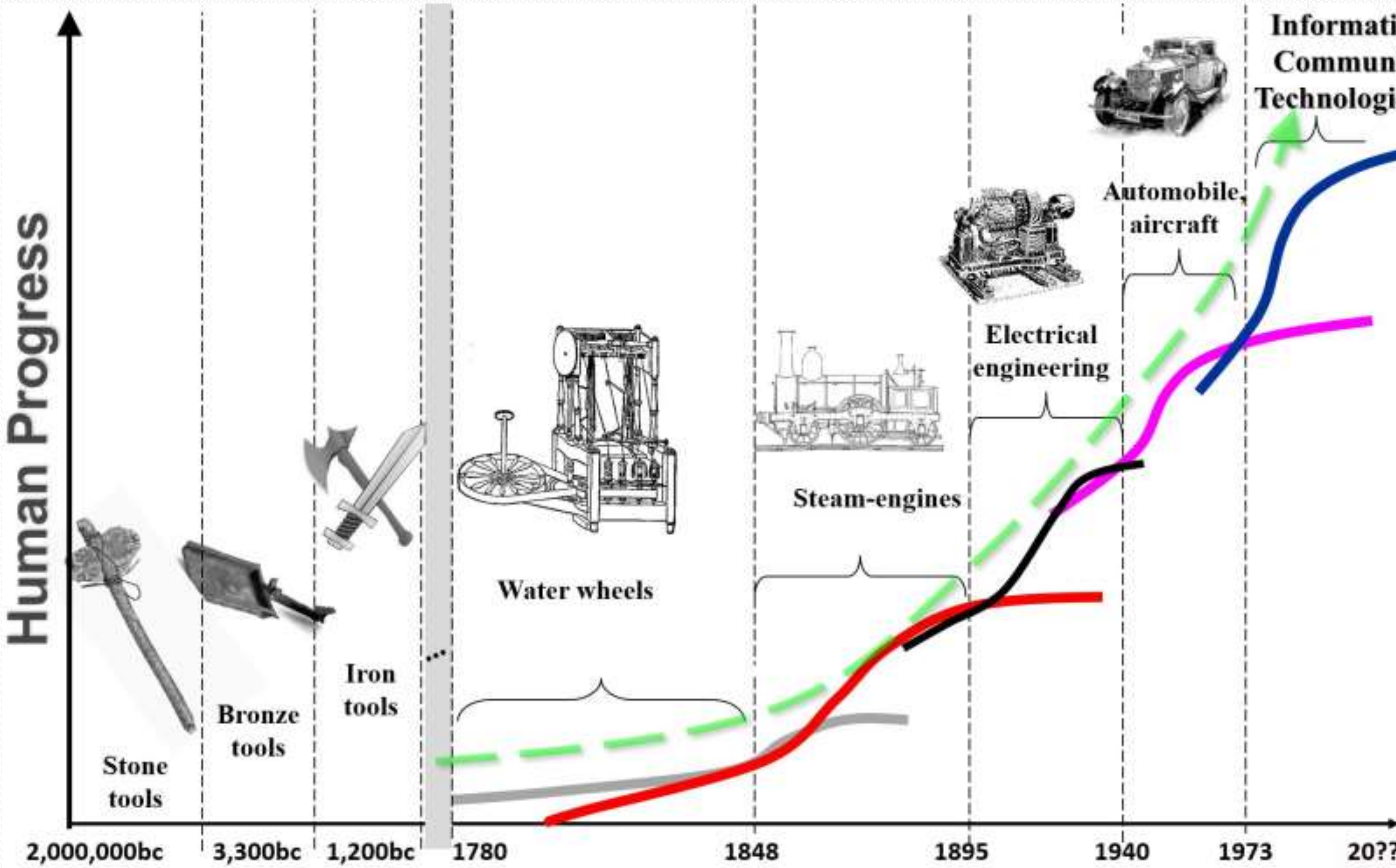
CEN0257
Modelagem de Sistemas Agrícolas e Ecológicos
Aula #1

“natural”

agrícola

urbano

Quarta Revolução Agrícola: Agricultura Digital?



M. Hilbert, Online Course *Digital Technology & Social Change*, University of California: https://canvas.instructure.com/courses/949415

Agricultura Digital

Leia matéria completa em:
http://www.economist.com/news/business/21602757-managers-most-traditional-industries-distrust-promising-new-technology-digital

The Economist

World politics | Business & finance | Economics | Science & technology | Cultu

Schumpeter

Digital disruption on the farm

Managers in the most traditional of industries distrust a promising new technology

May 24th 2014 | From the print edition

Timekeeper | Like 830 | Tweet

Brett Ryder

INNOVATION is a word that brings to mind small, nimble startups doing clever things with cutting-edge technology. But it is also vital in large, long-established industries—and they do not come much larger or older than agriculture. Farmers can be among the most hidebound of managers, so it is no surprise that they are nervous about a new idea called prescriptive planting, which is set to disrupt their business. In essence, it is a system that tells them with great precision which seeds to plant and how to cultivate them in each patch of land. It could be the biggest change to agriculture in rich countries since genetically modified crops. And it is proving nearly as controversial, since it raises profound questions about who owns the information on which the service is based. It also plunges stick-in-the-mud farmers into an unfamiliar world of "big data" and privacy battles.

Terminologia do mundo da modelagem:

MODELO

Um algoritmo representando parte da natureza

MODELAGEM

A arte de construir um modelo

SIMULAÇÃO

A realização de um cálculo com um modelo

CENÁRIO

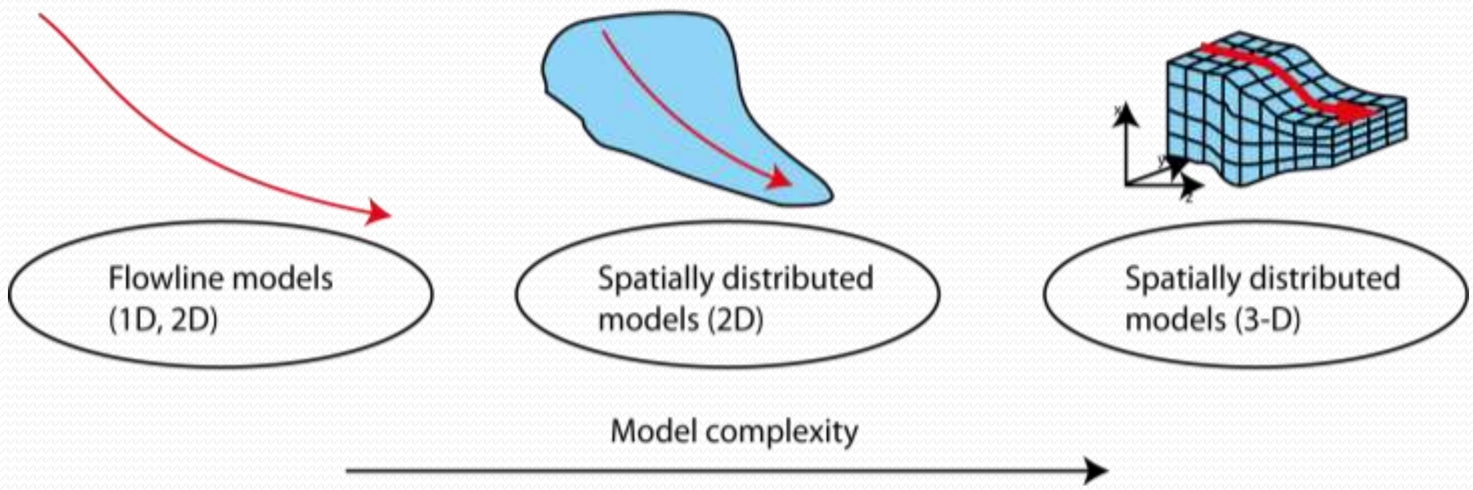
Conjunto das condições de contorno de uma simulação

