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Technologies for rational water use in Brazilian agriculture

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ABSTRACT

Brazil has the highest water availability of any country in the world. Nearly 20% of all the world's rivers flow on Brazilian soil. Brazil's herds of cattle, pigs and poultry are among the largest in the world, and the country uses irrigated agriculture extensively, which accounts for most water consumption (approximately 70% of the water consumed in the world). The Brazilian Agricultural Research Corporation (Embrapa), the largest and most important public institution of Brazilian agricultural research, has attempted to develop environmental technologies in order to minimize the impact caused by the scarcity and pollution of water resources. This paper describes the technologies this institution offers to different regions. For this purpose, a descriptive and exploratory study was conducted in various Embrapa research units. The results showed that research on the rational use of water in agriculture has intensified since the early 2000s. However, the pace of growth in agricultural activities and their impact is much greater than that of the generated technologies, demonstrating the difficulty in striking a balance in this relationship. Furthermore, it is clear that that water scarcity and the increasing pollution of shallow and deep waters are complex issues with no short-term solution.

Keywords: Brazilian agriculture, Embrapa, rational use of water.

Tecnologias para o uso racional da água na agricultura brasileira

RESUMO

O Brasil é o país com a maior disponibilidade hídrica do mundo, quase 20% das vazões de todos os rios do planeta, fluem em solo brasileiro. Possui um dos maiores rebanhos mundiais de suínos, aves e gado e utiliza largamente a agricultura irrigada, principal consumidora dos recursos hídricos (cerca de 70% da água consumida no mundo). A Empresa Brasileira de Pesquisa Agropecuária – Embrapa, como a maior e mais importante instituição pública de pesquisa agropecuária brasileira, tem envidado esforços na tentativa de buscar soluções para, minimizar os impactos causados pela escassez e poluição dos recursos hídricos, por meio do desenvolvimento tecnologias ambientais. Esse trabalho descreve as tecnologias disponibilizadas por esta instituição para as diferentes regiões brasileiras. Para isso, foi desenvolvida uma pesquisa descritiva e exploratória junto às diversas unidades de pesquisa da Embrapa. Os resultados demonstram que houve uma intensificação das pesquisas voltadas para o uso racional da água na agricultura, a partir da década de 2000. Todavia, o ritmo de crescimento das atividades agropecuárias e seus impactos é bem maior do que o das tecnologias geradas, o que dificulta se encontrar um equilíbrio nesta relação. Além disso, deve-se considerar que o problema da escassez da água assim como da crescente poluição das águas rasas e profundas, é complexo e não existe uma solução a curto prazo.

Palavras-chave: agricultura brasileira, Embrapa, uso racional da água.

1. INTRODUCTION

Brazilian society is embroiled in a number of conflicts regarding the use of water, especially in regions where this resource is historically scarce. Conflict over the use of water tends to intensify due to increasing demand, the pollution of water resources and the instability of the climate. Therefore, seeking solutions for the adequate monitoring and use of these resources is considered a priority by public research institutions and management agencies.

The supply of food is a huge priority in countries that are essentially agricultural, such as Brazil. One of the major challenges is the development and application of rational methods and techniques concerning the use of water in agriculture and raising livestock.

In the agriculture sector, it took a long time for farmers and the government to realize that exploitation of the ecosystem could cripple agriculture in the long term, depending on the methods employed. This occurs through the exhaustion of natural resources like water and soil, which are directly involved in the process. When this connection was made, it inspired a drive to seek new farming methods and technologies that would lead to environmental and economic sustainability. Without this sustainability, any changes that might be made would not endure (WWF, 2002). In this respect, Conceição et al. (2013) emphasize that agriculture is growing at a much faster pace than are efforts to achieve sustainable management of water resources.

According to the Sebrae (2014), agriculture is responsible for the consumption of almost 70% of the water in rivers, lakes and aquifers. However, much of the water is wasted, especially in distribution. Only 15% to 50% of the water intended for irrigation reaches its destination. This means that it is very important to search for new technologies and knowledge that will not only help to preserve natural resources but also result in greater efficiency of distribution.

