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The paradox of irrigation scheme modernization: more efficient water use linked to higher energy demand

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Abstract

In recent years, many modernization processes have been undertaken in irrigation districts with the main objective to improve water use efficiency. In southern Spain, many irrigation districts have either been modernized or are currently being improved. However, as part of the modernization process some unexpected side effects have been observed. This paper analyzes the relative advantages and limitations of modernization based on field data collected in a typical Andalusian irrigation district. Although the amount of water diverted for irrigation to farms has been considerably reduced, consumptive use has increased, mainly due to a change in crop rotations. The costs for operation and system maintenance have dramatically risen (400%) as the energy for pumping pressurized systems is much higher now compared to gravity fed systems used previously. Then a regional analysis in ten Southern Spain irrigation districts of the relationship between energy requirements and irrigation water applied has been carried out. Results show that to apply an average depth of 2590 m^3 ha, the energy required was estimated to be 1000 kWh ha^{-1}. A new approach is needed that involves efficient management of both water and energy resources in these modernized systems. Finally, some energy saving options are identified and discussed.

Additional key words: energy use; performance indicators; pressurized irrigation networks; Spain.

Resumen

La paradoja de la modernización de zonas regables: uso más eficiente del agua vinculado al aumento de la demanda energética

En los últimos años se han llevado a cabo numerosos procesos de modernización en comunidades de regantes con el principal objetivo de mejorar la eficiencia en el uso del agua. En el sur de España se han modernizado, o están en proceso, muchas comunidades de regantes, pero se han observado efectos diferentes a los previstos. En este trabajo se analizan las ventajas e inconvenientes de la modernización usando datos de campo obtenidos en una comunidad de regantes típica de Andalucía. Aunque la cantidad de agua destinada para el riego de las parcelas se redujo, el uso consuntivo de agua se incrementó, fundamentalmente debido al cambio de cultivos. Los costes de operación y mantenimiento del sistema aumentaron considerablemente (400%) ya que la energía requerida para bombear el agua a la red de presión es muy superior en comparación con la situación anterior. Posteriormente se analiza la relación entre el uso del agua y el consumo energético en diez comunidades de regantes del sur de España. Los resultados muestran que para aplicar una lámina media de 2590 m^3 ha^{-1}, la energía requerida es de 1000 kWh ha^{-1}. Por ello, en este tipo de redes, cada vez es más necesario manejar los recursos agua y energía de una manera eficiente. Finalmente se discuten diversas medidas de ahorro energético.

Palabras clave adicionales: eficiencia energética; España; indicadores de gestión; redes de riego a presión.

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Abbreviations used: BMD (right bank of the River Bembezar); ETc (crop evapotranspiration); IDAE (Spanish Institution for Diversification and Energy Savings); IPTRID (International Programme for Technology and Research in Irrigation and Drainage); MARM (Spanish Ministry of Agriculture and Environment); MOM (management, operation and maintenance); PEE (pumping energy efficiency); RIS (relative irrigation supply).

Introduction

The improvement of agricultural water management to increase crop productivity, reduce the influence of drought and promoting water conservation is one of the main objectives of current irrigated agriculture in Spain. Since 2002, the Spanish government has developed a National Irrigation Plan and an Emergency Plan for Modernization of Irrigation with the aim of saving 3000 Mm^3 of water per year (MARM, 2002 and 2006). These involved an investment of some M€ 7400, affecting about 2 Mha of the 3.5 Mha of existing irrigation area (Lecina *et al.*, 2010). The National Strategy for Sustainable Irrigation Modernization, Horizon 2015 aims to continue efforts to improve water management and promote sustainability of irrigation by pursuing energy efficiency (MARM, 2010). In 1980, surface irrigation accounted for 80% of the irrigated land, by 2009 it represented only 31%. Drip irrigation has changed over the same period from 2% to 46% and use of sprinkler irrigation has increased slightly (MARM, 2009a).

