UNDERSTANDING RISKS ASSOCIATED WITH THE SÃO FRANCISCO INTER-BASIN WATER TRANSFER IN THE SEMIARID REGION OF BRAZIL

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1 Introduction

Risk analysis have become a popular practice to justify a wide range of disaster risk reduction public policies (STERN; FINEBERG, 1996; COX, 2012). It usually addresses basic questions such as: What can go wrong? How likely is it? What are the consequences? How certain is this knowledge? (KAPLAN; GARRICK, 1981). Its success depends on systematic analysis of hazards, vulnerabilities, and local capacities, as well as the cause-and-effect relationship between social-economic development actions and their probable consequences (LAVELL, 2012; WISNER *et al.,* 2011). Based on appropriate methods to understand the problem, risk analysis should also contribute to clarify uncertainties of importance to the decision problem in a comprehensible way (STERN; FINEBERG, 1996).

These features of risk analysis, as advocated by some disaster science scholars, should be an integral part of national and local development processes to identify and minimize present risk of disasters, and avoid political decisions that can create new risks (LAVELL, 2012; WISNER *et al.,* 2011). However, despite major efforts at the international level to include disaster risk reduction into development discussions, like the Sendai Framework for Disaster Risk Reduction (UNISDR, 2015), losses from extreme events continue to mount, showing that modern society is still systematically producing more and greater risk of disasters than it can reduce (BECK, 2011; LAVELL; MASKREY, 2013). Globalization and technology generally seen as positive outcomes of development are, from a risk perspective, also unleashing hazards and new potential threats to an extend previous unknown (BECK, 2011). Differently from localized risks created before the industrial period, these side-effects of modern society are manifested as regional and global threats such as climate change, sea-level raise, radioactive waste, pandemics, and many others that are both interconnected and simultaneously happening. Even when taking measures to minimize the impact of disasters and climate change, modern technology and mega-infrastructures can increase the risk of new and sometimes even worst disasters than the ones it intends to mitigate, like the case study presented in this chapter.

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In a tentative to minimize the impacts of drought in the driest and one of poorest region of Brazil, the federal government invested more than US$4 billion in the biggest water infrastructure in Latin America: The São Francisco Inter-Basin Water Transfer (SFIWT), with the objective to ensure water security for 12 million people in 390 different municipalities (MINISTRY OF REGIONAL DEVELOPMENT, 2020). It is expected that this mega-infrastructure, beyond benefiting the most vulnerable population to drought in Brazil with a reliable source of freshwater, will also increase social-economic development in the semiarid region (CASTRO, 2011).

However, if on the one hand the SFIWT presents a great opportunity for social and economic development of the semiarid region, on the other it is creating new risks with potentially more destructive impacts than drought for the whole country. The SFIWT coupled with unforeseen climatic events, environmental degradation, and man-made changes in the ecosystem are considered by many specialists a real threat to the existence of the São Francisco river (one of the most important rivers of Brazil), some of its tributaries, and the different basins the SFIWT is connecting. Understanding the main characteristics that make this mega-project a high-risk system can contribute with national water security and promote awareness of risks associated with inter-basin water transfers as a strategy to mitigate drought.

2 Methodology

The SFIWT provides an opportunity to investigate risks associated with inter-basin water transfer to mitigate drought in arid and semiarid regions around the world. Using the theoretical framework of risk analysis, this research gathered for more than 2 years a wide variety of primary and secondary data source related to this mega-project, mainly peer-reviewed articles, books, textbooks, government documents, official government website and media releases. Then, data analysis was conducted using directed content analysis to interpret the data sources and identify three main types of risk: social, economic, and environmental risks. After a careful analysis of the data sources, all information was put together in an integrated risk analysis to understand which the most eminent risks are and the extend losses and damages it can cause to Brazil.

3 The São Francisco Inter-Basin Water Transfer: Context, History, and Technology

3.1 Context

The SFIWT project was designed to provide a steady supply of freshwater water to 12 million people living in the semiarid region of Brazil. The semiarid is one of the poorest regions of the country, home for more than 28 million people. It comprises an area of 1.128.697 km^2 stretching over nine federal states, totalizing almost 10% of the total area of Brazil (SUPERINTENDÊNCIA DO DESENVOLVIMENTO DO NORDESTE, 2018), equivalent to the size of Texas and Colorado states combined. Hydrologically, it is characterized by a reduced water availability and very limited storage capacity of rivers, where most of the rivers are intermittent, with just a few exceptions that are perennial through streamflow regulating reservoirs (CENAD, 2014).

