

EMPOWERING BRAZILIAN NORTHEAST RURAL COMMUNITIES TO DESALINATED DRINKING WATER ACCESS: *PROGRAMA ÁGUA DOCE*

Authors: Renato Saraiva Ferreira, Henrique Pinheiro Veiga, Regina Gleice Batista dos Santos, Alexandre Saia, Samuel Coelho Rodrigues, Anderson Felipe de Medeiros Bezerra, Luiz Carlos Hermes, Alexandre Moura, Luis Henrique Cunha.

Presenter: Renato Saraiva Ferreira, LL.B.
Director of the Department of Watersheds Revitalization and Water-Access,
National Secretariat of Water Resources and Environmental Quality,
Environmental Ministry-Brazil.

Abstract

The *Programa Água Doce - PAD* (in English: *Fresh Water Program*) promoted by the Brazilian Federal Government under the coordination of the Environmental Ministry, seeks to promote sustainable use of groundwater resources and provide potable water for human consumption in areas with critical water scarcity in the Brazilian Semiarid region, through the use of the Reverse Osmosis Technique. The Program is guided by the following principles: community empowerment, environmental sustainability and technical capacity building. The methodology that led the Program to become a success case was conceived in 2003, through a participatory process with the contribution of public Brazilian institutions such as: Federal University of Campina Grande-UFCG (Social Engagement Procedure); Brazilian Geologic Service-CPRM (Ground Water information), Brazilian Agriculture Research Corporation – EMBRAPA (Methodology for the reuse of desalinated water concentrate), besides 10 Brazilian State's Governments and the civil society. The Program was launched in 2004. It has, presently, more than 460 installed Desalination Plants, which, together, can produce a total of approximately 1.5 million liters (around 400,000 gallons) of potable water per day (considering a 8h/per day production). It has, so far, benefited about 184,000 people in over 460 rural communities spread throughout the Brazilian semiarid region, ensuring safe water access to its residents. The program has already trained more than 1,000 people, including state technicians and operators of desalination systems. The Program contributes to improving the health and life quality of people in the semiarid region as it takes into account the natural and social potential of each community, ensuring ways to address the vulnerabilities to which they are subjected because of climate variability. Social engagement is a mandatory aspect for the Program's success. Local communities are stimulated to gain their independence by having, through the PAD methodology, their empowerment encouraged and demanded. The ultimate goal of the first large scale plan is to take Desalination Systems to at least 1,300 communities throughout the Brazilian Semiarid region. The Environmental Ministry is seeking to improve the systems with solar energy and automatized machinery, looking forward to improve local communities' independence.

I. INTRODUCTION

The Brazilian semiarid region (Figure 1) presents low volume of runoff water from rivers. This is due to the lack of rainfall and the dominant geological characteristics, predominance of shallow soils capping on crystalline rocks. The consequence is low water exchange between the river and the surrounding soil. That scenario also implies in the groundwater physical-chemical characteristics not allowed for human consumption. These characteristics involve high rates of salt concentration in most of the semiarid groundwater.



