Disentangling the social, macro and micro-economic effects of agricultural droughts: An application to Spanish irrigated agriculture

A. Garrido*, M. Gil* and A. Gómez-Ramos**

*Research Centre for the Management of Agricultural and Environmental Risks (CEIGRAM), Universidad Politécnica de Madrid, Avda. Complutense s/n, 28040 Madrid (Spain)
** Dpto. Economía, Sociología y Política Agraria.
Universidad de Valladolid, Avda. Madrid 57, 34004 Palencia (Spain)
E-mail corresponding author: alberto.garrido@upm.es

Abstract. Droughts affect irrigated agricultural production, reducing economic output and creating social stress. The economic consequences of droughts begin at the farm level, reaching the macro level along the production chain value. To the extent that crop markets adjust to the supply shocks and because droughts do not affect all sectors at the same time and with the same severity, it is instructive to conduct economic evaluations of drought effects at both micro- and macro-economic levels. The objective of this paper is to estimate the impact of water availability variations on the crops' market values, the total value added of the agricultural sector and farm employment. We run regression models for these three economic variables and 14 provinces in Spain, comprising more than 50% of the Spanish irrigated area. Results show that the macro economic variables are only sensitive to water availability in the provinces where aridity and water stress are more severe. The value of the harvests obtained in irrigated land is largely explained by water availability. The time trend explains the largest percentage of variance of the three economic variables, including micro and macro.

Keywords. Droughts – Socio-economic impacts – Irrigation – Farm economy.

Dissocier les effets sociaux, macro et microéconomiques des sécheresses en agriculture : application à l'agriculture irriguée espagnole

Résumé. *Les sécheresses affectent la production de l'agriculture irriguée, réduisant les revenus économiques et entraînant des tensions sociales. Les conséquences économiques des sécheresses commencent au niveau de l'exploitation, pour atteindre ensuite le niveau macroéconomique à travers la valeur dans la chaîne productive. Vu que jusqu'à un certain point les marchés de produits agricoles s'ajustent aux chocs de l'offre, et étant donné que les sécheresses ne touchent pas tous les secteurs en même temps ni selon la même intensité, il est intéressant de mener des évaluations économiques des effets de la sécheresse au niveau tant microéconomique que macroéconomique. L'objectif de cet article est donc d'estimer l'impact des variations de la disponibilité en eau sur la valeur de marché des cultures agricoles, sur la valeur ajoutée totale du secteur agricole et sur l'emploi au niveau des exploitations. Nous avons appliqué des modèles de régression pour ces trois variables économiques au niveau de 14 provinces de l'Espagne, ce qui représente plus de 50% des zones irriguées de l'Espagne. Les résultats montrent que les variables macroéconomiques sont sensibles à la disponibilité en eau uniquement dans les provinces où l'aridité et le manque d'eau sont les plus sévères. La valeur des récoltes obtenues dans les terres irriguées est largement expliquée par la disponibilité en eau. La tendance temporelle explique le plus grand pourcentage de variance des trois variables économiques, y compris les variables micro et macroéconomiques.*

Mots-clés. *Sécheresses – Impacts socio-économiques– Irrigation – Économie de l'exploitation.*

I – Introduction

Droughts give rise to periods of water scarcity that affect all water supply systems servicing urban, industrial, and agricultural uses, and disturb the flow of environmental services. Water infrastructure alleviates the effects of meteorological droughts, but requires efficient managing of reservoirs and aquifers together with demand management (Iglesias *et al.*, 2007, 2009). Garrido and Gómez-Ramos (2009) analyzed the role of the risk sharing mechanism as an instrument to be incorporated in drought planning. Any model or protocol designed to mitigate the effects of water scarcity requires, among other things, updated information about the social and economic consequences of droughts. In this sense risk analysis can be a helpful instrument to design policies able to anticipate economic effects of drought. The incorporation of risk analyses in resource management thus requires a precise knowledge of the economic impacts of droughts at the basin level, and even smaller domains (Iglesias *et al.*, 2009).

