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RESEARCH ARTICLE

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Hydrological drought index insurance for irrigation districts in Spain

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Abstract

Hydrological droughts are a major risk for irrigated agriculture in many regions of the world. The aim of this article is to propose an insurance tool to help irrigators manage the risk of water scarcity in the framework of the Spanish Crop Insurance System (SCIS). Only the United States Insurance System provides this type of coverage, but has very restrictive conditions. To determine the type of insurance scheme that better fits with the SCIS and to the Spanish irrigated agriculture, an expert panel was held with the participation of all stakeholders involved in crop insurance. Following the expert panel conclusions, an hydrological drought index insurance (HDII) addressed to irrigation districts (ID) is proposed. It would compensate water deficits suffered in the whole ID. We detail the conditions that the ID should fulfill to be eligible for HDII. HDII is applied to the Bardenas Irrigation District V (ID-V) in Spain, and the hedging effectiveness of the instrument is analyzed comparing ID-V's gross margins with and without the insurance contract. Results suggest that the proposed insurance scheme could provide an effective means of reducing farmers' vulnerability to water shortages and there is no major impediment for it to be included as a new line in the SCIS. This type of insurance can be generalized to any ID fulfilling the conditions mentioned in this paper.

Additional key words: water supply risk; Spanish Crop Insurance System; Drought Index; water allotment; Bardenas Irrigation District.

Abbreviations used: Aux I (Auxiliary Index); C (Irrigation District's conditions); DI (Drought Index); DMP (Drought Management Plan); DSI (Drought Status Indicator); EU (European Union); FD (Insurance scheme with franchise deductible); GM (Gross Margin); HDII (Hydrological Drought Index Insurance); ID (Irrigation District); ID-V (Bardenas Irrigation District V); MRSL (Mean Root Square Loss); NDVI (Normalized Difference Vegetation Index); NFD (Insurance scheme without franchise deductible); NVAP (Net Value of Agricultural Production); SCIS (Spanish Crop Insurance System); γ (franchise deductible).

Authors' contributions: Conception and design: TM, MB and AG. Expert panel definition and organization: MB and AG. Data acquisition: TM and MB. Quantitative analysis and interpretation of results, and drafting of the manuscript: TM. Supervising the work and manuscript revision: BM and AG.

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Introduction

Drought is one of the main environmental risks in Mediterranean Europe. Climate change predictions indicate that droughts will intensify in the 21st century in the region (IPCC, 2012). One of the main adaptation tools to climate change in arid zones is irrigation. Drought does not only affect rainfed agriculture; it also affects the availability of water for irrigation. Meteorological droughts predate hydrological droughts, reducing the availability of surface and groundwater sources, and giving rise to water shortages both for consumption uses and for environmental flows. Water scarcity in irrigated farming systems results in potentially greater economic losses than in rainfed systems, due to the higher investments being made on the farm.

To manage water scarcity, deficit irrigation has been studied and implemented, particularly to ligneous crops, showing satisfactory results (Ruiz-Sanchez *et al.*, 2010). Water markets are commonly used in Australia, Chile and the United States under widely different regulatory frameworks, facilitating the reallocation of water resources among users, therefore allocating water to high-value uses and improving water use efficiency. At the European Union (EU) level, only Spain has developed a regulatory framework to permit water trading (Easter and Huang, 2014; Rey *et al*., 2014). Insurance is also a means to manage water supply instability (Pérez & Gómez, 2013; Rey *et al*., 2015).

The Spanish Crop Insurance System (SCIS) is one of the most advanced and widespread systems in the EU, serving as a benchmark for international comparisons of insurance systems (OECD, 2011).Yet, irrigated agriculture is unprotected against losses due to the lack of water for irrigation. In Spain, irrigated land covers 13% of the useful agricultural surface, contributing to 50% of the total agricultural production value (INE, 2012). In spite of the recurrent drought episodes that affect Spain (Estrela & Vargas, 2012), irrigated surface is still increasing. In the period 2004-2014, irrigated surface increased on average 1% per year (MARM, 2014a). In consequence, there is an evident need for an insurance policy to cover the risk of water scarcity, as has already been demanded by the agricultural sector.

As far as we know, the only experience on drought insurance for irrigated agriculture is implemented in the USA. The Multiple Peril Crop Insurance program in the USA covers the unexpected failure of irrigation water supply. Irrigated yield losses are covered when water shortages are due to a naturally occurring event and cannot be foreseen at the time of the insurance take-up (prevented planting insurance is a possible alternative when a water shortage is expected). The insurance scheme has detailed provisions in order to avoid moral hazard. Besides, decreased water allocations due to a diversion of water for environmental reasons, selling water to municipalities, or other causes are not covered (Risk Management Agency - Topeka, 2015).

Several researchers have proposed other insurance schemes covering water shortage risk. Traditional schemes, using crop production functions or crop simulation models to assess the economic impact of drought have been proposed in some irrigated regions of Spain (Quiroga *et al*., 2011; Pérez & Gómez, 2013; Ruiz *et al*., 2013, 2015). Index insurance mechanisms have been proposed in the literature seeking to cover financial risks for water managers (Brown & Carriquiry, 2007; Zeff & Charaklis, 2013) and offering coverage for agricultural production (Zeuli & Skees, 2005; Leiva & Skees, 2008).

The aim of this article is to propose an insurance tool to protect irrigators against water scarcity in the framework of the SCIS. The tool would mitigate the economic cost of water shortages. The novelty of our approach, with respect to other insurance schemes proposed, is the use of an expert panel formed by 8 individuals representing all stakeholders to select which design is more adapted to the needs of the Spanish irrigators. The Panel included experts and stakeholders related to both water management in the Spain and the SCIS. As a result of the expert panel (the next section offers a detailed description), the best option to ensure irrigated crops in Spain would be a Hydrological Drought Index Insurance (HDII) contracted by the Irrigation District (ID). Index insurance to protect irrigators against water scarcity had already been proposed in the literature by Zeuli & Skees (2005) and Leiva & Skees (2008). However, we propose a simpler design, detail the conditions that the ID should fulfill in order to be insured under this policy, and analyze the hedging effectiveness of the instrument comparing the gross margin of the ID with and without the insurance contract. Similarly to Brown & Carriquiry (2007), we propose a unitary indemnity, but based on crop production and adapted to the ID. HDII is applied to the Bardenas Irrigation District V (ID-V). Besides, to respond to the interest shown by some expert panel participants, we discuss the possibility to subsidize the proposed insurance scheme within the EU legislative framework.

Material and methods

Selection of the insurance type: Expert panel

An expert panel[1] was called on to define the insurance scheme the more appropriate to cover water supply risk in the Spanish irrigated agriculture, the difficulties that the implementation of this instrument would involve, and its potential acceptance among irrigators, insurance suppliers and the administration. The Panel met on May 2014 in the Technical University of Madrid with four participants from IDs, one from crop insurance companies, one from the Ministry of Agriculture, one from the Spanish State Agency for Agricultural Insurance and one from River Basin Water Boards. Figure 1 represents the options proposed to the expert

[1] The expert panel is part of the project "Hydrological drought insurance for irrigation: an adaptation tool for climate change" (AGL2010-17634).

