



SOUTH DAKOTA
STATE UNIVERSITY

Integrating real-time precision livestock data into dynamic models using R

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OUTLINE

- Definitions
- Data/Code Access Links (See alberto folder)
- Dynamic Rumen Model (Tedeschi and Fox, 2018, 2020)
- How to transfer to Program R
- Simulation of dynamic model (**Program R**)
- Simulation of dynamic with points (**Program R**)
 - **Shiny App**

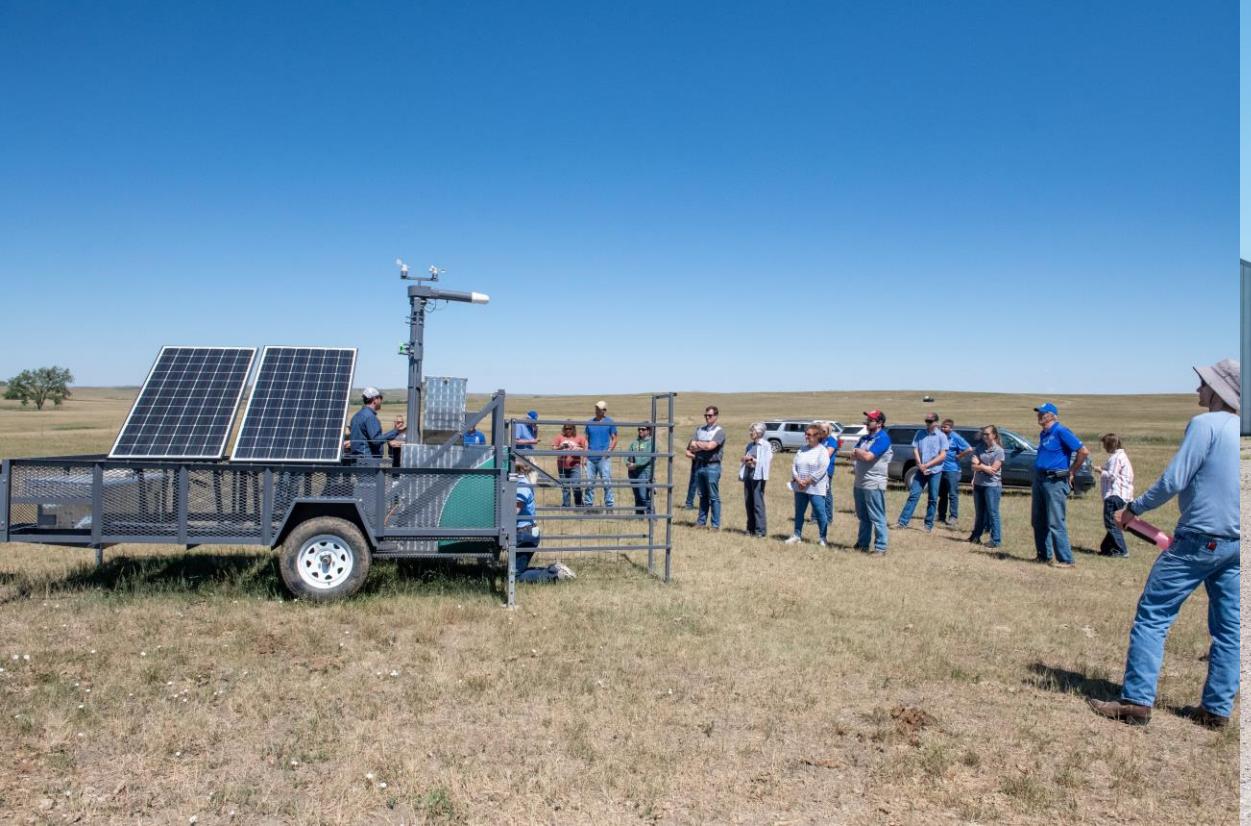
Definitions

- **Real-time:** The data are recorded and are simultaneously available.
(Jacobs et al., 2022)
- **Precision Livestock Data:** Any data collection that is collect with hardware and software that can be automatically transferred digitally.
- (Menendez et al., 2022).
- **Dynamic Models:** Models account for “feedback” over time.
- (Sterman, 2000).
- **Vensim:** A visually based programing software.
- (<https://vensim.com/free-download/>)
- **Program R:** An open-source programming software.
(<https://www.rstudio.com/products/rstudio/download/>)

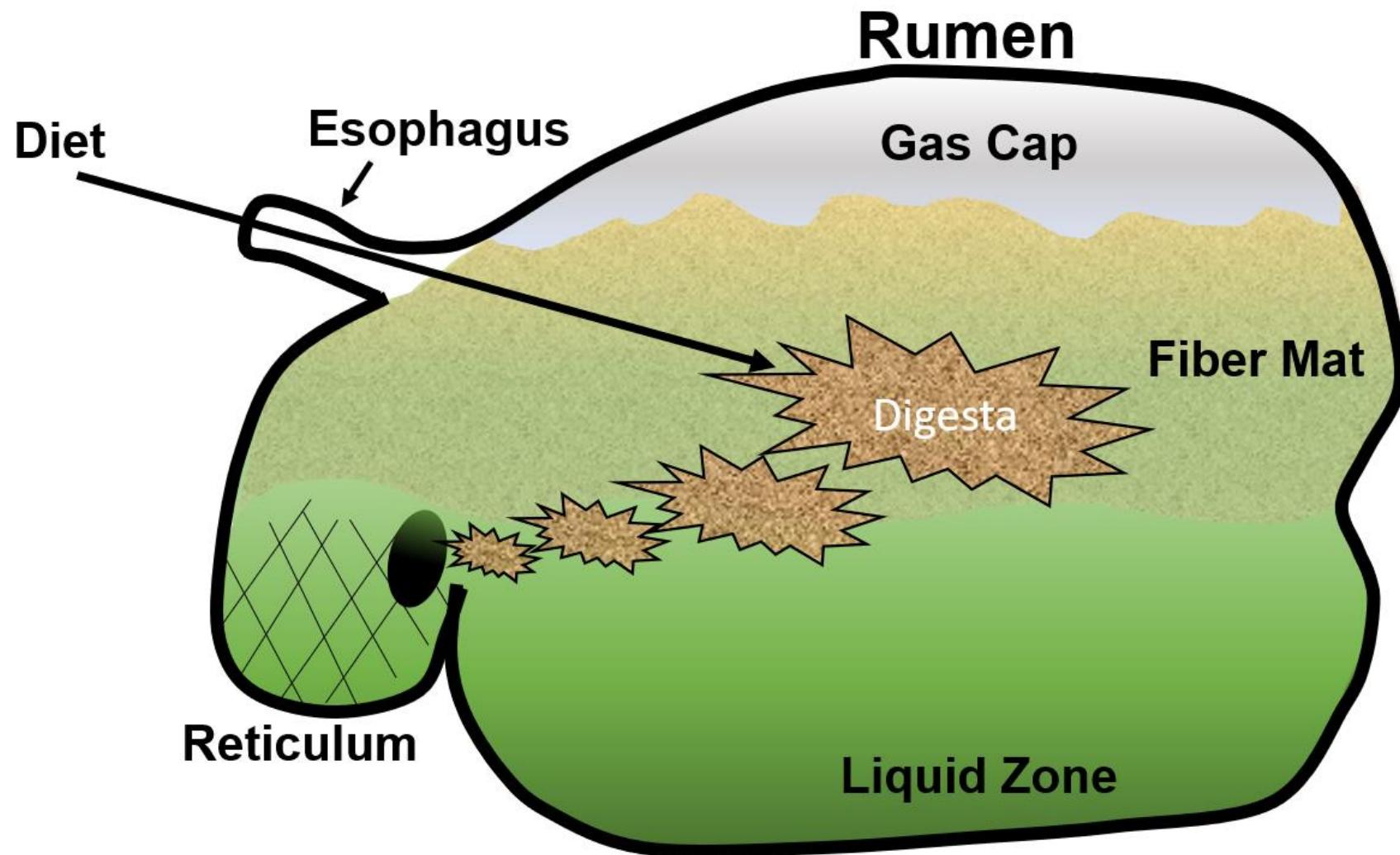
Data Processing Pipelines in Program R for Multi-Integrated Technologies

Examples of precision data management and measurement tools that require data processing for research:

- GreenFeed™
- Smart Scales™
- Super Smart Feed Pro™
- Smart Feed Producer™
- Vence™
- Drones
- Soil Sensors



Rumen Passage Rate: Aging Chain

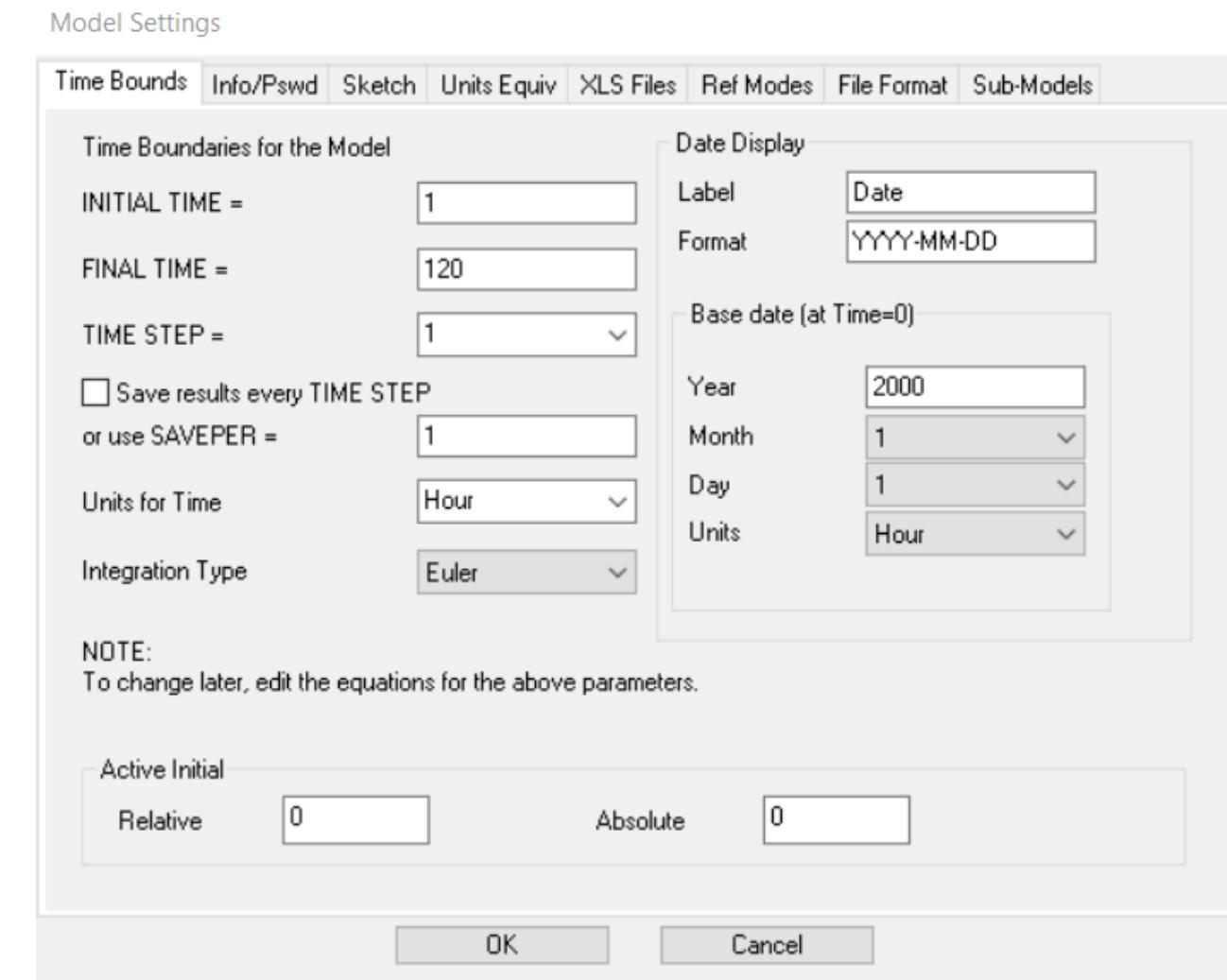
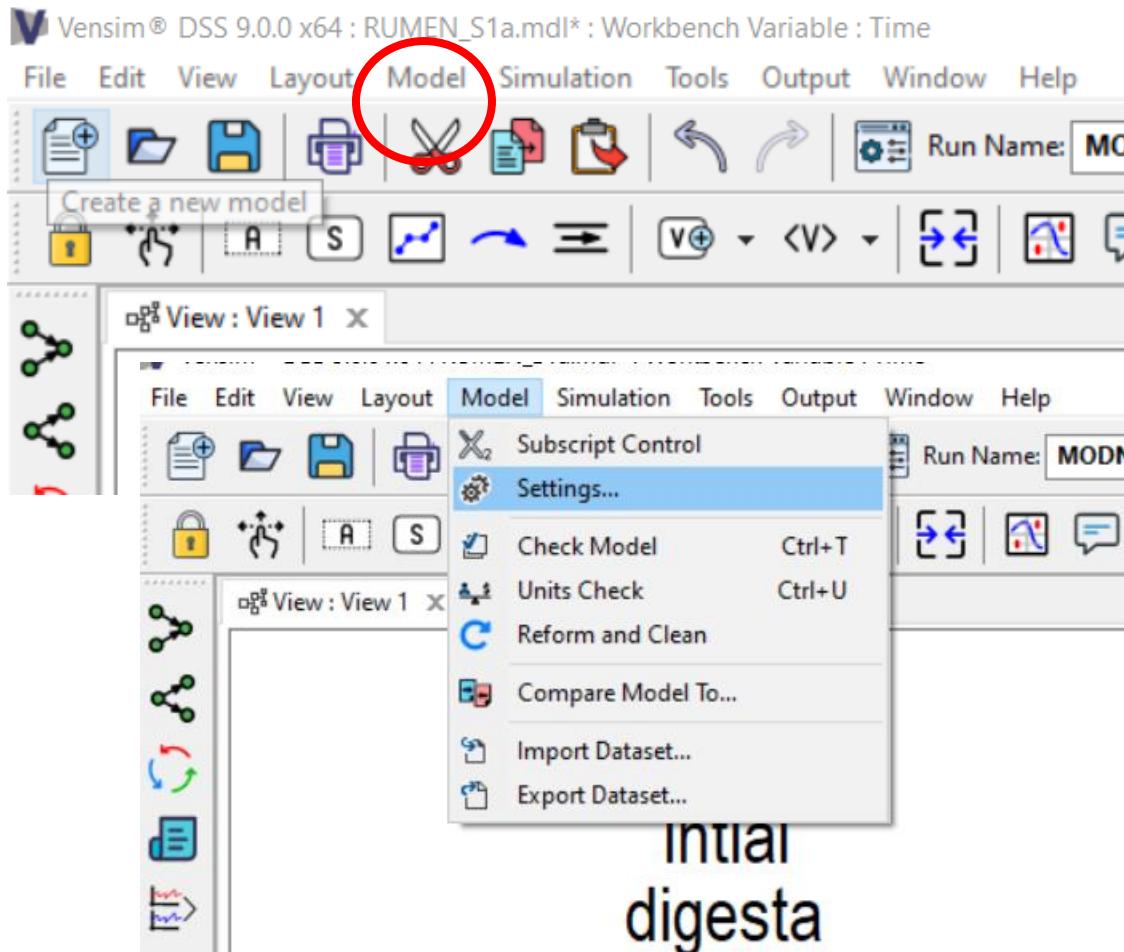


Model Components

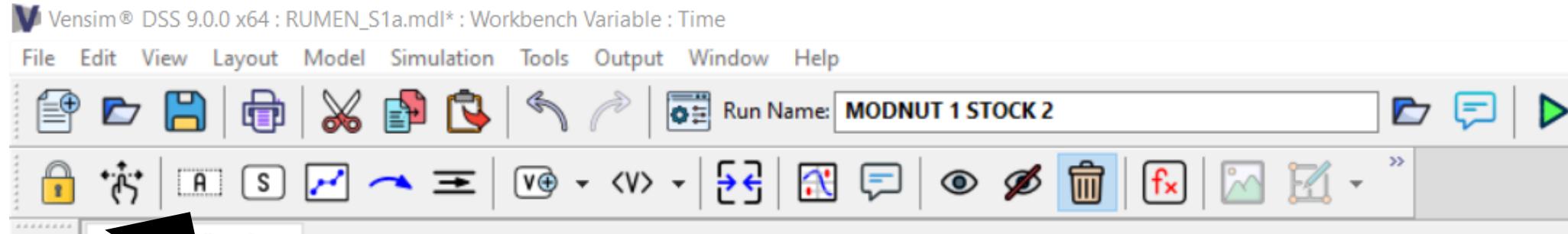
- Continuous (Tedeschi and Fox, 2020)
- Perfect Mixing (Sterman, 2000)
- 4th Order = 4 Stocks

also known as “pools” or “levels”.

