Economic modelling of climate change scenarios and adaptation of Mediterranean agriculture

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4th AIEAA Conference"Innovation, productivity and growth: towards sustainable agri-food production"

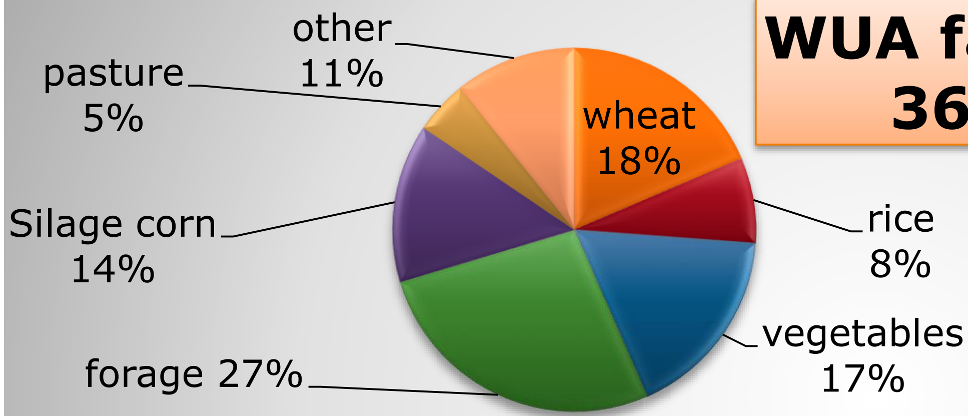
11-12 June, 2015
Ancona, Italy

Objectives

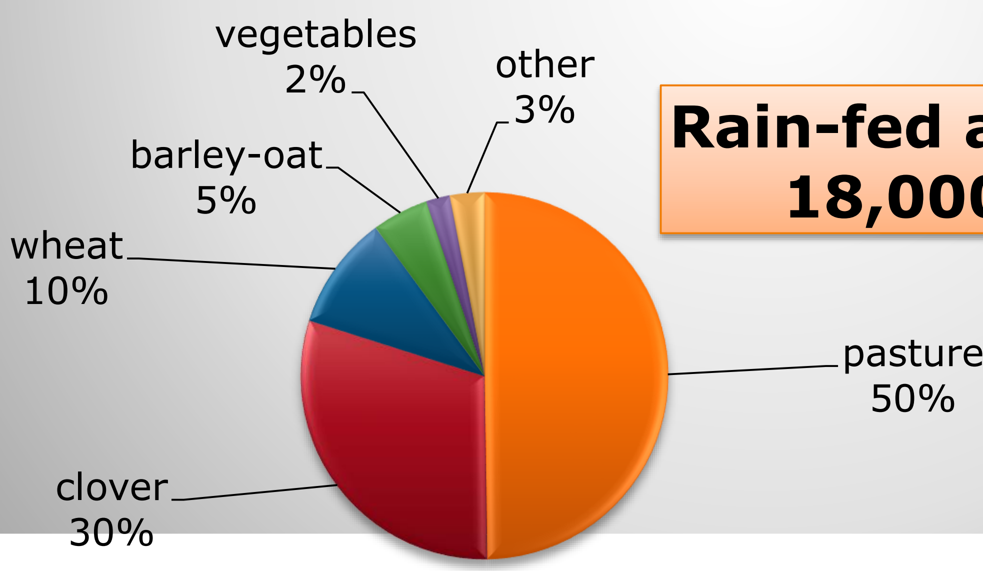
- Define a possible strategy to integrate climate change aspects into mathematical models
  - using Discrete Stochastic Programming (DSP)

- Evaluate the economic impact of climate change on the agricultural sector
  - of the study area (but transferable to other cases)