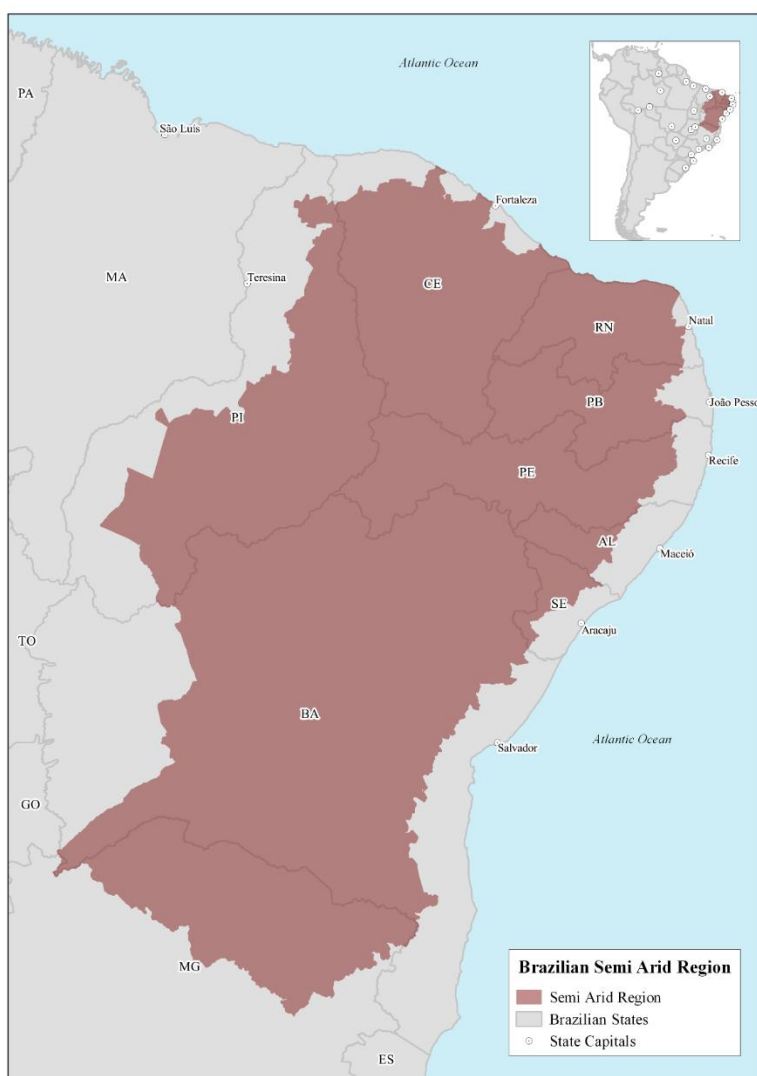


Figure 1: South America, Brazil, and Brazilian Semi-arid Region

Although it has low water availability, with annual precipitation averages about 800mm and potential evapotranspiration of 1300-2000 mm/year, the Brazilian semi-arid region is one of the most populous in the world: 22 million inhabitants, of which 9 million are in rural areas (Census, IBGE 2010⁵). Socially characterized by the lowest income rates among the entire country, the semi-arid region presents a GDP per capita of less than US\$ 2,000 per year, while the Brazilian rate was, in 2015, of approximately US\$ 8,500.

Since the 1990's the Federal and some States Governments were installing small desalination plants in the Brazilian semi-arid region. Those actions were, however, not developed wisely. The desalination equipment were installed without the proper dimensioning and maintenance planning or the training of technical staff to operate the equipment. No environmental precaution was taken at any level. These plants lead to soil degradation, misuse of the equipment and waste of scarce public resources. Being aware of that situation, the National Secretariat for Water Resources and Environmental Quality, within the Brazilian Environmental Ministry, addressed the issue, launching the PAD as an answer to those problems.

The Program was designed in 2003, through a multilevel participatory process, with the contribution of several organizations that deal with the Water Access topic, at both federal and state levels and

with the civil society participation. Among the main partners are BNDES (Brazilian National Bank for Social Development), Petrobras (Brazilian National Oil Company), Fundação Banco do Brasil (Bank of Brazil Foundation), Embrapa (Brazilian Agriculture Research Corporation), Universidade Federal de Campina Grande (Federal University of Campina Grande), DNOCS (National Department of Works Against Drought) and CPRM (Brazilian Geological Survey).

Launched in 2010, its large-scale actions have been guided by the State Implementation and Management Plan (each of the 10 Brazilian participant States built their own plan, under the supervision of the Environmental Ministry), which aimed to benefit approximately 0.5 million people by 2019. The implementation of the State Plans started, in each state, at the most critical municipalities. Therefore, technical criteria have been defined as to first meet population agglomerates most in need, which have been defined by the Plans as the municipalities with the lowest Human Development Index (HDI), highest percentage of infant mortality, highest percentage of poverty incidence, presence of high levels of salinity in the groundwater resources, low rainfall and poor access to water resources. The classification was based on an Index of Water-Access Condition, established from the intersection of the above indicators².

