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Water Use in the São Francisco River Basin, Brazil: An Interregional Input-Output Analysis

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Abstract

The planning and management of water resources aiming to a sustainable development must necessary pass through a series of studies that will reveal the interrelations and links among economic activities, and if one is considering that there is a set regions involved in the process, the direct and indirect regional interdependencies. Increasing demands of water-use for industrial, agricultural and urban sectors may became very competitive and can result in conflicts among multiple users. In the case of the São Francisco River Basin, Brazil, consisting of a wide-range five states - most of them having drought problems - the water in the basin plays an essential role and any activity in this area has to consider the effects of the water use in the intersectoral and interregional economic relations. Considering the three main states in the basin - Minas Gerais, Bahia and Pernambuco - an interregional input-output system for the economy and for the water flows was constructed by the authors. The above interregional system is then used to analyze the interregional and intersectoral dependencies among the states and the economic activities on the São Francisco river basin area and their relations with the use of water.

1 Introduction

As a resource, water use can be divided into 3 main uses: agriculture, industrial and domestic. Depending on the amount and quality of water available for use by the society it can be treated either as a free good or as market good.

The decision related to the water use in a region that comprises an hydrographic basin do depend on the relations among the states and the sectors that made use of this resource. So, the success of a economic policy may be very dependable of how a limited resource, like water, is used in the productive process.

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In the case of the São Francisco river basin that is locate in a region that has draught problems and comprises 5 Brazilian States, some of them with low level of development, the use of the water should be done such the most can be obtained from it.

Taking into consideration those aspects, this study tries to better understand how the water use takes place among the three most important states (Minas Gerais, Bahia, and Pernambuco), in terms of water use, in the São Francisco river base. To do so it is constructed an interregional input-model for the region and estimated the interactions that take place among the States in terms of production and water use.

In the next section it is presented a brief overview of the São Francisco River Basin. The third section will presented the methodology, in the forth section the results are presented, while some final remarks are made in the last section.

2 The São Francisco River Basin

It this study it is taking into consideration the states of Minas Gerais, Bahia and Pernambuco. As can be seen in Table 2-1 Minas Gerais has a share of 9% in the Brazilian GDP, Bahia 3% and Pernambuco 2%.

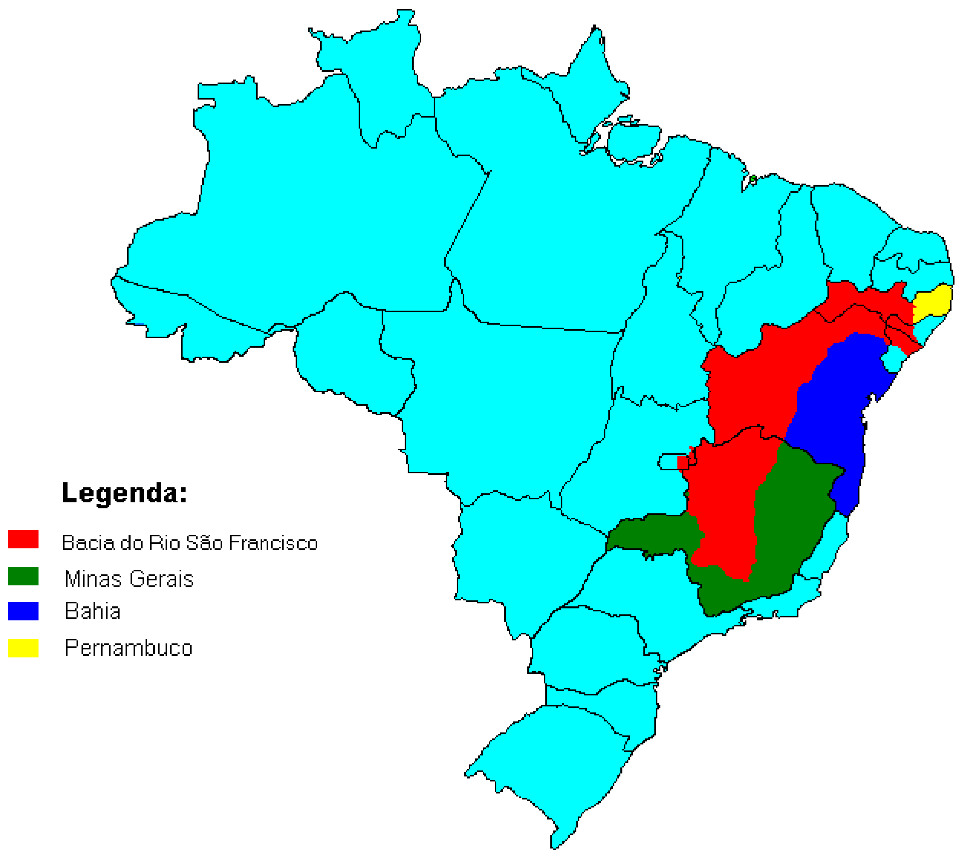
Table 2.1 - Main economical and geographical indicators of the Brazil, Minas Gerais, Bahia and Pernambuco.

	Brazil	Minas Gerais	Bahia	Pernambuco
Size (Km2)	8 511 996	588 383	561 026	98 281
Population (1996)	157 070 163	16 672 613	12 541 675	7 399 071
Urban	123 076 831	13 073 852	7 826 843	5 476 855
Rural	33 993 332	3 598 761	4 714 832	1 922 216
Urbanization (%)	78	78	62	74
GDP (1995) (US$ Million)	707 358	61 837	22 850	12 527
GDP per capita (US$)	4 554	3 737	1 801	1 678

Source: IBGE, 1997; Considera e Medina, 1998.

The São Francisco river basin occupies and area of 640 thousand km^2 (Figure 2.1), being 36,8% of it in Minas Gerais, 0,7% in Goiás and the remaining 62,5% in the states of Bahia, Sergipe, Alagoas e Pernambuco. With an extension of 2700 km, there are around 14 million people living in the basin area (CODEVASF, 1998b).

From Table 2.2 one can see that in terms of area the States of Bahia, Minas Gerais, and Pernambuco are the ones more dependable from the São Francisco River basin.



Source: EMBRAPA - Sistema de Monitoramento por Satélite.

Figure 2.1 - São Francisco River Basin, Brazil.

Table 2.2 - Area and population of the states in the São Francisco river basin.

States	Area (Km^2)			Population [3] 1991		
	Total	Area Total in the basin [1]	Area in the basin [2]	Total	Urban	Rural
Minas Gerais	588 383.6	262 201.9	235 471.3	6 931 099	5 667 175	1 263 924
Bahia	567 295.3	331 724.7	307 940.8	2 500 422	1 056 487	1 443 935
Distrito Federal	5 822.1	5 822.1	1 335.6	1 601 094	1 515 889	85 205
Goiás	341 289.5	13 133.8	3 141.8	94 383	71 494	22 889
Pernambuco[4]	98 937.8	71 973.8	69 518.4	1 583 854	732 117	851 737
Sergipe	22 050.3	8 689.8	7 473.3	279 448	131 022	148 426
Alagoas	27 933.1	16 225.2	14 338.2	966 312	431 793	534 519
Total	**1 651 711.7**	**709 771.3**	**639 219.4**	**13 956 612**	**9 605 977**	**4 350 635**

Source: CODEVASF (1998b).

