Impact Analysis and Extraction Method:

Applications on water resources in Andalusia

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1. Introduction

We would like to begin by remembering a text that reflects the spirit with which this work has been undertaken. According to Tom Stacey, “Looking at the evidence of the total ecological crisis faced by humanity today, only four reactions are possible. One is to reject the evidence, claiming it to be absurd. In our opinion, this argument is no longer valid for an intelligent person. Another reaction is <<eat, drink and be merry because life is short>>, a philosophy that strikes us as presumptuous. The third consists of the reply that that <<scientists will invent something to solve it>>, an optimistic and carefree attitude that the current knowledge of the situation does not completely allow us. The fourth reaction consists of facing the facts and fighting for those deep readjustments, without which there is no foundation to lodge hopes” (Goldmisth, 1972). One evidence of the previously mentioned ecological crisis is the increasing shortage of a vital resource like water; a shortage, which is sometimes due to other climatic and physical reasons, but at others is due to an inadequate management of the resource which could derive from a non reasonable use. This shortage is perhaps made clearer in a region like Andalusia, in the south of Spain, a country with a water management policy, which is at least, controversial.

In this situation, we are going to continue research already initiated (Velázquez Alonso, 2003) and we aim to go deeper into the relationship between the Andalusian productive system and water consumption. Let us consider an input-output analysis as an appropriate method for this intention; there are some studies that have tried to analyse by means of this methodology the relationship between the consumption of natural resources and the productive structure (Isaard, 1968; Leontief, 1970; Leontief and Ford, 1972; Stone, 1972). Most of them have focused on energy resources and the consumption of energy (Hudgson and Jorgeson, 1974; Forsund, 1985; Proops, 1988; Proops, Faber and Wagenhals, 1993; Hawdon and Pearson, 1995; Pajuelo, 1980; Alcántara and Roca, 1995); Nevertheless, few have focused on the economic relationships and the consumption of water resources (Lofting and McGauhey, 1968; Sánchez-Chóliz, Bielsa and Arrojo, 1992; Sáez de Miera, 1998; Duarte, Sánchez-Chóliz and Bielsa, 2002).

Our main objective in this work is to make an adaptation of the Impact Analysis and Hypothetical Extraction Method (HEM), after carrying out a basic analysis, which can allow us to detect most water consumer sectors in Andalusia. After doing this, we will see how in the region there are sectors that are great water consumers, both directly and indirectly; and it is important to notice that the Andalusian economy specializes, precisely, in these sectors. It may be surprising that one region can specialize in sectors which need great amounts of a resource that is scarce. In this situation, we wonder how a certain change in productive specialization could contribute to water saving in Andalusia. The case that we propose is the following. If an important sector in the region, which at the same time is a great water consumer, devotes a big part of its production to export, we could say that a limited resource is being used as an export. In a situation like this, we wonder if a reduction in the exports of one of these greatest water consumer sectors, and therefore of their demand, could contribute to water saving in the region. We will try to answer this question using Impact Analysis, which will allow us to simulate the effects on water consumption of a change in the demand in these sectors.

We could raise one more question: How would sectorial water consumption be affected if one of these high consumption water sectors were removed from the production system? The HEM answers this new question by analysing, in the hypothetical situation in which we removed one sector from the production system, how it would affect sectorial water consumption.

The data that we will use is *Tables Input-Output of Andalusia, 1990*, elaborated by the Institute of Statistics of Andalusia (1995a) and the *Environmental Tables of Andalusia, 1990*, made by the Andalusian Environmental Agency (1996). The first tables offer sectorial data of the Andalusian economy, expressed in monetary units; and the second, the data of water consumption by sectors, expressed in physical units[1]. In order to run the model, we use the Pyio program (Nazara, S., Guo, D., Hewings, G.J.D., Dridi, C., 2003), developed in the Regional Economics Applications Laboratory of the University of Illinois.

The paper is organised as follows. After this initial introduction, we develop the methodology used, and we analyse the results in the third section. In the fourth section we present the main economic variables of Andalusia in order to relate these one with the water results. Finally, in the fifth part we outline the most relevant conclusions of this study.

2. Methodology

2.1. Water input-output model

We can express in terms of water consumption[2] the classical production Leontief equation, in such a way that the amount of water directly consumed by sector i (w_{di}) depends on the intersectorial relationships established between that sector and the remaining sectors of the economy (w_{ij}) and on the quantity of water consumed directly by sector i to satisfy its own demand (w_{di}^{y}):

$$w_{di} = \sum_{j=1}^{j=n} w_{ij} + w_{di}^{y} \tag{1}$$

[1] Although more recent Andalusia input-output tables already exist, this paper is limited to 1990 because the water sectorial consumption data is the lastest one that exists for the region and we needed a monetary table compatible with the physical one.

[2] Water *consumption* here means the water used by each sector minus returns.

In accordance with the Leontief production model, we can formulate a water consumption technical coefficient (q_{ij})[3], defined as the quantity of water consumed by sector j in providing inputs to sector i (w_{ij}), in relation to the total amount of water directly consumed by sector j (w_{dj}):

$$q_{ij} = \frac{w_{ij}}{w_{dj}} \tag{2}$$

If these coefficients are taken into account, equation (1) becomes:

$$w_{di} = \sum_{j=1}^{j=n} q_{ij} w_{dj} + w_{di}^{y} \tag{3}$$

or in matrix notation:

$$w_d = Q w_d + w_d^y \tag{4}$$

where Q, by analogy with the standard Leontief model, is a (nxn) water technical coefficient matrix with elements q_{ij}, given n productive sectors. By solving this equation, we obtain the expression that defines the model for water consumption:

$$w_t' = u'(I - Q)^{-1} \hat{w}_d^y \tag{5}$$

where $(I - Q)^{-1}$ is the water Leontief inverse matrix, u is a unit column vector, (^) places the vector on the diagonal of the matrix, and (‘) indicates transposition of the vector. By analogy with the inverse matrix in the production model, the matrix $(I - Q)^{-1}$ determines the change in water consumption if the demand for water changes in one unit, and its elements – which we call β_{ij}[4] – indicate the additional quantity of water sector i will consume if the water demand of sector j increases in one unit. As usual, when the Leontief inverse matrix is rewritten in terms of water, $(I - Q)^{-1}$, the model takes into account the direct and indirect requirements of water, that is, the total amount of water any given sector consumes in order to satisfy an increase in demand, as opposed to the matrix Q, which only reflects the direct requirements of water. This is the reason why the vector of direct water consumption (w_d) in equation (4) is substituted by a vector of total

[3] The q_{ij} coefficients are equivalent to the technical coefficients in the Leontief model (a_{ij}).

