Regional Input-Output Matrix for Sub-Middle Hydrographic Region of the São Francisco River Basin in Brazil

Ana Cristina Guimaraes Carneiro[1]
Ignácio Tavares de Araujo Jr. [2]
Marcia Alcoforado [3]

ABSTRACT
Currently there is much discussion about the challenges of combining economic issues with environmental issues. The Brazilian government has been investing in the expansion of irrigated areas, especially in the Northeast of Brazil. The São Francisco Water Transfer Project, involving resources on the order of R$ 8.2 billion, seeks to expand the water infrastructure to deliver water from the Sub-Middle São Francisco River Basin (SMSF) - one of the four hydro-geographic regions into which the basin is divided - to the north and to the east in northeastern areas out of the basin. The water for a significant part of the new irrigation projects in Northeast will either come directly from the São Francisco River or from the channels being constructed. There are estimates that in about three decades, the area under irrigation supplied by the Sub-Middle could increase by more than 10 times its current average. Together, climate changes and expansion of irrigated areas in Northeast may increase conflicts between other water uses. In this context, public policies must be established to promote more efficient inter -and intra- sector water allocation schemes. Economic models are able to support effective management instruments that induce economically optimal and equitable allocations. This study used a regional Input-output matrix 2010 of Brazil adapted for the Sub-Middle hydrographic region of the São Francisco river basin (IO-SMSF), to simulate economic impacts accompanying changes in water availability by economic sector in the sub-basin due to the water allocation decisions . The regionalization was based on the Location Quotient method and the data used was the Brazilian national input-output tables, regional databases and municipal GDPs (all from IBGE). For the direct coefficients of water, we used the Matrix of Technical Coefficients for Water Resources in Brazil, published by FEBRABAN in 2011.

[1] CNPq/ CT-Hidro Scholarship in Project 35/2013 coordinated by Federal Univeristy of Pernambuco, Recife – PE. And Professors in the Economics and Administration Department, Universidade Católica de Pernambuco.

[2] Department of Economics, Federal University of Paraíba – Brazil.

[3] Associate Professor at Economics Department and Graduate Program at Federal University of Pernambuco, Recife – PE, marcia.alcoforado.ma@gmail.com

1. INTRODUCTION

The Brazilian government has been investing in the expansion of irrigated areas, especially in the Northeast of Brazil. The greatest federal government initiative has been the *Programa Mais Irrigação* [Program for more irrigation], aimed at increasing /revitalizing the irrigated area by 538,000 hectares, of which 414,000 hectares are in the Northeast, to promote further development in Brazil (BRASIL, 2012).

Besides the 'More Irrigation' program, other initiatives have been announced, such as "irrigation program of the Brazilian semiarid region" which aims to explore more efficiently the regional potential for irrigation (BRASIL, 2014a). Further, huge works like the transposition of the São Francisco River, involving resources on the order of R$ 8.2 billion (US$ 2.5 billion), mostly coming from public funds, seek to expand the water infrastructure to provide water to the new irrigated areas (BRASIL, 2014b).

Although Brazil has about 12% of the available fresh water on the planet, about 80% of this water is in the Amazon, and the remaining 20% is unevenly distributed among the other regions. Currently, irrigated agriculture in Brazil is the largest consumer of fresh water available on the surface, with 61% of water diverted from rivers and lakes for irrigation. The largest share of irrigated area is in the Southeast with 37%, followed by the South with 27%, 22% in the Northeast, the Midwest and the North with 12% and 2% respectively. Despite being a naturally dry region, and not being one of the most irrigated, the Northeast (NE) region produces about 30% of national agricultural production, only behind the South East (54%), which demonstrates the potential of irrigation in this region. (IBGE, 2006).

The São Francisco River Basin provides approximately 70 per cent of the surface water for the Northeast of Brazil. About 95 percent of the irrigation projects in NE region use surface water diverted from the regional rivers, particularly the São Francisco River. The basin takes up about 8 per cent of Brazil’s area and the river has an average annual flow of about three thousand cubic meters per second. The basin has a diverse ecosystem with average temperatures ranging from 20 degrees Celsius in the center-southern portion of the basin to twenty-six degrees Celsius in the northeastern areas. The rainfall rates also differ both seasonally and in the different areas. Because of these differences, policy makers and institutional researchers have divided it in four hydrographic sub- regions: from the highlands, through a middle region and then a sub-middle region, to the ocean, sea level.

Among these hydrographic regions, the Sub-Middle (SM) hydrographic region is the driest one. The region (SM-SFRB) contributes to water availability in the overall basing with an inflow of approximately 4%. The different water demands in the region represent 33% of the entire basin. Related to the water uses / users, there is a history of a series of conflicts in that region. Currently, the most important is that between electricity generation and irrigated agriculture. There are important and large reservoirs that were built for electricity generation and are very important to control the river (to avoid floods and ensure navigation) and to generate hydro energy for the region.

