Agent-Based Modelling to support the development and the assessment of Agricultural Policies

Dott.ssa Lisa Baldi, Prof. Filippo Arfini, Dott.ssa Sara Calzolai, Prof. Michele Donati

9 aprile 2024

AGENDA

- The H2020 **AGRICORE** project
- **AGRISP**: “Short-period” model for the Analysis of Regional and National Agricultural Policies
- Discussion of the **results** of selected case studies
- Path forward:
  - Last steps in the AGRICORE project
  - Roadmap for further use of the AGRISP short-term model

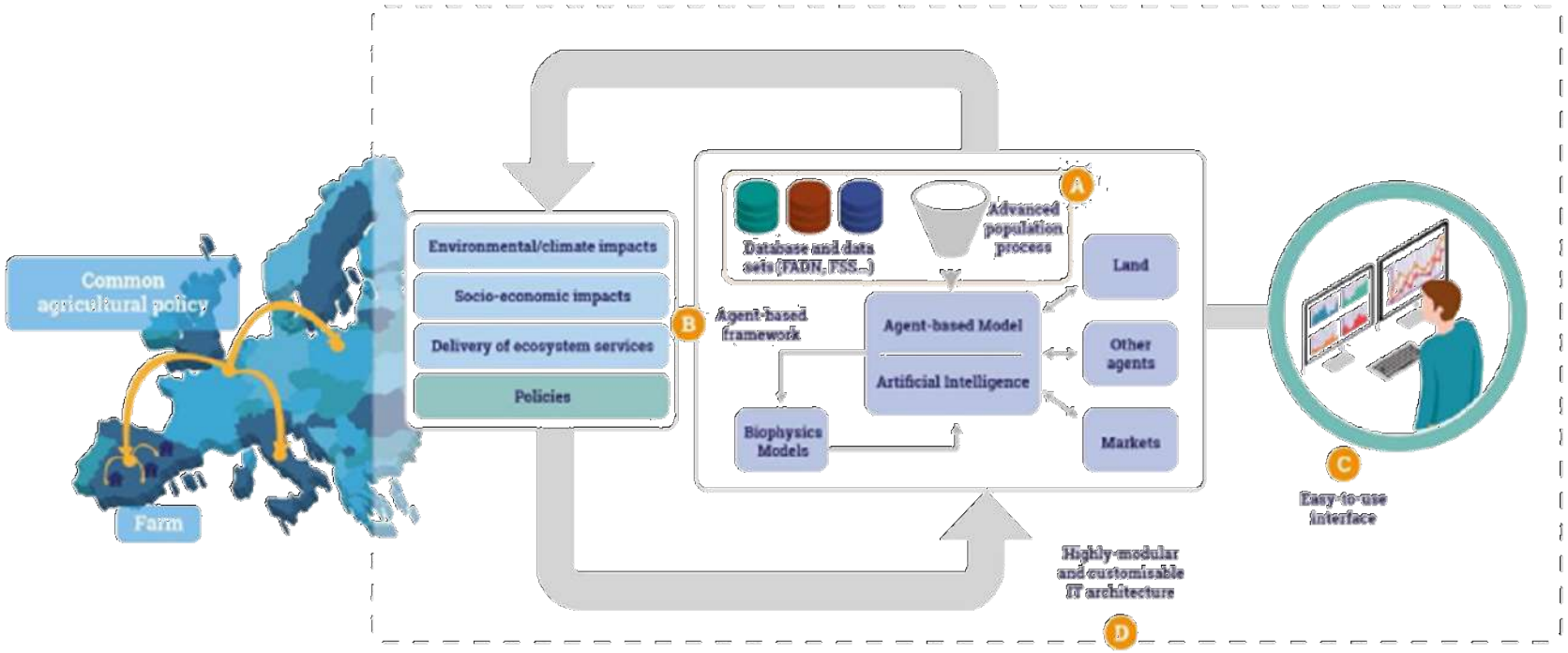
The H2020 Project

- The **AGRICORE** project introduces a new highly technological tool kit aiming at improving the current modelling capabilities in the field of agricultural policies.

- Furthermore, it addresses the socio-economic effects, as well as the environmental and climatic impact of policies by means of a set of specific modules that establish links between the targeted policies and the corresponding KPIs.

- The **Consortium of partners** is a muti functional team, composed by 10 partners, that includes academia in the fields of agricultural economics and agrophysics, but also software developers, expert in AI, and provider of technology and hi-tech engineering services.

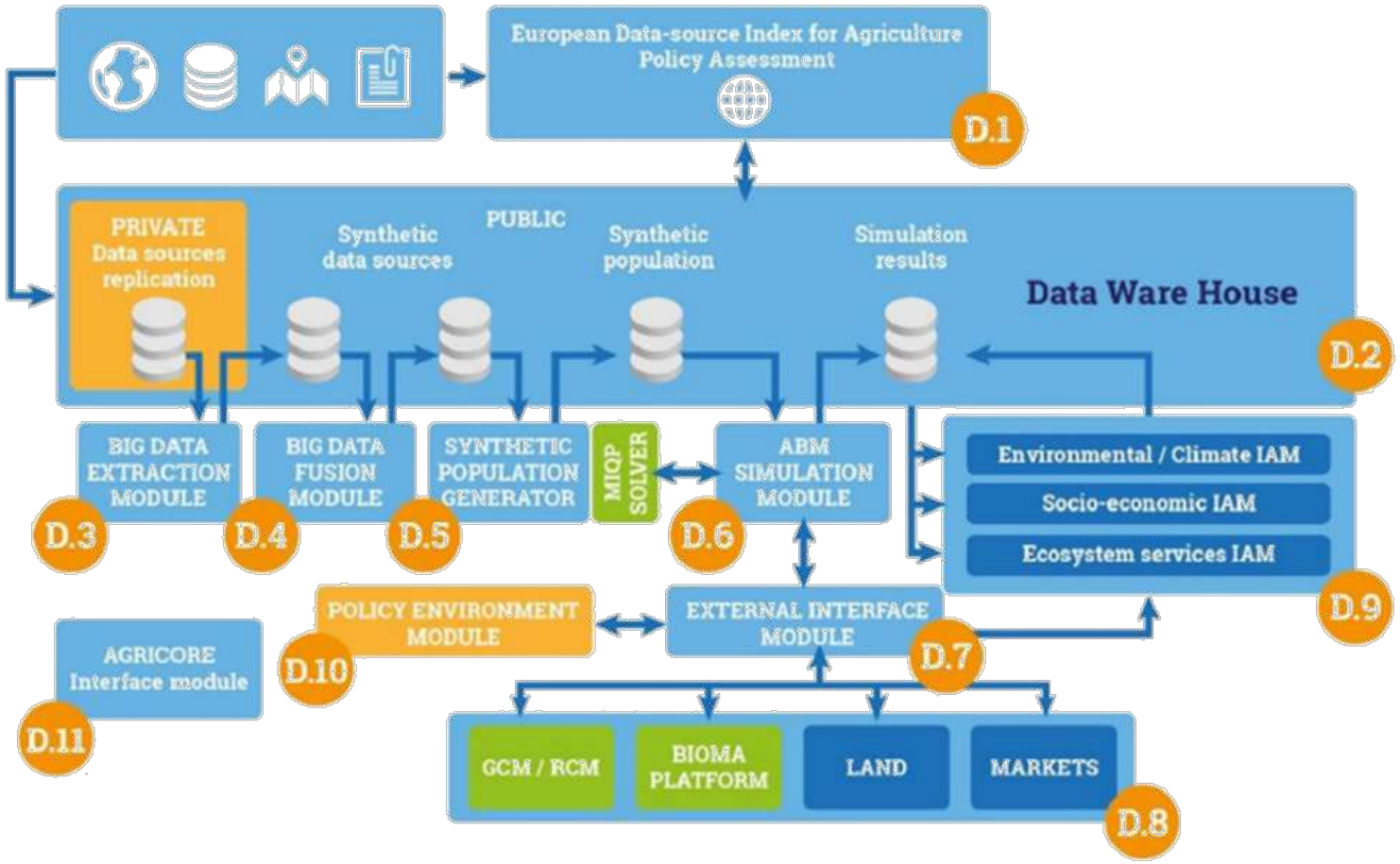
Innovations introduced by the project



Main innovation introduced by the AGRICORE project are:

A. Advance population concept
B. AB modelling
C. User friendly interface

The Architecture



A. Advance population concept

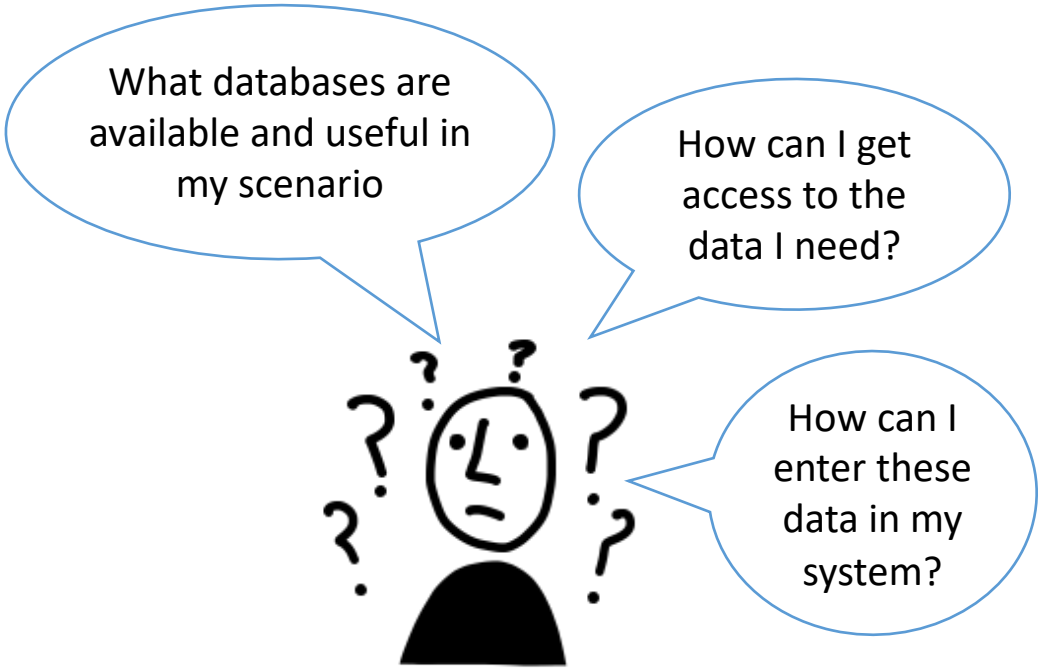
1. Data source: identification & usage
2. Synthetic population

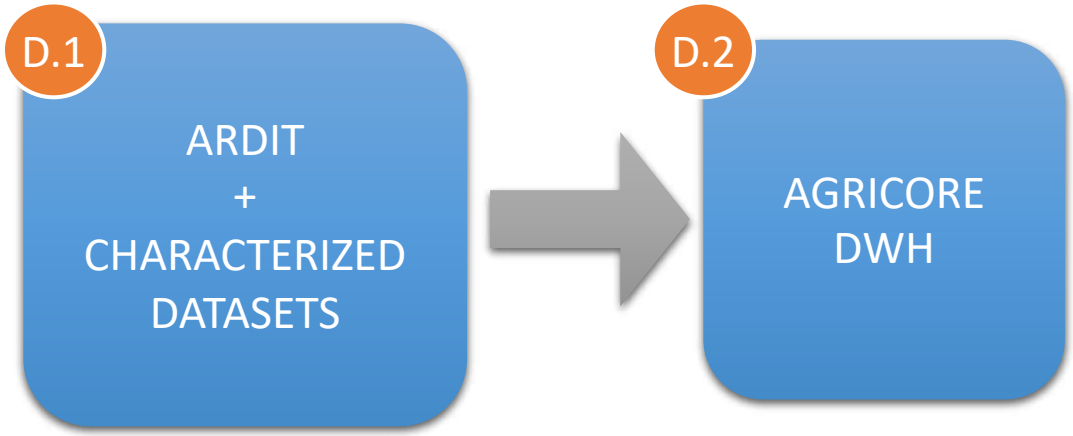
B. AB modelling

3. ABM Farm-level analysis
4. Biophysical and other modules interactions
5. Interaction with IAM

C. User friendly interface

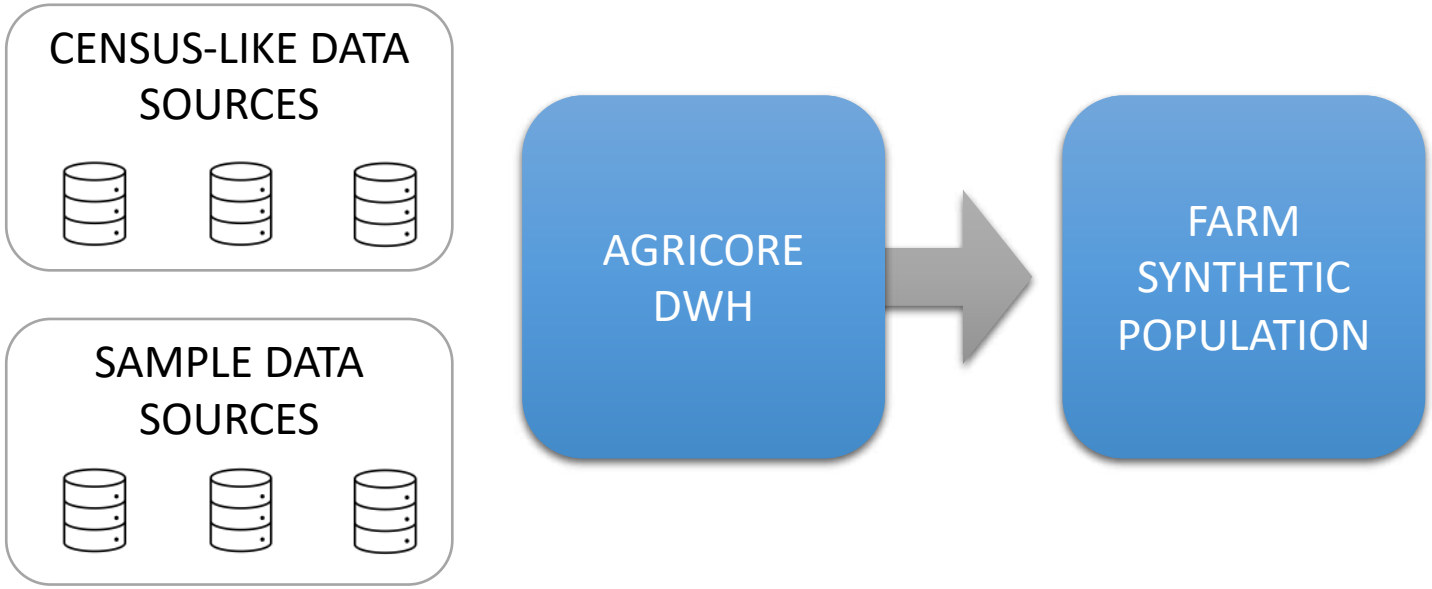
Advance Population: 1. Data Source and Usage





ARDIT is a publicly available index tool that allows to search for the most appropriate data set, at the level of the variable, and is designed to facilitate the data transfer from available dataset to the AGRICORE Datawarehouse.

Advance Population: 2. The Synthetic Population



The Synthetic Population allow for:

- Automated population generation
- Reusable data for other simulations
- Remove data protection constrains

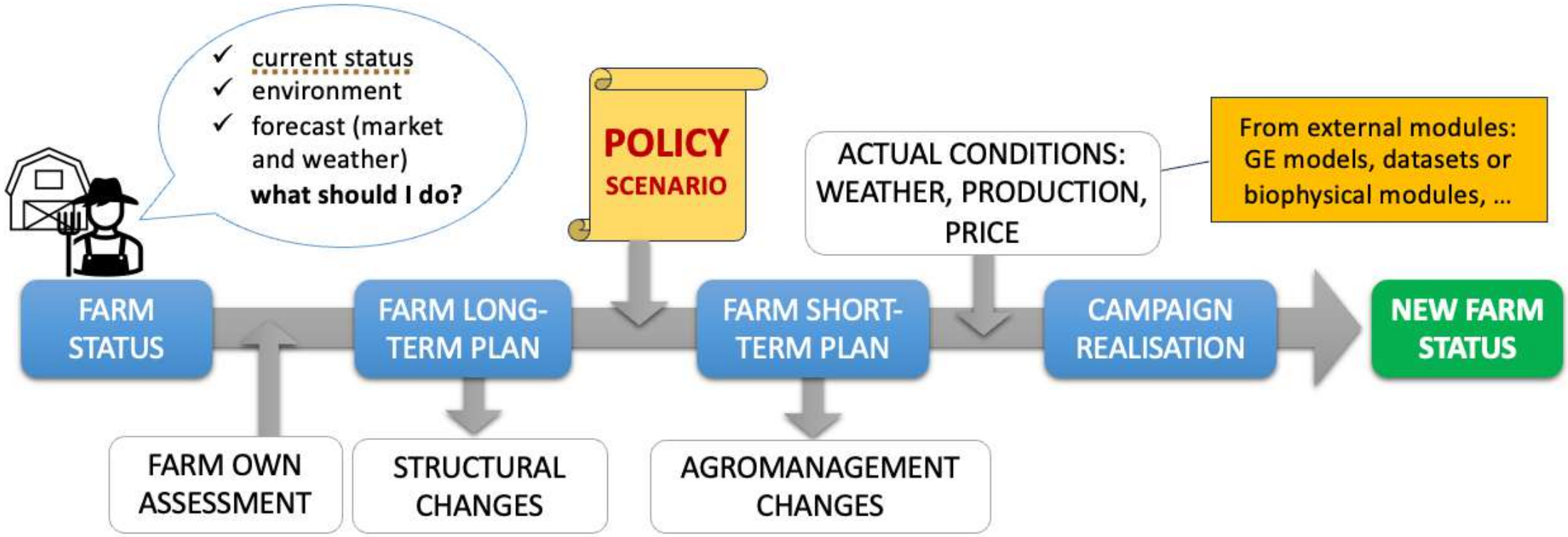
The ABM Approach – Farm level analysis

Once the Synthetic Population is created, it is used in the modelling stream for 2 main purposes:

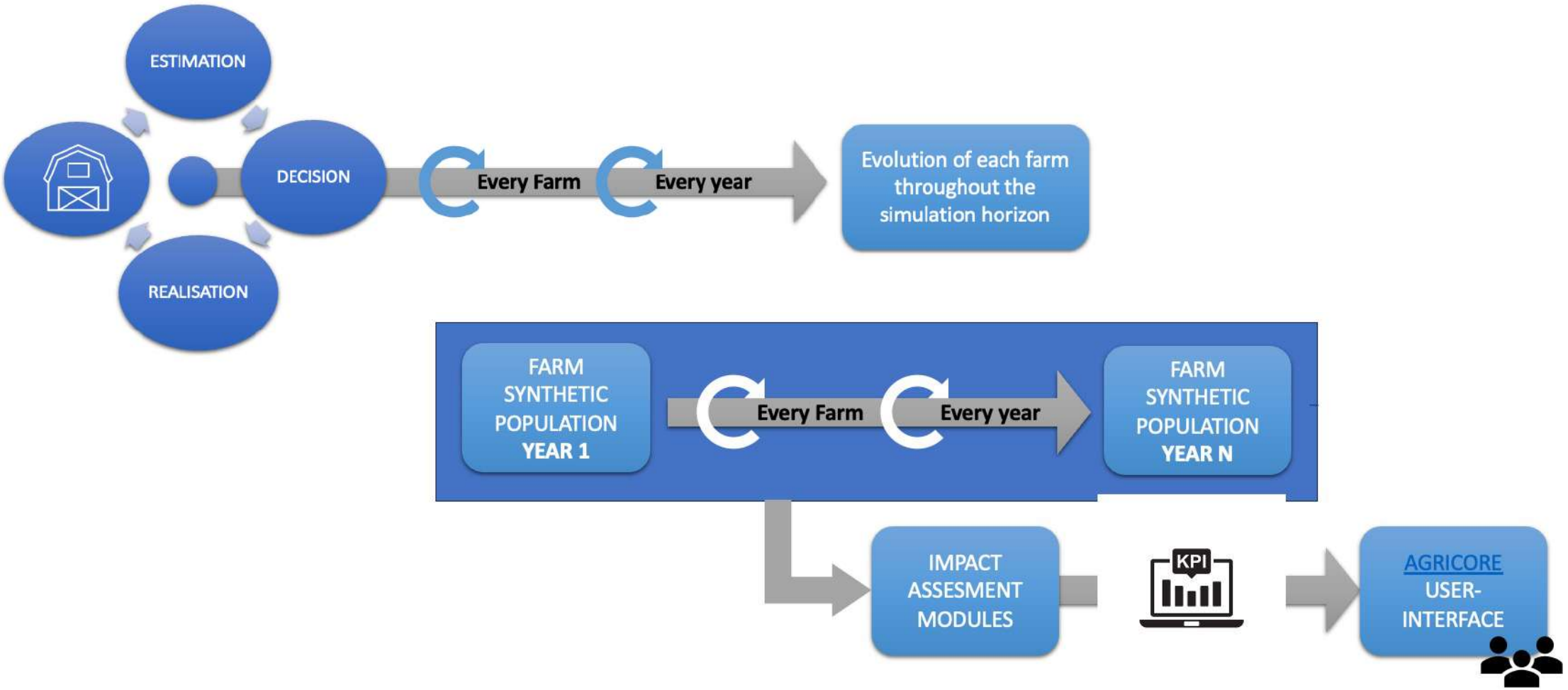
For calibration: the model is calibrated based on simile-real data

For instantiate every single agent, to which specific eco-socio and production related characteristics, are associated.

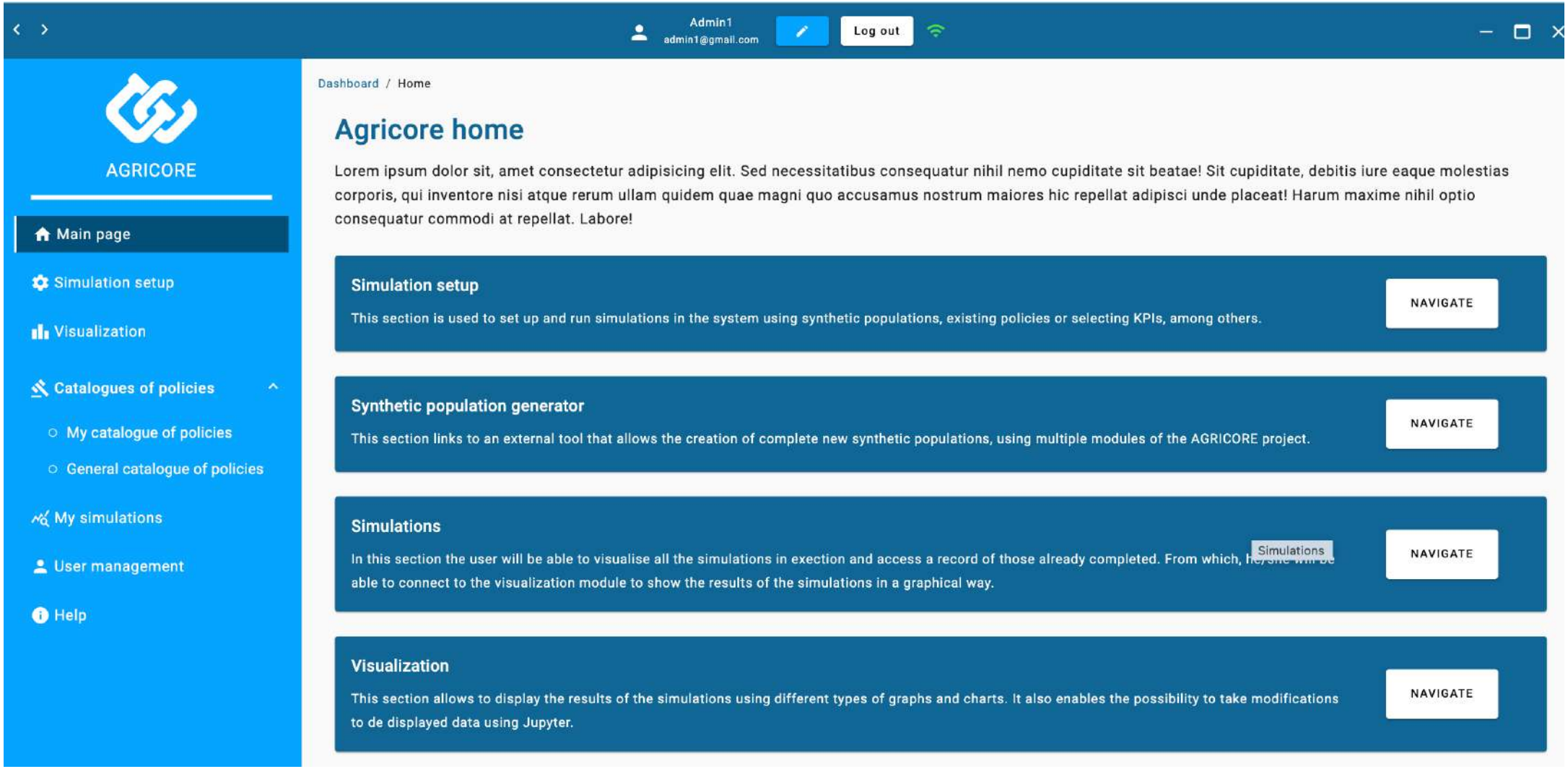
The ABM Approach – Simulation process



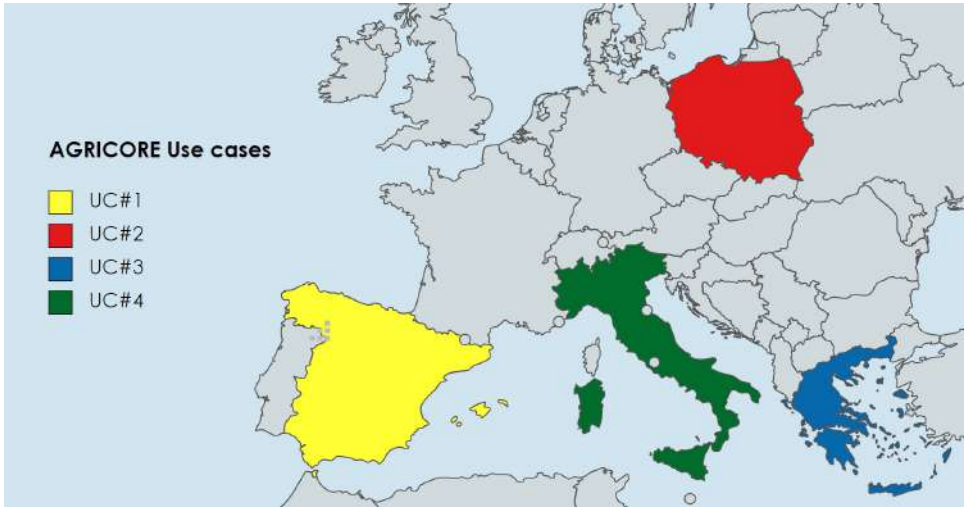
Simulation reiteration and evaluation against KPIs



The Interface



The AGRICORE use cases



[UC#1] M11 – Ecological Agriculture

[UC#3] M6.1 – Settlement of Young Farmers

[UC#2] M10.1 Agri-environment-Climate Commitments

[UC#4] Extra: CO2 Emissions reduction through inc. taxes

The AGRISP Milestones use cases

- Positive Quadratic Programming (PQP) used to **maximise the profit function of one farm** (Paris & Arfini, 40th EAAE Seminar, 1995)
- Positive Mathematical Programming (PMP) used to maximise the profit functions of **multiple farms**, using the ME, “Ill-posed problem and implicit cost estimate” (Paris & Howitt, 1998)
- PMP: the **self-selection** approach (Paris & Arfini, 2000)
- PMP-AGRISP: switch from Farm-Type model (by OTE) to Regional model. Integration of **multiple farm-type models** within the same region using IACS and FADN data (Arfini F., Donati M., Zuppiroli M., 2005)
- PMP: the **latent crops and latent technology** (Arfini & Donati, 2013)
- PMP: from Maximum Entropy to the **Least Square approach** using endogenous dual information (Arfini F., Donati M., Solazzo R., Veneziani M., 2016)
- PMP-AGRISP-ABM: A regional AB model for the analysis of regional and national agricultural Policies and their **impact on the environment** (Baldi et al. 2023).