Step 1: Select Model and then Model Settings, set model parameters



Step 2a: Create an initial value “initial digesta” add



intial
digesta

Step 2b: Use the equation editor to parameterize the variable.

Vensim® DSS 9.0.0 x64 : RUMEN_S1a.mdl* : Workbench Variable : Time

File Edit View Layout Model Simulation Tools Output Window Help

Run Name: MODNUT 1 STOCK

Units: kg

initial digesta

100

OK Chk Functions Common Keypad Buttons Subscripts Range Variables Causes

ABS
DELAY FIXED
DELAY1
DELAYII
DELAY3
DELAY3I
EXP
GET 123 CONSTANTS
GET 123 DATA
GET 123 LOOKUPS
GET DIRECT CONSTANTS

7 8 9 + :AND:
4 5 6 - :OR:
1 2 3 * :NOT:
0 E . / :NA:
() , ^ <>
> >= = < <=
! { } ^

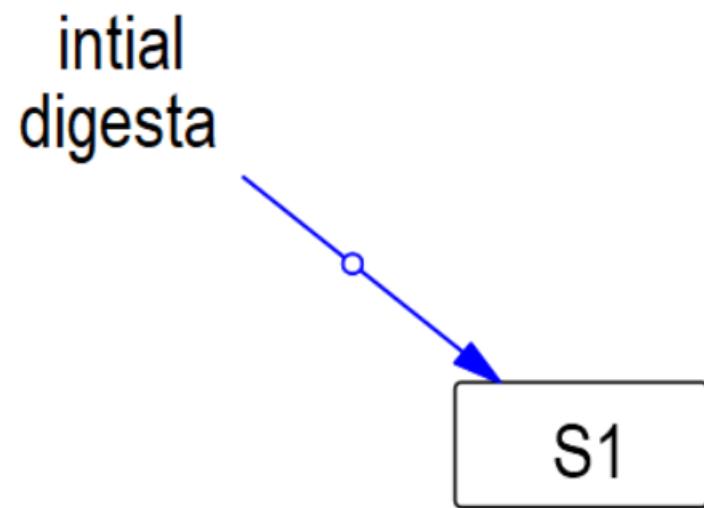
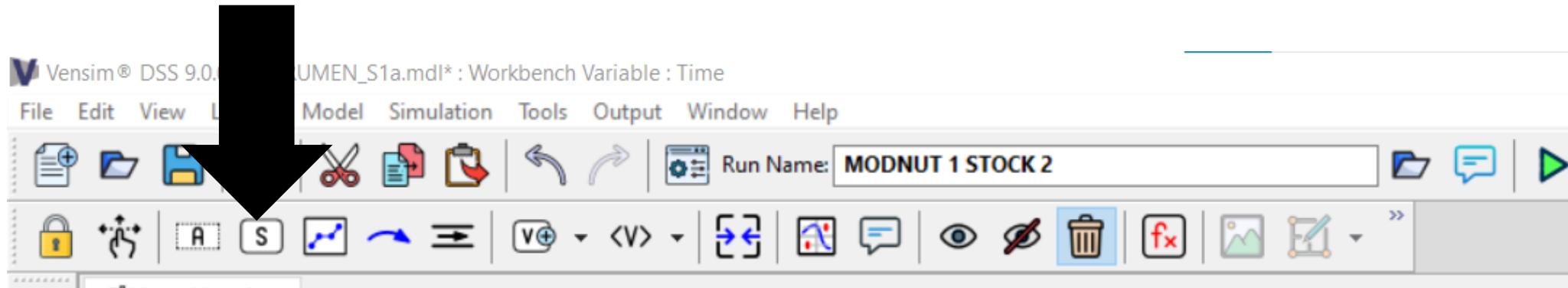
Comment

Errors: Equation OK

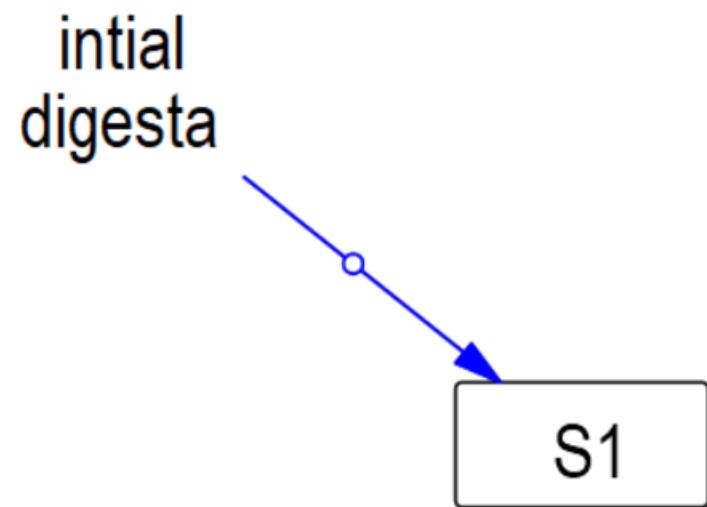
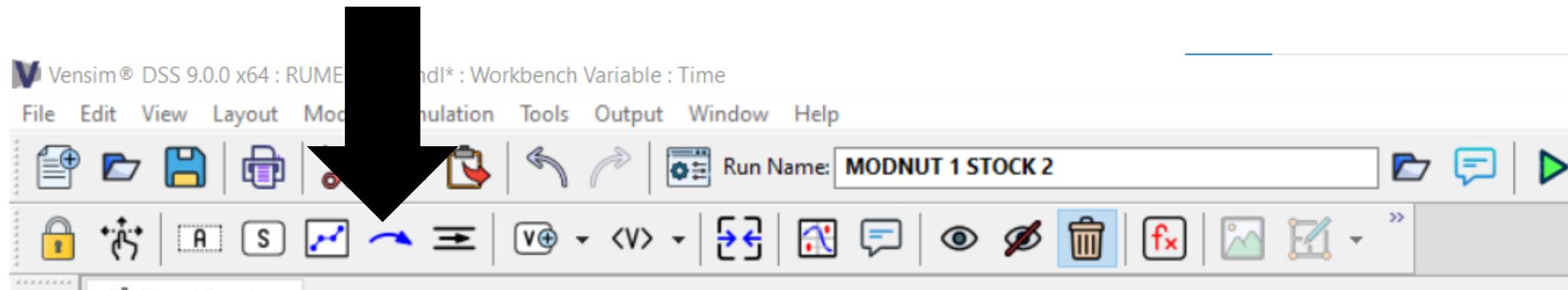
OK Check Syntax Check Model Delete Variable Cancel Help

The screenshot shows the Vensim DSS software interface. The main window title is "Vensim® DSS 9.0.0 x64 : RUMEN_S1a.mdl* : Workbench Variable : Time". The toolbar has various icons for file operations like Open, Save, Print, and simulation controls. Below the toolbar is a menu bar with File, Edit, View, Layout, Model, Simulation, Tools, Output, Window, and Help. The main workspace shows a variable dialog box for "initial digesta". The dialog box has sections for "Variable Information" (Name: initial digesta, Type: Constant, Sub-Type: Normal, Units: kg, Group: RUMEN S1a) and "Edit a Different Variable" (dropdown set to All, showing FINAL TIME, INITIAL TIME, initial digesta, S1, SAVEPER, and TIME STEP). The variable value is set to 100. A large black arrow points from the text "parameterize the variable." in the slide to the trash can icon in the toolbar. To the left of the dialog box, the text "initial digesta" is written vertically, and above it, "Units: kg" is written horizontally. The bottom of the dialog box contains a keypad, variables, causes, and a comment section. The status bar at the bottom shows "Errors: Equation OK" and standard window controls.

Step 2c: Create a stock called “S1”



Step 2d: Link “initial digesta” to the Stock (i.e., S1)

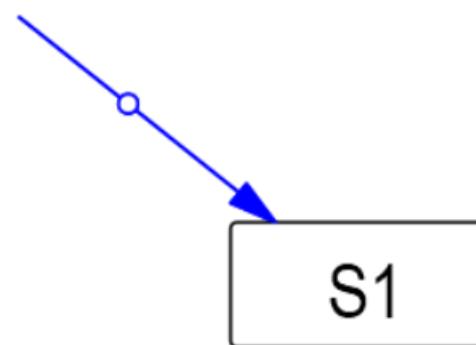


Step 2e: Set “S1” parameters and add units “kg”

Vensim® DSS 9.0.0 x64 : RUMEN_S1a.mdl* : Workbench Variable : Time



initial
digesta



LEAVE THIS BLANK

Initial Value *initial digesta*

OK Chk Functions Common Keypad Buttons Subscripts Range Variables Causes S1 initial digesta

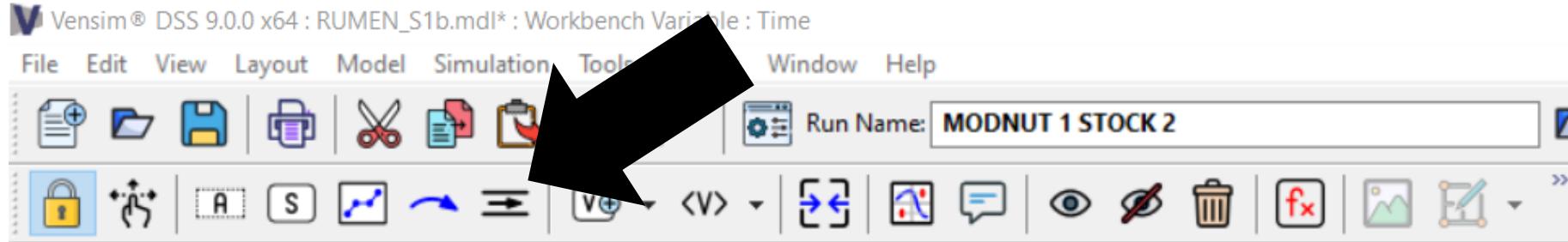
Comment This represents the digesta when it first enters the rumen or the youngest.

Errors: Incorrect/Incomplete Equation

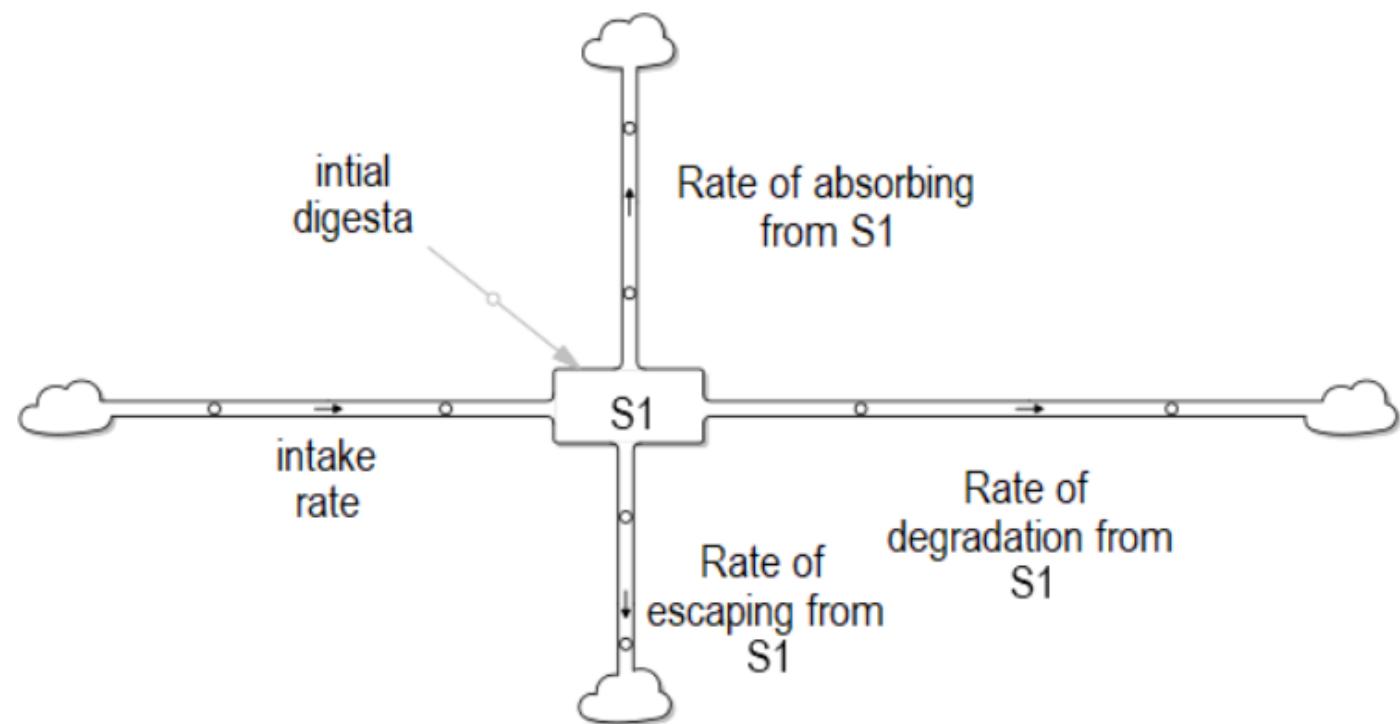
OK Check Syntax Check Model Delete Variable Revert Help

The variable editor window shows "Edit S1" and "Variable Information" for "S1". The "Units" field is set to "kg". The "Equations" section contains "= INTEG (". The "Initial Value" field is highlighted with a red oval and contains the text "initial digesta". The "Variables" and "Causes" panes show "S1" and "initial digesta" respectively. A keypad and function library are visible at the bottom.

STEP 3a: Add Rates (i.e., inflow and outflows)



