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The Traditional Technological Approach and Social Technologies in the Brazilian Semiarid Region

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Abstract: There are different technological approaches to deal with the social-ecological adversities found in the Brazilian Semiarid region (BSA). They vary according to the interpretation of what the roots of these adversities and the causes of the resulting vulnerability are. This paper analyses two technological approaches to the BSA, the first provided by the government through public policies and the other driven by civil society. It focuses on the initiatives promoted by each approach during the 20th and 21st centuries, and discusses how they have enhanced or reduced the sustainability of the Brazilian Semiarid region. This assessment is based on document analysis, fieldwork and open/semi-structured interviews. The traditional technological approach did not reduce the social-ecological vulnerability of the BSA system or increase resilience of family farmers and of the deciduous forest, the most vulnerable parties. It has boosted development from a classical development perspective, promoting macro-infrastructure and growth, but also contributed to keep the same pattern of dependence of farmers. Social technologies have been promoting the BSA sustainability and can have a long-lasting impact if extensively applied. While the traditional approach mostly benefits large landowners, social technologies benefit family farmers, the deciduous forest and the entire social-ecological system.

Keywords: technological approach; Brazilian semiarid region; vulnerability; sustainability; resilience

1. Introduction

The type of technologies applied in the Brazilian semiarid area is one of the variables that defines the degree of exposure to shocks and the vulnerability of the Semiarid social-ecological system (Figure 1). The BSA is characterized predominantly by the *Caatinga* biome, in which nature is dominated mostly by deciduous forests. When not degraded, this biome offers protection to climatic variation, plagues, wind and rain erosion, and provides natural resources for human use, as long as consumption patterns are sustainable.

The BSA is also known as the *Sertão*, a word used in the past to indicate unexplored and low population regions in the countryside, as a synonym of hinterland or backland. Within time, it became closely associated with the Northeast Brazilian Semiarid region, encompassing political, ecological, social and cultural dimensions, such as artistic work, cultural manifestations and people's way of life. "*Sertão*" and "Semiarid", which outpaced the original climatic reference, are interchangeably used in Brazil to express the dynamics of life found in the region.

Figure 1. The Brazilian Semiarid region, according to the recent delimitation by the Brazilian Ministry of Integration [1].

Similar to other semiarid regions, the *Sertão* presents uneven rainfall patterns and land ownership distribution, climatic variation and social disparities. Family farmers, usually dispersed, are the most vulnerable group and a very important part of the social-ecological dynamics. These adversities can be interpreted as a result of water shortage, leading to exclusively counter drought measures. Alternatively, they can be explained as part of a complex social-ecological system, grounded on political interests that lead to inadequate access to resources, depletion of nature, unsustainable use of natural resources and reduction of the social-ecological resilience to climate and non-climatic factors. Understanding the factors that contribute to the low economic and social development and the persistence of the current status of the *Caatinga* biome is crucial to assess which set of instruments is best suited to face the adversities in the BSA. Therefore, it defines the type of technology to be employed to address those issues.

Technology can be a valuable ally in promoting resilience of vulnerable regions. Its proper use has the potential to facilitate the achievement of sustainable development goals but it can also increase the already existing social disparities or ecological vulnerability, when inappropriate to the context. The benefits engendered by the technology depend on who chooses it. This paper presents the collaborative work undertaken in the BSA and discusses some responses developed to socioeconomic, governance and environmental issues of the BSA. It highlights the main achievements of two different technological approaches in the 20th and 21st centuries: of governmental policies and of stakeholders from civil society, discussing how they enhance or reduce the sustainability of the BSA. This study is part of a PhD research project undertaken during four years (2013–2017) and the authors are the PhD student and her thesis supervisor. The thesis focused on climate change resilient development for family farmers in the Brazilian semiarid through public policies and the coexisting with the semiarid paradigm. Within this subject, we came across multiple variables that shape development proposals and influence family farmers' resilience: technology and access to technology were found to be major determinants. They were not issues set out at first, nevertheless they have insistently appeared during literature review and even more during fieldwork.

Brazilian semiarid technologies were developed for several reasons, among them: to promote infrastructure and access to resources; and to improve technical assistance, land use and social inclusion. Most cited concerns in Semiarid regions around the world are similar to those we have seen in the *Sertão* [2], although their conditions vary greatly: the soil, the climate, the social factors, availability of mechanization and of labor and type of livestock, to cite some. It is a complex interaction of population growth rates, climate, and environmental responses linked to human activities [3]. A major common concern regards the impact of climate change on Semiarid lands [4]. Lessons learnt from the Brazilian Semiarid experience can help other Semiarid regions to adapt to the multiple adversities faced by them, including climate change. Its contribution can be especially relevant to Semiarid regions of African countries and Mexico, more alike the Brazilian semiarid.