However, the causes of drought in the semiarid of Brazil are multi-dimensional and can be only fully understood if also considering social, economic, and political processes that create and maintain vulnerabilities in the region. Although geological and hydro-meteorological characteristics play an important role as triggers for drought, it is well documented that the primary factor for poverty, starvation, crops failure, and rural-urban migration is not lack of water, but lack of investments in social welfare, public infrastructures, urban and rural planning, and risk mitigation measures (ARONS, 2004; TOMÉ SILVA, 2012).

Throughout decades, innumerous actions and public policies were implemented in the attempt to minimize the effects of drought in the semiarid region of Brazil, nevertheless none of them obtained permanent results (PASSADOR; PASSADOR, 2010). One possible explanation from the disaster science perspective is that disaster mitigation actions are prompt to fail in places with high level of economic inequalities, like the semiarid region of Brazil, if not considering social and economic differences within communities (GILLINGHAM, 2001) and integrating the most vulnerable and marginalized groups in the decision-making and implementation processes (ADGER, 2003; BRONDIZIO; OSTROM; YOUNG, 2009; LAVELL, 2012; ALDRICH, 2012).

The semiarid region of Brazil has a long history of political decisions regarding local water resource management that excludes the most vulnerable population and manipulates water resources in exchange for votes, cheap labor, and control of local economy (ARONS, 2004). Constantly referred as the "politics of drought" or "the industry of drought", this systematic social marginalization practice fails to accommodate participation in the management and administration of water resources by actors other than the local elites.

It all started with the occupation of the semiarid land in the beginning of the 18th century, when a Royal Charter (1701) prohibited cattle raising activities along the coastal strip to 60 kilometers (37.5 miles) into the hinterland (JUCA, 1994). Thereafter, cattle raising started to play an important role in the regional economy together with cotton crops, introduced in the middle of that century (CAMPOS; STUDART, 2008). Over two decades, both human and cattle population grew rapidly, but the demand growth was not followed by any augmentation of the water supply, resulting in a very vulnerable population, highly dependent on small reservoirs and alluvial aquifer storage (CAMPOS; STUDART, 2008).

From 1877 to 1879, the semiarid region of Brazil had its deadliest drought, known as "The Great Drought", which caused the death of more than 500 thousand people and massive migrations to the Amazon and Southeast regions (ARONS, 2004; MARENGO, 2010). It also disrupted the local economy based on cattle raising and cotton crops, forever changing economic activities in the region (LINDOSO; EIRÓ; ROCHA, 2013). The Emperor Pedro II, ruler at the time, visited the most affected communities and, impressed by the horrors of famine, promised to sell until the last crown jewel to minimize the problem. After that, even though not a single crown jewel had been sold, drought mitigation solutions for the semiarid region of Brazil begun to be stimulated (ARONS, 2004; CAMPOS; STUDART, 2008). Basically, there were three groups of solutions: those favorable to dams and irrigation; those favorable to water transfer from São Francisco River; and those favorable to changes in the economic profile of the Region (CAMPOS; STUDART, 2008).

This paper will focus on the water transfer from the São Francisco river, currently called the São Francisco Inter-Basin Water Transfer, or SFIWT, and will question whether it is the best solution to mitigate the impacts of drought in the semiarid region of Brazil or if it will only increase local risk by creating new threats and vulnerabilities.

3.2 History

Inter-basin water transfer is a technique to manage water supplies by transporting water from a hydrographic basin with water availability to another basin with water shortage. It became a common strategy to increase the amount of water available to farmland, rural productivity, urban development, and mitigate the impact of droughts in many countries. Inter-basin water transfers have already been implemented in Brazil (although in a much smaller scale than the SFIWT project) and all over the world with very different outcomes varying from successful cases of blooming and permanent agricultural production to armed conflicts and extensive environmental disasters. One way or another, as water becomes increasingly scarce, political barriers against inter-basin water transfers increase, particularly when it is necessary to cross the border between countries or different states (CAMPOS; STUDART, 2008). The SFIWT project is an example of a controversial project of difficult technical and political viability, which caused nationwide conflicts between those in favor and against the project.

Since the nineteenth century, the SFIWT project has been proposed by a group of scientists and politicians as the definite solution for social, economic, and environmental problems in the semiarid region of Brazil. The first proposal was made in 1818 and discussed for more than a century until be discarded in 1920 due to lack of technology to overcome geological barriers (HENKES, 2014 *apud* RIBEIRO, 2017).

