# *Teaching complexity with System Dynamics: examples from animal science and food*

Co-funded by the Erasmus+ Programme of the European Union

ILHAM-EC

## Participatory workshop

Cairo, 29-30 November 2016

**Alberto Stanislao Atzori**

**Section of Animal Science - Department of Agriculture, University of Sassari**

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Interuniversity Learning in Higher Education on Advanced land Management

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# Alberto Stanislao Atzori

**Position:** Assistant Professor (*RTD*) - since 2011

**Education**

Degree in Agriculture - 2003
PhD in Animal Science - 2008
Visiting Scholar UCLM (Spain) - 2004 (6 months)
**Post-doc** Texas A&M University (USA) - 2011 (8 months)

**Areas of research**

Ruminant nutrition
Dairy farm management
Environmental impact of dairy farms
System Dynamics Modeling

**Teaching**

Animal production Undergraduate course
System Dynamics Modeling PhD course

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# Sustainability, teaching, complexity

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Simple Cake Recipe

225g (8 oz) self-raising flour.
225g (8 oz) soft butter (i.e. room temperature).
225g (8 oz) caster sugar.
4 eggs.
1 teaspoon baking powder.

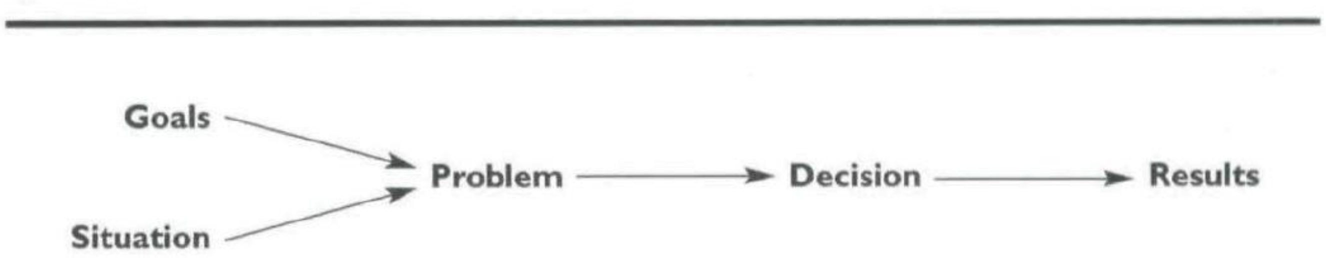
Mix the ingredients well in a large bowl using an electric whisk.
Halve the mixture and pour into 2 non-stick 18cm (7 inch) cake tins.
Cook till golden brown (15-25 minutes) in a preheated oven at 180 degrees C (gas mark 4).
Cool on a wire rack before serving, add jam between the two halves and optionally top with butter cream.

Sustainability: no simple recipes

Teaching sustainability:

examples, criteria, practices, actions, strategies, skills, management….

Event oriented view of the world (Sterman, 2001)




Linear approach of decision making

Then complexity comes up!

# Real world is not linear

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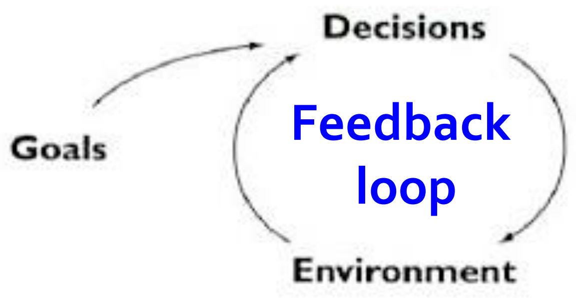
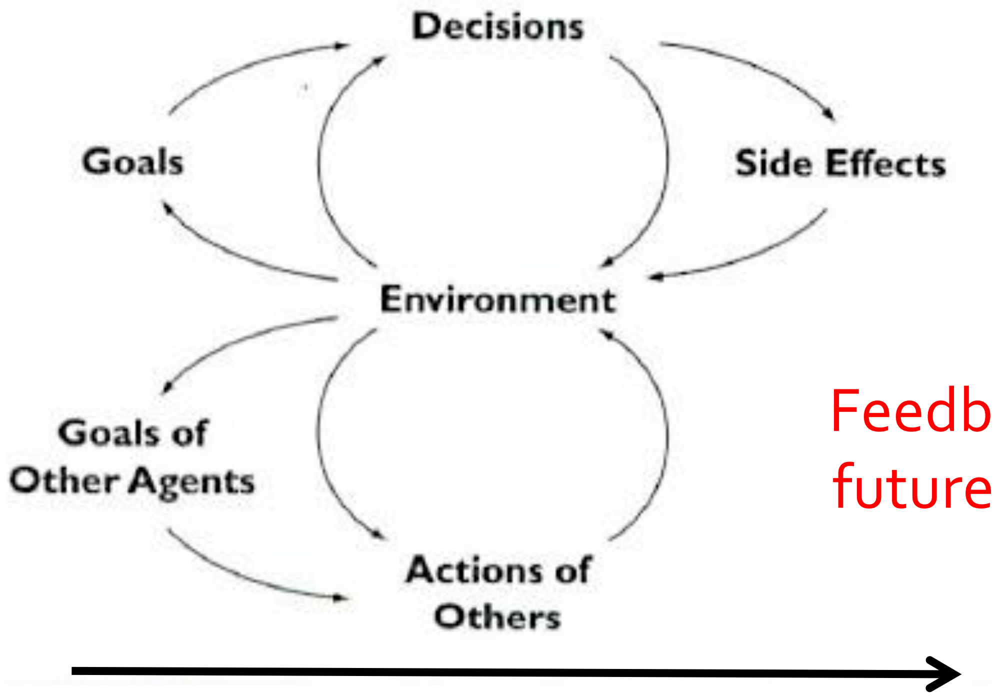
Complexity shows up as unintended consequences
(side effects, delays, stock accumulation)




Feedback loops connect everything to everything else




TIME

Feedbacks drive future behaviors

(Sterman, 2001)

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# Management requires a systemic approach, big picture

Meat production

Lambs    Health    Profit    Crops

Sheep flock

Costs    Revenues

Reproduction

Land use    Environment

Time

***Mental models are often limited***

Even the most trained minds are not generally capable of managing more than 3 loops over time!!!!

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# Facing complexity

TIME

**Future Sustainability:**
Will depend from our ability to manage feedback loops

(Sterman, 2001)

# We could have a math approach…

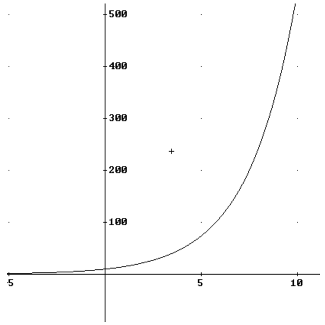



Spreadsheets


## 1.Exponential equation

$$\frac{dP}{dt} = kP$$

Integral of differential equation is the exponential function




$$P = P_0 e^{kt}$$

$P_0$ è il valore della popolazione a t=0; per t→∞, f(t) →∞

Mathematical demonstration

$$\frac{dP}{dt} = kP \qquad \frac{dP}{P} = k\,dt \qquad \int \frac{dP}{P} = \int k\,dt \qquad \ln|P| = kt + c$$

$$P = e^{kt+c} \qquad P = e^{kt} e^{+c}$$

$$e^{c} = P_0$$

With t = 0

$$P = P_0 e^{kt}$$

# ... or we could use System Dynamics

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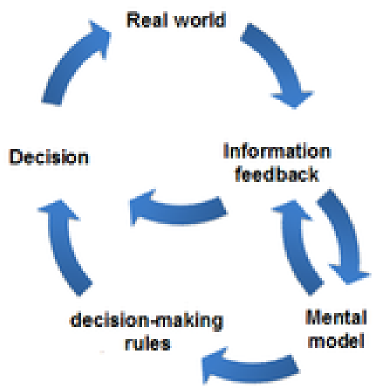
Work with:

- ✓ graphical tools
  - powerful annotation
  - able to capture feedback loops in holistic views
  - open access material and software




**Teaching goal:**

- ✓ Students develop its own mental models of the system
  - Share, discuss, validate with literature
  - Play with policies
  - To get its own recipe of sustainability!