Why an Agent Based Model?

- Farm heterogeneity in terms of structure, size and farm type
- Assess interactions among farms according to behavioural rules
- Agents' production choices under the assumption of not-fully rational behaviour

The AGRISP model

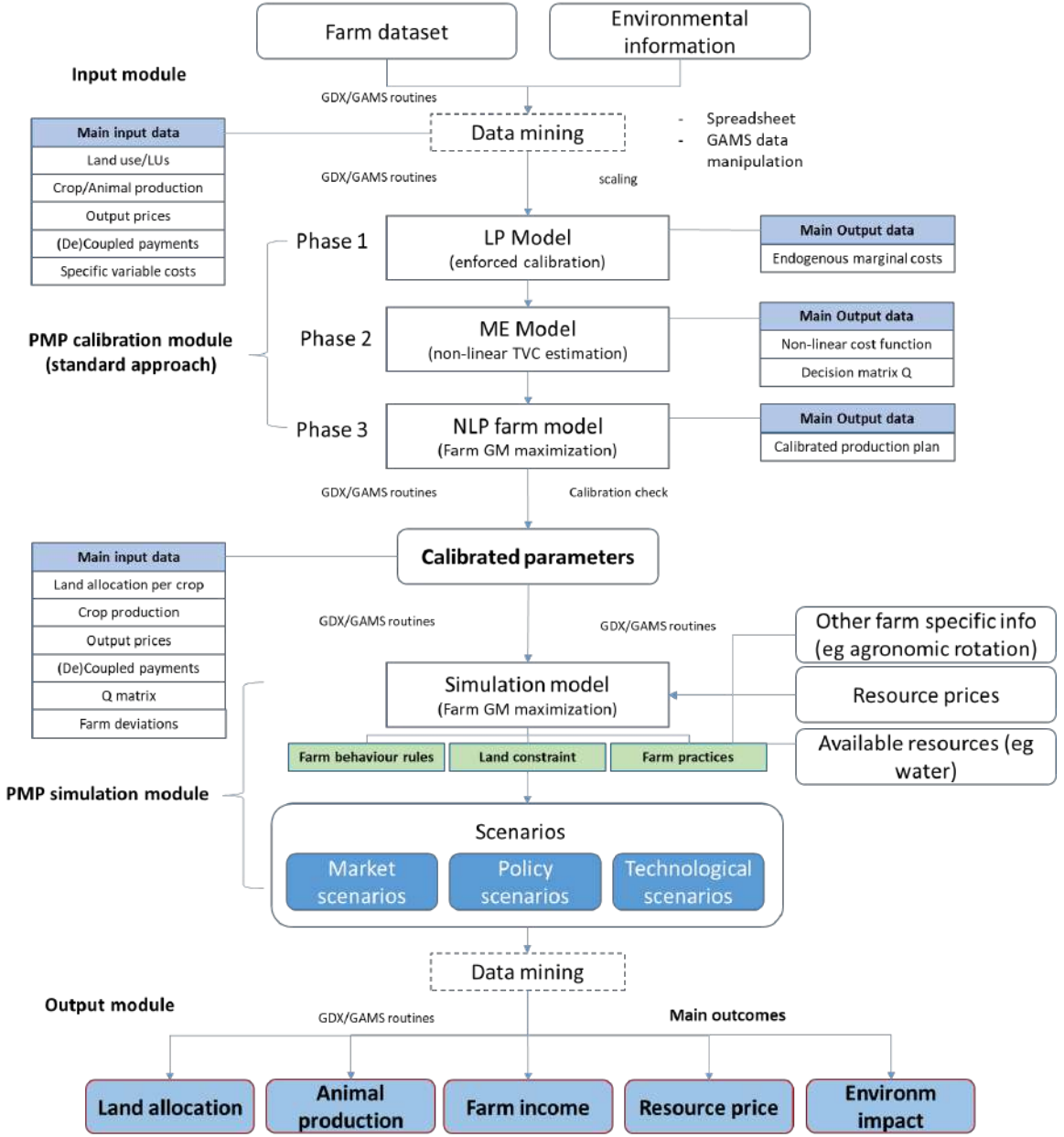
- Agents are owners of farms with specific socio-economic characteristics, located in an agricultural region.

- Each farm model is calibrated to its level of production.

- Interaction between farms, represented by the exchange of resources (land, labour, water, etc.) between agents, is made possible by cost/opportunity constraints linking farms to each other.
- The exchange of technology is made possible by sharing the frontier cost function.

ASSUMPTION: all agents interact with each other knowing the different technologies that can be applied and can make the optimal choices by deciding whether or not to exchange factors of production, according to the specific rules of the model.

The AGRISP structure



The AGRISP Simulation

$$\max_{x_n \geq 0} \left(p'_n x_n - 1/2 x'_n \hat{Q}_n x_n - \hat{u}_n x_n\right)$$

$$A_n x_n \leq b_n$$

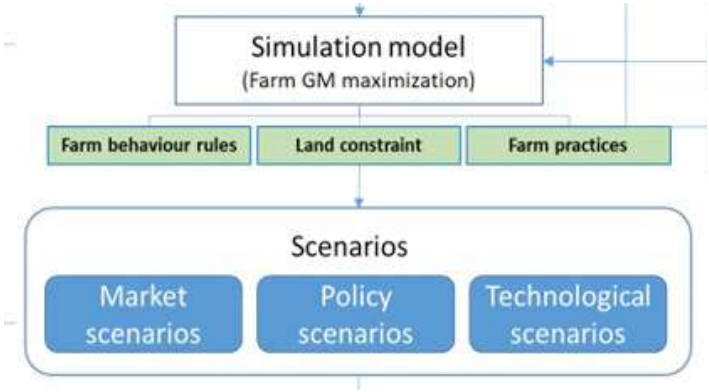
$$x_n \geq 0$$

$$\max_{x_c \geq 0, x_g \geq 0} p'_c x_c + p'_g x_g - \frac{1}{2} \begin{bmatrix} x_c & x_g \end{bmatrix} Q_{cg} \begin{bmatrix} x_c \\ x_g \end{bmatrix}$$

$$S.t. \quad A_c x_c + A_g x_g \leq b$$

$$A_{nc} x_{nc} \cdot A_{ng} x_{ng} = 0$$

Farmers > 65 and with no successors do not rent land



Milk output price covers the costs of milk production.

Livestock is linked to the available land through the use of fodder crops produced on farm:

$$y_{nr} x_{n,milk} - x_{nr} \leq 0 \ \forall n \ \forall r$$

Milk quota are not considered.

$$\sum_j \left(A_{nj} x_{nj}\right) \leq b_n + Z_n - V_n \ \forall n$$ Each farm can rent (Z) or rent out (V)

$$Z_n V_n = 0 \ \forall n$$ Each farm cannot rent or rent out land at the same time

$$\sum_n Z_n - \sum_n V_n = 0$$ The total land exchange should be equal to the total regional UAA

ASSUMPTION: All farms can exchange land only within their agrarian regions. Land price is uniform in the region: 589 € (CREA, 2020)

The Research Question

Estimate the impact that measures aiming at reaching the F2F target may have in context of the CAP specific objective 1, that focuses on supporting viable income.

The research question is two folded:

1. What is the impact of “green” measure on the environment and on the farms income
2. Is there trade-off between SO5 intended to foster sustainable development and SO1 aiming at supporting viable farm income?

The possible contradiction arises when the methods to achieve SO1 potentially increase the environmental footprint of agriculture, which would be at odds with the environmental and resource efficiency goals of SO5.

