

Public Policies and Adaptation to Climate Change: Three Case Studies in the Brazilian Semi-Arid Region

Políticas públicas e adaptação às mudanças climáticas: três estudos de casos no semiárido brasileiro

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ABSTRACT

Adaptation to climate change, understood as the moderation of sensitivities and the strengthening of adaptive capacities modifies the conditions and, consequently, the impacts of climate change on vulnerable populations. On the other hand, adaptive capacity depends on public policies tailored to different groups' social, economic, and environmental realities. This article discusses specific vulnerabilities, adaptive measures and opportunities identified through semi-structured interviews and participatory workshops in three groups with different socio-environmental profiles: the Fundo de Pasto (FP) traditional communities in Northern Bahia, the Tuxá indigenous community in Rodelas/BA and the irrigated perimeters of the Juazeiro/BA-Petrolina/PE pole. These case studies confirm that adaptation is strongly conditioned by the physical characteristics of the region where the population is located (such as rainfall levels and proximity to perennial water bodies, which condition "risks"); but that it also depends on a wide range of social, economic, cultural, and political factors.

Keywords: Adaptation. Climate change. Public policies. Semiarid region. Brazil.

RESUMO

A adaptação às mudanças climáticas, entendida como moderação das sensibilidades e fortalecimento das capacidades adaptativas, modifica as condições e conseqüentemente os impactos do clima nas populações vulneráveis. Por outro lado, a capacidade adaptativa depende de políticas públicas adequadas à realidade social, econômica e ambiental. Nesse contexto, o presente artigo discute vulnerabilidades específicas, medidas adaptativas e oportunidades identificadas por meio de entrevistas semiestruturadas e oficinas participativas em três grupos de diferentes perfis socioambientais: as comunidades tradicionais de Fundo de Pasto (FP) no norte da Bahia, a comunidade indígena Tuxá em Rodelas/BA e os perímetros irrigados do polo Juazeiro/BA-Petrolina/PE. Os estudos de caso confirmam que a adaptação está fortemente condicionada às características físicas do local em que a população se encontra (como o regime de chuvas e proximidade de corpos hídricos perenes, fatores que condicionam o "risco"), mas que também depende de uma ampla gama de fatores sociais, econômicos, culturais e políticos.

Palavras-chave: Adaptação. Mudanças climáticas. Políticas públicas. Semiárido. Brasil.

1 INTRODUCTION

Climate change is one of the main challenges for global environmental governance in the 21st century. These risks are being addressed on two fronts. The first, called *mitigation*, acts on the drivers of climate change by reducing (mitigating) the concentrations of greenhouse gases. The second front, adaptation, brings together efforts to mitigate the already inevitable impacts of climate change and manage present and future vulnerabilities.

Initially treated as a separate issue from the environmental political agenda, since the 2000s, climate change adaptation has emerged as a cross-cutting theme in sustainable development (SD) (ADGER *et al.*, 2009; LAHSEN *et al.*, 2010). More recently, it was incorporated by the UN into the Sustainable Development Goals - SDGs¹. In Brazil, adaptation was institutionalised in the National Policy on Climate Change - PNMC² and, in 2016, a specific government plan was created to address the topic, the National Adaptation Plan³, aiming at its consideration by sectoral agendas. The increasing internalisation of adaptation in the political process has been demanding from the scientific community theoretical and analytical frameworks capable of providing operational concepts and methods of analysis that dialogue with decision-making. In this sense, different frameworks have been proposed, from which we highlight the *vulnerability* framework employed by the Intergovernmental Panel on Climate Change - IPCC and the *resilience* one.

The approach to vulnerability, which originated in Geography, has different proposals for theoretical and conceptual frameworks, but those that have acquired greater popularity are those synthesised by the IPCC. In its 2014 AR5 report, the IPCC brought a framework of vulnerability slightly different from the ones adopted until then (OPPENHEIMER *et al.*, 2014). It identifies vulnerability as the predisposition or propensity of a system to be adversely affected by a *hazard*. *Hazard* refers to a physical event, natural or human-induced, with the potential to cause loss and damage to ecosystems and human systems and the ecosystem services they depend on. Another critical concept is *exposure*, which describes the presence of social-ecological systems in shapes and areas that may be adversely affected (OPPENHEIMER *et al.*, 2014).

Vulnerability is determined by the confluence of different socioeconomic, environmental, and institutional factors, synthesised in two concepts by the IPCC: *sensitivity* and *adaptive capacity*. The first refers to the internal characteristics of the systems with which the *hazard* interacts in determining the magnitude of the adverse effect (LINDOSO, 2017). The second, on the other hand, refers to the capacity of systems, institutions, people and other organisms to adjust to potential adverse effects, seize opportunities or respond to concrete climate impacts (IPCC, 2014). As of AR5, the risk approach has gained significant relevance in the IPCC, whose concept is understood as a function of exposure, vulnerability and probability of *hazard* occurrence, thus functioning as the organising element of the conceptual and analytical framework (OPPENHEIMER *et al.*, 2014).

Despite AR5's focus on *hazard*, there are approaches in the literature on socio-environmental vulnerability that place greater emphasis on social, economic, political, and historical-structural factors as sources of pressure on specific population sectors (GALLOPÍN, 2006; VALENCIA, 2016). Such approaches do not employ vulnerability as the linear consequence of the incidence of a physical risk (the *hazard*) on a group but understand it as a circular and multidimensional process (O'BRIEN *et al.*, 2007). In this sense, institutional, socioeconomic and biophysical factors make up the contextual conditions that determine vulnerability. These conditions affect and are affected not only by physical risks and events but also by social, economic and political structures and changes.

