Integrated simulation & optimization models to deal with multiple farming objectives

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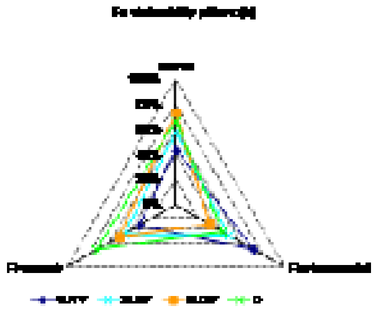
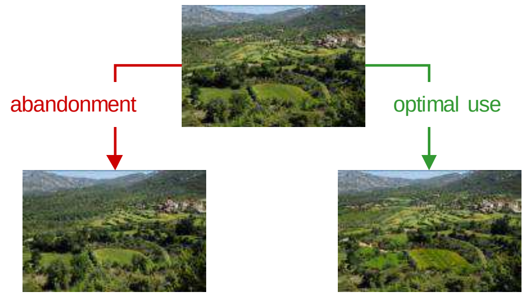
Research areas

- integrated evaluation of **sustainability**



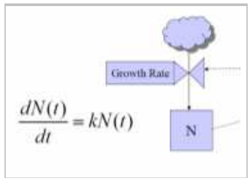
- decision support systems through **modelling**

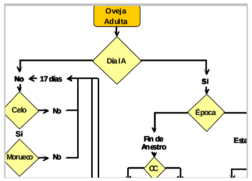
- relationships between pasture-based LFS and the **environment**



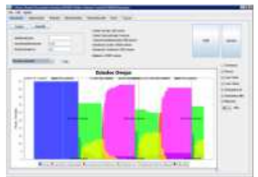
Outline

- Introduction
  - *Models in LFS*
  - *Modelisation of variability*
  - *Optimization using GA*
- Sim & Opt Model *"PASTOR"*
  - *Description*
  - *Use*
  - *Discussion*

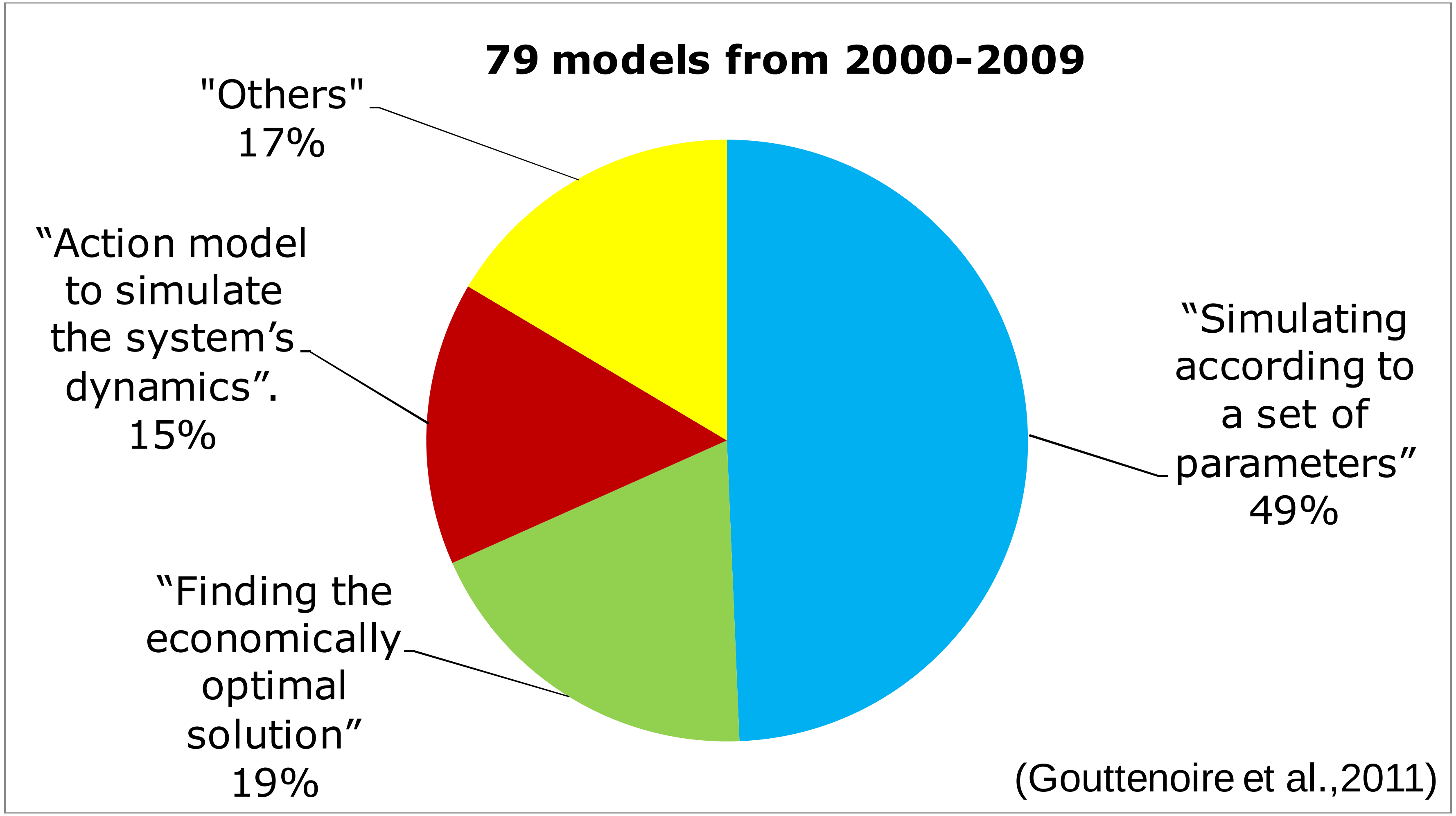








Models in LFS. Classification

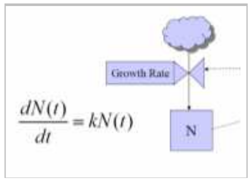


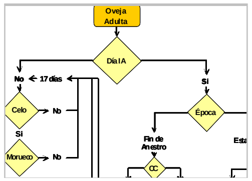
Models in LFS. Simulation

- In general the combination of submodels that explain part of the LFS
  - **Complexity?**
  - **Suitability?**
  - **Usability?**

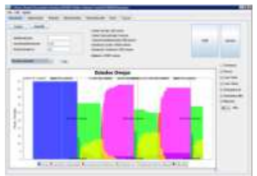
challenging but essential

"A model, like a map, cannot show everything. If it did it would not be a model but a duplicate. Thus the classic definition of art as 'the purgation of superfluities' also applies to models and the model-maker's problem is to distinguish between the superfluous and the essential."

