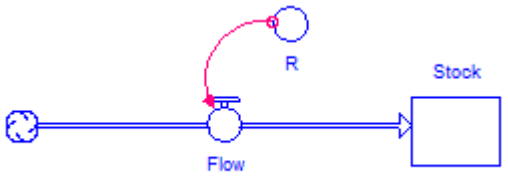
SIMULATION MODELLING

Antonio F. Nogueira Júnior
Lilian Amorim



Piracicaba
Junho de 2016

Simulation Modelling

1 “All models are wrong. Some models are useful” George E.P. Box

2 “Simulation modeling is an art and a science”. P. S. Teng

3 “Make it as simple as possible, but no simpler”. Albert Einstein

4 “Simulation allows us to control time”. R. E. Shannon

Histórico

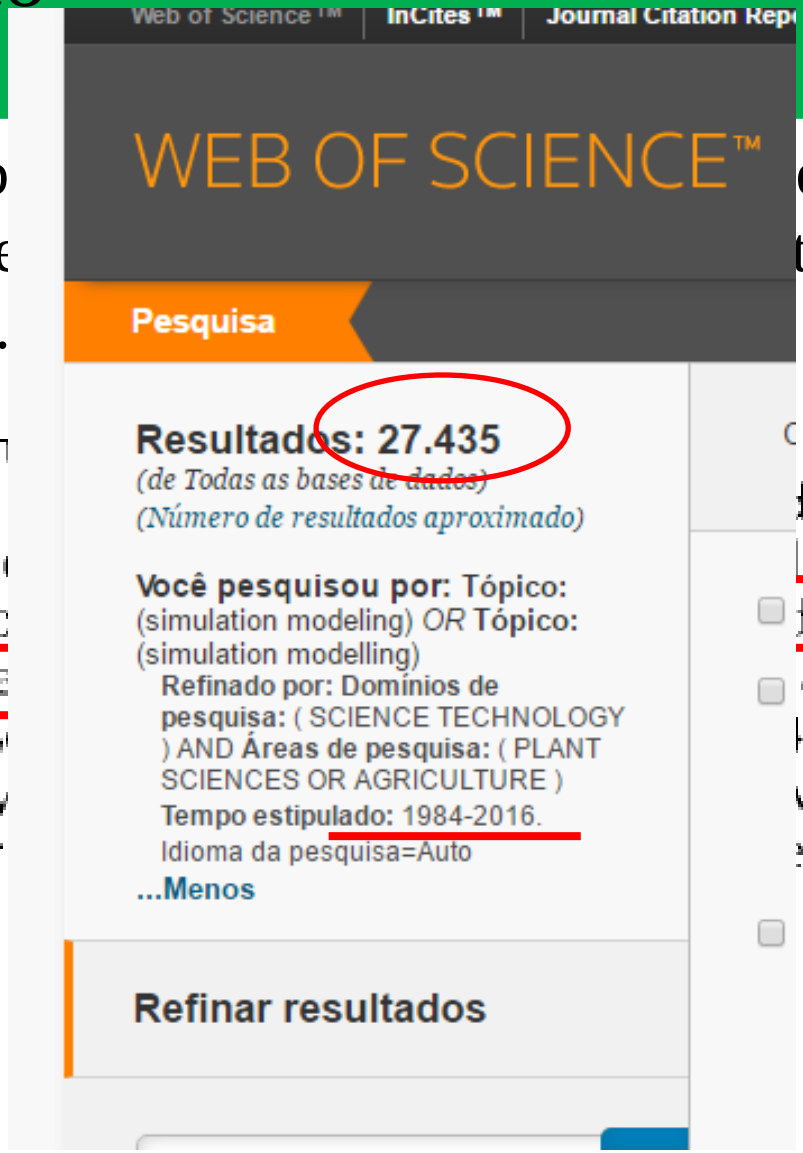
Names of published computer models in the environmental biological sciences: A partial list and new potential risks. Kickert, R. N. Simulation, **1984**.

duplicate names for different modeling projects and their resulting models, even if no commercialization is planned. This list (Table 2) includes names and references for 305 named models from 523 agricultural modeling publications and 878 wildlands modeling publications in my files. At this point, a preliminary estimate shows that only 21.8% of these modeling publications (305 of 1401) refer to named models. Many system simulation models are never given a specific name by their developers. The scope of model selection I have used

Histórico

Names of pub environmental
biological scie tential risks.
Kickert, R. N.

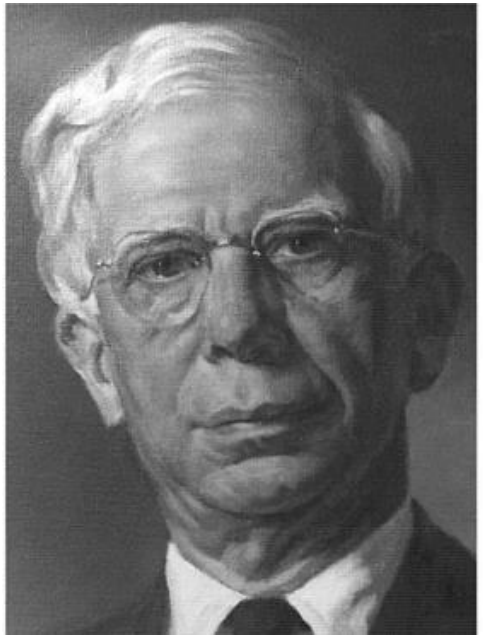
duplicate nam and their resulting
models, even d. This list (Table 2)
includes nam models from 523
agricultural mc ds modeling publica-
tions in my file ate shows that only
21.8% of thes 401) refer to named
models. Many ver given a specific
name by their election I have used



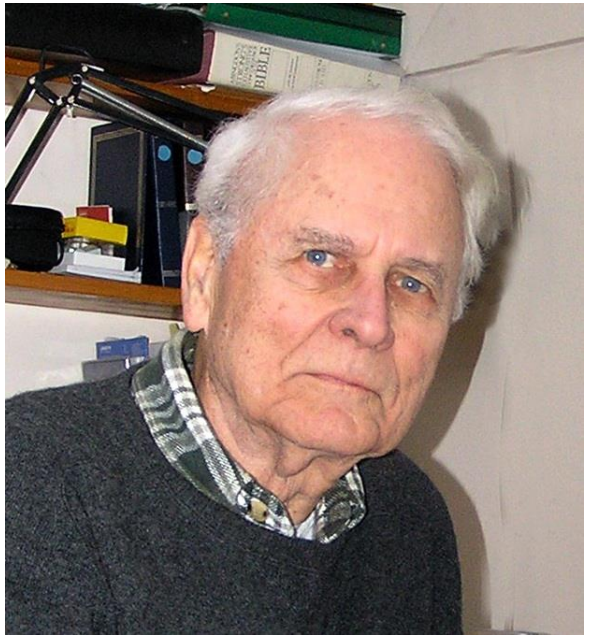
Histórico

Simulação em Doenças de Plantas:

J. C. Zadoks



J. G. Horsfall



P. F. Waggoner

WAGENINGEN UR
For quality of life

Agricultural University

CAES
The Connecticut Agricultural Experiment Station
Putting Science to Work for Society since 1875

The Connecticut
AGRICULTURAL EXPERIMENT STATION

Histórico

Simulação em Doenças de Plantas:

- EPDEM - Waggoner (1968) – **Requeima da batata**
- EPIDEM - Waggoner and Horsfall **(1969) – Pinta Preta Tomateiro**
- **Zadoks (1971) – System analysis and the dynamics of epidemics**
- EPIMAY - Waggoner and Horsfall (1972) – **Corn leaf blight**
- EPIVEN – Kranz et al., (1973) – **Sarna da Macieira**
- EPIDEMIC – Shrum (1975) – **Ferrugem do trigo**
- **Teng, P. S. (1978) – Tese defendida com simulação da ferrugem da cevada**

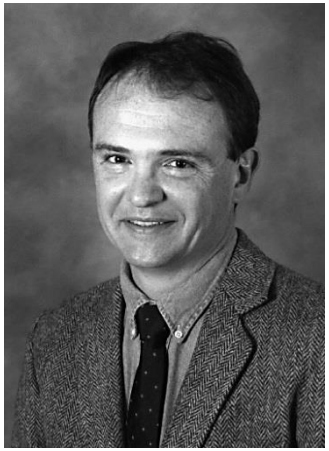
Histórico

"Nova Geração"

Serge Savary

Laetitia Willocquet

Kenneth J. Boote



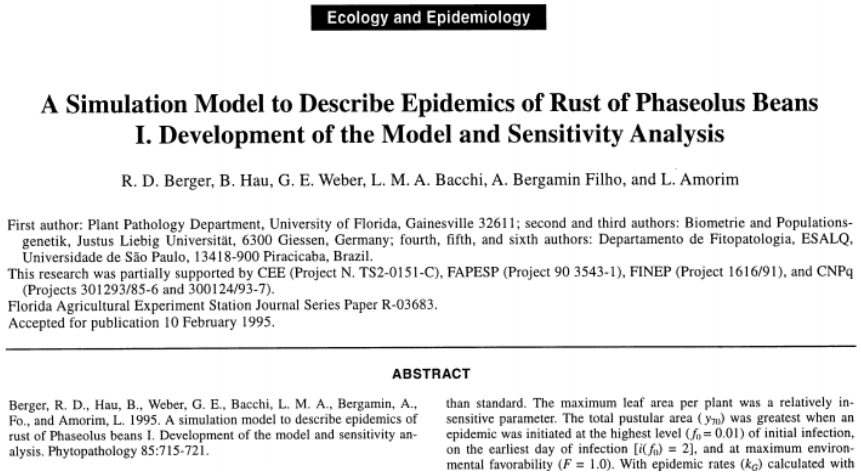
Kenneth B. Johnson

Tito Caffi

Vittorio Rossi

Histórico

Simulação em Doenças de Plantas:



Ecology and Epidemiology

A Simulation Model to Describe Epidemics of Rust of Phaseolus Beans I. Development of the Model and Sensitivity Analysis

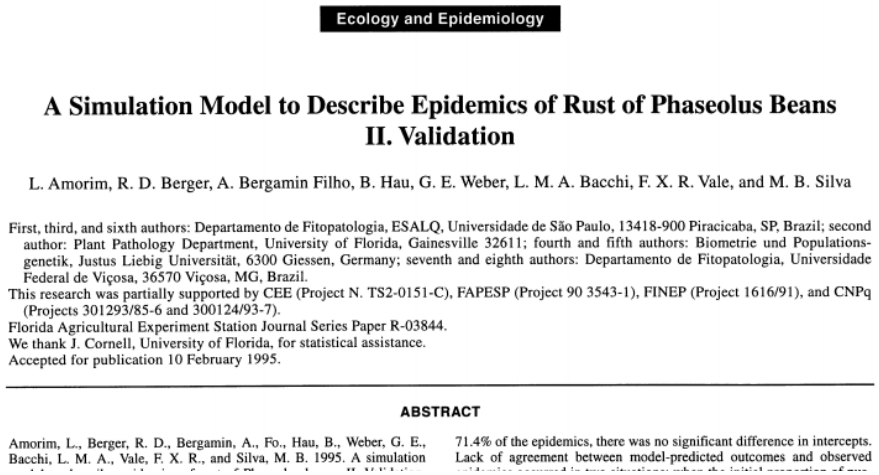
R. D. Berger, B. Hau, G. E. Weber, L. M. A. Bacchi, A. Bergamin Filho, and L. Amorim

First author: Plant Pathology Department, University of Florida, Gainesville 32611; second and third authors: Biometrie and Populationsgenetik, Justus Liebig Universität, 6300 Giessen, Germany; fourth, fifth, and sixth authors: Departamento de Fitopatologia, ESALQ, Universidade de São Paulo, 13418-900 Piracicaba, Brazil.
This research was partially supported by CEE (Project N. TS2-0151-C), FAPESP (Project 90 3543-1), FINEP (Project 1616/91), and CNPq (Projects 301293/85-6 and 300124/93-7).
Florida Agricultural Experiment Station Journal Series Paper R-03683.
Accepted for publication 10 February 1995.

