Probabilistic analysis of water availability for agriculture and associated crop net margins

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Institutional framework

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Introduction – Objectives

Context

- Rising water demands
- Importance of irrigated agriculture
- Hydrological droughts – water shortages

Objectives

- **Analyze the variability of water shortage in an irrigation district and the effect on farmer's income**

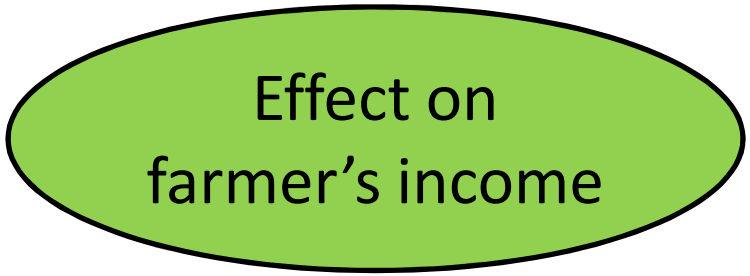
Methods

Variability of water shortage

- Supply system simulation
  - Software SIMDRO (Rossi, Nicolosi, & Cancelliere , 2008)
  - Stochastically generated inflows with SAMS (Sveinsson, Salas, Lane, & Frevert, 2003)
- Probabilistic analysis
  - Frequencies of annual water availability for agriculture

WHY a simulation approach ?
BECAUSE: - lack of a long time-series of water allocations in agriculture
- changes in supply system configuration and water demands

Methods



- Crop income estimation
  - relationship between crop yield and water allocation:

    CROP PRODUCTION FUNCTION
- Optimization model
  - it is necessary to know the crop surface distribution in the farm and water allocation by crop: in this case through an OPTIMIZATION MODEL

Methods

OPTIMIZATION MODEL. Solved with GAMS

Function to optimize:

$$FarmIncome = \frac{\sum_c NetMargin_c * S_c}{\sum_c S_c}$$

Changing the variables:

S_c surface by crop

w_c water allocation by crop

Being…

$$NetMargin_c = Revenue_c - Costs_c$$
$$= (Subsidy_c + Price_c * Y_c) - (FixCosts_c + VariableCosts_c * Y_c)$$

Crop yield estimated from **w_c**, through crop production functions

Subjected to the following restrictions:

$$WaterAvailability = \frac{\sum_c w_c * S_c}{\sum_c S_c}$$

$$\sum_c S_c = SurfaceTotal$$

Model solved for different levels of Water Availability

Application to Bardenas Irrigation District

Localization and crop repartition

Crop Repartition in Bardenas (2011-12)	
Winter cereal	43%
Alfalfa	19%
Maize	12%
Fodder crops	7%
Fallow	6%
Rice	4%
Horticulture	2%
Others	3%

