Water and energy consumption after the modernization of irrigation in Spain

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Abstract

The goal of this paper is to analyze aspects relating to saving water and energy consumption of the modernization of irrigation in Spain. In relation to water saving, it studies the most important irrigation modernization processes and their water saving goals. Next, it presents water accounting as a tool for water resource assessment of irrigable areas. Based on this, it concludes that, in general, modernized irrigation in Spain consumes more water than before, mainly due to changes in crop patterns, the increase in irrigated areas, and the greater satisfaction of the water requirements of crops. Different case studies are analyzed, all revealing higher water consumption after modernization. Regarding energy consumption, it studies the greater electricity consumption arising from irrigation modernization when surface irrigation is replaced by pressurized irrigation using pumping systems. It analyses the high economic cost of this pressurization since the liberalization of the electricity market in 2008, and how this high operating cost constitutes a serious threat to the economic viability of some modernized areas. As a general conclusion, it observes that irrigation modernization policy in Spain, mainly financed with billions of euros from Europe, Spanish state and Spanish regions, and justified socially by hypothetical water savings, has not in practice led to any water savings, but rather the reverse. Productivity in modernized farms has increased, but their general costs and the costs of amortizing the investments made have also increased. Thus, despite substantial public funding, in certain cases modernization can be a threat to the economic viability of the same farm which is modernized, which may find it needs new public funding.

Keywords: irrigation modernization, water consumption, energy consumption.

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1 Introduction: water accounting in irrigation systems

Typically, for agricultural irrigation water is taken from a body of water (rivers, aquifers, etc.), but not all the extracted water is used on the crops, as the storage, transport and application systems are not completely efficient. Thus some of the extracted water will return to the natural cycle, and some will not.

This fact, characteristic of irrigated agriculture, obliges us to define the concepts of water use and water consumption precisely, which is fundamental when establishing how much water a given irrigated area consumes and extrapolating this for concepts such as water conservation.

Water use is considered to be the volume of water withdrawn from the body of water supplying irrigation. Part of the water used will be consumed and will not return to the natural cycle: this is consumed water. The other part of the water used will return to the natural cycle: this is non-consumed water.

In irrigation systems, water is typically consumed in evapotranspiration (beneficial or not), non-recoverable runoff and non-recoverable deep percolation. However, recoverable runoff and recoverable deep percolation are not considered to be water consumption.

This starting point is essential for the hydrological analysis of the capacity for water conservation in the modernization of an irrigation system. In fact, at the scale of the basin, at the scale of hydrological planning, at the political scale and at the social scale, water saving should be understood as a reduction of water consumption, not as a reduction of water use.

However, sometimes water saving is regarded as a reduction of water use, leading to paradoxical situations: lower water use may be accompanied by higher consumption, so a supposed water saving may really involve an overall loss of water at the level of the catchment area.

2 Water consumption in the modernization of irrigation systems in Spain

As explained above, modernizing an irrigation system will save water if it can reduce water consumption. For example, watering a smaller area, applying deficit irrigation or planting crops that need less water. Reducing non-recoverable runoff and non-recoverable deep infiltration would also save water, as would reducing non-productive evapotranspiration. These are situations which are unlikely to occur at a sufficient scale to be considered as a modernization which has led to water conservation.

Typically, the opposite will happen. Greater availability of water plus the higher economic cost of modernization (amortization of the investment, energy costs) will oblige irrigation users to try to get more value from the available water, by increasing the irrigated areas, getting the crops to take up more water or changing to more profitable crops which require more water.

Nevertheless, the modernization work undertaken in Spain in recent decades has been justified to society in the name of “water conservation”. Thus, the idea that “modernizing irrigation saves water” is now very widespread. Together with

the idea that "we have to save water", society now sees the modernization of irrigation systems, and by extension the substantial contribution of public funds, as fully justified.

Table 1 summarises the economic and hydrological forecasts of the two main public initiatives for modernizing irrigation systems in Spain: the Plan Nacional de Regadíos Horizonte 2008 (Horizon 2008 National Irrigation Plan) and the Plan de Choque (Shock Plan) of 2006. In both, and particularly the latter, "water conservation" was one of the main goals justifying the initiatives.

Table 1: Main Spanish public initiatives on irrigation modernization.