2. Historical Background

The *Sertão* has been historically associated to poverty and considered an undeveloped region until policies in the 1970s promoted large irrigation infrastructure investments. Although the stigma remains, there are areas now showing signals of development and economic growth. The question behind "development" is how the distribution of the benefits are done. As Furtado [5] mentioned, 19 out 20 people tend to be excluded from benefits achieved through development, an argument confirmed by the reality in the *Sertão* [6]. Several historical and political obstacles have been identified in the literature, especially uneven land distribution, power structure and the political and economic aspects unfolded from droughts events, called "drought industry".

The land distribution problem in Brazil started in 1530 with the colonization policy, where land portions were given to Portuguese citizens willing to cultivate them in exchange for one sixth of the output (this policy was called "sesmarias"). Uneven land distribution resulted in large land properties (*latifúndio*) owned by few people which also control other resources. In the BSA, family farmers establishments outnumber non-family farming by almost ten times, as there were 1,527,861 family establishments against 185,684 in 2006 [7]. The Brazilian Institute of Geography and Statistics (IBGE) methodology [7] assumes only one family farmer responsible per establishment (therefore counting 1,527,861 establishments = 1,527,861 family farmers). Nevertheless, considering the rural reality observed during fieldwork and the law criteria to define a family farmer (Law 11,326 from 24 July 2006; Article 3, II essentially uses family work force in the economic activities of its establishment [8], at least two members of the family (husband and wife, but so often many more) work as family farmers, so the number of family farmers was, at least, three million people. Despite that, the total area (ha) of agricultural and livestock establishments in the BSA was 49,517,046, from which only 21,449,047 were used by family farmers in 2006 [7].

In the past, landowners of large properties were called colonels by Brazilians, because of their private power, including the use of violence and political influence, which often overcame the public power. *Latifúndios* operated as a power system, where the dominant elite was—and still is—forged by agricultural oligarchies inserted in a patronage (*coronelismo*) power structure, although the colonel figure has changed into a more institutionalized personification nowadays, such as city councilors or political positions in general.

Family farmers had to work in the "*latifúndios*", especially during drought seasons, frequently owing money to their landlords. It created a subordinate relationship with landowners, leaving family farmers more vulnerable to potential social, political, economic and environmental shocks. Landowners, on the other hand, centralized and concentrated power, allowed them to influence public policies to suit their own interests and resist alternative policies with transformation potential. This power imbalance and struggle contributed to shape a socially excluded society [9].

The landlords who withheld access to political and natural resources started profiting from the drought periods, selling water when needed and using the basic needs of people to obtain political advantages, such as voting promises. They held the job offers for those who needed to migrate or find work as a result of having lost their livelihoods due to drought events. This context reinforced the concentration of power and the dependent relation for most of the local population [10]. In addition, local politicians used and use drought events to request from the government more funding for the region, but a great share is devoted to mega constructions that benefit landlords, or used in private properties. This phenomenon was named "Drought Industry" for the first time by Antonio Callado in the 1940s [11].

The historical land use in the BSA also contributed to the social-ecological problems in the region. The 500 years of exploitation of the *Caatinga* biome were characterized by a predatory soil cultivation through a low productivity subsistence agriculture, combining annual cereal species with extensive cattle raising [12]. The depletion of the by extensive cattle and monoculture associated with large infrastructure projects resulted in deforestation, biodiversity loss and soil impoverishment. Unsustainable techniques of vegetal extractivism, overgrazed areas and slash-and-burn agriculture have also contributed to shape the social-ecological problems [13–16] now aggravated by climate change, especially in areas under desertification [17,18]. Because of natural constraints associated with the historical impact of the land and power structure supported by the drought industry, 45% of the Semiarid natural vegetation coverage has been degraded [19] and there are 21,379.45 km^2 of desertification nucleus (areas characterized as high risk to desertification, that affect 390,207 people [20].

The overexploitation of native vegetation associated with climate change will result in further losses in biodiversity, ecosystem services and potential for adaptation [21], and contribute to desertification processes. Climate models agree that future changes in the BSA are likely to happen, including increased temperature, rainfall variability, longer droughts and intensification of the hydrological deficit [22]. Thus, there has been a negative anthropogenic impact in degrading the Semiarid area and substituting the *Caatinga* forest for agriculture, cattle and wood extraction [20].

However, several public policies have been developed with the aim of improving social and economic conditions in the BSA. There is a long historical trajectory—since the 18th century—of dealing with the Semiarid adversities through the building of water reservoirs [23]. A great number of institutions were created embedded in this context, being one of the most important the Work Inspection Sector Against Droughts (IOCS), later renamed Federal Work Inspection Against Droughts (IFOCS) and turned into the National Department of Work Against Droughts (DNOCS) in 1945.