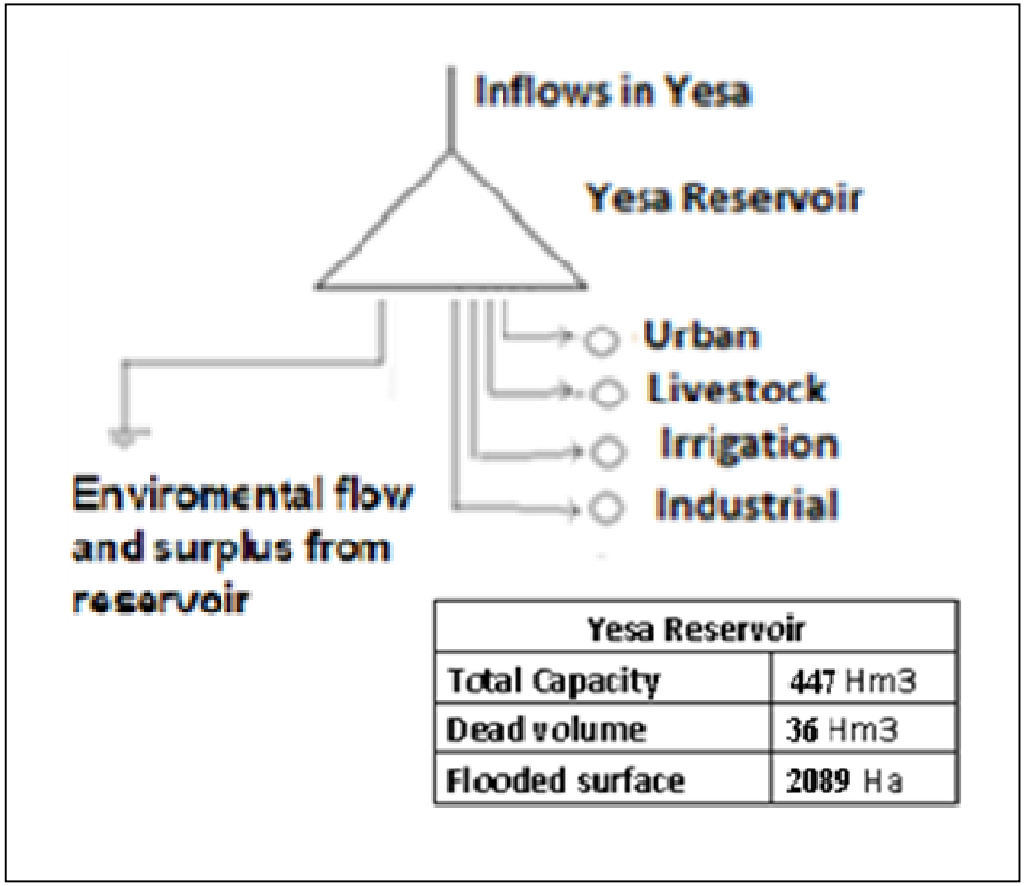
Source: Own elaboration. Data from Bardenas General Irrigation District (2012)

Application to Bardenas Irrigation District

Supply System configuration

YESA RESERVOIR
(source: www.saihebro.com)

BARDENAS CHANNEL
(source: www.ejeadigital.com)



Yesa Reservoir	
Total Capacity	447 Hm3
Dead volume	36 Hm3
Flooded surface	2089 Ha

Source: own elaboration

Application to Bardenas Irrigation District

Crop production function (Uku, 2011)

$$Y_c = \beta_{0c} + \beta_{1c} * w_c + \beta_{2c} * {w_c}^2 + \beta_{3c} * n_c + \beta_{4c} * {n_c}^2 + \beta_{5c} * n_c * w_c$$

Y_c [Tm/ha] is the crop yield for each crop c

c is related to the crop: alfalfa, wheat (soft wheat and durum

β_{0c}, β_{1c}, β_{2c}, β_{3c}, β_{4c}, β_{5c} are parameters for each crop

w_c [m^3/ha] is irrigation water allocated to the crop;