It has, so far, benefited about 184.000 people in over 460 communities spread throughout the semiarid region, ensuring safe water access to its residents. The program has already trained more than 1.000 people, including state technicians and local residents who will act as operators of the PAD Desalination Systems.

The Program aims to establish a permanent public policy of access to good-quality water for human consumption, incorporating technical, environmental and social precautions in the management of desalination systems. The program operates in communities of the Brazilian semiarid region. It undertakes its mission through a network of 200 institutions, involving 10 Brazilian states as well as other federal partners.

The PAD is focused in reducing the vulnerability to Climate Change, especially on events of severe droughts in the northeast of Brazil. This region faces rainfall levels higher than in any other desert region in the world. However, the precipitation, which in some areas is around 300 mm/year, occurs in small periods of the year. Some areas have not received any kind of precipitation for more than half a decade. The low latitude (proximity to the Equator line) and the presence of shallow soils, or even the absence, does not favor the local population, whose efforts to access safe water have to increase every new dry season.

Another important aspect is the Program's relationship with the Brazilian National Policy on Climate Change. By reducing vulnerabilities regarding water access in the semiarid region, the Program is considered a measure of adaptation to climate change. Studies indicate that climate variability in the region may increase, intensifying the occurrence of extreme events (mostly severe droughts) with direct consequences on water availability. Thus, initiatives such as the PAD, which promote the sustainable use of groundwater, help fighting the effects of climate change. It is a governmental effort to internalize such concerns, thus disseminating best practices of sustainable water use.

In 2009, the Brazilian Federal Court of Accounts, in an operational audit of public climate change policies, identified the PAD as an initiative to be expanded. The Court considered that the Program contributes to improving the life quality of people in the semiarid region as it takes into account the natural potential of each place, ensuring ways to address the vulnerabilities to which they are subjected because of climate variability.

In 2011, the Program became part of the *Programa Água para Todos* (Water for All Program) under *Plano Brasil sem Miséria* (Brazil without Extreme Poverty Plan), which aims to fight extreme poverty, reduce social inequalities and promote improvements in Brazilians' life quality. The Program has taken



the goal of applying its methodology for the recovery, deployment and management of 1,300 desalination systems. Since 2011, the Federal Brazilian Government has invested around R\$ 256 million, approximately US\$ 80,000,000 (eighty million dollars). To achieve this goal, agreements were signed with the states of Rio Grande do Norte, Alagoas, Paraíba, Sergipe, Ceará, Bahia, Maranhão, Minas Gerais, Piauí, and Pernambuco in order to deploy, recover and promote the management of desalination systems, thus supplying potable water for the neediest population in those states.

This paper presents and discusses the Program's status of implementation. This includes reporting on lessons learnt, suggesting further developments and adaptations of the original approach. The direct participation and training of the involved communities have, for instance, been strengthened and further technical solutions have been introduced, such as solar energy to enhance reliability of energy supply under certain conditions.

II. PRESENTATION OF THE PAD

The *Programa Água Doce* (PAD) is coordinated by the Secretariat for Water Resources and Environmental Quality from the Environmental Ministry, in partnership with Federal, State, Municipal and Civil Society's Institutions.

The goal is the establishment of a permanent public policy that enables access to high-quality water supplies fit for human consumption, by promoting the establishment, the recovery and the management of sustainable environmental desalination systems to contribute for water security of low-income families from the Brazilian Semiarid region.

In each Brazilian State, there is a PAD unit which is the supreme decision-making body, supported by a state committee and its executive group made up of qualified technicians, coordinated by specific state agencies, e.g. the State Secretariat for Water Resources. In the communities the system is managed by a local PAD unit, guided by an agreement among the state, the municipality, the community and the federal government, represented by the Environmental Ministry. The agreement is called "Local Management Agreement" and it ensures all rights and obligations for the users, system operators and it establishes the Local Executive Group.

