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International experiences of water transfer between river basins: reflections on benefits and disadvantages

Experiências internacionais de transferência de água entre bacias hidrográficas: reflexões sobre benefícios e desvantagens

Experiencias internacionales de transferencia de agua entre cuencas: reflexiones sobre beneficios y desventajas

Expériences internationales de transfert d'eau entre bassins: réflexions sur les avantages et les inconvénients

José Antônio da Silva Filho
Universidade do Estado do Rio Grande do Norte
josebmrn@gmail.com

Francisco Fernando Pinheiro Leite
Universidade Federal do Rio Grande do Norte
fernaandopl@gmail.com

Larissa da Silva Ferreira Alves
Universidade do Estado do Rio Grande do Norte
larissa0185@gmail.com

Jairo Bezerra Silva
Universidade Estadual da Paraíba
jairrobezerra@hotmail.com

ABSTRACT

The problem of unequal supply of fresh water in the world, linked to population growth and industrial demands, will worsen with the occurrence of extreme weather phenomena such as droughts. For centuries, several countries have used water transfer between surplus and deficit river basins as a way of overcoming water scarcity and ensuring socioeconomic development. The present study, an exploratory, descriptive and interpretative basic research, aims to discuss international experiences of interbasin water transfers, reflecting on their benefits and disadvantages. To this end, bibliographical research was carried out with scientific articles published in national and international journals that deal with interbasin transpositions in countries such as Spain, China and the United States of America. It is concluded that projects of this magnitude cause impacts of the most diverse shades, both for donor and recipient areas, such as geomorphological

impacts, biological invasion, restoration of water quality, and greater water availability for economic activities.
KEYWORDS: water resources; interbasin transposition; regional development.

RESUMO

A problemática da oferta desigual de água doce no mundo, atrelada ao crescimento populacional e demandas industriais, agravar-se-á com a ocorrência de fenômenos climáticos extremos como as secas. Há séculos, diversos países utilizam da transferência de água entre bacias hidrográficas superavitárias e deficitárias como forma de superar a escassez hídrica e garantir o desenvolvimento socioeconômico. O presente estudo, uma pesquisa básica exploratória, descritiva e interpretativa, objetiva discutir experiências internacionais de transferências de água interbacias, refletindo sobre seus benefícios e desvantagens. Para isso, realizou-se uma pesquisa bibliográfica com artigos científicos publicados em periódicos nacionais e internacionais que versam sobre transposições interbacias em países como Espanha, China e Estados Unidos da América. Conclui-se que projetos desta magnitude causam impactos das mais diversas matizes, tanto para as áreas doadoras quanto para receptoras, a exemplo de impactos geomorfológicos, invasão biológica, restauração de qualidade de água, e maior disponibilidade hídrica para atividades econômicas.
PALAVRAS-CHAVE: recursos hídricos; transposição interbacias; desenvolvimento regional.

RESUMEN

El problema del suministro desigual de agua dulce en el mundo, vinculado al crecimiento demográfico y a las demandas industriales, empeorará con la aparición de fenómenos climáticos extremos como las sequías. Durante siglos, varios países han utilizado la transferencia de agua entre cuencas fluviales excedentes y deficitarias como forma de superar la escasez de agua y garantizar el desarrollo socioeconómico. El presente estudio, una investigación básica exploratoria, descriptiva e interpretativa, tiene como objetivo discutir experiencias internacionales de trasvases de agua entre cuencas, reflexionando sobre sus beneficios y desventajas. Para ello se realizó una investigación bibliográfica con artículos científicos publicados en revistas nacionales e internacionales que abordan las transposiciones intercuencas en países como España, China y Estados Unidos de América. Se concluye que proyectos de esta magnitud provocan impactos de los más diversos matices, tanto para las zonas donantes como receptoras, tales como impactos geomorfológicos, invasión biológica, restauración de la calidad del agua y mayor disponibilidad de agua para actividades económicas.

PALABRAS-CLAVE: recursos hídricos; transposición entre cuencas; desarrollo regional.

RÉSUMÉ

Le problème de l'approvisionnement inégal en eau douce dans le monde, lié à la croissance démographique et à la demande industrielle, va s'aggraver avec l'apparition de phénomènes météorologiques extrêmes tels que les sécheresses. Pendant des siècles, plusieurs pays ont utilisé le transfert d'eau entre bassins fluviaux excédentaires et déficitaires comme moyen de surmonter la pénurie d'eau et d'assurer le développement socio-économique. La présente étude, une recherche fondamentale exploratoire, descriptive et interprétative, vise à discuter des expériences internationales de transferts d'eau entre bassins, en réfléchissant à leurs avantages et inconvénients. À cette fin, une recherche bibliographique a été réalisée avec des articles scientifiques publiés dans des revues nationales et internationales traitant des transpositions inter-bassins dans des pays comme l'Espagne, la Chine et les États-Unis d'Amérique. On conclut que les projets de cette ampleur provoquent des impacts des plus divers, tant pour les zones donatrices que bénéficiaires, tels que les impacts géomorphologiques, l'invasion biologique, la restauration de la qualité de l'eau et une plus grande disponibilité de l'eau pour les activités économiques.