However, Corominas (2009) reported that whilst water use has reduced from 8250 $m^3\ ha^{-1}$ to 6500 $m^3\ ha^{-1}$ (21%) at a national level between 1950 and 2007, energy demand has increased from 206 kWh ha^{-1} to 1560 kWh ha^{-1} (657%). The Spanish Institution for Diversification and Energy Savings (IDAE) indicates that modernized areas require 2 kW ha^{-1} of power (Abadía *et al.*, 2008). It should be noted that the power cost increase has been in recent years more than 200%. During the last two years, energy tariffs for irrigation in Spain have also increased by 120% and a further 6% is expected. As total energy costs have significantly risen in recent years, modernization is sometimes an additional problem for farmers because it has led to an increase in water costs (Rodríguez Díaz *et al.*, 2009).

Other additional costs that arise after the modernization process are the amortization costs of the infrastructure and installation of irrigation systems and operating costs. The Spanish Ministry of Agriculture and Environment, in their study of cost-effectiveness analysis indicated an approximate annual cost of € 600 ha^{-1} each year to cover amortization charges and operating costs (MARM, 2009b).

One of the most worrying problems concerning to the irrigation sector is the energy cost, which is analyzed and discussed in this work in a systematic manner. The paper is structured in three parts: first, the impact of a typical modernization of an irrigation district (*e.g.* Bembézar MD) is analyzed; then the analysis is extrapolated at basin level using water and energy use data from ten irrigation districts in the Guadalquivir river valley; and finally, different energy saving measures are discussed, showing the potential savings that would be possibly achieved with each one. Thus this work offers a broad perspective of the current situation of the energy demand for irrigation supported by real data from irrigation districts and shows different alternatives for improvement.

The modernization process of a typical irrigation district. The case of "Bembezar margen derecha"

Many irrigation districts in Southern Spain are based on open channels networks to distribute water from the reservoir or main canal to the user. In most cases, these farmers use surface irrigation systems receiving a certain amount of water during fixed periods. Therefore, the so-called modernization process usually consists of replacing old open channel distribution networks by pressurized systems arranged to provide water 'on-demand' (Plusquellec, 2009). These new systems provide a better service to the user (Pérez Urrestarazu *et al.*, 2009), reducing water losses in transportation and distribution (hence, conveyance efficiency is improved) and enhancing the flexibility of the system.

Study area

Bembezar Margen Derecha (BMD) (right Bembézar river bank) is a typical irrigation district in the Guadalquivir river basin (Southern Spain). It covers an area of nearly 12000 ha, providing service to around 1300 users. In 2007, this irrigation district went through a modernization process resulting in a total investment of over M€ 43.7, which was 60% subsidized by the Andalusian regional government and the remaining paid by the farmers.

Before modernization, the open distribution network covered the entire irrigated area with one main canal and a secondary network. Water losses via conveyance were estimated to be approximately close to 25% (Rodríguez-Díaz *et al.*, 2008). More than 70% of the area used surface irrigation with only a small proportion using drip irrigation, usually where farmers had their own small reservoirs and booster pumps. They had to organize themselves in turns as the water was only available on arranged demand from May to September. The user paid a fix rate per irrigated hectare without any consideration of the volume of water actually consumed.

In 2007 the BMD's hydraulic infrastructure was replaced, converting it from a traditional open channel network to an on-demand pressurized system. Eleven new pumping stations were constructed along the main channel to supply water to each independent sector of the pressurized network. This network was designed to supply on demand 1.25 L s^{-1} ha^{-1} with a minimum operation pressure at hydrant level of 3.5 kg cm^{-2}.Water is now continuously available to farmers without the need for them to organize themselves in turns as was common practice before modernization. Rodríguez-Díaz *et al.* (2011) reported that 0.15 kWh m^{-3} and an average pressure head of 47 m are now necessary to supply water in BMD.