n_c [kg/ha] is average active nitrogen applied

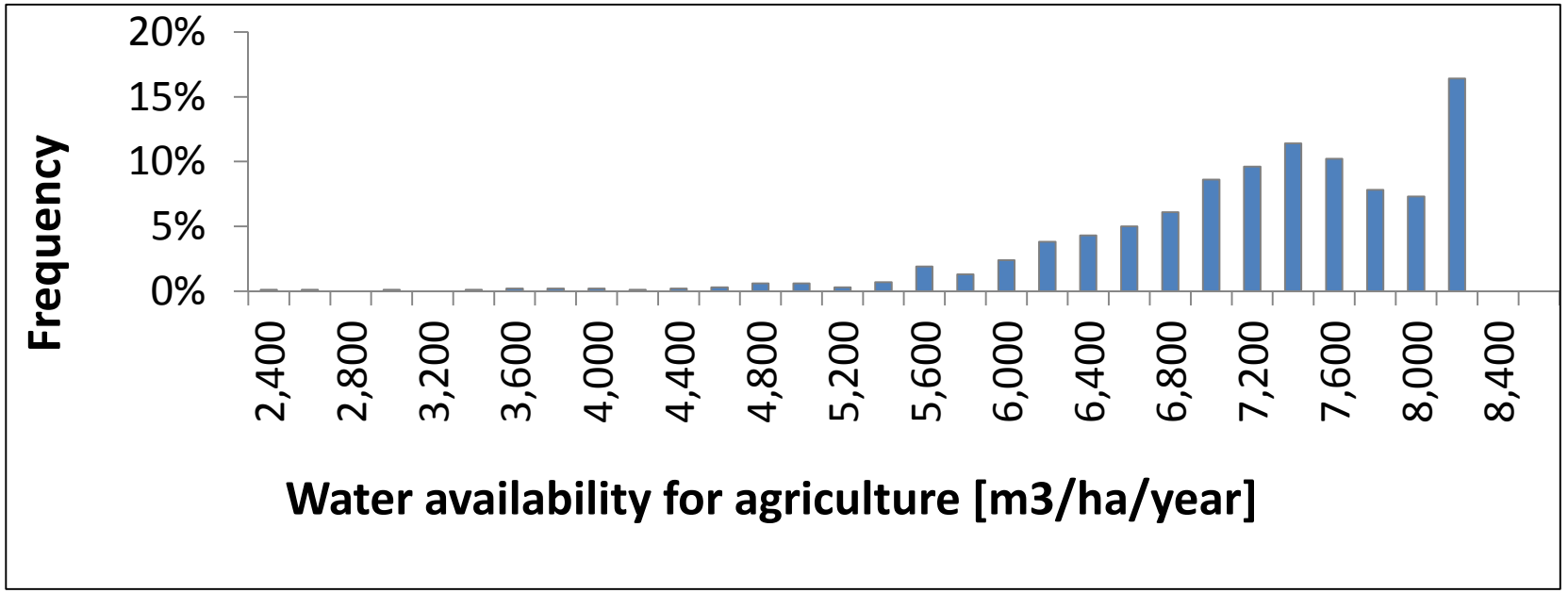
Application to Bardenas Irrigation District

DATA sources for SUPPLY SYSTEM SIMULATION	
DATA	SOURCE
Supply system characteristics	http://www.chebro.es
Industrial, Livestock and Urban water demands	Confederación Hidrográfica del Ebro (2011).
Repartition of agricultural demand by month	Confederación Hidrográfica del Ebro - CSIC (2004).
Inflows and reserves in Yesa Reservoir (1959-2008)	Ministerio de Medio Ambiente Medio Rural y Medio Marino (2009).
