Suggested citation: Hassan, Q.K. 2018. Lecture note on: Modelling process, *In Environmental Modelling*, Calgary, AB, Canada.

# *Environmental Modelling*
# (ENGO 583/ENEN 635)

**Lecture Note**
**on:**
**Modelling Process**

**Dept. of Geomatics Engineering; and Centre for Environmental Engineering Research and Education**
**Schulich School of Engineering**
**University of Calgary**

## Review of Last Topics

Suggested citation: Hassan, Q.K. 2018. Lecture note on: Modelling process, *In Environmental Modelling*, Calgary, AB, Canada.

## Topics of Discussion

- Overview of modelling process
- Identifying the problem
- Developing the conceptual model
- Constructing the computational model
- Evaluating the model
- Two example cases
  - Our class model
  - Interaction between solar radiation and plant $CO_2$ exchange

## Steps in Modelling Process

**Step 1: Identifying the problem**

**Step 2: Developing the conceptual model**

**Step 3: Constructing the computational model**

**Step 4: Evaluating the model**

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## Identifying the Problem

- Identification of the problem is the first and most critical step of the environmental modelling process.
- When setting out to identify and characterize a problem, it is often most appropriate to involve the stakeholders, such as the modellers, intended knowledge users and decision makers.
- When approaching a problem, it is important to first develop a comprehensive definition of the system. Both spatial and temporal dimensions of the processes should be investigated. For example:
    - If the intention is to develop flood forecasting model at local, regional, and country-levels, then the details required in each of the cases would vary significantly.

## Developing the Conceptual Model

- Upon defining the problem, an environmental modeler should develop a conceptual model.
- A conceptual model can be in the form of a schematic/block diagram, pictorial, or written statements. Whatever form it takes, the relationships and flows amongst the components should be clearly be defined.
- In this phase, it is common to formulate a set of assumptions. It may be possible for some of the assumptions to be proven unnecessary later on.
- The conceptual model will also define the data requirements in order to accomplish the modelling objectives.

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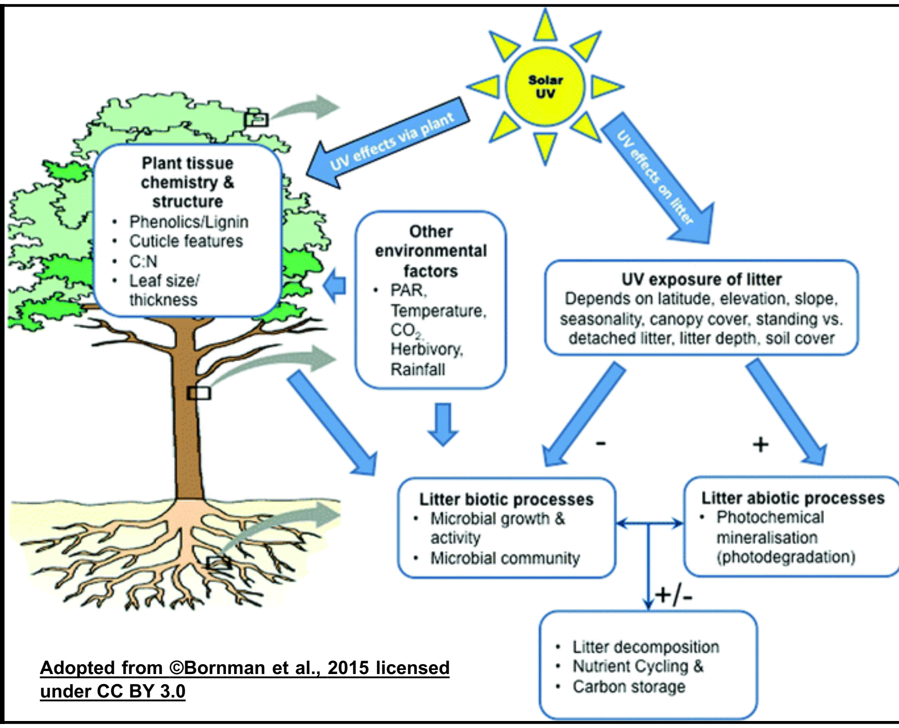
**Conceptual model illustrating the effect of ultra violet radiation on terrestrial litter decomposition**

