

Looking for efficiency through integrated water management between agriculture and urban uses

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ABSTRACT

Many urban water systems must cope with water scarcity and climate change and additionally they must be able to fulfil the objectives of environmental protection, efficiency and sustainability. At the end they must provide the expected level of service now and in the future horizons. Some new comprehensive approaches are assessing the total water footprint in a territory using the concept of virtual water and incorporating interactions between agriculture, urban and industrial uses. Besides this broader method of analysis it is important to go further and make analysis of opportunities for efficiency based on a new paradigm of integrated use of water. Investing in improvement of efficiency not only in urban distribution systems, studying the possibilities of permanent or temporal reallocation of water rights from agriculture to urban. Establishing agreements for interchange of raw water for urban regenerated water. Signing options contracts for water trading under drought conditions. Risk of shortage is the factor to complete the framework and it is a key component to review and to manage

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INTRODUCTION

Sharing and using water follows a cyclic model of transformations, transfers and exchanges. Urban and agricultural uses account for most of the water consumed on the planet and are main agents in the processes of exploiting and transforming water resources.

Until the present time, these two types of use have exploited the available resources in different and unequal ways where total volumes, technologies and management systems are concerned, but in most cases no major conflicts have been detected so far, with respect to water use. The priority for urban use that is given in many planning and water management regulations has served as guidance for dealing with conflicts caused by water scarcity situations.

Population growth and the trend towards greater concentrations in the cities, combined with changes in land use and food production and transport technologies and markets are bringing about dramatic changes in water availability and demand balances in many areas; the same

also applies to the economic and social context in which all these water-related activities develop. Climate change does not help where maintaining the balance is concerned.

Every year, there is an increase in the number of zones on the planet in which scenarios occur where there is an insufficiency of resources available to cater for the water demand in the cities. Furthermore, the food production and transport models are changing and altering the economic and social benefits obtained from food production.

Water rates show different values between urban and agricultural use and reflect the differences in supply conditions. As a general rule, the rates that are applied to agricultural uses do not make it possible to completely recover all the costs, which are compensated with some kind of subsidy.

The technological solutions that would facilitate the transfers and transformations needed to meet all demands are not always feasible or affordable for the economies of

many zones on the planet. The conventional solutions involve an increase in the use of energy that, to a greater or lesser extent, has a negative effect on both the carbon footprints and environmental impact and, of course, this leads to greater operating costs.

The search for an increase in productivity and efficiency in water use in agriculture could prove to be a valid solution in some cases of resource insufficiency, (a few points of saving in such amount of volumes would release water for thousand of citizens) but this generally involves major changes in operating costs and production models; this would be beyond the economic possibilities of many agricultural practices and requires deep cultural changes.

Solutions based upon improving efficiency in urban use have to cope with a different scenario with lower volumes, lower potential for absolute saving, higher water quality requirements, bigger social engagement and a greater ability to pay the total cost of water availability.

Problems are a sign of imbalance that rise in a variable way throughout time. As they are very much dependent on meteorological conditions, the climate change scenarios that have been forecast amount to a major threat. The imbalances and insufficiencies emerge during periods of meteorological drought and give rise to periods of scarcity and water shortage.

The ecological status of the water masses is now a basic target of water management that no longer plays a secondary role where imbalances are concerned, all the more so in scarcity episodes. In Europe, for example, the Water Framework Directive, [European Union \(2000\)](#) set the attainment of good ecological status as a priority aim in the planning and management of water resources in such a way that environmental flows are yet another use (or constraint) to be considered when distributing resources and overcoming conflict situations. In general, there is no well-defined methodology for assess the cost of the upkeep of environmental conditions, but they are clearly exposed to the negative effects of insufficiency. Sustainability and ensuring that water masses are in a good ecological status have led to resources being allocated to this question on a long-term basis. In some cases, the State has also involved itself by taking on the responsibility for the cost of paying compensation to other uses and owners' rights.