Notes: (1) Include total area of the borough partially in the Basin's area.
(2) Not include outside area of the borough partially in the Basin's area.
(3) Include total population of the borough partially in the Basin's area.
(4) Total area of the Pernambuco state include Fernando de Noronha's area.

3. Theoretical Background

3.1. The Rasmussen/Hirschman Approach

The work of Rasmussen (1956) and Hirschman (1958) led to the development of indices of linkage that have now become part of the generally accepted procedures for identifying key sectors in the economy. Define b_{ij} as a typical element of the Leontief inverse matrix, B; B^* as the average value of all elements of B, and if $B_{\bullet j}$ and $B_{i\bullet}$ are the associated typical column and row sums, then the indices may be developed as follows:

Backward linkage index (power of dispersion):

$$U_j = B_{\bullet j} / n \ / B^* \tag{1}$$

Forward linkage index (sensitivity of dispersion):

$$U_i = B_{i\bullet} / n \ / B^* \tag{2}$$

One of the criticisms of the above indices is that they do not take into consideration the different *levels* of production in each sector of the economy, what it is done by the pure linkage approach presented in the next section.

3.2. The Pure Linkage Approach

As presented by Guilhoto, Sonis and Hewings (1996) the pure linkage approach can be used to measure the importance of the sectors in terms of production generation in the economy.

Consider a two-region input-output system represented by the following block matrix, *A*, of direct inputs:

$$A = \begin{pmatrix} A_{jj} & A_{jr} \\ A_{rj} & A_{rr} \end{pmatrix} \quad (3)$$

where A_{jj} and A_{rr} are the quadrate matrices of direct inputs within the first and second region and A_{jr} and A_{rj} are the rectangular matrices showing the direct inputs purchased by the second region and vice versa.

From (3), one can generate the following expression:

$$B = (I - A)^{-1} = \begin{pmatrix} B_{jj} & B_{jr} \\ B_{rj} & B_{rr} \end{pmatrix} = \begin{pmatrix} \Delta_{jj} & 0 \\ 0 & \Delta_{rr} \end{pmatrix} \begin{pmatrix} \Delta_{j} & 0 \\ 0 & \Delta_{r} \end{pmatrix} \begin{pmatrix} I & A_{jr}\Delta_{r} \\ A_{rj}\Delta_{j} & I \end{pmatrix} \quad (4)$$

where:

$$\Delta_j = (I - A_{jj})^{-1} \quad (5)$$

$$\Delta_r = (I - A_{rr})^{-1} \quad (6)$$

$$\Delta_{jj} = (I - \Delta_j A_{jr} \Delta_r A_{rj})^{-1} \quad (7)$$

$$\Delta_{rr} = (I - \Delta_r A_{rj} \Delta_j A_{jr})^{-1} \quad (8)$$

By utilizing this decomposition (equation 4), it is possible to reveal the process of production in an economy as well as derive a set of multipliers/linkages.

From the Leontief formulation:

$$X = (I - A)^{-1} Y \quad (9)$$

and using the information contained in equations (4) through (8), one can derive a set of indexes that can be used: a) to rank the regions in terms of its importance in the economy; b) to see how the production process occurs in the economy.

From equations (4) and (9) one obtains:

$$\begin{pmatrix} X_j \\ X_r \end{pmatrix} = \begin{pmatrix} \Delta_{jj} & 0 \\ 0 & \Delta_{rr} \end{pmatrix} \begin{pmatrix} \Delta_j & 0 \\ 0 & \Delta_r \end{pmatrix} \begin{pmatrix} I & A_{jr}\Delta_r \\ A_{rj}\Delta_j & I \end{pmatrix} \begin{pmatrix} Y_j \\ Y_r \end{pmatrix} \tag{13}$$

which leads to the definitions for the Pure Backward Linkage (PBL) and for the Pure Forward Linkage (PFL), i.e.,

$$\begin{aligned} PBL &= \Delta_r A_{rj} \Delta_j Y_j \\ PFL &= \Delta_j A_{jr} \Delta_r Y_r \end{aligned} \tag{14}$$

where the PBL will give the pure impact on the rest of the economy of the value of the total production in region j, $(\Delta_j Y_j)$: i.e., the impact that is free from a) the demand inputs that region j makes from region j , and b) the feedbacks from the rest of the economy to region j and vice-versa. The PFL will give the pure impact on region j of the total production in the rest of the economy $(\Delta_r Y_r)$.

3.3 The Structure of Production: Economic Landscapes

The view that has been proposed by Sonis, Hewings and Guo (1997) and by Sonis and Hewings (1999) for the interactions among the sectors to be arranged in a normalized hierarchical fashion and presented in a three-dimensional matrix that has been termed an *economic landscape*. This approach provides a consistent and complementary exploration of structure to the more traditional approach associated with Rasmussen and Hirschman. However, in this case, attention is directed to a matrix derived from the product of row and column multipliers extracted from the Leontief inverse matrix. This matrix, the input-output multiplier product matrix (MPM), reveals the *hierarchy* of backward and forward linkages and their associated *economic landscapes,* reflecting the cross-structure of the multiplier product matrix. The developments will be elaborated below.

Consider the column and row multipliers of the Leontief inverse defined in section 3.1 above and define $b_{\bullet\bullet}$ as been the sum over all elements of the Leontief inverse matrix.

Then, the intensity matrix, or the input-output multiplier product matrix (MPM) is defined as:

$$M = \frac{1}{b_{\bullet\bullet}} \left\| b_{i\bullet} b_{\bullet j} \right\| = \frac{1}{b_{\bullet\bullet}} \begin{pmatrix} b_{1\bullet} \\ b_{2\bullet} \\ \vdots \\ b_{n\bullet} \end{pmatrix} \begin{pmatrix} b_{\bullet 1} & b_{\bullet 2} & \ldots & b_{\bullet n} \end{pmatrix} = \left\| m_{ij} \right\| . \tag{15}$$

One can reorganize the locations of rows and columns of M in such a way that the centers of the corresponding crosses appear on the main diagonal. In this fashion, the matrix will be reorganized in such a way that a descending *economic landscape* will be apparent, based on the rank-size sequence of the column and row multipliers. One can reorganize the locations of rows and columns in such a way that a descending *economic landscape* can be apparent. Furthermore, by adopting the rank-size ordering from one economy as the *numeraire*, the economic landscapes can be compared visually; deviations from the smoothly descending landscape of the numeraire economy will reflect differences in economic structure. These differences will reflect variations in the industry mix of regions, variations in the degrees of intraregional intermediation as well as variations in technology.

One of the attractive features of the economic landscape analysis is that the patterns revealed are consistent with the key sector identification procedures associated with Hirschman-Rasmussen. As Sonis, Hewings and Guo (1997) and Sonis and Hewings (1999) have pointed out, the rank-size hierarchies of the Rasmussen/Hirschman indices coincide with the rank-size hierarchies of column and row multipliers of the MPM. This rearrangement also reveals the descending rank-size hierarchies of the Rasmussen/Hirschman forward and backward linkage indices.

Thus, the economic landscape provides a complementary tool in the preliminary elaboration of differences and similarities across economies. It will not replace other techniques but will serve as a first-stage filter that may help in focusing attention on potentially important similarities and differences across economies.

