SUSTAINABLE
DEVELOPMENT
GOAL
6

CLEAN WATER AND SANITATION

CONTRIBUTIONS OF EMBRAPA

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Technical Editors

Embrapa

Brazilian Agricultural Research Corporation
Ministry of Agriculture, Livestock and Food Supply

Sustainable Development Goal 6

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“We have the ability to provide clean water for every man, woman, and child on the Earth. What has been lacking is the collective will to accomplish this. What are we waiting for? This is the commitment we need to make to the world, now”.

Jean-Michel Cousteau

“Although we take it for granted, sanitation is a physical measure that has probably done more to increase human life span than any kind of drug or surgery”.

Deepak Chopra

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Foreword

Launched by the United Nations in 2015, 2030 Agenda for Sustainable Development is powerful and mobilizing. Its 17 goals and 169 targets seek to identify problems and overcome challenges that affect every country in the world. The Sustainable Development Goals (SDG), for their interdependent and indivisible character, clearly reflect the steps towards sustainability.

Reflecting and acting on this agenda is an obligation and an opportunity for the Brazilian Agricultural Research Corporation (Embrapa). The incessant search for sustainable agriculture is at the core of this institution dedicated to agricultural research and innovation. Moreover, sustainable agriculture is one of the most transversal themes for the 17 goals. This collection of books, one for each SDG, helps society realize the importance of agriculture and food in five priority dimensions – people, planet, prosperity, peace, and partnerships –, the so-called 5 Ps of 2030 Agenda.

This collection is part of the effort to disseminate 2030 Agenda at Embrapa while presenting to the global society some contributions of Embrapa and partners with potential to affect the realities expressed in the SDGs. Knowledge, practices, technologies, models, processes and services that are already available can be used and replicated in other contexts to support the achievement of goals and the advancement of 2030 Agenda indicators.

The content presented is a sample of the solutions generated by agricultural research at Embrapa, although nothing that has been compiled in these books is the result of the work of a single institution. Many other partners joined in – in universities, research institutes, state agricultural research organizations, rural technical and extension agencies, the Legislative Power, the agricultural and industrial productive sector, research promotion agencies, in federal, state and municipal ranges.

This collection of books is the result of a collaborative work within SDG Embrapa Network, which comprised, for 6 months, around 400 people, among editors, authors, reviewers and support group. The objective of this initial work was to demonstrate, according to Embrapa, how agricultural research can contribute to achieve SDGs.

It is an example of collective production and a manner of acting that should become increasingly present in the life of organizations, in the relations between public, private and civil society. As such, this collection brings diverse views on the potential contributions to different objectives and their interfaces. The vision is not homogeneous, sometimes it can be conflicting, as is society's vision about its problems and respective solutions, a wealth captured and reflected in the construction of 2030 Agenda.

These are only the first steps in the resolute trajectory that Embrapa and partner institutions draw towards the future we want.

Maurício Antônio Lopes
President of Embrapa

Preface

In September 2015, the United Nations (UN) launched the document 17 Sustainable Development Goals (SDGs). These global goals are divided into 169 targets, which constitute a global agenda for the construction and implementation of public policies that should guide humanity by 2030, focusing on improving the population's quality of life. In this agenda, actions are planned worldwide, concerning poverty eradication, food security, agriculture, health, education, gender equality, reduced inequalities, energy, water and sanitation, sustainable patterns of production and consumption, climate changes, sustainable cities, protection and sustainable use of oceans and terrestrial ecosystems, inclusive economic growth, infrastructure, industrialization, among others. The 17 SDGs were elaborated in a worldwide participatory negotiation process that began in 2013 and which counted on the participation of Brazil in its discussions and definitions regarding the foundations and directives present in the agenda.

In this book, Embrapa exposes its interfaces and synergies with SDG 6 (ensure the availability and sustainable management of water and sanitation for all) and its respective targets, showing the alignment of this SDG with 3 of its 5 impact axes and with 4 of the 12 strategic objectives, expressed in its VI Plano Diretor (VI Master Plan), as detailed in Chapter 2.

SDG 6 draws the attention of global authorities to the need for access to safe drinking water and sanitation by populations around the world. In order to achieve this goal, there is a set of targets to be considered, among which the improvement of the water quality offered, the increased efficiency in the use of this resource in all sectors (including its sustainable use), and the protection or restoration of ecosystems.

Based on the alignment of its work agenda with international commitment to SDG 6, Embrapa selected 6 of the 8 targets established by the UN for this goal, with which it can effectively contribute to reach within the established deadlines, through research, technological solutions and support in the definition and implementation of policies, programs and actions developed or under development and also future studies. The targets selected were: 6.3 (by 2030, improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials, halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse globally); 6.4 (by 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity); 6.5 (by 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate; 6.6 (by 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes); 6.a (by 2030, expand international cooperation and capacity building support to developing countries in water- and sanitation-related activities and programmes, including water harvesting, desalination, water efficiency, wastewater treatment, recycling and reuse technologies); 6.b (support and strengthen the participation of local communities in improving water and sanitation management[1]).

From these targets, nine chapters were elaborated on the different themes that cover the selected goal. In Chapter 1, a contextualization is presented containing the relationship of SDG 6 with the world, with Brazil and with Embrapa, emphasizing the importance of sustainable water management and sanitation and water governance in Brazil. Chapter 2 summarizes the contributions of Embrapa to SDG 6, through its technological solutions, its role in federal government policy programs, and the numerous experiences with families and civil society partners, as well as its expressive collaboration with the universal access and use of water programs. In chapters 3, 4, 5 and 6, water is addressed involving quality, scarcity, efficient use, water resources management and water ecosystem conservation. Chapter 7 presents the actions developed by Embrapa for technical cooperation and training of farmers, technicians and policy makers on the rationalization, exploitation and integrated management of land use and water resources. Water and sanitation management in local communities is the focus of Chapter 8. And finally, Chapter 9 shows perspectives and challenges that will be faced to ensure quality water and sanitation for all by 2030.

Numerous technological solutions were generated and / or adapted by Embrapa concerning water and sanitation, throughout its 47 years of history. In this book, some of these technological solutions are compiled in order to organize a panel of the main technologies that deal with the six selected targets, providing society knowledge of the systemic and strategic vision of Embrapa in relation to water and sanitation in rural areas. Thus, this book presents examples of how Embrapa can contribute to the achievement of SDG 6 targets assumed by Brazil.

Technical Editors

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[1] Available at: <https://nacoesunidas.org/pos2015/ods6/>.

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Chapter 1

SDG 6 and its relationship with the world, Brazil and Embrapa

Rachel Bardy Prado
Lucília Maria Parron
Mônica Matoso Campanha
Maria Sonia Lopes da Silva
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Global context

Global water issues have been a source of concern and discussion at different levels of society. The United Nations (UN) estimates that global water demand is expected to increase by 50% by 2030. Two-thirds of the world's population currently lives in areas that experience water restriction for at least 1 month a year. About 500 million people live in areas where water consumption exceeds the availability of water resources, which in turn is intrinsically linked to quality, as pollution of water sources can curb different types of uses. Increased untreated sewage disposal, agricultural waste disposal and inadequately treated wastewater in the industry pose a risk of degradation of water quality throughout the world (Progress..., 2017).

Clean, quality water is essential for human health, well-being and prosperity. Access to sufficient water is a basic human need, both for their own consumption and for the development of their economic, cultural, leisure and other activities. However, water quality can be compromised by population growth and consequent increase in demand for this resource and the generation of waste in the development of such anthropogenic activities, which tends to worsen in the face of possible climate change, which threatens the global hydrological cycle (Nações Unidas, 2017).

Access to adequate and safe sanitation facilities is also vital for hygiene, disease prevention and human health. According to a recent report released by the World Health Organization (WHO) and the United Nations Children's Fund (Unicef) (Progress..., 2017), the number of people in the world without access to safe drinking water at home is 2. 1 billion, about 4.5 billion do not have access to safe basic sanitation, and about 892 million people practice open defecation.

Because of population growth, this situation has become more critical in sub-Saharan Africa and parts of Southeast Asia. In conflict-affected countries, children are four times less likely to use water services and two times less likely to have basic sanitation compared to children in other countries. Lack of basic needs, such as clean water, hygiene and sanitation under adequate conditions, increase the incidence of acute diarrheal diseases (ADD). According to WHO (Progress..., 2017), around 88% of ADD deaths worldwide are caused by lack of water, sanitation and hygiene treatment. A global picture related to such key factors, in the year 2015, by WHO (Progress..., 2017), is summarized in the following numbers:

- 6.5 billion people (98% of the population) have access to at least one water source 30 minutes from the collection point.
- 844 million people do not have access to drinking water.
- 263 million people spend more than 30 minutes traveling to collect water from a source.
- 159 million people still collect water for consumption directly from untreated surface sources, with 58% of them living in sub-Saharan Africa.
- 1.2 billion people (two out of five) who use securely managed health services live in rural areas.
- 1.9 billion people (27% of the population) use private sanitation services connected to sewage networks that are treated.
- The current available data are insufficient to estimate the proportion of the population using septic tank and latrines, where excreta are emptied and treated elsewhere.
- 2.3 billion people still lack basic sanitation services.
- 892 million people still practice open defecation.

According to a World Bank study (Nações Unidas, 2016), Brazil, Colombia and Peru are among the ten countries of the world with the greatest amount of fresh water available in their territories, Latin America being the continent that holds the largest resource. Despite this, 106 million Latin Americans still do not have a bathroom at home, and 34 million do not have permanent access to safe drinking water. This disparity can be explained in part by the fact that regions with greater water availability are not necessarily the areas with the highest population concentration, as is the case in the Amazon region, for example. However, as in other parts of the world, there are also extensive arid and semiarid areas in Latin

America, regions with water availability, often less than that necessary for the adequate care of the population present in these environments. These situations, aggravated by social, cultural and management issues, impose on the global community challenges to bring water, in quantity and quality, to all. This is the major objective advocated and stated by the Sustainable Development Goal 6 (SDG 6).

National context

In general, Brazil has a large water supply. At the same time, however, it also shows a significant difference between its regions in terms of water supply and demand. This results in watershed situations with scarcity and water stress where there is low availability and great demand of water resources, and places where there is an abundance of water due to high availability, but low demand. Since the beginning of the 1990s, the water sector in Brazil has been organized through the approval of legislation on water resources (Law 9,433/1997 and state laws) and the implementation of integrated management systems. According to the Sistema Nacional de Informações sobre Saneamento (National Information System on Sanitation – SNIS) (Brasil, 2014), linked to the Ministry of Cities, 83.3% of the Brazilian population has access to treated water for consumption. That means that there are still about 35 million Brazilians without access to this basic service. On social issues, the very structure of the cities that mostly grow without proper planning, the dimensions and environmental and social inequalities of the country present challenges to be overcome. The issue of supply in rural areas falls within the scope of difficulties of this goal of achieving the universalization of water supply and sanitation services for all.

Also in relation to water supply in Brazil, it is important to emphasize that the conflicts over water use have intensified in different river basins of the country, partly due to variations in the rainfall regime and, consequently, in the reduction of the flows normally observed in certain regions, but also due to a territorial planning and water resources that, in recent years, has been carried out in a more adequate way. Given this scenario, it is highlighted the importance of rational water use for irrigated agriculture, which accounts for about 70% of water consumed in Brazil (Agência Nacional de Águas, 2017). It should be noted that only a small portion of this water consumed for food production competes effectively and represents potential conflict with other sectors. This analysis should be done by river basin, case by case, and not by means of global averages. However, in urban environments, it is also important to highlight the need to improve treated water distribution systems, which have, on average, losses of 37% of water that already has a cost associated with the treatment, a value considered too high and that ends up being paid by the company without its usufruct.

In official reports on the situation of the national water situation (Agência Nacional de Águas, 2017), water quality data are usually presented as environmental indices. The water quality indexes systematize a large number of variables, classifying water bodies into quality bands. They are numbers that allow the attribution of a qualitative value to the environment, and translate a large number of complex information into simpler parameters to interpret and therefore serve as a tool in public policy decision-making. In this way, they enable the institutions responsible for water management to identify priority areas for action that deserve some form of intervention and more immediate control.

The water quality parameters analyzed reflect the environmental stress due to the human occupation and the activities practiced in the basin. In relation to water quality, there is a differentiation of polluting sources in urban and rural environments. In urban areas, where population density is highest, there is a predominance of pollutant sources related to domestic sewage and urban drainage effluents. In rural areas, diffuse loads, mainly associated with agricultural activities, represent the main source of pollution.

In Brazil, the Basic Sanitation Law, Law 11,445/2007 (Brasil, 2007), which establishes the guidelines for basic sanitation throughout the country and covers water supply, sewage, urban cleaning, waste management solid, drainage and urban storm water management) has already reached 10 years old. Although the water and sanitation sector has undergone improvements in recent decades, with significant advances, some 35 million people still do not have access to treated water, and half of the population – about 100 million – has no sewage collection. Furthermore, only 40% of the collected sewage is treated, the other 60% is released without treatment into water bodies (Rios; Sales, 2004). According to data from SNIS (Brasil, 2014), in the North region, where the situation is less favorable, only 16.4% of the sewage is treated, and the total service index is 8.7%. In the Northeast, only 32.1% of the sewage is treated. In the Southeast, 47.4% of the sewage is treated, and the total sewage service index is 77.2%. In the South, 41.4% of the sewage is treated, and the total service index is 41.0%. Finally, in the Midwest, 50.2% of the sewage is treated, being the region with the best performance, but the average treated sewage does not reach half the population. There is a great disparity within the same state, which may have cities with very high and very low rates of sewage treatment, and cities served by privatized services and others by public services. The problem is serious, and although the issue of basic sanitation affects everyone, the biggest losers and those who suffer the greatest impact are low-income families, many living in irregular and rural areas.

The water resources management system has several instruments: granting of use rights, information system, classification of water bodies into classes of use, collection for water use and river basin plans. In general, the implementation of these instruments is more difficult and slow in rural areas. For example, information on irrigation and watering of animals in terms of demand and their impacts on water quality are the most fragmented and precarious of information systems; the water uses in rural areas are the least regularized through the rights of use guarantee; water resources plans are still timid to ensure the protection of water sources; and charging for water use still faces resistance, especially concerning potential economic impacts and willingness to pay, competitiveness and uncertainties about the benefits generated by the application of the collection resources in the basin (Agência Nacional de Águas, 2017).