1. Intake rate
2. Rate of absorbing from S1
3. Rate of degradation from S1
4. Rate of escaping from S1



STEP 3c: Add auxiliary variables and parameterize



1. Fractional rate of absorption (Ka)

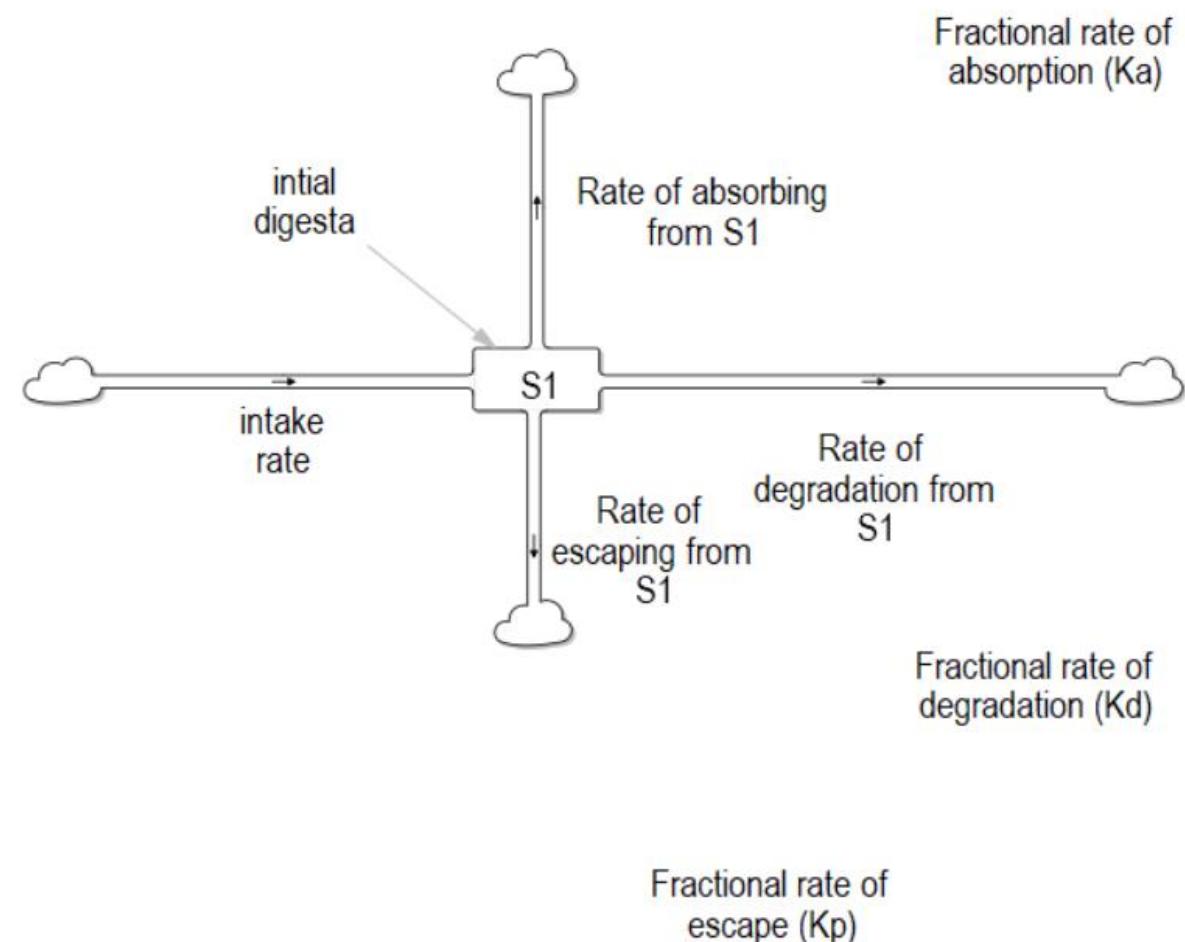
= 0.02, units = 1/hr

2. Fractional rate of degradation (Kd)

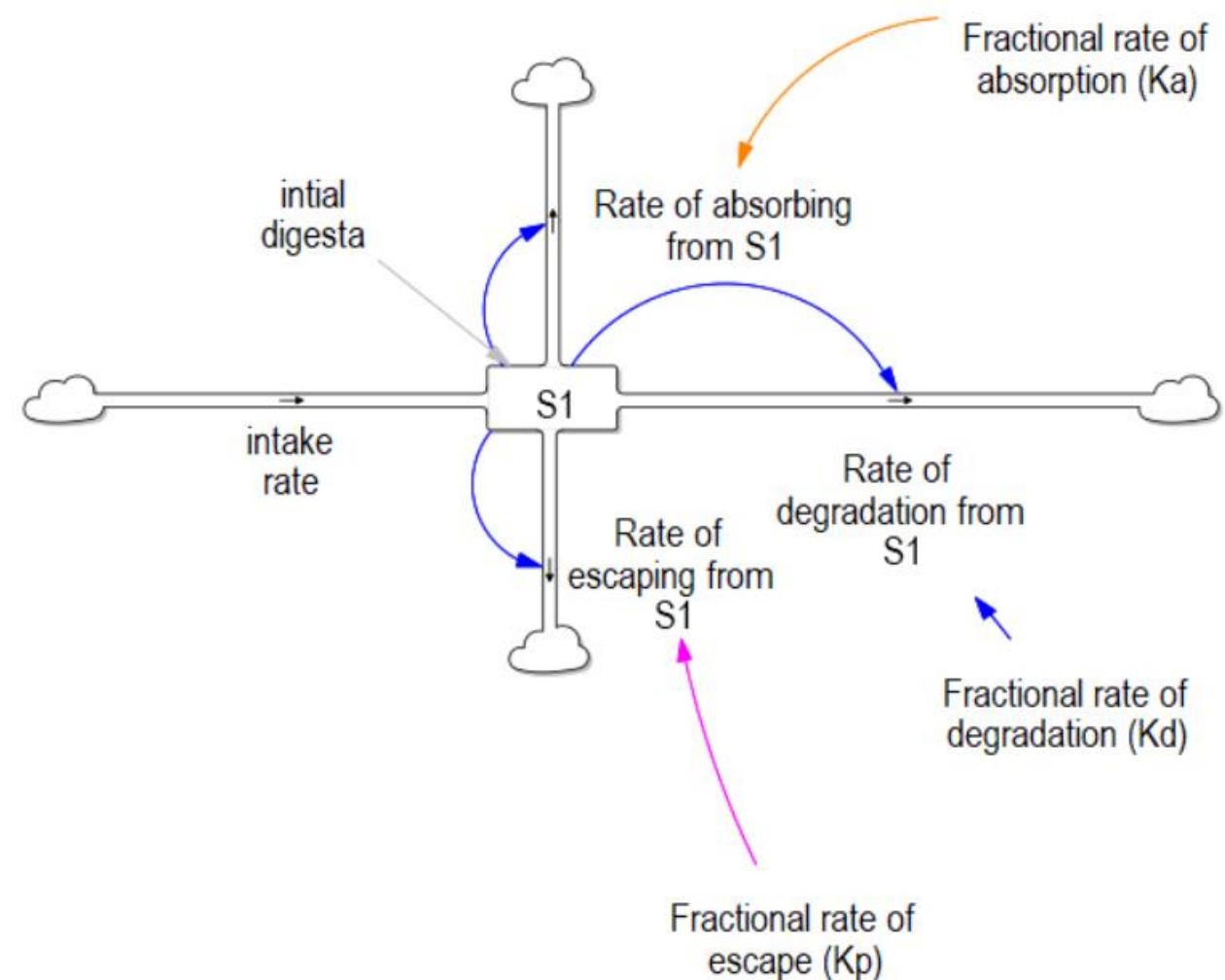
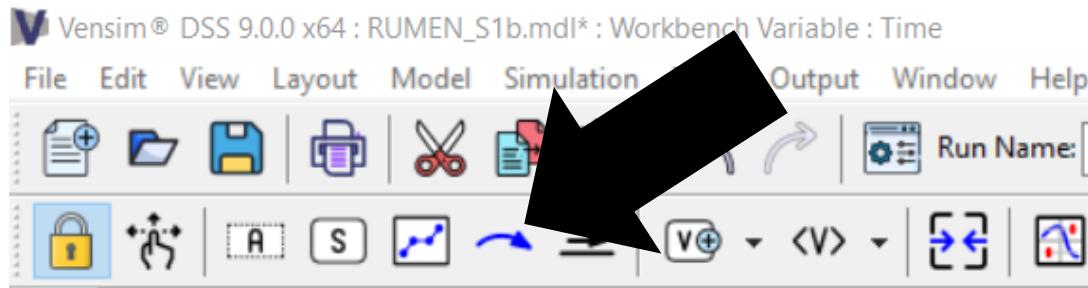
= 0.25, units = 1/hr

3. Fractional rate of escape

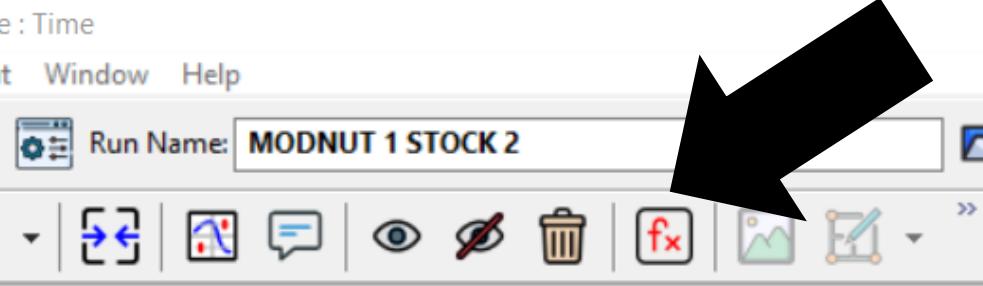
= 0.05, units = 1/hr



STEP 3b: Add linkages (blue arrows) from “S1” to each rate, except “Intake rate”



Step 3c: Parameterize rate variables



1. Rate of absorbing from S1

$$= S1 * \text{Fractional rate of absorption (Ka)}$$

2. Rate of degradation from S1

$$= S1 * \text{Fractional rate of degradation (Kd)}$$

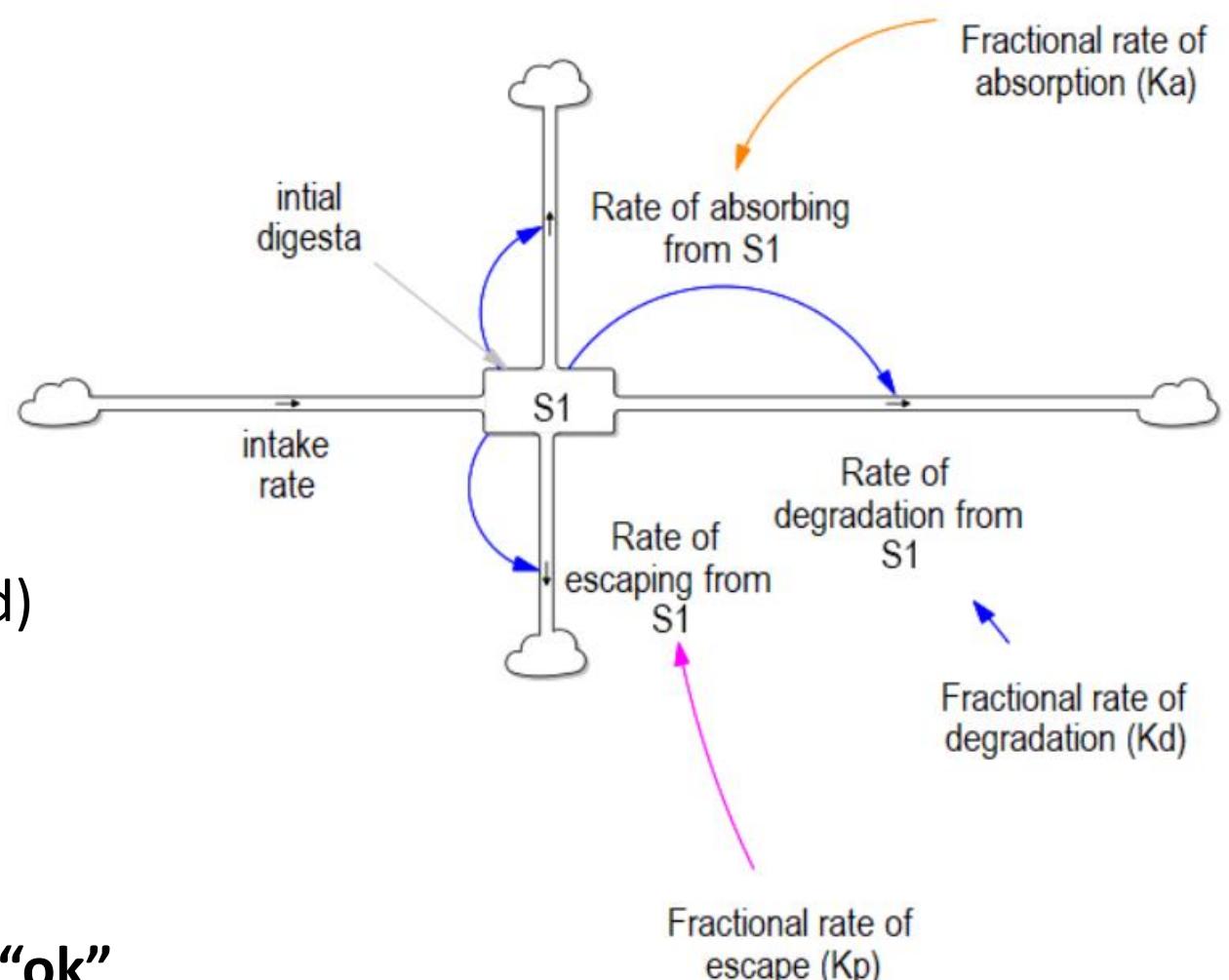
3. Rate of escaping from S1

$$= S1 * \text{Fractional rate of escape (Kp)}$$

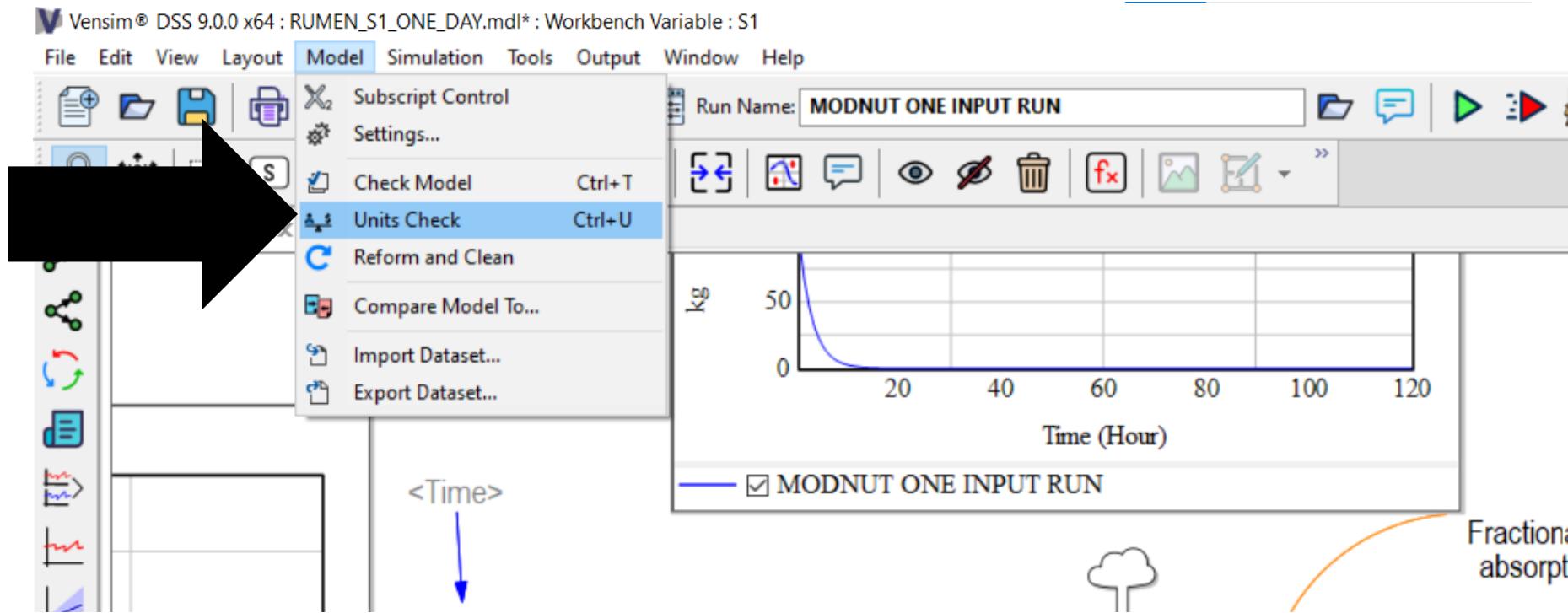
4. Intake rate

$$= 0$$

5. Click on "S1" and press check units and "ok"



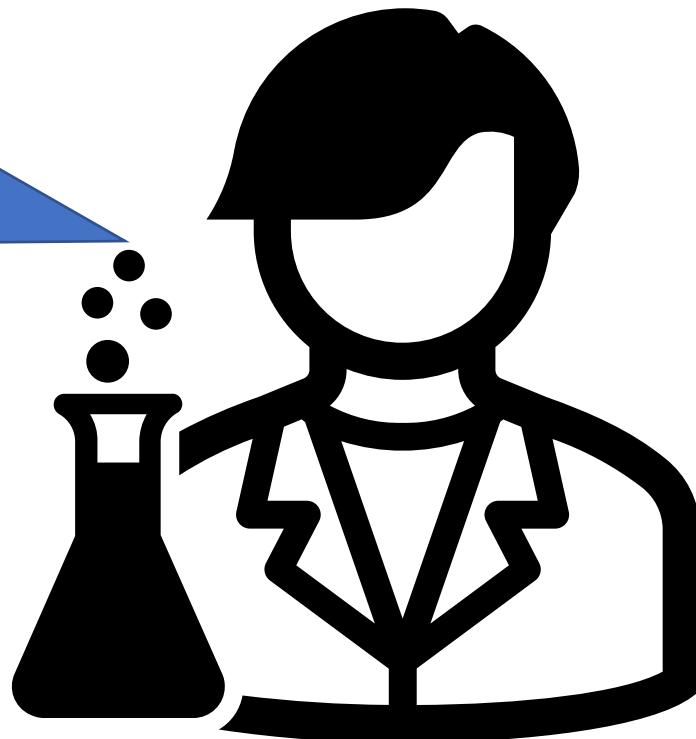
Step 4. Check Units



- THIS IS NOT AN OPTION!