3.4 The Field of Influence

The concept of field of influence was introduced and elaborated by Sonis and Hewings (1989, 1994). It is mainly concerned with the problem of coefficient change, namely the influence of a change in one or more direct coefficients on the associated Leontief inverse matrix.[3] Since, given an economic system, some coefficients are more "influential" than others, the sectors responsible for the greater changes in the economy can be determined. Together with the Rasmussen/Hirschman linkage indices and the pure linkage indices, it completes our analytical framework for the determination of key sectors in an economic system.

Considering a small enough variation, ε, in the input coefficient, a_{ij}, the presentation of the *basic* solution of the coefficient change problem proposed by Sonis and Hewings may be presented as follows. let $A = (a_{ij})$ be an *nxn* matrix of direct input coefficients; let $E(e_{ij})$ be a matrix of incremental changes in the direct input coefficients; let $B = (I - A) = \|b_{ij}\|$, $B(\varepsilon) = (I - A - E) = \|b(e)_{ij}\|$ be the Leontief inverses before and after changes.

Using the notion of inverse-important input coefficients that is based on the conception of the field of influence associated with the change *in only one* input coefficient, assume that this change occurs in location (i_1, j_1), that is,

$$e_{ij} = \begin{cases} \varepsilon & i = i_1,\ j = j_1 \\ 0 & i \neq i_1 \text{ or } j \neq j_1 \end{cases} \tag{16}$$

then, the field of influence can be constructed as the matrix $F(e_{ij})$ generated by multiplication of the j^{th} column of the Leontief matrix, B, with the i^{th} row:

$$F(e_{ij}) = \begin{pmatrix} b_{1j} \\ b_{2j} \\ \vdots \\ b_{nj} \end{pmatrix} \begin{pmatrix} b_{i1} & b_{i2} & \ldots & b_{in} \end{pmatrix}, \tag{17}$$

where $F(\varepsilon_{ij})$ is a *nxn* matrix, interpreted as the field of influence of the change on the input coefficient, a_{ij}. For every coefficient, a_{ij}, there will be an associated *nxn* field of influence matrix.

In order to determine which coefficients have the greater field of influence, reference is made to the rank-size ordering of the elements, S_{ij}, from the largest to the smallest ones. Therefore, for every matrix $F(\varepsilon_{ij})$, there will be an associated value given by:

$$S_{ij} = \sum_{k}^{n} \sum_{l}^{n} f_{kl}(\varepsilon_{ij}) . \quad (18)$$

It is possible to see that $S_{ij} = b_{\bullet j} b_{i\bullet}$ and thus provides a direct relationship with the intensity matrix defined in (15). Thus, from the values of S_{ij}, a hierarchy can be developed of the direct coefficients, based on their fields of influence, i.e., ranking sectoral relations in terms of their sensitivity to changes, in a sense that they will be responsible for more significant impacts on the economy. It is important to stress that each field of influence and the MPM matrix as well have a cross structure; the largest elements define the largest column and row. After exclusion of these entries, the next largest element defines the second largest cross and so on. This property is of importance in the empirical analysis.

[3]We considered here only the simplest case, i.e., the case in which the change occurs in only one input parameter. However, the analysis can be extended to the cases of changes in whole rows or columns.

4. Analysis of the results

4.1 The Rasmussen/Hirschman Linkages

The results for the Rasmussen/Hirschman linkages are presented in Table 4.1 and in Figures 4.1 to 4.4 for the 26 sectors of the interregional system. In the system as a whole, the sectors that present the greater values for the backward linkages are: a) Metal Products (4), Food Products (16), and Transport Equipment (7) in the Minas Gerais State; b) Food Products (16) in the state of Pernambuco; and c) Food Products (16) in the Bahia State. In relation to the forward linkages the sectors are: a) Chemicals (11) in Bahia; b) Metal Products (4), Chemicals (11), Agriculture (1), and Trade (20) in Minas Gerais.

From Figure 4.4 one can observe that the Minas Gerais State is the one that presents the more complex productive structure of the three states considered in the analysis.

Following the definition of key sector as the one that presents the values of the backward and forward linkages greater than one (McGilvray, 1977) one has the following sectors: a) Nonmetallic Minerals (3), Metal Products (4), Machinery (5), Transport Equipment (7), Chemicals (11), Textiles (14), and Food Products (16) in Minas Gerais; b) Metal Products (4), and Chemicals (11), in Bahia; and c) Metal Products (4), Paper and Printing (9), and Food Products (16) in Pernambuco.

Table 4.1 - Rasmussen-Hirschman Linkages for São Francisco Interregional System, 1995

	States	Minas Gerais		Bahia		Pernambuco		Minas Gerais		Bahia		Pernambuco	
	Sectors	BL	RBL	BL	RBL	BL	RBL	FL	RFL	FL	RFL	FL	RFL
1	Agriculture	0.972	43	0.950	50	0.909	63	1.636	3	1.404	8	1.323	13
2	Mining	1.099	17	1.023	30	1.010	36	0.915	32	0.968	27	0.725	63
3	Nonmetallic Minerals	1.190	7	1.021	32	1.023	29	1.062	24	0.761	54	0.832	41
4	Metal Products	1.409	0	1.153	9	1.129	12	2.602	1	1.289	15	1.238	17
5	Machinery	1.061	22	0.917	60	0.923	58	1.040	25	0.866	37	0.845	38
6	Electrical Equipament	1.063	21	0.938	55	0.994	40	0.726	62	0.671	70	0.779	50
7	Transport Equipament	1.301	2	0.962	47	0.964	45	1.089	22	0.654	75	0.672	69
8	Wood and Wood products	1.150	10	1.103	15	1.065	20	0.802	45	0.761	55	0.734	60
9	Paper and Printing	1.088	18	1.030	27	1.129	11	0.889	35	0.757	56	1.022	26
10	Rubber Products	0.991	41	1.039	25	0.903	64	0.719	64	0.757	57	0.681	67
11	Chemical Products	1.017	33	1.102	16	0.939	54	2.236	2	2.889	0	1.301	14
12	Pharmaceuticals and Cosmetics	1.041	24	1.006	38	0.999	39	0.658	74	0.651	77	0.654	76
13	Plastics	1.035	26	1.115	13	0.954	49	0.701	65	0.726	61	0.791	46
14	Textiles	1.108	14	1.017	34	1.016	35	1.082	23	0.825	42	0.957	28
15	Clothing and Footwear	1.051	23	0.946	52	1.025	28	0.672	68	0.667	72	0.688	66
16	Food and Kindred Products	1.352	1	1.223	4	1.242	3	1.133	20	0.934	31	1.109	21
17	Other Industrial Products	1.079	19	1.021	31	1.008	37	0.736	58	0.663	73	0.667	71
18	Public Utilities	0.982	42	0.971	44	0.948	51	1.402	9	1.344	12	1.174	18
19	Construction	0.961	48	0.871	68	0.888	66	0.734	59	0.780	49	0.777	51
20	Trade	0.930	56	0.940	53	0.914	61	1.435	4	1.424	5	1.417	6
21	Transport	0.963	46	0.920	59	0.890	65	1.269	16	0.949	30	1.142	19
22	Communication	0.763	73	0.749	74	0.770	72	0.788	47	0.772	53	0.782	48
23	Financial Institutions	0.822	71	0.828	70	0.854	69	0.839	39	0.904	33	0.950	29
24	Public Administration	0.651	75	0.650	77	0.650	76	0.872	36	0.836	40	0.902	34
25	Realty Services	1.193	6	1.166	8	1.208	5	0.812	43	0.775	52	0.805	44
26	Other Services	0.928	57	0.877	67	0.914	62	1.363	11	1.392	10	1.408	7
	Average	1.0461		0.9822		0.9718		1.0849		0.9776		0.9374	