Thresholds for hydrological status	Confederación Hidrográfica del Ebro (2007).
Drought Mitigation measures	Confederación Hidrográfica del Ebro (2007).

Application to Bardenas Irrigation District

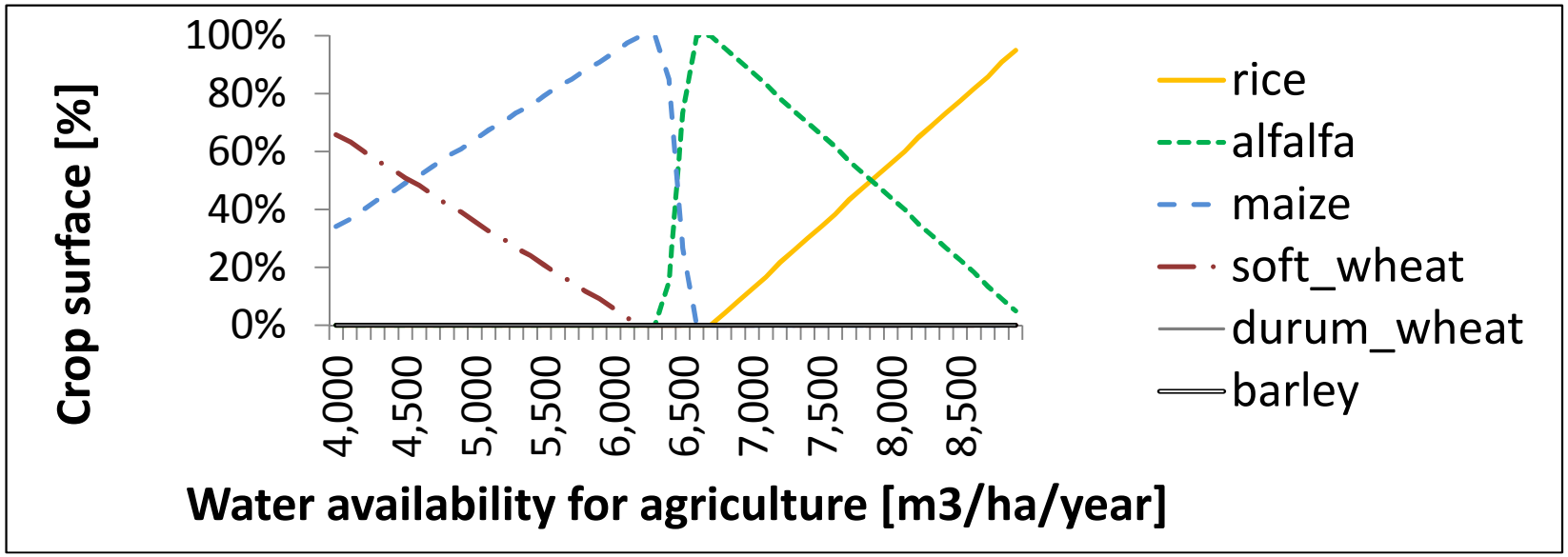
DATA sources for NET MARGIN CALCULATION	
DATA	SOURCE
Crop production function and associated parameters	Uku, S. (2011), Causapé, J. (2002).
Variable costs, fixed costs, prices and subsidies	Ministerio de Agricultura Alimentación y Medio ambiente (2012).
Historic crop surfaces and water allocation by crop (2000-2011)	Bardenas Irrigation District V (2011).