A number of studies that have analyzed the economic impact of droughts use mathematical programming models to simulate economic impacts (Iglesias *et al.*, 2003; Calatrava and Garrido, 2005; Peck and Adams, 2009; Salami *et al.*, 2009). Others use econometric models, fitted at the macroeconomic level (Alcalá Agulló and Sancho Portero, 2002; Martínez-Cachá, 2004), irrigation district level (Lorite *et al.*, 2007), irrigated farm (Rubio Calvo *et al.*, 2006) or even single crops (Quiroga and Iglesias, 2009). Input-output models have also been used to study the regional effects of water scarcity (Pérez y Pérez, 2007). Finally, other authors use computable general equilibrium models (Goodman, 2000; Gómez *et al.*, 2004; Berrittella *et al.*, 2007).

The use of mathematical programming models must overcome the calibration problem, which in many cases is performed with reference to a number of representative units, typically farms (Iglesias and Blanco, 2008), one or very few periods (in most cases) or based on behavioral features, such as risk aversion (Mejías *et al.*, 2004). Furthermore, the use of a single geographical or economic level prevents managers from setting realistic scenarios concerning microeconomic and macroeconomic aspects. Computable general equilibrium models (CGE) serve as an analytical tool but their parameters, such as elasticities or the coefficients of production functions, are not frequently revised, rendering the CGEs' results partially outdated.

The positive approach based on econometric models is able to reproduce the reality from observed data projecting it to a temporal horizon. The goodness of the estimator will be more robust when data are consistent and longer records. These models permit quantifying in a systematic way the economic impacts of drought on agriculture for different geographic units through economic and profitability indicators of agricultural sector. Also this approach allows for identifying hydrological factors that explain the variability of farm production and profitability of irrigated agriculture assuring statistical ex-post adjustment. This is a global approach capable of disaggregating results at the desired scale, showing which percentage of the results variability is attributable to water scarcity. It is possible to isolate the effects of hydrological variables on economic results of agricultural sector from sources of economic instability.

The aim of this paper is twofold. First, it estimates econometric models to explain the variability of economic performance of irrigated agriculture, using among other explanatory variables a common indicator for drought management (the level of surface reservoirs before the start of the irrigation season). The second objective is to establish a framework for drought planning which informs about the potential economic consequences of droughts at the micro and macro levels. The methodological approach is applied to the 14 most important Spanish provinces for irrigation, which are also representative of all major geographic Iberian basins. Working at province scale permits focusing the analysis of droughts impacts at a homogenous socio-economic territory considering data from the same scale.

The article consists of three sections. In the first one, the methods are presented, including the econometric models and our data sources. Subsequently we present the economic and hydrological variables together with the geographical scope of the paper. The most relevant results are presented in the third section, where the impacts of drought on micro and macro variables are summarized.

II – Econometric models and data sources

1. Econometric models

The methodology proposed in this work combines macro and micro-economic approaches. We assume the hypothesis that the economic impacts on irrigation agriculture derived from water scarcity are less important when the analysis includes wider scales, because other elements, not explicitly considered, compensate drought effects at a global scale. For instance, total agricultural output includes rainfed crops and livestock production, which may not be affected by the lack of water resources generated by a drought. Product, input and labor markets adjust to accommodate the supply shocks of irrigated farm production. At the micro-level, irrigated farms are obviously more affected by the lack of water resources, but still other variables will also affect their production performance. In any case both micro- and macro-economic approaches are complementary and non exclusive. The information obtained from them is useful to achieve more effective policies in order to reduce risk and vulnerability to drought.

We propose two econometric models to estimate the macro-economic variables. The first explains the variation of Gross Value Added (GVA, €), and the second the farm employment (both hired and self-employed) based on water availability data, and a time trend for each province (two nested model). Both GVA and farm employment are referred to the entire farm sector, which includes rainfed and irrigated farms, and livestock farms. Time trend tries to capture the positive or negative changes of macroeconomic variables due to general increases of the economic development in the province.

