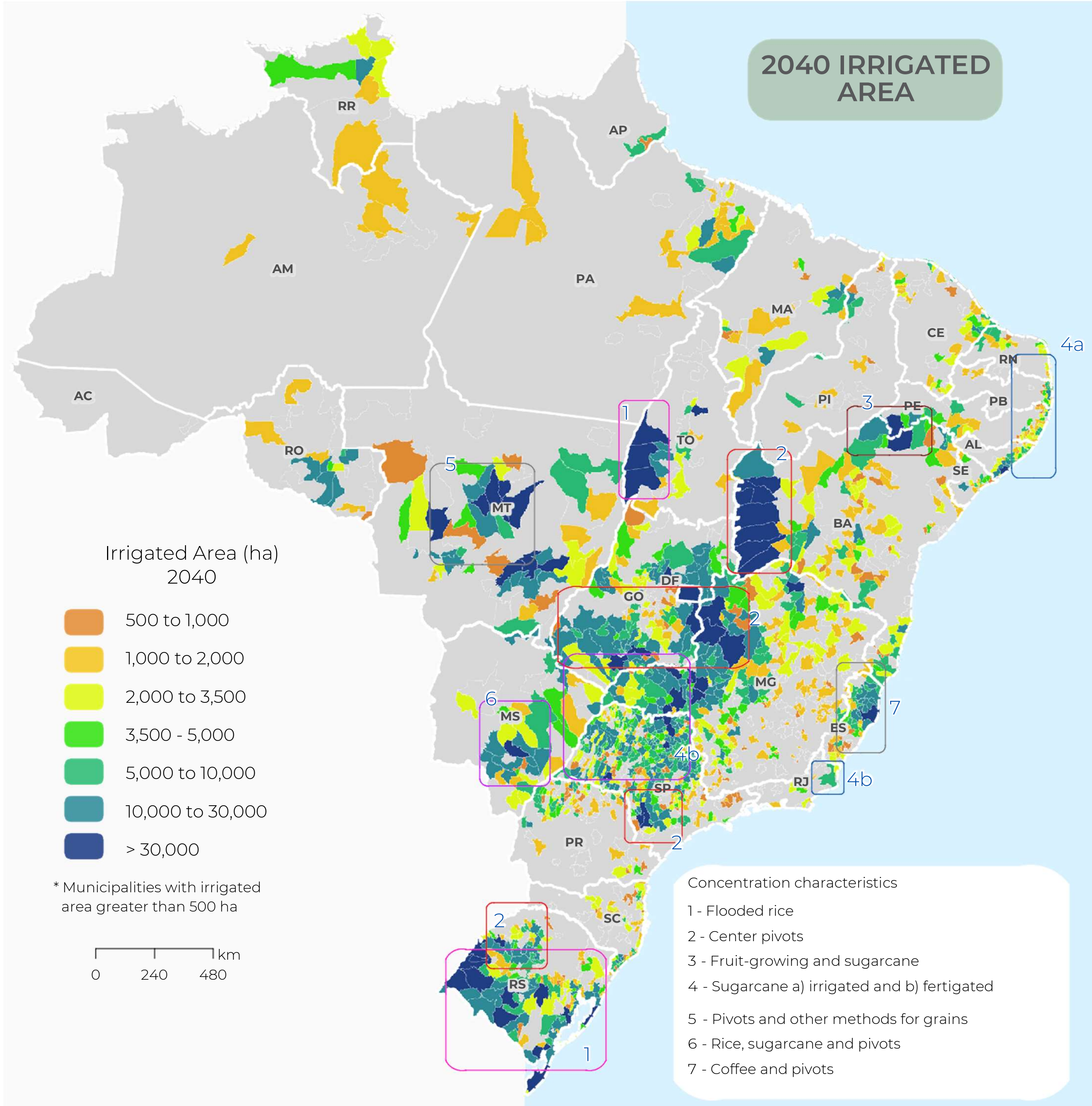
Thus, although all typologies show absolute growth, the relative participation will change. Disregarding fertigation, flooded rice tends to reduce its participation in area from 25% in 2019 to 17% in 2040; sugarcane will slightly reduce its participation from 14% to 12.1%, as well as coffee (from 8% to 6.5%); center pivots tend to increase their participation from 27% to 37.6%; and other crops in other systems should fluctuate from 25% to 26.9%. As for the latter group, it should be noted that the estimated growth balance should focus on localized irrigation and micro-sprinklers, while surface methods (furrow, strips and flooding, except rice) should show retraction (areas with deactivated irrigation or replaced with other methods).

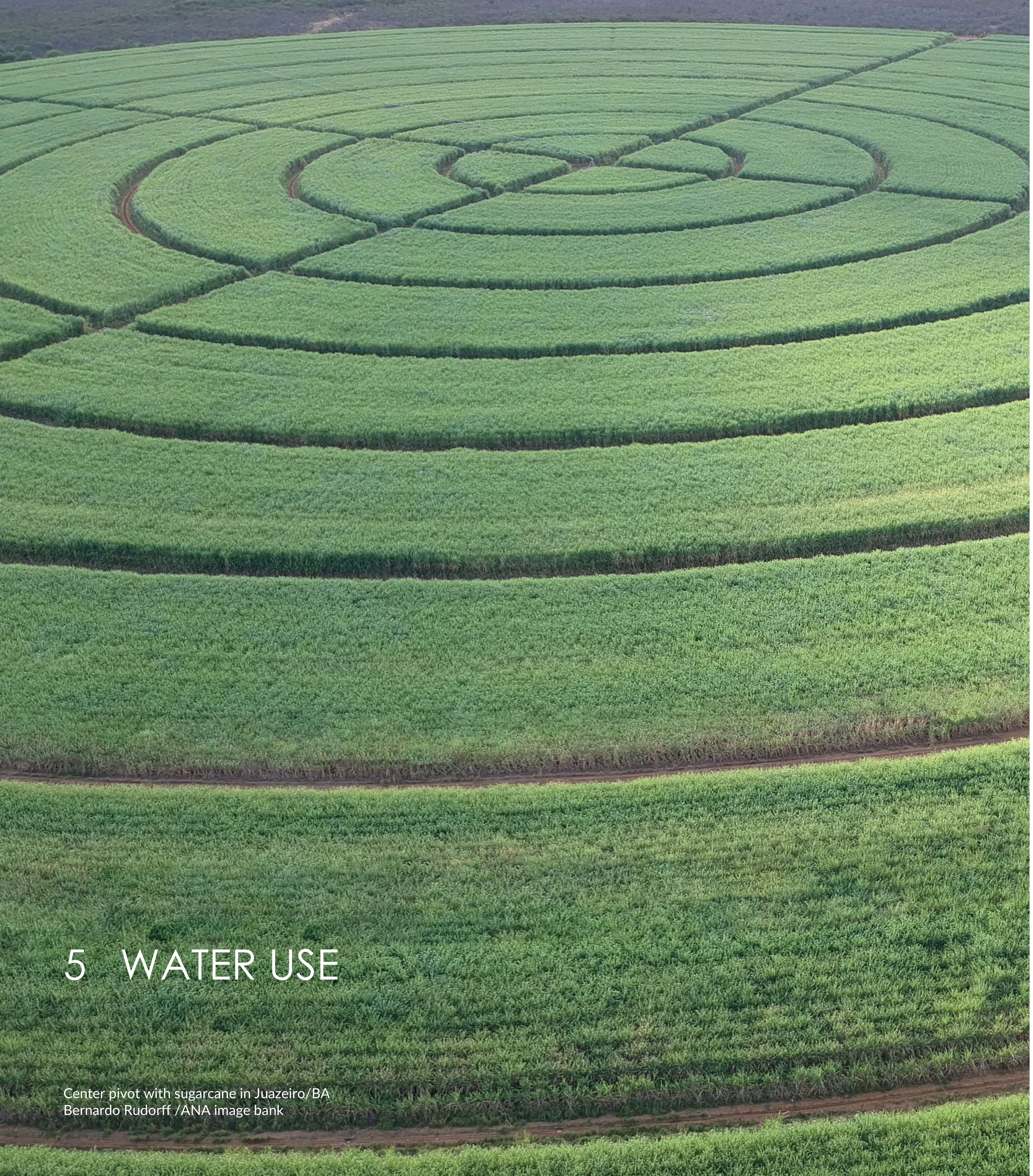
Irrigated Area in Brazil by typology - 2019 and 2040



The growth prospects are compatible with the time series analyzed, such as: irrigated areas of the Census of Agricultural (IBGE); crops and harvests with a high participation of irrigation in Municipal Agricultural Productions – PAM (IBGE); estimates of the equipment sales sector (CSEI/Abimaq, 2020); and sector projections for agribusiness (FIESP, 2019). CSEI/Abimaq (2020), for example, estimated an average annual increase of 211 thousand hectares in recent years (2011-2019), with a variation between 176 thousand ha in 2011 and 272 thousand ha in 2013. In 2019, the expansion was estimated at 210 thousand ha.

Although the estimated expansion is compatible with the recent rates, there are challenges for its continuation in the next 20 years, especially regarding credit, climate changes/variability, and the environmental and water support capacity of the irrigation hubs. There are, at the same time, opportunities to accept this expansion with sustainability, leading to a new level of growth of around 300 thousand ha per year, which could lead Brazil to incorporate 6 Mha by 2040 (43% higher than the 4.2 Mha projected in the trend scenario).





Center pivot with sugarcane in Juazeiro/BA
Bernardo Rudorff /ANA image bank

Context

Irrigation is a ***consumptive use*** of water, i.e., it changes its conditions as it is stored, removed from the environment and most of it is consumed through crop evapotranspiration, not returning directly to water bodies. Although the hydrological cycle is closed, this consumption means that water is unavailable for other uses at that location and time.

Currently, irrigation accounts for about 50% of the abstraction of raw water from surface and underground springs in Brazil (urban supply, for example, accounts for 24% of the total withdrawal). This share of irrigation is similar to that observed in the global average.

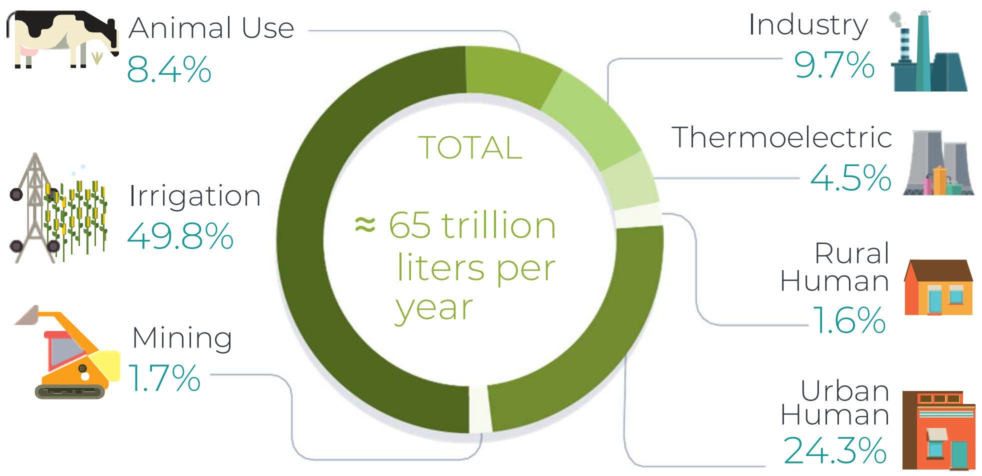
There are several techniques for calculating water demand for irrigated agriculture, the most common being the use of indirect methods based on the crop's water requirement at a given stage of development and in a given location. This type of estimation simplifies the processes that occur at the irrigated agriculture-hydrological cycle interface, based on the availability of climatic information and the characteristics of the crops and irrigation systems.

The ***climatic data*** informs the rainwater supply to the plants and the potential evapotranspiration of a region. For the current estimate, about 10 thousand rainfall stations (rainfall data) were consulted, of which 3,700 presented a relevant number of data consisted for use in the estimates. The number of meteorological stations was increased from 524 to 654 - the variables and the result of the calculation of potential evapotranspiration underwent a broad process of consistency in partnership between ANA and the Federal University of Paraná - UFPR. In the Atlas, estimates are presented both with the climate observed in the time series until 2019 and with the average climate obtained from these series.

Each ***crop*** needs an amount of water and this amount varies at each stage of development of the same crop. This information is aggregated to calculate the actual evapotranspiration of the crop, i.e., the water supply necessary for its physiological processes in that local climate. The climate and crop, along with information about the ***soil***, help in estimating the availability of water in the soil and the effective precipitation (rainwater that the plant can effectively take advantage of). Irrigation aims to supplement what the plant needs, i.e., it complements what is provided by other sources (soil and rain).

Finally, it is necessary to know the efficiency of the ***irrigation system*** adopted to estimate the losses that occur between the volume of water collected and the volume of water used by the plant. Water use efficiency is addressed at the end of this chapter.

Demands for water abstraction in Brazil in 2019

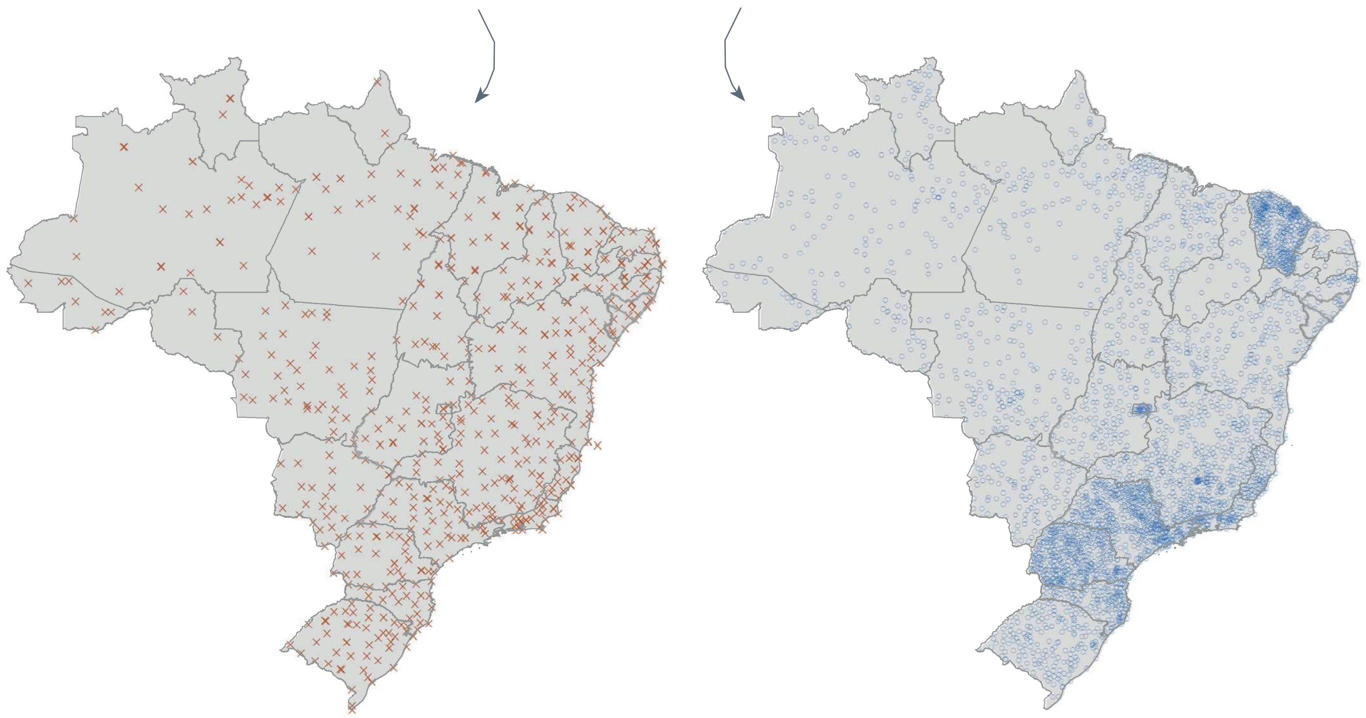


Source: adapted from the Brazilian Water Resources Report (ANA, 2020)

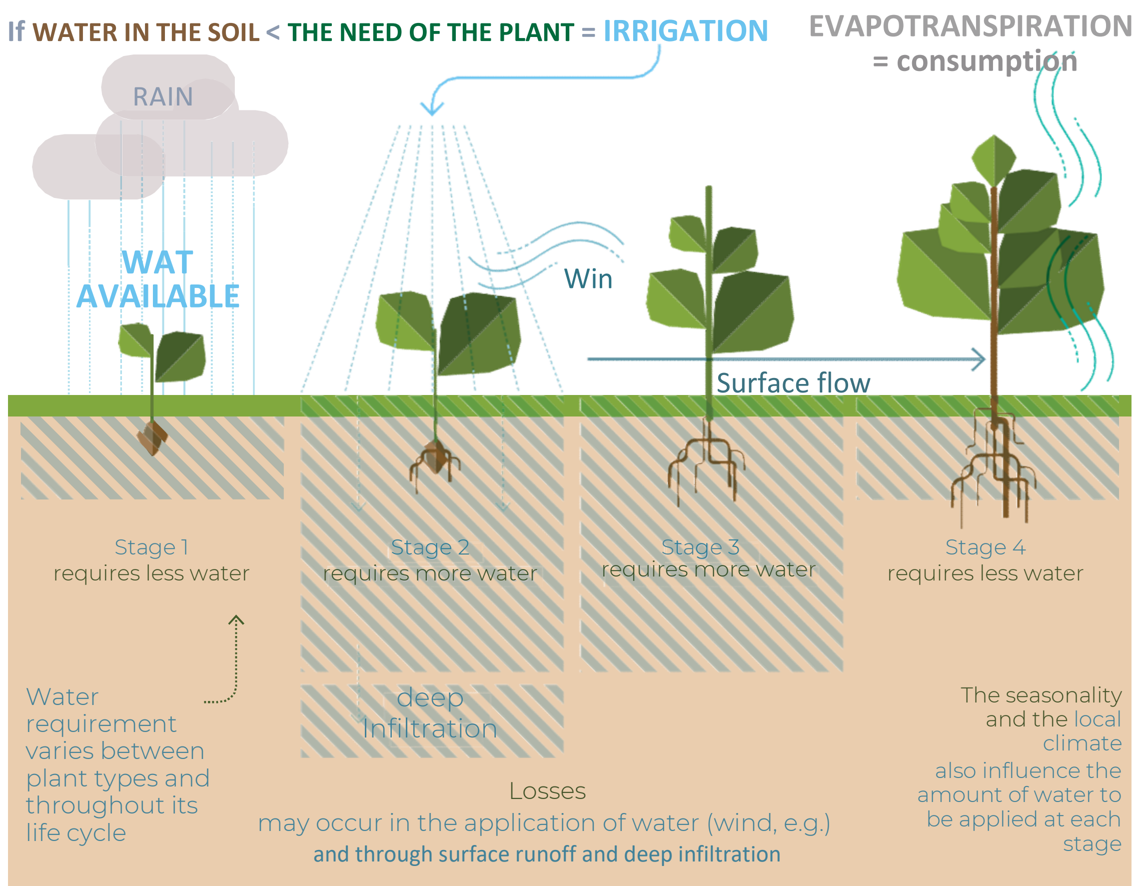
The calculation of water demand is complex - it involves dozens of variables, constants and equations that result in a need for specific irrigation of each crop in that place and period of the year, i.e., in the volume of water to be applied for crops to fully develop. These specific slides are then multiplied by the ***irrigated area*** – hence the importance of this variable in estimating water use.

More information on the methodology of the data can be found in the ***Handbook of Consumptive Water Use in Brazil*** (ANA, 2019) and in the ***Technical Coefficients for Irrigated Agriculture in Brazil*** (ANA, 2020). It should be noted that, in addition to the general method for all crops, ANA adopts methodological adaptations to estimate the demands of flooded rice and sugarcane, as they have different dynamics of water use and management.

Rain and stream gage stations used (average climate)



Schematic representation of water needs in irrigation



Source: adapted from the Brazilian Water Resources Report (ANA, 2017)

Areas of irrigated rice in Manoel Viana (RS)
Zig Koch /ANA Image Bank

Water use in flooded rice

In rice flooding, evaporation of the water blade is a critical factor to be considered in the calculation, as well as the different types of management – grouped in conventional and pre-germinated systems. In the first case, sowing is carried out in non-flooded soil, and flooding begins a few days after the plants emerge. In the pre-germinated system, irrigation begins before sowing, during the final soil preparation procedures. After this step, the height of the water blade is raised to a certain level and maintained until sowing, which occurs in flooded soil. Due to these peculiarities, it is considered in the frame filling and pre-seeding periods that the water demand is evaporation, since the crop is not yet established.

Considering an average cycle of 122 days, the conventional system requires between 80 and 100 days of irrigation until it is time to empty the trays and prepare for harvest. In pre-germination, irrigation starts about 25 days before sowing, totaling about 100 to 125 days of irrigation. Despite the difference in the number of days under irrigation, water consumption is equivalent, because the need for water replacement through percolation losses in the pre-germinated system is less than in the conventional system.

The water supply required for rice under flooding varies from 6 to 12 thousand m^3 per hectare (flow rate of 0.7 to 1.75 liter per second per hectare) (SOSBAI, 2018). In the estimates made by ANA (2017), the national average is 8.9 thousand m^3/ha. The conditions of management, soil, slope, climate and the selected cultivars condition different volumes of water applied by the producers. A longer cycle cultivar in sandier soil, with greater slope, in drier years will require more water, for example.

Water use in sugarcane

With regard to sugarcane, three different ways of managing water abstracted from springs are considered: full irrigation, supplementary irrigation, and salvage irrigation, the latter being the predominant one.

Full irrigation consists in the application of the water blade to supply the total water deficit of the crop, as calculated for the other crops. However, in the tenth month of the crop cycle, irrigation must be suspended to favor maturation, meaning a cut in water use. Additional irrigation consists of partially supplying the water deficiency (about 50%), in addition to also planning the irrigation cut in the tenth month of the cycle. Salvage irrigation, which accounts for more than 80% of the irrigated area of sugarcane, consists of the application of water in a relatively short period.

Salvage is performed with a reel (hydro roll) or with towable pivot and around 20 to 80 mm/year of blades are applied, in general after each annual cut of sugarcane, favoring its recovery, productivity and longevity. This management varies between plants and harvests - the average value obtained in the Atlas survey was 58 mm, distributed mostly in two applications after cutting.

Salvage is intermixed (mixed or alternated) with fertigation itself, which consists of the agronomic reuse of industrial effluents from the sugar and ethanol production processes. Due to this characteristic, it is not possible to accurately distinguish the volumes specifically abstracted and those of reuse applied in the salvage areas. On average, a 1:1 or 1:2 ratio occurs.

In the areas identified as fertigation, water demands are not estimated. These are presumably areas with reuse only - with the demand for abstraction already accounted for in the agro-industrial sector. there are mills working with concentrated vinasse around 2 to 4 mm and even mills that apply higher blades similar to those of salvage.

Fertigation with vinasse and wastewater is the result of integrated and dependent agricultural and industrial management decisions. The main purpose of this type of irrigation, widely used by the sugar and energy sector, is the rational use of the fertilizing potential of the industry's effluents and compliance with the sector's sustainability regulations and practices. Fertigation is carried out following technical criteria for sugarcane nutrition and specific environmental standards that regulate its adoption. This practice usually occurs through the application of small blades to reduce water stress and improve the conditions of growth and development of the sugarcane, notably after cutting, however, this effect is subtle in the vegetative vigor of the sugarcane in the satellite images analyzed, compared to neighboring areas where it was not applied.

The macro-flow of water in the agro-industrial process of sugar and ethanol production in Brazil is presented in the infographic. The reference values aim to portray standards found in the literature and in consultation with experts, but in specific industrial units the numbers may deviate significantly depending on the technologies used, good practices of use and reuse, proportion of ethanol and sugar production, among other factors.

In view of environmental standards, 100% of the discharge tends to be reused agronomically with reference values between 800 and 1,100 liters per ton of processed sugarcane. The goal of water abstraction ("blue water") for values around 1,000 liters/t sugarcane in the Central-South region has been achieved by the sector - these values have been around 15 to 20 thousand liters/t sugarcane for about four decades, due to the open water use circuits. In addition, 700 liters/t of sugarcane enter the agro-industrial flow from sugarcane itself.

Considering the application of water in the sugarcane plantations, Brazil currently has 2.9 million ha (Mha) fertigated (79.5%) and 749 thousand ha irrigated (20.5%), totaling 3.66 Mha. The volume of water applied annually exceeds 2.1 billion m^3 (or 2.1 trillion liters), 27.7% for fertigated areas (582.6 million liters) and 72.3% for irrigated areas. The results reiterate the association of low volumes per unit area in fertigation and salvage; and higher volumes in deficit and full irrigation.