As pressurized water is available at the hydrant, drip is now the dominant irrigation method. Water is available from March to November and users are charged according to a mixed tariff pricing system: costs related directly with water consumed (mainly energy costs) are considered per unit of volume while other expenses such as maintenance, operation and management costs are paid at a unit rate based on irrigated area. Amortization costs for the water supply network and on-farm irrigation systems are paid by each farmer and not managed by the irrigation district.

Methodology

Performance indicators are ratios that relate variables (*i.e.* irrigated area, volume of irrigation water applied or productivity) in such a way that a large amount of information can be reduced to a single number. Although they have been widely used for irrigation water use assessments, in most of these previous experiences, indicators were applied in comparative analyses of different irrigation districts within a single year. However these indicators were rarely applied to analyse the impacts of system modernization.

In this work, the indicators proposed by the IPTRID (International Programme for Technology and Research in Irrigation and Drainage) (Malano and Burton, 2001) and adapted to the Andalusian irrigation districts by Rodríguez-Díaz *et al.* (2008) were calculated in BMD irrigation district for eight irrigation seasons: six before modernization (from 1996 to 2002) and two after the upgrade (2008 and 2009). Then the averages before and after the modernization were then compared.

Improvements in efficiency of water services and water use

Is water used more efficiently after modernization? This question does not have a straightforward answer and depends largely on the perspective and scale of enquiry (field, irrigation district or basin). The total water diverted for irrigation in this district was reduced from 8000 m^3 ha^{-1} to 4700 m^3 ha^{-1} after modernization, so approximately 40% less was diverted from the reservoirs. The main reason for that could be improvement in conveyance efficiency, with less water losses in distribution, and the changes in irrigation system (surface to drip). Also, the new situation has enabled farmers to apply the right amount of water only when needed, due to improved system flexibility, avoiding fixed irrigation schedules.

Another explanation for the reduction of water supplied is price. Rodríguez-Díaz *et al.* (2008) observed that in irrigation districts in southern Spain where the costs were charged in part per volume of water, less water was diverted per area of irrigated land. In BMD, farmers shifted from no charge per water applied to a rate around € 0.027 m^{-3}.

Hence, it seems that the local farmers' practices have changed towards a strategy of deficit irrigation. This can be observed by looking at the values for Relative Irrigation Supply (RIS) which is the ratio of the total annual volume of water diverted for irrigation and the volume of crop irrigation requirements (difference between crop water requirements and effective rainfall). Whilst average RIS before modernization was 1.36, in the two years after this process the RIS became 0.68, meaning that the irrigation requirements were not being completely met. RIS values under 1 are typical under deficit irrigation scheduling (García-Vila *et al.*, 2008).

On the other hand, the cropping pattern has also changed following modernization. Citrus, maize and cotton are still the major crops in this district (representing between 70 and 80% of total irrigated area). However, the area devoted to cotton has dramatically reduced (from 24 to 5%) while citrus has increased considerably (from 15 to 46%). In general, farmers tend to move to more profitable crops, trying to offset the higher costs of the new system with an increase in farm income.

Negative impacts

This modification of crop rotations often leads to an increment in consumptive use of water (Playán and Mateos, 2006; Perry *et al*., 2009), that is, the water that is actually lost to the atmosphere and cannot be recovered. Therefore, it is not entirely true that a modernization process can lead to water savings. There is also a reduction in return flows. For example, in BMD, both irrigation requirements (highly influenced by rainfall) and crop water requirements or theoretical crop evapotranspiration (ET_c) increased by around 20% after modernization (Figure 1). While the irrigation water supply exceeded the irrigation requirements by nearly 40% before modernization, now it represents only 70% of irrigation needs. This means that previously much water was not used by the crops and therefore returned to the system and now with deficit irrigation, those return flows are significantly reduced. Few studies have analyzed the situation before and after modernization. For example, Lecina *et al.* (2010) compared the effect of modernization under various scenarios, using hydrological and economic indicators. Their results are consistent with these findings and indicate that irrigation modernization will increase water depletion and the consumptive use of water.