In this context, Embrapa, as a public agriculture research institution, has a mission to develop technologies and rational methods for the use of water in agriculture and livestock. Thus, the aim of this study is to describe the technologies developed by this institution for the rational use of water in different regions of Brazil. It should be highlighted that the concept of technology used in this work is broad, encompassing knowledge, tools and techniques derived from science and practical experience that are used in the development, production and application of products, processes, systems and services.

The methodology employed is descriptive and exploratory, using secondary data such as websites and articles published in digital and print media. We also reviewed documents maintained by Embrapa, where research on this theme is conducted.

This work is divided into five sections. Following this introduction, the methodology is described. The third section addresses the availability of water in Brazil and agriculture activities. The fourth section presents the technologies developed by Embrapa for the rational use of water in Brazilian agriculture. Finally, we discuss conclusions suggested by our research.

2. METHODOLOGY

This study is descriptive and exploratory. The Embrapa website was consulted in order to obtain data. The site has clusters of information from 46 decentralized research units. Data and reports from these units were also accessed using corporate internal access programs. To complement the data obtained, each unit was sent a list of the technologies they had developed and asked to confirm the information and provide any other data that was considered relevant. The data were collected and confirmed between 30 April and 2 June 2015.

3. AVAILABILITY OF WATER IN BRAZIL AND FARMING ACTIVITIES

Brazil can be said to have an ample supply of water resources, although there is some imbalance between availability and need. According to Senra (2001), Brazil has 12% of the planet's water reserves but only 2.8% of the population. In comparison, China has 25% of the population but only 10% of water reserves. According to Tucci et al. (2000), the average surface water production in Brazilian territory is 168,790m3/s. The surface water resources produced in Brazil account for 50% of the total resources of South America and 11% of the resources worldwide. However, the distribution of these resources is uneven, with an excess of water in some regions, such as the Amazon Rainforest, and a shortage in other regions, such as the Northeast (Tucci et al., 2000).

To Gomes and Barbieri (2004), there is considerable disparity between water production and demographic concentration. Less than 20% of national water discharge supplies approximately 95% of the population, while 80% of this production originates from regions occupied by only 5% of the population (Gomes and Barbieri, 2004).

According to Christofidis (2002), of the total water used in the world, around 70% is destined for irrigated agriculture, which is far higher than the demands of the industrial sector (21%) and of the urban sector (9%). In Brazil, the irrigated area corresponds to approximately 18% of total cultivated area, with 42% of total production (Christofidis, 2002). The author points out that, with the incorporation of more efficient technologies and processes for managing the treatment and use of water, this consumption should fall over the years. Even so, it is estimated that by 2025 three billion people will be affected by water shortages and availability will be lower than 1,700 m^3/ha/year (Christofidis, 2002).

Due to the high consumption of water in irrigated agriculture, most of the technologies and knowledge generated for the rational use of water are focused on this type of farming. According to the Sebrae (2014), almost every method concentrates on the use of climate information to help calculate the irrigation needs of crops and methods for monitoring parameters, such as soil humidity, that enable a significant reduction in the use of water and energy (Sebrae, 2014).

To Garcia and Vieira Filho (2014), Brazilian agriculture and livestock is a modern and highly dynamic activity. It has been highlighted as a source of development and economic stability, providing jobs and income and playing a central role in ensuring food safety and bridging poverty and inequality gaps. Nevertheless, the sector faces considerable challenges in terms of sustainable development. In addition to meeting the new ecological requirements, it must satisfy the growing demand worldwide for farming products. Therefore, preparing the

Brazilian economy to meet these goals and challenges is a strategy for future growth, which may result in an increase in exports of farming and livestock products (Garcia and Vieira Filho, 2014).

Zamberlan et al. (2014) highlight the need to rethink the use of natural resources in farming and livestock systems. Technologies should be developed with a view to a more rational use of these resources. In the opinion of these authors, the environmental variable should be incorporated into production in order to adopt new technologies that minimize environmental impact.

3.1. Regional farming activities

According to Oliveira and Souza-Lima (2003, p. 33), the "development of a region can be explained as the result of the interaction of three forces: allocation of resources, economic policy and social activation". The more intensive farming becomes, and the less concern there is over the availability of resources, the harder it will be for that region to develop. This approach makes it easier to understand the Brazilian agriculture and livestock context, as highlighted by Garcia and Vieira Filho (2014).