Economic instruments involving payment for environmental services, a promising route for the protection of springs, are being adopted by basin committees and water management bodies, such as the Produtor de Água (Water Producer) program of the Agência Nacional de Água (National Water Agency – ANA) (Santos et al., 2010) and other similar initiatives throughout the country. Potential benefits include reduction of diffuse pollution, silting and water treatment costs, among others. The implementation of collection in the country, as an economic and financial management instrument, aims to prevent and respond to situations of conflict over water use and pollution, contributing to water security, and consequently favoring economic growth and well-being (Organização para a Cooperação e Desenvolvimento Econômico, 2017).

It is necessary, however, to advance the water governance in Brazil, which involves political decisions, greater investments, mobilization and participation of society, efficiency in management, but also for the development of research solutions for the optimization of financial and human resources, for the reduction of water losses and reuse, by treatment and disposal of effluents and effective methods for agro-environmental conservation, which directly reflect water resources.

The SDG 6 at Embrapa scope

Embrapa, as a federal government's official research, development and innovation corporation, has contributed a great deal of technological solutions to the advancement of water governance in Brazil. An important advance is to understand water no longer as an unlimited resource. In this sense, the most efficient environmental policy is one that creates the conditions for economic agents to internalize the costs of the degradation they cause (Romeiro, 2012). The action of the State to correct this market failure consists of assigning to water use, in agricultural and industrial activities, values comparable to those attributed to the other economic inputs produced and traded on the market.

In September 2015, the UN (Nações Unidas, 2015) defined the 17 SDGs as part of a new agenda that should finalize the work of the Millennium Development Goals (MDGs), established in 2000. Embrapa plays an important role in fulfilling this new agenda through the knowledge and technologies generated that are increasing the efficiency of the use of water resources in the countryside.

As food and agriculture are related to practically all targets of SDG 6, Embrapa has aligned its work with the Brazilian commitment to the SDGs, in order to contribute with a theme as transversal as water, and thus to effectively participate with its researches and technological solutions to "ensure availability and sustainable management of water and sanitation for all" (Nações Unidas, 2015, our translation) in Brazil, collaborating with alternatives that may also be adopted in other countries.

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Chapter 2

Contributions of Embrapa overview

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Introduction

Everyone on the planet must have access to clean water and sanitation. This is the focus established by the SDG 6, inserted in a sustainability agenda to be adopted by the member countries of the United Nations (UN) and to be fulfilled until 2030. In this goal, targets are defined as the access to clean water and sanitation; improving water quality, reducing pollution, safe treatment and re-use; increasing the efficiency of use in all sectors; the integrated management of water resources; and the protection and restoration of water-related ecosystems, making use of both international cooperation and the participation of local stakeholders.

The issue of water and sanitation is transversal, with water being considered as a key resource for sustainable development, for the promotion of the well-being of people and communities, and for the growth of the countries' economies. In this sense, in Brazil, the theme has been worked by different sectors of government at different federative levels; and fostering the best tune between them is an institutional challenge.

Embrapa is among these sectors, developing research and disseminating its results related to several thematic lines aligned with the SDG 6. This chapter aims to present its main researches, as well as related strategic actions of Embrapa and its partners that have much to contribute in order to meet the SDG targets.

Strategic goals

The strategic programming of the Brazilian Agricultural Research Corporation (Embrapa), established in the VI Plano Diretor da Embrapa (Sixth Embrapa Master Plan – PDE) (Embrapa, 2015), presents the interfaces and synergies, directly or indirectly, by generating knowledge and technological assets for the sustainability of Brazilian agriculture, with the 17 SDGs and their targets (Brasil, 2016).

The impact axes and the strategic goals and guidelines of the PDE represent the directions for achieving the desired transformations (Embrapa, 2017b). Of Embrapa's five impact axes (IA), three have adherence to SDG 6, namely:

- IA 1 – Advances in the search for agricultural sustainability.
- IA 2 – Strategic and competitive insertion in the bioeconomy.
- IA 3 – Contribution to public policies.

Of the 12 strategic goals (OE) of the PDE, four are strongly aligned with SDG 6, which are:

- OE 1 – Develop knowledge and technologies for the adequate management and sustainable use of Brazilian biomes.
- OE 6 – Develop innovative production systems capable of increasing agricultural, forestry and aquaculture productivity with sustainability.
- OE 11 – Generate knowledge and technologies that promote managerial innovations to address the increasing complexity and multifunctionality of agriculture with efficiency, efficacy and effectiveness.
- OE 12 – Develop and disseminate information products and communication strategies that contribute to the valorization of agricultural research and to the expansion of society's support to Brazilian agriculture.

Research, development and innovation projects

Embrapa's research, development and innovation projects are organized into strategic themes of the Brazilian agriculture whose management has corporate information systems and management support tools called portfolios (23), covering topics of national relevance, and arrangements (84), organized to address priority challenges in a given theme (Embrapa, 2017b). Within Embrapa's research program, the portfolios and arrangements with the greatest affinity to the water theme in agriculture are: Irrigated Agriculture, Coping with Drought, Climate Change, and Environmental Services in Rural Landscapes – Arranjo SA and Coping with Droughts – Agrichuva (arrangements). Several others have affinities with the water theme, either by the technologies used in the different agricultural and forestry production systems, such as integrated crop-livestock-forest system, social innovation in agriculture, Aquaculture, Rational Management of Agrochemicals, Ecological Basis Production System, Food: safety, nutrition and health, Amazon; either through the vision of the ecosystems they work with, such as the portfolios Intelligence, Territorial Management and Monitoring, and Brazilian Soils.

Technological solutions

The knowledge generated is largely translated into products, processes and services for the agricultural sector, composing a wide range of technological solutions. There are also included in this set of technological solutions to the methodologies, agricultural practices and production systems. In addition, this information also contributes to the formulation and improvement of public policies in areas related to Embrapa's mission.

In accordance with SDG 6, Embrapa has several Technological Solutions developed or adapted for the different Brazilian biomes, which show how to use water in agriculture with rationality and without waste, for plant and animal production (Embrapa, 2017d). In addition to agricultural production, technological solutions are available for the recovery/maintenance of ecosystems, improvement of water quality and the quantity of water available.

Within the thematic of water use in agriculture, Embrapa highlights the following technologies: irrigation management; monitoring of water availability; technologies of adequacy of properties for abstraction of rainwater; recharge of groundwater and revitalization of springs and streams; in addition to others such as underground dam, reuse of agricultural water and use of inferior quality water (brackish and saline); rural cisterns, soil and water conservation practices in production systems; use of cultivars adapted to the water conditions of the region (Embrapa, 2017a).

Among the technological solutions related to the quantity and the water supply, the following stand out: the lakes of multiple use, that in addition to the storage avoid the contamination of the water table; the different methods for collecting rain in situ (furrow, plowing), cistern, *barraginha* (mini-dams), underground dam, floating cages, among others. For irrigation, they involve both the improvement of irrigation systems for different crops, such as equipment technologies, sensors, irrigation parameters (evapotranspiration, crop coefficient, soil water retention curve) and modeling for greater efficiency in water use, as hydrological models that simulate the availability of water; besides the possibility of fertigation and use of secondary waters, as effluent of fishery.

In relation to the soil and water conservation practices, there are those that reduce soil erosion and help the storage of soil water, such as building *barraginhas* (mini-dams); no-tillage; management of green cover crops and dead cover crops; underground dam; use of crop consortia and integrated production systems such as integrated crop-livestock-forest (ILPF), agroforestry systems and afforestation of pasture; design and construction of terraces; besides the good agricultural practices for different cultures, that aim at the rational use of inputs and pesticides and compliance with the legislation for rural property. The technologies of concentration evaluation and leaching of pesticides in the soil are also presented; treatment of wastewater as wash water for animal facilities, post-harvest treatment of fruit and mining waste; composting of animal and vegetable waste; mini-dam building.

Among the technological solutions related to farms, it is important to highlight: technologies for the recovery of degraded areas, such as revegetation of gullies with legume species; implementation and management of both natural and planted forests. In the rural sanitation, Embrapa stands out with technologies widely used and applied by it and partners, namely: Embrapa chlorinator, used to chlorinate water for domestic supply; the biodigester septic tank, which enables the treatment of domestic sewage (black waters) with the production of liquid fertilizer; and the filtering garden, with the purpose of purifying the gray water, complementing the treatment of sewage in the rural areas through the biodigester septic tank.

Many of these technological solutions aimed at meeting SDG 6 will be described in subsequent chapters, pointing out their current application, future potential and limitations.

Governmental partnerships and programs

Embrapa operates in the federal sphere with implementation or expansion of government programs/policies, especially the Water Producer program of the National Water Agency (ANA); the payment program of the Serviço Florestal Brasileiro (Brazilian Forest Service), of the Ministry of the Environment (MMA); and the Programa de Capacitação para Gestão Integrada e Sustentável da Água no Meio Rural (Training Program for Integrated and Sustainable Water Management in the Rural Environment). In this sense, Embrapa presents other technological solutions that also include methodologies such as those for mapping and evaluating environmental service indicators, as well as manuals for implementing programs of Environmental Payments for Services – PSA) and environmental valuation; consulting services; mapping products and agro-climatic and agro-ecological zoning; software to support irrigation management, such as IrrigaFácil; and several courses of training and qualification of agent multipliers of knowledge. All these technological solutions have a positive impact on society and the country. In 2016, the economic impacts and social gains of 117 technologies and around 200 Embrapa cultivars were determined, indicating that each US$ 1.00 invested in the Company returned US$ 11.34 for the Brazilian society (Embrapa, 2017c).

Embrapa has shared many experiences with families and government and civil society partners in order to promote knowledge exchange, which has greatly contributed to advances in the proper use of natural resources, especially soil, aiming to capture and store rainwater, in order to collaborate with the socioecological strategies for family farmers of regions with water shortages to face climate change. This fact has helped overcome the social and environmental limitations of the Brazilian semiarid region, using the technologies of coping with the semiarid region as the source to improve and balance the productive process, promoting greater stability of the family agro-ecosystem, consequently improving the family's quality of life.

Embrapa has also had significant collaboration with federal government water access programs, such as the Plano Brasil sem Miséria (Brazil Without Misery Plan – PBSM) and the Programa Nacional de Universalização do Acesso e Uso da Água (National Program for Universal Access to and Use of Water for All – Água para Todos). Both programs were conceived by the federal government based on the need to universalize access to and use of water for poor populations living in rural communities, not served by this essential public service, served by poor water supply systems, or by diffuse supply. Through its innumerable technological solutions, Embrapa has participated in several actions aimed at the uses of water for food production, which has contributed to food and nutritional sovereignty and security, consequently to the valorization of citizenship and the quality of life of the families of agricultural production systems in regions with water shortages. Another significant performance of Embrapa concerns technical cooperation aimed at supporting capacity building for developing countries, especially in rainwater harvesting and storage activities.

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Chapter 3

Water quality and pollution reduction

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Introduction

This chapter addresses Embrapa's contribution to target 6.3, which relates to water quality and pollution reduction. Decreasing the availability of good quality water is a growing and global concern. Monitoring water quality, coupled with the adoption of good soil and water management practices and the use of technologies to reduce the production of contaminants, can contribute significantly to minimizing this problem and ensuring good quality water for all. The present chapter sought to list search results that point out paths that can be followed. More information is available on the portal Technological Solutions at Embrapa (Embrapa, 2017b).

The water situation of most rivers in Latin America has been critical since the 1990s. Organic and pathogen pollution increased by more than 50% between 1990 and 2010, while pollution by total dissolved solids (salinization) worsened by almost one-third in the rivers of Latin America, Asia and Africa. The concentration of fecal coliforms increased by almost two thirds in the rivers of Latin America, Africa and Asia between 1990 and 2010 (A snapshot..., 2016). The release of dangerous chemicals, including those that can cause hormonal disorders, has increased during this time. The contribution of nutrients, such as phosphorus and nitrogen, promotes the eutrophication of rivers and lakes, harming natural processes. This increase in pollution was attributed to population growth, increased economic activity, the intensification and expansion of agricultural activities and the increase of wastewater discharge with little or no treatment in water courses. The negative consequences have an impact on health, fisheries, ecosystems, water use for irrigation and industry, and the cost of water treatment, among other uses (A snapshot..., 2016).

Actions for the maintenance and recovery of water quality

Among the actions required for the maintenance and recovery of water quality, the most important are those related to the monitoring and evaluation of water quality and to those associated with technical and management measures for pollution prevention, reduction of the pollutant load, integrated use of water in complementary activities and restoration and protection of ecosystems. Most of the solutions presented here were developed in partnership with research and extension institutions, governmental and civil society.

Monitoring and evaluation of water quality

Quality is not a static condition of an environment or system, nor can it be defined by the measurement or estimation of a single quantity. When it comes to water, quality is perceived as the variation of a set of intrinsic parameters that limits its use, being extremely variable in time and space. When reliable data are available on water quality, its safe use becomes possible. This data can be used as support for implementation of public policy. However, reliable data will only be available when monitoring and diagnostic programs are well designed and conducted (Matthiensen, 2014). The definition of quality benchmarks is an important aspect of water monitoring (Oliveira-Filho et al., 2014). Some of the contributions of Embrapa in this area are listed as follows. Detailed information and reference materials on contributions from Embrapa can be found on the portal Technological Solutions, such as:

- Estimation of pesticide concentration in soil and water (Embrapa Environment).
- Monitoring of water quality in tambaqui fattening in fish ponds without water renewal (Embrapa Coastal Tablelands).
- Method for assessing the aquatic toxicity of mining solid waste (Embrapa Cerrados).
- Methodology for environmental risk assessment in water resources (Embrapa Territorial).
- Numerical simulation of the presence of organic contaminants in soil and water (Embrapa Environment).

- Evaluation of the degree of restriction to the use of groundwater in crop irrigation considering soil sodification in the Vaza-Barris River Basin (Embrapa Coastal Tablelands).
- Araquá 2014 – environmental risk assessment of pesticides (Embrapa Territorial and partners).
- Analysis of the impact of cattle breeding on water quality (Embrapa Cerrados).
- Comparative analysis of the quality of water resources in urban and rural areas (Embrapa Cerrados).
- Analysis of the impact of burnt ash on the quality of water resources (Embrapa Cerrados).
- Watershed quality index – a methodology to support strategies for water resources management (Embrapa Pantanal).
- Agroscre – support for the evaluation of transport trends of active pesticides (Embrapa Environment).
- Estimation of pesticide concentration in soil and water (Embrapa Environment).

