Efficient water use in irrigated agriculture: An exploratory study of fruit cultivation in southeast Spain

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Abstract:

Water is a limited resource, which requires careful, efficient, environmentally friendly management to meet the needs of agriculture, industry, and the public. Good public management and administration of this resource is therefore paramount. Under the EU Water Framework Directive, the Member States of the European Union are set to undertake measures to promote the efficient, sustainable use of water across Europe. This article presents a study of the Vega Baja del Segura region of Alicante in southeast Spain. This region comprises the agricultural units (unidades de demanda agrícola, UDAs) 46, 48, and 51, as defined by the Segura basin project (Proyecto de la Cuenca del Segura, PCHS). Within these units, farmers employ numerous irrigation techniques to cultivate a variety of crops, predominantly citrus fruits. The aim of this research is to determine the efficiency of water usage in fruit cultivation. Questionnaire responses from local farmers, irrigation communities (Comunidades de Regantes), and water-management courts (Juzgados Privativos de Agua) were analysed to achieve the research aims. Analysis of these responses yielded the following key findings. First, agricultural business owners in the area are predominantly male older adults. Second, farming in this area is experiencing a lack of involvement from younger generations. This acts as a barrier to investment in new irrigation technologies in the county, where smallholdings prevail over larger farms. Drip irrigation systems are used by 49% of respondents, especially citrus fruit farmers. According to indicators used to reflect production efficiency in terms of manpower, the cultivation of lemons is the most efficient fruit cultivation process in the region. In terms of water usage, the most efficient fruit cultivation is pomegranate farming.

Keywords: Efficiency indicators, Spain, water use

1. Introduction

Water is a scarce, limited resource, and it is an essential commodity for many of life’s basic needs. Water must therefore be efficiently managed, and responsibility for its management, administration and regulation should lie in the hands of the public administration. The EU Water Framework Directive (WFD) stipulates that Spain must undertake the following actions: 1) perform an exhaustive analysis of the characteristics of each region; 2) conduct a study of the effects of human activity on the state of surface and ground water; and 3) carry out economic analysis of water usage (Directive 2000/60/CE).

The EU’s objective is thus to ration the use of resources, with a particular focus on the use of scarce or limited resources. The EU also aims at reducing the use of resources that may cause environmental pollution, such as fertilizers or pesticides. Spain is currently in the process of revising and approving its water laws to comply with these EU directives.

Robust estimates predict that climate change will be responsible for an average drop of between 10 and 20% in the volume of water flowing into Spain’s basins. Since 2004, the state of Spain’s water supplies has been getting steadily more precarious, with the severest effects being felt in southeast Spain and in Mediterranean coastal regions (MAGRAMA,
The adoption of technological innovations in irrigation in these regions is therefore of great interest, and may enhance the efficiency of water use and promote technological change (Alcón, 2007).

The region under study is the most southerly county within the Valencian Community (Comunidad Valenciana). The county is Vega Baja del Segura, which has a total area of 957.73 km² and comprises 32 municipalities. The Valencian Community is one of 17 autonomous communities (comunidades autónomas) that constitute the nation of Spain. It is located in the southeast of the Iberian Peninsula and comprises three provinces: Castellón, Valencia (the regional capital), and Alicante. Our study focuses on the province of Alicante.

Agricultural activity accounts for 674,563 arable hectares; 29% of the region’s available terrain. Of this arable land, unirrigated land covers an area of 341,455 hectares, whereas irrigated land accounts for 333,108 hectares. The regional distribution of land dedicated to agriculture is as follows: 22% in Castellón, 27% in Alicante, and 51% in Valencia. Citrus cultivation accounts for 31% of the Valencian Community’s total farming, other fruits, both irrigated and unirrigated, make up 24%, olive cultivation accounts for 16%, cereals 7%, wine 13%, and vegetables 3%. The distribution of the economic contribution of each of these crops, however, is quite different. Citrus fruits supply 50% of the total economic output of agricultural activity in the Valencian Community, versus just 10% from all other fruits. Vegetables, including flowers and plants from nurseries, represent 32% of the total value. Wine and grape juice, olive oil, and cereals represent 2.5, 2.0, and 2.6%, respectively (Valencian Government, 2011).

Irrigation in the Valencian Community has a somewhat unusual history, but it follows the general tendency common to Spain as a whole. Today, a third of the irrigation within the Valencian Community is gravity irrigation. The remainder is localized irrigation. Irrigation occupies 7.8% of the arable surface area in the Valencian Community (ESYRCE, 2013).