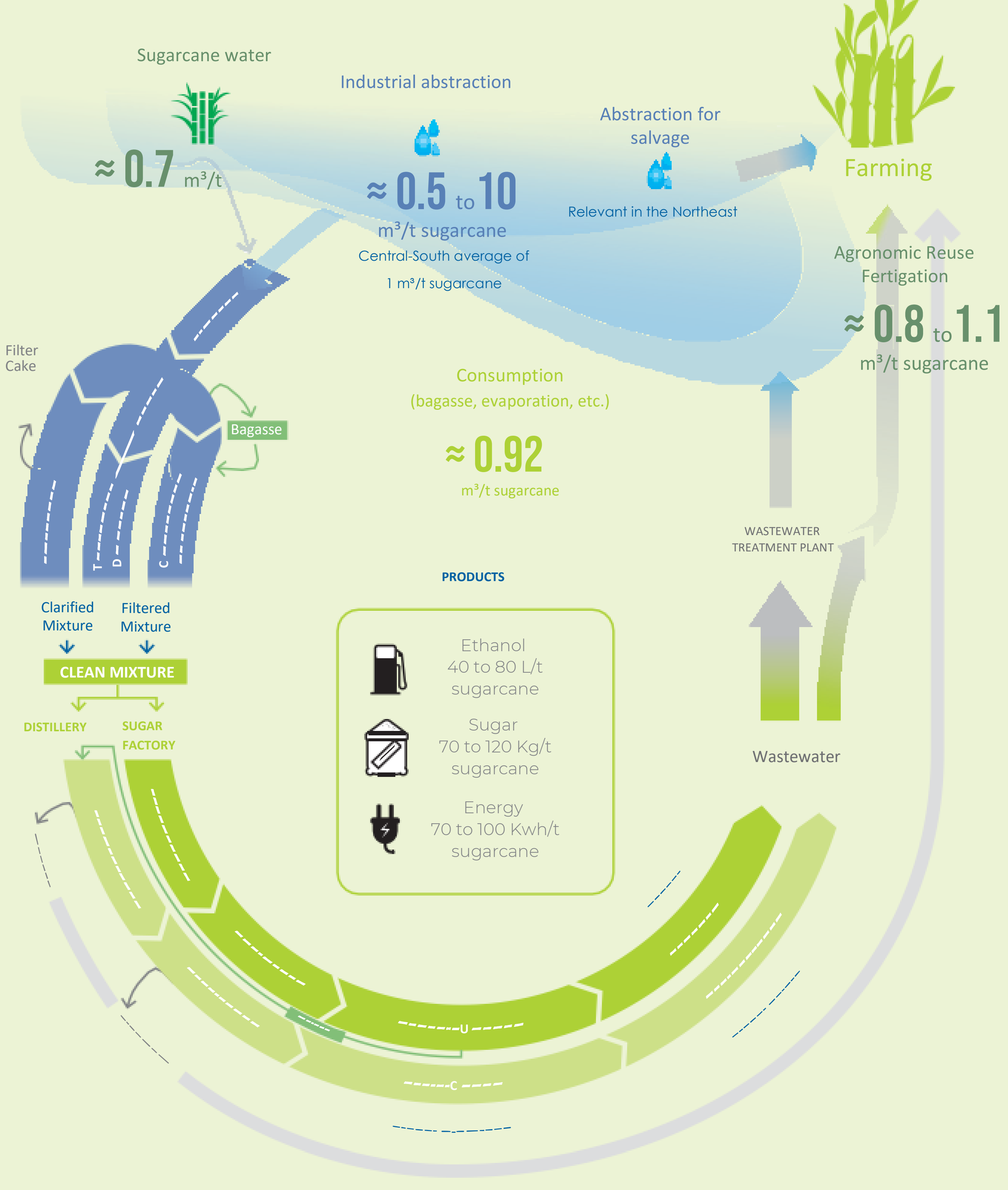
The importance of the first group lies in the large application area that reaches 3.48 Mha (95% of the total) and the location of large areas on the Northeastern coast, in coastal river basins with less water availability. The group with the highest water intensity (deficit and full), although occupying only 5% of the area, is responsible for 56.7% of the water volume that is demanded from a restricted number of springs.

Irrigated and fertigated sugarcane area and average annual water

TOTAL IRRIGATED AND FERTIGATED	AREA (%)	VOLUME (%)
FERTIGATION	79.5	27.7
SALVAGE	15.5	15.6
WITH DEFICIT	4.2	40.6
FULL	0.8	16.1

TOTAL IRRIGATED	AREA (%)	VOLUME (%)
SALVAGE	75.7	21.6
WITH DEFICIT	20.6	56.2
FULL	3.7	22.2

Water flow in the sugar and ethanol agro-industrial process



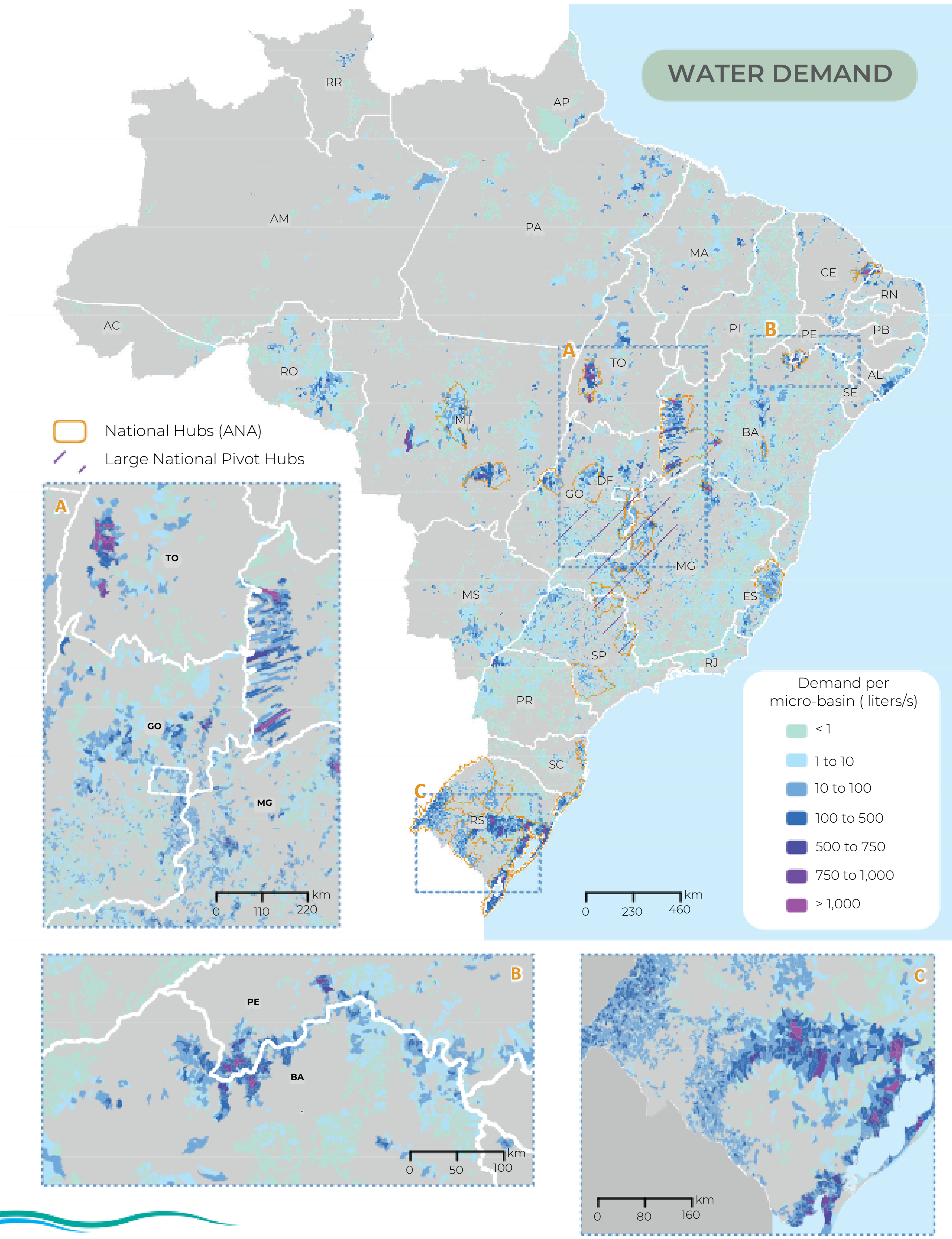
Source: Survey of Irrigated and Fertigated Sugarcane in Brazil (ANA, 2020) and Industry in the Paranapanema River Basin: water use and good practices (ANA, 2020).

Note: reference values can deviate significantly at specific sugar and ethanol units, depending on the technologies used, good practices of use and reuse, proportion of ethanol and sugar production, etc.

Water Demand

The water demand updated by the Atlas, assuming an average climate scenario in 2019, points to water use by irrigated agriculture of 965 m³/s - 941 m³/s are abstracted from springs (blue water) and about 24 m³/s represent the agronomic reuse of effluents (gray water) in sugarcane areas (fertigation and salvage).

Among the typologies adopted in the Atlas, rice demands 357 m³/s from springs (or 38% of the demand in 2019). The other systems and crops (class with high participation of Northeastern fruit-growing and horticulture) demand 276 m³/s (29%), followed by annual crops grown in center pivots



(167 m³/s or 18%). Coffee (97 m³/s or 10%) and sugarcane (44 m³/s or 5%) complete the most relevant typologies of the national water demand.

In terms of water intensity (demand per hectare), rice, sugarcane irrigated by deficit or full, coffee and crops located in the Semiarid region provide proportionally more water than crops under pivots. Flooded rice management, although concentrated in only 100 to 120 days a year, is quite water-intensive, while the other cases are (semi)perennial crops, which need water supplementation throughout the year, and/or regions of lower water availability in the environment.

In the 2040 horizon, a greater participation of center pivots and localized irrigation (centered on the typology other crops and systems) in the demands of irrigated agriculture is expected. These methods use water more efficiently. Although ***all groups should show growth in area and demand***, these sectors should continue to grow at more significant rates.

Thus, with the increase in the participation of more efficient systems, ***growth of the irrigated area is estimated at 76% by 2040***, while ***water demand is expected to grow 66%***.

Among the typologies, a tendency is foreseen for flooded rice to recover from areas lost in recent years, which will lead to an increase in demand (+21%), but with a reduction in its participation from 38% to 27% in 2040.

Sugarcane and coffee are also expected to have their water demand increased (+67% and +89%, respectively). Sugarcane should largely maintain its lower unit water use characteristics (salvage and fertigation), while coffee should continue to advance in the conversion from rainfed to irrigated areas in the coming decades.

Annual crops on center pivots will have the largest growth (+133%) increasing its share in water demand from 18% to 25% in 2040. The pivots demand lower annual average blades than the other classes (except sugarcane salvage), due to its temporary nature (with off-season and less than 30% of active pivots in the drier period) also because they are concentrated in the areas of supplementary irrigation where rainfall contributes an important part of the crops' needs.

The typology of other crops and systems is concentrated in areas of lower rainfall and higher evapotranspiration, as well as encompassing many perennial crops (bananas, grapes, mangoes, oranges, etc.) - which results in proportionally higher average annual rainfall. The demand for this typology is expected to grow 79% by 2040, increasing its share in the total water demand from 29% to 31%.

The geography of water use reveals more clearly the significant increase in demand in regions with a concentration of mechanized methods (especially pivots and localized irrigation). The possibility of intensifying use is evident in the current producing hubs - mainly in Western Bahia and Northwestern Minas Gerais (source regions of the São Francisco River tributaries); Central Bahia (Mucugê-Ibicoara region, in the source region of the Paraguaçu and Contas rivers); Eastern Goias and the Minas Gerais triangle (sources of the Grande and Paranaíba Rivers, which form the Paraná River); and Southeastern São Paulo (sources of the Paranapanema River, an important tributary of the Paraná River). Hubs still in development tend to present even more significant demands until 2040, especially in the consolidated agricultural borders of Mato Grosso and Goiás and in the Northwest of Rio Grande do Sul (basins of the Uruguay and Jacuí rivers).

Seasonality of Use

The average annual flows characterize the use of irrigated agriculture for various applications and facilitate comparison with other water uses. On the other hand, there is strong seasonality in the activity, varying with the local climatic characteristics and with the ***calendars and types of cultivation***. Several ***management*** practices also influence the seasonality of use, such as the soy waiting period - a period in which the producer cannot have live plants in order to prevent Asian rust.

In the case of flooded rice, the use is only concentrated in the annual harvest period (in hubs with the most production), which occurs between September/October (planting) and February/March (harvesting) in the main hubs. Average monthly water use shows that

Use of water (m³/s) for irrigation by typology and state (average climate)

	2019				2040			
State	Rice	Sugarcane	Coffee	Other crops	Rice	Sugarcane	Coffee	Other crops
RO			8.2	2.1			14.4	3.7
AC				0.2				0.3
AM				0.5				0.9
RR	4.1			2.8	1.2			5.0
PA	0.7			7.8	2.1			13.8
AP				0.7				1.3
TO	20.8	0.7		3.0	34.7	1.0		8.2
MA	0.4	5.3		4.2	0.4	8.2		7.1
PI	1.7	2.1		6.4	0.8	3.3		11.1
CE	0.3			32.0				52.7
RN	0.3	0.6		10.0	0.6	0.9		16.3
PB		0.9		1.8		1.3		3.3
PE	0.2	1.3		34.8	0.0	1.8		55.0
AL	1.0	8.1		0.5		11.		1.0
SE	2.3	1.3		3.9		1.8		5.8
BA	0.0	9.9	13.4	106.3	0.1	16.9	26.8	199.8
MG	0.3	12.7	34.0	92.5	0.2	25.0	72.4	189.8
ES		0.0	36.2	5.5		0.0	59.3	9.3
RJ			0.0	3.1			0.0	5.4
SP	1.4	0.0	1.4	40.6	0.6	0.1	2.4	80.4
PR	4.8	0.0	0.0	2.6	6.0	0.0	0.1	5.3
SC	31.			0.7	35.9			1.3
RS	277.7			16.4	346.1			47.0
MS	3.0	0.2		4.5	1.0	0.3		11.6
MT	1.6	0.1	0.2	21.9	0.5	0.1	0.4	64.5
GO	5.1	5.9	2.8	34.4	0.9	10.4	5.6	76.1
DF			0.7	3.9			1.2	6.7
BRAZIL	356.9	49.1	96.9	443.2	431.0	82.2	182.7	882.9

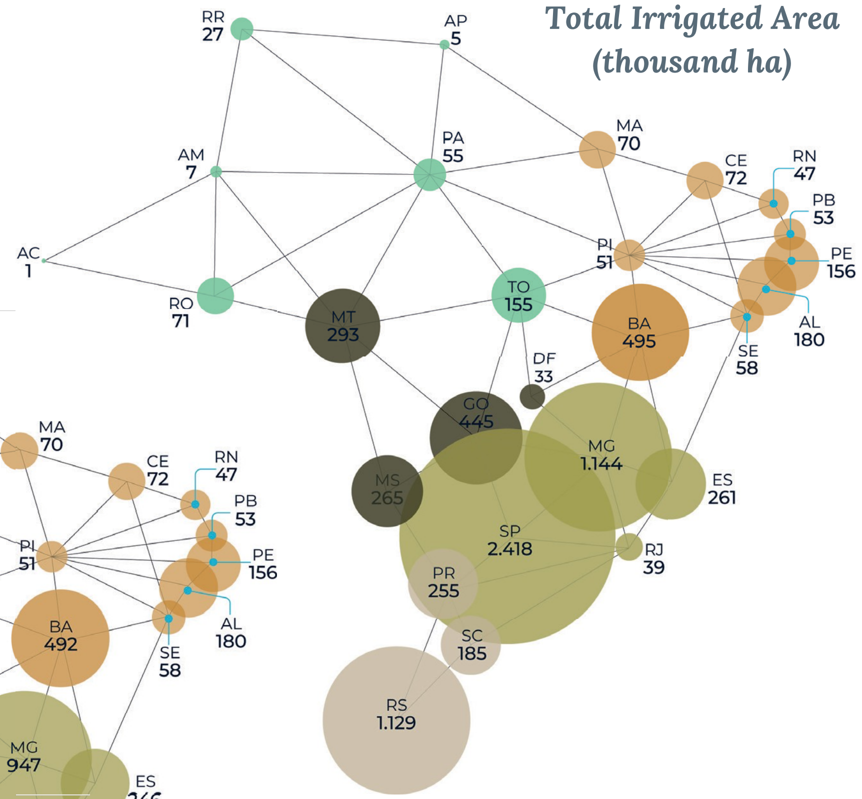
in just two months (November and March) flows similar to the annual average occur, with use much higher than the average between December and February, and lower between April and August.

Coffee demands more irrigation, on a national scale, between May and October, when monthly average flows are higher than the annual average. Between November and March, with more rainfall in the main producing areas, the irrigation flow is lower than the annual average.

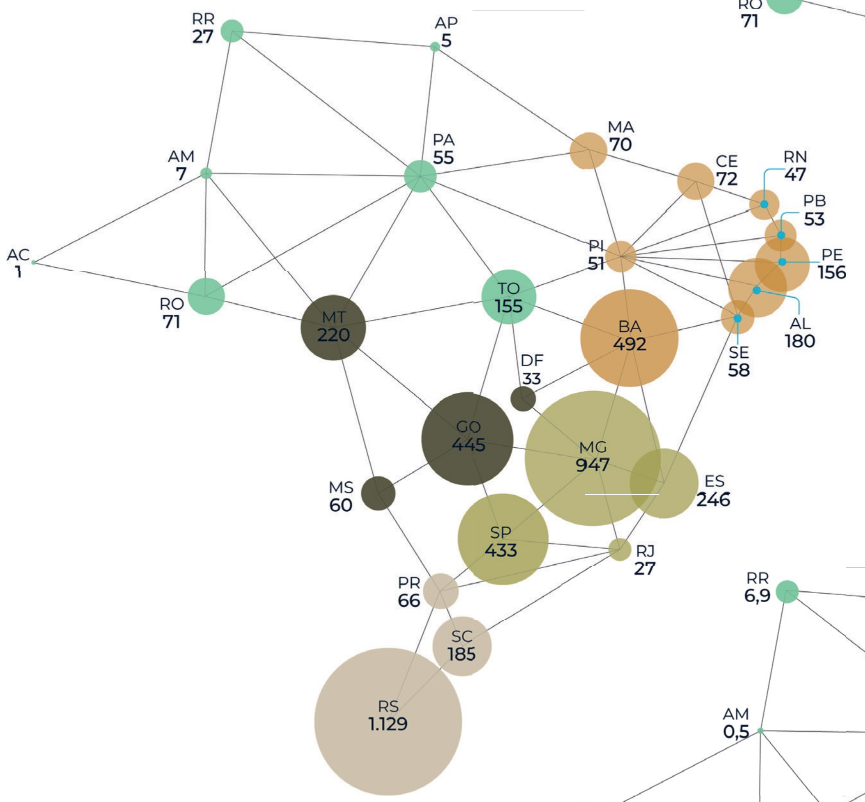
In the case of other crops, except rice, coffee and sugarcane, the monthly average of use is highly influenced by production in the Cerrado biome and in the Northeast regions. Seasonality has less accentuated monthly deviations in relation to the average. It can also be observed that in only two months of the year the use is similar to the annual average, which is higher between May and September (period of greater water deficit in the main producing regions) and lower between November and March (rainy period, with less water deficit). The greater demand converges with the periods of lower rainfall in these producing regions.

On the map of monthly average demands per micro-basin, the aspects related to seasonality are more clearly noted, especially with the high demand in the rice regions (RS, SC, TO) between September and February; the demand throughout the year in the Central-South region - which is higher in the months of greatest water deficit (May to October); and of sugarcane concentrated mainly in months where the cut occurs, when salvage irrigation is applied, as a rule.

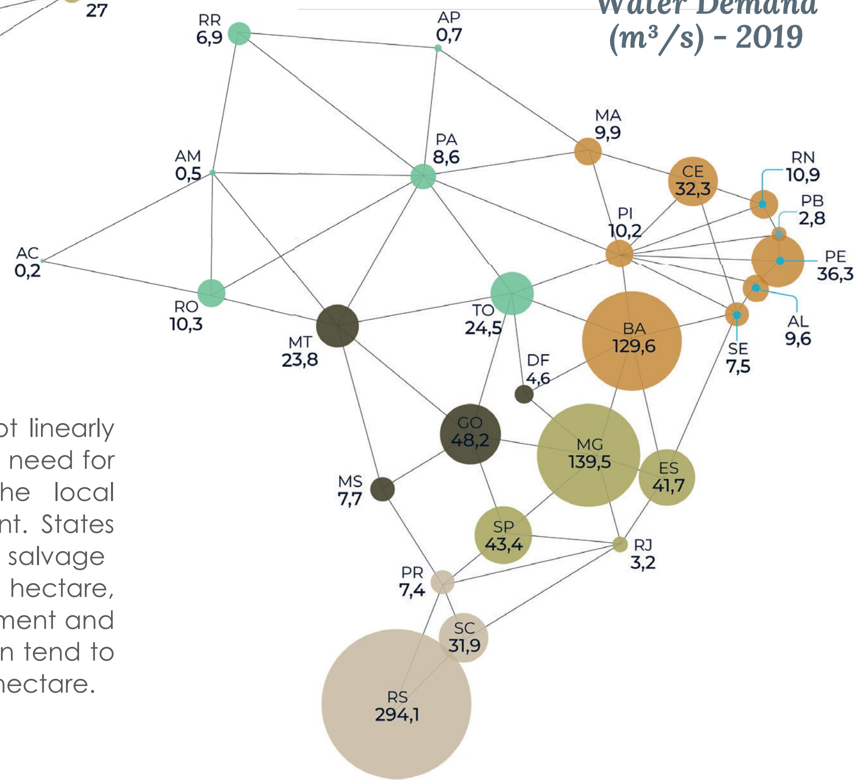
Total Irrigated Area (thousand ha)



Irrigated Area (thousand ha) (except fertigated)

