Assessing robustness and optimality of ecosystem services trade offs: a probabilistic approach

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INRA SCIENCE & IMPACT

VetAgro Sup

Introduction

- **Can we use agro-ecological practices to optimize ecosystem services bundles in order to reduce trade-offs (*sensu* Constanza *et al.* 1997, MEA 2005)?**
- **Definition of agro-ecology: ecology applied to agronomy to make the best use of biological processes (Altieri 1989)**
- **Does making the best use of complex biological processes require a fine-tuning of management decisions?**
- **Fine-tuning of management decisions can be a source of uncertainty**
- **Use of robustness *sensu* Stelling *et al.* (2004) (ability to maintain performance in the face of perturbations and uncertainty) to assess the validity of practices**

=> Develop a framework focused on farmer management decisions crossing robustness and optimality metrics

Agro-ecological practice studied: sheep/cattle mixed grazing

- Improves liveweight gain through parasitism dilution and complementary exploitation of forage niches
- Improvements quantified by d'Alexis *et al.* (2014)
- Liveweight gain follow a humped-shaped curve peaking for intermediate sheep/cattle ratio

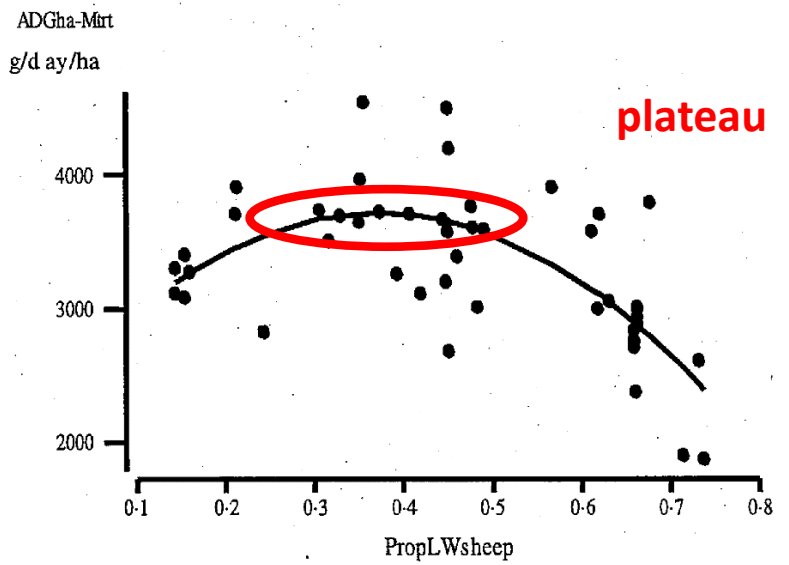


Fig. 5. Average daily gains per ha in mixed grazing (ADGha-Mtrt, g/day/ha) according to the proportion of liveweight of sheep in the association (PropLWsheep).

Exploratory model of sheep/cattle mixed-grazing implemented on a permanent pasture of central France uplands (Massif Central)

- **Study period = the grazing season**
- **Simulation of regulating and provisioning ES, most of the time antagonistic (Maes *et al.* 2012)**
- **Model made of interacting herd and pasture components providing:**
  - **Provisioning services: meat**
  - **Regulating services: erosion prevention and climate regulation (GHG assessment)**

- **Use of monetary valuation to match farmer expectations (assessment of ES and valuation from web-agri.fr, IPCC 2006, Van der Ploeg and de Groot 2010)**