ABSTRACT

Berger, R. D., Hau, B., Weber, G. E., Bacchi, L. M. A., Bergamin, A., Fo., and Amorim, L. 1995. A simulation model to describe epidemics of rust of Phaseolus beans I. Development of the model and sensitivity analysis. Phytopathology 85:715-721.

than standard. The maximum leaf area per plant was a relatively insensitive parameter. The total pustular area (y_{Th}) was greatest when an epidemic was initiated at the highest level ($f_0 = 0.01$) of initial infection, on the earliest day of infection [$i(f_0) = 2$], and at maximum environmental favorability ($F = 1.0$). With epidemic rates (k_G) calculated with



Ecology and Epidemiology

A Simulation Model to Describe Epidemics of Rust of Phaseolus Beans II. Validation

L. Amorim, R. D. Berger, A. Bergamin Filho, B. Hau, G. E. Weber, L. M. A. Bacchi, F. X. R. Vale, and M. B. Silva

First, third, and sixth authors: Departamento de Fitopatologia, ESALQ, Universidade de São Paulo, 13418-900 Piracicaba, SP, Brazil; second author: Plant Pathology Department, University of Florida, Gainesville 32611; fourth and fifth authors: Biometrie und Populationsgenetik, Justus Liebig Universität, 6300 Giessen, Germany; seventh and eighth authors: Departamento de Fitopatologia, Universidade Federal de Viçosa, 36570 Viçosa, MG, Brazil.
This research was partially supported by CEE (Project N. TS2-0151-C), FAPESP (Project 90 3543-1), FINEP (Project 1616/91), and CNPq (Projects 301293/85-6 and 300124/93-7).
Florida Agricultural Experiment Station Journal Series Paper R-03844.
We thank J. Cornell, University of Florida, for statistical assistance.
Accepted for publication 10 February 1995.

ABSTRACT

Amorim, L., Berger, R. D., Bergamin, A., Fo., Hau, B., Weber, G. E., Bacchi, L. M. A., Vale, F. X. R., and Silva, M. B. 1995. A simulation

71.4% of the epidemics, there was no significant difference in intercepts. Lack of agreement between model-predicted outcomes and observed

iCROPM2016

15-17 March 2016, Berlin, Germany

MACSUR and AgMIP jointly presented the **International Crop Modelling Symposium**

"Crop Modelling for Agriculture and Food Security under Global Change"

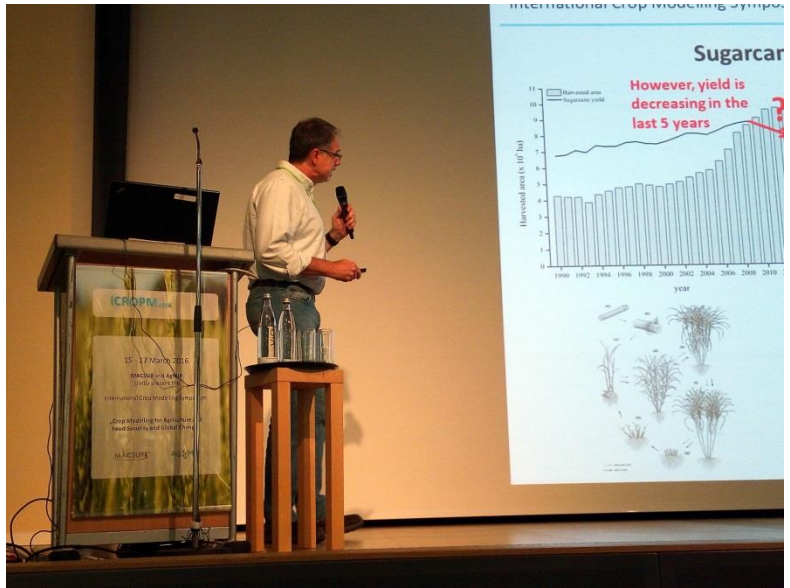
Models for crop diseases: Overview of approaches & scales

S Savary, P Esker, N McRoberts,
L Willocquet, T Caffi, V Rossi, J Yuen,
A Djurle, L Amorim, A Bergamin Filho,
N Castilla, A Sparks, K Garrett

iCROPM2016

INRA SCIENCE & IMPACT

MACSUR



Paulo Sentelhas

Conceitos e Filosofia

Sistema: “Série de elementos conectados, com limites específicos e tempo característico pré-determinado”.

(Savary & Willocquet, 2014).

Sistemas Fitopatológicos (?)

Modelo – Representação simplificada da realidade (Zadoks, 1971).

Conceitos e Filosofia

Na epidemiologia:

- Uso de modelos para representação de um fenômeno epidemiológico (Vanderplank).

Conceitos e Filosofia

Na epidemiologia:

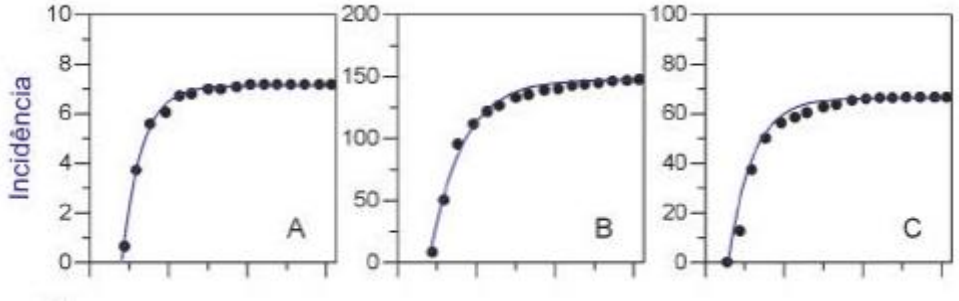
- Uso de modelos para representação de um fenômeno epidemiológico (Vanderplank).

- Classificação de modelos (dentre várias):

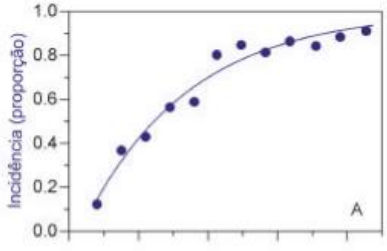
- Modelos empíricos – ex. Regressões

- Modelos mecanísticos – feito com uma série de modelos empíricos - Simulação

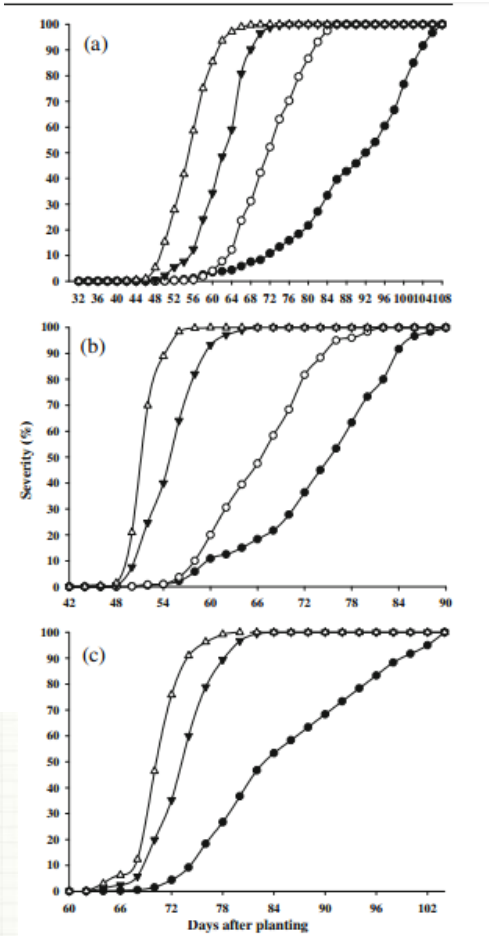
Por que Simular Epidemias?