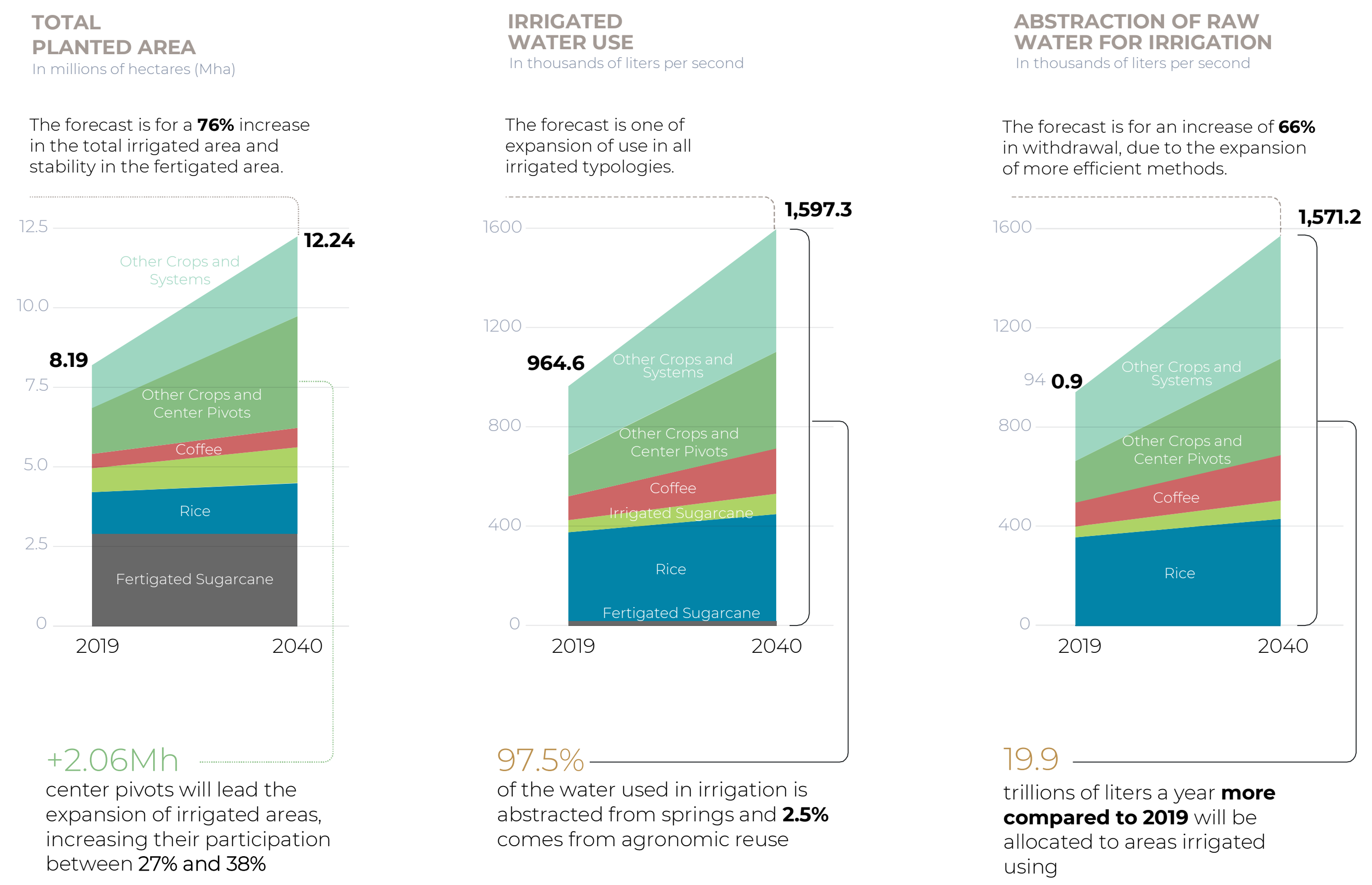


Water Demand (m³/s) - 2019



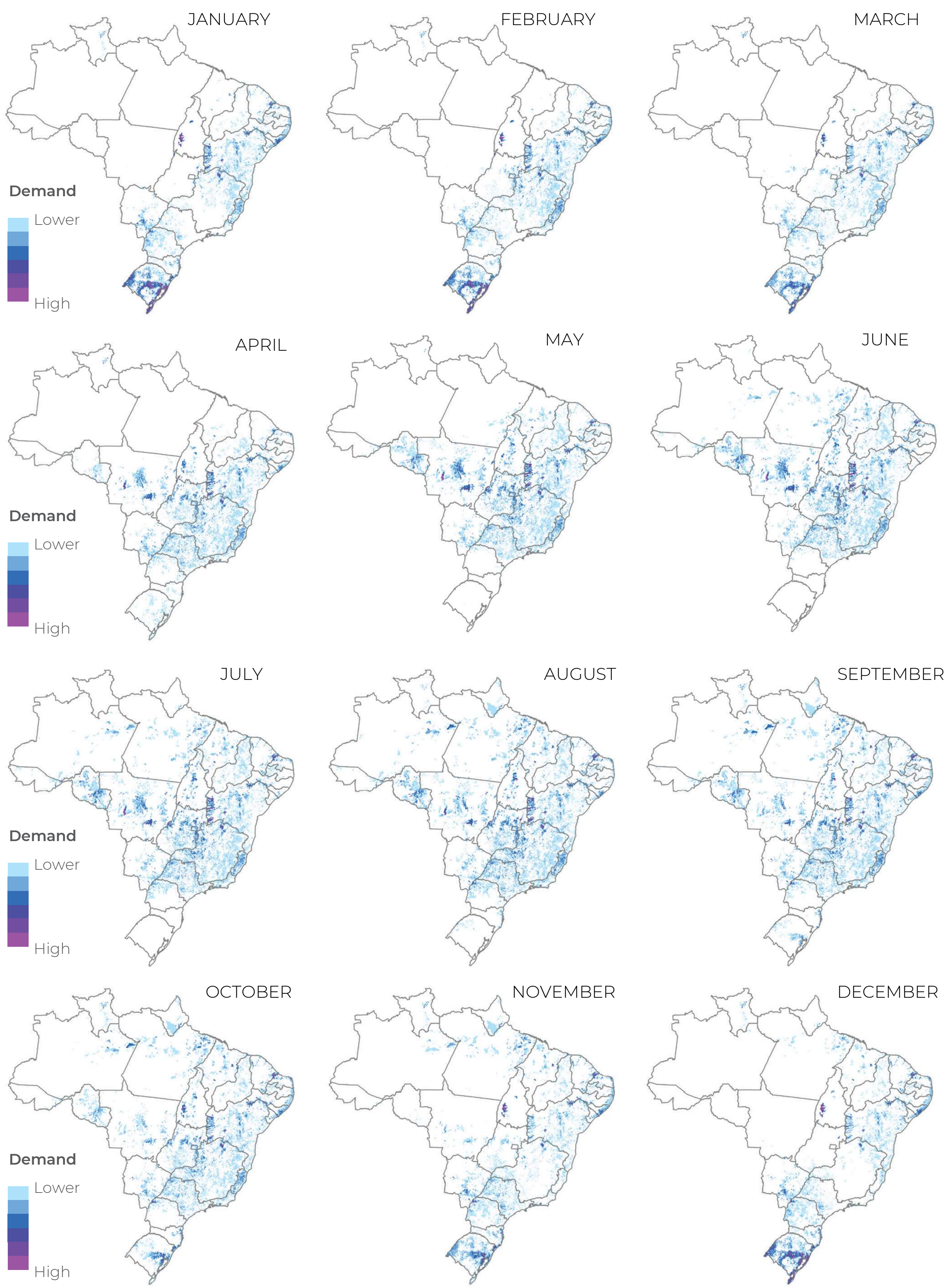
The water demand in the springs is not linearly proportional to the irrigated areas. The need for irrigation depends on the crop, the local climate and the type of management. States with greater participation in sugarcane salvage demand proportionally less water per hectare, while rice crops with flooded management and permanent crops in the Semiarid region tend to present greater need for irrigation per hectare.

SUMMARY OF AREAS EQUIPPED FOR IRRIGATION AND WATER USE - 2019 to 2040

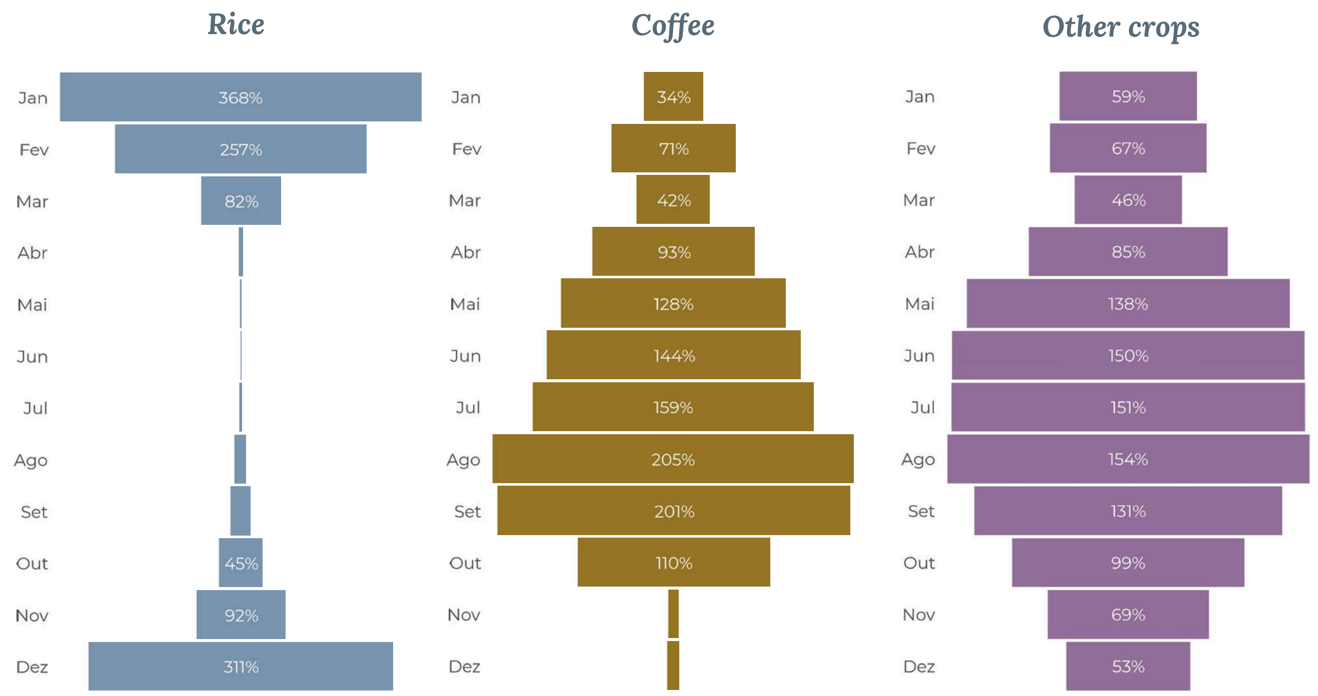


Rice cultivation in the municipality of Cachoeira do Sul (RS)
Bernardo Rudorff /ANA Image Bank

Seasonality of water use for irrigation



Monthly water use in relation to the annual average (average climate)



Water demand and Rain

The climatic water balance for estimating crop water demand is greatly affected by precipitation, since irrigation (***blue water***) seeks to complement the need for the crop not supplied by the rain stored in the soil (***green water***). Precipitation still shows strong variation in space and time, including high intra-annual and inter-annual deviations from the historical average, making its estimation challenging in the national territory.

The density of rain gage stations presents great heterogeneity, and the North and Midwest regions have the lowest coverage. The lower the density of stations and the greater the variation in physical parameters, such as relief, the greater the uncertainties related to interpolating rainfall between stations. The stations also present problems of failures, inconsistencies, different time spans and time lag between the collection and availability of the data series.

Remote sensing products from orbital stations have the potential to mitigate the lack of data with frequency, resolution and temporal coverage and accuracy appropriate to the studies.

These products may replace or be supplementary to the ***monitoring network*** data. In an assessment conducted by ANA and UFPR on the performance of 10 remote sensor products in Brazil (2000-2017), the CHIRPS v0.2 (Climate Hazards Group InfraRed Precipitation with Stations) (FUNK et al., 2015) and CMORPH – CDR (Center Morphing Method – Climate Data Record) (XIE et al.; 2017) products stood out.

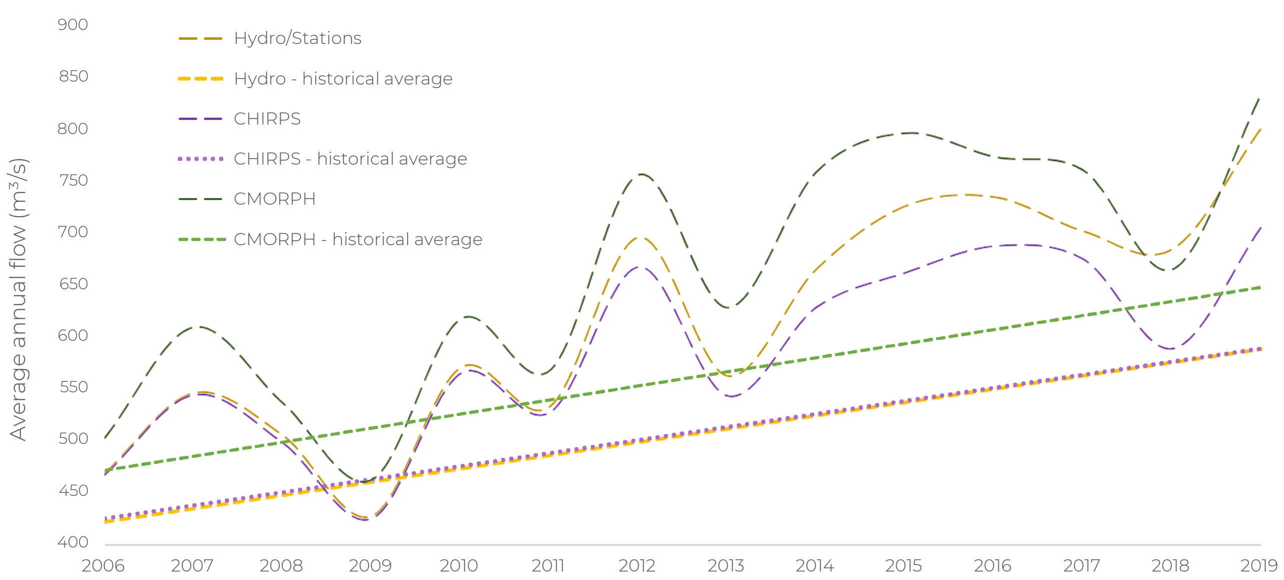
In order to highlight the importance of rainfall in irrigation demand estimates, the Atlas has simulated the water demand (2006-2019) using the three data sources: the monitoring network and its interpolations, CHIRPS, and CMORPH; and considering the ***historical average climate and observed climate*** scenarios. All other calculation parameters are identical in the simulations.

Local monitoring is always desirable and will provide a better estimate for the producer on his/her property, but for large surfaces the satellites have advantages over the interpolated data between distant stations, therefore, a priori there isn´t a more accurate simulation.

The strong impact of rainfall variability on the demands of irrigated agriculture can be seen - which is aggravated by the reduction of the supply in the springs. With the exception of 2009, the average rainfall in the producing regions was lower than the time series, boosting water demand, especially in 2007, 2010 and 2012. The 2014-2019 period has been especially challenging due to the ***persistence of below-average rainfall***, with the exception of 2018, which was less severe.

The relevant impact of different precipitation sources on the estimates for the same year can be seen. The data interpolated from the monitoring network managed by ANA (from Hidro) and CHIRPS show similar average rainfall as well as in the 2006-2014 period, but the estimates are off in recent years (2015-2019). CMORPH presents the lowest average rainfall in irrigated regions, resulting in greater demand.

Water demand of irrigated agriculture 2006-2019 (except rice) with different precipitation scenarios



Water demand and Climate Change

Can the persistence of unfavorable climatic variabilities for agriculture in Brazil be an indication of ***permanent changes***? Climatic changes have gained great public visibility in recent decades and have occupied a considerable space on environmental, political and social agendas around the world. The successive reports of the Intergovernmental Panel on Climate Change (IPCC), formed in 1988, have reaffirmed the ***increase in global temperature*** due to anthropogenic carbon emissions and warned of the risks of this change.

According to IPCC (2013), climate changes are significant variations in the average state of the climate or its variability, persisting for an extended period. These changes can happen due to natural processes that are part of the climatic system or anthropogenic processes (caused or altered by humans); or by the combined effect of both. The IPCC and the Food and Agriculture Organization (FAO) have listed agriculture as one of the most vulnerable sectors of society to be impacted by climate change.

One can consider three major components of agriculture that are impacted by climate change: water demand for irrigation, potential agricultural productivity (those achievable under stress-free conditions) and plant health problems. In addition to these direct impacts, there is concern about future water needs for agriculture in view of water availability for other uses under the combined effects of climate change. Moreover, with the tendency to increase unit demand and with the possibility of a decrease in water at the springs, there may be a significant ***reduction in the potential for expansion*** of areas irrigated by water restrictions.

To mitigate some of these impacts, irrigation remains an efficient and secular strategy used to adapt to adverse weather conditions, and is still one of the most important means used to ensure food production around the world. As a result, irrigation can both be impaired in some regions, as it is one of the main measures of adaptation to change, which is a challenge for the productive sector and in water resources management.

Regarding the ***extreme events*** that affect agriculture, the national plan for adaptation to climate change (MMA, 2016) pointed out an expectation of an increase in the frequency of heat waves throughout Brazil, with maximum daily temperatures above 32°C that are responsible for the fall in agricultural production, since they interfere with the phases of the phenological cycle of crops and the development of vital organs of plants. It is also expected that by 2050, the productivity of most agricultural crops will decrease sharply due to excess heat. Regarding summers, the plan pointed out the increase in the frequency of drought periods, accompanied by heat, strong insolation and low relative humidity in the middle of the rainy season or in the middle of winter. Soy cultivation may become increasingly difficult in the South region and some states in the Northeast may significantly lose their agricultural area. Finally, an increase in the frequency of heavy rains and storms is expected in the South, which could cause problems for agricultural mechanization due to the flooding of cultivated areas. Sugarcane, wheat and rice plantations can also suffer losses due to strong winds, which leads to the lodging of these crops. Spraying with pesticides against pests and diseases will be made difficult due to strong winds or intense rain.

For the ***Irrigation Atlas***, a study was prepared on the impact of climate change on the demand for irrigated agriculture in 2040. In other words, keeping all other variables the same (area, crops, calendars, etc.), how much the demand can vary just due to changes in climate in relation to the monthly average observed in the time series. This study will continue to be detailed in the context of the ***2022-2040 National Water Resources Plan***, which is in preparation.

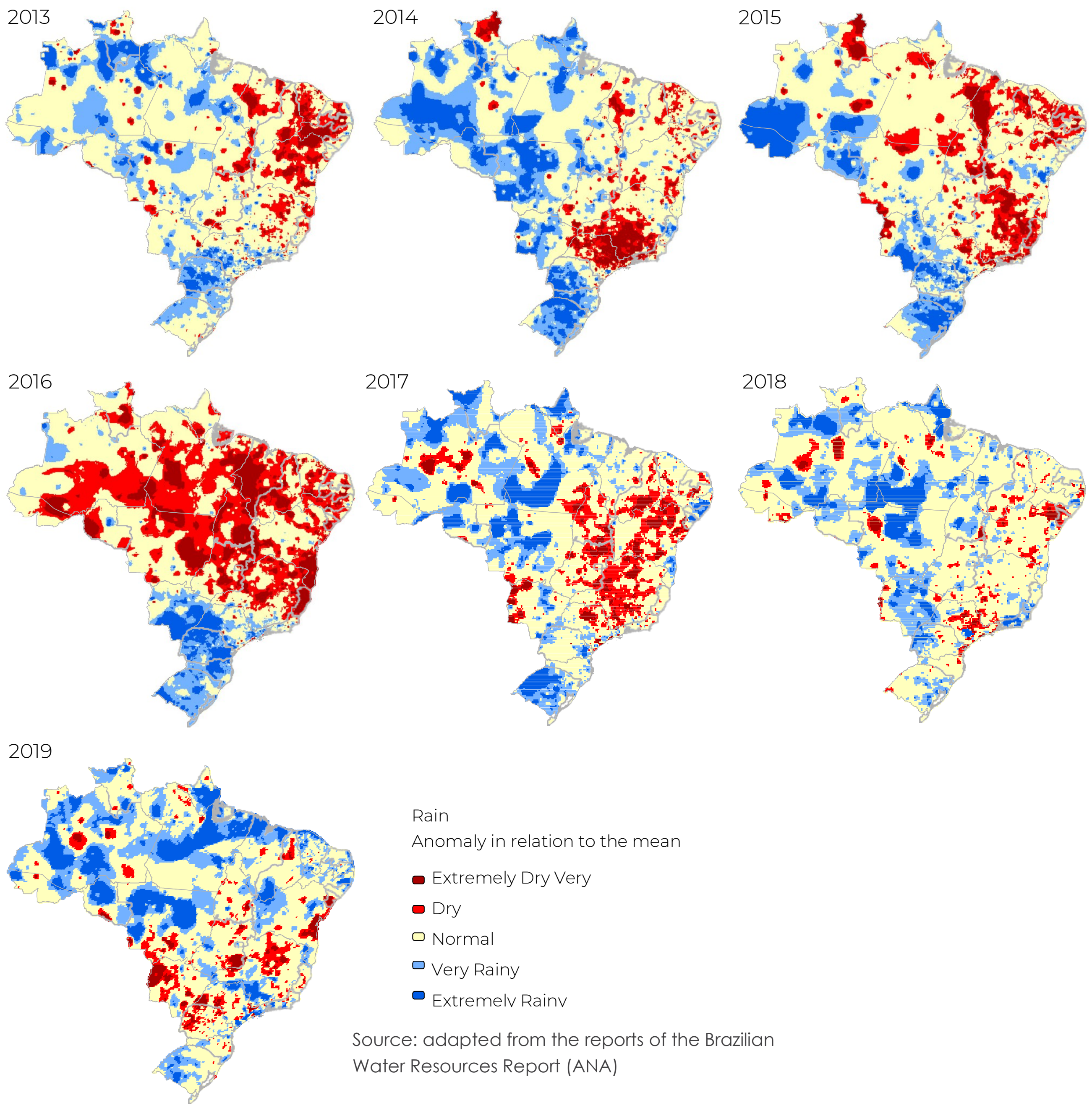
In this analysis, ***40 future climate scenarios*** were used, resulting from the combination of two greenhouse gas emission scenarios (RCP4.5 and RCP8.5, corresponding to radiative forces of 4.5 and 8.5 W/m², respectively) and from 20 climate models published in the NASA Earth Exchange Global Daily Downscaled Projections - NEXG- DDP project. This project carried out a broad statistical downscaling of global climate models (MCGs) used in the fifth phase of the IPCC called CMIP5 (Coupled Model Intercomparison Project Phase 5), making the results available in a single grid with a resolution of 0.25° degree (about 25 km x 25 km)[1]. The results of the NEXGDDP underwent additional bias correction through data observed from weather stations and were expressed, in the 2040 horizon in Brazil, in terms of precipitation anomaly and potential evapotranspiration anomaly (ET0).

In general, the results showed the consensus among the scenarios that temperatures are increasing and consequently, the evapotranspiration demand (potential evapotranspiration) - the magnitude of this variation ranges from subtle to extreme among the scenarios. As for precipitation, the scenarios indicate both reduction and increase, with different seasonal magnitudes and annual averages.

Three of the 40 assessed scenarios were chosen as references because they represent – in addition to having had good performance in representing the present climate (thus are good candidates to represent the future climate) - two limiting situations and an intermediate one. The scenario composed of the BCC-SSM11 model and the RCP8.5 emission scenario is prone to greater increases in irrigation demand, since it resulted in lower rainfall and higher evapotranspiration in regions with irrigation. The intermediary cCSM4_RCP8.5

[1] More details about the project and how to download the data can be found at: https://www.nccs.nasa.gov/services/data-collections/land-based-products/nex-gddp

Precipitation anomalies in relation to the historical average - 2013-2019



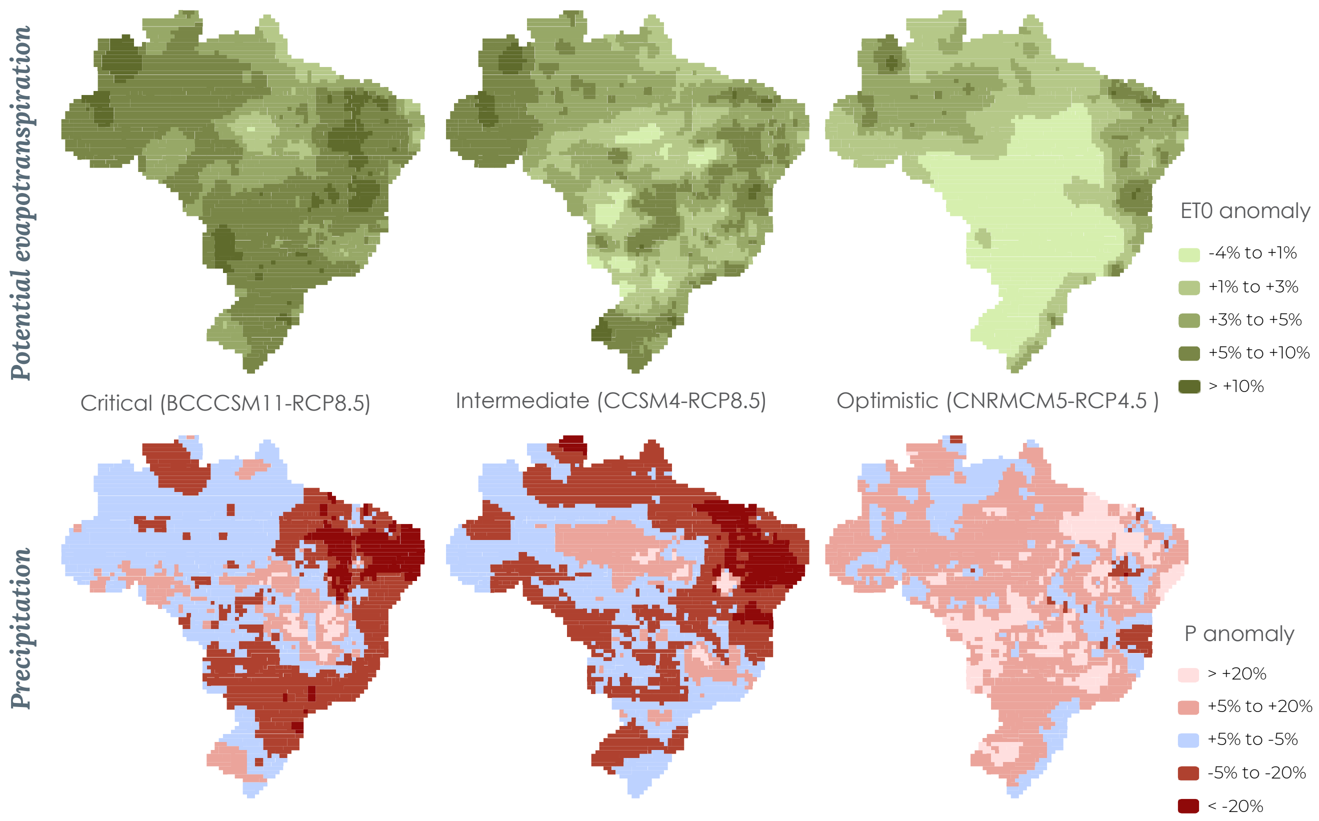
Source: adapted from the reports of the Brazilian Water Resources Report (ANA)

mediator signals lower rainfall than the BCCCSM11-RCP8.5 scenario, however, there is a less intense change in evapotranspiration. The CNRMCM5-RCP4.5 scenario would be considered optimistic from the point of view of irrigation, as it estimates more favorable rainfall and subtle increases in evapotranspiration.