[4] Notice that these coefficients are analogous to those in the Leontief inverse matrix (α_{ij}).

water consumption (w_t) in (5). So, this expression tells us the total amount of water the productive sector needs in order to satisfy its own demand.

From this model we can obtain several indicators[5] such as direct water consumption (w_d^*). This is a column vector (nx1) which shows the water consumed directly by one sector per production unit. The indicator of total water consumption (w^*), a column vector also, is defined as the change in the total amount of water consumed by the economy if the demand of any given sector changes in one unit. We use these indicators below to obtain other necessary mathematical expressions.

At this point, we can obtain a water demand matrix, (WD), with (nxk) order, given k components of the demand and n sectors; its elements, (wd_{ik}), tell us the water total demand of sector i because of the k demand's component. In order to do that, we consider the six demand elements of the Andalusia input-output table[6] and, in this way, we can decompose the final demand vector in each component. As it is known, total water consumption can be determined by production or demand. Now, we will determine it by the latter. So, if we define a demand matrix F , (nxk) order, in monetary terms; and diagonalize the direct consumption indicator ($\hat{w}_d^*$), we will have the total consumption by demand components. The matrix (WD) can be written as following:

$$WD = \hat{w}_d^* (I - A)^{-1} F \qquad (6)$$

2.2 Water input-output table

Now, once we already have the model, we need to construct the water input-output table, expressed in cubic meters . The way in which we have to do that is the following. As we know, the input-output table has five matrixes; in water terms, we have the following: the direct water transaction matrix (W), with (nxn) dimension. The second matrix is the water total[7] demand (WTD), as a column vector, which represents the total demand of each sector; this means, the sum of all production components. The water total consumption (WTC) is the third matrix, which is defined as another column vector, where we have the total water demand plus intermediate

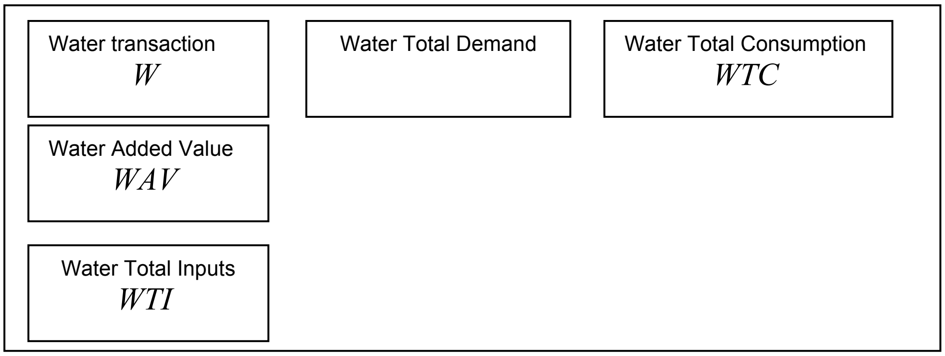
[5] Here, we show the concept of these indicators only. See Velázquez Alonso (2003) to for more detail

[6] The components of the demand in Andalusia's TIO are public consumption, private consumption, investment, exports within Spain, exports to EU, exports to the rest of the world.

[7] Notice that water demand matrix (WD) and water "total" demand vector (WTD) are not the same. Water demand matrix expresses the demand of each sector, breaking this demand down into each of its components. And, on the other hand, total demand is the sum of all components of the final demand. So, $WTD = \sum_{j=1}^{j=k} wd_{ij}$, is a vector (nx1).

consumptions. The water added value (WAV) is the fourth one, defined as a row vector; and finally, the fifth matrix is the water total inputs (WTI), another row vector. We can see in figure (1) this water input-output table:

Figure 1. Water Input-Output Table Structure.



Source: created by the author.

Focusing on these matrixes, as we already have the water demand matrix (WD) through water model, we can obtain the water total demand (WTD) and, after that, we need to obtain the water transaction matrix (W) as a first step in obtaining the whole table. In order to do that, we can follow our water input-output model. We know the water technical coefficients (q_{ij}) from equation 2. So, the elements of water transaction matrix (w_{ij}) can be written in the following way:

$$w_{ij} = q_{ij} w_{dj} \tag{7}$$

So, in matrix notation:

$$W = Q\hat{w}_d \tag{8}$$

Andalusia's environment input-output table offers direct water consumption by sectors (w_{dj}) and by means of a water input-output model and, through its water indicators, we can obtain water technical coefficients[8]. So, in this way, we can obtain the elements of the water transaction matrix (W). Once we have this matrix, we already have water intermediate consumption, by the sum of the rows of the elements of this matrix. And so, taking into account these new elements and the water total demand (WTD), we can obtain the water total consumption (WTC). As, in accordance

[8] Water technical coefficients can be expressed through water indicators defined above as $q_{ij} = \frac{w_{ij}}{w_{dj}} = \frac{w^*_{di}}{w^*_{dj}} a_{ij}$, being a_{ij} the production technical coefficients (Velázquez Alonso, 2003).

with the Leontief model, the water total inputs (WTI) must be equal to the water total consumption (WTC), we can obtain the j element of water added value (wav_j) as follows :

$$wav_j = wti_j - \sum_{j=1}^{j=n} w_{ij} \tag{9}$$

In this way, finally, we obtain the water input-output table (Annex 1).

2.3. Basic analysis: Multipliers and key sectors

In classical input-output literature we can find the traditional multiplier analysis as output, input, income and employment multiplier. In this study we will focus on the first two in order to know which the most relevant water consumption sectors are. For this reason, we express the traditional analysis in terms of our water model.

The water output multiplier (WO) is calculated as the column sum of water Leontief inverse. So, given this matrix as (B), with elements (β_{ij}):

$$B = (I - Q)^{-1} \tag{10}$$

where Q is a water technical coefficient matrix, as we said before. Then, the expression which defines sector j multiplier is the following:

$$WO_j = \sum_{i=1}^{i=n} \beta_{ij} \tag{11}$$

This multiplier tells us how much sector j influences the others through its purchases in terms of water. Another way to interpret this multiplier is how much this sector depends on the rest of the sectors. That is, how much this sector depends on the water that it buys from the rest of the sectors; water that is embodied in bought products. On the other hand, the water input multiplier (WI) is calculated as the sum of Ghoshian inverse. In the same way that output multiplier, given a Ghoshian inverse matrix as $\vec{B}$, with elements $\vec{\beta}_{ij}$:

$$\vec{B} = (I - L)^{-1} \tag{12}$$

The expression which defines this multiplier is the following:

$$WI_j = \sum_{i=1}^{i=n} \vec{\beta}_{ij} \tag{13}$$

The meaning of this multiplier is how much sector j influences on the others through its sales in terms of water. This means, how much this sector depends on the water that it sells to the others; water, which is embodied in sold products.