This is a general model in which the variable to be explained:

$$GVA_{it} = a_i + b_i T_t + c_i R_{it} + \varepsilon_{it} \quad \text{[Eq. 1]}$$

$$Empl_{it} = a_i + b_i T_t + c_i R_{it} + \varepsilon_{it} \quad \text{[Eq. 2]}$$

in both cases with: $u_{it} = \varepsilon_{it} + \rho\varepsilon_{it-1}$; $E(\varepsilon_t) = 0$ and $\sigma^2 = \sigma^2$

with *i* denoting province, *t* year. The Gross Value Added is obtained from the Final Agrarian, Fishery and Forestry Production minus all production factors except labour and capital depreciation. This macro-economic variable represents the represent the returns of labour and capital of the entire farming sector of the province. The advantage of connecting GVA with irrigation water availability is that it is possible to determine the impact of drought to global economy. The major disadvantage is that irrigated agriculture represents only a percentage of the GVA, so its variation depends on others factors not directly related with water availability. T_t is the time variable expressed in years, R_{it} is the hydrological variable expressed in % of water reservoirs.

The third econometric model, based on three nested models, explains the variation of the economic value of the harvests obtained from irrigated area. The explanatory variables are water availability data, a time trend and an index price of crop prices received by farmers representing each geographical unit of analysis. This is a general model in which the variable to be explained is IPV_{it} (irrigated production value) estimated for each year (index *t*) and each province (index *i*). The statistical model is defined for each province *i* as follows:

$$IPV_{it} = a_i + b_i T_t + c_i R_{it} + d_i Ip_{it} + u_{it} \quad \text{[Eq. 3]}$$

with $u_{it} = \varepsilon_{it} + \rho\varepsilon_{it-1}$; $E(\varepsilon_t) = 0$ and $\sigma^2 = \sigma^2$

where T_t and R_{it} have already being described and Ip_{it} is a price index for each province. IPV_{it} is the production value, and it was calculated from the data of irrigated area and crop yields along with their annual prices, obtaining disaggregated production values (in nominal euro), for irrigated field crops and greenhouses. IPV_{it} is expressed in thousands of €, and is calculated as follows:

$$IPV_{it} = \sum_{j=1}^{94} Suf_{jt} \times Yield_{jt} \times p_{jt} \qquad \text{[Eq. 4]}$$

where Suf_{jt} is the irrigated surface in province *i*, year *t*, and crop *j* (*j = 1,…, 94*), $Yield_{jt}$ denotes the yield of each crop, province and year, and p_{jt} is the national annual price for each crop evaluated at the farm gate.

The explanatory variable referring to the availability of irrigation water, R_{it}, corresponds to the percentage storage levels of reservoirs in the basin where each province is located, measured on May 1st every year (actual levels measured in hm^3 over total capacity in hm^3). The data are obtained from the MARM Hydrological Bulletin between 1994 and 2009 (MARM, 1993-2009). We consider May the period when the irrigation season begins.

A weighted price index for each geographical unit has been calculated to capture the product value variations due to crop price variation (denoted by Ip_{it}). This index takes into account the importance of each group of crops within each unit and has been calculated using the formula:

$$Ip_{it} = \frac{\sum_{k=1}^{12} IPV\_tc_{ikt} \times Ip_{kt}}{IPV_{it}} \qquad \text{[Eq. 5]}$$

In this way it is possible to isolate the model from the price variations in order to not impute to drought the effects of agricultural market volatilities.

Where, IPV_tc_{ikt} is the total value of crops' group *k* (*k = 1,.., 12*) which are representative of the crops grown in each province. These 12 groups include all the crops, so that each group has a special price index, Ip_{kt}, published by the official statistical sources (MARM, 1995-2007).

As for the error term, the estimates were performed by the Prais-Winsten method for time series with which the Durbin-Watson statistic was evaluated, correcting the effect of errors' serial correlation.

2. Geographical scope and data sources

The models are applied on 14 provinces as represented in the graph. The selection is based on the major presence of irrigated agriculture in this comprising more than 50% of the Spanish irrigated area.

Macroeconomic data for each province are obtained from the following sources:

(i) Gross Value Added (€) are obtained from data of National Institute of Statistic between 1995-2006, updated to 2001 constant euros.

(ii) Farm employment is corresponding with number of monthly registrations in Social Security during the period 1999-2007.

(iii) Data of annual surface devoted to each crop and its corresponding yields are obtained from official statistic of agricultural sector for the period 1995-2007 (MARM, 2008).

(iv) Percentage storage levels of reservoirs in the basin where each province is located are obtained for the period 1995-2009 from the monthly data showed in Hydrological Bulletin (MARM, 2009).