In 1981, after a period of severe drought, the project got back to the political agenda and started to be reconsidered by subsequent governments but rejected by different motives like economic resources and judicial problems (CASTRO, 2011). In the beginning of the 90's, main hurdles against the project were political rather than technological, imposed by the local oligarchy who detain 80% of all arable lands and who also control the use and distribution of water in the region (PÉRICLES, 2012). They rule by the principle of scarcity, exchanging water for favors, votes, and work, in what became known as the "industry of drought" in Brazil (ARONS, 2004). With the diversion of the São Francisco river, these powerful families and politicians who compose the local oligarchy were too afraid of losing their main source of political control and started to put a series of barriers to stop the project.

During the subsequent administration of President Fernando Henrique Cardoso (1994–2002), the project was designed more slowly and for the first time environmental issues were discussed in public meetings (CAMPOS; STUDART, 2008). Nevertheless, the discussions surrounding the SFIWT were heated and incredibly divisive (LEE, 2009). In summary, those supporting the project considered the SFIWT as the definitive solution for drought related problems (CAMPOS; STUDART, 2008), arguing that it would bring social and economic development for the semiarid region by increasing agricultural production, attracting industry and large companies, creating jobs, and promoting urban development.

The opposition claimed that the project would benefit only the wealthiest portion of the population, as large construction companies and large-scale farmers, have a negative impact on the local indigenous population, and become an economic burden for the country. The project price tag was estimated at $6.3 billion dollars, but the Brazilian group charged with watching federal spending (TCU) advised that the Brazilian Government had "severely miscalculated the costs of the project" (LEE, 2009). It worth mentioning that all funding for the SFIWT project would have to come from the Federal Government, since the World Bank refused to assist in the effort (LEE, 2009). Yet, the most emphatic and disturbing critique, especially from the environmental side, was that the SFIWT could cause the collapse of whole São Francisco River basin (CAMPOS; STUDART, 2008; LEE, 2009; PÉRICLES, 2012; HENKES, 2014 *apud* RIBEIRO, 2017).

After years of heated debates and intense political opposition, the constructions finally started in June 2007. A court order tried to stop the construction in December 2007, but it re-started one month after, in January 2008.

3.3 Technology and Complexity

The São Francisco Inter-Basin Water Transfer project is the biggest water infrastructure of Brazil. It has a total of 477 km of water canals connecting six different watersheds[2], with the objective of ensuring water security for 12 million people spread over 390 different municipalities. It creates a complex and integrated system of small dams and artificial reservoirs connected by 700 km of water tunnels, aqueducts, and tubes pumped by more than 2,000 machines controlled by different kinds of technologies and operational systems (MINISTRY OF REGIONAL DEVELOPMENT, 2020).

The SFIWT have two water channels: One heading north (North Canal) and the other heading east (East Canal) from the São Francisco river. The project includes nine pumping stations, 27 aqueducts, eight tunnels, 35 water reservoirs, two hydroelectric plants, and connects 6 different watersheds (ANDRADE; BARBOSA; SOUZA, 2011).

One of the main technological challenges of the engineering project was to find means of overcoming the differences in altitude between water catchment areas on the São Francisco River and the receiving basins. In the North Canal a volume of 45,2 m^3 of water have to be pumped more than 160 km up, and in the East Canal a volume of 20 m^3 have to overcome an unevenness of more than 300 km up. A robust pumping system that requires a great among of energy will do the job (MINISTRY OF REGIONAL DEVELOPMENT, 2020). This system is entirely connected to the six hydroelectric power plants along the São Francisco river, which together provides 88% of the total energy for Northeast of Brazil (where the semiarid region is located). In practice, it means that if the SFIWT cause shortage of water to the São Francisco river just enough to reduce the production of electricity, it will impair or even completely obliterate its own pumping system.

Currently, the project is in its final phase of conclusion with 93% of all infrastructural work completed. The East Canal was inaugurated on March 2017 but is not fully operation yet. It is in the pilot phase, undergoing tests and adjustments, and only a couple of municipalities are being supplied with water from the São Francisco river. There is no expected date for the inauguration of the North Canal, even though the official government website of the project says it is in its "final stretch"[3].

After the conclusion of both canals, treatment, maintenance, and distribution are going to be responsibilities of state governments (MINISTRY OF REGIONAL DEVELOPMENT, 2020). These efforts demand complementary hydraulic infrastructures to give capillarity to water distribution and a network of more than 960 km of main and branch pipelines will be needed. Some of these complementary infrastructures were due 2018, but the states have declared they do not have the resources needed to fulfill their part of the agreement.

The lack of synchronism between federal and state governments is just one of the imbroglios delaying the normal operation of this mega-infrastructure. Besides, the local water management model is still under discussion on the five states benefited by the project. Also, it is a matter of fact that these states will have to pay for the entire operation and maintenance of the complementary water infrastructure. However, it is not known yet how they will make it, and how the final consumer will be charged for the use of water, and what guarantees the states will offer to the federal government in case of nonpayment or no compliance to their responsibilities.

