# BÚMODEL:
# AN HISTORICAL GRAZING MODEL

INSTRUCTION MANUAL

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This instruction manual is a working guide and is by no means exhaustive. Please contact Amanda Thomson (amath@ceh.ac.uk) or Ian Simpson (i.a.simpson@stir.ac.uk) if you have any problems with the model.

## Overview of Búmodel

Búmodel is an historical environmental simulation model. It was designed to predict spatial and temporal patterns of vegetation biomass and utilization in pre-modern Iceland (pre-1900 A.D.), with regard to vegetation degradation, farm viability and sustainability. Búmodel allows the user to model the Icelandic grazing system at the estate or community level, in order to investigate the interactions between vegetation, climate and management. The model user can control the number and type of livestock, where they are grazing at different times of the year, and how much, if any, fodder they are fed in winter. Búmodel is designed as a package of linked Visual Basic programs in the MS Excel spreadsheet package. It produces results that can be displayed in a geographical information system.

Detailed information on the development of the model can be found in Thomson (2003) and Thomson & Simpson (2004).

Thomson, A.M. 2003. A modelling approach to farm management and vegetation degradation in pre-modern Iceland. PhD thesis, University of Stirling, Stirling, UK.

Thomson, A.M. and Simpson, I.A. 2006. A grazing model for simulating the impact of historical land management decisions in sensitive landscapes: Model design and validation. Environmental Modelling and Software, 21, 1096-1113.

## Running Búmodel

- When you open Búmodel in MS Excel it will ask you to Enable Macros before opening the workbook.
- Búmodel will open on the *Livestock Inputs* worksheet – other worksheets for model inputs and results can be accessed using the tabs along the bottom of the page.
- The model is run from the grey Búmodel button half way down the page (column H, rows 27-29).
- Beside this are two options: the statistical results can be ordered by the cell ID number, or by land use type, and
- You can choose the number of runs in a model simulation. Búmodel contains stochastic elements, so two single runs using the same inputs will produce different results. You can choose the number of runs from the drop-down list.
- A single run will give the results of that run in the worksheets *Pasture Results, Herbage Results* and *Offtake Results.*
- The results from multiple runs (10, 20 and beyond) are averaged and given in the worksheet *Statistical Results* (see below).
- The worst and best individual runs of the set of runs are also saved in the *WorstScen* and *BestScen* worksheets. The results for a final run of a simulation are also stored in the single run results worksheets.
- I used 20 runs for most of the work I've done, because it gives a good spread of results from the inputs but minimizes the running time. The computer I was using for this had 512 MB RAM and a 1.1GHz processor, so a faster machine would be able to cope with more runs in a simulation, which might be better from the statistical point of view.
- With the single run simulation a message box will appear half way through the run to report the success of failure of the winter feeding, and how much hay is left over. Click on the OK button to clear the box and continue the model simulation.
- If all biomass is removed by grazing before the end of the model year, a 'You are doomed!' message box will appear and the simulation will stop.

- With multiple model simulations if a run fails then the model will record the failure and start a new run.

## Model inputs

### Vegetation inputs

- The vegetation inputs are entered in the *Pasture Inputs* spreadsheet.
- Búmodel has eight vegetation categories: hayfield, grassy heath, dwarf shrub heath, moss heath, bog/mire, riverine vegetation, birch woodland, and sparsely vegetated land.
- Each model cell is represented by one row record in the spreadsheet.
- Each cell has a unique cell identifier **Cell ID**.
- These cell identifiers must be numbered consecutively in the spreadsheet, otherwise the model will not run.
- The cell record contains:
  - the area of each vegetation community in m²
  - the area in m² of ungrazeable land in each model cell, which may be water, bare or inaccessible ground, or land which lies outside the study area but which is covered by the cell
  - the land-use of the model cell, in the column **Cell Type**, which can be set to rangeland (U) or outfield (O) using a drop-down menu
  - In Búmodel 2: whether the model cell can have snow cover, in the **Snow Cover in winter** column, which can be set to Yes or No using the drop-down menu
- Areas of hayfield within a cell are considered to be ungrazeable. These areas are used to calculate the fodder available for byred animals in winter.
- Each model cell must contain at least some grazeable vegetation, or the model will report an overflow error when it tries to divide by zero.