The key sectors are those sectors whose activity has a great influence on the whole water consumption process, through both purchase and/or sales, which means, through their water backward linkage (WBL) and/or their water forward linkage (WFL). Following the Rasmussen (1956) proposal concerning these indicators, and given the following expressions:

$$B_j = \sum_{i=1}^{i=n} \beta_{ij} \tag{14}$$

$$B_i = \sum_{j=1}^{j=n} \beta_{ij} \tag{15}$$

$$V = \sum_{i=1}^{i=n} \sum_{j=1}^{j=n} \beta_{ij} \tag{16}$$

We can define water backward linkage as:

$$WBL_j = \frac{\frac{1}{n}\sum_{i=1}^{i=n} \beta_{ij}}{\frac{1}{n^2}\sum_{i,j=1}^{i,j=n} \beta_{ij}} = \frac{\frac{1}{n}B_j}{\frac{1}{n^2}V} = \frac{B_j}{\frac{1}{n}V} \tag{17}$$

And, in a similar way, water forward linkage as:

$$WFL_j = \frac{\frac{1}{n}\sum_{j=1}^{j=n} \beta_{ij}}{\frac{1}{n^2}\sum_{i,j=1}^{i,j=n} \beta_{ij}} = \frac{\frac{1}{n}B_i}{\frac{1}{n^2}V} = \frac{B_i}{\frac{1}{n}V} \tag{18}$$

The meaning of the results of these indicators is as follows. If WBL_j is >1, a unit change in a final demand in sector j, will generate an above-average increase in the water consumption of all of the sectors. On the other hand, if WFL_i >1, a unit change in all sectors´ final demand would create an above average increase in the water consumption of sector i.

We can say that a sector will be a key sector when water backward and/or water forward linkage, are greater than one.

2.4. Impact analysis

Impact analysis consists of setting new final demand scenarios and analysing the effects on the final output. In our water input-output model, we have already obtained the water demand matrix (WD) as equation number (6). Now, we can change the element (ik) of this matrix (wd_{ik}), and we will have a new element ($nwd_{ik'}$) being (k') the new demand component of sector i, and we can calculate the new water total demand ($NWTD$), as usual, as the sum of its other old elements and the new one:

$$NWTD = WTD^* + diag(nwd) \qquad (19)$$

where,

$$WTD^* = \sum_{j=1}^{J=k-1} wd_{ij} \qquad (20)$$

and $diag(nwd)$ is a diagonalized vector, whose elements are zeros , except the demand element (k) which has been changed. Given this new water total demand, we recalculate the water total consumption of each sector and of the whole economy. In this case, as we have said in the introduction, we change water demand for changes in water exports and, in this way, we are able to analyse the effects on the final water consumption of each sector under consideration as well as the whole economy .

2.5. Extracting Method

Once we know, by means of the previous analysis, the greatest water consumers, we may wonder what would happen to water consumption if we extracted those sectors from the economy; in other words, we wonder if this fact would affect water saving. We can answer this question by means of the HEM, developed by Strassert (1968) and Schultz (1976).

Focus on water model equation (5) and in order to simplify, we can clear the transposition symbol (‘), so vector u disappears. Then, equation (5) becomes (21):

$$w_t = (I - Q)^{-1}\hat{w}_d^y = B\hat{w}_d^y \tag{21}$$

Using water backward linkage and water forward linkage, we apply this method as outlined in Dietzenbacher et al (1993). So, in water terms, the total water consumption (w_t) is made up of the total water consumption of sector 1 (w^1) and the total water consumption of the rest of the economy (w^R). Expressing these sectors in a partitioned form:

$$w^1 = B^{11}\hat{w}_d^{y1} + B^{1R}\hat{w}_d^{yR} \tag{22}$$

$$w^R = B^{R1}\hat{w}_d^{y1} + B^{RR}\hat{w}_d^{yR} \tag{23}$$

In the same way, water technical coefficient matrix (Q) and water Leontief inverse (B) can be rewritten:

$$Q = \begin{pmatrix} Q^{11} & Q^{1R} \\ Q^{R1} & Q^{RR} \end{pmatrix} \tag{24}$$

$$B = \begin{pmatrix} B^{11} & B^{1R} \\ B^{R1} & B^{RR} \end{pmatrix} \tag{25}$$

Now, extracting sector 1 from the economy, we have the water consumption for the rest of the sectors. Therefore , it is the reduced water model and it can be expressed as the following:

$$\overline{w}^R = (I - Q^{RR})^{-1}\hat{w}_d^{yR} \tag{26}$$

The difference between w and $\overline{w}$ expresses the effect of extracting sector 1 from the economy and its formulation is as follows :

$$w - \overline{w} = \begin{pmatrix} w^1 - \overline{w}^1 \\ w^R - \overline{w}^R \end{pmatrix} \tag{27}$$

Let us develop the elements of this matrix:

$$w^1 - \overline{w}^1 = (B^{11}\hat{w}_d^{y1} + B^{1R}\hat{w}_d^{yR}) - ((I - Q^{11})^{-1}\hat{w}_d^{y1}) \tag{28}$$

$$w^R - \overline{w}^R = (B^{R1}\hat{w}_d^{y1} + B^{RR}\hat{w}_d^{yR}) - ((I - Q^{RR})^{-1}\hat{w}_d^{yR}) \tag{29}$$

So, these expressions become :

$$w^1 - \overline{w}^1 = (B^{11} - (I - Q^{11})^{-1})\hat{w}_d^{y1} + B^{1R}\hat{w}_d^{yR} \tag{30}$$

$$w^R - \overline{w}^R = B^{R1}\hat{w}_d^{y1} + (B^{RR} - (I - Q^{RR})^{-1})\hat{w}_d^{yR} \tag{31}$$

Then, in matrix notation:

$$w - \overline{w} = \begin{pmatrix} w^1 - \overline{w}^1 \\ w^R - \overline{w}^R \end{pmatrix} = \left[\begin{pmatrix} B^{11} & B^{1R} \\ B^{R1} & B^{RR} \end{pmatrix} - \begin{pmatrix} (I - Q^{11})^{-1} & 0 \\ 0 & (I - Q^{RR})^{-1} \end{pmatrix}\right]\begin{pmatrix} \hat{w}_d^{y1} \\ \hat{w}_d^{yR} \end{pmatrix} \tag{32}$$

Water forward linkage can be obtained in the same way, but now instead of water Leontief inverse, we will use water Ghoshian matrix.