The PAD is divided into 6 basic components – Management, Desalination Systems, Social Mobilization, Environmental Sustainability, Integrated Productive Systems, Development Research – and encompasses three phases of implementation, which are: 1. Assessment; 2. Construction and recovery of desalination plants; and 3. Monitoring and maintenance. Each component must act to contribute to the sustainability of the Program, maintaining a high level of working systems, engaging the community and other stakeholders in the management of the desalination plants and minimizing the environmental impacts of brine disposal.

2.1. Management

The management component is divided into the following sub-components: management support and institutional strengthening; capacity building; information system; operation & maintenance; monitoring.

The management support and institutional strengthening empower stakeholders and institutions at the State and Federal levels. It also empowers the communities to act in integrated water management, desalination, social mobilization and support.



2.2. Social Mobilization and the Local Management Agreement

Social Mobilization is a component coordinated by Federal University of Campina Grande's Laboratory of Applied Sociology and performed by a group of technicians trained by the PAD in each one of the participant states

The components' objectives consist in:

- Contributing to the establishment of solid cooperative base and social participation on the management of desalination systems;
- Taking part in the processes of defining agreements that will guarantee longevity of the desalination process and productive systems;
- Mediating negotiations and interest conflicts between the different social actors involved as to the implementation of the desalination and productive systems.

The Local Management Agreement is a document elaborated and approved by the community, in which the rules are established. It defines rights and duties of all people to benefit from the potable water and the use of the saline concentrate (the result of desalination process). It must also be signed by the families benefited by the desalinated water and by the representative of the public institutions supporting the management of the desalination system for the community, e.g. mayor.



Figure 2 - The Local Management Agreement elaborated and approved by the community.

The methodological processes involved in the social mobilization component require the community's representatives and the PAD State Management Team to be familiarized with the Program's methodology and objectives. Most conflicts will show themselves at this point. Conflicts related to past uses given to the water that is now about to be driven for the Desalination System may determine a "no good" for that specific system. When conflicts are identified and solutions are suggested the path to sustainability becomes clearer. That is why the Communal Management Agreement is one of the most important parts the PAD methodology.

The Communal Management Agreement lists a series of responsibilities and rights of the Communal Users Group. It also identifies the members of the community that compose the Local Management Group

and the Operators Group, which will receive specific training to operate and maintain the desalination equipment operational.

2.3. Productive Systems

The integrated production system was developed by the semiarid branch of *Embrapa* in order to provide an alternative use for the saline concentrate, which results from the desalination process of the saline ground water, seeking to minimize the environmental impacts and contribute to nutrition security.

The System uses the saline concentrate added to a sustainable reuse process. It is made up of 4 independent sub-systems.

- 1- First, the desalination, which provides drinkable water;
 - 2- Second, the desalination effluent (concentrate), or saline solution, which is sent to fish hatchery tanks, in the integrated production systems;
 - 3- Third, the effluent (concentrate) of the fish hatchery, which is enriched with organic substances and used for the *Atriplex Nummularia* irrigation, cultivated to produce hay;
 - 4- Fourth, pasture with protein percentage between 14% to 18%, which is used to feed cattle herds.
- This last subsystem finally closes the cycle of a sustainable and environmental integrated process.