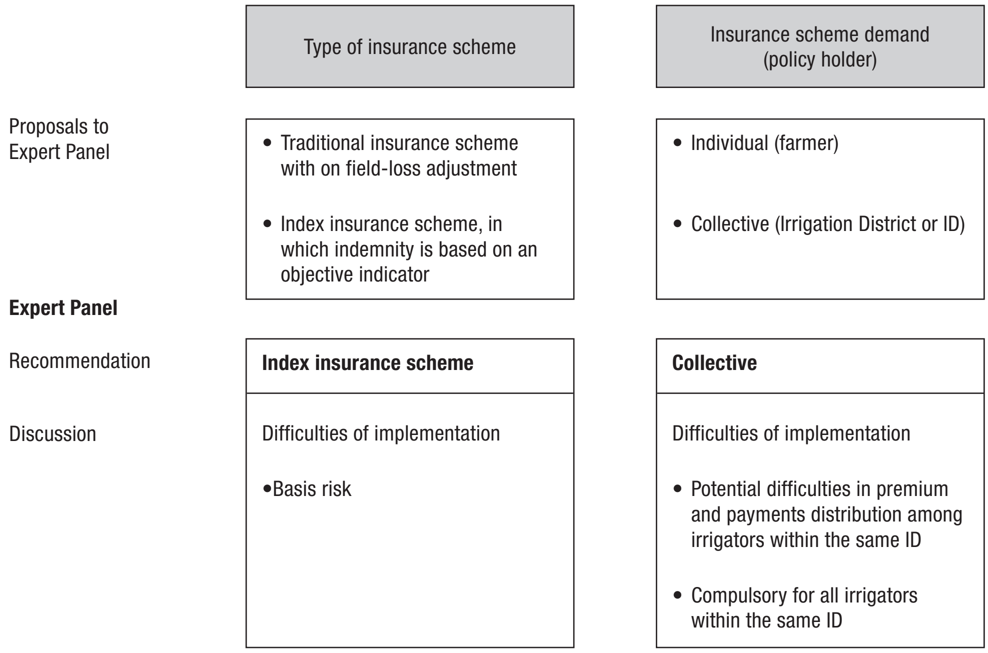

Figure 1. Expert panel development and results. *Source:* own elaboration.

panel in respect to the insurance design and the policy holder. Conclusions derived from the expert panel development are exposed in next paragraphs and summarized in Figure 1.

Two types of insurance schemes were discussed (1) a traditional insurance scheme, with on–field loss adjustment, and (2) an index insurance. In this paper, we refer to index insurance as a type of weather or hydrological based index insurance, in which the indemnity is based on measurements of a specific weather or hydrologic parameter which is the Drought Index (DI). In the proposed index insurance the indemnities are calculated from an hydrological DI which is multiplied by a unitary value of water (calculated from the added value of water of the region). Index insurance gathered more acceptances among the participants to the expert panel. Although on-field loss-assessment provides a better adjustment of the losses suffered by farmers, it is not compatible with water markets and transfer of water rights. An insured irrigator that sells water rights will suffer a yield loss and would receive a double compensation or payment for the loss, from the insurance scheme and from water rights transfer. In consequence, the sale of water rights is not permitted in this type of schemes. Besides, the use of more efficient irrigation methods, water banking and other water sources (via water markets, groundwater, desalinated water, etc.) is not encouraged, since the payoff is adjusted based on the yield finally obtained, so there is no interest in obtaining a higher yield. On the other hand, an index insurance, in which the indemnity is based on an external objective indicator, would be compatible with voluntary exchanges of water rights. In the case of an irrigator selling water rights, the index insurance scheme will only compensate for the potential loss associated to the DI value, while the actual additional decrease in the crop production value due to the transfer of water rights will be compensated exclusively by the water rights price. In consequence both compensations are complementary, and do not overlap as in the previous case. At the same time, the use of more efficient irrigation methods, water banking and the use of other water sources is not discouraged. The farmer would still want to obtain the highest possible yield, since the insurance will anyway pay the indemnity that corresponds to the potential loss of each farm. Irrigators will not hesitate in buying water to other irrigators, investing on more efficient irrigation techniques, in order to obtain a higher yield. Index insurance is also easier to implement because there is no need to monitor moral hazard and to perform on field loss-assessment.

Several difficulties hindering the implementation of such scheme were identified. Basis risk is one of them, which implies that the payment may not necessarily correspond to the actual losses incurred by the insurance policy holder (Skees *et al*., 2008). This is due to the fact that there is some flexibility when applying water allocation rules. As a consequence, the relationship between indicator and water allotments may change from year to year. This flexibility in applying water distribution rules is transformed in basis risk of the index insurance. Basis risk leads to discontent among policyholders, and providers too. An example of the importance of basis risk in index insurance is the case of the Normalized Difference Vegetation Index or NDVI insurance for pasture in Spain, which has been in place since 2008 (Agroseguro, 2014). Due to the differences between payments and actual losses, the design is still being adapted in order to reduce the basis risk.

Concerning who should be the policyholder, either (a) individual farmer or (b) collectivity, a collective insurance policy, contracted by the ID as a whole, is preferred. This preference is explained by the fact that usually, within the same ID, irrigators do not receive the same water allotment per hectare. Water allotments for each irrigator are not only dependent on water availability, but they might be dependent as well on (i) the type of crops cultivated, (ii) water rights hold and /or purchased (in case there is a running water market) by the irrigator, and also on (iii) the quantity of water that each irrigator asks for at the beginning of the irrigation season. These water distribution mechanisms promote a more efficient use of water, since the most productive lands would probably receive more water than the least productive lands. But at the same time, all these variables (from (i) to (iii)) taking part in water distribution mechanisms within an ID make difficult defining clear rules in water distribution that would remain constant over the years. In consequence, a collective insurance policy is the insurance scheme most appropriate to cover water supply risk. Nevertheless, it was highlighted that the implementation of a collective policy, especially with regard to the premium share and the indemnities distribution, is a delicate issue, since individual risk aversion and cropping patterns might be highly diversified within the same ID. Additionally, the fact that the insurance is bought by the ID, makes it compulsory for all irrigators, even for those who are not interested in buying it.

According to the ideas drawn from the expert panel we conclude that the best option to ensure irrigated crops in Spain is a HDII contracted by the ID. HDII uses a DI to estimate farmer losses due to water shortages. The unitary indemnity is given per square meter of water deficit per hectare.

Index insurance design, hedging effectiveness, and contract conditions

The HDII defines a guaranteed level of water allotment measured in m^3/ha. This guaranteed water allotment (*GWA*) is the expected water allotment and is calculated as the average water allotment delivered to irrigators in the period analyzed. Water shortage in the ID (ws_t) is measured in m^3/ha, and corresponds to the difference between the guaranteed water allotment or *GWA* and the water allotment in year t or wa_t (equation 1):

$$ws_t = max(GWA - wa_t, 0) \qquad [1]$$

The water allotment in an ID (wa_t) in a year t is estimated from the Drought Index (DI_t). The model f is estimated empirically, from historical data (equation 2).

$$wa_t = f(DI_t) \qquad [2]$$

The model reflects the decisions related to water management and infrastructure operations. The design of index insurance requires that hydrological data should be stationary (DI and water allotments), otherwise detrending procedures should be implemented. In addition, operating rules should remain constant over the guarantee period of the contract. The selection of the index *DI* in which the insurance should be based has been widely discussed in the literature (Bielza *et al*., 2008; Leiva & Skees, 2008). The two basic prerequisites of an appropriate DI are: (1) high correlation with the potential loss, and (2) fulfillment of the quality standards of the insurance industry (transparent, verifiable, observable, reported in a timely manner, and not subject of manipulation). Underlying DI must be carefully selected or designed for each ID given the high diversification of irrigated crops, water sources, water management, and water irrigation practices (Vedenov & Barnett, 2004).