MODELO

- Um modelo é uma representação simples de um processo ou fenômeno mais complexo;
- **Para interpretar dados precisamos sempre de algum tipo de modelo, implícito ou explícito;**
- Modelos variam quanto a
  1. Escala
  2. Complexidade
  3. Tipo (...)
- **Um modelo permite entender e prever fenômenos, analisar sensibilidades, indicar necessidades de pesquisa e experimentação, ...**

Dimensões de modelos

- **Tempo**
- **Espaço – 1,2,3D**



Constantes, parâmetros e variáveis

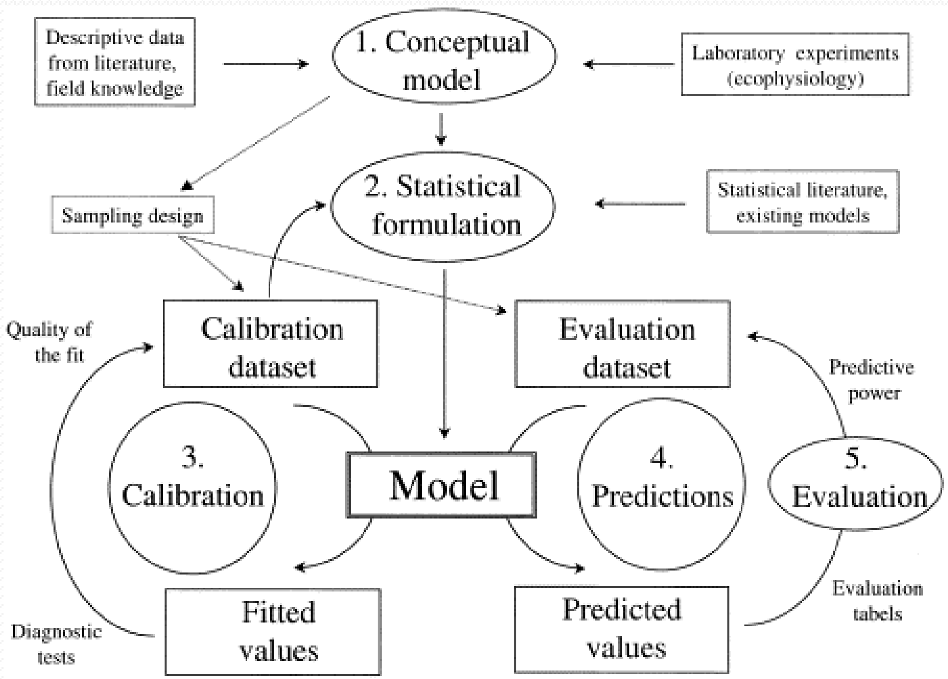
- CONSTANTES – invariáveis no tempo e no espaço
  - Constantes universais
  - Constantes locais (p.e., globais)

- PARÂMETROS – variam na natureza, mas são considerados invariáveis no modelo
  - Parâmetros são calibráveis

- VARIÁVEIS – variam ao longo do tempo e/ou espaço, dentro de uma simulação
  - Podem ser valores de entrada e/ou de saída do modelo

Etapas da modelagem:

1. Conceituação
2. Formalização
3. Calibração
4. Teste/Validação
5. Utilização

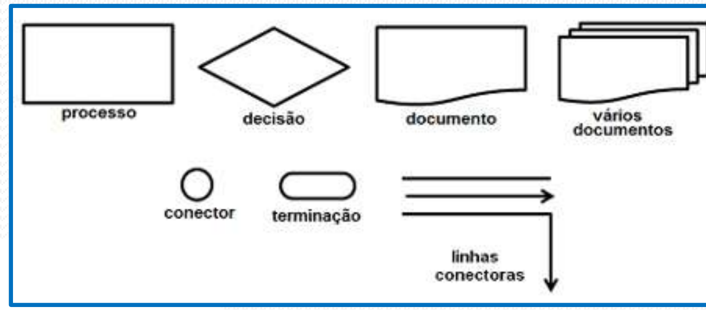


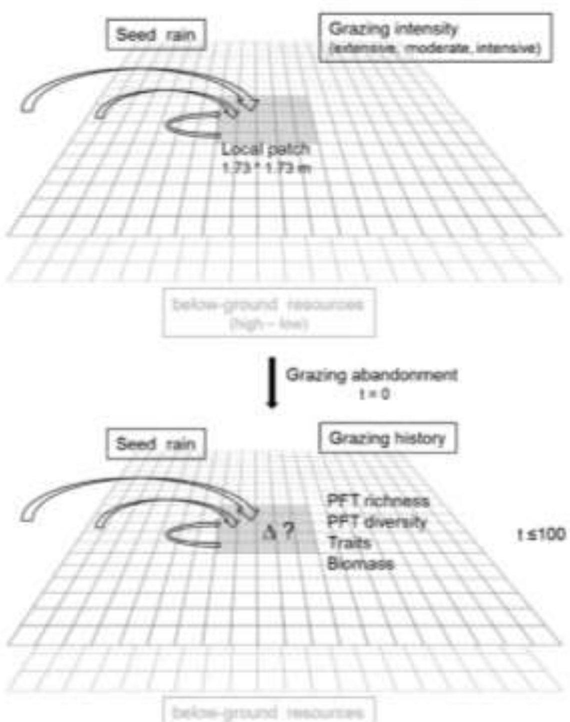
CONCEITUAÇÃO do modelo

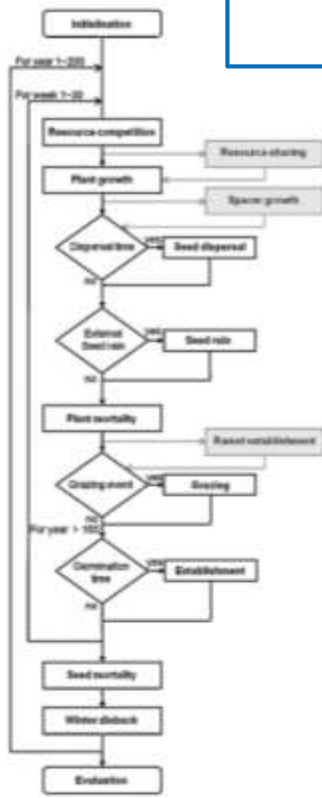
Etapa descritiva, definindo

- as finalidades do modelo a ser construído
- as variáveis de entrada e de saída
- a resolução temporal e espacial
- ...

