

Water pricing and irrigation across Europe: opportunities and constraints for adopting irrigation scheduling decision support systems

Elias Giannakis, Adriana Bruggeman, Hakan Djuma, Jerzy Kozyra and Jürg Hammer

ABSTRACT

Despite the plethora of irrigation scheduling decision support systems that have been developed over the past decades, there is little evidence of widespread adoption by farmers. This paper investigates the structural, institutional and political rigidities that affect the adoption of irrigation scheduling technologies in southern European countries and highlights the corresponding opportunities. The recent implementation of water pricing policies, as required under the European Water Framework Directive, could motivate farmers to invest in technologies for improving water management. A review of irrigation water prices in southern Europe found a large range of prices both within and between countries, from 0.054–0.645 €/m³ (Greece) to 0.23–1.50 €/m³ (France). However, inadequate monitoring infrastructure and a lack of political will to impose the new water prices are giving a mixed signal to farmers. An ageing and poorly trained farm population, small farm size and low level of farm investment also impede the uptake of irrigation technologies. Within this context, European-funded research needs to consider these constraints and pay closer attention to the conversion of knowledge and innovation into successful commercial products.

Key words | decision support systems, irrigation scheduling, Water Framework Directive, water pricing

Elias Giannakis (corresponding author)

Adriana Bruggeman

Hakan Djuma

The Cyprus Institute; Energy, Environment and Water Research Center,
20 Konstantinou Kavafi Street,
2121 Nicosia,
Cyprus
E-mail: e.giannakis@cyi.ac.cy

Jerzy Kozyra

Institute of Soil Science and Plant Cultivation – State Research Institute,
Czartoryskich 8 Street,
24-100 Puławy,
Lubelskie,
Poland

Jürg Hammer

DRM Disaster Risk Management Switzerland SA;
SUPSI Trevano, CP 31,
6952 Canobbio, Lugano,
Switzerland

INTRODUCTION

Water resources efficiency gained policy significance in Europe with the adoption of the Water Framework Directive (WFD) 2000/60/EC. The WFD promotes the efficient use of water resources by urging users to be responsible for the costs their activities impose on water resources. Irrigation is the largest water user in the EU and exhibits great variability, increasing from the temperate climates of the north to the semi-arid climates of the south. The share of irrigated land in the total utilized agricultural area in EU-27 is 6.7%. The EU's irrigated area is mainly concentrated in the Mediterranean region, accounting for 8.49 million ha or 85% of the total EU-27 irrigated land. Irrigation is an indispensable input for Mediterranean agriculture and

as a result a large share of the water abstracted is used for agricultural purposes (e.g. Greece 88%, Spain 64%) (Eurostat 2013). Climate change is expected to stress the limited water resources of the Mediterranean countries even further, while the escalating demand for water from other economic sectors with higher economic water productivity is already exerting high pressures on irrigation water uses (Milano *et al.* 2013).

To achieve a water-efficient agricultural sector, new technologies and best practices need to be adopted. Irrigation scheduling decision support systems (IS-DSS) are computer-based tools that provide advice on when and how much to irrigate. Numerous IS-DSS have been

developed in the last decades (Rinaldi & He 2014). However, despite the successful application of IS-DSS in some parts of southern Europe, such as Irrinet IS-DSS, which is currently applied in 12,500 parcels in Italy (Mannini *et al.* 2013), there is little evidence in the literature of widespread adoption by farmers.

Within this context, the objectives of this paper are: (a) to present an overview of the advances and use of IS-DSS; (b) to review the current status of water pricing in southern Europe; (c) to improve our understanding of the opportunities and constraints for the adoption of IS-DSS.