When it comes to regional development, it is noted that water shortages due to intensive farming can lead to restrictions on freedom and other issues for the population, as mentioned by Azevêdo et al. (2013). To these authors, "water shortages condemn millions of people to a life of poverty, with precarious living conditions and health issues and limited opportunities. This serves to perpetuate serious inequalities not only between countries but within them" (Azevêdo et al., 2013: p. 5).

Brazil is one of the major producers of sugarcane, cocoa, corn and oranges. Other important crops are soy, tobacco, potatoes, cotton, rice, wheat, cassava and bananas. Annual grain production is approximately eighty million tons. Beef cattle are raised in almost every region, especially Mato Grosso do Sul, São Paulo and the southern states, where there are also dairy cows, pigs, poultry, sheep, goats, donkeys, mules and oxen. Brazil is divided into five major regions: The South, Southeast, Midwest, Northeast and North. These regions each have their own characteristics and diversity in farming and livestock.

Most of the swine and poultry industries are concentrated in the South. This type of farming has a high potential for the pollution of water resources, soil and air (Tucci et al., 2000).

In the Southeast, sugarcane, soy and oranges are grown. The region also has the second largest herd of cattle in the country.

In the Midwest, the major crops are rice, corn, coffee, cotton and soy. The raising of beef cattle is the region's most important economic activity. The Pantanal is located here, which suffers from the effects of economic development and requires soil conservation measures as well as controls on mining and management of the potential impacts of sailing on the Paraguay River. The Cerrado ecoregion has the greatest farming potential in the country, but requires care to avoid disastrous impacts.

In the Northeast, sugarcane, soy, cotton, tobacco, cocoa and fruit are grown. Agriculture is a great challenge, especially in the semiarid region, given limitations such as low precipitation, high temperatures, evaporation, subsoil with little capacity for storing water, low levels of education of the local rural population and a system of land ownership that concentrates income in the hands of a few people (Tucci et al., 2000).

In the North, there has been a rise in the planting of crops such as soy, rice, guarana, cassava, cocoa, coconut, passion fruit and cupuassu. The Amazon Rainforest is located in this region, with a great forest reserve. Despite the capacity for regeneration, the constant deforestation and expansion of the occupied areas, especially close to the Cerrado, has considerable potential for environmental impact.

Due to the economic and social importance of agriculture and livestock and the intensive use of natural resources, especially water, it is essential that technologies be developed to minimize the negative impacts or to enable the rational use of these resources.

Tundisi (2003) claims that it is technically possible to achieve greater efficiency in the use of water in agriculture. Investing in the use of new technologies can reduce water consumption by 30% to 70%. Therefore, it is important to assess techniques for more efficient water use together with optimized farming in order to enable gains in crop productivity, avoid impacts on soil and plant systems and to avoid wasting water.

In the next section, we present the main technologies developed by Embrapa for the rational use of water in farming and livestock in the different regions of Brazil.

4. TECHNOLOGIES DEVELOPED BY EMBRAPA FOR RATIONAL WATER USE IN DIFFERENT REGIONS OF BRAZIL

The Brazilian Agricultural Research Corporation (Embrapa) is the largest and most important Brazilian institution for agricultural research. It operates through a network of 46 decentralized research units and has formed partnerships with a number of public and private institutions.

As a public research institution, it has been charged by the government and society with fostering the sustainability of water use by farming production chains. The institution also defines priorities for water use in basins and closely monitors those that are facing water shortages. While water use is not currently threatened in most of the country, it is important not to lose sight of the issue of efficient water use in diverse economic sectors and activities (Rodrigues, 2015).

According to Embrapa (2015), the scientific knowledge generated in recent years proves that it is possible to use water in agriculture rationally and without waste. With the water crisis in important regions of Brazil, it is fundamental that this knowledge be made available to society. Many of these technologies are already being adopted in the field, while others are beginning to attract the attention of farmers (Embrapa, 2015).

It would be opportune to define the word “technology”, as it will be used in this work. There are several definitions of the word “technology”. According to Kruglianskas (1996) "technology is the set of knowledge necessary for conceiving, producing and distributing goods and services competitively”. This encompasses all the knowledge related to a company’s activities.