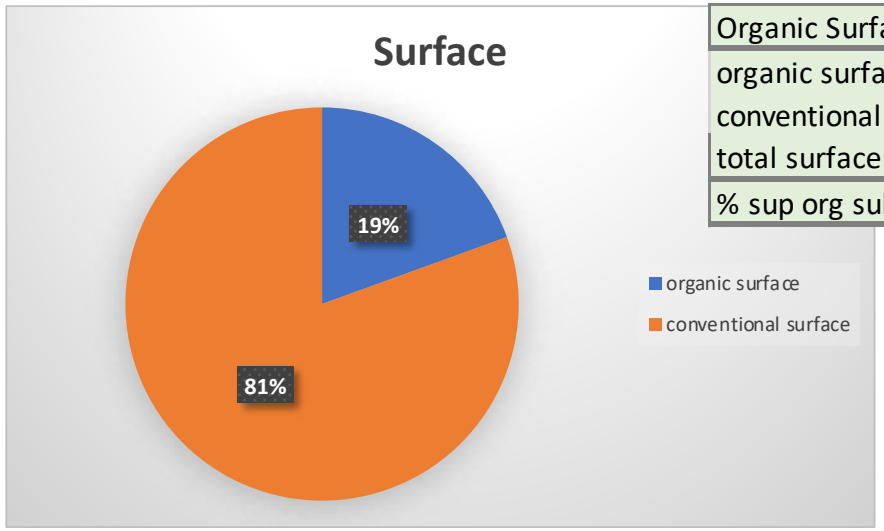
Scenarios

Baseline

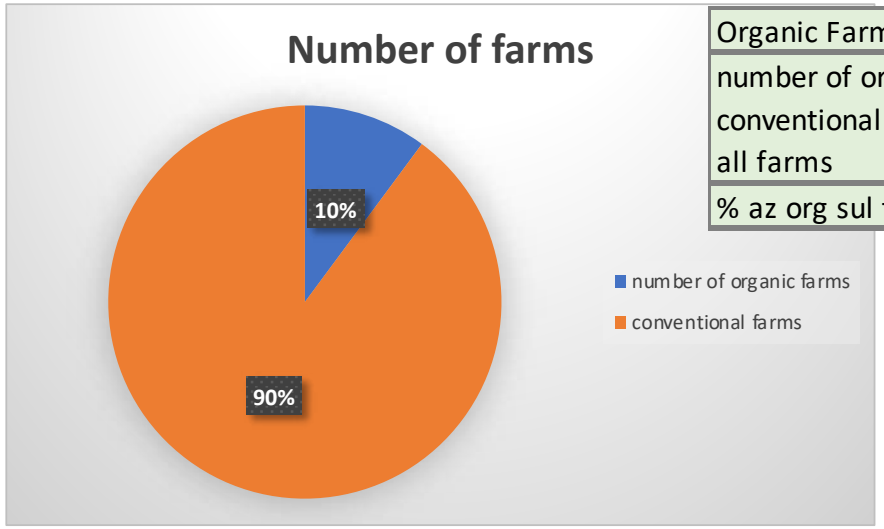
- CAP 2023 -2030: greening payment, single payment and crops coupled payment (Pillar I and II)
- Exchange arable land by renting or renting out land
- Farmers over 65 and with no successors receive a retirement pension of 1,000€/month

Nitrogen Directive	GHG Emissions	Organic Conversion	Fertilisers Decrease
Right to spread manure according to the EU Nitrate Directive 91/676/CEE “S_Nitrogen” and Regional Regulation 15/12/2017)	Progressive CO2 taxes (2[illegible], 50, 100 e 150 €/tCO2eq) are coupled to each activity (IPCC 2006)	Organic farming payments to encourage farm holders to increase the area under organic farming to 25% (RDP 2014-2020).	20% decrease in the use of chemical fertiliser for conventional farms. A 15% decrease in yield, except for alfalfa, is estimated.

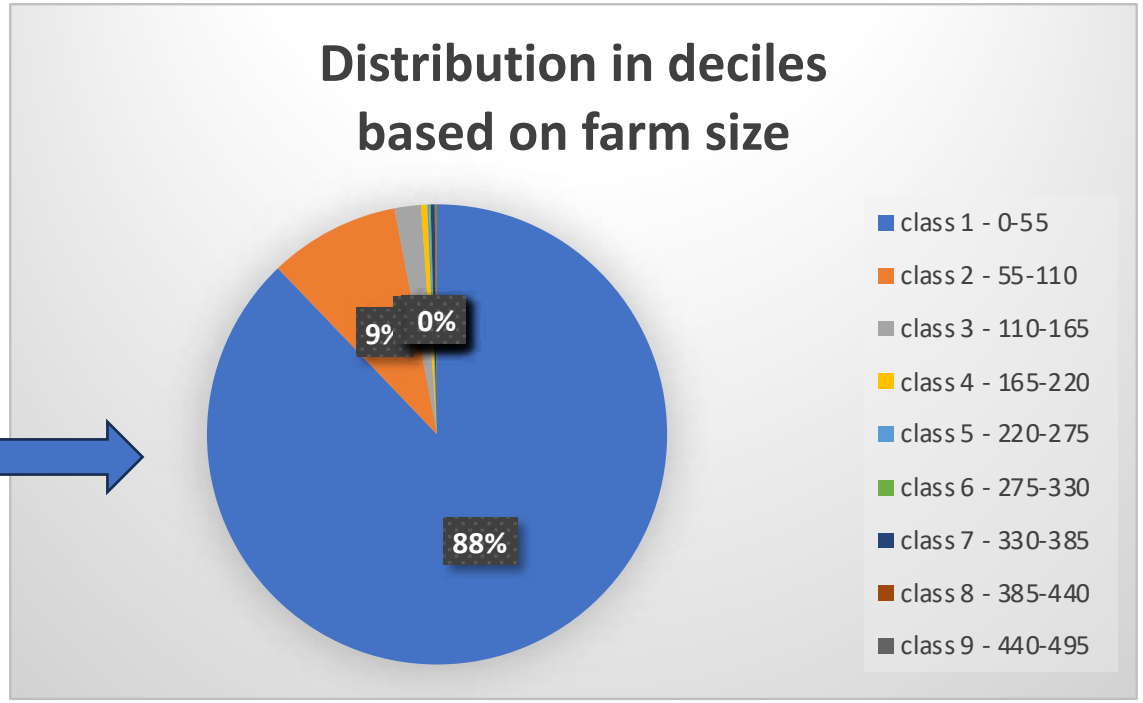
The sample: Emilia Romagna FADN 2021



Organic Surface (ha)	Superficie
organic surface	126,309
conventional surface	522,433
total surface	648,742
% sup org sul totale	19.47%



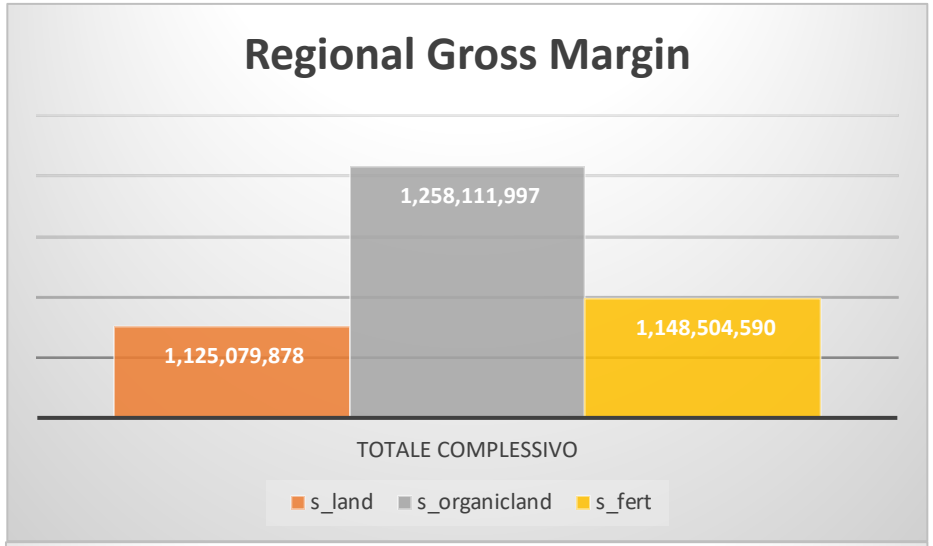
Organic Farms	# Aziende
number of organic farms	2,856
conventional farms	25,292
all farms	28,148
% az org sul totale	10.15%