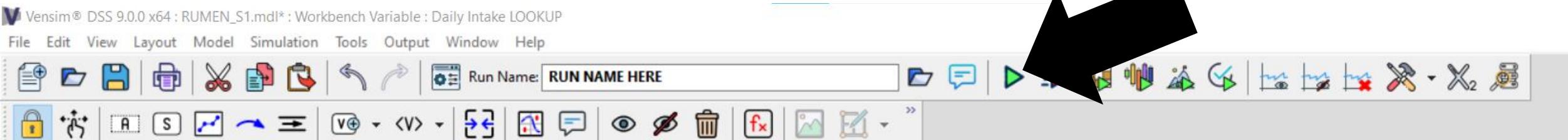
If you do not check units, you will hear this from reviewers:

“Your model is not good enough , and it won’t be accepted ”

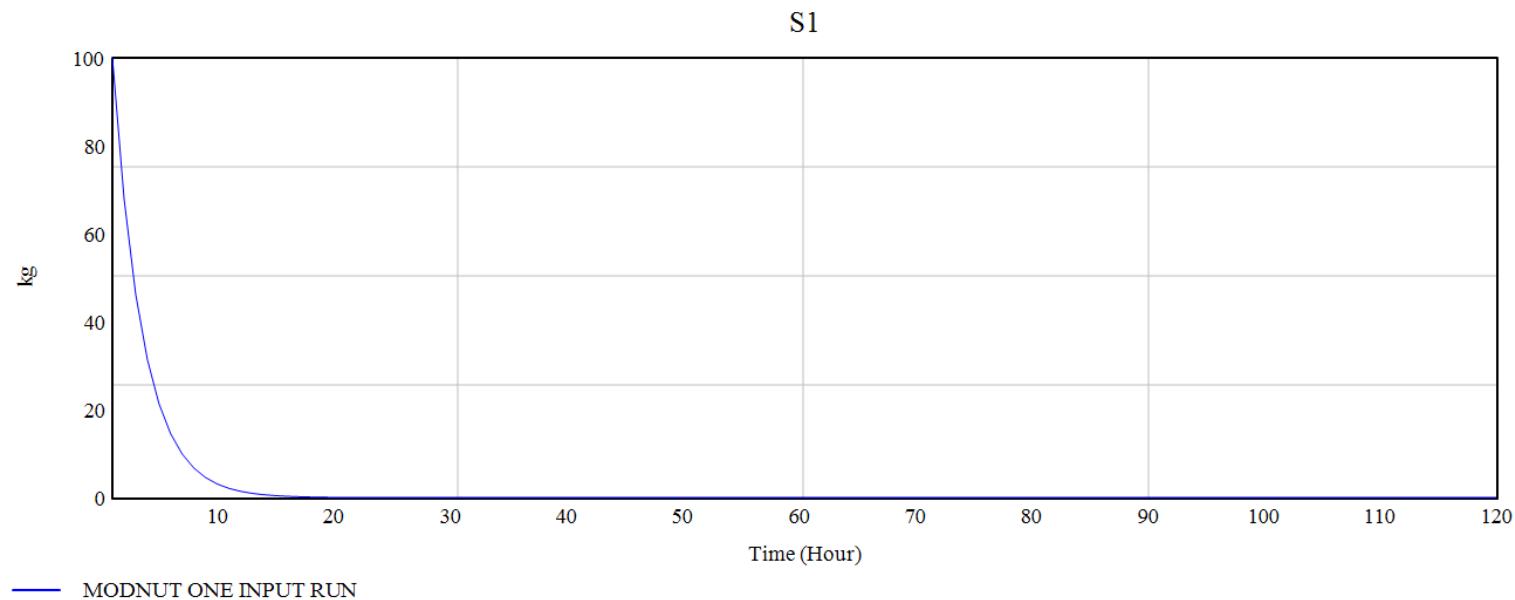


RUN THE MODEL

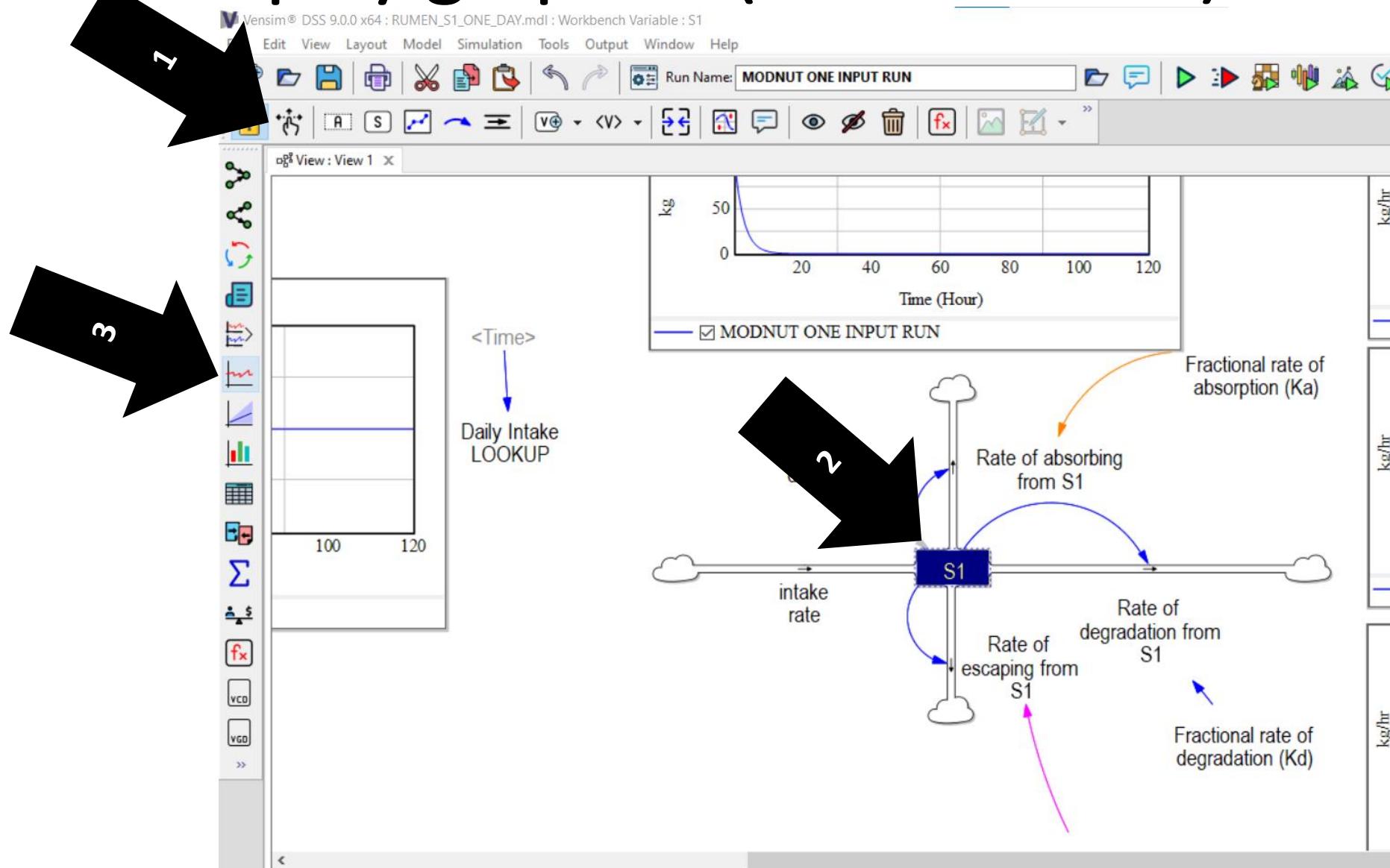
Step 5a: Run the Model! (See Model 1 in Folder)



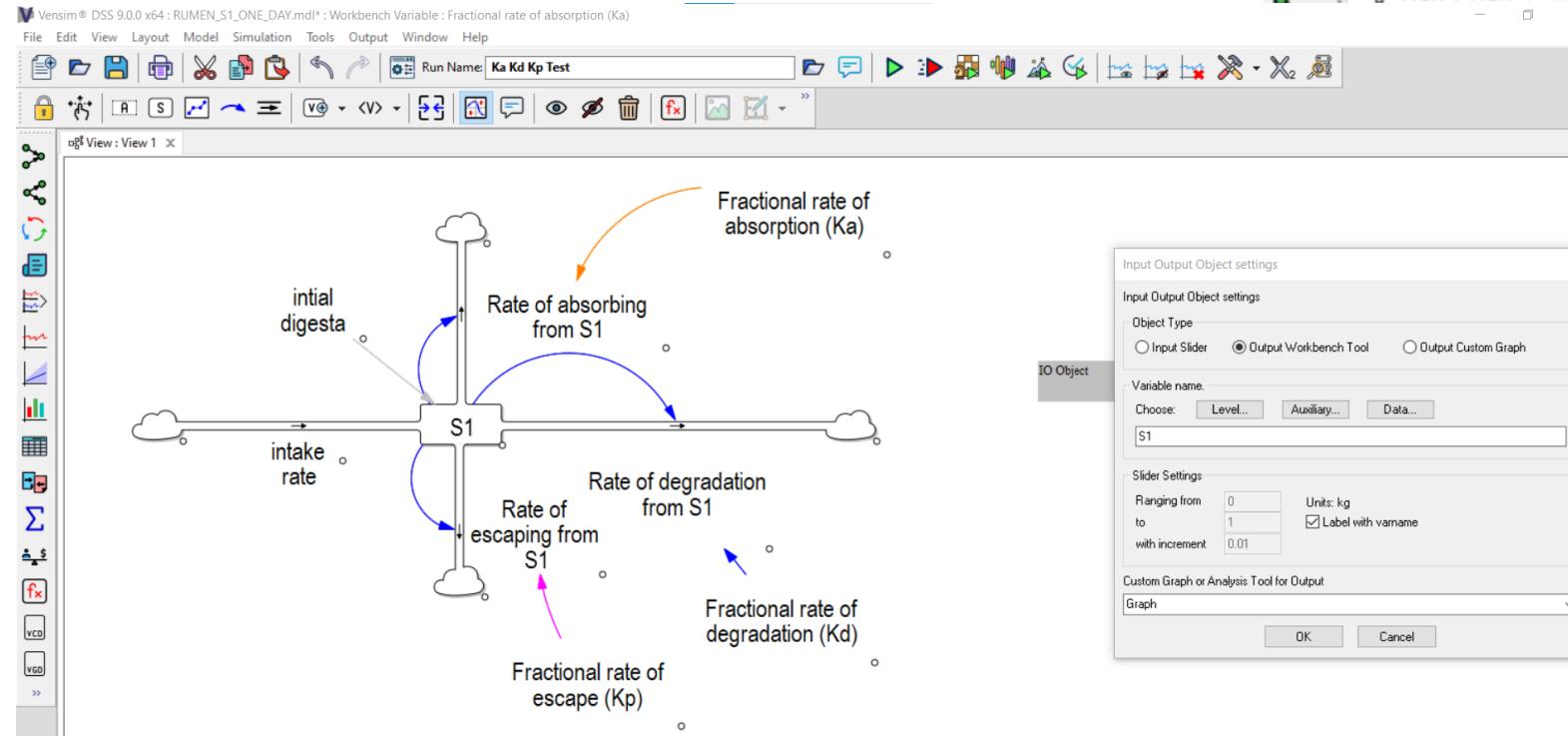
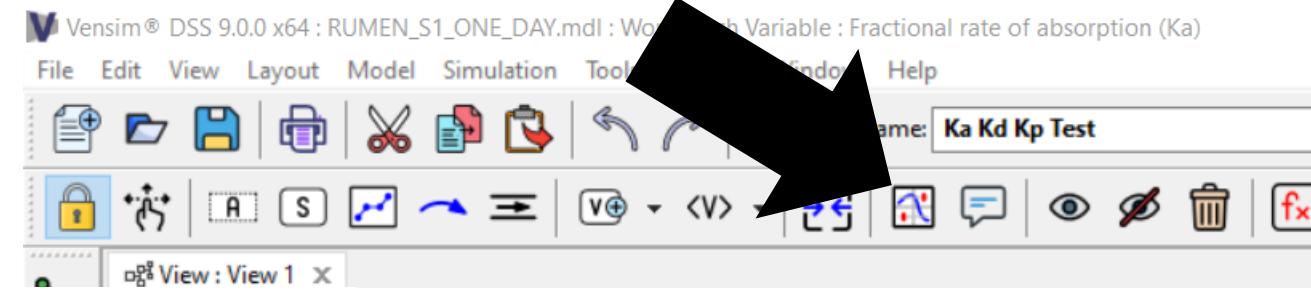
1. Save the model.
2. Enter “Run Name”
3. Press the green arrow
4. Let’s evaluate



Step 5b. Display graphics (click in order)

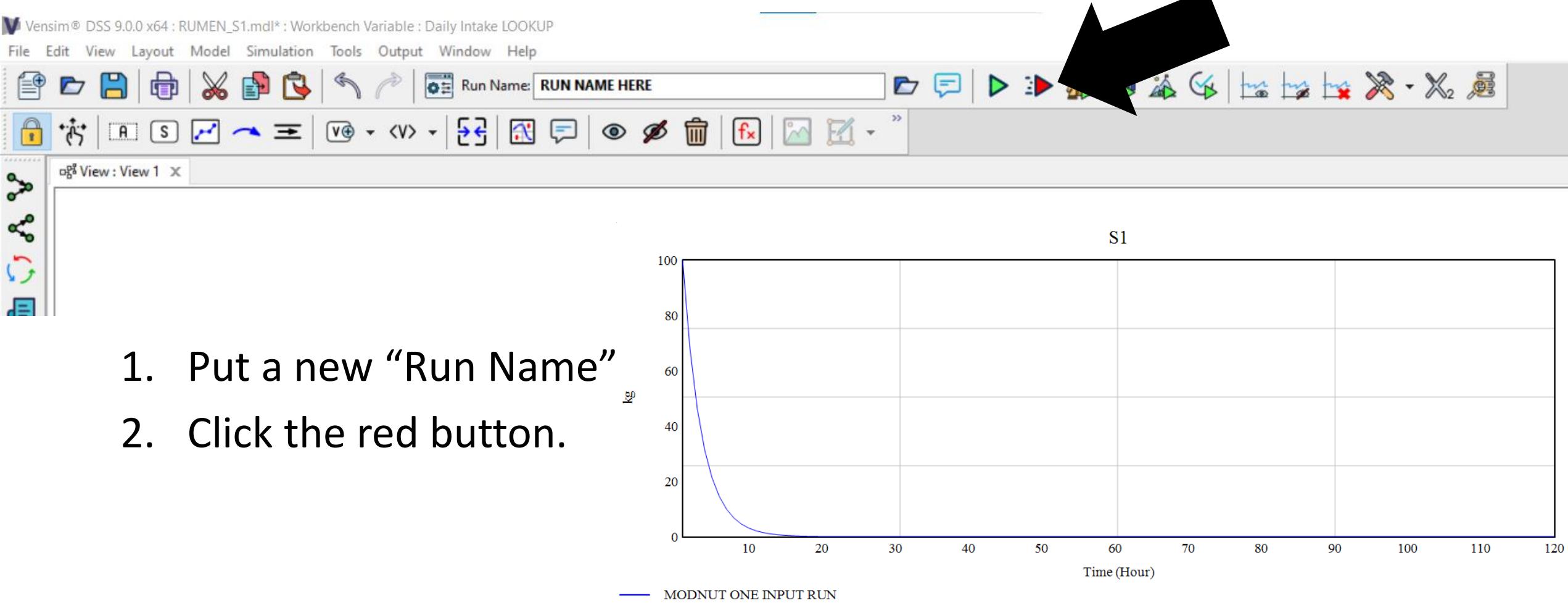


Step5c. Make a graph

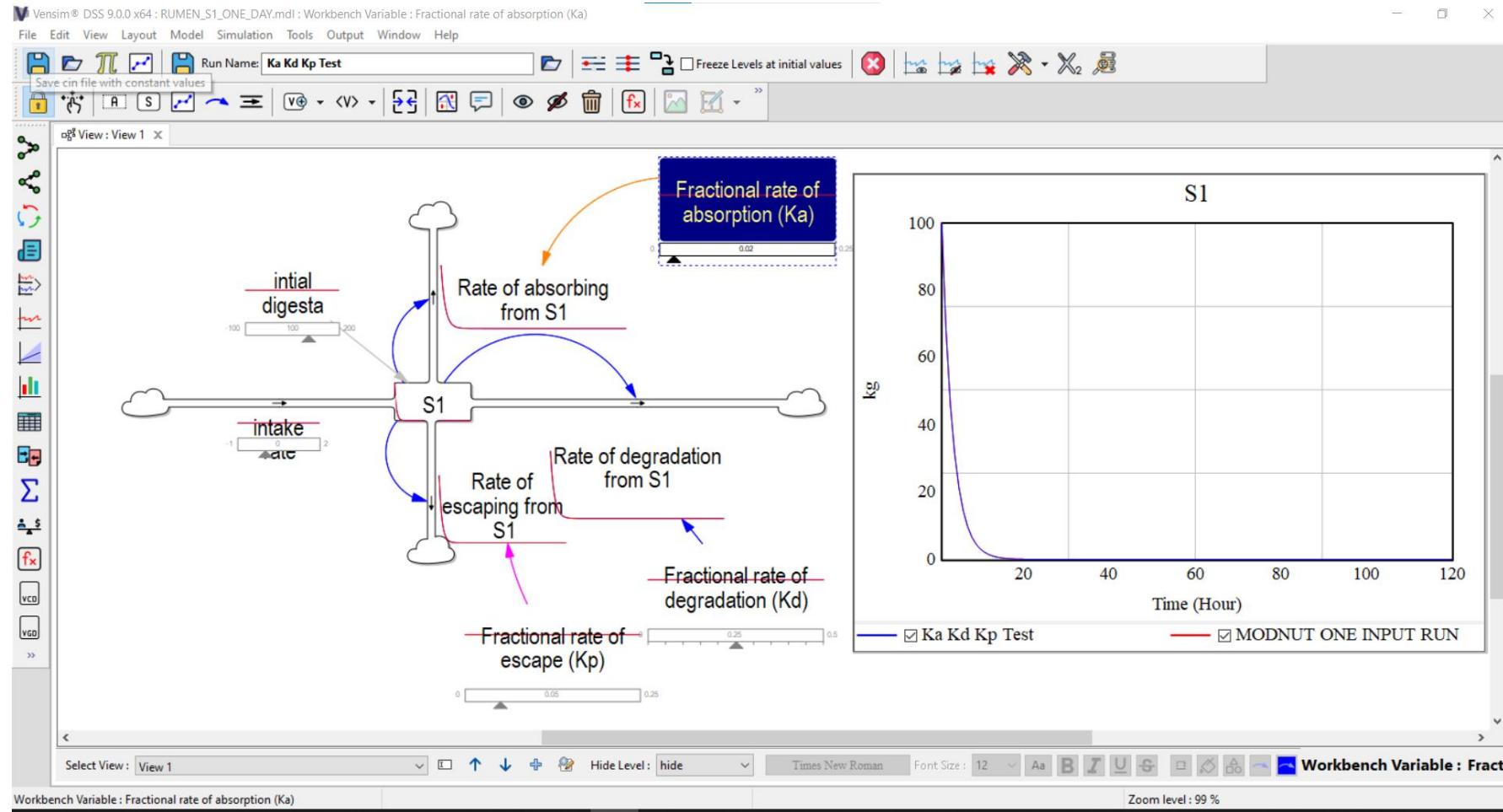


1. Click graph tool
2. Click location on screen
3. Select:
 - a) **“Output Workbench Tool”**
 - b) Level, **“S1”**
 - c) Pull down arrow
“Graph”