This institution has worked in collaboration with major organizations for the Northeast development, among them the Superintendence for the Development of the Northeast, (SUDENE, from 1959), the Northeast Bank (BNB) and the San Francisco Valley Development Company, (CODEVASF), from 1974 (for more information on these institutions, please see [23–28]). Major infrastructure works were dams, railroads and roads. The focus was on hydraulic works at three levels: construction, operation and use of water supply facilities, including irrigation, well drilling for groundwater use and dams. Some, but less attention was destined to electrification, sanitation and education. The recovery and forest defense, development of fish farming, agricultural and pastoral culture, photogrammetric, geological, hydrographic and hydrological studies were under DNOCS authority.

In the 1960s and 1970s, the main focus was on irrigation processes [29]. SUDENE launched the "special programs" to promote irrigation, reinforced by the National Irrigation Program (PRONI) and CODEVASF. The government invested in irrigated modern areas intended to export its production, especially fruits. The region of Petrolina (PE)/Juazeiro (BA) is the most important of these areas in the BSA. At this stage, DNOCS worked under the coordination of SUDENE in emergency actions to assist communities affected by droughts.

Throughout this article, we refer to the solutions based on large construction projects extensively applied during the 20th century in the Brazilian Semiarid region as "traditional technologies". We use "traditional technologies" as a synonym of the traditional technological approach or traditional techniques, using mainstream technological governmental policies most related to "engineering solutions". This conceptual reference is found in both national [19] and international literature when referred as "government policies ... characterized by ... a technical vision in the BSA" [22] (p. 2). Moreover, those terms are frequently used interchangeably in the Brazilian Semiarid field by different stakeholders, such as farmers, researches, organizations and decision makers, as verified during our fieldwork.

The traditional technological approach can be identified in several periods of public policies. These periods are divided according to their strategies for the BSA in the literature [19,30–33] and in primary documents [19]. These policies are mainly based on the rationale that addressing the social-ecological vulnerability of the Semiarid system can be attained by programs designed to combat drought by focusing on water security improvement through almost exclusively hydraulic solutions.

The other approach of this research is called Social Technologies. They were identified as part of the activities of the paradigm and social movement called "Coexisting with the Semiarid" (CSA) and can be found in the CSA guidelines [34], in several websites of CSA organizations [35,36] or in surveys on this topic, including government institutions like the *Empresa Brasileira de Pesquisa Agropecuária* (Embrapa) [37]. (Coexisting with the Semiarid is defined by the *Instituto Regional da Pequena Agropecuária Apropriada* (IRPAA) as the lifestyle and production choices that respect local knowledge and culture by using technologies and procedures appropriate to the environmental and climatic context [36]. There are 38 guidelines [34] for coexisting with the semiarid, organized in 2013 by diverse stakeholders with the goal of subsidizing public policies [38]). This term is found in the literature [39–43], and sometimes alternatively described as "appropriate technologies" or "technologies for social inclusion". It was also verified to be a common term used by different stakeholders during our fieldwork. In general, social technologies as found during this research are adapted technologies with a participatory approach that take place mostly through local and decentral projects referring to problems of a social character.

Social technologies are presented by researchers, farmers and government as technologies that rely on the coexistence with local characteristics. They are based on forestry integration, the adoption of new productive systems, agro-ecological production, the potential for the productive use of plants native to the *Caatinga* and the use of water reservoirs [24,34,42]. These are achieved through capacity building of the communities in water management for food production (called Gapa), simplified water management systems (called Sisma) and mason training before the technology is implemented, among other initiatives.

Social technologies have spread in the BSA through actions led by organizations or simply adopted by farmers. As a paradigm and a social movement, the CSA approach was implemented by family farmers, charity/NGO institutions, rural workers' unions, activists and academics who have worked in the region since the 1980s.

Relevant institutions working in the Semiarid are the *Instituto Regional da Pequena Agropecuária Apropriada*-IRPAA, Brazilian Cáritas, *Centro Sabiá*, *Caatinga* and *Associação Caatinga*. The *Articulação*

Nacional do Semiárido-ASA (Semiarid Articulation network) plays a pivotal role because it consists in more than three thousand civil society organizations, including some of the above [44].

3. Methodology

To carry out this research, we have first identified technological approaches to the BSA present in the literature. We have then analyzed the main assumptions behind them. The next step consisted in a survey of the technological initiatives of each approach. At this stage, our interviews were very useful, as several of the people we interviewed carried out some of the technological projects themselves and were also able to point to other relevant projects and material. Finally, we have developed a critical analysis of how they enhance or reduce the sustainability of the Semiarid social-ecological system.