The framework of resilience, in turn, has its roots in ecology. It is a concept employed in the climate change literature to describe the capacity of social-ecological systems to undergo disturbance, maintaining their basic structure, functions and identity through learning, reorganisation and development (IPCC, 2014; NORBERG; CUMMING, 2008). It is often used as a synonym for adaptive capacity in the climate change literature (LINDOSO, 2017).

In the vulnerability approach, climate adaptation is understood as moderating sensitivities, reducing exposure and strengthening adaptive capacities. This approach focuses on understanding contexts that condition the vulnerability of social-ecological systems (LINDOSO, 2017). In the resilience approach, adaptation is used to describe resilience building. This approach focuses on understanding these systems' response processes (LINDOSO, 2017). In a context where a variety of factors, including structural ones, limit the ability of social-ecological systems to adapt, response processes such as learning, reorganisation and development are as relevant as the context that determines the response.

There is, therefore, a convergence of the two theoretical and conceptual frameworks. In this context, the socio-ecological systems perspective is a favourable epistemic space for interdisciplinary encounters (BINDER *et al.*, 2013). It is dear to both the resilience and vulnerability approaches and has its analytical relevance in recognising that the dynamics of human and natural systems establish inextricable relationships (GALLOPÍN, 2006; TURNER *et al.*, 2003). Separating them into isolated analyses can produce misleading results.

This same understanding is shared by the Nexus approach, which is gaining significant prominence in the SDGs policy agenda and has a great interface with climate change adaptation - and mitigation efforts (LINDOSO *et al.*, 2018; RASUL; SHARMA, 2015). The Nexus approach adopts mainly, but not exclusively, the perspective of three securities: water, food and energy, always taken together. The innovation of the approach lies in the relationships of *trade-offs* and synergies between the silos, thus placing great emphasis on the policy-institutional and normative dimensions (KURIAN, 2017). Nexus critics are wary of the approach's ability to be operative, as it still lacks conceptual and methodological consensus (GALAITSI *et al.*, 2018), while its proponents argue that this flexibility is what makes the approach interesting within a scientific and policy context grounded in different areas of knowledge and agendas (BROUWER *et al.*, 2018).

One region that has deserved attention due to its complexity and the possibility of greater evidence of the water security component articulated with the others is the São Francisco River Basin, especially in its Submédio (Middle) section. The main *hazard* to which the region is subjected is rainfall variability. The SSF is inserted in the Brazilian semiarid region, which faces a dry climate and low precipitation, and has prolonged droughts as an important exposure vector. Recently, the region has been exposed to one of the most intense drought periods. In the SSF, in 2010, there was a strong reduction of the Rainfall Anomaly Index (CAI⁴), and between 2012 and 2016, the CAI remained negative, in most years below -2, indicating a very or extremely dry climate (SOBRAL *et al.*, 2018). Despite this, the São Francisco River that runs through the area enables different water availability and access dynamics.

Furthermore, the distinct groups and sub-areas of the HFS have, on the one hand, contextual vulnerability factors in common as they belong to the same region with specific physical, cultural and historical features. At the same time, there are many differences in the contexts of the vulnerability of these groups, as social, economic and political processes and even geographical location have outlined contrasts between them. Especially since the development and modernisation policies of the 1960s to 1980s, the HFS has changed and become more heterogeneous. The formation of the public irrigated agricultural perimeters and the Petrolina and Juazeiro agro-industry hub, as well as the energy ventures on the São Francisco River, gave rise to new sub-groups benefiting from the projects, new inequalities and altered the dynamics of the region (ANDRADE, 1984; ARAÚJO, 2000; BURSZTYN, 2008; SCOTT, 2009).

The sensitivities and adaptive capacities of communities living in the SSS are quite different and concern several dimensions, such as land, water, food, work, income, health, migration and mobility, and vary according to the condition of each social group. However, some indicators can provide a perspective of the general socioeconomic conditions under which the population of the Submédio was exposed to the recent drought period. The Firjan municipal development indexes in 2016 pointed to a moderate development level for health and education (0.753 and 0.683, respectively) but low for employment and income (0.385). Access to energy is ample - 97% of households have electricity - while adequate sanitary supply and sewerage reach only 18% of the population (FIRJAN, 2018). The conditions represented by these indicators are part of the factors that measure how drought is felt and the impacts it causes.

Adaptation, as moderation of sensitivities and strengthening of adaptive capacities, modifies the conditions and, consequently, the impacts on communities. However, the measures adopted, as well as the potential adaptations, vary according to the reality of each social group. On the other hand, adaptive capacity depends on public policies appropriate to Brazil's social, economic, and environmental reality (RODRIGUES FILHO *et al.*, 2016).

In this sense, the following sections discuss in more detail specific vulnerabilities, adaptive measures, and opportunities for three different social groups: the traditional communities of Fundo de Pasto (FP) in northern Bahia, the Tuxá indigenous community in Rodelas/BA and the irrigated perimeters of the Juazeiro/BA-Petrolina/PE pole. These communities live in different socio-environmental situations, given the biophysical conditions of the regions where they are settled and because of specific historical processes to which they have been subjected. The Tuxá and the irrigated perimeters are on the banks of the São Francisco River, a location that gives them greater water access than pastureland communities, geographically distant from the perennial river channels. On the other hand, the indigenous community and the pastoralists are traditional groups based on centuries of traditions and informal norms that govern relations. The irrigated perimeters were only formed as a group after the formation of the irrigation districts in the 1970s. These contrasts between the three groups illustrate the plurality of contexts and specific issues within a region subject to the same climatic stress: drought.