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## Constructing the Computational Model (1)

- **After the development of the conceptual model, the focus should be on the determination of the type of model required to solve the problem.**

- **EPA (2009b) defines the following steps to transform a conceptual model into a computational one as follows:**
  - **Develop appropriate algorithms**
  - **Formulate equations**
  - **Implement equations into computer code**
  - **Choosing hardware platforms and software**
  - **Developing a user interface (if applicable)**
  - **Calibration/parameter determination**

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## Constructing the Computational Model (2)

- **There are many available options for the software to be used for modelling, including:**
  - **Spreadsheet packages**
  - **Specialized modeling software**
  - **High-level computer programming and scripting languages**
  - **Integrated modeling environments**
- **However, the selection of the software highly depends on the following factors:**
  - **Accessibility**
  - **Price**
  - **Personal preference**
  - **Prior knowledge/experience**
  - **How hard it is to learn a specific software**

## Evaluating the Model (1)

- **The aim of model evaluation is to guarantee the quality of the model and how it represents the environmental issue under investigation.**
- **EPA (2009a) defines the fundamental parts of model evaluation process as follows:**
  - **Peer Review: offers a way of independent examination and review of the environmental models.**
  - **Quality Assurance (QA) Project Planning: defines how model evaluation may be executed. It also ensures whether a model performs the intended operation, and assesses the data quality as well.**
  - **Model Corroboration: evaluates how a model corresponds to real conditions using qualitative and/or quantitative analysis.**
  - **Sensitivity and Uncertainty Analyses: sensitivity analysis quantifies the impact of changes in input values of the entities on the model outputs. Uncertainty analysis examines how the model may produce potential errors in the model outcomes.**

## Evaluating the Model (2)
### Other Aspects

**Verification:**

**In environmental modelling, the words "verify" and "validate" are not same! Verification is the process of investigating of the algorithms, logic and numerical technique in the computer code. Thus, it mimics the conceptual model and also execute properly in generating desired outcome.**

**On the other hand, validation is the process of assessing the reliability of a model output in the context of issue under investigation.**

**Model Simplification:**

**A modeller should always consider constructing simpler conceptual models, as more complex ones may cause uncertainty in model outcomes. Consequently, the model building process, including the mathematical formulation of the model, computing algorithm, verification, validation and application may be easier to accomplish.**

## Our Class Model

**Problem Statement**

- **Exploring the relationship among some of the physical variables in (an) ENGO 583/ENEN 635 classroom. Those include:**

- **Height and weight**
- **Height and shoe size**
- **Weight and shoe size**

The 3rd year Geomatics Engineering Class in Fall 2017 has permitted Q. Hassan to use this picture in lecture note production.

## Our Class Model

### Conceptual Model

**There may be relationships among the following the physical variables:**

- **Height**
- **Weight, and**
- **Shoe size**

### Assumption

**For adults**

- **For a specific person, height and shoe size don't change over time. However, weight can vary.**
- **The height and weight also can be related, but with a less possibility, and this assumption is also applicable for the relation between weight and shoe size.**

## Our Class Model

| | A | B | C |
|---|---|---|---|
| 1 | Height (cm) | Weight (kg) | Shoe no. |
| 2 | 178 | 70 | 9 |
| 3 | 157 | 59 | 8 |
| 4 | 177.8 | 72.6 | 10 |
| 5 | 177 | 72 | 10 |
| 6 | 170 | 77 | 9 |
| 7 | 160 | 60 | 7.5 |
| 8 | 178 | 70.5 | 10 |
| 9 | 155 | 40 | 5.5 |
| 10 | 161 | 70.5 | 7 |
| 11 | 163 | 57 | 7.5 |
| 12 | 163 | 54 | 7.5 |
| 13 | 185 | 64 | 8 |
| 14 | 173 | 57 | 9 |
| 15 | 173 | 60 | 8 |
| 16 | 170 | 63 | 9 |
| 17 | 156 | 56 | 6 |