Another important issue to consider is the financial impact. In most cases a modernization process has led to an increase in total Management, Operation and Maintenance costs (MOM). Figure 2 shows the MOM costs and the productivity for BMD. Regarding MOM costs related with the volume supplied, before modernization they represented € 0.01 m^{-3}, whereas currently this unit cost has increased by a factor of nine (€ 0.09 m^{-3}). Thus, energy costs represents 30% (€ 0.03 m^{-3}) represent the main contributor to total MOM costs after modernization; prior to modernization these costs were negligible. There is also an increase in costs per unit area: MOM costs represent now almost four times the value prior to modernization (before modernization the MOM costs were approximately € 100 ha^{-1}, now they are in excess of € 400 ha^{-1}). The amortization costs which represent an additional cost of € 250-300 ha^{-1} for both, distribution network and on-farm irrigation system, are also not included.

On the other hand, productivity (total value of agricultural production in € per volume supplied) has nearly doubled from € 0.47 to 0.85 m^{-3} though if these outputs are referred to unit area the difference is not so apparent. Taking into account these numbers is is clear that while farmers originally needed 2.6% of their income to cover water costs, in the current situation, this ratio has now increased up to 10%. The main reason for this increment is the high energy consumption required to pump and distribute water which forces the farmer to think about the profitability of irrigating their crops. Therefore, in BMD as in other many districts, energy has become an important cost that limits irrigation more than water availability.

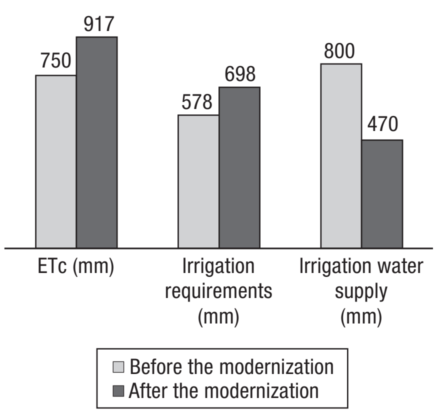

Figure 1. Crop water requirements, irrigation requirements and water supply in BMD irrigation district before and after modernization.

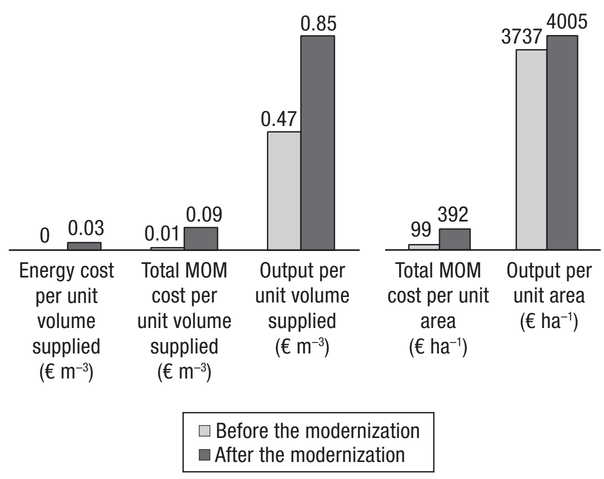

Figure 2. Costs and productivity per unit area and volume supply in BMD irrigation district before and after modernization. MOM: management, operation and maintenance

Upscalling the energy problem in pressurized systems

Ten typical Andalusian (Southern Spain) irrigation districts were studied to visualize the efficiency of the use of water and energy simultaneously at a regional scale. For that, performance indicators were calculated for the 2006-07 irrigation season (Rodríguez-Díaz *et al*. 2011). Collectively, the selected irrigation districts cover a total irrigated area of more than 66,000 ha representing a wide variety of crops. All of them are arranged on-demand 24 h day^{-1} with pressurized water available to farmers. A detailed description of the water and energy performance indicators analysis is available at Rodríguez-Díaz *et al.* (2011).