The concept of technology has a broader or narrower scope depending on the focus of analysis. However, it includes not only products, but also knowledge that can be translated into processes and services. Therefore, the concept of technology used in this work is provided by Abetti (1989), who defines technology as "a body of knowledge, tools and techniques derived from both science and practical experience that is used in the development, design, production and application of products, processes, systems and services".

Due to the geographic and climatic diversity of the Brazilian regions, some of the technologies developed by Embrapa are developed for a specific region. Others may be used in any region of the country. These technologies are made known to farmers in several ways, such as field trips, lectures, courses, fairs and demonstrations. Furthermore, Embrapa is supported by rural extension institutions that help transfer these technologies.

Tables 1 to 4 contain summaries of the main technologies developed by Embrapa for the rational use of water in agriculture for the different regions of Brazil.

Table 1. Technologies developed by Embrapa for the rational use of water in agriculture in the South and Midwest regions of Brazil.

Technology	Type	Objective/description	Region	Year	Unit
Use of controlled water stress to standardize the quality of irrigated coffee crops	Practical	To enable irrigated coffee plantations in the Cerrado region, reducing the amount of water and the cost of energy	Midwest	2005	Cerrados (DF)
Software for the efficient use of water and savings in irrigation costs for crops in the Cerrado	Online service	To enable decision-making regarding the time for irrigation and water depth for irrigated crops in the Cerrado	Midwest	2014	Cerrados (DF)
Efficient water use in irrigated rice farming	Practical	To reduce waste and increase efficiency in the irrigation of rice crops	South	2006	Temperate Climate (RS)

Source: Research data

The technologies developed for the Midwest and the South are for use in irrigated crops (coffee, crops in the Cerrado Region and rice). As mentioned above, these are the crops with the highest water consumption.

Table 2. Technologies developed by Embrapa for the rational use of water in agriculture in the northern region of Brazil.

Technology	Type	Objective/description	Region	Year	Unit
Irrigation and water management for watermelon crops in Roraima State	Methodology	To reduce water consumption and production costs without affecting productivity	North	2010	Embrapa Roraima (RO)
Irrigacaju (Irrigation for Cashews)	Methodology	To calculate the volume of water necessary for irrigating dwarf cashew trees	North	2005	Tropical Agribusiness (CE)
Cowpea crop with fish farm effluents	Practical	To optimize the use of water resources and agriculture with the shared use of water	North	2010	Meio Norte (“Mid North”) (PI)

For the North, characterized by a warm and damp climate, Embrapa developed two methods for use in irrigated watermelon and cashew crops and a practice for the shared use of water, i.e., fish farms and crops.

Of the ten technologies developed for the northeast, seven focus on irrigated agriculture and three on rainwater harvesting, as the region has low levels of rainfall. Therefore, like the other regions, the types of technologies that are developed are practical and users are shown how to use them and improve results.

Table 3. Technologies developed by Embrapa for the rational use of water in agriculture in the Northeast of Brazil.

Technology	Type	Objective/description	Region	Year	Unit
Small dam for irrigating subsistence crops	Practical	To increase water storage	Northeast	1981	Semiarid (PE)
In situ rainwater collection for food production	Practical	To make water available for crops and conserving the soil and its nutrients	Northeast	1983	Semiarid (PE)
Ridge-furrow rainwater harvesting	Practical	To increase water storage	Northeast	1989	Semiarid (PE)
Underground dam	Practical	To retain rainwater that oozes into the soil	Northeast	2005	Semiarid (PE)
Management of irrigation for dwarf coconut trees	Practical	To increase the productivity and efficiency of water usage in the irrigation of dwarf coconut trees	Northeast	2006	Tropical Agribusiness (CE)
Drip irrigation in the semiarid region of the Northeast	Practical	Drip irrigation methods	Northeast	2007	Cassava and Fruit (BA)
Management of irrigation for tabasco pepper crops	Practical	To determine the needs for irrigation considering the climate and soil, maximizing productivity and water use	Northeast	2008	Tropical Agribusiness (CE)
Optimization of modular systems for irrigated crop production with brackish water	Practical	Use of desalination rejects, brackish water from low production wells for small rural properties	Northeast	2011	Environment (SP)
Evapotranspiration and coefficient of watermelon crop irrigated by drip irrigation in Piauí State	Practical	To estimate water consumption for the watermelon crop in its different phases of development	Northeast	2012	Meio Norte (“Mid North”) (PI)
Projected water demand for irrigation of muskmelon in the semiarid region in times of climate change	Zoning	To evaluate the impact of climate change on water requirements for muskmelon irrigation in the Brazilian Semiarid region.	Northeast	2013	Tropical Agribusiness (CE)

Table 4. Technologies developed by Embrapa for the rational use of water in agriculture in all regions of Brazil.

