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Alternative subsidy scenarios for different agricultural practices: A sustainability assessment using fuzzy multi-criteria analysis

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BIOSUS project

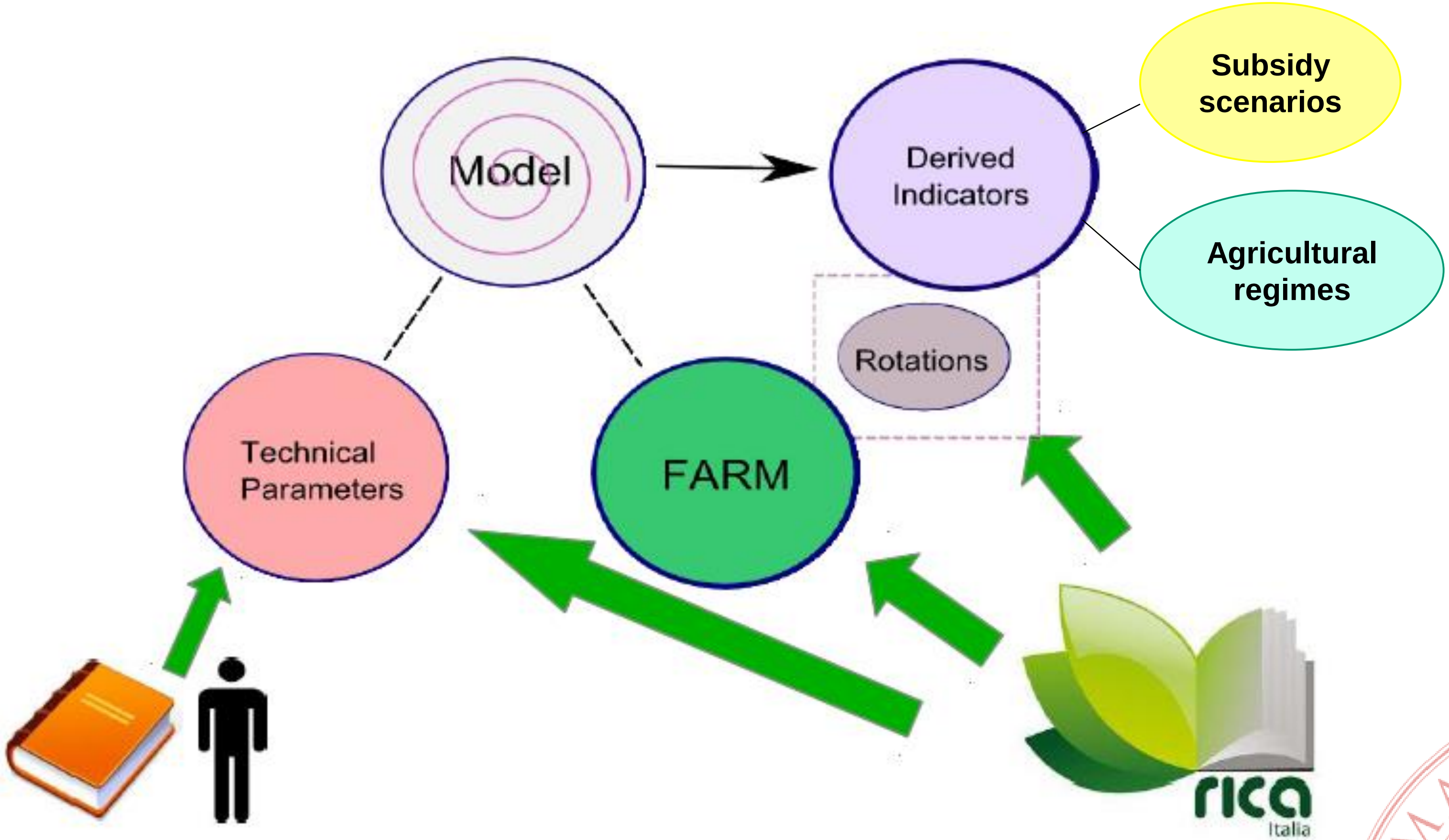
- Italian Ministry of Agriculture funding
- Impacts of organic agriculture on environmental sustainability and greenhouse gas emissions (2010-2013)
- Specific objectives:
  - to estimate the difference in greenhouse gas emissions between conventional and organic agriculture
  - to assess the environmental sustainability of both conventional and organic farming

  in different alternative subsidy scenarios
- General objective
  - to assess the effects of subsidy policy scenarios on behaviour and (economic and environmental) performance of farms