# Powerful communicative tools

## notation to identify feedback

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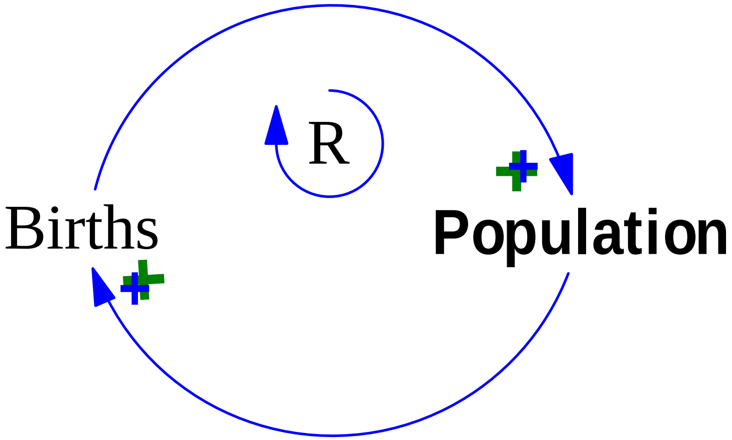
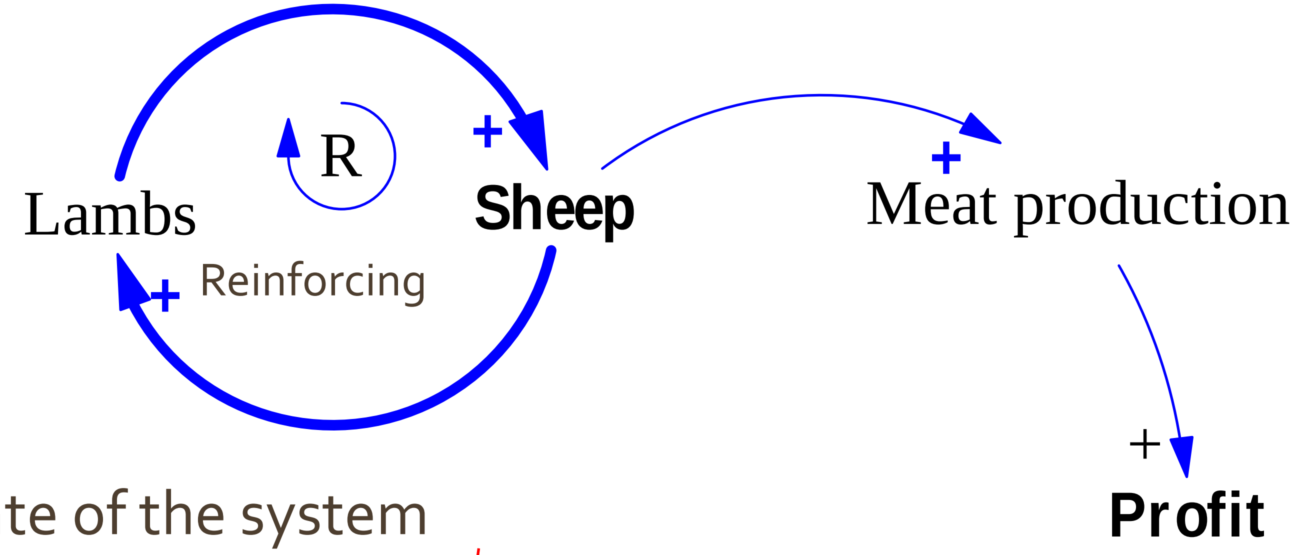


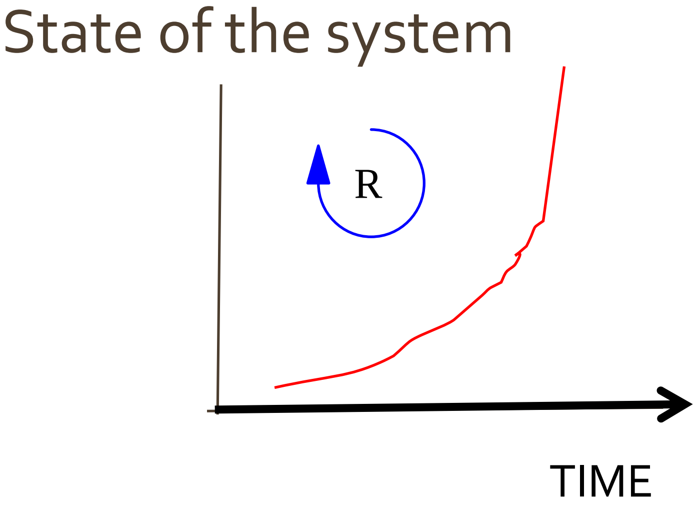

Causal connections (arrow)

Polarity and Correlations (sign)