Fig. 1. Maps of the analyzed provinces and hydrological basins. ***Source: MARM (2009).***

III – Results

Tables 1 and 2 show the statistical parameters of the regression models proposed above. Table 1 presents the results of the two nested models that explain the macro-economic magnitudes, Gross Value Added and Farm employment distinguishing between self labour and hired labour. First column presents adjusted R^2 of a regression model where the unique explanatory variable is the time variable T, which reflects the time trend of variation of each macro magnitude. The second column considers water availability as an additional explanatory variable.

Table 1. Adjusted R^2 of the regression models of Gross Value Added and Farm labor

Province	Gross Value Added		Hired Labour		Own Labour	
	T	***T + R***	***T***	***T + R***	***T***	***T + R***
Albacete	0.46	0.46	0.43	0.34	0.93	0.92
Badajoz	0.16	0.50	0.70	0.80	0.97	0.97
Castellón	0.31	0.46	0.92	0.95	0.99	0.99
C. Real	0.12	0.06	0.79	0.86	0.74	0.73
Córdoba	0.45	0.39	0.81	0.96	0.80	0.77
Huesca	-0.04	0.30	-0.11	-0.29	0.66	0.66
Jaén	0.51	0.76	-0.07	0.40	0.94	0.93
León	-0.03	0.03	-0.14	-0.32	0.99	0.99
Lleida	-0.06	-0.03	0.48	0.40	0.99	0.99
Murcia	-0.03	0.37	0.33	0.22	0.95	0.95
Sevilla	0.14	0.79	0.69	0.91	0.97	0.98
Valencia	-0.08	0.21	0.76	0.72	0.51	0.75
Valladolid	0.01	0.24	-0.09	-0.22	0.98	0.99
Zaragoza	-0.07	0.32	-0.14	0.10	0.99	0.99

Source: own elaboration.

The economic impact of droughts at the macro-economic level is in many provinces insignificant. Time trend is the primary explanatory factor of the models, in which the availability of water does not add any explanatory power. This fact is remarkable in the case of the model estimates "Own Labour" where the negative trend in the use of labour explains the total variability of it. This is the common finding for the provinces with continental climate, with little irrigated areas devoted to horticultural and fruit crops.

In the Mediterranean provinces and Southern provinces (Valencia, Castellón, Jaén, Sevilla, Córdoba or Badajoz) Gross Value Added and hired farm employment are clearly dependent on the water availability. This means that prolonged droughts that give rise to water shortages generate job losses and reduced farm incomes. The evolution of self-employment is independent of the hydrologic cycle, and follows a negative trend due to the loss of importance of agricultural sector in the global economy.

Figure 2 plots the GVA of Seville against the observed value. Model 2 includes water and trend and model 1 only the trend. In the left panel, black line is the observed GVA, grey line the predicted and pale line the trend. In the right panel, blue line represents the error of model 2 against the observed; grey line is the error of the trend against the observed.