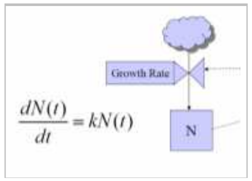


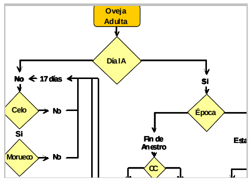


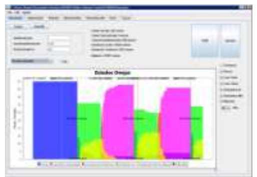

Models in LFS. Optimisation

- 86 % of the models on a year basis
- 86 % of the models with only **one** viewpoint: economic
- There are few models on a **system** basis with **multiobjective optimization.**

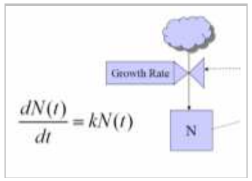


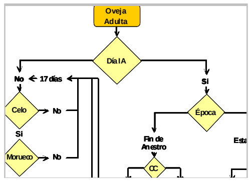


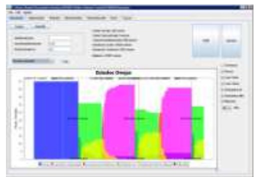

Models in LFS. Multiobjective

- Social, Economical, Environmental → **Sustainable**
- **Assesing sustainability involves multiple dimensions** some of which are dependent on location, time and socio-economic context.
- **Finding** and **weighting** relevant indicators that can be applied and compared across farming regions and geographical remains a great challenge.





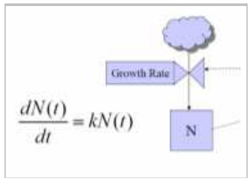



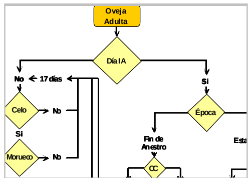

Modelisation of variability

- Uncertain context in which farms operate: **stability** (resilience), adaptive capacity and self-reliance are key attributes in understanding how farms might face changes in the future.

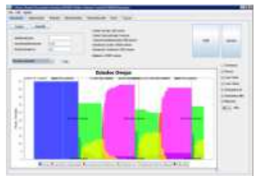
- The analysis of **variability** is essential for decision-making

- Stochastic simulation:
  - Temporal variability
  - Animal variability
    - Genetic
    - Environmental
    - Parametrization!!





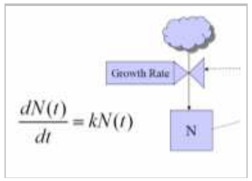



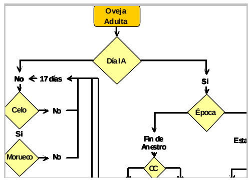

Optimisation using GA

- Most of the optimisation models are based in **Linear Programming (LP) Methods**.

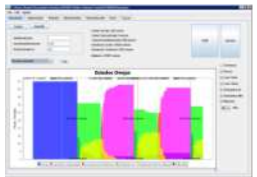
- Limitations of the LP for the valuation of new technologies at the farm-level. (Pannell, 1997)
  - that inputs and outputs are divisible
  - that the relationship between variables is linear
  - that the combined effect of inputs and outputs is additive

- LFS systems could be linearized and simplified to cope with LP, but there are **other optimization methods**





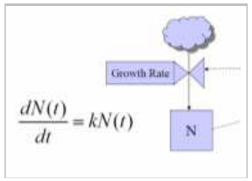



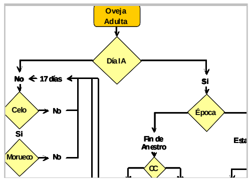

Genetic Algorithms

- Complex models optimization appear to be promising areas for the application of evolutionary optimization

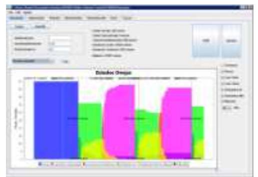
- based on mimicking the natural selection process that allows species to adapt to environment

- each solution of the problem is considered an individual with a value indicating the degree of goodness