IRRIGATION SCHEDULING DECISION SUPPORT SYSTEMS AND SERVICES

Irrigation scheduling decision support research projects

Knowledge for the development of technical innovations for irrigation water management in EU countries is partly generated by EU funds. The European research community has put much effort into providing innovative technologies and DSS to support the implementation of water resources management under the WFD. There have been 10 EU funded projects (two still running) in the last 10 years, according to the Community Research and Development Information Service Database (<http://cordis.europa.eu>) (Table 1). The websites of most of these projects report notable water savings and production increases. The projects have also advanced into crop modelling and yield optimization (e.g. FIGARO) and the consideration of the energy efficiency of irrigation (WEAM4i), applying the so-called water – energy nexus approach.

However, EU-funded research has not always succeeded in converting research outputs into marketable products and commercial success stories. Research activities seem often more researcher-driven than farmer-driven and very few projects, two out of the 10, have developed business plans to commercialize their research innovations. In some cases, the research may not be ready for the market yet. For example, the Earth Observation products for irrigation water management developed by the PLEIADeS project (D'Urso *et al.* 2010) were still at a stage of technical testing rather than farmer application. In this sense, the European

Commission aims to improve the transfer of research knowledge and results to intended users in Horizon 2020 projects, by identifying the technology readiness level towards commercial use of proposed research products.

Application of irrigation scheduling decision support services

There are several organizations that provide irrigation scheduling advice in the EU, either governmental or commercial. Irrinet, a web-based irrigation scheduling tool, is co-funded by the Emilia-Romagna regional government. It aims to ensure an efficient use of water resources in the agricultural sector and provides real-time irrigation scheduling (Mannini *et al.* 2013). Currently, services are available in selected areas in 11 regions in Italy (www.irriframe.it).

In Spain, large investments have been made in irrigation advisory services. The provincial government in Albacete (Spain) developed an irrigation scheduling service (ISS-ITAP) that provides farmers with weekly predictions of crop water requirements tailored to each field (Montoro *et al.* 2011). Up to 2011, ISS-ITAP served about 160 of 1,080 farms, covering 33,500 ha. Yields of ISS-ITAP farmers were higher than provincial averages (Montoro *et al.* 2011). Similarly, in Andalusia (Spain), three Local Irrigation Advisory Services (LIAS) were created in 2003 in 16 irrigation districts covering more than 100,000 ha (Lorite *et al.* 2012).

In Crete (Greece) a pilot system of tele-information for scheduling irrigation was tested in 2005–2007. Farmers were provided with irrigation advice by phone according to crop, location, climate and their reported last irrigation (Chartzoulakis *et al.* 2008). However, several limitations impeded the further use of the system including sociological reasons, such as irrigation tradition, level of training and age.

Irrigation decision support has also been provided in northern Europe. The PlanteInfo Irrigation Manager was launched in 1997 in Denmark as a part of an internet-based information and decision system for crop production (Thyssen & Detlefsen 2006). The irrigation DSS uses weather observations and forecasts of the Danish Meteorological Institute. The internet application is free for Danish farmers and the IS-DSS is used actively by 3% of Danish irrigation farmers and by 12% of agricultural advisers in crop production.

Table 1 | European research projects on developing innovative irrigation scheduling technologies