	Investment (10^6 euros)	Affected area (10^6 m^2)	Estimated water savings (10^6 m^3/year)
H-2008	5024	13776	2000
Shock Plan	2344	8668	1162

Given the importance of the stated goal, one would expect precise assessments of water consumption before (ex ante) and after (ex post) the projects in order to quantify the claimed savings. One would also expect the supposed water savings to be made available to the water authority (by the reduction of irrigation permits) in order to determine its new use (for example, to comply with the Water Framework Directive on the recovery of good status for bodies of water by 2015).

But the administration says that "there is no assessment which can quantify the resulting water savings" (Government answer to Parliamentary Question 186/293, 3rd May 2013). This also means there is no basis for reviewing irrigation permits. Without official information, it is difficult to analyse the savings which are supposed to be achieved by modernization. The only official statistic is that no permits have been revised downward, which is significant. For analysing water savings in modernization projects, practically the only information available comes from a scant few scientific studies by universities and research centres, which we will analyse in this document.

3 Water consumption in modernized Spanish irrigation systems

3.1 General analysis

Paradoxically, modernizing an irrigation system increases water consumption, at least in the way modernization projects are carried out in Spain. There are many reasons why this happens, but the most frequent are a change in the cropping pattern, irrigating a larger area, meeting all the water needs of the crops, and evaporation and wind drift losses associated with sprinkler irrigation.

At this point we should note that we refer throughout to "consumptive water use" as the appropriate indicator for measuring water consumption, and that the statement "modernizing irrigation consumes more water" is equivalent to "modernizing irrigation increases consumptive water use".

In other words, none of this refers to "water use", the volume of water withdrawn from the body of water which supplies an irrigable area. This volume of withdrawn water can in fact be reduced thanks to the modernization of an irrigation system, which can benefit the irrigators (they "buy" less water, although it is pumped, they end up paying substantially more money for the water than they used to). Other users may also benefit from this reduction in withdrawals, as the water saved can be put to other uses.

But even if we accept that less water withdrawal may be a form of water conservation attributable to modernizing irrigation, by far the greatest beneficiary of these savings is irrigation agriculture itself, which uses and consumes more and more water, due to its publicly funded transformation and modernization processes.

Figure 1 shows how water use and water consumption in Spain have changed, according to official data gathered by Corominas [1]. It can be seen that the "classical efficiency" of irrigation has increased noticeably (water consumption as opposed to water use) due to modern irrigation techniques, going from 67% in 1950 to 82.5% in 2007. Paradoxically, water use by the agricultural sector is now 2.4 times higher, due to the many different processes transforming and modernizing irrigation systems. Meanwhile, water consumption has quadrupled.

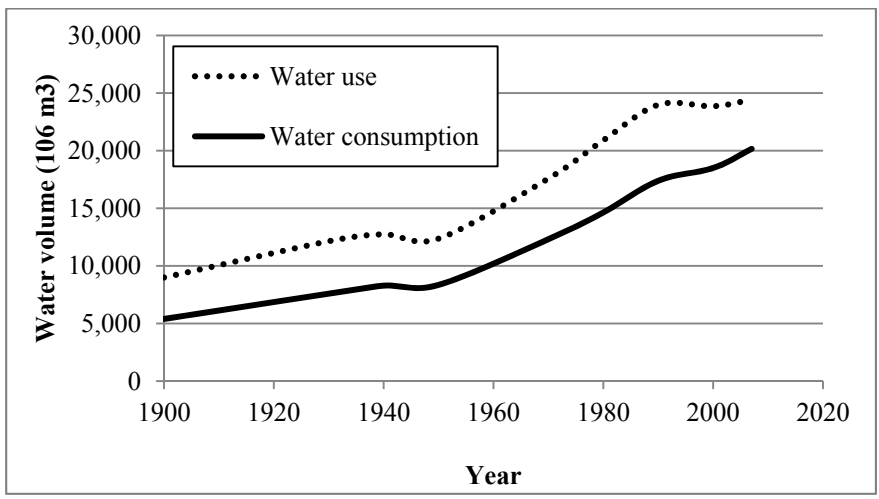

Figure 1: Water use and water consumption in Spanish agriculture.

To summarise, after billions of euros worth of public investment in modernizing irrigation, with water conservation as one of the main goals, far from saving water which could be put to other uses, irrigation systems are actually using and consuming ever-increasing amounts of water.

Irrigation modernization, it would appear, is an example of the rebound effect or Jevons paradox. More often applied to energy resources, the rebound effect states that improved efficiency in the use of a resource will probably lead to an overall increase in the use of that resource.

From this point of view, it would be misleading to relate the more efficient water use provided by the modernization of an irrigation system with water savings. Many studies point in this direction from different authors [2–8].