The analysis of vulnerabilities and specific adaptations discussed below is based on secondary data, semi-structured interviews with community leaders and participatory workshops in the communities. The interviews were conducted in 2017 to map the consequences the drought that began in 2010 left on these populations' various aspects of life (Figure 1).

The workshops were held in 2018, aiming to consolidate and re-discuss the main impacts, threats, and opportunities for the future.

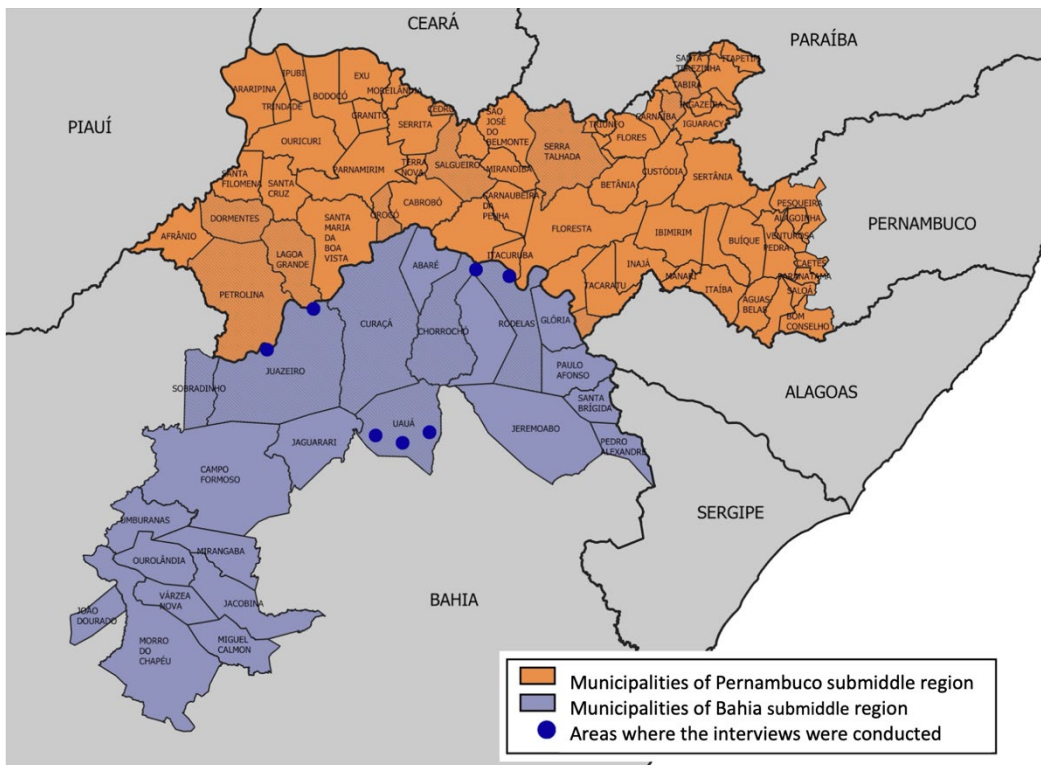


Figure 1 | Location of the interviewed communities in the Submédio da Bacia Hidrográfica do Rio São Francisco

Source: Prepared by the authors.

2 RESISTANCE AND COLLECTIVE PRODUCTION IN TRADITIONAL TERRITORIES OF SEMIARID BAHIA: THE CASE OF THE FUNDOS DE PASTO (COMMUNAL USE OF PASTURES)

The Fundos de Pasto (FP) are a social group that became territorialised in the semiarid region of the state of Bahia about two centuries ago, accumulating the values of traditional and peasant communities (MARQUES, 2016; SANTOS, 2011). The communities are identified by a “pattern of land occupation and use”, associated above all with the communal use of land and pastures for grazing small animals (SANTOS, 2011). In general, the communities were formed based on family and crony ties and are an inheritance of the pattern of land occupation by *sesmarias* and unoccupied farms, dating from the 18th and 19th centuries, which partly became vacant lands (after the Land Law of 1850) (FERRARO, 2008).

The invisibility of the FPs throughout the 19th and early 20th centuries – because of low state interest in the territories they occupied - was, according to Ferraro (2008), fundamental to their consolidation as a social group. However, the advances in capital and water infrastructures brought changes resulting in the valorisation of the lands of the semiarid region of Bahia (SAB) and those occupied by the pastoralists. The FP conflicts with land grabbers - farmers - in the 1970s and 1980s, and the recognition of the FP by the state of Bahia at the end of the 1980s, boosted the formal organisation of these communities (SANTOS, 2011).

There were, in 2018, 373 Fundos e Fechos de Pasto communities formally identified by the state government of Bahia in 37 municipalities in Bahia, with Uauá being the municipality with the highest concentration of Fundos de Pasto (GEOGRAFAR, 2018). However, based on research surveys with social organisations, it is estimated that there are more than 500 communities, integrating 20,000 families distributed in 52 municipalities in Bahia in an area of over 1,200 hectares (FERRARO, 2008; REIS, 2015).