MOTS-CLÉS : ressources en eau ; transposition inter-bassins ; développement régional.

INTRODUCTION

Although the amount of water on earth is relatively constant, the demand for this resource has increased considerably. Among the activities that use water the most are food and energy production. At the 2021 United Nations Water Conference, it was announced that in the world, 72% of water collected from nature is used for agriculture, 16% is used to supply residences in municipalities and 12% is used by industry. With population growth and the economic development model of rich countries, there will be increasing contradictions between the demand for water and the finite quantity of this resource (SHENG; TANG; WEBBER, 2020).

Therefore, at the 2020 World Economic Forum, water crisis was listed as one of the 10 main risks of global impact on humanity, together with extreme climate events, such as loss of biodiversity and the occurrence of natural disasters. Universal access to quality water for human consumption was also recalled as one of the UN's Sustainable Development Goals (SDGs). The demand for water for these activities will increase, with economic and population growth being the main problems of contemporary societies for sustainable development (GOHARI et al., 2013).

The water crisis will worsen for arid and semi-arid areas in the coming decades, making this natural resource a strategic factor for human survival and economic and social development. Projections show that more than half of the world's population will face problems with water scarcity by 2030, increasing the population's demand for water by 40% (UN-WATER, 2021).

However, the availability of freshwater across the globe is uneven across time and space (SHUMILOVA et al., 2018). It is estimated that 97.5% of the water in the world is salty and is not suitable for our direct consumption or for the irrigation of crops. Of the 2.5% of freshwater, the majority (69%) is difficult to access, as it is concentrated in glaciers, 30% is groundwater (stored in aquifers) and 1% is found in rivers (ANA, 2023).

Furthermore, it is possible to notice a disparity in the relationship between water availability and population, both on continents and within countries. In this way, some places in national territories will have water sufficiency while others will be deficient.

The problem of the unequal supply of freshwater in the world, linked to the increased need for this resource due to population growth and industrial demands, is expected to worsen with the occurrence of extreme weather phenomena such as droughts. Regarding this, UN-WATER (2021, p. 7) points out that “climate changes have generated changes in water availability, increasing situations recognized as water scarcity in some regions and causing floods in others”. In addition to this, human actions contribute to reducing the amount of water available through polluting activities.

Given this scenario historically, the implementation of large river basin interconnection projects, taking water from surplus basins to deficit basins, has been carried out in order to solve the problem of water scarcity in certain locations and to enable the economic and social development of these areas. (GOHARI et al., 2013; SEGUIDO; CANTOS; AMORÓS, 2018).

Historical records show that the first water transfer project dates back to 2,400 BCE with the construction of canals that transported water from the Nile River to what today corresponds to the southern areas of Ethiopia, and served for irrigation and navigation. This project promoted the development and prosperity of Egyptian civilization (ZHUANG, 2016).

Other examples are the water infrastructure projects carried out by the Romans on the European continent, with aqueducts, the first of which was built around the year 312 BCE. In the Americas, we have the case of the Inca people, around 1200 CE. With their complex irrigation systems (on the American continent) they made use of these strategies as a way to enable the survival of their people and to develop their territory (FERREIRA , 2018).

However, despite having been used as a way of guaranteeing development,water supply and the expansion of agriculture, these large structures have encountered various challenges in recent decades, such as: reducing the flow of rivers, unbalancing ecosystems and disrupting traditional water use, changes in the landscape, generationof waste water and not meeting the demands of the entire community (FERREIRA, 2018). In view of the above, we seek in this work to reflect on the main environmental and socioeconomic impacts, provided through water transfer projects between river basins in the world.

To this end, methodologically, a narrative literature review was carried out to develop a systematic evaluation of the subject. To select the works used in this study, a search was carried out with CAFe[1]accessing the journal database of the Coordination for the Improvement of Higher Education Personnel (CAPES), through which we selected academic works from national and international specialized bibliography that deal with the topic of interbasin

1 CAFe is a service that brings together Brazilian teaching and research institutions through the integration of their databases.

water transfer. It is to note that a time frame was not stipulated to search for the works used in this literature review.