**Reinforcing loop**

# To stimulate qualitative system thinking

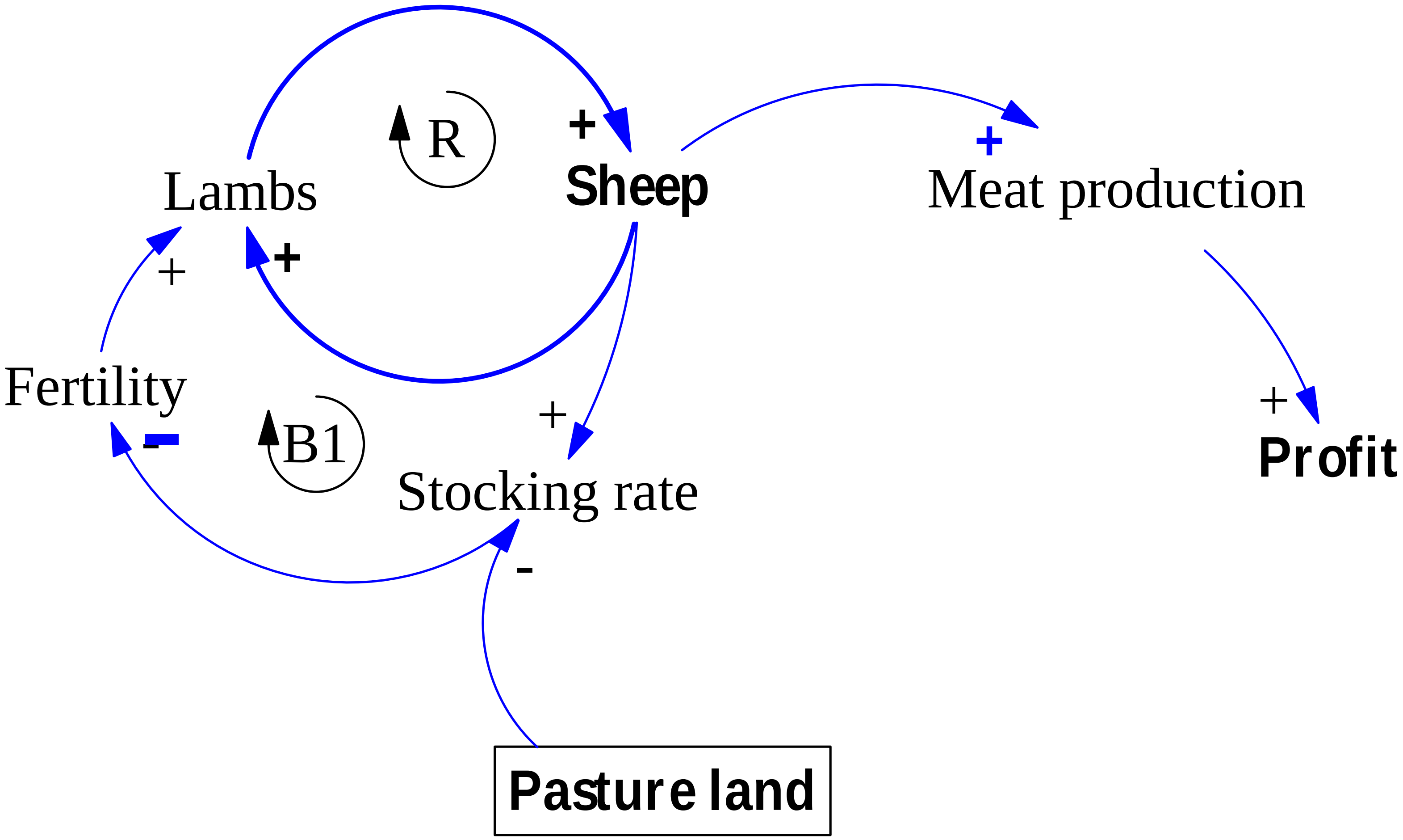



Expected future behavior

Reinforcing loops drive exponential growth

# To develop mental models
## add new structures




# To develop mental models predicting dominant behavior

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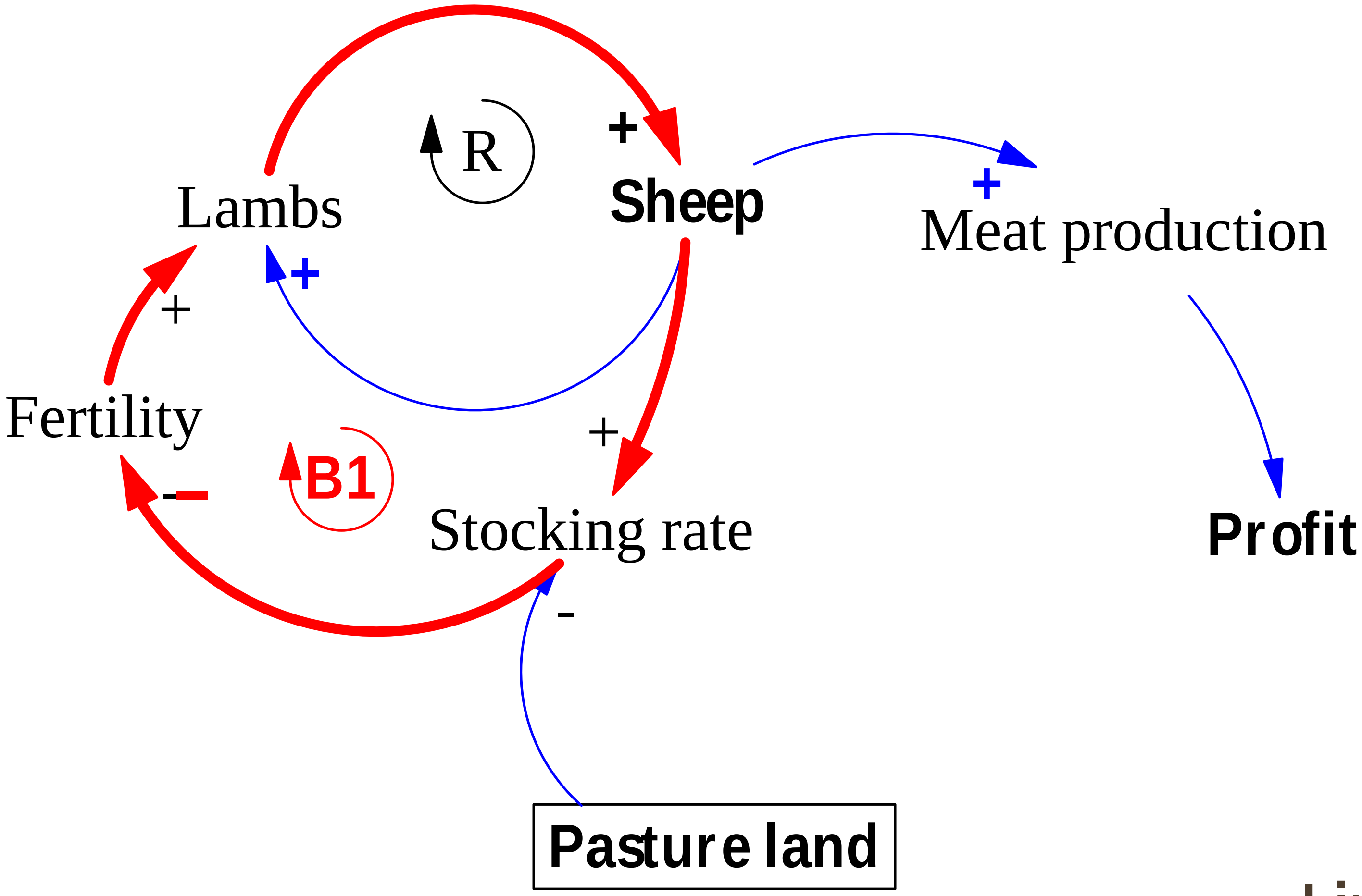


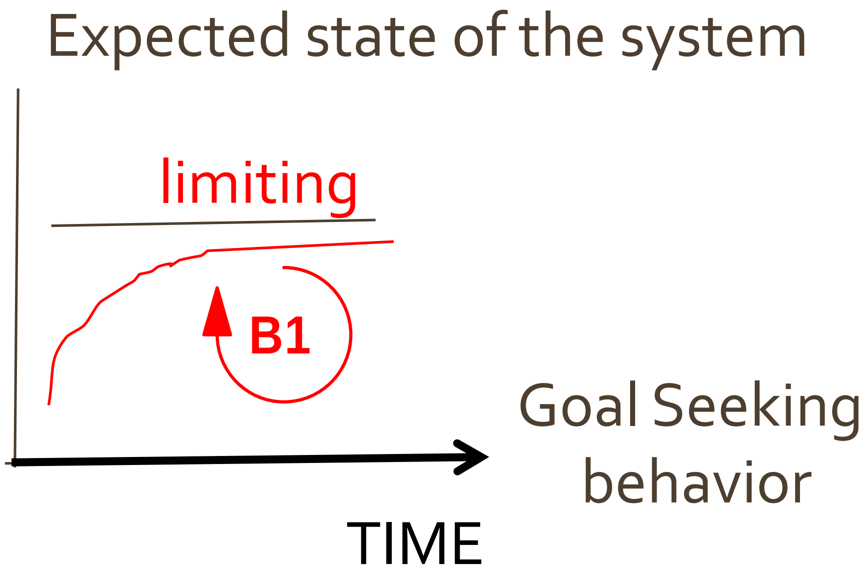


**Limiting resources!**

**Balancing loop B1 drives goal seeking!!!**

# To develop mental models
# identify viable solutions

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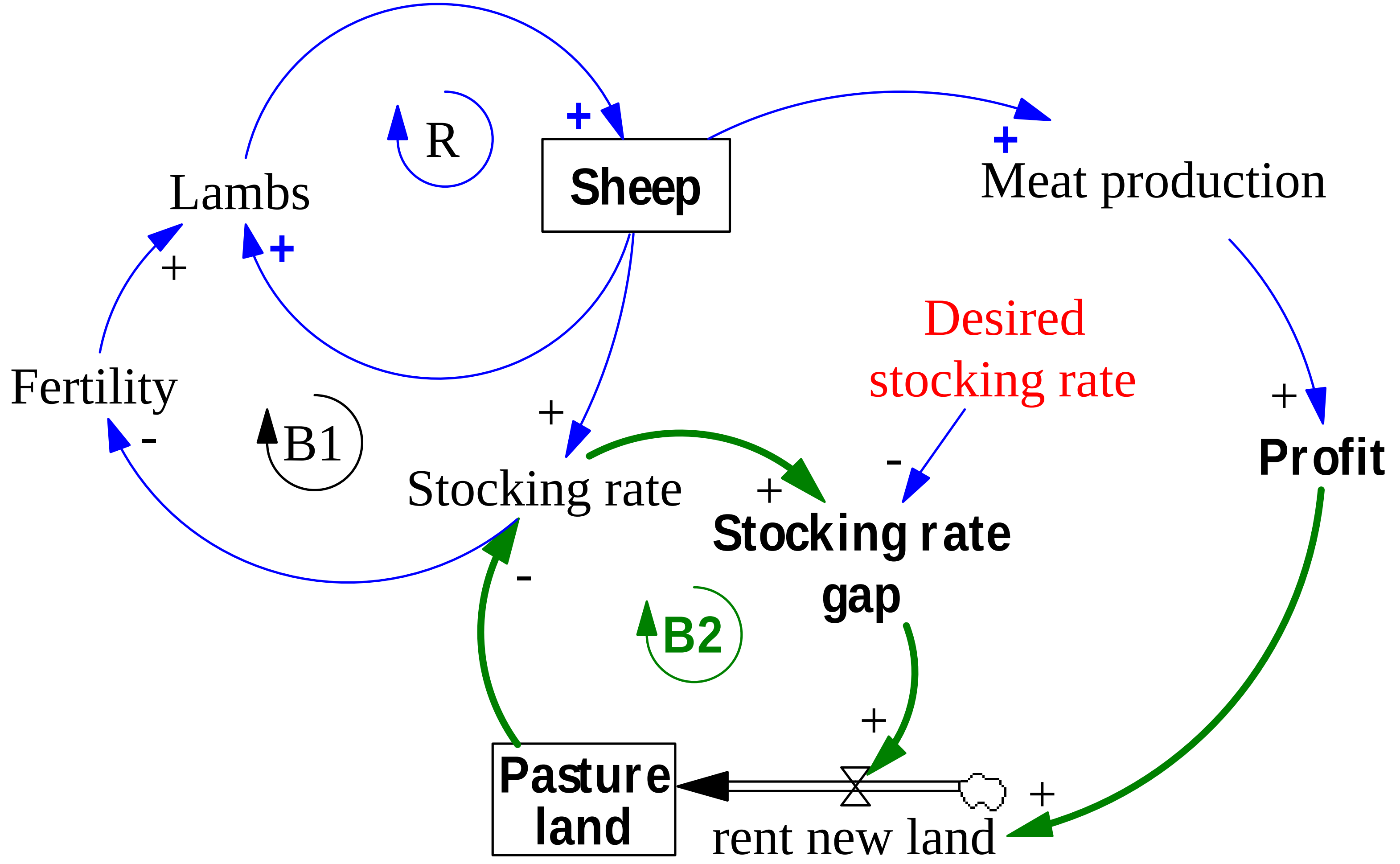
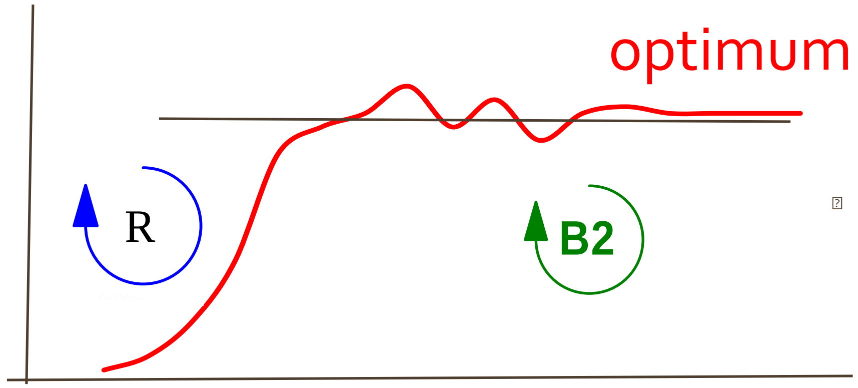