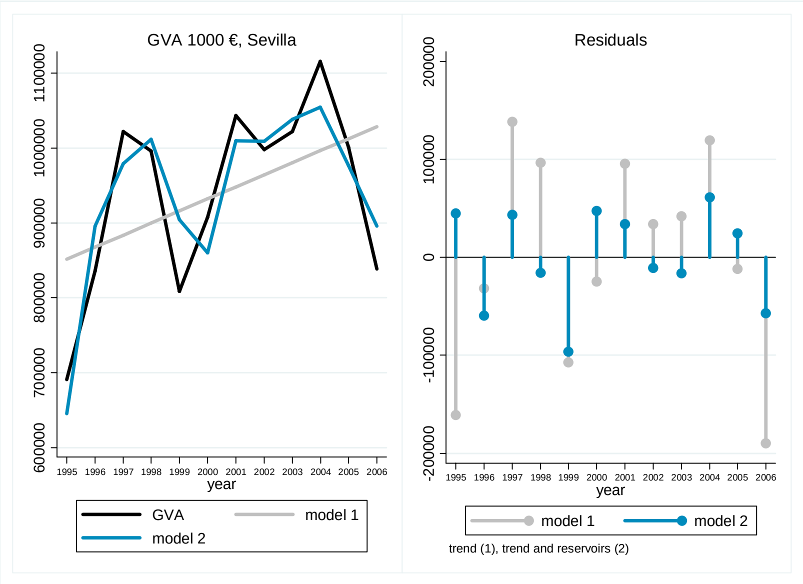

Fig. 2. The Gross Value Added of Seville. *Source: Own elaboration.*

As Fig. 2 shows in the province of Seville, water availability due to drought periods has an important influence in the variations of GVA. In this case, Model 2 is a good predicting instrument of drought effects in the agricultural sector. It can be concluded that in the province where the agricultural sector has relative economic importance the influence of drought periods is more evident than in the others where the agriculture sector is marginal.

Table 2 shows the results of the regression models that explain the variability of the Production Value (IPV) within the three nested models.

Focusing on irrigated agriculture (micro level), Table 2 presents the results of the regression that estimates the variation of irrigation production value for the 14 provinces selected. The coefficients of determination (R^2) together with the level of significance of the explanatory variables provide generally good but somewhat ambiguous results. In most of the provinces the time trend explains the variability of production value, being positive in all of them except in

Castellón and Valencia. In these provinces the production value has decreased due to a reduction of irrigation surface caused by changes in land use. The significance of the hydrological variable and the price indices in some provinces reflects that it is possible to measure the economic impact of droughts in areas highly dependent on the stored surface waters (Córdoba, Sevilla or Huesca). But they also suggest that price drops in some cases are primarily responsible for economic losses even in hydrological periods of scarcity (see provinces like Murcia, Badajoz or Lleida).

Table 2. Results of IPV Regression models. Adjusted R^2, sign and significance of explanatory variables

Province	IPV = a + bT		IPV = a + Bt + cR			IPV = a + bT + cR + Ip			
	Ad-R^2	T	Ad-R^2	T	R	Ad-R^2	T	R	Ip
Albacete	0.58	+ (**)	0.56	+ (**)	+	0.63	+ (**)	-	-
Badajoz	0.67	+ (**)	0.70	+ (**)	+	0.81	+	+	+ (*)
Castellón	0.20	- (*)	0.12	-	-	0.22	-	-	+
C. Real	0.80	+ (**)	0.78	+ (**)	-	0.80	+ (**)	-	-
Córdoba	0.81	+ (**)	0.91	+ (**)	+ (**)	0.92	+ (**)	+ (**)	+
Huesca	0.38	+ (*)	0.59	+ (**)	+ (*)	0.74	+ (**)	+ (**)	- (*)
Jaén	0.55	+ (**)	0.51	+ (**)	-	0.49	+ (**)	+	+
León	0.02	-	0.29	-	+ (*)	0.31	-	+ (*)	+
Lleida	0.19	+	0.30	+ (*)	+	0.53	+	+	+ (*)
Murcia	0.52	+ (**)	0.48	+ (**)	+	0.81	+ (**)	+	+ (**)
Sevilla	0.44	+ (**)	0.59	+ (**)	+ (*)	0.74	+ (**)	+ (**)	+ (*)
Valencia	0.23	- (*)	0.20	- (*)	-	0.15	-	-	+
Valladolid	0.87	+ (**)	0.86	+ (**)	+	0.86	+ (**)	-	+
Zaragoza	0.75	+ (**)	0.78	+ (**)	+	0.82	+ (**)	+	-

*p < 0.05; **p < 0.01.
Source: Own elaboration.

In general it can be concluded that the provinces where fruits and vegetables are important crops, IPV is more dependent on price volatility than on water availability. On the contrary, provinces where extensive crops have more presence (maize, winter cereal, sugar beet) water availability better explains agricultural production variability. This is true only in the cases where surface water is the main source of irrigation water, while where groundwater is predominant that premise is not valid because there are other factors that influence water management.

Figures 3 and 4 show the relationship between macro and micro variables along the period analyzed in the province of Sevilla and Huesca. In both cases it can be observed a high correlation between GVA (macro-economic variable) and IPV (micro-economic variable). That is because the agricultural sector has an important role in the regional economy. In the case of Sevilla the agricultural employment has also a positive and high correlation with the GVA due to the labour costs of the main irrigation crops (cotton, vegetables). By contrast in Huesca, with predominant extensive crops, labour and GVA are not dependent on water availability. But in both cases econometric models are a robust instrument to predict drought impacts at micro level. Drought preparedness requires economic models to be used in conjunction with hydrological models. The joint analysis of macro- and micro-economic variables allows for predicting how will be the impact of hydrological drought in the macro-economic agricultural variables.