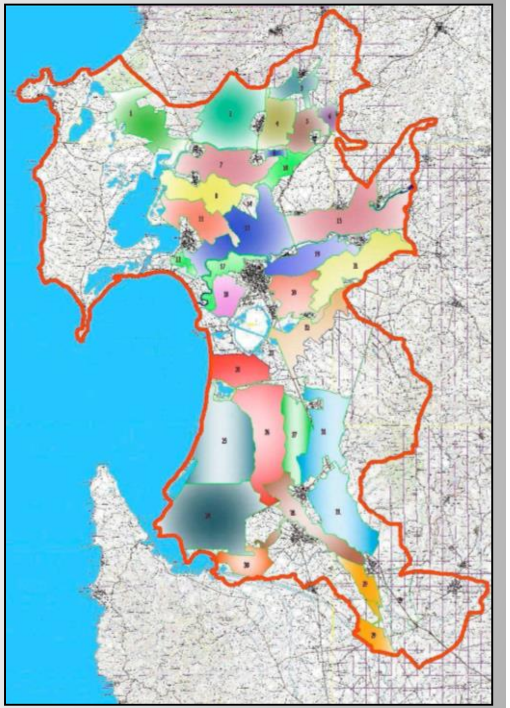
Study area: *CBI Oristanese*



WUA facilities
36,000 ha



Rain-fed area
18,000 ha



Two sides of agriculture

- Irrigated area
  - Intensive production and relevant economic dimension (dairy, citrus, vegetables)

- Rain-fed area
  - Cereals and dairy sheep sectors, important to prevent land abandonment

Territorial structure – Farm types

	Farms (n)	Land (ha)	Net Income (€ 000)
WUA facilities			
Rice	*24*	115.3	139.5
Citrus	*68*	12.6	45.7
Cattle A	*130*	30.9	199.2
Cattle B	*40*	31.9	112.7
Greenhouse	*46*	12.9	29.7
Vegetables - Cereals	*562*	22.2	34.2
Cereals - Forages	*55*	146.4	126.3
Tree and arable crops	*100*	5.8	11.8
Rain-fed			
Vegetables - Fruit	*100*	4.1	18.2
Cereals - Forages	*94*	24.5	16.9
Sheep A	*45*	86.9	43.6
Sheep B	*188*	41.2	16.1
Sheep C	*129*	62.4	42.5

Climate Model and Scenarios

- The numerical model for future climate scenarios downscaling is the Regional Atmospheric Modelling System - RAMS (www.atmet.com).

- RAMS is forced from a global simulation model, from surface temperatures of the sea coming from the ocean model coupled with the atmosphere.