Technical and management measures

Pollution prevention

Pollution sources can be classified as point or diffuse. Point source pollution occurs when the source of pollution is easily identifiable and usually comes from a single location. Industrial effluents and domestic sewage are examples of point sources. Nonpoint source pollution does not present a definite source, and it is difficult to identify its origin. Unlike point source pollution, nonpoint source pollution is always associated with a specific use of soil (Matthiensen, 2017). Agriculture is a major contributor to nonpoint source pollution in rural areas. In areas of planting and animal production, sources of nonpoint pollution include pesticides, chemical fertilizers, fertilizers and animal waste that, when in excess in the soil, are infiltrated or carried along with the sediments by rainwater into the water bodies (A snapshot..., 2016). Excess sediment in water bodies results in high turbidity, silting and eutrophication, compromising areas of species reproduction and leading to the loss of aquatic habitats. Agrochemicals are transported by surface waters, which can compromise the health of domestic and wild animals, as well as of the people who make use of this water. The degradation of water resources by agricultural activities can be mitigated by conservationist practices in the property, such as the dimensioning of production, proper waste management and maintenance of ciliary forest (Matthiensen, 2017).

Information and reference materials related to pollution prevention are available on the Embrapa Technological Solutions portal. Some of the contributions of Embrapa to reduce the use of pesticides and chemical fertilizers are:

- Biological insecticide INOVA-Bti (Embrapa Genetic Resources & Biotechnology).
- Clean technology for post-harvest treatment of fruits (Embrapa Environment).
- Sustainable management of the main pests in the sugarcane crop (Embrapa Western Agriculture).
- Control of weeds in pasture (Embrapa Beef Cattle).
- Evaluation of environmental behavior (leaching, dissipation, surface runoff, etc.) of agrochemicals in different production systems and soil management (Embrapa Cerrados, Embrapa Western Agriculture and Embrapa Environment).
- Determination of the percentage of water exchange in fish farms (Embrapa Environment).
- Method for determining the quantity of sewage sludge for agricultural use as a source of nitrogen (Embrapa Environment).
- Safety analysis of microbiological agents for pest control (Embrapa Cerrados).
- Anonáceas – instructions for the use of pesticides (Embrapa Cerrados).
- Mango – instructions for the use of pesticides (Embrapa Cerrados).
- Integrated citrus production in Rio Grande do Sul (Embrapa Temperate Agriculture).
- Integrated strawberry production – PIMo (Embrapa Environment).
- Integrated management of soybean pests – MIP-Soybean (Embrapa Soybean).

- Organic coffee production system (Embrapa Agrobiology).
- Integrated production of mangoes, fine table grapes and melon (Embrapa Semiarid Agriculture and Embrapa Grape & Wine).

Regarding the reduction of the release of contaminants, the following contributions may be mentioned:

- Tambaqui production in excavated tanks with aeration (Embrapa Western Amazon).
- Training for waste management in the dairy farm (Embrapa Dairy Cattle).
- Biobed Brazil – final disposal of effluents contaminated with pesticides originating in agriculture (Embrapa Grape & Wine).

As for the reduction of sediment transport, the main technological solutions are:

- Agronomic practices of soil and water management and conservation and recovery of degraded areas (Embrapa Soils).
- Revegetation of gullies with inoculated and mycorrhized tree legumes (Embrapa Agrobiology).
- Good agricultural practices for the areas of springs: erosion control and optimized application of pesticides (Embrapa Environment).
- Multiple use pond (Embrapa Maize & Sorghum).

Reduction of the pollutant load that reaches the water bodies

Brazil has approximately 31 million inhabitants living in the rural area. Out of this population, 22% have access to basic sanitation services, and almost 5 million people do not have toilets. The use of rudimentary pits (septic tank, well, hole, etc.) is common and they contaminate groundwater. Sewage contains pathogens (viruses, bacteria, parasites), organic matter and chemical residues such as drugs. When organic pollution is severe, it can reduce the levels of dissolved oxygen in the water and raise the concentrations of ammonia and hydrogen sulfide, which are associated with the sediments and the bottom waters of rivers, compromising aquatic life (A snapshot..., 2016). Embrapa has simple and feasible solutions for rural basic sanitation, sewage and effluent treatment, and fundamental to change this reality, available in the rural basic sanitation (Embrapa, 2017a) and Technology Solutions portal, such as:

- Treatment of waste water from the acaricide bath (Embrapa Southeast Livestock).
- Cellulose nanocrystals for sorption of metals (Embrapa Genetic Resources & Biotechnology).
- Biodigester septic tank (Embrapa Instrumentation).
- Filtering garden (Embrapa Instrumentation).
- Biobed System (Embrapa Grape & Wine).

Integrated water use in complementary activities

The integration and optimization of multiple uses is among the alternatives pointed to increase water efficiency. In this management model, the water supply usually comes from a common system – the river basin – and the surplus of use and the effluents are once again integrated into the system. Thus, water resources are used more efficiently, maximizing the benefits. In several countries, this integration of uses is consolidated. In Brazil, Embrapa's studies with these integrated production systems are recent, requiring research to define the best form of exploitation (Santos, 2009). Two of Embrapa's technological solutions available on the portal are:

- Oyster bioremediation in aquaculture (Embrapa Mid-North).
- Recommendation of multiple use of water in the cultivation of cowpea with effluent from fish farming (Embrapa Mid-North).

Ecosystem restoration

Ecological restoration can be defined as the process and practice of assisting the recovery of an ecosystem that has been degraded, damaged or destroyed. The role of natural or restored ecosystems in protecting the quality of surface water is well understood, especially in riparian zones. Restoration interventions should prioritize the recovery of soil and vegetation in the most fragile sites, in the uncovered areas and in the sections of the basin subject to greater surface runoff and, therefore, exposed to greater risks of erosion and silting. Springs and sloping lands should therefore be primarily protected (Honda; Durigan, 2017). There are several ways to do the restoration, and choosing the right model is partly responsible for success. Among the contributions of Embrapa for the restoration of ecosystems available in the Technological Solutions portal are:

- Diagnosis and planning of actions for the recovery of degraded ecosystems – RED (Embrapa Forestry).
- Direct tree seeding for ecological restoration of the Brazilian *Cerrado* (Embrapa Genetic Resources & Biotechnology).
- Topsoil for restoration of *Cerrado* vegetation in degraded areas (Embrapa Genetic Resources & Biotechnology).
- Implantation and management of forests in small-scale farms (Embrapa Forestry).
- Agroforestry systems – SAFs (Embrapa Agrobiology e Embrapa Western Agriculture).
- Management of molasses grass (*Melinis minutiflora*) in areas with *Cerrado* native vegetation (Embrapa Genetic Resources & Biotechnology).
- Production of seedlings of forest species (Embrapa Forestry).

Final considerations

When a water source is exposed to human activity, there are risk situations that increase its vulnerability. Conservation measures of this resource need to be studied and adopted to mitigate impacts that alter its quality and quantity, but without affecting its availability to meet its demand.

There are available technologies of different degrees of complexity capable of minimizing, or even avoiding, problems related to water contamination. It is important that this information reaches society, and especially the technicians and promoters of public policies capable of causing greater impact and facilitating the effective adoption of these technologies. The availability of the material in the Embrapa portal is an important step in facilitating this disclosure, allowing also the research centers involved in the process to collaborate more closely, if necessary, both to deepen their studies and seek solutions to specific problems, such as the elucidation of technical aspects for the implementation of these technologies.

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Chapter 4

Water use efficiency and supply in agricultural production

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Introduction

This chapter discusses aspects related to the water-use efficiency in irrigated agriculture and animal production, as well as possibilities to use rainwater as a way to reduce the effects of regional climate irregularities, and alternatives to using brackish/saline water, constituting a strategy of utilization of available water resources. This information, expressed in the form of knowledge and technologies generated by Embrapa, has the potential to contribute to the achievement of target 6.4, which seeks, by 2030, to substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity, and substantially reduce the number of people suffering from water scarcity (Nações Unidas, 2017).

Water use efficiency in irrigated agriculture

Agricultural production depends fundamentally on the water availability, in which this activity corresponds to 72% of water consumption in Brazil (Agência Nacional de Águas, 2018). The high consumption demand, coupled with the increasing scarcity of water resources, requires commitment and responsibility of all to guarantee food production for the growing population, so that less water is used without reducing the maximum production potential of the crops. In Brazil, irrigation efficiency is approximately 60%. The impact of the improvement of only 1% of this efficiency is observed when evaluating the effect of applying a water slide of 4 mm day^{-1} in 1 ha, which will save about 1.3 thousand L ha^{-1} (Coelho; Silva, 2014). In the Northeast, the irrigated areas with fruits and vegetables have increased significantly, since the climate is highlighted by the high incidence of solar radiation and low and irregular precipitations. In practice, the efficient use of technologies generated by Embrapa and partners has provided productions at different times of the year. Aware of the water problem in the region and with due competence, Embrapa has provided adequate knowledge and technology to minimize water consumption in irrigated crops, but not reducing its productive capacity. Following there are some of the technological solutions generated and/or adapted by Embrapa and partners that can contribute to Brazil's effective collaboration with target 6.4 of SDG 6.

Management of irrigation water by soil water balance

This practice consists of avoiding that the soil reaches a level of moisture between the irrigation systems, which compromises the maximum productivity of the crops, and it is ideal to keep it close to its maximum water retention capacity up to the effective depth of its root system. Embrapa has contributed with the following techniques of optimization and practicality of this management:

- Use of the Irrigas Sensor: (Marouelli et al., 2010). In this study, the effect of different irrigation systems was evaluated. It is a simple and inexpensive system, much more accessible than other equipment available in the market for soil moisture measurement.
- Recommendation of the number and positioning of soil water sensors for irrigation water management: a technological solution developed by Embrapa Cassava & Fruits has helped producers to define the ideal installation site and the number of soil moisture sensors for different crops, soil types and irrigation systems (Coelho; Coelho Filho, 2007; Silva et al., 2007; Sousa et al., 2011; Coelho et al., 2012; Coelho; Simões, 2015).
- Recommendation of the moment of irrigation by critical soil moisture: a technological solution to indicate the momentum and irrigation depth in banana and papaya under climatic conditions of Coastal Tablelands, from the critical moistures for different types of soil (Sousa et al., 2011; Coelho et al., 2012).

- Description of the effective depth of the root system of the crops: technological solution to facilitate irrigation water management by the producers (Coelho; Simões, 2015; Coelho et al., 2008).

Management of irrigation by crop evapotranspiration

The knowledge of crop evapotranspiration is fundamental to irrigation management, resulting from the product between the reference evapotranspiration (ETo) and the crop coefficient (Kc). In ETo determination, climatic data provided by meteorological stations, as well as the evaporation obtained through the class A tank, are used. In practice, ETo data available for a given location can be used in areas up to 40 km away from the station (Moura, 2007). The Kc is directly related to the variety, the phenological stage, the height, the coloring of the leaves, the location of the property, among others. In order to improve water-use efficiency, Embrapa has conducted research to determine Kc for the main crops harvested in the country's irrigated poles (Teixeira et al., 1999, 2008; Moreira et al., 2001).

Other irrigation management strategies aiming at greater efficiency of water use being tested by Embrapa researchers are the application of irrigation with controlled deficit, which reduces the amount of water applied in one of the phases of the crop; alternating lateral irrigation, with a deficit in parts of the irrigation system; and planting with soil cover, which minimizes evaporation, reducing the amount of water to be applied. In addition to the reduction of the amount of water applied, these strategies do not interfere with the production and quality of the final products (Stone et al., 2008; Santos et al., 2014).

Rainwater harvesting and efficient use

In the Brazilian semiarid region, precipitation is the only source of replenishment for water reservoirs used to meet the consumption demands of families, animals and agriculture. It occurs variably in quantity, intensity, space and time. The underground water potential is restricted and of low quality, due to the predominance of crystalline rocks, which have low flows and high salinity levels. Among the alternative solutions, the strategies for capturing rainwater for productive coexistence in the region are mentioned. These technologies are consolidated in public policies, through the Programa Cisternas (Cisterns

Program) (Brasil, 2017)[1], with 1.3 million cisterns installed throughout the country, especially in the Brazilian semiarid region.

In situ capture

In situ uptake is made up of soil preparation techniques to induce runoff to the planting area, increasing the time of infiltration of water into the soil (Anjos et al., 2007; Brito et al., 2008).

Cistern

The research carried out at Embrapa Semiarid Agriculture had the challenge of reducing construction costs, filling the insufficient coverage of rural facilities that could be used as a catchment area, and demonstrating its technical efficiency as a reservoir for the storage of rainwater in semiarid conditions. The most widespread models, which are being implemented throughout the Brazilian semiarid region by the Cistern Program are 16 m^3 for human and animal consumption and 52 m^3 for food production (Figure 1). Embrapa Semiarid Agriculture has been developing researches on the efficiency of water applied in the production of fruits and vegetables for both types of cistern (Brito et al., 2012; Brito, 2016). The rural cistern, due to its importance in human and animal watering, as well as in food production, has been the main technology for water abstraction for rainfall dependent areas in the Brazilian semiarid region.

Underground dams

The research carried out by Embrapa Semiarid Agriculture since 1982 contributed to technological innovation, with the inclusion of drainage lines/waterways as one more favorable location option for construction; with a reduction in costs and construction time, of which excavation started to be done with a backhoe excavator, and as a layer of impediment the use of PVC plastic canvas or polyethylene of 200 microns thickness (Brito et al., 1989). Experiences shared by Embrapa Semiarid Agriculture and Embrapa Soils (UEP Recife) with family farmers confirm that the underground dam (Figure 2) reduces the risks of regional climate irregularity, thus favoring crop development and productivity, which has

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[1] Message sent by e-mail, on November 16, 2017, by the coordinator of the Cistern Program.

Photo: Nilton de Brito Cavalcanti

Figure 1. Tank for food production.

Photos: Maria Sonia Lopes da Silva

Figure 2. Opening of the dam of the underground dam (A); placing the plastic in the ditch by waterproofing the wall (B); ditch closing (C); underground dam ready, with wall, well, bleeding and planting area (D).

contributed with the socioecological and economic resilience, consequently with the sustainability of the agroecosystems of the Brazilian semiarid region (Melo et al., 2013; Nascimento et al., 2015; Silva, 2017).