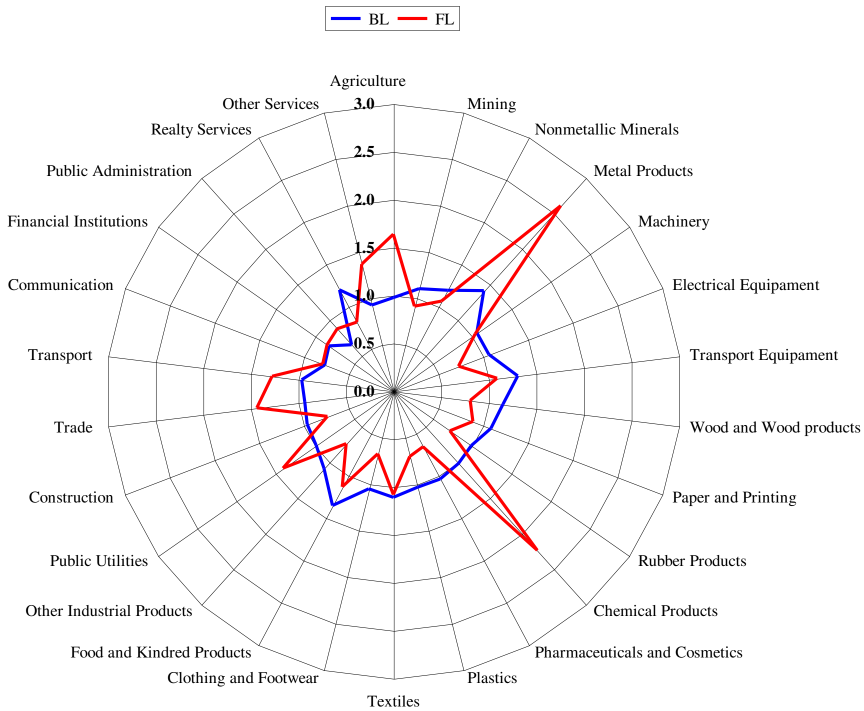


Figure 4.1 - Rasmussen-Hirschman Linkages for Minas Gerais in the São Francisco Interregional System.

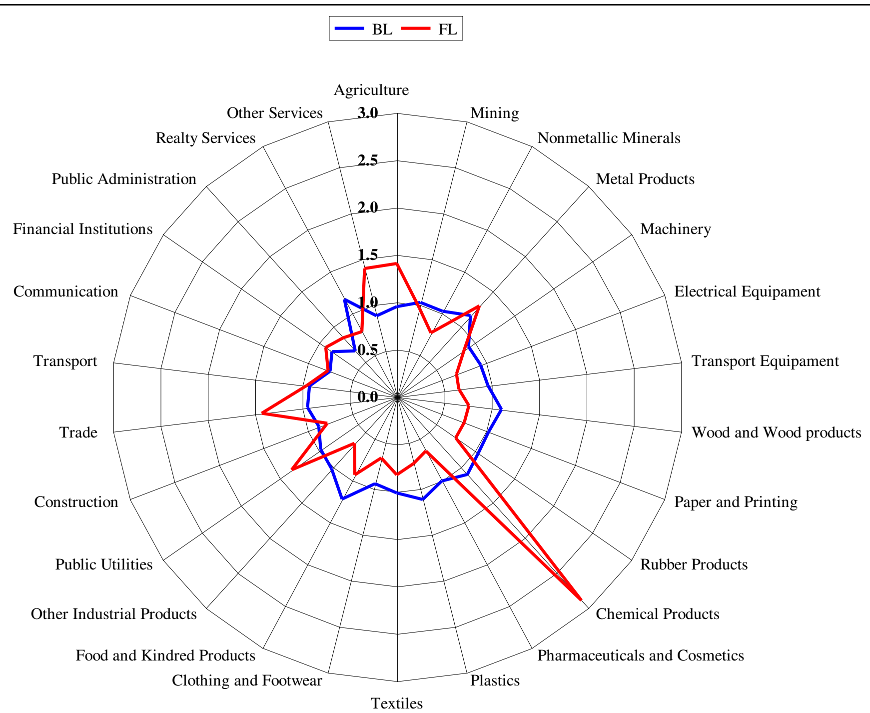


Figure 4.2 - Rasmussen-Hirschman Linkages for Bahia in the São Francisco interregional system.

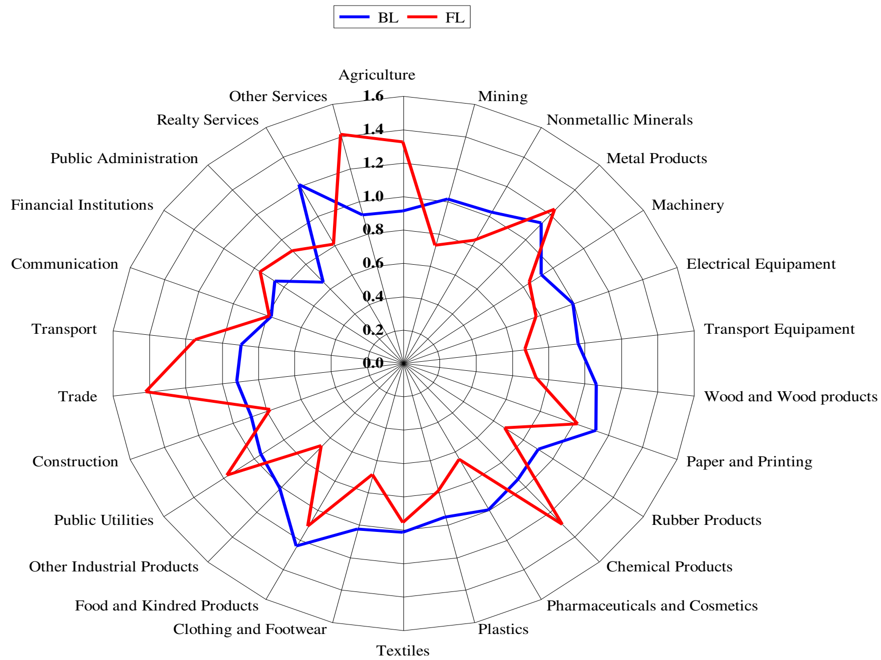


Figure 4.3 - Rasmussen-Hirschman Linkages for Pernambuco in the São Francisco interregional system