BIOSUS project

- MICRO level
  - Dynamic Farm Model (MAD) (mathematical programming model) developed in order to
    - Optimization of income based on farming systems (organic/conventional/greening) and scenarios (alternative policy options)
    - Estimation of technical, economic, and environmental indicators based on optimization of income
- MACRO level
  - Identification of different alternative subsidy scenarios
  - Aggregation of the performance of each farm indicators for each scenario
  - Fuzzy multi-criteria analysis for the assessment of the identified subsidy scenarios

Output from preceding Biosus research



Objective of this research

- To identify the 'best' subsidy scenario(s) for Italian farms, by considering their performance with respect to economic and environmental indicators under such scenarios

Scenarios

CONVENTIONAL

	BAU	CAP 14	CAP 14 FITO
Base subsidy	300 €/ha	250 €/ha	250 €/ha
Subsidy for natural areas	100 €/ha	x	x
Subsidy for greening	x	120 €/ha	120 €/ha
Subsidy for small farms	x	1500 €/farm (UAA<3 ha)	1500 €/farm (UAA<3 ha)
Farm restrictions for greening	x	At least 7% UAA natural land	At least 7% UAA natural land
Certification costs	x	x	x
Tax on pesticides	x	x	30%

Scenarios

ORGANIC

	BAU	CAP 14	CAP 14 FITO
Base subsidy	300 €/ha	250 €/ha	250 €/ha
Subsidy for natural areas	100 €/ha	x	x
Subsidy for greening	x	120 €/ha	120 €/ha
Subsidy for small farms	x	1500 €/farm (UAA<3 ha)	1500 €/farm (UAA<3 ha)
Farm restrictions	x	x	x
Certification costs	250 € + 6 €/ha (natural land), 12 €/ha (arable crops), 18 €/ha (tree crops), 5 €/LU (husbandry)	250 € + 6 €/ha (natural land), 12 €/ha (arable crops), 18 €/ha (tree crops), 5 €/LU (husbandry)	250 € + 6 €/ha (natural land), 12 €/ha (arable crops), 18 €/ha (tree crops), 5 €/LU (husbandry)
Tax on pesticides	x	x	0 %

Area	Sub-area	Indicator	U. o. M.	Acronym
Environment	Climate change	Sensitivity	v./ha	iccs
		GHG emissions	ton C/ha yr	ighg
		GHG emissions due to products (fertilizers, pesticides, fuel)	ton C/ha yr	ilai
	Environmental impact	Crop intensity	v./ha	iint
		Naturality	%	inat
		Landscape biodiversity	v./ha	ilbd
		Soil erodibility	v./ha	iler
		Average quantity of pesticides used	€/h	ipcl
Economic	Economic efficiency	Average yearly net income/ha	€/ha yr	ivni
		Average efficiency of labour force	€/h	ivmg/ilab
		Total quantity of public support	€/ha yr	ipol
	Required economic effort	Purchased fertilisers over requested fertilizers	%	ipnl
		Average amount of labour	h/ha yr	ilab
	Dependence on market	Average quantity of fuel used	l/ha	ipfl
		Purchased feed over requested feed	%	isdz

Methodology

Alternative scenarios　　　Different indicators

Multi-criteria analysis

- Basic ingredients:
  - A finite or infinite set of actions (alternatives, solutions,…)
  - At least 2 criteria
  - At least 1 decision-maker
- helps making decisions mainly in terms of choosing, ranking or sorting the actions

Fuzzy multi-criteria tool: Scryer

- Originally developed for the ex ante impact assessment of food safety regulations (Mazzocchi, Ragona, & Zanoli, *Food Policy*, 2013)
- Ad-hoc development of the NAIADE multi-criteria method, developed for environmental impact assessment at JRC-EC
- Characteristics:
  - Synthesis of both quantitative (model-based) and qualitative assessments without the need for monetization
  - Fuzziness: Uncertainty in outcomes evaluations (lack of data / internal uncertainty / variability of data)
  - Weighting of criteria