After choosing the works to be used, and excluding those that did not have the theme as its main scope or approached it in a secondary manner, the search concluded with 35 (thirty-five) works that became the subject of study for this article. Among the authors used, we highlight Rollason, Sinha, Bracken (2022) and Zhuang (2016) who point out benefits and concerns related to the interconnection of river basins and Shumilova et al. (2018) who surveyed large water transference projects around the world.

It is believed that studies on other transference projects direct us to reflect on their successes and problems, helping to improve the management of other projects, especially when considering their long-term impacts on ecosystems together with the uncertain effects of climate change on the environment, and, consequently, in water transfer projects (YAN et al., 2012). Therefore, the analyzes of the articles, dissertations and theses presented in this literature review can contribute to advancing the necessary understanding of such water infrastructures.

Thus, the present study is structured with the following sections: 1. Introduction, the research object and methodological procedures; 2. Interconnection of river basins: state and territorial planning and the ultimate expression of water management, seeking to understand the objectives for large water transfer works, common to several countries; 3. The Spanish experience: the case of the Tagus-Segura transference; 4. The Chinese experience: the case of the south-north water transfer project (PTASNC).5. Final considerations. Section 3 and 4 both address the specific realities of the countries in focus, which transferred water to arid and semi-arid areas of their respective territories, focusing on the positive and negative impacts of these projects in the light of international literature.

INTERCONNECTION OF RIVER BASINS: STATE AND TERRITORIAL PLANNING AND THE ULTIMATE EXPRESSION OF WATER MANAGEMENT

Interbasin water transfers are considered the greatest manifestation of excellence in hydraulic planning for territorial planning actions developed by the state. They mean public intervention to balance water availability in localities and guarantee agricultural, urban and tourist use supply with significant social and economic gains (SEGUIDO; CANTOS; AMORÓS, 2017). In other words, a facet of territorial planning that aims for a more strategic and balanced distribution of water resources in the national territory. When looking for studies on the various international experiences of water transfer between river basins, it is noted that the main themes investigated and debated are socioeconomic development, ecological and environmental impacts and strategic-territorial planning. More specifically, the projects' primary objectives are: irrigation, human and industrial supply, flood control, improvement in water quality, improvement of the ecological system and energy generation (ROLLASON; SINHA; BRACKEN, 2022).

It is also clear that developing countries are more affected by the arid and semi-arid conditions of certain portions of their territories due to the challenges of strategic planning and investment. Such climatic characteristics, together with urbanization and industrial development, are the driving forces for implementing water transfers between basins. In developed countries, what mainly influences the execution of this type of project is the presence of extreme climates and, more locally, water stress problems (ROLLASON; SINHA; BRACKEN, 2022).

When observing transference projects, it is possible to notice a change in their main objectives over the years, which reflect the concerns of the times in which they were carried out. As an example, in 1940 most projects were concerned with irrigation, industry and energy production, reflecting the development of industries in cities that demanded greater production of food and energy, as well as the considerable contribution of water for the stages of industrialized production. By 1980, reflecting a greater concern with environmental issues, projects focused on controlling floods and environmental impacts (ROLLASON; SINHA; BRACKEN, 2022).

Table 1 below shows the main benefits and concerns regarding socioeconomic, ecological and environmental aspects when it comes to water transfers that require attention.

Table 1 – Benefits and concerns related to the interconnection of river basins

Theme	Benefits	Concerns
Socioeconomic	Promotes more equitable regional development; Socioeconomic development based on the resolution of water stress; mitigation of water deficit; tourism promotion.	Population displacement; Resettlements and rehabilitation of people; submersion of properties; Costs with social and environmental issues; need to calculate costs and benefits; water prices and financing; economic evaluation of the project; decrease of water in the donor basin.

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Ecological and environmental	Alleviation of drought and environmental degradation; restoration of river flow or supplementation; improvements in the quality of available water; flood control; preservation of extensive fauna and flora; improvement of meteorological conditions; relief in groundwater exploration; purification of water from the receiving river.	Ecological disturbances; changes in biodiversity; species invasion; environmental and morphological changes; concerns related to climate change; river flow; ambiental degradation; soil salinization; salinization of the donor river estuary.

Source: Elaborated by the authors (2023), based on Rollason, Sinha, Bracken (2022) e Zhuang (2016).

Transfers between basins can cause relevant changes in ecological terms, such as desertification due to soil salinization through inadequate practices combined with the high rate of evaporation in regions with arid or semi-arid climates. The authors Wilson et al. (2017) exemplify the case of the Yangtze River, in China, which had its water flow reduced with the implementation of the South-North Water Transfer Project, causing the salinization of its estuary and degradation of the Han River.Wilson et al. (2017, p. 8) highlight that “the salinization of the Yangtze River estuary tends to worsen, especially during the driest months and years, at the same time that environmental concerns in this region increase, which are already critical”.