### Livestock and management inputs

- The livestock and management inputs are entered in the *Livestock Inputs* spreadsheet.
- When the model is opened certain input values are initialized:
  - The livestock numbers are initialized to 0
  - The climate scenario is initialized to Baseline

    - The livestock bodyweights are initialized to ‘typical’ pre-modern Icelandic values
- The location of the study area can be set to North or South using the drop-down menu, although this only affects hay production rather than overall vegetation production.
- The climate scenario can be set to Baseline (for a ‘typical’ year), Warm, Cold, or Extreme Cold using the drop-down menu. The choice of climate scenario controls vegetation production, hay production and livestock fodder requirements. Further details are given in Thomson (2003).
- Búmodel 1 can model **Ewes** (fertile ewes), **Lambs** (sheep under one year, born in May), **Immature sheep** (sheep older than one year but not yet fertile or fully grown), and **Rams or wethers** (male sheep principally kept for wool).
- Búmodel 2 also includes **Dairy cattle** (milk producing fertile cattle), **Calves** (cattle under one year, born in May), **Immature cattle** (cattle less than two years old), **Non-dairy cattle** (bullocks or bulls), and **Horses** (all ages).
- Numbers for each livestock type can be specified. NB: specifying lambs but no ewes may produce inaccurate results, because the model assumes that lambs are suckling for the first six weeks of life. The same applies to calves.
- At present the bodyweights for cattle and horses are estimated as being approximately 350kg for adults (for comparison, a Jersey dairy cow weighs approximately 450 kg). It would be nice to refine these estimates if possible.
- It is possible to specify a weight loss for adult sheep in winter. This should not be more than 40% of the total bodyweight.
- Young animals can be culled in autumn (Búmodel 1) or in spring (Búmodel 2), specified using the drop-down menu. The numbers of animals retained <u>after</u> slaughter are specified in cells B14:B17.
- The location of each livestock type can be specified for each month in the **Monthly livestock distribution** panel. Livestock can be placed on the Outfield or Upland pastures, in the Byre or Elsewhere. The Elsewhere option is intended for use when livestock were moved away from the estate entirely for a period of time.

- The **Snow cover** row allows the user to specify the months when there is snow cover in the study area. The model cells that had Yes for snow cover in the *Pasture Inputs* sheet are considered to be snow covered in these months and therefore cannot be grazed.
- The **Additional fodder** and **Fodder per animal per day** rows allow additional winter feeding to animals that are otherwise grazing outside. The months when additional feeding takes place can be specified Yes or No in the same way as snow cover. The amount of fodder can be set between 0 and 2.0 kg per day in increments of 0.5kg. I've not really used these options so there may be glitches still hidden in the code….
- In the **Fodder Production Inputs** panel, the '**Feed units consumed in previous winter'** button, the '**KG of DM per unit of hay'** button and the **'% content of effective nitrogen'** button are used to calculate the amount of effective nitrogen fertilizer from animal manure. This can be augmented with additional nitrogen fertilizer, for example from fuel ash, using the '**Additional N fertilizer, kg'** button.
- These inputs are used to calculate the quantity of hay that can be produced from the hayfield area. The button '**Hay stored from previous year'** allows additional hay stores to be added to those produced from the hayfield.

## **Model outputs**

### Individual offtake sheet

- This sheet records the monthly feed requirement of an individual of each livestock type according to whether it is grazing on the upland, on the outfield or being fed indoors.
- These feed requirements will vary according to livestock weight and climate scenario.
- The feed requirements of ewes and dairy cattle will also increase in the later stages of pregnancy and during lactation.
- The feed requirements of lambs and calves also have a growth component.

### For a single run:

### Pasture Results sheet

- This sheet records the plant type composition of plant types in each cell for the run. This composition can vary between runs as the composition of each vegetation category is selected from within the ranges given in the *Limits* worksheet.
- The sheet also records the relative palatability (on a score from 0 to 15) of each cell to sheep, cattle and horses in summer and winter. Note that this value is per hectare, rather than per cell.

### Herbage Results sheet

- This sheet gives the cell results for the utilizable biomass in each cell in each month. When there is snow cover, the cells recorded as covered will have zero utilizable biomass.
- This sheet also records the live body per ha in each cell. Búmodel 1 gives sheep per ha, but the increased number of livestock types in Búmodel 2 makes this impossible.
- Cells B2 and B3 also give the simulation run number and the total amount of hay available for winter feeding.

### Offtake Results

- This sheet gives the offtake per ha from each cell in each month, which is the amount of biomass removed by grazing.

- It also gives the cumulative utilization, which is the percentage of the annual biomass production which is removed by grazing (peak utilizable biomass in July/August is used as a proxy for annual biomass production).
- Lastly the monthly utilization is given which is the percentage of the utilizable biomass in the cell which is removed by grazing in that month. This can be used to assess the potential for grazing damage in the winter months.

## For multiple runs:

### Statistical Results sheet

- This worksheet records the statistical outputs from simulations including multiple runs. Cell B3 records the number of runs in a simulation.
- Rows 6 and 7 record the number of failures in either the grazing (through the complete removal of all biomass) or in winter fodder (when more livestock are housed indoors than there is fodder to feed) and the months in which these failures occur.
- This worksheet gives the predicted values for utilizable biomass, live body weight, offtake, monthly utilization and cumulative utilization per cell per month from top to bottom of the worksheet. The biomass, body weight and offtake values are given in kg per ha, and the utilization values are given as percentages.
- The means, standard deviations, minimum and maximum values are given from left to right. The minimum and maximum values are from the complete set of runs.