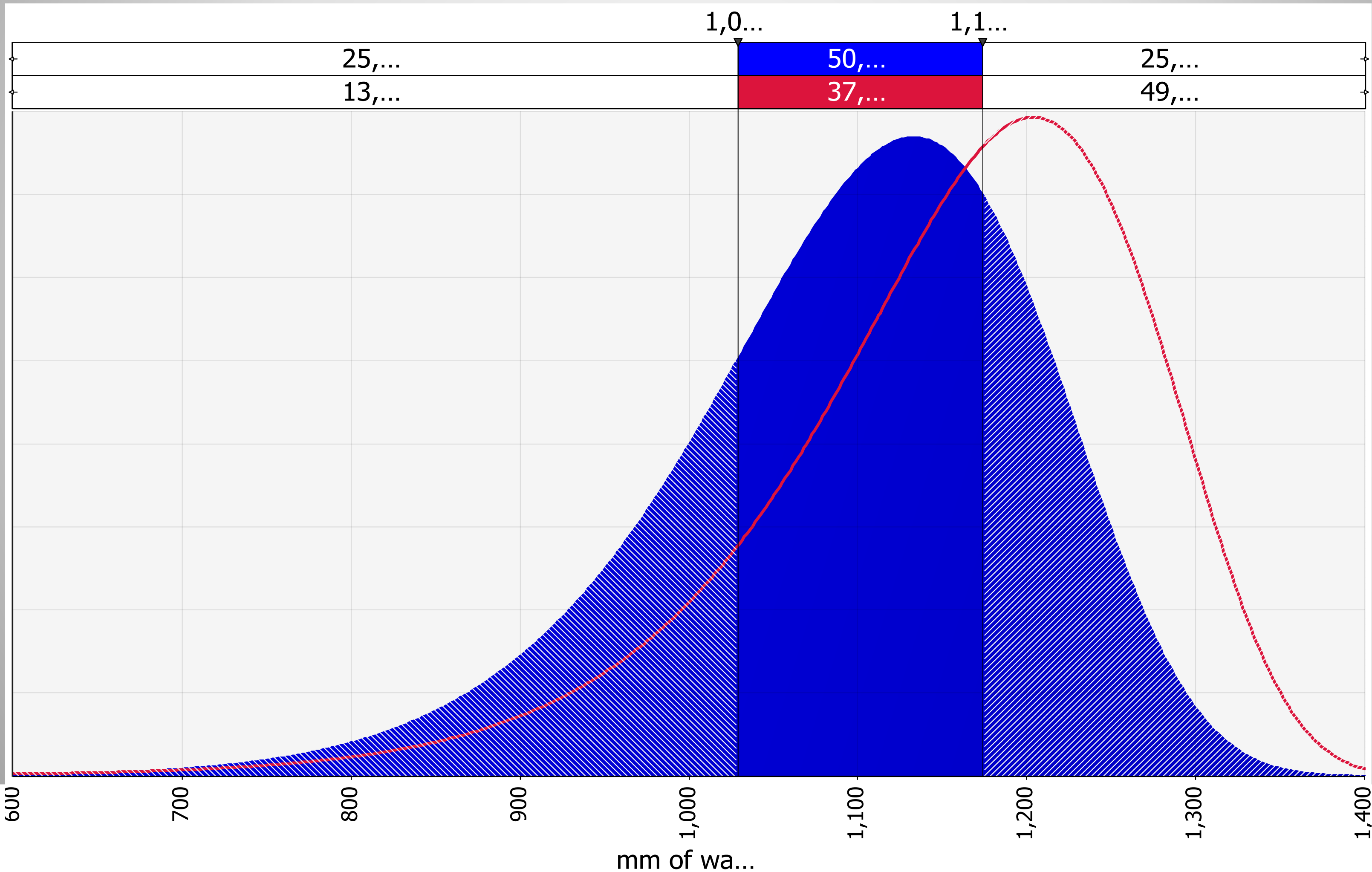
- The global climate change is simulated by ECHAM 5.4 developed and used by the Euro - Mediterranean Centre for Climate Change (CMCC - www.cmcc.it).

- The greenhouse gas emissions scenario is A1B.