Water use efficiency in animal production

In the livestock context, the topic water must be worked in all points of the production chain of the different species and in several fronts of the production system. Water must be calculated for animal watering, food production, animal hygiene, among others, and free access to quality water is a basic condition essential to good production practices and animal welfare. In this sense, Embrapa has been working with guidelines to assist producers, technicians, extension workers and managers to manage natural resources and conserve the environment, through publications on the quantity to be offered for each animal category, adequate sizing of the drinkers according to the number and category of animals, adequate water flow to supply drinking fountains, adequate distribution of drinking fountains (Campos, 2000); practical solutions to reduce water and feed waste in pig farms (Lima et al., 2012); good water practices related to the activity of dairy cattle production (Palhares, 2016b); water quality in animal production (Palhares, 2014); rainwater harvesting and use in animal production (Brito et al., 2007; Palhares, 2016b); water challenges for animal production (Palhares, 2016c); among others.

An important source of water that contributes to the reduction of its consumption by the animals is the food that has in their composition 40% to 90% of water. As an example, there are rich forages such as forage palm, mandacaru, grasses, vegetables and forage watermelon (Araújo et al., 2010). Another important source is in fodder preserved in the form of silage, such as corn, sorghum and millet. Agroindustrial byproducts (brewer's residues, sisal defibration and fruit processing) are also viable alternatives for the water supply to the semiarid herds, as they can contribute to the attendance of up to 80% of the water demand of the animals. The additional input of water contained in food is especially important for animals raised in regions and communities with little access to drinking water.

Multiple uses of saline water

It is estimated that, in the Northeast, there are more than 100 thousand deep wells, with average flows around 2 thousand L per hour. It is important to emphasize that, in most cases, the waters of these wells present levels of salts higher than 1 g L^{-1}, rendering them unfit for human consumption. However, these sources of water are essential for animals, especially goats, whose water demand for watering the entire herd in the region is about 40 million m^3 per year. Embrapa Semiarid Agriculture, in partnership with other institutions, developed an integrated production system in which parameters were established for the use of brackish or saline waters, both for human and animal consumption, as well as for plant production and aquaculture (Porto et al., 2004).

Several studies on the subject were developed involving management of irrigation with brackish/saline water in the crops bean, beet, forage and grain sorghum, maize and salt grass (forage) (Nogueira Filho et al., 2003; Assis Júnior et al., 2007; Carvalho Júnior et al., 2010; Guimarães et al., 2016; Simões et al., 2016), with information on water management techniques such as: ideal leaching factors (LF), the amount of water being greater than necessary, which is applied to provide reduction of the amount of salts of the root zone of the crop; and the varieties adapted to the saline environment, highlighting the choice of soil with good drainage to facilitate the leaching of salts in the rainy season, which facilitates new crop cycles.

Regarding animal intake, from the salinity point of view, waters with high salt content, as well as those containing toxic elements, represent a danger and can affect the quality of the meat and milk produced. The management of animal consumption in relation to water salinity is based on the classification of Runyan and Bader (1994). It is emphasized that the use or the ingestion of water by the animal can be directly related to different variables, besides the quality (Nutrient..., 2007).

Another alternative is the use of brackish/salted waters for aquaculture. Species such as tilapia (*Oreochromis niloticus*) and Pacific white shrimp (*Litopenaeus vannamei*) are suitable for cultivation in brackish waters, since they are rustic and accessible in Brazil. Currently, there is the possibility of producing tilapia and shrimp intensively using water from salinized wells. In this system, rejects from fish farming are being indicated for the cultivation of salinity-tolerant crops that serve for human and animal feeding (Dias et al., 2012). However, as described previously, this model of biossaline agriculture requires that the management be sustainable in a rational, economic and environmental way.

Final considerations

The efficiency of water use is an indispensable tool for the sustainability of agroecosystems. In the case of biossaline agriculture, the choice of irrigation and crop management is fundamental for a socioeconomic and environmental sustainability. Rainwater harvesting technologies respond to the demands of the Brazilian semiarid rural environment, both in the context of family consumption, focusing on aspects of quality, quantity and regularity, attending to the consumption of animals, as well as reducing the risks of agricultural exploitation climate variability. Much needs to be done to provide families in this region with rainwater harvesting technologies capable of overcoming years of drought, similar to 2011/2012 to 2017, and enabling productive coexistence of the population with climatic adversity. The use of rainwater, accompanied by a set of technologies adapted to local conditions, combined with the training of families and extension agents, could contribute to the change of this scenario. In the socioeconomic context, most of these technologies are inserted in the concept of social technologies.

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Chapter 5

Integrated water resources management

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Introduction

Target 6.5 of SDG 6 – implement integrated water resources management at all levels – is the subject of this chapter and is discussed in four topics. The introduction topic presents a general explanation on the concept, implementation and tools of integrated water resources management (IWRM). The second item deals with the conditions and instruments needed for the implementation of IWRM and how they have been applied in Brazil. The third presents the challenges to be overcome and some examples of contributions from Embrapa to the implementation of IWRM. The fourth and last topic shows a reflection on future perspectives to increase Embrapa's contribution to the implementation of integrated, participatory and decentralized water management giving support on science, technology and information.

The concept of integrated management has been developed throughout history, incorporating new meanings since the last decades of the 20th century, when the increase of environmental problems on the Earth led to the proposition of sustainable development goals (Report..., 1987; Snellen; Schrevel, 2004). The Global Water Partnership (Integrated..., 2000, p. 22) presented the following definition of IWRM:

> IWRM is a process which promotes the co-ordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.

In order to implement integrated management, it is necessary to develop an adequate environment with legislation, policy and management plans besides an institutional infrastructure in which tools, rules and stakeholders' roles are well defined. The IWRM advocates social participation through monitoring and evaluating water management applied in the smallest possible territorial unit identified as a river basin. Strategies for capacity building management monitoring should be established, implemented and constantly updated. Management evaluation should be based on indicators selected to demonstrate the progress of the measures adopted and their effects on the quality of water system management.

Integrated management of water resources

According to Status... (2012), IMWR proposes some conditions for its viability, as:

- Cross-sectoral management and consideration of multiple uses of water.
- The development of an enabling environment of management.
- The decentralization and participation of the different actors involved.
- The creation of institutional infrastructure: legal framework and roles definition.
- An information system on water resources for sharing.

In Brazil, the legal and institutional framework to create an enabling environment for IWRM was established by the Política Nacional de Recursos Hídricos (National Policy of Water Resources – PNRH), Law 9,433/1997 (Brasil, 1997), known as the Lei das Águas (Water Law). This policy was based on the IWRM principles enrolled in United Nations (UN) documents: The Dublin Statement (International Conference on Water and the Environment, 1992) and Agenda 21 (United Nations Conference on Environment and Development, 1992). The fundamentals of the PNRH (Brasil, 1997) are:

- Water is a public good.
- Water is a limited natural resource endowed with economic value.
- Under scarcity conditions, the priority water use is the human and animal supply.
- The management of water resources should always provide multiple use of water.
- The water basin is the territorial unit for the implementation of PNRH and the Sistema Nacional de Gerenciamento de Recursos Hídricos (National System of Water Resources Management – Singreh).

- The management of water resources should be decentralized and involve the participation of government, users and communities.

The objectives and general guidelines of the PNRH make clear reference to the integrated management of water resources as well as the needs of the current and future generations. The Law of Water, or Law 9,433/1997, also established instruments for the management of water resources and created Singreh with integrated, decentralized and participatory management as its guideline. The decentralizing character of the PNRH was expressed by the creation of a national system that integrates the federal government and states. The participatory character of this system requires the installation of river basin committees, in which the federal, state and municipal authorities, water users and civil society operate.

The instruments of integrated management of water resources are (Status..., 2012):

- Evaluation of water resources (monitoring networks, assessment techniques and environmental impact studies – EIA).
- Communication and information to enhance the awareness of decision makers.
- Instruments of water allocation, cost and benefit assessment and conflict resolution.
- Direct regulatory instruments (master plans of use, regulations, etc.) and economic instruments (prices and tariffs, taxes, subsidies, incentives, fines, etc.).
- Technology (research and development, guidelines for evaluation and selection of technologies).
- Public and private financing of IWRM considering its high rate of return for society.

In Brazil, the PNRH established the following management instruments (Brasil, 1997):

- The water resources plans of states and basins.
- The classification of bodies of water into classes, according to the predominant water uses.
- The granting of rights to water use.

- The charging for the water use.
- The compensation to municipalities.
- The Sistema de Informações sobre Recursos Hídricos (Water Resources Information System – SIRH).

In addition to these instruments, Law 9,433/1997 defines Singreh and the roles of stakeholders that participate in the systems instances:

- The Conselho Nacional de Recursos Hídricos (National Council of Water Resources – CNRH).
- The Agência Nacional de Águas (National Water Agency – ANA).
- The Water Resources Councils of the States and the Federal District.
- The River Basin Committees.
- The federal, state, Federal District and municipal institutions related to the water resources management.
- Water Agencies.

The creation of an information system for compiling, organizing and sharing of water resources data is one basic requirement for integrated management. The PNRH law established the Sistema Nacional de Informações sobre Recursos Hídricos (National Information System on Water Resources – SNIRH), defined as "[...] a system for collecting, processing, storing and retrieving information on water resources and factors involved in its management" (Brasil, 1997, art. 25, our translation). Its principles include the decentralization of the collection and production of data, the coordination of the system and the guarantee of access to data and information to all members of society.

Challenges to reach IWRM and the contributions of Embrapa

Since the publication of Law 9,433/1997 (Brasil, 1997), there has been much progress in the institutional framework to IWRM, including the creation of the National Water Agency (ANA) by Law 9,984/2000. ANA is responsible for implementing the National Policy of Water Resources (PNRH) and the federal water resources management. The agency also integrates the National System of Water Resources Management (Singreh) (Brasil, 2000).

Considering the IWRM demands for cross-sectorial action and for integrated water and land management, Embrapa offers fundamental contribution to development of knowledge and technology in the agricultural sector, which also includes forestry production, fishery and aquaculture.

Agriculture accounts for 54% of total water withdrawals (Conjuntura..., 2017) with impact on water resources even in a scenario where rain-dependent agriculture is predominant. ANA's annual report on water resources, *Conjuntura das águas* (Conjuntura..., 2017), points out that total water withdrawals for the different sectors reached 2,057 $m^3 s^{-1}$ in 2016, while consumption was 1,081 $m^3 s^{-1}$, calculated as the difference between the withdrawals and the return water volume. The agricultural sector accounts for 78% of this total consumption, 67% for irrigation and 11% for animal supply. The difference between agriculture participation in water consumption and withdrawals is due to the low return volume from irrigation diverted water as a greater part is used evapotranspiration.

According to the management adopted, the farming systems can be either detrimental or beneficial to water services in terms of quality, availability and habitat for biodiversity. As an agricultural research institution, Embrapa aims at the generation of technologies for the sustainable management of production systems, improving the integrated management of land and water resources. A set of these technological contributions to reach IWRM are grouped according to five challenges presented in the report *Conjuntura 2017* (Conjuntura..., 2017), as follows.

Environmental management

Considering the conflicts between the demands of the user sectors and the environmental agenda, one of IWRM challenges is to improve the integration of water resources management with this agenda through seeking the internalization of concepts such as sustainability, ecosystems and ecosystem services by economic sectors. The main technological contributions developed by Embrapa to cope with this challenge are the following:

- The ARAquaGEO tool: spatial analysis of the environmental risk of water contamination.
- Monitoring and quali-quantitative characterization of rural basins (The AgroHidro Project).

- Characterization of hydrological behavior and parameterization of models applied in different Brazilian biomes (The SWAT-Cerrado Project and Rede Nacional de Bacias Experimentais e Representativas – National Network of Experimental and Representative Basins – ReHidro).
- Spatially explicit approach for mapping ecosystem services and assessing environmental impacts including water-related services and impacts (MapES).
- Payment for environmental services: monitoring and selection of areas.
- Diagnosis of suspended sediment flow in Brazilian rivers.
- Methods of drinking water treatment for rural communities of the Brazilian semiarid region (Sodis).

Demand-side water management

The practices of rational use of water, loss reduction, demand control and water management by the agricultural sector have gained valuable contributions from Embrapa through decision support models and other technologies to an efficient use of water in agriculture. Some of these contributions are listed as follows:

- Mapping of irrigated areas in Brazil.
- IrrigaWeb: online training on the use and management of irrigation.
- Low-cost irrigation management for family farming in the semiarid region.
- Rede de Agricultura de Precisão (Precision Agriculture Network): technological development to improve accuracy and efficiency in the use of water, soil and inputs by agriculture.

Water security and risk assessment

The concept of water security has raised challenges related to the commitment ensuring water for human supply and productive activities in a sustainable way, such as reducing the risks of critical events of droughts and floods associated with climate change and variability. The main technological solutions proposed by Embrapa are:

- Impacts of climate change and agriculture on water resources in several biomes (AgroHidro Network and the Chuva-Vazão/Rainfall-Runoff Project).
- System of water sustainability indicators for sugarcane.
- Geo-Hidro Pantanal: online hydrological information of the Upper Paraguay River-Pantanal Basin; local news on flood risks to allow the planning herds movement.
- Zoning of water availability and demand for agriculture in the *Cerrado* biome (The Rainfall-Runoff Project).
- Zoneamento Agrícola de Risco Climático (Agricultural Zoning for Climate Risk – ZARC).
- Agroecological zoning, including the land suitability for irrigation.
- Sistema Brasileiro de Classificação de Terras para a Irrigação (Brazilian Land Classification System for Irrigation – SiBCTI).
- Underground dam: rainwater harvesting and storage technology for food production.
- *Barraginhas* (Small Dams).
- Simulation of regionalized climate change in semiarid fruit crops, impacts and adaptation.
- Rural cisterns.
- Rainwater harvesting in situ.

Groundwater

Referring to the integration between surface and groundwater management, Embrapa has results that can contribute to the mitigation of the agriculture impacts on the groundwater and territorial planning improvement in aquifers zones. The main technological contributions/solutions are as follows:

- ARAquá 2014 – ARAquá – Environmental Risk Assessment of Pesticides.
- Numerical simulation of organic contaminants in soil and water (Paraíba; Pulino, 2003).

