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Energy savings, cogeneration of electricity and water use in rural areas: Case study of Algarrobo irrigation community

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This study analyzed the effects of irrigation modernization on energy savings, cogeneration of electricity and water conservation, using the Algarrobo irrigation community (Spain) as a case study. Traditional surface irrigation systems and modern sprinkler systems occupy 73 and 27% of the irrigated area, respectively. Virtually all the irrigated area is devoted to field crops. Nowadays, farmers are investing on irrigation modernization by switching from surface to sprinkler irrigation because of the lack of labour and the reduction of net incomes as a consequence of reduction in European subsidies, among other factors. In this study, measures for energy savings, cogeneration of electricity and water management were proposed in order to improve the economic productivity of the community.

Key words: Irrigation community, hydraulic turbine, energy savings, renewable energy.

INTRODUCTION

The use of systems capable of generating clean and sustainable energy is having in recent years a huge growth in order to reduce the problems of climate change and resource depletion facing our planet. These systems are taking on more importance following the decision of the European Community, together with other countries to accept obligations to reduce emissions that cause climate change, as outlined in the Kyoto Protocol.

The use of the available potential energy of water between an upper and a lower height, had application for centuries: the water mills made possible the use of force provided by nature to perform different tasks.

Since the late eighteenth century, the use of water resources has been the most common electricity production. However, there has not been until recent years when added value has been ascribed for other types of energy production, the environmental benefits of its low impact from the emission of pollutants to the atmosphere, as opposed to coal combustion or oil.

On the other hand, some Irrigation Communities shows that, certain pumping systems are oversized, perhaps because they were built at a time when duties of water were much higher than the current ones, or because they are sized to supply 100% of the irrigable area and annually for various reasons, only irrigate a less percentage than the maximum irrigable. In any case, although 100% of the irrigable area was irrigated, they are always sized to the time of peak demand, usually one or two months a year, running well the rest of the year below its optimum operating point, may be even lower if the irrigated area is much less than the irrigable.

The design of the distribution network is a very important factor in providing efficiently irrigation water from the energy point of view. The topography determines the network design. It is very common that, there are significant slopes in the area irrigated by an

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irrigation community. In designing the distribution network, it is important to define various irrigation sectors so that each of them supplies the hydrants with uniform height. Thus, each pump unit consumes the energy demanded by the sector that supplies water and an efficient use of energy is obtained.

The efficiency concept has traditionally been used to design irrigation systems and to schedule irrigation. However, several authors have pointed out (mainly since the 1990s) that this concept is not appropriate for assessing the hydrological impact of irrigation in a basin (Willardson et al., 1994; Seckler, 1996; Perry, 1999; Seckler et al., 2003; Jensen, 2007; Perry, 2007). Efficiency does not take into account issues such as water reuse, the distinction between total water use and water consumption, the influence of location of use within the basin, and water quality. These issues are particularly important for water management in a context of water scarcity. The above mentioned authors, as well as others (Huffaker, 2008; Ward and Pulido-Velázquez, 2008), reported examples of misunderstandings in water management practices and water conservation programs due to an inadequate use of the efficiency concept.

This study applies the water accounting and water productivity concepts to the assessment of irrigation modernization in terms of water conservation, energy savings, and generation of electricity with hydraulic energy. The analysis has been applied to the case study of the irrigation community of Algarrobo, representative of large irrigation communities in interior Spain and in similar semi-arid areas. The objective of this work is to contribute to the optimization of water use in irrigation communities. The application of water accounting concepts to irrigation modernization constitutes another objective of this study.

MATERIALS AND METHODS

The irrigation community of Algarrobo, under study is located in the Axarquía (Málaga), and cover the towns of Algarrobo, Arenas, Sayalonga, and Vélez-Málaga (Spain). The irrigable area of the community comprises about 757 divided into four sectors.

Algarrobo has a subtropical climate. It has one of the warmest winters in Europe, with average temperatures of 17°C (62.6°F) during the day and 7 to 8°C (45 to 46°F) at night in the period from December to February. The summer's season lasts about 8 months, from April to November, although also in remaining 4 months temperatures sometimes reach around 20°C (68.0°F).
The current crops of the area are distributed as follows:

(i) Tropical crops: avocado, mango, lychee, palms .- 100 ha,
(ii) Greenhouse: tomato, pepper, melon, etc. - 100 ha,
(iii) Outdoor-Vegetables: potato, strawberry, onion, beans, peppers, etc.- 350 ha,
(iv) Other woody crops: 207 ha.