In terms of improving water quality, with the increase in the flow of the receiving river, its capacity to assimilate organic matter increases – water self-purification. In this way, the amount of water available for multiple uses is expanded, as well as reducing the environmental costs of treatment.

In areas with a lack of water availability, one of the ways to access water is through the utilization of wells to access groundwater. The over exploitation of these sources dipleates the water table, making it difficult to recharge. Surface water transference projects also seek to mitigate the dependence on groundwater in areas with water deficit. When looking at social issues, the fact stands out that in order to carry out such works, it is sometimes necessary to organize the displacement of traditional people/communities, leading to conflict and whose resistance in the face of situations of this magnitude are difficult to resolve, given the territorial identity bond created with the locality to which they belong.

Within these large systems, there is also the construction of large reservoirs with different purposes: energy generation, flood control, irrigation use, diversions to other basins. Such structures modify the hydrological dynamics of the river, by impacting its geomorphology, for example, causing situations such as: change in the river’s cross-section, increased erosion of the river bed and banks, modification in the shape of the bed, greater sediment deposition, variation in slope, changes in the substrate, changes in water quality, modification in the alluvial aquifer (BRANDT, 2000).

Based on the literature surveyed, it is clear that the presence of positive and negative points in these projects is inevitable. However, what should be looked at analytically is for a given situation, what are the pros and cons and whether it is really worth the execution of the project. Therefore, studies of previous cases of transferences are necessary in order to reduce negative impacts.

Gupta and Van der Zaag (2008) proposed 5 criteria to be considered when evaluating the proposal of whether or not to carry out a river basin interconnection project. In a reduced form, they are: 1) if, objectively, the donor basin is actually in surplus and the receiving basin is in deficit, with the project being the most viable solution; 2) the project must be economically, socially and environmentally sustainable; 3) good governance must be adopted in its management; 4) it must take into account the rights and needs of the populations involved, both in the donor and receiving basins; 5) the project must have scientific support, that is, the most diverse studies must be carried out: hydrological, ecological and socioeconomic.

Added to this is the ability of these projects to be integrated into national structuring plans for territorial planning, as they create other territorial trends, which will (re)organize economies, resettle people and interfere in sensitive dimensions of society, such as culture and the symbolic appropriation of the landscapes and places to which they belong.

Moreno and Ortiz (2020) state that water transfers must comply with basic economic conditions, namely: transference must be the lowest-cost economic measure for reliable supply, its benefits must exceed its costs and the situation of the people involved cannot be in a worse condition than before the project.

In this context, Zhuang (2016, p. 12875) states that

> Successful transfers are basically equipped with many regulating reservoirs along the route and established stable foundations for water resources, so as to provide the fundamental guarantee for the redistribution of water resources (Authors' translation).

An example of this, according to Zhuang (2016), is the North-South project in California, which, through large reservoirs distributed along its route, transfers water to several locations through canals, ensuring water supply. These reservoirs enable the storage of surplus water, enabling the redistribution of resources and truly increasing the guarantee of water supply.

Through this project's system, electrical energy is generated for southern California, supplying the city of Los Angeles and other surrounding cities, in addition to providing irrigation for huge areas of land (2 million m2) and for tourism in the reservoir of Lake Mead (NEVES; CARDOSO, 2009). However, this is also the focus of public controversy "essentially motivated by increased pressure on the resource and its quality, with public supply competing with the intensive agriculture that characterizes the region" (FERREIRA, 2018, p. 6).

When developing a study on the existence of water transfer megaprojects, Shumilova et al. (2018) identified the existence of 34 projects already built, the majority of which are in North America (17) and Asia (10); 25 projects in the construction phase and 51 in the planning phase. Likewise the majority of these latter projects are in the North American (33) and Asian (18) continents. Most of these projects are related to the development of agriculture and electricity production. In Table 2 below, are some of the main river basin interconnection projects in the world and their main characteristics.

Table 2 – Some of the main river basin interconnection projects in the world

Project	Country	Water transferred in Billions of m³	Channel length/KM	Project features
California North-South Water Transfer Project	EUA	5.2	900	It is the largest multi use development project in America to resolve the condition of flooding in the north and drought in the south.
Central Arizona Project	EUA	3.7	800	The project aims to address ground subsidence caused by excessive groundwater mining in central Arizona. It is one of the projects in the world that has adopted the most advanced control system for water supply management.
Quebec water transfer project	Canada	25.2	861	It diverts water from adjacent rivers and gathers it into a river for terraces, serving to produce electrical energy, reflecting economic efficiency and rationality in terms of development of water resources.
West-North Water Transfer Project	Pakistan	14.8	622	It takes advantage of the sloping topographic condition downstream and flexibly organizes three transfer channels according to elevation. It is an example of a model for open channel artesian transfer in a flat area.