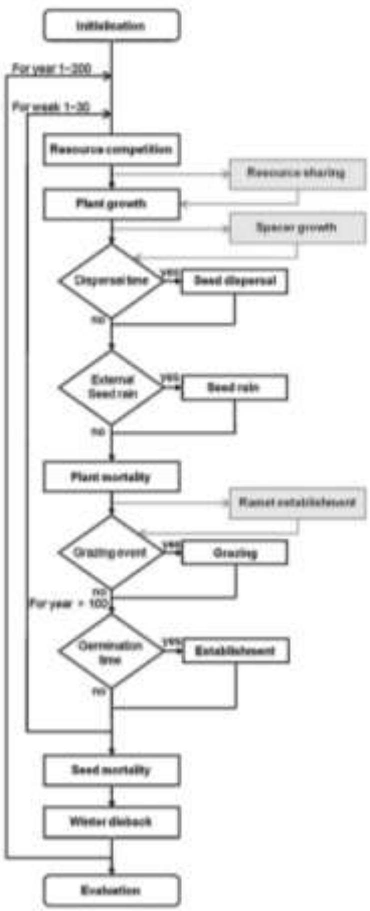
CONCEITUAÇÃO e FLUXOGRAMA







FORMALIZAÇÃO: o algoritmo



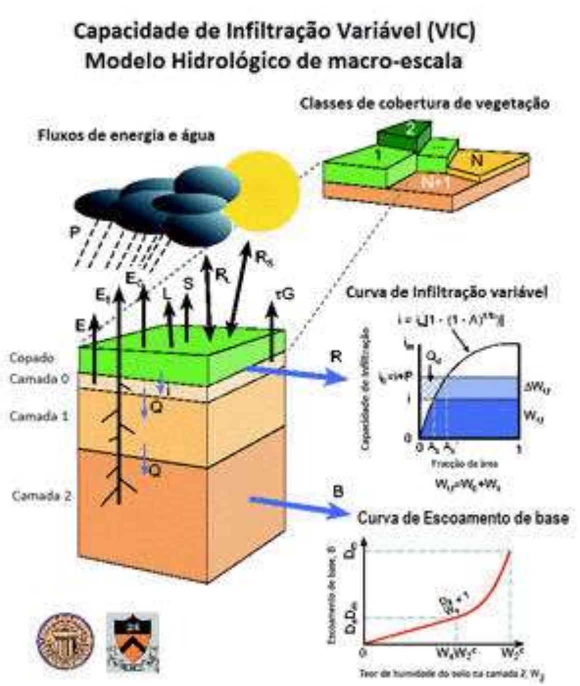
Quadro 2 – Algoritmo Transgenético para o PCCC.

```
Gerar população de cromossomos
Carregar o banco de informações do hospedeiro, BIH
j ←β;
repetir
    i ←1
    repetir
        u ← random(η)
        se (u ≥ j) então
            t ←1
    senão t ← 2
    para cada cromossomo C
        se (t =1) então
            gerar k cadeias e escolher a melhor para compor plasmídio λ
            C'← ataque_plas(C, λ)
        senão
            gerar um transposon λ
            C'← ataque_trans(C, λ)
        fim_se
        se (procedimento_p1(C',C)) então
            C ← C'
            se (campeão(C)) então
              atualiza(BIH,C)
        fim_se
    fim_para
    i ← i+1
até (η/β = i)
j ←j+β
```

CALIBRAÇÃO

- **Utilizam-se dados experimentais (observações) de variáveis de entrada e de saída**
- **Ajuste estatístico de parâmetros (geralmente para minimizar o RMSE**

$$\mathrm{RMSE} = \sqrt{\frac{\sum_{i=1}^{n} \left(P_i - O_i\right)^2}{n}}$$

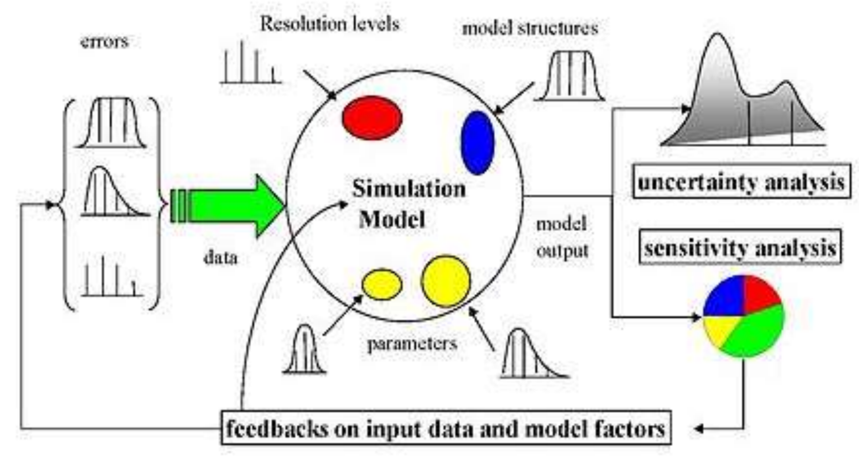


VALIDAÇÃO (ou TESTE)

- Verificar o funcionamento do modelo com dados experimentais diferentes daqueles usados na calibração
- O erro (RMSE) na validação é um indicador do poder preditivo do modelo

UTILIZAÇÃO do modelo

- **Circunstancial:** simulação de cenários de interesse
- **Sistemática:** análise de sensibilidade de parâmetros
- **Tendencial:** estudo do efeito de alterações das condições de contorno segundo tendências esperadas



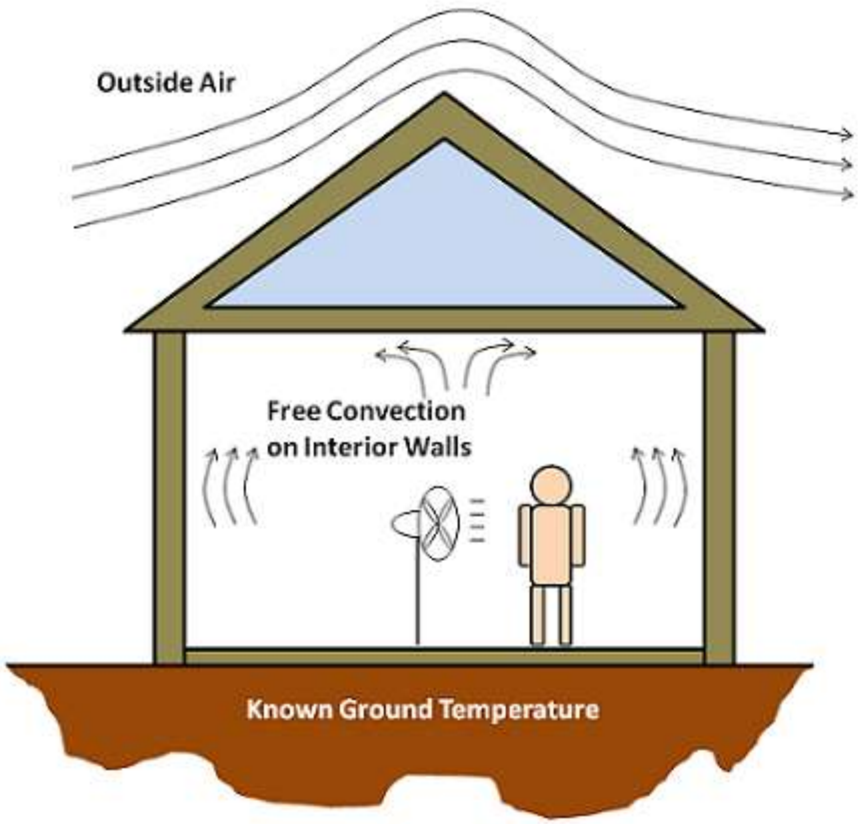
Sobre a modelagem:

"Everything should be made as simple as possible, but not simpler"