Starting point: assessment matrix

Criteria		BAU		CAP14		CAP14FITO	
	Weight	Value	Uncertainty	Value	Uncertainty	Value	Uncertainty
ilab	0.07	-95.400	5.882	-92.620	5.897	-88.288	5.918
ighg	0.07	-0.433	0.016	-0.415	0.016	-0.385	0.016
iint	0.07	-0.591	0.013	-0.563	0.012	-0.563	0.012
inat	0.07	0.001	0.000	0.043	0.001	0.042	0.001
ilbd	0.07	2.278	0.087	6.339	0.116	6.320	0.116
iler	0.07	-0.130	0.014	-0.129	0.014	-0.129	0.014
iccs	0.07	-1.343	0.011	-1.291	0.012	-1.291	0.012
ipnl	0.07	-1.000	0.000	-1.000	0.000	-1.000	0.000
ipcl	0.07	-156.183	2.218	-149.782	2.207	-142.404	2.419
ipfl	0.07	-831.006	23.419	-800.128	23.476	-748.538	23.763
ivni	0.07	3502.397	276.570	3544.411	277.657	3515.160	277.987
ilai	0.07	-1.290	0.037	-1.292	0.037	-1.243	0.036
ipol	0.07	-300.154	0.029	-382.812	5.109	-382.812	5.109
ivmg/ilab	0.07	67.891	3.209	67.882	3.209	68.201	3.200

Scryer - Steps

1) Preliminary assessment of the performance of farms for each indicator (criterion) under each subsidy scenario

   - Weighted mean

$$\bar{x} = \sum_{i=1}^{n} w_i x_i$$

   - Standard error of the mean

$$se = \frac{\sqrt{\sigma^2}}{\sqrt{n}} = \frac{\sigma}{\sqrt{n}}$$

2) Computation of distances between pairs of scenarios for each criterion

   - Hellinger distance

$$DH = \sqrt{1 - \sqrt{\frac{2s_1 s_2}{s_1^2 s_2^2}} \cdot e^{-\frac{1}{4} \cdot \frac{(x_{i1} - x_{i2})^2}{s_1^2 + s_2^2}}}$$

Scryer - Steps

3) Pairwise comparison between scenarios based on the distances and the weights assigned to criteria

   a) for each criterion: <u>Credibility values</u> for a set of 6 preference relations

- P_1 is much better than P_2
- P_1 is better than P_2
- P_1 is more or less like P_2
- P_1 is identical to P_2
- P_1 is worse than P_2
- P_1 is much worse than P_2

$$c_{>>,i}(P_1,P_2)=\begin{cases}0 & \text{if } x \le y \\ \dfrac{1}{\left(1+\dfrac{\chi_{>>}^{2}\left(\sqrt{2}-1\right)}{D^{2}}\right)} & \text{if } x > y\end{cases}$$

- [0,1]
  - $c_* = 0$ not credible at all
  - $c_* = 1$ maximum credibility
  - $c_* = 0.5$ confidence that the statement is credible = confidence that the statement is not credible →(uncertainty)

Scryer - Steps

3) Pairwise comparison

   b) across criteria: aggregate preference intensity index for each pair of scenarios

$$\mu_*(P_1, P_2) = \frac{\sum_{i=1}^{c} max(c_* - \alpha, 0) w_i}{\sum_{i=1}^{c} |c_* - \alpha| w_i}$$

$$\sum_{i=1}^{c} w_i = 1$$

Scryer - Steps

4) Rank the scenarios based on their performance in pairwise comparisons: **Best/worst scenario index**

- degree of membership to the statements
  - 'Scenario *i* is better than all other scenarios (the 'best scenario')
  - 'Scenario *i* is worse than all other scenarios' (the 'worst scenario')
- [0,1]

$$\varphi^{+}(P_i) = \frac{\sum_{j \neq i}^{p} \mu_{\gg}(P_i, P_j) + \mu_{>}(P_i, P_j)}{2(p-1)}$$

$$\varphi^{-}(P_i) = \frac{\sum_{j \neq i}^{p} \mu_{<}(P_i, P_j) + \mu_{\ll}(P_i, P_j)}{2(p-1)}$$

Final output

	BAU	CAP14	CAP14+FITO
Best scenario	0.211	0.389	0.711
Worst scenario	0.814	0.391	0.105

Data

- 1 assessment matrix for selected groups of Italian farms
  - Geographical location (5)
  - Farm main activity (6)
  - Environment (phyto-climates & slopes) (6)

↓

17 assessment matrices

- Results for 3 different weightings of criteria
  - Equal weights
  - Weights to economic criteria 10 times higher than environmental criteria
  - Weights to environmental criteria 10 times higher than economic criteria