4 Risks associated with the SFIWT project

4.1 Large scale Inter-Basin Water Transfer: What can go wrong?

Previous experiences have shown the potential of large-scale inter-basin water transfers to cause or aggravate disasters. One of the most iconic examples is Karakum Water Transfer Project in the former Soviet Union for irrigations purposes, especially cotton crops, which caused a decrease of 92% of the total volume of the Aral Sea (MICKLIN, 2010) and the collapse of all economic activities dependent on the regional ecosystem, which is now virtually extinct (GLANTZ, 2012). Some specialists consider this to be the worst man-made environmental disaster of human history.

In China, where river diversion and inter-basin water transfer have been traditionally used for millennia (with some water canals dating back 456 BC), many scientists are now searching for alternative solutions to water shortage for understanding that inter-basin water transfers can indeed increase the risk of new and different disasters. Even though attention has been slowly shifting on the development of local strategies, the Chinese government has started in 2002 the construction of the South-to-North Water Transfer Project, the biggest water infrastructure in the world, to stimulate regional development and maintain China's rapid economy growth (HE *et al.*, 2010; WORLD COMMISSION ON DAMS – WCD, 2000). The clear focus on economic growth, however, have created environmental, social, and economic problems related to inter-basin water transfer projects countrywide, such as loss of land and riparian habitat, change of hydrology of river systems, damage to fisheries and wildlife species, alteration of scenery, relocation of people, and increase of water-borne diseases like schistosomiasis, malaria, and intestinal parasites (GLEICK, 1998; HE *et al.*, 2005, 2007, 2010; WCD, 2000). Just to have a dimension on the scale of social, political, and economic problems caused by inter-basin water transfers, only in the period of 1960-1990, more than 10 million people were officially displaced in China (GLEICK, 1998).

Just like in China, waterworks for irrigation, mineral extraction, and urban development has been important in the Iberian Peninsula from ancient times (ALBIAC *et al*., 2006). However, more recently, in 1993, the Spanish National Hydrological Plan to interconnect all main basins of the Iberian Peninsula caused so much controversy, conflicts, and distrust between social and political groups (ALBIAC *et al*., 2006) that it had to be abandoned. The Spanish government then, due to heavy increase of water demand from the highly profitable fruit and vegetable sector, proposed a much smaller inter-basin water transfer bringing water from the Ebro basin to the Júcar, Segura and Sur basins. Once more, the renewed project met with strong opposition from water resource experts, environmental and social organizations, who argued that this project would have a strong negative environmental impact on the fluvial ecosystem, as well as on the estuarine and marine ecosystems, which could cause subsequent economic and social problems (IBANEZ; NARCIS, 2003). Finally, the Ebro water transfer was cancelled in 2005 by the Spanish Parliament and the policy to solve the severe degradation of water resources in the Iberian Peninsula basins changed focus to a project that augment water supply with seawater desalination (ALBIAC *et al.,* 2006).

Negative side-effects of many other large inter-basin water transfers around the world could be mentioned here to justify why these kinds of projects, generally designed to promote economic development in semiarid or arid regions, can actually increase the risk of disasters. However, since this paper will analyze with more details the specific case of the São Francisco Inter-Basin Water Transfer, this space will be used to highlight one common and important characteristic of all inter-basin water transfer projects: They all adopt an engineering economics approach (ALBIAC *et al.,* 2006), and leave out some critically important theoretical and empirical analysis on environmental and social impacts, as well as complex interconnectedness between them.

In the case of the São Francisco Inter-Basin Water Transfer, the whole project was designed to promote economic growth in the semiarid region to mitigate the effects of drought without considering that "social production of wealth is systematically accompanied by social production of new and sometimes unpredictable risks" (BECK, 2011). The value of water was measured in its availability, access, and use for human production and consumption, ignoring or giving much less importance to the water cycle in the semiarid region and its impact on the local ecological system.

Instead of developing strategies to live within the natural conditions of semiarid biome, respecting its physical and geological characteristics and managing the quantity of water already found in the region, technologies like inter-basin water transfers are developed to change nature, control it, and some would even say, improve it for the sole benefit of humans.

According to Perrow (1984) "as we invade more and more of nature, we create systems – organizations, and the organization of organizations – that increases the risks for operators, passengers, innocent by-standers, and for future generations." This paper argues that inter-basin water transfers are the result of complex interactions between human organizations, technology, and environmental systems, and present a greater risk of adverse social and ecological impacts than any other kind of waterworks. For that reason, it should not be considered a safe strategy to mitigate the impact of droughts worldwide.