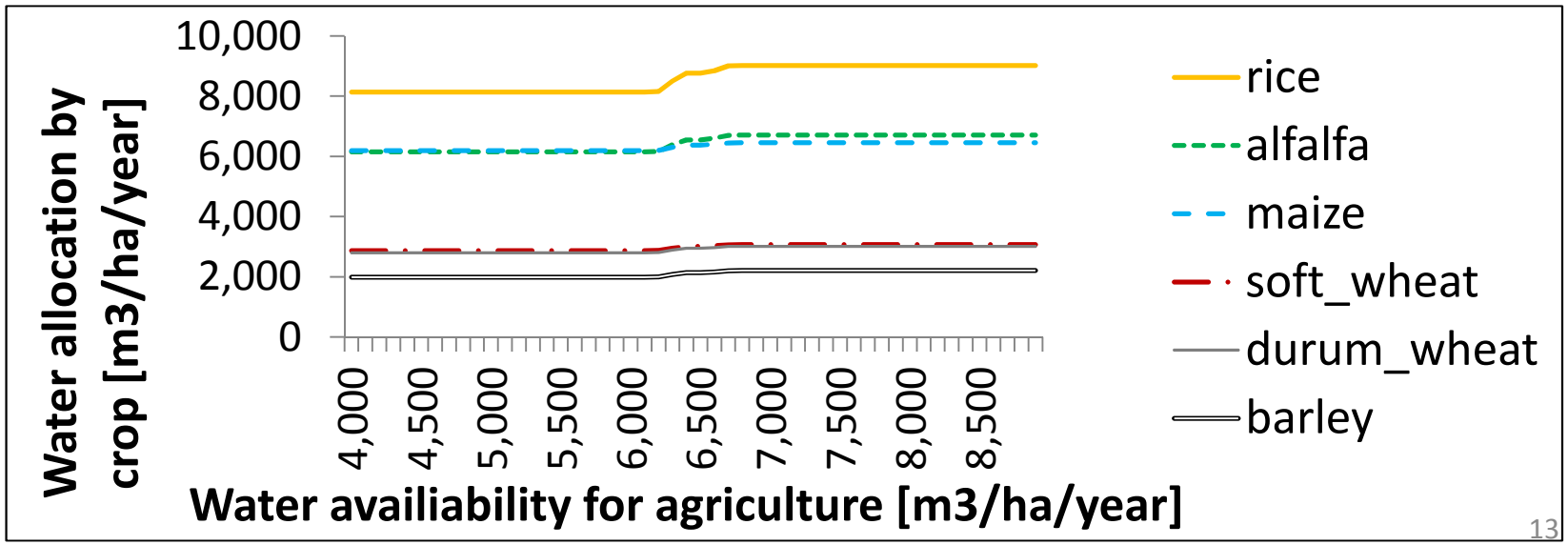
Results – supply system simulation



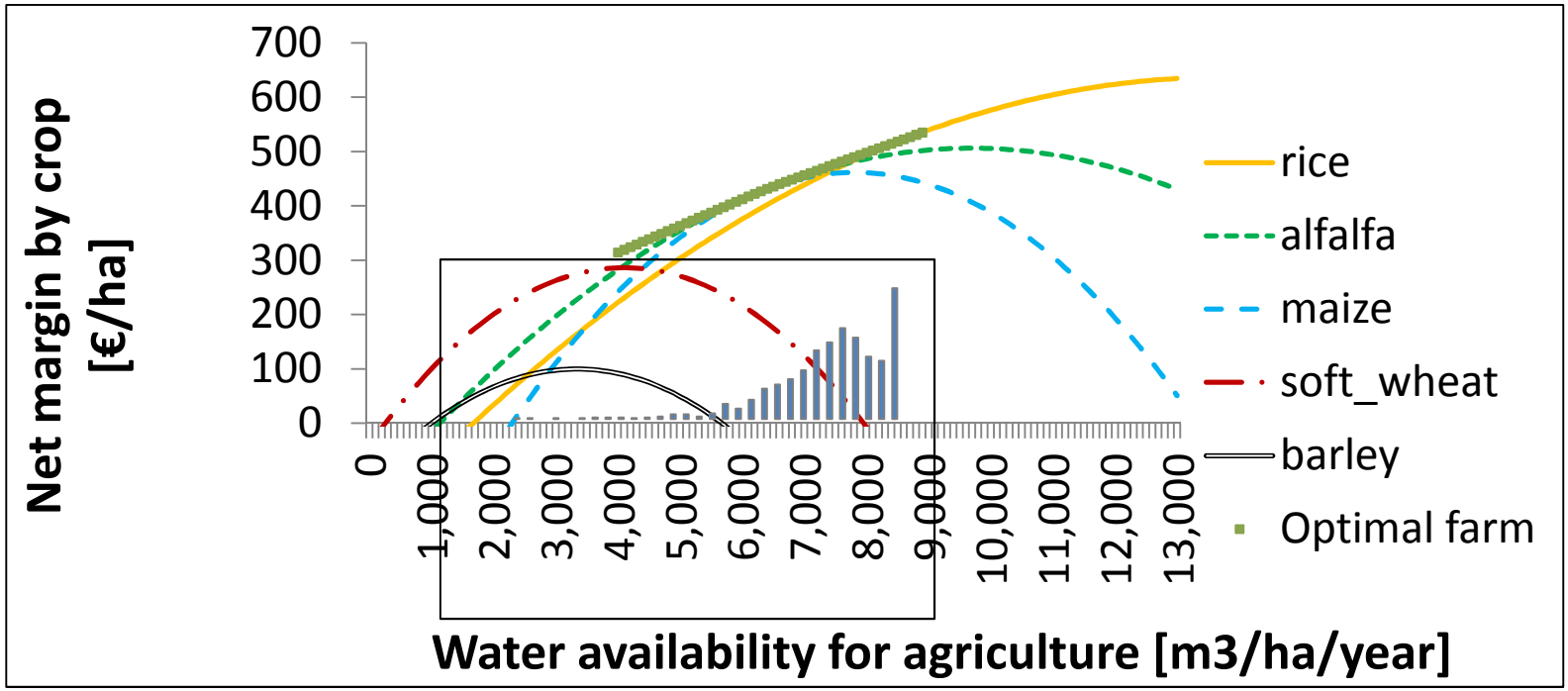
- The more frequent water availability under this set of simulations is between 8,000 and 8,200 m^3/ha/year
- Distribution is right-truncated due to the maximum capacity of the channel