The Sub-Middle (SM) region also includes a highly diverse agricultural system that includes well-capitalized export-focused enterprises, medium- and small-scale commercial farmers and semi-subsistence farmers. In Brazil as a whole, irrigated agriculture can be divided into private and public schemes. Public schemes or projects are mostly in the northeast region (67 percent of the total irrigated area in 1996). These are based in complex productive systems and capital and water intensive use (CASTRO, 2011; DNOCS, 2013; CODEVASF, 2013) and in charge of two federal institutions: Companhia de Desenvolvimento do Vale do São Francisco (CODEVASF) and (DNOCS).

As the driest part of the basin and with conflicts already stablished, the SM-SFRB had all of its sub-basins classified as critical or with an indispensable need for management, according to an evaluation of availability and demand of water resources made by the United Nations, and publicized a decade ago in the Ten Year Plan of the São Francisco Basin Committee (CBHSF, 2004)

This conflict between irrigated agriculture and energy production has the potential to worsen over time. Starting from the San Francisco River Basin, two channels(are being built to deliver water to the north and the east of the region. This large water transfer project is known as the Transboundary Project of São Francisco river (Projeto de Transposição do São Francisco - PTSF). In response to this project, many public/ private irrigation schemes have been projected and are expected to increase the areas under irrigation in the whole of the Northeast. The water for the significant part of these new irrigation projects will either come directly from the San Francisco River or from the artificial canals being constructed. There are estimates that in about three decades, the area under irrigation supplied by that region could increase by 10 times the number of hectares affected. This can worsen the conflict of use already existing between irrigated agriculture and energy production (MORAES, et al., 2016).

In this context, public policies must be established to promote more efficient inter- and intra-sector water allocation schemes. Economic models are able to support effective management instruments that induce economically optimal and equitable allocations. It is very important that evaluations of water allocation policies consider direct and indirect economic impacts. Different water allocation values not only lead to different economic impacts, affecting all water users and uses, but also have backward and forward linkages associated with the inputs and outputs of the production cycle. Moreover, impacts need to be differentiated according to different social strata to assess impacts on the most vulnerable and the poorest (ROGERS et al., 1998).

The question of measurements of indirect and sector-based economic impacts of water policies (the demand management side) is of particular importance, given the large and growing significance of these impacts. Water policy impacts can also be compared in terms of impacts on job creation and welfare (UNEP, 2011).

The present study used a regional Input-output matrix adapted for the Sub-Middle hydrographic region of the São Francisco river basin (IO-SM-SFRB), to simulate direct and indirect economic impacts from different strategies used in supply and demand management. An increase in demand for sugarcane for ethanol production as well as a decrease in water production for agriculture in the basin, due to transposition, will be simulations and the effects of final demand and production are measured using a regionalized Matrix.

2. METHODOLOGY

2.1 Regional Input-Output Model

The input-output model is a recommended methodology for measuring economic impact taking into consideration the inter–sectoral linkage of a given region or country. This model was developed by Leontief, who was one of the authors of a work on organization, formalization and improvement of studies associated with inter-sectoral relationships.

The degree of interdependence among the sectors of an economy can be assessed through the inter-sectoral requirement coefficients of the input-output matrix. We used the national input-output matrix to construct the regional input-output matrix. Regional input-output matrixes can be elaborated in two ways: by using research performed directly with data relating to the regional economy (survey methods) and by regionalizing national input-output matrixes (non-survey methods). Since the costs involved in direct research are prohibitive, the usual method is to resort to regionalization procedures.

The method for regionalizing a national input-output matrix used here is the Location Quotient (LQ) method. This mixes survey-type procedures with non-survey routines (KRONENBERG, 2009). The **Location Quotient (LQ) method** assumes that each regional technical coefficient a_{ij}^{R}, is related to the national coefficient, a_{ij}^{N}:

$$a_{ij}^{R} = t_{ij} . a_{ij}^{N} \tag{8}$$

To estimate t_{ij}, which quantifies the relationship between regional and national technical coefficients, the relative importance of an industry is considered. This importance is determined precisely by the Location Quotient (LQ): LQ “(...) is a measurement that compares the relative importance of an industry to a region with its relative importance to the nation” (RICHARDSON, 1978, p. 120).

This LQ is calculated as follows:

$$LQ_i = \frac{EMP_i^{SBSF}}{\sum_{i=1}^{n} EMP_i^{SBSF}} \Bigg/ \frac{EMP_i^{BR}}{\sum_{i=1}^{n} EMP_i^{BR}} \tag{9}$$

Where:

EMP_i^{SBSF} = Number of employees in sector i in the region (SBSF)

EMP_i^{BR} = Number of employees in sector i in the country (BR).

$\sum_{i=1}^{n} EMP_i^{SBSF}$ = Total employees in the region (SBSF);

$\sum_{i=1}^{n} EMP_i^{BR}$ = Total employees in the country (BR);

However, if $LQ_i < 1$, this means that activity “i” is underrepresented in the productive structure of the region, in comparison with the national situation. Therefore, this region absorbs national production in this sector, making it an importer (KRONENBERG, 2009). In Equation 8, t_{ij} is replaced by the LQ_i value calculated in Equation (9).