This research is grounded on the concepts of sustainability [45,46], endogenous [47,48] and local development [48], sustainable development [49–51] and resilience [21,52,53], and it is based on published material, primary documents and fieldwork. An in depth discussion of these concepts is out of the scope of the present manuscript as they have already been extensively discussed in the literature, including sustainability of social-ecological systems [54]. However, our analysis covers the three main pillars recognized in the debate over sustainability presented in the literature: social, ecological and economical. Indicators in this multi-dimensional field are highly debatable [55,56] and we chose to use the perception of the interviewees and literature review based on secondary sources supported by primary sources (mostly government and social society reports) that were available. Ex-post evaluations were a large limitation found during the research and confirmed during our interviews, as most governmental programs did not conduct or provide them.

Methods adopted were participatory observation, open and semi-structured interviews, and collaboration, commonly used in most qualitative exploratory researches [57]. Interviews were considered fundamental, first because scientific literature specifically on our topic are not vastly published, secondly to allow us to gain knowledge on stakeholders' perception of change. There were two semi-structured questions grounded on the overall PhD research used in the interviews: (1) What have been the most beneficial public policies for family farmers in the BSA? (2) What are the major challenges for family farmers in the BSA? The semi-structured method was chosen to allow interviewees to define themselves what they considered relevant and cross these answers to check if there was a common ground between different stakeholders, as well as to comprehend their different bias. Techniques used to register the interviews were voice and written record. From the frequently resulting answers (summed up and available in the Results Section) and already researched literature, we drew out the four research questions that conducted this paper:

1. What are the technological approaches to the Brazilian Semiarid region?
2. Who chooses the technologies applied?
3. Who benefits from them?
4. In what way do these technologies contribute to improve the sustainability of the social-ecological system of the Brazilian Semiarid region?

We conducted two more interviews after these four questions were set, totalizing 19 interviews with: government authorities in the Ministry of Environment and Ministry of Integration; public employees from the Superintendence for the Development of the Northeast (SUDENE); government employees and academics of the National Institute of the Semiarid (INSA), *Fundação Joaquim Nabuco* (FUNDAJ), the National Department of Work Against Drought (DNOCS) and Embrapa; and with NGOs employees, from the Articulation of the Semiarid (ASA), the *CAATINGA* and the *Instituto Regional da Pequena Agropecuária Apropriada* (IRPAA). They were performed by phone, email and in person, for about one or two hours each.

The above institutions were selected based on their relevance, which was previously investigated. Our goal was to engage with the main stakeholders available that work in the field to find out their perceptions. The interviewees were selected based on their job positions, referrals from other interviewees and availability. They hold political and technical positions, including directors of well-known institutions and others recently hired fieldwork agents. We had the chance to speak with professionals responsible for complex engineering constructions, with young, middle-term and long-term career employees.

Data collection included individual unsystematic observation during the attendance of three seminars and individual participatory observation [57] in the three-week workshop promoted by the *Instituto Brasileiro de Desenvolvimento e Sustentabilidade* (IABS) in the Alagoas *Sertão*, Brazil (2016), as part of a Coexisting with the Semiarid program. The workshop was an immersion program where participants, including one of the authors, had to live in the 70 hectares of the Xingó center during three weeks with approximately 40 other participants which were family farmers, employees of public institutions for the Semiarid, agricultural technical assistants, academics, networkers, policy makers and activists. During the workshop, participants discussed adversities and opportunities found in the BSA; productive activities; and the diffusion of social practices and technologies and technical assistance provided by public programs. We visited sites where social technologies were being implemented, such as units of cisterns for rainwater harvesting and bio-construction; and where family farmers were involved in promoting sustainable local technologies referred by them as social technologies. In addition to these activities, there was also opportunity to visit traditional technologies implemented by the government, specifically hydropower sites.

The experience in the field allowed us to engage in a series of local discussions and field visits to a National Institute of Colonization and Agrarian Reform (INCRA) settlement, where we spoke with members of the Landless Workers' Movement (MST), and to the *Jacaré-Curituba* community settlement.

4. Results

The Results Section is divided into findings obtained during interviews and fieldwork, literature review on traditional technologies and literature review on social technologies. Findings obtained by one method were often confirmed by the other method.

4.1. Interviews and Fieldwork through a Participatory Approach

We briefly summarize the most frequent feedback obtained from the interviews and during direct interactions with farmers (i.e., local discussions and field visits). Regarding what the most beneficial public policies for family farmers in the Semiarid have been, social safety net mechanisms were cited by all stakeholders, including family farmers. The period following 2002 was unanimously considered positive. Two governmental programs in partnership with NGOs from this period were cited by all participants, "Uma terra, duas águas" (One Land, Two Waters − P1 + 2) and "1 milhão de cisternas" (One Million Cisterns—P1MC).