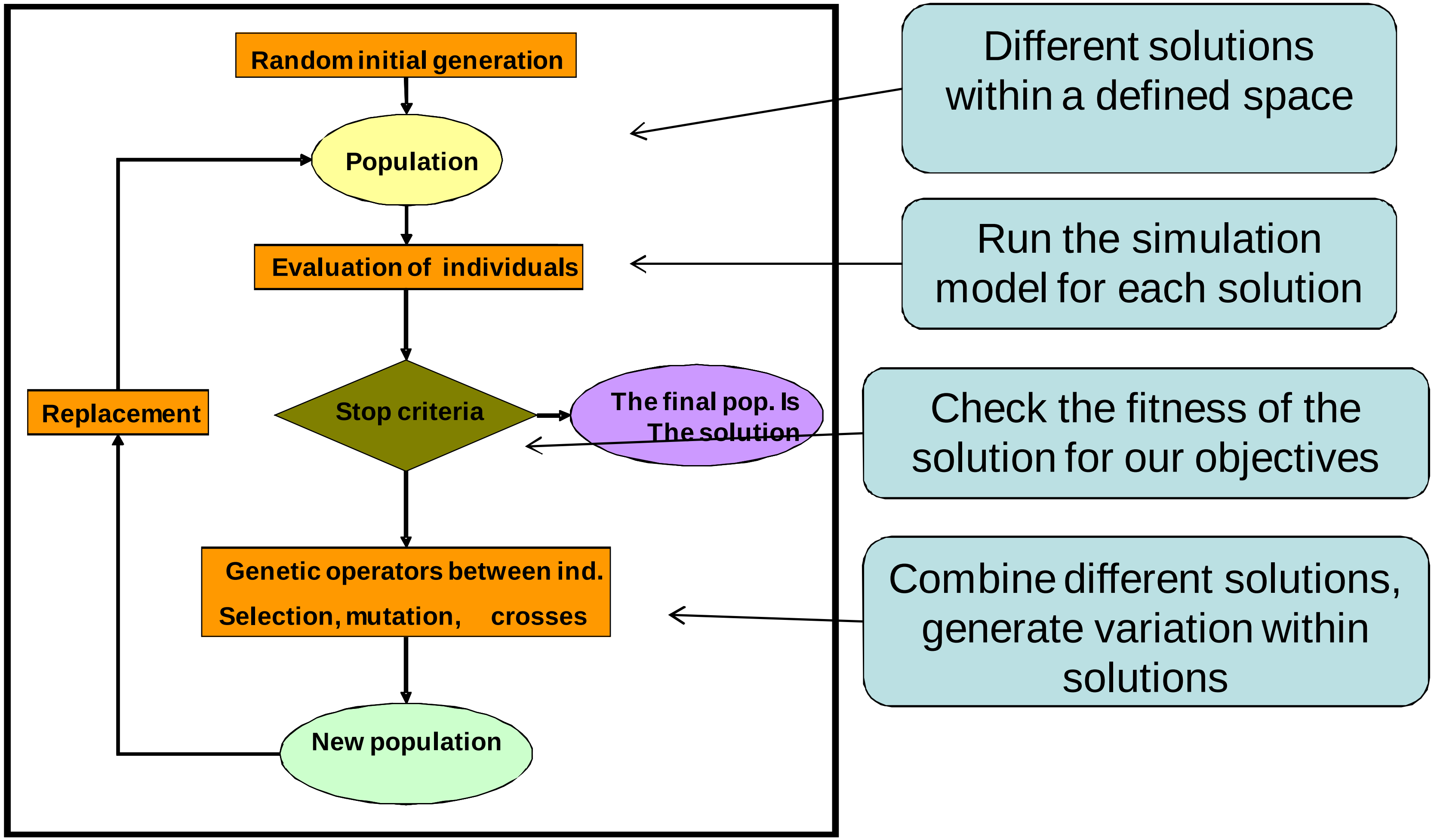








GA: operation



Sim & Opt Model *"PASTOR"*

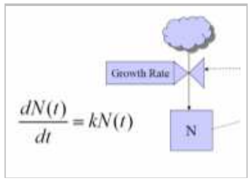
Decisions Support System

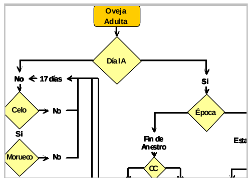
Simulation + Optimisation multiobjective

Java:

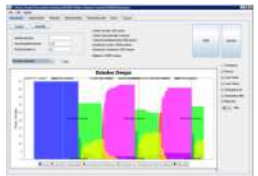
Object Oriented Programming

Genetic Algorithms Approach






Simulation module

ANIMAL

- Voluntary Intake
  - AFRC
- Reproduction
  - Seasonality

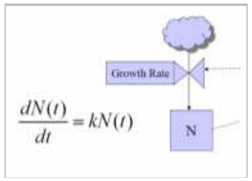
Body Condition Score

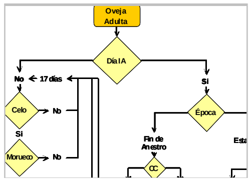
FLOCK

- Management Practices
  - Supplementation
  - Artificial Insemination
  - Rams

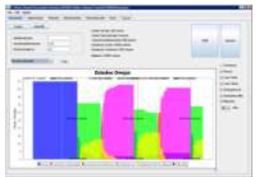
FARM

- Availability of resources
- Economy:
  - Costs
  - Incomes

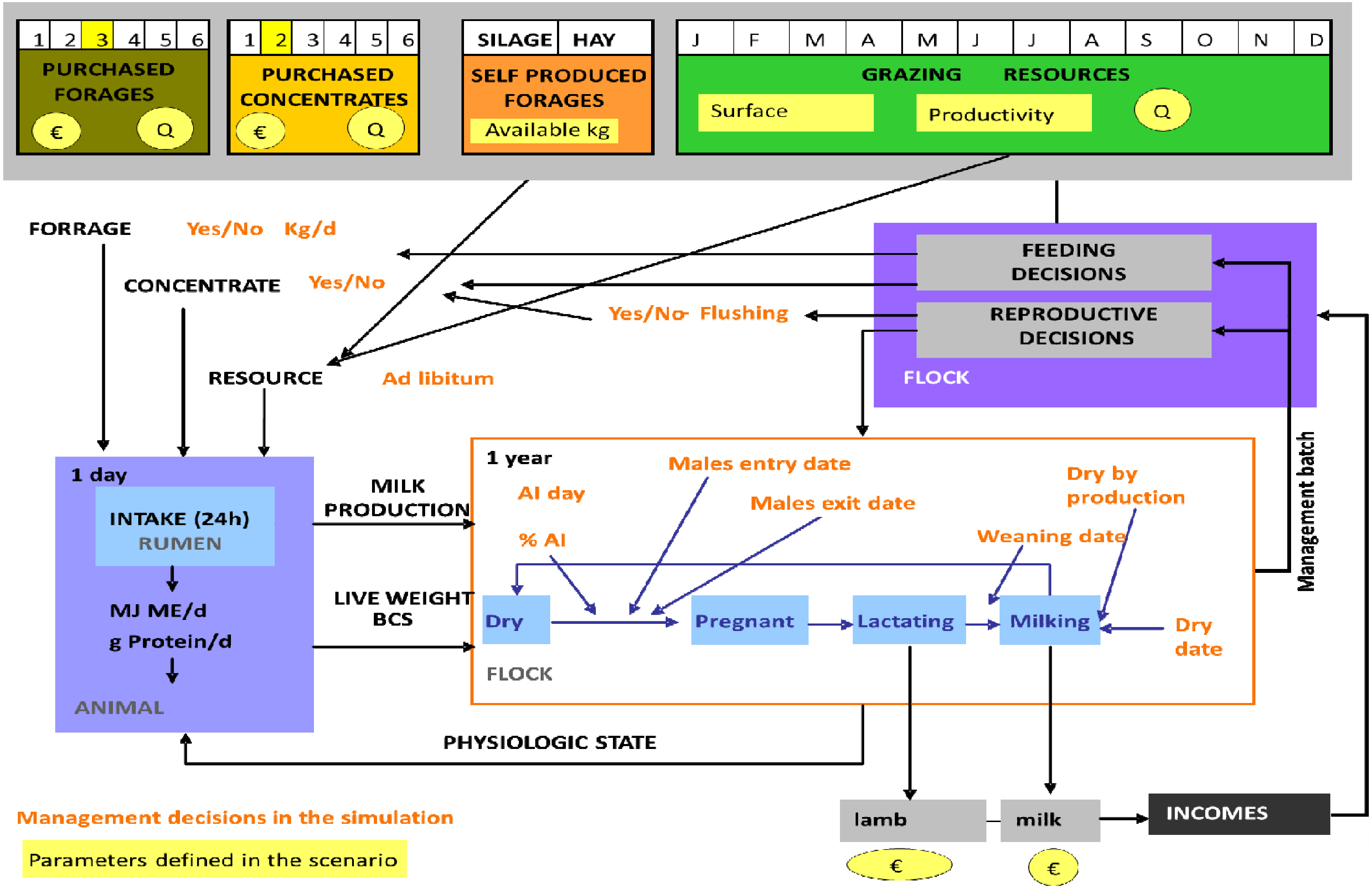





