Economic analysis of alternatives for eliminating aquifer overdraft in the Segura basin

D. Martínez-Granados, J. Calatrava

ETSIA, Universidad Politécnica de Cartagena. Paseo Alfonso XIII Nº 48, 30203 Cartagena, España.
david.martinez@upct.es.

RESUMEN

Aquifer overdraft is a major environmental and water management problem in Southeast Spain. In some coastal areas, the recent development of desalinisation provides an opportunity to address this problem at a lower social and economic cost. We analyse the economic impact of using several instruments to address this problem in the Alto Guadalentín aquifer: a tax on groundwater pumping, the buyback of groundwater rights and the subsidization of desalinised resources. Their impact is assessed using a mathematical programming model that maximises the farm net margin resulting from the use of the available water resources for irrigation in the area. Our results show that all the alternatives have significant economic impacts, although the availability of desalinised water significantly reduces them. Whereas the outright restriction of non-renewable pumping and an environmental tax have the lowest budgetary cost, they are very unpopular and rather politically unfeasible. Although more expensive for the public budget, purchasing water rights and subsidising desalinised water in exchange for reducing groundwater pumping have the same impact on the agricultural sector, but are likely to be much better received by farmers. Moreover, the former permanently solves the problem.

Keywords: groundwater; irrigation; desalinised water; water economics; mathematical programming

1. Introduction

Aquifer overdraft is a major environmental and water management problem in Southeast Spain. The expansion of intensive horticulture over the last decades has put pressures on all water resources, especially of groundwater that is a major source of water, causing over-exploitation to reach alarming proportions in many aquifers.

In the Segura basin, the most severe pressures over water resources that difficult accomplishing with the environmental objectives established to comply with the European Water Framework Directive (WFD) are: reduced river flows, non-point source pollution and unsustainable groundwater pumping [1]. The last one is of special social and economic importance because of its severity and the relevance of groundwater for the agricultural sector, one of the most productive and profitable in Europe.

According to the WFD [2], water agencies must propose a set of measures to achieve the environmental objectives in each area. Apart from assessing their potential for achieving the environmental objectives, they must also analyse their economic impact. The main economic instruments considered by the Segura River Basin Authority are the buyback of water rights and the substitution of over-exploited groundwater resources by desalinised water [1].

Our objective is to analyse the economic impact of several economic instruments that could serve to eliminate aquifer overdraft in the Alto Guadalentín aquifer, one of the most severe cases of groundwater depletion in Spain: the public purchase of groundwater rights, an environmental tax on groundwater pumping and the subsidised substitution of groundwater by desalinised resources. We analyse both the effectiveness of this instruments in achieving such objective, and its impact in terms of public budgetary cost, farm profitability, agricultural production and employment.

2. Methodology

2.1 Description of the problem and area of study

The Alto Guadalentín aquifer is located in the Guadalentín sub-basin that belongs to the Segura basin in SE Spain. The Guadalentín is one of the most productive agricultural areas of Spain because of its climate, which ranges between the semi-arid and the Mediterranean, making it an ideal setting for out-of-season horticulture. On the other hand, rainfall is scarce, ranging from 250 to 500 mm, although most of the basin receives less than 350 mm.

Structural water scarcity is especially severe in the Segura, despite of receiving external water resources through the Tajo-Segura Aqueduct (TSA). The huge expansion of irrigation over the last three decades has caused a structural water deficit that positions it as one of the most water stressed basins in the Mediterranean [3]. For information on the physical environment, the agricultural sector and the water budget in the Segura basin, see [4].

According to the Segura River Basin Authority [1], the total irrigation area in the Alto Guadalentín aquifer is 36,026 hectares, of which 21,107 hectares are irrigable. Agricultural water demand accounts for 116.42 Mm^3/year, while theoretical water availability is 94.26 Mm^3/year, including several sources of water (Table 1). This unbalance between resources and demands is in fact greater. The official data on water resources availability is merely theoretical, based on existing rights and concessions, and serves only for planning purposes. In practice, using data from [5], effectively available resources are estimated at 74,35 Mm^3/year, leaving the new desalinised resources aside (Table 1).

Available resources for irrigation only cover 64% of water demand, the latter exceeding the former by 42.1 Mm^3/year. Such deficit is covered with a deficit application of water to crops and a reduction in the irrigated area. However, as 27.6 out of 74.35 Mm^3/year of available resources are non-renewable pumping of groundwater, such water deficit is in fact greater. If only 46.75 Mm^3/year of renewable resources were used, they would cover only 40% of the agricultural water demand.