The indemnity (€/ha) received in a year t results from multiplying ws_t by a unitary indemnity that is equal to the water value (*wv*) in €/m^3. A franchise deductible or γ is the minimum amount of loss that must be incurred before insurance coverage applies (IRMI, 2014). A γ would help to decrease the premium rate and decrease operating costs of the insurance policy, since low severity losses would not be covered. Indemnity calculation in the presence of a γ would then follows equation 3:

$$Ind_t = \begin{cases} 0 & if \;\; wa_t \geq (1-\gamma) \times GWA \\ ws_t \times wv_t & if \;\; wa_t < (1-\gamma) \times GWA \end{cases} \qquad [3]$$

We estimate this unitary indemnity or *wv* as a water value equivalent to the average decrease of expected gross margin exclusively due to the water shortage in the ID. The productivity of water equals the revenue under irrigation minus the revenue under rainfed conditions (Lorite *et al*., 2012). Irrigation variable costs not incurred under water restriction situations should not be compensated; consequently the variable costs of irrigation are subtracted from water value. The fixed costs of irrigation (water basin authority fees, irrigation scheme infrastructure amortization/maintenance, and irrigation scheme personnel/administrative costs) should be compensated by the insurance indemnity, because they are borne by the farmers even if water deliveries are suspended during drought episodes. In consequence, they are not subtracted in the water value calculation. In any ID, crop pattern varies from year to year (unless the whole ID cultivates permanent crops) depending on the prevailing hydrological conditions. Therefore, we adapted the methodology applied by Lorite *et al.* (2012) to take this into account. Based on historical data, we established different crop pattern scenarios S_i associated to a water allotment finally received in the farm (wa_i). Several crop pattern scenarios were defined, ranging from a full rainfed scenario (S_0) with no allocated irrigation water to a scenario with full guaranteed water allocation (S_I), and including several intermediate scenarios (S_i), where i takes values between 0 and I. Each scenario has an associated value of agricultural production (VAP_i) net of variable costs of irrigation (VCI_i), that is equal to the Net Value of Agricultural Production ($NVAP_i$), all three in €/ha (equations 4, 5 and 6):

$$VAP_i = \sum_{c=1}^{c=C} \left[S_{ic} \times Y_c \times P_c \right] \qquad [4]$$

$$VCI_i = \sum_{c=1}^{c=C} \left[S_{ic} \times VCI_{ic} \right] \qquad [5]$$

$$NVAP_i = VAP_i - VCI_i \qquad [6]$$

where S_{ic} is the share of crop c area on the ID for the I scenario in the ID with C crops, Y_c and P_c are the 5-year Olympic average[2] of the irrigated yield and crop price in kg/ha and €/kg respectively; and VCI_{ic} are the variable costs of irrigation converted in €/ha associated to the scenario i for the crop c.

We estimate a water value that varies depending on the water allocated to the ID. The average water value corresponding to water allotment received is calculated comparing a scenario S_i with the scenario with full guaranteed water allocation S_I (equation 7):

$$wv_i = wv_i\left(wa_i\right) = \frac{NVAP_I - NVAP_i}{GWA - wa_i} \qquad [7]$$

Consequently, there is an average water value for each water allotment wa_i characterizing each scenario. Scenarios are always compared to the GWA scenario S_I. With the discrete water values that arise from each scenario i, we can establish a relationship that will represent the water value (or unitary indemnity) to be applied dependent on the water allotment finally received (see Figure 2 and equation 8).

$$wv_t = wv_t(wa_t) \qquad [8]$$

The liability or guaranteed value of the insurance scheme is determined following equation 9:

$$Liability = GWA \times wv_t \qquad [9]$$

The threshold of the DI that triggers a payoff (*Trigger*) meets equation 10:

$$(1 - \gamma) \times GWA = f(DI = Trigger) \qquad [10]$$

The premium rate of the insurance scheme is calculated based on the expected indemnity (equation 11), where t is the year and T is the number of years:

$$Premium = \left(Ind_t\right) = \frac{1}{T} \times \sum_{t=1}^{t=T} Ind_t \qquad [11]$$

All premium rates calculated in this paper are pure premiums, without subsidies or any additional costs. A charge to cover administrative, underwriting, reserves, reinsurance and operating costs should be added to the premium. However, the charge should be smaller than in traditional insurance because there is no need of on-field loss adjustment.

In case ligneous crops are present in the ID, several characteristics are to be considered when establishing the premium rate and the unitary indemnity: (i) crop distribution in the farm that presents exclusively ligneous crop does not change, consequently, the unitary indemnity to be received by the farmer is specific to the crop; (ii) unitary indemnity should reflect that

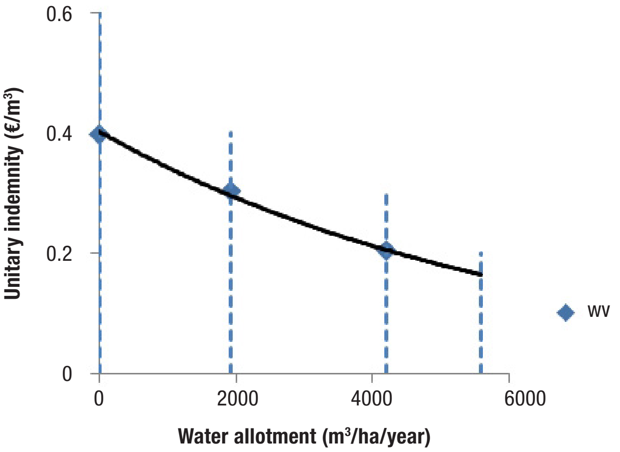

Figure 2. Water value (wv) depending on the water allocation received on the ID.

[2] The Olympic average is defined as an arithmetic mean calculated after first dropping the highest and lowest values within the last five years, measure that is established in the World Trade Organization's risk management agreements.

ligneous-crop economic losses might be higher (investment is higher) and might be prolonged several years after the cause of loss, since the plant health might be threatened and next season's yield may be lower; (iii) Drought Management Plans in Spain prioritizes water allocation to ligneous crops over annual crops, in consequence risk of water shortage is smaller.

Basis risk of the index insurance is analyzed comparing insurance indemnities and actual losses. Insurance indemnities are calculated according to the index insurance scheme, so that water allotments are estimated from past records of drought indices. Actual losses are calculated directly from historical water allotments. The probable farmer losses and gains due to index insurance basis risk are denoted as basis loss and basis gain respectively (Zeng, 2000).

The hedging effectiveness of index insurance is analyzed by comparing ID gross margin with and without the insurance contract, measuring the standard deviation (Kellner & Musshoff, 2011). Additionally, we compare the mean root square loss (MRSL), and minimum gross margin with and without the insurance contract. In addition to the pure premium, we consider different premium loadings representing potential administrative and capital costs of the insurance company. MRSL is a simple function of the semivariance (*i.e.* losses) with respect to the gross margin trend without insurance (Vedenov & Barnett, 2004).

