Appendix 1
Introduction to STELLA

STELLA is a flowchart-based modelling software. It enable users to construct model by drawing boxes, circles and arrows. **STELLA** is similar to ModelMaker.

During this session you will learn to build a model, step by step using **STELLA**. The purpose of this session is to familiarize yourself with **STELLA** and to learn how to use basic features of **STELLA** for simulation modelling.

Initiating STELLA

Start STELLA by clicking on its icon on the window screen. You will be automatically inside a new file.

STELLA is a multi-level hierarchical environment. It consist of 3 layers:

(1) the High Level Mapping Layer; which contain input output relationship

(2) Model Construction Layer; where you construct the model

(3) an Equation View; to view list of all model elements and relations

Move between layers

- Currently you are in the second layer. You can move between layers by clicking on arrow at the top left hand corner.
- You will find all the layers are still empty because you have not construct anything.

Let's try building a simple model based on Trenbath (1984).

Trenbath formulated a simple model of restoration and depletion of 'soil fertility' during fallow and cropping periods, respectively.

'Soil fertility' is defined as a complex of effective nutrient supply and biological factors (diseases, weeds) affecting crop yield. Crop yield is assumed to be directly proportional to 'soil fertility'.

Assume during a cropping period soil fertility declines with a fraction D per crop, while during a fallow period soil fertility can be recreated with a fraction of R.

Constructing a model

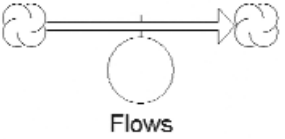
- Make sure you are in the second layer. You will notice a globe (world) icon underneath the arrow at the top left hand corner. On the top you will see 14 icons, starting with 'box' icon at the furthest left and 'ghost' at the furthest right.
- Make a variable of soil fertility. To do this, click on the box icon then click again anywhere on the empty space. Change the name from 'Noname1' into 'Soil Fertility' or any variable name you like. There are no restriction on length. What you have just made is called **building blocks**.

STELLA has 4 types of building box:

1. Stocks

Stocks are accumulations. They collect whatever flows into and out of them.

2. Flows

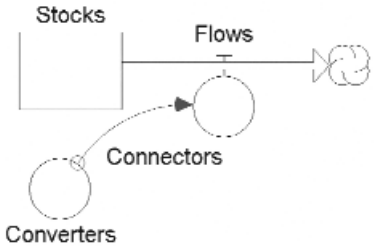


The job of flows is to fill and drain accumulations. The unfilled arrow head on the flow pipe indicated the direction of the flow.

3. Converters

The converter serves a practical and handy role. It holds values for constants, defines external inputs to the model, calculates algebraic relationships and serves as the repository for graphical functions. In general it converts inputs into outputs.

4. Connectors



The job of the connector is to connect model elements.

This is an example of how building blocks are used.

Constructing a model (Continued.)

- Since 'Soil Fertility' will decrease during cropping year, you will have to make an outflow from 'Soil Fertility'. Name the flow as 'Depletion'.
- 'Depletion' depend on depleting factor (D), length of cropping year and length of fallow year (if it is a fallow year, depletion will not occur). Make 3 converters and name them as D, TimeCrop and TimeFallow. Connect all 3 converters to 'Depletion'
- Now you will need to define the relationship between those parameters into an equation in 'Depletion'. See what happen if you click twice on 'Depletion'.
- Click Cancel and see what happen if you click on the globe icon then clicking twice on 'Depletion'.
- You are now in equation box. Type out the following equation:

  IF(MOD(TIME, (TimeCrop+TimeFallow)) <TimeCrop) THEN (Soil_Fertility*D) ELSE(0)1
  Make sure there is a connection from 'Soil Fertility' to 'Depletion'
- You will see that all building blocks except 'Depletion' has question mark on them. They are asking for a value. Put the following value just for a try out. D=0.4, Soil fertility=10, TimeFallow=3, TimeCrop=3
- Now, do the same step for recreation factor, which is an inflow to 'Soil Fertility'. What do you think should be the equation in 'Recreation'? First try a constant value, for example put

  IF(MOD(TIME, (TimeCrop+TimeFallow)) > TimeCrop)THEN(0.2) ELSE(0)
- The Trenbath model used a 'saturation' function in which the recreation depends on the difference between current fertility and a maximum value (Finf), modified by a 'half-recovery time' Kfert, so we make converters for Finf (value e.g. 10) and Kfert (value e.g. 5):

  IF(MOD(TIME, (TimeCrop+TimeFallow)) >TimeCrop)THEN((Finf-Soil_Fertility)*Soil_Fertility/(Finf-Soil_Fertility+Kfert*Finf)) ELSE(0)
- Now go to the third layer. You will now see the values and equations of your model.

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1 MOD(TIME,(TimeCrop+TimeFallow)) will give current time minus the already completed cycles. The early part of a new cycle is cropped, the latter part is fallow.

Two types of output can be generated from STELLA; graphs and tables.

Making an Output

- To make a graph click on graph icon (7th icon from left) and click again anywhere. A box named untitled graph will emerge.
- Click twice on the graph then select 'Soil Fertility' from Allowable Box. Click the arrow pointing to the right. Then click OK.
- You may do the same thing with table icon (8th icon from left)

Running the Program

- To run the program choose **Run** from Run Menu. You can also run the program by pressing **Ctrl-R** or clicking the running-man icon in the bottom left hand corner then click an arrow pointing to the right.
- To see the simulation result, click twice on the graph or table.
- You will notice that the simulation run until time 12 with Delta Time (DT)=0.25. You can change this by choosing **Time Spec** on Run Menu. Try putting DT=1 and length simulation to 50.
- Run the model again and see what happen.
- Try changing R and D value. At what value would they result in stable condition?

Sensitivity Analysis

STELLA has a sensitivity analysis option. Let's try to see how sensitive 'Soil fertility' to changes in 'Depletion'

- Choose **Sensi Spec** from Run Menu. Choose D from Allowable Box then click an arrow pointing to right.
- Click D on Selected Box, then fill the following value: Start=0.2, End=0.6. Click on **Set** then **OK**.
- Click twice on graph, then choose graph type as Comparative.
- Now Run the model and see the result.

Exercises

The model you have built is very simple. Now try adding other variables to add complexity into it. Below are several exercises you may like to try out.

- Add crop production into it. Assume crop production is linearly proportional to decreased in 'soil fertility'/depletion. Find the total crop production during simulation.
- Assume that in the sum of cropping time and fallow time is a constant over time (a constant cycle). Fallow time is a function of total cumulative production. If the cumulative production meet a certain target then continue with the same length of fallow time. If cumulative production below target you need to shortened the length of fallow time to make up for.
- Assume target production as a function of population density and food needed per capita.