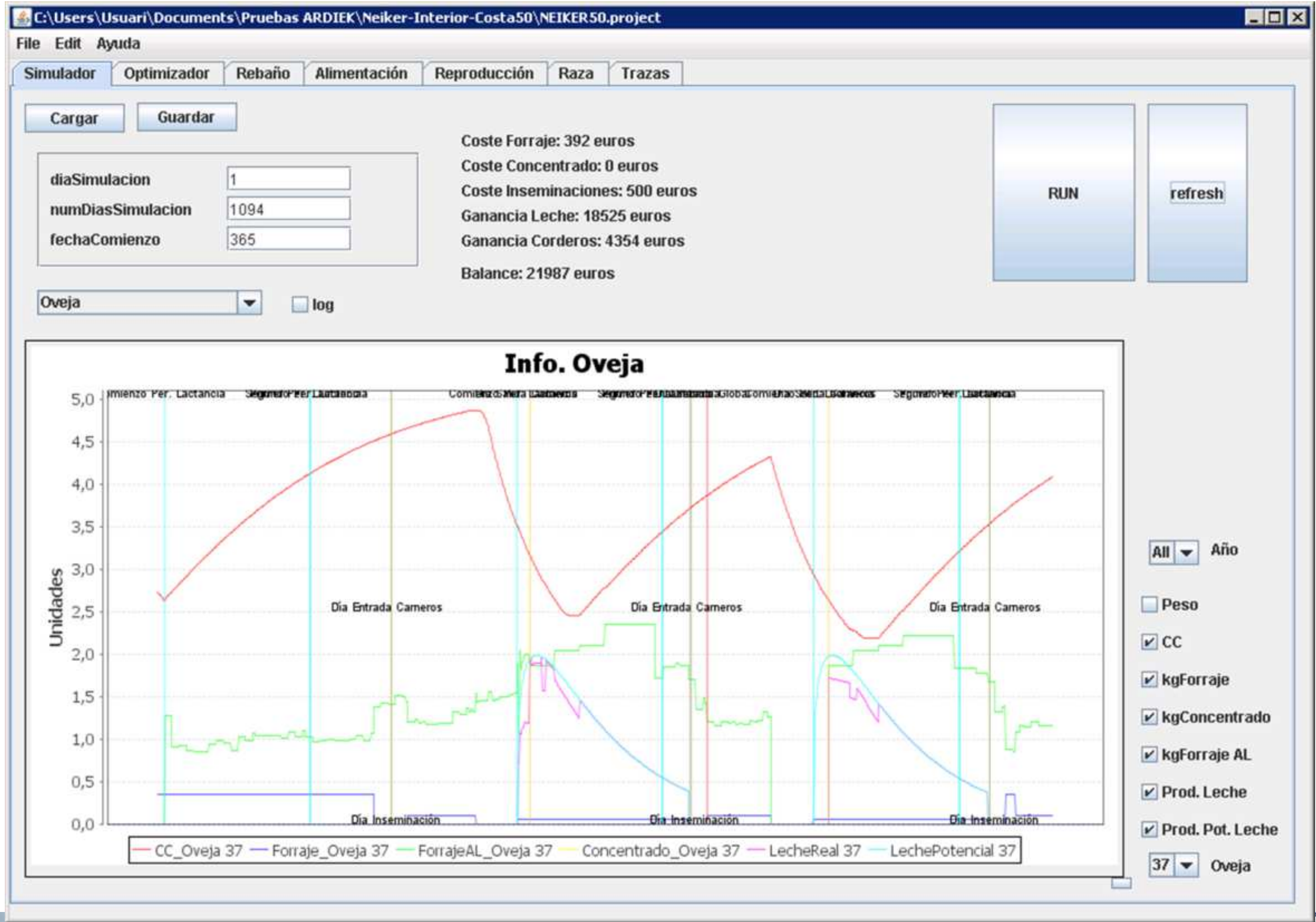



Simulation module



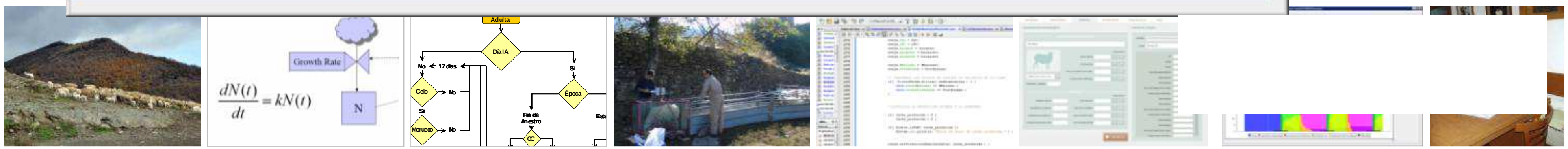
SIMULATION: Animal Level



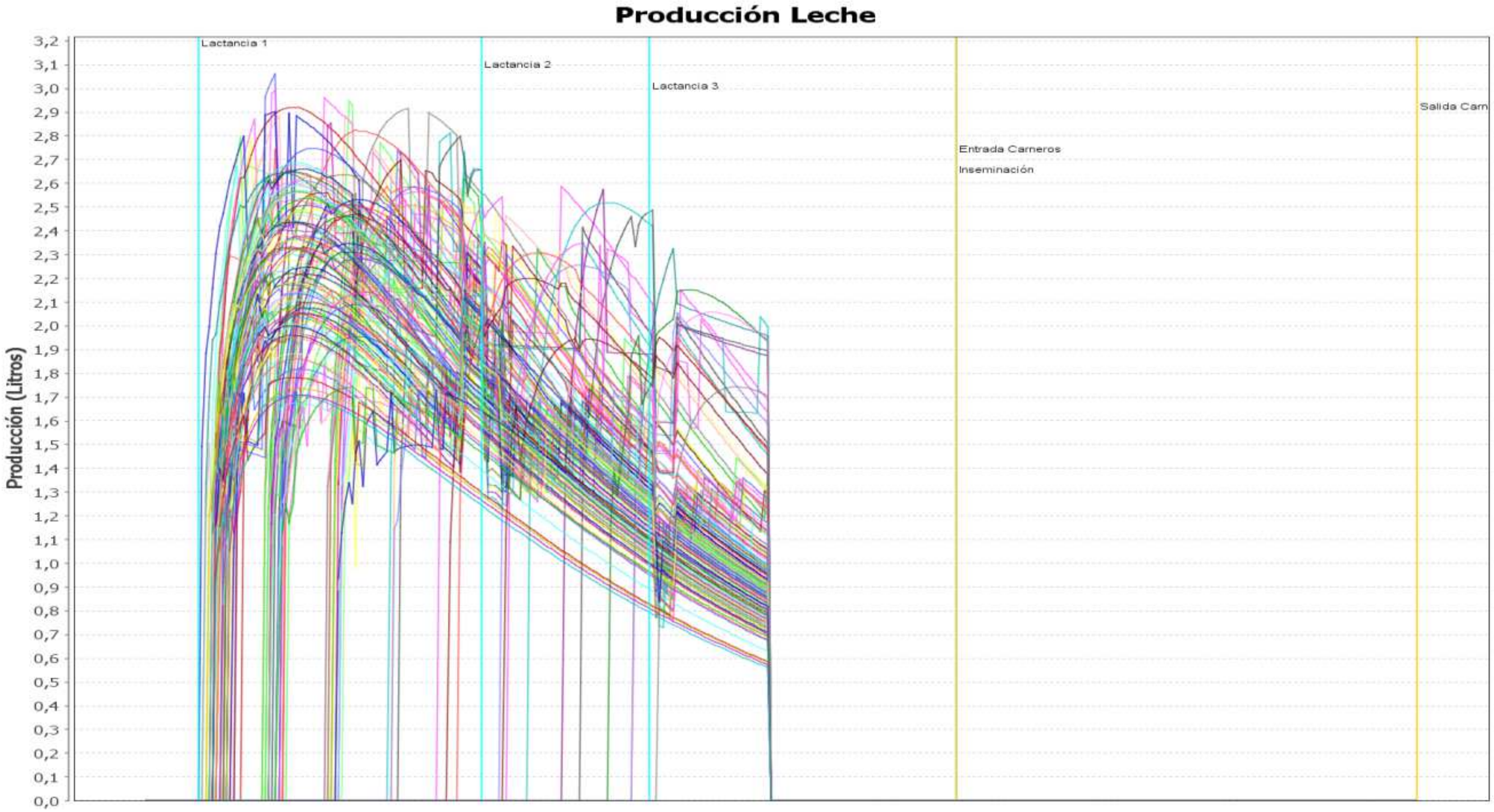
BCS

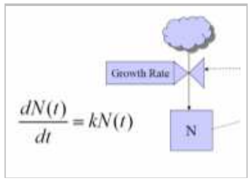
Intake

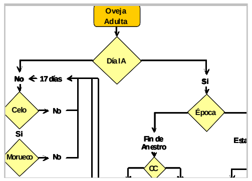
Milk yield

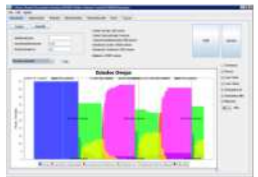


Individual variability

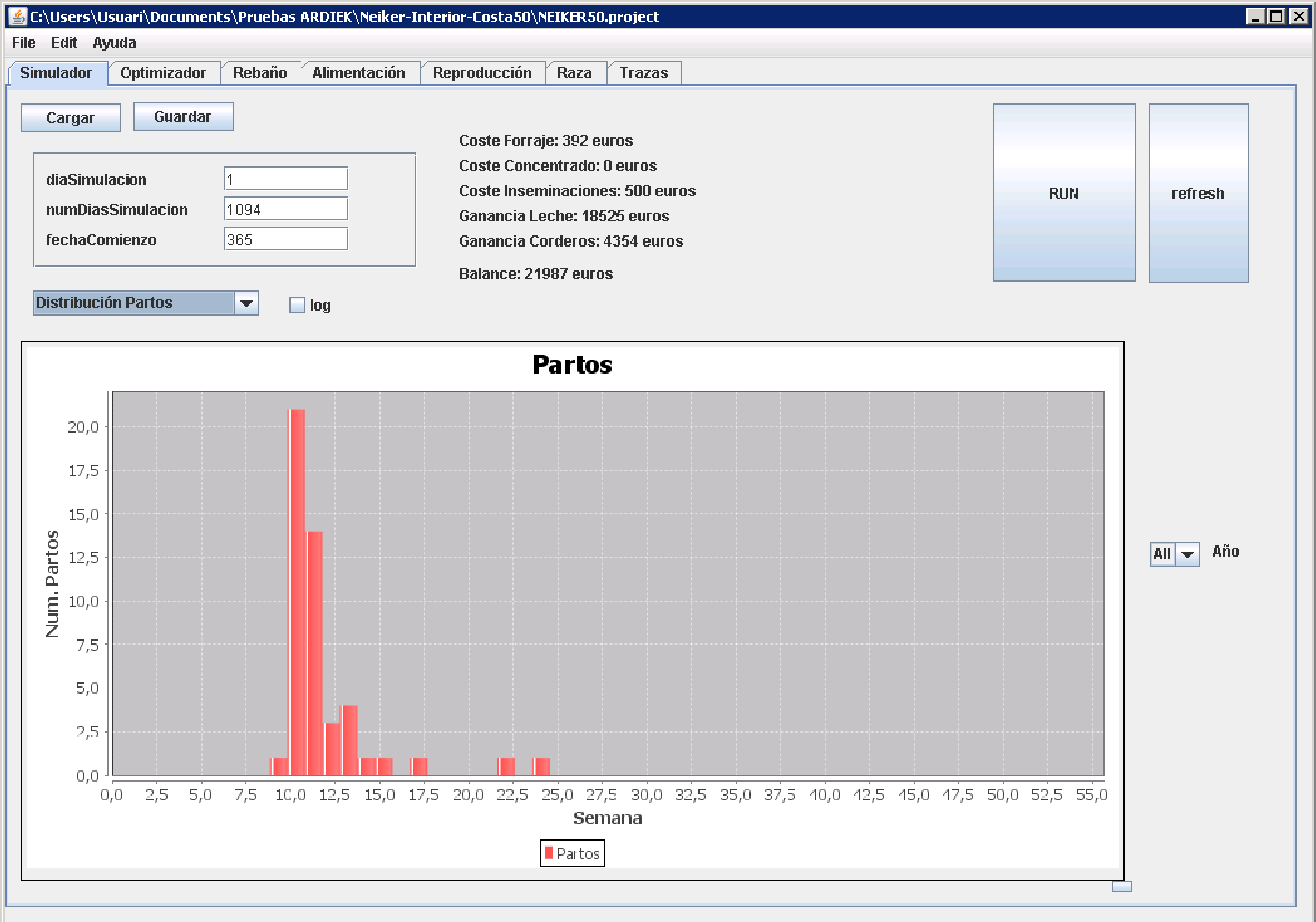








SIMULATION: Flock & Farm level



Margin =
Incomes - Costs

Lambing
distribution

Optimization:(GA) methodology.