### Data Acquisition

- **Data was requested to the students in the classroom, without revealing their identities during 2009-2011**
- **2009 data was employed in the development of the model**
- **2010 and 2011 data were used to validate the model**

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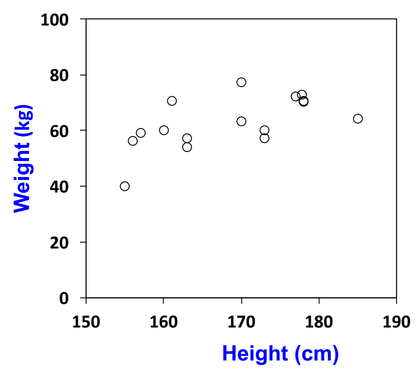
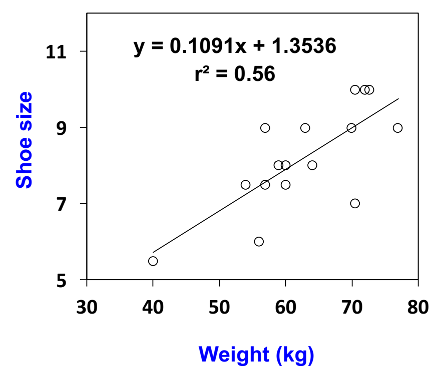
## Our Class Model

### Constructing Computational Model



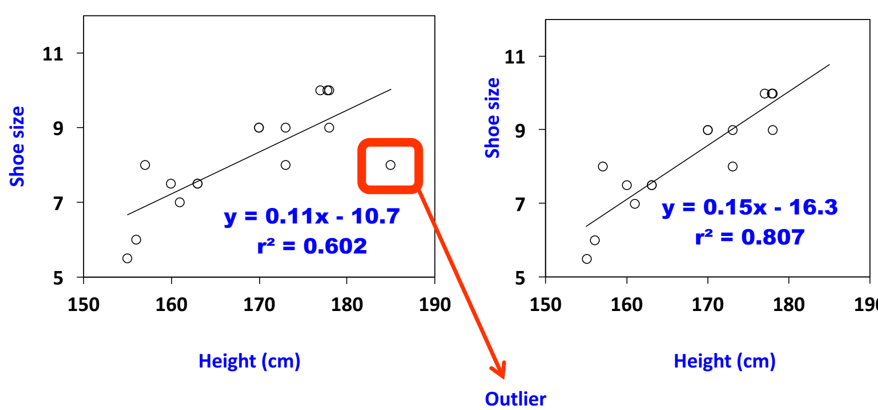




- **The scatter plot above reveals a weak relationship between height and weight**

- **A good relationship ($r^2$=0.56) exists between weight and shoe size**

## Our Class Model

### Constructing Computational Model




**A strong relationship ($r^2$=0.81) exists between height and shoe size without the outlier.**

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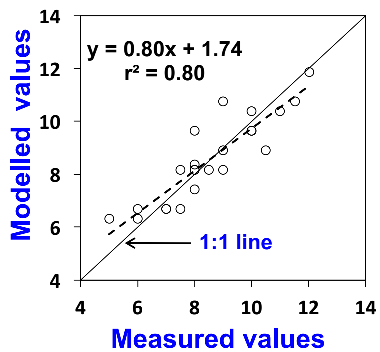
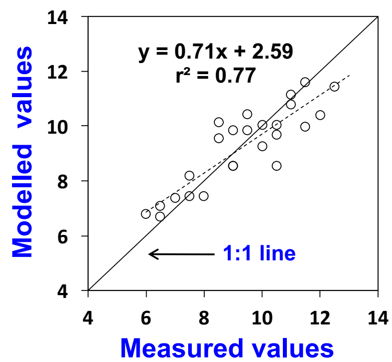
## Our Class Model