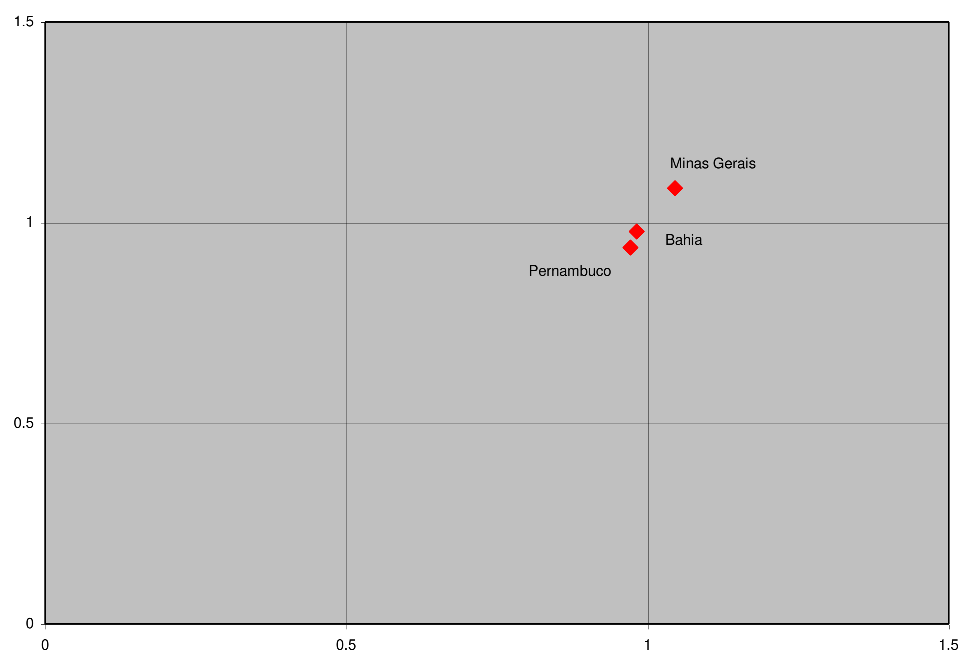


Figure 4.4 - Synthesis of average standard of the Rasmussen - Hirschman linkages for São Francisco interregional system, 1995

4.2 The Field of Influence Approach

The results for the field of influence approach are presented into Figure 4-5 where the coefficients with the 125 bigger values are showed. The dominant sectors in the system are Metal Products (4) in Minas Gerais and Chemicals (11) in Bahia. Also it can be seen that the states of Minas Gerais and Bahia are the main ones in the interregional system.

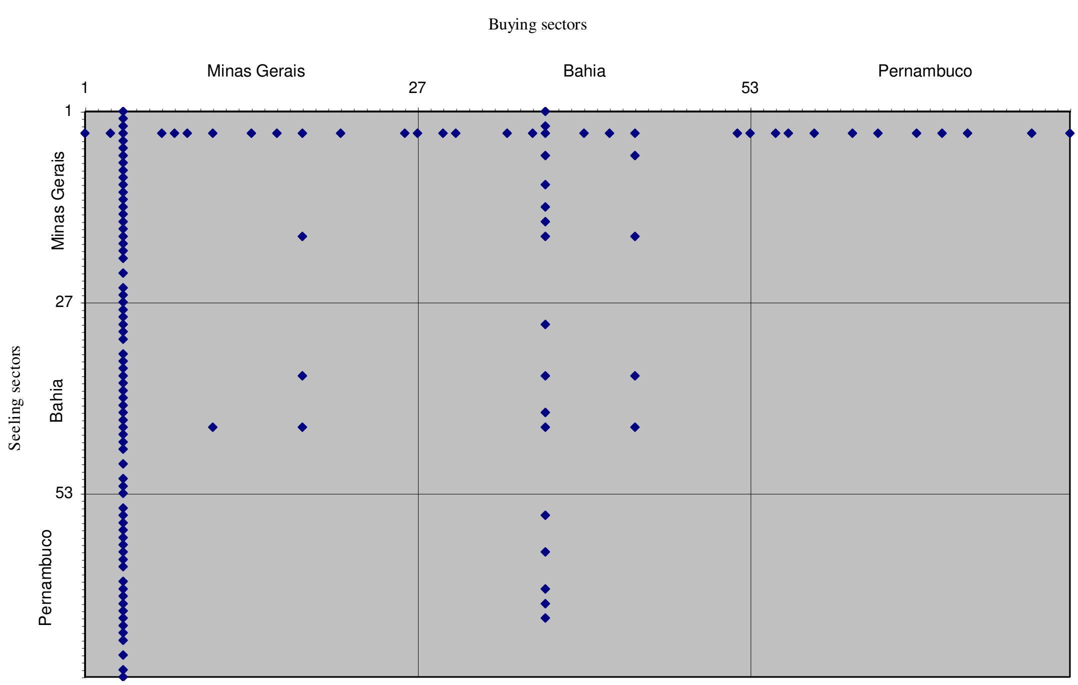


Figure 4.5 -Coefficients with the largest field of influence for São Francisco interregional system.

4.3 The Pure Linkage Approach

The results for the Pure linkage approach are presented into Table 4.31. and in Figures 4.3.1 and 4.3.2.

In terms of backward linkages the most important sectors are: a) Food Products (16), Realty Services (25), Transport Equipment (7), Metal Products (4), and Other Services (26) for Minas Gerais; b) Chemicals (11), Civil Construction (19), and Realty Services (25) for Bahia; and c) Food Products (16) for Pernambuco.

In terms of forward linkages the most important sectors are: a) Agriculture (1), Metal Products (4), Chemicals (11), Trade (20), and Other Services (26) for Minas Gerais; b) Agriculture (1), Chemicals (11), and Other Services (26) for Bahia; and c) Other Services (26) for Pernambuco.

The analysis of the Pure linkages reinforce the importance of the Minas Gerais State in the interregional system as showed above.

It is important to call attention for the fact that while the sectors of Metal Products (4) in Minas Gerais and Chemicals (11) in Bahia are key sectors for the system, the Chemical sector does not use water from the São Francisco river basin while the same is not true for the Metal Products sector in Minas Gerais.

The values for the total Pure linkage show that the most important sectors are: a) Agriculture (1), Metal Products (4), Food Products (16), Trade (20), and Other Services (26) for Minas Gerais; and b) Chemicals (11) for Bahia.

Table 4.3.1 - Pure Linkages of the São Francisco Interregional System, 1995.