3. Results

Focusing on the water output multipliers (table 1) it is possible to make a difference between two groups of sectors. On the one hand, and in general terms , we can see that some of the industrial and service sectors are those which have the largest water output multiplier and the agricultural sectors the lesser ones. In particular , the food and agriculture (14) and the textile industries (15) are the sectors which have the largest water output multiplier. This means that when these sectors buy products from the others, they push water consumption up more than if the agricultural sector does so .

On the other hand and in an inverse way, the agricultural sectors are the ones which push water consumption up when they sell their products to the rest of the economy, more than the industrial and services sectors do . This can be seen in the agricultural sector's larger water input multiplier, especially , the industrial plant (4), olive (5) and cereals and leguminous sectors(1).

In accordance with these results, we can analyse water forward linkage and water backward linkage, as we have mentioned. In general terms , the agricultural sectors are those which have the largest water forward linkage, especially cereals and leguminous plants (1), vegetables and fruits (2) and olive plants (5). This means that, in the case of a unit increase in their final demand, water consumption will increase to an above average level. The same happens with tourism (22), sales services (24) and the paper industry (18).

Table 1. Water Output Multiplier (WO), Water Input Multiplier (WI), Water Forward Linkage (WFL) and Water Backward Linkage (WBL).

	SECTORS	WO	WI	WFL	WBL
1	Cereals and leguminous plants	1.04353	1.75513	1.62226	0.79348
2	Vegetables and fruits	1.01079	1.08631	1.06502	0.76859
3	Citrus fruits	1.00146	1.08993	0.91480	0.76149
5	Industrial plants	1.10594	1.84282	1.39775	0.84093
4	Olive groves	1.00246	1.78021	1.14784	0.76225
6	Other agricultural productions	1.39151	1.41949	1.47192	1.05808
7	Extractive industry	1.30685	1.43106	1.07612	0.99370
8	Water	1.00000	1.00000	0.76038	0.76038
9	Metallurgy	1.14591	1.29706	1.07954	0.87133
10	Construction materials	1.46207	1.55331	0.84841	1.11173
11	Chemicals and plastics	1.19344	1.43996	1.14908	0.90747
12	Machinery	1.47474	1.04389	0.76863	1.12136
13	Transportation material	1.40300	1.03628	0.78002	1.06681
14	Food and agriculture industry	2.06042	1.00577	0.78539	1.56670
15	Textiles and apparel	1.83162	1.01822	0.78129	1.39273
16	Footwear and Leather products	1.31393	1.02864	0.76706	0.99908
17	Lumber industry	1.43609	1.09941	0.79006	1.09198
18	Paper, printing and publishing	1.26984	1.29289	1.11388	0.96556
19	Miscellaneous manufacturing	1.37152	1.02008	0.76182	1.04287
20	Construction	1.44105	1.02248	0.79972	1.09575
21	Trade	1.27345	1.11015	0.85042	0.96831
22	Hotel and catering trade	1.40976	1.06410	1.31681	1.07195
23	Transportation, communications	1.35052	1.48502	0.98002	1.02691
24	Sales related services	1.31468	1.32021	1.21079	0.99965
25	Non-sales related services	1.26372	1.00087	0.76096	0.96091

Source: created by the author.

Focusing on water backward linkage, the industrial and service sectors are the largest, especially the food and agriculture industry (14) and the textile industry (15). This means that when a unit change is asserted in all sectors, final demand would create an above average increase in the water consumption of a considered sector. Not all of them have a great water backward linkage, but we can state that the agricultural sectors are not large ones.

From the previous analyses, we can find sectors that have great water consumption, through purchase or sales, and some of them are the biggest water exporters (the agricultural industry (14), cereals and leguminous plants(1) and vegetables and fruits (2), in this order). The first exports 41% of its total water exports; the second 23% and the third, 11% . As our main objective is to know if we could save water through reducing water exports, we can analyse what will happen to the final water consumption if we reduce the exports from these sectors. It is important to mention that the tourism sector (22) has not been considered in this analysis because, despite being a great water consumer also, it does not export water, as is usual in this sector[9]. On the other hand and as we said previously, if we want to study impact analysis, the sector must fulfil two requirements: that it is a great water consumer and that it exports a great percentage of water. Although sector (5) is a great water consumer, it only devotes 5% to export, the reason for which we have not considered in the impact analysis.

We have chosen ten different scenarios. The first is the original situation, where nothing has changed. The second is 20% reduction of water exports; the third is 30%, and so on until scenario ten, which represents 100% reduction of water exports. We have done the simulations separately, by sectors . This means that if we are changing sector 1´s exports, for instance, the others remain constant.

Firstly, we observe (table 2) that the water saving obtained when reducing exports is greater for the sector under consideration than for the whole economy. So, we can observe that sector (1) only reduces its water total consumption by 26.29% whereas sector (14) reduces it by 65.33%. Nevertheless, if we focus on own sector consumption, we can see that the water saving for sector (14) is barely 30% and for sector (1) the saving does not reach 5%.

According to the results, sector (14) has the greatest water saving when water exports are reduced. Remember that this sector has the highest water output multiplier and water backward linkage. This means that this sector is the one which has the greatest influence on the others through purchase. So, if water exports of (14) sector are reduced, the water output of this sector will be reduced also. Therefore purchases of (14) from other sectors will go down and, the sales of the rest of the sectors also. Therefore, if the rest of the sectors have to produce fewer goods than before, they will reduce their water consumption. Elsewhere, in accordance with water forward linkage, sector (1) has the least water saving when water exports are reduced. When exports are reduced, the water consumption of the buyer sectors are diminished also; but as its influence by means of purchase is very low, since it influences through sales, the water saving that can be obtained by means of the reduction of exports is low; and so, the saving that it generates is the least of the three sectors considered in this paper.

[9] The water consumption of this sector is like a private consumer ; so, there are not exports.

Table 2. Impact analysis. Effects on water consumption through reducing water demand (%).