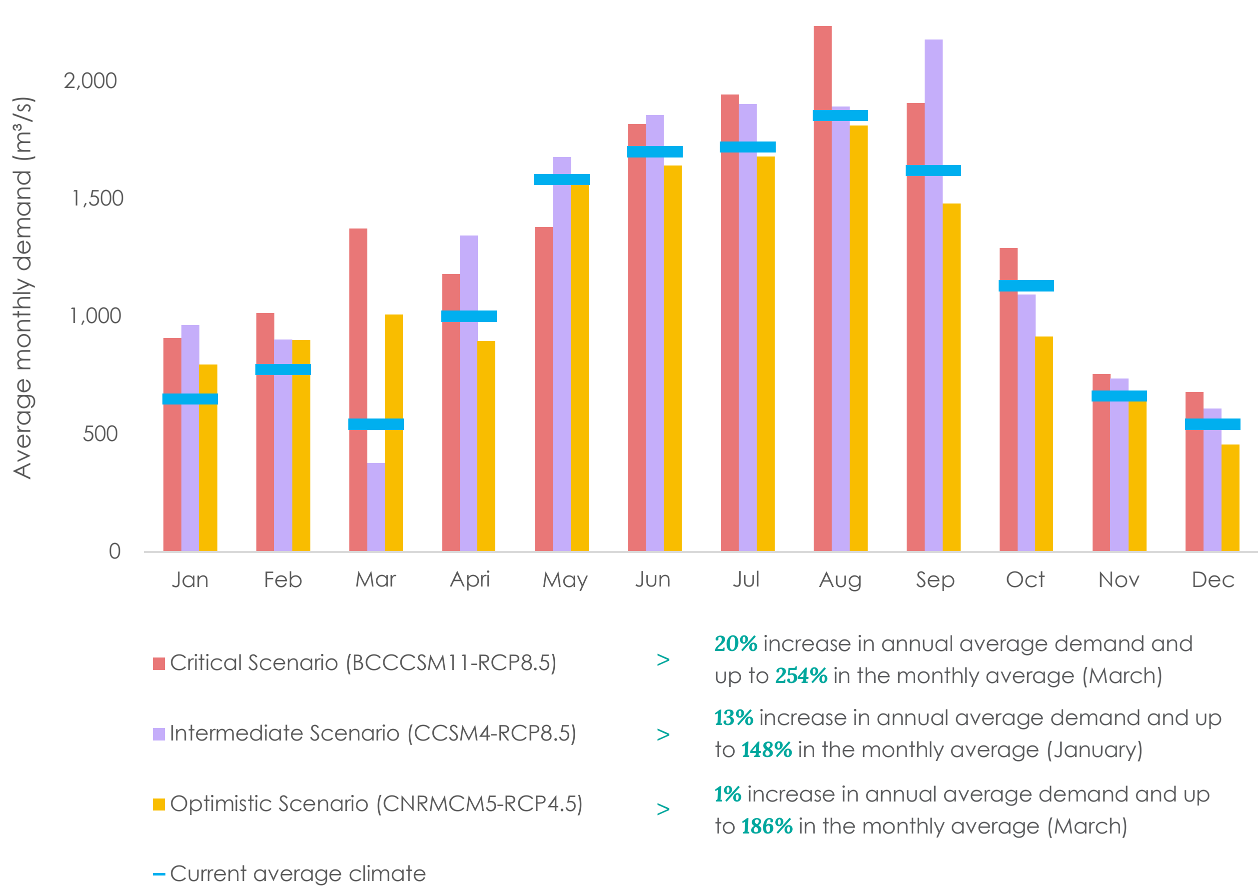
Potential evapotranspiration and precipitation in the reference scenarios point to ***important changes in climate geography in Brazil in 2040***, with a trend of ***negative impacts*** on agriculture (irrigated and rainfed).

In terms of the magnitude of increase in average annual water demand, the scenarios range from +1% in the optimistic scenario to +20% in the critical scenario, with the increase being +13% in the intermediate scenario. In addition, seasonality is affected in different magnitudes and proportions, with a maximum increase in the average monthly demand of 254% in the critical scenario and 186% in the optimistic scenario (both peaks occur in March). In the intermediate scenario, the maximum monthly variation was verified in January (+148%).

Potential evapotranspiration and precipitation anomalies in the scenarios -



Water demand of irrigated agriculture in 2040 (except rice) with different climate change scenarios



Granting, Registering and Allocating Water

For water abstraction from surface or underground springs, regularization (granting and/or registration) is mandatory with the State and Federal District water resource management agencies or, in water bodies under Federal domain, with the ANA. The uses of low expression considered insignificant (small abstractions) can be dispensed with, but registration with the respective managing agency remains mandatory.

Among the most relevant aspects of improvement of the ***grants and registrations*** for irrigators, we highlight the following: automation and digitization of the process, seasonality of the authorization, collective and preventive grants, allocation and regulatory milestones. It should also be noted that most irrigators abstract water from springs managed by the States and the Federal District (76% of interventions). For grants in larger rivers, ANA concentrates 42% of the volume of regular abstractions, referring to 24% of users. About 40% of the number of interventions regularized by ANA are in the Semiarid region, due to the fact that the main water bodies are under Federal domain (Federal rivers and reservoirs in state rivers).

The granting and the registry have been conceptually and operationally improved since the enactment of the Water Law (Law no. 9,433/1997) and of the state policies for water resources. One of the improvement initiatives occur through the Consolidation Program of the ***National Water Management Pact - Progestão***, which provides a financial incentive with payment for achieving goals defined between ANA and the States. Created to strengthen water management in the national territory, in an integrated, decentralized and participatory manner, Progestão also aims to promote the multiple and sustainable use of water resources. The granting and registration have recurrent targets for their central role as instruments of water resource policies (for more information, visit: http:// progestao.ana.gov.br).

The ***National Water User Registry*** (CNARH) was created to contain the records of water resource users (surface and underground) that abstract water, discharge effluents or perform other direct interventions in water bodies (river or watercourse, reservoir, dam, well, spring, etc.). ANA is responsible for managing the CNARH and storing the information on users from the federal (Federal government) and state domains, as well as making computational tools available to the managing entities for data management. The respective management agencies are responsible for inserting information into the CNARH, according to ANA Resolution no. 1,935/2017. ANA supplies the CNARH with the interventions in water bodies of Federal domain and the states can adopt the CNARH as their official user registration

Overview of irrigation users in 2020
National Water User Registry - CNARH

CNARH

≈ 31
trillions of liters/year
42% Federal Government (ANA)
58% States and DF

≈ 53
thousand interventions
24% Federal (ANA)
76% States and DF

	Groundwater	Surface water
of volume	7%	93%
of interventions	24%	76%

	Insignificant use (registration)	Granting and registration
of volume	1%	99%
of interventions	16%	84%

system (as well as ANA) or insert this information in the format of the system from their own registration systems.

The continuous and recurrent supply of CNARH (http://cnarh.ana.gov.br), preceded by an analysis of consistency of tabular and spatial data, is essential for the safety of the grantor and the irrigators. With the registration of users, it is possible to understand the real demand already compromised by the installed users, avoiding conflicts and eventually stimulating the proposal of adjustments in granting the set of users of a basin to allow the entry of new users with water security. In other words, the regularization of users is insufficient without the consolidation of records in a common user base that allows a basin-wide view, the analysis of water balances, and the incorporation of the technicians in the decision making process who analyze the requests.

ANA issues grants using the ***Federal System of Regulated Use*** (REGLA) - the registry (CNARH) and the request for regularization happen concomitantly. This System, released in 2017, made the process of requesting, monitoring and analyzing requests faster, which started to be carried out 100% online and, in most cases, without the need to send paper documents. Based on the information presented by the user, REGLA estimates the amount of water that the undertaking will need – if these values are accepted and depending on the level of commitment of the water body and the size/type of the enterprise, REGLA does the electronic processing of the allocation request and the result is published within a few weeks. Not meeting the criteria or not agreeing on the estimated amount of water, or disagreeing with the geographic information presented by the system, the user will be asked to provide more detailed information and the request for a grant will be submitted to detailed (or specific) analysis by the Agency's technicians.

For irrigation, the automatic flow of REGLA is adopted when the irrigated area is less than 100 ha, the collective commitment of the spring (water balance) is less than 70% of the reference flow and the system is mechanized (i.e., it does not include

Granting the right to use water resources

Granting the right to use water resources is one of the instruments of the National Water Resources Policy (Law no. 9,433/1997). The grant corresponds to an authorization for using water, either for the uptake or disposal of effluents, with the objective of ensuring quantitative and qualitative control and the effective exercise of water access rights. Through the grant, we seek to ensure the rational use of water resources and the compatibility of multiple uses. In some situations, such as in small volume uptakes in basins with good availability, the irrigator may be exempted from the grant, but must be registered with the competent authority.

The grant is granted by the water resource management entity according to the dominance of the waters. In the waters under Federal domain, as in rivers that cross through more than one State e.g.: São Francisco river), ANA is responsible for the issuing it. In rivers under State and Federal District domain, as in rivers that are born and flow in the same State, the authority is of the respective state and district management entities. Groundwater is state-owned. The Figure represents a hypothetical river basin, with three States and several rivers and abstraction points, helping to understand the domain of the waters and the respective granting authority.

Concepts

1. The waters of the R2 and R4 rivers are under Federal domain.
2. The waters of rivers R1, R3, and R5 are under state domain.
3. If reservoir 1 (Res.1) is Federal, the waters are Federal; otherwise, they are state waters.
4. Water from well P1 is state owned.

Authorizations

1. Grants 02, 06, 07 and 08 are state.
2. Grants 03, 04, and 05 are federal.
3. Grant 01 will be federal if reservoir 1 is Federal.

Legenda
- - - Limite entre estados
Hidrografia
Limite da bacia hidrográfica
Poço
Reservatório

For more information, visit: www.snirh.gov.br > Regulation and Supervision the surface methods). If the user agrees with the demand calculations, it is exempted from manual technical analysis, i.e., the grant is analyzed and issued automatically.

REGLA has incorporated improvements in the digitalization (online process), automation (for interventions of less impact on the collective commitment of the springs) and seasonality (values are monthly).

The ***negotiated allocation*** of water is another important instrument of planning and regulation, and it improves the processes of granting and registration, mainly in water systems (reservoirs and stretches of rivers) in situations of water scarcity and conflicts of use. These are the agreements entered into between the granting authority and the users, with participation from the river basin committee, when applicable, aiming at the distribution of the water resources of the respective river basin. It is often used to regulate the uses of water systems that are subject to intense droughts, with emergency or strong potential for conflict. The allocation term is a prerequisite for establishing regulatory framework, which formalizes the process through a joint resolution of ANA and the States(s), increasing the legal certainty of the rules defined for each specific water system.

By setting more specific criteria and limits for the grant, establishing hydrological states (normal, requires attention and critical), defining the allocation rules for each hydrological state and requiring contingency plans for public supply and other uses, the allocation is also a powerful instrument of conflict prevention and management organization by users at the scale of the basin or water system. It is a model to be strengthened not only in the current molds, but as inspiration for the self-management of irrigator associations. It must also be adapted to private irrigation hubs in humid regions where low water conservation predominates, where the allocation still becomes unsatisfactory since the water supply is not concentrated in a large reservoir or perennial stretch of common use, which makes the available water difficult to monitor and the negotiation between users. The negotiated allocation can be configured as an opportunity to further develop the seasonal allocation, with more rainy season permits and fewer dry season permits.

In this same approach (allocation and self-management of the irrigators), the ***collective and preventive grant*** can be rethought, seeking regulatory paths that enable it. Indirectly, this model already occurs in large grants of public projects, when the grant in the common infrastructure is given to a manager (Codevasf, DNOCS etc.) who manages the distribution, collection and guarantee of the terms of the grant with the irrigators that occupy family or business lots. The Duro Stream Irrigation Perimeter Users Association (AUD), which has been managing the Duro stream/RS perimeter since 1990, has the granting power and manages the water abstraction of more than 400 rice producers, most with small properties (http://aud. org.br/).

Another example is that of preventive grants issued by ANA for the extinct Ministry of Fisheries. Based on the support capacity of the reserves, the preventive grant allows the requesting entity to seek investments and partnerships with the private sector to effectively develop the activity.

In the energy sector, the preventive grants allow the conservation of the hydraulic potential of a water body, subtracting the current consumptive uses and those projected for the future - they are issued under the name of the National Electric Energy Agency - ANEEL and converted into a grant to the undertaking after the concession/authorization process.

The mechanisms of preventive allocation, collective allocation, and negotiated allocation can evolve in the irrigated production hubs and contribute to the sector's water security and multiple uses.

Efficiency in Water Use and Quality

Irrigated agriculture depends on ***adequate availability*** and ***good water quality*** . In the same way that it can affect these parameters, irrigation can also be affected by the inefficiency and pollution resulting from other water uses.

Although the practice may cause negative economic, social, and environmental impacts, it can be observed that irrigation tends to be installed in areas previously occupied by pasture or rainfed agriculture. The ***technological package*** that accompanies irrigation, i.e., improvements in inputs, services, machinery and implements, result in relative improvements in the environmental quality of these regions, such as the adoption of more appropriate management techniques, no-tillage and better soil use (with less exposure to erosive processes).

On the other hand, there are increasing concerns about water resources. Problems of quantity and quality of water tend to occur in an interconnected manner: the same excess of water applied in an irrigated area, not being used by crops, is what can return to surface and underground water bodies with soluble salts and pesticides. In another perspective, the loss of other user sectors can limit the availability of water for irrigation, as well as the water that reaches the polluted rural environment can limit or make the activity unfeasible.

Thus, the efficiency of water use and water pollution are intertwining themes. Requirements and legal incentives to control efficiency and pollution occur in the processes of environmental licensing and granting the use of water resources of the undertakings, in addition to usage charges. For example: projects that incorporate more efficient irrigation equipment and methods have priority in ***licensing*** (CONAMA Resolution no. 284/2001); and water resource management agencies require minimum water use efficiencies to receive the grant (ANA, 2013). The ***grant*** also seeks to ensure that the amount of water required by the irrigator is compatible with the existing water availability and with other current and future uses, at both the local scale and the scale of the river basin. It is known, on the other hand, that there is great room for improvement and further advancement in the implementation of these instruments, as well as in the promotion and awareness of producers.

In the area of water resources, the term ***water use efficiency*** is used as a synonym for irrigation efficiency (ANA, 2013), expressing the relationship between the volume of water required for plants and the volume of water abstracted from the water body. The difference can be considered as loss, i.e., the portion of water removed from the water body that is not used by the plants. ***Losses*** can occur due to leaks in distribution and storage, evaporation, dragging or drifting by wind, surface runoff and deep percolation. The losses do not necessarily express water waste, as no equipment ensures 100% efficiency and it is not possible to accurately control all variables under field conditions (such as wind). Part of the losses can return directly to the water bodies.

Irrigation efficiency is correlated with the method and the irrigation system adopted, but in field conditions is also greatly influenced by local practices of equipment operation and maintenance and water and soil management. Efficiency is also commonly affected by errors in the planning and implementation stages of irrigation on the property. Poorly sized motor pumps, equipment with low quality, poor anchoring of pumps and pipes, dirt entering the pipes during assembly, lack of maintenance and installation different than the project design are some of the most common failures in these stages (Testezlaf, 2017).

There is no a priori ideal irrigation method or system and there should be an integrated assessment of socioeconomic and environmental components – of which efficiency is one of the variables. For the most common irrigation systems - and in good conditions of installation, management and operation - the reference values of water use efficiency range from 60% (flood) to 95% (drip).

Water use efficiency indicators for irrigation systems

Method	Irrigation system	Reference Efficiency (%)	Losses (%)
Surface	Open furrows	65	35
	Closed or interconnected furrows in basins	75	25
	Flooding	60	40
Underground	Underground or buried drip	95	5
	Sub-irrigation or elevation of the water table	60	40
Sprinkling	Conventional with side or mesh lines	80	20
	Perforated hoses	85	15
	Self-propelled gun/Reel	80	20
	Center pivot (fixed or towable)	85	15
	Linear	90	10
Localized	Drip	95	5
	Micro-sprinkler	90	10

Source: adapted from ANA (2013)

There is a great lack of knowledge about the efficiencies actually practiced in Brazil. A more comprehensive study conducted in the São Francisco river basin assessed the efficiency of water application in 55 projects, 33 with localized method (drip and micro-sprinklers) and 22 in spraying (conventional, gun and center pivot). The average efficiencies were 79.1% and 70.3%, respectively (ANA, 2003). The study highlighted the low adequacy of the applied blades in relation to those required by the plants, there are higher or, in most cases, lower blades than those required.

The portion of irrigation losses (or inefficiency) that do not go through evapotranspiration and remain in the soil can carry salts, sediments, organic matter and pollutants to surface and groundwater bodies, contributing to their contamination. Although agriculture can cause point pollution (direct disposal of pesticides in channels, for example), pollution usually occurs indirectly, in a nonpoint and complex manner.

Soil salinization (increased salt concentration) and ***decreased infiltration capacity*** are by-products of inadequate management of equipment and environmental resources. The salts come from the water itself used in irrigation or by means of elevation of the water table. Various irrigated areas around the world are affected by this process, resulting in significant reductions in productivity, abandonment of the agricultural areas and salinization of watercourses themselves with impacts on other water uses and biodiversity. Although in Brazil it is a growing concern, most of the irrigated areas are in regions with good leaching and soil drainage and use good quality water, which attenuates the salinization process. In the Northeast, where soils do not have these characteristics, the process already occurs in a more advanced manner. The crops have different tolerance levels to the salt concentrations.

Regarding the transport of ***pesticides***, the situation is worrisome when one observes that the expansion and modernization of Brazilian agriculture have been accompanied by an intensification in the use of fertilizers. Between 2009 and 2014, the commercialization of fertilizers in Brazil grew 20.3%, while the total planted area grew 11.8%.

The poor quality of the water that arrives for irrigated agriculture can cause limitations to its development. A common example is around urbanized areas. Although there have been advances in basic sanitation in recent years, only 61% of the Brazilian urban population is served with sewage collection and 43% with treatment (ANA, 2017). Mills have different sensitivities to contaminants present in soil and water. Depending on the concentrations, there may be a relative drop in yield or the total or partial unfeasibility of the activity.

The ***deterioration of irrigation equipment*** and associated infrastructure (channels and reservoirs) is another common problem of poor water quality, causing corrosion, crustations, clogging of sprinklers, etc. In addition to the economic impacts, this deterioration tends to decrease irrigation efficiency, which can cause more pollution of the water resources.

Reuse of Industry Effluents and Sanitation

Irrigated agriculture can be an important ally for reducing or mitigating water pollution in industry and cities.

The sugar and ethanol sector performs the largest agro-industrial reuse in Brazil with the fertigation of sugarcane from the effluents generated during sugarcane processing. The discharge of these effluents into rivers was one of the main environmental problems in the country, having been equated by adjustments in environmental standards and the commitment to sustainability of the sector. Currently, all mills in the country have irrigation equipment (mainly reels) annually allocating about 600 million liters of effluent to the sugarcane fields. As a result, this volume is no longer released into water bodies and is reused as an input in the sugarcane plantation itself.

In order for ***fertigation*** to express all its potential and not only be carried out as effluent disposal in the soil, but it must also follow technical criteria for sugarcane nutrition and specific environmental standards. Specific programs, regulations and studies should be strengthened by the institutions responsible for improving and expanding the potential of fertigation in minimizing environmental problems and increasing the productivity, quality and longevity of sugarcane fields.

Sugarcane and other industrial crops are the main focus for reuse of effluents from other sectors, especially other agribusinesses and cities. The ***new role of ANA in the regulation of sanitation***, brought about by Federal Law no. 14,026/2020, should also bring synergies with it, especially in the discussion of the use of treated sanitation in agriculture. It is expected that this practice will decrease water quality problems in the receiving bodies, especially in headwater regions, attenuate the demand on springs and strengthen agribusiness.

2017 study of the current MIDR (2017) – Preparation of the Proposal of the Action Plan to establish a Policy for Reusing Treated Sanitation in Brazil - estimated a potential for reuse in the short-medium term in Brazil of approximately 410 billion liters per year (equivalent to 13 m^3/s - at the time of the estimate, the current reuse was estimated at 1.6 m_3/s), with more than half of this potential concentrated in the Southeast region. The potential considers that secondary treatment would be the minimum desirable level of treatment for reuse.

Additionally, the study presented international experiences and best practices found in global reuse projects and the difficulties faced in Brazil in implementing reuse projects.

The actions identified in these projects related to good reuse practices for the different modalities, and lessons learned regarding the level of treatment required per water reuse modality and sanitation treatment technologies used, as well as the formation of partnerships could foster the construction of a positive agenda to develop a realistic and sustainable reuse policy.

6 IRRIGATED AGRICULTURE HUBS

Plantations in Ribeirão Preto /SP
Raylton Alves /ANA Image Bank

In a country of continental size and great geodiversity, water resource management is a major challenge. In this sense, it is important to advance in the implementation of policies and their instruments in a broad manner, but also define ***special areas*** where management can be carried out differently in favor of water security, according to the specific conditions of these areas and the scale of operations of the institutions. For management to be distinct, the technical basis of information and monitoring of these areas must also be distinct.

Most of the river basins with quantitative criticality indicators have irrigated agriculture as their main consumptive use. Conflicts or competitive uses can occur between sectors (between irrigators) or with other sectors such as urban supply and energy generation. Criticality occurs due to the high demands of irrigation, but also in regions with moderate demands, but with low water availability, such as the Semiarid region. With the prospect of water use in irrigation increasing by up to 66% by 2040, increased planning and management efforts are required.

The most dynamic water-using sector in Brazil and worldwide and an important vector for regional development is irrigated agriculture. If on one hand the growth of irrigation means more water use, on the other hand investments in this sector also result in a substantial increase in productivity and production value, reducing the pressure to incorporate new areas for cultivation and contributing to the food security of the population and the productive security of the agro-industrial sector. The important thing, therefore, is that the ***expansion occurs with water security*** for the sector itself and for other water uses.

The data consolidated in the 2017 ***Irrigation Atlas*** allowed a first identification of special areas of water resources management for irrigated agriculture on a national scale. Subsequently, and in line with the sectoral irrigation policy, these areas were called national irrigated agriculture hubs. The identification and classification of the hubs was improved in the study ***National Irrigated Agriculture Hubs: mapping irrigated areas using satellite images*** (ANA, 2020) – the publication detailed information in six national hubs using innovative methodologies to analyze remote sensing images, supported by field visits. The methodologies were subsequently applied to other areas as part of the preparations for the 2020 Atlas.

In this edition of the Atlas – and based on the total irrigated area, the occupation concentration/density, growth potential and growth achieved in the short and medium term – ***28 National Hubs*** are identified, i.e., special areas of water resource management for irrigated agriculture on a national scale. ***50% of the irrigated area and 60% of the current water demand is concentrated*** in these hubs. The classification of national hubs is dynamic and can be adjusted according to specific analysis objectives or with the specific public policies to be developed. Regional, state and local hubs can also be identified based on information in the Atlas and can be detailed in specific works in these territorial groups. The delimitation of the hubs considers the ***hydrographic division***, taking into account that water resource management adopts the river basin as a territorial unit.

Among the 28 National Irrigated Agriculture Hubs identified in this edition, 09 have rice by flooding as their predominant typology, and in 15 center pivots predominate. The typologies do not indicate exclusivity of the method or irrigated crop(s), but the predominant pattern.

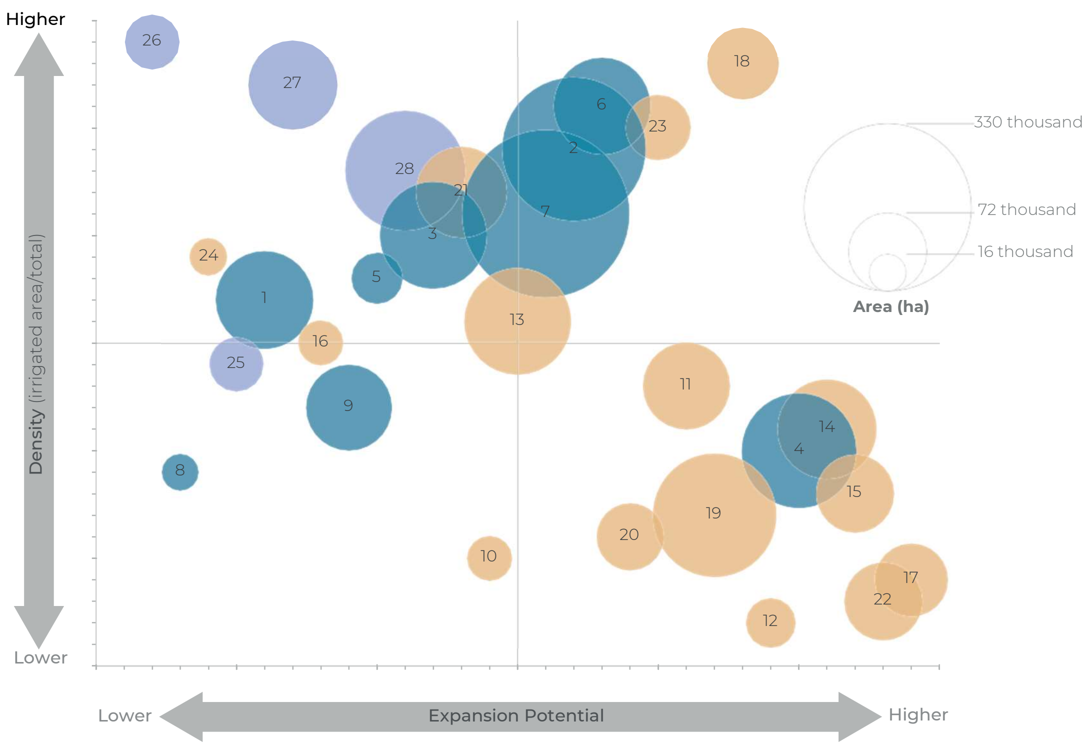
Flooded rice is the most present typology in traditional producing areas of Rio Grande do Sul and Santa Catarina, in addition to Southwest Tocantins in the basins of the Javaés and Formoso rivers, totaling nine hubs - many of them bordering, but in different river basins. In these consolidated hubs there is less prospect of expansion of irrigation and part of its estimated potential may be related, in fact, to the rotation of land use where neighboring areas rotate rice cultivation.