Sector	Minas Gerais		Bahia		Pernambuco		Minas Gerais		Bahia		Pernambuco		Minas Gerais		Bahia		Pernambuco	
	PBL	RPBL	PBL	RPBL	PBL	RPBL	PFL	RPFL	PFL	RPFL	PFL	RPFL	PTL	RPTL	PTL	RPTL	PTL	RPTL
1 Agriculture	1933431	7	676169	21	331729	28	3559473	0	1182861	10	739602	16	5492904	2	1859030	14	1071331	26
2 Mining	1155454	14	-73775	78	14964	69	465038	26	784541	15	32875	67	1620492	18	710767	32	47839	72
3 Nonmetallic Minerals	254705	33	12265	70	5924	75	967890	13	205844	47	176171	49	1222595	23	218109	54	182095	56
4 Metal Products	2357573	3	294228	30	147051	39	3519383	1	497464	23	252182	38	**5876956**	0	791693	30	399233	42
5 Machinery	465662	23	127726	42	81621	46	1045536	12	266606	37	101691	56	1511198	22	394333	43	183313	55
6 Electrical Equipament	412981	24	49066	55	138795	41	161250	50	32880	66	90316	59	574230	36	81945	68	229111	53
7 Transport Equipament	2697698	2	19053	68	31162	61	719878	18	5509	78	13072	71	3417577	8	24562	75	44234	73
8 Wood and Wood products	374597	25	124854	43	50299	53	242420	42	118519	53	51335	63	617017	35	243373	51	101634	66
9 Paper and Printing	172813	38	49627	54	40325	58	486222	25	112627	55	245692	41	659035	34	162253	57	286017	48
10 Rubber Products	10924	72	23244	64	2841	76	98827	58	49684	64	10090	74	109751	64	72928	69	12932	78
11 Chemical Products	265084	32	2133447	6	56662	51	3502079	2	2002617	5	408309	30	3767163	7	**4136065**	5	464971	41
12 Pharmaceuticals and Cosmetics	233868	35	55411	52	43636	56	47102	65	11903	72	10406	73	280970	49	67314	70	54042	71
13 Plastics	26230	62	25641	63	9306	73	116116	54	89659	60	99688	57	142346	59	115299	61	108994	65
14 Textiles	225372	36	68392	49	35451	59	300458	35	55679	62	78289	61	525829	40	124071	60	113740	63
15 Clothing and Footwear	272042	31	81074	48	107763	44	16902	69	5835	76	6445	75	288943	47	86909	67	114209	62
16 Food and Kindred Products	4403530	0	1333803	11	1171934	13	1314318	9	418393	29	377820	31	5717848	1	1752196	16	1549753	20
17 Other Industrial Products	105746	45	11680	71	7312	74	222212	44	19806	68	14172	70	327958	44	31487	74	21485	76
18 Public Utilities	318825	29	237683	34	42508	57	1659137	7	714033	19	268463	36	1977962	13	951716	28	310971	46
19 Construction	2290149	5	1566671	9	866300	19	314232	33	245938	40	149280	51	2604381	10	1812610	15	1015579	27
20 Trade	1775268	8	1233544	12	874306	18	2499323	4	1167355	11	674477	20	4274591	4	2400899	11	1548783	21
21 Transport	1045591	15	180844	37	145411	40	1829131	6	502145	22	423293	28	2874721	9	682989	33	568705	38
22 Communication	81360	47	34377	60	22627	65	459788	27	207141	46	139264	52	541148	39	241518	52	161890	58
23 Financial Institutions	578784	22	374305	26	350460	27	536940	21	371889	32	222906	43	1115724	25	746194	31	573365	37
24 Public Administration	59280	50	22004	66	19428	67	734322	17	302284	34	251195	39	793603	29	324288	45	270623	50
25 Realty Services	3636837	1	1383112	10	943540	17	494387	24	221127	45	180553	48	4131224	6	1604238	19	1124092	24
26 Other Services	2291998	4	979073	16	785321	20	2652520	3	1337427	8	867039	14	4944518	3	2316500	12	**1652359**	17
Average	1055608		423981		243334		1075572		420376		226332		2131180		844357.2		469665.4	

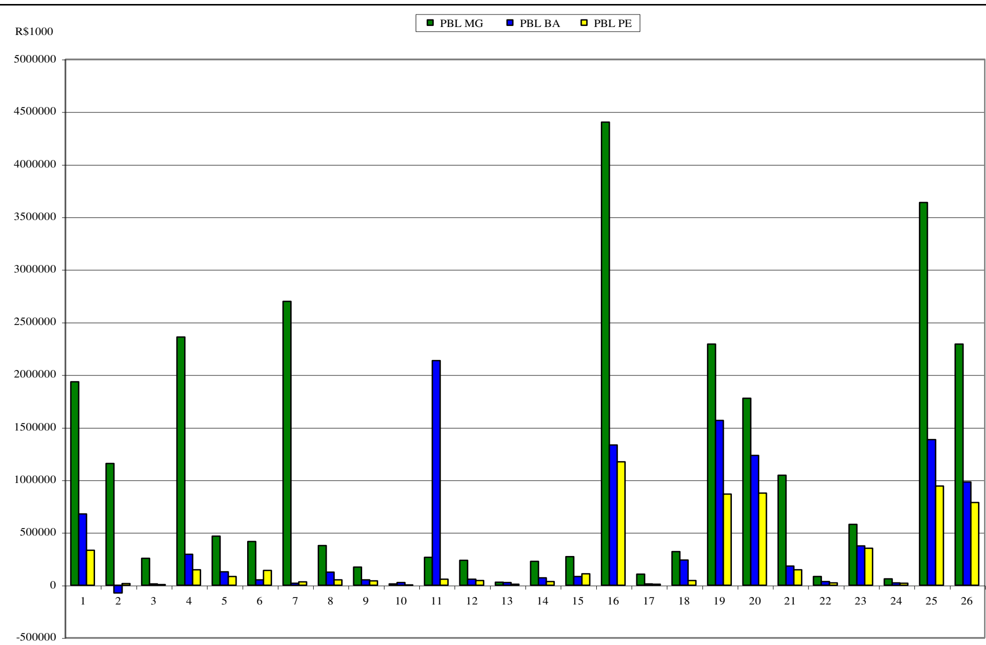


Figure 4.3.1 - Pure backward linkage of the São Francisco Interregional System.

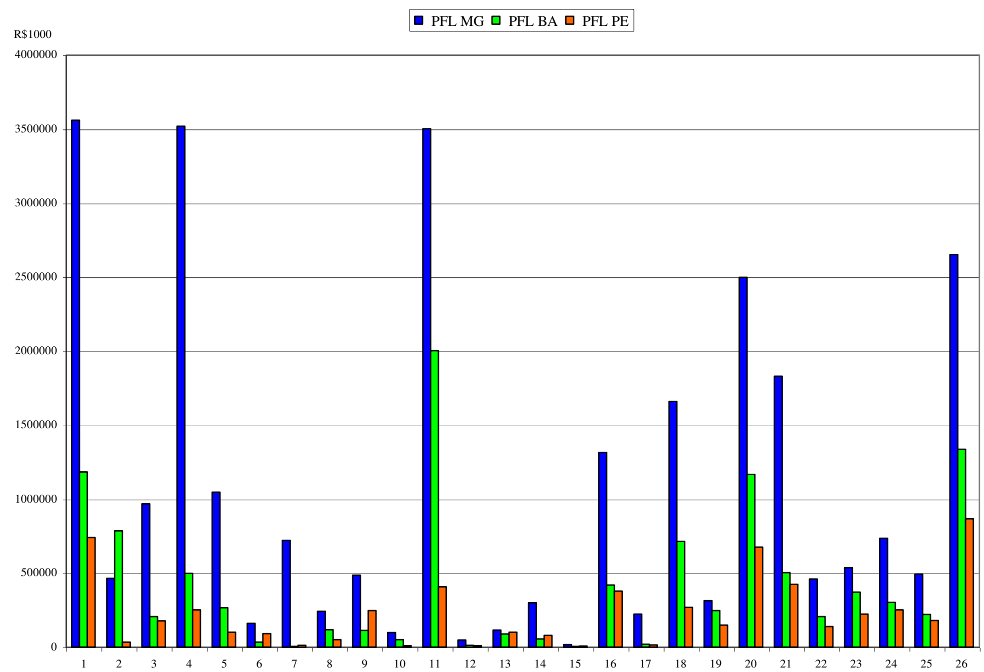


Figure 4.3.2 Pure forward linkage of the São Francisco Interregional System.