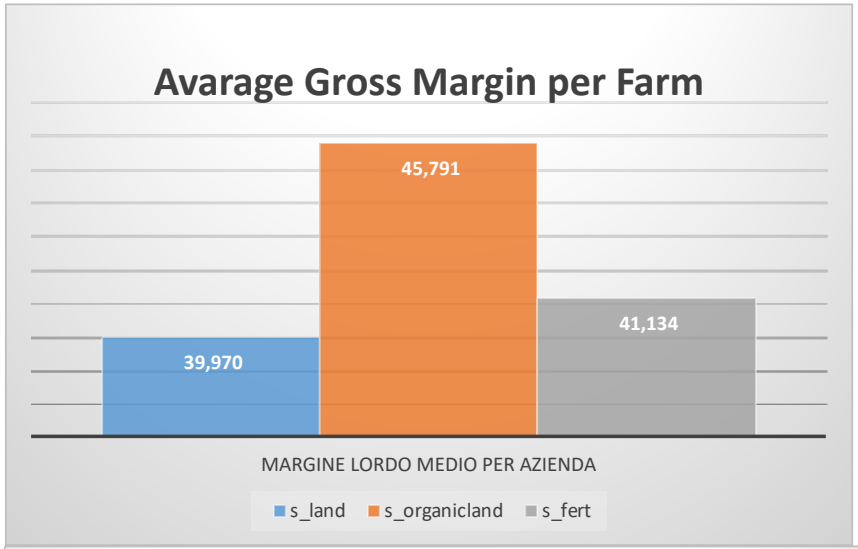


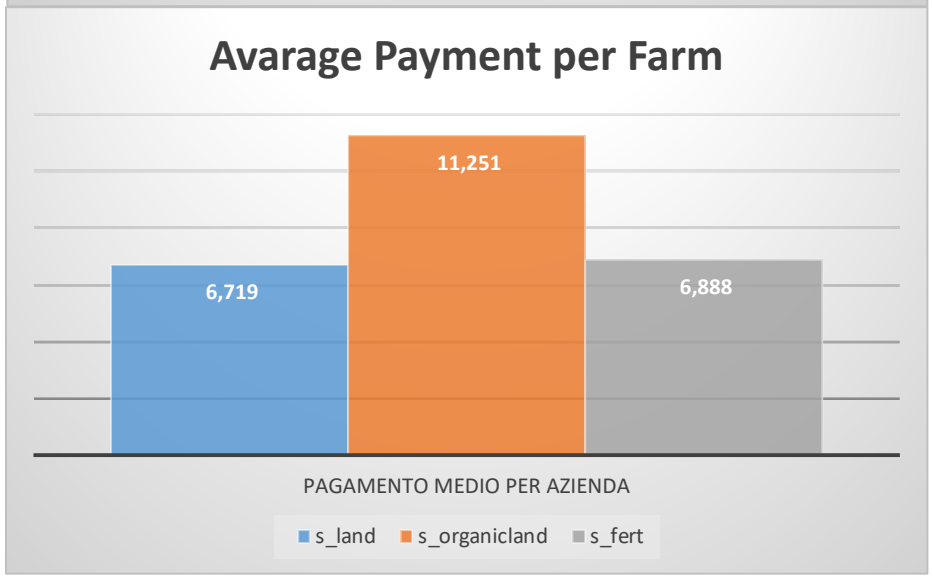
Results

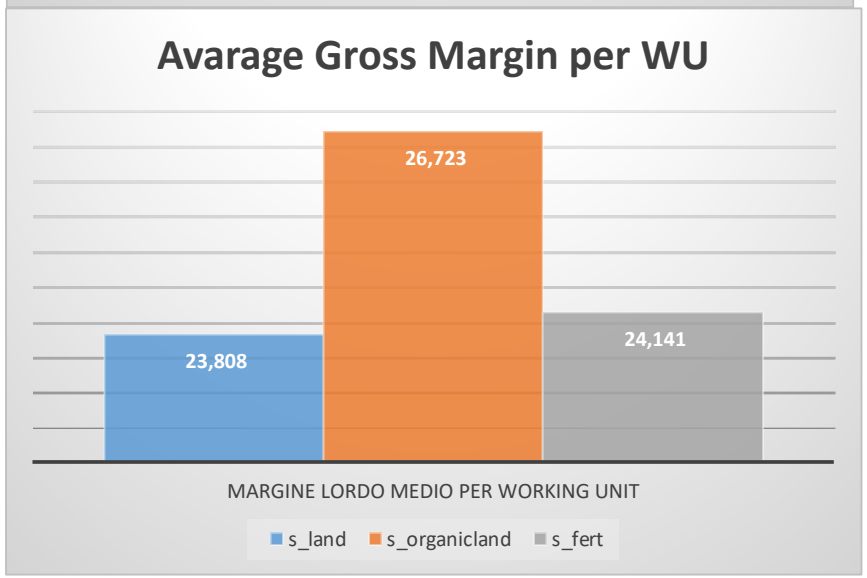
- Economic impact:
  - Regional Gross Margin
  - Average Gross Margin per Farm and per Annual Working Unit
  - Level of Payments per Farm
- Impact analysis using the Gini index
- Environmental impact

Results: Economic impact



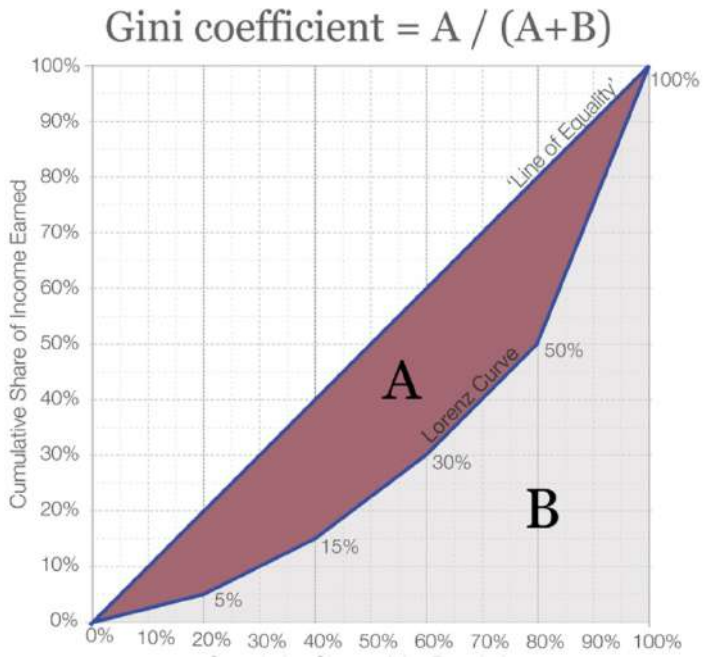




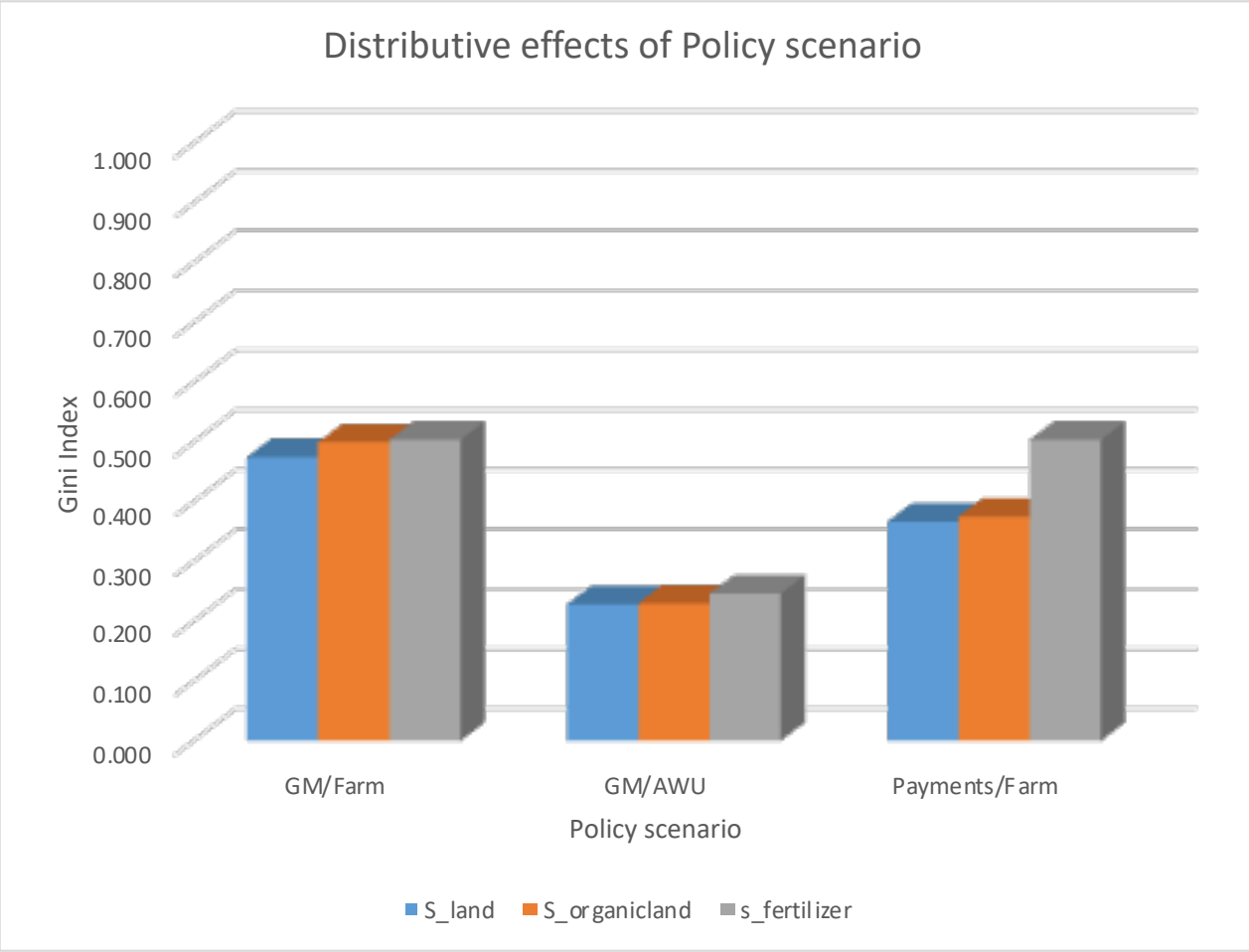


Results: Gini index

- The Gini coefficient measures the extent to which the distribution of income within a country or a region deviates from a perfectly equal distribution.
- A coefficient of 0 expresses perfect equality where everyone has the same income, while a coefficient of 100 expresses full inequality where only one person has all the income.