The 15 national ***center pivot*** hubs are dedicated to the production of grains (soy, corn, beans, cotton, etc.), most of them in the Cerrado biome, but also in transition regions between the Cerrado and the Amazon (Alto Teles Pires) and between the Atlantic Forest and Pampa (Uruguay and Alto Jacuí), in addition to Mucugê-Ibicoara in the Caatinga region. The hubs are distributed between seven states (BA, DF, GO, MT, MG, SP and RS). In the Paracatu/ Entre Ribeiros (MG) hub, sugarcane irrigation under pivots and other spraying methods is also relevant; and in the Mucugê-Ibicoara hub, the crop profile is different from the others, with potatoes and coffee predominating.

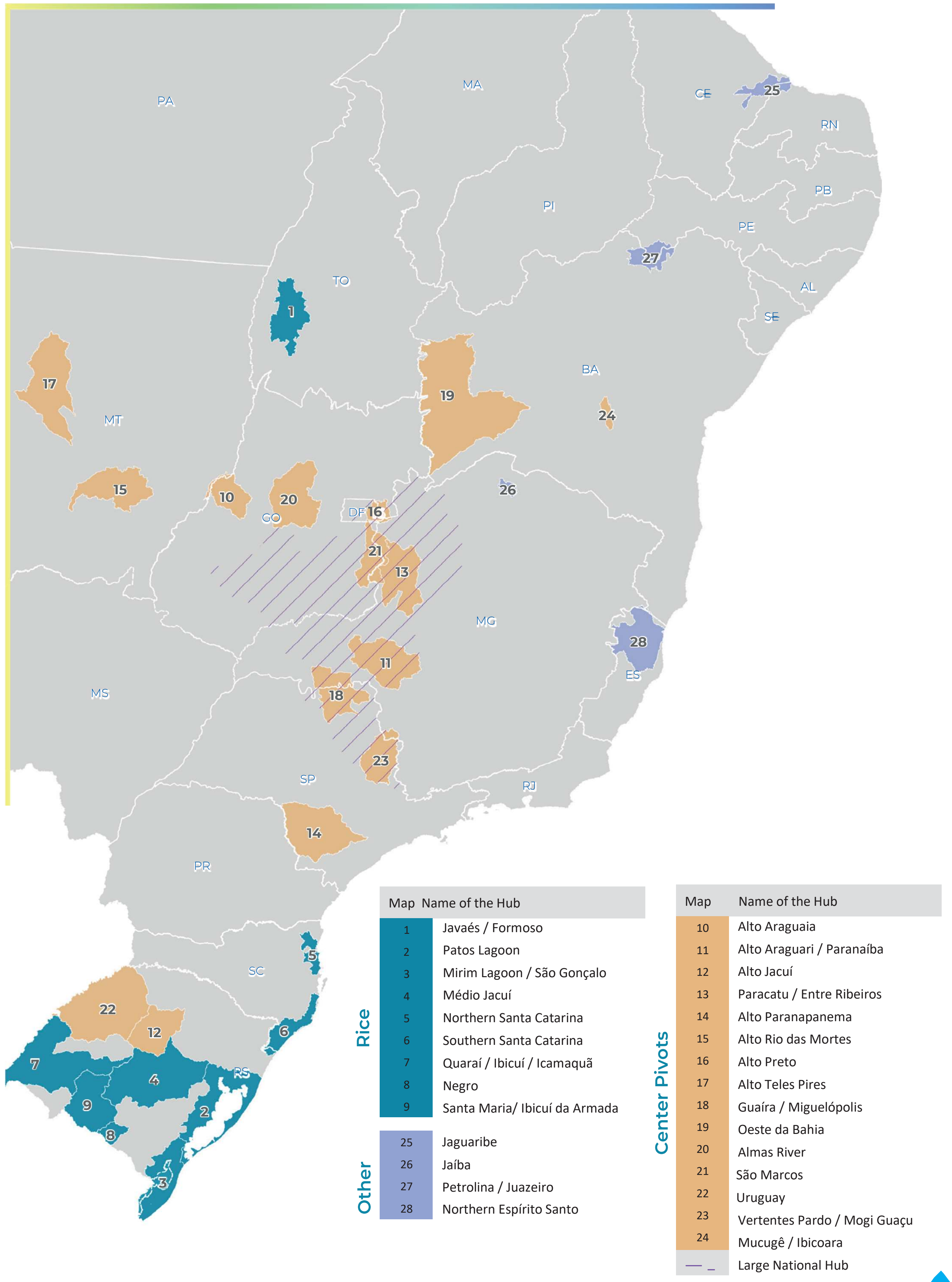
The recent growth and the high potential for expansion also allow us to delimit a Great National Hub of pivot irrigation, formed by six national hubs in the central region of Brazil and other nearby expansion areas in the river basin regions of the Paraná and São Francisco rivers. In this area, expansion is accelerated and new hubs are in formation.

In the other four national hubs, three are located in the Semiarid region: predominantly fruit-growing and sugarcane in Petrolina/Juazeiro (PE/BA) and in Jaíba (MG); and fruit-growing in the Jaguaribe and in the North of Espírito neighboring coastal basins (CE/RN). In Northern Espírito

National Irrigated Agriculture Hubs - Density and Potential



NATIONAL IRRIGATED AGRICULTURE HUBS



Santo, coffee predominates and there is also expansion of center pivots. Irrigation methods are also diversified in these hubs, with localized irrigation (micro-sprinkler and drip) being more expressive.

Below, the main characteristics of the national hubs are detailed with the indicators developed in the Atlas. Additional information can be found at http://atlasirrigacao.ana.gov.br.

National Hubs - Irrigated Rice

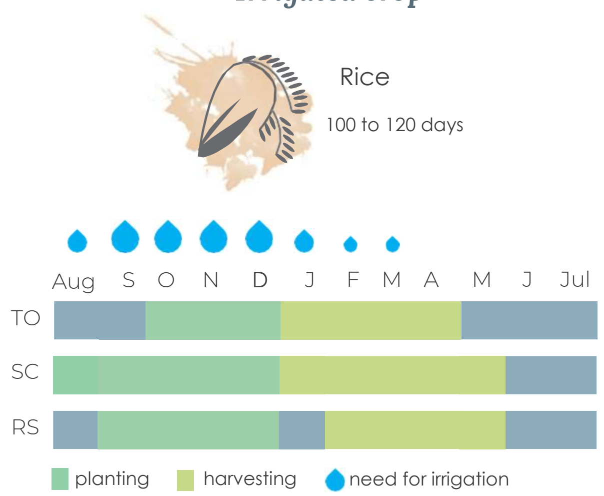
The calendar for planting/harvesting rice is similar at the hubs and the harvest lasts between August and May. Rice has an average cycle of 110 to 125 days, which in conventional management requires between 80 and 100 days of irrigation until the trays can be emptied and harvest preparation can begin. In pre-germinated management, irrigation starts about 25 days before sowing, totaling about 100 to 125 days of irrigation.

Of the nine hubs, six are located in Rio Grande do Sul - four near the border. Two hubs are located in Santa Catarina and South Santa Catarina has a small area within Rio Grande do Sul. In Tocantins, the Javaés-Formoso hub stands out.

In water management, one can observe the dominance of pre-germinated management in Santa Catarina and conventional management in Tocantins. In Rio Grande do Sul, according to IRGA, 9% of the irrigated area was allocated to pre-germination and 91% to conventional in the 2019/2020 harvest.

Important part of the estimated potential at the rice hubs (total and effective) may already be in use to rotate with the rice itself, may not present implementation feasibility, in addition to other economic and environmental limitations that affect the potential. The hub with the greatest expansion potential is Médio Jacuí (RS) whose potential can also be reduced by upstream water consumption – the Alto Jacuí region is a pivot hub and is one of those with the highest recent growth and expansion potential.

Irrigated crop



Irrigated rice in satellite images

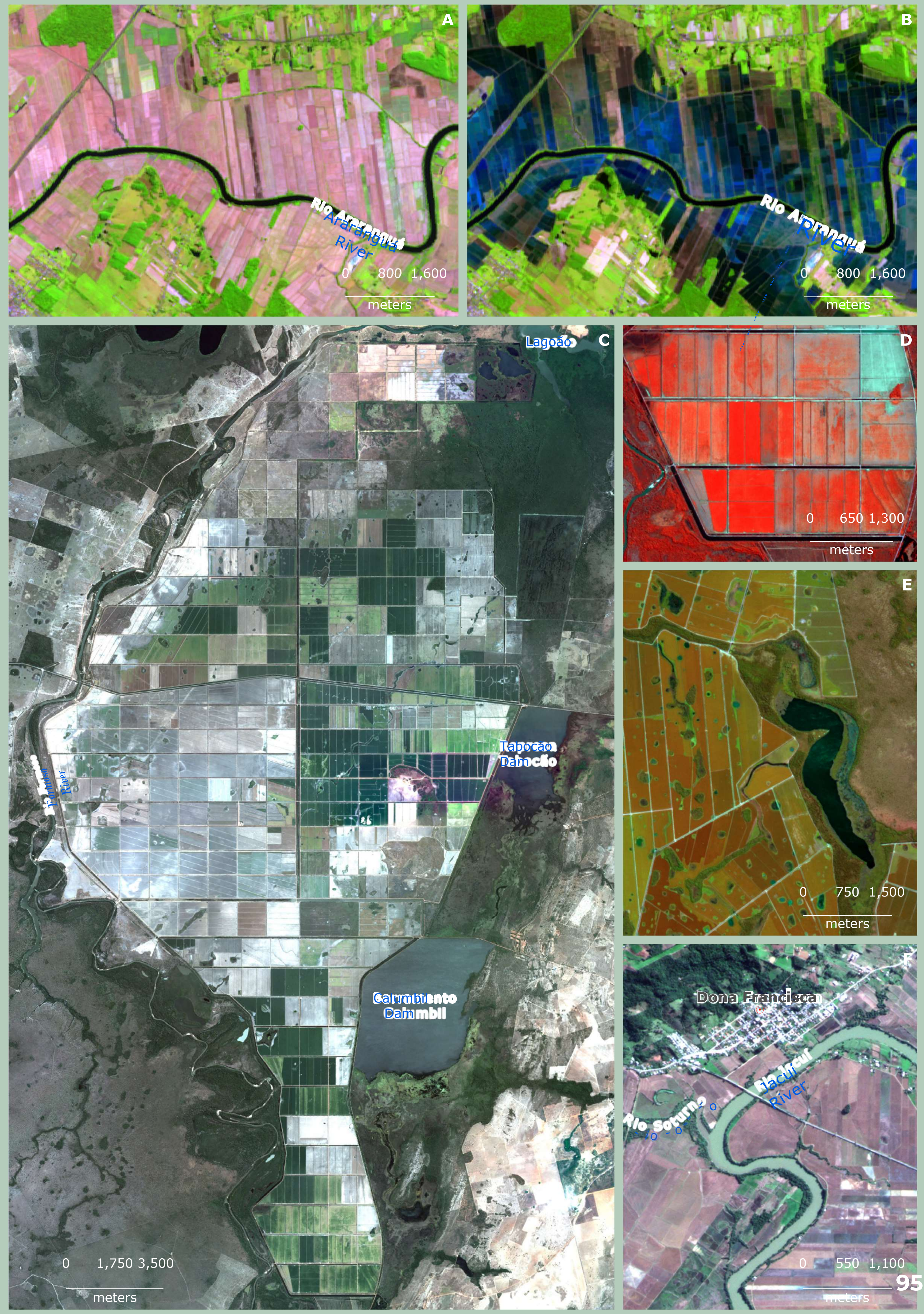


Image A - Rice irrigated by flooding in the planting phase.

Border between the municipalities of Araranguá and Maracajá/SC - Mampituba Irrigation Hub. Sentinel Image 2 RGB 11/8A/4

Image B - Rice irrigated by flooding in the fallow phase.

Border between the municipalities of Araranguá and Maracajá/SC - Mampituba Irrigation Hub. Sentinel Image 2 RGB 11/8A/4

Image C - Formoso do Araguaia/TO - Javaés-Formoso Irrigation Hub. Planetscope Image RGB 3/2/1 of 06/2020.

Image D - Formoso do Araguaia/TO - Javaés-Formoso Irrigation Hub. Planetscope Image RGB 4/2/3 of 06/2020.

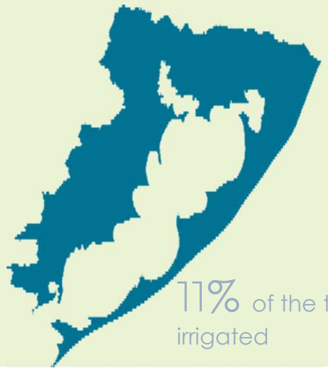
Image E - Confusão Lake/TO - Javaés-Formoso Irrigation Hub. Sentinel Image 2 RGB 11/3/4 of 08/20/2020.

Image F - Border between the municipalities of Agudo, Dona Francisca and Restinga Sêca/RS - Médio Jacuí Irrigation Hub. Planetscope Image RGB 3/2/1 of 06/2020.

National Hubs - Irrigated Rice

Key
- Current water demand
- Current irrigated area
- Total physical and water potential
- Effective potential

PATOS LAGOON



11% of the territory is irrigated

2.2 trillion liters/year
- 243 thousand ha
- 148 thousand ha
- 98 thousand ha

77% conventional management and 23% pre-germinated management

Main irrigating municipalities : Mostardas, Camaquã, Viamão, Tapes, Arambaré, Palmares do Sul, Santo Antônio da Patrulha, Eldorado do Sul, Capivari do Sul, Barra do Ribeiro, Pelotas

QUARAÍ / IBICUÍ / ICAMAQUÃ

10% of the territory is irrigated

2.9 trillion liters/year
- 331 thousand ha
- 146 thousand ha
- 107 thousand ha

98% conventional management and 2% pre-germinated management

Main irrigating municipalities : Uruguaiana, Itaqui, Alegrete, São Borja, Maçambará, Barra do Quaraí, Quaraí, São Vicente do Sul, Rosário do Sul and Cacequi

MIRIM LAGOON / SÃO GONÇALO

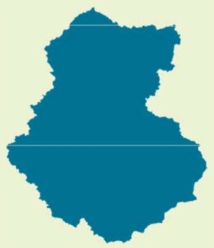
9% of the territory is irrigated

1.3 trillion liters/year
- 135 thousand ha
- 97 thousand ha
- 65 thousand ha

100% conventional

Main irrigating municipalities : Santa Vitória do Palmar, Arroio Grande, Rio Grande, Jaguarão, Capão do Leão, Pelotas

SANTA MARIA/ IBICUÍ DA ARMADA



6% of the territory is irrigated

799 billion liters/year
- 88 thousand ha
- 51 thousand ha
- 31 thousand ha

99% conventional management

Main irrigating municipalities : Dom Pedrito, Sant'Ana do Livramento, Lavras do Sul, São Gabriel, Rosário do Sul and Cacequi

NORTHERN SANTA CATARINA

8% of the territory is irrigated

182 billion liters/year
- 31 thousand ha
- 75 thousand ha
- 28 thousand ha

100% pre-germinated management

Main irrigating municipalities : Massaranduba, Guaramirim, Joinville, Ilhota, Gaspar, Araquari, Itajaí

MÉDIO JACUÍ

5% of the territory is irrigated

1.3 trillion liters/year
- 155 thousand ha
- 425 thousand ha
- 297 thousand ha

81% conventional management and 19% pre-germinated management

Main irrigating municipalities : Cachoeira do Sul, Restinga Sêca, São Sepé, Formigueiro, Agudo, Rio Pardo, Santa Maria, Candelária, Santa Margarida do Sul and São Gabriel

SOUTHERN SANTA CATARINA

14% of the territory is irrigated

725 billion liters/year
- 111 thousand ha
- 152 thousand ha
- 89 thousand ha

100% pre-germinated management

Main irrigating municipalities : Turvo, Meleiro, Forquilhinha, Nova Veneza, Jacinto Machado, Araranguá, Tubarão

NEGRO

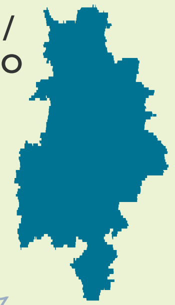
5% of the territory is irrigated

153 billion liters/year
- 16 thousand ha
- 6.5 thousand ha
- 3 thousand ha

100% conventional management

Main irrigating municipalities : Bagé, Aceguá, Hulha Negra

JAVAÉS / FORMOSO



8% of the territory is irrigated

664 billion liters/year
- 113 thousand ha
- 31 thousand ha
- 5 thousand ha

100% conventional management

Main irrigating municipalities : Confusão Lake, Formoso do Araguaia and Pium

National Hubs - Center Pivots

Pivot hubs have been the main drivers of irrigation expansion in Brazil and this trend is expected to continue. It can be observed, on the other hand, that there are already consolidated hubs with lower expansion prospects, due to: the relative exhaustion of their physical and water potential; economic-financial limitations; or due to competitive uses of water with other uses or operating rules.

The calendar for planting/harvesting and irrigation is very dynamic in the center pivot hubs: as it is mostly temporary crops (soy, corn, beans, cotton, etc.), it is common to have 4 to 5 harvests over two harvest years. The dynamics of the climate and the market influence this dynamic annually.

Among the most common rotation patterns, there is the soy harvest (1st summer harvest) followed by the second harvest with corn (2nd harvest); soy harvest, followed by second corn harvest and 3rd bean harvest; 1st harvest (corn or soy), followed by long term harvest (cotton – 180 days). Also, around 8% of the pivot area is occupied with (semi)perennial crops, especially with coffee and sugarcane.

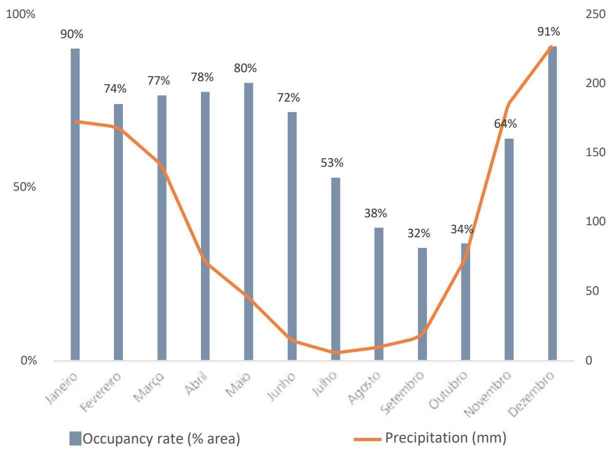
The producers seek to minimize the crop in periods of greater water deficit, maximizing production in the rainy period and transition to the dry period. With this, seasonality and idleness in water use are even more pronounced in the dynamics of irrigation under center pivots. In 2017, for example, occupancy rates of around 90% in the months with the highest amount of rainfall, i.e., reduced need to activate the equipment. This well-known strategy aims to reduce the costs related to the application of irrigation water, especially electricity, which is costly in these production systems.

In the second harvest, which in the pivot areas occurs mostly from February/March to May/June, the average occupation rate of the equipped area oscillates between 72% and 80%. The second season tends to be the period of greatest water demand when associating high occupancy rates with intermediary irrigation needs per hectare (not as high as in the dry season, but much higher than in the rainy season). Thus, the data reinforce that the activation of center pivots has been used mainly to increase production and productivity in the second harvest. Although the rains have already decreased at the end of the second harvest, the soil still has water reserves and harvesting takes place during the rainy season, which contributes to mechanized operations and low incidence of pests and diseases in crops.

In the third harvest, which advances in the driest period of these irrigated regions (July to September), precipitation practically ceases and the water stored in the soil is drastically reduced. In this period, the occupation rate of pivots drops to levels around 30% to 40%. In addition to reducing water availability, high temperatures, increased costs and waiting periods for soy and beans contribute to lower occupancy rates. Still, water use is significant, as the water blade required per hectare reaches high levels.

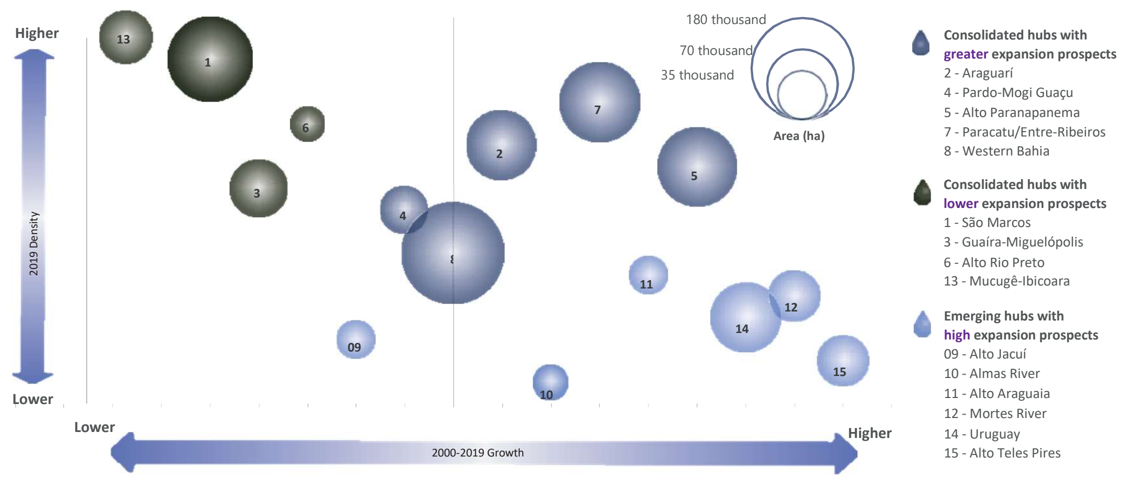
The 15 irrigation hubs with a predominance of center pivots are distributed in all regions (except the North) and in seven states (BA, DF, GO, MT, MG, SP and RS). Four hubs - São Marcos, Alto Preto, Guaíra-Miguelópolis and Pardo-Mogi Guaçu - extrapolate a state and also contain water bodies under Federal domain, requiring even more integrated planning and management efforts.

Center Pivots - Seasonality



The pivot hubs, including the Large National Hub, represent the main frontier of current and future expansion of irrigation in the country. However, the estimated physical and water potential (total and effective) can be limited by the economic, environmental restrictions and the allocation of water between different uses - in addition to cyclical issues. In addition, some consolidated hubs already exploit areas greater than the estimated additional effective potential, indicating the proximity of their support capacities.