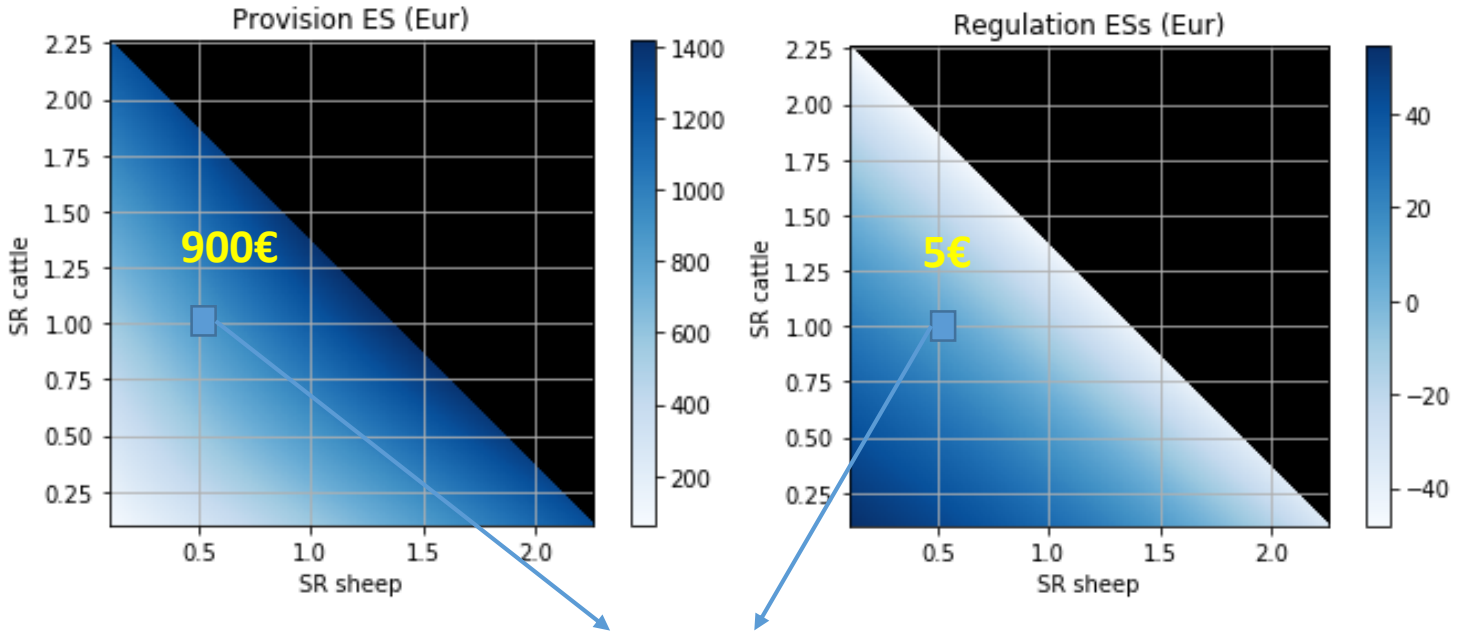
Formally

Given management decision i:

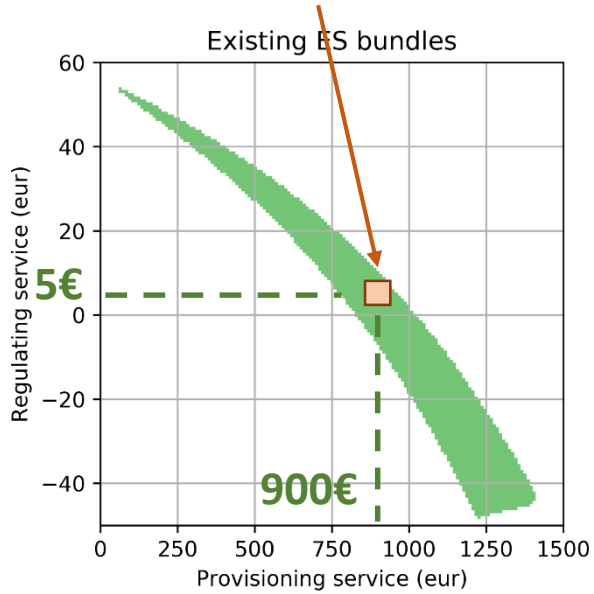
$$\begin{pmatrix} ESp_i \\ ESr_i \end{pmatrix} = f\begin{pmatrix} SR_{i,cattle} \\ SR_{i,sheep} \end{pmatrix} \quad \textbf{(Eq 1)}$$