Step 5d: Evaluate Ka, Kd, Kp



Step 5e. Move the sliders

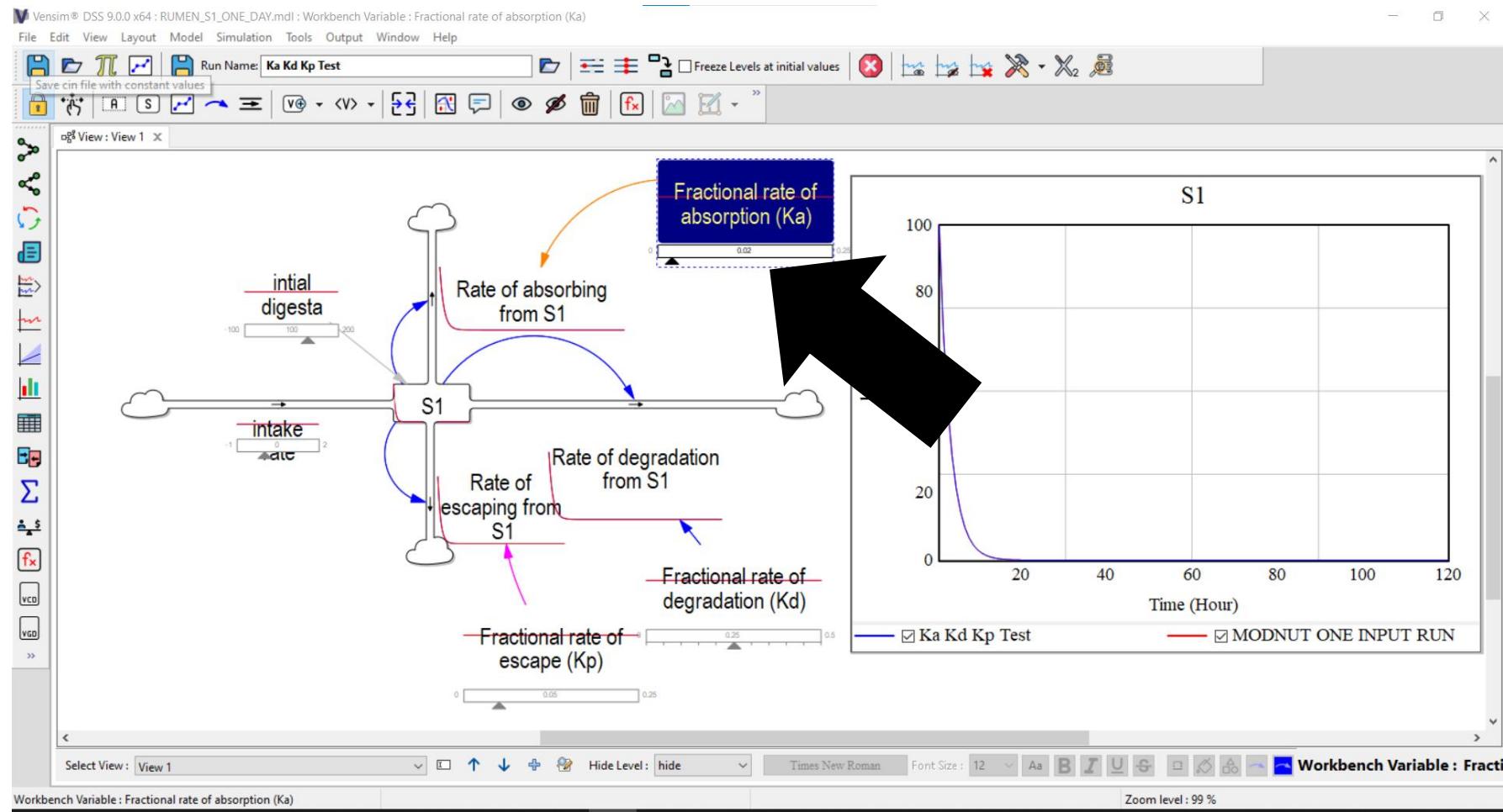


For **Ka**, **Kd**, and **Kp**
move the “black
arrow” under the
variable name.

What happens?

You broke your model! Good!

Step 5e. Move the sliders



Double-click the
“white bar” under
Ka, Kd, and Kp.

Set the parameter
bounds and select
“make slider change
permanent”

Step 5f. Set the input sliders

"Fractional rate of absorption (Ka)"

Value for Sim

Slider Min Max Increment

Make slider changes permanent (modify model)

OK Cancel

"Fractional rate of degradation (Kd)"

Value for Sim

Slider Min Max Increment

Make slider changes permanent (modify model)

OK Cancel

"Fractional rate of escape (Kp)"

Value for Sim

Slider Min Max Increment

Make slider changes permanent (modify model)

OK Cancel

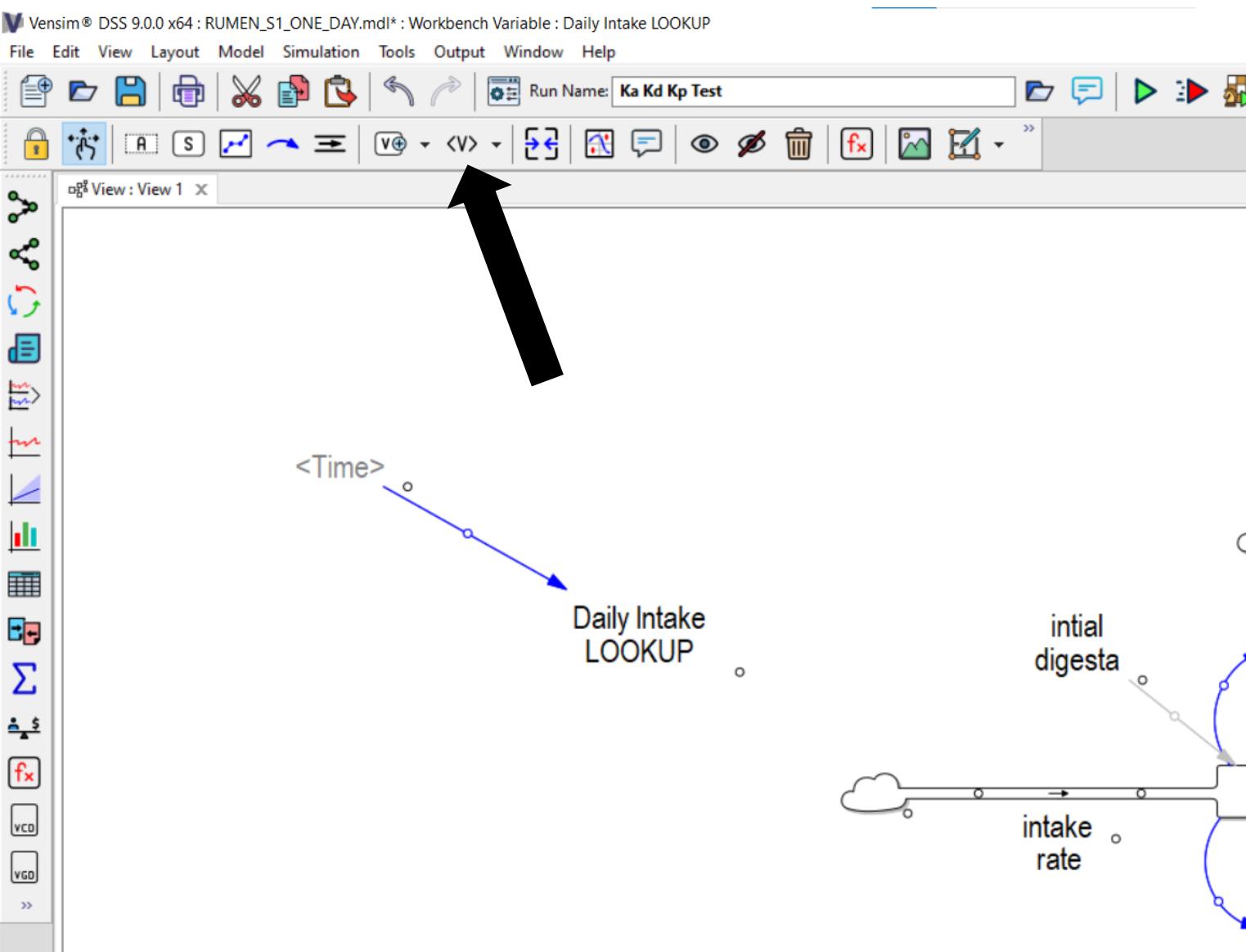
Ka

The sum of Ka,
Kd, Kp fractions
cannot be
greater than 1!

Kd

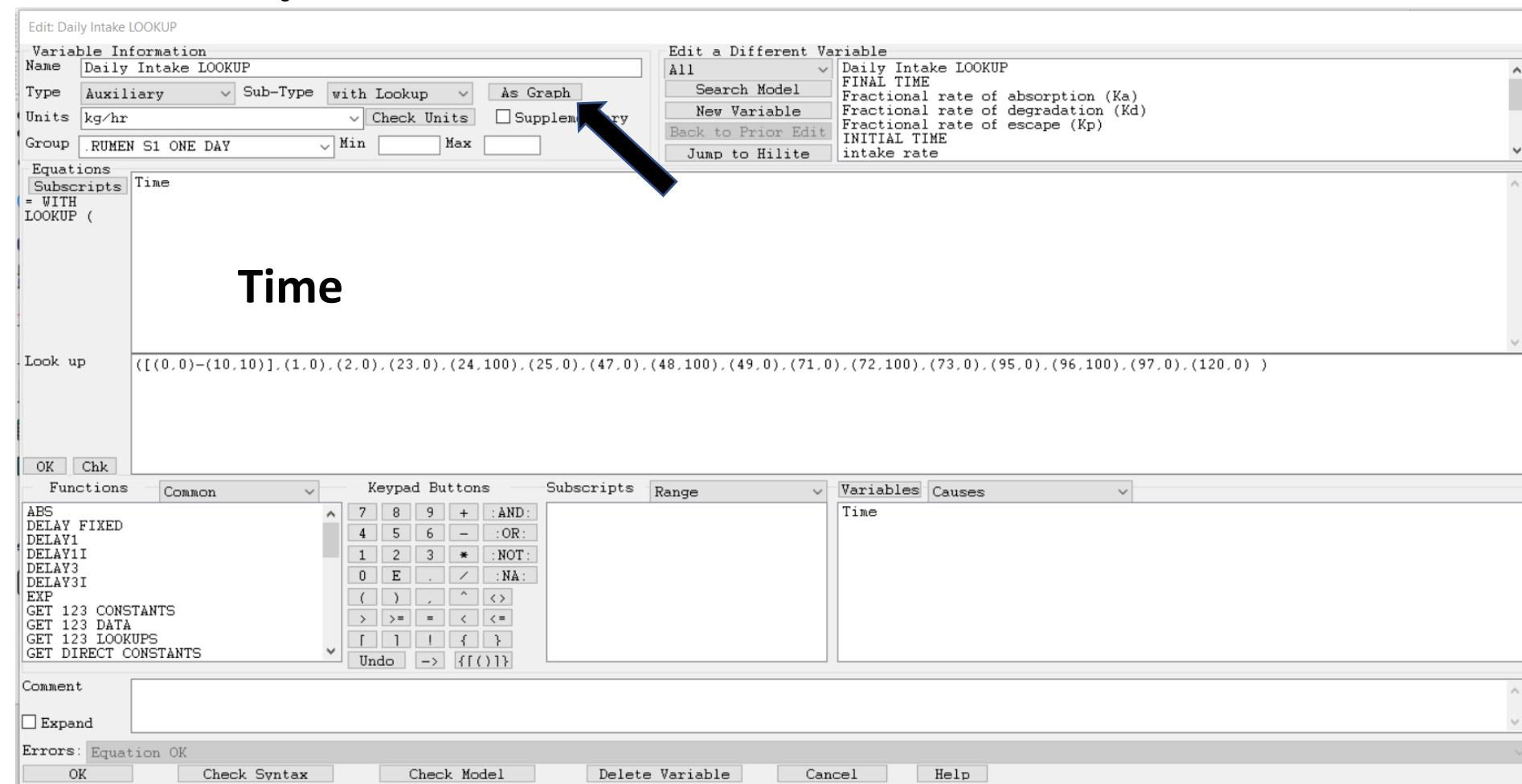
Kp

Step 6a. Add “LOOKUP” or Table Function



1. Click the “shadow variable” button
2. Select “Time”
3. Make another auxiliary variable called “Daily Intake LOOKUP”
4. Link “Time” to “Daily Intake LOOKUP”