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Project	Country	Water transferred in Billions of m³	Channel length/KM	Project features
South-North Water Transfer Project	China	44.8	3.833	It is a large-scale project system that transfers some redundant water from the Yangtze River basin to the Yellow River and the region on its northern side for the purpose of supplementing the water sources for China's north and northwest region where there is a shortage of water sources. It will become the interbasin project with the largest annual amount of water transfer in the world upon completion. Its ecological impact has caused great controversy.
Tagus-Segura Project	Spain	0.65	275	It connects the Tagus river basin to the Segura basin through a 275 km pipeline from the Bolarque reservoir, on the Tagus river, to the Talave reservoir, on the Mundo river, one of the main tributaries of the Segura. With the main objective of supplying irrigation and urban supply projects in the receiving basin.
São Francisco River Integration Project with the Basins of the Northern Northeast - PISF	Brazil	3.9	477	The largest water infrastructure project in Brazil, its objective is to bring water to 12 million inhabitants, in 390 municipalities, in the states of Pernambuco, Ceará, Paraíba and Rio Grande do Norte. The work leads to job creation and promotes social inclusion. The project aims to provide water supply for human consumption, agricultural and industrial activities.

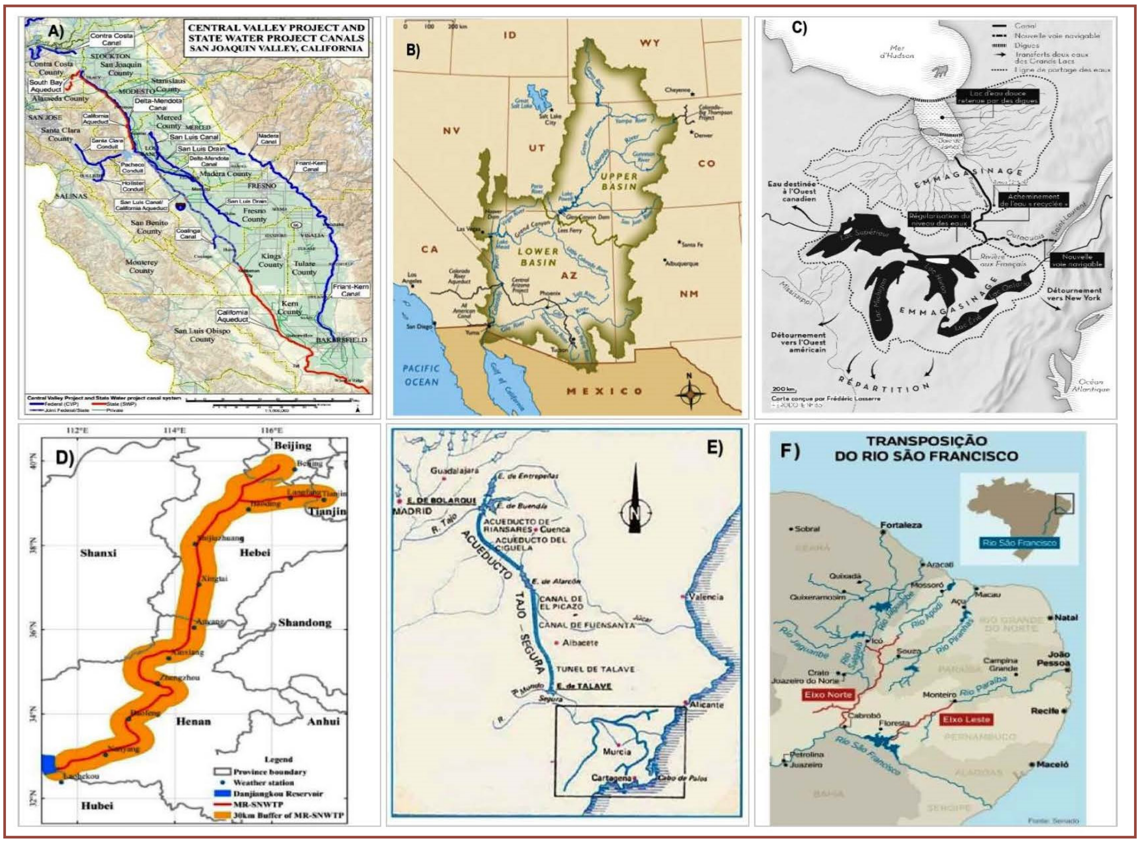
Source: Zhuang (2016); Martinez (2001) e Brazil (2023).

In Figure 1 are the geographic location of the projects covered in table 2, for a better visualization.

