

1. Hardware and Software Requirement

SHIMMER is written and can be executed in the free open source computing environment and programming language R, which is available for download on the web (<http://www.r-project.org/>). SHIMMER uses the adaptive time-step solver “lsoda” from the deSolve package (Soetaert et al., 2010) **which must also be installed**. On a standard desktop computer running R, the model usually takes less than 1 min to simulate 10 years of succession.

2. Download SHIMMER

A package named “SHIMMER”, containing the source code of SHIMMER as well as example input and testing data is available as supplementary material.

The package contains 3 sub-folders:

- 1) Sub-folder named “SHIMMER”, which contains the model source code.
- 2) Sub-folder named “input_data”, which contains the following time-series of forcings:
 - par.csv – solar radiation (already accounting for inhibition by snow)
 - temp.csv – soil temperature
 - snow.csv – snow depth
 - ICS1.csv – input (deposition) of C substrate (labile)
 - ICS2.csv – input (deposition) of (refractory)
 - IPON1.csv – input (deposition) of organic N (labile)
 - IPON2.csv – input (deposition) organic N (refractory)
 - IPOP1.csv – input (deposition) organic P (labile)
 - IPOP2.csv – input (deposition) organic P (refractory)
 - IDIN.csv – input (deposition) DIN
 - IDIP.csv – input (deposition) DIP
- 3) Testing data
 - Cmic.dat – total microbial biomass
 - CS.dat – total carbon substrate

The package folder should be copied to a local computer such that the directory is:

“C:/RFolder/SHIMMER_SOURCE/”, or the folder paths contained in SHIMMER.R should be modified (path, pathdr, pathte) according to where the source code is copied to.

3. Source Code Files Description

This section provides a brief description of all source code files present in the sub-folder “SHIMMER”. This should be read alongside the manuscript (*SHIMMER (1.0): a novel mathematical*

model for microbial and biogeochemical dynamics in glacier forefield ecosystems) for clarity on variables, parameters etc.

SHIMMER.R

- Specify length of model run here (nyears) (note: must be a positive integer).
- Execute this code (copy and paste into R Console window) to run the model.

Library > SHIMMER_set_parameter_values.R

- Specify parameter values here.
- The default settings of the model correspond to the optimised Damma Glacier simulation presented in our manuscript.
- See the manuscript for a description of parameters.

Library > SHIMMER_load_and_make_drivers.R

- Load the forcing data and replicate for duration of model run (nyears).
- Note: forcing data must be specified as daily values (as per examples).

Library > SHIMMER_set_start_values.R

- Specify initial conditions here (starting value for each state-variable).

Library > SHIMMER_model_definition.R

- Contains the equations which formulate the model.

Library > SHIMMER_compute_totals.R

- Derive rates from time-series of output variables.

Library > SHIMMER_construct_array.R

- Construct 3-D array from output variables.

Library > SHIMMER_basic_plots.R

- Examples of basic plots of model output.

4. Model Operation

In R, specify working directory to: "C:/RFolder/model/SHIMMER/"

Open SHIMMER.R script and execute in console (note: package "deSolve" (Soetaert et al., 2010) must be installed).

To run the model, copy and paste the *SHIMMER.R* script into the R Console window.

5. Output

Model output is created as variables within R (out, out2 and out_array). By default, they are not saved locally, however this can be done by using a command such as:

```
write.table(out,file=paste("out","model_run.csv",sep="_"),sep=";",row.names=FALSE)
```

The dataframe “out” is a 2-D time-series of output data comprised of columns for each output (variables, totals and rates), and rows for each day simulated. All units are in $\mu\text{g g}^{-1}$ dry soil or equivalent.