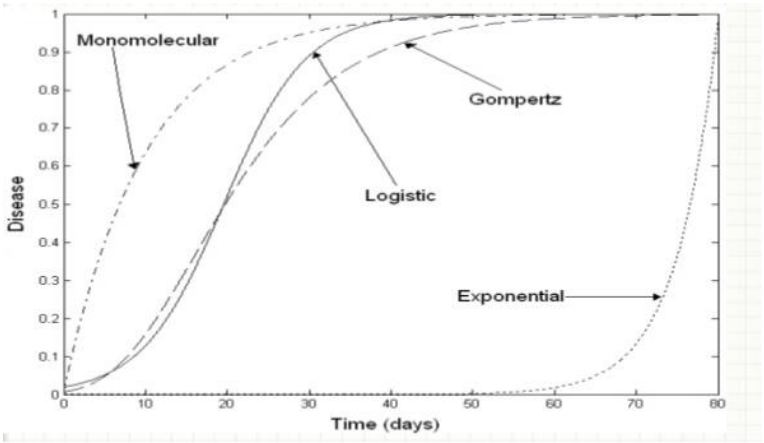
Amorim, 1997. Carvão da cana



Spósito , 2002.
Pinta Preta do Citros



Duarte, et al., 2012.
Requeima da batata



Por que Simular Epidemias?

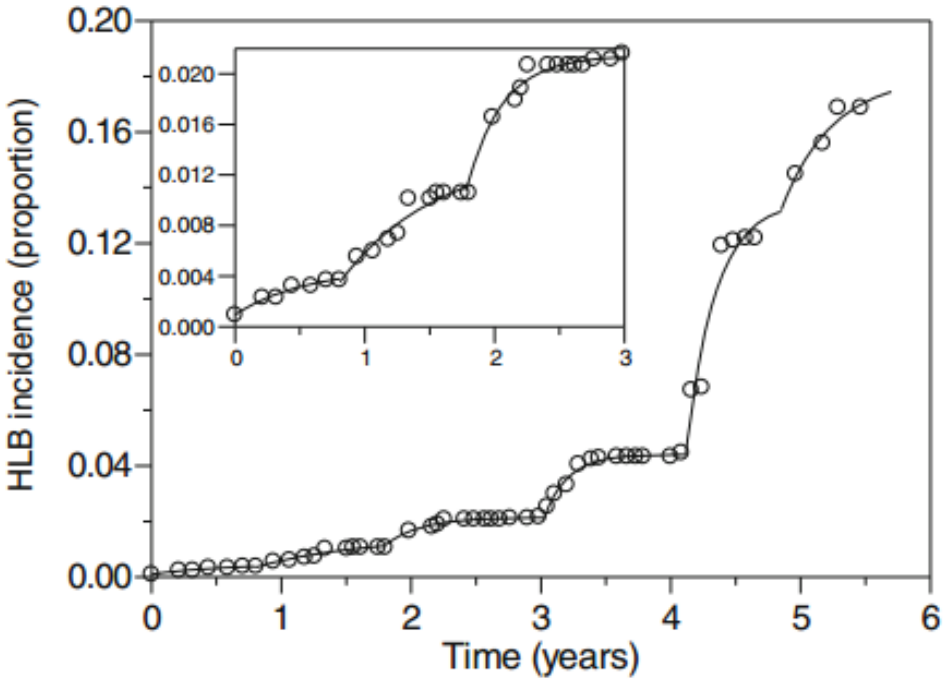


Fig. 6 Polyetic HLB progress curve showing waves of infection in each year (from 2008 to 2013) in São Paulo, Brazil. The inner graph shows a magnified view of the first 3 years of assessment

Bergamin Filho et al., 2016

Conceitos e Filosofia – **Por quê?**

A Visão Holística:

Holístico, relativo a holismo: (holos – inteiro ou todo)
Abordagem, no campo das ciências humanas e naturais, que prioriza o entendimento integral dos fenômenos, em oposição ao procedimento analítico em que seus componentes são tomados isoladamente;

O sistema como um todo determina como se comportam as partes.

Conceitos e Filosofia – **Por quê?**

A Visão Holística:

Single equations models are not holistic and cannot be holistic because they are incapable of recognizing all the components and levels of organization in an epidemic.

The user of single equation models of epidemics (e. g. logistic, Gompertz) would be the first to admit that single equations are incapable of representing or predicting the dynamic course of epidemics.

P. S. Teng (1985). A comparison of simulation approaches to epidemic modeling. Ann. Re. Phytopathol. 23:351-79.

Por que Simular Danos?

(a) milho - *Erwinia stewartii*
Phytopathology 78: 175-178

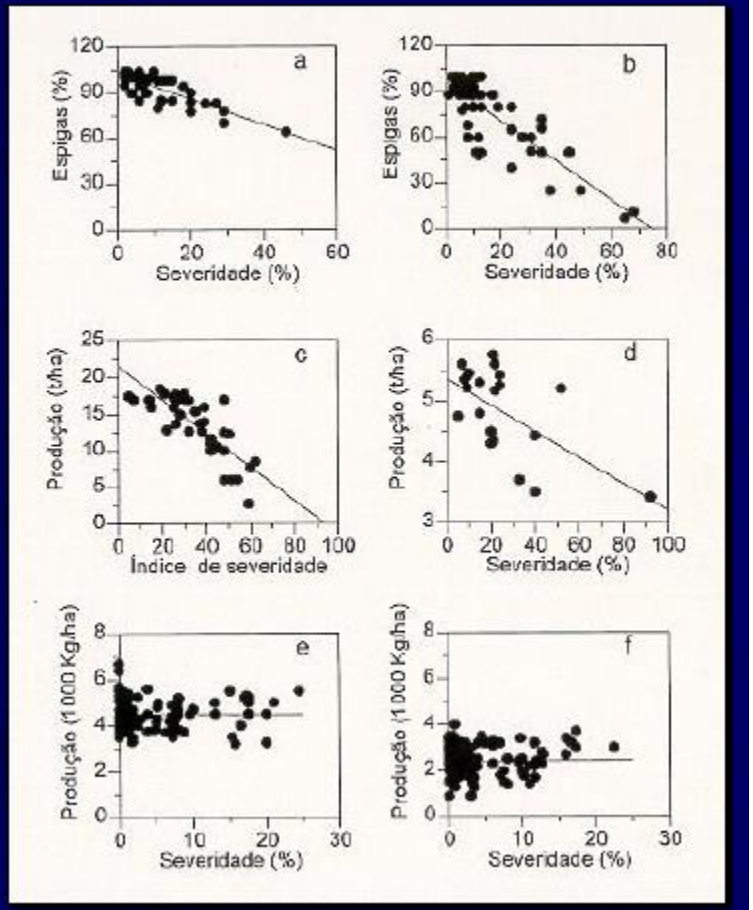
(b) milho - *Clavibacter michiganense*
Phytopathology 78: 175-178