$SR_{i,cattle}$: cattle stocking rate of decision i (LU/ha)
$SR_{i,sheep}$: sheep stocking rate of decision i (LU/ha)
ESp_i: sum of monetary values of ES provisionning of i (€)
ESr_i: sum of monetary values of ES regulation of i (€)

Stocking rate capped by pasture forage capacity

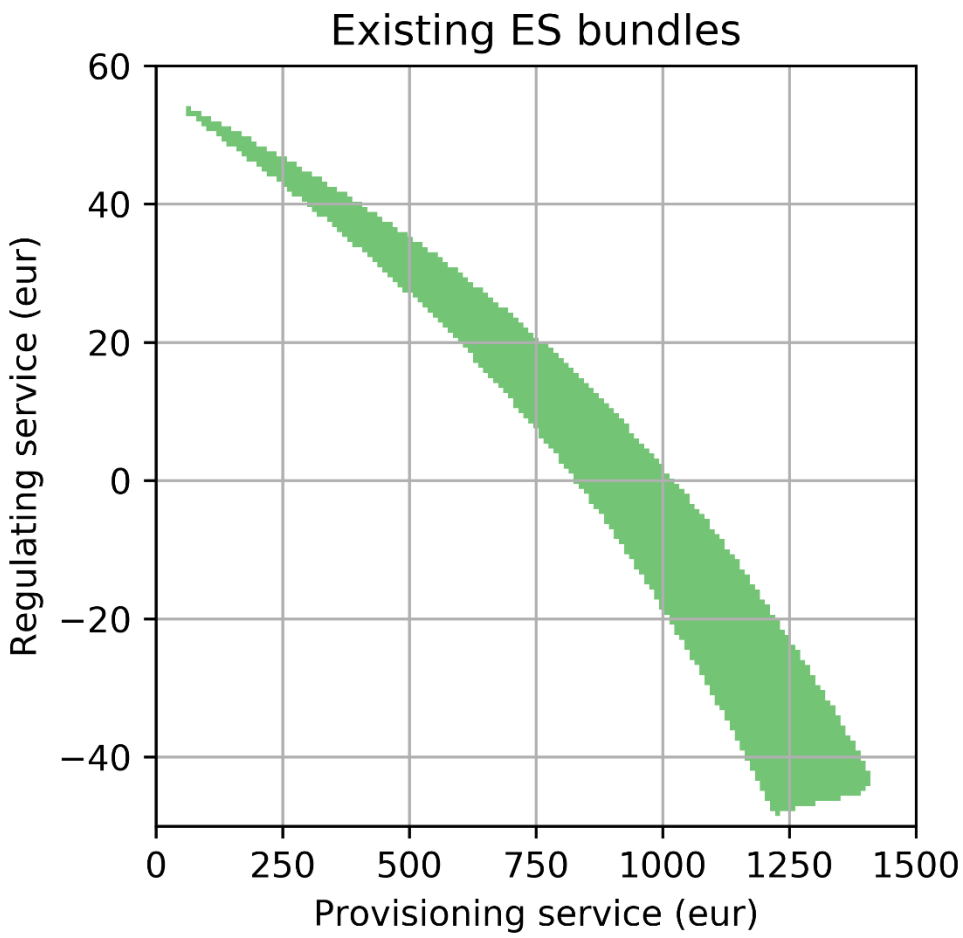


Prov. and regul. ESs = X/Y coordinates in a new graph plotting ES bundle (ESp/ESr)