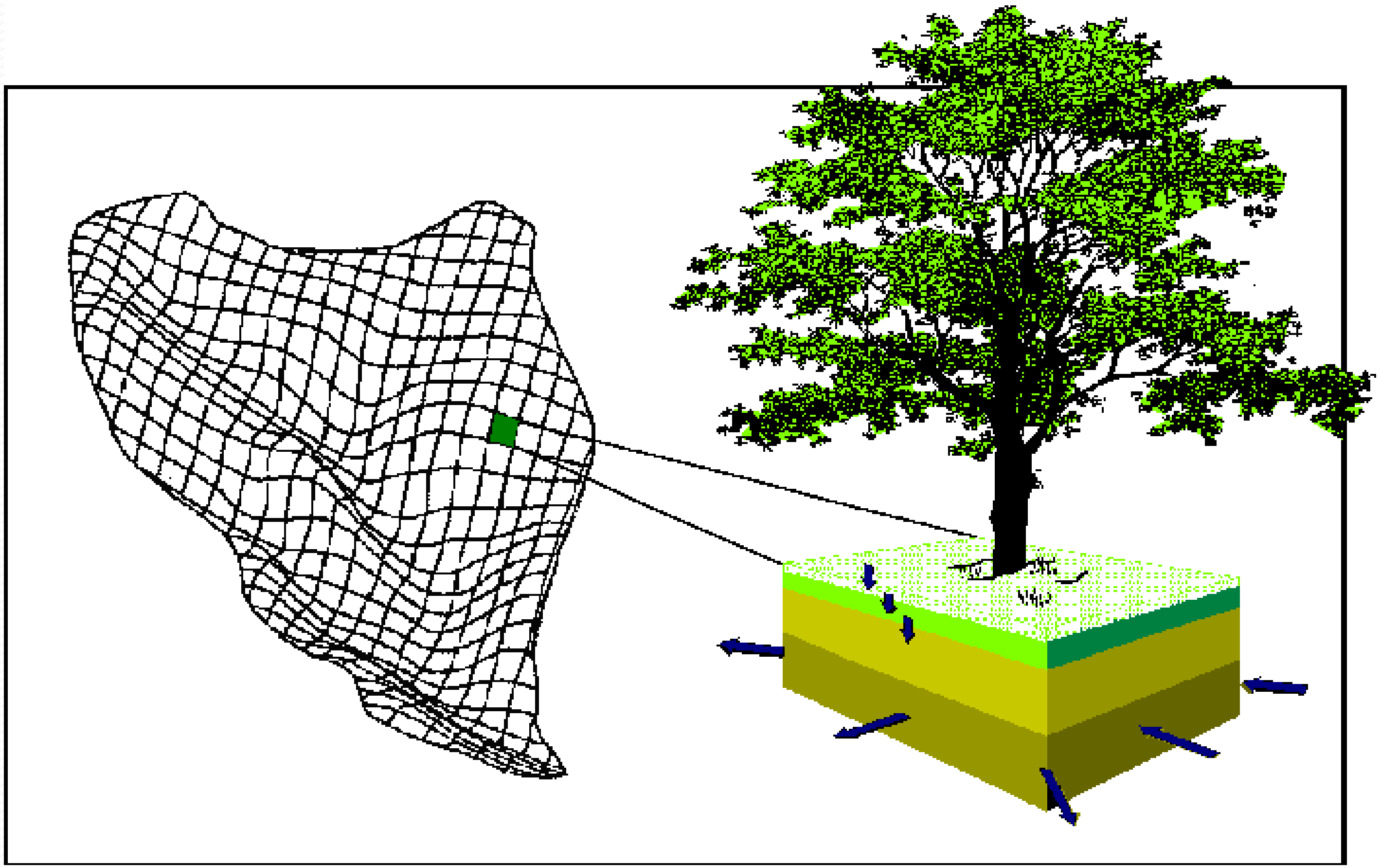
Albert Einstein

Qualquer modelo do sistema agrícola ou ecológico requer conhecimento sobre seu funcionamento, bem como as condições iniciais e de contorno.

Um SISTEMA – o que podemos modelar aqui?



e aqui, o que podemos modelar?