Title	Countries of application	Duration	Business plan	Website
WEAM4i 'Water and energy advanced management for irrigation' (FP7)	Spain, Portugal, Germany	2013–2017	no	http://weam4i.eu/
FIGARO 'Flexible and precise irrigation platform to improve farm scale water productivity' (FP7)	Bulgaria, Denmark, Greece, Israel, Italy, Portugal, Spain, UK	2012–2016	no	http://www.figaro-irrigation.net/
ENORASIS 'Environmental optimization of irrigation management with the combined use of high precision satellite data, advanced modeling, process control and business innovation' (FP7)	Cyprus, Poland, Serbia, Turkey	2012–2014	yes	http://www.enorasis.eu/
EFFIDRIP 'Enabling next generation commercial service-oriented, automatic irrigation management systems for high efficient use of water, fertilizers and energy in drip irrigated tree crops' (FP7)	Spain, Portugal, Greece	2012–2014	no	http://effidrip.eu/
SIRRIMED 'Sustainable use of irrigation water in the Mediterranean region' (FP7)	Greece, Spain, Italy, France, Lebanon, Egypt, Morocco	2010–2014	no	http://www.sirrimed.org/
SIRIUS 'Sustainable irrigation water management and river-basin governance: Implementing user-driven services' (FP7)	Spain, Italy, Romania, Turkey, Egypt, Mexico, Brazil, India	2010–2013	no	http://www.sirius-gmes.es/
DESIRAS 'Addressing desertification by efficient irrigation in agriculture' (EC-DG Environment)	Cyprus, Spain	2010–2011	no	http://www.ewp.eu/activities/desiras/
Water-Bee 'Low cost, easy to use intelligent irrigation scheduling system' (FP7)	Estonia, Malta, Italy, Spain, Sweden, UK	2008–2010	yes	http://waterbee.iris.cat/
FLOW-AID 'Farm level optimal water management assistant for irrigation under deficit' (FP6)	Lebanon, Jordan, Turkey, Italy, The Netherlands, Spain	2006–2009	no	http://www.flow-aid.eu
PLEIADeS 'Participatory multi-level EO-assisted tools for irrigation water management and agricultural decision support' (FP6)	Portugal, Italy, Spain, Greece, Turkey, Mexico, Brazil, Peru	2006–2009	no	http://www.pleiades.es/

Several companies in the EU now also provide irrigation scheduling support systems (e.g. www.netsens.it; www.dacom.nl). These systems generally include wireless soil moisture sensors, a rain gauge or weather station and display data and advice to farmers through a web-interface or mobile App. Some of these systems can also control the opening and closing of irrigation valves.

WATER PRICING IN EUROPE

The sustainable use of water resources and the viability of farming depend largely on the efficient use of agricultural water. In this perspective, the WFD (Article 9) highlights the role of economic principles, i.e. full cost recovery and polluter-pays principle, and economic instruments, i.e.

water pricing, on the internalization of the environmental externalities and the correction of ‘market failures’ (European Commission 2000). Member states are required to price water in a way that ensures full cost recovery and provides adequate incentives to use it efficiently.

The on-going implementation of the WFD, which imposes new costs on irrigated agriculture, could encourage the adoption of irrigation technologies and water-saving practices (Cornish *et al.* 2004; Gómez-Limón & Riesgo 2012; Medellín-Azuara *et al.* 2012; Levidow *et al.* 2014). However, technology adoption depends on the responsiveness of irrigators to water price changes. Several studies support that farmers’ water-use decisions are unresponsive to irrigation water charges and thus, an increase in water prices may not create adequate incentives for the adoption of modern irrigation technologies (Fraiture & Perry 2007). Water use becomes elastic only beyond a certain price threshold (Fraiture & Perry 2007).

Table 2 presents an overview of the irrigation water prices in selected Mediterranean countries. Water prices vary significantly both within and across countries. Per-area charges are difficult to compare because they are generally set per crop (i.e. within Greece there is a large variation from 90 to 210 €/ha). The implementation of the WFD has

led to a significant increase of irrigation water prices. In the case of Cyprus, the volumetric irrigation charges increase by 41%, while the fixed per-area charges are almost tripled. However, irrigators are not yet charged these rates due to the lack of political will to impose additional costs on them. Farmers experience the raising of irrigation water prices as a penalty (Molden *et al.* 2010; Levidow *et al.* 2014). For example, farmers in Alentejo region (Portugal) have lobbied authorities to delay the increase of irrigation water prices towards full cost recovery as they used to pay a low water price set at only 30% of full cost recovery (Levidow *et al.* 2014).