4.2 Risks associated with the São Francisco Inter-Basin Water Transfer

The São Francisco River is one of the most important and iconic rivers of Brazil for its size, water provision, and cultural symbolism. Many communities depend on it for agriculture, fishery, transportation, tourism, and daily use of water.

All these economic and social activities, together with six hydroelectrical power plants, have been causing great pressures on the river, already considered overused by environmentalists and water management experts. It worth to mention that water from the São Francisco River is also withdrawn illegally for small mining operations, for small wells, and by farmers who simply build their own reservoirs (HARVEY, 2008), increasing even more the stress on the river and its tributaries.

Beyond all environmental problems related to unsustainable water use, other common environmental concerns regarding the São Francisco basin are deforestation of the riverbed, pollution, and biodiversity loss (MINISTRY OF NATIONAL INTEGRATION, 2004). Most of the communities alongside the river are poor and explore the local environment as an economic resource without any kind of sustainable environmental management techniques or adequate environmental impact assessment.

Even though considering all these social, economic, and environmental issues, the Government of Brazil decided to go ahead with the inter-basin water transfer project to divert water from the São Francisco river to water reservoirs, dams, other basins in the semiarid region, where the poorest among poor communities of the semiarid are found. The São Francisco river was chosen for its size and strategical location, very close to the area where droughts are more frequent and cause a greater social and economic impact.

The main actors involved in SFIWT are the Federal Government, State and Municipal Governments, local NGOs, residents of the areas to be affected, including farmers, small businesses, and others whose lives and livelihoods may be permanently affected by such large-scale projects (ANDRADE; BARBOSA; SOUZA, 2011). All these groups have subgroups in favor and against the project.

Those in favor of the diversion of the São Francisco River justify that this project will bring social, economic, and environmental benefits to the semiarid region as mentioned before, changing forever the scenario of scarcity in the region (MINISTRY OF NATIONAL INTEGRATION, 2004). It is argued that a reliable source of water during the whole year will attract new market investments, employment opportunities, rapid urbanization, and consequent social improvements. Poor populations of the semiarid region won't have to migrate to wealthier urban centers in search of a better life on every new drought event, nor should exploit the local environment to increase their monthly income.

On the other hand, those who oppose the diversion of São Francisco river understand that it would generate more problems than real solutions, alerting even for the possibility of killing the São Francisco river and causing water scarcity in other places where the river is the main resource of social and economic activities (HARVEY, 2008). With new industries being attracted to such a poor region as the semiarid, these groups also alert for the possibility of labor exploitation to maximize profits, as well as environmental degradation due to natural resource extraction and all sort of chemical pollution and waste (BRAGA *et al*., 2009; ANDRADE; BARBOSA; SOUZA, 2011; PÉRICLES, 2012).

Between these two extremes opinions regarding the SFIWT, there are infinite other arguments against and in favor of the project. For that reason, the assessment of who will benefit or suffer because of this project has become a great challenge. As the main investor, the Federal Government is likely to overestimate the benefits of the project to all stakeholders and underestimate the potential damages. The opponents of the project usually tend to exaggerate the damages and minimize the potential benefits (ANDRADE; BARBOSA; SOUZA, 2011). Thus, it is easy to understand the resulting complexity for decision-makers which can be enlarged by the media, which often highlights the antagonistic views, making it more difficult to achieve a final consensus (BRAGA *et al*., 2009).

So, to examine the main risks of the SFIWT, this paper will focus on the Official Environmental Report (MINISTRY OF NATIONAL INTEGRATION, 2004) of the São Francisco Inter-Basin Water Transfer and articles published in scientific journals.

The Official Environmental Report of the SFIWT mentions 44 potential environmental, health, social, and economic impacts of the project on the semiarid region of Brazil. Among them, according to the same Environmental Report, 23 are of greater relevance, where 11 are considered positive and 12 negative impacts (Table 1).

Table 1. Most relevant positive and negative impacts of the SFIWT

Positive Impacts	**Negative Impacts**
1. Increased supply of freshwater.	1. Changes in the composition and characteristics of water biological communities in the receiving basins.
2. Generation of jobs during the implementation phase.	2. Temporary loss of jobs and expropriations.
3. Stimulation of regional economy.	3. Risk of reducing aquatic biodiversity in the receiving basins.
4. Increased supply of water on urban centers.	4. Introduction of social tensions and risks during the construction phase.
5. Increased supply of water for rural populations.	5. Rupture of socio-community relations during the construction phase.
6. Reduced exposure of the local population to drought.	6. Possible interference and conflicts with indigenous populations.
7. Increased agricultural activities and incorporation of new productive areas.	7. Loss of 430 hectares of native vegetation and wildlife terrestrial habitats.
8. Improved water quality in receiving basins.	8. Introduction of potentially dangerous fish species in the receiving basins water ecosystem.
9. Decrease of rural-urban migration.	9. Increased pressure on urban infrastructure.
10. Reduced exposure of the local population to diseases and death related to drought.	10. Changes on the river regime of receiving drains.
11. Reduced pressure on health infrastructures.	11. Interference on fishing activities in the receiving dams.
	12. Risk of loss of cultural heritage.