The county of Vega Baja de Segura spans the final stretch of the River Segura and the southernmost part of the hydrographic region of the River Júcar. The county covers the region from Orihuela to the mouth of the Segura, where it meets the Mediterranean Sea in Guardamar del Segura (Alicante). Agricultural production in this county is of a very high quality and is intensely competitive. Despite this, the region’s traditional industry, agriculture is nonetheless being overtaken by other sectors, with the scarcity of water emerging as a key factor in this shift. Currently, 67% of the arable area relies on irrigation systems. A total of 32,000 hectares are irrigated versus 16,000 hectares of unirrigated land. In this area, smallholdings yield the majority of the agricultural produce: 76% of agricultural estates cover less than five hectares. The main cultivation, in terms of area, is in trees (22,900 hectares). The rest of the land is devoted to vegetables and plants. In spite of these great swathes of land covered by trees, variety is limited. Citrus trees (lemon, orange, and mandarin) are the main trees grown in the area (INE, 2009).

The guidelines that regulate the use of water in the county are set forth in the Segura basin plan, which dates back to 1998 but whose latest draft (2013) is currently pending approval. The hydrographic region of Segura arranges irrigation areas into agricultural units (unidades de demanda agrícola, UDAs). The land within aUDA has common features, which means that UDAs are differentiable, manageable units. Differentiation may be because of the origin of the region’s resources, its administrative conditions, the type of irrigation employed within the unit, its hydrological similarity, or strictly territorial reasons (CHS, 2013). According to the latest version of the Segura basin plan, the UDAs that constitute the Vega Baja are 46, 48, and 51. UDA 46 corresponds to the parts of the Vega Baja del Segura that fully adopt historical and traditional irrigation techniques. UDA 48 comprises irrigation areas that arose as a consequence of the Decree of the 25th of April 1953, which made it possible to apportion water resources to irrigation systems created post-1933. Finally, UDA 51 corresponds to areas with irrigation systems that draw their water from wells in the Vega Baja. Irrigation in UDA 46 is almost completely (95%) gravity fed. In UDA 48, 60% of irrigation is drip irrigation, and the rest works by gravity. Similarly, in UDA 51, the majority (85%) is also drip irrigation.

This research presents a study of the efficiency of water usage for fruit cultivation in southeast Spain. The study took place in the county of Vega Baja del Segura, a region whose agricultural industry is based around smallholdings. Our main research aim is to identify the crops with the most efficient cultivation in terms of water resource management.
2. Materials and methods

The study was exploratory, and used survey methodology to gather data from farmers and water users in the area under study. We defined water users as people able to provide direct, trustworthy information on water and irrigation management in the area. We gained direct access to local farmers from census data held in the records of the irrigation communities (Comunidades de Regantes) and water-management courts (Juzgados Privativos de Agua), the entities responsible for water allocation.

The questionnaire sent to farmers comprised five main sections: farming, the type of irrigation and water consumption, technology use, socioeconomic aspects and its links to farming, and environmental concerns. The questionnaire had 40 questions. Data collection took place in July 2013, and 35 farmers responded.

From the survey data, we calculated the production indicators used to measure the efficiency of water usage. Table 1 offers a description of these indicators.

<table>
<thead>
<tr>
<th>Gross margin</th>
<th>Net margin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross margin / amount of water employed in gravity-fed irrigation</td>
<td>Net margin / amount of water employed in drip irrigation</td>
</tr>
<tr>
<td>Gross margin / volume of water supplied by irrigation communities to agricultural farming</td>
<td>Net margin / manpower needed in the cultivation process</td>
</tr>
</tbody>
</table>

3. Results and discussion

Results show that the farming population is composed of older adults, with 43% of the respondents aged 60 years old or more. The percentage of older adults in the farming population tends to increase over time: In 1999, the percentage of agricultural workers over 60 in Alicante was 31.6% (Bernabé, 2003). Only 6% of respondents were female, which implies a lack of participation from women in business decisions.

The percentage of the active population that sought to move into other manufacturing sectors or construction was significant in the years leading up to the recession of 2008. This has created a shortage of workers from younger generations, who preferred to seek employment in more attractive sectors. The current economic and financial situation is driving some individuals to return to agriculture, and it is conceivable that the proportion of agricultural workers aged between 35 and 45 could rise in the future.

The majority of farmers in the Vega Baja del Segura, especially those working in fruit cultivation, work full-time. Around three quarters are the owners of the land they work on (more than 75%). The education level of these farmers is not high. Nearly half (47%) completed only primary studies, and very few have received higher education (21%). Half of the respondents (49%) stated that they use drip irrigation.

The arable land in the county of Vega Baja is mainly used to cultivate trees (71%). The cultivation of citrus fruits accounts for 58% of the surface area of the county. In UDAs 48 and 51 the percentage of land devoted to the farming of citrus fruits is 65%, whereas in UDA 46 citrus-fruit cultivation occupies 46% of the arable land.