The massive use of groundwater resources during the last decades has caused the severe depletion of the Alto Guadalentín aquifer [1]. To address this problem, the river basin authority has proposed several measures [1]: a management plan to reduce extraction quotas and to control pumping over the quotas, which has not been approved yet because of its great economic impact; the compulsory purchase of groundwater rights; substituting groundwater by desalinised resources.

2.2 Economic instruments considered

In accordance with the previous discussion, the instruments that we analyse are: (i) Purchasing groundwater rights and concessions to reduce pressure over the aquifer; (ii) An environmental tax on groundwater to reduce extractions; (iii) Substituting non-renewable groundwater resources by subsidised desalinised ones.

Purchasing water rights has the advantage of permanently reducing extractions and is less conflictive than consumption quotas and other command and control policies, but it has both a high public budgetary cost and significant impacts on the rural economy.

As the purchase of rights, the substitution of groundwater by desalinised seawater is also considered by the CHS in the set of measures to eliminate aquifer depletion [1]. However, the CHS does not take into account the large differences in their cost for farmers. It is very unlikely that they will substitute groundwater with a more expensive resource without having any incentive to do so. We have thus incorporated a subsidy for desalinisation subject to a reduction in groundwater extractions. However, as desalinisation plants are already built or being built, farmers will also have access to non-subsidised desalinised water.

On the other hand, setting an environmental tax on groundwater extractions is a very unpopular measure. In any case, should it be applied, it is very politically unlikely that a tax high enough to promote a sustainable groundwater use could be set. We consider it because it provides revenue for the government, instead of putting pressure on public budgets, although we recognise the difficulty of its implementation.

Last, we also consider the prohibition of non-renewable extractions, an option that has been considered but never implemented by the water authority because of its high political cost. It is less conflictive and more effective to purchase water rights or provide alternative resources. However, we have included it to measure its economic impact, i.e. the economic contribution of non-renewable extractions.

2.3 Economic assessment of the impact of each instrument

The economic impact of each instrument is assessed using a mathematical programming model that maximises agricultural net margin derived from using the different sources of water supply available for irrigation in each area under different water availability scenarios and economic instruments. The economic data used in the model comes from [4] and [5]. For reasons of space we do not show the model's equations, but these are available from the authors upon request.

The model is run independently for each instrument to obtain the optimal use of water from each source and four economic indicators (farm net margin, agricultural production, agricultural employment and public budgetary cost) that allow assessing each instrument.

3. Results and Discussion

First of all, results for the **"no intervention" scenario** show that, because of the high water demand in the area, and despite their relatively high price, a proportion of the available desalinised resources are used, specifically 7.44 out of 28.0 Mm^3 (second column in Table 2). However, this increased use of desalinisation does not result in a reduction of groundwater extraction because of the severe existing water scarcity. Neither does it result in all the available desalinised water being used, as it is far more expensive for farmers than other resources. In this situation, the value of agricultural production generated is nearly 202 million euros/year, farm net margin is 64.6 million euros/year and agricultural employment is 126,3 million days per year.

Restricting groundwater pumping to the level of aquifers' recharge by **forbidding non-renewable pumping** has a lower impact than it could be anticipated, as farmers can partly substitute groundwater for desalinised resources. As shown in the third column of Table 2, this alternative reduces agricultural production by 12.5 million euros/year (a 6.2% reduction), farm net margin by 6 million euros/year (a 9,2% reduction) and agricultural labour by 114,000 days/year (a 9% reduction). The availability of desalinised water partly offsets the negative impact of this option on the agricultural sector.

Similarly, the **purchase of groundwater rights** has a lower impact than anticipated, as farmers can substitute the sold groundwater rights for desalinised resources (fourth column of Table 2). A price of 0.38 euros/m^3/year, measured as an annual equivalent cost, would be required to buyback enough water rights to eliminate non-renewable pumping. The impact in terms of agricultural production and labour is the same as in the previous case, as the total water use is identical. On the other hand, the purchase of water rights increases farm net margin by 4.5 million euros/year (7.6%) but incurring in an annual budgetary cost of 10.5 million euros.

As expected, the effectiveness of the **environmental tax on groundwater extraction** is reduced because of the low water demand elasticity, and a high environmental tax of 0,38 euros/m^3/year would be required to eliminate non-renewable pumping. The tax has the same impact in terms of lost agricultural production and employment (fifth column of Table 2) as the purchase of groundwater rights but, unlike the latter, it notably reduces farmers' net margin (a 14.4%). On the other hand, public revenue from the tax is 3.33 million euros per year. In Table 2, we can see that the environmental tax has a greater impact in terms of farm net margin than the prohibition of non-renewable pumping.