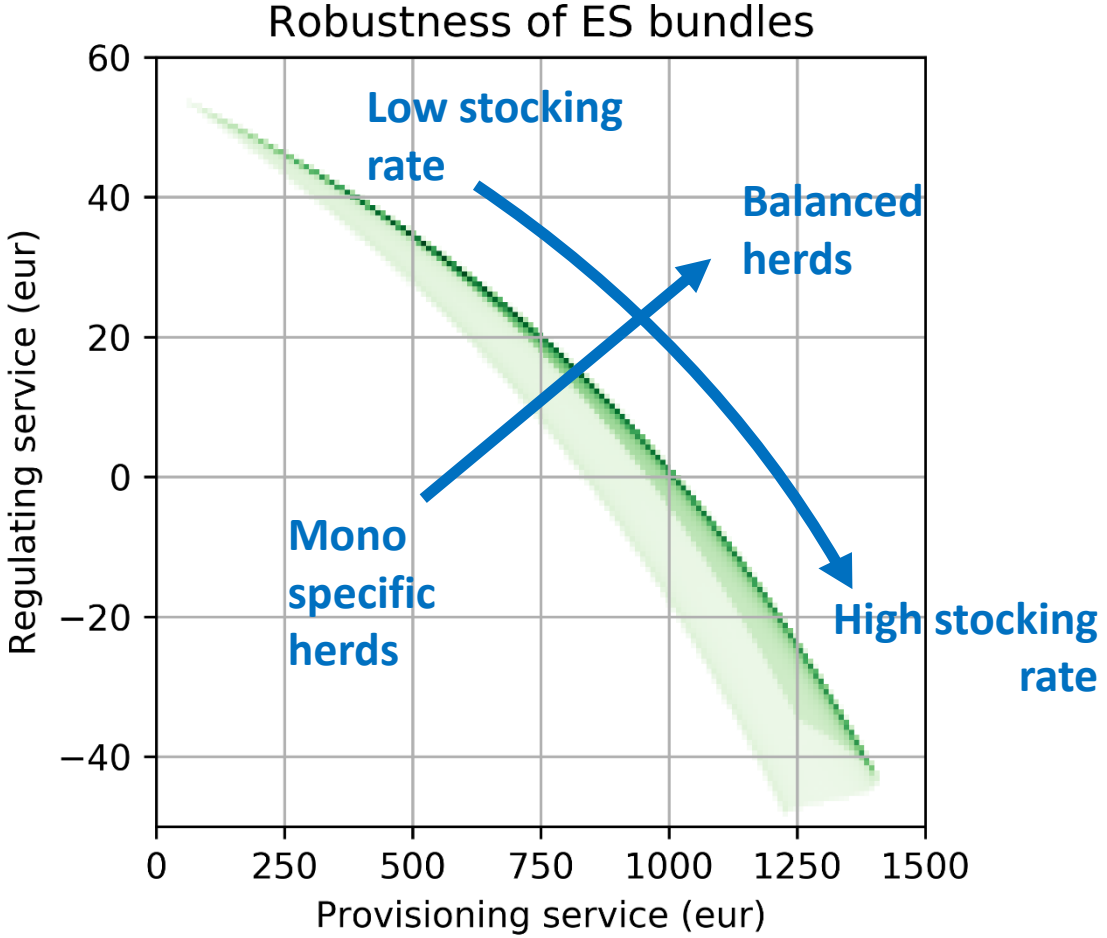


Binary and probabilistic representations of ES bundles

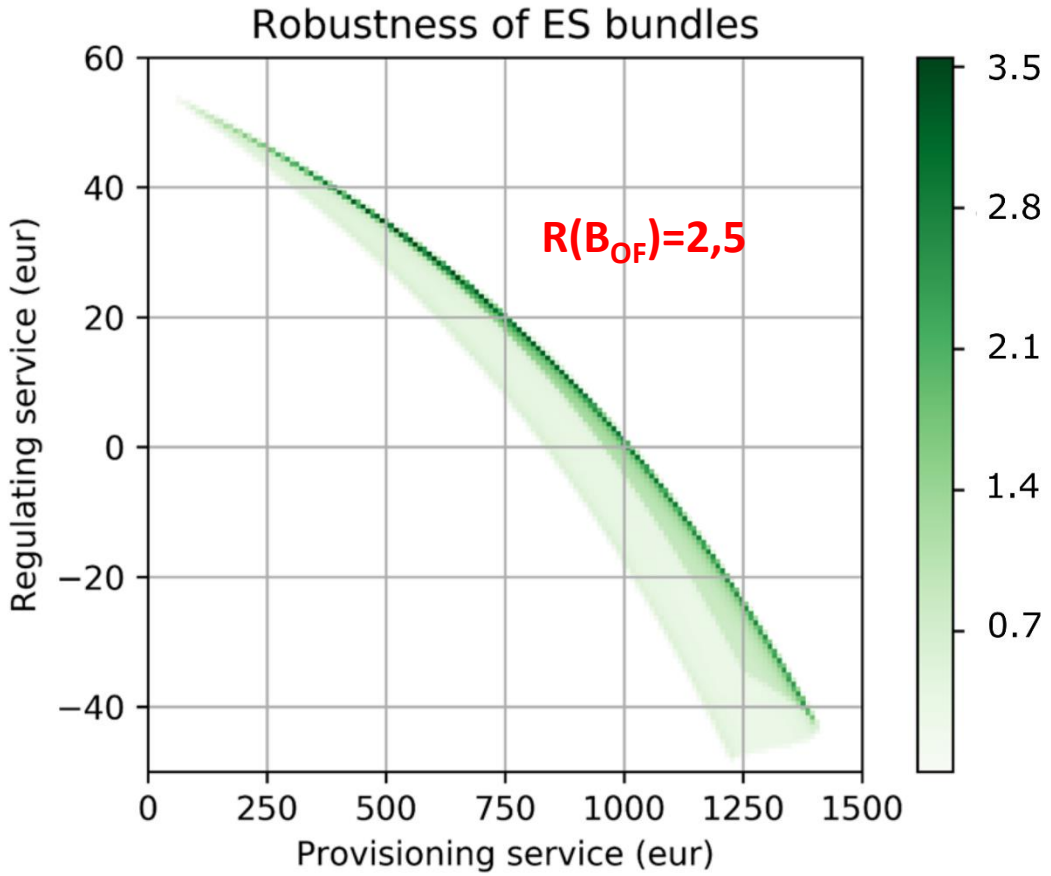
Binary (Absence / Presence)



Probabilistic (sum =1)



Metrics



Robustness

Robustness: relative probability of applying a decision delivering B_k (>1 above mean probability / < 1 below mean probability)

$n(MD_k)$: nb mgmt decisions delivering B_k

$R(B_k)$: Robustness -> $R(B_k) = n(MD_k)/ \overline{n}(MD_{km})$ (Eq 2)