In such panorama, sharing the available resources necessarily falls within the context of risk management; this invariably causes conflicts of interests, so it is necessary to find temporary solutions to overcome the crisis, and to do so in the fairest and surest way possible.

That is why the most suitable parameter when approaching the search for efficiency in the use of water resources, has to be the risk factor, or, to put it in a positive way, the factor that measures the reliability of supply to the different uses in the potential abundance and shortage circumstances. It is the quality of service and the availability of suitable water.

Planning the actions to be taken to ensure that urban water demands can be met in a suitable, sustainable and efficient way necessarily involves firstly carrying out a review of the efficiency opportunities in urban systems themselves, but this must also be completed with a comprehensive analysis of agricultural availabilities and demands. In many cases, this will be the most efficient of the potential options, but when analysing it, a series of planning and operating considerations must be taken into account, in both normal and crisis situations. An attempt will be made to analyse several options in this document but all of them could be summarised in an integrated model for sharing and exchanging volumes, risks and costs.

The insufficiency situations described occur with increasing frequency in Spain, and specifically in the Autonomous Region of Madrid, as a result of the aforementioned scenarios overlapping. The low reliability for urban uses and the emergence of severe drought spells in recent decades has made it necessary to study a wide range of solutions based on exchanging water with the nearest agricultural users. [Figure 1](#) shows the water distribution on the planet, in Spain and in the small surface area of the Autonomous Region of Madrid (8,000 km²), where over 6 million people live in 177 municipalities served by one single supply system that is managed by Canal de Isabel II.

CURRENT CONTEXT

The current water use context in agricultural and urban environments can be evaluated by taking into account the following factors:

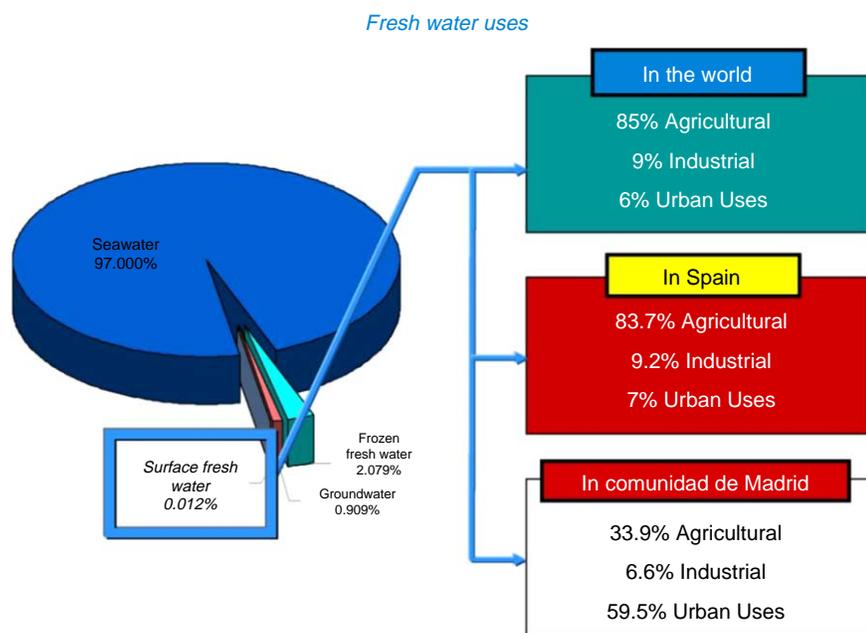


Figure 1 | Water distribution on the planet, in Spain and in the small surfaces area of the Autonomous Region of Madrid.

Water use flows and hydrological footprint for the area

It is important to conduct the more extensive potential analysis of water consumption either in its physical form or as virtual water incorporated into goods or processes. By way of an example, Table 1 summarises the use and water flows in the Autonomous Region of Madrid, using virtual water and hydrological footprint assessment techniques. It has not been possible to accurately carry out the economic evaluations of these flows owing to a lack of data for evaluating the virtual water imported (Naredo *et al.* 2008). These data shows the typical distribution of water footprint of a megacity area where relationship between water used for water supply services and net virtual water use is less than 1/20.