The gross margin in the ID in a year t (GM_{IDt}) is estimated considering the gross margin by crop c (GM_c) and the surface that each crop represents in the ID that year (S_{tc}). To estimate the gross margin in the ID with insurance, we should add the indemnity in the year t (Ind_t) and subtract the premium rate (*Premium*) (equation 12).

$$GM_{IDt} = \left(\sum_{c=1}^{C} S_{tc} \times GM_c \right) + \left(Ind_t - Premium \right) \quad [12]$$

The average gross margin by crop is calculated following equation 13.

$$GM_c = \left(Y_c \times P_c \right) - \left[\left(dc_c + e_c + l_c \right) \times Y_c \right] \quad [13]$$

where c is the crop, Y_c and P_c are the 5-year Olympic average of the irrigated yield and crop price in kg/ha and €/kg respectively; and dc_c, e_c, and l_c are the 5-year Olympic average of the direct costs, equipment costs and labor force costs for producing 1 kg of crop c (in €/kg). Direct costs include the costs of plants and seeds, fertilizers, and pesticides.

For calculating the gross margin, indirect costs, amortizations, and subsidies were not considered. Gross margin of fallow land was then equal to 0. For the evaluation of the hedging performance of the index insurance, we considered a constant gross margin per crop, because the instrument is meant to stabilize the losses due to water scarcity, and not to changes in prices, production costs, or crop yields due to other causes (*e.g.* pests, temperatures, hail) than just water stress. In consequence, using the gross margin per year could distort the instrument performance.

In order to generalize the methodology, we detailed the conditions (C) that an ID should meet to be insured under the insurance scheme proposed:

– (C1) The ID (actual policy holder) assembles all irrigators that irrigate their farm from the same water source. The ID is responsible of the water distribution among irrigators and is in charge of collecting water fees.

– (C2) Ideally, water supply in the ID comes from a reservoir or a reservoir system situated in the headwaters, where inflows do not depend on human actions, but only on weather conditions. Otherwise, the DI should be selected carefully in order to be objective.

– (C3) Water shortages cannot be predicted at the beginning of the crop season (the take up period). In other words, the correlation between historical volumes stored at the beginning of the crop season and the historical volume stored at the beginning of the irrigation season should be not significant.

– (C4) When implementing the insurance scheme, the payment of the premium and management of economic compensations in case of drought is carried out by the ID's managers. The ID distributes water, the premium share and the economic compensation between the farmers in order to optimize water productivity in the whole ID. The sharing rule shall be signed by every member of the ID.

Description of the case study

The region of study was selected in order to fulfill all conditions described in the previous section and is vulnerable to hydrological droughts. The most restrictive condition is C3, since it is common that reservoirs servicing the main irrigated areas store more than one-year of water demands to face drought episodes. Collaboration and data provided by the ID was also decisive to select the study area.

Case study selected is located in the Bardenas General Irrigation District, in the Ebro River Basin. It distributes irrigation water to 82,000 ha of irrigable land divided into 20 irrigation sub-districts (ID) located mainly in the province of Saragossa. Crop water demand is established at 7512 m^3/ha (CHE, 2013).

Each of the ID is responsible of the water distribution among the farmers. Our methodology is applied to the sub-district V (ID-V), located in Ejea de los Caballeros.

ID-V is serviced by the Bardenas Canal, which is serviced with water from the Yesa Reservoir (with a maximum capacity of 447 hm^{3}[3]) on the headwaters of Aragón River. Yesa reservoir's purpose is mainly servicing the ID (irrigation represents 99% of the consumptive demands). Correlation between the Yesa Reservoir stocks in October and Yesa Reservoir stocks in May is equal to 0.21 and not significant (p>0.1). In consequence, water scarcity cannot be predicted at the beginning of the crop season.

The Bardenas General Irrigation District is irrigated mainly by surface irrigation (78%) and to a lesser extent by sprinkler irrigation (22%). The main irrigated crops are winter cereals (38%), maize (21%) and alfalfa (20%) (Bardenas, 2012). Bardenas ID has been studied before by Causapé (2009), Uku (2011), and Ruiz *et al*. (2013). There is a Drought Management Plan (DMP) in the Ebro River Basin (CHE, 2007) that establishes preparedness and mitigation measures, depending on the water supply system drought status (emergency, alert or watch, pre-alert and normality) that is determined by the DMP's Drought Status Indicator (DSI). The DSIs are calculated either from reservoir inflows, stocks, or in some cases piezometric levels and precipitation. DSI's are standardized between 0 and 1 (CHE, 2007). The standardized values of the DSIs define the drought status according to basin-specific thresholds (Estrela & Vargas, 2012). In emergency and in alert drought status (0 to 0.15, and 0.15 to 0.30 respectively) the measures include restrictions in water allocation for agriculture, which get more severe as drought intensifies. Also priority in water uses is established, for instance, ligneous crops are given priority over other crops.

For the unitary indemnity calculation and for calculating the hedging effectiveness, data concerning provincial crop yields and national crop prices are sourced from the Statistical Yearbook data set published by the Ministry of Agriculture, Food and Environment (MARM, 2014b). Crop surfaces and variable irrigation costs from ID-V are sourced from the Bardenas annual reports (Bardenas V, 2015). Production costs in Bardenas and regional crop prices are sourced from Technical Reports (MARM, 2012, 2013a, b)[4].

For the empirical estimation of the regression that estimates water allotments depending on the Indicator, Drought Status Indicators (DSI) were facilitated by the Confederación Hidrográfica del Ebro. Last, crop water allotments, were sourced from the Bardenas annual reports (Bardenas V, 2015).

In order to estimate the unitary indemnity, depending on the water allotment finally received, we have defined different crop distribution scenarios (see Figure 3):

– *Fully irrigated scenario in Bardenas:* crop surfaces and yields have been sourced from historical data under the 'normal' drought status following DSI definition which is $DSI>0.5$ (10 out of 13 years), which corresponds to the fully irrigated scenario.

– *Partial drought scenario in Bardenas:* crop surfaces and yields have been sourced from historical data under drought status: 'pre-alert', 'alert' or 'emergency', according to DSI ($DSI<0.5$). Water allotment associated to this scenario is the average of the water allotment received in the historical period under these circumstances (3 out of 13 years).

– *Extreme drought scenario in Bardenas:* only rainfed crops. We have associated to the rainfed scenario ($wa=0$) three hypotheses of crop distributions based on the discussion with irrigators. In these scenarios, surfaces dedicated to cereals, sunflower and fallow increase, and the surface dedicated to rice and maize (high water demanding crops) disappear. Alfalfa crop, being a multiannual crop, remains constant.

Results

Index insurance design and premium rating

We tested several DIs, and selected the one that best correlates with water allotments in the ID. The DIs tested are those defined in the 2007 Drought Management Plan (DMP), called DSIs measured in February, March, April, May and June, for regulated sections (DSI based on reservoir stocks) and non-regulated sections (DSI calculated from river flows) in the Aragon River Operating system (CHE, 2007). The DI that best correlates is the one measured in February for the regulated section (correlation coefficient=0.74; p= 0.009), based on water stocks in Yesa reservoir. Although DI represents accurately the water availability for irrigation, it might not be a valid

[3] Yesa reservoir enlargement Project is being executed since October 2014. It is expected that works will conclude by April 2018. Enlargement will allow to supply urban water to Saragossa, to Bardenas General Irrigation District, and to environmental purposes, and will reduce the risk of floods downstream Yesa reservoir (CHE, 2014).