The experience of the São Francisco River Integration Project (PISF) in Brazil was added to the table above, given the magnitude of the project, comparing it to the others mentioned. In this vein of evaluating the magnitude of projects, Shumilova et al. (2018, p. 6) show in their studies that

> The scale of these infrastructures has the potential to cause fundamental changes to the global water cycle. The total volume of water transferred by such projects will represent up to 48% of global water withdrawal (the current rate of total water withdrawal from these projects is 4,000 km3 per year, representing 5% of the total water that the continents discharge into the oceans). (Translated by the authors).

Figure 1 – Geographic location of river basin interconnection projects around the world



Map Legend: A) North-South California Water Transfer Project (USA); B) Central Arizona Project (USA); C) Water transfer project in Quebec (Canada); D) South-North Water Transfer Project (China); E) Tagus-Segura Project (Spain); F) Integration Project for the São Francisco River with the basins of the Northern Northeast (Brazil).

Sources: A) and B) United States Geological Survey website, 2009; C) Lasserre, 2017; D) MA et al, 2016; E) Segura River Hydrographic Confederation, 1996; F) Federal Senate website, 2017.

Among the projects identified in Table 2, some considerations are presented about the Tagus-Segura transference, in Spain, and the South-North water transfer project in China. The choice of the first is justified due to the operating time it already has and because it is one of the projects that has had the most studies on its positive and negative impacts; the second project due to its magnitude and potential for socioeconomic and environmental change.

THE SPANISH EXPERIENCE: THE CASE OF THE TAGUS-SEGURA TRANSFERENCE

In several regions of the world there is the possibility of periods of water scarcity and drought, which are linked to a climatic origin, with unequal rainfall in time and space, which imposes limitations on the availability of water for humans. It is combined with the reality of the lack of management of available resources, such as: misuse, waste, lack of technical and economic means and conflict of political interests (SEGUIDO; CAMPOS; HERNÁNDEZ, 2020). In the Spanish southeast, in the Segura River basin, it appears that due to orographic and climatic issues, the occurrence of a semi-arid climate is possible, which is characterized by a gradual reduction in annual precipitation from west to east, towards the coast. This gives the region the largest water deficit on the Spanish peninsula.

In 1966 as a way of overcoming water scarcity in this region, in order to guarantee sufficient water for the demands of agriculture, human and industrial consumption, as well as tourism, the Spanish government began work to transfer water from the head of theTagus river to the Segura river basin. This work was inaugurated in 1979, which became known as the Tagus-Segura Aqueduct (TSA) (FERREIRA, 2018).

This project connects the Tagus river basin to the Segura, in southeastern Spain. In terms of canal length, it is 275 km from the Bolarque reservoir, on the Tagus River, to the Talave reservoir, on the Mundo River, one of the main tributaries of the Segura River (MARTINEZ, 2001). The project could initially transfer up to 600hm³ annually, its capacity later reaching 1000hm³, although this value was never reached. Of this total value, 400 hm³ is destined for irrigation, 110 hm³ for urban supply and 90 hm³ for losses in all forms, such as evaporation and leakage (OLCINA, 1995; MESEGUER; ESPÍN, 2015).

For Melgarejo et al. (2009) the water resources that came from the Tagus basin increased the demand for water in the Segura basin, making it increasingly dependent on the TSA.

This strong dependence was felt between May 2017 and April 2018, during the severe drought that the region experienced. With reservoir levels below 2,494hm³, water supplies were interrupted by the TSA to the municipalities of Almería, Alicante and Murcia[2]. This occurred due to the Spanish government taking into account the principle of protecting the rights of citizens from the area of origin to ensure that only surplus resources from the donor basin can be transported (FERREIRA, 2018).

To guarantee the water demand of these territories, alternative supply measures were adopted: artesian wells, contracts for the assignment of ri-

2 In 2013, the Spanish government stipulated, that if the water volumes in the reservoirs at the head of the Tagus River fall to 2,494 hm3 at the beginning of each month, the water supply be suspendedby the TSA to guarantee the necessary water for the people of the donor basin (FOLLOWED; CAMPOS; AMORÓS, 2018).

ghts and use of desalinated water. In 2018, the use of desalinated water used for urban supply reached 47.62% (historical maximum, corresponding to 92.8hm³) while water supplies from the STA represented 25.96% (corresponding 50.6hm³) (FOLLOWED; CAMPOS; AMORÓS, 2018). In other words, during the dry period, the transposition did not meet its maximum objective, with the urban supply being, for the most part, supplied by desalinated water.

According to Ferreira (2018), the storage needs of the Tagus River during periods of intense drought were also not taken into account, and these issues were crucial in stipulating the amount of water to be transferred, which is the cause of the biggest clashes of interests between the populations involved. However, the importance of this project for the development of southeastern Spain is undeniable, as in more than four decades of operation, the ATS has proved essential for regional socio-economic development, enabling the development of irrigated agriculture, tourism and industrial activities (SEGUNDO; CAMPOS; AMARÓS, 2018; MORENO; ORTIZ, 2020).