Furthermore, several EU countries including Germany, Austria, Denmark, Finland, Hungary, Sweden and the UK have not considered water abstraction for irrigation as a ‘water service’ and as such they are not applying mandatory cost recovery regimes to it. The European Court of Justice (ECJ) has dismissed the European Commission’s action against Germany for misapplying the scope of Article 9, which concerns the recovery of the costs of water services, the water pricing policy and the application of the polluter-pays principle to water users (ECJ 2014). The ECJ found that ‘Member States may, subject to certain conditions, opt not to proceed with the recovery of costs for a

Table 2 | Irrigation water prices in selected Mediterranean countries

Country (governmental supply)	Cyprus	Greece	Italy	France	Portugal	Spain
Financial cost (€/m ³)	0.34 ^a	0.005–0.115 ^b				
Environmental cost (€/m ³)	0.1 ^a	0–0.151 ^b				
Resource cost (€/m ³)	0.01 ^a	0–0.334 ^b				
Cost recovery (%)	56 ^a	54 ^b	50–80 (North); 10–30 (South) ^c	94.8 ^{d;***}	23 ^d	87.1 ^{d;***}
Irrigation water price after WFD (€/m ³)	0.24 ^{a;*}	0.054–0.645 ^a	0.01–0.80 ^a	0.23–1.50 ^a		
(€/ha)	66.1 ^{a;*}		450–1705 ^a			
Irrigation water price before WFD (€/m ³)	0.17 ^{a;*}	0.011–0.137 ^{b;***}	0.04 to 0.07 (South) ^{c;***}		0.02 (average) ^{d;***}	0.02–0.096 ^{d;***}
(€/ha)	17.1 ^{a;*}	90–210 ^c	50–150 (North) ^c ; 30–100 (South) ^c	104 (average) ^d	120 (average) ^d	113–463.8 ^d

^aDjuma *et al.* (2012).

^bMEPPPW (2008).

^cMassarutto (2003).

^dOECD (2010).

*Irrigators are charged a fixed per-area fee plus a volumetric fee based on actual use.

**Volumetric charging is very rare and is usually included in a mixed system.

***Not including environmental and resource costs.

given water-use activity, where this does not compromise the purposes and the achievement of the objectives of that directive’.

A recent evaluation report of the European Commission on the progress of the implementation of the programmes of measures for achieving the environmental objectives of the WFD revealed that transparent water pricing is not applied across all member states, mainly due to lack of metering (European Commission 2015). Thus, the need for widespread metering in basins where irrigation is the main water use is strongly highlighted. The report also recommends the urgent implementation of measures on cost recovery and water pricing in Greece and Italy. The practical difficulties (e.g. lack of metering) and the lack of political will to impose higher costs on irrigators are giving mixed signals to farmers and hamper the raising of water prices (Cornish *et al.* 2004).

IRRIGATION SCHEDULING TECHNOLOGY ADOPTION: OPPORTUNITIES AND CONSTRAINTS

The European Commission’s intention to use the required cost recovery of water services as an incentive to invest in water saving technologies has not been achieved, due to the complexities surrounding irrigation water pricing in Europe. Furthermore, there are several technical factors that impede the uptake of IS-DSS. These include poor system design and inadequate marketing and dissemination (Morrison 2009). IS-DSS often suffer from a limited understanding of farmers’ needs and use terminology and logic that are unfamiliar to farmers. Furthermore, many farmers are not used to consulting computers and the Internet for daily decision making. In this sense, the research community is currently putting much effort into representing stakeholders’ perspectives in the design of these tools (Rinaldi & He 2014).

Other explanation for the low adoption rate of IS-DSS is that farmers are not confident whether their use would actually transform into benefits (Morrison 2009). Farmers exhibit substantial risk aversion and they tend to adopt new technologies to obtain financial benefits relative to their current practices. This uncertainty can be alleviated through on-farm testing and demonstrations, farmer-to-farmer communication and the active involvement of farmer advisory systems.