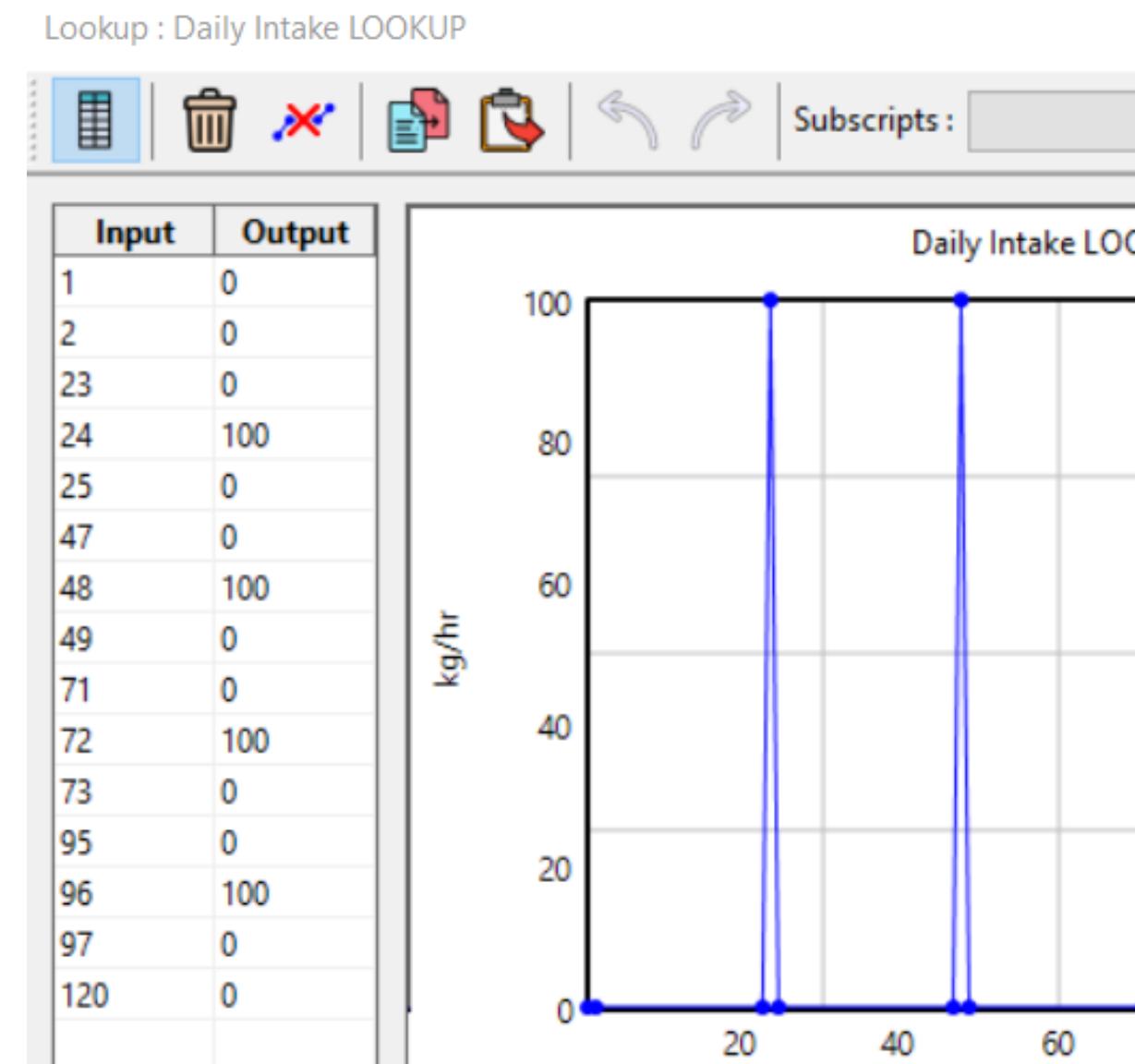
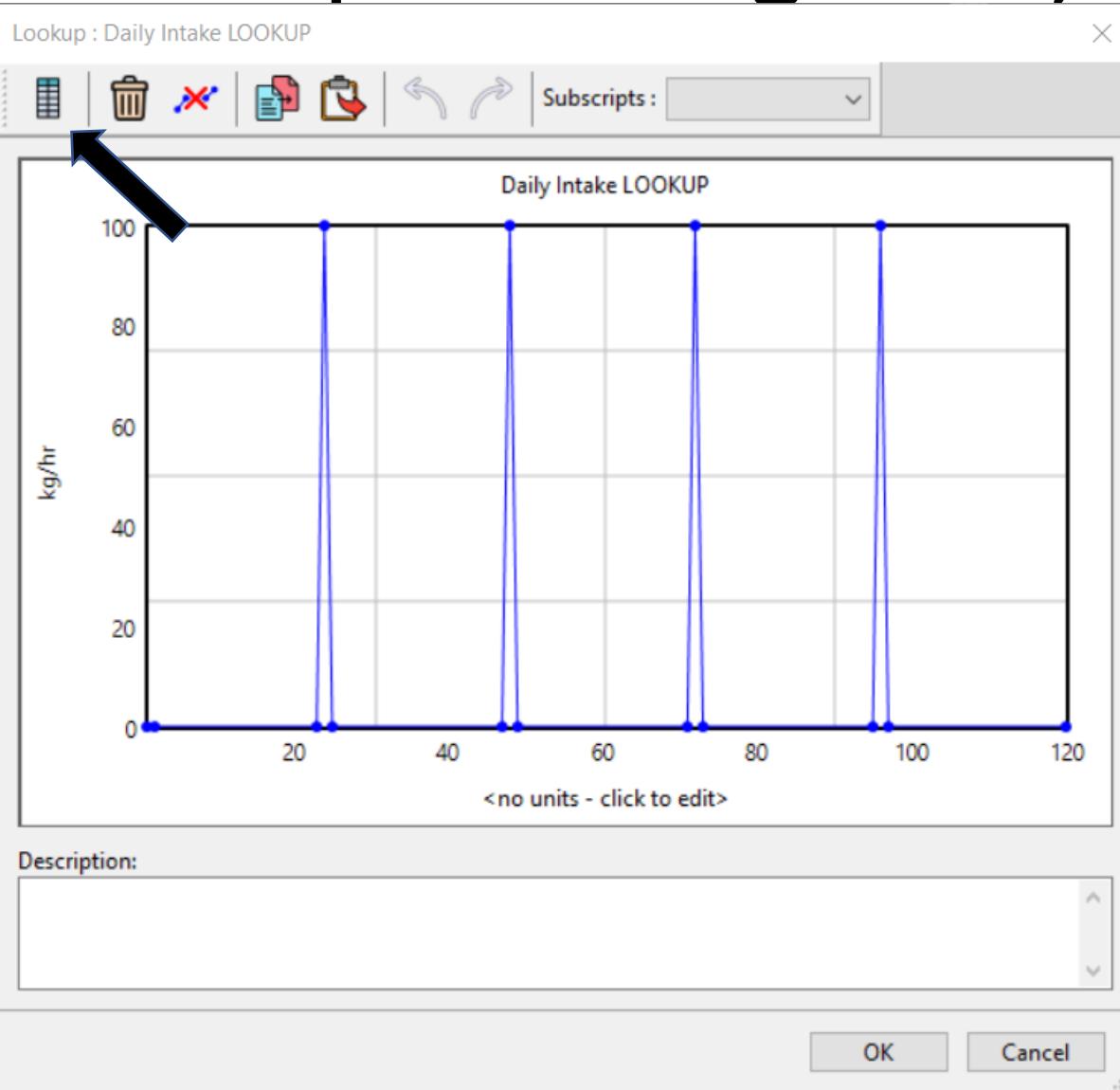
Step 6b: Parameterize the LOOKUP



Units = kg/hr

1. Select “As Graph”

Step 6c. Using the X,Y input table



Step 6d. Link to “Intake rate” and use the equation editor to set “Daily Intake LOOKUP” as the input for Intake rate.

Edit: intake rate

Variable Information	
Name	intake rate
Type	Auxiliary
Sub-Type	Normal
Units	kg/hr
<input type="checkbox"/> Check Units	
<input type="checkbox"/> Supplementary	
Group	RUMEN S1 ONE DAY
Min	
Max	

Equations

Subscripts

Daily Intake LOOKUP

<Time>

Daily Intake LOOKUP

The diagram illustrates a rumen model labeled S1. It features a central vertical column representing the rumen. At the top, there is an inlet labeled "intake rate" leading into the rumen. Inside the rumen, an arrow labeled "initial digesta" points downwards. From the bottom of the rumen, four arrows emerge: one pointing upwards labeled "Rate of absorbing from S1" (orange), one pointing downwards labeled "Rate of degradation from S1" (grey), one pointing leftwards labeled "Rate of escaping from S1" (blue), and one pointing rightwards labeled "Fractional rate of absorption (Ka)" (orange). A pink arrow points upwards from the bottom of the rumen towards the "Rate of escaping from S1" path. On the right side of the diagram, there is a vertical stack of buttons with labels: "Edit", "All", "Search", "New", "Back", and "Jump".

Fractional rate of absorption (Ka)

Rate of absorbing from S1

initial digesta

intake rate

S1

Rate of degradation from S1

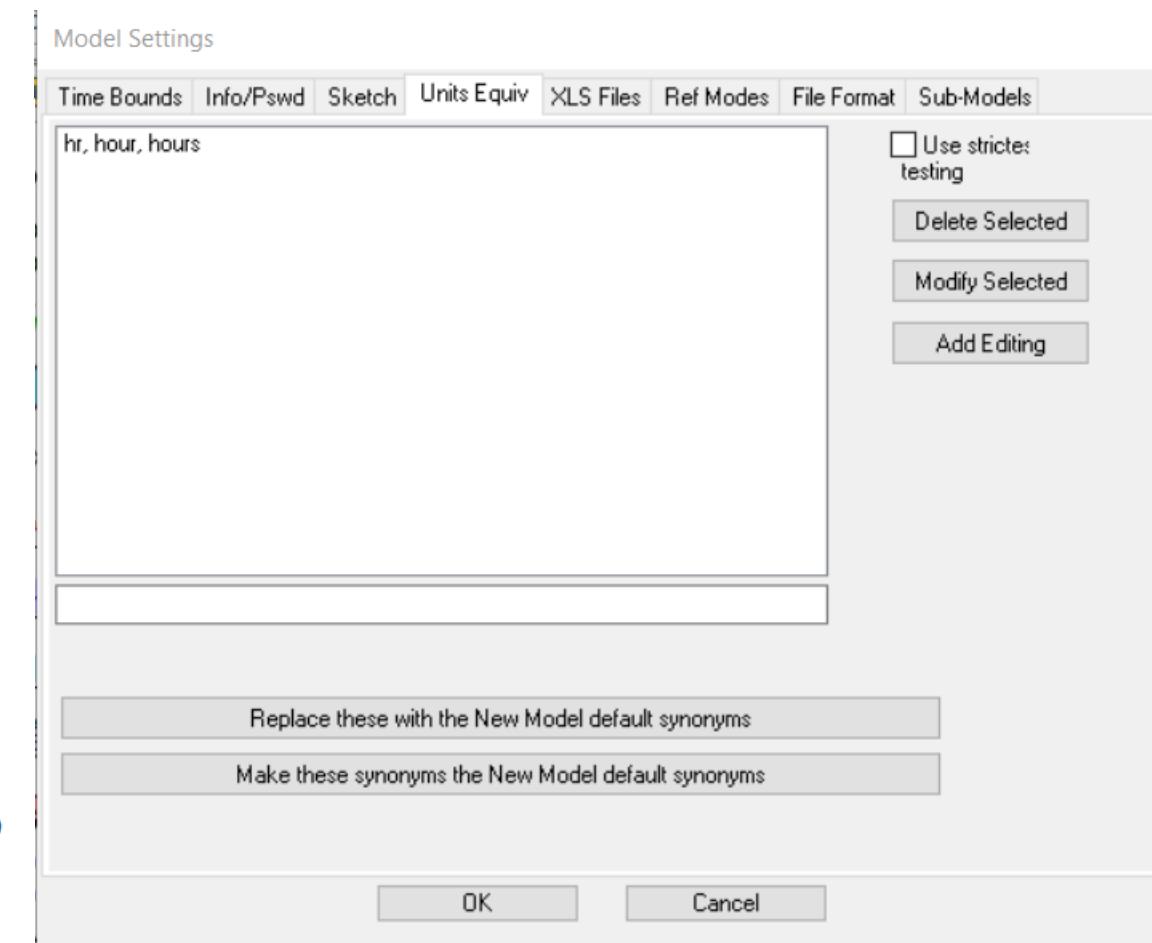
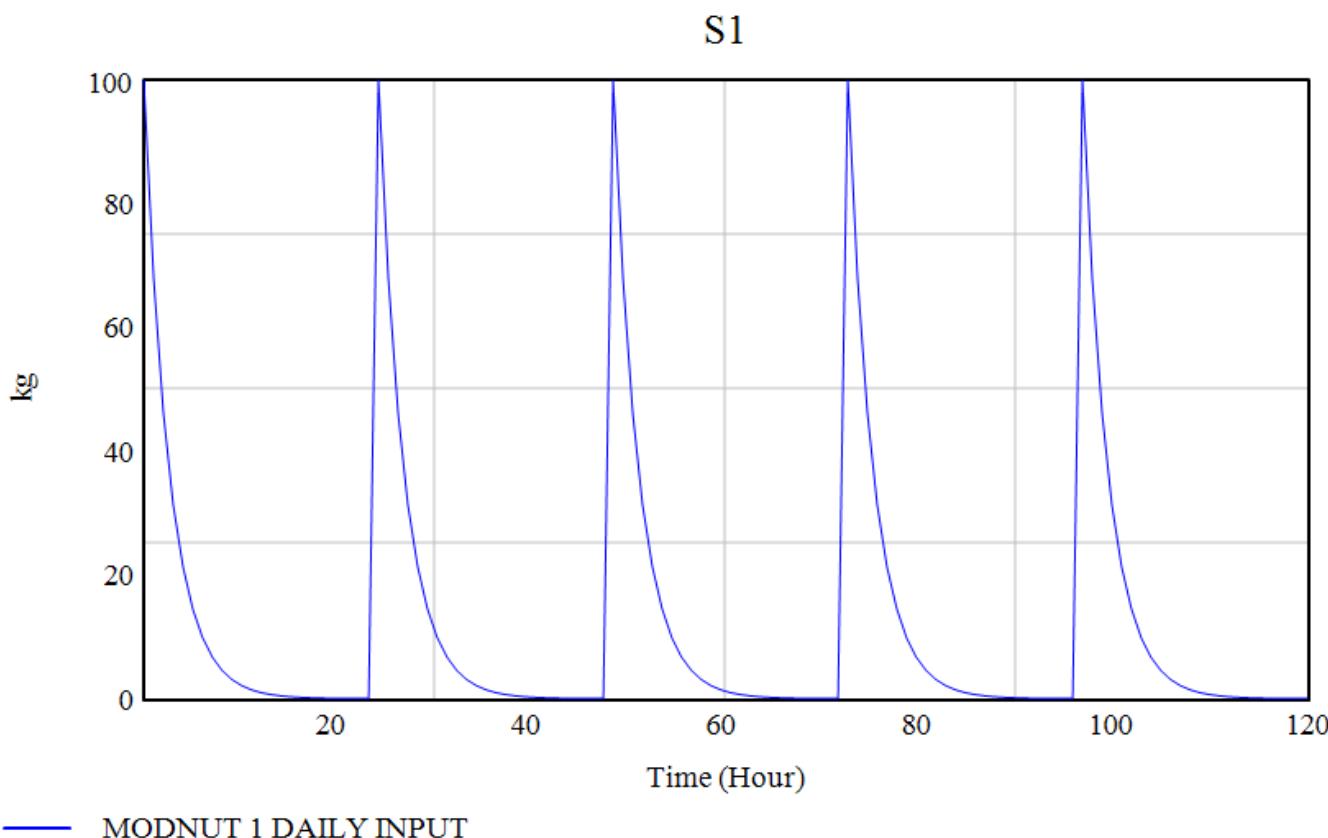
Rate of escaping from S1

Fractional rate of escape (Kp)

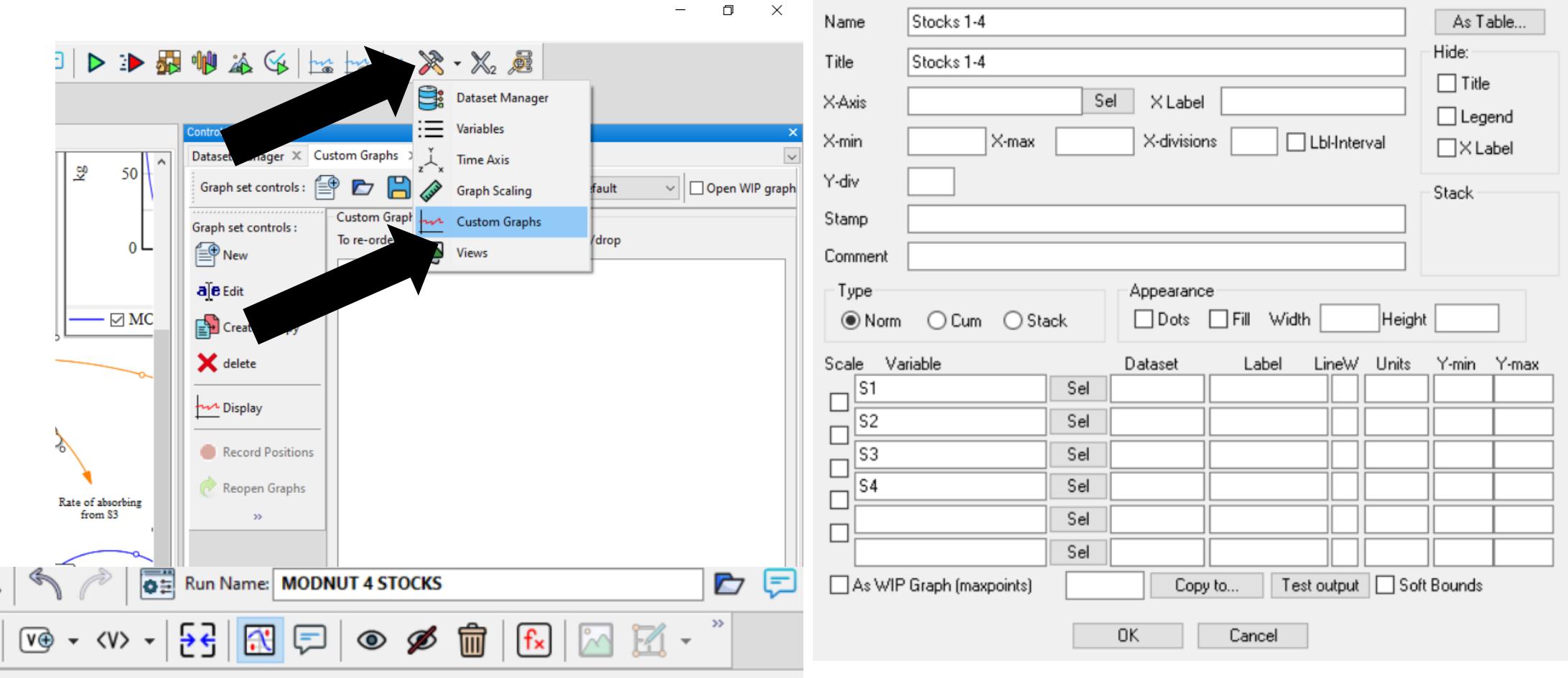
Fractional rate of degradation (Kd)

Step7. Open “Model 2” from files

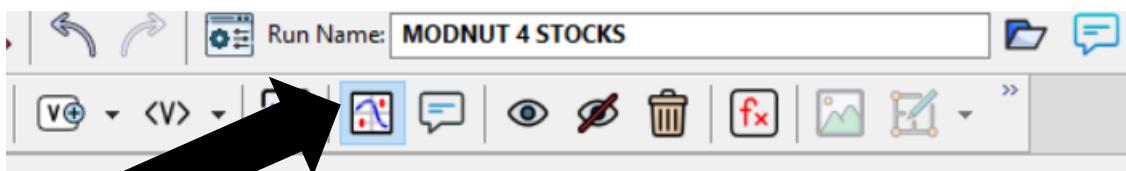
- Click the Green Run button.