4.4 Intensity Matrices - Applications to the São Francisco Interregional System

The results for the intensity matrices are presented into figures 4.4.1 to 4.4.3 taking the hierarchy of Minas Gerais State as the basis for comparison. From the figures one can see that the states have different productive structure. The Minas Gerais State shows a more linked industrial structure while for the Bahia State the bigger relations occur in the Chemicals sector, the Pernambuco State shows to be the one that has a less complex productive structure with a greater importance for the service related sectors.

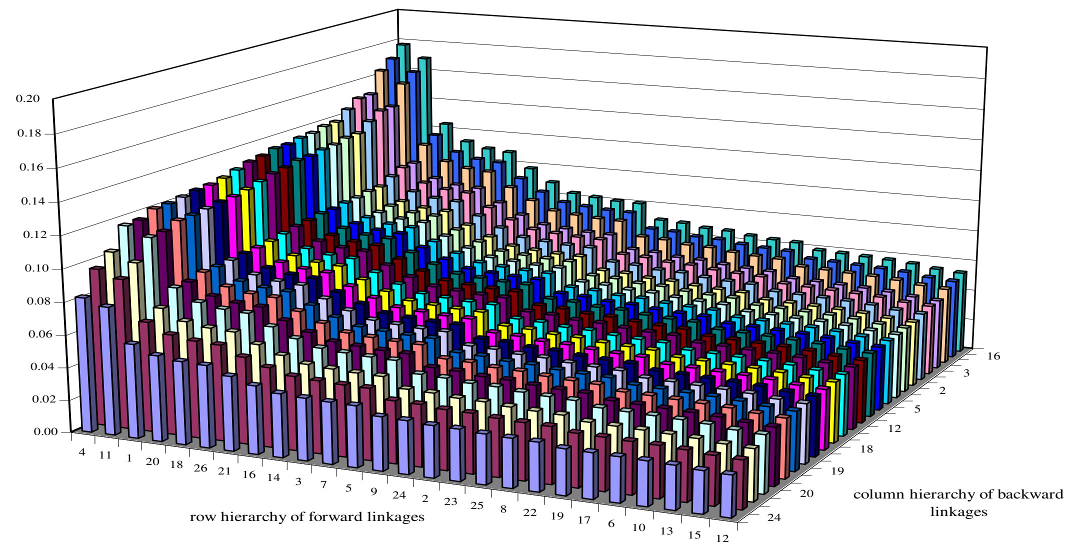


Figure 4.4.1- Minas Gerais: Cross-structure "landscape for first order intensity field

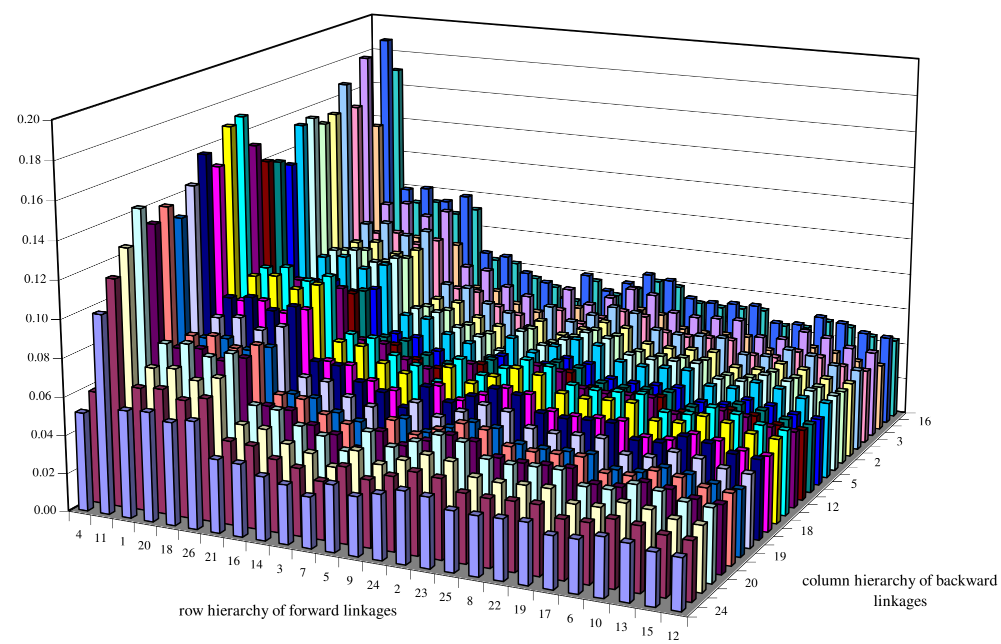


Figure 4.4.2 - Bahia: Cross-structure "landscape" using Minas Gerais imposed hierarchy

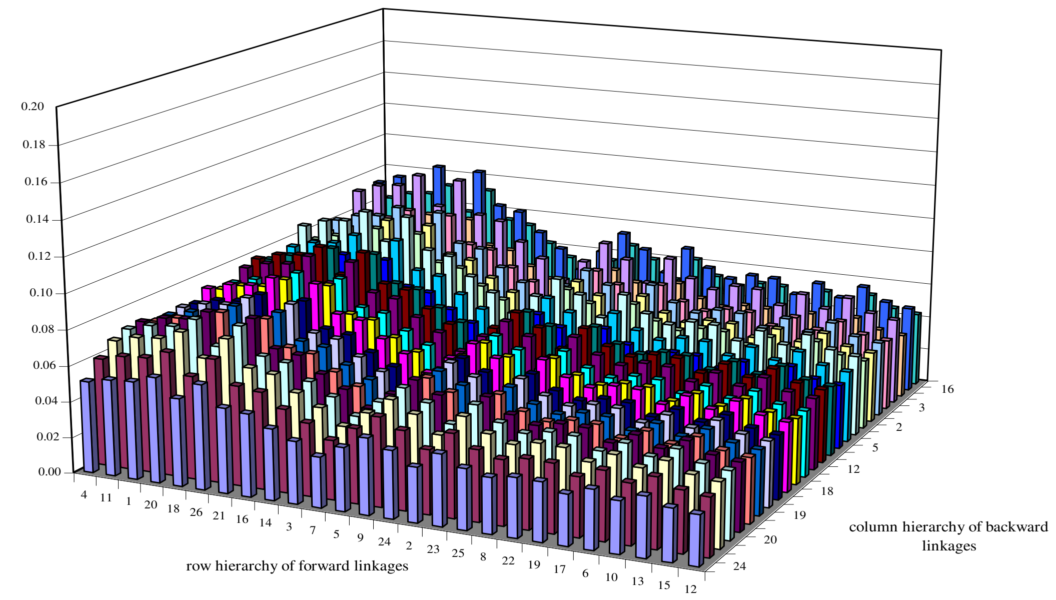


Figure 4.4.3 - Pernambuco: Cross-structure "landscape" using Minas Gerais imposed hierarchy

4.5. Water Use in the São Francisco River Basin

As show in Table 4.5.1 the greater volume of water withdraw is made by the Bahia State with 359874 l/s, followed by the Minas Gerais State with 184700 l/s, and finally the Pernambuco State with 145145 l/s. In terms of water use by category, agriculture uses around 59% of the water withdraw, while the industrial sector uses around 20% (Table 4.5.2) .