Apart from the above specific technical issues, the decision of an irrigator to invest in irrigation technologies is influenced also by multiple socioeconomic, demographic, structural, environmental and institutional factors (Genius *et al.* 2014). Human capital characteristics of the farm population play a prominent role in the adoption and management of irrigation technologies. Lichtenberg *et al.* (2015) found that farmers with a higher level of education are more likely to adopt sensor network irrigation technology. In particular, farmers with high school education are 23% less likely to adopt the technology than those with a post-secondary degree. Genius *et al.* (2014) recorded similar findings, i.e. farmers with a higher educational level (more than 9 years) are more likely to adopt irrigation technology. Genius *et al.* (2014) found also that farmers up to 60 years old are more likely to adopt technology than farmers older than 60 years, highlighting thus the short planning horizon of the older farmers. Innovative technologies such as IS-DSS can be efficient only when the farmer is trained and educated in modern irrigation management issues (Levidow *et al.* 2014). Farm training can improve farmers’ capacity to interpret the measurements of the IS-DSS and fully understand their potential utility. Farm education can be expressed by the share of farmers that have attained formal agricultural training (Giannakis & Bruggeman 2015). The ageing farm population and the low farm training level in Mediterranean countries (Table 3) negatively affect the adoption of new irrigation technologies, because farmers may not understand the benefits of these innovations or may have problems managing and operating them. In general, the adopters of advanced technologies tend to be innovative, younger, more educated and full-time farmers who operate larger holdings and have higher incomes (Bjornlund *et al.* 2009).

Farm size is also a crucial factor for the uptake of such technologies (Morrison 2009). The most common indicator of farm size is the utilized agricultural area (UAA) per farm holding, which however can be misleading, particularly for farms specialized in farm activities that do not need much land (e.g. horticulture). Thus, the economic size criterion expressed by farms’ standard output (SO) measures the average monetary value of the agricultural output from one hectare at farm-gate prices (European Commission 2013). Larger farm operations in both physical

Table 3 | Farm structural characteristics in EU-27 (2010)

	Farmers older than 55 y.o. (%)	Farmers with agricultural training (%)	Physical farm size (ha/farm)	Economic farm size in euro (SO ^a /farm)	Gross fixed capital formation as % of GVA ^b	UAA ^c in LFA ^d (%) (2005)
Greece	55	3	5	9,267	21	78
Spain	55	15	24	34,525	26**	82
France	38	50	54	98,301	29	44
Italy	61	11*	8	30,514	34	51
Cyprus	63	6	3	11,809	4**	60
Malta	57	10	1	7,652	37	100
Portugal	71	12	12	15,199	23	92
EU (27)	53	29	14	63,144	46	54

Source: European Commission (2013).

*In the case of Italy, Eurostat data of 2005 are used because the current definition of 'Training in agriculture' in Italy does not correspond to the Eurostat one.

**These values refer to the year 2009.

^aSO: Standard Output (euro).

^bGVA: Gross Value Added (euro).

^cUAA: Utilized Agricultural Area (ha).

^dLFA: Less Favoured Areas (ha).

(acres) and economic (revenue) terms are more likely to adopt sensor network irrigation technology (Lichtenberg *et al.* 2015). The presence of small and split-up holdings in the Mediterranean region and the small economic size of the holdings do not create the adequate economies of scale for the uptake of the technology (Table 3).

The high cost of IS-DSS in terms of both financial investment and labour requirements may impact negatively on the uptake of the technology (Whittenbury & Davidson 2009). Developers of IS-DSS need to consider funding capacity constraints when designing innovative tools for agricultural water-use efficiency. The gross fixed capital formation (GFCF) in agriculture, which expresses how much of the gross value added (GVA) is invested in the sector rather than consumed, portrays farmers' willingness to adopt new technology (Giannakis & Bruggeman 2015). The low level of farm investment in the southern EU member states (less than 50% of the agricultural gross value added) can explain to some degree the low adoption rate of IS-DSS (Table 3).