State of the system




**Goal Seeking behavior**

Play with loops

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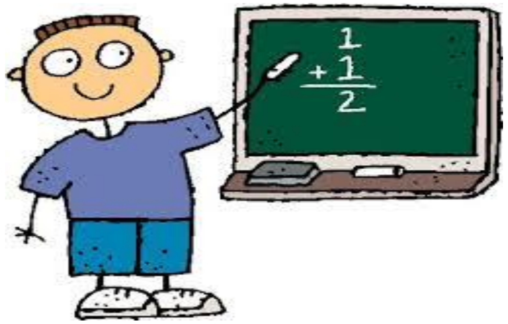
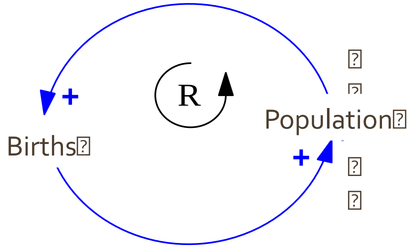
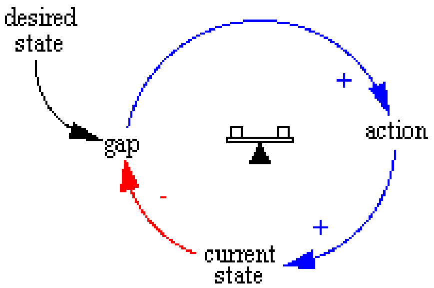


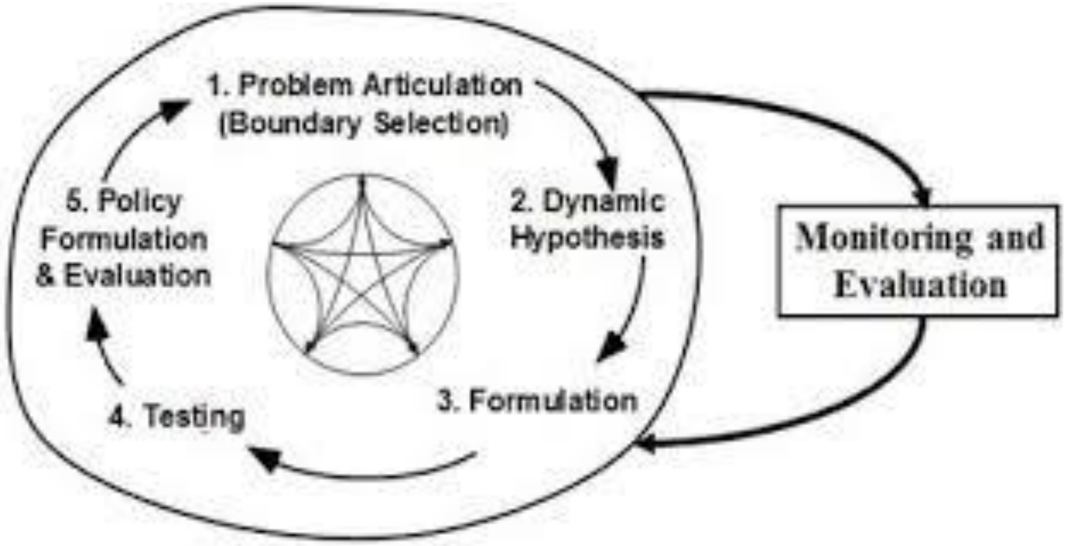

CONGRATULATIONS!!!


Follow the modeling step!

We have successfully created a first complex map using well known structures




Check scientific robustness of input and outputs

# R & B loops combinations drive fundamental behaviors

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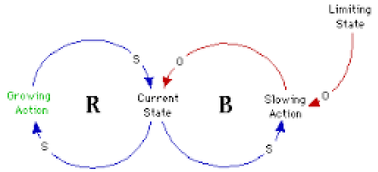
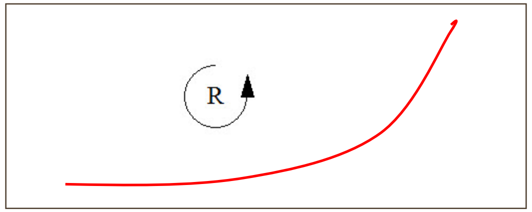
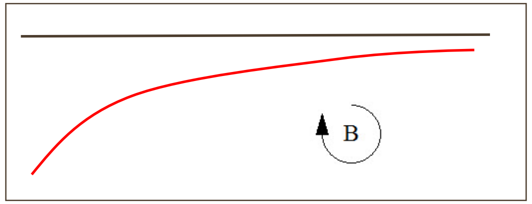
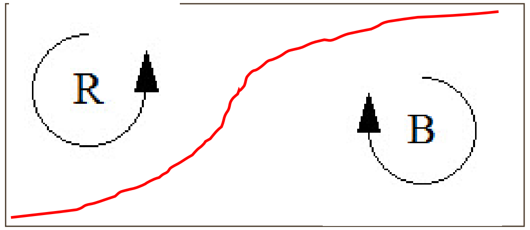



Reinforcing loops drives exponential growth

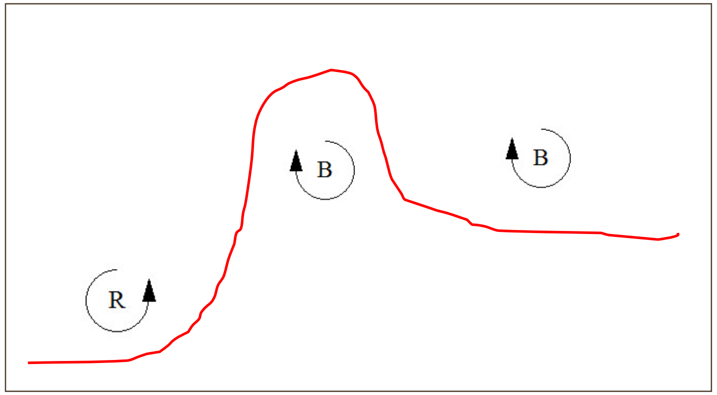


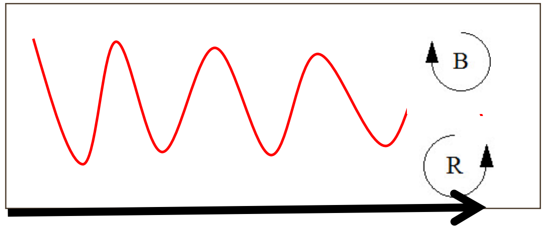

Balancing loops drives goal seeking




S shape: from Reinforcing + Balancing loop;

Overshoot




Oscillations: from delays and stock accumulations.