Examining all 23 greatest positive and negative impacts enumerated by the official Environmental Report of the SFIWT through the lens of risk studies perspective, makes it clear that: First, these potential new risks have been reported as if they were separated or disconnected from each another, and not as parts of an integrated system. This kind of disconnection between different events and knowledges have been pointed by some scholars as one feature of modern society, where the production of scientific knowledge is compartmentalized and different disciplines seldom dialogue to each other (BECK, 2011).

Second, most of the positive and negative impacts listed by the Environmental Report are very vague and some of them are contradictory. For example, "improved water quality in receiving basins" was mentioned as one of the most positive impacts of the SFIWT. On the other hand, negative impacts such as "changes in the composition and characteristics of water biological communities in the receiving basins", "introduction of potentially dangerous fish species in the receiving basins water ecosystem" and possible "interference on fishing activities in the receiving dams" also gained prominence at the top12 negative impacts.

"Reduced pressure on health infrastructures" is also numbered as one of the most relevant positive outcomes. However, besides its vagueness and lack of explanation of what is this pressure on health infrastructure on the Environmental Report, it is subsequently contradicted by many others minor negative impacts that, if summed, could actually increase pressure on health infrastructures, such as "increased risk of accidents due to heavy traffic of people and vehicles in the construction site", "increase dust emissions", "increased onset of diseases" described in the Environmental Report as waterborne diseases as dengue and schistosomiasis, as well as sexually transmitted diseases among workers.

Third, many of the impacts described as positive could in turn be understood as potential new risks. Let's take the example of "Increased agricultural activities and incorporation of new productive areas". From a pure economic perspective, this could be perceived as a positive outcome of the SFIWT. However, from an integrated risk studies perspective, it could mean an aggravation of local vulnerabilities and a significant increase of risk. Not that increasing agricultural productivity and croplands would always imply an increase of risk, even though Beck (2011) would argue that any economic production implies creation of risks that are both ignored and symbolically manipulated and perpetuated but considering the context in the semiarid region of Brazil, it gets more likely that agricultural expansion would create more risks than benefits. Brazil is the largest global consumer of agri-chemicals that are directed link with human health problems and environmental degradation (CARNEIRO, 2015). An expansion of agricultural production in this case would be accompanied by an increase of agri-chemicals pollution of already scarce water sources as small reservoirs and alluvial aquifer storage. Agricultural expansion is also responsible for the depletion of the natural fauna of the semiarid region (the Caatinga) and pointed as the main cause of desertification of the landscape due to man-made fires to clean-up local forest for agricultural purposes (FREIRE; PACHECO, 2005).

Add to the environmental dimension the fact that the local oligarchy detains 80% of all arable lands in the semiarid region (PÉRICLES, 2012), and a scenario where agricultural expansion could mean environmental degradation and deepening of economic inequalities is made. After all, all the profits of the agricultural expansion would be in the hands of a few families who control water and production. Of course, this is only true if considering that "disasters are more a consequence of social-economic than natural factors" (O'KEEFE; WESTAGARTE; WISNER, 1976) or, as in Alexender (2006) "vulnerability is a greater determinant of disaster risk than hazards themselves", meaning that disasters can only be fully understood if also considering social, economic, political, and cultural processes that create and maintain vulnerabilities at the first place (WISNER *et al.,* 2004; LAVELL; MASKREY, 2013).

Also "Generation of jobs during the implementation phase", considered by the Environmental Report a positive impact of the SFIWT in the short-term, could mean in the long-term an increase of local vulnerabilities like poverty, unemployment, escalation of crime and violence. After the implementation phase, many people will lose their jobs, and unless more jobs are created quickly in the region all these people and their families will soon join the poorest population of Brazil, which are located exactly in the semiarid region where these temporary jobs are being created, but not maintained by the SFIWT.