[4] Technical Reports are not publicly accessible. They have been provided by the Office of the Undersecretary General for Analysis, Prospective and Coordination at the Spanish Ministry of Agriculture, Food and Environment. Therefore, they are subject to a privacy commitment. They can be made available upon permission from Spanish Ministry of Agriculture, Food and Environment.

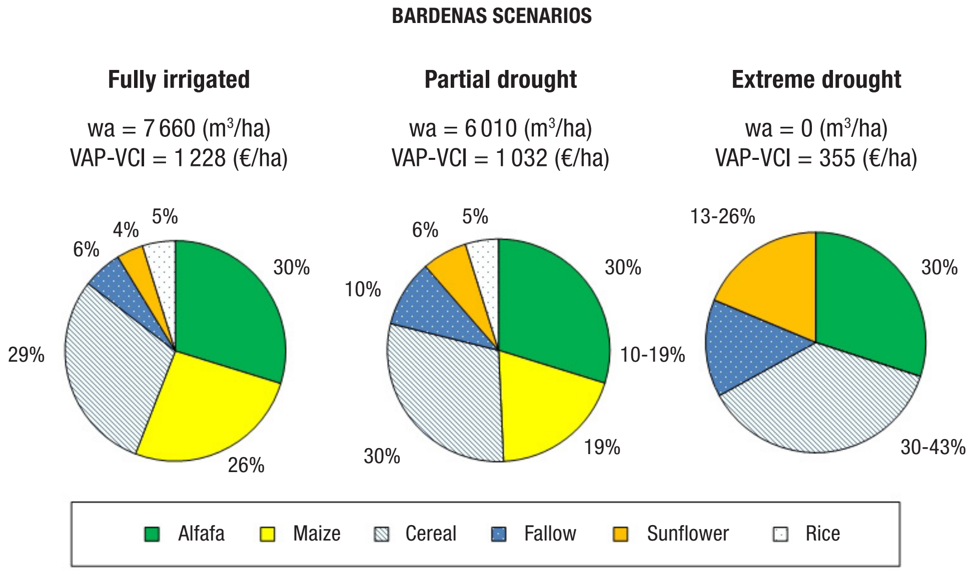

Figure 3. Crop surface distribution, water allotment and net value of agricultural production (NVAP) associated to scenarios for the calculation of the water value (or unitary indemnity) in Bardenas. wa: water allotment correspondant to the scenario. VAP-VCI: value of agricultural production (VAP) net of variable irrigation costs. GM: gross margin, which is the VAP net of variable production costs.

index due to the fact that it can be manipulated and thus be subject to moral hazard (Zeuli & Skees, 2005; Brown & Carriquiry, 2007). In order to avoid moral hazard, the DI is predicted using an auxiliary Index (Aux I). The Aux I is the sum of the inflows between October and January (see equation 14). Using 2000-2013 data, the model that predicts DI is represented in equation 15.

$$Aux\ I = \sum_{oct}^{feb} inflows \qquad [14]$$

$$\widehat{DI}_t = f(Aux\ I) = \text{MIN}\left(0.9,\ 0.0037 \times Aux\ I^{***} - 0.4788^{***}\right) Adj\ R^2 = 0.34 \qquad [15]$$

Asterisks denote significance level *=10%, **=5%, and ***=1%.

Linear and log linear models linking the DI selected and water allotments are compared by means of the Box-Cox transformation. Data series from 2000 to 2014 and OLS estimation were used for the model estimation. Despite the fact that water management regulations have changed (Drought Management Plan is being applied since 2007), water management rules are consistent over the whole period 2000-2014, since no statistically significant changes are detected before and after 2007.

Water allotments delivered in 2000 and 2001 are considered outliers, since they are far larger than the crop water demand that is planned in the River Basin Plan (CHE, 2013), which equals to 7512 m^3/ha. In consequence, we have included in the regression a Binary variable *d* that controls for all years in which the water allotment is bigger than crop water demands established (*d*=1), otherwise, *d*=0 means that water allotments are smaller or equal to crop water demands established. For the index insurance design, we use the regression where the Binary variable *d*=0. Water allotments are then estimated from DI_t following equation 16 that is also represented in Figure 4:

$$wa_t = 5791^{***} + DI_t \times 1235^{**} + d \times 4005^{**} \text{adj } R^2 = 0.88 \qquad [16]$$

Asterisks denote significance level *=10%, **=5%, and ***=1%.

The crop surface distribution, the water allotment and the NVAP associated with each scenario described in previous section are presented in Figure 3. ID water values calculated following equation 7 are a set of values between 0.11 and 0.12 €/m^3. Given the small difference between the two values, for simplicity we applied the average water value as the unitary indemnity regardless of the water allotment received: 0.115 €/m^3.

The index insurance guarantees the average water allotment received in the ID in the period 2000-2014, for *d*=0 equal to 6537 m^3/ha. To avoid problems of adverse selection, insurance should be sold at the beginning of the crop season (October), before the rainfall and snow period begins. We have established two types of contracts: a scheme without franchise deductible (NFD) and with a franchise deductible (FD) equal to 8.6%. The γ is established in 8.6% so the *Trigger* corresponds to the threshold of the DI indicating a status of Emergency (DSI=0.15). Premium rates, liability and the *Trigger* are presented in Table 1. Premiums are

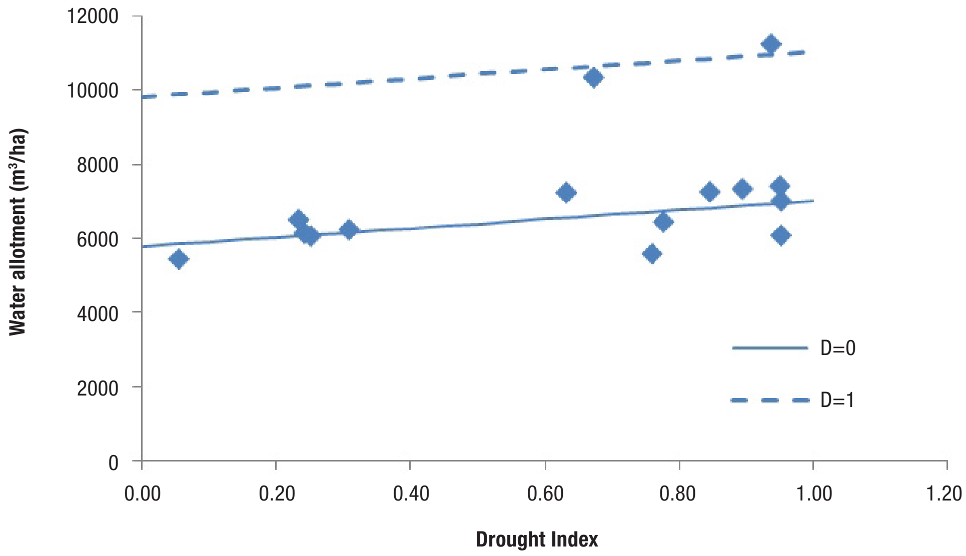

Figure 4. Model to estimate water allotments based on drought index considering 2000-2014 period. Binary variable *d* controls for all years in which the water allotment is bigger than crop water demands established (*d*=1), otherwise, *d*=0 means that water allotments are smaller or equal to crop water demands established.

calculated from both DI, and based on data series from 1961 to 2014.