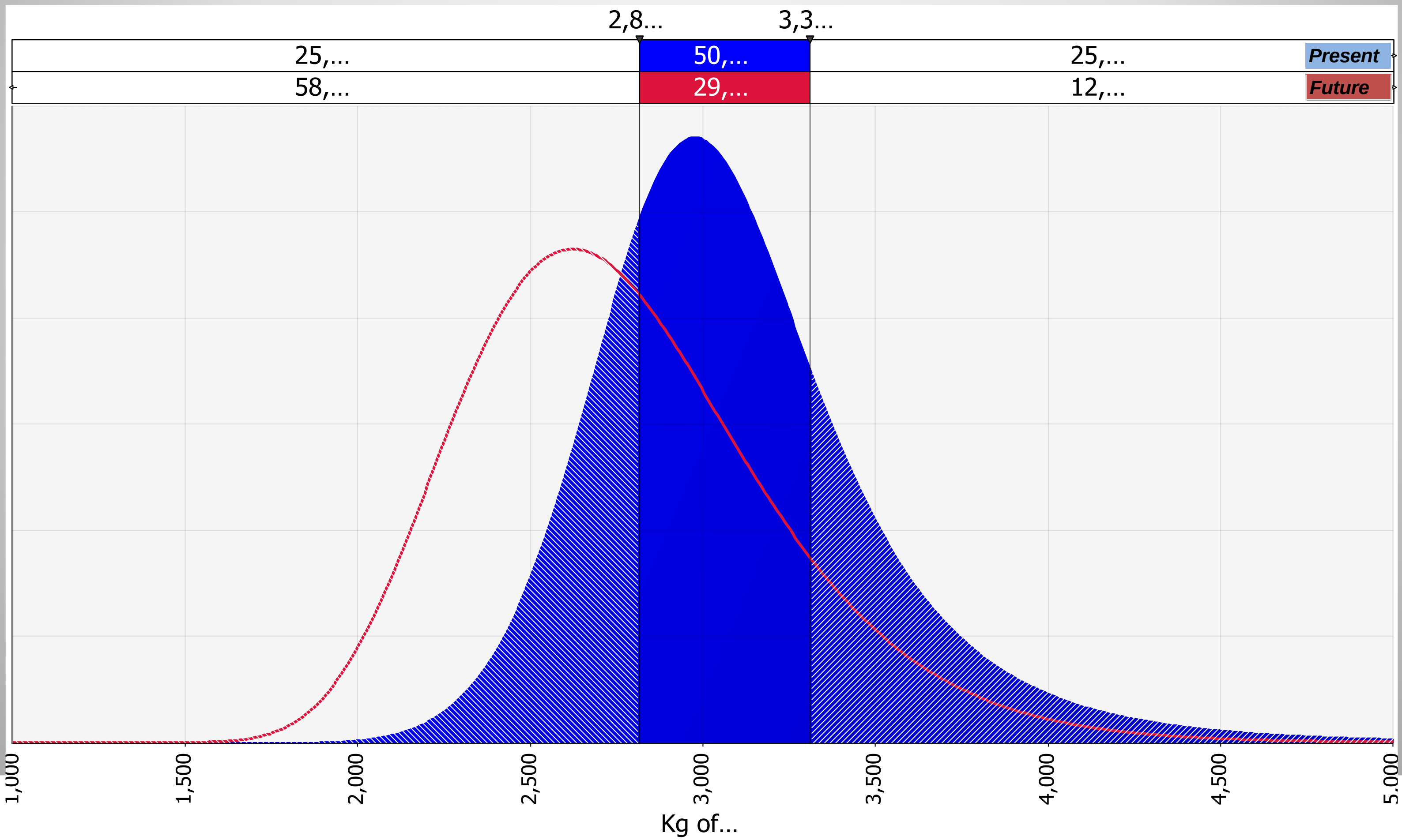
- Two scenarios:
  - **Present climate o Current (2000 – 2010)**
  - **Near future climate o Future (2020 - 2030)**