### WorstScen and BestScen sheets

- The worst and best runs of the simulation are recorded in these worksheets, based upon the mean April cumulative utilization.
- The run number is recorded in cell B3 and the mean April cumulative utilization value is recorded in C3.
- The run results are given in the order of utilizable biomass, live bodyweight, offtake, monthly utilization and cumulative utilization.

## Producing the vegetation inputs

1. Produce a vegetation area map in GIS (preferably Arc/Info or ArcGIS). The vegetation coverage should have an attribute item which records the vegetation type. These vegetation types should correspond to the Búmodel vegetation categories (although you can have mixtures of several categories, for example heath/grass mosaics). Convert this coverage to an ArcView shapefile.
2. Generate a rectangular grid of cells completely covering the study area. This can be done using the GENERATE command at the ARC prompt in ArcInfo (see ArcDoc Help for more details) using the FISHNET option. An example is given below.

   Example from Leirvík, Faeroe Islands (coverage names are given in italics)

   ARC: GENERATE *lv_net*

   GENERATE: COPYTICS *lvik_cont*

   GENERATE: FISHNET

   Origin coordinate (X, Y): 616200.000, 6897200.000

   Y-axis coordinate (X, Y): 616200.000, 6901000.000

   Cell size (width, height): 200, 200

   No. of rows, columns: 21, 37

   GENERATE: quit

   This gives a grid of 4 hectare cells (200 x 200m) covering the Leirvík study area, with the same tic marks as the contour coverage *lvik_cont.* 25 hectare cells (500 x 500m) also work well. Try to use integers for cell widths and heights, otherwise the fishnet generated may not have identical cells, due to rounding errors.
3. Display the vegetation map and cell grid together and remove any cells that do not contain vegetation (this includes bare ground and ungrazeable land).
4. Add a new field/item, *cell_id*, to the cell grid coverage and number the cells sequentially. Convert the cell grid coverage to an ArcView shapefile.
5. In ArcView display the vegetation map and the cell grid shapefiles together. Use the Spatial Analyst Analysis>Tabulate Areas command, with a 1m cell size, and the same

extent as the cell grid theme. Use the cell grid and *cell_id* as the row theme and field and the vegetation map and *vegetation_code* as the column theme and field.

6. Export the resulting table as a delimited text file.
7. Open the text file in MS Excel and calculate the Búmodel vegetation category covers. The ungrazeable land category should consist of all land within the cell that is not covered by vegetation. Format the *cell_id* field as text and other fields as numbers with 3 d.p.
8. Copy and paste the table into the Pasture Inputs sheet in Búmodel.

## Exporting Búmodel results to ArcView

All model results are produced with a unique cell identifier, **Cell ID**. This identifier can be used to link a results table with the original cell geographic dataset in ArcView geographical information system.

1. In Búmodel copy the cells you want to map (including the month headers) and paste them into a new spreadsheet. You can only do this for one parameter at a time, e.g. for the cumulative utilization mean results.
2. Make sure the column headers are completely visible and unique within the first 8 characters.
3. Save the pasted cells in the DBASE IV (.dbf) format. This is available from the File/Save As… menu in the Save as type: drop-down list. Click OK and Yes on the following message boxes.
4. Open the ArcView project you are working in.
5. Make the project window active (which will have an .apr suffix). Click on the Tables icon on the left hand side. Click the Add button at the top and select the dbf table you just made. This will open this table in ArcView
6. Add a copy of the cell shapefile to the View you are going to display the results in.
7. Open the table of this shapefile.
8. Display the shapefile table and your dbf table side by side. Make your dbf table active and click on the *Cell_ID* column heading, then make the shapefile table active and click its *Cell_ID* column. (The order of clicking is important).
9. Under the Table menu, click the Join… option. Your dbf table is now joined to the shapefile table and you can display the results in the map by altering the legend (see ArcView manual).

## Troubleshooting

- *Overflow error in the Visual Basic editor:* Usually because the program has attempted a division by zero. Check that all cells contain at least some vegetation. Remove any empty cells from the spreadsheet and try again.
- You cannot have more than 999 cells in a simulation. If the study area at the current cell size exceeds this limit, consider using a larger cell size, or dividing the study area into different areas, such as rangeland and outfield.
- When running simulations of a new study area/time period double check that the model is doing what you expect, e.g. that the livestock numbers through the year are correct (cells x in the check window) and the sum of the vegetation categories and ungrazeable area match the chosen model cell size.
- If you have a new session of Búmodel check that all the settings are how you want them, as some settings will be retained from the previous session.
- The Visual Basic code is accessed through the Tools/Macro…/Visual Basic Editor. The code for Búmodel 1 is listed in the appendix of Thomson (2003) and the content of the macros remain broadly the same in Búmodel 2, as the main changes are in the management options.