In this research we have identified several sources of basis risk: basis risk associated to the selected DI, and basis risk associated to the use of an Aux I to estimate water stocks in order to reduce the risk of index manipulation. Both measures of basis risk are disaggregated in basis loss and basis gain comparing indemnities from the insurance scheme (based on drought indices either actual or estimated) to potential indemnities calculated from past records of whole-farm wa_t for the historical period 2000-2014 (Table 1). Basis loss is always greater than basis gain, meaning that the insurance scheme is overestimating water allotments in the period 2000-2014.

Hedging effectiveness

In order to test the performance of the index insurance in reducing economic consequences of water supply risk, we compared the ID gross margin or GM with and without insurance in the period 2000-2014. Data available for GM calculation by crop in ID-V is at Autonomous Community[5] scale (MARM, 2012 2013a, b). Average GMs by crop are calculated for the Aragon region considering data period 2007-2011. Alfalfa and forage GMs are equal to 916 €/ha, maize GM is equal to 976 €/ha, cereals GM (soft and durum wheat and barley) is equal to 392 €/ha, sunflower GM is 24 €/ha and rice GM is 834 €/ha. Then GM in the ID by year is estimated considering average GM by crop and past records of crop surfaces in Bardenas ID-V for the period 2000-2014.

In addition to the pure premium rate, we consider premium loadings of 20%, 30%, and 40%, representing possible administrative and capital costs of the insurance company. Results of the hedging effectiveness analysis of the index insurance scheme can be observed in Table 2. Compared to the no insurance scenario, both insurance designs have a lower standard deviation of GMs, a lower Mean Root Square Loss (MRSL), and a larger minimum GM, for the pure premium and for all different premium loadings. In comparing both insurance designs, the γ=0% design seems the most effective in reducing risk exposure under all criteria, except for the MRSL criteria.

Discussion

The proposed insurance scheme has some issues related to its implementation that merit a few comments. Firstly, the implementation of the collective policy may confront some difficulties since all irrigators in the ID should agree on the decision to insure and on contract conditions. In case farmers from the ID do not find a consensus that satisfies all of them, one alternative would be to establish individual contracts (so contract conditions C1 & C4 would no

[5] Spain is divided in 17 regions, also called 'Autonomous Communities'.

Table 1. Average indemnities, guaranteed water allotment (GWA), liability, premium rates and basis risk for hydrological drought index insurance (HDDI) in Bardenas, for an insurance scheme without franchise deductible (NFD) and an insurance scheme with a franchise deductible (FD). Calculations are made based on actual drought index (DI) and estimated DI ($\widehat{DI}$)

		NFD		FD (γ=8.6%)	
		DI	$\widehat{DI}$	**DI**	$\widehat{DI}$
Average indemnity		0.115 €/m^3			
GWA and liability		6 537 m^3/ha and 752 €/ha			
DI trigger (–)		0.6		0.15	
Premium rate	% (liability)	1.77	1.33	0.4	0.61
	€/ha	13.33	10.01	3.03	4.596
Basis risk	Basis loss %	2.19	2.3	1.85	1.88
	Basis gain %	0.7	0.78	0	0.8

Table 2. Hedging effectiveness of the insurance schemes considering 2000-2014 period, for an insurance scheme without franchise deductible (NFD) and an insurance scheme with a franchise deductible or **γ** (FD)

	Premium loading	**Gross margin standard deviation (€/ha)**	**Minimum gross margin (€/ha)**	**Mean root square loss (€/ha)**
Without insurance	–	55.14	612.31	127.59
With insurance NFD (γ=0%)	0%	44.92	631.34	71.44
	20%	44.92	628.68	77.24
	30%	44.92	627.34	80.24
	40%	44.92	626.01	83.29
With insurance FD (γ=8.6%)	0%	50.59	628.6	69.14
	20%	50.59	628.0	70.56
	30%	50.59	627.7	71.27
	40%	50.59	627.4	71.99

longer be applicable). Individual contracts following the scheme proposed can only be established in the case water allocation between the farmers is fixed and not subject to the irrigators water allocation's requests. However, this is unlikely, since usually irrigators make a formal request to the ID concerning the water allocation they need. Then, ID tries to meet all irrigators' requests taking into account water availability and water rights. As a consequence, insurance is to be based on the average water allotment granted to the ID by the Basin Agency. The insurance design would then offer excessive coverage to irrigators cultivating low water demanding crops and would fall short offering coverage those cultivating high-water demanding crops. Another alternative would be to let the irrigators set freely the liability, as proposed by Zeuli & Skees (2005). The unitary indemnity received would change as a consequence and so would change the premium rate. The scheme would then work as a weather derivative, since the unitary indemnity is no longer estimated from past records of water allotments and GMs in the farm. Therefore, this could lead to some disagreements with crop insurance laws, given that it could provide a coverage beyond the actual farm loss.

Secondly, the insurance scheme requires that water management rules should be implemented in full over the validity period of the insurance policy and no significant changes in water infrastructure should be observed. In case it does not hold, the model and all the calculations will need to be updated. Since there would not be historic data on DI and water allotments for the new situation, we could only rely on water simulation models to generate water allotments and DI values under the new situation. In case of technical change in crop production, it would not affect the index insurance model that estimates water allotments from a DI. However, it might affect the water allotment guaranteed and also the unitary indemnity estimation, since technical changes would result in larger farmer's income, yielding higher GM for the same water allotment.

Thirdly, the probability and severity of droughts can also be influenced by climate change. Climate change introduces an additional factor of uncertainty in drought risks (Bielza *et al.*, 2008). Increasing drought risk resulting from climate change affects the price of insurance in two ways. First, ambiguity and catastrophe loads may increase because uncertainty associated with future climate change impacts leads insurers to plan for the worst likely scenario when establishing these loads. Historical return periods may not be valid since they might underestimate the likelihood of agricultural losses in the future. Second, increasing drought risk changes the pure risk (Collier *et al.*, 2009). In consequence, insurance parameters have to be adjusted over time to effectively hedge future weather risk (Kapphan *et al.*, 2012).

Finally, unitary indemnity estimation does not completely offset economic losses that might affect ligneous crops in case of drought, especially when drought affects production in subsequent years.

Some limitations specifically related to our findings for the Bardenas case study are associated to data availability. The unitary indemnity estimation and hedging effectiveness analysis rely on provincial and regional data, and not on local data. Besides, some of the crop patterns linked to water allotment scenarios, used for the unitary indemnity calculation, are designed based on the discussion with irrigators, due to the lack of longer data series. This could be a source of inaccuracies in the results that could be addressed with appropriate and longer data series. Collaboration among insurance companies, producers associations, and/or public entities would be required to have access to a more appropriate data. Besides, we have detected the presence of outliers in water allotments in the period analyzed, which had to be addressed including a Binary variable to the model.