↓

51 output tables

Overall results

Indexes	Scenarios		CEN	ISO	MER	NOC	NOR	ARB	ARB+SEM	NAT+ARB	NAT+SEM+ZOO	SEM	SEM+ZOO	Z1G1	Z2G1	Z2G2	Z3G1	Z3G2	Z4G1
EQUAL	Best scenario	BAU	0.346	0.211	0.211	0.211	0.211	0.211	0.211	0.211	0.199	0.211	0.199	0.211	0.211	0.211	0.211	0.211	0.211
		CAP14	0.611	0.240	0.244	0.001	0.376	0.363	0.348	0.000	0.000	0.389	0.269	0.211	0.171	0.000	0.376	0.369	0.038
		CAP14+FITO	0.926	0.238	0.508	0.000	0.468	0.627	0.686	0.000	0.064	0.711	0.326	0.364	0.345	0.000	0.450	0.712	0.000
	Worst scenario	BAU	0.831	0.479	0.597	0.001	0.690	0.788	0.719	0.000	0.032	0.814	0.573	0.529	0.448	0.000	0.709	0.805	0.035
		CAP14	0.568	0.105	0.260	0.105	0.223	0.308	0.391	0.105	0.131	0.391	0.122	0.152	0.173	0.105	0.187	0.381	0.105
		CAP14+FITO	0.484	0.105	0.106	0.106	0.142	0.105	0.134	0.105	0.100	0.105	0.099	0.105	0.105	0.105	0.140	0.105	0.108
ENVIRONMENT	Best scenario	BAU	0.306	0.033	0.033	0.033	0.033	0.033	0.033	0.033	0.032	0.033	0.032	0.033	0.033	0.033	0.033	0.033	0.033
		CAP14	0.700	0.290	0.269	0.000	0.365	0.374	0.378	0.000	0.000	0.433	0.343	0.231	0.209	0.000	0.391	0.412	0.005
		CAP14+FITO	0.895	0.290	0.572	0.000	0.540	0.672	0.797	0.000	0.093	0.781	0.419	0.409	0.424	0.000	0.528	0.773	0.000
	Worst scenario	BAU	0.855	0.580	0.656	0.000	0.743	0.811	0.820	0.000	0.047	0.893	0.727	0.578	0.540	0.000	0.802	0.886	0.005
		CAP14	0.464	0.016	0.201	0.016	0.173	0.250	0.367	0.016	0.062	0.337	0.051	0.078	0.110	0.016	0.129	0.316	0.016
		CAP14+FITO	0.582	0.016	0.016	0.017	0.021	0.016	0.020	0.016	0.016	0.016	0.016	0.016	0.016	0.016	0.021	0.016	0.017
ECONOMIC	Best scenario	BAU	0.436	0.612	0.612	0.612	0.612	0.612	0.612	0.612	0.602	0.612	0.601	0.612	0.612	0.612	0.612	0.612	0.612
		CAP14	0.377	0.108	0.153	0.008	0.529	0.331	0.301	0.000	0.000	0.238	0.144	0.116	0.079	0.000	0.404	0.219	0.167
		CAP14+FITO	0.970	0.105	0.276	0.000	0.270	0.415	0.365	0.000	0.028	0.427	0.171	0.183	0.155	0.000	0.240	0.423	0.000
	Worst scenario	BAU	0.730	0.212	0.361	0.008	0.544	0.664	0.402	0.000	0.014	0.512	0.305	0.281	0.206	0.000	0.442	0.496	0.151
		CAP14	0.791	0.306	0.374	0.306	0.356	0.387	0.436	0.306	0.314	0.460	0.310	0.323	0.334	0.306	0.338	0.451	0.306
		CAP14+FITO	0.262	0.306	0.306	0.307	0.511	0.306	0.439	0.306	0.301	0.306	0.301	0.306	0.306	0.306	0.475	0.306	0.322

- Equal & Environment
  - CAP14+FITO : Best for the majority
  - BAU: Worst for the majority
- Economic
  - BAU : Best for all (only 1 exception: CEN)
  - CAP14: Worst for the majority

Final considerations

- High variability within each group
  - Different uses of land, different climatic conditions, etc.
- Qualitative/quantitative (overcome limits of CBA)
- Uncertainty (standard error)
- Weightings
- First step towards calibration of policies/subsidies to different groups of farms

Thank you for your attention!

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