### Model Evaluation: Measured vs. Modelled Shoe Sizes




(a) 2010




(b) 2011

## Our Class Model

### Model Evaluation

- **The relation between height and shoe size during 2009, was used to model/predict the shoe size as a function of height.**
- **The developed model using 2009 data could capture ~80% and 77% variability in 2010 and 2011, respectively.**
- **In environment systems, coefficients of determination between 40-80% are generally considered ~~as~~ acceptable.**
- **A number of factors might enhance the relations:**
  - **Segregation of male and female students**
  - **Separation of the origin of the students**

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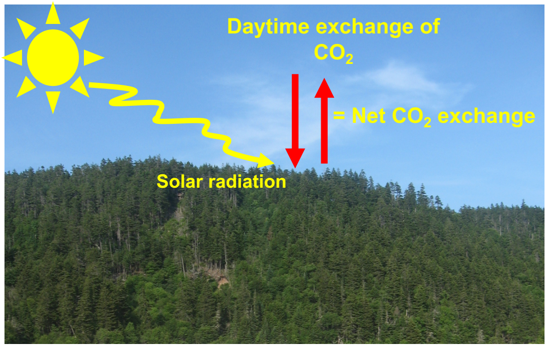
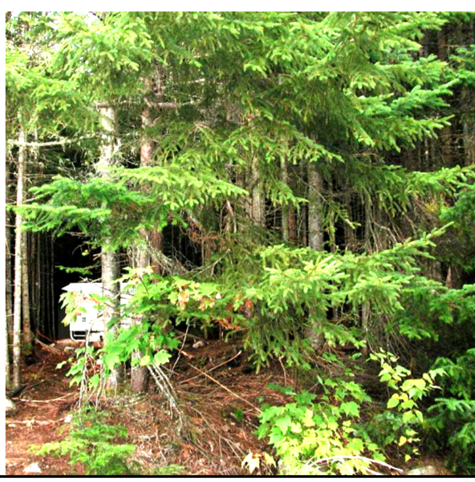
## A Simple Modelling Example:
**Interaction between Solar Radiation and Plant $CO_2$ Exchange**




## A Simple Modelling Example:
**Interaction between Solar Radiation and Plant $CO_2$ Exchange**

**Problem Statement**

- **Understanding the $CO_2$ exchange for the species of balsam fir, i.e.,**



- **the most commercially important tree species**
- **the species that occupies ~19% of total forest in the eastern Canadian province of New Brunswick**

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## A Simple Modelling Example:

**Interaction between Solar Radiation and Plant $CO_2$ Exchange**

### Conceptual Model

- **According to our understanding about the plants, the plant $CO_2$ exchange can be modelled as a function of the following factors:**
  - **Incident solar radiation**
  - **Water in the soil**

  - **Temperature**
  - **Soil nutrients**

  - **Age of the trees**
  - **Forest structure**
  - **Competition among other trees**

## A Simple Modelling Example:

**Interaction between Solar Radiation and Plant $CO_2$ Exchange**

### Assumption

- **The $CO_2$ exchange for balsam fir is directly influenced by incident solar radiation**
- **The age and structure of the forest have not been changed during the study period**
- **The developed model could be applicable for the forests with having similar age, structure, composition; and exist under similar environmental conditions**

### Data Availability

- **This study is to be conducted during May-Sept. for the years of 2004 and 2005**
- **Data for the $CO_2$ exchange and the incident solar radiation are acquired**