IV – Conclusions

In this work we demonstrate the interest of combining macro- and micro-economic approaches in order to analyze the economic effects of droughts. In most provinces, the macro-economic effect of the time trend is larger than that of water availability. The time trend captures a great percentage of the variance of the economic variables. Water availability explains a significant part of the macro-economic variability in the provinces where horticultural and fruit crops grown. Trends account for changes in irrigated land (it grows in some provinces and diminishes in others), and they should be taken into account to evaluate the economic effects of water scarcity.

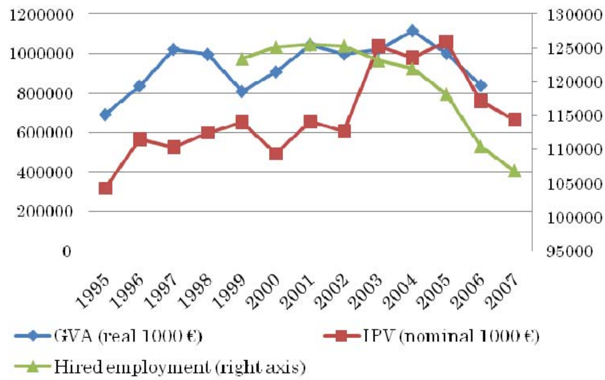

Fig. 3. Evolution of macro and micro variables in the province of Seville (€ and employment).

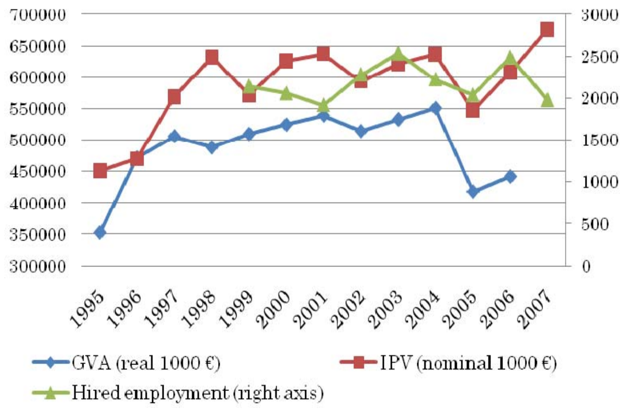

Fig. 4. Evolution of macro and micro variable in the province of Huesca (€ and employment).

The effects of water scarcity on the irrigated market production are more exacerbated at the micro level than at the macro-economic level. This is because droughts effects can be compensated by output, input and labor markets of the entire farm sector (the macro level, including Gross Value Added and farm employment), because livestock production and rainfed agriculture are also included.

In order to explain the effects of droughts on the agricultural final production it is essential to include the effects of crop prices' variation to avoid overestimating the effects of droughts. The results of this study demonstrate that price indices are significant in many provinces. This depends on the elasticities of supply and demand and on trade flows. It is an indication that many crop prices respond to water scarcity because reduced harvests increase crop prices and vice versa. This suggests that the more flexible and efficiency the crop markets are the larger the compensating effect on irrigators' total revenue.

As a conclusion, agricultural macroeconomics and labour result sensibility to water available are insignificant. Droughts have very little impact on agricultural incomes and labour, so macro-effects are less important than micro-effects even within the agricultural sector. Economic impacts of drought must be carefully analyzed, using robust attribution models, able to isolate the effects of water supply variability from other non water-related effects (trends and farm prices). Each geographical unit (province) has idiosyncratic components like use of groundwater, type of products and markets, surface storage system, cropping patterns, and labour requirements, that explain changes and trends in agricultural economy.

The results obtained in this work make us to reflex about the impacts on the economy of virtual water trade. Since irrigation production is more closely linked to water availability, *virtual water trade* may not hit rural employment severely if we consider the model results'. So hired farm employment is weakly linked to water availability.