(c) espinafre - complexo solo
Phytopathology 82: 403-406

(d) cevada - *Puccinia hordei*
Plant Disease 78: 256-260

(e) aveia - *Puccinia coronata*
Phytopathology 84: 363-371

(f) aveia - *Puccinia coronata*
Phytopathology 84: 363-371



Por que Simular Danos?

- Bergamin et al., 1997 – Dano relacionado com a área verde remanescente (LAI, HAA, RUE…) – Fotossíntese…

- Múltiplas doenças ocorrendo no mesmo ciclo de cultivo.

Evaluation of a Mechanistic Model that Describes Potato Crop Losses Caused by Multiple Pests

Kenneth B. Johnson

Department of Botany and Plant Pathology, Oregon State University, Corvallis 97331-2902.
Research supported by state funds of the Minnesota and Oregon Agricultural Experiment Stations and federal funds including USDA NC-IPM grant 85-CRSR-2-2679. This is Oregon Agricultural Experiment Station technical paper 9656.
Accepted for publication 11 October 1991 (submitted for electronic processing).

Porque…

- Principais objetivos na modelagem e simulação de doenças de plantas:

1- Analisar e entender epidemias;

2- Analisar e entender os danos causados por patógenos;

O objetivo final de (1+2) é melhorar o manejo de doenças e plantas e reduzir os danos.

Porque…

- Muita informação disponível sobre os mecanismos de dano (redução na fotossíntese, índice de área foliar…)

- Pouca informação sobre funções (modelos) de danos.

3- Com as informações dos mecanismos de danos é possível criar modelos para uma ou múltiplas doenças em uma determinada cultura.

Porque…

4- Sintetizar dados e conhecimentos disponíveis na literatura;

5- Prever padrões epidemiológicos;

6- Desenhar experimentos para comprovar uma teoria;

7- Excelente ferramenta educacional

Conceitos e Filosofia

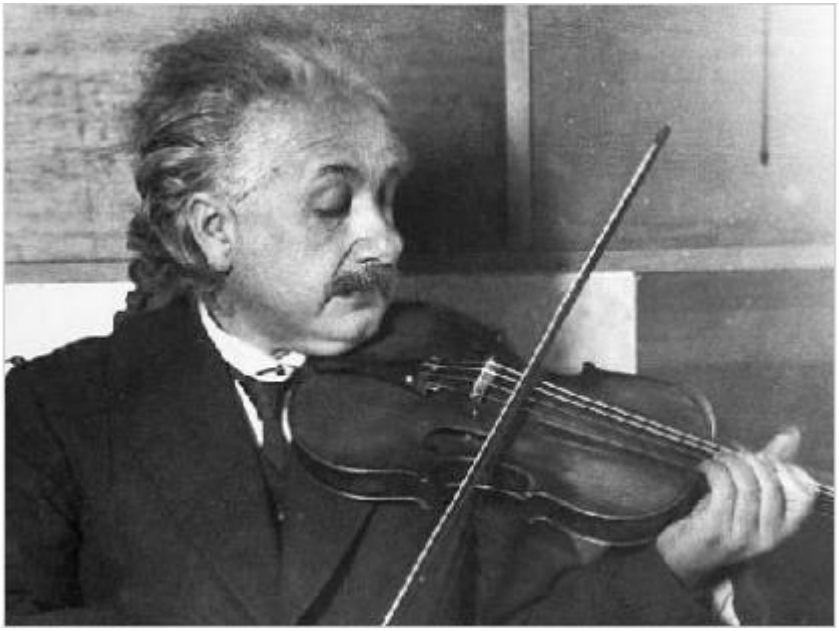
Proceedings of the 1998 Winter Simulation Conference
D.J. Medeiros, E.F. Watson, J.S. Carson and M.S. Manivannan, eds.

INTRODUCTION TO THE ART AND SCIENCE OF SIMULATION

Robert E. Shannon

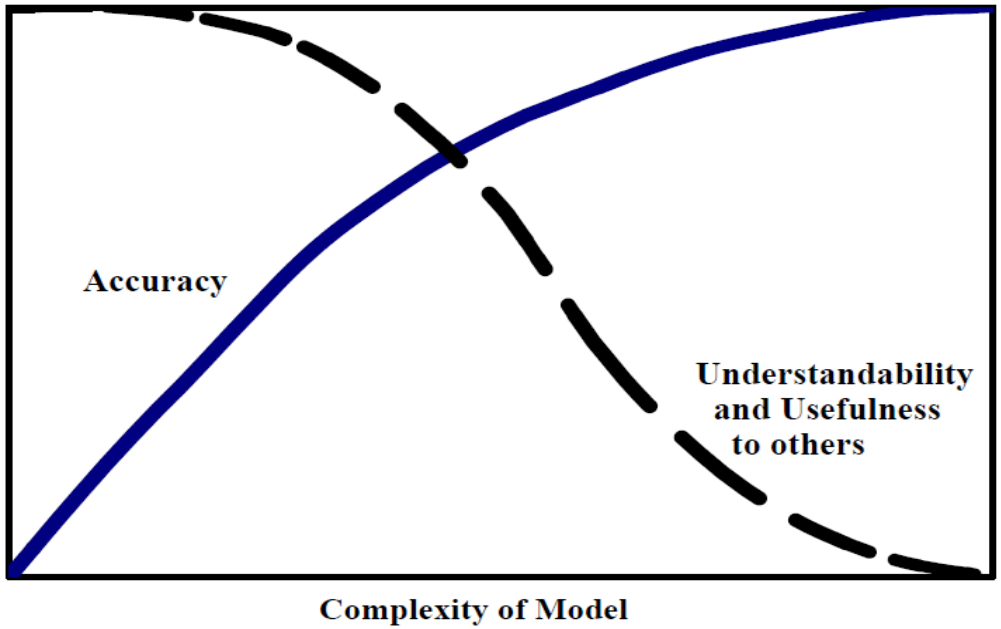
Industrial Engineering
Texas A&M University
College Station, Texas 77843-3131 U.S.A.