TIME

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# Higher levels: quantitative to quantitative

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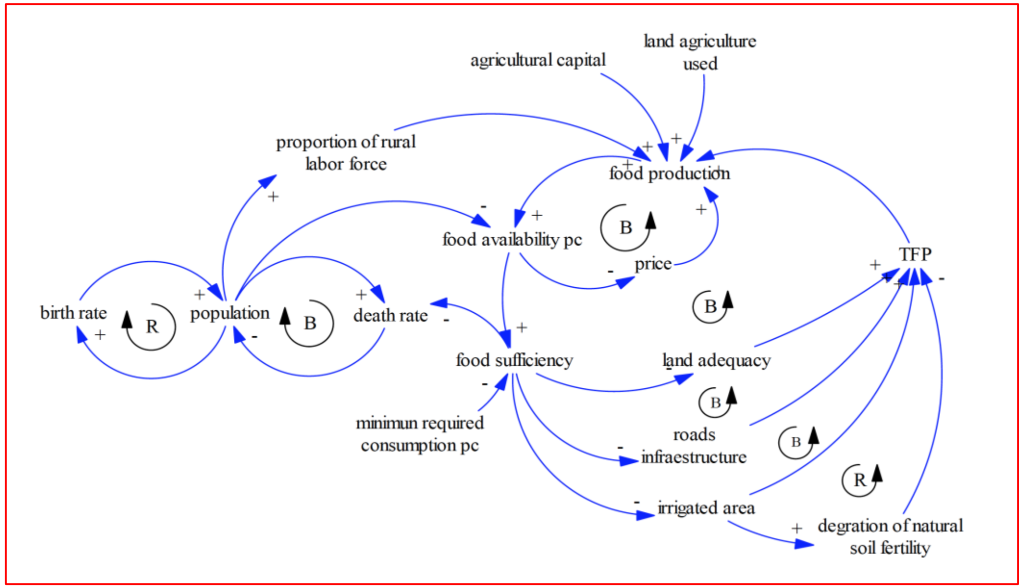
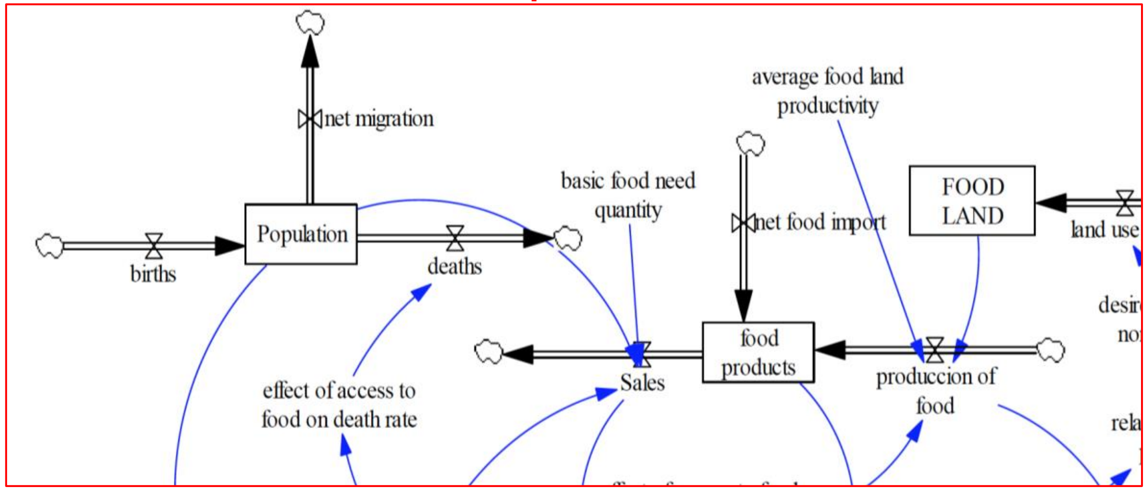
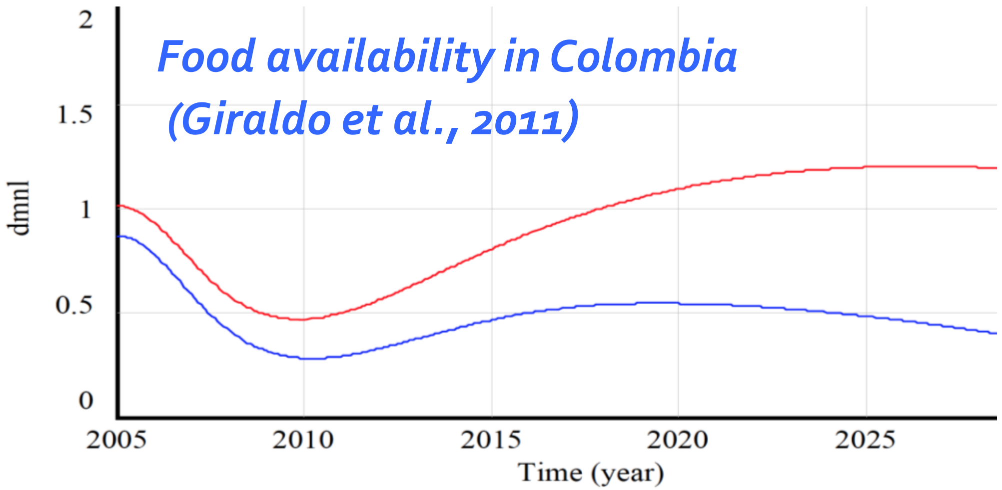



## Mental model and causal maps

(qualitative)

## Stock & Flows diagram (quantitative)




## Quantitative simulation scenarios

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# Stock & flows

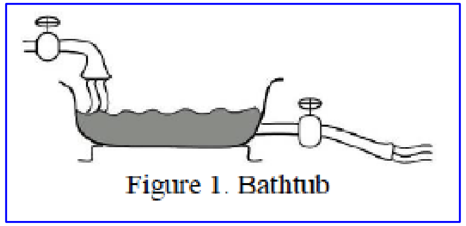
Figure 1. Bathtub

Hydraulic metaphor

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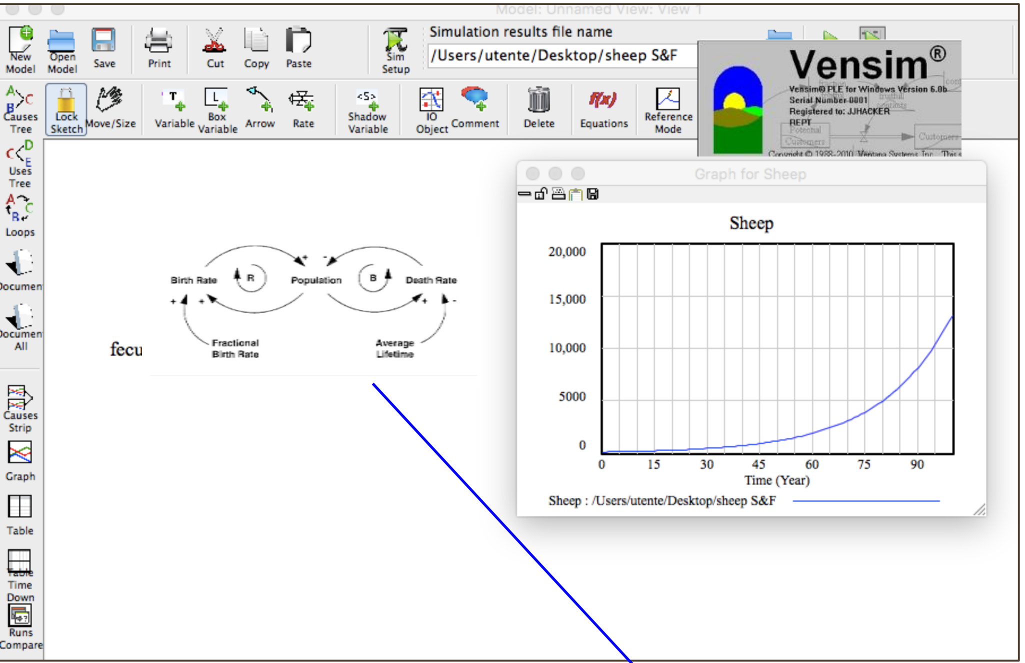