Civil society initiatives known as social technologies (such as the ones above) were highlighted by family farmers, NGOs and some SUDENE and Embrapa employees as better fitted to attend dispersed family farmers. However, they were also mentioned as very important by the rest of the interviewees.

In the opinion of members of the MST, INSA, ASA, IRPAA and family farmers, recent droughts did not result in death by hunger or in farmers' migration like in the past due to the "Bolsa Família" program (public income transference program) and the P1MC. The three first organizations also cited rural retirement as one of the major achievements for farmers.

In respect to the major challenges for family farmers in the Semiarid, lack of access to land and uneven land distribution were mentioned by all stakeholders, but highlighted as more relevant than access to water by ASA and IRPAA. Lack of access to infrastructure and resources in general was pointed out by all civil society organizations and family farmers, as well as by some governmental organizations.

In the opinion of the representatives of civil and governmental organizations and family farmers present in the Xingó workshop, employees from Embrapa and SUDENE (the younger employees), and ASA and IRPAA, traditional technologies used by public policies to deal with the adversities of the BSA based on engineering/hydraulic solutions were considered inappropriate. They argue that these policies have enhanced the social gap by privileging big landowners with technologies family farmers do not have access to.

NGOs, family farmers and some members of SUDENE mentioned difficulties in funding social technologies promoted by civil society. For instance, the institutional nature of SUDENE poses a constraint as it can only operate at the state level.

Government-wise, there is an absence of strategy, ex-post evaluation or proper monitoring of programs, according to members of government institutions, especially the ones that have been there longer. Young employees focused more on the absence of planning. Inappropriate technical assistance and credit were unanimously cited, although, for some representatives of governmental institutions, this was linked to what they considered low levels of education among farmers. Education was mentioned by all stakeholders, but with different meanings and it will not be detailed here.

Stakeholders unanimously highlighted how programs and projects were limited by government bureaucracy and lack of coordination between different government departments. However, some stakeholders spontaneously cited them, while others mentioned them after being asked specific questions during the interviews, such as what prevents public policies from improving live conditions or why programs and projects did not achieve their goals.

Data available in the literature on the results of the technological and social approaches are summarized in the next two sections.

4.2. The Traditional Technological Approach

The main achievements by DNOCS and partners using Traditional Technologies found in the period 1909–2013 were related to four predominant initiatives: hydraulic constructions, fish-related initiatives, transport infrastructure and basic services. Table A1 (in the Appendix) provides quantitative findings relating these initiatives to the activities and benefits achieved by 2013.

Hydraulic development has consisted mostly in building water infrastructure like reservoirs, wells, water supply systems, hydropower plants, dams, irrigation projects and cisterns. Among fishing-related initiatives, we found fisheries stations, a research and aquaculture Center, and fishing monitoring activities in public dams. Transport and basic services projects delivered highways, bridges, landing fields and electric power transmission lines [58].

Our findings (summarized in Table A1) show that the technological approach has focused on developing large hydraulic infrastructure projects despite including other activities.

4.3. Social Technologies since the 1980s

The main systems, activities and achievements of social technologies are shown in Table A2 (in the Appendix). The majority of these systems have been put in practice for a long time, but started to expand in the 1980s and on a more regular basis after the 1990s. Social technologies involve the structuring of family production systems, mobilization and formation of households, promoting meetings, exchange of experiences and strengthening of an action network of family farmers' representative organizations, and increasing the capacity to influence public policies with the ideas of the coexistence with the semiarid.

It was found during literature review [59] and confirmed by participatory observation and interviews [60] that women have been playing a fundamental role in agroecological production, in the rescue of creole seeds and in the protection of the *Caatinga* biome. In addition, households with greater capacity to store rainwater, diversified their productive activities and involved in social formation and mobilization processes have preserved the *Caatinga* and managed to go through this period with less difficulties than those who followed the conventional technological model.

4.4. The Traditional Technological Approach Influenced by the CSA Mentality: 2002–2016

We have found several official documents and institutions from the Brazilian government that refer to the CSA approach as a necessary component of the strategies to be adopted. Among these documents is the Semiarid Sustainable Development Strategic Plan (PDSA) [19]. In governmental research institutions, we have found reference to the CSA in *Fundação Joaquim Nabuco* (FUNDAJ) and the (Brazilian) National Institute for the Semi-Arid (INSA). Among local governmental Plans, it is worth mentioning: *Convivência com o Semi-Árido: Um Plano de Vida para o Ceará* [61], *Plano de Desenvolvimento Rural Sustentável e Solidário* (PDRSS); and *Projeto São José*, a project carried out by the Ceará state government [62]. References are also found in the Ministry of the Environment [63] and Ministry of Agrarian Development [64] websites.