The environmental conditions of farms such as aridity, altitude and soil quality influence irrigation effectiveness and could induce farmers to adopt irrigation technologies (Genius *et al.* 2014). Farmers cultivating a lower quality and highly sloping land earn greater benefits from precision irrigation technology than farmers cultivating better quality and level land (Schoengold *et al.* 2006). The share of a farm's

utilized agricultural land in less favoured areas (LFA), as established by Council Directive 75/268/EC, indicates to what extent the land of the farm is unfavourable to farming (Kimura & Le Thi 2013). Mediterranean farm holdings experience a high share of their UAA under LFA (Table 3). These are areas with adverse climate, sloping lands and tendency for depopulation. The diffusion of IS-DSS in these territories could support farmers in their efforts to raise their income and avoid farm exodus.

The lack of political will to impose additional costs on producers usually turns the attention of policy-makers to the approach of subsidizing water-efficient irrigation technologies (Scheierling *et al.* 2006). García-Mollá *et al.* (2014) found that significant increase in water-use efficiency would not have been possible without public subsidies. They also noted that these water savings have in turn led to a significant decrease in the percentage of cost recovered.

The European Agricultural Fund for Rural Development (EAFRD) supports investments in irrigation scheduling infrastructure to provide economic and environmental benefits. Several measures can be used for the protection and the maintenance of water resources in agriculture, namely, measure 121 (modernization of agricultural holdings), measure 125 (infrastructure related to the development and adaptation of agriculture and forestry), measure 111 (vocational training and information actions),

measure 214 (agri-environment payments), and measure 216 (non-productive investments). In total, 51% of the Rural Development Programmes (RDP) budgets of EU member states were allocated to measures that related to a certain or limited extent to water for the 2007–2013 period (European Court of Auditors 2014).

CONCLUSIONS

Water scarcity is expected to be a major constraint for the sustainable development of the semi-arid regions of southern Europe. Research, demonstration and technology development projects commissioned by the EU have identified a large potential for water saving in Mediterranean regions by the use of IS-DSS. However, the problem of water scarcity in these regions is not so much the development of new technologies, but more the dissemination and the actual transfer of this knowledge in the field. IS-DSS need to be user-friendly for farmers since many of them are not used to consulting complex applications for daily decision making. Participatory approaches are currently being utilized to encompass stakeholders' perspectives in the design of IS-DSS and build farmers' trust in technology.

Higher irrigation water prices induced by the on-going implementation of WFD encourage the adoption of IS-DSS. However, low water price elasticities combined with the large variety of prices both within and across countries, as well as the political difficulties in enforcing them may hamper the efficiency of water pricing mechanisms.

The chronic structural weaknesses of Mediterranean agriculture, namely, the ageing and less educated farm population, the small farm size and the low level of farm investments, do not favour of the adoption of irrigation scheduling technologies. The low aptitude of farmers to innovate makes them reluctant to introduce new technologies and abandon traditional irrigation practices. Our analysis underscores the importance of removing those impediments to the modernization of Mediterranean agriculture. European rural development policy offers great opportunities for increasing the uptake of IS-DSS. Policy measures that improve the passing of farms from elder farmers to younger farmers (young farmers schemes), increased support for farm training schemes and advisory services, including

issues such as agro-ecological innovation and climate change mitigation and adaptation, could improve the knowledge and skills of farmers and increase the adoption of new technologies. There is a substantial potential for improving the environmental and economic performance of the farm sector in these regions. However, an increase in the awareness and technical skills of farmers may not come about without the expansion of the resources and capacity of extension and irrigation advisory services.

ACKNOWLEDGEMENTS

This study was supported by the FP7 ENORASIS project (GA 282949). We are grateful to Alessandra Hembury (Noveltis, France) and Dimitrios Daskalakis (Q-PLAN International LTD, Greece) for their contributions to the research. We would also like to thank the reviewers for their suggestions.