Enhancement of the participatory process

Several committees have been installed in the Brazilian river basins although many have operational constraints, as well as problems of representativeness. Embrapa has been invited to participate in several instances of Singreh to provide knowledge-based information and technological solutions to handle the water use conflict resolution. Some ways of Embrapa contribution to the participatory process in IWRM are as follows:

- Participation in the National Council of Water Resources (CNRH), in water councils of the states and the Federal District and in the river basins committees of basins (CBH), such as the CBH Paranoá, Guanabara Bay, Jaguaribe River, sub-basins of Preto River, etc.).
- Application of participatory methodologies and knowledge building approaches in rural river basins focused on soil and water conservation and improved management of farming systems.

Final considerations

Considering the challenges pointed out in the report *Conjuntura...* (2017) and current contributions from Embrapa to water management in agriculture, one can find many opportunities for agricultural research to improve IWRM.

As a management tool, water resources plans must be formulated for states and basins and may count on an effective contribution from Embrapa. The studies to characterize basins in terms of territorial, ecosystem and biogeochemical dynamics, as well as the production systems make available important information for the development or review of the Basin Plans by the committees. An example of this contribution is the Programa Nacional de Solos (National Soil Program – PronaSolos), under the coordination of the Ministry of Agriculture, Livestock and Food Supply (Mapa), which has Embrapa as executive branch through Embrapa Soils, the Unit responsible for research and development in soil science. With a national network of research institutions, PronaSolos will produce information and soil maps in scales compatible with the land use planning throughout the country territory, starting with selected priority areas. Many of these areas are river basins responsible for water supply to populations and productive sectors. Soil maps on compatible scales for the elaboration of Basin Plans is an old demand of the water resources sector.

The National Information System on Water Resources (SNIRH) also provides a wide range of collaborative opportunities. For exemple, the SNIRH infrastructure may integrate information about technologies and knowledge on water resources produced by Embrapa research groups, such as the AgroHidro Network and the project portfolios on Climate Change, Drought Management, Irrigated Agriculture and Aquaculture. Available results from these projects are useful to inform and train representatives of civil society, water users, farmers, water management staff in public service, government authorities, members of Ministério Público Federal (the Public Justice Service) and the population in general.

Sharing information and knowledge about water and agriculture management technologies contributes to capacity building and enhancement of members' participation in water resources committees and councils. Joint actions for training promoted by Embrapa, ANA, the water management institutions, the basins committees, the universities and civil society cooperate to an IWRM enabling environment. This is essential for decentralized, participatory and knowledge-based management.

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Chapter 6

Conservation of ecosystems and water supply

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Introduction

This chapter presents an overview of anthropogenic pressures on water resources and their ecosystems, some strategies for conserving these resources for water production, as well as a picture of Embrapa's actions with the potential to contribute to the achievement of the target 6.6 of the SDG 6: protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes by 2020.

The technological solutions that Embrapa research has generated are related to the reduction of the erosive processes and the sedimentation of the water bodies; planning, monitoring and valuation of ecosystem services, with emphasis on water resources; to conservation practices with consequences for maintaining the quantity and quality of water, among others.

This chapter exposes society the results of research that have greatly contributed to improving the quality of life of men in the field, as well as being a vehicle for attracting new partners that can strengthen these actions.

Water shortage and pressures on hydrological ecosystem services

Although it has large fresh water reserves, including a majority of the world's largest aquifer – Aquifer Guarani (70%) –, Brazil is subject to water distribution in an inhomogeneous way, both in space (North region 68.5%, Midwest region 15.7%, South region 6.5%, Southeast region 6.0% and Northeast region 3.3%) and in time (some regions have their rainfall regime concentrated in a few months, followed by long drought and intermittent rivers). Population concentration and water demand are also differentiated. Income distribution, water management, the amount of investments in infrastructure and human resources and other socioeconomic aspects may also influence the availability of water resources. These natural and social differences are partly responsible for the situation of water scarcity in some regions of the country (Prado et al., 2017).

Hydrological ecosystem services are defined as the benefits offered by freshwater and terrestrial ecosystems, which include fresh water supply, water quality regulation, flood mitigation, erosion control and water-related cultural services (Brauman et al., 2007; Terrado et al., 2009).

The main anthropogenic pressures on ecosystem services are related to the dynamics of land use and cover, changes in biogeochemical cycles, the destruction and fragmentation of environments, the introduction of new species and the interference of human activities in natural resources and climate (Sala et al., 2000). In Brazil, losses of natural environments would be 15% to 18% in the Amazon biome, 50% in the *Cerrado*, *Pampas* and *Caatinga* biomes and 88% in the Atlantic Forest (Relatório..., 2012). It is also worth mentioning the deforestation of Áreas de Preservação Permanente (Permanent Preservation Areas – PPAs), the inadequate construction of roads, the management of lands without the conservationist care that revert to pressures on water resources (Sparovek et al., 2010; Soares-Filho et al., 2014). As a consequence, annual soil losses in Brazil are of the order of 500 million tons by erosion, causing the average loss of storage capacity of the reservoirs very high, in the order of 0.5% per year, which has contributed to many rivers reach the sea with a very low flow due to sedimentation, as is the case of the Paraíba do Sul and São Francisco Rivers, essential for the water supply of a large part of the Brazilian population (Prado et al., 2017).

Sources of pollutants are also a threat to water resources, in the form of domestic and industrial sewage (punctual) and residues from agriculture (nonpuctual). As a result, contamination and diminution of aquatic biodiversity occurs, leading to negative impacts on human health and water supply. Anthropogenic pressures and climatic changes in water resources may be transboundary and there may even be influence of one biome in another, as shown in the recent study by Bergier et al. (2018) regarding the influence of the Amazon in the control of rains in the *Pantanal*.

Strategies for conservation of ecosystems for water production

Tropical forests are in environments rich in natural resources and are influenced by a range of biophysical factors that contribute to the provision of various ecosystem services. It is possible that forests are the environments that most benefit humanity, since these benefits are also systemic, with synergies between them (Locatelli et al., 2014). Protecting forests, the protection of ecosystem services is assured (Arriagada; Perrings, 2009).

Despite the pressures arising from land use and its cover by agriculture and livestock on ecosystem services (Ferreira et al., 2014; Lapola et al., 2014) (Figure 1), Brazil has excelled in measures, policies and legislation related to conservation of ecosystems. As an example of laws and policies, the law of protection of native vegetation (Brasil, 2012), which establishes the preservation of permanent areas such as riparian forests and a legal reserve on rural properties, can be highlighted. In addition, the Sistema Nacional de Unidades de Conservação (National System of Conservation Units – SNUC) (Brasil, 2000) establishes a set of federal, state and municipal conservation units, covering about 20% of the national territory (Hassler, 2005).

The Ecological ICMS is an example of a financial mechanism to encourage conservation at the municipal level. It consists of a tax mechanism that allows municipalities to access parcels – greater than those to which they are already entitled – from the financial resources collected by the states, through the Imposto sobre Circulação de Mercadorias e Serviços (Tax on Circulation of Goods and Services – ICMS), due to the environmental criteria established in state laws (Novion; Vale, 2009; Mattos; Hercowitz, 2011). It is also worth mentioning some methods of logging, fishing, fiber and fruit in a sustainable way in the different Brazilian biomes, with emphasis on the Amazon (Becker, 2006; Gariglio et al., 2010), adding value to the production of small-scale farmers. With regard to water resources, Law 9,433/1997 established the Política Nacional de Recursos Hídricos (National Water Resources Policy – PNRH), providing for various instruments for integrated and participatory management within the framework of river basin committees.

Although soil conservation was not been considered a priority in government agendas in the past (Guerra et al., 2014), many agricultural production systems have been developed by Embrapa, focused on soil conservation, which are

Photo: Rachel Bardy Prado

Figure 1. Land use dynamics on ecosystem services.

currently in use in Brazil, such as the no-till system, integrated crop-livestock system (ILP) and integrated crop-livestock-forest system (ILPF) (Machado; Silva, 2001).

Brazil made a voluntary commitment during the *15th Conference of the Parties* (COP-15) in 2009 to reduce greenhouse gas (GHG) emissions from the agricultural sector by 2020. To do so, it stablished the Política Nacional sobre Mudanças do Clima (National Policy on Climate) (Brasil, 2009), which resulted in the Plano Setorial de Mitigação e de Adaptação às Mudanças Climáticas para Consolidação de uma Economia e Agricultura de Baixa Emissão de Carbono (Sectorial Plan for Mitigation and Adaptation to Climate Change to Consolidate a Low Carbon Economy and Agriculture – Plano ABC). In the Brazilian agricultural sector, new integrated ecologically based systems have been encouraged, such as organic agriculture, agroecology and agroforestry systems (Martinelli et al., 2010; Porro; Miccolis, 2011), which allow greater sustainability of the rural landscape, income support to small-scale farmers, increased food security maintenance of ecosystem service. The adoption of soil and water conservation technologies at the farm level tends to reduce erosive processes and sedimentation of water bodies and contribute to reducing the use of fertilizers and pesticides in agroecosystems.

However, there are many challenges for policies and laws to be effective and for the scale of soil and water conservation programs be expanded in order to cover the great territorial extensions of Brazil (Sparovek et al., 2010; Grisa; Schneider, 2015).

Technological solutions and potential impacts

Embrapa's mission is to contribute, through the results of its research, to the development of agriculture, but also to ensure the sustainability of the environment. Thus, Embrapa technologies and solutions aimed at the conservation of ecosystems and water production are many, being generated, validated, disseminated and adopted by different sectors of society. Some of them are presented in the sequence, but far from exhausting the list of technological solutions focused on the theme of this chapter.

Barraginha

Barraginha (mini-dam) is a technology developed by Embrapa Maize & Sorghum with the objective of capturing rainwater, eliminating floods and providing gradual infiltration of this water throughout the rural property, which contributes to soften the negative effects of drought and enables planting of crops. It is a small basin dug (Figure 2) that fills and empties several times throughout the rainy season. It usually measures 16 m in diameter, and can vary according to the type of soil (Barros; Ribeiro, 2009). Several *barraginhas* must be opened in several places of the property, where significant floods occur, in the pastures and plantations. The set of *barraginhas* provokes the elevation of the groundwater, increasing the availability of water, which can be perceived by the elevation of the water level in cisterns *cacimbão*-type (Figure 3), by the wetting of the lowlands, giving rise to springs and the revitalization of streams and rivers.

Biomonitoring in aquatic systems

In the last 14 years, Embrapa Environment has been working on biomonitoring with benthic macroinvertebrates in natural ecosystems (rivers and lakes) (Silveira et al., 2005) and aquaculture production systems (tanks in reservoirs and excavated fishponds) (Silva et al., 2016). Benthic macroinvertebrates are aquatic organisms that live in the bottom of rivers and lakes, that is, they inhabit the bottom of rivers and lakes attached to stones, gravel and leaves, or buried in mud or sand (Queiroz

Photo: Luciano Cordoval de Barros

Photo: Paulo Eduardo de Aquino Ribeiro

Figure 2. Excavated *barraginhas* (A) and *barraginha* crops (B).

Photo: Luciano Cordoval de Barros

Figure 3. Elevation of water level in *cacimbão*-type cisterns.

et al., 2008). They are organisms that are sensitive to pollution or degradation of aquatic ecosystems (Figure 4), so they are able to reflect in an integrated way the impacts occurring in the water and surrounding environment, for a longer period than the routinely measured physical and chemical variables. Among the compartments of the aquatic ecosystem, pond sediments and fish farms are often the ones that accumulate most organic matter and other pollutants, and

Figure 4. Fresh water ecosystems.

the last (local) repository of anthropogenic contaminants (human action) (Batley; Maher, 2001). It is important that partnerships be established with aquaculture producers to disseminate the method and so that they can – albeit superficially – make a diagnosis of the quality of their water at a lower cost. A tool widely used in natural ecosystems and being tested in the fish culture of excavated fishponds is biomonitoring with samplers with artificial substrate, whose methodology of preparation and application is detailed in Silva et al. (2012). In aquaculture, good quality water means a healthy end product, as well as minimizing impacts on water outside the enterprise. The challenges encountered are mainly to know the colonizing benthic fauna of the water bodies associated to the aquaculture system, and to identify the expected changes in the structure of this aquatic community in case of implantation of the activity.

Monitoring of soil and water in conservationist production systems

Embrapa, in a participatory manner with technicians and farmers, has carried out research on the monitoring of parameters of water quality, climate, soils and the carbon stock in reference areas and in farming systems, with the adoption of soil conservation practices and of water in the state of Rio de Janeiro. These researches are allowing the identification of a set of environmental indicators capable of assessing and monitoring the impacts of these systems on soils and water resources in microcatchments, through the correlation between land use and cover and agricultural production systems. The information generated may support agro-environmental planning and the formulation of public policies, as well as generate information for compensation programs for environmental services (Monteiro et al., 2017).

Tools for evaluation and valuation of water ecosystem services

The identification and measurement of ecosystem services (SEs) and ecosystem disservices (DEs) allow to translate the welfare benefits and losses into monetary metrics (Zhang et al., 2007; Costanza et al., 2014). This is possible because SEs have a positive value for society, and DEs represent a loss (negative cost), and therefore both are valuables. However, it is not always possible to present the result of the valuation in the monetary metric. Therefore, biophysical identification or measurement of SEs and DEs is a step forward in terms of the information available for decision-making. Embrapa Forests and the Federal University of Paraná (UFPR) developed two tools, one to evaluate SEs in productive systems and another to evaluate monetary metrics. The first uses radar-type graphics. For this, it is necessary to previously have a database containing the values of SEs in the same unit of area and/or time. Each system is represented on a graph where the indicators of the SEs are compared to each other. For this to occur, the values for each axis are relative to the maximum values for each service evaluated. A complete axis of the graph represents the maximum provision of services in the system, while a smaller portion represents a reduction in the provision of SEs relative to that provided by another system (Syswerda; Robertson, 2014). The systems in which there is a higher provision of SEs associated to water resources, such as soil water infiltration rate, soil, water and nitrate losses, surface runoff volume, erosion reduction (which directly affect water quality and increase of water flows) are perceived as being more sustainable. The economic valuation tool is a spreadsheet designed to calculate the value of non-measurable goods in the economic market. The value is the product of the quantity of SEs at their respective price. The evaluation of the losses of soil, water and nitrate, volume of surface runoff, as well as erosion reduction is performed based on the replacement cost method (Garcia et al., 2015). The method consists of estimating the economic costs of replenishing soil nutrients in productive areas, and the purpose of valuation is to reverse soil degradation and its effects on water resources. The limitations of the tool can be the low values of the indicators evaluated and the obtaining of the market prices of the inputs.