Two programs developed within the scope of civil society became public policies: the "One Million Cisterns" and the "One Land, Two Waters" programs. As pointed out by Pérez-Marin et al. [65], access to water infrastructure with the use of diverse technologies from 2002 to 2016 has improved, mainly related to Domestic Cisterns (DC, +58%Δ) and Production Cisterns (PC, +95%Δ).

Water storage has shown significant increase through Micro-Reservoirs (MR, +43%Δ), Stone-lined Reservoirs (SR, +25%Δ), Cement-lined Wells (CW, +45%Δ), and Watering Holes (WH, +53%Δ). Most disseminated water infrastructure works between 2002 and 2016 were DC, PC, and WH. There were similar outcomes for the indicators of agroecosystem diversification in comparison to the indicators of water infrastructure [65].

Regarding social and political aspects, access to social (public) programs by farmers was expanded during this period. Although they do not correspond to technological solutions, rather to social public policies, they are worth mentioning since the increasing social character paves the way to positively increase the impact of both social and traditional technologies. Social safety programs include income transfer, housing, food, education, health and infrastructure such as: *Brasil sem Miséria Fome Zero*, *Bolsa Família*, *Brasil Carinhoso*, *Bolsa Estiagem*, *Garantia Safra* (income transfer); *Minha casa, minha vida* (Housing); *Programa de Aquisição de Alimentos* (PAA), *Programa Nacional de Fortalecimento da Agricultura Familiar* (Pronaf), (Food); *Ciência sem Fronteiras*, *Educa Mais Brasil*, *FIES*, *Fundeb*, *Jovem Aprendiz*, *Pronatec, ProUni* (Education); *Sistema Único de Saúde*, *Mais Médicos*, *Rede Cegonha*, *Saúde da Família*, *Farmácia Popular*, *Saúde não tem Preço* (Health); *Água para Todos*; and *Luz para Todos*, *Viver sem Limite* (Infrastructure).

5. Discussion

Traditional technologies for the BSA have been adopted by public policies and are a top-down approach. They are the product of a centralized decision-making process based on the "combating droughts" ideology, but these measures have not been able to address the roots of the social-ecological problems of the *Sertão* [66]. They focus on a single element—water or water scarcity—in a complex reality. Therefore, it fails to identify the key reasons of the BSA vulnerability, which are related to political constraints showed in this paper. Silva [67] (p. 362) explains that "the concentration of land and the exploitation of labor of the BSA inhabitants are fundamental to explain the maintenance of misery in the Semiarid region". The literature suggests that the Brazilian semiarid region remains social-ecologically vulnerable despite unprecedented levels of investment, myriad policy programs, and innumerable technological fixes [68].

As a centralized process, it does not involve the stakeholders in the process of decision-making, therefore it addresses droughts' challenges without social participation. Technology is thus chosen by the politicians and the local elite. This approach mostly benefits big land owners, not the most vulnerable population. Activities found in Table A1 (hydraulic constructions, fish-related activities, transport infrastructure and basic serves) show that government actions benefited large economic activities. An important example lies in Petrolina/Juazeiro irrigation centers, which mainly benefit the agribusiness [24]. Charcon and Bursztyn [6] point out that, despite all efforts promoted to achieve sustainable development, extensive areas do not share its benefits.

It is so because the poor do not have access to water dams, irrigation and hydraulic infrastructure in general. It is usually far from their homes and it requires expensive tools to allow its use. In addition, many are in private properties. Therefore, it increases the social-economical gap.

From an ecological perspective, it fails to understand droughts as a feature of the region, inserted in the ecosystem balance in which the resilient nature finds its own way to adapt. Deciduous forests remain dry as a survival strategy during droughts, other plants only flourish during the droughts season, and several can resist long periods of restricted water. Such ecological resilience can be used in favor of people, when the balance is respected and management done sustainably.

Many of the interventions presented in the Results Section had severe environmental impacts as described during the years. Among them is the reduction of fish stock and flooding of extensive parts of land, destroying its fauna and flora, harming the ecosystem balance and forcing the displacement of traditional communities. Besides, constructions were carried out in areas with water sources dependent on the perpetuation of water courses resulting from medium- and large-scale accumulation works, and with known risks regarding the irregular cycle of droughts [58]. These consequences contributed to increase the desertification process of the Semiarid region.

Nevertheless, there were some positive outcomes. The work fronts and emergency relief actions have assisted a great amount of people. They had an emergency and not a long-term planning character, but contributed to save lives. Other positive results were the construction of roads to remote areas, employment generation and attention to the problems in the region that allowed the BSA to enter the national budget. Highways built between 1909 and 2013 formed the network of what is now the northeastern road network.