Scenarios	Sector 1		Sector 2		Sector 14	
	On own sector	On total consumption	On own sector	On total consumption	On total sector	On total consumption
Scenario 1	-	-	-	-	-	-
Scenario 2	-5.26	-0.90	-9.76	-1.72	-13.07	-6.14
Scenario 3	-7.89	-1.35	-14.64	-2.57	-19.60	-9.21
Scenario 4	-10.52	-1.80	-19.52	-3.43	-26.13	-12.28
Scenario 5	-13.15	-2.25	-24.40	-4.29	-32.67	-15.35
Scenario 6	-15.78	-2.70	-29.28	-5.15	-39.20	-18.42
Scenario 7	-18.40	-3.15	-34.15	-6.00	-45.73	-21.48
Scenario 8	-21.03	-3.60	-39.03	-6.86	-52.26	-24.55
Scenario 9	-23.66	-4.05	-43.91	-7.72	-58.80	-27.62
Scenario 10	-26.29	-4.49	-48.79	-8.58	-65.33	-30.69

Source: created by the author.

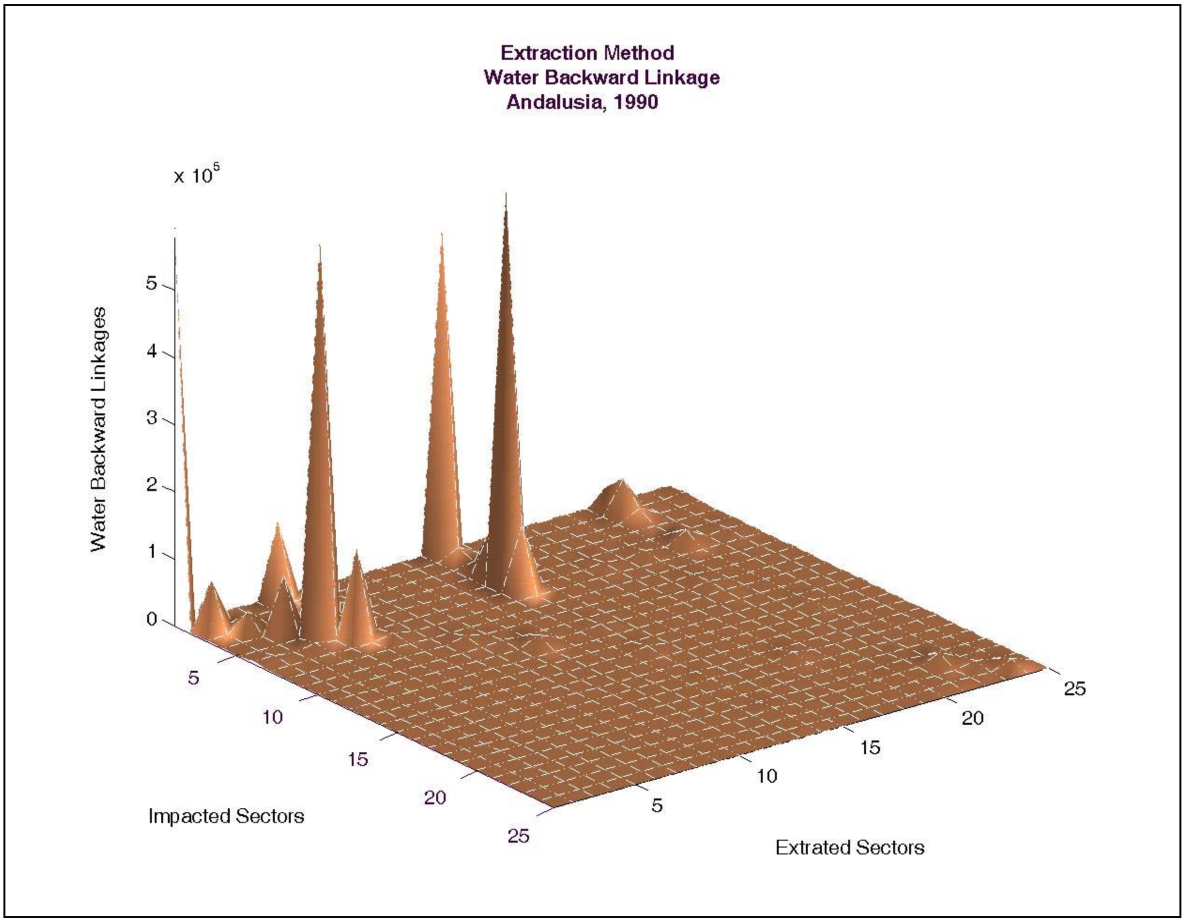
Given these results, and in order to analyse the results from the extracting method, we will focus on those sectors that are the biggest water consumers previously mentioned. We will show the results in the next set of figures[10] because they are easier to understand than numerical tables. Figure 1 represents the impacts that produce the different extracted sectors on the rest of the productive sectors, from the point of view of backward linkage. X-axis represents the extracted sectors; on Y-axis, impacted sectors are represented and on Z-axis the produced impact. We must take into account that, according to the analytical development made in the previous section, the impact measures the difference between the water consumption of sector i, considering the whole water consumption system, and the water consumption of this same sector i, having extracted sector j. If this difference is positive, the consumption of sector i, with the complete productive system, is bigger than the consumption of this same sector when sector j has been extracted. That is to say, when extracting sector j, savings in the water consumption of sector i take place. This is the way in which we must interpret z-axis of the graphical associate. The greater the difference, that is to say, the greater the value of z, the greater is the reduction in the water consumption of the hit sector.

Having made these observations, it is possible to confirm that, without doubt, the greater water saving takes place in the agricultural sectors when the food and agriculture industry (14) is extracted; and more specifically, the agricultural sectors which have a greater reduction in the

[10] The author would like to thank Professor Guilhoto (Universidad de Sao Paulo) for his useful lessons about this type of graph through the Matlab Program.

consumption of water are the olive grove (5) and the cereals and leguminous (1) sectors, in this order. It must also be pointed out that when extracting tourism (22) certain water saving takes place in the agricultural sectors.