Manual for payment for water environmental services

The manual is available, in accessible language, aiming at

> [...] deepen knowledge, promote the identification of priority areas for intervention, selection of indicators and guidelines for monitoring, and thus contribute to a more appropriate environment for the application of Payment for Environmental Services (PES), identifying how and when to use it with security and guarantee, the effectiveness of its use. (Santos, 2017 cited by Fidalgo et al., 2017, p. 12, our translation).

Rotational system for family farming in the Amazon

Embrapa's research in the Eastern Amazon confirms the gain in productivity and environmental advantages when the traditional system in family farming with the preparation of planting area by the fallow-and-burning of fallow vegetation (*capoeiras*/secondary vegetation) is replaced by the preparation of area by choping-and-mulching biomass above ground (Davidson et al., 2008; Figueiredo et al., 2013). In this rotational system based on the use of secondary vegetation (*capoeira*), the permanence of the roots in the soil promotes the formation of "protective nets", reducing the leaching of nutrients, avoiding their loss and the contamination of the neighboring water bodies (Sommer et al., 2004).

Watershed assessments indicated that this situation is also detected at the landscape level and potentiated by the presence of riparian vegetation along the streams (Amazonian streams) (Figure 5), avoiding larger transfer of nutrients and sediments to the watercourses. When comparing a catchment area with slash-and-burn with another one with chop-and-mulch, the hydrological evaluations concluded that this last microbasin had a lower variation of the static level between rainy and dry periods, and, consequently, a greater capacity of underground recharge (Wickel, 2004). Consequently, the flows are larger in the *igarapé* (stream) in mulched area compared to the *igarapé* in burned area, since the discharge is are mainly regulated by the underground water stored. In addition, significant

Photo: Ricardo de Oliveira Figueiredo

Figure 5. Riparian vegetation along the Amazonian streams.

changes were observed in the chemical composition of fluvial waters in the watershed with burned areas, with significant calcium and magnesium inputs from the ash into the *igarapé* waters, thus altering the physico-chemical characteristics of this ecosystem and their functions (Comte et al., 2012, 2013). Due to these results, the following are recommended as tools for sustainable agriculture and management of the basins in the region: the conservation of riparian vegetation, nowadays mostly secondary vegetation; the substitution of practices such as the use of fire by sustainable production techniques; and care regarding the use of agrochemicals (Figueiredo, 2009).

Final considerations

Many measures (laws and policies) have been established in recent decades with ecosystem conservation in mind, but the pace of degradation is high and efforts are needed to bring laws and policies into practice. It is important to emphasize that it is important to increase the perception of all sectors of society that the services that ecosystems provide to man are exhaustible.

Embrapa, with its research focused on the sustainability of agriculture, plays an extremely important role in this scenario, and can contribute with its various technological solutions, to reverse the degradation of ecosystem services, especially watershed services, to a more conscious and sustainable agriculture, with gains also environmental and social, as well as economic. To this end, it is necessary to join the different public and private sectors to further advance low cost and easy to apply solutions.

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Chapter 7

Technical cooperation and training for developing countries

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Introduction

Target 6.a of Sustainable Development Goal 6 (SDG 6) addresses water and sanitation related activities and programs for developing countries through technical cooperation and training support, including water collection, desalination, water-use efficiency, effluent treatment, recycling and reuse technologies. This chapter addresses Embrapa's international cooperation actions with developing countries regarding the use and efficiency of water as a way to contribute to the achievement of this target.

Although it presents 18% of the water availability that flows through all the rivers of the world (12% of this availability produced in the national territory), due to its dimensions and climatic variability, associated with the distribution of the population in its different regions, Brazil presents different situations and experiences regarding the use and management of water resources. As the country is one of the world's great agricultural powers and the agricultural sector is an important user of its territory and water, it is natural that, throughout its history, Embrapa, as an official agricultural research company of the federal government, has accumulated expertise and technologies to be shared with other regions of the world. In turn, as a developing country, Brazil has also interacted with several countries to exchange and improve these experiences, as a way of exchanging and adapting technologies, knowledge and actions that, in some way, contribute even more to the sustainable development of Brazilian agriculture. Thus, Embrapa has formalized cooperation agreements, projects and partnerships with institutions and researchers from different regions of the world related to water, which will be presented in this chapter.

Rationalization of water use in the production of vegetables

Throughout its history, Embrapa Vegetables has worked in order to improve the production systems of vegetables that also include irrigation systems. The transfer of technology from more efficient water use systems of irrigation, training technicians and farmers, has also been carried out with developing countries, such as Mozambique and Haiti, through technical cooperation, for example. In addition, in the many editions of the Programa de Treinamento para Terceiros Países (Training Program for Third Countries – TCTP), in partnership with the Japan International Cooperation Agency (Jica) and the Brazilian Cooperation Agency (ABC), technicians, rural formulators of public policies have been trained in subjects related, mainly, to sustainable vegetables cropping. Among the main topics addressed were the efficient use of water in irrigation through systems such as drip and micro sprinkler, as well as the use of technologies that indicate the correct moment for irrigation and/or the amount of water needed, such as use of the Irrigas sensor (Figure 1) (Marouelli et al., 2010), developed by Embrapa Vegetables. Another significant performance of Embrapa Vegetables was in the scope of trilateral cooperation involving Brazil, the United States and Mozambique, through the Apoio Técnico aos Programas de Nutrição e Segurança Alimentar de Moçambique (Technical Support to Food and Nutrition Security Programs of Mozambique) (Embrapa, 2018b), which has had in its many activities developed the training of farmers and technicians on irrigation systems in the production of vegetables.

Rainwater harvesting in semiarid regions

Since its creation, Embrapa has contributed to technical cooperation and support for training in the collection and storage of rainwater for agricultural use, mainly in the Brazilian semiarid region, in research, training and technology transfer actions developed with the participation of family farmers and the partnership of municipal, state and federal governments, civil society and rural extension. The technological innovations made available by Embrapa have increased the supply of water, ensuring it for human and animal consumption, and reduced the risks

Photo: Paula Fernandes Rodrigues

Figure 1. Use of irrigas to define the need for irrigation.

of agricultural exploitation, contributing to the agricultural production mainly of grains, fruits and vegetables, as well as, consequently, improving the quality of life of families in the region. Based on these experiences, Embrapa has been present in international technical cooperation, in the scope of technical cooperation projects and cooperation missions between Brazil and developing countries, aiming at the implementation of some technological solutions and training of farmers and technicians.

Through the generation and/or adaptation of technologies, such as cistern, underground dam, in situ rainwater harvesting, among others, for a better dealing of the families with the semiarid region, Embrapa Semiarid Agriculture has collaborated with training of farmers, technicians and public managers through visits and courses given. As a highlight of this technical cooperation, the following actions are mentioned: a) visit of the government of Zimbabwe (Africa), led by the minister of agriculture, mechanization and irrigation; b) visit of researchers from Uganda (East Africa); c) visit of the Mozambican delegation composed of technicians, managers and secretaries of State; d) visit of representatives from

El Salvador, Guatemala, Honduras and Nicaragua, responsible for the theme of water in rural areas, who spent 5 days in Petrolina, in the state of Pernambuco, for an exchange of experiences of the countries of the Dry Corridor with the Brazilian program Água para Todos (Water for All); e) visits of Embrapa technicians to several developing countries (Haiti, Mozambique, Mexico, Angola, among others) for training in the most different topics involving technologies, water use and management; f) training for government technicians of Argentina; g) Brazil-Argentina-Haiti Tripartite Cooperation Project, with the objective of training Haitian technicians of the Pro-Huerta project in cistern construction, aiming at the evaluation of water quality, as well as the catchment and storage of rainwater for household consumption of local communities.

Another important action of Embrapa, involving Embrapa Semiarid Agriculture, Embrapa Soils and Embrapa Cotton, was the publication of the book *Captação, manejo e uso de água de chuva* (*Catchment, management and use of rainwater*) (Santos et al., 2015), resulting from the technical cooperation between Embrapa and the Associação Brasileira de Captação e Manejo de Água de Chuva (Brazilian Association of Catchment and Management of Rainwater – ABCMAC), Intituto Nacional do Semiárido (National Institute of the Semiarid – Insa), Federal Institute of Bahia (IFBA), International Rainwater Catchment Systems Association (IRCSA) and several universities in the Northeast. The book shows the different experiences on the subject of rainwater in several Brazilian regions and some regions of China, Nepal and Mexico.

Embrapa Soils, through its team at the Unidade de Execução de Pesquisa e Desenvolvimento do Recife (Research and Development Execution Unit of Recife – UEP), has contributed to some technical cooperation programs through programs/projects focused on catchment and storage of water. One of these projects was the Us-Brazil-Honduras Trilateral Technical Cooperation Project: Reinforcement to Food and Nutritional Security in Southern Honduras – Phase I, coordinated by ABC/Ministry of Foreign Affairs and executed by Embrapa in Honduras, where training activities were carried on technical aspects of construction and catchment, storage, use and management of soil and water/irrigation in underground dam for technicians and farmers. Another important technical cooperation action, undertaken by UEP Recife, was the Brazil-Mozambique-Switzerland Technical Cooperation Mission in Nampula Province (Embrapa, 2017), which, in addition to training catchment, storage and use of rainwater, three underground dam units were built, one in 2016 and two in 2017. Training was carried out through workshops and field days, which addressed the technical aspects of construction, potentialities and limitations of soils for installation and dimensioning of the volume of water and its multiple uses. The target audience was technicians from the Instituto de Investigação Agrária de Moçambique (Institute of Agricultural

Research of Mozambique – IIAM) and from the Swiss Cooperation (HortiSempre), farmers and extension agents from the District Services of Economic Activities and other institutions in the Northeast region of Mozambique. The mission was supported by HortiSempre – counterpart of the Swiss Cooperation and implementer of the project Income Creation Through Microirrigation in Northern Mozambique.

Integrated management of land use and water resources

Embrapa has important actions in technical cooperation on integrated management of water resources, mainly involving irrigation management, climate changes, hydrological modeling and environmental services.

Embrapa Cotton, in technical cooperation on cotton crop management, has carried out several training activities on irrigation, water use and management systems, which have much to contribute to target 6.a of the SDG 6. As The main cooperations established are: a) Technological Strengthening and Dissemination of Good Agricultural Practices for Cotton in the C-4 and Togo Countries, developed by Brazil together with Benin, Burkina Faso, Chad, Mali and Togo, countries located in West Africa ; b) Regional Project to Strengthen the Cotton Sector in the Lower Shire and Zambezi Basins in Southern Africa; c) Embrapa is a signatory of country projects to strengthen the cotton sector in South America, within the framework of the Brazil-FAO trilateral South-South Cooperation program. In this scope, Embrapa currently supports the execution of two distinct country projects with the Ministry of Agriculture and Irrigation of Peru (Minagri) and with the Ministry of Agriculture and Livestock of Paraguay (MAG).

Other Embrapa Units, such as Embrapa Mid-North, Embrapa Vegetables, Embrapa Maize and Fruits, among others, also have a significant role in international cooperation with developing countries with actions aimed at managing beekeeping, vegetables, beans, manioc, etc., where the components of irrigation management are part of the training.

Embrapa Cerrados, for over 10 years, has been working on the tropicalization of certain hydrological models applied in different regions of the world, such as in the SWAT-Cerrado, GeoCerrado, Rainfall-Flow and AgroHidro projects, all of them with international partnerships, which have been making it possible the parameterization, adaptation or even the development of important tools for the integrated planning of land use and water resources. These models are also the basis for projects that seek to evaluate the potential impacts of climate changes scenarios and changes in land use on water resources in the Brazilian territory (Chuva-Vazão and AgroHidro projects) and on different ecosystem services, including those related to quantity and quality of water (EcoHidro Project). Through the participation of Embrapa in programs such as the Produtor de Águas (Water Producer), the dissemination and training of people from Brazil and from the world, especially from developing countries, have been intense in the visits that mainly the Pipiripau Project (DF/GO) receives every year.

Embrapa Cerrados has also developed a relevant international partnership in the study of water allocation in small multi-use reservoirs in Brazil and Africa, bringing another contribution, in partnership, to the exchange of experiences about the management of water resources.

Final considerations

Embrapa, through its research and development activities, has much to contribute to the expansion of international technical cooperation and support for developing countries in the area of water. Technical cooperation initiatives foster development, promote human and institutional empowerment, and contribute to structural changes in the socioeconomic reality of developing countries. These initiatives, within Embrapa, are materialized through the so-called Technical Cooperation Instruments which categorize cooperations in: structuring projects, specific projects, Agricultural Innovation Marketplace and training on tropical agriculture courses (Embrapa, 2018a).

The scenario of water shortage observed in recent years in several Brazilian regions and in some countries, combined with the possibility of worsening this situation due to climate changes and disordered urban expansion, has led to the need to search for alternatives and quick solutions to guarantee quality water and sanitation for all by 2030. To reach that, Embrapa believes that it is essential to exchange and share responsibility and experience through international cooperation.

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Chapter 8

Water management and sanitation in rural communities

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Introduction

In recent years, in Brazil, local and community water and sanitation management has been strengthened as a viable alternative, which has contributed to the improvement of quality of life and sustainable rural development. However, there are still some major challenges to be overcome with regard to regular and permanent access to any source of water and sanitation in rural areas.

Over more than 40 years, Embrapa has been developing technological solutions that make possible to use water for human, animal and agricultural supplies, as well as access to adequate basic sanitation services for rural property, providing local communities with conditions for agricultural planning of the use of soil and water resources.

This chapter describes agricultural practices, products, processes, methodologies and services (trainings and consulting) that may contribute to target 6.b of Sustainable Development Goal 6 (SDG 6), aiming at supporting and strengthening water management and sanitation in the rural communities.

Use and management of water for crop and animal production

Food production is a priority in many countries, and agriculture, the main user of water resources, must not only provide food for a growing population but also save water for other uses. The challenge is to develop and apply rational methods of use, reuse and water management in agricultural production in rural communities, in order to obtain higher productivity with less water waste.