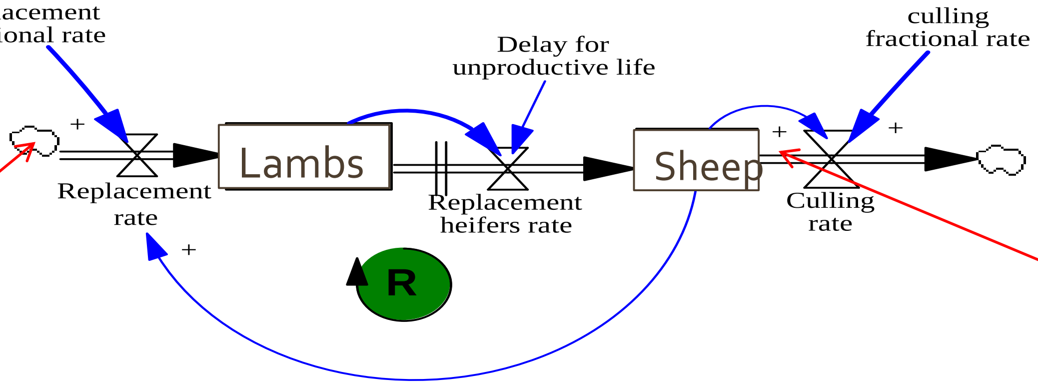

Software Open source

Object oriented

Only **arithmetic** calculations

**Patterns arise from feedback not from math function**

Constants




Flows: rates (units/time)

Stock: state variables (units)

# A simulation model for wheat-related policies and food insecurity in Egypt

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Co-funded by the rasmus+ Programme f the European Union

**Miral H. Khodeir[1] (corresponding author), Hisham M. Abdelsalam[2]**

[1] Operations research and decision support department,
Faculty of computers and information,
Cairo University, Cairo, Egypt
miral.h.khodeir@fci-cu.edu.eg

## Stock and flow diagram

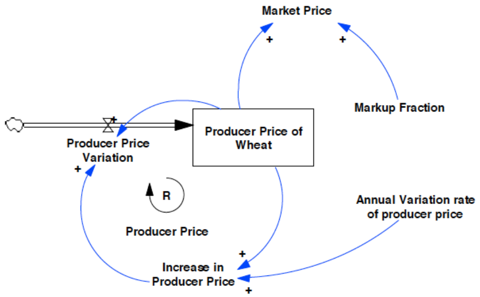



**Figure 5. Producer price of wheat**

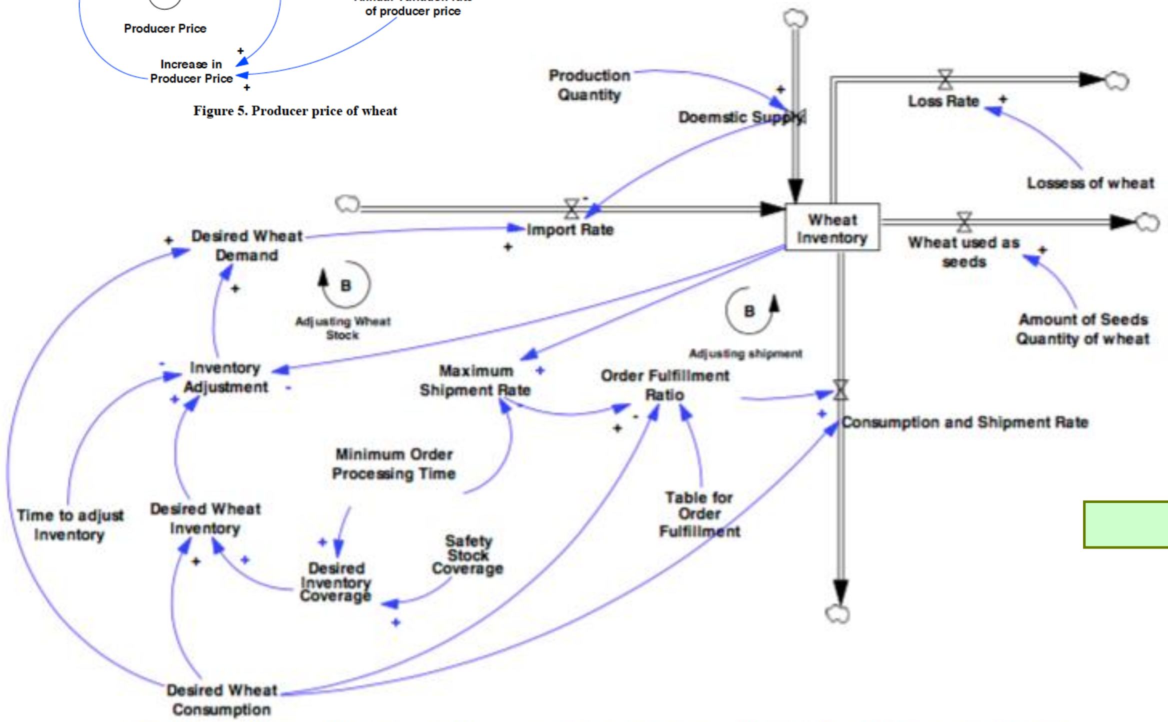



**Figure 3. Wheat inventory and the process of domestic supply, imports and shipment quantities**

## Quantitative simulation Policies

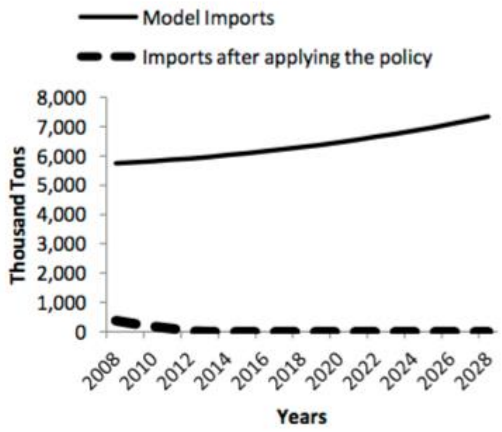



**Figure 18. Imported wheat after applying the policies of birth rate, annual income and productivity**

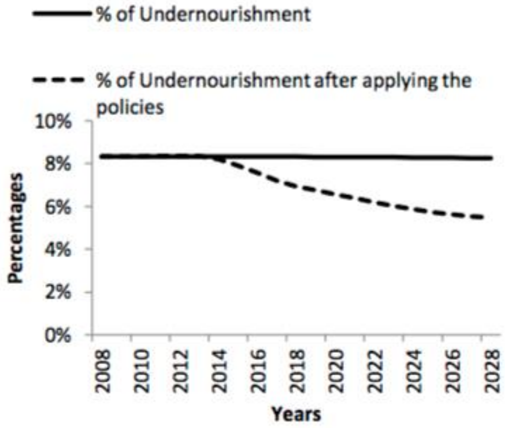
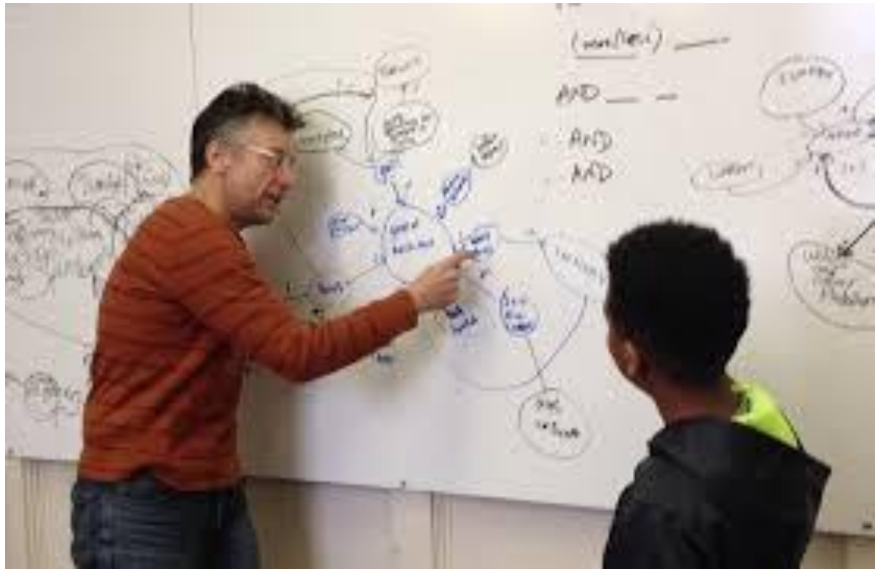