As previously stated, the main fruit crops are citrus fruits (lemon, orange, mandarin, and grapefruit) and the pomegranate, which easily adapts to arid terrains and is highly resistant to salty earth and shortages of water, all traits of soil of Vega Baja. Figures 1 and 2 show the distribution of fruit production in the county of Vega Baja. Figure 1 depicts the surface area dedicated to each of the main crops, whereas Figure 2 displays the yield in kilograms per hectare.
To determine the gross and net margins for each crop, we considered its modal value, according to its representativeness and importance in terms of area (Figure 1) and yield (Figure 2). Grapefruit was omitted from the calculation of the indicators on account of its lack of representativeness.

Table 2 presents the results of the indicators of production and efficiency for these fruits across the whole of the Valencian Community. Table 3, on the other hand, displays these indicators for just the county of Vega Baja. Mandarin groves in the area have a low yield. This is because they are still in an early growth stage.

### Table 2: Indicators of production efficiency for fruits in the Valencian Community (2012)

<table>
<thead>
<tr>
<th></th>
<th>Lemon</th>
<th>Orange</th>
<th>Mandarin</th>
<th>Pomegr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production (kg/ha)</td>
<td>31,353</td>
<td>29,860</td>
<td>26,740</td>
<td>20,000</td>
</tr>
<tr>
<td>Income (€/ha)</td>
<td>7,838</td>
<td>6,569</td>
<td>7,487</td>
<td>11,700</td>
</tr>
<tr>
<td>Gross margin (GM) (€/ha)</td>
<td>4,211</td>
<td>2,524</td>
<td>2,910</td>
<td>5,825</td>
</tr>
<tr>
<td>Net margin (NM) (€/ha)</td>
<td>2,454</td>
<td>670</td>
<td>1,017</td>
<td>4,714</td>
</tr>
<tr>
<td>Production efficiency indicator (GM/gravity)</td>
<td>0.63</td>
<td>0.45</td>
<td>0.53</td>
<td>1.02</td>
</tr>
<tr>
<td>Production efficiency indicator (NM/drip)</td>
<td>0.44</td>
<td>0.14</td>
<td>0.22</td>
<td>0.98</td>
</tr>
<tr>
<td>Production efficiency indicator (NM/MP)</td>
<td>10.10</td>
<td>2.44</td>
<td>3.08</td>
<td>10.33</td>
</tr>
<tr>
<td>Production efficiency indicator (GM/Volume of water supplied)</td>
<td>6.24</td>
<td>3.74</td>
<td>4.31</td>
<td>8.63</td>
</tr>
</tbody>
</table>

Source: authors’ own work; MP = manpower

### Table 3: Production efficiency indicators for fruits in Vega Baja del Segura (Alicante, Valencian Community) (2013)

<table>
<thead>
<tr>
<th></th>
<th>Lemon</th>
<th>Orange</th>
<th>Mandarin</th>
<th>Pomegr.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production (kg/ha)</td>
<td>59,906</td>
<td>22,700</td>
<td>7,913</td>
<td>23,854</td>
</tr>
<tr>
<td>Income (€/ha)</td>
<td>14,726</td>
<td>4,994</td>
<td>949</td>
<td>13,955</td>
</tr>
<tr>
<td>Gross margin (GM) (€/ha)</td>
<td>11,099</td>
<td>949</td>
<td>- 2,361</td>
<td>8,079</td>
</tr>
<tr>
<td>Net margin (NM) (€/ha)</td>
<td>9,342</td>
<td>- 905</td>
<td>- 4,254</td>
<td>6,969</td>
</tr>
<tr>
<td>Production efficiency indicator (GM/gravity)</td>
<td>1.66</td>
<td>0.17</td>
<td>- 0.43</td>
<td>1.41</td>
</tr>
<tr>
<td>Production efficiency indicator (NM/drip)</td>
<td>1.39</td>
<td>- 0.16</td>
<td>- 0.77</td>
<td>1.22</td>
</tr>
<tr>
<td>Production efficiency indicator (GM/MP)</td>
<td>45.68</td>
<td>3.45</td>
<td>- 7.16</td>
<td>17.70</td>
</tr>
<tr>
<td>Production efficiency indicator</td>
<td>38.45</td>
<td>- 3.29</td>
<td>- 12.89</td>
<td>15.27</td>
</tr>
</tbody>
</table>
Results show that the most efficient crop in terms of water used for irrigation is the pomegranate. This result holds for both the Valencian Community and the country of Vega Baja. The most efficient production in terms of manpower was for lemons. The fruit with the least efficient production is oranges in the Valencian Community, whereas in Vega Baja mandarin production is the least efficient, although this is partly because the mandarin groves in this area are still in an early growth stage.