Suitability of small-scale farms

The characterization of the small-scale rural property consists of compartmentalizing and georeferencing the different environments existing in the property from the studies of geology, soil, climate, relief, water resources and vegetation. For each delimited unit, it is made the recommendation of its main skills of use of the soil. The information from a cartographic map and from a technical report includes the knowledge of the geoenvironmental conditions that constitute the different landscapes of the agroecosystem, which allows to organize and plan, in a rational way, agroforestry activities and environmental services, aiming at the best use and management of the soil and water by the local community.

Embrapa, through its training and consulting, carries out a participatory manner with farmers, technicians and development agents, the horizontal and collective construction of how to compartmentalize and optimize the different environments existing in family-based agroecosystems. The main trainings and consulting offered, within the theme of better use of water in the rural community, are intended for farmers, local development agents and Assistência Técnica e Extensão Rural (Technical Assistance and Rural Extension – Ater) technicians, and consist of:

- Course on Agroecological Zoning of Small-Scale Rural Property.
- Course on use of the Global Positioning System (GPS) in the small-scale rural property, aiming at obtaining sketches, measurements of the property, location of areas, natural resources and improvements in the area.
- Consulting on pedoclimatic zoning, with the objective of guiding technicians and producers on the most suitable areas for agricultural and forestry crops, considering soil and climate aspects, according to the

species' requirements, aiming at reducing environmental and economic risks in agriculture and forestry.

Other courses and consulting related to community participation in water management involve the following technological solutions: soil management and conservation and recovery of degraded areas; equipment and sensors for evaluation of soil water; underground dam; new technological approach for dealing with the semiarid region reality; water in the dairy farm; agroforestry systems (SAFs): composition and management; and characterization of communities and water resources for the implementation of the Programa Água Doce (Fresh Water Program – PAD).

Irrigation techniques accessible to family farming

Despite the availability of water to family farmers in the Northeastern rivers, such as São Francisco and Parnaíba, the water crisis and the competitiveness of the agricultural market have encouraged the change of the irrigation system and the way of applying it to improve the efficiency of water use. In this sense, Embrapa Cassava and Fruits, Embrapa Semiarid Agriculture and Embrapa Mid-North worked in several rural communities in the semiarid region of the Brazilian Northeast to adapt irrigation techniques accessible to the conditions of the family farmers. These techniques, in accordance with targets 6.4, 6.5, 6.6, consisted of procedures to construct low-cost irrigation systems as well as water management in order to use it effectively. Among them, there are:

- Bubbler irrigation system (Coelho et al., 2017) for family farming, without the use of cuttings to control water at the exit of each microtube (Figure 1).
- Surface irrigation system with water delivery in basins around the plants (banana, papaya, melon trees, etc.) using coated channels (Coelho et al., 2017) (Figure 2).
- The use of plastic tarpaulins on beds (Coelho et al., 2017) used in the production of vegetables to save irrigation water (Figure 3).
- Tables used for irrigation water management with irrigation dates, based on day and month of planting, and irrigation time for systems of micro sprinkler, microdiffuser, conventional sprinkler and perforated hose (Coelho et al., 2017).

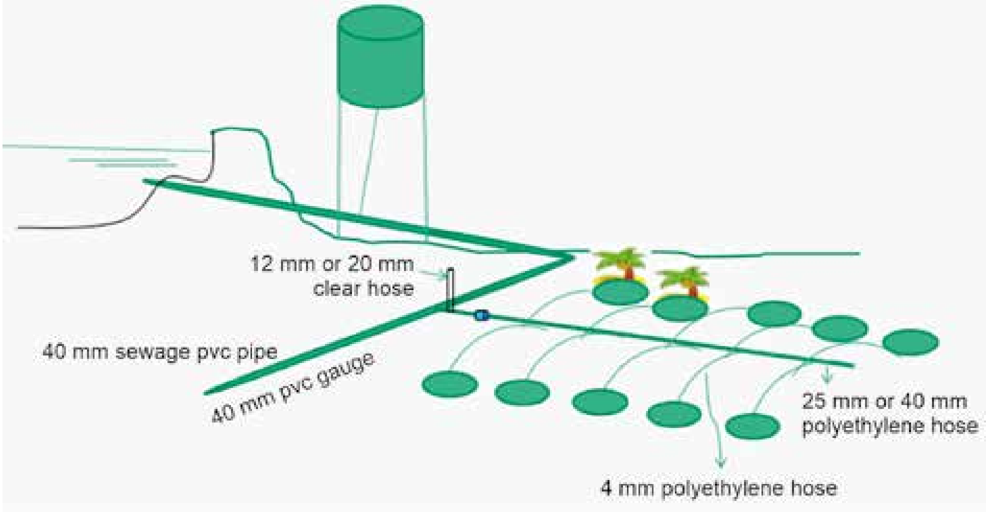

Figure 1. Bubbler irrigation system adapted for use in family farming. Suitable especially for fruit plants.

Illustration: Eugênio Ferreira Coelho

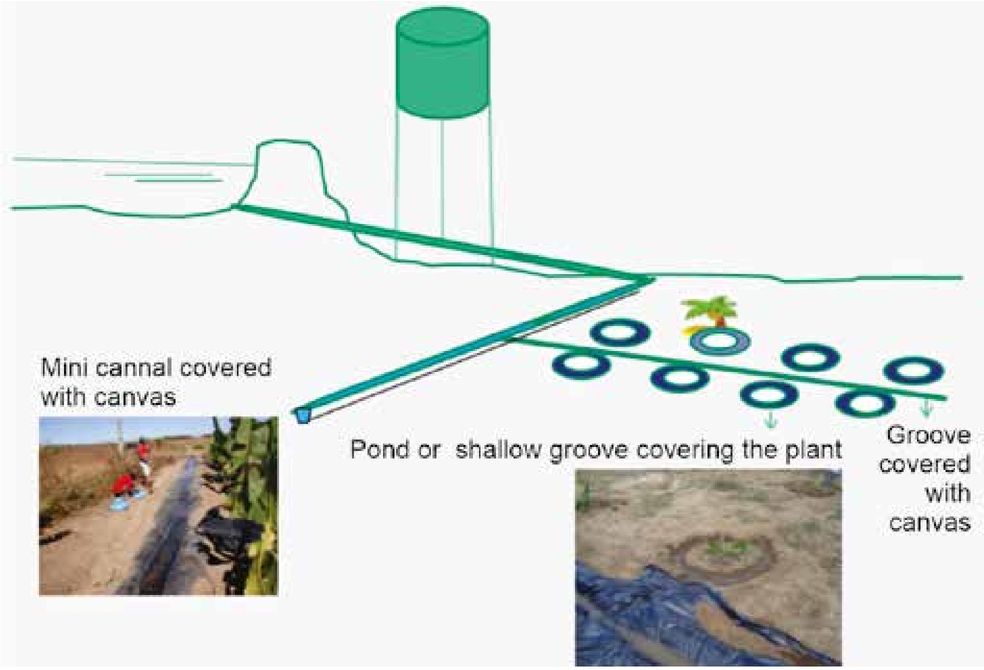

Figure 2. Basin irrigation system with channels and furrows coated with plastic tarpaulins.

Illustration: Eugênio Ferreira Coelho

Photos: Ildos Parizotto

Photos: Tibério Santos Martins da Silva

Figure 3. Use of plastic tarpaulins as background for plant beds.

Use and management of water for fish production

Integrated system for food production

The integrated system for food production or simply Sisteminha Embrapa (Sistema..., 2013) is a technological alternative for rural communities in regions with water shortages and consists of fish production integrated with raising chickens, quails, preys and other small animals, in addition to earthworms, vegetables, hydroponics, biogas, etc. The main objective of the system is the integrated production of food for families and animals. The system works from small 8,000 L tanks built with cardboard, plastic, mud, masonry, cement slabs, fiberglass, etc., which act as the engine of an integrated system for food production, with low consumption of electricity and water. The Sisteminha (Figure 4) is another efficient alternative that Embrapa has been making available to families in areas with water scarcity in the Brazilian Mid-North and semiarid regions, aiming at

Photos: Luiz Guilherme

Figure 4. Sisteminha Embrapa.

socioeconomic and environmental sustainability by combating hunger, reducing poverty and increasing opportunities in rural communities without harming the environment. One year after its implantation, the system is supposed to produce about 100 kg of fish, 1,000 hens, 1,000 ears of corn, 500 kg of earthworm compost and 300 kg of fruits and vegetables.

Floating cages

Brazil has 5.3 million hectares of freshwater in artificial and natural reservoirs that can have a significant economic use through fish farming, considering the growing demand of the domestic market, currently supplied by fish imports (Sonoda et al., 2016). From the available technologies for captive fish breeding, floating cages or net tanks are appropriate alternatives for these environments and constitute an intensive breeding system, whose implementation cost is comparatively lower than that of other systems used in fish farming (Figure 5). Having water in quantity and quality is a fundamental condition for the viability of this technology, being necessary to adopt adequate management practices to guarantee its economic and environmental sustainability.

Embrapa has been operating in practically all the national territory with researches and transfer actions that aim at the safe adoption of this technology. In this section Embrapa's activities in the North and Northeast regions with the species tambaqui (*Colossoma macropomum*) and Nile tilapia (*Oreochromis niloticus*), respectively, aiming mainly at the environmental management of the activity and stimulating the adoption of good practices of management (BPMs). Technology transfer actions are developed under different Embrapa projects, strengthening their adoption and stimulating the publication of diverse materials (books, folders,

Photo: Roselany de Oliveira Corrêa

Figure 5. Net-tanks installed in a hydroelectric reservoir.

booklets, videos) that are easily accessible to the public (Teixeira et al., 2009; Moro, 2014; Taniguchi et al., 2014; Seleção..., 2015; Ituassú, 2015; Queiroz; Rotta, 2016).

Multi-purpose lake

The multi-purpose lake consists of a tank built with a soft ramp, covered with ordinary plastic tarpaulin, covered by a 25 cm soil layer for its fixation and protection, used for irrigation and fish farming purposes. The system, developed by Embrapa Maize & Sorghum, is an efficient, long-lived and low-cost alternative when compared to lakes constructed with special tarpaulins (Figure 6).

Water reuse in dairy farming

The reuse of wastewater consists of the reuse of certain water that was an input in the development of an activity. The reuse in dairy farming occurs from corral cleaning water, which can be used again for this purpose, after passing through simple treatment systems, as it can be used in fertigation.

Embrapa works to reuse water in dairy farming in rural communities as a technological solution for efficient use of water and reduction of inputs with the

Photo: Luciano Cordoval de Barros

Figure 6. Multi-purpose mini lake used for irrigation of gardens and fish farming.

application of biofertilizer produced in the substitution or complementation of nitrogen fertilization, preserving the water resource, conditioning and fertilizing the soil.

The treatment processes of these waters are for the removal of suspended solids and organic load and the reduction of pathogenic microorganisms present in the waste. The reuse of water from hydraulic cleaning of corrals, for example, should be considered in the planning and sustainable management of water resources as a substitute for the use of waters intended for agricultural and irrigation purposes, among others. In this way, this practice results in good quality water sources for activities of other priority uses, contributing to the conservation of water resources, reducing the demand on water sources because of the substitution of drinking water for water of inferior quality (Otenio, 2015). The reuse of wastewater from the dairy cattle for hydraulic cleaning of floors reduces water consumption by 85% in relation to the processes that do not use the reuse (Torres et al., 2002), besides significant electrical energy and labor savings. In addition to the environmental conservation that the reuse of water resources promotes, there is also a reduction of costs, making production more sustainable. The biofertilizer generated from the final effluent produced has been used for fertigation, and some studies have already proven its application in sugarcane manure and in the cultivation of maize for silage (Otenio et al., 2017).

Water in cattle breeding

In rural properties, the use of water from different sources or without adequate treatment is common. However, water quality is determinant in the search for better results in production, as it contributes to animal welfare and positively impacts milk quality. Contaminated water can carry bacteria that cause mastitis in cows and also bacteria that contaminate milk.

Issues such as good agricultural practices, safe food production and normative instructions No. 51 and No. 62 (Brasil, 2002, 2011) dictate requirements for quality milk production, reflect the demand for a specialization in the production process and indicate the chlorination of water for use from milking to entering the dairy industry.

Embrapa offers several technologies to meet the current legislation for milk production, from small to large-scale dairies. When the consumption of water for animal production and use in the milking process area is less than 1,000 L per day, Chlorator Embrapa is indicated. For consumptions above 1,000 L per day, Embrapa indicates chlorination by diffusion (Otenio et al., 2017). Other Embrapa technologies relevant to this subject are the consulting on water in the dairy rural property and the analysis of the impact of the cattle breeding on the quality of the water.

Reuse of water in rural sanitation

Basic sanitation and elimination of contaminants

Brazil has greatly advanced in the area of basic public sanitation, but the numbers are still worrying. It is estimated that a daily volume of 4.8 billion liters of sewage is released in the countryside, considering direct release and inadequate treatment systems. Embrapa has developed technologies aimed at rural basic sanitation, whose premises involve the simplicity and efficiency of the systems, low implementation/maintenance costs and easy appropriation and use by farmers. Social technologies were proposed for the treatment of rural sewage (black and gray waters) and disinfection of water used for consumption:

- Septic tank biodigestor (Silva, 2014) – an easy-to-install, low-cost technological solution, efficiently treating sewage from the toilet (Figure 7).

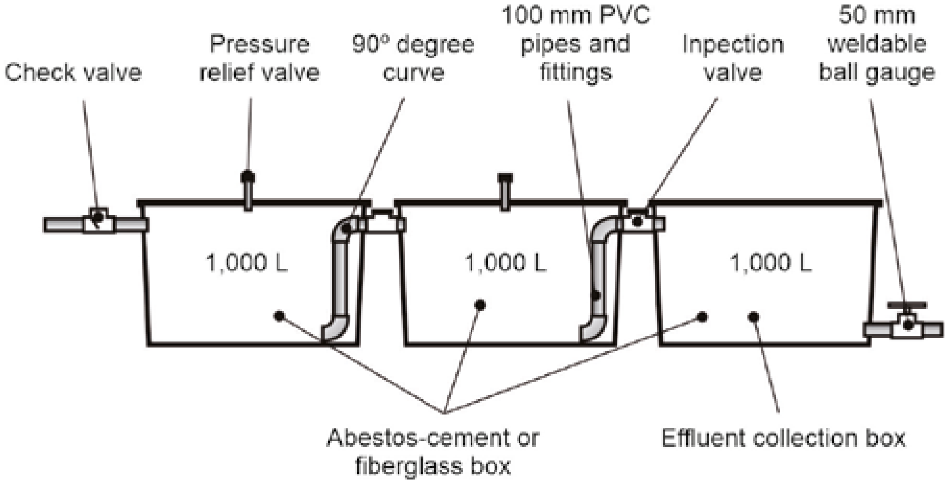

Figure 7. Septic tank biodigestor: technological solution for treatment of sanitary sewage from rural residences.