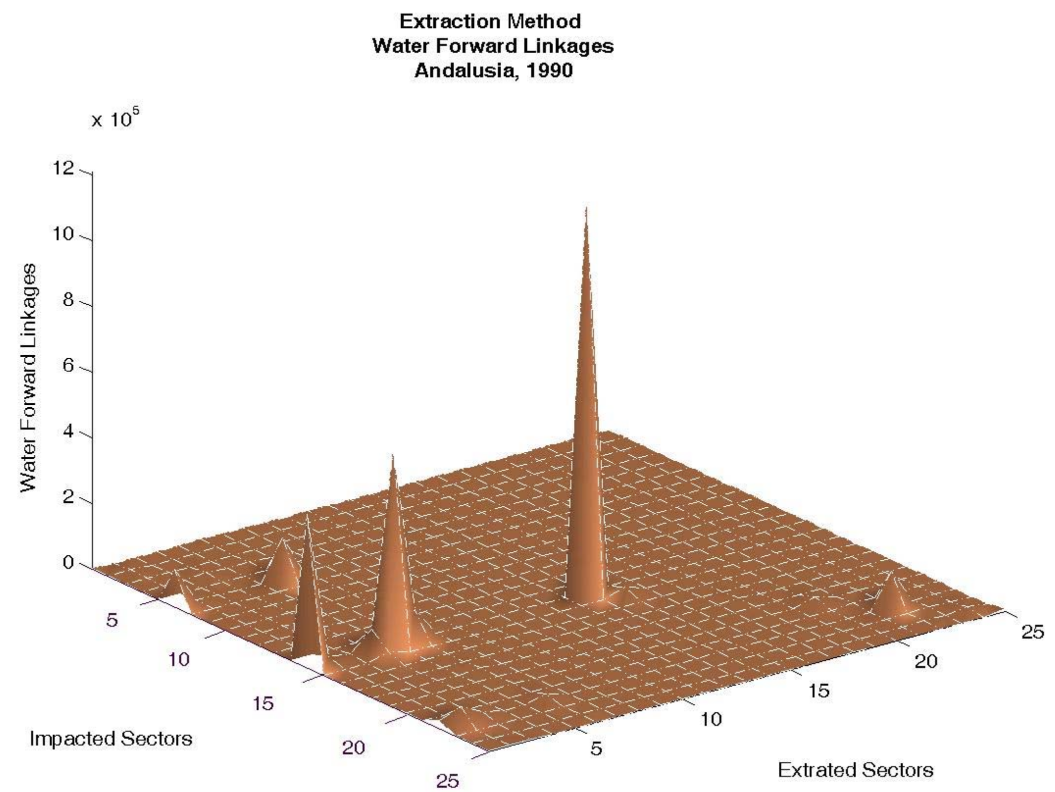
Figure 1. Extraction Method, water backward linkage.



Source: created by the author.

These results can be read the other way round , that is to say, by means of water forward linkage. Figure 2 shows us how the sectors that have more influence on the reduction of water consumption by means of their sales (or those that depend more on others because they sell their production to them) are sectors 1 and 5 that the food and agriculture industry sells to them (14).

Figure 2. Extraction Method, water forward linkage.



Source: created by the author.

4. Andalusian economy: a brief review

Before concluding, we must relate these results on water consumption in Andalusia to the economic variables of the region. Andalusia is characterized by a service sector, with 30% of employment in 1990 and 37% of added value. We can observe in table 3 the sectorial added value, employment (in percentage) and output multiplier.

Despite the strong output multiplier of the food and agriculture(1.72) and tourism (1.52) industries, both present a not too large added value (5%) as opposed to 25% of sales services, for instance. On the other hand, we can observe the low production added by all the agricultural sectors (6.3%). With regard to employment, we must highlight the 4% of people employed in the food and agriculture industry. The percentage for tourism is slightly higher (7%) and significantly more the employment in the cereals and leguminous sector (almost 15%).

Tabla 3. Output multiplier, Added value (percentage), Employment (percentage). Andalusia, 1990.

SECTORS	Output Multiplier	Added Value	Employment(*)
1 Cereals and leguminous plants	1.43	0.7	14.9
2 Vegetables and fruits	1.25	2.5	-
3 Citrus fruits	1.29	0.2	-
5 Industrial plants	1.49	0.7	-
4 Olive groves	1.27	1.4	-
6 Other agricultural productions	1.67	0.8	-
7 Extractive industry	1.32	4.7	1.0
8 Water	1.44	0.2	0.2
9 Metallurgy	1.32	1.8	1.5
10 Construction materials	1.54	1.4	1.1
11 Chemicals and plastics	1.51	1.7	1.0
12 Machinery	1.26	0.3	0.3
13 Transportation material	1.36	1.7	1.4
14 Food and agriculture industry	1.72	5.0	4.0
15 Textiles and apparel	1.37	1.0	2.3
16 Footwear and Leather products	1.21	0.1	0.2
17 Lumber industry	1.33	0.7	1.6
18 Paper, printing and publishing	1.42	0.8	0.6
19 Miscellaneous manufacturing	1.13	2.0	1.3
20 Construction	1.42	10.6	13.8
21 Trade	1.28	12.1	14.1
22 Hotel and catering trade	1.59	5.0	7.4
23 Transportation, communications	1.29	7.0	4.1
24 Sales related services	1.18	25.4	12.6
25 Non-sales related services	1.18	12.2	16.5

Source: created by the author. from Instituto de Estadística de Andalucía, Junta de Andalucía (1995a*): Contabilidad regional y tabla input-output de Andalucía, 1990. Presentación de resultados*. Instituto Estadístico de Andalucía.

(*) The celerals and leguminous plants' percentage of employment (14.9) corresponds to all of the agricultural sectors.

To summarize, we can say that the food and agriculture and tourism are important from the point of view of the economy because of their output multipliers, but lesser because of added value terms. Nevertheless, it is convenient not to forget that these sectors generate a considerable level of employment, together with the agricultural sectors, in the Andalusia region.

5. Conclusions

In this paper we have used an input-output methodology to analyse more deeply the relationship between the production system and the use of its water resources. By means of the analysis of water output multipliers and water input multipliers, on the one hand, and through water forward linkage and to water backward linkage, on the other, we have been able to state that the agricultural sectors are the greatest water consumer and in a direct way. But also, we were able to conclude that sectors like the food and agricultural industry (14) and tourism (22) have an influence on the system by means of the their water purchases, increasing, therefore, the pressure on water resources through their demands. And also, some of these sectors, in addition to being great water consumers, dedicate part of the their water consumption to export.

This fact has led to us to study the effects that a reduction of the demand of these sectors would have through reduction of their exports. By means of impact analysis, we have been able to verify that if the exports of such sectors are reduced, their water consumption is reduced considerably, but smaller is the saving that is generated on the system as a whole. As it could not be otherwise given the previous results, the greater water saving in the system is generated by reducing food and agricultural industry (14) exports, which oscillate from a 6% reduction of consumption with a reduction of 20% to a saving of 31% when reducing exports to zero.

These results raised the following question: what would happen if we, hypothetically, extracted certain sectors from the production system? Thus, by means of the EHM we have been able to verify that when extracting the food and agricultural industry (14), a greater water saving is generated, as we have seen previously, and this takes place fundamentally in the agricultural sectors, especially in sector (1) and in (5).