The selected indicators and their averages, value ranges and standard deviations for different measures of energy and power consumption are shown in Table 1. The average energy per irrigated area needed to supply the 2589 m^3 of water applied was around 1000 kWh ha^{-1} and the maximum value registered almost doubles that figure. When analyzing energy consumption per cubic meter of water pumped, the average was 0.41 kWh m^{-3} but with significant variability between districts. This variability in consumed energy can be explained by the difference in pressure head at the pumping stations. While the average was around 90 m, the maximum value was 168 m implying a large component of expenditure on energy pumping. In terms of power consumption, in this study the average power was slightly lower (1.56 kW ha^{-1}) than the average power of 2 kW ha^{-1} reported by IDAE (Rocamora *et al*., 2008) but the maximum value reached was 3.48 kW ha^{-1}.

The pumping energy efficiency (PEE) is defined as the relationship between the hydraulic power given to the water flow and the consumed electricity, so it takes into account the efficiency of the pumping station(s). Although the average PEE was around 60% the minimum value was close to 30% and maximum was around 75%. These low efficiencies in some districts indicate that significant energy savings that could be achieved if the hydraulic infrastructure was improved.

When analyzing the energy consumption in irrigated areas, it is important to highlight that in the Mediterranean regions, where rainfall and crop water demand do not coincide in time, irrigation is not equally distributed throughout the year. Therefore, irrigation demand is highly concentrated in few months, usually from May to August, and consequently, during this period, energy consumption is around 70% of the annual consumption.

The analyses confirmed that energy is the most important budget item in the MOM costs, as has been shown in the BMD study. In average, if water costs were € 0.10 m^{-3} (they range from € 0.04 to 0.18 m^{-3}), energy represents the biggest expenditure with almost 40% but in some extreme situations this ratio rose to 65%.

Finally a clear relationship between energy required for pumping and irrigation efficiency was found (Table 2) where the annual energy consumption per unit of irrigation water and the RIS are shown. Although there are exceptions, it can be observed that in districts with smaller energy requirements, the RIS was bigger and when more energy was needed for pumping the water, less irrigation water was applied. In most of the evaluated districts, RIS was under 1 which implies deficit irrigation practices. Actually in these pressurized systems it is quite common that even in the driest years farmers never use their full annual water rights and

Table 1. Average, range and standard deviation of the selected indicators for ten irrigation districts

Irrigation district	Average	Range	Std dev.
Annual irrigation water supply per unit irrigated area (m^3 ha^{-1})	2589	5138-1435	1079
Pressure head (m)	89	168-47	40.4
Annual energy consumption (MWh)	4647	9148-855	2797
Energy consumption per unit of irrigated area (kWh ha^{-1})	1003	1901-455	418.1
Energy consumption per unit of irrigation water supplied (kWh m^{-3})	0.41	0.89-0.15	0.2
Power per unit of irrigated area (kW ha^{-1})	1.56	3.48-0.88	0.8
PEE[1] (%)	58	85-31	16.1
Total MOM[2] cost per unit volume supplied (€ m^{-3})	0.10	0.18-0.04	0.04
Energy to total MOM[2] costs ratio (%)	36.4	65.3-16.1	15.1

[1]PEE: pumping energy efficiency. [2]MOM: management, operation and maintenance.

Table 2. Irrigated areas, relative irrigation supply (RIS) and energy consumption per unit of irrigation water supplied for ten irrigation districts

Irrigation district	Irrigated area (ha)	RIS	Energy consumption per unit of irrigation water supplied (kWh m^{-3})
F. Palmera	5611	0.41	0.73
Palos	3343	3.70	0.25
Las Coronas	450	0.96	0.34
El Villar	2726	0.24	0.89
Genil-Cabra	16100	0.85	0.33
M. D Bembezar	11262	0.85	0.15
P. Guadiana	4520	0.78	0.33
P. Bancos	1336	0.46	0.53
Los Dolores	4500	0.50	0.39
C. Noroeste	8383	0.51	0.17

every year their water consumption is being reduced (Rodríguez-Díaz *et al.*, 2007). This effect is quite common in Andalusian irrigation districts with high elevations devoted to low-value crops. Crop revenues are unable to provide a reasonable profit to farmers and their choice is not to irrigate, or apply the minimum amount of water to avoid losing the entire crop.