REFERENCES

- Bjornlund, H., Nicol, L. & Klein, K. K. 2009 *The adoption of improved irrigation technology and management practices – a study of two irrigation districts in Alberta, Canada*. *Agricultural Water Management* **96**, 121–131.
- Chartzoulakis, K., Kasapakis, I. & Tzobanoglou, I. 2008 Improving water efficiency: The irrigation advisory service of Crete, Greece. Paper presented at the 3rd International Conference on Water Resources and Arid Environments and the 1st Arab Water Forum, Crete, Greece.
- Cornish, G., Bosworth, B., Perry, G. & Burke, J. 2004 *Water Charging in Irrigated Agriculture – An Analysis of International Experience*. FAO Water Reports 28, FAO, Rome, Italy.
- Djuma, H., Bruggeman, A., Daskalakis, D., Hembury, A., Kozyra, J., Hammer, J. & Bajkin, J. 2012 *Irrigation Water Governance*. Enorasis Project Report, The Cyprus Institute, Cyprus. http://www.enorasis.eu/uploads/files/D2%201_ENORASIS_GOVERNANCE_AND_BUSINESS_v12.pdf.
- D'Urso, G., Richter, K., Calera, A., Osann, M. A., Escadafal, R., Garatuza-Pajan, J., Hanich, L., Perdigão, A., Tapia, J. B. & Vuolo, F. 2010 *Earth observation products for operational irrigation management in the context of the PLEIADeS project*. *Agricultural Water Management* **98**, 271–282.
- European Commission 2000 Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000. Establishing a framework for community action in the field of water policy. *Official Journal of the European Communities*, **L 327/1**, 12–13, Brussels.