This leads us to conclude that Andalusia, a region with powerful food and agricultural (and the agricultural sector that supplies it) and tourism sectors, has an economy specialized in intensive water sectors. The reduction of the demand of these sectors and the hypothetical situation of their disappearance leads us to raise the possibility of considering a structural change in the productive specialization of the region, if we want to face a sustainable economic development. We are not suggesting the hypothetical situation of the total reduction of its exports or of the disappearance of the sector; both unrealistic situations, but a certain reduction of the production of these sectors, replaced with imports coming from other countries or regions where water is a less restrictive factor. In another case, this specialization could even lead to an excessive consumption of the resource, possibly causing the economic strangling of the region.

The analysis carried out in this paper may seem a little extremist, but we have only tried to focus on the possible excessive water consumption in Andalusia through its great water consumer productive structure; contributing, in this way, to the shortage of a resource which is already limited in itself . Since these sectors have a great output multiplier, and an important level of employment but not such a relevant added value , we are aware that a more in-depth study is necessary in which we can analyse all variables together to allow us a broader vision of the situation.

We would like to finish these conclusions returning to the Tom Stacy text that we mentioned in the introduction to this paper. Let us think that a possible way to face the present ecological crisis, when analysed from the water resource perspective, could consist of raising resource saving production forms and not wasteful ones. These new forms could produce important structural changes, but we believe that, without these adjustments or any others that take into account water saving in the Andalusia's production, the region could face a problematic situation due to production bottlenecks brought about by the lack of one of the basic resources: water.

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ANNEX 1

Water Input/Output Table (Andalusia, 1990) (cubics meters).

Sectors	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1 Cereals and leguminous plants	32,137,830.96	0.00	0.00	0.00	0.00	108,857,609.64	0.00	0.00	0.00	0.00	88,062.45	0.00	0.00	440,780,440.79
2 Vegetables and fruits	0.00	1,942,055.59	0.00	0.00	0.00	5,655,535.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14,271,923.10
3 Citrus fruits	0.00	0.00	0.00	0.00	0.00	751,813.09	0.00	0.00	0.00	0.00	1,484,511.29	0.00	0.00	6,034,040.76
4 Industrial plants	0.00	0.00	0.00	218,176.02	0.00	0.00	0.00	0.00	0.00	0.00	126,912.87	0.00	0.00	63,736,443.69
5 Olive groves	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	592,982,255.45
6 Other agricultural productions	2,987,552.22	3,442,412.47	179,372.57	5,420,979.19	500,653.64	18,701,908.17	0.00	0.00	0.00	0.00	3,514.97	0.00	0.00	84,010,691.74
7 Extractive industry	54,080.81	52,359.31	9,326.45	107,244.05	61,205.09	85,294.04	2,156,911.21	0.00	162,658.08	624,270.63	934,119.02	17,403.13	55,410.94	284,432.55
8 Agua	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9 Metallurgy	163,550.37	110,638.98	10,205.76	235,957.72	113,861.44	94,343.58	69,090.42	0.00	2,098,359.22	107,873.83	68,508.48	251,387.52	744,834.24	458,412.59
10 Construction materials	0.00	0.00	0.00	0.00	0.00	0.00	15,134.51	0.00	31,526.64	281,725.25	4,952.22	10,878.09	5,831.26	219,120.89
11 Chemicals and plastics	562,287.52	1,678,795.28	81,610.11	1,365,610.82	506,037.31	508,925.88	701,156.82	0.00	304,411.47	162,865.51	4,110,878.74	104,651.66	168,986.50	1,271,245.64
12 Machinery	2,896.52	1,981.57	923.36	4,177.31	1,655.40	2,140.05	724.39	0.00	8,887.13	4,794.31	3,201.22	22,205.76	9,417.40	10,313.53
13 Transportation material	0.00	0.00	0.00	0.00	0.00	4,674.90	0.00	0.00	19.73	0.00	680.38	167.45	166,585.40	0.00
14 Food and agriculture industry	0.00	0.00	0.00	0.00	0.00	1,404,061.42	0.00	0.00	0.00	3,525.67	6,036.25	0.00	0.00	1,029,014.65
15 Textiles and apparel	784.99	1,987.18	171.73	1,471.45	633.34	58,046.24	0.00	0.00	1,667.61	1,689.08	3,996.41	293.91	3,630.82	19,522.81
16 Footwear and Leather products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	48.44	0.00	0.00	0.00
17 Lumbre industry	2,419.11	6,380.17	471.01	4,300.34	1,627.45	25,981.17	5,374.04	0.00	2,739.43	9,357.07	4,664.48	3,932.90	26,676.30	49,550.07
18 Paper, printing and publishing	5,062.02	13,346.54	920.44	8,987.17	3,465.34	202,417.12	24,066.58	0.00	165,617.93	438,325.13	113,835.13	130,257.43	56,376.52	1,655,193.16
19 Miscellaneous manufacturing	0.00	0.00	0.00	0.00	0.00	6,931.45	1,617.96	0.00	218.32	1,661.67	163.70	245.29	4,627.30	6,604.79
20 Construction	6,731.43	17,698.50	1,306.20	11,912.82	6,762.77	18,767.44	87,528.84	0.00	13,057.17	18,318.66	18,175.25	57,650.38	13,664.75	37,726.04
21 Trade	24,349.57	49,680.27	4,833.24	45,265.57	24,165.44	223,807.30	185,155.60	0.00	133,563.68	88,842.56	35,730.77	46,991.86	94,778.01	465,919.78
22 Hotel and catering trade	122,757.50	428,794.11	45,840.05	319,113.57	136,176.34	604,956.18	1,033,698.08	0.00	245,127.35	344,157.30	518,888.67	386,526.37	438,269.85	1,744,927.62
23 Transportation,comunications	56,041.81	67,418.94	8,230.95	87,440.34	48,930.26	295,270.99	341,344.62	0.00	141,538.99	306,451.12	209,903.44	100,176.66	128,988.48	767,825.31
24 Sales related services	41,688.91	100,554.17	8,781.92	65,044.93	42,603.78	210,770.95	812,174.54	0.00	244,398.25	242,467.55	228,936.98	194,856.65	430,179.07	853,503.26
25 Non-sales related services	1,664.37	4,366.36	313.60	2,927.42	1,660.73	4,605.73	9,779.57	0.00	0.00	0.00	0.00	0.00	313.60	96.47
Total water Interm. consump.	36,169,698.10	7,918,469.44	352,307.40	7,898,608.72	1,449,438.33	137,717,860.52	5,443,757.20	0.00	3,553,791.00	2,636,325.35	7,965,721.16	1,327,625.07	2,348,570.44	1,210,689,204.67
Added value	859,408,743.80	909,916,839.21	321,252,259.93	92,003,769.74	762,967,333.37	250,713,755.35	17,885,915.17	174,092.99	25,945,157.59	4,922,693.18	41,149,688.12	2,328,753.51	5,108,122.74	-8,690,013.66
Total Inputs	895,578,441.90	917,835,308.65	321,604,567.32	99,902,378.45	764,416,771.71	388,431,615.87	23,329,672.37	174,092.99	29,498,948.59	7,559,018.52	49,115,409.28	3,656,378.58	7,456,693.18	1,201,999,191.01

Source: created by the author.