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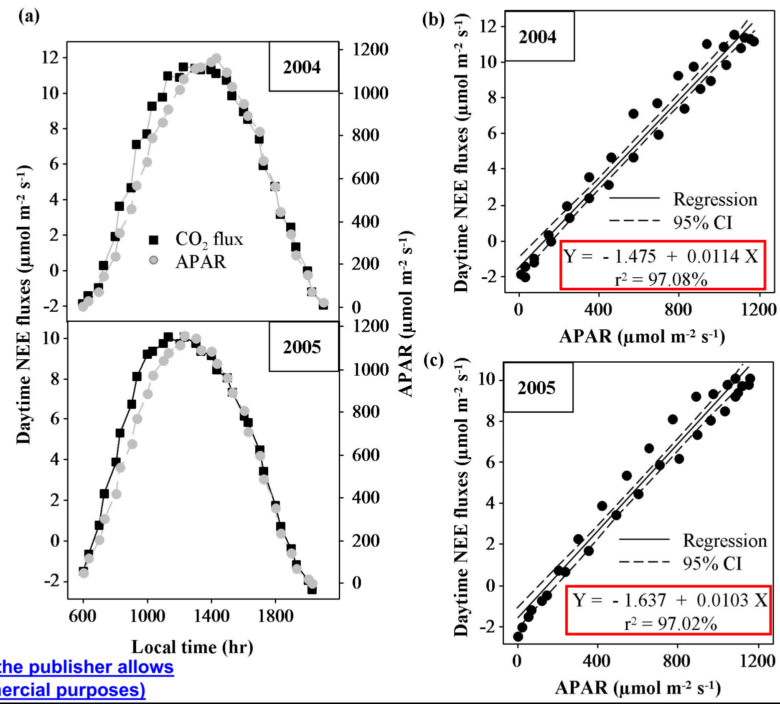
**Constructing Computational Model**

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## A Simple Modelling Example:

**Interaction between Solar Radiation and Plant $CO_2$ Exchange**

**Constructing Computational Model**

**Fig. (a)**

- **The long-term average diurnal patterns of incident solar radiation and net $CO_2$ exchange followed each other in a distinct manner.**
- **The incident solar radiation (the secondary y-axis) for both 2004 and 2005 were identical**
- **Despite identical incident solar radiation, the amount of net $CO_2$ exchange (the primary y-axis) was higher in 2004 with compare to that of 2005**

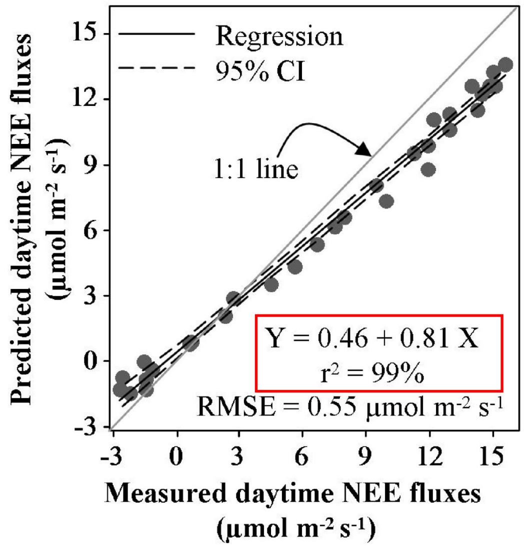
**Fig. (b) & (c)**

- **In both 2004 [Fig. (b)] and 2005 [Fig. (c)], there were strong relations (i.e., $r^2 > 97\%$) between incident solar radiation (x-axis) and $CO_2$ exchange (y-axis)**

## A Simple Modelling Example:

**Interaction between Solar Radiation and Plant $CO_2$ Exchange**

### Model Evaluation




- **The measured $CO_2$ exchange (x-axis) was acquired at a site, which is ~100 km away from the site where the model was developed**
- **The forest at both sites were similar**
- **The modelled/predicted $CO_2$ exchange (y-axis) and the measured values showed strong relations (i.e., $r^2 = 99\%$)**

