**Conceptual Agent-Based Model of Sustainable Land-Use Farming Adoption**

## Model Equations

### 1. Utility Calculation

$$
\begin{aligned}
U_i &= \alpha\, U_{\mathrm{econ},i} + (1-\alpha)\, U_{\mathrm{social},i} \\
U_{\mathrm{econ},i} &= S - w_i^{(p)}\, P_i^{(\mathrm{conv})} + w_i^{(p)}\, P_i^{(\mathrm{nat})} \\
U_{\mathrm{social},i} &= SCF \cdot w_i^{(s)} \cdot \phi
\end{aligned}
$$

### Legend

- $U_i$: Total utility for agent $i$(EUR/ha)
- $\alpha$: Weight for economic utility ($0 \le \alpha \le 1$)
- $U_{\mathrm{econ},i}$: Economic utility (EUR/ha)
- $U_{\mathrm{social},i}$: Social utility (EUR/ha)
- $S$: Subsidy for adoption (EUR/ha/year)
- $w_i^{(p)}$: Profit weight (range: 0.5–2.0)
- $P_i^{(\mathrm{conv})}$: Profit from conventional agriculture (EUR/ha)
- $P_i^{(\mathrm{nat})}$: Profit from nature-based agriculture (EUR/ha)
- $SCF$: Social capital factor (EUR/ha)
- $w_i^{(s)}$: Peer weight (range: 0.5–2.0)
- $\phi$: Fraction currently adopting ($0 \le \phi \le 1$)

### 2. Adoption Probability

$$
p_i = \frac{1}{1 + \exp\left(-\frac{U_i}{k}\right)}
$$

### Legend

- $p_i$: Probability of adoption
- $U_i$: Utility (EUR/ha)
- $k = 100$: Scaling factor (adoption sensitivity to utility)

### 3. Agent Learning

**Peer Weight Update (Temporal)**

$$w_i^{(s)}(t+1) \;=\; w_i^{(s)}(t) \;+\; \lambda_{\text{social}}(\phi(t) - w_i^{(s)}(t)), w_i^{(s)}(t) \in [0.5, 2.0]$$

**Profit Weight Update (Temporal)**

$$w_i^{(p)}(t+1) \;=\; w_i^{(p)}(t) \;+\; \lambda_{\text{econ}}(U_{\text{econ},i}(t) - w_i^{(p)}(t)), w_i^{(p)}(t) \in [0.5, 2.0]$$

**Legend**

- $w_i^{(s)}$: Peer weight (0.5–2.0)
- $\lambda_{\text{social}}$: Social learning rate (0.0–1.0)
- $\phi$: Fraction adopting ($0 \leq \phi \leq 1$)
- $w_i^{(p)}$: Profit weight (0.5–2.0)
- $\lambda_{\text{econ}}$: Economic learning rate (0.0–1.0)
- $U_{\text{econ},i}$: Economic utility (EUR/ha)

### 4. Emissions Calculation

$$E_i \;=\; 5.0 \cdot (1 - 0.5 \cdot A_i)$$

**Legend**

- $E_i$: Emissions (t $CO_2$-eq/ha/year)
- $A_i$: Adoption status (1 if adopted, 0 otherwise)
- 5.0: Baseline emissions for non-adopters (t $CO_2$-eq/ha/year)
- 0.5: Emissions reduction factor for adopters

## 5. Policy Cost and Cost-Effectiveness

$$\text{PolicyCost}_{ha} = S \cdot \phi$$
$$\text{EmissionsSaved}_{ha} = \max\ (5.0 - \bar{E}, 0)$$
$$\text{CostPerTonne} = \begin{cases} \dfrac{\text{PolicyCost}_{ha}}{\text{EmissionsSaved}_{ha}}, & \text{if EmissionsSaved}_{ha} > 0.01, \\ \text{NaN}, & \text{otherwise.} \end{cases}$$

## Legend

- $\text{PolicyCost}_{ha}$: Policy cost per hectare (EUR/ha/year)
- $S$: Subsidy for adoption (EUR/ha/year)
- $\phi$: Fraction adopting ($0 \leq \phi \leq 1$)
- $\bar{E}$: Average emissions (t $CO_2$-eq/ha/year)
- 5.0: Baseline emissions for non-adopters (t $CO_2$-eq/ha/year)
- $\text{EmissionsSaved}_{ha}$: Emissions saved per hectare (t $CO_2$-eq/ha/year)
- 0.01: Threshold to avoid division by very small numbers
- CostPerTonne: Cost per tonne $CO_2$ saved (EUR/t $CO_2$)
- NaN: Not a Number, used when savings are too small