For Melgarejo et al. (2009), the STA has a strategic value for the national trade balance, with a significant share of the export of vegetables, citrus fruits and grapes. Notably, the irrigation systems present in Cartagena, on the lower Tagus and in the Guadalentín Valley, constitute irrigation areas of the greatest economic and social significance in Spain (SEGUNDO; CAMPOS; AMARÓS, 2018).

In this same reasoning Meseguer and Espín (2015, p. 143) show that

> faced with random rainfed areas, small oasis-orchards linked to their own scarce water resources, emigration and abandonment of scattered farms, villages and towns: hydraulic infrastructures and the road network associated with them have allowed socioeconomic growth to be prolonged and talk about a development based on a new territorial model marked by the distribution of water in a semi-arid environment.

A fact that also deserves to be highlighted is that, with the transference and the promise of abundant water, the amount of irrigable land has increased considerably, generating more demand for water. However, the amount of water transported was not enough to meet this created demand, since the STA was unable to meet the water values predicted in the initial project. In this way, it overused groundwater on an unforeseen scale (OLCINA, 1995; MARTINEZ, 2001). According to Meseguer and Espín (2015), in the period from 1979 to 2014, the average volume of water transported by the STA was 315hm³ per year.

It is important to consider that these projects always impact the two river basins involved. For this reason, Ferreira (2018) argues that despite the arrival of waters from the STA having transformed southeastern Spain into the " vegetable garden of Europe", by encouraging and enabling the expansion of intensive agriculture, the course of the Tagus River up to its mouth presents awater supply deficit for abstraction to supply cities such as Madrid, in addition to noting problems with water pollution.

However, by focusing on the use of STA water for intensive irrigation agriculture for export purposes, the traditional riverside people of the Tagus River have had their natural and built heritage harmed. Thus, there is a need to create new formulas relating to water and rivers. A vision that looks at water not only as an economic resource, but also as having cultural, social, historical and symbolic value (FERREIRA, 2018 apud BERNARD, 2013), since water is a natural resource for the entire population and the state is responsible for planning the use of this resource in a way that benefits the entire society (MORENO; ORTIZ, 2020).

THE CHINESE EXPERIENCE: THE CASE OF THE SOUTH-NORTH WATER TRANSFER PROJECT (PTASNC)

Another example of river basin interconnection that has caught the attention of several scholars is the China South-North Water Transfer Project (PTASNC) with an estimated expenditure of 62 billion dollars, transforming it into the largest and most ambitious water transfer project in the world (SHENG; TANG; WEBBER, 2020). Regarding project costs, Wilson et al. (2017) state that this figure considers the resources allocated to the construction of the channels, not including those needed for its operation.

This is one of the biggest Chinese attempts to solve the water shortage in the north of the country. According to Rogers (2016, p. 429), "the objective of the project is to resolve an apparent imbalance in the distribution of China's water resources, transferring water from the Yangtze River to the Hai, Huai and Yellow river basins."

The project has three large water transfer channels (Central, East and West[3]), which, together, have the capacity to transport 44.8 billion m³ of water per year from the Yangtze River in southeast China to rivers in North China. (Hai, Huai and Yellow). The three channels, combined, are 2,922 km long.

Historically, northern China has experienced a water deficit that has a negative impact on its economic production. The Hai, Huai and Yellow river ba-

3 The western canal has not yet been completed.

sins account for 45% of China's arable land, are home to 35% of the country's population, but have less than 12% of available water resources, while the Yangtze River basin, with less than 40 % of cultivable land, produces more than 80% of national production (LI; LI; ZHANG, 2011).

Since 2014, although it is not yet completely finished, this infrastructure has doubled the capacity of the Chinese state in transposing water in the country,supplying many urban centers with irrigation, the latter being in growing demand in light of population and urban area growthin the country (SUN et al. 2021).

With greater water availability and incentives for the development of irrigated agriculture, the increase in agricultural production could positively impact Chinese agriculture, both domestically and abroad. However, the primary objective of transference is domestic and industrial use (BERRITTELLA; REHDANZ, 2006).

One of the justifications for implementing this project was the recovery of river ecosystems by increasing water supply, as the rivers in northern China are degraded. In this sense, when analyzing the water quality of rivers that make up the receiving basin, Li, Li and Zhang (2011) identify that there is a spatial variability of economic activities that determine the sources of pollution of river water, with industrial and domestic activity responsible for heavy metals and agriculture for nitrogen in the provinces of Henan and Hebei, while the rivers near Beijing and Tianjin suffer from industrial and domestic effluents as the main pollutants.