Results – optimization model



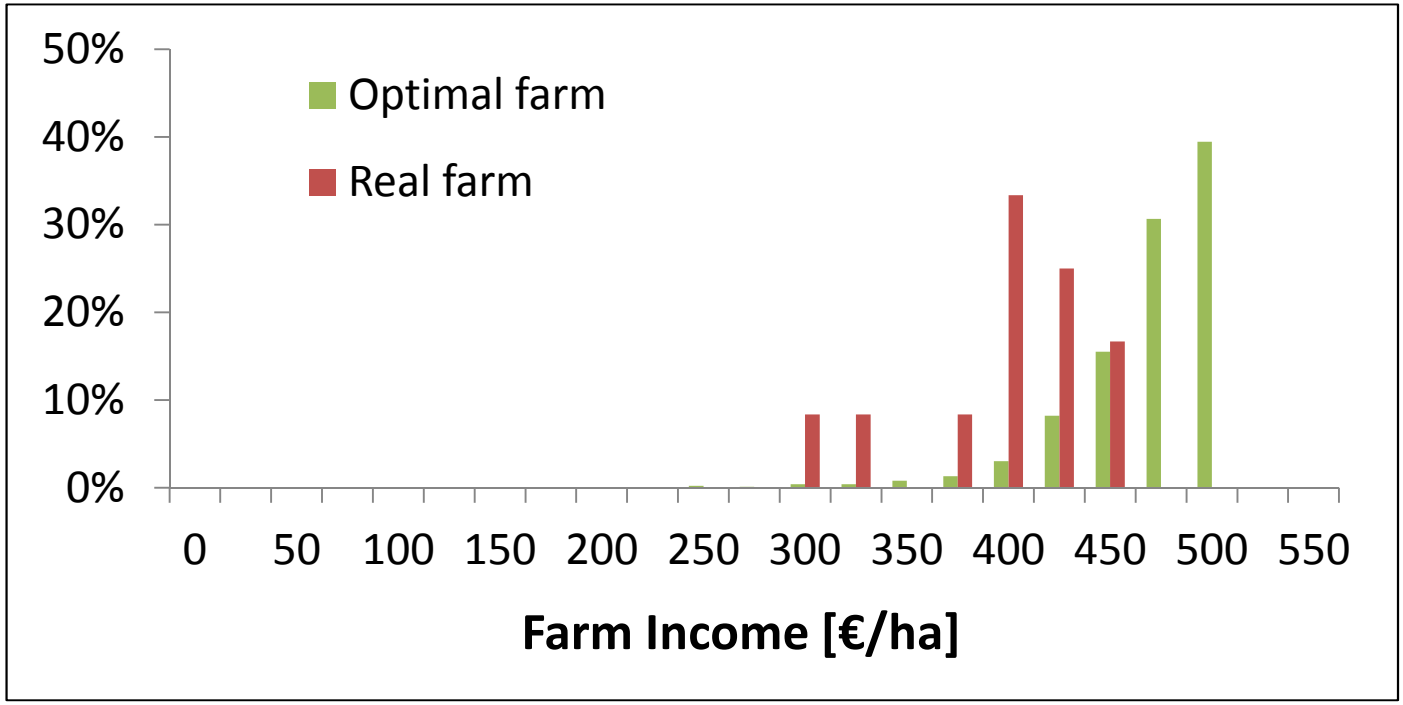


Results - farmer's income



	Alfalfa	Wheat	Maize	Barley	Rice	Optimal farm
Expected Net margins [€/ha]	441.99	274.81	431.67	95.67	430.80	446.13

Results - farmer's income



The **real farm** net margins are calculated considering surfaces and water allocations from the **period 2000-2011** in an **irrigation sub-district** from the BGID. Only cereals, maize, alfalfa and rice are considered.

Conclusions

- Depending on water availability for irrigation

  → the optimal crop distribution and water allocation between the crops is calculated.

- Results taken as a decision making support tool for farmers, when water availability can be estimated at the beginning of the sowing season.

- The optimal farm is the most profitable system, followed by the alfalfa system, maize, rice, then wheat and finally barley.

Conclusions

- Comparing optimal farm with real farm the more frequent net margin is:
  - Optimal: 475 - 500 euros per hectare
  - Real: 375 - 400 euros per hectare.

This difference is due to the fact that on field, it is difficult to forecast accurately the annual water availability for agriculture.

Further research

- Expected net margins as a guaranteed net margin for an insurance scheme, covering losses due to hydrological drought

- Take into account not only annual allocation, but also how it is distributed along the year

- Analysis of other crops besides the main ones

Thank you for your attention

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