In the case where $LQ_i > 1$, sector “i” meets local needs. In this case, and in cases where $LQ_i = 1$, $t_{ij} = 1$: i.e. the regional technical coefficient is equal to the national one. Thus it is possible to obtain the regional coefficient matrix, the regional product vector and the regional inter-industrial consumption matrix. Respectively:

$$a_{ij}^{R} = \begin{cases} cl_i^1 a_{ij}^{BR} & \text{se} \quad LQ_i < 1, \\ a_{ij}^{BR} & \text{se} \quad LQ_i \geq 1, \end{cases} \tag{10}$$

$$\mathrm{A^R = \{a_{ij}^R\}} \tag{11}$$

$$\mathrm{X^R = t_{ij}.X^N} \tag{12}$$

$$\mathrm{Z^R = A^R.X^R} \tag{13}$$

The result presents a regional Input-Output matrix (MIPR). In this article, it was not necessary to estimate the value of regional production (XR) by means of the Location Quotient, since the Brazilian Institute of Geography and Statistics (IBGE) provides official regional accounts for Brazil and for the states for 22 sectors. The municipal GDPs weighted by the gross value of production of the regional accounts of the states of Pernambuco and Bahia were used as the production value for regional matrix. The RAS method was applied to correct possible imbalances.

The Sub-Middle São Francisco (SMSF) comprises 13 municipalities of two Brazilian states: Pernambuco and Bahia. In these municipalities about 32% of workers are employed in rural activities. Then, water availability is essential for local economies and its scarcity may induce important negative effects on income and jobs opportunities. In this work we will discuss the methodology of our study, the database, and the results.

The resulting regional input-output matrix obtained from this methodology has eighteen productive sectors, as listed below:

AT1- Temporary Agriculture
AT2- Permanent Agriculture
AT3 - Livestock, including livestock support
AT4- Forestry, fishing and aquaculture production
AT5 - Extractive Industries
AT6- Processing Industries
AT7- Electricity and gas, water, sewage, waste management and decontamination activities
AT8- Construction
AT9- Trade and repair of motor vehicles and motorcycles
AT10- Transport, storage and mail
AT11- Accommodation
AT12 - Food

AT13- other services
AT14- Administration, education, health, research and development. Public, defense.
AT15- Education
AT16- Health
AT17- Arts, culture, sports and recreation
T18- Domestic services

The input-output model can cover extensions, incorporating the use of water. The technical coefficients of direct water use measure the primary water use factor as input from the various economic sectors. Using the coefficients obtained, both the Direct and Indirect Effects on the Regional economy of the different limitations in the water input can be measured by different allocation policies used in the basins, as developed below.

2.2 *Water Supply*

The Technical Coefficients of Direct Water Use are one of the so-called Exogenous Input Coefficients (NAKAMURA and KONDO, 2009). Through these, it is possible to measure the effects on the economy of a limitation in water resources, resulting from changes in the supply or demand management of the river basins.

To obtain the technical coefficients of water use, the inputs needed for production are divided into endogenous and exogenous inputs. The endogenous inputs are the economic ones and the exogenous ones are the environmental inputs, in this work that is the 'water supply'.

$$\mathrm{Proces} = \left(\frac{\mathrm{Input}}{\mathrm{Output}}\right) = \left(\frac{\begin{matrix} x'_i \\ z'_i \end{matrix}}{\begin{matrix} x' \\ w' \end{matrix}}\right) \tag{14}$$

Where:

x'_i = i's Endogenous inputs;
z'_i = i's exogenous inputs (water);
x' = Production of the good x;
w' = Waste production.

If we divide the endogenous and exogenous inputs by the production, that is, the amount of inputs (endogenous and exogenous) needed to produce a unit of x:

$$a_i = \frac{x'_i}{x'}; \tag{15}$$

$$b_i = \frac{z'_i}{x'}. \tag{16}$$

As all inputs, both endogenous and exogenous, are required for the production of an end product, then assumption is made that $x_i > 0$ and $z_i > 0$, for all i. And, by definition, $a_i > 0$ and $b_i > 0$. Rewriting:

$$x'_i = a_i . x'; \tag{17}$$

$$z'_i = b_i . x'. \tag{18}$$

However, the hypothesis $a_i > 0$ is required, which means that $x'_i < x'$, that is, the input amount has to be smaller than the product amount, but this alone is not a sufficient condition. If $a_i \geq 1$, the amount of product does not exceed the amount of input used in production, then the process is not efficient. Therefore, the sufficient condition is $0 < a_i < 1$. Consider a model with n sectors. Dividing the demand into the intermediate and final demand gives:

$$x_j = x_{ij} + y_j. \tag{19}$$

$$x_j = a_{ij}.x_j + y_j. \tag{20}$$

Where $a_{ij}.x_j$ is the intermediate demand for good j and y_j the final demand for good j. Organizing:

$$\left(1 - a_{ij}\right).x_j = y_j. \tag{21}$$

$$x_j = (1 - a_{ij})^{-1} y_j. \tag{22}$$

In relation to exogenous inputs:

$$z_i = b_{ij} x_j\ . \tag{23}$$

Where: $x_j = \left(1 - a_{ij}\right)^{-1} y_j$.