The main productive activity consists of raising goats and sheep, which graze in areas of the Caatinga biome. However, in a varied way, the communities practice agriculture aimed at self-consumption, the raising of other animals (such as chickens) and the extraction of native fruits of the biome, such as umbu (*Spondias tuberosa*) and passion fruit (*Passiflora cincinnata*) (REIS, 2015).

The nearly seven years of drought in the SAB, starting in 2010 (MARENGO *et al.*, 2018; SEYFFARTH; RODRIGUES, 2017), illustrate the impacts and resilience of FPs to climate stresses in the region. Rainfall shortages first affected food production for self-consumption. The decrease in this production - often cessation - impacts the family budget and quality of life by increasing food purchases, often with low nutritional quality.

The lack of rain not only compromises agricultural activity but also impacts the productivity and reproduction of the fauna and flora of the Caatinga itself. In this sense, agricultural and extractive activities are negatively affected. For some communities, extractivism is a complement to family income. Furthermore, the activity is synonymous with financial autonomy for many women. In the region of Uauá, Curaçá and Canudos, the Cooperative of Family Farming (Coopercuc) carries out the processing and marketing of fruit extracted from the Caatinga, mainly in the form of sweets and jams. Such production - with higher added value than the sale of the fruit *in natura* - was born from products made by women from the communities in their own homes. However, the prolonged drought has contributed, in recent years, to a significant decrease in extraction. The death of the umbuzeiro trees is one of the effects that most concern communities dedicated to extractivism in the region - a loss of about 40% of the species' tree population is reported (GAIVIZZO *et al.*, 2018).

Despite the impacts and the degree of water scarcity, the socioeconomic scenario in which the great drought from 2010 to 2017 allowed the maintenance of FP activities and livelihoods in the SAB (BUAINAIM; GARCIA, 2013; MARENGO *et al.*, 2018; SEYFFARTH; RODRIGUES, 2017). The public policies that have affected the region and the existing articulation between FP groups have provided the

population with adaptive capacities to deal with this climatic event. Two dimensions driven by public policies that have changed the communities' scenario in the recent past stand out: water security and food security.

Food security is associated with guaranteed income through institutional markets. In this sense, programmes for access to food and incentives for family farming - the Food Purchase Programme (PAA), the National School Meals Programme (Pnae) and social protection - the Bolsa Família Programme - have ensured, in recent years, income for food, production and other needs, including during droughts. The Bolsa Família contributes directly to the household budget by directly supplementing income constantly and stably. Thus, the cash transfer is especially relevant during periods of climatic stress - such as the last drought - because it is not sensitive to climate fluctuations. Institutional markets have indeed had a direct positive impact on production, as happened with the expansion of the cooperative Coopercuc, which has an increasing role in the income of communities in the region and, above all, in the economic empowerment of women, according to the narratives of FP leaders (ALMEIDA, 2018; GAIVIZZO *et al.*, 2018; LITRE *et al.*, 2018). The PAA and Pnae, therefore, enabled a greater flow of income from agro-extractive activities.

Water security - such as access to water for human consumption - has been transformed in recent decades by the implementation of cisterns for rainwater storage. In the view of the leaders interviewed, the expansion of this technology was one of the greatest recent transformations for local communities. Civil society organisations and, later, the 1 Million Cisterns Programme (P1MC) were responsible for the diffusion of the cistern for domestic use. The household cistern allows access to and storage of water next to the residence, dispelling the need to travel long distances to fetch small amounts of water for basic domestic activities. Given the last drought, the lack of rainfall to fill the cisterns was frequently reported. Even so, for the interviewees, having a form of storage close to their homes is fundamental for more continuous and secure access to water in emergency situations since it allows for storage when there is a tanker supply.

The role of mobilisation among communities in building water (SAITO, 2018) and food security, reiterated in the interviewees' statements, is worth highlighting. The FP associations are organised into Centrais and the Articulação Estadual, mobilised mainly around the purpose of land regularisation of the communities, which, in turn, integrate a broad network of territorial organisation, the Articulação para o Semiárido (ASA) (CARVALHO, 2014; SANTOS, 2011).

According to Gaivizzo *et al.* (2018), the territorial organisation of the FP is configured as an adaptive resource, as it allows and fosters the flow of knowledge. On the one hand, this organisation capacity is relevant for defending territorial rights - still in progress - necessary for the continuity of the communities. On the other, it transcends the land issue and promotes exchanges in technologies, experiences and learning in the direction of living with the Semi-Arid.

The scenario of coping with the latest drought in view of, among other factors, water and food security policies, contrasts with the past of the communities (BUAINAIM; GARCIA, 2013), which is still present in the memory of its members. However, it is possible to note the persistence of migration out of the communities. In the SSF, the intercensal survival ratio⁵ (an index that points to emigration and/or mortality if below zero) of rural spaces was negative in 1980, 1991 and 2010 censuses - even if it went from 0.70 in 1980 to 0.81 in the last measurement - indicating a continuous rural exodus in the region. Migration out of the SSF towards other regions of the country increased in the same decades: the net migration rate⁶ in 1980 was -2.5 compared to the sum of -3.5 in 2010 (ALMEIDA, 2018).

In the actors' view, however, migration has changed qualitatively. The interviewees described the exodus of the past as a survival-oriented measure. In this sense, entire families migrated, especially in periods of drought, due to a lack of alternatives. Distinctly, current migrations are led by young people and are not conditioned to the rains as they were in the past. Present-day migration is described

as a search for social mobility and is associated - by the elders - with a worrying devaluation of the traditional ways and customs of the communities (ALMEIDA, 2018).