Thus, achievements of this approach have improved the development of the region from a classical development perspective, that is, increased growth and improved macro-infrastructure, and forged some ground for the development of the regional economy. However, it did not reduce the social-ecological vulnerability of the BSA system or increase resilience of family farmers. Employment generation, for instance, did not promote autonomy of family farmers; instead, it kept the same pattern of dependence. It did not promote sustainability or sustainable development.

Social technologies have been proposed by civil society different stakeholders who have required changes in policy practices for the BSA. Therefore, this is a bottom-up approach that emerged from the need of transformation, that is, a movement that in itself creates resilience. Even if we understand resilience as an ability and not an outcome [69], adversities that derived from political constraints presented an opportunity to the social-ecological system of the semiarid to evolve into something new. In other words, it allowed transformation to happen because the adversities brought to light the strength of a transformational driver—the people of the semiarid—showing an ability to overcome a shock.

In this perspective, technologies are implemented with the participation of the people who will use it, teaching them the know-how and the know why, avoiding the alienation of workers. In this approach, natural resources, especially water, can be stored locally, benefiting farmers who are dispersed in the BSA. Family farmers improve their autonomy, as they do not depend on the government for water reserve and have acquired the technological knowledge, although they still depend on the irregular rain. As mention by Adger [68], decentralized water planning has the potential to increase long-term resilience, especially if we consider the geographical dispersion of family farmers, the impact on the environment and the conditions of the region.

The benefits of this approach are to allow family farmers to plan in advance their water storage, food supply and their products' sales. Changes in soil management, appropriate use of natural resources, reuse of previously disregarded elements and the valorization of the *Caatinga* biome—through native seeds, recovery and conservation of the natural forest—allows the system of the Semiarid to profit from the benefits of the conserved *Caatinga*. That is, to increase the resilience of the social-ecological system of the Semiarid and to promote sustainability.

It remains questionable whether these activities are able to promote changes fast enough to prevent extreme damages from climate change as they are being conducted—time and space wise, with the available funding and partnerships. Furthermore, it remains unclear whether the current practice suffice to conserve what is left of the *Caatinga* before it is too late, or even to promote the benefits to the vast majority of family farmers. Although the activities themselves promote sustainability, their optimization depends on the ability to spread them on a fast pace, given the upcoming shocks, specifically climate change, that will increase the challenges already faced in the BSA. This could be done with more involvement of the government, that could include these activities in public policies.

Concerning the adoption of the CSA approach in official documents by the government, it is not clear to what extent it is really being put in practice. Besides, most of the achievements of the traditional technological approach influenced by the CSA mentality were related to social technologies promoted by civil society.

Social safety net mechanisms that took place after 1990 and especially after 2002 were presented as the most efficient policies during our interviews. Income transferring programs such as *Bolsa Família*, *Bolsa Estiagem* and *Garantia Safra* [24,70] were the most beneficial, which have helped improving life standards of family farmers. They were not influenced by the CSA ideas, but the income transferring programs have provided the ground to implement them. Nevertheless, despite improvements in water storage and social transfer projects, these were insufficient to withstand multi-year periods of below-average rainfall [71].

Recent federal public policies mentioned in the Results Section regarding the expanded access to public social programs by farmers are not further discussed in this paper and serve to illustrate relevant frequently mentioned both in literature and interviews—policies that provide support to increase the benefits of technological and social approaches.

6. Conclusions

We have identified and discussed two technological approaches to the Brazilian Semiarid region: the traditional approach found in public policies and the social approach seen in the *Coexisting with the Semiarid* movement and paradigm.

The first is a top-down approach, where technologies are chosen by the government. The second, bottom-up, has its base on the local people and stakeholders, in a participatory approach, where technologies also promote social engagement and avoid alienation. The traditional approach mostly benefits large landowners, while family farmers profit more from the social approach.

Achievements of the technological approach did not reduce the social-ecological vulnerability of the BSA system or increase resilience of family farmers. It boosted development from a classical development perspective, promoting macro-infrastructure and growth, but also contributed to keep the same pattern of dependence of farmers. It did not promote sustainability or sustainable development.

Achievements of social technologies have been promoting the sustainability of the social-ecological system of the BSA, including family farmers and the deciduous forest, and are likely to have a long-lasting impact, especially if there is more involvement of the government in the social technological activities. These promote the sustainable use of natural resources, respect and cherish local knowledge, and assist family farmers to store water and become more independent.

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Appendix A

Table A1. Main achievements by DNOCS and partners using Traditional Technologies in the period during 1909–2013 [58].