- Estimation of probability distributions of agro-climatic events

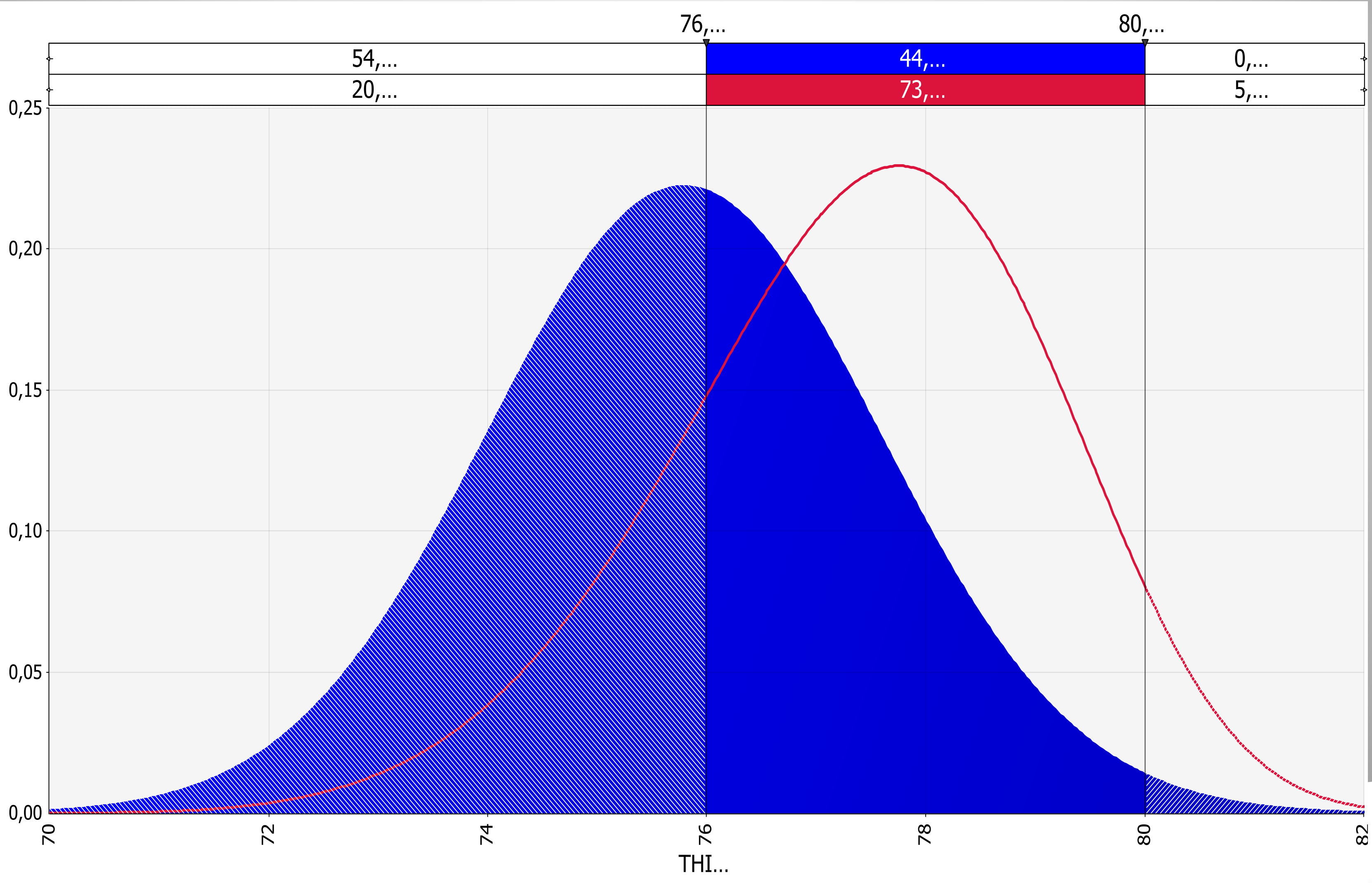
Evapotranspiration



Spring Hay yield from rain-fed crops



TH Index max



DSP: Choices under uncertainty

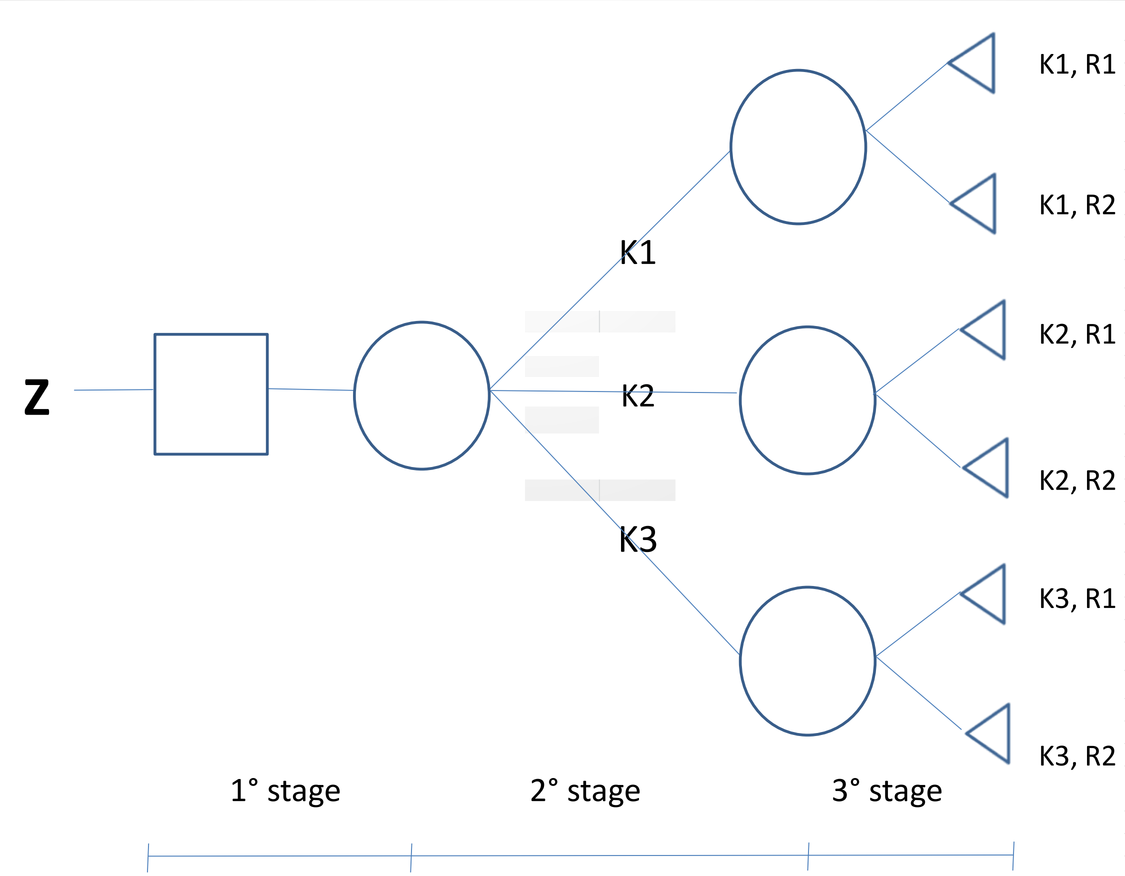
- Farmer's annual decision making under uncertain agro-climatic events:
  - formulating hypotheses about the pdf*s* of uncertain parameters, and discretize them (states)
  - partial correction of wrong decisions during the year

- Farmer minimizes the possible impact of sub-optimality by choosing the *state* with the highest expected income, once corrective actions are undertaken
  - resulting income lower than optimal solution under certainty (cost)

- The cost can increase if CC alters *representative values* or probability of *states of nature*

DSP: tree decision

DSP Choice Process:
eg 3 stages with uncertainty on 2 uncertainty events



DSP: Mathematical formulation

$$\max_{x_{n_s}, cr_{n_s}, ca_{n_s}} z = \sum_s P_s * (GI_s * x_{n_s} - C_{cr} * cr_{n_s} - C_{ca} * ca_{n_s}) \quad (1)$$

subject to

$$A_s * x_{n_s} \leq B_s + cr_{n_s} \qquad \forall s \quad (2)$$

$$x_{n_s} = x_{n+1_s} \qquad \forall s \quad (3)$$

$$N_s * Y_s * x_{n_s} + ca_{n_s} \geq R_s \qquad \forall s \quad (4)$$

$$x_{n_s} \geq 0, cr_{n_s} \geq 0 \; and \; ca_{n_s} \geq 0 \qquad \forall s \quad (5)$$