Table 4.5.1 Total water withdrawals by water-use category, 1995

liter per second

	Minas Gerais	Bahia	Pernambuco
Irrigation	115611.24	259258.48	75145.54
Industrial[1]	56	1342.73	-
Domestic and commercial	69033	79273	70000
Total	184700.24	359874.21	145145.54

Note: 1) Partial withdrawal
Source: SRH, 1995.

Table 4.5.2 Proportion of the water-use by category, 1995

	Minas Gerais	Bahia	Pernambuco	USA
Irrigation	0.5910	0.5910	0.5910	0.3930
Industry	0.1966	0.1966	0.1966	0.0607
Users Publics	0.1271	0.1271	0.1271	-
Commercial	0.0430	0.0430	0.0430	0.0085
Domestic	0.0430	0.0430	0.0430	0.0099

Source: IGAM, 1998; COPASA, 1999; Solley; Pierce e Perlman, 1998.

Using different sources of information and different techniques of estimation it was possible to calculate the volume of water use for the interregional system as showed into Table 4.5.3.

The sectors that use more water in the three states are: a) Agriculture (1), Mining (2), and Chemical (11), in Minas Gerais; b) Agriculture (1), Mining (2), and Chemical (11) in Bahia; and c) Agriculture (1), Mining (2), and Public Utilities (18) in Pernambuco.

From the results presented in Table 4.5.3 and the total value of production in each sector in each state it was possible to estimate the interregional freshwater withdrawal coefficients (m^3/R$) as showed into Table 4.5.4.

In analyzing the results presented into Table 4.5.4 some interesting points are revealed like that fact that the coefficients of the Mining (2) sector are greater than the ones for the Agriculture (1) sector in the States of Minas Gerais and Pernambuco.

As this work is still under way the next step in process of analysis is the construction of an interregional water-content matrix such that it can be used to estimate interregional multipliers of water use allowing in this way a better understanding o how the use of water take place among the regions and the sectors being analyzed in this work.

Table 4.5.3 - Estimate water-use by sector

	States and Sectors	Minas Gerais		Bahia		Pernambuco	
		Water withdrawal (m^3)	%	Water withdrawal (m^3)	%	Water withdrawal (m^3)	%
1	Agriculture	115.611240	62.26	212.704230	59.10	85.788505	83.95
2	Mining	32.695670	17.61	28.470795	7.91	4.256235	4.16
3	Nonmetallic Minerals	7.508742	4.04	7.310330	2.03	0	0
4	Metal Products	1.934203	1.04	0.700109	0.19	0	0
5	Machinery	0.023039	0.01	0.031441	0.01	0	0
6	Electrical Equipament	0.009353	0.01	0	0	0	0
7	Transport Equipament	0.179154	0.10	0	0	0	0
8	Wood and Wood products	0.418963	0.23	0.415596	0.12	0.407000	0.40
9	Paper and Printing	0.573277	0.31	0	0	0	0
10	Rubber Products	0.003325	0.002	0	0	0	0
11	Chemical Products	11.898565	6.41	83.825047	23.29	0	0
12	Pharmaceuticals and Cosmetics	1.136132	0.61	1.247520	0.35	0	0
13	Plastics	0.423936	0.23	0	0	0	0
14	Textiles	0.006077	0.003	0.009291	0.003	0.007492	0.01
15	Clothing and Footwear	0.011339	0.01	0.001451	0.0004	0.029821	0.03
16	Food and Kindred Products	1.061120	0.57	1.426871	0.40	2.016635	1.97
17	Other Industrial Products	0.005905	0.003	0.000960	0.0003	0.002424	0.002
18	Public Utilities	7.872712	4.24	15.339374	4.26	6.186722	6.05
19	Construction	0.040075	0.02	0.065528	0.02	0.124612	0.12
20	Trade	0.701502	0.38	1.366822	0.38	0.551271	0.54
21	Transport	0.486805	0.26	0.458958	0.13	0.233573	0.23
22	Communication	0.098808	0.05	0.198008	0.06	0.065679	0.06
23	Financial Institutions	0.341815	0.18	1.006992	0.28	0.448931	0.44
24	Public Administration	1.196041	0.64	2.316157	0.64	0.964097	0.94
25	Realty Services	0.539285	0.29	0.930456	0.26	0.334831	0.33
26	Other Services	0.928242	0.50	2.086206	0.58	0.774851	0.76
	Total	185.705323	100.00	359.912142	100.00	102.192676	100.00

Table 4.5.4 Interregional freshwater withdrawal coefficients

	States and Sectors	Minas Gerais m^3 /R$	Bahia m^3 /R$	Pernambuco m^3 /R$
1	Agriculture	0.010367	0.058147	0.040100
2	Mining	0.013618	0.043420	0.070669
3	Nonmetallic Minerals	0.004926	0.031416	0
4	Metal Products	0.000170	0.000543	0
5	Machinery	0.000012	0.000052	0
6	Electrical Equipament	0.000011	0	0
7	Transport Equipament	0.000033	0	0
8	Wood and Wood products	0.000471	0.001202	0.002775
9	Paper and Printing	0.000680	0	0
10	Rubber Products	0.000027	0	0
11	Chemical Products	0.002626	0.008374	0
12	Pharmaceuticals and Cosmetics	0.002626	0.011165	0
13	Plastics	0.002626	0	0
14	Textiles	0.000007	0.000042	0.000038
15	Clothing and Footwear	0.000023	0.000007	0.000138
16	Food and Kindred Products	0.000134	0.000570	0.000789
17	Other Industrial Products	0.000015	0.000024	0.000088
18	Public Utilities	0.001920	0.005457	0.010903
19	Construction	0.000007	0.000012	0.000043
20	Trade	0.000099	0.000321	0.000177
21	Transport	0.000108	0.000462	0.000253
22	Communication	0.000108	0.000462	0.000253
23	Financial Institutions	0.000108	0.000462	0.000253
24	Public Administration	0.000108	0.000462	0.000253
25	Realty Services	0.000108	0.000462	0.000253
26	Other Services	0.000108	0.000462	0.000253

5. Conclusions

The motivation for the work done here was the need for a model that could be used to study the interrelations among the regions and the sectors in respect to water use in the São Francisco river basin.

As a starting point, from the national input-output tables for the Brazilian economy for the year of 1995 and using information from various census it was constructed an interregional system comprising the 3 major states in the São Francisco river basin, i.e., Minas Gerais, Bahia, and Pernambuco.

The analysis of the interregional system has show that the more complex productive structure is found in the Minas Gerais State which has the Metal Products (4) as the main sector in the system. In second place comes the state of Bahia in which the main sector is the Chemical (11). The less complex productive structure is found in the Pernambuco State.

In terms of water use one has that the in terms of volume the sectors that use more of this resource are: a) Agriculture (1), Mining (2), and Chemical (11), in Minas Gerais; b) Agriculture (1), Mining (2), and Chemical (11) in Bahia; and c) Agriculture (1), Mining (2), and Public Utilities (18) in Pernambuco.

In term of freshwater withdrawal coefficients (m^3/R$) some interesting points are revealed like the fact that the coefficients of the Mining (2) sector are greater than the ones for the Agriculture (1) sector in the States of Minas Gerais and Pernambuco.

As this work is still under way the next step in process of analysis is the construction of an interregional water-content matrix such that it can be used to estimate interregional multipliers of water use, allowing in this way to a better understanding of how the use of water take place among the regions and the sectors being analyzed in this work.

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