Opposing the idea of revitalizing ecosystems, Berrittella, Rehdanz and Tol (2006) state that even if economic sectors use techniques that allow the use of smaller amounts of water, their interests must be served first, with environmental issues taking second place. Corroborating the critical view, Sheng, Tang and Webber (2020) analyzed the impacts of this project on consumption and pollution in the receiving basin. They argue that the project failed to supply water to the cities that received water from the transference, with restriction[4] of its use due to the high price charged for the resource, and was not able to reduce pollution in the receiving cities.

However, when analyzing data from water quality monitoring centers in the eastern channel, Rogers et al. (2020) point out that there was a significant

4 Water quality scale III in China represents water bodies from protected areas to centralized drinking water sources and protected areas for common fish and swimming areas. The Chinese classification has 5 (five) classes. See more at: mee.gov.cn.

improvement between 2003 and 2013. According to the authors, in 2003 only 3% of the stations showed that the water was in grade III quality. In 2013, all control stations showed water at level III.

In ecological terms, Ding et al. (2020) highlight the importance of PTASNC for water recharge and ecosystem restoration in several rivers in China. According to this author, in 2018, 870 million m³ of water were channeled to restore the ecological deterioration of 30 rivers in Henan and Hebei province. In view of the environmental degradation of water bodies currently seen in different regions of the world, this project highlights an important measure for the restoration of water ecosystems, enabling access to quality water for many people.

Zhang et al. (2021) point out that the transference proved to be positive in the long term in restoring phytoplankton diversity, while enabling a balance in the quantity and diversity of this important organism for the ecological chain of water bodies. On the other hand, the PTASNC, by connecting river basins with different characteristics, contributed to the dispersion of locally absent species, favoring biological invasion. It was found that demersal species endemic to the mouth of the Yangtze River were found in lakes further north in China (GUO et al., 2020).

Bringing to light the complexities of PTASNC from a social perspective, Wilson et al. (2017) consider that the transference will have significant impacts on the citizens of both basins, as it can contribute to disease transmission (specifically schistosomiasis) and generate reorganizations in water management and water governance on a spatial and managerial scale in the most diverse spheres of government.There is, therefore, a need for intergovernmental agreements that cover both river basins.

Still in the social field, Webber et al. (2017) warn that the transfer will reduce the development capacity of the donor area, impact access to water, and cause resettlement of hundreds of thousands of people. However, the project would reduce rural exodus in the receiving basin by improving access to water. In terms of resettlement, according to Rogers et al. (2020) just to build infrastructure, around 410,000 people were resettled.

Liu et al. (2020) regarding this Chinese water transfer project between river basins, argue that although alleviating water scarcity in the north, the nexus between water and energy of the project is inefficient, since such infrastructure requires a large amount of electrical energy to operate . They advocate that the resolution of water scarcity be resolved through new uses of the resource, that is, actions that target the demand and not the supply of water, such as: reused water and rainwater. Still in this direction, the energy spent to transport 100 million m³ of water through the PTASNC would be capable of producing 101 million m³ of reused water and 122 million m³ in rainwater collection (LIU et al., 2020).

Another issue to be raised is the loss of water through evaporation from the channels that make up the PTASNC. Although studies on this topic are scarce, Ma et al. (2016), when applying a mathematical model to verify the central channel of this project, concluded that 6.43x108 m³ of water was lost to evaporation in 2015. Therefore, analyzes like these are important to implement actions that reduce losses and maximize the use of transported water.

FINAL CONSIDERATIONS

After these considerations of projects of international experiences of water transfers between river basins, it was possible to verify that these water engineering solutions have always been and will still be widely used to solve the problem of what is considered water scarcity.

The fact that these projects were designed and executed with different objectives was also identified. However, the main ones are: urban and industrial supply, development of irrigated agriculture and ecological restoration of degraded rivers (although they also generate other impacts).

It is noted that projects of this magnitude will tend to cause positive and negative impacts, both for water donor areas and receiving areas, such as biological invasion, restoration of water quality, greater water availability for use in economic activities and resettlement of people. It is up to the government, as executor of the work and holder of the power to accommodate the divergent interests of their people, to implement measures that seek to minimize or compensate for the negative impacts on all subjects involved and always seek the greatest possible social good.

Inherently there will be a need to make socioeconomic development compatible with environmentally balanced development for the sustainable construction of the regions in question, which is a very challenging task. However, it is necessary to list which actions are necessary and possible in the search for a more equitable distribution of resources in a given country.

Aware that this debate does not end in this work, it is believed that it is necessary to carry out more studies that seek to measure the positive and negative impacts of other water transfer projects between river basins in the world, and propagate technical, scientific and financial support for the theme. ●

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