The effects of drought on the FP reflect the possibilities of future adaptation, given that climate change may intensify extreme regional events (PBMC, 2013). For the case of the FP, the availability of water for production, environmental degradation and land tenure insecurity are highlighted. Social technologies to collect water for production are not yet as widespread as cisterns for consumption. However, the reports point to the complete abandonment of agricultural activities. Although less central, technologies that support productive backyards would potentially improve food and the household budget. The degradation of the Caatinga - both by direct anthropic action and lack of rainfall - means a growing threat to extractivism. In this sense, conservation measures for the Caatinga and the role of the FP in this process are relevant for future actions. Finally, access to and permanence on land is still uncertain among the FP, as many communities have not been recognised, and others face land-related pressures. Ensuring land tenure security is a starting point for further adaptive measures.

In this context, the results indicate that the design and access to public policies on food and water security, articulated with environmental conservation policies, among others, appropriate to the social contexts in the SAB is essential for the regulation of economic, migratory and sustaining dynamics of the productive activities of the FP over time, and thus, for coping with the climate impacts and risks projected for the region (PBMC, 2013).

3 THE DOUBLE EXPOSURE OF THE INDIGENOUS PEOPLES OF THE NORTH-EAST: THE TUXÁ OF RODELAS (BA) AND THEIR LONG STRUGGLE FOR LAND

The Tuxá indigenous people in Rodelas/BA, unlike the Fundos de Pasto communities, did not feel the immediate impact of the lack of rainfall due to their location on the banks of the Itaparica dam. However, the vulnerabilities of this community are conditioned to the reservoir itself, which some 30 years ago displaced them from their original territory. The lack of access to land - as well as its material and symbolic implications - represents, therefore, the main axis of insecurity, a threat intensified by the recent transfer of the prerogative of delimitation of indigenous lands to the Ministry of Agriculture, Livestock and Supply (BRAZIL, 2019) - which may embargo the recognition of the new territory demanded by the group.

O'Brien and Leichenko (2000) propose the concept of *double-exposure* to express the combined action of climate change and globalisation on populations, social groups and sectors that, over time, find themselves in a situation of heightened vulnerability. In the case of the Northeastern semiarid region and SSF, the impacts of globalisation have intensified since the modernising efforts conducted by the central government between the 1960s and 1980s, aimed at inserting the region into the emerging industrial dynamics and generating economic growth from this area. The dams in the São Francisco valley were one of the main vectors of this modernisation at the time, producing various local social and ecological impacts (ANDRADE, 1984), including the expropriation of the territory of the communities living around the river. According to Andrade (1984), the planning of the projects emphasised the technical and economic aspects of energy production without considering local aspects: agricultural areas, villages and towns were flooded. Added to the effects of this modernising process of the mid-20th century - which still have repercussions today - are the more recent dynamics of globalisation, notably land pressure for the implementation of new ventures, such as wind farms in the SSF. However, such initiatives have reinforced socio-environmental inequalities and vulnerabilities in the region (MILHORANCE *et al.*, 2019).

The Northeast is one of the Brazilian regions most subject to the adverse effects of climate change, leaving many populations unprotected (NOBRE; SAMPAIO; SALAZAR, 2008). However, indigenous peoples, in general, are among the most vulnerable populations: besides feeling these impacts,

they are affected by the adverse effects of globalisation, which strips them of their customs and induces them to paid work and processed food consumption. These groups have been experiencing economic and cultural difficulties due to the lack of demarcation of their territories. Due to the lack of space for the reproduction of their culture, and especially the production of subsistence food, they are at greater exposure.

According to the Socio-environmental Institute - ISA, land remains the main banner of the Brazilian Indians' claims. Although this right has been ratified by law in the Federal Constitution since 1988, many peoples continue to fight to recover their traditional territories (ISA, 2007). For indigenous peoples, besides being a natural resource and a means of subsistence, land adds other values and represents their physical and cultural survival. ISA states that in the Northeast, only 20% of indigenous territories are demarcated, in contrast to indigenous areas in the Amazon, where demarcation reaches over 90% of the lands.

According to the 2010 Census, there are 305 indigenous ethnic groups in Brazil which speak one or two of the 274 languages identified. In that year, these ethnic groups numbered 896,900 individuals, 36.2% in urban areas and 63.8% in rural areas. The Northeast contains 38 indigenous tribes, agglomerating 81 thousand people, which means 21% of the total indigenous population of Brazil (IBGE, 2012). Among these peoples are the Tuxá, who today, like several other peoples, await the demarcation of their territory lost after the construction of the Luiz Gonzaga Hydroelectric Power Plant (1985), causing the flooding of their main islands (Vieira *et al.*, 2015)⁷. According to members of the Tuxá community, in the past, the indigenous territory was made up of several river islands between Chorrochó (Barra do Tarrachil) and the Pajeú River, in the state of Bahia, an area of approximately 1,600 ha (VIEIRA *et al.*, 2015).

Today the Tuxá are divided and scattered into different groups in Bahia (in the municipalities of Rodelas and Ibotirama) and Pernambuco (Fazenda Funil). However, 30 years after losing their territory, they still await fair compensation or reparation from the São Francisco Hydroelectric Power Company (Chesf) and the State. They offered a restricted urban area for the resettlement of the community - in contrast to the vast area where they grew food - leaving a feeling of dissatisfaction, provoking a demand for the delimitation of an area suitable for the reproduction of their customs and food production.