$$z_i = b_{ij}(1 - a_{ij})^{-1} y_j. \tag{24}$$

Where $(1 – a_{ij})^{-1}$ is the coefficient of the inverse of Leontief, which means how much of the product x_j is needed to supply the demand y_j. In matrix terms:

$$X = (I - A)^{-1} Y \tag{25}$$

$$Z = \widehat{B}(I - A)^{-1} Y \tag{26}$$

Where:

X = Matrix (vector) of Total Production;
Y = Matrix (vector) Final Demand.
$(I - A)^{-1}$ = Leontief Matrix of Impact or Matrix.
Z = Vector Demand for Exogenous Inputs;
A = Matrix Endogenous Input Coefficients (n x n);
$\widehat{B}$ = Matrix Exogenous Input Coefficients (n x n);

When the B in question corresponds to water, then the application of the above equation in the input-output model allows the calculation of virtual water $[\widehat{B}(I - A)^{-1}]$. Otherwise, the vector Z takes into account the direct and indirect needs of water in the economy. As the water-associated element of vector B represents the direct needs of each sector and Leontief's matrix of inter-sectoral relations, the aggregation of the two represents the total impact.

As the exogenous / environmental inputs are usually scarce, their supply is limited. Substituting Equation (25) into Equation (26) has $Z = \widehat{B}X$. Considering that Z is scarce:

$$\mathbf{X} \leq \widehat{\boldsymbol{B}}^{-1}\mathbf{Z} \tag{27}$$

That is, production is limited by the water input.

Using the technical coefficients (B) and different water distributions we can have the maximum economic return, or economic production due to water. This means that we can associate different allocations of water with different economic products by sector. In addition, this reallocation will also cause a variation in the final demand. Rewriting Equation (26), we have:

$$Y = (I - A)(\hat{B})^{-1}Z \tag{28}$$

In this way, it is possible to realize that a reallocation of scarce input, water can be simulated for different allocation models, resulting in different values of Z, which causes a change in production, X, and in the final demand, Y (NAKAMURA and KONDO, 2009). Which can then be measured using the technical coefficients (vector B) and the input-output matrix of the region (matrix A).

As the region to be evaluated is the sum of the municipalities of the Sub-Medium, it is hereafter referred to as the Sub-Medium of São Francisco (SBSF). This work had the objective of simulating the possible scenarios of water management in the SBSF (ΔZ), especially for irrigated agriculture. Following this, to estimate the consequence on the demand (ΔY), the production (ΔX) and employ (ΔL):

$$\Delta Y = (I - A)(\hat{B})^{-1}\Delta Z \tag{29}$$

$$\Delta X = (I - A)^{-1}\Delta Y \tag{30}$$

$$\Delta L = \widehat{EMP} \cdot \Delta X \tag{31}$$

Where:

ΔL = vector that represents the impact on the number of people employed

$EMP = L'.X$ is the Impact vector on jobs in the region (SBSF)

L'= Transposed from the vector of direct employment coefficient of the region (SBSF)

3. DATABASE

As a database to estimate the IO-SMSF we have the IO-Brazil (2010), the Brazilian Regional Accounts 2010 and the municipal GDP from IBGE. Some procedures were adopted to aggregate this information into tables that relate demand and supply to the eighteen sectors. The first procedure was to aggregate the 53 sectors of the national input-output matrix to the 18 sectors.

The information for the Brazilian VBP is available in the National Accounts System, while the information for the states of Pernambuco and Bahia can be found in the Regional Accounts. The two pieces of information were already available for the new GDP calculation methodology.

To estimate the VBP of the sectors in the Municipal Accounts, the procedure was somewhat different. This is because there is no information available for the Gross Value of Municipal Production, neither by sector nor by aggregate.

The assumption adopted here was that the technology employed in each sector in the regions was similar to the technology employed in the state. Thus, the participation of the Intermediate Consumption Sector in the sector's VBP for the State would be similar to the municipalities. On the basis of this hypothesis:

$$\mathrm{VBP}_i^R = \frac{\mathrm{VBP}_i^E}{\mathrm{VA}_i^E} \times \mathrm{VA}_i^R. \qquad (29)$$

Where VBP_i^R is the value to be estimated for the VBP of sector i in the region R. VPB_i^E is the VBP of sector i in Pernambuco (or Bahia) and VA_i^E is the Value Added by sector i in Pernambuco (or Bahia), both available in the Regional Accounts. , VA_i^R is the Added Value for sector i in region R. Information on VA in municipalities was available aggregated for four sectors (Agriculture and Livestock, Industries, services and Public Administration).