- Fitness
  - Technical objectives:
    - minimisation of feeding costs
    - minimisation of mortality due to undernutrition
  - Economic objectives:
    - maximisation of incomes due to milk and lambs
  - Environmental objectives:
    - minimisation of nitrogen and energy surplus

OPTIMISATION

1) "GENES"

Flushing (Y/N)	Y	N	Y	N
Concentrate (kg)	0.2	0	0	0.5
Mating season (d)	70	140	35	105

2) FARM SIMULATION

Economic margin (€)	100	50	85	110
N surplus	10	0	0	30

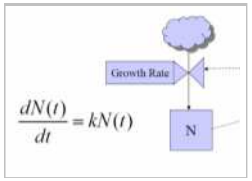
3) FITNESS VALUE THROUGH WEIGHTING

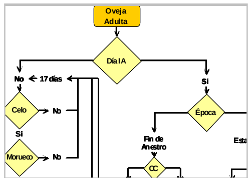
Fitness	90	50	85	80

4) SELECTION

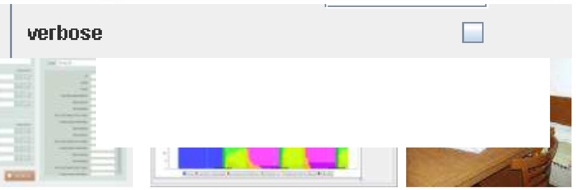
Fitness	90	50	85	80

FEEDING STRATEGY INDOORS	% period 1 milking
	% period 2 milking
	% period 3 milking
	Forrage (kg) during milking__1
	Forrage (kg) during milking__2
	Forrage (kg) during milking__3
	Forrage (kg) during maintenance
	Forrage (kg) during Precalving
	Concentrate (kg) during Flushing
	Concentrate (kg) during gestation
	Concentrate (kg) during milking__1
	Concentrate (kg) during milking__2
	Concentrate (kg) during milking__3
	Concentrate (kg) during maintenance
	Concentrate (kg) during Precalving
	Days from calving to dry time
	Days concentrate Precalving
	Days concentrate Flushing
REPRODUCTIVE	day start mating season
	day end mating season
	Use of AI (Y/N)
	threshold of milk
	% of AI

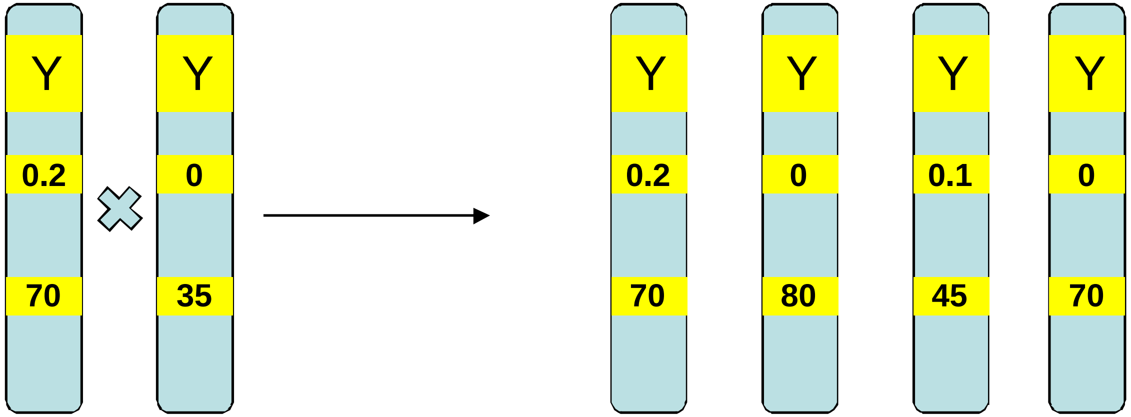



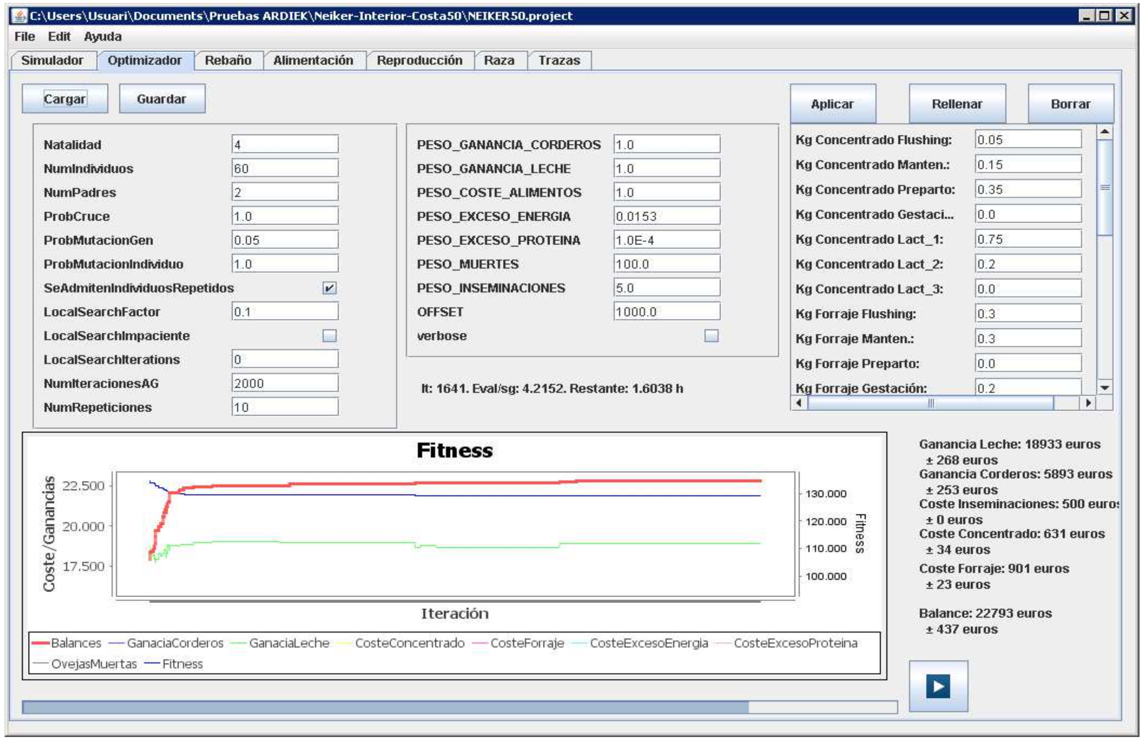






“REPRODUCTION”
Crossover
Mutation
….





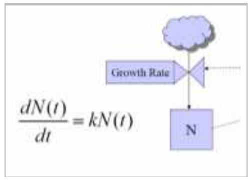
NEW POPULATION of SOLUTIONS
New selection (iteration)

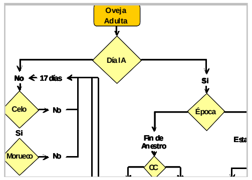
Last runs:

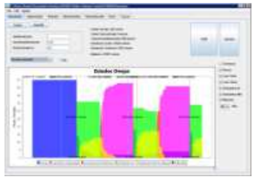
- 60 solutions
- 2 parent solutions selected
- 50 ewes simulated 4 years each repetition
- 50 repetitions
- 2000 iterations