Potential energy saving measures

In pressurized systems, energy is now becoming a major factor influencing cost as important as others such as water availability, rainfall or evapotranspiration. In this context, recent international research has highlighted the need to optimize both water and energy efficiency. For example, the California Energy Commission (CEC) launched the "Agricultural Peak Load Demand Program" with the main objective of reducing peaks in energy consumption in irrigation districts (ITRC, 2005); Moreno *et al.* (2009) focused on the improvement of energy efficiency at pumping stations and the determination of optimal pump curves; Pulido Calvo *et al.* (2003) developed a pump selection algorithm for reducing energy costs in irrigation districts and Vieira and Ramos (2009) introduced a water turbine in the network in order to use any excess available hydraulic energy. In Spain, the IDAE has developed a protocol where some of the most common energy saving measures for pressurized systems are identified (Rocamora *et al.*, 2008). Some of the proposed actions by several authors are summarized below.

Irrigation network sectoring

Usually the pressure head at the pumping station is set to supply pressurized water to the highest pressure demanding hydrant while other hydrants receive an excess of pressure that must be removed by hydraulic valves. Network sectoring consists in grouping hydrants with similar energy requirements. Then the network is operated in turns and each sector is enabled a few hours every day only and the pressure head is set according to the worst hydrant (pressure demand) in the sector. Thus, significant energy savings can be achieved when the lower pressure demand hydrants irrigate (Jiménez-Bello *et al.*, 2010; Moreno *et al.*, 2010a). With this measure irrigation districts should go back to a semi-arranged model. However this change does not imply the lack of flexibility that existed some years ago when farmers had to apply for water even a few days in advance, but it could mean reorganizing demand according to homogeneous pressure groups of hydrants.

Rodríguez-Díaz *et al.* (2009) modeled the potential effects of the sectoring measures in the algorithm OPTIEN that was applied to the Fuente Palmera irrigation district (Spain). Results showed that savings of more than 20% in energy could be achieved in the peak demand period for the current water demand levels, by operating the network in sectors and concentrating irrigation events per sector into 12 h rather than 24 h. Thus farmers would lose some flexibility but in return would obtain significant savings in water costs. However a detailed analysis for every irrigation district is necessary as the optimum sectoring is highly dependent on the network's topology and monthly water demand (Carrillo-Cobo *et al.*, 2011).

Critical points detection

Critical pressure points are those with special energy requirements, usually caused by their distance from the pumping station and/or their elevation, which determine the minimum pressure head required at the pumping station. Thus, sometimes a few points are responsible for large fractions of the total pressure head at the pumping station. In these cases other strategies such as booster pumps or changes in pipes size, would lead to important energy savings. In Fuente Palmera irrigation district, Rodríguez-Díaz *et al.* (2009) showed that 15 critical points (from a total of 85 hydrants) were responsible for almost 15 m of the total pressure head.

Also, if booster stations were installed only for the three most critical points, the pressure head at the pumping station could be reduced by 10 m, implying energy savings of 3,000 kWh day^{-1}, approximately in the peak demand period.

Improving the energy efficiency of the pumping system

Usually pumping stations are designed to provide water at the peak demand period. However, as this period takes only 2 or 3 months, and the rest of the year the demanded flows are much lower, and therefore the pump operation point is not the optimum to maximize their PEE. By installing new smaller pumps, more appropriate for flows demanded during off-peak periods, and using variable speed pumps, it is possible to increase PEE significantly and therefore reduce energy consumption (Moreno *et al.*, 2009).