Thus, the estimation was made considering these sectors. After using the Location Quotient method (Equation 9), we obtained the regional coefficient matrix, the regional product vector, and the regional inter-industry consumption matrix.

The direct coefficients of water use were distinguished for irrigated agriculture, livestock, industry and services. To estimate the direct coefficients of water use for irrigated agriculture in the region the Technical Coefficients Matrix for Water Resources in Brazil published by FEBRABAN in 2011 was used as the basis. For livestock, the coefficient of withdrawal per animal (liters/day) per type of animal published by Funarbe, 2011 was used. This coefficient was applied to the number of heads for the municipalities of the SBSF. For all other sectors, the IWE-MAIN coefficient applied to the number of persons employed by sector (in the municipalities of the SBSF) published in the 2010 IBGE demographic census was used.

Tabela 1: Water use coefficient (IWE-MAIN)

Economic Activity	Water use coefficient (liter/Employment.day)
Construction	78.4
Manufacturing	500.8
Transportation, Communication, Utilities	186.2
Wholesale Market	162
Retail Market	352.4
Finance, Insurance, Real Estate	268
Services	520.5
Public Administration	400.1

Source: Planning and Managment Consultants, apud FUNARBE (2011).

4. RESULTS

The sectors that generate the largest production in the region are: public administration, manufacturing industry and agriculture (sum of temporary agriculture, permanent and livestock). However, the sectors that use the most amount of water (Z) are the agricultural ones, as expected. This means that one company alone accounted for approximately 27%. All sectors together consume 29% of this flow. Table 2 presents the main results of IOM-SBSF 2010.

Table 2: Results of IPM-SBSF 2010

Setores	Exogenous Inputs Water (Z) (1.000m3 in 2010)	Total Production (X) (R$ 1.000.000)	Exogenous Input Coefficients (B) (1.000m3 in 2010/ R$1.000.000)	virtual water $\hat{B}(I-A)^{-1}$
Temporary Agriculture	435,424	851	511.6	536.5
Permanent Agriculture	342,477	415	825.9	850.7
Livestock, including livestock support	74,926	131	572.5	597.4
Forestry, fishing and aquaculture production	1	48	0.0	24.9
Extractive Industries	33	64	0.5	4.1
Processing Industries	3,678	3,041	1.2	44.3
Electricity and gas, water, sewage, waste management and decontamination activities	757	1,043	0.7	4.2
Construction	791	776	1.0	7.0
Trade and repair of motor vehicles and motorcycles	6,547	1,960	3.3	10.6
Transport, storage and mail	854	353	2.4	7.9
Accommodation	260	36	7.2	25.1
Food	2,069	196	10.5	28.4
other service	8,116	1,121	7.2	10.4
Administration, education, health, research and development. Public, defense.	3,043	3,688	0.8	4.4
Education	4,399	607	7.2	10.2
Health	2,027	279	7.3	11.9
Arts, culture, sport and recreation	428	59	7.2	9.9
Domestic services	4,430	589	7.5	7.5

Source: The author

The agriculture and livestock sector are the ones that use the most water in the SBSF, with the highest direct coefficients (B). Therefore, *these are* the sectors that present the greatest Virtual Water (Total effect). High-user non-agricultural sectors include food and domestic services. The manufacturing industry stands out among the non-agricultural sectors in relation to Virtual Water use. Despite its low direct coefficient, both its participation in production and large indirect effect increase its weight in the Virtual Water effect.

The SBSF Region is a major exporter of fruit (sector 2, Permanent Agriculture), and potential producer of sugar cane (Sector 1, temporary agriculture). To understand the direct and indirect effects of the increase in demand in this sector, assuming an increase in exports, for example, the impact of this increase (1 R$ million more in the demand for this sector) is shown in Table 3.

Table 3: Effects of the demand shock in the Permanent Agriculture sector

Sectors	Demand shock ΔY	Product Effect $\Delta X = (I - A)^{-1}\Delta Y$	employment effect $\Delta L = \widehat{EMP} \cdot \Delta X$	water effects $\Delta Z = B(I - A)^{-1}\Delta Y$
Temporary Agriculture	0.0	0.030	3	15.6
Permanent Agriculture	1.0	1.001	86	826.7
Livestock, including livestock support	0.0	0.0135	1	7.7
Forestry, fishing and aquaculture production	0.0	0.0073	0	0.0
Extractive Industries	0.0	0.0018	0	0.0
Processing Industries	0.0	0.1054	1	0.1
Electricity and gas, water, sewage, waste management and decontamination activities	0.0	0.0413	0	0.0
Construction	0.0	0.0021	0	0.0
Trade and repair of motor vehicles and motorcycles	0.0	0.0543	2	0.2
Transport, storage and mail	0.0	0.0256	1	0.1
Accommodation	0.0	0.0002	0	0.0
Food	0.0	0.0004	0	0.0
other services	0.0	0.0289	1	0.2
Administration, education, health, research and development. Public defense.	0.0	0.0000	0	0.0
Education	0.0	0.0002	0	0.0
Health	0.0	0.0000	0	0.0
Arts, culture, sports and recreation	0.0	0.0000	0	0.0
Domestic services	0.0	0.0000	0	0.0
TOTAL	1.0	1.31	95	850.7