Application

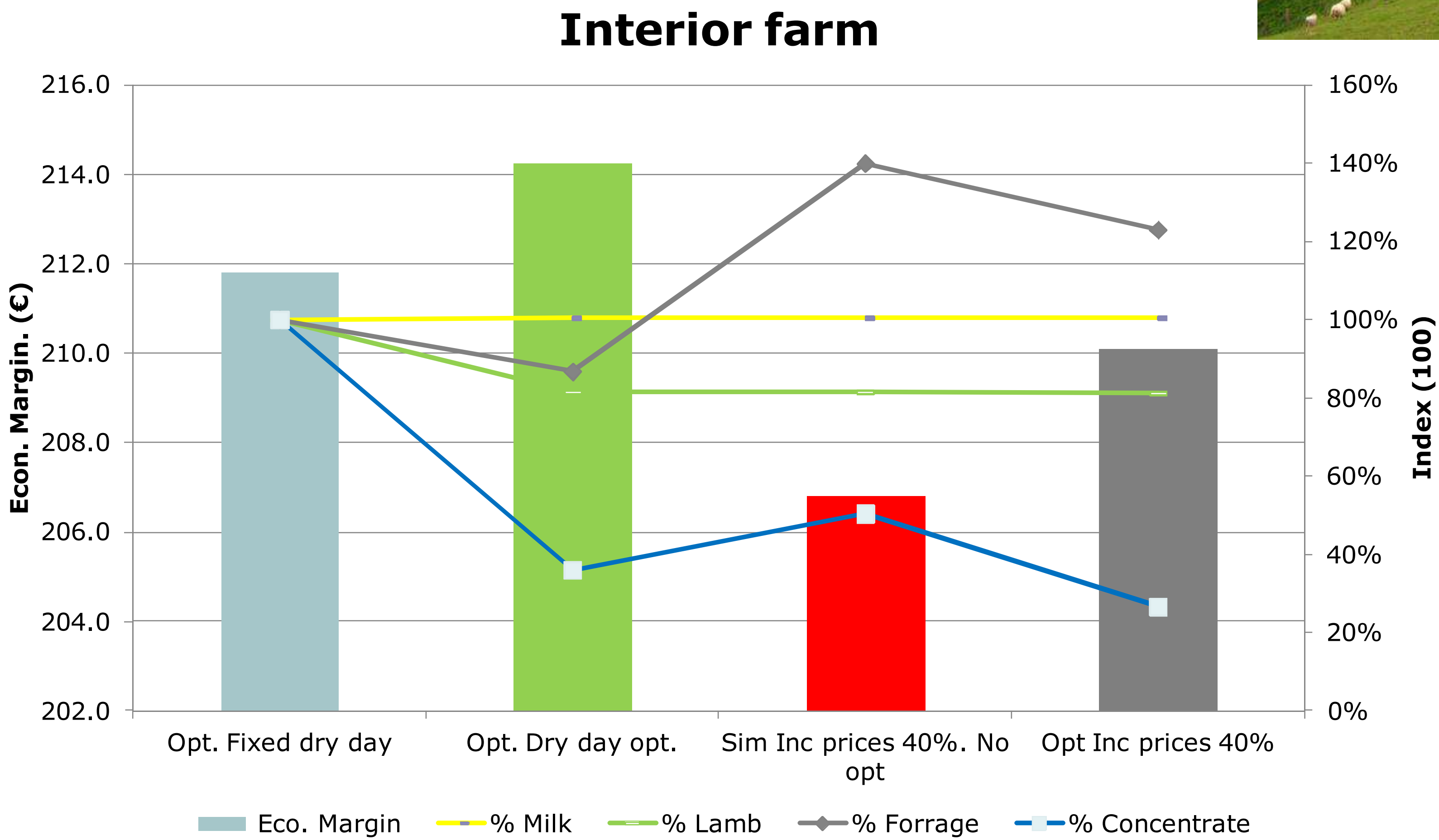
- Latxa dairy sheep (Basque Country, Spain)
- Use of natural resources and indoor feeding
- One lambing per year
- Two case farms:
  - "Interior". Higher altitude, less quality and quantity of pastures
  - "Coast". Sea level, higher pastures availabiliy

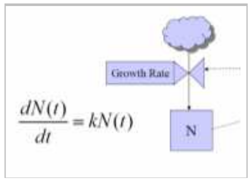


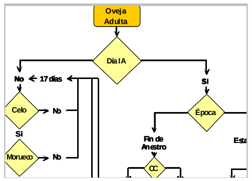


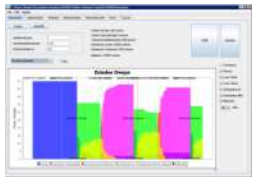


Some preliminary results









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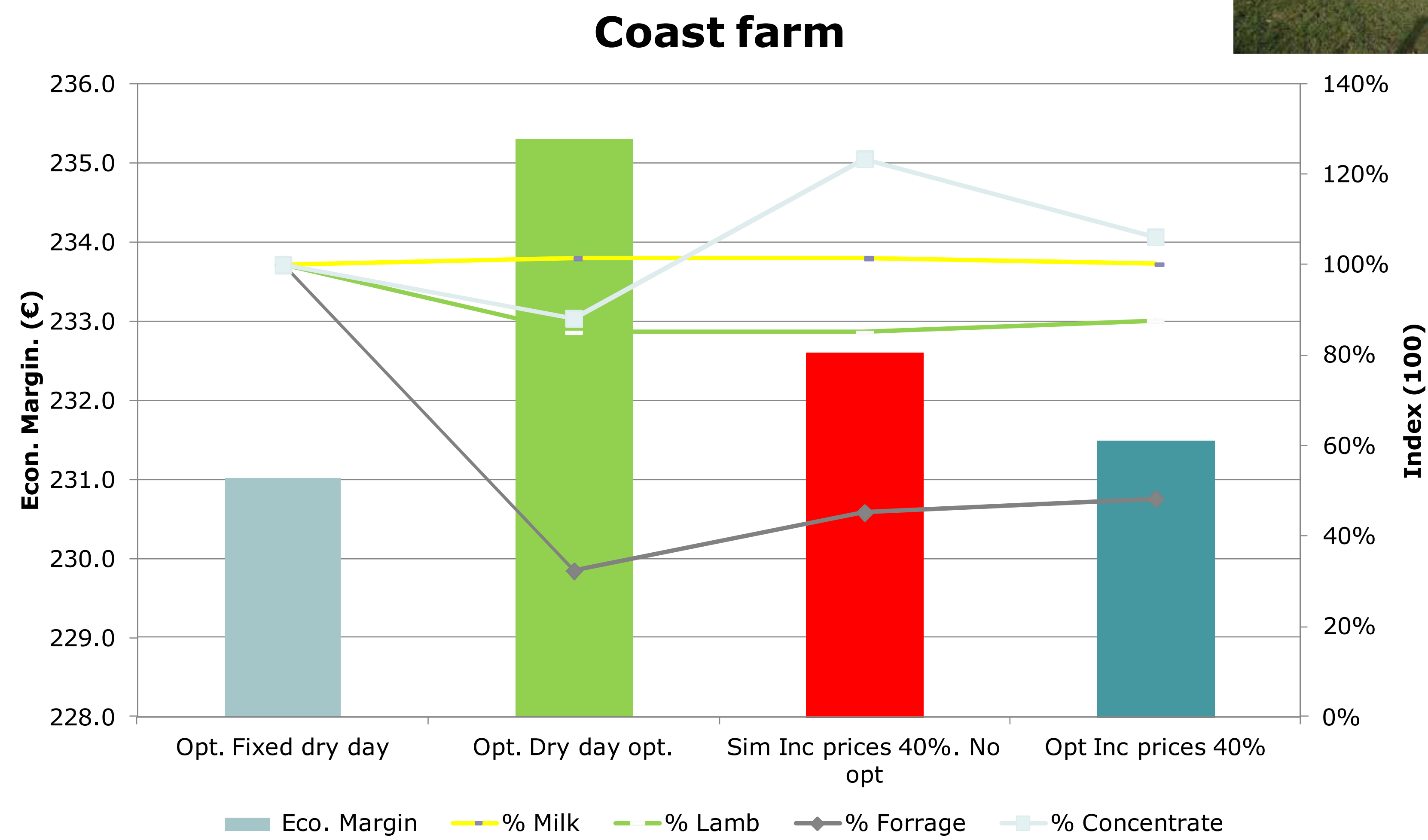
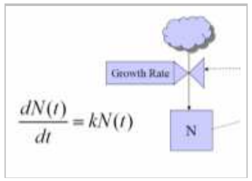
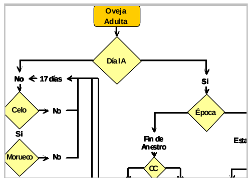
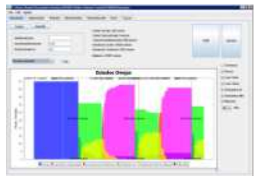