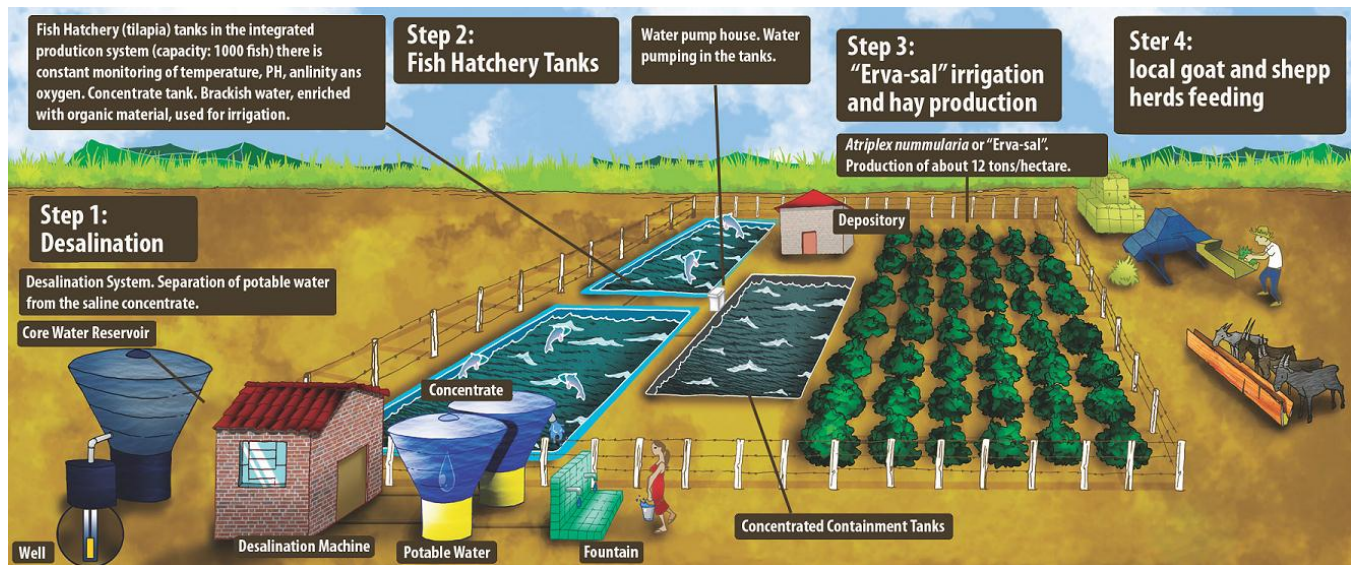


Figure 3 - The integrated production system.

The productive system uses about two hectares incorporating two fisheries for the tilapia hatcheries, one tank to recycle the concentrate enriched with organic matter form the fisheries (one hectare), another for the production of "salt-herb" (*Atriplex Nummularia*) and extra space for hay production. In order for the Community to receive an implementation of the integrated productive system, aside from the general criteria of the PAD, it also must follow certain conditions:

- Minimum groundwater outflow from the well of at least 5,000 liters/hour, containing sufficient chemicals concentration for the desalination process.
- Presence of at least 1 meter deep soil;
- High level of social mobilization among the community members.

2.4. Environmental Sustainability

The PAD is committed to ensure the sustainable use of water resources, so that the communities can live in harmony with environmental sustainability in the Brazilian Semiarid region.

Thus, its management sub-component operates on five different levels: social, environmental, economic, geographical and cultural. It is coordinated by the Environment branch of Embrapa and monitored by trained technicians in each of the participant states.

One of its goals is to make the productive and desalination systems self-sustainable, by training local agents who involve the community in the Program.

Part of the analysis is an evaluation of the social-environmental risk, used to partially determine which host cities should benefit from the program.

The basis of this evaluation is the New Rural method and on the Environmental Sustainable Index (ISA-AGUA, characterizing and prioritizing families that demonstrate critical factors related to:

- Availability, access to and use of water from desalination process;
- Availability, access to and use of water coming from other resources;
- Desalination of effluents (concentrate, sewage, served waters);
- Other aspects (roads, energy, cooperatives etc).

2.5. Desalination

The desalination component shelters all physical structures and machinery necessary to run the Desalination System (e.g. pumps, reservoirs, desalination machine, etc).



Figure 4 – Fresh Water Program design, incorporating technical, environmental and social precautions in the management of desalination systems.

The saline groundwater is furnished by a deep cylindrical well and stored in the core reservoir. Thereafter, the water passes through the desalination machine (Figure 5), which employs reverse osmosis.



