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LECTURE 08: INTRODUCTION TO PLANT GROWTH MODELS

Models are only useful if they help you solve problems

ANALYSIS
- Why certain things happen
- How a system works

Everything should be made as simple as possible, but not simpler, A. Einstein

SOMETHING TO THINK

1. Everything happens for a reason. Nothing happens by chance or by means of good luck (http://www.phoenixmasonry.org/everything_happens_reason.htm)
2. **The law of causality** is the basis of all our intellectual capability (Schopenhauer).
   - We call X a necessary condition for Y; Y cannot happen without X.

     X ì Y

   - And all necessary conditions taken together make a sufficient basis (a cause): if there is no lacking condition for Y, Y *must* happen.

3. Everything is relative as we almost always use a reference to value something.
   - A watch of somebody at stationary position ticks at a faster rate than the watch of somebody on a train running fast.

$$\mathbf{t} = \frac{\mathbf{t}_0}{\sqrt{1 - \frac{\mathbf{v}^2}{\mathbf{c}^2}}}$$

   - The time is felt to run very fast for busy people to do many things, and very slow for others in a waiting position.

STRUCTURED TASK

1. English Presentation
   - ~~Every student has to make English Presentation~~
2. Dictionary
   - Take your English dictionary every time I give my lecture
3. My Dictionary
   - Buy a writing book (100-pages) and name it MY DICTIONARY
   - Write down all English words with Indonesian meanings that you do not know yet

4. Literature Study
- Every student has to undertake literature study to obtain more and detail information as to the lecture materials

5. Study Groups
- Organize your study group, 5 member each to discuss the lecture materials

6. Paper (NO COVER, NO COVER, NO COVER,)
- *Write a paper about Plant Growth Analysis, an extended summary of* a published papers in international Journal (internet)
- *One (1) page only, single space arranged in several paragraphs (4-5 sentences/paragraph), font (Times New Roman 12)*

LECTURE OUTCOMES

After mastering the lecture materials at the end of the lecture, students should be able

1. to apply modeling approach to understand, explain, and develop ways to improve performance of agriculture systems
2. explain various models that can be used to study plant systems in relation to plant growth
3. Initiate the development of a model using conceptual approach

LECTURE FLOW

1. INTRODUCTION
2. DEFINITION
3. TYPES OF MODELS
    1. **Empirical/Statistical Models**
    2. **Mechanistic Models**
    3. **Static Models**
    4. **Dynamic Models**
    5. **Deterministic Model**
    6. **Stochastic Models**
    7. **Simulation Models**
4. CONCEPTUAL MODELS

1. INTRODUCTION

1. Analysis

Why we need analysis

- *Why certain things happen*
- *How a system works*

What is Analysis

- *Analysis*
- *Systems analysis*
- *Systems synthesis*

2. Model Analysis Approach

1. EVENTS

2. MODELLING

3. INFORMATION TECHNOLOGY

4. A LEVEL OF CONTROL

1. Analysis

Why certain things happen

- Why a ripe durian fell down to the ground
- Newton asked himself ; "*Why should that apple always descend perpendicularly to the ground, why should it not go sideways, or upwards?*"

How a system works

- How does it (*the apple falling perpendicularly to the ground*) work
- The apple is accelerated (an increase in its velocity), since its velocity changes from zero as it is hanging on the tree and moves toward the ground, so there must be a force that acts on the apple to cause this acceleration.

- Further analysis led to the development of the Newton's Second Law (F = ma; F = force, m = mass & a = acceleration).

Analysis is

- Detailed examination of the elements or structure of something, typically as a basis for discussion or interpretation.
- The process of separating something into its constituent elements.

Systems analysis is

- **the dissection of a system into its component pieces to study how those** component pieces interact and work.

Systems synthesis is

- the re-assembly of a system's component pieces back into a whole system-it is hoped an improved system.