Technology	Type	Objective/description	Region	Year	Unit
Collecting rainwater: plowing and strip farming	Practical	To increase water storage in the soil	All	1989	Semiarid (PE)
Rainwater collection: plowing before and after planting	Practical	To increase water storage in the soil	All	1989	Semiarid (PE)
Multiple-use lake	Practical	Waterproofing for environmental protection	All	1991	Corn and Sorghum (MG)
Upgrading soil and water management	Training	To train people for the sustainable management of the soil and water in agriculture	All	2000	Meio Norte (“Mid North”) (PI)
Irrigas	Equipment	Systems and accessories for management of agricultural and domestic irrigation	All	2000	Vegetables (DF)
Diagnosis and planning to recover ecosystems	Practical	To teach techniques for recovering polluted ecosystems	All	2000	Soil (RJ)
Course on irrigation and management	Training	To provide training on irrigation and management of equipment for monitoring water in the soil	All	2002	Semiarid (PE)
EPS method for managing irrigation in pastures	Practical	EPS (evaporation-precipitation-soil) method for low-cost irrigation	All	2002	Livestock Southeast (SP)
Collecting rainwater: cistern	Consultancy	To provide instructions for building cisterns to capture rainwater	All	2005	Swine and Poultry (SC)
Irriga fácil (Easy Irrigation)	Software	To estimate the time for irrigation and the required water depth	All	2006	Corn and Sorghum (MG)
Small dams	Practical	To collect rainwater and contain the erosive force of flashfloods	All	2006	Corn and Sorghum (MG)
Analysis of water for irrigation purposes	Analysis	To determine the potential of water for irrigation purposes	All	2008	Semiarid (PE)
Consultancy regarding water on dairy farms	Consultancy	Management of water sources and use of technologies for treating water on the farm	All	2010	Dairy Cattle (MG)
SiBCTI (Brazilian system for the Classification of Land for Irrigation)	Software	To evaluate land that is fit for irrigation, minimizing environmental impacts	All	2011	Soil (RJ)
Optimization of modular system for irrigated crop production with brackish water.	Practical	Enables the use of desalination rejects, brackish water from low production wells	All	2011	Environment (SP)
Environmental risk assessment in water resources	Methodology	Providing instructions on the use of the ARAquáGeo software for spatial analysis of the environmental risk of water contamination	All	2013	Territorial Management (DF)
ARAquá (Evaluation of Pesticide Risk)	Software	To assess the environmental risks of pesticides in surface and underground water	All	2014	Cerrados (DF)
Monitoring the quality of rural water resources	Training	To monitor the quality of water and recognize the effects of the use of land on the hydro geochemistry of waterways	All	2015	Environment (SP)
Igstat Sensor	Equipment	Water tension sensor in the soil to manage and monitor irrigation.	All	2015	Instrumentation (RJ)
Dihedral Sensor	Equipment	Sensor to evaluate tension, potential and activity of water in soil and crops	All	2015	Instrumentation (RJ)

Embrapa has concentrated its efforts on the development of technologies that can be used in all regions of Brazil. Given the diversity of the regions, the technologies are less specific than those that are developed for a particular region. The types of technologies are more varied. In addition to practical technologies and training, they include equipment, software and water analyses.

Since 2000, Embrapa has intensified its research efforts in a drive for technologies that reduce or maximize the use of water in agriculture and livestock. Of the thirty-seven technologies mentioned, twenty-five were developed in the last fifteen years. This is an example of the growing concern over rational water use, which is concomitant with the diminishing availability of this natural resource.

Figure 1 shows that the Embrapa research units located in the northeast and southeast were the ones that developed the most technologies for the rational use of water.