Column Name	Description	Column Name	Description
<i>time</i>	Day of simulation	<i>cum_I_Sub</i>	Cumulative C substrate input
<i>A1</i>	A1 biomass	<i>cum_G_X</i>	Cumulative C substrate from losses (G) and exudates (X)
<i>A2</i>	A2 biomass	<i>years</i>	Year of simulation
<i>A3</i>	A3 biomass	<i>A_total</i>	Total autotrophic biomass
<i>H1</i>	H1 biomass	<i>H_total</i>	Total heterotrophic biomass
<i>H2</i>	H2 biomass	<i>S_total</i>	Total C substrate
<i>H3</i>	H3 biomass	<i>Cmic_total</i>	Total microbial biomass
<i>S1</i>	C substrate (labile)	<i>PON_total</i>	Total organic nitrogen
<i>S2</i>	C substrate (refractory)	<i>POP_total</i>	Total organic phosphorus
<i>DIN</i>	Dissolved Inorganic Nitrogen	<i>cum_A</i>	Cumulative growth (production) of autotrophs
<i>DIP</i>	Dissolved Inorganic Phosphorus	<i>cum_H</i>	Cumulative growth (production) of heterotrophs
<i>PON1</i>	Organic Nitrogen (labile)	<i>rate_A1</i>	Daily A1 growth rate
<i>PON2</i>	Organic Nitrogen (refractory)	<i>rate_A2</i>	Daily A2 growth rate
<i>POP1</i>	Organic Phosphorus (labile)	<i>rate_A3</i>	Daily A3 growth rate
<i>POP2</i>	Organic Phosphorus (refractory)	<i>rate_H1</i>	Daily H1 growth rate
<i>cum_A1</i>	Cumulative growth (production) of A1	<i>rate_H2</i>	Daily H2 growth rate
<i>cum_A2</i>	Cumulative growth (production) of A2	<i>rate_H3</i>	Daily H3 growth rate
<i>cum_A3</i>	Cumulative growth (production) of A3	<i>rate_DIC_A</i>	Daily DIC from autotrophs
<i>cum_H1</i>	Cumulative growth (production) of H1	<i>rate_DIC_H</i>	Daily DIC from heterotrophs
<i>cum_H2</i>	Cumulative growth (production) of H2	<i>rate_DIN</i>	Daily DIN assimilation
<i>cum_H3</i>	Cumulative growth (production) of H3	<i>rate_nf</i>	Daily nitrogen fixation
<i>cum_DIC_A</i>	Cumulative DIC from autotrophs	<i>rate_A</i>	Daily autotrophic growth (production)
<i>cum_DIC_H</i>	Cumulative DIC from heterotrophs	<i>rate_H</i>	Daily heterotrophic growth (production)
<i>cum_DIN</i>	Cumulative DIN assimilated into biomass	<i>rate_I_Sub</i>	Daily C substrate input
<i>cum_nf</i>	Cumulative nitrogen fixed	<i>rate_G_X</i>	Daily loss (G) and exudate (X) input

The dataframe “out2” is a 2-D time-series of annual totals (or rates), comprised of columns for each output, and rows for each year simulated. All units are in $\mu\text{g g}^{-1}$ dry soil or equivalent.

Column Name	Description	Column Name	Description
<i>year</i>	Year of simulation	<i>annual_DIC_A</i>	Total annual DIC efflux from autotrophs
<i>annual_A1</i>	Total annual A1 production (biomass growth)	<i>annual_DIC_H</i>	Total annual DIC efflux from heterotrophs
<i>annual_A2</i>	Total annual A2 production	<i>annual_DIN</i>	Total annual DIN assimilated from soil
<i>annual_A3</i>	Total annual A3 production	<i>annual_nf</i>	Total annual nitrogen fixed from air
<i>annual_H1</i>	Total annual H1 production	<i>annual_A</i>	Total annual autotrophic production
<i>annual_H2</i>	Total annual H2 production	<i>annual_H</i>	Total annual heterotrophic production
<i>annual_H3</i>	Total annual H3 production		

The array “out_array” is a 3-D array of data from “out”. The columns (x- axis) represent each output variable, total and rate, the rows (y-axis) represent each day of the year (1-365), and the depth (z- axis) represents each year. For example, out_array[2,5,3] is the biomass of A1 (the 2nd column in out) for the 5th day of the 3rd year. All units are in $\mu\text{g g}^{-1}$ dry soil or equivalent. The purpose of the array is that it is simpler to average and sum data across specific time-intervals.

References

SOETAERT, K., PETZOLDT, T. & SETZER, R. W. 2010. Solving Differential Equations in R: Package deSolve. J Stat Softw, 33, 1-25.