Additional insight into the quality of our results is gathered by comparing our findings to previous literature results. Firstly, the liability of our insurance scheme (equal to 752 €/ha) is smaller than the liability reported by Ruiz *et al.* (2013) in a drought whole-farm insurance with on-field loss adjustment covering irrigated crops, also in Bardenas (equal to 1488 €/ha). This difference is due to the fact that our index insurance scheme takes into account that farmers not being able to irrigate may still have the alternative of producing rainfed crops (when cultivating annual crops), and thus earning some revenue (except for the case of rice, which is cultivated on marginal soils). Secondly, our unitary indemnity estimation can be compared to Lorite *et al.* (2012) works in a southern river basin in Spain. We obtained a unitary indemnity of 0.115 €/m^3 that is in the range of Lorite *et al.* (2012) results: wheat (0.054 €/m^3), sunflower (0.092 €/m^3), and maize (0.15 €/m^3).

There are some issues about the use of the Aux I, which is required in case the selected DI might be subject to manipulation. One disadvantage of its use is the increase in basis risk. In our case study, the use of an Aux I increases basis loss (0.11% for NFD and 0.03% for FD) and basis gain (0.08% for NFD and 0.8% for FD). Another important fact to take into account is that the Aux I would not reflect some impediments that might prevent water from being delivered to irrigators, such as a breakdown in the canals or conveyance system, or a pollution problem. Under these circumstances, irrigators would not receive an indemnity, but would suffer economic losses. This would need to be clearly stated in the policy wording. If water management is performed according to predefined rules, there would be no need of such an Aux I, which may be warranted when the selected DI (*e.g.* water stocks in the reservoir) might be subject of manipulation. This would need further discussion with all stakeholders involved.

It is interesting to observe how basis risk is distributed among basis loss and basis gain. Ideally basis loss and basis gain should be similar, so the insurance scheme is favoring neither the farmer nor the insurance company. In Bardenas, basis loss in the analysis period is larger than basis gain in all cases, meaning that the insurance scheme is overestimating water allotments. This is due to the fact that in several years the DI was above the trigger, and irrigators received a water allotment below the guaranteed water allotment. These cases would require further investigation. Despite this, the hedging effectiveness analysis shows that NFD and FD insurance schemes are effectively reducing risk exposure, even considering a 40% premium load to cover administrative and capital costs of the insurance company. Note that premium loading for the FD scheme might be smaller than for the NFD scheme, because the more frequent the payoffs take place, the higher the administrative costs that the insurance company is going to charge.

Results suggest that the insurance scheme would be useful to provide economic stability to IDs. It would constitute a means for irrigators to adapt to climate variability and it could encourage investment in irrigation technologies as a means of adaptation for dryland farmers. It would also promote a more efficient use of the irrigation water. This insurance can be generalized to any ID fulfilling the conditions mentioned in Section "Index insurance design, hedging effectiveness, and contract conditions". IDs not fulfilling condition C3 might be subject to intertemporal adverse selection. Intertemporal adverse selection comes from the fact that preseason weather information can influence crop insurance decisions (Carriquiry & Osgood 2012), as farmers could use this information to purchase insurance only in years with enhanced drought risk and probability of payout (Luo *et al*., 1994). Further research is needed to propose other insurance schemes dealing with intertemporal adverse selection.

The use of an expert panel to determine the type of insurance scheme that better fits with the Spanish framework is expected to bridge the gap between theory and practice, contributing to a more attractive and adapted insurance scheme to local conditions. Further discussions with the expert panel exploring the implementation difficulties of the insurance scheme selected and developed would be of interest for the research.

Public support to index insurance is currently accepted in EU legislation, under certain conditions. Specifically, EC (2014) and EU (2013) refer to insurance premiums[6] of schemes (i) using "weather indexes (including quantity of rainfall and temperature) established at local, regional or national level" to quantify the economic losses. For that, (ii) "the occurrence of an adverse climatic event has to be formally recognized as such by the competent authority of the Member State concerned" and (iii) financial contribution to premiums for crop insurance shall only be granted for insurance contracts which "cover for loss caused by an adverse climatic event, which destroys more than 30% of the average annual production of the preceding three-year period or the 5-year Olympic average". Concerning our HDII, although EU legislation and guidelines allows the use of weather indexes (including quantity of rainfall and temperature), streamflows or water stocks (in which our DI is based) are not explicitly mentioned as weather indexes and could be manipulated. In the case streamflows and specially water stocks would not be accepted as weather variables, Aux Is could be used, with the consequent increase in basis risk. The compliance with condition (ii) would not represent a problem as it would easily be reached if the DI triggering the indemnity was at the same time an official indicator that indicates a natural disaster, which is the case in our insurance scheme. Particularly, the FD scheme is triggering a payment whenever the DI indicates a status of Emergency. Lastly, the use of a γ might help comply with condition (iii). In our case study, the FD scheme has established a γ at 8.6% of the water allocation. Although water allocation and annual production might not follow a linear relationship, a γ of less than 10% of water deficit would probably be far from being equivalent to the 30% required (moreover, in the period analyzed, there are not historic records showing a 30% loss in terms of water allotment). Although the insurance scheme in our case study will not be considered to be compatible with EU legislation[7], FD scheme in other regions would be, provided irrigators would be exposed to water shortages destroying more than 30% of the average annual production and the DI would be accepted as a weather variable.

The main strength of this insurance scheme is the compatibility with water markets, water banking, transfer of water rights, and groundwater use. Another important strength is that farmers might receive the economic compensation as soon as the DI is measured, far before the end of the crop season, allowing them to have ready cash for any eventuality arising in the crop season, such as the possibility of participating in water market mechanisms.

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References

Agroseguro, 2014. Seguro de compensación por pérdida de pastos. http://agroseguro.es/fileadmin/propietario/Publicaciones/Folletos/PASTOS.pdf [1 Dec 2014].

Bardenas, 2012. Comunidad General Canal de Bardenas. Modernización de regadíos. Jornada Técnica de Modernización de Regadíos, 6 octubre 2012. http://www.coiaanpv.org [10 Jan 2015].

Bardenas V, 2015. Memoria de la Comunidad de Regantes V de los riegos de Bardenas (2003-2014). http://www.comunidadv.com/ [10 February 2015].

Bielza M, Conte C, Catenaro R, Gallego FJ, 2008. Agricultural Insurance Schemes Report. Agriculture Unit, Joint Research Center, European Commission.

Brown C, Carriquiry M, 2007. Managing hydroclimatological risk to water supply with option contracts and reservoir index insurance. Water Resour Res 43(11): W11423. http://dx.doi.org/10.1029/2007WR006093.

Causapé J, 2009. Aprovechamiento del agua en los regadíos de Bardenas. ITEA-Inf Tecn Econ Agrar 105(3): 202-221.

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[6] The gross aid intensity must not exceed 65 % of the cost of the insurance premium (EU, 2013, Annex II; EC, 2014, art 412).

[7] It could be subsidized from national funds under *De Minimis* rule (EC, 2006).

Carriquiry M, Osgood DE, 2012. Index insurance, probabilistic climate forecasts, and production. J Risk Insur 79(1):287-300. http://dx.doi.org/10.1111/j.1539-6975.2011.01422.x.

CHE, 2007. Plan especial de actuación en situaciones de alerta y eventual sequía en la cuenca hidrográfica del Ebro. Confederación Hidrográfica del Ebro, Saragossa.

CHE, 2013. Anejo VI Sistemas de explotación y balances. In: Propuesta de proyecto de plan hidrológico de la cuenca. Confederación Hidrográfica del Ebro, Saragossa.