Other risks associated with the SFIWT are being published in scientific journals, especially from the environmental science. Although the National Integration Ministry had reported that the environmental impacts of the SFIWT will be minimal (BARBEL-FILHO; MARTINEZ; RAMOS, 2015), some researches raise concerns not only about the area of influence of the water transfer project, but for the whole biome of the semiarid region, known as the Caatinga. Like stated before, the Caating Biome is the driest biome of Brazil, characterized by reduced water availability and very limited storage capacity of rivers, where most of the rivers are intermittent (CENAD, 2014). It has been recognized that the extremes of flooding and total absence of water flow are the principal hydrological characteristics of rivers and streams in this region (MALTCHIK; MEDEIROS, 2006). However, the SFIWT is about the dramatically change this essential characteristic of the Caatinga by transforming some of the most important intermittent rivers into perennial streamflow. As in the official Environmental Report, the SFIWT "will result in the expansion and perpetuation of 24 reservoirs, creating a perennial surface of water of approximately 6,846 hectares, interconnected through canals and local rivers".

Emerging concepts in temporary-river ecology consider this perpetuation of temporary rivers a threat to the ecological integrity of rivers and streams in semiarid regions of the world (MALTCHIK; MEDEIROS, 2006). The dynamics of temporary rivers such as advancing and retreating wetted fronts, hydrological connections and disconnections, and gradients in flow permanence, have a direct influence on biotic communities, nutrients, and organic matter processing, on which large-scale biodiversity depends upon (LARNED *et al*., 2010). For instance, the maintenance of the natural flow patterns in the semiarid of Brazil would be paramount to ensure that benthic algae, a basic and important energy source, is available for consumers up in the food chain (MALTCHIK; MEDEIROS, 2006). Because algae are highly sensitive to changes in flow (ROBSON, 2000; ROBSON; MATTHEWS, 2004), regulation or alterations in the flow regime of intermittent streams may lead to loss of this resource. Therefore, the SFIWT can cause important hydrological disturbances which are directly related to the biodiversity of aquatic systems in semi-arid Brazil, "leading inevitably to the extinction of species and the loss or disruption of natural patterns of flow in these intermittent environments" (MALTCHIK; MEDEIROS, 2006).

Barbosa (2017) also alerts that the perpetuation of temporary rivers in the semiarid region of Brazil will cause the quick silting of tributary rivers and consequently the silting of all main rivers of the basins involved in the project. According to Barbosa (2017), this is likely to happen because the soil of the semiarid region is composed basically by loose sandstone, that will quick change the dynamic flow of the local rivers and fatally lead to the death of most of the tributaries of the São Francisco river and the receiving basins, causing a systemic collapse of the local aquatic and terrestrial ecosystem.

Another environmental impact of great concern caused by inter-basin water transfers is the consequent introduction of new species in different ecosystems, enhancing ecological problems on both giving and receiving basins, as well as on their connections. As in (AZEVEDO *et al*., 2014) the introduction of exotic species is the second most important cause for biodiversity loss in global scale, and the SFIWT is likely to cause ecological damage to the receiving basins with the introduction of exotic species, water pollution and decrease in discharges of the São Francisco river as well as proliferation of green algae. The introduction of exotic species of mollusk (Corbiculidae largillierti) have already been reported for the first time in the Paraiba basin river (one of the receiving basins of the SFIWT) due to the SFIWT. The introduction of this species in freshwater ecosystems may alter fish diets and impair industrial activities, leading to economical loss (DARRIGRAN, 2002, SANTOS *et al*., 2012). It can also cause damage to human health given that some Corbiculidae are bioaccumulators of heavy metals (DARRIGRAN, 2002; SANTOS *et al*., 2012). Furthermore, biologists and environmentalists are alerting for the risk of the introduction of other mollusk invaders in this basin due to the diversion of waters from the São Francisco river (AZEVEDO *et al*., 2014).

Other important risk factor not mentioned in the official Environmental Report nor in any scientific articles accessed by this paper is the fact that Brazil doesn't have a disaster risk management system capable of dealing with new risks created by the SFIWT. Based on few documentations available on disaster risk management in Brazil, it is clear that the national risk management system is still dominated by the structural functionalism paradigm, in which disasters are understood as an unforeseen, unpredictable, and natural phenomenon that randomly disrupt the "normal" social life. This perspective is related to the "preparedness and response" paradigm, which reactively manages disasters and emergencies as they occur. Even though the law states very clearly that risk management should be a priority, the whole system is still, to be optimistic, in a transitional process.

There are many reasons for that. First, the law determines that funds and resources should obligatorily be transferred to states or municipalities in case of disasters, but only voluntarily (and with much more bureaucracy) for mitigation actions, making it easier for municipalities to wait disasters to happen to have access to funds. Adding to this, Brazil still have a militarized civil defense system that may be not feel comfortable in interfering on development issues, but rather doing what they have been trained to do with great expertise and skills, which is responding to disasters and rescuing people (VALENCIO, 2010).