**Figure 19.The percentage of undernourishment**

# Broad application of System Dynamics?



# Aggregation levels

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## Production system level

Ecological Modelling 333 (2016) 51–65

Contents lists available at ScienceDirect

Ecological Modelling

journal homepage: www.elsevier.com/locate/ecolmodel

Exploring agricultural production systems and their fundamental components with system dynamics modelling

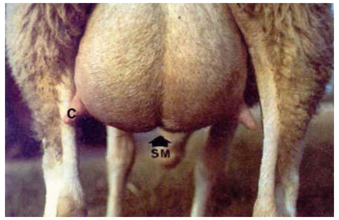
Jeffrey P. Walters[a,*], David W. Archer[b], Gretchen F. Sassenrath[c,1], John R. Hendrickson[d], Jon D. Hanson[d,2], John M. Halloran[e,3], Peter Vadas[f], Vladimir J. Alarcon[a,4]


## Animal Level

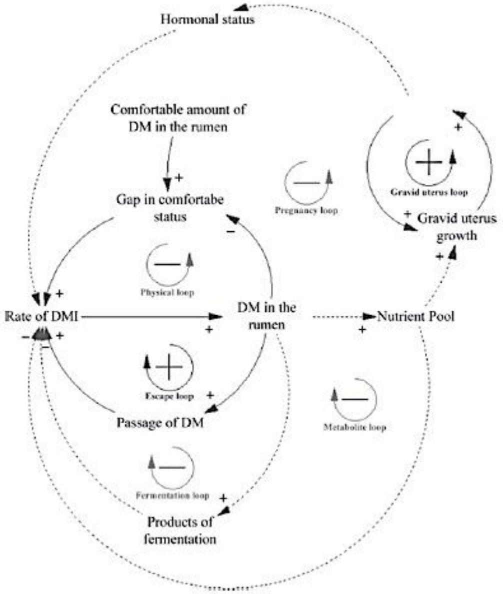
J. Dairy Sci. 96:1–16
http://dx.doi.org/10.3168/jds.2012-6070
© American Dairy Science Association®, 2013.

A dynamic model to predict fat and protein fluxes and dry matter intake associated with body reserve changes in cattle

Luis O. Tedeschi,*[1] Danny G. Fox,† and Paul J. Kononoff‡
*Department of Animal Science, Texas A&M University, College Station 7743-2471
†Department of Animal Science, Cornell University, Ithaca, NY 14853
‡Department of Animal Science, University of Nebraska-Lincoln, Lincoln 68583




### Body fat and intake



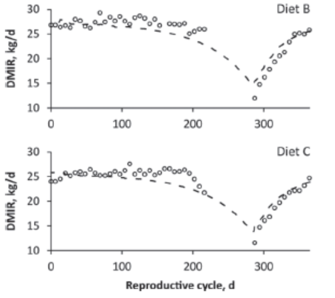
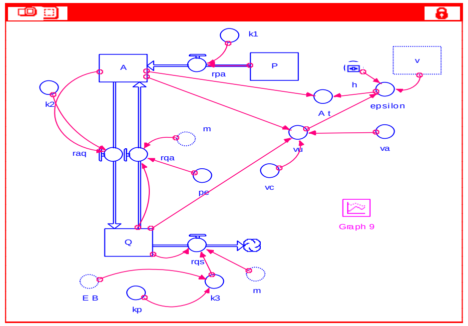




Figure 6. Predictions of DMI rate (DMIR; left panel) and body fat (B... eters for diets A, B, and C. The BF was predicted using the observed D...

### Mammary gland model



# SD for teaching?

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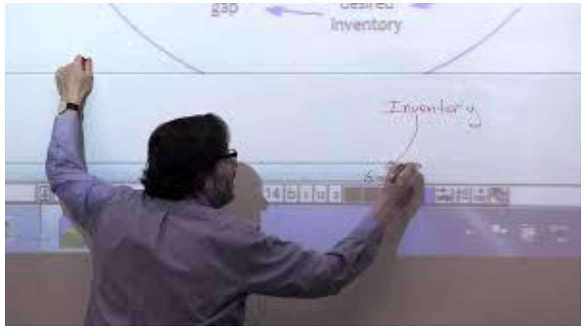
MITSloan MANAGEMENT

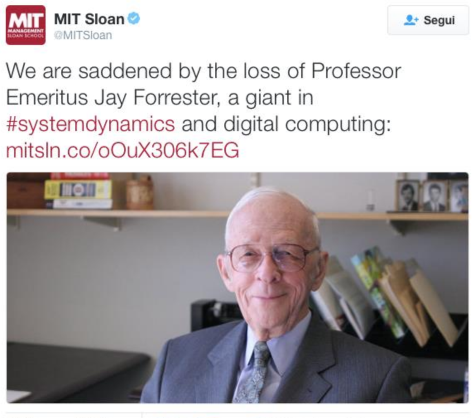
## K-12

## High school

CREATIVE LEARNING Exchange
System Dynamics & Systems Thinking in K–12 Education

## Undergraduate and graduate Masters, PhD edu programs




MIT Sloan
@MITSloan
Segui

We are saddened by the loss of Professor Emeritus Jay Forrester, a giant in #systemdynamics and digital computing: mitsln.co/oOuX306k7EG

Jay Forrester (1918-2016)
System control theory

## Consultancy and business

# SD info?

System Dynamics Society

Albany , NY - US

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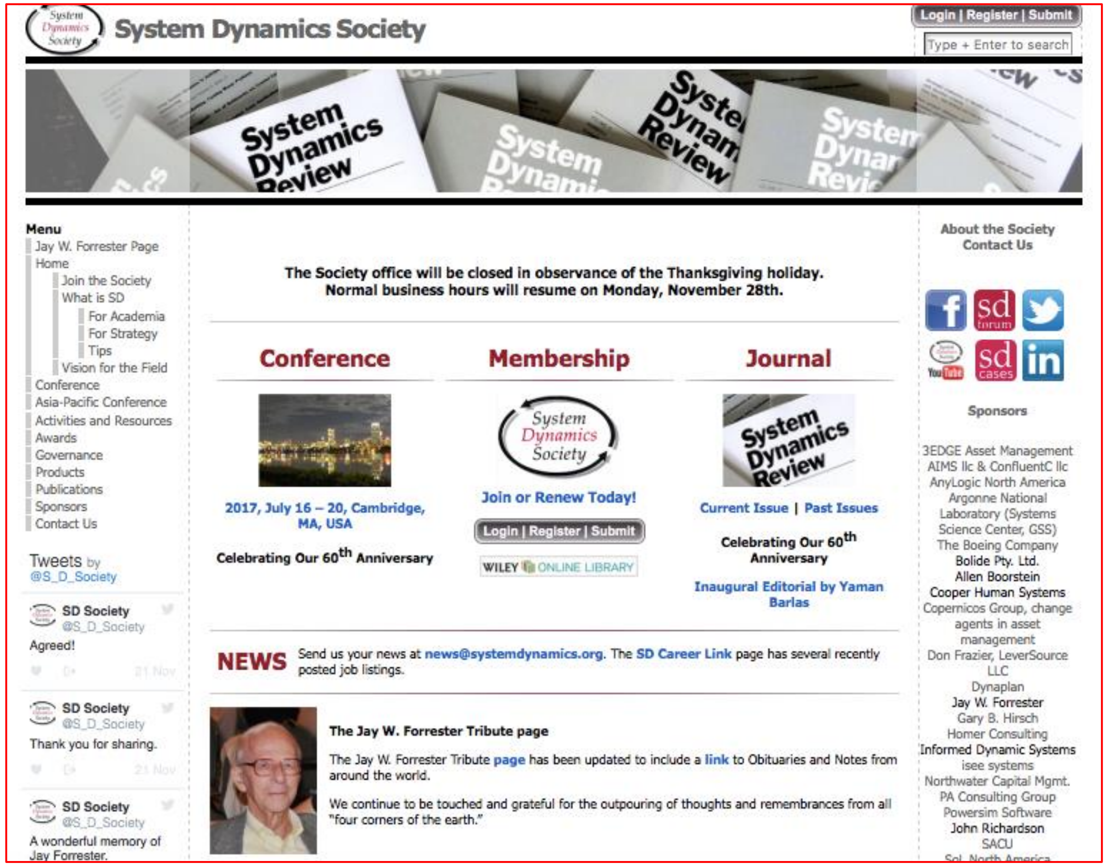
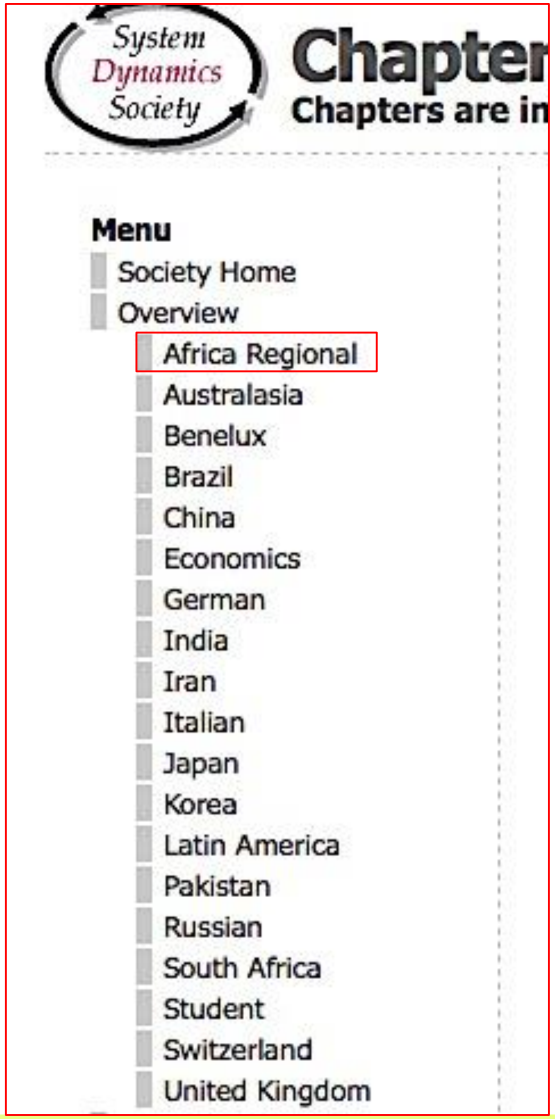
**www.systemdynamics.org**