Table 1 | Hydrological footprint in Comunidad de Madrid (2005)

	hm ³	m ³ /inhab	l/inhab/day
Agricultural	9.217	1.583	4.366
Industrial	64	11	30
Urban & commercial	423	73	200
Total	9.704	1.667	4.566
Virtual water imports	13.193	2.266	6.208
Virtual water exports	4.601	790	2.163

Relationship between real availabilities (considering all the uses, limitations and their priorities) and water rights under normal hydrological conditions

Evidence of climate change can already be seen in many basins, with runoff and flows in recent decades that fall well below those that can be deduced from statistical analysis of the longer time series that were used for water allocation. The new requirements to conserve ecological flows in order to ensure the good ecological status of rivers constitute a further modification to the analysis of availabilities on which the water allocations were made. In recent decades, the values measured for the runoff time series input to the reservoirs in the Upper Tagus Basin—close to and upstream from the Autonomous Region of Madrid—have fallen by 30% when compared to the 100-year historic time series.

Relationship between the volumes actually used under normal conditions and those allocated

This is a value that it is difficult to establish accurately, but the rates are generally higher than the unit, because they reflect situations where the infrastructures have deteriorated and irrigation practices are rather inefficient. In some irrigation areas of the Tagus Basin, the volumes actually

used are greater than 50% when compared to their water rights (Estevan & Lacalle 2007) and it is these values of real use that are considered for the short term horizons in the Hydrological Plans until measures are taken to improve and modernise the irrigation systems.

Real capacity of the infrastructures to cater for the real irrigation demands

In many cases, the infrastructures have deteriorated to such an extent that it is not possible to abstract, transport or distribute the flows demanded at the consumption points, which would tend to cause difficult situations for agriculture and lead either to a wide range of interim or temporary solutions or to the abandoning of crops.

Target supply reliability for both uses

The guarantees established as target, or reference, are generally different for the two types of use, more demanding values being established for urban use (4% of years with small shortages is the planning target for supply systems in Spain). The problem lies in the uncertainty that exists about the data that are used for calculation purposes, the way in which the data are evaluated and a lack of integration when it comes to the approaches made to sharing out, as well as for taking compensatory measures when faced with insufficiency scenarios and taking preventive measures. It is necessary to review and update the calculation criteria and procedures used when establishing supply reliability, which were based upon generally accepted notions of sufficiency and abundance, and replace them with criteria and procedures that are adapted to very different contexts that take into account climate change and environmental targets. What is often referred to as “firm yield”, is a term used in planning that will only make sense when operating in contexts of great certainty. The difference between reliabilities for every use will only be effective if it is applied in conjunction with operation procedures for implementing and sharing out the shortages and taking into account the environmental conditions whenever these are relevant.

Real supply reliability for both uses

It will not be possible to guarantee that all the demands can be supplied in a large number of cases, because it is now more likely that there will be episodes when risk management will make it necessary to reduce the demands to one or more uses while effective measures are implemented. This is a reality that must be incorporated to operation procedures till an accurate updated assessment is carried out.

Cost recovery for both uses

Cost recovery generally occurs in a large number of urban supplies, but where irrigation is concerned, the productivity (net profit per unit of volume consumed) reveals unsustainable values without subsidies of any kind. In an area such as the Autonomous Region of Madrid, the average rate for all the urban water services as a whole is around 1 Euro/m³, whereas for irrigation the resources rate is only 0.02 Euros/m³, and the productivity figures obtained from this agriculture failing to exceed 0.10 Euros/m³ (Estevan & Lacalle 2007).

Efficiency in the use of resources for each type of use and potential improvements

Resource use efficiency is generally greater where urban systems is concerned. Although certain systems yield high values of apparent and real losses, this is not the case with the Autonomous Region of Madrid, where the values for the losses lie below the threshold above which they could be regarded as uneconomical. As far as irrigation systems are concerned, the inefficiencies of their systems and infrastructures give rise to real abstractions that triple the actual crop needs. Improvements in irrigation systems would require increments in capital and operational costs that will absorb their productivity.