These characteristics of the National Civil Defense of Brazil, which is secretary responsible for disaster risk management, makes it clear that the risks created by the SFIWT will not be mitigated by them, and in case of a systemic failure of the project, there is little they can do other than coordinate the provision of water, food, and shelter for the affected people.

Finally, some of the risks described in this section are tightly coupled and part of a complex system composed by different ecosystems, technologies, and operators. The worst-case scenario, where some of these risks evolve simultaneously and in an unpredicted way, would take time to evolve, but would have catastrophic national and international impacts. Brazil is the world's largest producer and exporter of soybeans, sugar, poultry and one of the biggest exporters of coffee, wheat, rice, corn, cocoa, citrus, beef, and manufactured products as vehicles and aircraft including helicopters, airplanes, and spacecraft (OBSERVATORY OF ECONOMIC COMPLEXITY, 2016). Most of these products are totally depend on the São Francisco river and the basins the SFIWT will connect. Nationally, more than 18 million people live in the area of the São Francisco Basin, and other 12 million in the area of influence of the SFIWT, totalizing a minimum of 30 million directly affected in the case of a systemic accident.

Conclusion

To understand the risk of disasters associated with inter-basin water transfers, there must be an integrative risk analysis considering all stakeholders involved; social, cultural, economic, political, and environmental impacts; and consider the infinite possibilities of connections among these dimensions. It would demand an exhaustive inter and even transdisciplinary effort to provide enough elements to reach a conclusion whether inter-basin water transfers should or shouldn't be done, especially as a mitigation plan to drought. These facts suggest that inter-basin water transfer is a high-risk system, for it is very hard to predict the consequences of the complex interaction between technology, nature, and human society when trying to overcome natural barriers and change the course and connectivity of major river and basins. It is also clear the great potential to cause disasters with catastrophic environmental, social, and economic impacts that transcend the local area of influence of this kind of projects.

Considering different approaches on the relationship between technology, environment, and society, there are some evidences not to invest in the São Francisco Inter-Basin Water Transfer as a solution to economic growth or drought mitigation in the semiarid region of Brazil. First, there is a glaring lack of data, records, publications, and scientific articles to support a more in-depth analysis and develop technical standards for monitoring the risks created by the SFIWT.

The few official government reports on the SFIWT show little consideration for social, cultural, and environmental dynamics of the semiarid region of Brazil, and little understanding of the consequences of both success or failure of the project. As in Barbosa (2017) "the unbridled haste to inaugurate the Eastern Axis of the SFIWT fits in the mold dictated by the development economic model adopted by the Brazilian government, aiming the expansion of agricultural frontiers to meet the demands of the international capital, without due concern for the local environmental and social consequences, nor even for the future of the planet".

On the environmental side, there are too many uncertainties and, at the same time, solid evidences that the SFIWT have the potential to destroy the semiarid fragile ecosystem. As pointed by some scientific articles, the SFIWT can change the base of the food chain of the local ecosystem by making some intermittent rivers perennial. The extend of such dramatic environmental change is not clear, but together with other impacts in the ecosystem like the invasion of exogenous species, increasing of pollution and agro-chemicals in the soil and water sources, loss of more than 430 acres of native land, agricultural expansion, and unplanned growth of urban centers, can certainly endanger the Caatinga biome and consequently cripple the life of millions of people countrywide.

Another factor that significantly increases the catastrophic potential of the SFIWT is the fact that Brazil doesn't have a disaster risk management agency capable of dealing with all risks created by the SFIWT nor respond to disasters of the magnitude that can be unleashed by this water-transfer.

Considering all the risks involving the SFIWT and, as in Albiac *et al.* (2006), the existence of more modern solutions to water scarcity in semiarid regions, this paper suggests that the investment made in the SFIWT could have been done to foment and support multiple local strategies in the whole semiarid region, empowering local communities and supporting creative solutions utilizing a bottom-up approach that, in the long term, could bring more social and environmental benefits with much less risks.

In summary, this cahpater showed enough evidence that the SFIWT presents greater risk of catastrophic disasters than the drought it intends to mitigate.

Notes

2 Jaguaribe (CE), Apodi (RN), Piranhas-Açu (PB-RN), Paraíba (PB), Moxotó (PE) and Brígida (PE).
3 Ministry of National Integration – O Andamento da Obra (The Progress of the Work). Retrieved on 04/21/2017 from: http://www.mi.gov.br/web/projeto-sao-francisco/o-andamento-das-obras

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