The county of Vega Baja specializes in the cultivation of lemons. It was therefore to be expected that its production efficiency would surpass that of all other fruits (see Table 3). Indeed, lemon production is far more efficient than pomegranate production. Farmers attribute part of this efficiency to their belonging to the irrigation community (76% of respondents) that manages and distributes water to its members. Of these members of the irrigation community, 70% reported that they are satisfied with the irrigation community’s handling of affairs.

The majority of the farmers (65.7%) reported that they use water from the Tajo–Segura waterway, which joins two Spanish hydrographic basins. The next most common supply of water is water from wells, followed by surface water from the River Segura. The use of water from a process of desalination, whether private or from irrigation communities, is negligible.

The use of regenerated water seems to be scarce in this area, despite this source of water being suitable for crop irrigation under controlled conditions that minimize the risk of pollution, pesticides, or toxic substances, which could benefit the soil and ground water (Nicolás et al., 2011).

Farmers remember the drought of six years ago (in 2007), whereby they were forced to use low-quality water from wells (with a high salt concentration) causing huge crop losses. This has forged a clear opinion among farmers of the effects of a scarcity of water for agricultural activity. Indeed, 70% of respondents stated that water shortages negatively affect their crops and limit their activity. In addition, 52% responded that they have suffered losses because of a lack of quality or supply of irrigation water, and 72% asserted that they had had to forego the harvest of one of their crops. Nevertheless, few farmers (only 28%) would be prepared to pay more for a good supply of water, whereas more than half (54%) said that they would refuse to pay any such premium.

Farmers stated that they had deployed deficit irrigation on certain occasions. Some claimed that they used it deliberately, in other words with a clear understanding of what the technique entailed and how to apply it. Others, on the other hand, simply employed the technique as an intuitive solution to a water shortage. Respondents were also aware of good environmental practice. Nearly half (47%) of respondents said that they use vegetable cover in their farms, and 72% responded that they prune their crops, the majority of whom also used the cuttings from the pruning process to fertilize the soil. Finally, we asked farmers to respond to a question on whether they would consider changing which crops they cultivate in the future, or whether they had contemplated the idea of increasing their arable area so that they could cultivate another crop. In response to this item, 48% said that they would not be interested in doing so because, as explained above, the average age of farmers in this area is very high.

4. Conclusions

The study of water resources in Spain has always been, and indeed continues to be, of great interest because of the lack of uniformity in hydrological conditions across Spain. It is important to optimize the use of production factors to seek a viable—not only in economic terms but also as regards the environment—use of all resources, particularly water.
The results of our analysis help characterize traditional arable farmers in the county of Vega Baja. They are predominantly older-adult males who work full-time on their own smallholdings. In addition, there is a lack of recruitment of workers from younger generations. Farms remain small, even today. The professionalization of farm management and a greater influence from technology means that this kind of farming is highly appropriate for better-trained and -educated workers. Increasing the area of the smallholdings would also help improve efficiency and would be more conducive to the incorporation of modern technologies in the cultivation of crops in the area.

The recent recession has prompted younger workers to seek work in the agriculture sector, and many former agricultural workers are returning to farming after opportunities to find work in other sectors have shrunk. This trend paves the way for individuals with specific training to enter the sector, which would increase the percentage of farmers with secondary or higher education (more than half the respondents had no studies or had completed only their primary education).

Most of the land in Vega Baja is devoted to the cultivation of fruit. The main fruits grown in the county are citrus fruits and pomegranates. The pomegranate is in fact the crop with the most efficient production process in terms of water usage, and its resistance to a shortage of water and adaptability to salty soil means that it is particularly well suited to this county. The cultivation of lemons is also highly efficient compared to other citrus fruits grown in the region. Lemon trees cultivation covers the greatest surface area of fruit cultivation in the county of Vega Baja, with more than 70% of the farms in the area cultivating lemons. The cultivation of lemons is the most efficient farming process in the county in terms of manpower.

Although the attention that growers in this area dedicate to the quality and scarcity of water is noteworthy, results show that farmers have no intention to cultivate crops that require a more efficient use of water. Furthermore, the county’s farmers are unwilling to pay more for higher-quality water, even if failure to pay such a premium means sometimes being unable to cultivate and harvest certain crops. Older adult growers are reluctant to make investments, although their opinion may change if they began to perceive greater support from younger generations of workers. Nevertheless, famers do implement water-saving techniques requiring a certain level of technology and knowledge, such as deficient irrigation. They also express concern and awareness for good environmental practices.

5. Acknowledgements

We are grateful to the Spanish Ministry of Economy and Competitiveness, and the ERDF for their financial support under the GEAMED Project (AGL2010-22221-C02-01).

6. References


Directiva 2000/60/CE del Parlamento Europeo y del Consejo, de 23 de octubre de 2000 (DOCE, 22.12.2000), por la que se establece un marco comunitario de actuación en el ámbito de la política de aguas.