Water Input/Output Table (Andalusia, 1990) (cubic meters)

(Cont.)

Sectors	15	16	17	18	19	20	21	22	23	24	25	Final Demand	Total Consumption
1 Cereals and leguminous plants	0.00	0.00	0.00	0.00	0.00	0.00	0.00	19,981,180.86	0.00	72,835.97	539,836.69	293,120,644.54	895,578,441.90
2 Vegetables and fruits	0.00	0.00	0.00	0.00	0.00	0.00	0.00	48,558,506.98	0.00	349,938.43	2,591,349.00	844,466,000.36	917,835,308.65
3 Citrus fruits	0.00	0.00	0.00	0.00	0.00	0.00	0.00	16,314,921.66	0.00	248,674.68	1,955,938.92	294,814,666.93	321,604,567.32
4 Industrial plants	18,588,372.34	12,391.43	24,775.68	355,260.88	82,077.43	0.00	0.00	0.00	0.00	0.00	0.00	16,757,968.11	99,902,378.45
5 Olive groves	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	171,434,516.26	764,416,771.71
6 Other agricultural productions	145,115.53	0.00	964,455.11	4,019,324.90	71,220.13	3,533,611.05	0.00	15,807,129.61	0.00	3,384,641.51	456,451.39	244,802,581.68	388,431,615.87
7 Extractive industry	55,340.39	1,389.74	47,679.37	54,290.49	8,736.81	391,797.21	457,240.46	264,741.24	1,040,884.81	235,385.81	256,884.77	15,910,585.98	23,329,672.37
8 Agua	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	174,092.99	174,092.99
9 Metallurgy	70,102.35	7,226.57	82,088.10	1,250.25	88,327.82	2,545,765.28	0.00	0.00	40,116.54	18,846.19	42,819.98	22,075,381.32	29,498,948.59
10 Construction materials	0.00	0.00	7,801.53	9,068.47	629.66	3,282,210.62	0.00	49,254.91	53.81	2,252.90	4,983.77	3,633,593.99	7,559,018.52
11 Chemicals and plastics	145,664.26	16,296.02	210,633.44	321,925.12	63,585.49	2,089,949.58	69,461.91	520,118.49	459,649.39	722,308.92	154,028.16	32,814,325.25	49,115,409.28
12 Machinery	2,451.99	24.52	788.44	1,535.15	265.56	27,533.88	7,305.43	0.00	2,762.29	4,923.18	18,099.66	3,517,370.54	3,656,378.58
13 Transportation material	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	14,194.63	51,905.84	453.97	7,218,010.89	7,456,693.18
14 Food and agriculture industry	1,178.07	0.00	0.00	12,959.68	0.00	0.00	0.00	3,535,477.45	0.00	15,066.40	98,443.45	1,195,893,427.97	1,201,999,191.01
15 Textiles and apparel	253,582.41	7,925.46	2,526.58	1,212.89	686.90	1,955.70	11,450.79	35,119.60	13,741.68	10,310.53	14,355.02	26,784,802.15	27,231,565.27
16 Footwear and Leather products	759.58	4,928.84	274.64	143.79	113.10	0.00	7,428.46	0.00	31.76	925.98	1,034.31	580,321.23	596,010.12
17 Lumbre industry	0.00	299.79	148,737.36	4,022.24	2,183.75	200,157.02	15,235.71	0.00	7,384.76	54,538.47	5,674.90	6,006,554.91	6,588,262.45
18 Paper, printing and publishing	100,121.80	41,196.83	29,910.81	1,116,262.20	242,761.40	354,953.07	403,171.05	130,434.89	395,271.06	1,143,946.53	1,031,132.89	23,720,813.13	31,527,846.16
19 Miscellaneous manufacturing	2,812.56	0.00	941.74	26.99	150.15	2,706.75	2,346.56	1,047.05	818.24	2,296.70	8,601.47	2,464,540.91	2,508,359.60
20 Construction	10,653.10	890.09	7,735.82	1,461.87	2,167.39	34,370.55	119,318.24	103,012.02	70,287.35	199,148.68	118,547.28	51,950,640.52	52,927,533.14
21 Trade	55,974.61	3,604.51	86,045.28	38,965.11	9,076.89	582,255.01	143,187.53	306,792.90	69,936.58	165,682.12	58,500.93	28,528,795.78	31,471,900.89
22 Hotel and catering trade	328,230.20	26,033.24	239,815.71	176,198.75	94,628.95	2,288,744.46	1,735,847.29	241,136.55	897,931.71	2,162,312.95	936,409.28	276,385,645.39	291,882,167.48
23 Transportation,comunications	131,537.53	8,440.56	80,445.84	91,564.71	31,541.93	975,102.77	1,046,144.16	271,079.13	296,020.74	670,263.18	348,184.25	9,593,067.01	16,102,953.72
24 Sales related services	175,570.64	12,252.90	196,253.04	131,923.43	36,883.36	1,204,674.31	2,382,447.24	1,165,655.34	966,466.61	2,118,289.95	1,411,868.82	35,930,522.68	49,208,769.31
25 Non-sales related services	0.00	0.00	0.00	0.00	0.00	0.00	458.10	0.00	0.00	0.00	1,061.67	44,841,049.48	44,868,297.10
Total water Interm. consump.	20,067,467.36	142,900.48	2,130,908.51	6,337,396.90	735,036.72	17,515,787.24	6,401,042.94	107,285,608.69	4,275,551.97	11,634,494.91	10,054,660.58		
Added value	7,164,097.91	453,109.64	4,457,353.94	25,190,449.27	1,773,322.89	35,411,745.90	25,070,857.95	184,596,558.79	11,827,401.76	37,574,274.39	34,813,636.52		
Total Inputs	27,231,565.27	596,010.12	6,588,262.45	31,527,846.16	2,508,359.60	52,927,533.14	31,471,900.89	291,882,167.48	16,102,953.72	49,208,769.31	44,868,297.10		

Source: created by the author.