Recent dynamics at center pivot hubs



Center pivot in Itapeva (SP)
Raylton Alves /ANA Image Bank

National Hubs - Center Pivots

Key
- Current water demand
- Current irrigated area
- Total physical and water potential
- Effective potential

ALTO TELES PIRES

164 billion liters/year
63.6 thousand ha
773 thousand ha
703 thousand ha

Main irrigating **municipalities** : Sorriso, Lucas do Rio Verde, Vera, Ipiranga do Norte

4% of the territory is irrigated

ALTO RIO DAS MORTES

221 billion liters/year
72.3 thousand ha
458 thousand ha
384 thousand ha

Main irrigating **municipalities** : Primavera do Leste, Campo Verde Poxoréu, Dom Aquino, Novo São Joaquim, General Carneiro, Santo Antônio do Leste

9% of the territory is irrigated

ALTO ARAGUAIA

118 billion liters/year
24 thousand ha
138 thousand ha
2 thousand ha

Main irrigating **municipalities** : Jussara, Santa Fé de Goiás, Britânia

3% of the territory is irrigated

ALMAS RIVER

Main irrigating **municipalities**: Goianésia, São Luiz do Norte, Itaberaí, Santa Isabel, Nova Glória, Santa Rita do Novo Destino, Itapaci

143 billion liters/year
54 thousand ha
205 thousand ha
40 thousand ha

ALTO PRETO

96 billion liters/year
24 thousand ha
35 thousand ha
27 thousand ha

Main irrigating **municipalities** : Brasília, Cabeceira Grande, Cabeceiras, Formosa

7.5% of the territory is irrigated

SÃO MARCOS

361 billion liters/year
98 thousand ha
109 thousand ha
51 thousand ha

11% of the territory is

Main irrigating **municipalities** : Unaí, Cristalina, Paracatu

PARACATU / ENTRE-RIBEIROS

Main **irrigating municipalities**: Paracatu

461 billion liters/year
135 thousand ha
143 thousand ha
32 thousand ha

8% of the territory is irrigated

ALTO ARAGUARI-PARANAÍBA

299 billion liters/year
90 thousand ha 20 + thousand ha
309 thousand ha
140 thousand ha

6% of the territory is irrigated

Main irrigating **municipalities** : Uberaba, Perdizes, Patrocínio, Santa Juliana, Rio Paranaíba, Indianópolis

GUAÍRA-MIGUELÓPOLIS

Main irrigating **municipalities**: Guaíra, Morro Agudo, Conceição das Alagoas, Colômbia, Frutal, Miguelópolis, Ipuã, Campo Florido, Barretos, Guará, Pirajuba, Colina, Ituverava, Planura

141 billion liters/year
61 thousand ha 265 + thousand ha fertigated
318 thousand ha
81 thousand ha

23% of the territory is irrigated

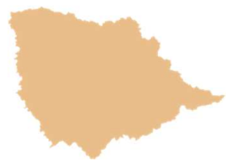
SLOPES OF THE PARDO AND MOGI GUAÇU RIVERS

155 billion liters/year
50.5 thousand ha 79 + thousand ha fertigated
232 thousand ha
66 thousand ha

12% of the territory is irrigated

Main irrigating **municipalities** : Casa Branca, Mococa, Santa Cruz das Palmeiras, Porto Ferreira, Leme, Vargem Grande do Sul, Mogi Guaçu, São João da Boa Vista, Aguaí

ALTO PARANAPANEMA

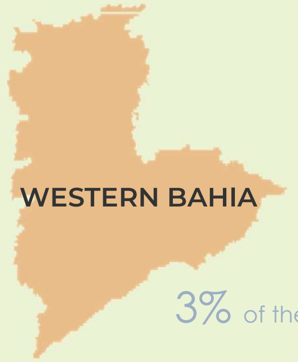


Main irrigating **municipalities** : Itaí, Itapeva, Paranapanema, Avaré, Itaberá, Buri, Itapetininga, Taquarituba, Cerqueira César

219 billion liters/year
117 thousand ha + 24 thousand ha
427 thousand ha
231 thousand ha

6% of the territory is irrigated

IRRIGATION



Main irrigating **municipalities**: São Desidério, Barreiras, Jaborandi, Luís Eduardo Magalhães, Riachão das Neves, Correntina

1.1 trillion liters/year

181 thousand ha

314 thousand ha

67 thousand ha

3% of the territory is irrigated

MUCUGÊ-IBICOARA

Main irrigating **municipalities**: Mucugê and Ibicoara

103 billion liters/year

17 thousand ha

7 thousand ha

< thousand ha

9% of the territory is irrigated

215 billion liters/year

72.5 thousand ha

572 thousand ha

476 thousand ha

2% of the territory is irrigated

Main irrigating **municipalities** : Cruz Alta, Tupanciretã, Santa Bárbara do Sul, São Luiz Gonzaga, São Miguel das Missões, Santo Antônio das Missões, Palmeira das Missões, Jóia, Boa Vista do Cadeado

ALTO JACUÍ

Main irrigating **municipalities** : Cruz Alta, Tupanciretã, Santa Bárbara do Sul, Boa Vista do Incra, Salto do Jacuí, Fortaleza dos Valos, Ibirubám, Júlio de Castilhos

83 billion liters/year

30 thousand ha

335 thousand ha

278 thousand ha

2% of the territory is irrigated

Center pivots in satellite imagery

Images A and B - Comparison of the advance of the expansion of center pivots in the irrigated hub of the Mortes River basin. Novo São Joaquim/MT - Alto Rio das Mortes Irrigation Hub. Sentinel Image 2 RGB 11/3/4 of 04/29/2016 and 07/02/2020.

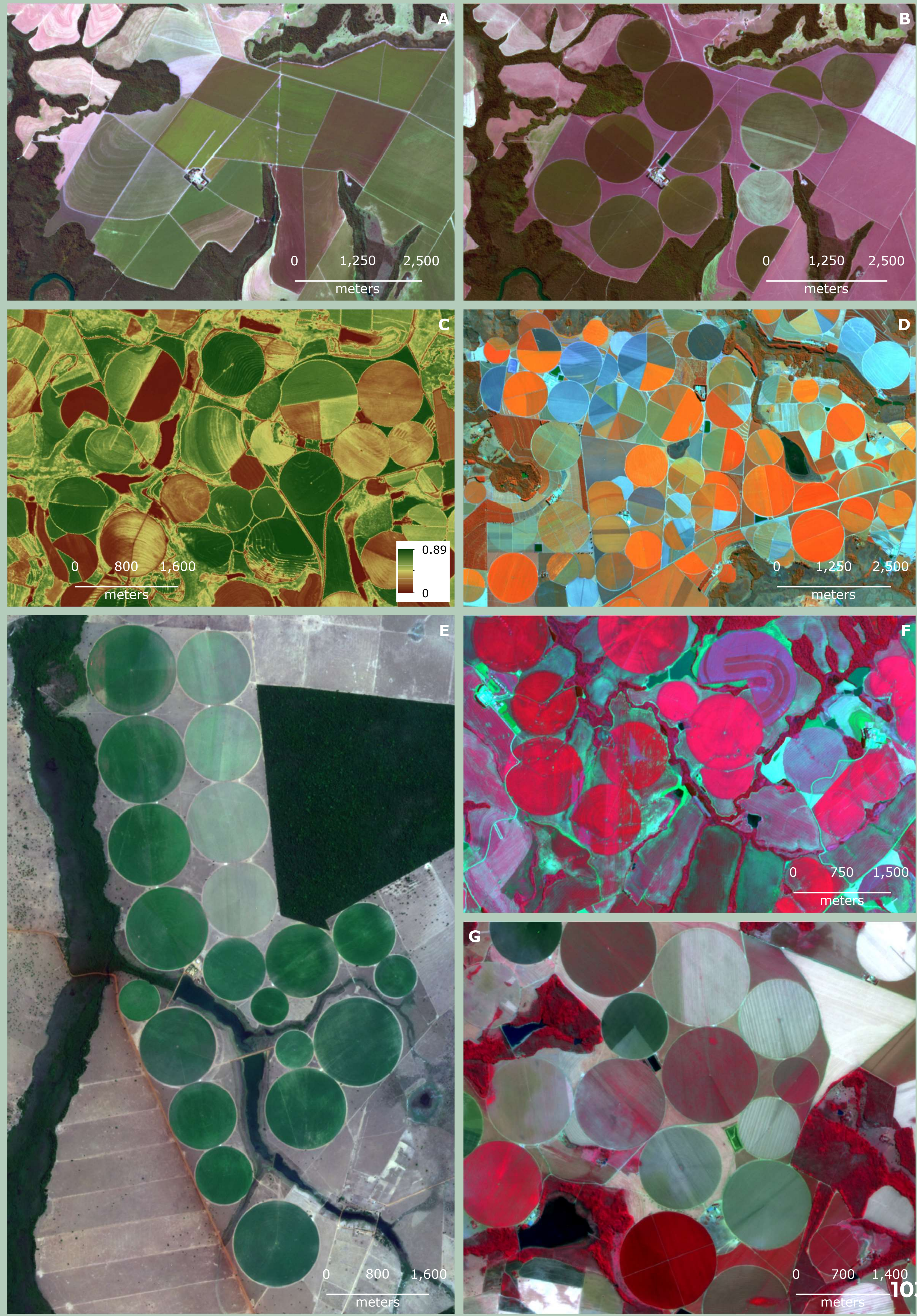
Image C - Center pivots with different crops in different vegetative development phases. Casa Branca/SP - Slopes of the Rio Pardo and Mogi Guaçu River Irrigation Hub. Normalized Difference Vegetation Index (NDVI) obtained with Sentinel 2 image from 01/15/2020.

Figure D - Center pivots with different crops in different vegetative development phases. Border between the municipalities of the Paranaíba River and Campos Altos/MG - Irrigation Hub Alto Araguari-Paranaíba. Sentinel 2 Image RGB 8/3/4 of 07/03/2020.

Image E - Center pivots with different crops. Jussara/GO - Alto Araguaia Irrigation Hub. Planetscope Image RGB 3/2/1 of 09/2020.

Image F - Center pivots with different crops. Palmeira das Missões/RS - Uruguay Irrigation Hub. Sentinel 2 Image RGB 8/4/3 of .

Image G - Predominantly inactive center pivots from various crops. The image shows a single center pivot for coffee in advanced vegetative development. Unaí/MG – São Marcos River Irrigation Hub. Planetscope Image RGB 4/3/2 of 07/2020.



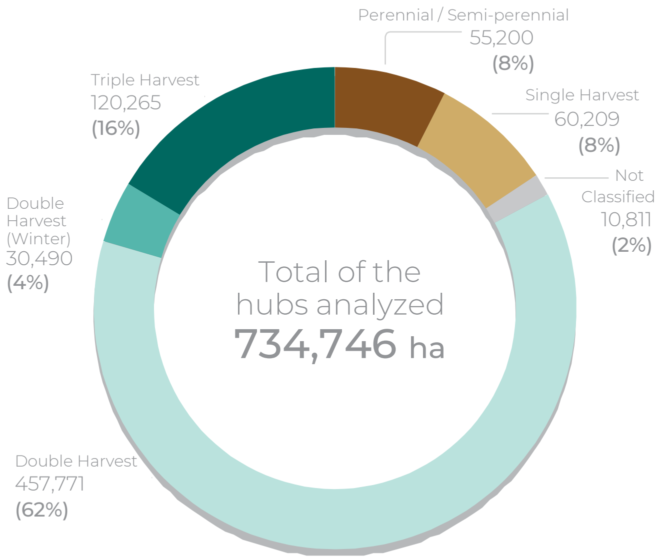
Among the 1.55 million hectares planted under center pivots in Brazil, 73% (1.14 Mha) are located in the Cerrado biome, including twelve of the fifteen National Hubs of center pivots. Such hubs concentrate 64% (735 thousand ha) of area equipped by this irrigation system.

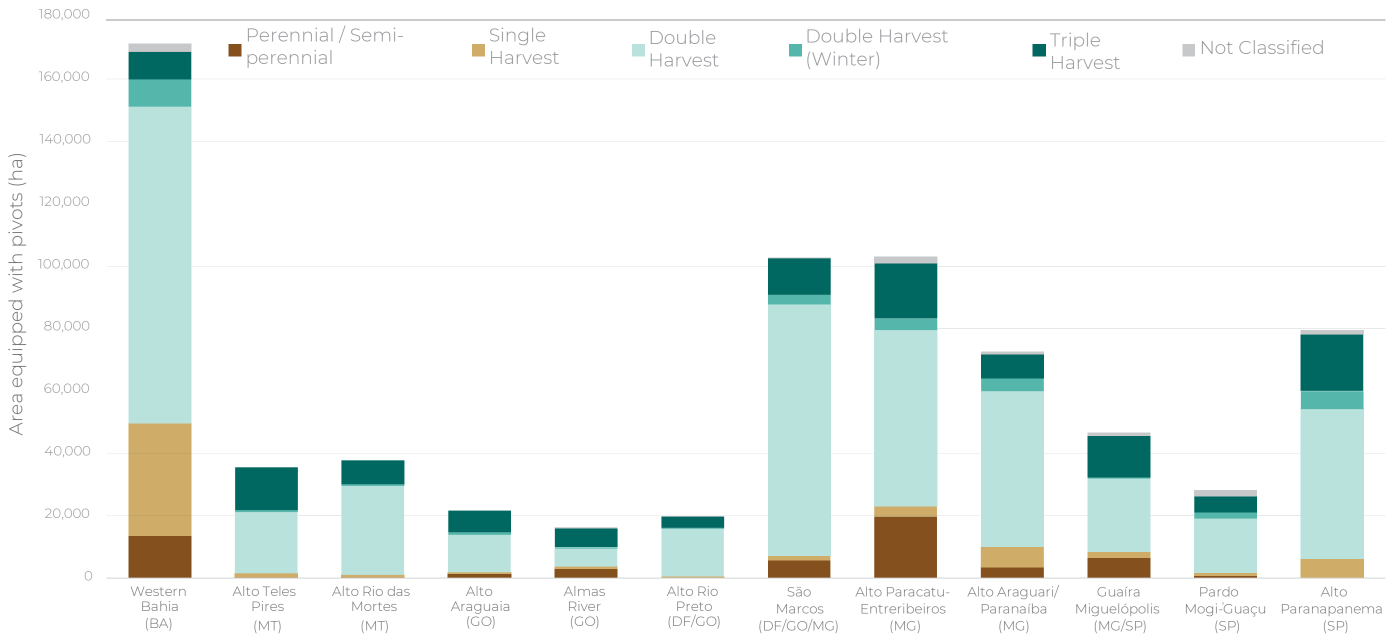
Unlike the rainfed agriculture that occurs mainly in the rainy season and the farmer harvests from one to two harvests (harvest and/or second harvest), in agriculture using center pivots, it is common to have on average two per year or five every two years. In other words, because it has greater water security throughout the year, the farmer plans for two or three grain harvests or opts for a perennial crop like coffee or semi-perennial like sugarcane, because they know that in cases of Indian summers or prolonged drought they will not lose the harvest, because the irrigation system will supply the water demand of the crop.

Using the methodology proposed by Bendini et al. (2019), which consists of extracting metrics from EVI (Enhanced Vegetation Index) curves, generated from filtered and smoothed time series of Earth observation satellites from the Landsat and Sentinel constellation, the Atlas carried out an assessment on cultivation patterns within the pivots in the Cerrado biome. The series includes 54 observations regularly spaced in time, in a regular interval of 8 days, in the period between August 2018 and October 2019 (harvest year).

EVI is a vegetation index that shows the vegetative vigor of a crop – the more leaf mass, the greater the vigor and the index (which ranges from -1 to +1). Observing the behavior of this index over time, in this case a harvest year, it is possible to estimate the intensity of use in each center pivot of the 12 Hubs. Intensity of use means the number of harvests, their duration and in which months it occurs. Five classes associated with the types of cultivation were established, namely: only one harvest, usually in summer (or single harvest); harvest followed by a second harvest (or double harvest); harvest or second harvest followed by winter harvest (or double harvest - winter); triple harvest; and perennial and semi-perennial harvests.

Dynamics of pivot use in Brazil and in the Hubs – 2018/19 harvest





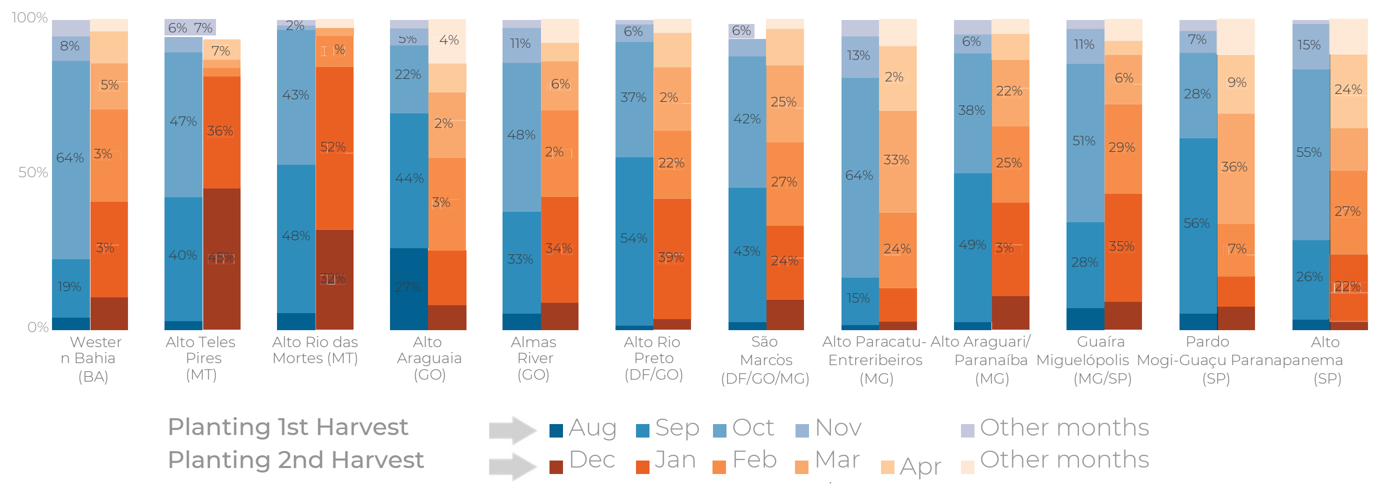
The results reiterate the intensity of use in the pivot areas – 62% of the occupied area performs double harvest (harvest followed by a second harvest) and 16% performs triple harvest. Only 8% performed a single harvest in the 2018/19 harvest. In other words, irrigation enables more harvests and they tend to occur in the rainy season and transition into the dry season, increasing the water security of production and avoiding drier periods, where costs also increase greatly.

When disaggregating the information in the 12 National Hubs studied, it can be seen that the double harvest has a significant area in all, representing more than 50% of the equipped area. The triple harvest prevails over perennial/semi-perennial crops and over the single harvest. In hubs like Alto Teles Pires/MT, where rainfall rates are higher when compared to the others, triple harvest is quite common and occupies a more significant area. In regions where there is a prolonged dry season, such as in Western Bahia, the single harvest has greater relevance. The semi-perennial cultivation area also stands out where the cultivation in irrigated sugarcane is greater, as are the cases of the Rio das Almas/GO, Paracatu and Entre-Ribeiros/MG and Guairá-Miguelópolis (MG/ SP) hubs.

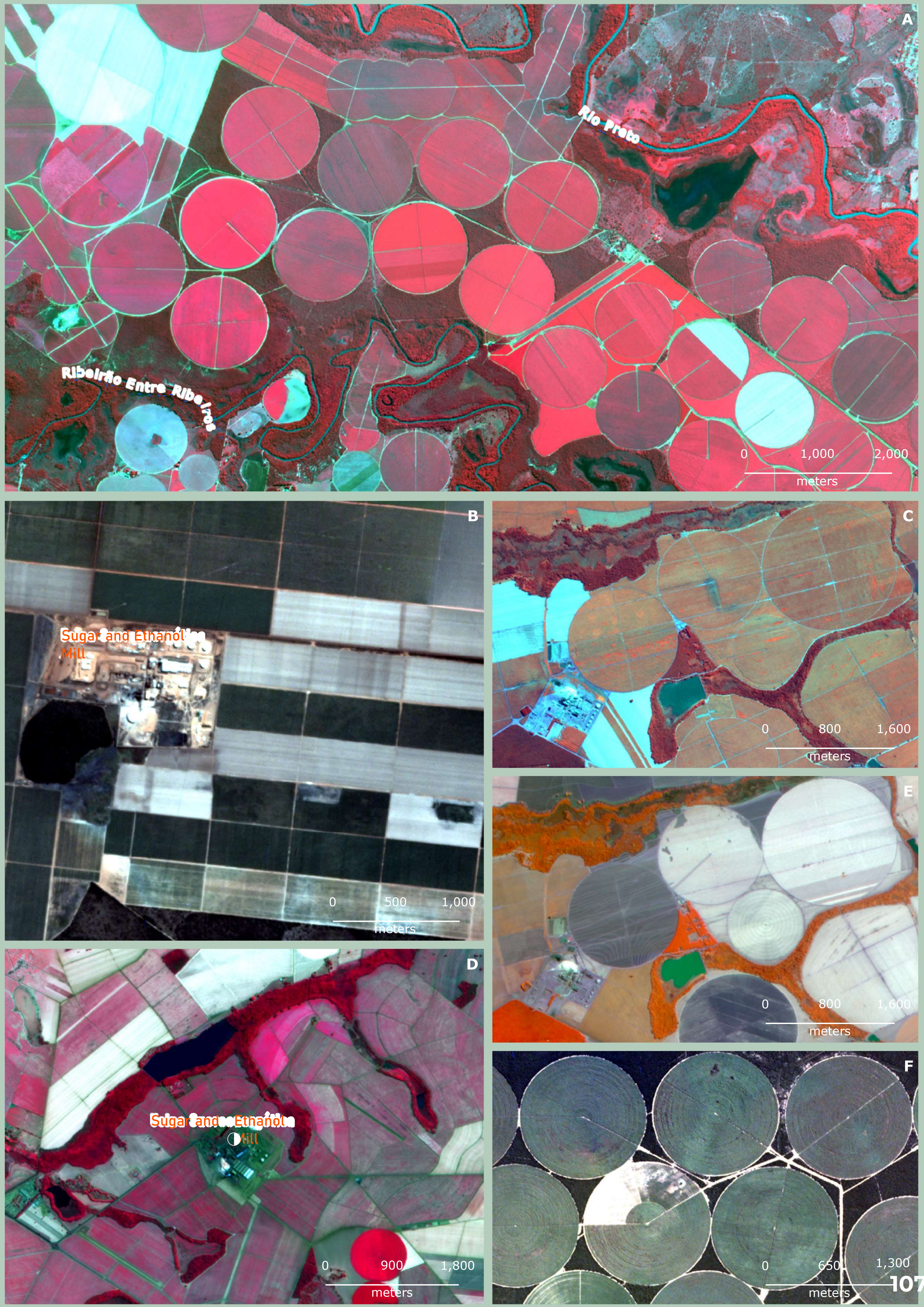
Since second harvest is the predominant management in all 12 hubs, we analyzed in which periods of the year these harvests occur. Knowledge of this seasonality of irrigated agriculture is crucial in the planning and management of water resources, since irrigation demands are different in the dry and rainy season. It is noted that the first harvest is planted between the months of August and November, but mainly in the months of September and October, the start of the rainy season. The second harvest is planted between December and April, concentrating months of greater precipitation in January and February. This is because although the irrigator has water via irrigation to supply the crop demand, there is a high cost involved in the irrigation operation. The operation of pivots in the dry period, from May to August, is extremely costly, since almost all water demand must be supplied via irrigation, so few irrigators grow during the dry period.

The four main annual crops planted under center pivot in Brazil are soy, corn, beans and cotton. The cycle of beans and early soy varies between 90 and 100 days; late soy and corn about 120 days; and cotton from 150 to 180 days. In this way the farmer rotates such crops in a harvest year, depending on the price of inputs, agro-climatological conditions, and the price in the domestic and foreign markets. One of the very common practices is the rotation of early soy in the first harvest followed by corn in the second harvest; or late soy followed by cotton. In general, in the hubs with better rainfall (more rainy months), the farmer plants earlier and does two to three grain harvests, because they supplement possible crop deficits with irrigation, and can rotate between corn, soy, and beans during this period - as is the case of the Alto Teles Pires/ MT hub. In drier regions, such as Western Bahia, the rainy season begins later, in October, concentrating mostly between December and April. Thus, the rotation of early soy with second harvest corn is more common to deal with the shorter rain calendar. Soy with cotton is another important pattern – cotton has a long cycle, but is tolerant to a certain water deficit, especially in the months before harvest, which usually occurs in the dry period.

Pivots with double harvest – months of planting in the first and second harvests



Sugarcane areas in Mesópolis (SP)
Raylton Alves /ANA Image Bank



Irrigated sugarcane in satellite images

Irrigated cane is not predominant in the hubs, but occupies important areas in the pivot hubs of Rio das Almas/GO, Paracatu and Entre-Ribeiros/MG and Guaíra-Miguelópolis/MG/SP; and in the diversified hubs of Jaíba and Petrolina-Juazeiro.

Image A - Border between the municipalities of João Ribeiro, Unaí and Paracatu/MG - Alto Paracatu - Entre Ribeiros Irrigation Hub. Planetscope Image RGB 4/3/2 of 12/2019.

Image B - Border between the municipalities of Brasilândia de Minas and João Pinheiro/MG - Alto Paracatu - Entre Ribeiros Irrigation Hub. Planetscope Image RGB 3/2/1 of 12/2019.

Image C - Colômbia/SP - Guaíra – Migueló polis Irrigation Hub. Planetscope Image RGB 4/2/3 of 12/2018.

Image D - Guaíra/SP - Guaíra Miguelópolis Irrigation Hub. Planetscope Image RGB 4/3/2 of 06/2020.

Image E - Colômbia/SP - Guaíra - Miguelópolis Irrigation Hub. Planetscope Image RGB 4/2/3 of 09/2020.

Image F - Border between the municipalities of Jaíba and Matias Cardoso/MG - Jaíba Irrigation Hub. Planetscope RGB 3/2/1 of 12/2019.

National Hubs - Other Typologies

The agricultural region of Petrolina/PE and Juazeiro/BA is the most developed region in the São Francisco river valley. Seven irrigation perimeters manage the distribution of water that reaches the crops through a dense infrastructure of channels, implemented in the 1960s with the purpose of developing this region located in the driest climate in Brazil. These are the perimeters: Bebedouro, Mandacaru, Maniçoba, Curaçá, Nilo Coelho, Tourão and Salitre. Fruit-growing is currently the main activity (2/3 of the total area) with emphasis on grapes and mango, but sugarcane also has significant irrigated area with high water use, due to the high evapotranspiration rate and low rainfall.