Management Issues	Uncertain Parameter	DSP Stages	Corrective Actions
Meet nutritional needs of flocks, given uncertainties on yields of pastures in Fall and Spring, and on hay production.	**Autumn grazing yields of pasture**	I: land allocation, uncertainty on Autumn and Spring grazing yields, and Spring hay yields II: known Autumn grazing yield III: known Spring yield of grazing and hay	Use stocks of hay and buy feed in Autumn, at additional costs, when lowest yields of grazing prevent meeting nutritional needs of flocks.
	Autumn grazing yields of hay-crop		
	Spring grazing yields of pasture		Use residual stocks of hay and buy feed in Spring/Summer, at additional costs, when lowest yields of grazing prevent meeting nutritional needs of flocks
	Spring yields of hay-crop		
Allocate water of dam with uncertain irrigation needs of crops	**Irrigation needs of ryegrass in April-May**	I: land allocation, uncertainty on irrigation needs of ryegrass and Summer crops II: known irrigation need of ryegrass III: known irrigation need of Summer crops	Take groundwater, at additionalcosts, when higher irrigation requirements generate scarcity of water dam
	Irrigation needs of Summer crops in June-August		
Meet nutritional needs of dairy cattle with uncertain yields of farm's fodder	**Yields of ryegrass, connected to its irrigation needs**	I:land allocation, uncertainty on yields of ryegrass and summer fodder crops II: known yield of ryegrass III: known yield of summer fodder crops	Buy feed, atadditionalcosts, when lowest yields of farm's fodderprevent meeting nutritional needs of the livestock
	Yields of corn silage and alfalfa, connected to their irrigation needs		

Economic results for the present climatic scenario, absolute values (000 €), and future climatic scenario, [percentage changes of future over current (%Δ)] for the total case study area, the irrigated sub-zone served by *WUA facilities* and the *rainfed* sub-zone

	Current scenario (000 €)			Future scenario (%Δ)		
	Total	*WUA*	*Rainfed*	*Total*	*WUA*	*Rainfed*
Total revenues	204,730	179,050	25,680	-0.3	-0.4	0.8
Animal	*89,806*	*75,278*	*14,528*	*-1.1*	***-1.3***	*0.0*
Variable costs	130,010	114,024	15,986	1.1	0.5	5.5
Technical means	*67,796*	*61,798*	*5,998*	*1.5*	*0.8*	***8.1***
Feed	*23,067*	*19,008*	*4,059*	*0.7*	*-5.4*	***29.3***
Extra-farm labor	*7,738*	*5,707*	*2,031*	*-2.6*	*-0.6*	*-8.0*
Payments to the WUA	*2,144*	*2,107*	*37*	*1.2*	*1.2*	*0.0*
Water pumping from farm wells	*278*	*121*	*156*	*0.5*	*-0.2*	*1.0*
Gross margin	106,365	89,095	17,270	-1.9	-1.5	-3.8
Net income	78,078	65,945	12,134	**-2.6**	**-2.1**	**-5.4**

Net Income per typology and farm: *present climate scenario* [absolute values (000 €)] and *future* climate scenario [percentage changes of future over current (%Δ)]

	Current scenario (000 €)		Future scenario (%Δ)
	Typology	Representative farm	
Rice	4,097	170.7	**9.9**
Citrus	2,670	39.3	-0.01
Cattle A	26,355	202.7	**-5.1**
Cattle B	6,825	170.6	**-5.9**
Greenhouse	1,231	26.8	0.4
Vegetables - Cereals	18,656	33.2	-0.8
Cereals – Forages	4,902	89.1	2.2
Tree and arable crops	1,209	12.1	0.04
Vegetables – Fruit	1,014	10.1	-0.04
Cereals - Forages	2,691	28.6	0.01
Sheep A	2,461	54.7	**-5.3**
Sheep B	1,984	10.5	**-11.8**
Sheep C	3,984	30.9	**-7.4**

Conclusions

- Water availability is strategic for adaptation of agriculture to future climatic scenarios
- Water accumulation is to be considered for dealing with the changing variability of CC
- Rain-fed agriculture must be sustained also for the prevention of land abandonment
- The economic impacts on milk production is relevant
- This approach is transferable to other cases

Next steps

- The economic impacts on milk production matter
  - livestock integration needs improvements
- Simulation of AgMip-CAPRI scenarios
- Impact of climate on weeds and pests spread
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