Besides causing the division of the Tuxá, the forced displacement generated intense changes in the group's daily life, including loss of identity, migration, poverty and, in some families, food deficiency. According to members of the indigenous people, the work undertaken by Chesf led to the removal of their ancestors and territories, their ethnic and symbolic values, which were territorialised on their main island, Viúva. Weist (1995) states that people involuntarily removed due to the construction of development projects undergo mourning, cultural involution and restructuring of their lives due to the impact their culture suffers after losing the connection with the accustomed areas or territories where they used to move and organise themselves.

Given that culture is the result of a process of identity construction carried out by people and their surroundings, the landscape forms part of the construction of identity and culture, which support their representations. Duncan (1990) states that landscape is one of the determining factors enabling culture creation. However, Cosgrove (1998) indicates that the possession of land or territory is crucial since it represents the disposition and possession of a fortune, generating comfort, security and stability.

The territory is the intersection of time and space based on territorial memories and imaginaries. It forms part of a sign whose meaning is only understandable from the cultural codes in which it is inscribed. Unlike physical space, it has a cultural significance and social implications, where social practices are established with distinct interests, with different perceptions, valuations and territorial attitudes, which generate complementary and reciprocal relationships (GARCÍA, 1976; GOTTMANN, 1973). Space is an activity of the soul, in which social action and reciprocal action are inscribed as

the act of filling a space, forming associations through expressions. There is an important relationship between subjects and objects of a space, establishing not only the characteristics of concrete societies but also their temporal evolution (SIMMEL, 1926; 1979).

In this sense, the Tuxá people, after suffering the banishment, moved away from their daily life and altered their perception of happiness and wealth, experiencing the delimitation of their temporal evolution and the loss of history and tradition that the symbolic value of the territory offered them, in addition to their own practical capacity to produce what they consumed. For some community members, the distance from their land limited the interaction between them and their sacred, ancient and natural spaces, such as the waterfalls that used to exist, distancing them from their ceremonial centres and reducing the interaction with their ancestors and divinities.

The Tuxá people witnessed a socio-cultural breakdown due to the miscegenation of its members with the non-indigenous population of nearby towns, as well as the move away from ancestral practices of cultivation, hunting and fishing, leading them to take on expenses they did not previously have, of feeding their families. According to members of the indigenous population, the lost land allowed them to cultivate approximately 100 fertile hectares, where they produced rice, onions, fruit trees, vegetables, products that were added to the families' daily diet, as well as fish extracted from the São Francisco, or meat from domestic livestock. For many residents of Rodelas, those times are remembered as periods of abundance, peace and harmony, memories that evoke nostalgia and revolt.

Currently, according to data from FUNAI's Local Technical Coordination in Rodelas-BA, of the 490 families living in the town, more than 70% (424 families specifically) receive benefits from the Bolsa Família programme and a quarterly basic food basket subministered by the National Supply Company - Conab (FUNAI, 2018). This highlights the existence of families in poverty or extreme poverty by the low opportunities for income generation, partly due to the lack of territory for cultivation, which prevents them from improving their current diet and their economic situation, which could be strengthened through the production and marketing of agricultural products grown. Therefore, a longed-for delimitation of the Tuxá territory is observed in Rodelas, a situation which, according to them, would allow the reconstruction of part of their history and promote a return to those times when cultivation in the territory brought them abundance and allowed them to ensure good food, within the context of their food security.

4 IRRIGATED PERIMETER AND WATER AND FOOD SECURITY: REALITY AND PERSPECTIVES

The SSF lies entirely within the semiarid territory. This region has a long history of living with periods of drought, with low average annual precipitation associated with a high evapotranspiration rate (CBHSF, 2016). According to data from the Ministry of Environment (MMA, 2017), in terms of agricultural suitability, the Submédio has only 7% of its soil ~with good potential, with the remaining 93% classified as regular, restricted, unfavourable or inadvisable. More recently, the region was pointed out, along with other areas, as having a high degree of desertification (MMA, 2017).

Given the drought scenario, the reduction of water availability in the Basin in the semiarid region limits the use of water, whether for human and animal supply or the development of economic activities. Although there is no land more suitable for the development of irrigation agriculture throughout the Basin, agriculture and livestock is the one that uses the most water, with around 540 m³ of withdrawal flow for each R\$ 1,000 of gross value added (GVA) (CBHSF, 2016). In the Submédio, the water demand for irrigation can exceed 10m³/s, as is the case of the sub-basins Curaçá [Curaçá 01] and Rio do Pontal [Pontal 01], which include the production hubs of Juazeiro-BA and Petrolina-PE (MMA, 2017).

Some public policies have been fostering the adoption of irrigation systems in the semiarid region, mainly in the last fifty years, as a promising practice for food production in the region, mitigating the impacts of irregular rainfall distribution on agricultural activities (CASTRO, 2018). Public Irrigation Projects (PPI or irrigated perimeters) are an example of such initiatives. The perimeters have a hydro-agricultural infrastructure, in parts of watersheds, with the demarcation of lots occupied by irrigating farmers (MACHADO *et al.*, 2017).

The irrigation perimeters were part of the Programme for the Development of Integrated Areas in the Northeast (Polonordeste), as part of a set of policies that aimed to form development poles in the less developed and less integrated areas of Brazil at the time (North and Northeast). The poles received infrastructure investments to receive activities of higher capital generation and promote a “conservative modernisation” of the local economy (ARAÚJO, 2000). In this sense, these places, including Juazeiro and Petrolina, became spots of higher income and more connected to the most dynamic economies of the country, as well as to external markets. The Polonordeste also had a collateral purpose of retaining the migratory flows that originated in the sertão towards the capitals and other regions. The development poles became intermediary centres that attracted emigrants from the region to their surroundings due to the economic dynamism of the pole (BURSZTYN, 2008).