2. Model Analysis Approach

1. EVENTS

In our daily lives, many events happen surrounding us that are necessary or challenging to understand. However, many events such as the growth of plants result from complex processes which are not easy to study

2. MODELLING

Modelling in agriculture, started in the 1970s, is an alternative approach to understand the agriculture systems owing to its inherent complexity characterized by many organizational levels from molecular to crop level

3. INFORMATION TECHNOLOGY

Rapid accumulation of knowledge in the agricultural field and the increased accessibility to information technology have contributed to the development of a wide number of agricultural models over the last three decades

4. A LEVEL OF CONTROL

The demand for a higher level of control of the environment in which the plants grow increases also support the development of models

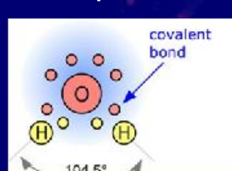
- This control ranges from better strategies of soil management to "closed" environments, where most, if not all, the atmospheric and soil variables can be adjusted.

2. DEFINITION

1. A model, in the most general sense, is anything used in any way to represent anything else.
2. A model is a description of reality
   - Models ≠ reality
   - Usually a simplification
   - Helps to understand reality
3. “Essentially, all models are wrong, but some are useful" (Box and Draper, 1987)
4. A model is representation of a system that allows for investigation of the properties of the system and, in some cases, prediction of future outcomes.

5. The main aim of constructing crop models is
   - to aid in explaining, understanding or improving performance of a system
   - to obtain an estimate of the harvestable (economic) yield

- Based on the above definitions, models can be a prototype, a simplified representation, as well as an abstraction of a reality (system).
- Examples



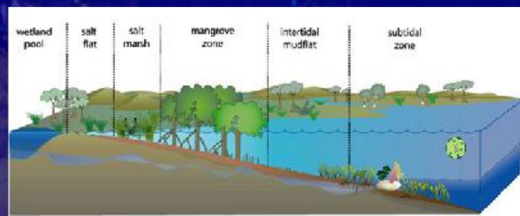
http://www.nrri.umn.edu/worms/images/forest/ecosystem_fig3.gif

DEFINITION

- The incomplete status of present knowledge and the complexity of the system make impossible to completely represent the system in mathematical terms
  - Unlike in the fields of physics and engineering, universal models do not exist within the agricultural sector
  - Models are built for specific purposes and the level of complexity is accordingly adopted.
- Inevitably, different models are built for different subsystems and several models may be built to simulate a particular crop or a particular aspect of the production system.

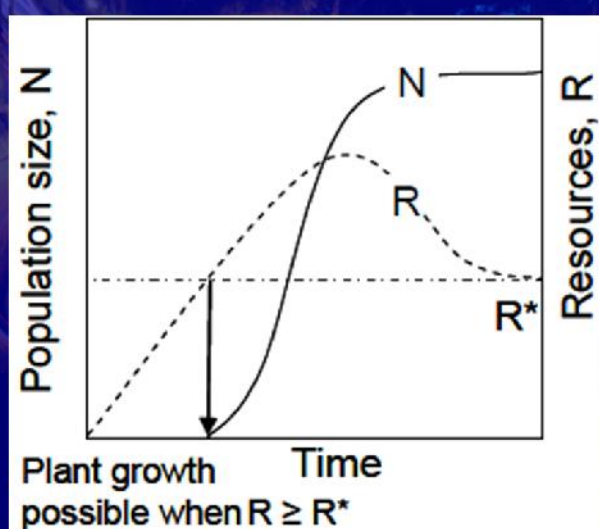
3. TYPES OF CROP MODELS

- Models can be classified in different types:
  - Conceptual models and Physical or Mathematical models (Acock & Acock, 1991), or
  - Empirical models and Functional (Mechanistic) models (Thornley and Johnson, 1990)
- Hall and Day (1977) describe four types of models that may also be viewed as stages in the model-building process.
  1. ***Conceptual Model:*** Synthesis of current scientific understanding, field observation and professional judgment concerning the species, or ecological system



Conceptual model of estuarine vegetation

2. ***Diagramatic Model:*** Explicitly indicates interrelationships between structural components, environmental attributes and ecological processes
3. ***Mathematical Model:*** Quantifies relationships by applying coefficients of change, formulae of correlation/causation
4. ***Computational Model:*** Aids in exploring or solving the mathematical relationships by analyzing the formulae on computers.