Figure 5 - Desalination machine.

2.6. Development Research

The PAD has a network of research institutions that carry out the development of new technologies that seek to promote sustainability by reinforcing the idea of a closed cycle, where wastes shall not be admitted, neither from water nor financial resources.

III. METHODOLOGY

Seeking to promote a sustainable use of groundwater resources, the Environmental Ministry focused on solving the issues related to the Sustainable Management of Common Pool Resources. Many scientific views approach that topic; however, the best accepted view was designed by Nobel Prize Winner, PhD Elinor Ostrom⁶. The American scholar compiled her empiric data and came out with a series of principles, which determine whether the Common-Pool Resources that are being managed will sustain or not the exploitation, without being completely depleted, as the “Tragedy of the Commons”³ (1968) suggests.

3.1. Index of Water-Access Conditions

The Index of Water-Access Conditions was developed by the National Coordination of the PAD. It compiles several social and environmental indicators, such as Human Development Index, Percentage of Infant casualties, Poverty Index, Presence of salts in groundwater resources and rainfall rates.

The use of all these aspects led public authorities to have considered technical approaches instead of political influence based approaches. The Index was thought to technically subsidize the Program’s Coordination on where to allocate the scarce financial resources. Therefore, the Fresh Water Program could aim its efforts on those communities that were facing the worst conditions: high rates of

infant casualties, high level of salts in the groundwater resources, low or zero access to drinkable water and high level of extreme poverty. This was done firstly, on a small-scale approach, and then on a large-scale approach.

Where to begin?

Worst case scenario: Pariconha, Alagoas.

Index of Water-Access Condition (ICAA)

- Rainfall (less)
- Index of Human Development (lower)
- Mortality of children under 1 year old (higher)
- Poverty Intensity (higher)
- High Salinity in Groundwater resources (higher)

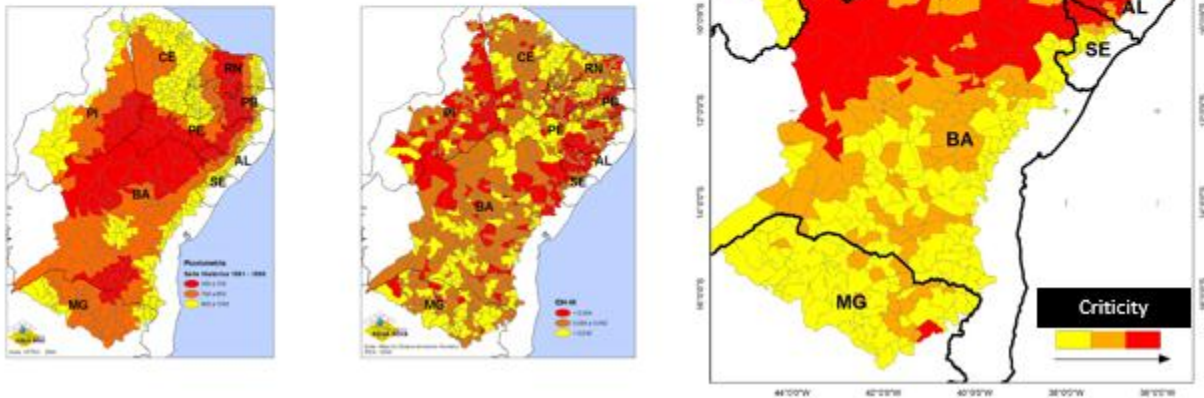


Figure 6 – Construction of the Water-Access Conditions Index (WACI)

IV. PROGRAM STEPS

Firstly, the PAD only implants Desalination Systems where there are active or easily activated wells. It also presumes a community of at least 20 families, within a 1 km radius. The third condition is having sufficient water flow to run the System. The well is then tested, both for water flow/pressure and physical-chemical characteristics. A process as complex as the PAD’s methodology requires a detailed plan of actions to avoid overlapping initiatives and to meet the criteria defined by Base Document of the PAD².