3.2 Case studies

Consumptive water use is the most appropriate indicator for analysing water consumption in an irrigation district. Table 2 summarises the available data on consumptive water use in the six irrigation districts whose modernization processes we analyse in this document. Each case is analysed in different ways by different authors (see Reference column), so the variation of water consumption is based on different criteria. In any case, there is a clear tendency to increase water consumption after modernization.

Table 2: Case studies.

	Water consumption per 10^4 m^2 of surface land (m^3)		Variation*	Reference
	Before modernization	After modernization		
Alto Aragón (Ebro basin)	4231	6025	+42%	[9]
Almudévar (Ebro basin)	5438	6422	+18%	[10]
La Campaña (Ebro basin)	5191	6134	+18%	[11]
Estremera (Tajo)	5948	6503	+9%	[12]
Guadalmellato (Guadalquivir)	8100	8389	+4%	[13]
Sector B-XII (Guadalquivir)	8300	8916	+7%	[13]
Bembézar MD (Guadalquivir)	7600	9500	+25%	[14]

*Estimation based on different criteria by different authors. See specific comments below.

The values shown in Table 2 should be clarified:

- *Alto Aragón Water Districts General Community (Ebro basin)*. Water consumption in pressurised irrigation is 42% greater than in surface irrigation. This increase can be an approximation of the effect of typical modernizations in the zone [9].
- *CR Almudévar (Ebro basin).* Consumptive water use has increased mainly because of increased evapotranspiration, due to the shift to a cropping pattern with greater water needs. It has also increased because of the evaporation and wind drift associated with sprinkler irrigation in this very windy region [10].

- *CR La Campaña (Ebro basin).* Consumptive use has increased due to expansion of the irrigated area, plus a shift to crops with greater water needs [11].
- *CR Estremera (Tajo basin).* In this case, more precise information was not available and the data used correspond to the increase in irrigation permits. We would expect consumptive use to rise more, due to reduced return flow [12].
- *CR Guadalmellato (Guadalquivir basin).* Total consumptive use has increased due to the shift to a cropping pattern with greater water needs, also influenced by subsidies for particular crops. Deficit irrigation could mitigate this increase [13].
- *CR Sector BXII (Guadalquivir basin).* Total consumptive use has increased due to the shift to a cropping pattern with greater water needs, also influenced by subsidies for particular crops. Deficit irrigation could mitigate this increase [13].
- *CR Bembézar MD (Guadalquivir basin).* Total consumptive use has increased due to the shift to a cropping pattern with greater water needs. Deficit irrigation could mitigate this increase [14].

4 Energy consumption in modernized Spanish irrigation systems

Most modernization projects in Spain change the water delivery system, from surface irrigation to pressurised systems.

In some, natural pressure can be used for the irrigation network, thanks to water being available at a higher level than the irrigated area. But most modernizations involve the installation of electric pump systems (or less frequently, diesel powered) to create the pressure needed for sprinklers or drip irrigation to work properly.

So while modernization projects mean lower costs in water and labour, the irrigators find themselves at the mercy of the energy market. To water the fields, the role of energy is now equivalent to that of water: it is an essential resource.

Thanks to modernization, irrigation agriculture has become a major customer of electricity companies, with its consumption increasing nineteen-fold from 1950 to 2007 (Figure 2). Consumption per hectare increased by a factor of 2.7 over the same period. At present, irrigation agriculture is the second largest electricity consumer in Spain, after ADIF (the company that manages high-speed rail), consuming 2.37% of the electricity produced in Spain. The sustainability of irrigation agriculture has a new enemy in its high energy consumption.

In general, irrigation modernization projects were planned considering the electricity prices applicable at the time, without too much thought given to the possibility of energy becoming much more expensive. Production was expected to increase more than energy costs, and on paper the investments were clearly profitable, especially given the substantial public funding available for modernization. But it is very difficult to forecast electricity prices and other variables over periods as long as those considered in the modernization projects.