In principle, **subsidising desalinised water in exchange for reducing groundwater pumping** has the advantage over the purchasing water rights or restricting pumping of not reducing water use and therefore not having any impact on the agricultural sector. However, the fact that farmers already have access to desalinised water, even at a higher price than groundwater, offsets the effectiveness of subsidising its price, as these resources are already available without the subsidy and will be used if the proper incentives are provided with any of the other instruments. As a result, although the amount of water used in the area is reduced with respect to the "no intervention" alternative, it is still the same than with the other instruments, and the impact of this instrument is identical to that of the public purchase of groundwater rights.

4. Conclusions

In this study we analyse the economic impact of several economic instruments that can be used to face the severe problem of unsustainable groundwater pumping in the Alto Guadalentín aquifer in Southeast Spain, one of the most profitable agricultural areas in Europe.

Our results show that demand for desalinised water accounts for a quarter of its availability, despite its high price. However, desalinisation alone does not reduce groundwater pumping because of the severe water scarcity in the area. This is a relevant result, as it shows that, just by making it available to farmers, groundwater extractions will not reduced.

The availability of desalinised water mitigates the relevant economic impact of eliminating aquifer overdraft using any of the instruments, as farmers can substitute groundwater with desalinisation.

Choosing the right one thus depends on the importance given to its impact on the farming sector and on the public budget.

Although the outright restriction of non-renewable pumping and the tax on extractions have the lowest budgetary cost, they are very unpopular and quite politically unfeasible, as experiences in other Spanish basins have shown.

Despite being more expensive for the public budget, the buyback of water rights and the subsidisation of desalinised water in exchange for reducing groundwater pumping have the same impact on the agricultural sector, but are likely to be much better received by farmers. Moreover, the former permanently solves the problem. The solution could be a combination of instruments that would share the cost among farmers and the administration with the lowest possible impact on the agricultural sector.

5. Acknowledgements

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Tables and Figures

Table 1. Available water resources and water cost in the Alto Guadalentín aquifer

	Available water rights (Mm^3/yr)	**Available water (Mm^3/yr)**	**Cost of water for farmers (€/m^3)**
Surface water	13.90	11.10	0.05
Tajo-Segura Transfer	37.16	22.25	0.127
Treated wastewater	4.70	4.70	0.08
Groundwater	38.50	36.30	0.24
Desalinised water	-	28.0	0.445
Total resources	**94.26***	**74.35***	
Non-renewable pumping (Mm^3/year)		27.60	

Source: Own-elaboration using data from [1], [5] and a survey made in 2012 to irrigation districts in the area. Groundwater resources include infiltration from water applications to crops. * Excluding desalinised resources.

Table 2. Economic impact of eliminating aquifer overdraft using each instrument

<table>
<tr><th></th><th>No intervention</th><th>Prohibition of non-renewable pumping</th><th>Purchase of rights (0.38 €/m³/yr)</th><th>Environmental tax (0.38 €/m³/yr)</th><th>Subsidy to desalinisation (0.38 €/m³/yr)</th></tr>
<tr><td>Total water use (Mm3/yr)</td><td>81.88</td><td colspan="4">74.44
(-9.09%)</td></tr>
<tr><td>Groundwater use (Mm3/yr)</td><td>36.32</td><td colspan="4">8.72
(-76%)</td></tr>
<tr><td>Reduction in Groundwater use (Mm3/yr)</td><td>0.00</td><td colspan="4">27.60</td></tr>
<tr><td>Desalinised water use (Mm3/yr)</td><td>7.44</td><td colspan="4">27.60</td></tr>
<tr><td>Subsidised desalinised water use (Mm3/yr)</td><td>0.00</td><td colspan="3">0.00</td><td>27.60</td></tr>
<tr><td>Agricultural production (million euros/yr)</td><td>201.97</td><td colspan="4">189.51
(-6.17 %)</td></tr>
<tr><td>Net margin (million euros/yr)</td><td>64.59</td><td>58.62
(-9.24 %)</td><td>69.11
(7 %)</td><td>55.30
(-14.4 %)</td><td>69.11
(7 %)</td></tr>
<tr><td>Agricultural employment (10^4 million days/yr)</td><td>126.26</td><td colspan="4">114.87
(-9 %)</td></tr>
<tr><td>Budgetary cost (million euros/yr)</td><td>0.00</td><td>0.00</td><td>10.47</td><td>-3.33</td><td>10.47</td></tr>
</table>

Source: Own elaboration. Proportional change with respect to the “no intervention” alternative in brackets