Legal framework for exchange

There are several legal frameworks in Spain for the exchange of water rights in the form of contracts for temporary transfer rights or through public interchange centres (water banks).

This possibility has been used to cope with shortage situations during drought episodes and in some specific imbalance zones to contribute to enabling overexploited aquifers to recover and reach good ecological levels.

CHALLENGES AND NEEDS

The challenges that have to be faced are a result of the water imbalances referred to in the preceding chapter and in the forecasts regarding how these will evolve; these forecasts expect future imbalances either to be the same or greater. Furthermore, this will take place within the context of increased costs for both uses, particularly where irrigation is concerned.

They can be summarised on below scenarios:

- A growing risk of resource insufficiency affecting urban uses to the extent that the established thresholds are exceeded (the thresholds set either in the regulations or in the planning targets)
- High marginal costs of the conventional options to achieve a balance between availability and demand.
- Insurmountable environmental and social impediments that prevent conventional options from being implemented.
- Considerable increases in the operating costs associated with the price of energy, an increase in labour costs for traditional irrigation activities and a greater use of energy associated with solutions based upon modernising and improving irrigation practices.
- Territorial development strategies aimed at benefiting rural settlements and rural activities, as well ensuring that rural population levels do not drop.

SOLUTIONS AND OPPORTUNITIES

There is always some risk of a scarcity crisis in the water systems, although the degree of risk will depend on the place and the circumstances. The solutions, for every zone, have to combine the actions to be taken in normal situations (when there is a low risk of insufficiency) and those to be taken in situations where there is a high risk of scarcity or insufficiency.

In the places where the zone availabilities for sustainable use are committed as a result of allocations, constraints or current and forecasted uses, efficient solutions must seek to achieve productivity integration by combining risks that are acceptable to society as a whole.

Sharing the resources will involve a combination of volumes, risks of not enough availability, capital and operational costs, cost of interchange of water rights, subsidies and compensations.

The solutions focused on water interchange could be grouped into the following:

Exchanging resources through temporary agreements in crisis situations

This is the solution that always ends up being formally implemented to a greater or lesser extent. In scenarios where there is a high risk of scarcity, crisis episodes frequently occur. In such situations there is always a distribution of the damage that is regulated to a greater or lesser extent and, in some cases; compensation is paid out for the damage. This solution is not desirable because it is based upon improvisation and causes greater overall damage and distribution that is more unfair.

In general, this solution is only possible when there are infrastructures that make exchange possible. Transfer agreements have been reached in the River Tagus Basin for several years running, for purchase values that are twice as high as the agricultural productivity in the zone; these agreements have been encouraged by the basin authority.

Planned option contracts for exchange of resources in crisis situations

This type of solution is like the previous one, but has the advantage of being planned thoroughly; it takes the form of an agreement between the parties, and there is also a greater likelihood of social acceptance. Such solutions ensure that the cost of compensation does not have a major impact on a particular area and negative social effects.

It is only possible to resort to solutions such as these if there are infrastructures that allow for the exchange jointly with the use of a seasonal indicator and threshold system that guarantees the availability of the reserves to be

transferred and enables decisions to be taken without the need for negotiations. This solution can be used in a supplementary capacity to the solutions involving exchange under normal conditions.

Transferring resources and/or rights in return for investing to improve the infrastructures and making operations more efficient

The initiatives taken to improve the efficiency of irrigation systems by investing in the renewal or modernisation of infrastructures releases resources, often used above the allocation values. Pumping is very often necessary when transforming irrigation systems and this consumes energy, which brings about an increase in operating costs. These increases in capital cost and operating cannot always be afforded by the farmers because of their low business margins, so such initiatives need usually to be largely financed by other entities. One way of managing to allocate to the urban systems those recovered volumes of water could be through contributing to the investment and the operating costs that are necessary. Evaluations have been made in the Autonomous Region of Madrid concerning the increase in cost to be charged on each cubic metre recovered through the use of these techniques. Total amounts of around 0.10 Euros/m³ were yielded. The total amounts involved in the investments needed to incorporate these water resources into the supply system and to treat them raised this marginal cost to 0.20–0.30 Euros/m³. If one compares this cost to the cost of the other options available, this solution proves to be advantageous, not only from an economic perspective but also from an environmental and social viewpoint. When one makes a comparative analysis of these types of options, it is also essential to take into account the further advantages of making use of the infrastructures for the planned exchange of water in crisis situations through option contracts.