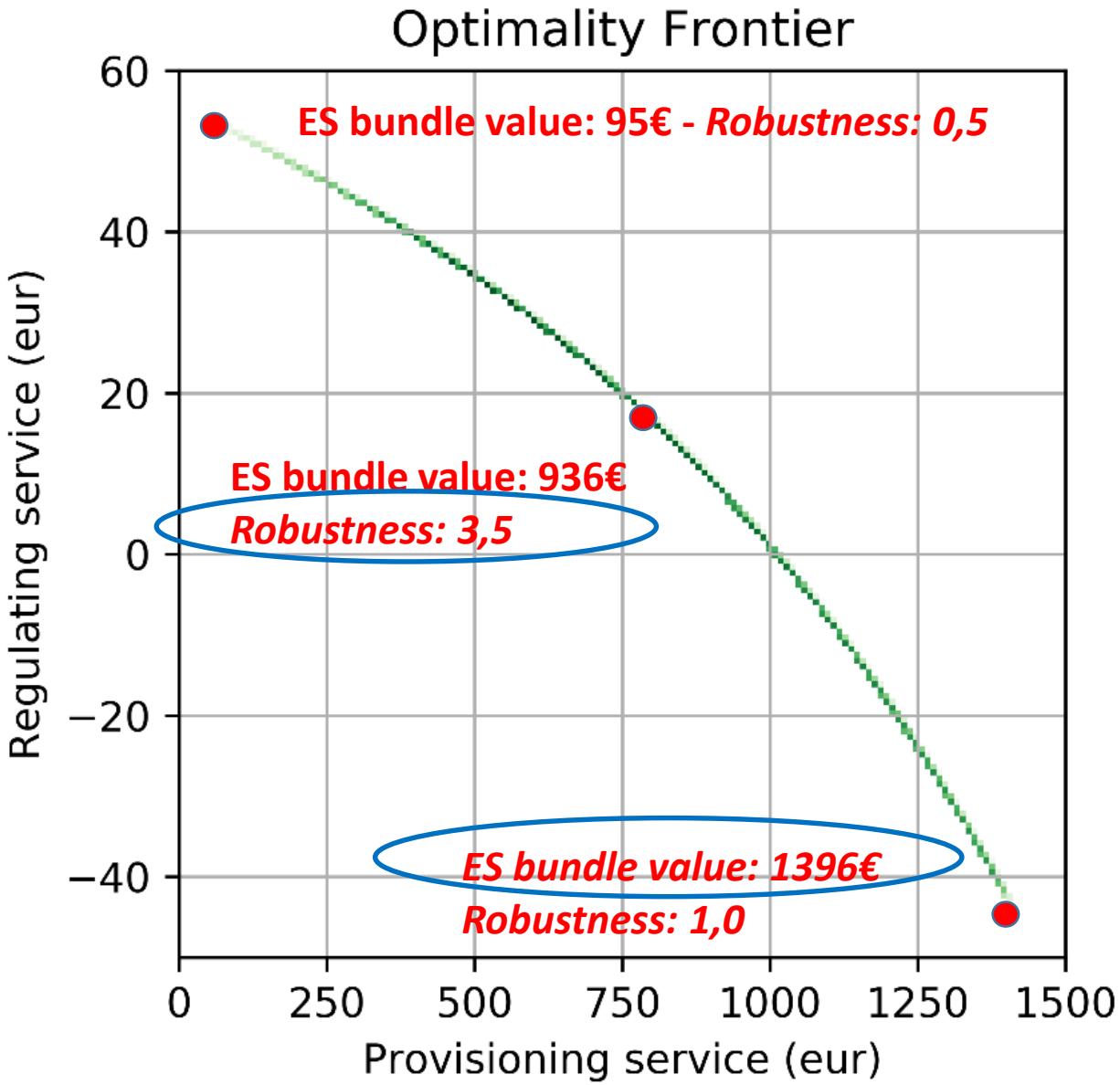
Optimality

Optimal frontier (OF) where it is impossible to find bundles better in prov. and reg. ES in the same time (Cord et al. 2017)

$OF = \{B_l \mid \nexists\ k \in \{1,\ldots,n\}$ such that $sp_k > sp_l$ and $sr_k > sr_l\}$ (Eq 3)

Good news!: OF bundles are the most robust -> pattern of the mixed-grazing gain curve buffers sub-optimal decisions