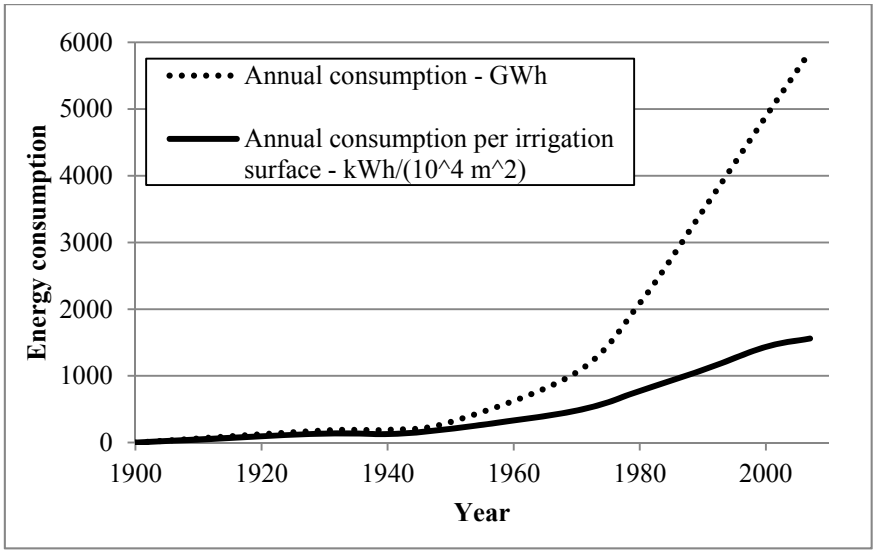

Figure 2: Energy consumption in Spanish agriculture.

Until July 2008, there was a special electricity rate for irrigation (the R rate) with stable prices set by the Ministry of Industry. But July 2008 brought the liberalisation of the electricity market and the extinction of the R rate. Since them, irrigation districts have had to contract a rate in a liberalised market. The rate is divided into two items: power and electricity. Both items have increased considerably in price in recent years.

To sum up, irrigation systems were modernized without giving much thought to the significant energy dependence they would introduce, in a climate of strong public support based on the need to save water, although water has not been saved and in fact more is being consumed. The short-term benefit to the irrigator may have been clear, but it is difficult to make medium or long-term predictions. The party which has benefited, and will continue to do so, is the power companies, for whom irrigation agriculture is a new captive client which needs enormous amounts of electricity to be able to water its crops.

5 Conclusions

5.1 Conclusions about water consumption

Associating water savings with reduced water use (or withdrawal) makes no sense from a hydrological viewpoint. For the modernization of an irrigation system to save water at the level of the catchment area, its consumptive use or consumption must be reduced. For example:

- Irrigating a smaller area.
- Farming crops which need less water.

- Applying deficit irrigation.
- Reducing non-recoverable runoff/percolation.
- Reducing non-productive evapotranspiration.

But generally, modernizations of irrigation systems in Spain have increased water consumption in irrigation agriculture, sometimes through counter-productive mechanisms:

- Increasing the effective irrigated area.
- Changing to cropping patterns with greater water needs.
- Eliminating deficit irrigation.
- Evaporation and wind drift losses in sprinkler irrigation.

Water use and water consumption in agriculture have increased continuously over the last century, by factors of 2.4 and 4 respectively, despite the efforts put into modernizing irrigation.

All the cases studied confirm an increase in water consumption after modernization: Almudévar (18%) and La Campaña (18%) in the Ebro basin; Estremera (9%) in the Tajo basin; and Guadalmellato (4%), Sector BXII (7%) and Bembézar MD (25%) in the Guadalquivir basin.

5.2 Conclusions about energy consumption

Many irrigation modernization projects basically consist of changing from a surface irrigation system (which is unpowered) to a pressurised irrigation system (which needs energy for sprinkler or drip irrigation).

These modernization projects have contributed significantly to the much greater consumption of energy by irrigation agriculture, which multiplied by 19 from 1950 to 2007.

Energy consumption in the modernized regions is now a significant running cost due to the sharp rise in electricity prices which began in 2006 and accelerated with the liberalisation of the energy market in 2008.

Some modernized irrigation districts question the advisability of the investment, as the economic viability of their farms is now threatened by the amount they have to pay for electricity, as well as other factors.

5.3 General conclusion

As a general conclusion, it can be observed that Spain's irrigation modernization policy, supported by billions of euros in public funding from Europe and the national and regional budgets, and justified socially by hypothetical water savings, has not in practice led to any water savings, but rather the reverse. No water resources have been freed up for environmental use, or any other kind. On the contrary, water consumption in irrigation farming has increased. Productivity in modernized farms has increased thanks to modernization, but their energy costs and the costs of recouping the investments have also increased in most cases. Thus, despite substantial public funding, in certain cases modernization can be a threat to the economic viability of a modernized farm, which may find itself in need of yet more public funding.

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