- European Commission 2013 *Rural Development in the European Union*. Statistical and Economic Information Report 2013. Directorate-General for Agriculture and Rural Development, Brussels, Belgium.
- European Commission 2015 *Report on the Progress in Implementation of the Water Framework Directive – Programmes of Measures*. Commission Staff Working Document, Brussels, Belgium.
- European Court of Auditors 2014 *Integration of EU Water Policy Objectives with the CAP: A Partial Success*. Special Report No. 4, Publications Office of the European Union, 2014, Luxembourg.
- European Court of Justice 2014 Judgment of the Court in Case C-525/12, Action for failure to fulfil obligations under Article 258 TFEU, brought on 19 November 2012. <http://curia.europa.eu/juris/document/document.jsf?jsessionid=9ea7d0f130dea51aa6cee32645c8bbe4d690c273ab6c.e34KaxiLc3eQc40LaxqMbN4ObhyTe0?text=&docid=157518&pageIndex=0&doclang=EN&mode=lst&dir=&occ=first&part=1&cid=341683>.
- Eurostat 2013 Water statistics at national level. http://epp.eurostat.ec.europa.eu/portal/page/portal/statistics/search_database.
- Fraiture, C. de & Perry, C. J. 2007 Why is agricultural water demand unresponsive at low price ranges? In: *Irrigation Water Pricing: The Gap between Theory and Practice* (F. Molle & J. Berkoff, eds). CAB International, Wallingford, UK, pp. 94–107.
- García-Mollá, M., Ortega-Reig, M., Sanchis-Ibor, C. & Avellà-Reus, L. 2014 The effects of irrigation modernization on the cost recovery of water in the Valencia Region (Spain). *Water Science & Technology: Water Supply* **14**, 414–420.
- Genius, M., Koundouri, P., Nauges, C. & Tzouvelekas, V. 2014 Information transmission in irrigation technology adoption and diffusion: social learning, extension services, and spatial effects. *American Journal of Agricultural Economics* **96**, 328–344.
- Giannakis, E. & Bruggeman, A. 2015 The highly variable economic performance of European agriculture. *Land Use Policy* **45**, 26–35.
- Gómez-Limón, J. A. & Riesgo, L. 2012 Agriculture and economics in the Water Framework Directive: progress and limitations. *Water Policy* **14**, 31–14.
- Kimura, S. & Le Thi, C. 2013 Cross country analysis of farm economic performance. *OECD Food, Agriculture and Fisheries Papers* **60**. OECD Publishing, Paris. <http://dx.doi.org/10.1787/5k46ds9ljxkj-en>.
- Levidow, L., Zaccaria, D., Maia, R., Vivas, E., Todorovic, M. & Scardigno, A. 2014 Improving water-efficient irrigation: prospects and difficulties of innovative practices. *Agricultural Water Management* **146**, 84–94.
- Lichtenberg, E., Majsztrik, J. & Saavoss, M. 2015 Grower demand for sensor-controlled irrigation. *Water Resources Research* **51**, 341–358, doi:10.1002/2014WR015807.
- Lorite, I. J., García-Vila, M., Carmona, M. A., Santos, C. & Soriano, M. A. 2012 Assessment of the irrigation advisory services' recommendations and farmers' irrigation management: a case study in southern Spain. *Water Resources Management* **26**, 2397–2419.
- Mannini, P., Genovesi, R. & Letterio, T. 2013 IRRINET: large scale DSS application for on-farm irrigation scheduling. *Procedia Environmental Sciences* **19**, 823–829.
- Massarutto, A. 2003 Water pricing and irrigation water demand: economic efficiency versus environmental sustainability. *European Environment* **13**, 100–119.
- Medellín-Azuara, J., Howitt, R. E. & Harou, J. J. 2012 Predicting farmer responses to water pricing, rationing and subsidies assuming profit maximizing investment in irrigation technology. *Agricultural Water Management* **108**, 73–82.
- MEPPPW, Ministry of Environment, Physical Planning, Public Works 2008 *Greece: Final Report for Article 5 of the Water Framework Directive*. Central Water Agency, Ministry of Environment, Physical Planning and Public Works, Athens, Hellenic Republic.
- Milano, M., Ruelland, D., Fernandez, S., Dezetter, A., Fabre, J., Servat, E., Fritsch, J.-M., Ardoin-Bardin, S. & Thivet, G. 2013 Current state of Mediterranean water resources and future trends under climatic and anthropogenic changes. *Hydrological Sciences Journal* **58**, 498–518.
- Molden, D., Oweis, T., Steduto, P., Bindraban, P., Hanjra, M. A. & Kijne, J. 2010 Improving agricultural water productivity: between optimism and caution. *Agricultural Water Management* **97**, 528–535.
- Montoro, A., López-Fuster, P. & Fereres, E. 2011 Improving on-farm water management through an irrigation scheduling service. *Irrigation Science* **29**, 311–319.
- Morrison, M. 2009 Encouraging the adoption of decision support systems by irrigators. *Rural Society* **19**, 17–31.
- OECD 2010 *Agricultural Water Pricing: EU and Mexico*. Organisation for Economic Co-operation and Development, Paris.
- Rinaldi, M. & He, Z. 2014 Decision support systems to manage irrigation in agriculture. In: *Advances in Agronomy*, Volume 123 (D. L. Sparks, ed.). Academic Press, Burlington, MA, pp. 229–279.
- Scheierling, S. M., Young, R. A. & Cardon, G. E. 2006 Public subsidies for water-conserving irrigation investments: hydrologic, agronomic, and economic assessment. *Water Resources Research* **42**, W03428.
- Schoengold, K., Sunding, D. L. & Moreno, G. 2006 Price elasticity reconsidered: panel estimation of an agricultural water demand function. *Water Resources Research* **42**, W09411, doi:10.1029/2005WR004096.
- Thysen, I. & Detlefsen, N. K. 2006 Online decision support for irrigation for farmers. *Agricultural Water Management* **86**, 269–276.
- Whittenbury, K. & Davidson, P. 2009 Beyond adoption: the need for a broad understanding of factors that influence irrigators' decision-making. *Rural Society* **19**, 4–16.