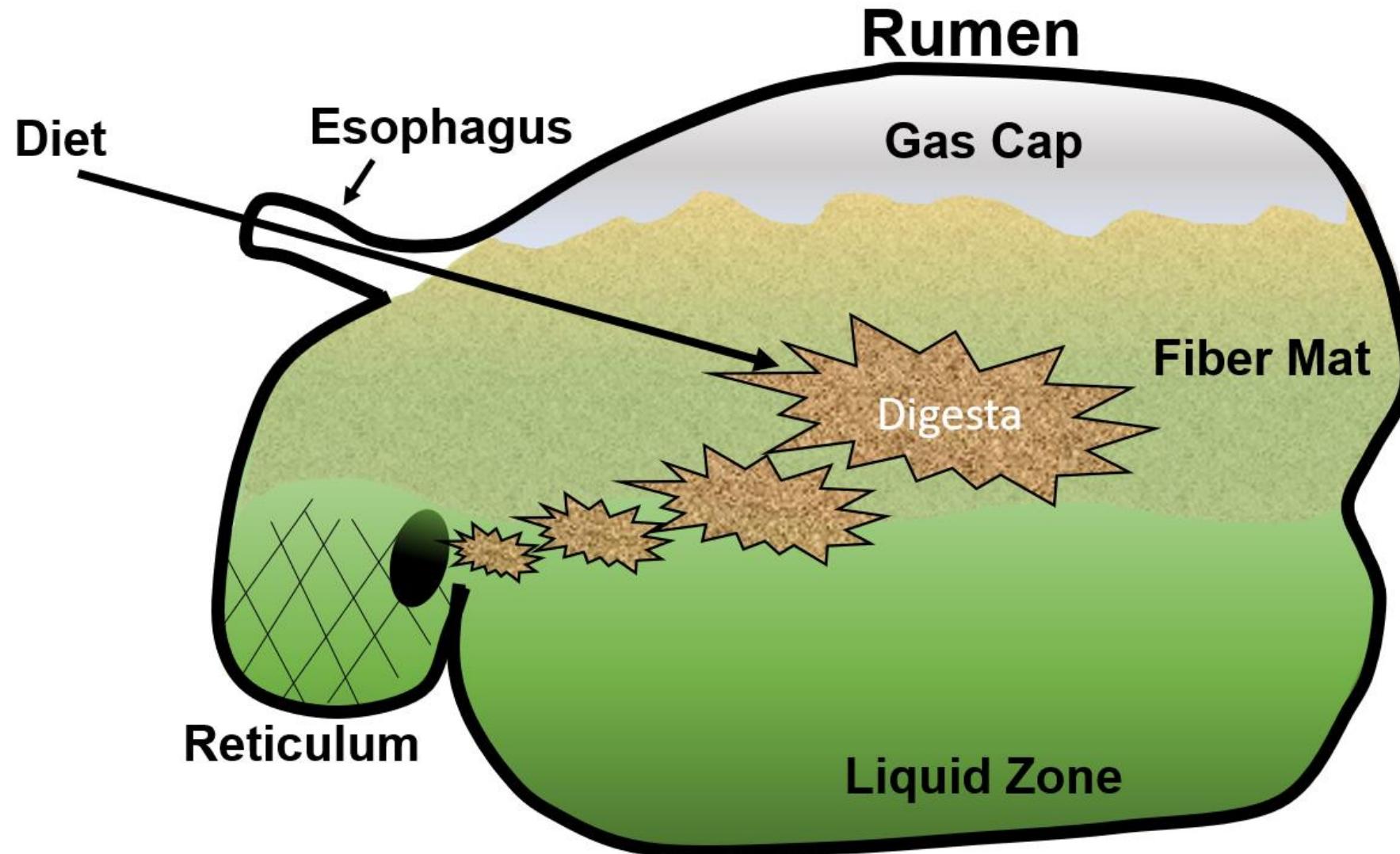
Custom Graphs



Then use the same process as creating a graph but select “**output custom graph**”

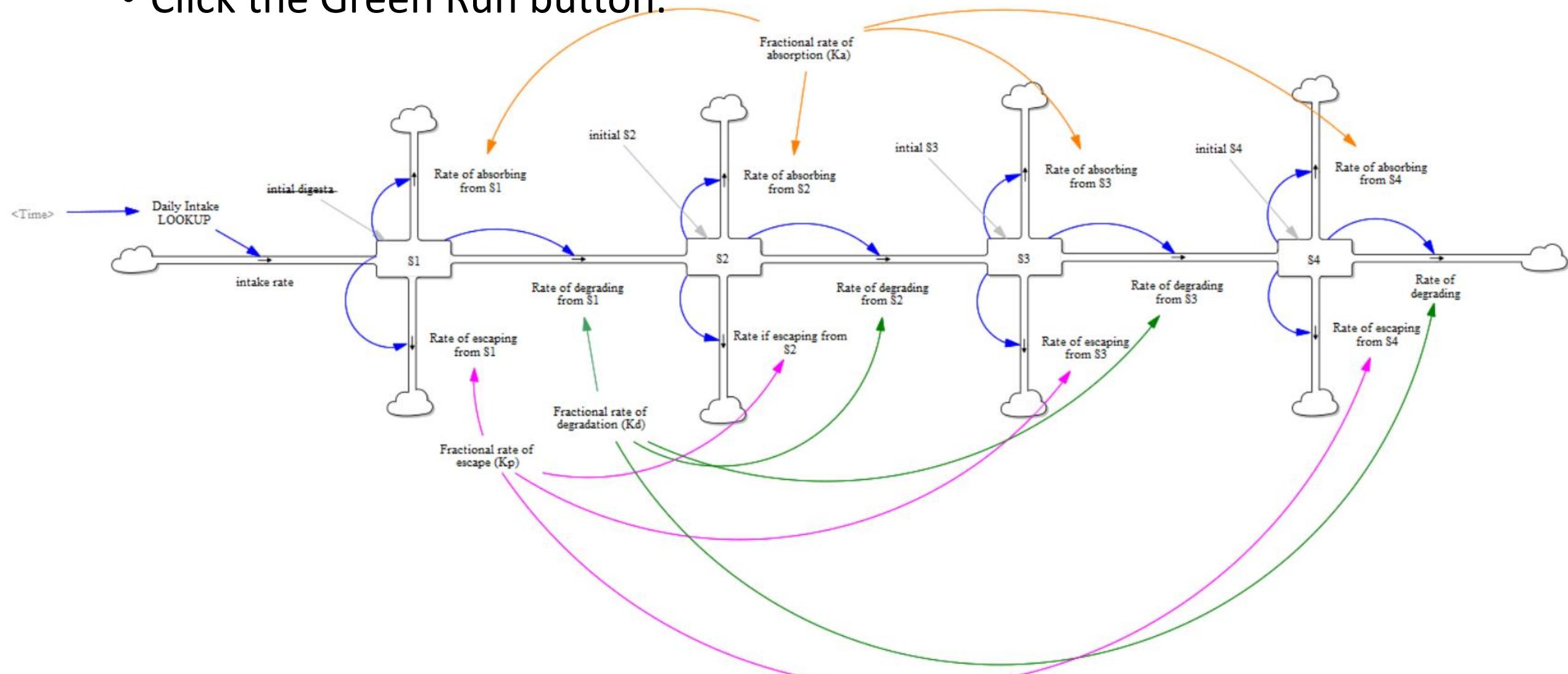


Making a four stock model to achieve an “**Aging Chain**”

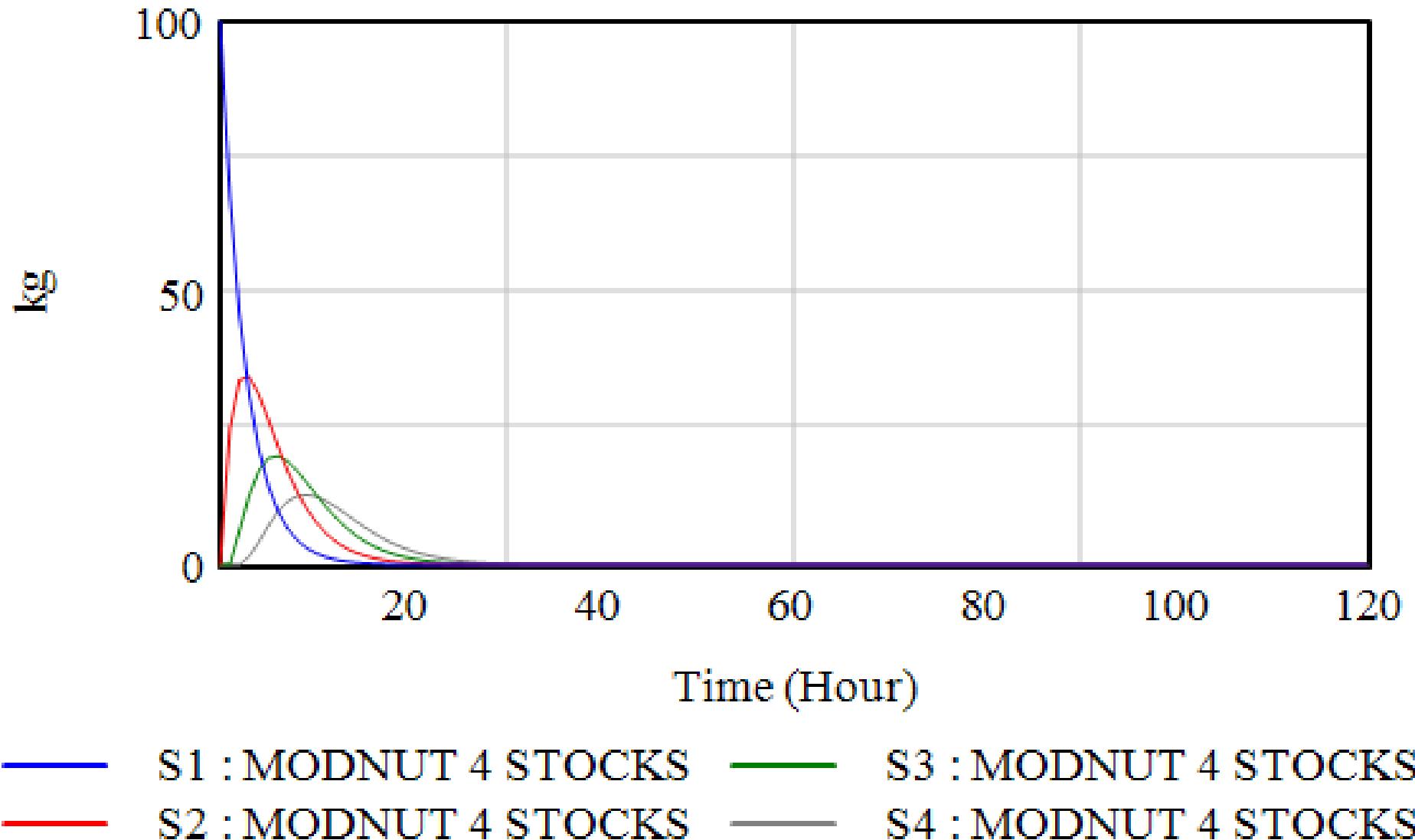


Step 8. Open “Model 3” from files

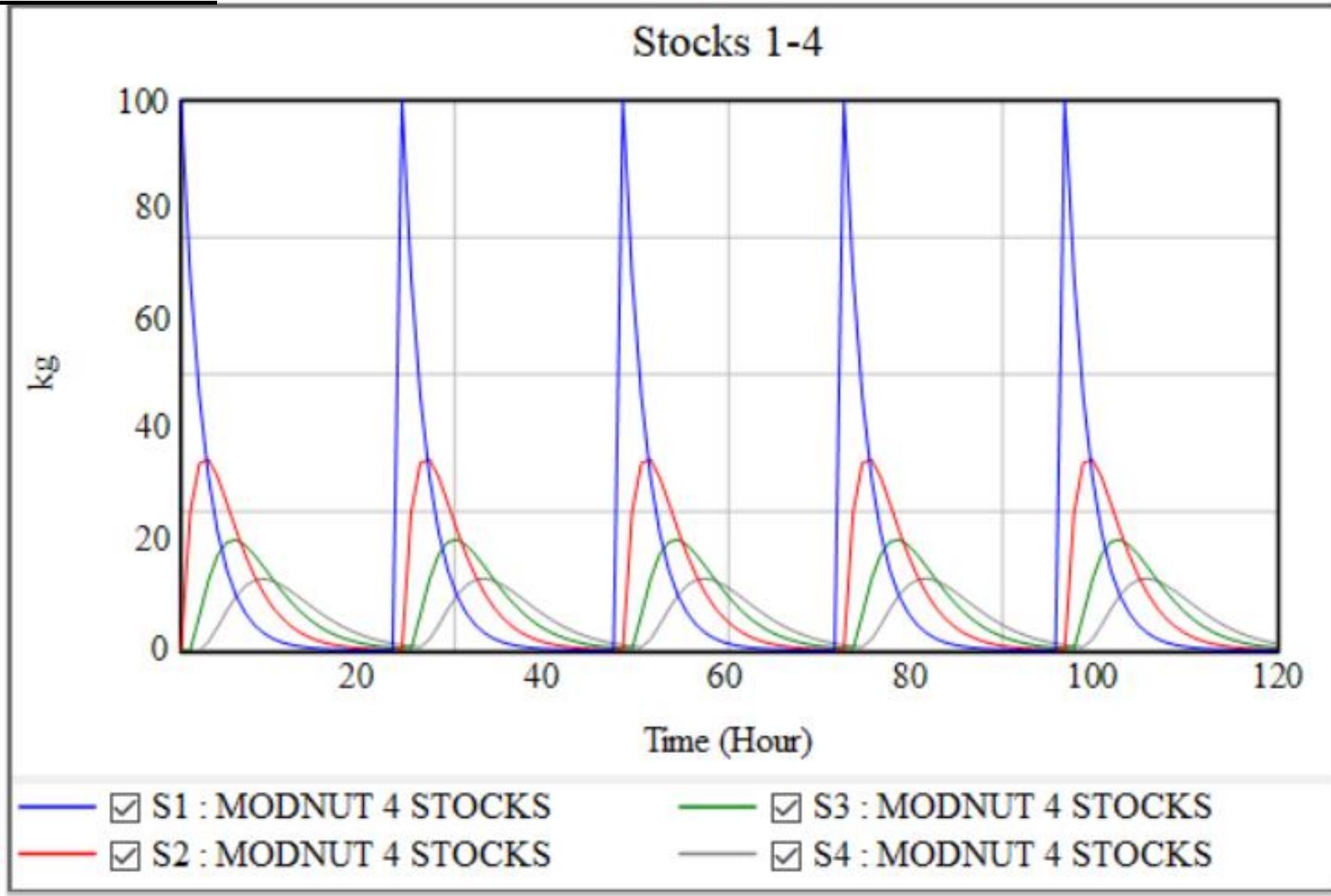
- Click the Green Run button.