In the case of the SSF, the irrigated perimeters are concentrated in the Juazeiro/Petrolina cluster, which is home to seven IPPs, all managed by the Companhia de Desenvolvimento dos Vales do São Francisco e Parnaíba (Codevasf). The first IPP was implemented in the region in 1968. Since then, a total area of over 114,000 hectares has been established. In these areas, the largest production is of fruit, mainly grapes and mango (SISPP, 2018). The Juazeiro/Petrolina hub is considered an incentive for developing a large part of the production chain through the overlap of large agricultural and livestock production areas with the concentration of industries, promoting intensive modernisation in the region. The pole has the highest gross value added (GVA) growth of the primary sector in the SSF in the last decade, and a growth trend pointed out as very high (MMA, 2017).

However, the last cycle of drought in the region has generated many impacts on the activity, threatening its water and food security. The Rainfall Anomaly Index (CAI)⁸ for the total annual precipitation for the municipality of Petrolina-PE in the period from 2010 to 2016 has remained negative (except for the year 2014, which had a timid positive value), with three years varying its intensity between very dry and extremely dry (SILVA *et al.*, 2017). Another important point to be analysed is the water availability of the Sobradinho reservoir upstream of the irrigated area. According to data from the National Water Agency⁹, in November 2017, the volume of the Sobradinho reservoir reached less than 2% of its maximum level. If we consider the beginning of the dry period in 2010 (taking the Petrolina IAC as a reference), in November of that year, the useful volume of the Sobradinho reservoir closed the month at just over 33%.

The region’s rainfall deficit and the consequent volume reduction is a climatic exposure factor that directly influenced the management of the Basin. Already in June 2017, the ANA released a resolution that established a measure to restrict the use of surface water withdrawal from the Basin, the so-called River Day, which took place on Wednesdays. The restriction even applied to water irrigation for perimeters irrigation (ANA, 2017). With a new resolution, in June 2018, withdrawals began to be suspended every fortnight, indicating an improvement in the hydrological conditions of the Basin (ANA, 2018).

Among the SSF social groups, family farmers in the Juazeiro/Petrolina irrigated area perceived the effects of the drought later. According to the farmers, the drought effects were noticed only after 2016, with more intensity after the 2017 use restrictions established by the ANA. However, even before this period, irrigators of some perimeters made some changes in the irrigation system of their properties. For example, farmers in the Mandacaru perimeter in Juazeiro use drip or micro-sprinklers to irrigate their crops. This change in irrigation method reduced approximately 50% of water and 30% of energy

use in the perimeter's properties as recently as 2013, according to Codevasf technicians (FEITOSA; MACHADO; FRANCO, 2017). In a way, the association of the infrastructure of the irrigation perimeters with the irrigation systems change contributed to improving water security for these farmers since their water availability had not been affected until that period.

Another impact perceived by farmers of the perimeter was the increased crop pests. They stated that, with the prolonged drought, pests do not find refuge in the dry Caatinga and begin affecting irrigated crops. With the increase in pests, these farmers use more pesticides to keep their crops productive. This increased use increases the total cost of production, which in most cases, cannot be passed on to consumers. Furthermore, the increased use of pesticides entails social and environmental consequences (e.g. soil and water contamination and health problems). In the case of water pollution, the problem is aggravated by scarcity itself, which means less capacity to dilute toxic substances.

On the other hand, most irrigation farmers do not have direct access to consumer markets but require the service of third parties who act as intermediaries in these transactions. The transfer of products to intermediaries further reduces the profitability of these farmers' production, reducing family income. To maintain food security, many farmers and their families need to supplement their income with other sources, usually outside the family farm enterprise. For Sabourin (2014), access to adequate markets is a problem faced by family farmers: "one of the difficulties of family farming forms lies in accessing partial and diversified markets adapted to their specific socioeconomic characteristics" (p. 21).

An alternative would be the creation of cooperatives as a form of social organisation to expand access to consumer markets or even strengthen associations of perimeter irrigators, the so-called irrigation districts. Currently, these associations are mainly responsible for the administration, operation, and maintenance of the irrigation infrastructure of common use. However, decisions on production and marketing are taken individually on each farm. In the case of the Mandacaru perimeter, a cooperative has already existed since the 1980s as a strategy of Codevasf. Although the company evaluated the results of the cooperative in the Mandacaru perimeter as satisfactory concerning the reduction of operating costs, the initiative was not successful, as were other cooperatives implemented by Codevasf in the irrigation districts. The main problems that may explain the failure of these cooperatives are associated mainly with the implementation process, cultural issues, and the lack of professional management of these enterprises (RIGO *et al.*, 2008).

The prospects for water security for irrigating communities are not encouraging. Trend scenarios point to a critical or very critical surface water balance for the SSF sub-basins in 2025 and 2035, showing a clear mismatch between demand and availability. In the case of agriculture and livestock, even adding a factor to analyse the ability to meet water needs, the Juazeiro/Petrolina hub still shows a tendency towards a very critical surface water balance in the two years considered (CBHSF, 2016). In this sense, it is a challenge to associate the perspectives of water availability with new alternatives for intelligent water use in agricultural production. However, other factors that promote the adaptive capacity of these social-ecological systems deserve to be considered (such as access to markets adapted to their particularities) in the promotion of water and food security of farming families in the irrigated perimeter.