Bundle values along the OF

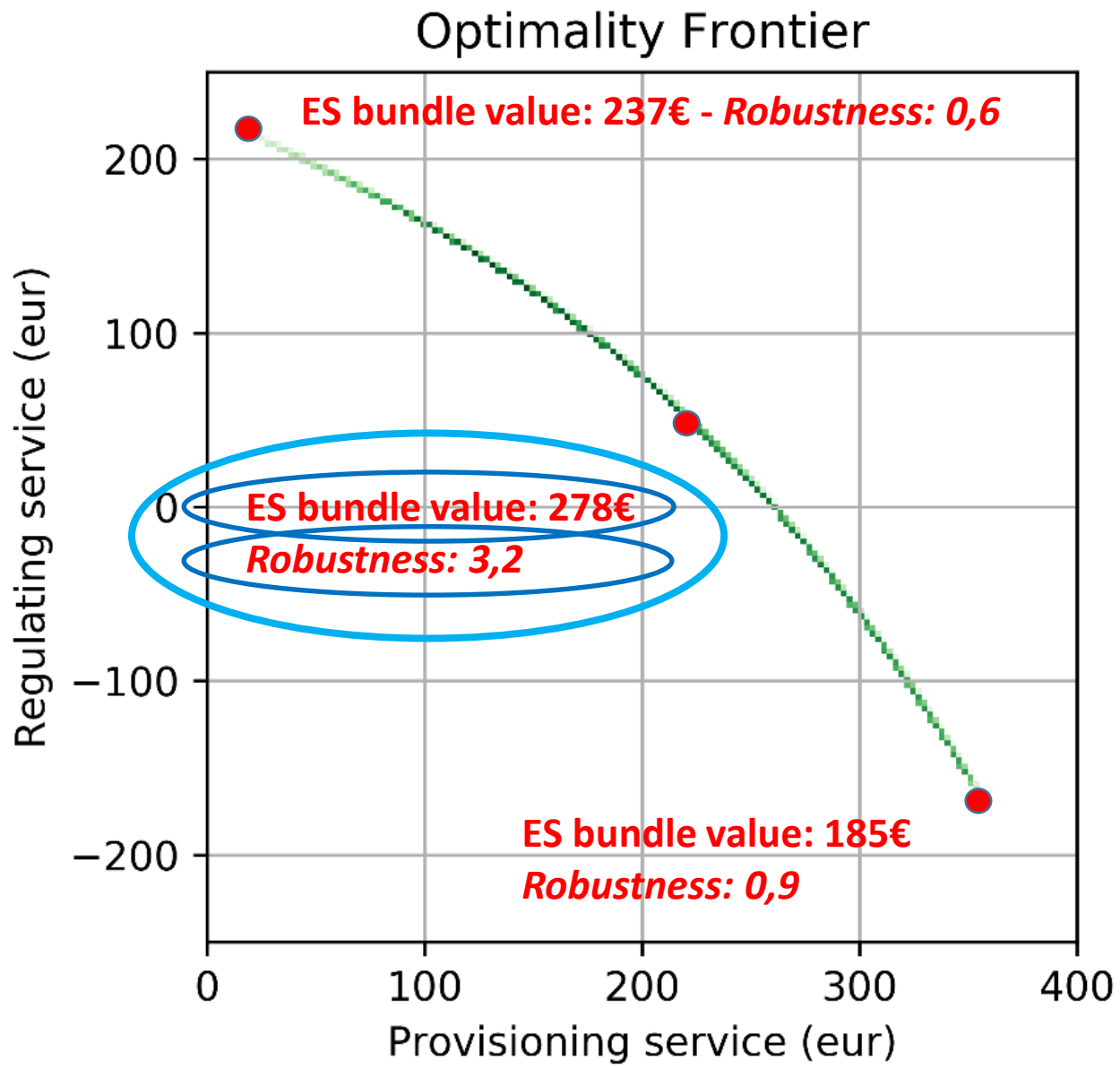


Financial optimal is at the provisioning end of the frontier whereas robustness is at the middle

Highest bundle value obtained with average robustness -> good deal obtained not too difficultly

Pertinent for farmers to focus on production

Price simulation



Context: high demand for regulating services and collapse of meat demand in a over-heated planet in 2050

Prices of regulating ESs X 4 and provisioning ESs ÷ 4 to balance ES values and incite produce balanced bundle