Transferring resources and/or rights in return for the increase in irrigation system operating costs

This solution would be equivalent to the preceding one, but limited to the payment of part of the irrigation system operating costs. In this situation urban uses would very

clearly be making a contribution to the subsidies for irrigated agriculture and to fulfilment of rural territorial policies. The marginal cost for the urban system would be very small and very likely lower than the ones necessary to incorporate those volumes to its system.

Transferring resources and/or rights

Simply transferring rights on a permanent basis is a complicated question because it means these resources are reallocated in exchange for economic compensation. This is not envisaged or endorsed by most legal frameworks and has been applied in cases where the administration has acquired those rights with a view to embarking on the task of ensuring that the status of deteriorated water masses is restored to ecologically acceptable levels.

Exchanging waters of different quality. Raw water suitable for treatment for domestic use in exchange for reused water that can be used for irrigation

This type of solution merely involves exchanging volumes and does not necessarily involve any economic reimbursement. The urban party must pay for the cost of treating the wastewater so that it can be reused in irrigation, as well as for providing the infrastructures that are needed to transfer resources in both directions. The wastewater must not be used for any other purpose and special importance must be attached analysing potential negative environmental impact on the watercourses and water flows (surface and underground) affected. The cost involved is very high, because apart from the costs of capital and the operations involved in wastewater treatment (if treatment facilities do not exist), it would be necessary to add the cost of reuse and the exchange infrastructures. These solutions are among the most expensive ones from an economic perspective and, from an environmental viewpoint, they use a lot of electricity. Values higher than 1.2 Euros/m³ were calculated in one study in the Autonomous Region of Madrid.

All mentioned type of solutions require not only an infrastructure that facilitates exchange but also infrastructures for transforming the water quality so that it complies with the quality requirements for the use to which the resources will eventually be put.

They need the resources to be available whenever they are necessary, which means applying integrated procedures for preventive operation and having the required water regulation capacity. However, what is most needed are comprehensive management procedures for scarcity situations.

The most efficient solutions will be the ones that achieve the best combination of risks at the lowest total cost, while at the same time guaranteeing the good ecological status of the water masses (at least in the established terms of risk). It will of course be essential to guarantee environmental sustainability and will have to be accepted by all the sectors of society involved.

CONCLUSIONS

Water interchange between Agriculture and Urban is a historical reality at least in the form of virtual water. Rely on unreliable water rights, due to impact of climate change or inaccurate assessments, is a frequent risky context in water supply systems.

The exchange of water allocation between agricultural and urban uses is an efficient option for the management of water resources in a zone. It can be the best option for planning with a view to guaranteeing urban water supplies but, in parallel could be the most reliable and cost/effective solution for irrigation systems. Without a doubt it is a very good adaptive procedure for drought prevention and mitigation.

There are many different ways in which it can be implemented that range from merely transferring resources

in crisis situations to integrated actions involving investment and operation in both systems with a view to the ongoing transfer or exchange of resources. Where the entities that receive the resources are concerned (cities), this is often the best option for facing up to the challenges of the future and all the uncertainties involved.

Exchanging water rights is an opportunity for basin water authorities and resource administrators to bring about a structured redistribution of volumes and risks and, especially, to achieve a harmonious integration with the environmental constraints.

It requires the involvement and acceptance of the water authorities, social acceptance of the parties associated with agricultural activities and the capacity of the urban systems to accept the increase in the cost of infrastructures, operating costs and the economic compensation that will have to be paid.

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