With only the initial value of 100 kg in S1



With only the “initial digesta” value of zero and the Intake Rate informed by the daily intake LOOKUP variable



How to transfer to Program R

Step 1. Open Program R Studio (See MODNUT.R file)

- Install packages (lines 1-2)

```
installed.packages("deSolve", "ggplot2", "gridExtra", "scales",
                   "readr", "data.table")
```

- Load packages

```
library(deSolve)
library(ggplot2)
require(gridExtra)
library(scales)
library(readr)
library(data.table)
```

Freely available code :

<https://github.com/JimDuggan>

Goal of this Exercise

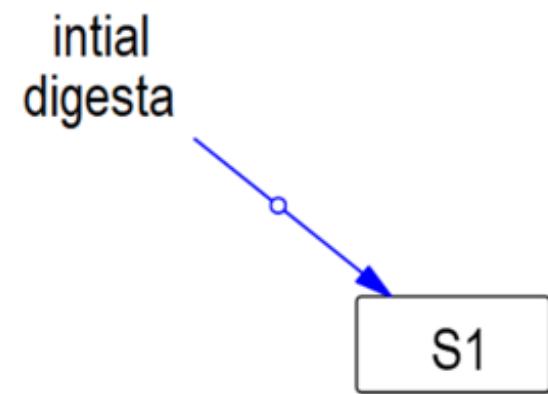
- **IS NOT** to become an R Wizard.
- **IT IS** to understand how to transfer a simple dynamic model to Program R. THE BASICS!

```

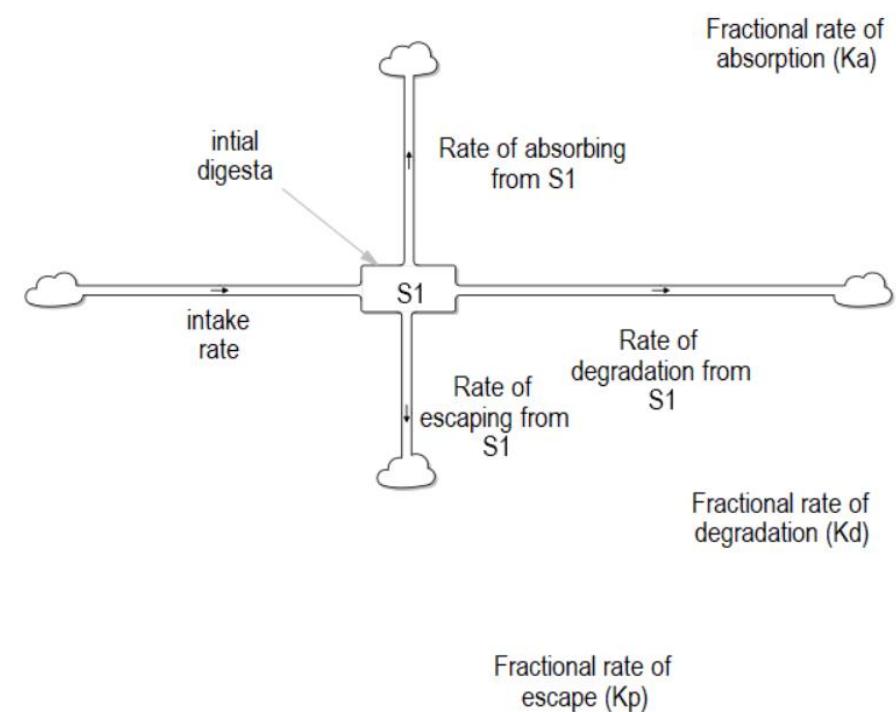
11 - ##MODEL 1#####
12
13 # Create the start time, finish time, and time step
14 START<-0; FINISH<-120; STEP<-1
15
16 # Create time vector
17 simtime <- seq(START, FINISH, by=STEP)
18
19 # Create stocks vector, with initial values
20 stocks <- c(ss1=100)
21
22 # Create auxiliaries vector, with values
23 auxs <- c(aKa=0.02, aKd=0.25, aKp=0.05)
24

```

- This is setting the initial conditions of the stock “S1” and the auxiliary variables “Ka, Kd, Kp”



- This is “model settings” see ppt: **Step 1**

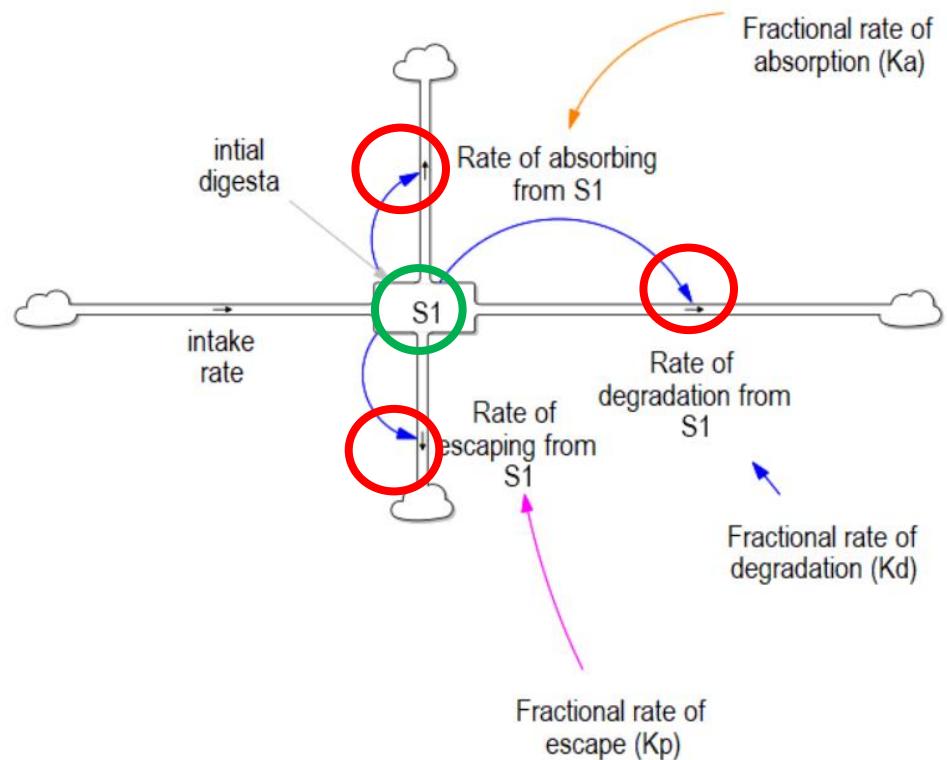


Step 2b and step 2c

```

25 # write callback function (model equations)
26 model <- function(time, stocks, auxs){
27   with(as.list(c(stocks, auxs)),{
28
29
30     KaR <- ss1 * aka
31     KpR <- ss1 * akp
32     KdR <- ss1 * akd
33
34     d_ss1_dt <- -(KaR+KpR+KdR)
35
36
37     return (list(c(d_ss1_dt),
38                  fKaR=KaR, fKpR=KpR))
39   })
40 }
41 }
42

```



This makes a functions that calculates rates and the “delta” of the S_1 stock.

```
43 # call solver, and store results in a data frame
44 o<-data.frame(ode(y=stocks, times=simtime, func = model,
45                   parms=auxs, method="euler"))
46
47 # Plot output
48 p1<-ggplot()+
49   geom_line(data=o,aes(time,o$ss1,color="1. s"))+
50   scale_y_continuous(labels = comma)+
51   ylab("Rumen Content")+
52   xlab("Day") +
53   labs(color="")+
54   theme(legend.position="bottom")
55
56 p1
57
```

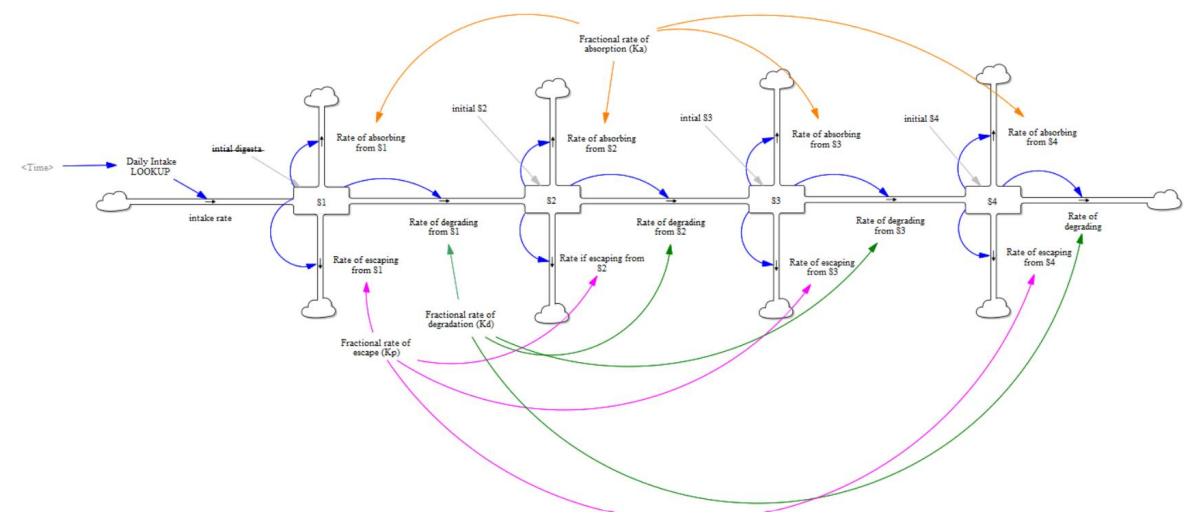
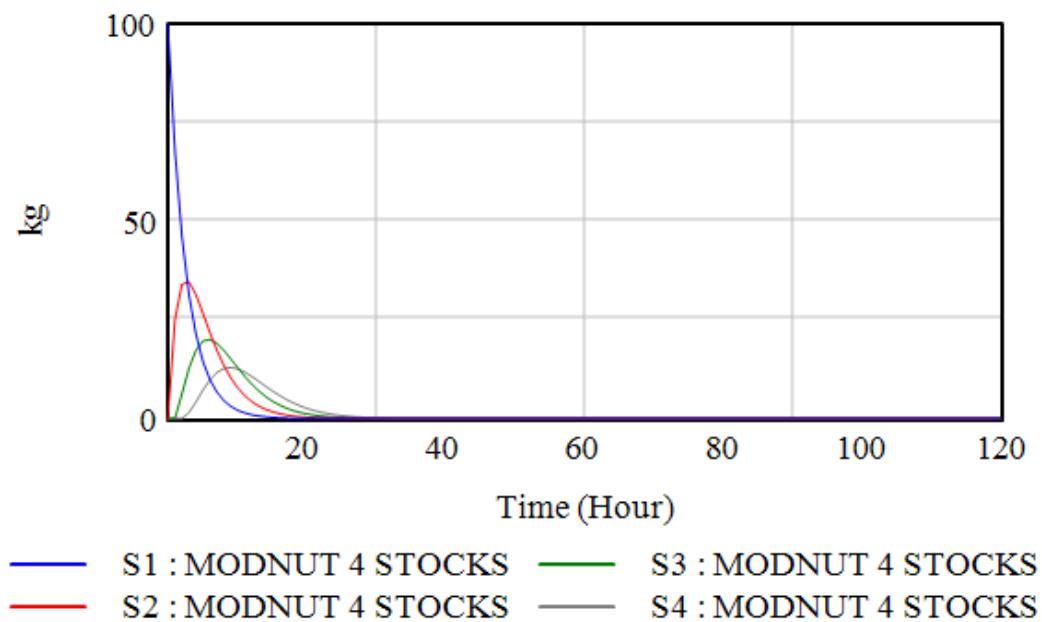
Integration method

We then employ the Ordinary Differential Equation (ode) function in R.
Next, we plot the stock value.

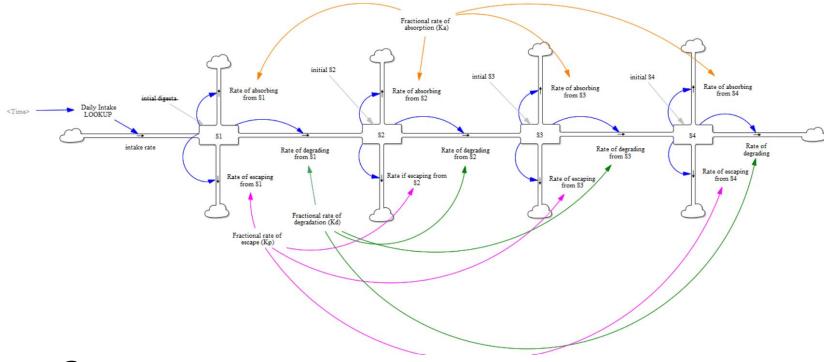
Models 2 (see “p2”)

- This code only add additional stocks and inputs

With only the initial value of 100 kg in S1



Models 3 (see “p3”)

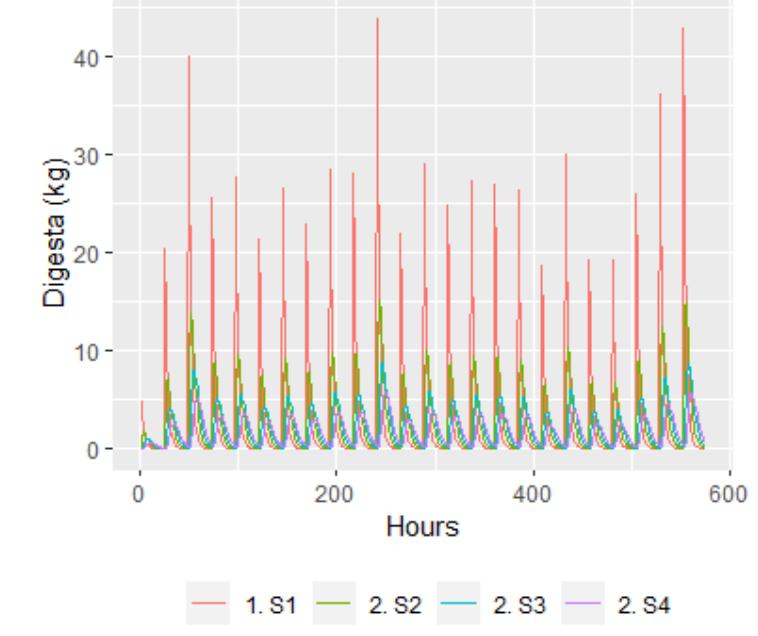
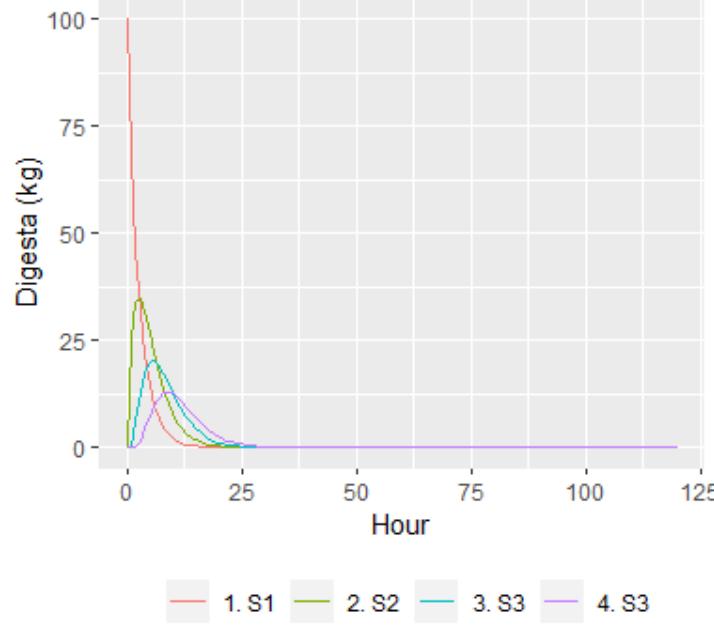
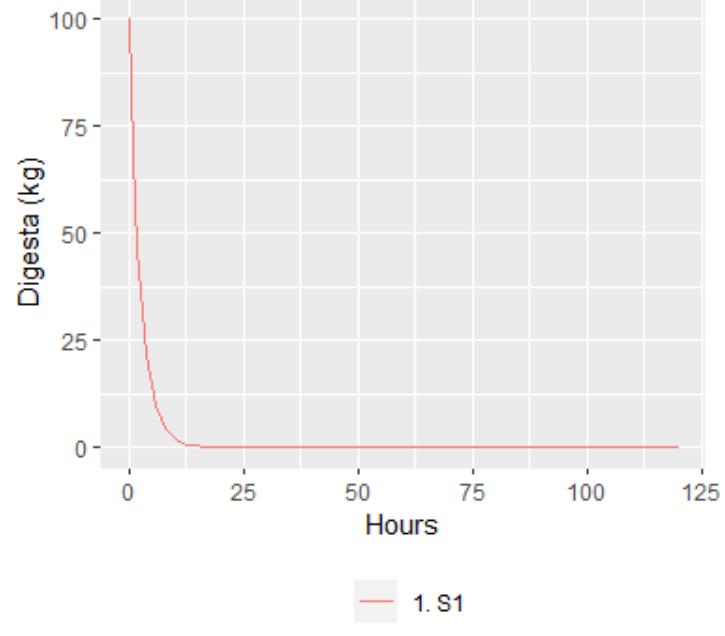


- This code imports precision DMI data from dry beef Angus cows (mean BW ~635 kg) consuming chopped hay (7 to 15 % CP) using **GitHub**

```
131 #### Model 3 Precision Data Integration ####  
132  
133 #load the data from github repo  
134 dmi = read_csv('https://raw.githubusercontent.com/rhensen/modnut/main/dmi_example.csv')  
135
```

- This code allows you to check the data and then subset data to assess a specific cow. In R [row#,column#]

```
146 #view data  
147 head (dmi)  
148  
149 #call the first cow  
150 dmi_2=dmi[1:24,2] #can subset by [row1:20,column]  
151
```



Models 1-3 Result Output

Open Shiny App

- https://agland.sdstate.edu/rumen_kinetics/



Contact

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Krista Ehlert

(Krista.Ehlert@sdstate.edu)

Luis O. Tedeschi

(Luis.Tedeschi@tamu.edu)

References

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