A conceptual model of plant growth as a function of resources. Source: Nuttle et al. (?)

The most pertinent aspects of crop models are as follows

1. **Empirical/Statistical Models**
2. **Mechanistic Models**
3. **Static Models**
4. **Dynamic Models**
5. **Deterministic Model**
6. **Stochastic Models**
7. **Simulation Models**

1. Empirical/Statistical Models

- The empirical models, sometimes called correlative or statistical models, describe relationships among variables without referring to the correlated processes
- Empirical models are **direct descriptions of observed data** and are generally expressed as regression equations (with one or a few factors)
- Examples of such models include
  - the response of crop yield to fertiliser application,
  - the relationship between leaf area and leaf size in a given plant species
- The specificity of the models (site and time) is one of the limitation of this model, so the models can not be used universally

- An example of empirical models at the organ level is the leaf area index of sugarcane calculated as a function of Growing Degree Days (GDD) (Teruel , 1995) as follows

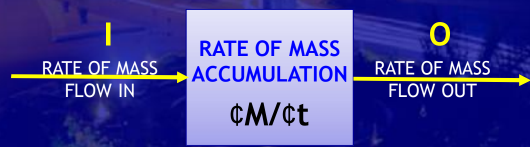
$$\mathbf{LAI_n} = \left(\sum_{i=1}^{n} \mathbf{GDD_i}\right)^{b} \mathbf{e}^{\,a+c\sum_{i=1}^{n} GDD_i}$$

where **LAI_n** = leaf area index at t (time) = n, **GDD**i = degree-days (^{0}C.day), and *a*, *b* and *c* are the fitting constants.

2. Mechanistic Models

- The mechanistic models (models at the level of processes or simulators), also called **explanatory models**, try to represent cause-effect relationships among the variables.
- A mechanistic model describes the behaviour of the system in terms of lower-level attributes. Hence, there is some mechanism, understanding or explanation at the lower levels.
- These models have the ability to mimic relevant physical, chemical or biological processes and to describe how and why a particular response results.

- An example of mechanistic models is mass balances which are statements of the principle of conservation of mass



- Rate of mass accumulation = $\delta M/\delta t$, rate of mass flow in = I, and rate of mass flow out = O
- So, $\delta M/\delta t = I - O$
- If $\delta M/\delta t = 0$, the I = 0

3. Static Models

- A static model is one that does not contain time as a variable even if the end-products of cropping systems are accumulated over time, e.g., the empirical models.
- An example is the model of animal growth rate (G) as a function of feeding rate (F)

$$G = G_1 \frac{F}{K + F} - G_2$$

G = the growth rate of the animal, F = the rate of food supply to the animal, G1, G2 & K = parameters (constants), G2 = -G at F = 0 (the animal is loosing weight), K = F at 1/2G

4. Dynamic Models

- In contrast dynamic models explicitly incorporate time as a variable, and most dynamic models are first expressed as differential equations

$$\frac{\partial W}{\partial t} = b$$

$$W = W_0 + bt$$

where W = the weight of an organism (animal or plant), t = time, and W0 and b = parameters. W0 is the value of W at t = 0, and b is the sole of the growth curve

5. Deterministic and Stochastic Models

- A deterministic model is one that makes definite predictions for quantities (e.g., animal liveweight, crop yield or rainfall) without any associated probability distribution, variance, or random element.
- However, variations due to inaccuracies in recorded data and to heterogeneity in the material being dealt with, are inherent to biological and agricultural systems.
- In certain cases, deterministic models may be adequate despite these inherent variations but in others they might prove to be unsatisfactory e.g. in rainfall prediction.
- The greater the uncertainty in the system, the more inadequate deterministic models becomes and in contrast to this stochastic models appears