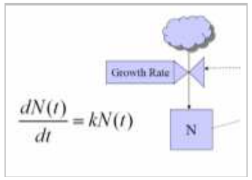


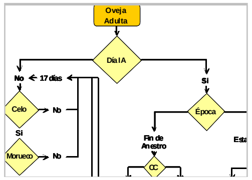




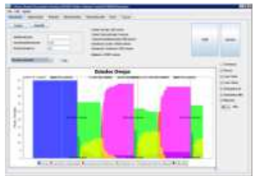
Discussion

- **Complexity**: a complex model with optimization of 23 variables! → Understanding the solutions increase knowledge but basically generates discussion
- **Variability:** The stochastic processes generated via probabilities for each animal simulated generates variability within each GA solution
  - **Interesting to evaluate the variability of response**
  - **... but each solution must be repeated to obtain a representative value of fitness.**
  - **Hard work to parameterize individual variability**

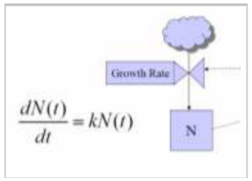
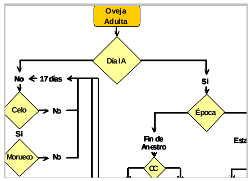




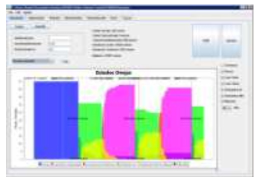




Discussion

- **Usability of Model**: each optimization run presented takes 7 h!
  - Simplification of the model (intake at a hour scale but simulation of 4 years)
- **Multiobjective:** Inclusion of more environmental items in the fitness function (i.e. GHG emissions, working on it) but each objective must be weighted to obtain **one fitness** value for each solution
  - **Weighting "traits" is not an easy work, even in real Animal Breeding**
  - **How obtain values for non economic aspects (Ecosystem services)**

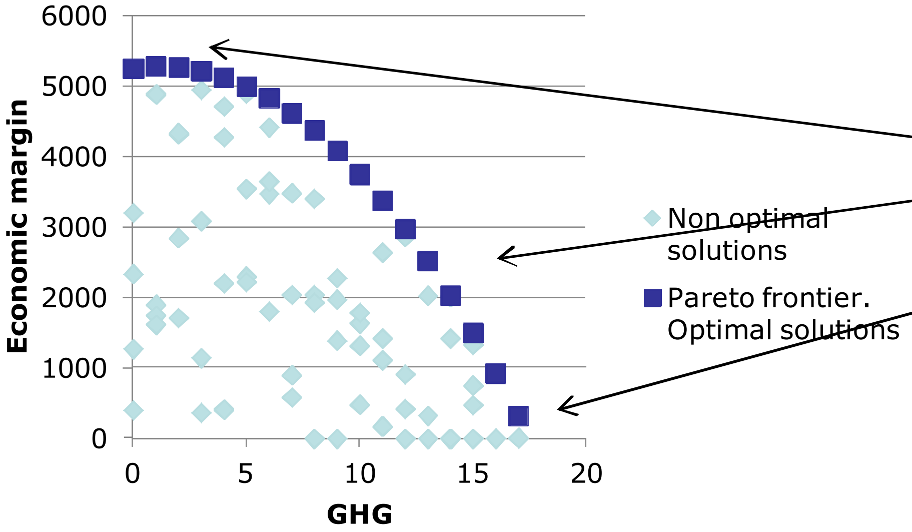






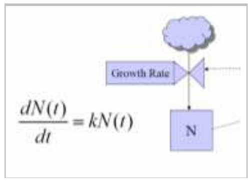


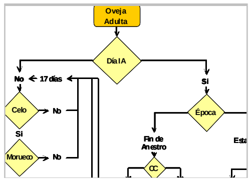

Discussion

- **Multiobjective:** Include the participation of farmers or actors a posteriori.
- Present the possible solutions

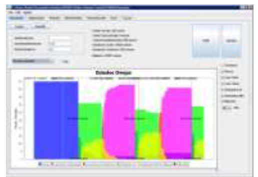


Depending on the weights the solution of GA will be one of the Pareto frontier

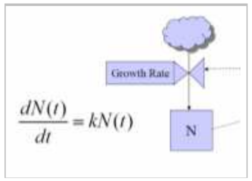


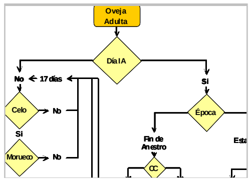


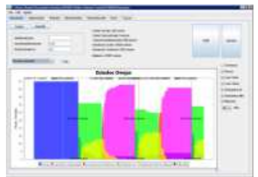
Conclusions

- The Genetic Algorithm methodology seems an interesting way to optimize LFS
- The multiobjective optimization needs further work in the calculation of weights for the objectives or using new approaches
- The Sim & Opt model “PASTOR” must help to the decision support of sheep farms.







THANKS FOR YOUR
ATTENTION