4.1. Steps for the implementation

The first step for the implementation of the PAD is to assess the communities pre-selected by technical criteria, according to the Water-Access Conditions Index (WACI), for each participant State.

Nowadays, the Program has at least 460 Small Desalination Plants, which are capable of producing together a total of approximately 1.5 million liters (400,000 gallons) of potable water per day (considering an 8h/per day production). The social engagement is a mandatory aspect for the success of the Program. That is why methodology previsions a sum of resources to allow each State Coordination to be supplied with sufficient tools. Local communities are therefore able to gain their independence by having, through the PAD methodology, their empowerment encouraged and demanded.

The Environmental Ministry is searching for financial resources to improve the systems with solar energy and automatized machinery in order to increase the local communities’ independence.



4.2. Social, Environmental and Technical Assessment

The assessment process is the basis of the entire Program. The definition of the amount of people to be supplied by the Desalinization System, specific measures for the groundwater treatment, investigation on how would the community deal with the operation of the desalination system and many other issues will be addressed by the Diagnosis Report, which is the final document of the first phase of the Program. After a group of communities is diagnosed, the PAD State Nucleus decides where there are better chances of success for the flow tests. They occur at a 3:1 rate, related to the communities diagnosed.

The wells that receive a “good” after the flow tests (minimum flow of 1m³/hour) will then be physically and chemically tested for the potable water parameters issued by the Brazilian Ministry of Health. On the first thousand wells, chemically and physically tested, only 1.7% could be used for human consumption without any previous treatment, as shown on Table 1.

Later, initiatives from the Brazilian Federal Government tried to address the water scarcity problem with the Reverse Osmosis Technique. However, no previous studies were made and neither there was a mobilization process involving the community, concerning maintenance, operational issues and environmental sustainability. The saline concentrate was spelt on the soil without any precautionary measure.

The next figure (Figure 7) represents the quantity of assessed communities throughout the Brazilian Semi-arid Region. Each dot on the map represents a community that received a visit from the State technicians, who questioned, studied and understood the local situation for subsidizing the decision makers' option of implanting a system or not, under the decision of the PAD State Nucleus.

Listing all characteristics of the community is a task of the Assessment Report. The referred document should bring information about the local environment, demographic data, local economy and relevant social aspects. The Report ought to be conclusive. It must indicate whether it is a viable solution to implement a Desalination Systems in that specific community. Veiga *et al*⁸, listed a series of issues addressed by the PAD Social, Environmental and Technical Report:

- i) Potential direct and indirect beneficiaries from the PAD and other (public sector and civil society) stakeholders;*
- ii) Conflicts and problems that led the Desalination Systems to be deactivate or present malfunctions;*
- iii) Social organization forms and local leaders that may cooperate in the management process;*
- iv) Relations between the community and political, economic and cultural spheres of the municipality;*
- v) Productive organization forms in the community and involvement in other projects that target the community development.*

The Report, final stage of the Assessment Processes, is the very basis that will lead all work done afterwards. All the groups of information about the construction procedures, social and environmental features are brought together so the PAD State Nucleus can decide the availability of the Desalination Systems' deployment. Afterwards, when the decision is made, hydraulic and electrical installations will also be covered by the Executive Project.