Ilustration: Valentim Monzane

- Filter garden (Silva, 2014) – alternative to treat the sewage coming from sinks, tanks and showers (gray water). It is a small lake with rocks, sand and aquatic plants where the sewage is treated through the interaction of plant species and microorganisms in this ecosystem (Figure 8). It is a technology adapted to complement the use of the septic tank biodigestor.

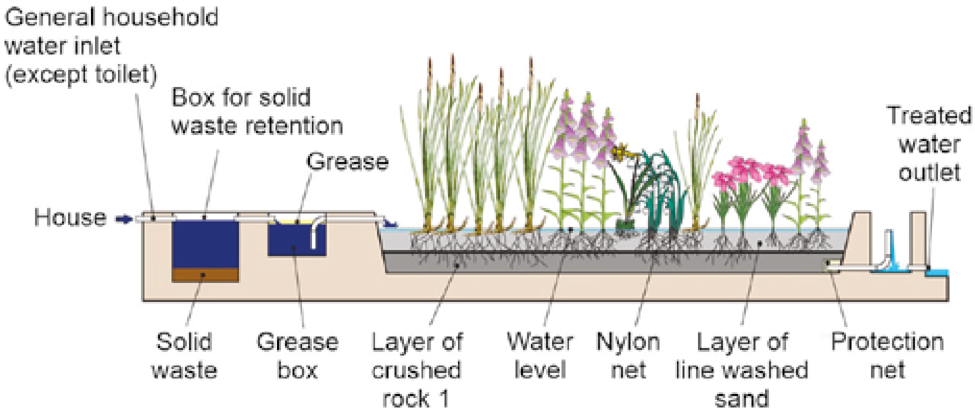

Figura 8. Filter garden: alternative technology for treatment of sewage from sinks, tanks and showers from rural residences.

Ilustration: Valentim Monzane

- Embrapa´s Chlorinator (Silva, 2014) – technology to chlorinate reservoir water from rural residences (Figure 9). Its main benefit is the disinfection of the water used at home, fostering good health of the residents.

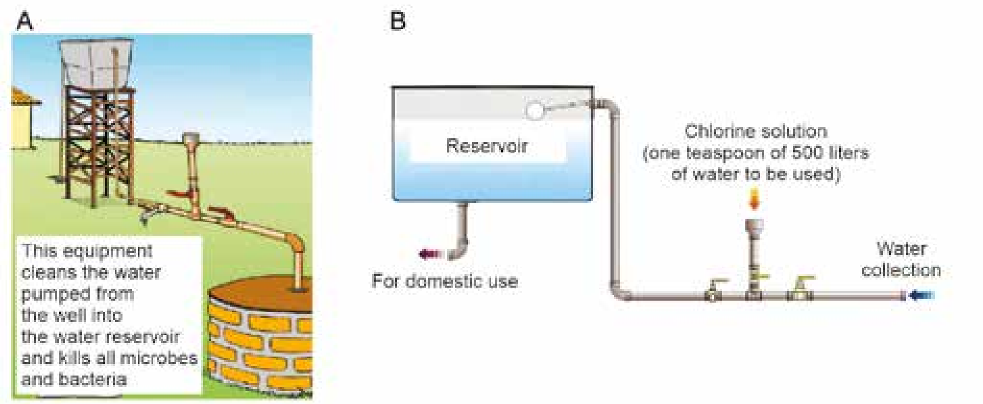

Figura 9. Embrapa's Chlorinator System: technological solution for the chlorination of water from residential reservoirs.

Illustrations: Renato Moura (A); Valentim Monzane (B)

The technologies of the septic tank biodigestor and filter garden are viable options for the reuse of water and fertigation in agricultural properties, mainly for family farming, bringing economic benefits by the application of the effluent in the fertilization of the soil. Within the scope of public policies, the septic tank biodigestor was defined as a reference in the Programa Nacional de Habitação Rural (National Rural Housing Program), within the scope of the program Minha Casa Minha Vida (My House, My Life – PMCMV). Public institutions may request funds for projects for the construction or renovation of bathrooms and sanitary facilities, provided that sewage treatment occurs according to one of the models defined in Ordinance 268/2017. The social technologies of rural basic sanitation of Embrapa have already been implemented in approximately 12 thousand rural residences in Brazil by the network of institutional partnerships formalized by Embrapa, benefiting almost 60 thousand people. Entities such as the Coodenadoria de Assistência Técnica Integral (Coordination of Integral Technical Assistance – Cati/SP), the Banco do Brasil Foundation and the Rio Rural Program (Seapec/RJ) have together installed more than 10 thousand units of the septic tank biodigestor.

Sanitary management in fish farming

Regardless of the type of cropping system, the fish farmer may be faced with diseases, whether due to inappropriate management (Figure 10) or external causes. In this sense, Embrapa Amapá recommends some basic measures of biosafety in order to subsidize farmers and technicians with regard to good management practices, ensuring the quality of the fish produced and the improvement of sanitary conditions of fish farms (Kubitza, 2004; Noga, 2010; Tavares-Dias et al., 2013, Tavares-Dias; Fujimoto, 2014). The effectiveness of sanitary measures depends on the farmer's awareness that important aspects should be taken into consideration when talking about sanitary management, as well as the presence of professionals trained to guide the fish farmer and correctly diagnose the disease, and sanitary inspection by government agencies, in fish farms and fish transportation between properties. Only by taking these precautions into account, can fish farming be more successful in implementing a sanitary control program in the farming system, becoming more competitive and profitable.

Photo: Marcos Tavares-Dias

Figure 10. Fish farming nursery with high presence of red algae due to eutrophication.

Final considerations

Considering the importance of water as a fundamental resource to develop any agricultural activity, it is essential that its rational use be discussed and, more than that, its management be constantly improved through technologies and good conservation practices, so that this resource is preserved in quality and quantity in rural properties. The technological solutions presented in this chapter constitute a "showcase" of the significant work that Embrapa has developed for the benefit of society and which, undoubtedly, has much to contribute to the achievement of target 6.b of SDG 6.

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Chapter 9

Future advances and challenges

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Introduction

In 2015, world leaders gathered at the United Nations (UN) to formally adopt a new agenda for sustainable development, resulting in the 17 Sustainable Development Goals (SDG) (United Nations, 2017a), which sought to define clearer and more pragmatic goals than those previously presented in the 8 Millennium Development Goals (MDGs) (United Nations, 2010). The decisions taken there determined the global actions to end poverty, promote prosperity and well-being for all, protect the environment and address climate changes (United Nations, 2010).

Brazil, as a signatory, is committed to compose a planning agenda for the implementation of the SDGs. The methodology proposed by the UN and conducted by the Government Office of the Presidency of the Republic and the Ministry of Planning has being carried out in three stages, with negotiation and internalization. At the moment, the SDGs are being internalized in government institutions.

At Embrapa, the Working Group (GT) – SDG Network was created, which accomplished the alignment of the Plurianual Plan (PPA) with the SDG targets, beginning the structuring of several mechanisms for the internalization of these objectives. One of these mechanisms is the elaboration of these collaborative e-books, based on the survey of the effective contributions that Embrapa can provide for compliance with the SDGs. In this way, 17 books by Embrapa's team of researchers, analysts and managers, and an institutional book were prepared showing the contribution of Embrapa's technological solutions, based on the proposed 2030 Agenda for Sustainable Development (Nações Unidas, 2017b), whose areas of importance are: eradication of poverty and hunger; protection of the planet through sustainable production; prosperity through economic, social and technological/environmental progress; peace through the promotion of peaceful, just and inclusive societies, free from fear of violence; and establishing a partnership based on a spirit of global solidarity.

The book 6, entitled *Clean Water and Sanitation: contributions of Embrapa*, addresses technological solutions and research/studies on clean water and rural sanitation, developed by this institution over its 45 years. The knowledge generated, based on scientific studies, shows that it is possible to develop agriculture with the adequate use of soil and water, making it possible the integrated management of water resources. SDG 6 book provides society with technological solutions developed or adapted for different biomes, showing how to use and manage soil and water in crop production, animal husbandry and sanitation, with the aim of avoiding or minimizing their possible/potential impacts on the environment.

Advances, opportunities and challenges

In recent years, in Brazil, water and sanitation management has been strengthened and has contributed to improving the quality of life and sustainable rural development. However, there are still challenges to be overcome with regard to regular and permanent access to water and sanitation, including rural areas. Brazil is one of the countries with the greatest water availability on the planet – approximately 18% of the fresh water flowing through the world's rivers. In order for the management of this social and environmental heritage to be adequate and sustainable, integration among governments, water users and organized civil society is a fundamental condition.

The major challenges regarding water in agricultural production relate to quantity and quality. In times of water crisis, the question of the rational use of water in productive processes is a mandatory agenda in any discussion forum. Faced with the current patterns of water availability and demand, the culture of waste must be replaced by another one of rationality and optimization of the use of such important resources as water, soil and biodiversity.

The theme on water can and must be worked on several fronts within a production system, but more than ever, these perspectives must be embedded in a river basin scale. Water concerns should begin in the source, in water catchment, storage and treatment, and in the design of productive physical structure in relation to local and regional availability of the resource. A correct quality monitoring plan should be addressed, as well as the conscious use of consumption levels, inside and outside the production areas and, where necessary, the stimulation of water reuse for less noble purposes.

Because it is an indispensable resource in any type of production, its quantity and quality are decisive in the performance of almost all economic activities developed by man. Any waste can be translated as a "bad use". The inclusion of a better use of a resource in the business agenda of an activity can generate profit or, at least, save expenses. Conserving water can be translated into reducing production costs. Recycling waste is transforming it into value-added product. However, it involves changes of attitude, not only by the government and sectors of industry and commerce, but by the entire society. The Reduction-Reuse-Recycling trinomial should increasingly be present in the water and its users' agenda, and, of course, the agricultural sector can play a fundamental role in the implementation of these concepts, not only in rural areas, but also in relation to the externalities of urban environments.

The rational use of water in agricultural production should always seek to optimize the conversion of water quality into healthy products. This is one of the key points for the sustainability of the agricultural production chain. Despite the great technological advances in recent years, many opportunities for improvement still exist.

Water should be thought of in terms of watershed, not only property. It is very important to keep in mind that water is different, from property to property, depending on its origin, its region, the time of year, the existing infrastructures, the treatments available, storage and manipulation. And for all these steps there is technical and scientific knowledge for the best use of water resources, which guarantees that it is possible to minimize the impacts of any scenario of water crisis, whether caused by droughts or floods.

In some places in Brazil, low reservoir levels impose the need for new approaches to water use, since their lack affects much more than just the consumption of this resource. In a country where the energy base is hydroelectric generation, water is also critical to any energy-dependent process. These new approaches involve a greater appreciation of this resource, often not ideally accounted in economic activities. Therefore, it is necessary to advance water governance in Brazil, which demands political decisions, greater investments, mobilization and participation of society, efficiency in management, and also the development of research solutions for the optimization of financial and human resources, reduction of losses and reuse of water, treatment and disposal of effluents and effective methods for agri-environmental conservation, which directly reflect on water resources.

According to the UN World Water Development Report: Water for a Sustainable World (Water..., 2015), the interconnections between water and sustainable development go far beyond their social, economic and environmental dimensions. Human health, food and energy security, sanitation, urbanization and industrial growth, as well as climate changes, are critical areas of challenge, where policies and actions of vital importance to sustainable development can be strengthened (or weakened) by means of water.

Persistence of poverty, unequal access to water supply and sanitation services, inadequate funding and poor information on water resources, their use and management, have imposed restrictions on the management of these resources and on the capacity to contribute to the achievement of sustainable development goals.

According to UN,

> A major priority for the **Latin America and the Caribbean** region is to build the formal institutional capacity to manage water resources and bring sustainable integration of water resources management and use into socio-economic development and poverty reduction. Another priority is to ensure the full realization of the human right to water and sanitation int the context of the post-2015 development agenda. (Water..., 2015, p. 4, emphasis add).

As far as agricultural research is concerned, there are many Brazilian challenges for sustainable development, including the systematization of all knowledge generated, standardization and integration of methods, translation of knowledge into solutions to be directly appropriated by society, sufficient financial resources, approximation of scientists and decision makers, among others.

The countless opportunities for agricultural research, specifically for Embrapa, regarding the potential for participation in the improvement of integrated water resource management from its innumerable technological solutions, are undoubtedly a valuable support for Brazil to effectively contribute to the achievement of the future challenges imposed by SDG 6. To develop and implement projects, programs and activities aimed at the training of human resources for the management of water resources, within the framework of the Sistema Nacional de Gerenciamento de Recursos Hídricos (National Water Resources Management System – Singreh), is one of the ways to meet the challenges of the future. Embrapa participation in Singreh is a way of bringing the agricultural sector closer to the spheres of discussion and management of water resources, leading, above all, knowledge to the decision-making processes.

The Programa Nacional de Solos (National Soil Program – PronaSolos) is an opportunity to adapt a soil research structure to increase the knowledge level of Brazilian soils, aiming at the sustainable management of natural resources, especially soil and water. PronaSolos will provide an instrument for soil governance in the national territory, enabling public power and private initiative to contribute to Brazil's orderly and long-term agricultural development. With a network of institutions from all over the country, PronaSolos will provide soil maps on compatible scales for the elaboration of river basin management plans, many of which are responsible for the water supply to populations and productive sectors.

Finally, the Brazilian law on water resources has as one of its main premises the need for participation and articulation among the different agents that are directly related to the theme. Decentralized and participatory management is undoubtedly something extremely modern and relevant, especially in a country with the extension of Brazil, however difficult to implement. The society was called to participate in the water resources management process and, considering that knowledge is fundamental for the management of any good, resource or activity, Embrapa has been contributing and can contribute even more to the proper territorial and water resources management in the country or even in other continents, with technologies and studies that support the decision-making process, especially in cases where the issues are related to the rural environment. Participation in the system can also guide and motivate new projects and partnerships in the search for solutions to existing problems and the effective achievement of the goals established by SDG 6, with clean water and sanitation for all.

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