6. Simulation and optimizing models

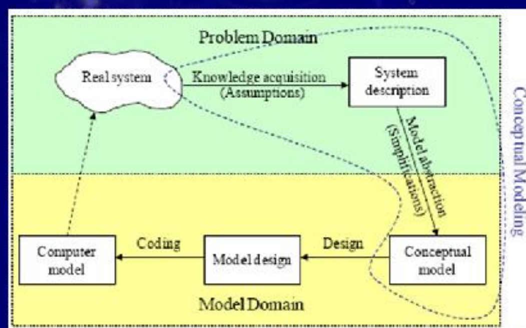
- Simulation models form a group of models that is designed for the purpose of imitating the behaviour of a system.
- They are mechanistic, and in the majority of cases they are deterministic. Since they are designed to mimic the system at short time intervals (daily time-step), the aspect of variability related to daily change in weather and soil conditions is integrated.
- The short simulation time-step demands that a large amount of input data (climate parameters, soil characteristics and crop parameters) be available for the model to run.
- These models usually offer the possibility of specifying management options and they can be used to investigate a wide range of management strategies at low costs. Most crop models that are used to estimate crop yield fall within this category.

IV. CONCEPTUAL MODELS

How is a model developed?

1. Conceptual models (mental models) can be used as a first step in the development of more complex models to help highlight important connections in real world systems and process
2. This can be defined as the process of information in understanding things in our surrounding environment to work.
   - Why certain things happen
   - How a system works

3. The conceptual model is the bridge between the real system (problem domain) and the model, which is a simplified representation of the real system (model domain).
4. Through knowledge acquisition we gain an understanding of the real system and through model abstraction we design a conceptual model.



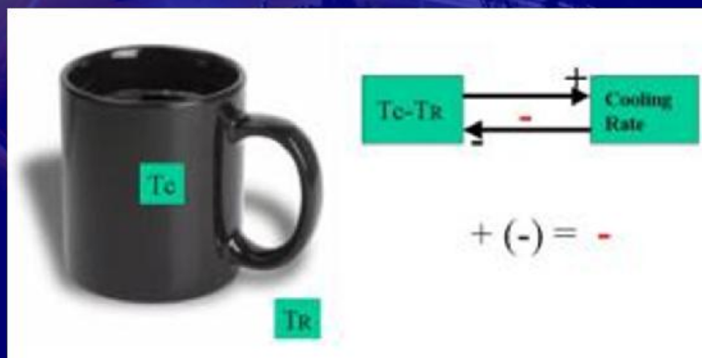
Artefacts of Conceptual Modelling (Robinson, 2010)

5. A conceptual model is a descriptive model of a system based on qualitative assumptions about its elements, their interrelationships, and system boundaries
   - This is a theoretical construct that represents something, with a set of variables and a set of logical and quantitative relationships between them.
   - Models in this sense are constructed to enable reasoning within an idealized logical framework about these processes and are an important component of scientific theories.
6. How a cup of coffee cools down can be approached by a conceptual model