Source: The author

Analyzing the impact on product third column on Table 3), an increase of 1 R$ million in the demand for permanent agriculture would generate a total increase in the product of 1.31 R$ million for the local economy. That is, 1.00 million for the sector itself. In the case of production, this would spread not to the agricultural sectors, but to the non-agricultural ones: The manufacturing industry (0.105 R$ million), commerce (0.054 R$ million and electricity (0.04 R$ million).

With regard to the employment generated (fourth column on Table 3), almost all the effect is on the sector itself. The demand shock would generate a total of 95 jobs, of which 86 would be in the sector itself. Others for the sectors, temporary agriculture, livestock, commerce and services. For effect on virtual water (final column on Table 3), the demand shock would generate a total impact of 850.07 million m^3 of water (27 m^3/sec).

In addition to the demand shock, we simulated the supply shock on the exogenous water supply. In this case, supposed a decrease in the available water for the productive sectors of the São Francisco sub-middle as a consequence of the river transposition.

As mentioned above, the project of integration of the São Francisco River (PISF), a project of the Federal Government, was conceived with the objective of guaranteeing water supply for the semi-arid region of the four States of the Northern Northeast (Paraíba, Pernambuco, Rio Grande do Norte and Ceará). Two hydraulic systems are being built (North Axis and East Axis) and will be operated and maintained by the Parnaíba and São Francisco Valley Development Company -

The North Axis has an extension of about 400 kilometers and is composed of three pumping systems with a total height of 169 m and is designed for a maximum capacity of 99 m³/s. The North Axis will operate with a continuous flow of 16.4 m³/s. The East Axis has an extension of about 220 kilometers to the Paraíba river and its storage in the Itaparica reservoir, for a maximum capacity of 28 m³/s, the East Axis will operate with a continuous flow of 10 m³/s (CASTRO, 2011).

The supply shocks for the water input are considered in this work based on the scenarios designed by Silva (2017) when estimating the post-implementation demand curve of the PISF considering the costs of transposition. Silva (2017) determines three scenarios: the Baseline scenario that predicts a continuous withdrawal of 26.4 m³/s, scenario A2 that predicts an increase in average withdrawal flow of 86 m³/s, and scenario B1 an increase in average flow of 76.5 m³/s.

The municipalities of the sub-middle region downstream from the Sobradinho dam, *which is* likely *to be the direct* source of water destined for the new axes. To simulate this competition, two scenarios are drawn here from the Sobradinho dam flow. The first scenarios for years that have more rain are the shocks: Baseline, A2 and B1 on a concession of 1300 m³/s for the Sobradinho dam. The second driest scenario considers the same shocks for a concession of 700 m³/s. The table below represents these shocks of water supply over the total water used in the sub-average São Francisco.

Table 4: Scenarios to simulate decrease in availability after transposition

	Wet Scenario Sobradinho release 1300 m³/s			**Dry Scenario** Sobradinho release 700 m³/s		
	Baseline	**B1**	**A2**	***Baseline***	**A2**	**B2**
Withdrawal	26,4 m³/s	76,5 m³/s	86 m³/s	26,4 m³/s	76,5 m³/s	86 m³/s
Total impact in sub-middle Sao Francisco						
In 1.000m3/year	-18,079	-52,388	-58,894	-33,575	-97,292	-109,374
In m³/s	-0.58	-1.68	-1.89	-1.08	-3.13	-3.52

Source: The author

Table 5 presents the results impact on the Final Demand, Product and Employment if this water restriction was only used for the agricultural sectors.

Table 5: Effect of the reduction in water supply for the agricultural and livestock sectors

	Wet Scenario Sobradinho release 1300 m³/s			**Dry Scenario** Sobradinho release 700 m³/s		
Sectors	***Baseline***	**B1**	**A2**	***Baseline***	**A2**	**B2**
Temporary Agriculture	-16.6	-48.0	-54.0	-30.8	-89.2	-100.2
Permanent Agriculture	-8.4	-24.4	-27.4	-15.6	-45.2	-50.9
Livestock, including livestock support	-2.4	-6.8	-7.7	-4.4	-12.7	-14.3
Total Final Demanda (R $ 1,000,000)	**-22.00**	**-63.80**	**-71.70**	**-40.90**	**-118.40**	**-133.10**
Total de Production (R $ 1,000,000)	**-28.36**	**-82.19**	**-92.39**	**-52.67**	**-152.63**	**-171.59**
Employed Employment (*people employed*)	**-2431**	**-7043**	**-7918**	**-4514**	**-13080**	**-14704**

Source: The author

The reduction of water availability to the agricultural sectors would cause a decrease in demand, in the sense that there would be less water for crops. That in turn would also cause a drop in *production* and employment.