The hydraulic irrigation scheme presented by this community is this: take water from Algarrobo River, leaving an ecological flow, at an elevation of 185 m. and carried through a natural pressure driving to a tank in Sector 2, which has a storage capacity of about 17000 m^3 and whose elevation of entrance is located at 156 m. In this tank also comes through pumping, the flow produced by the Waste Water Purifying Station of Algarrobo and water from the La Viñuela reservoir. From this tank, Sectors 1 and 2 will be directly irrigated, that cover 370 ha, and water is pumped to a tank located in Sector 4 (21000 m^3 capacity and 296 m elevation) to supply 387 has of Sectors 3 and 4. The last one has a higher pumping energy cost for the community and is required to raise a flow of 368 l/s for 16 h to meet the water needs of the Sectors 3 and 4.

This study seeks an improvement in the water use of Algarrobo River, energy savings in pumping the community and the generation of electricity from clean energy sources taking advantage of the steep topography of the area. We analyzed the average daily flows of the river over the past 25 years, and the ecological flow required. The ecological quality of rivers must be maintained by maintaining a minimum flow. Rivers must not dry-up or have their physical regimes significantly altered in order to conserve the hydrological and ecological functions of their drainage networks. This question must be borne in mind when planning and managing the water resources, especially in semi-arid zones. Ecological discharges, which take place as a result of the aquifer discharges in a natural regime, can be artificially maintained by reservoir management. The determination and mapping of ecological flows for semi-arid areas of EEA is, therefore, considered to be of paramount importance (INAG, 1995) (Figure 1).

Furthermore, we studied the availability of land for the inclusion of a storage ponds to allow better use of water resources of the Algarrobo River and evaluated from technical, economic and financial point the possibility to install a hydraulic turbine station that generates electricity from the difference in height between the ponds above mentioned and the current diversion dam that the irrigation community has.

RESULTS AND DISCUSSION

The results obtained from the analysis were as follow; The location of a new diversion dam located at elevation of 350 m. in Algarrobo River would allow gravity filling of two storage ponds (140000 m^3 and 50000 m^3) located at an elevation of 340 m. that have previously been calculated according to the analysis of the water needs of the sectors and the average daily flows of the Algarrobo River. From these ponds, it would be allowed to take water by gravity to the tank of Sector 4 so that the crop water requirements would be fulfill in Sectors 3 and 4 of the irrigation area, avoiding the pumping from sector 2 to sector 4 for a large part of the year, because increasing the elevation of the diversion dam would allow to fill the sector 4 pond using gravity.

On the other hand, there is the central location of Pelton turbines that allow cogeneration of electricity taking advantage of the steep topography of the land (150 m of drop), so that the water needed for irrigation of Sectors 1 and 2 is diverted by this station and then injected into the current diversion dam following the hydraulic scheme used nowadays by the irrigation community.

The nominal characteristics of the turbine are:

(i) Net head (m.): 155.00,
(ii) Nominal flow (m^3/seg.): 0.45,

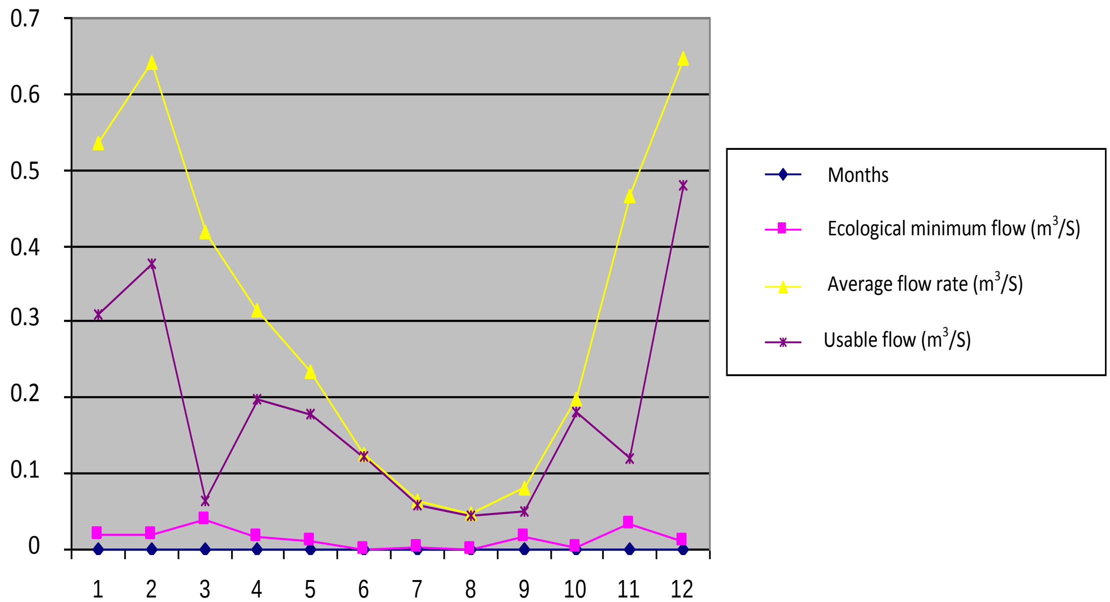

Figure 1. Average flow rates of Algarrobo River.

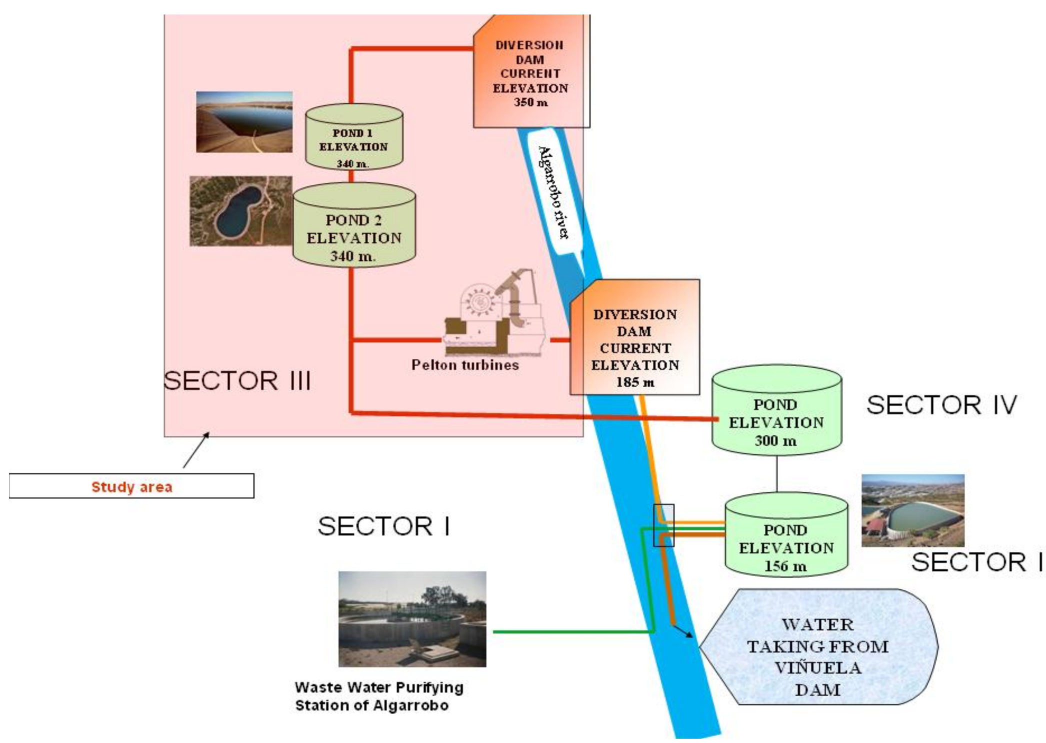

Figure 2. General diagram of the study.

(iii) Power (kw.): 604,00,
(iv) Spindle speed (rpm.): 750.00,
(v) Runaway speed (rpm.): 1450.00,
(vi) Operating hours (h): 2800.00,
(vii) Electricity production (kw/h.año): 1691200.00.

The aim is also to provide the excess water to the La Viñuela reservoir (main water resource of the region of Axarquia) by using the water intake of the community, shown in Figure 2. These improvements in the irrigation community mean incomes and savings for the community

Table 1. Savings and incomes of the alternative.

Concept	Volume (m^3)	Electricity production (kwh/year)
Energy saving pumping	2454447.29	
Water provided by La Viñuela reservoir	4000000.00	
Electrical cogeneration		1691200.00

which bears the cost of necessary works to carry out the purpose of this study, leading to improve the management of the main water resource (Algarrobo River), an energy saving for most of the year and the cogeneration of electricity from clean sources (Table 1).

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