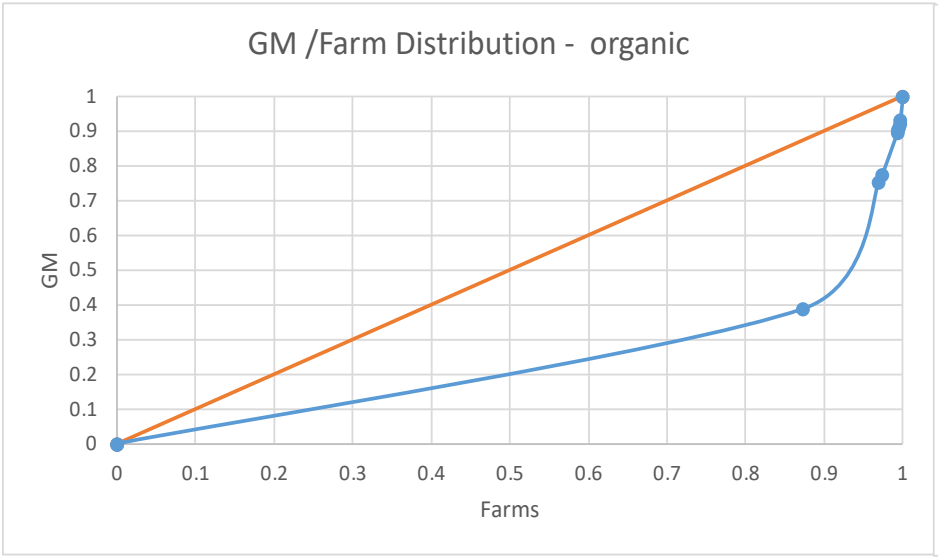


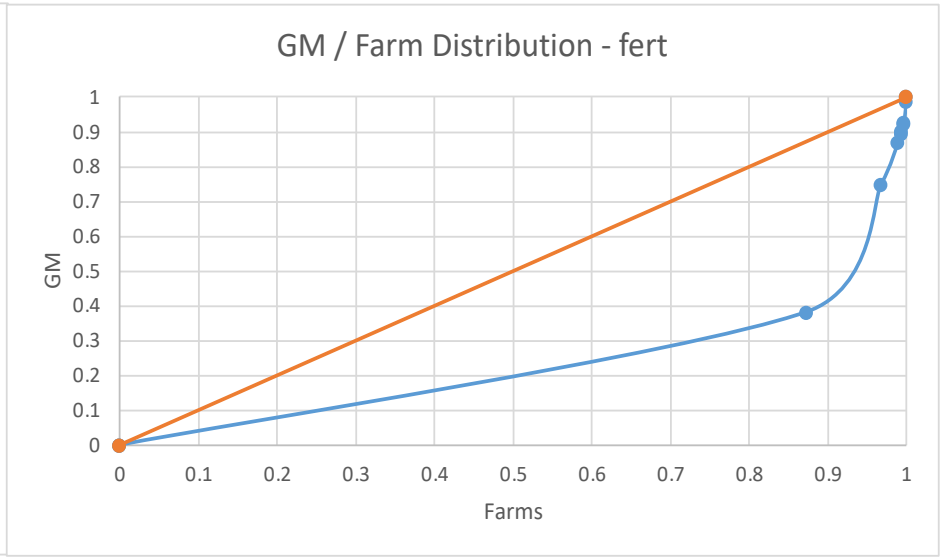
Results: Gini index

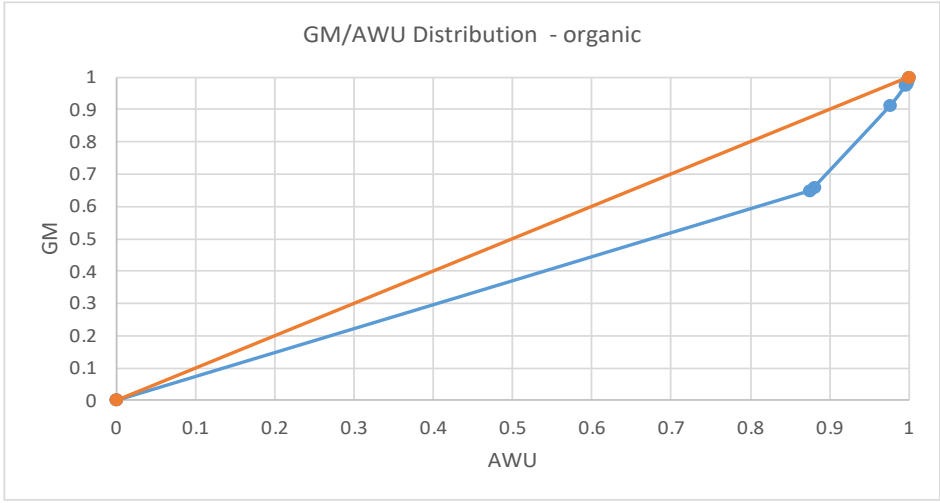


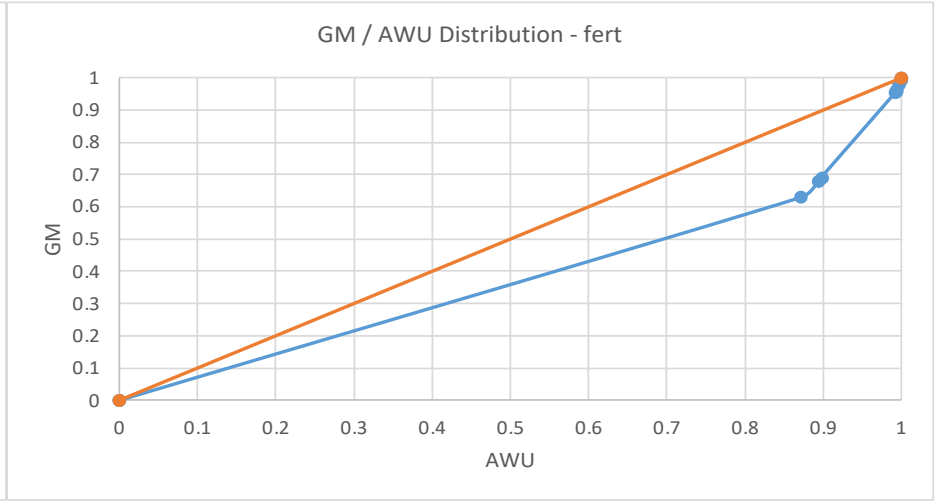
	s_land	s_organicland	s_fert
GM/Farm	0.475	0.500	0.504
GM/AWU	0.229	0.230	0.246
Payments/Farm	0.367	0.375	0.504

Results: Gini index





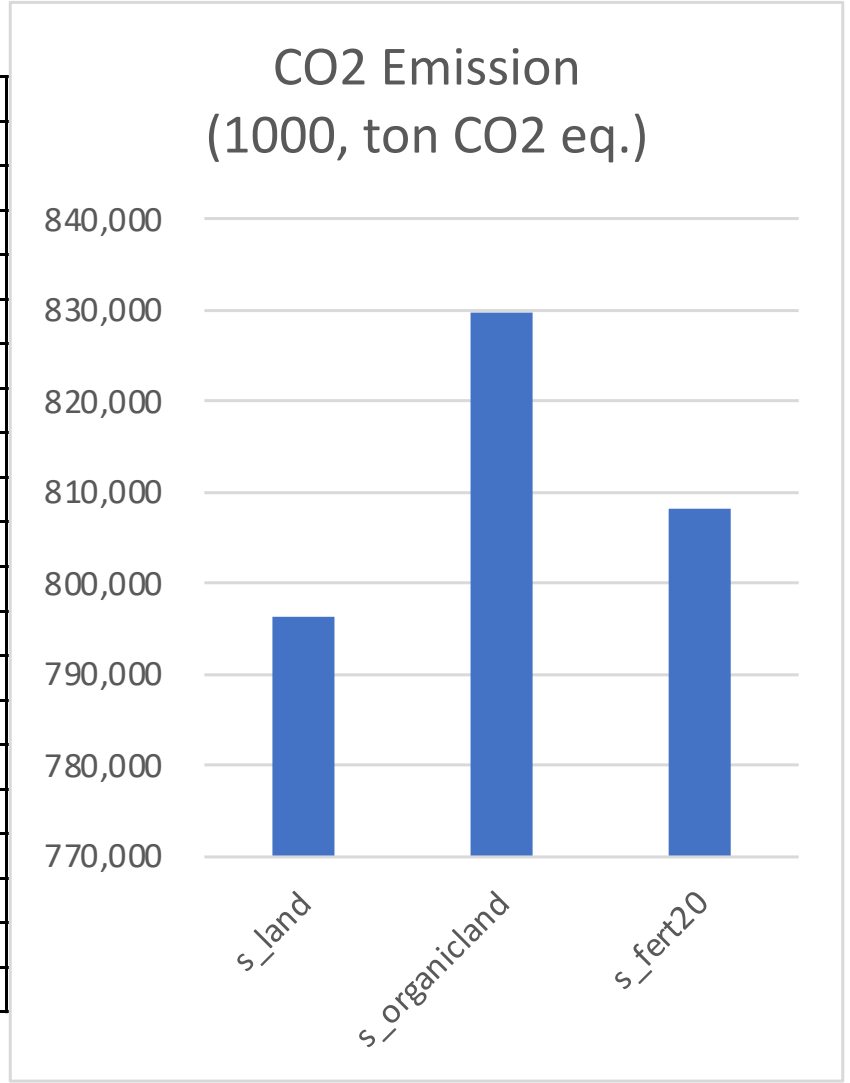




The distribution of the GM/AWU shows that farmers are homogeneous in their ability to produce income.