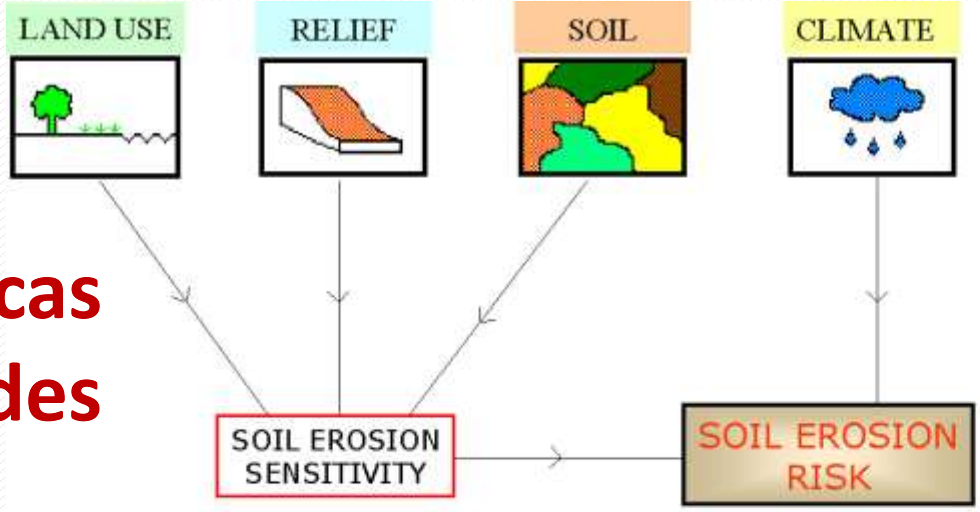


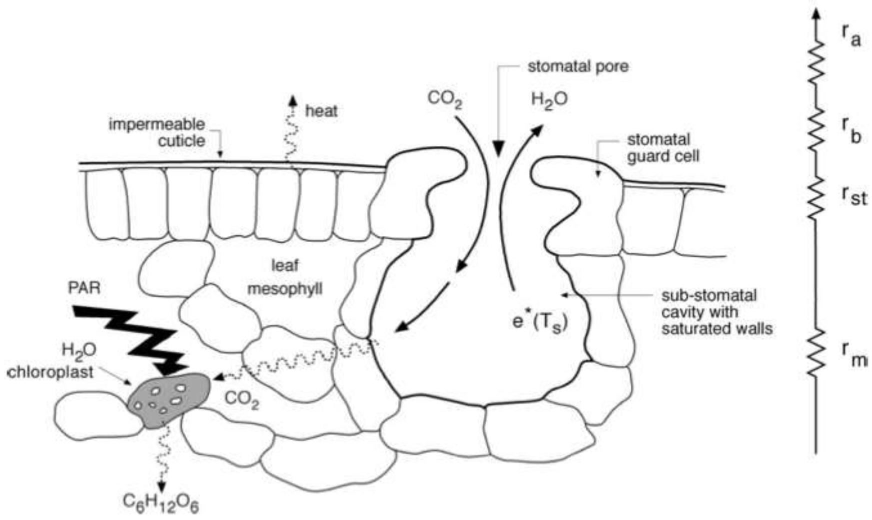
processo

experimentação

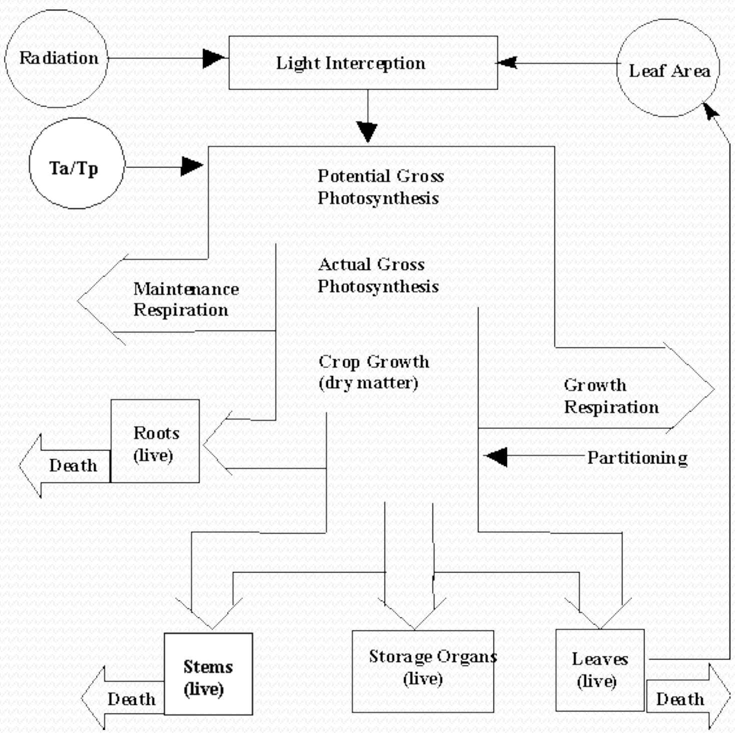
modelo

características
e propriedades

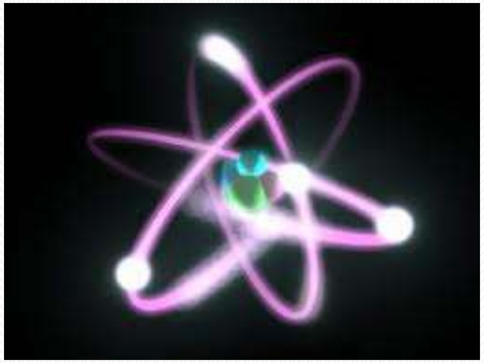


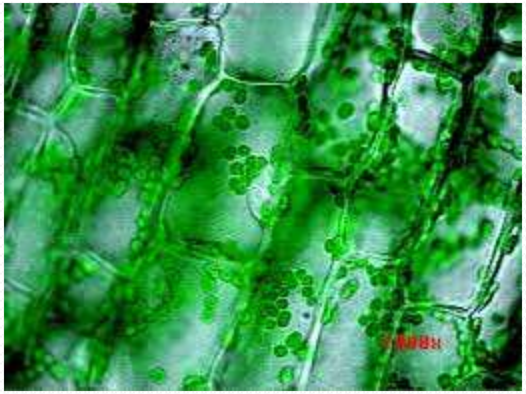


Um fluxograma



Sistemas e Escalas

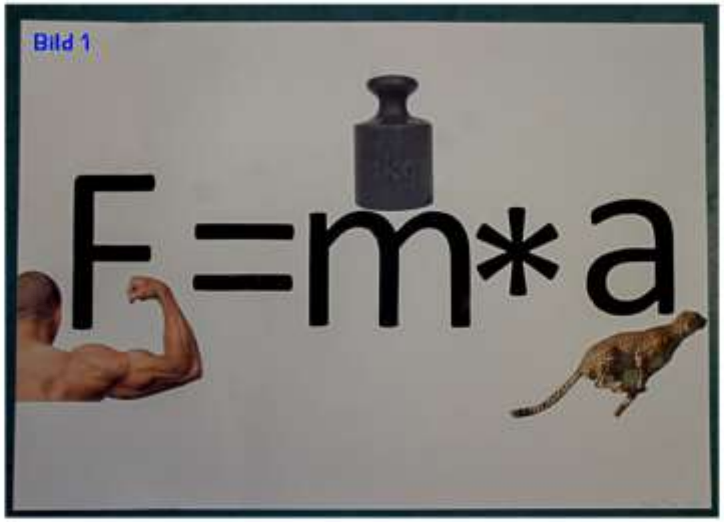


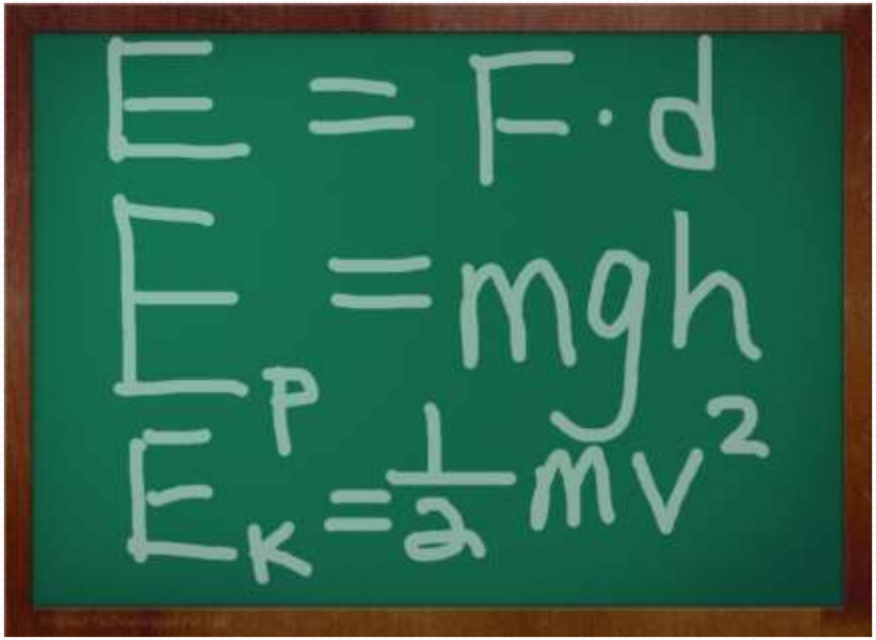


RAIZ - CAPILAR

EXEMPLO DE UM SISTEMA E ESCALAS

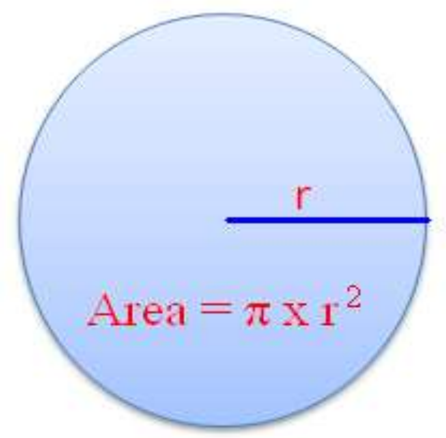
TIPOS DE MODELOS:
1 O MODELO FÍSICO