"Apart from the use of established statistical techniques, simulation modelling requires **ingenuity**, **interpretatio**n, **resourcefulness**, and **integrity** on the part of the modeler. It is both and (2) **art and a science**" Teng, 1985



Conceitos e Filosofia

“Make it as simple as possible, but no simpler”. Albert Einstein



Goldschmidt and Lakso, 2005

Passos para criação de um modelo de simulação em doenças de plantas:

- Definição do objetivo do modelo de simulação:

1- É necessário?

2 - Modelar: Epidemia, Danos, Crescimento do hospedeiro, tudo?

2- Melhor entendimento do sistema?

3- Ranquear mecanismos de dano?

4- Modelar um padrão de epidemia “não-convencional”?
(...)

Passos para criação de um modelo de simulação em doenças de plantas:

- Delimitar o sistema: Uma planta, uma folha, uma espiga… e seus componentes (elementos que atuam no sistema).

- Determinar o Time Step: Tempo que muda o estado das variáveis do sistema; Time frame;

- Unidades e Dimensões

Unidades e Dimensões

Variable type	Variables	Dimensions	Units (examples)
State variables	Length	[L]	m
	Mass	[M]	kg
	Number (population size)	[N]	number
	Leaf area	$[L^2]$	m^2
	Leaf area index	$[L^2.L^{-2}] \equiv [1]$	$m^2 \cdot m^{-2}$
	Root length	[L]	m
	Population deny	$[N.L^{-2}]$	$number \cdot m^{-2}$
Rates	Speed	$[L.T^{-1}]$	$m \cdot s^{-1}$
	Growth	$[M.T^{-1}]$	$kg \cdot d^{-1}$
	Population increase	$[N.T^{-1}]$	$number \cdot d^{-1}$
Coefficients	Acceleration	$[L.T^{-1}.T^{-1}] \equiv [L.T^{-2}]$	$m \cdot s^{-2}$
	(Bio)mass relative growth rate	$[M.M^{-1}.T^{-1}] \equiv [T^{-1}]$	d^{-1}
	Relative population growth rate	$[N.N^{-1}.T^{-1}] \equiv [T^{-1}]$	d^{-1}

Passos para criação de um modelo de simulação em doenças de plantas:

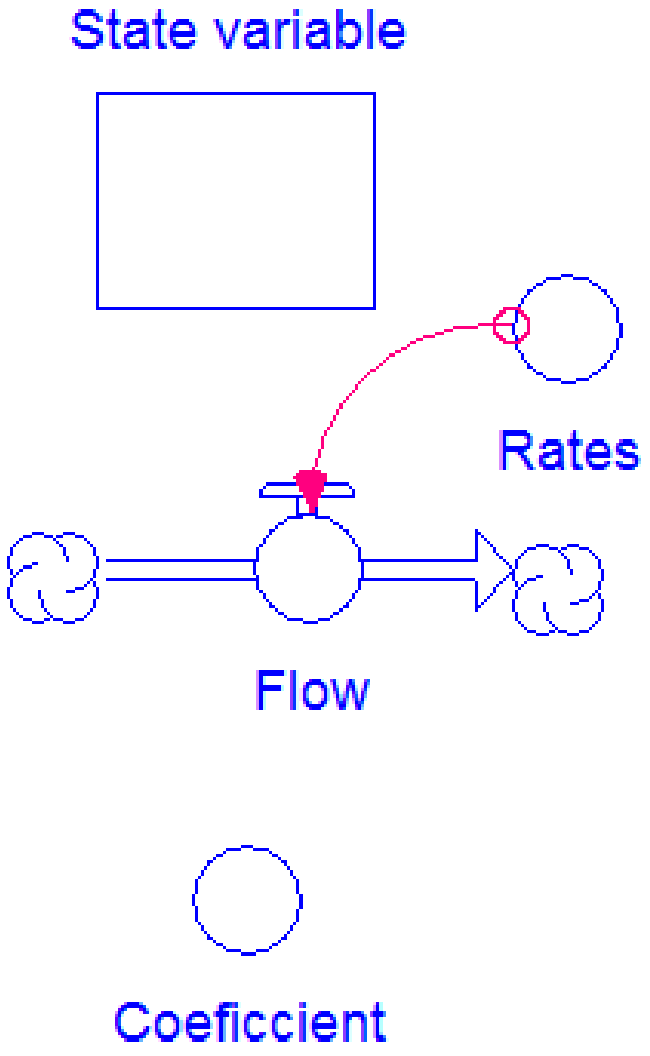
Modelo de Crescimento de uma bácteria

Sistema: população de bactérias

Time step 1 minuto

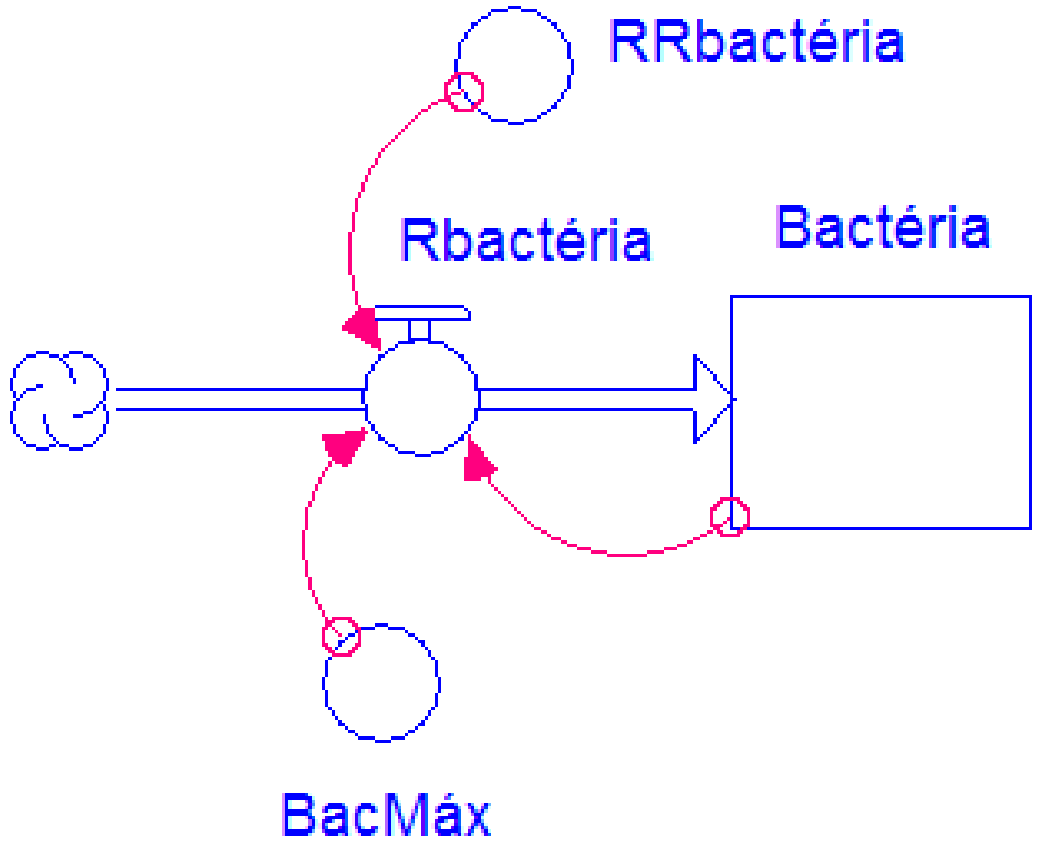
Time frame (?)