The effect on the production (ΔX) is greater than the effect on demand (ΔY). This is because to meet demand (consumption, export ...) products can be replaced to some degree. For example, with the fall in the availability of water to the agricultural sectors, there would be an increase in the demand of the processing industry. In addition, products can be imported from outside the sub-region to meet the demand. In terms of over-all production, the unavailability of water in the agriculture and livestock sectors, would only cause a regional decrease of production in the agricultural sectors.

The effect on employment (ΔEMP) follows the same logic as the effect on production (ΔX), a fall in the availability of water for agriculture would cause a decrease in the number of jobs for the agricultural sectors and a small decrease in the other sectors.

However, this reduction in the supply of water could be felt by all productive sectors of the sub-region of São Francisco, and not only to the agricultural sectors. Table 6 presents the results of this shock on the final demand (ΔY), production (ΔX) and the employment (ΔEMP).

The drop in total demand for the São Francisco sub-basin would range between R$237 million and R$1,434 million. And since all sectors would be affected by the water scarcity, the sectors that suffer the greatest shock on the final demand are the most important sectors for the region (Table 2): Public Administration, Manufacturing and trade.

The same logic applies to production and employment. The fall in production would range between R $ 310 million and R $ 1,874 million. This represents a variation between 2% and 12% on the total production in the region, demonstrating the importance of water resources. Job availability reflects on the generation of income and the well-being of the population of the region in general. In the worst case scenario, a drop in water supply could result in 48,198 fewer jobs.

Table 6: Effect on final demand ($\Delta Y = (I - A)(B)^{-1}\Delta Z$)

	Wet Scenario Sobradinho release 1300 m³/s			Dry Scenario Sobradinho release 700 m³/s		
Sectors	***Baseline***	**B1**	**A2**	***Baseline***	**A2**	**B2**
Temporary Agriculture	-14.0	-40.5	-45.6	-26.0	-75.2	-84.6
Permanent Agriculture	-8.1	-23.3	-26.2	-15.0	-43.3	-48.7
Livestock, including livestock support	-0.8	-2.3	-2.6	-1.5	-4.3	-4.8
Forestry, fishing and aquaculture production	-0.6	-1.6	-1.8	-1.0	-3.0	-3.4
Extractive Industries	-0.4	-1.1	-1.2	-0.7	-2.0	-2.3
Processing Industries	-45.7	-132.4	-148.8	-84.8	-245.8	-276.3
Electricity and gas, water, sewage, waste	-11.6	-33.7	-37.9	-21.6	-62.6	-70.3
Construction	-12.2	-35.2	-39.6	-22.6	-65.4	-73.5
Trade and repair of motor vehicles and motorcycles	-31.1	-90.0	-101.1	-57.7	-167.1	-187.8
Transport, storage and mail	-1.2	-3.4	-3.8	-2.2	-6.3	-7.1
Accommodation	-0.5	-1.3	-1.5	-0.9	-2.5	-2.8
Food	-2.7	-7.9	-8.9	-5.1	-14.8	-16.6
other service	-3.0	-8.7	-9.8	-5.6	-16.2	-18.2
Administration, education, health	-74.9	-217.0	-244.0	-139.1	-403.0	-453.1
Education	-12.1	-35.0	-39.4	-22.4	-65.0	-73.1
Health	-5.4	-15.7	-17.7	-10.1	-29.2	-32.9
Arts, culture, sport and recreation	-1.1	-3.2	-3.6	-2.0	-5.9	-6.6
Domestic services	-12.0	-34.6	-38.9	-22.2	-64.3	-72.3
Total Final Demanda (R $ 1,000,000)	**-237**	**-687**	**-772**	**-440**	**-1276**	**-1434**
Total de Production (R $ 1,000,000)	**-310**	**-898**	**-1009**	**-575**	**-1667**	**-1874**
Employed Employment (*people employed*)	**-7967**	**-23086**	**-25953**	**-14796**	**-42874**	**-48198**

Source: The author

5. Conclusion

The Brazilian government's policy of expanding irrigated areas, especially in the Northeast of Brazil, tends to increase competition for water resources. From the regional input-output matrix adapted to the sub-river basin region of the São Francisco river, it was possible to simulate economic impact from changes in water available. Considering only the productive sectors with permissible use, our study showed agriculture and livestock to be the sectors with the highest coefficient of withdrawal, but not be the only ones affected by the reduction of available water, as a result of the São Francisco River transposition, for example. Even if the restriction applies only to the agricultural sectors, the damage to the region would expand to all sectors. If the restriction were applied to all the advisory sectors included in the matrix, the impact would be even greater, reaching 12% in the fall of production, and a total of 48,198 fewer jobs, across all sectors. The scarcity of water in the semi-arid region of the Brazilian Northeast certainly represents a hurdle for the development of that region, but the transfer of water from another region does not necessarily mean expansion of the supply of water to the two regions if water is limited and already suffers from competition between allowed and non-allowed uses.