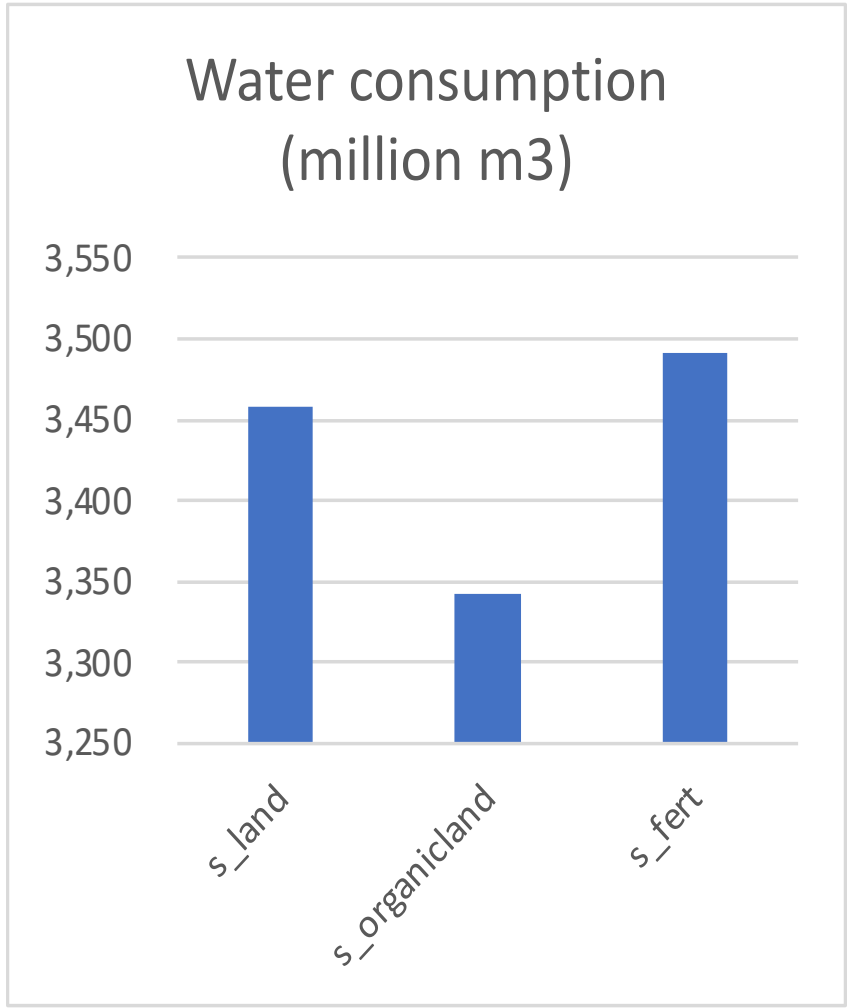
Results: Environmental Impact (CO2)

	Surface (hectars)			T CO2 eq/Ha	Carbon Emission (1,000 tCO2 eq)		
Product	s_land	s_organicland	s_fert	-	s_land	s_organicland	s_fert
BEET	38,700	38,100	36,600	1.4457	56,000	55,100	52,800
CER	1,490	1,770	1,190	1.3276	1,980	2,350	1,580
D_WHEAT	45,900	54,100	42,900	1.6633	76,300	89,900	71,300
FRG	6,340	6,460	4,820	0.6700	4,250	4,330	3,230
C_WHEAT	68,900	63,500	66,800	1.5541	107,000	98,800	104,000
SUNFL	8,560	11,300	8,000	0.8188	7,010	9,270	6,550
PROT	13,300	12,900	10,300	1.0435	13,900	13,500	10,800
MAIZE	31,400	34,700	29,800	3.5235	111,000	122,000	105,000
ALFA	263,000	248,000	273,000	0.5026	132,000	125,000	137,000
SILAGE	13,500	14,700	18,700	1.7676	23,800	26,000	33,000
OIL	234	649	226	0.8188	191	531	185
BARLEY	11,700	9,320	9,210	0.9876	11,500	9,200	9,100
POTATO	4,780	4,980	5,440	2.2735	10,900	11,300	12,400
TOMATO	23,800	25,600	29,000	2.1134	50,400	54,200	61,300
GRAZ	71,200	61,800	61,000	2.2397	138,000	139,000	137,000
RICE	1,820	2,060	1,920	8.4969	15,400	17,500	16,300
SOJA	31,400	42,200	30,200	0.8096	25,400	34,100	24,400
SORG	8,410	13,300	16,800	1.3276	11,200	17,600	22,300
TOT ARABLE	644,434	645,439	645,906	-	**796,231**	**829,681**	**808,245**

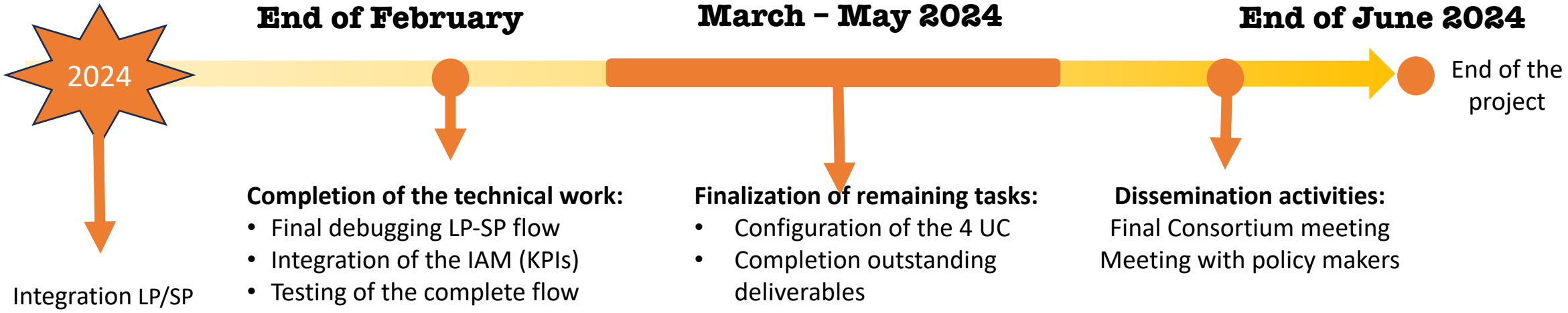


Results: Environmental Impact (water)

	Surface (hectars)			Water FP (Million m3)		
Product	s_land	s_organicland	s_fert	s_land	s_organicland	s_fert
BEET	38,700	38,100	36,600	5.070	4.990	4.790
CER	1,490	1,770	1,190	7.740	9.180	6.180
D_WHEAT	45,900	54,100	42,900	54.700	64.400	51.100
FRG	6,340	6,460	4,820	59.300	60.500	45.100
C_WHEAT	68,900	63,500	66,800	82.100	75.800	79.600
SUNFL	8,560	11,300	8,000	17.400	23.000	16.300
PROT	13,300	12,900	10,300	107.000	104.000	82.700
MAIZE	31,400	34,700	29,800	21.600	23.800	20.500
ALFA	263,000	248,000	273,000	2,470.000	2,320.000	2,550.000
SILAGE	13,500	14,700	18,700	9.260	10.100	12.800
OIL	234	649	226	2.690	7.480	2.610
BARLEY	11,700	9,320	9,210	13.900	11.100	11.000
POTATO	4,780	4,980	5,440	2.340	2.440	2.670
TOMATO	23,800	25,600	29,000	2.470	2.660	3.010
GRAZ	71,200	61,800	61,000	552.000	554.000	547.000
RICE	1,820	2,060	1,920	1.950	2.220	2.060
SOJA	31,400	42,200	30,200	42.100	56.500	40.400
SORG	8,410	13,300	16,800	6.990	11.000	14.000
TOT ARABLE	644,434	645,439	645,906	**3,458.610**	**3,343.170**	**3,491.820**



AGRICORE - Remaing tasks prior to project closure



AGRISP - Roadmap

1. Restructuring of the archive:

- Analysis of existing models and archive structure
- Definition of a new organisational structure of the archive
- Definition of versioning policies for models and related data and documents
- Selection of a revision control tool
- Reorganisation of existing models, data and documents
- Documentation of the archive structure and management procedures

2. Data acquisition :

- Analysis of the data import functionalities offered by GAMS
- Definition of a procedure for the automatic and direct import of data
- Prototype implementation of a direct data import script
- Technical documentation of the import script: structure, operation and extensions
- Documentation of the import procedure

3. Graphical presentation:

- Analysis of the functionalities offered by the GAMS Mirò environment and evaluation of feasibility
- Implementation of a simple demonstration interface for accessing certain results

Thanks for your attention

lisa.baldi@unipr.it