The Jaguaribe hub, which dates back to 1989 when it was established by DNOCS as the Jaguaribe-Apodi public perimeter, it is located on the banks of the Jaguaribe river, downstream of the Castanhão Reservoir - CE to almost its mouth in the Atlantic, with its limit being the area of influence of the Banabuiú river downstream from the Arrojado Lisboa reservoir and the Eastern limit formed by the basins of the Mata and Gangorra springs (coastal basins between the Jaguaribe and Apodi basins). The main municipalities located in the hub are Limoeiro do Norte, Quixeré, Jaguaruana and Russas in the state of Ceará, and Tibau, Mossoró and Baraúna in Rio Grande do Norte. It is a diversified pole in terms of crops and irrigation systems, ranging from annual crops of corn and rice planted in small to large pivots (12 to 120 ha), to fruit, especially melon, banana, watermelon and papaya, mostly irrigated using micro-sprinklers or drip.

Like the Jaguaribe hub, the Jaíba hub also began as a public perimeter, established by CODEVASF in 1975 in the far North of Minas Gerais on the banks of the São Francisco River. Its irrigated areas are concentrated in the municipalities of Jaíba, Matias Cardoso and Itacarambi. If, initially, the hub was characterized by irrigation using micro-sprinklers and drip for fruit-growing, especially mango, lemon and banana, today it is more diversified, having corn and extensive sugarcane fields irrigated under center pivots.

The fourth and last hub where there is a diversity of crops and irrigation systems is Northern Espírito Santo. A fairly extensive area, covering almost all the municipalities between Linhares in the North-Central region of the state and Montanha in the far North, encompassing the basins of the Itaúnas, São Mateus, Barra Seca and São José rivers as its main springs. In terms of irrigated area, there is a strong predominance of coffee, the conilon variety, in micro-sprinkler and drip systems; but papaya, coconut, black pepper and pineapple are also important. Irrigation under center pivots is concentrated in the far North of the state in the Itaúnas river basin, producing sugarcane, coffee and grains.

The three hubs of the semiarid region do not have significant effective potential, requiring detailed assessment regarding water supply and alternatives for reuse and transfer of water from neighboring basins. The Espírito Santo hub has more significant areas that can be analyzed for expansion.

Hubs in satellite imagery

Image A - Conceição da Barra/ES – Northern Espírito Santo Irrigation Hub. Sentinel Image 2 RGB 11/8/3 of 07/09/2020.

Image B - Petrolina/PE - Petrolina – Juazeiro Irrigation Hub. Planetscope Image RGB 3/2/1 of 06/2019.

Image C - Border between the municipalities of Aracati (CE), Icapuí (CE) and Tibau (RN) - Jaguaribe Irrigation Hub. Image CBERS 4A RGB 4/3/2 of 08/02/2020.

Image D - Jaíba/MG – Jaíba Irrigation Hub. Planetscope Image RGB 3/4/1 of 12/2018.

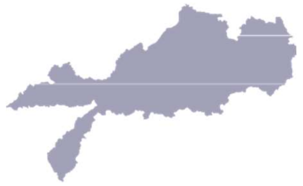
Image E - Casa Nova/BA – Juazeiro - Petrolina Irrigation Hub. Image CBERS 4A RGB 3/2/1 of 09/18/2020.

Image F - Limoeiro do Norte/CE – Jaguari Irrigation Hub. Planetscope Image RGB 3/2/1 of 09/2020.

National Hubs - Other Typologies

Key
- Current water demand
- Current irrigated area
- Total physical and water potential
- Effective potential

JAGUARIBE / CHAPADA DO APODI



7% of the territory is irrigated

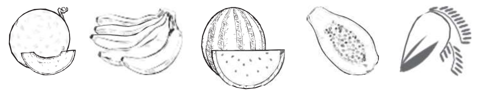
446 billion liters/year

35 thousand ha

29 thousand ha

5 thousand ha

Irrigated crops



melon, banana, watermelon, papaya and rice

Main irrigating **municipalities** : Limoeiro do Norte/CE, Mossoró/RN, Quixeré/CE, Baraúna/RN, Aracati/CE, Tibau/RN and Russas/CE

National Hubs - Other Typologies

Key
- Current water demand
- Current irrigated area
- Total physical and water potential
- Effective potential

JAÍBA

24% of the territory is irrigated

397 billion liters/year

35 thousand ha

5 thousand ha

< thousand ha

Irrigated crops

banana, sugarcane, lemon, corn and mango

Main irrigating **municipalities** : Jaíba, Matias Cardoso, Itacarambi

PETROLINA / JUAZEIRO

15% of the territory is irrigated

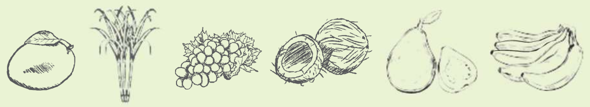
1.5 trillion liters/year

94 thousand ha

32 thousand ha

< thousand ha

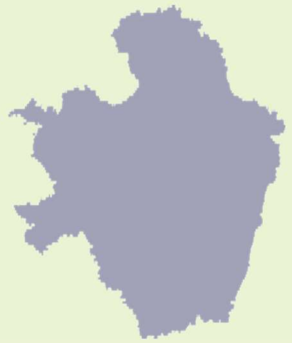
Irrigated crops



mango, sugarcane, grapes, coconut, guava and banana (perennial or semi-

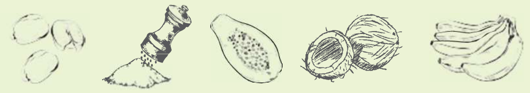
Main irrigating **municipalities** : Juazeiro/BA, Petrolina/PE and Casa Nova/BA

NORTHERN ESPÍRITO SANTO



11% of the territory is irrigated

Irrigated crops



coffee, black pepper, papaya, coconut and banana

908 billion liters/year

170 thousand ha

81 thousand ha

39 thousand ha

Main irrigating **municipalities** : Linhares, São Mateus, Rio Bananal, Pinheiros, Vila Valério, Jaguaré, Nova Venécia, Governador , Lindenberg, Boa Esperança, Montanha, Águia Branca, São Domingos do Norte, Sooretama, São Gabriel da Palha

Irrigated Agriculture Hubs - MIDR

The identification of ***special management areas*** and the leverage of more detailed information in these regions, especially regarding the supply and demands for water, aid in decision-making with a view to making multiple uses compatible and ensuring water security of the productive activity. Refinement of the water balance also provides more detailed data for users' risk estimates, which can result in both an increase and a reduction in the water accounted for by the management bodies in the authorization processes for use (grant).

It is worth highlighting the role of the Ministry of Integration and Regional Development (MIDR) in the recent ***Irrigated Agriculture Hubs*** initiative (MIDR Ordinance no. 1,082/2019, replaced by MIDR Ordinance no. 2,154/2020) - part of the implementation of the National Irrigation Policy and to encourage regional development. It consists of an important strategy to leverage the activity, through joint work between the organizations of rural irrigating producers and the various governmental spheres.

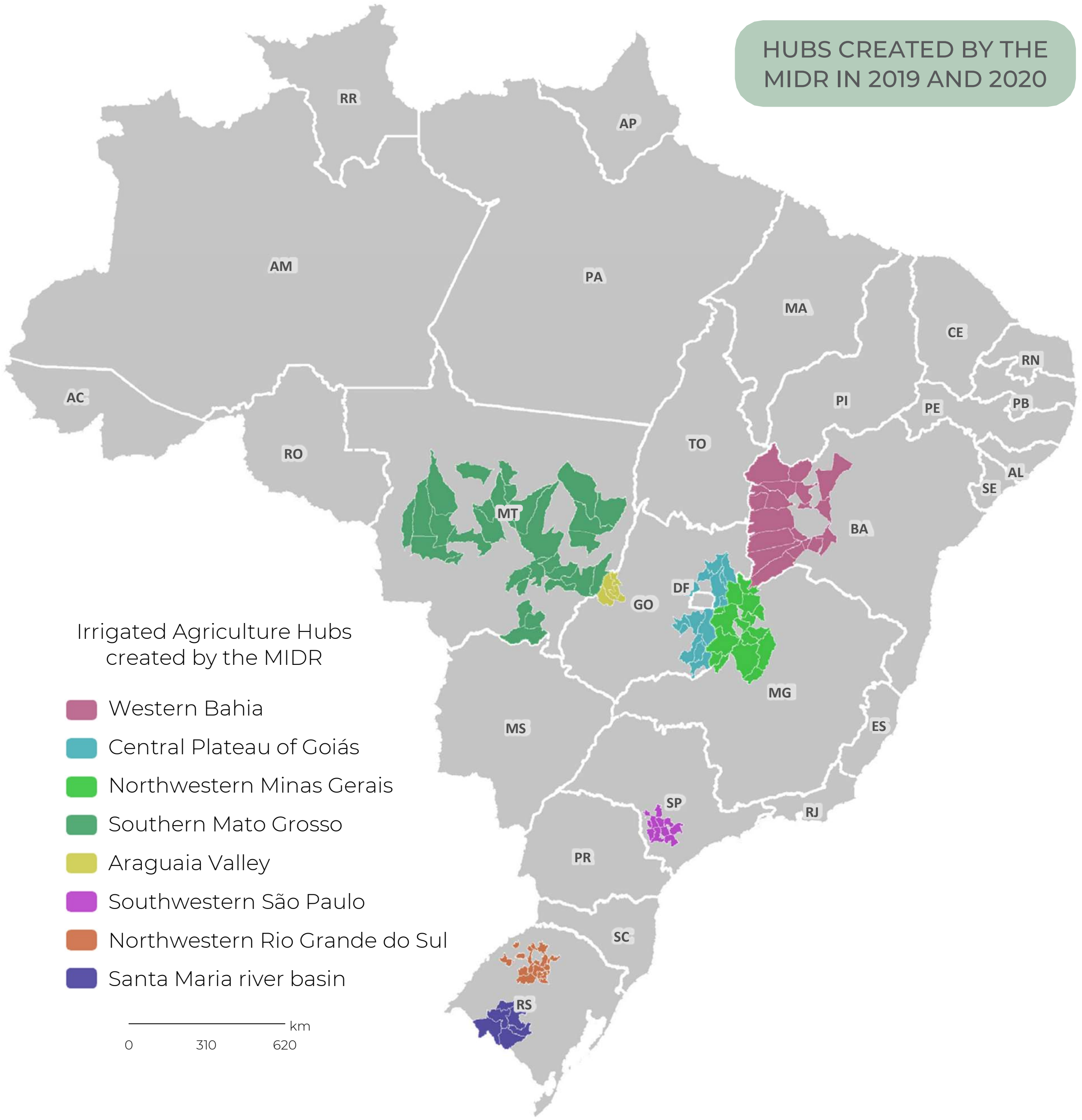
Implementation of the MIDR´s initiative involves the mobilization of actors, selection of technical partners, formation of management groups, definition and management of the project portfolio and prioritization of actions. Based on the special areas identified in the 2017 Irrigation Atlas and the articulation with producers and public agents, the MIDR created eight Hubs in 2019 and 2020: Santa Maria (RS), Araguaia Valley (GO), Planalto Central/ São Marcos (GO),Western Bahia, Southern Mato Grosso, Southeastern São Paulo, Northwestern Minas Gerais and Northwestern Rio Grande do Sul. These hubs encompass a total of 119 municipalities.

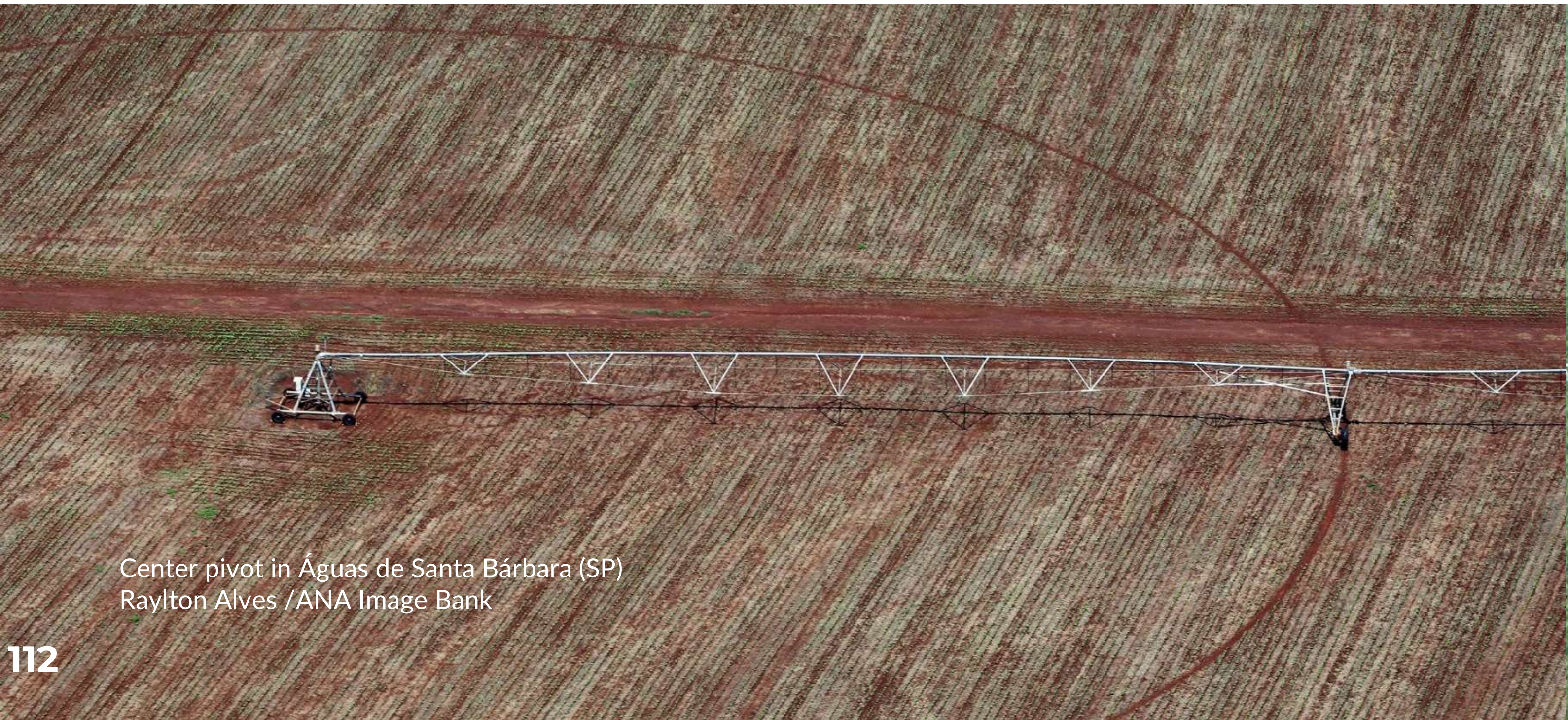
The ***MIDR hubs*** represent aggregations of communities within the same state, facilitating the implementation of irrigation policy actions; and these municipalities are defined in the installation workshop with local actors. Hubs delimited by ANA include the river basins (unit defined by the water resources policy) and the concentrations of current and potential irrigated areas.

In the sectoral sphere, the road to water security for irrigation requires continued recognition of irrigated agriculture hubs by both the MIDR and the states. And, more importantly, monitoring and executing the actions foreseen in the ***project portfolio*** of these hubs.

In the sphere of the blue agenda, ***the hubs must be recognized by the management entities*** as areas of special interest for managing water resources (or similar instrument) so that the implementation of instruments such as the grant is improved with specific measures for these areas; and that in the respective water resource plans, the basin committees can discuss guidelines for management instruments and priorities for water use, intra-sectoral and inter-sectoral.

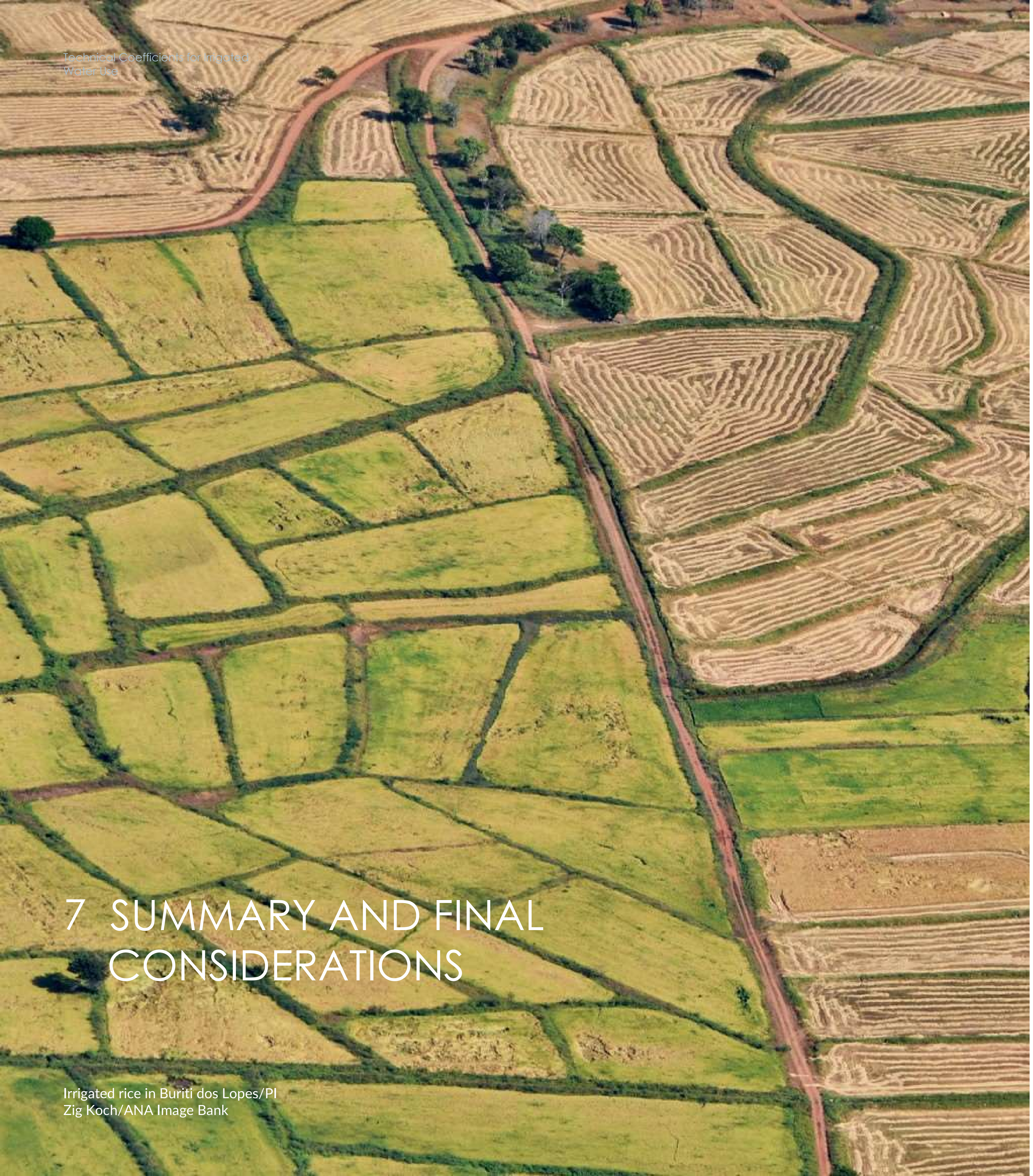
HUBS CREATED BY THE MIDR IN 2019 AND 2020





Center pivot in Águas de Santa Bárbara (SP)
Raylton Alves /ANA Image Bank

Center pivot operating in the Alto Paranapanema River (SP) region
Raylton Alves /ANA Image Bank



7 SUMMARY AND FINAL CONSIDERATIONS

Irrigated rice in Buriti dos Lopes/PI
Zig Koch/ANA Image Bank

Synthesis

Brazilian irrigated agriculture has a history of ***increasing and persistent development***, often during unstable and negative periods of the Brazilian economy. In addition to this history is a great potential that can be exploited on a sustainable economic and environmental basis. However, the role of irrigation in increasing Brazilian agricultural production is still underestimated in view of its potential and the positive results it presents. Much of this ignorance is due to the lack of data and information and the lack of dissemination of activity in Brazilian society.

It is also worth noting that irrigated agriculture is essential for the population's food supply. The necessary expansion of rice, beans and wheat production, for example, can occur with greater stimuli to irrigation, with zero deforestation. The production of higher value-added foods is also a vast field to be explored.

The ***Irrigation Atlas*** has among its objectives to contribute to the recognition of the importance of activity in society and to the economy of modern Brazilian irrigated agriculture and, at the same time, provides a ***robust technical basis*** for monitoring and planning the expansion of the sector, notably regarding ***water security*** for multiple uses.

Thus, the results presented in Atlas and its by-products (previous publications, databases and interactive content) allowed a refining of irrigated areas and water use by irrigated agriculture, in addition to providing a vision of the future of intensification or the emergence of new areas where conflicts may occur in Brazil.

With irrigated agriculture´s expansion prospect of 200 thousand hectares per year, generating an additional pressure of raw water abstraction of ***2 trillion liters per year***, this technical base will have its noblest use in technical development and decision-making on ***key topics for water security and production*** of the activity.

Among the main indicators consolidated by the Atlas, we highlight the following conclusions:

The ***gross value of irrigated production*** was at least ***BRL 55 billion*** in 2019 - 16 crops presented an annual value greater than BRL 1 billion.

Brazil totals ***8.2 million hectares equipped for irrigation*** - 35.5% with fertigation with reuse water (2.9 Mha) and 64.5% with irrigation with spring water (5.3 Mha).

The private sector occupies 96.2% of the irrigated area. The area in production that belongs to public projects is 3.8% (200 thousand hectares), which generate 580 thousand direct and indirect jobs in 79 projects and 88 municipalities.

The ***demand for water abstraction*** from springs was 941 thousand liters per second in 2019 (average climate), which corresponds to ***29.7 trillion liters per year***.

The ***additional irrigable area*** is 55.85 million hectares (total physical and water potential). The ***effective potential*** is ***13.69 Mha*** - 45% located in the Midwest, in particular in Mato Grosso and Goiás.

By ***2040***, it is estimated that ***4.2 million hectares of irrigated land will be incorporated*** (+76%), with a smaller impact on the expansion of water use (+66%) due to the trend of expansion of more efficient methods.