➢How a cup of hot coffee cools down with time

T_C = coffee temperature
T_R = Room temperature

Assume K = cooling rate



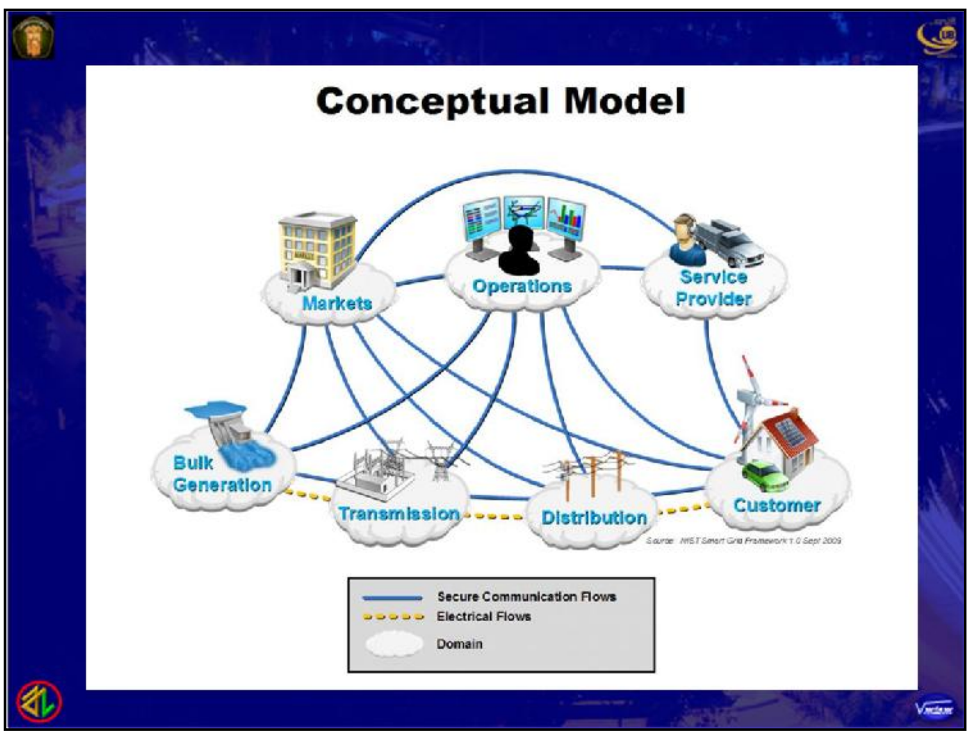
The higher the difference between T_C and T_R (T_C - T_R), the higher the cooling rate (K), and a high K will lessen (T_C - T_R) in proportion

Test your hypothesis

Measure the temperature of coffee at 0, 5, 10, 15, 20 & 25 minutes after it was made (each group)

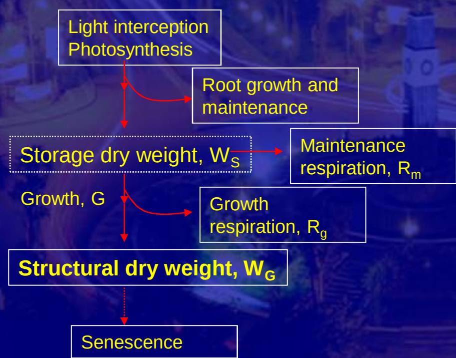
No.	Time (minutes)	Temperature (^{0}C)		K = T_C-T_R	T_{Cn}-T_{Cn-1}
		Room (T_R)	Coffee (T_C)		
1	0				
2	5				
3	10				
4	15				
5	20				
6	25				


THANK YOU
Спасибо
謝謝
شكراً


Conceptual Model
Markets
Operations
Service Provider
Bulk Generation
Transmission
Distribution
Customer
Secure Communication Flows
Electrical Flows
Domain

Presentation of VATO

A model of grass growth



$$\left[\frac{dW_S}{dt}\right] = P - G/Y - Rm$$

$$\left[\frac{dW_G}{dt}\right] = G - S$$

$$\left[\frac{dL}{dt}\right] = ¢°G - S$$

$$¢ = ¢m(1 - W/Ws)$$

A compartmental model based on an hourly time step

Johnson et al. (1983) A model of Grass Growth, *Ann. Bot.* 51, 599-609.
Johnson and Thornley (1983) Vegetative crop growth model incorporating leaf area expansion and senescence, and applied to grass, *Plant, Cell and Environment* 6, 721-729.

IRSN EMRAS II, Paris 09/28/2009

- Conceptual Model in Cassava: The amount of biomass partitioned into storage root production during cassava crop growth can be conceptualized in terms of the mass balance equation (Gray, 2000):

$$\frac{\mathrm{d}R_s}{\mathrm{d}t} = A_d - R - G_l - G_{sb} - G_{rf} - \frac{\mathrm{d}C}{\mathrm{d}t}$$

where
R_S = the storage roots
A_d = canopy photosynthetic rate
R = the total respiratory substrate demand,
G_l = the gross growth rate of leaves and petioles,
G_{sb} = the gross growth rate of stems and branches,
G_{rf} = the gross growth rate of fibrous roots and
C = the reserve substrate carbon pool.