Convergence of optimals -> The best deal corresponding to balanced bundles can be obtained easily (high robustness)

Bundle obtained through a balanced, mid-size herd

Conclusion

- **Framework taking into account farmer management decisions, market prices and some of the biological processes underlying livestock production being developed**
- **Bundles on the OF are the most robust -> optimization of ES bundles at the range of a farmer which supports the operational pertinence of the agro-ecological practice tested**
- **Farmer could positively respond to a new ES societal demand (from focus on provisioning ES to a balanced provisioning/regulating demand)**
- **Approach of interest to validate applicability of future agro-ecological and biological innovations**
- **Three equations used to use this approach (Eq 1; 2; 3) which suggests framework pertinence**

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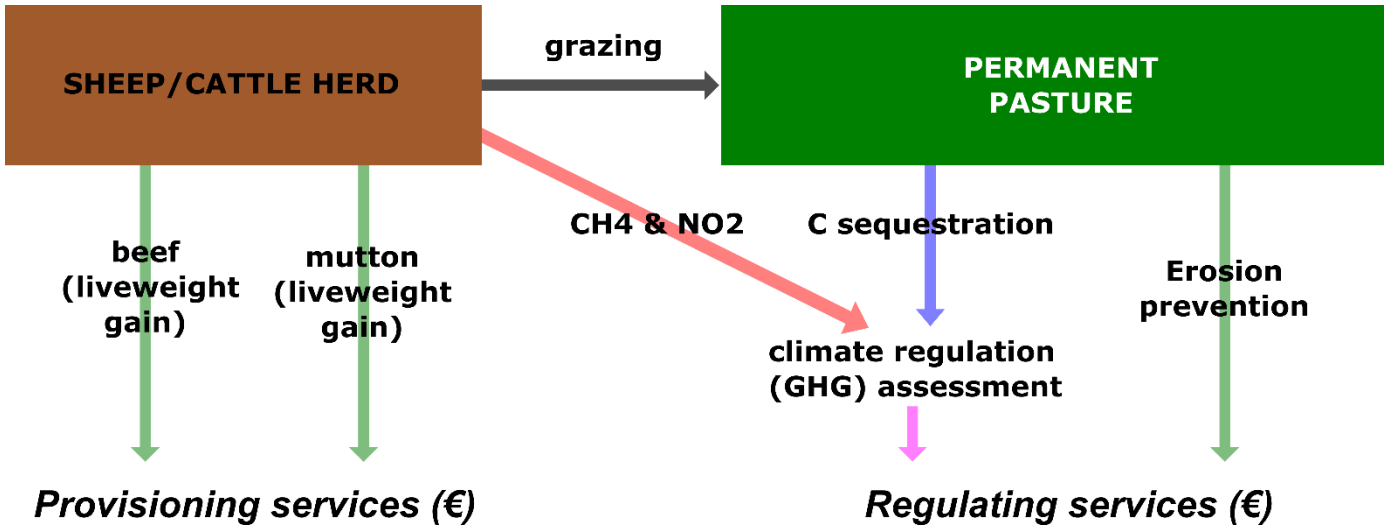

Quantification des services

ESr_i

Sequestration CO_2 from IPCC (2006) Tier 1 with comparative approach
-> Difference between CO_2 stored according to stocking rates of mgmt. decision i and max stocking rate tested (based on forage availability)
Enables converting static stocks into annual fluxes

Emission CH_4 et NO_2 = f($SR_{i,cattle}$,$SR_{i,sheep}$)
–> IPCC 2006 Tier 1

$SE_{erosion\_prevention}$= f(Residual biomass)
-> Residual biomass normalized (0 à 1) and multiplied by a reference coefficient

GHG assessment

Regulation ES assessment

ES assessed monetarily (Liveweight from web-agri.com, CO_2 EU stock exchange, erosion via database Van der Ploeg and de Groot (2010))