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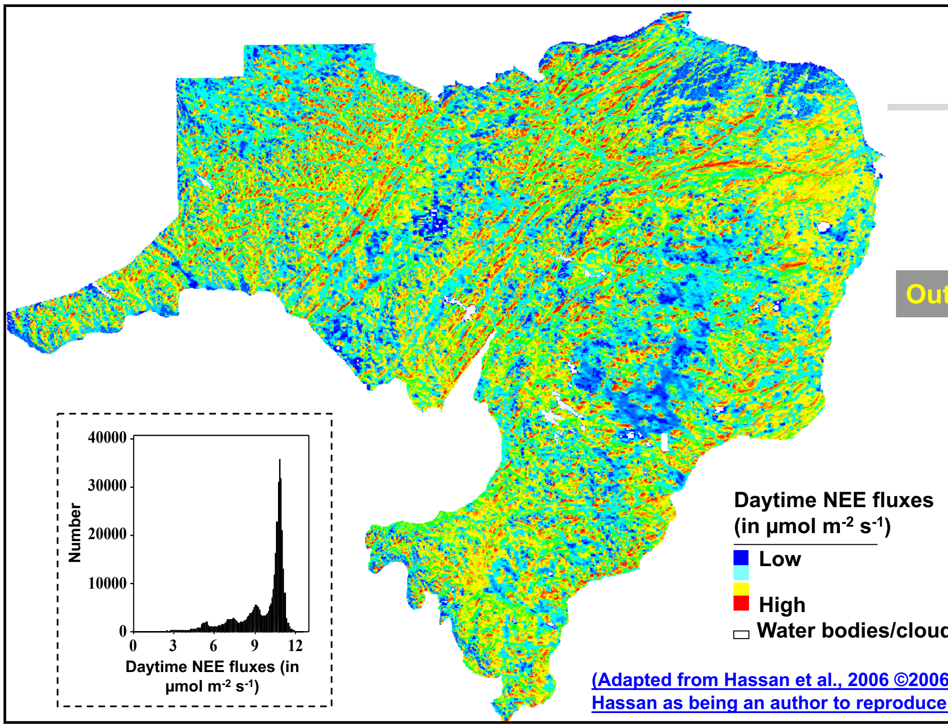


### Output/Model Application

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## A Simple Modelling Example:

**Interaction between Solar Radiation and Plant $CO_2$ Exchange**

### Understanding or Our Learning

- **Plant $CO_2$ exchange exhibits a linear relationship with solar radiation.**

### Scope or Limitations

- **Inter-annual variability's of plant $CO_2$ exchange may be influenced by other factors beyond solar radiation.**

## References


- **EPA (US Environmental Protection Agency) (2009a) Guidance on the Development, Evaluation, and Application of Environmental Models. EPA/100/K-09/003. Washington, DC. Office of the Science Advisor.**
- **EPA (US Environmental Protection Agency) (2009b) The Model Life-cycle, *In EPA's Council for Regulatory Environmental Modeling Training*, https://www.epa.gov/sites/production/files/2015-09/documents/mod2-mod-lc-final.pdf**
- **Hassan, Q.K., Bourque, C.-P.A, Meng, F.-R. (2006) *Estimation of daytime net ecosystem $CO_2$ exchange over balsam fir forests in eastern Canada: combining averaged tower-based flux measurements with remotely sensed MODIS data. Canadian Journal of Remote Sensing, 32, 405-416***
- **Bornman, J.F., Barnes, P.W., Robinson, S.A., Ballare, C.L., Flint, S.D.,Caldwell, M.M. (2015) Solar ultraviolet radiation and ozone depletion-driven climate change: effects on terrestrial ecosystems. *Photochemical & Photobiological Sciences* 14, 88-107.**

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## Sample Review Questions

- **What are the main four (4) steps in developing an environmental model?**

- **Why do you need to understand the following:**
  - **Identification of the problem**
  - **Development of the conceptual model**
  - **Construction of the computational model**
  - **Evaluation of the model**

- **Consider an illustration of an environmental model is given. Formulate the following:**
  - **Identify the problem**
  - **Conceptual model**
  - **Assumptions and data requirements**
  - **Computational model**