Elementos: bactéria, taxa, fluxos, coeficientes…



Passos para criação de um modelo de simulação em doenças de plantas:

Ex – crescimento de bácteria com restrição do crescimento



Passos para criação de um modelo de simulação em doenças de plantas:

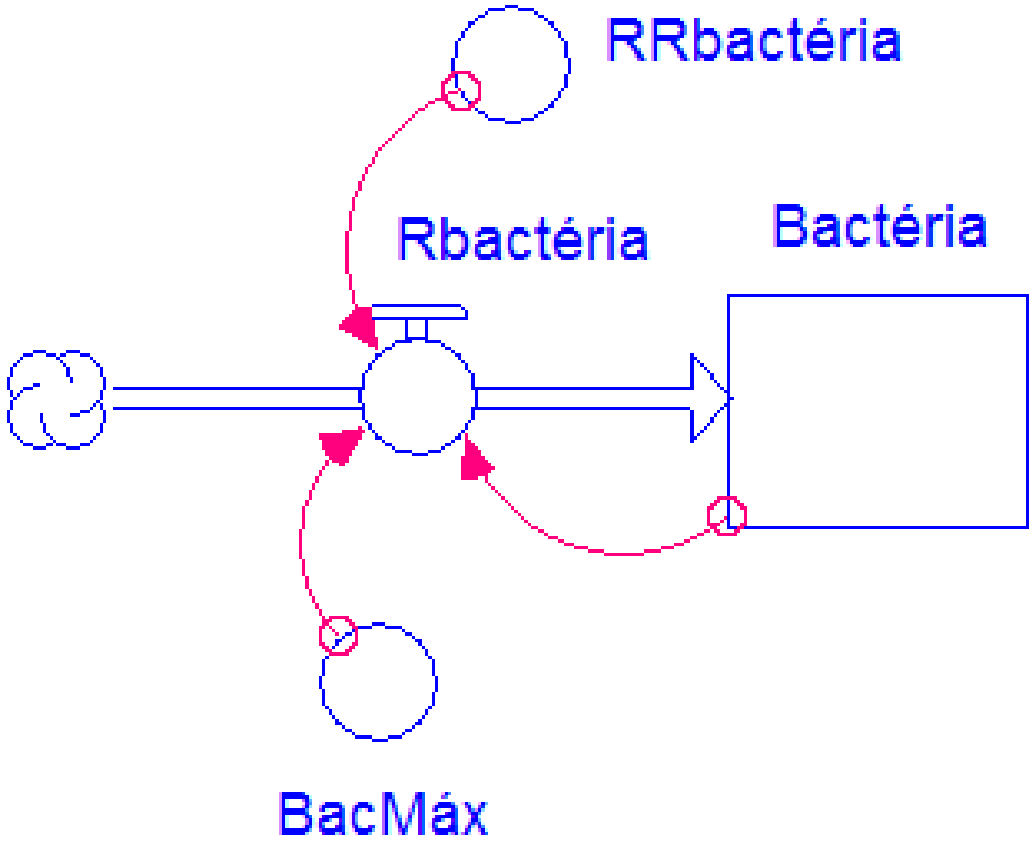
- Determinar Equações

Rb= B*RRb*(1 - (B/BMax)
B(t) = B(t - dt) + (Rb) * dt

- Determinar

Coeficientes

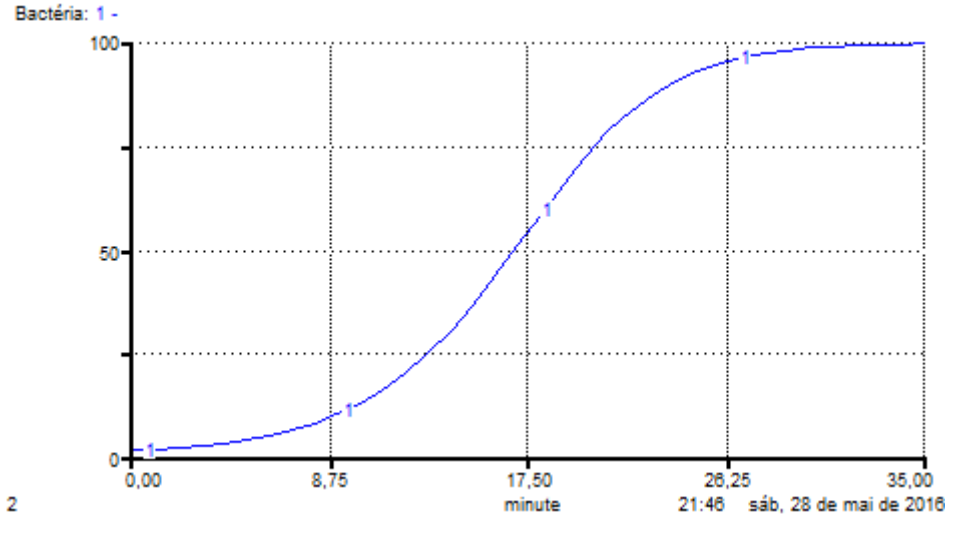
Rrbactéria = 0,3

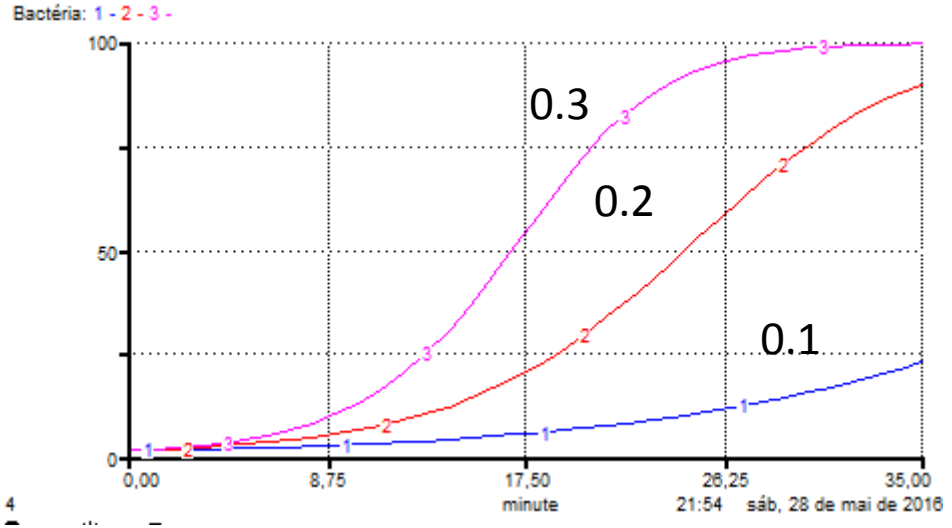


Stella

Passos para criação de um modelo de simulação em doenças de plantas:

- Outputs





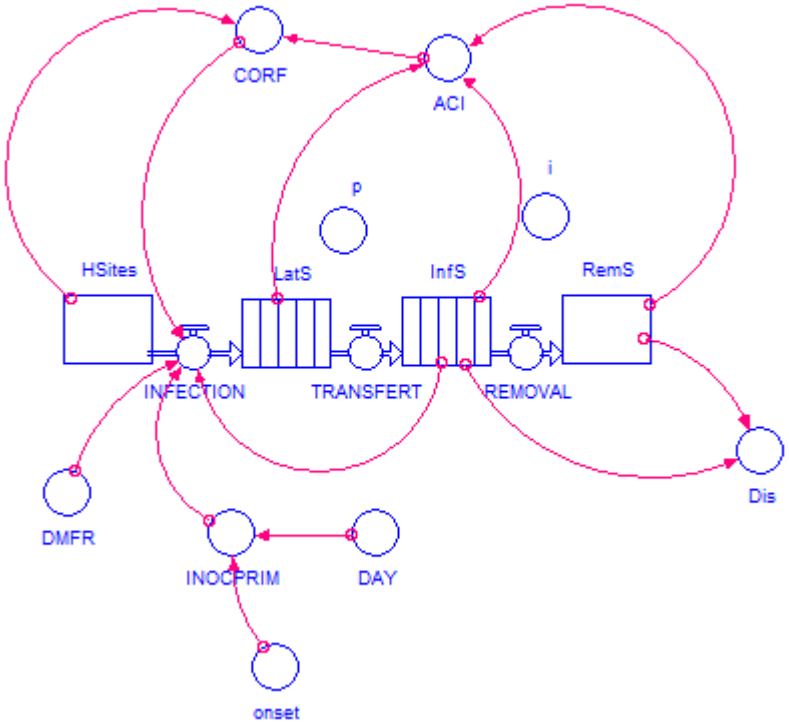
Passos para criação de um modelo de simulação em doenças de plantas:

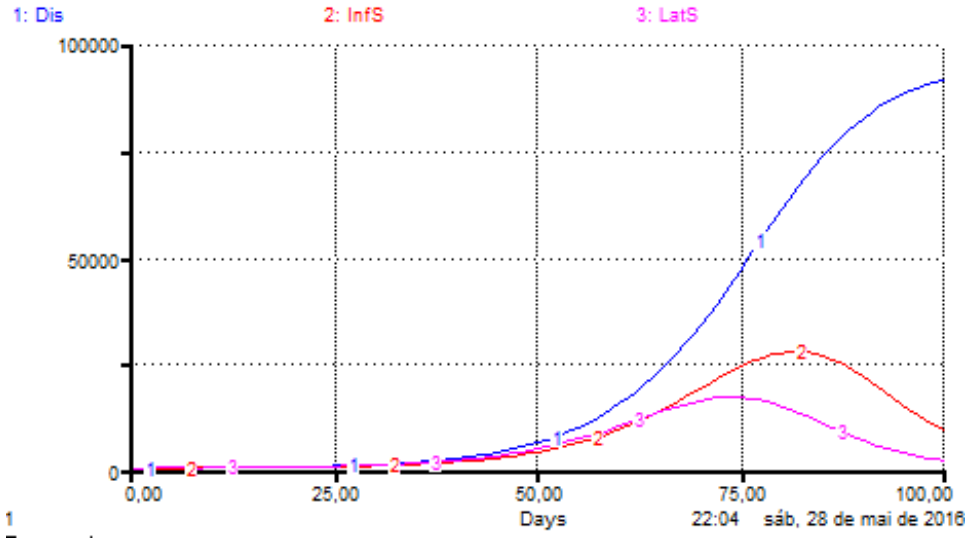
- Model Teste

- Design de experimentos para avaliação do modelo/ Mobilização de dados da literatura

- Comparação dos dados simulados com dados observados

Exemplo de um modelo epidemiológico





Savary & Willocquet
2014.APS

Simulation allows us to control time. *Thus we can operate the system for several* ***months or years*** *of experience in a matter of seconds allowing us to quickly look at long time horizons or we can slow down phenomena for study.* R. E. Shannon 1998

Obrigado!

Savary, S. and Willocquet, L. (2014). Simulation Modeling in Botanical Epidemiology and Crop Loss Analysis. The Plant Health Instructor. DOI: 10.1094/PHI-A-2014-0314-01 Capítulo 1 e 2

J. C. Zadoks (1971) – System analysis and the dynamics of epidemics. Phytopathology 61, 441-598

P. S. Teng (1985). A comparison of simulation approaches to epidemic modeling. Ann. Re. Phytopathol. 23:351-79.

Boote, K.J., Jones, J.W., Mishoe, J.W., Berger, R.D., (1983). Coupling pests to crop growth simulators to predict yield reductions. Phytopathology 73, 1581–1587.