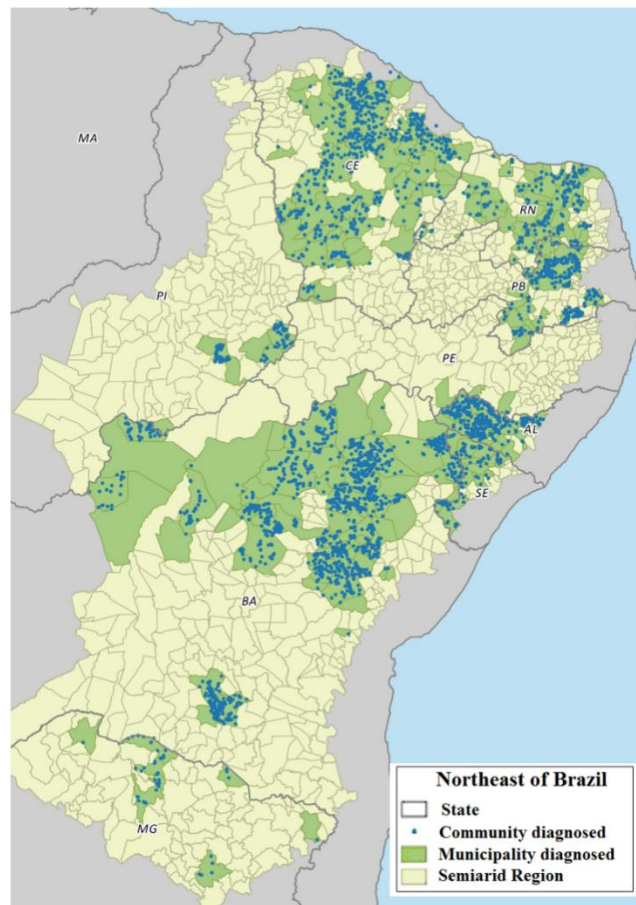


Figure 7- Assessed Communities.

4.3. Implementation of the Desalination System

The building sight starts with the cleaning and compliance of the land chosen, followed by procedures of foundations constructions (reservoirs, shelter, saline concentrate pool). Hydraulic and electrical installations are put together as the walls are built. The desalination machine shelter has a concrete slab to guarantee the safety of the machinery and operators.

When the shelter and every other component of the system is set, the State Coordination issues the order to install the desalination machine in that specific community.

4.4. Groundwater Sources in the Brazilian Semi-arid Region

Finding a usable well in the Brazilian Semi-arid Region is one of the most difficult procedures of the PAD. To illustrate that finding, we draw attention to Table 1, which shows the amount of assessed communities related to the tested well and those that had conditions of being exploited without prior water treatment. The table below expresses how much importance the PAD has to isolated communities in the Brazilian Semi-arid Region *vis-a-vis* the severe water scarcity situation faced.

Table 1: Data until April, 2017.

Communities Diagnosed	Flow and water characteristics analyzed (physical-chemical tests)	Water eligible for human consumption without treatment according to the Brazilian Health Ministry standards (Regulation n. 2914/2011)
3,142	1,000 (31.83%)	17 (1.7%)
*Average salinity of groundwater sources = 3,523.99 mg/l		

V. PRESENT RESULTS AND FUTURE PERSPECTIVES

Up to this date (June, 2017), the PAD has promoted sustainable use of Groundwater resources in almost 500 communities in the Brazilian Semiarid. This action has benefited approximately 200,000 people in the most critical conditions to access water for human consumption. The positive results are being recognized by Brazilian and international institutions, such as the United Nations Environment Program – UNEP, which has recently invited the Brazilian Environmental Ministry to present the PAD's results in the United Nations headquarters on May 8th, 2017, in an event entitled: Sustainable Development in Practice, Applying an Integrated Approach in Latin America and the Caribbean.

Nowadays, the Brazilian Federal government is planning investments in building conditions to support more efficient use of water resources in the semiarid region of Brazil, advancing in solar energy supplied systems, fomenting reforestation actions and biosaline agriculture, specifically using a mix of *Atriplex Nummularia*, *Gliricidea Sepium* and *Opuntia ficus-indica*, species with resistance to high salinity soils.

Its methodology, incorporating technical, environmental and social care, allows real participation of the population in the management of desalination systems, which is the great differential of the PAD.

Looking forward to a better use of scarce water resources in the Brazilian semiarid region, the PAD establishes itself as a public policy to guarantee access to good quality water as a human right, enabling coexistence with prolonged water scarcity and adaptation to climate changes to Brazilian northeast rural communities.

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