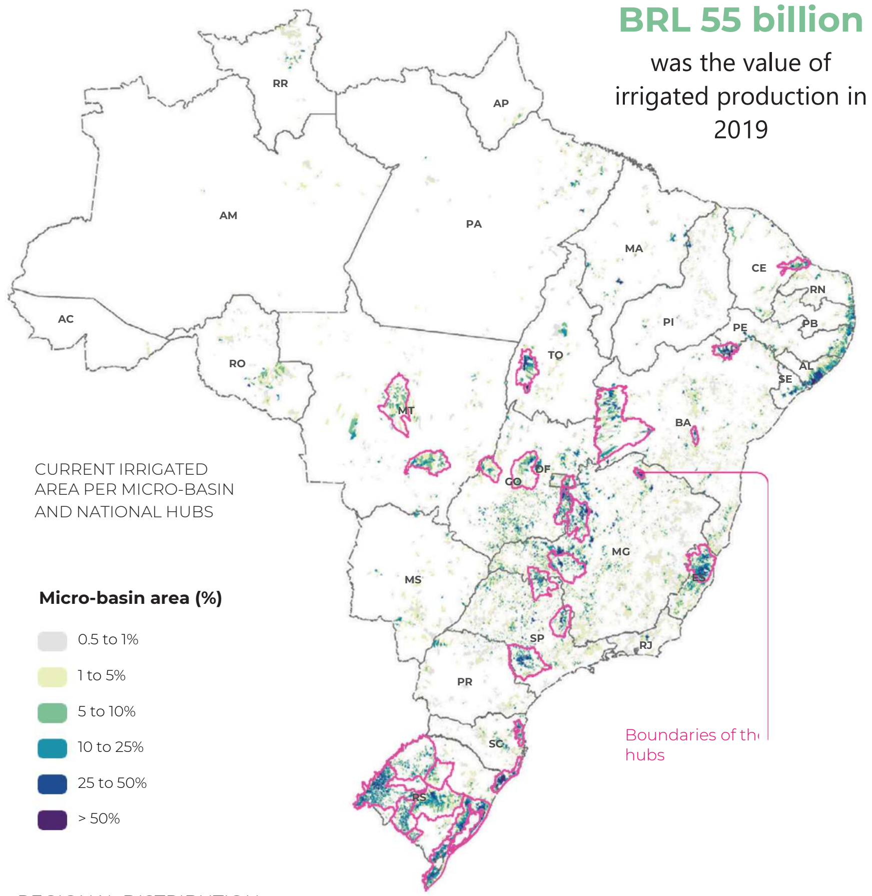
The ***28 National Irrigated Agriculture Hubs*** contain 50% of the irrigated area and 60% of the water demand, constituting ***special areas for sectoral and water resources management.***

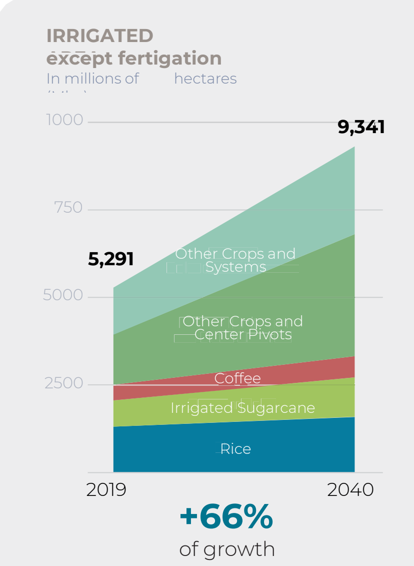
CONCLUSIONS

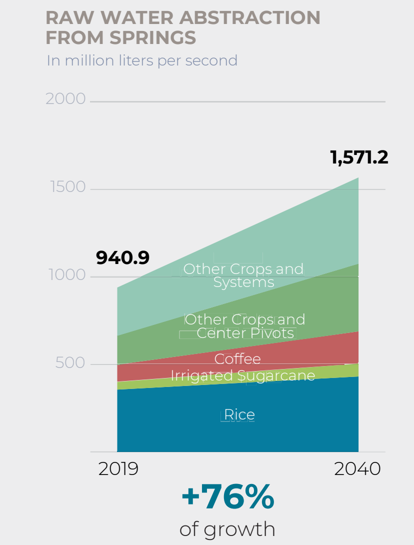
IRRIGATION TODAY

BRL 55 billion

was the value of irrigated production in 2019

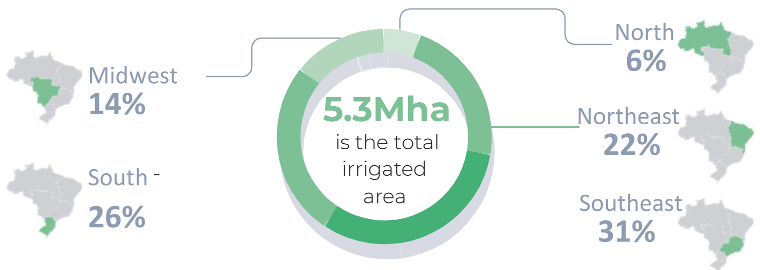




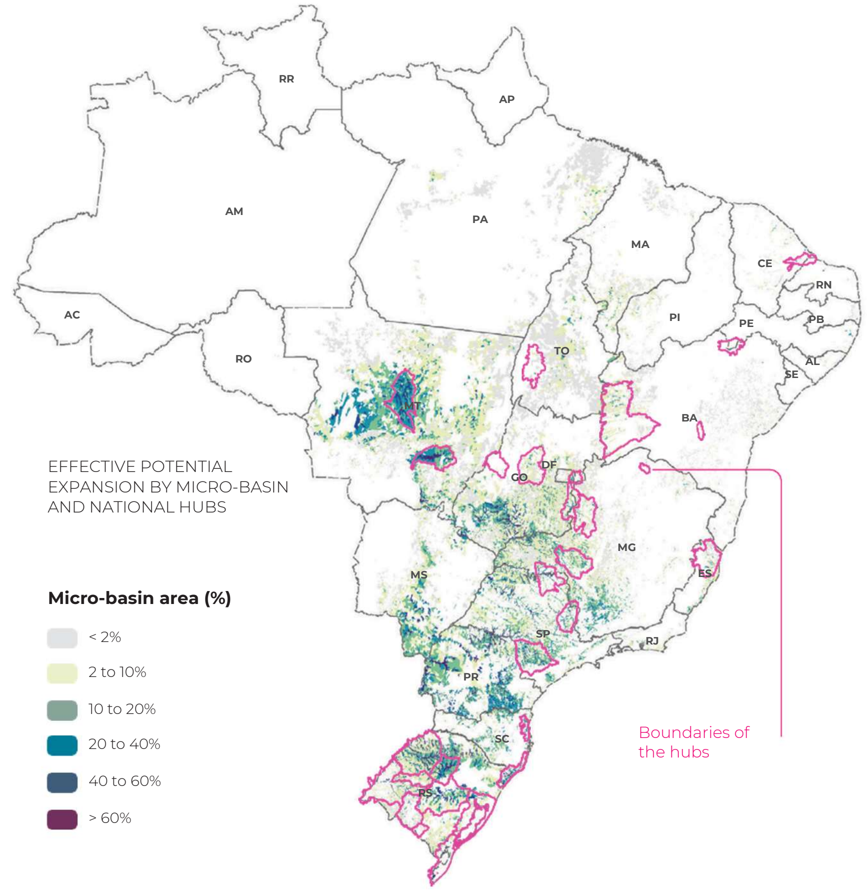


REGIONAL DISTRIBUTION OF IRRIGATED AREA

2019



IRRIGATION IN THE FUTURE



REGIONAL DISTRIBUTION OF EFFECTIVE POTENTIAL

2040

Irrigated areas in the basins of the Paranapanema and Grande rivers
Raylton Alves\ ANA Image Bank

Interface of Water Resources with Agricultural and Irrigation Policies

The search for ***water security, current and future***, of irrigated agriculture depends on an integrated effort of policies, institutions and management instruments. The Water Law (Law no. 9,433/1997) established the ***National Water Resources Policy*** and created the National Water Resources Management System (SINGREH) - its institutions are mainly deliberative (Water Resources Councils and River Basin Committees) or operational (Management Entities and Water Agencies).

The new ***National Irrigation Policy*** (Law no. 12,787/2013) provides, in some aspects, for the harmonization and integration of its instruments with those of the PNRH, but so far few provisions have been regulated or implemented. Despite this fragility, there is an opportunity for the PNI to develop while taking advantage of the results and lessons learned in the PNRH.

There is also the ***Agricultural Policy***, which operates in agriculture as a whole, but already considers irrigation as a specific sector in some of its programs and projects.

Some of the central interface themes of the water resources and irrigation sector agendas are discussed below - agendas that are understood as being inherently integrated, but which have at their operational core distinct institutions responsible for their governance and implementation.

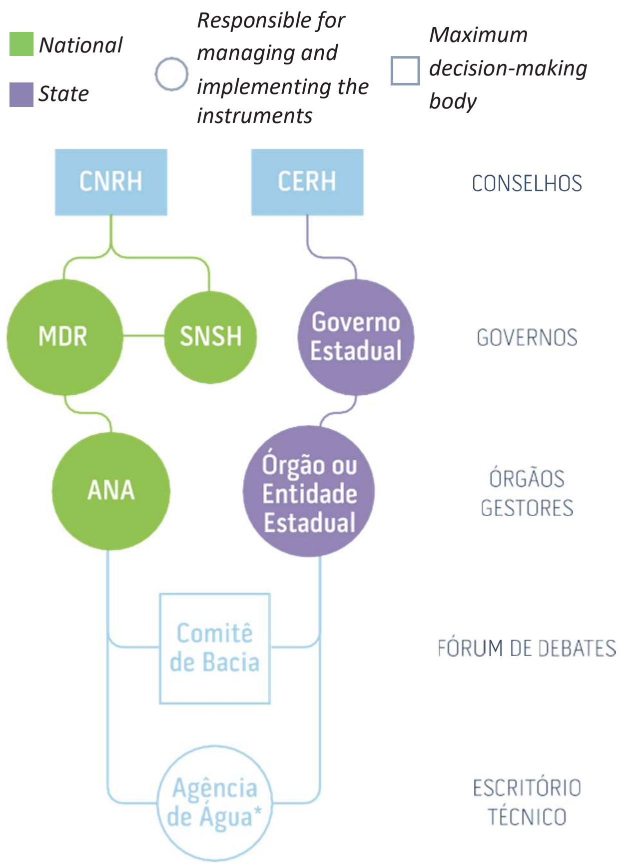
National Information Systems

Both policies (PNRH and PNI) legally instituted National Information Systems: the **SNIRH** (on Water Resources), coordinated by ANA, is still being implemented (www.snirh.gov.br) and includes publications, maps, indicators, dynamic displays, as well as sub-systems such as REGLA (for issuing grants), Hidroweb (hydrological information) and the CNARH (user registry). The Irrigation Atlas database also makes up the SNIRH, which is made available in different formats.

The National Irrigation Information System - **SINIR** did not progress as expected, and only developed only one initial module in the test phase for public projects (SISPPI – Information System on Public Irrigation Projects).

The PIN highlights which core information should be included in the SINIR: irrigated areas, exploited crops, irrigation methods; inventory of water resources and hydrological information; suitability mapping; agroclimatology; support infrastructure; availability of electricity; socioeconomic information about the irrigator; indicators on irrigated products (quantity, value) and public Federal areas suitable for irrigation projects. SINIR must also maintain a single national registry of irrigators (art. 8, paragraph 2). Among the objectives of the system are to provide support for the national and state/district irrigation plans and planning of the expansion of irrigated agriculture (art. 10).

Institutional matrix of SINGREH



* River basin agency or entity with similar legal function or state water resources management entity

After a few years of initiatives related to implementing systems, in particular SNIRH, and advances in the Irrigation Atlas database, there is recognition of the importance of a ***common and updated technical base***, which aids in decision making related to both the blue agenda and the yellow agenda. Having the same numbers and analyses on irrigated agriculture facilitates the articulation and communication of the various actors, and, consequently, the implementation of policies.

Examples of this synergy were: a) adoption of the 2017 Atlas results to create the water security index, in its economic dimension - basis for planning the PNSH; b) incorporation of the 2017 Atlas in the estimates of the Handbook of Consumptive Water Use in Brazil - a reference for studies on water resources, including the diagnosis and prognosis of water uses in plans for water resources of interstate basins such as the Grande, Paraguay and Paranapanema rivers; and c) use of the Atlas in the MDR´s actions, which includes selecting where the irrigated agriculture hubs will be installed.

This means that the technical basis on irrigated agriculture produced by ANA and made available via SNIRH has already aided in the implementation of both the National Water Resources Policy (PNRH), of which ANA is directly responsible, and the National Irrigation Policy (PNI), under the direct responsibility of the MIDR. In addition, it contributes to sectoral planning conducted by the private sector and to sectoral public policies under the responsibility of the Ministry of Agriculture, Livestock and Food Supply (MAPA) and other public sector agents, in the different spheres of the federal government.

The way to achieve water security for irrigated agriculture is through ***jointly coordinated information systems*** among the responsible entities, and technical and financial conditions for its development and maintenance. Therefore, the SINIR will have more synergy and effectiveness if this system is interconnected to the SNIRH - it is understood that the systems will have some modules in common.

It is essential for the PNI regulation to define the MIDR as the federal entity responsible for the unified coordination of SINIR, in close collaboration in the operationalization and interconnection of the systems (SINIR's operational core). With states, sectoral representations and other actors, the coordination of the MIDR must be in the collecting and receiving of information, as well as in the formats in which the information is released to society.

Water Resource Plans and Irrigation Plans

In addition to establishing specific actions and an implementation agenda for water resources management, the water resource plans (PRH) guide the other management instruments (granting, classification, information system and collection). HRPs can also advance in auxiliary instruments that have a bearing on the others, such as in the determination of water use priorities and areas subject to use restriction. The PRH must be prepared by river basin, by state and for the Country.

In the national context, there is the National Water Resources Plan (PNRH), which contains strategic and structural elements of the National Water Resources Policy, and the river basin plans (PRHBH), which includes more operational elements. The two dimensions complement each other in collaborating to develop a governance strategy for water security. These plans continue to be prepared throughout Brazil (learn more at: http://conjuntura.ana.gov.br).

Another important benefit of the PRHBH are the ***areas subject to use restriction***. The most recent PRHBH (Paranapanema, Paraguay and Grande) treat these areas as Priority Management Areas (APG). The constraints guiding the design of the APG can be addressed in several ways. For example, if the restriction is related to water quality, the framework targets should be the most restrictive. Thus, if the restriction of use is related to an aspect of water security, this aspect can guide the management actions in that APG.

The Irrigation Policy also provides for the plans as an instrument, and must be prepared in accordance with the Water Resources Plans (art. 6). Plans with national and state/district scope are foreseen. The ***National Irrigation Plan*** will guide the preparation of irrigation plans and projects by the states and the Federal District and will be decisive for the implementation of Federal irrigation projects.

The then Ministry of National Integration (MI), starting in 2009, in the context of the discussion of the new irrigation law, carried out some initiatives to implement ***State Irrigation Plans***. The governmental articulation with the states to implement the plans advanced in some regions of the country, with the construction of the State Irrigation Plan of Tocantins, the Irrigated Agriculture Master Plan of the State of Minas Gerais, the Irrigation Master Plan in the context of Multiple Water Uses for Rio Grande do Sul and the Irrigated Agriculture Master Plan of the Federal District. These experiences and the difficulties of implementing actions should help to remodel the content of this type of plan with a focus on also establishing the necessary bridges for its effective implementation.

Based on this effort, in 2014, the MI, in partnership with IICA and the Luiz de Queiroz School of Agriculture (USP/ESALQ), prepared the "Territorial Analysis for the Development of Irrigated Agriculture" study as a first step towards the National Irrigation Plan.

The ***Irrigation Atlas*** can be adopted as a diagnosis and preliminary prognosis of the ***National Irrigation Plan***, and its results are submitted to a public sector consultation for debate, adjustments and complementation, with subsequent formalization of these steps. It would remain to supplement the plan with elements of the minimum content provided for in Law no. 12,787/2013. The MDR has been working on the ***Immediate Action Plan for Irrigated Agriculture***, which may be the embryo for this final stage of the Plan. Another advantage of this arrangement refers to the fact that the Atlas will be the sectoral technical base in the 2022-2040 National Water Resources Plan, which is under preparation, which would allow the planning of both sectors to start from a common base, minimizing potential future conflicts by using divergent data.

Another important planning tool is the ***Regional Development Plan***, recommended by the National Water Security Plan for a detailed and integrated analysis of the effectiveness of water supply associated with large potential supply driven works (designed primarily to induce development from the water supply, with no current effective demand). This concept was applied in the PNSH recognizing that water infrastructure should be treated only as one of the development variables, which is added to issues related to the investment capacity of the public and private sectors to install demands, the consumer market, energy supply, transportation logistics, environmental preservation, among others, to measure and qualify the induction of development based on water supply. Therefore, the feasibility of these induction projects cannot be confirmed a posteriori, as if the available infrastructure naturally leads to development.

Finally, the plans (water resources, irrigation and regional development) should give priority to the construction of their respective ***operational manuals*** (MOP). The MOP establishes, for the set of priority goals proposed by the plan, the roadmap for its practical implementation during the first years of its horizon, i.e., for the short term, detailing those responsible, the necessary procedures, the prerequisites and the intermediate and final results expected from each of these goals (see the MOP of the PIRH Paranapanema as an example: http://paranapanema.org/plano/mop/).

Environmental Service Charges and Payments

Charging for the use of water resources is another instrument instituted by the National Water Resources Policy. Its main objectives are: to recognize water as an economic asset and to give the user an indication of its real value; to encourage rational water use; and to obtain financial resources to finance the programs and interventions included in the water resource plans.

For this, it is necessary to use methodologies to establish the amounts to be charged that consider economic mechanisms related to the value of water, in order to encourage users to review their grants to values more similar to the effective uses and implement optimization processes of their abstractions, in order to minimize waste, as well as of their effluent discharges, reducing the polluting potential.

The revenue from charges must be applied to the basin of origin. A positive agenda for water security lies in the greater participation of users and the establishment of ***plans for the application of resources*** where the price paid is fair and at the same time the amount can be used for actions in the basin. However, if the amounts charged are low or there is a lack of more accurate studies of economic viability, the investment capacity of the committees will tend to be very limited and the benefits of charging are not very sensitive to users.

Still in this vein of economic instruments, the ***Environmental Service Payments*** (PSA) initiatives have gained prominence in the planning of basins and other actions of environmental agencies and water resources. The PSA encourages producers to invest in water treatment care, receiving technical and financial support to implement conservation practices. To encourage the rural producer to invest in actions that help conserve water, ANA maintains the ***Water Producer*** Program (http://produtordeagua.ana. gov.br/), which is an inspiration for other PSA initiatives and, in the future, can be thought of as a compensation or reinvestment mechanism associated with charges.

Credit Zoning and Rural Insurance

Credit and insurance are essential to the development of irrigation. Currently, there is no credit zoning that seeks to stimulate the development of irrigated areas with better aptitude and discourage producers from settling in risk zones (those with low or already depleted support capacity).

The Agricultural Climate Risk Zoning (ZARC) are important instruments for the guarantee and credit programs, which can be improved for the specificities of irrigation. However, the ZARCs provide guidance right from the beginning by indicating planting periods that minimize weather adversities in sensitive stages of the crops.

Increasing water security for irrigation requires improving credit instruments in their main components (limits, interest, terms and grace periods). Currently, the credit is concentrated in the Irrigation and Storage Incentive Program (Moderinfra) of the Annual Agricultural and Livestock Plans – PAPs (since 2000/2001). Operations are carried out through accredited financial institutions.

The technical basis of the ***Irrigation Atlas***, along with the ZARCs and other technical criteria, can be used for ***credit zoning***, defining areas of high, medium and low risk, which ultimately contributes to the effectiveness of subsidized financing in its regional development function, mitigating the risk of credit itself.

Recently, ANA and IBGE published a study about water use and water deficits in rainfed agriculture (ANA & IBGE, 2020), which points out areas that have suffered recurrently with the water deficit. This base that makes up the Atlas also has potential zoning stimulus applications.

Rural insurance is another point to be improved for irrigation security. Investment in irrigation minimizes considerably, but does not eliminate the vulnerability of producers to other problems that the climate (such as hail) or operational issues can bring. Insurance can be applied to consider the specificities of irrigated production, including possible zoning (in space, time and per crop) to stimulate the increase in the production of key crops – such as beans and wheat in the dry period of the third harvest in the Cerrado biome.

Water Conservation

Dams (dams in a permanent or temporary watercourses, and associated structures) can be built for the purpose of containing and elevating the water level (water flow) or accumulation itself (reservoir). Water conservation for irrigation purposes also occurs in reservoirs built in parallel to watercourses or other reservoirs, supplied via pump, and are characterized not as dams, but as storage tanks.

The use of small dams and their effect on water availability is often not adequately accounted for in water balances, given the lack of knowledge of volumes and the low effect on water availability that is commonly adopted. The characterization of this supply in order to assist in the analysis of support capacity and in defining conservation policies (collective dams, for example) is also a challenge.

The comparison between water supply and demand water define the water balance. The estimation of water demands depends on precise information about irrigated areas, as well as climatic data and irrigation systems. The challenges of characterizing supply and demand in irrigation hubs, as well as outlining actions to address them, were analyzed in the Water Resource Plans (PRHs) recently prepared by ANA with the respective River Basin Committees, especially those of the Paranaíba, Paranapanema and Grande River basins, occupying a central role in of the implementation strategy of the respective Plans.

Defining dams and reservoirs as ***social interest*** is a recurring demand of irrigators. Under the new forest code (Law no. 12,651/2012), the intervention or suppression of native vegetation in a Permanent Preservation Area will only occur in cases of public interest, social interest or low environmental impact (art. 8). Therefore, this characterization would facilitate the construction of necessary dams, reservoirs and facilities necessary for the accumulation, uptake and conduction of water to support agricultural production. The execution would continue to be subject to other environmental standards and incident legislation, such as the National Dam Safety Policy and the National Water Resources Policy.

It is understood that the expansion of reservoirs for irrigation, with or without their definition as of social interest, should be equated as a central element of water security for the sector. Different state regulations also cause asymmetries that can harm sustainable development. The definition of clear and operational rules from the environmental and water point of view will contribute to this positive agenda and priority should be given to larger and collective dams managed by the irrigators (or multiple use users) benefited by the project.

It should be noted that the unrestricted release for the construction of thousands of small reservoirs, without general rules, may create a false idea of water security, which in the short term will not be confirmed by the low water storage capacity of these reservoirs and by the interference that they can generate in reservoirs already installed downstream.

Final Considerations

Expansion of the irrigated area in the country has been taking place, and should continue to occur, along three main lines: public perimeters planned by government agencies; joint private initiatives, organized in the form of cooperatives or associations; and individual private initiatives.

The first case is usually linked to a more comprehensive design, in which the size of the project is compatible with the hydropower availability. However, its implementation suffers from discontinuities inherent to the changes of managers and the emancipation - handing over the management of the built infrastructure to the users, who have faced difficulties in obtaining financial self-sufficiency. The expansion of existing projects and planning new ones requires the implementation of firm local productive arrangements, agreed upon between the actors, and that are concerned with the chain from the input through to the consumer market.

The second and third cases are driven by the attractiveness and risk inherent in the private sector. Usually, the success of certain irrigators attracts others and the expansion follows market logic, not always adhering to government policies and local and regional planning. In this context, it is important to strengthen planning and organize the state's role as an inducer and partner of this development, especially at the federal level, in articulation with states, municipalities and the private sector.

In any of the cases cited above, the expansion of irrigated agriculture in river basins with vulnerability between supply and demand for water resources and with low implementation of the National Water Resource Policy instruments increases the possibility that uses will approach or exceed supply at a certain time of the year. This is aggravated when water availability is lower than expected - which is natural in the ***hydrological regime*** - and can turn into water crises, causing uncertainties regarding water supply, straining the relationship of users established in the region and strengthening ***competitive uses between irrigators*** and these with other user sectors.

As a result, it is already observed that most of the river basins with quantitative criticality indicators in Brazil are mainly used for irrigated agriculture. Intra-sectoral conflicts (between irrigators) or conflicts with other sectors such as urban supply and power generation occur. Criticality occurs due to the high demands of irrigation, but also in regions with moderate demands, but with low water availability. With high potential for expansion and with the prospect of a relevant increase in water use for irrigation in the next 20 years, ***increased planning and management efforts*** are required.

This effort should increasingly consider the variation and perspectives of ***climate change***, where irrigated agriculture is both a victim and an important adaptive measure to face water scarcity and extreme events. The increase in unit demand, on the other hand, will decrease the potential for expansion of the activity, which will be added to the decrease in supply in the springs.

Given this context and the importance of the sector for Brazilian society and for managing water resources, ANA has been working on refining data and information through studies and partnerships, which not only qualify the Agency's operations but also make products available that are used in both the private and governmental spheres - especially in the development of policies for the sector. In this edition of the Atlas, it was possible to make significant progress in the consistency of the surveys of irrigated areas and in the consolidation of water use estimates in the national territory. This depiction of current irrigation and planning for the future has been crucial to ***decreasing uncertainty.***

The preparation and implementation of sectoral planning in an integrated manner with water resource planning (***blue agenda***) is essential for economic activity to develop in a sustainable manner, both in expansion areas and in those already consolidated. The ***irrigated agriculture hubs*** (national, regional or local) are crucial territorial units for the sector´s planning and implementation of the instruments of irrigation and water resource policies. The delimitation of these areas and the detailing of their attributes provide focus for management and serve as an example to develop other initiatives.

Decisions at the property level alone can cause collective negative impacts in a river basin. The ***organization of water users*** , at the level of the basin – within the limits imposed by the respective authorizations for water use and with the monitoring of management entities – empowers irrigators in risk analysis and management. It also facilitates communication and the creation of consensus, and may even result in proposals for revising grant criteria, user training, and the creation of areas subject to use restriction. This ***local governance*** (political leaders, public agents, producers and their representations) also allows greater continuity of the implemented actions.

The development and implementation of strategies to increase the water security of irrigated agriculture become even more relevant at this time of strengthening the Agricultural Policy in terms of irrigation, including the proposals for the regulation of provisions of the National Irrigation Policy. This discussion is even more strategic during the preparation of the ***new 2022-2040 National Water Resources Plan***, a key instrument in the new implementation cycle of the Water Resources Policy.

Finally, we reiterate that this technical base created over the last few years will continue to be the object of continuous improvement, which depends on the strengthening of partnerships with state and federal public agencies (MIDR, MAPA, Conab, Embrapa, IBGE); international organizations (FAO, USGS); the user sector (cooperatives, unions and other irrigation representation); specialized consulting firms; and universities and research centers. Translated with www.DeepL.com/Translator (free version)

As carried out between the first and second edition (2017-2021), the ***Irrigation Atlas*** will remain a technical base that is constantly being updated, with consolidated results always made available to society on the **SNIRH** (www. snirh.gov.br) and on ANA's communication channels.

Current and future results will continue to aid both the implementation of water resource management instruments (notably grants, water resource plans and information systems) and private decision-making and public policies, especially those made by the MIDR and MAPA. For water management, the ***current and future water security of irrigated agriculture and the guarantee of multiple uses*** are key factors, guiding the continuous improvement of knowledge and its application in the development of the water resources policy.

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Grape cultivation in the municipality of Petrolina (PE)
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