References

Alcalá Agulló F. and Sancho Portero I., 2002. Agua y producción agrícola: Un análisis econométrico del caso de Murcia. In: *Revista Española de Estudios Agro-sociales y Pesqueros*, 197, p. 129-158.

Berrittella M., Hoekstra A.Y., Rehdanz K., Roson R. and Tol R.S.J., 2007. The economic impact of restricted water supply: A computable general equilibrium analysis. In: *Water Research*, 41(8), p. 1799-1813.

Calatrava J. and Garrido A., 2005. Modelling water markets under uncertain water supply. In: *European Review of Agricultural Economics*, 32(2), p. 119-142.

Garrido A. and Gómez-Ramos A., 2009. Risk management instruments supporting drought planning and policy. In: Iglesias A., Garrote L., Cancelliere A., Cubillo F. and Wilhite D.A. (eds). *Coping with Drought Risk in Agriculture and Water Supply Systems*. Springer Science+Business Media BV, p. 133-151.

Gómez C.M., Tirado D. and Rey-Maquieira J., 2004. Water exchanges *versus* water works: Insights from a computable general equilibrium model for the Balearic Islands. In: *Water Resour. Res.*, 40, W10502.

Goodman D.J., 2000. More reservoirs or transfers? A computable general equilibrium analysis of projected water shortages in the Arkansas River Basin. In: *Journal of Agricultural and Resource Economics*, 25(2), p. 698-713.

Iglesias A., Garrote L., Cancelliere A., Cubillo F. and Wilhite D.A., 2009. *Coping with Drought Risk in Agriculture and Water Supply System*. Springer Science+Business Media BV.

Iglesias E. and Blanco M., 2008. New directions in water resources management: The role of water pricing policies. In: *Water Resour. Res.*, 44, W06417.

Iglesias E., Garrido A. and Gómez-Ramos A., 2003. Evaluation of drought management in irrigated areas. In: *Agricultural Economics*, 29, p. 211-229.

Iglesias E., Garrido A. and Gómez-Ramos A., 2007. An economic drought management index to evaluate water institutions: Performance under uncertainty. In: *The Australian Journal of Agricultural and Resource Economics*, 51, p. 17-38.

Lorite I.J., Mateos L., Orgaz F. and Fereres E., 2007. Assessing deficit irrigation strategies at the level of an irrigation district. In: *Agricultural Water Management*, 91(1-3), p. 51-60.

MARM, 1993-2009. *Boletín Hidrológico Semanal del Ministerio de Medio Ambiente y Medio Rural y Marino*. Ministry of the Environment and Rural and Marine Environs, Madrid, Spain.

MARM, 1995-2008. *Anuarios de Estadística del Ministerio de Medio Ambiente y Medio Rural y Marino*. Ministry of the Environment and Rural and Marine Environs, Madrid, Spain.

Martínez-Cachá A., 2004. *Impacto Económico de las Sequías en el Sureste Agrario Español*. Fundación Universitaria San Antonio, Murcia, 187.

Mejías P., Varela-Ortega C. and Flichman G., 2004. Integrating agricultural policies and water policies under water supply and climate uncertainty. In: *Water Resour. Res.*, 40, W07S03.

Peck D. and Adams R.M., 2009. Persistence of drought impacts across growing seasons: A dynamic stochastic analysis. In: *Journal of Agricultural and Resource Economics* (forthcoming).

Pérez y Pérez L., 2007. Evaluación de los Efectos Socioeconómicos de la Sequía en la Cuenca del Ebro. Confederación Hidrográfica del Ebro. Oficina de Planificación Hidrográfica.

Quiroga A. and Iglesias A., 2009. A comparison of the climate risks of cereal, citrus, grapevine and olive production in Spain. In: *Agricultural Systems*, 101, p. 91-100.
Rubio Calvo E., Abad J., Gimeno Y., García M. and Oliva C., 2006. *Repercusión de la Sequía en los Riegos del Alto Aragón*. Riegos del Alto Aragón.
Salami H., Shahnooshi N. and Kenneth J.T., 2009. The economic impacts of drought on the economy of Iran: An integration of linear programming and macroeconometric modelling. In: *Ecological Economics*, 68, p. 1032-1039.