CHE, 2014. La Confederación del Ebro inicia los trabajos de ejecución del cuerpo de presa para el recrecimiento del embalse de Yesa. Confederación Hidrográfica del Ebro, Saragossa.

Collier B, Skees J, Barnett B, 2009. Weather index insurance and climate change: opportunities and challenges in lower income countries. Geneva Pap R I-Iss P 34 (3): 401-24.

Easter W, Huang Q, (eds.), 2014. Water markets for the 21st century: What have we learned? Springer, New York. http://dx.doi.org/10.1007/978-94-017-9081-9.

EC, 2006. Commission Regulation (EC) No 1998/2006 of 15 December 2006 on the application of Articles 87 and 88 of the Treaty to de minimis aid. Official Journal of the European Union L 379: 5-10.

EC, 2014.European Union guidelines for state aid in the agriculture and forestry sector and in rural areas 2014 to 2020. Official Journal of the European Union C204:1-97.

Estrela T, Vargas E, 2012. Drought management plans in the European Union. The case of Spain. Water Resour Manag 26 (6): 1537-1553. http://dx.doi.org/10.1007/s11269-011-9971-2.

EU, 2013. Regulation (EU) No 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005. Official Journal of the European Union L347: 487-548.

INE, 2012. Censo agrario 2009. Instituto Nacional de Estadística, Madrid, Spain.

IPCC, 2012. Summary for policymakers. In: Managing the risks of extreme events and disasters to advance climate change adaptation. A special report of working groups I and II of the Intergovernmental Panel on Climate Change; Field CB, *et al.* (eds.). pp: 1-19. Cambridge Univ. Press, Cambridge, UK, and NY, USA.

IRMI, 2014. Glossary of insurance and risk management terms. http://www.irmi.com/online/insurance-glossary/default.aspx [14 Jul 2014].

Kapphan I, Calanca P, Holzkaemper A, 2012. Climate change, weather insurance design and hedging effectiveness. Geneva Pap R I-Iss P 37 (2): 286-317.

Kellner U, Musshoff O, 2011. Precipitation or water capacity indices? An analysis of the benefits of alternative underlyings for index insurance. Agr Syst 104(8): 645-653. http://dx.doi.org/10.1016/j.agsy.2011.06.007.

Leiva A, Skees J, 2008. Using irrigation insurance to improve water usage of the Rio Mayo irrigation system in Northwestern Mexico. World Dev 36(12): 2663-2678. http://dx.doi.org/10.1016/j.worlddev.2007.12.004.

Lorite IJ, García-Vila M, Carmona MA, Santos C, Soriano MA, 2012. Assessment of the Irrigation Advisory Services' Recommendations and Farmers' Irrigation Management: A case study in Southern Spain. Water Resour Manag 26(8): 2397-2419. http://dx.doi.org/10.1007/s11269-012-0023-3.

Luo H, Skees JR, Marchant MA, 1994. Weather information and the potential for intertemporal adverse selection in crop insurance. Rev Agr Econ 16(3): 441-451. http://dx.doi.org/10.2307/1349702.

MARM, 2012. Análisis de la economía de los sistemas de producción. Resultados técnico-económicos de explotaciones agrícolas de Aragón en 2007-2011. Ministerio de Agricultura Alimentación y Medio Ambiente, Madrid, Spain.

MARM, 2013a. Resultados técnico-económicos de cultivos herbáceos 2011. Subdirección General de Análisis, Prospectiva y Coordinación, Subsecretaría Ministerio de Agricultura Alimentación y Medio Ambiente, Madrid, Spain.

MARM 2013b. Resultados técnico-económicos de cultivos leñosos 2011. Subdirección General de Análisis, Prospectiva y Coordinación, Subsecretaría Ministerio de Agricultura Alimentación y Medio Ambiente, Madrid, Spain.

MARM, 2014a. Anuario de estadística. Ministerio de Agricultura, Alimentación y Medio Ambiente. http://www.magrama.gob.es [2 Jun 2014].

MARM, 2014b. ESYRCE: encuesta sobre superficies y rendimientos de cultivos. Ministerio de Agricultura, Alimentación y Medio Ambiente, Madrid, Spain.

OECD, 2011. Managing risk in agriculture. Policy assessment and design. Organisation for economic co-operation and development, OECD Publishing.

Pérez Blanco CD, Gómez Gómez CM, 2013. Designing optimum insurance schemes to reduce water overexploitation during drought events: A case study of La Campiña, Guadalquivir River Basin, Spain. J Environ Econ Policy 2(1): 1-15. http://dx.doi.org/10.1080/21606544.2012.745232.

Quiroga S, Garrote L, Fernandez-Haddad Z, Iglesias A, 2011. Valuing drought information for irrigation farmers: potential development of a hydrological risk insurance in Spain, Span J Agric Res 9(4): 1059-1075. http://dx.doi.org/10.5424/sjar/20110904-063-11.

Rey D, Garrido A, Calatrava J, 2014. The water markets in Spain: Moving towards 21st century mechanisms and approaches with 20th century regulations. In: Water markets for the 21st century: What have we learned?; Easter W & Huang Q (eds.), pp: 127-147. Springer.

Rey D, Garrido A, Calatrava J, 2015. Comparison of different water supply risk management tools for irrigators: option contracts and insurance. Environ Resour Econ 2015: 1-25. http://dx.doi.org/10.1007/s10640-015-9912-2.

Risk Management Agency-Topeka, 2015. Risk Management Agency Update. Arkansas Valley Farm/Ranch/Water symposium. http://www.farmranchwater.org [19 Jul 2015].

Ruiz J, Bielza M, Garrido A, Iglesias A, 2013. Managing drought economic effects through insurance schemes based on local water availability. Proc 8th Int Conf of European Water Resources Association, Porto (Portugal), 26-29 June 2013.

Ruiz J, Bielza M, Garrido A, Iglesias A, 2015. Dealing with drought in irrigated agriculture through insurance schemes: an application to an irrigation district in Southern Spain. Span J Agric Res 13(4): e0106. http://dx.doi.org/10.5424/sjar/2015134-6941.

Ruiz-Sanchez M, Domingo R, Castel J, 2010. Deficit irrigation in fruit trees and vines in Spain. Span J Agric Res 8: 5-20. http://dx.doi.org/10.5424/sjar/201008S2-1343.

Skees JR, Barnett BJ, Collier B, 2008. Background and context for climate adaptation discussions. GlobalAgRisk, Lexintong, KY, USA.

Uku S, 2011. Water management policies to improve surface irrigation. Alban J Agric Sci 10(2): 29-37.

Vedenov DV, Barnett BJ, 2004. Efficiency of weather derivatives as primary crop insurance instruments. J Agr Resour Econ 29(3): 387-403.

Zeff H, Characklis G, 2013. Managing water utility financial risks through third-party index insurance contracts. Water Resour Res 49: 1939-1951. http://dx.doi.org/10.1002/wrcr.20364.

Zeng L, 2000. On the basis risk of industry loss warranties. J Risk Financ 1(4): 27-32. http://dx.doi.org/10.1108/eb043452.

Zeuli KA, Skees JR, 2005. Rainfall insurance: A promising tool for drought management. Int J Water Resour Dev 21(4): 663-675. http://dx.doi.org/10.1080/07900620500258414.