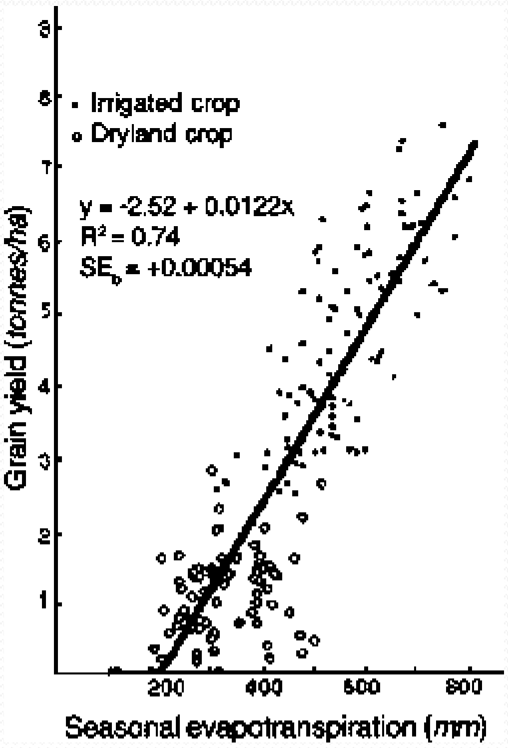




Tipos de modelos:
2 O Modelo Empírico

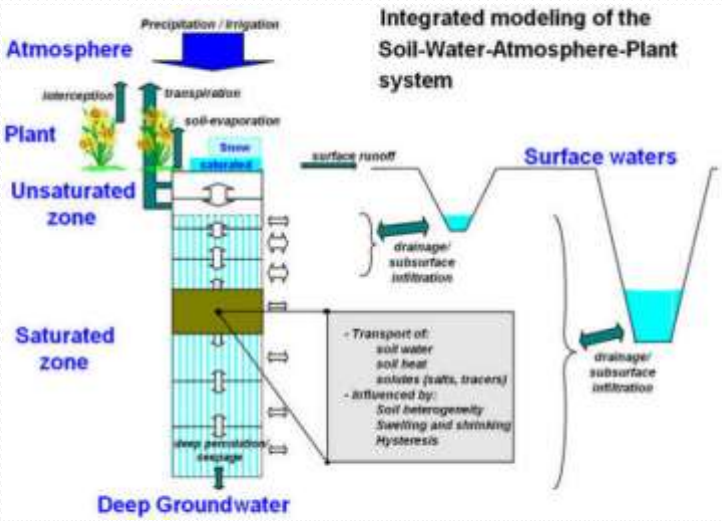
$$F_g = \frac{G m_1 m_2}{r^2}$$

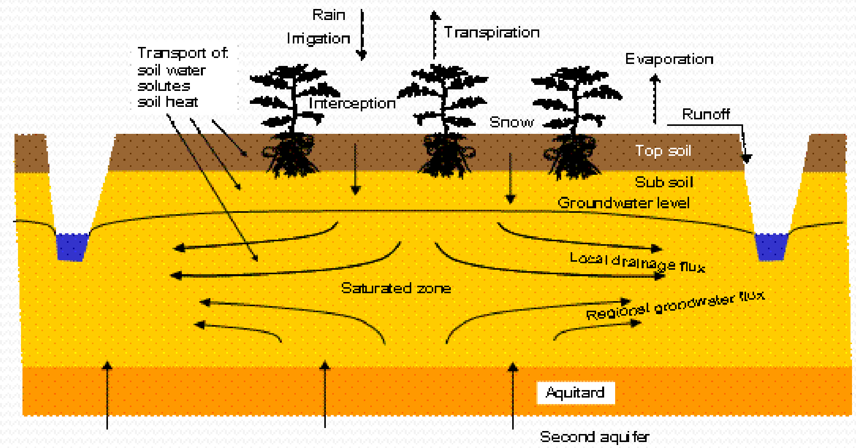




TIPOS DE MODELOS:
3 O MODELO MECANÍSTICO

simulação dinâmica, exemplo “SWAP”





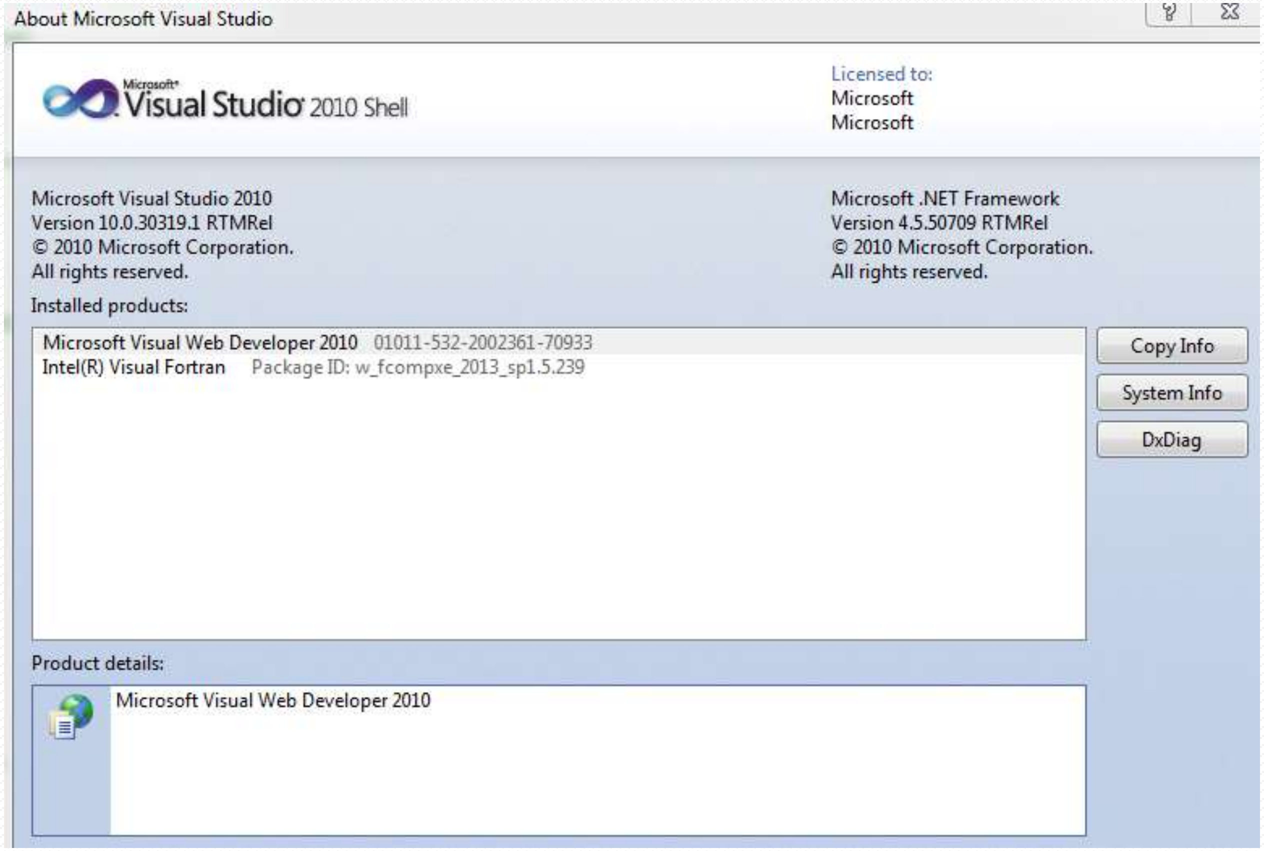
SWAP *Soil Water Atmosphere Plant*

A construção de um modelo (ou: qualquer processamento computacional de dados) requer uma plataforma, uma linguagem

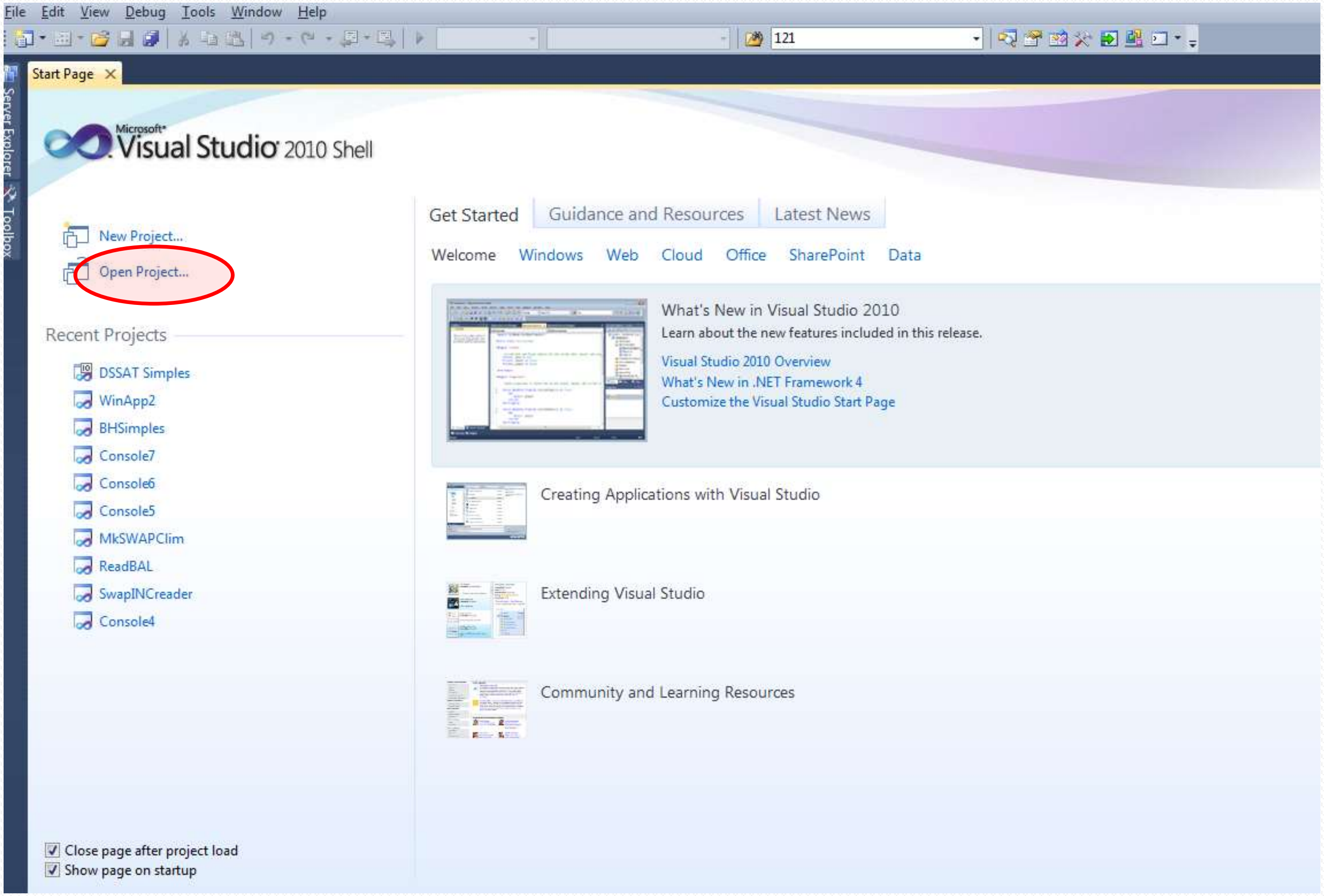
Exemplos:

- **MS Excel (planilha eletrônica)**
- **Fortran, C, Pascal, ... (compilador de linguagem de programação)**

Nessa disciplina iremos utilizar o compilador FORTRAN “Intel® Visual Fortran” acoplado ao Microsoft Visual Web Developer.



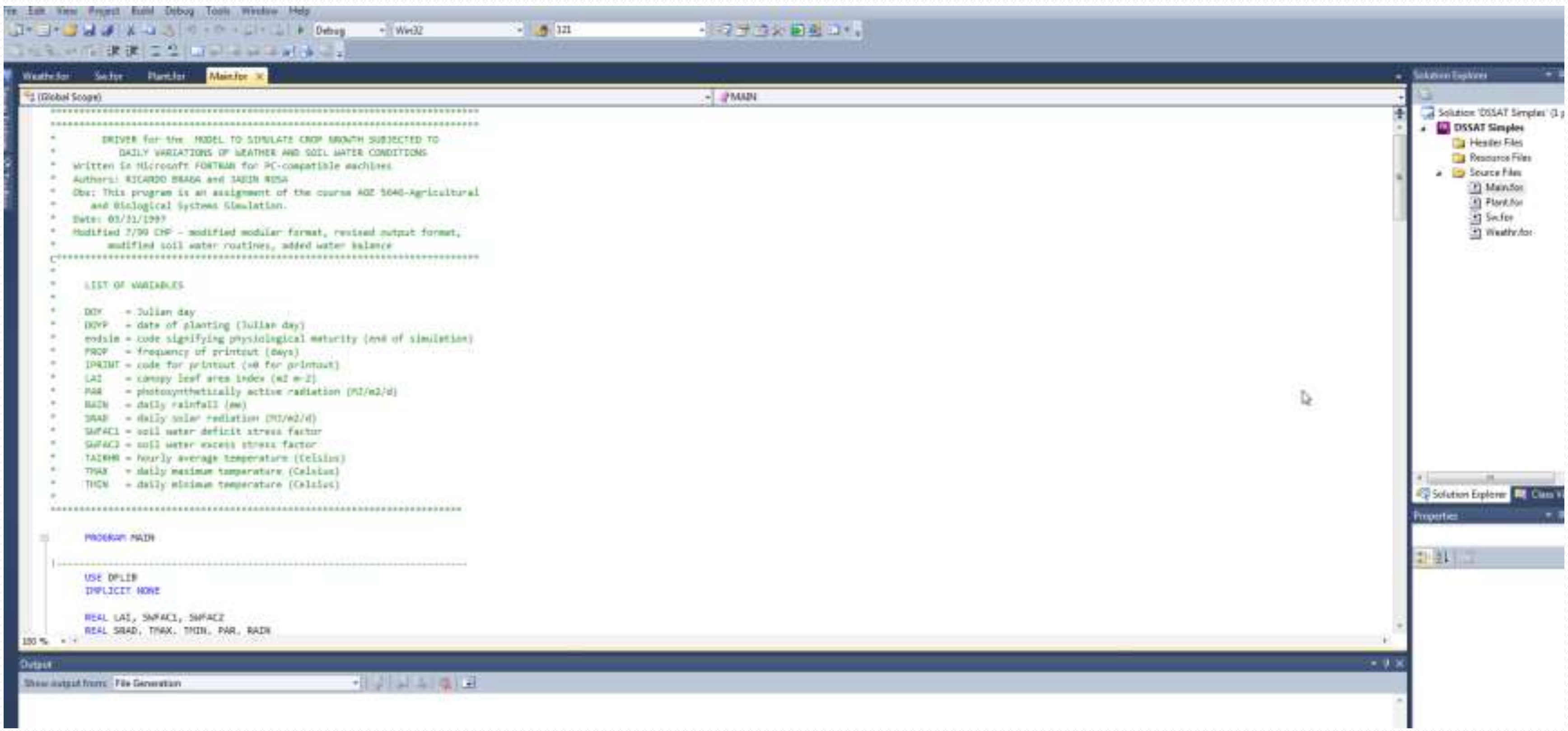
A janela inicial do compilador



O nosso projeto / modelo inicial:

Nome	Data de modificaç...	Tipo	Tamanho
Debug	15/02/2018 11:03	Pasta de arquivos	
DSSAT Simples	14/02/2018 16:37	Pasta de arquivos	
DSSAT Simples.sln	15/02/2018 11:05	Microsoft Visual S...	1 KB
DSSAT Simples.vfproj	15/02/2018 11:05	Intel Fortran Proje...	3 KB

O nosso projeto / modelo inicial:



An Approach for Modular Crop Model Development

August 3, 1999

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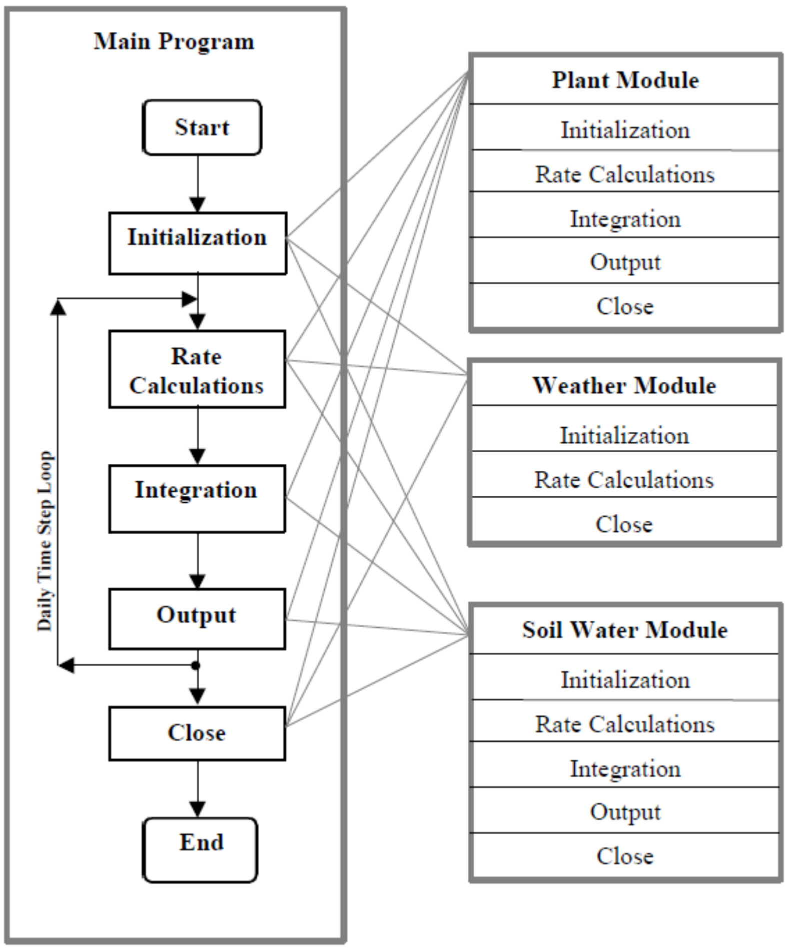
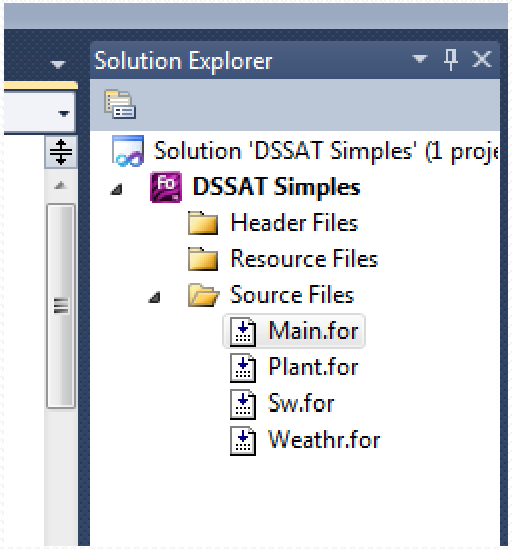


Figure 1. Modular Structure



```fortran
!
************************************************************
      PROGRAM MAIN

!------------------------------------------------------------
      USE DFLIB
      IMPLICIT NONE

      REAL LAI, SWFAC1, SWFAC2
      REAL SRAD, TMAX, TMIN, PAR, RAIN
      INTEGER DOY,DOYP, endsim
      INTEGER FROP, IPRINT

!************************************************************
!************************************************************
!     INITIALIZATION AND INPUT OF DATA
!************************************************************
```

```
!************************************************************************
!************************************************************************
!     INITIALIZATION AND INPUT OF DATA
!************************************************************************
      CALL OPENF(DOYP, FROP)

      CALL WEATHR(SRAD,TMAX,TMIN,RAIN,PAR,'INITIAL   ')

      CALL SW(
     &    DOY, LAI, RAIN, SRAD, TMAX, TMIN,               !Input
     &    SWFAC1, SWFAC2,                                  !Output
     &    'INITIAL   ')                                    !Control

      CALL PLANT(DOY, endsim, TMAX, TMIN,
     &    PAR, SWFAC1, SWFAC2,
     &    LAI,
     &    'INITIAL   ')

!-----------------------------------------------
!     DAILY TIME LOOP
!-----------------------------------------------
      DO 500 DOY = 0,1000
        IF (DOY .NE. 0) THEN

          CALL WEATHR(SRAD,TMAX,TMIN,RAIN,PAR

!***********************************************
```

```
************************************************************************
*     SUBROUTINE OPENF(DOYP)
*     This subroutine opens the simulation control file, and reads date of
*     planting (DOYP)
*
*     SIMCTRL.INP => date of planting, frequency of printout
************************************************************************

      SUBROUTINE OPENF(DOYP, FROP)

      IMPLICIT NONE
      INTEGER DOYP, FROP

      OPEN (UNIT=8, FILE='SIMCTRL.INP',STATUS='UNKNOWN')
      READ(8,5) DOYP, FROP
      IF (FROP .LE. 0) FROP = 1
    5 FORMAT(2I6)
      CLOSE(8)

!-----------------------------------------------------------------------
      RETURN
      END SUBROUTINE OPENF
************************************************************************
************************************************************************
```

SIMCTRL.INP

121 3

DOYP FROP

```fortran
!************************************************************************
!************************************************************************
!     INITIALIZATION AND INPUT OF DATA
!************************************************************************
      CALL OPENF(DOYP, FROP)

      CALL WEATHR(SRAD,TMAX,TMIN,RAIN,PAR,'INITIAL   ')

      CALL SW(
     &    DOY, LAI, RAIN, SRAD, TMAX, TMIN,               !Input
     &    SWFAC1, SWFAC2,                                  !Output
     &    'INITIAL   ')                                    !Control

      CALL PLANT(DOY, endsim, TMAX, TMIN,
     &    PAR, SWFAC1, SWFAC2,
     &    LAI,
     &    'INITIAL   ')

!-----------------------------------------------------------------------
!     DAILY TIME LOOP
!-----------------------------------------------------------------------
      DO 500 DOY = 0,1000
        IF (DOY .NE. 0) THEN

          CALL WEATHR(SRAD,TMAX,TMIN,RAIN,PAR,'RA

!************************************************************************
```

```fortran
      SUBROUTINE SW(
     &    DOY, LAI, RAIN, SRAD, TMAX, TMIN,               !Input
     &    SWFAC1, SWFAC2,                                  !Output
     &    DYN)                                             !Control

!-----------------------------------------------------------------------
      IMPLICIT NONE
      SAVE

      INTEGER   DATE, DOY
      REAL      SRAD,TMAX,TMIN,RAIN,SWC,INF,IRR,ROF,ESa,EPa,DRNp
      REAL      DRN,DP,WPp,FCp,STp,WP,FC,ST,ESp,EPp,ETp,LAI
      CHARACTER*10 DYN

      REAL CN, SWFAC1, SWFAC2, POTINF
      REAL SWC_INIT, TRAIN, TIRR, TESA, TEPA, TROF, TDRN
      REAL TINF, SWC_ADJ

!************************************************************************
!************************************************************************
!     INITIALIZATION
!************************************************************************
      IF (INDEX(DYN,'INITIAL') .NE. 0) THEN
!************************************************************************
        OPEN(3,FILE='SOIL.INP',STATUS='UNKNOWN')
        OPEN(10,FILE='sw.out',  STATUS='REPLACE')
        OPEN(11,FILE='IRRIG.INP',STATUS='UNKNOWN')
```

SIMCTRL.INP | Soil.inp

```
   0.06      0.17      0.28    145.000      0.10     55.00     246.5
    WPp       FCp       STp         DP      DRNp        CN       SWC
(cm3/cm3) (cm3/cm3) (cm3/cm3)      (cm)  (frac/d)        -      (mm)
```

Table 2 – Input data read for soil water balance module

Variable Name	Definition	Units
CN	Runoff curve number	--
DP	Depth of soil profile	cm
DRNp	Daily drainage percentage (fraction of void space)	1/day
FCp	Soil water content at field capacity (fraction of void space)	cm^3/cm^3
STp	Soil water content saturation (fraction of void space)	cm^3/cm^3
SWC	Soil water content in the profile (value read from file represents initial soil water content)	mm
WPp	Soil water content at wilting point (fraction of void space)	cm^3/cm^3

5.3 Integration

The integration portion of the soil water balance module updates the value of the soil water content based on the computed values of infiltration (INF), soil evaporation (ESa), plant transpiration (EPa), and vertical drainage (DRN):

```
SWC = SWC + (INF -
```

The computed value is limite
minimum of zero. If the com

Variáveis de estado (*State variables*) Biomassa Y (kg/ha)

Variáveis de taxa (*Rate variables*) Taxa de crescimento dY/dt (kg/ha/d)

Integração $Y_{t+1} = Y_t + dY/dt * dt$ (kg/ha)

estado

taxa

passo de tempo