REFERÊNCIAS BIBLIOGRÁFICAS

BRASIL. Ministério da Integração Nacional. **Governo Federal lança PAC da irrigação.** Disponível em: < http://www.integracao.gov.br > Acesso em: 12 jan. 2014a.

BRASIL. Ministério da Integração Nacional. **O que é o Projeto São Francisco**. Disponível em: < http://www.integracao.gov.br/pt/web/guest/o-que-e-o-projeto > Acesso em: 21 jan. 2014b.

BRASIL. Ministério da Integração Nacional. **Programa Mais Irrigação:** irrigando a terra para produzir mais. Disponível em: <http://www.integracao.gov.br/c/document_library/get_file?uuid=ac648b0e-d31b-498b-a946-d8ed96de0a21&groupId=10157> Acesso em: maio 2012.

CASTRO, C. N. D. **Transposição do rio São Francisco:** Análise de oportunidade do projeto. Rio de Janeiro: [s.n.], 2011.

CBHSF. **Plano Decenal de Recursos Hídricos da Bacia Hidrográfica do Rio São Francisco**. Versão preliminar. ed. São José: CBHSF, 2004.

CODEVASF. **Relatório de Gestão. Companhia de Desenvolvimento do Vale do São Francisco**. [S.l.]: [s.n.], 2006.

FUNARBE – Fundação de Apoio a Universidade de Viçosa. Relatório 6 – **Relatório Final dos Coeficientes Técnicos de Recursos Hídricos das Atividades Industrial e Agricultura Irrigada**. Desenvolvimento da Matriz de Coeficientes técnicos para recursos hídricos no Brasil. Brasilia, DF. Fundação Banco do Brasil. Ministério do Meio-Ambiente. Outubro de 2011.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Produção Agrícola Municipal. **Sistema IBGE de Recuperação Automática - SIDRA**, 2006-2012. Disponivel em: <http://www.sidra.ibge.gov.br/>. Acesso em: 12 jun. 2016.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Censo Demográfico 2010.** Disponível em: < http://www.ibge.gov.br>Acesso em: 04 jan. 2017. 2012

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Contas Regionais 2010.** Rio de Janeiro, 2013. Disponível em:< http://www.sidra.ibge.gov.br> Acesso em: 12 jan. 2017.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Matriz Insumo-Produto 2010**. Rio de Janeiro, 2016. : < http://www.ibge.gov.br>Acesso em: 04 jan. 2017.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **PIB municipal.** Rio de Janeiro, 2013. Disponível em:< http://www.sidra.ibge.gov.br> Acesso em: 12 jan. 2017.

INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Sistema de Contas Nacionais**. Rio de Janeiro: Fundação IBGE, 1997.

KRONENBERG, Tobias. **Construction of regional input-output table using nonsurvey methods**: the role of cross-houling. International Regional Science Review, vol. 32, nº 1, 2009.

LEONTIEF, Wassily, **A economia do insumo-produto**. São Paulo, Abril Cultural, 1983 (1951).

LIMA, J P e MIRANDA, E A. 2000. **Fruticultura irrigada***: os casos das regiões de Petrolina-Juazeiro e norte de Minas Gerais.* Fortaleza : Banco do Nordeste do Brasil, 2000.

MDIC. **Sistema de análise das informações de comércio exterior via internet**. Disponível em: Aliceweb. http://aliceweb.desenvolvimento.gov.br. Acessado em: agosto/2016.

MILLER, Ronald E.; BLAIR, Peter D. **Input-output analysis: foundation and extenstions**. 2 ed. Cambridge: Cambridge University Press, 2009.

MORAES, M. M. G. A. D.. et al**. Integrated economic models to support decisions on water pricing in biofuel production river basins: three case studies from Brazil**. *Biofuels, Bioproducts & Biorefining.* 10, 2016, Vol. 3, pp. 255–269. 2016

NAKAMURA, Shinichiro; KONDO, Yasushi. **Waste input-output analysis**: concepts and application to industrial ecology. Berlin: Springer, 2009.

RICHARDSON, H. W. **Insumo-produto e economia regional**. Rio de Janeiro: Zahar Editores, 1978.

ROGERS, P.; BHATIA, R.; HUBER, A. **Water as a Social and Economic Good:** How to Put the Principle into Practice. Stockholm, Sweden: Global Water Partnership/Swedish International, 1998.

SOUZA DA SILVA, G.N. 2017. **Apoio a gestão sustentável de recursos hídricos através de um modelo hidro-econômico desenvolvido em diferentes cenários de uso do solo e clima: o caso do Sub-médio do São Francisco**. 2017. Doctorate Thesis at Graduate Program in Civil Engineeringat Federal University of Pernambuco.

UNITED NATIONS ENVIRONMENT PROGRAMME. Oeko-Institut and IEA Bioenergy Task **The bioenergy and Water Nexus,** n.43, 2011.