Initiatives	Activities	Benefits
hydraulic constructions	Construction of 328 public water reservoirs.	Total capacity of 25.8 billion m^3 of water.
	Construction of 622 reservoirs in cooperation with states, municipalities and private individuals.	Total accumulation capacity of 1.5 billion m^3 of water.
	Drilling and installation of 28,682 deep tubular public wells.	Utilization rate of 90%.
	Installation of 405 desalination plants.	
	Implementation of 177 public water supply systems in inland cities.	It benefited a population of 2 million inhabitants and provided water supply through state concessionaires to more than 5 million users.
	Installation of eight small hydropower plants in public dams.	Total nominal capacity of 10.3 MW.
	4000 km of intermittent rivers into perennial rivers in the northeastern semi-arid region, with an average of 100 m^3/s.	It allowed the irrigation of 65,000 ha (65%) for 18 million inhabitants (35%).
	Installation of 71,739 irrigable hectares through 38 irrigation projects.	41,271 ha delivered for 7197 producers using small irrigation systems; 1090 ha for 66 agronomists; 864 ha for 67 agricultural technicians; and 20,097 ha for 335 agricultural companies.
	Use of upstream areas of 91 dams.	It enabled the exploitation of 75,462 ha by 15,552 families of small farmers.
	Construction of 1724 km in four regional pipelines in operation.	Designed to serve 1.6 million people.
	Construction of 4878 cisterns.	
	Construction of the *Castanhão* dam.	
Fish-related initiatives	Construction and operation of 14 Fisheries Stations, a Research and Aquaculture Center.	They produced 45 million fingerlings and 700 thousand shrimp larvae in 2008.
	Construction of four fish farming stations (underway and/or in start-up).	With the potential to increase annual production capacity to 100 million fingerlings per year.
	Monitoring of fishing in 181 public dams.	Production of 17,583 tons of fish in 2008.
transport infrastructure	Construction of 22,600 km of highways and 10 km of bridges.	
	Construction of 89 landing fields.	
basic services	Implementation of 795 km of electric power transmission lines.	

Appendix B

Table A2. Main systems, activities and achievements of social technologies [60,72].

Systems	16 L Cisterns made of pre modeled concrete for human and domestic consumption (*Cisterna de placa*).
	52 L Concrete cisterns for agriculture (*Cisterna Calçadão*).
	Canvas and cardboard cisterns.
	Ecological ovens—using firewood, solar or sawdust.
	Sustainable practices for production diversification (*quintal produtivo*).
	Native seeds storage for exchange (*sementes crioulas*).
	Inland wall up to 50 cm above surface in the contrary water course, leaving the land humid for up to 5 months (*barragem subterrânea*).
	Rock barriers (*barramento de pedra*).
	Non-irrigated cultivation (*cultivo de sequeiro*).
	Hotbed for good quality seeding.
	Stone tank.
	Popular water pump.
	Exchanges between farmers.
	Systematization of experiences.

Table A2. *Cont.*

Activities	Registration of families belonging to banks and community seed houses.
	Technical training, training of municipal commissions.
	Training in community management of seed diversity.
	Training in stock management of community seed banks.
	Territorial training on seed selection, production and multiplication.
	Regional training of teams.
	Exchange visits.
	Implementation of banks and seed houses.
	Training and mobilization of people for protecting the Semiarid, demystifying and combating the ideas and practices of the drought industry.
	Family farming as a proposal of good practice for sustainable and inclusive development, including the recycling and reuse of inputs from the property, previously ignored.
	Implementation of about 350 agroecological stoves; 30 biowater (*Bioáguas*) and at least 100 Agroforestry Systems initiated. These technologies are disseminated through the councils and other public policy fora.
Achievements	143 municipalities of the Semiarid were benefited with rural cisterns between 2009 and 2011. In total, 603,348 rural cisterns in family farmers' houses were implemented until 10 July 2017, from the "One Million Cisterns" program in partnership with the Brazilian government.
	4.725 cisterns in rural schools were installed until 10 July 2017, from the "Cisterns at Schools" program.
	94,468 technologies of family use, 1318 technologies of community use until 10 July 2017, from the "One Land, Two Waters" program in partnership with the Brazilian government.
	663 seeds houses (*casas de sementes*) until 10 July 2017, from the "Seeds from the Semiarid" program.
	Regarding territorial governance, Participation in the Management of Common Pool Resources (PMCPR)—including Family Seed Reserves (FSR), Community Seed Banks (CSB), Rotating Solidarity Funds (RSF), and collective Fruit Processing-experienced, indicators have shown an average positive change of 49%. Involvement in Spaces of Political Organization (ISPO) showed an average positive change of 28% [65].

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