**OPEN ACCESS MATERIAL**

System Dynamics Italian Chapter

www.systemdynamics.it

# Applications

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System Dynamics Society

Many fields

## SIGs of the System Dynamics Society

Special interest groups bring together people with shared interest in specific topics

**Menu**

- Society Home
- Overview
  - Agriculture & Food
  - Biomedical
  - Business
  - Conflict, Defense and Security
  - Education
  - Energy
  - Environmental
  - Health Policy
  - Information Science and Information Systems
  - Model Analysis
  - Psychology and Human Behavior

## Agriculture & Food

Approved in March 2016

SIG *Agriculture & Food* SDS

### Scope

Food systems comprise agricultural input supply, crop and livestock production, and postfarm processing, distribution and retailing. The dynamics of food systems often have important impacts on the well-being of agricultural producers and consumers, the environment and nutritional outcomes. Given their importance, food systems have been the focus of many policy initiatives, including farm-level support policies, environmental regulations, food safety requirements and price-related interventions. Given this importance and a growing number of researchers applying System Dynamics (SD) to provide insights into the dynamics of food systems, a SIG would serve as a focal point for food systems researchers active in the SD community. The proposed SIG will focus on food systems as integrated dynamic systems in which economic, social and biophysical are important elements to enhance our understanding and management. This group welcomes a multidisciplinary perspective to deal with topics such as:

- Input supply sector dynamics (e.g., seeds and fertilizer)
- Farm management
- Innovation dynamics (adoption of new technologies or techniques in agricultural production, processing and distribution)
- Environmental impacts, including land use change, nutrient dynamics and climate change
- The role of food systems in economic growth and rural development;
- Market dynamics and supply chain issues
- Social dynamics and human cultural aspects linked to food systems
- Human health and nutritional aspects
- Livestock and crop health
- Food safety (sanitary and phytosanitary) practices, policies and outcomes
- The dynamics of food value chains
- Food processing and distribution (including, but not limited to, logistics)

### List of leaders/ representatives to the Society

**Alberto Stanislao Atzori**
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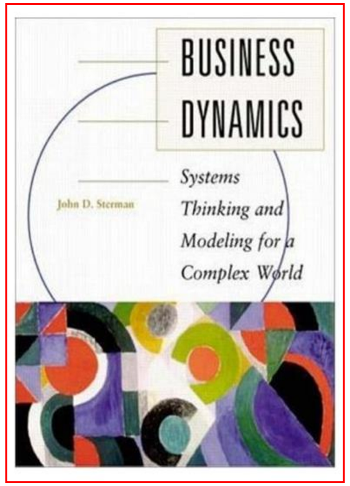
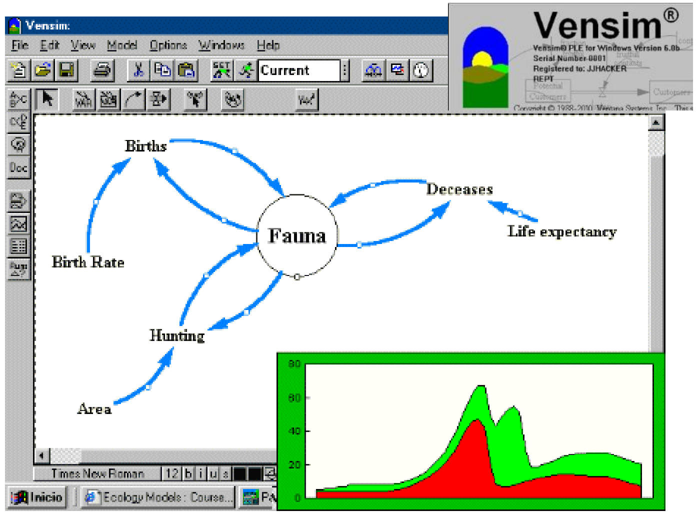
Viale Italia 39, 07100 Sassari,
Sardinia – Italy
Email: **asatzori@uniss.it**
Vice president secretary of the System Dynamics Italian Chapter

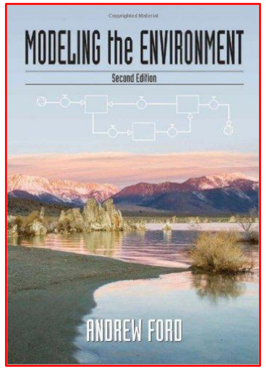



John Sterman (2000)

[www.systemdynamics.org](http://www.systemdynamics.org)

[Books – Software - Papers]()




Andrew Ford (2009)

*Resources* **2016**, *5*(4), 40; doi:10.3390/resources5040040

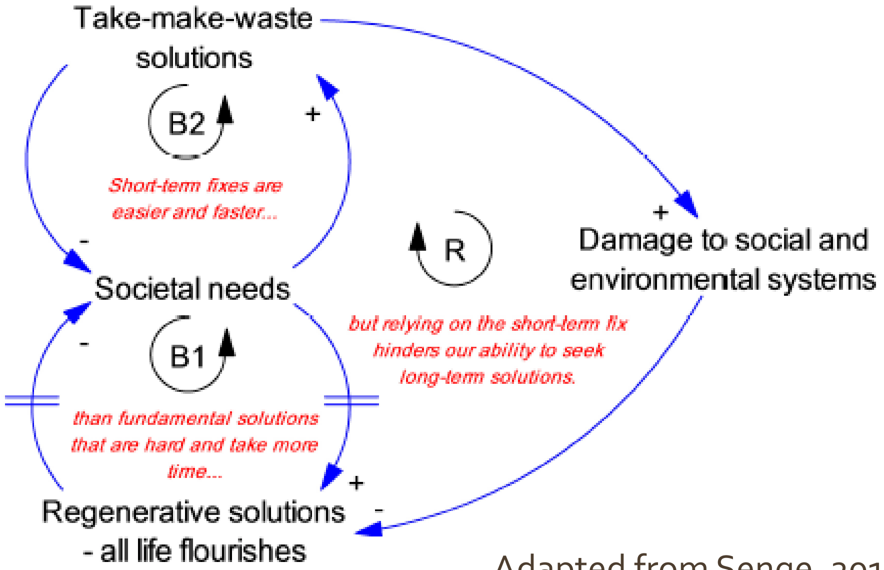
resources

MDPI

*Review*

# System Dynamics Modeling for Agricultural and Natural Resource Management Issues: Review of Some Past Cases and Forecasting Future Roles

Benjamin L. Turner [1,*], Hector M. Menendez III [2], Roger Gates [3], Luis O. Tedeschi [4] and Alberto S. Atzori [5]




Adapted from Senge, 2015

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asatzori@uniss.it

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## Enjoy your teaching with SD!

System dynamics is learning by doing!

(Sterman, 2000)

www.watersfoundation.com