Irrigation systems at farm level

In theory more efficient irrigation systems and better irrigation scheduling lead to significant simultaneous energy and water savings. Better irrigation scheduling techniques make it possible to apply the right amount of water when needed, avoiding excess applications. With more efficient irrigation systems the water is applied in a more efficient way and therefore water losses are reduced. Thus, both measures contribute to reduce both water diversion for irrigation and total energy requirement for pumping. Also low pressure irrigation application systems are in widespread use nowadays so many can work with less than 10 m pressure. However, it is important to remember that for most farmers' the concept of water efficiency is linked to maximizing their farms' economic productivity rather than saving water per se, except perhaps when their own allocated resources may be inadequate (Knox *et al.,* 2011).

Jackson *et al.* (2010) explored the links between irrigation water use and energy consumption in Australia, and the influence of water source and irrigation method on these relationships. They compared the energy requirements for surface irrigation, drip irrigation and centre pivots both for surface and groundwater. They concluded that pressurized irrigation methods reduce energy consumption in regions where groundwater is used, because more efficient irrigation systems reduce the pumped water, while the opposite can be true in surface water regions. For them, in surface water regions investments should target improvements to gravity-fed irrigation systems to improve water use efficiency and avoid increments in energy consumption. Only in groundwater regions, the adoption of pressurized irrigation methods should be promoted as they offer an opportunity to reduce both water and energy inputs.

Optimal contracting with the energy supplier

Due to the liberalization of the Spanish Electricity Market on 1st January 2008, when special tariffs for irrigation disappeared, irrigation districts now have to use the same tariffs as the rest of the industry. During June and July, when peak irrigation demand occurs, most of the operating hours are included in the expensive tariff period (Carrillo-Cobo *et al*., 2010). But in this new market, the irrigation districts can negotiate directly with their energy suppliers to obtain better contracting conditions. In Castilla-La Mancha (Region of Spain), Moreno *et al.* (2010b) concluded, after analyzing energy saving measures for 15 irrigation districts, that the estimated economic savings can be higher than the energy savings mainly due to optimal contracting with the energy supplier, with irrigation during the off-peak hours and energy rates negotiation or the power factor correction. However, these measures lead to economic savings but not to proper energy savings. It is necessary to conduct an energy audit to detect which of these measures are most appropriate in each situation related to the network characteristics (Abadía *et al*., 2008; Carrillo-Cobo *et al.*, 2010).

Conclusions

In recent years many irrigation districts have been facing the challenge of how to improve efficiency in their water distribution systems. In Spain the traditional way to achieve this has been the replacement of open channel distribution networks by on demand pressurized networks. However this may lead to an increase in consumptive use of water because of the switch in cropping to more water demanding crops.

This effect has been evaluated in the particular case of Bembezar MD. Although results show a reduction of approximately 40% in the unit water diverted for irrigation, the consumptive use of water (ET_c) has increased considerably due to the adoption of new crop rotations, mainly citruses. Thus, most of the decrease in water consumption corresponds to reductions in return flows and not to water savings per se. Total MOM costs have also dramatically increased after modernization, typically increasing fourfold. After modernization, energy represents 30% of total MOM costs.

The close relationship between irrigation and energy was evaluated in other ten irrigation districts where to apply an average depth of 2589 m^3 ha^{-1}, around 1000 kWh ha^{-1} were required. Power requirements per unit of irrigated area were 1.56 kW ha^{-1}. As energy represents an important percentage of the total water costs (around 40%), nowadays water use in agriculture and energy efficiency cannot be considered independently. Actually, results showed that usually high energy requirements have led farmers to apply less water than the maximum theoretical irrigation needs, thus applying deficit irrigation as strategy to maximize profits versus the traditional maximization of yield applied when the resource cost was smaller.

There are necessary options for improving the efficiency in the energy use, in this work some energy saving measures have been presented and discussed. However a particular analysis is necessary for every case in order to select the optimum measures.

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