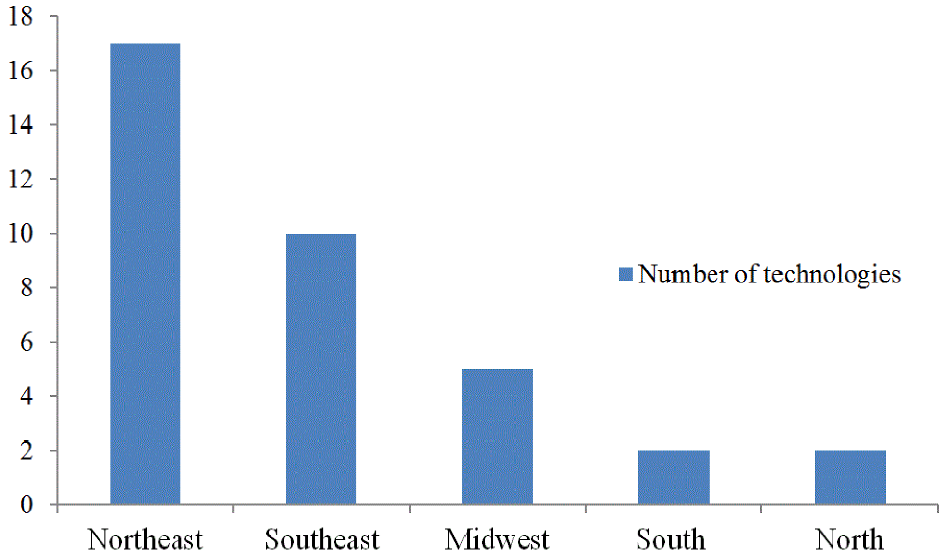

Figure 1. Number of technologies developed by the Embrapa units by region.

This fact can be explained by the water shortages in the northeast of Brazil and the existence of large areas of irrigated crops in the southeast. This means that the need for solutions for the rational use of water is more pressing and important.

Most of the technologies developed are practical methods and training courses aimed at irrigated agriculture.

It should be highlighted that knowledge and techniques are also considered "technologies" and can have a considerable effect on the water cycle, with greater groundwater recharging and better regulation of water flow throughout the year. The ability of farmers is essential, for instance, to the increased adoption of soil, plant and irrigation management. This will help make the use of water in agriculture sustainable, especially when irrigation is employed. In addition to greater economic profitability, better quality of farming can be achieved, as excess water can in many cases be harmful (Embrapa, 2015).

5. CONCLUSION

Despite the efforts by Embrapa in recent years to provide technologies focusing on the rational use of water in agriculture and livestock, this problem cannot be solved in the short term, especially in a country like Brazil that is essentially agricultural.

The results show that in spite of increased research by Embrapa, problems of water shortages and growing pollution in both shallow waters and deep wells are complex, as stated by Conceição et al. (2013), and tend to intensify more rapidly than solutions emerge. The growth rate of agribusiness and its consequent impacts are much greater than the technologies being developed, demonstrating how difficult it is to strike a balance in this relationship. In this sense, there is a greater need to incorporate environmental variables, such as water, into the rationalization of productive systems, as pointed out by Zamberlan et al. (2014). In this respect, Embrapa has introduced new technologies to improve these processes and to include the water variable in production systems.

The technologies developed by Embrapa are focused on application to specific crops or small rural properties, which shows the need to increase research efforts for the development of wider-ranging technologies that can be applied to agriculture and livestock on a large scale, as big farmers are the largest consumers of water. However, it should be noted that more technologies have been developed since the year 2000. Twenty-five of the thirty-seven technologies that have emerged were developed in the last fifteen years. This shows an alignment between the problem of water shortages in the production system and the growing importance and complexity of the issue in the agriculture and livestock sector.

The research tends to be concentrated in the Northeast and Southeast, the regions most affected by the climate. However, it should be emphasized that the intense farming practices in other regions, such as the South, have not aroused interest in the importance and urgency of the work of this research institution. There should be greater concern over the problem of water shortages in the medium and long term, especially in the South. Alternatives for production systems and the water supply in the region should be proposed and monitored.

Finally, it should be noted that this study set out only to describe the technologies developed by Embrapa as a public research institution for the rational use of water in agriculture. Consequently, the feasibility, adoption and efficiency of these technologies do not fall within the scope of the present study.

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