5 FINAL CONSIDERATIONS

The analysis of different vulnerable groups shows that adaptation - as moderation of sensitivities and strengthening of adaptive capacities - varies according to the specific vulnerabilities of the multiple and contrasting realities that coexist in the SSS. From a systemic vision, one can understand the potential and future possibilities for the region, defined as the properties of social and natural systems that favour adaptation to climatic stresses. The cases presented illustrate that adaptation is conditioned to the physical characteristics of the place where the population is located (such as the rainfall regime

and proximity to perennial water bodies, factors that condition the “risk”). However, it also depends on various social, economic, cultural and political factors.

Beyond the specificities of each population, it is necessary to consider the interconnectedness of sectors, scales and actors, as well as integrated approaches that minimise trade-offs and maximise synergies between sectoral policy responses. The interdependence of society and the environment reflects the importance of integrated analyses and actions that relate physical, biological, social, political and economic aspects in the search for strategies that promote the resilience of such systems. This interdependence is well represented, on the one hand, by ecosystem services (the benefits to people produced and delivered by naturally functioning ecosystems, their characteristics, functions, or ecological processes), which are the pillars that sustain humanity and its activities (COSTANZA *et al.*, 2017; CUMMING *et al.*, 2017; MILLENIUM ECOSYSTEM ASSESSMENT, 2005).

On the other hand, the interconnection of society with the environment is also exemplified through policies regulating access to and use of such services. The Nexus approach - which explores the connections between water, energy, and food - appears as a proposal to promote adaptations and resilience in an integrated manner. The groups studied point to the relevance of addressing overlaps and connections in adaptations. In other words, actions for the region should address not only the specificities but the relationship between them and the systemic panorama of the region.

The lack of rainfall and water scarcity highlight the various uses of water and, above all, the conflicts and potentialities that emerge between sectors and groups. Water in the region is used to supply urban centres through dams and reservoirs; for human consumption and food production in family agriculture through reservoirs, wells, water tankers and social collection technologies; the dammed water that serves these publics also serves to irrigate irrigated agriculture plots (both corporate and family) and is used to produce energy distributed in the region and beyond. In this sense, as Nexus postulates, water is a resource that connects a diversity of actors and interests within the region and evokes the need for policies and analytical approaches that understand them in a connected way.

The three groups worked on here demonstrate the plurality of impacts occurring within a region with the same historical background and under the same climatic stress. However, we can observe that the apparently specific vulnerabilities cannot be understood in isolation. The water for energy production dammed in Sobradinho Lake is the same water required to irrigate the agricultural perimeters of Juazeiro and Petrolina. Electricity generation generates conflicts of interest of a different nature 300 km downstream, where the Tuxá are still trying to recover their productive and cultural dynamics 30 years after the flooding of the Itaparica lake. 120 km away, the challenges of rural activity in Juazeiro/Petrolina and in Uauá illustrate the contrasts inherited by public action (or omission) in the region’s past: the food and income security of the Fundo de Pasto communities are still subject to rainfall variation and uncertainties regarding land regulation, as opposed to the public irrigated perimeters, which have not felt the effects of six years of drought so intensely but lack the mobilisation capacity of traditional communities.

As such, climate adaptation and, more broadly, the sustainable development of regions such as the one exemplified by the studies carried out in the SSF depend on understanding their heterogeneity and complexity and connections established within the sub-basin and beyond.

NOTES

1| Agenda 2030. Available at: <https://nacoesunidas.org/pos2015/agenda2030/>.

2| National Policy on Climate Change (PNMC), Law 12.187, 2009. Available at: http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2009/lei/l12187.htm.

3| National Adaptation Plan (NAP). Available at: <http://www.mma.gov.br/clima/adaptacao/plano-nacional-de-adaptacao>.

4| The IAC is a method to assess climate change at local level based on the behaviour of the rainfall regime (SILVA *et al.*, 2017). The IAC analyses the frequency and intensity of dry and rainy years. If it is positive (positive anomaly), it indicates that the observed values are above the historical average of precipitation in the region. If it is negative (negative anomaly), it indicates that the rainfall volume was lower than the historical average (SOBRAL *et al.*, 2018).

5| The Intercensal Survival Ratio (ISSR) provides an indication of the out-migration of young people from rural areas in the submontane region. The RIS is the difference of a population cut-off between a Demographic Census and the previous census. In this sense, it reflects the decrease (values less than 1) or increase (values greater than 1) in the population of a given age group. In cases of negative RIS, the value can indicate three different phenomena: i) emigration, ii) mortality and iii) changes in the definition of rural and urban spaces between the censuses (MAIA; BUAINAIN, 2015).

6| Difference between immigrant and emigrant population, over total population of region, multiplied by 100.

7| The Luiz Gonzaga Hydroelectric Power Plant (formerly known as Itaparica Hydroelectric Power Plant) is located in the Brazilian states of Bahia and Pernambuco. It belongs to the Chesf company and was renamed in honour of the Brazilian singer-songwriter Luiz Gonzaga do Nascimento (1912-1989).

8| Method for assessing climate change at local level based on the behaviour of the rainfall regime (SILVA *et al.*, 2017).

9| Data from the Reservoir Monitoring System/SAR. Available at: <http://sar.ana.gov.br/MedicaoSin>. Accessed: dec. 2018.

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